# Final Report: UCB - LANL Institutional Stewardship Studies - 1998-2000

## Stewardship and the Design of 'Future Friendly' Technologies: Avoiding Operational Strain in Nuclear Materials Management at Scale.

The LANL/UCB
Stewardship
Project

Final Report

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University of California
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# Final Report -- Overview and Organization.

The project's primary objective is to identify the organizational conditions associated with credible, publicly trusted institutional stewardship of nuclear materials over many management and worker generations, especially as the Los Alamos National Laboratory (LANL) becomes a critical location in maintaining the U.S. nuclear deterrence capability.

Three work elements follow from this objective. The papers devoted to each task are noted below in *italics*. They provide the overall structure of this report. While each can be read as an independent effort (with slightly different audiences and formats), they are intended to inform each other, and address several unexplored facets of the long term institutional stewardship of nuclear materials.

A) Develop conceptions of institutional stewardship and highly reliable operations as they might be expressed within LANL.

*I. "Institutional elements for long term stewardship in a nuclear age." Todd R. La Porte* [31 pp.]

B) Description of work requirements and operating dynamics involved in working with nuclear and weapons related materials, especially those that will be required for multiple generations.

*II. "Sustained, highly reliable operations across multiple generation: Management challenges of assuring nuclear weapons components." Todd R. La Porte*[1] [63 pp.]

III. *"Revealing (micro)operational networks: Life in the emerging (down-scaled) post cold war world of nuclear weapons." Adam Stone and Todd R. La Porte* [23 pp.]

C) Explicate the regulatory environments of the laboratory's defense and non-defense programs within which technical operations will be conducted for multiple generations. This requires describing regulatory relationships and networks within and outside the laboratory, and examining the effects of the internal structure and dynamics of these domains on the consistency of regulatory interpretation as experienced by technical designers and operators.

*IV. "Regulatory ecology mapping and evaluating the regulatory environment of LANL." Adam Stone and Todd R. La Porte* [32 pp.]

*V. "Technical operations in the shadow of the law:Two stories of interpretation and compliance at Los Alamos National Laboratory." Jude Egan and Todd R. La Porte* [43 pp.]

*VI. "Strategic regulatory action: A framework for analyzing design and regulation."* [36 pp.] *Adam Stone*

D) Research Processes.

*VII. Methodological Afterward: Project Team Field Research Activities – 1998-2000.*

1 The paper's original title was to be "Operational characteristic for highly reliable operations and reducing regulatory surprise", encompassing both operational and regulatory aspects. We now know this was an unrealistic reach. Due to LANL's complexity, especially the domains of institutional interest here, this paper concentrates on the operations.

## Forward and Acknowledgements

This work had its beginnings some five years ago with a visit to the Berkeley campus by Paul Cunningham, then the manager of the Los Alamos National Laboratory's (LANL) Nuclear Materials and Stockpile Management Program. He posed the following question to a small group faculty and students associated with the Center of Nuclear and Toxic Waste Management. "Could you assume that there will never be a rogue state that would turn to plutonium as a means of political domination?" This unsettling question set in train a series of conversations and visits to LANL exploring the consequence of the only answer that can be given. Some of the answer's implications are technical. Under what physical conditions could the stockpile of existing nuclear weapons be safely stored? What are the requirements for periodically re-manufacturing the components for a small number of weapons as the years go by? Other implications entail a deep understanding of the organizational and institutional patterns that would have to be developed, and sustained for a very long time.

This report summarizes sustained efforts to understand the latter aspects of these challenges. Our work is oriented first toward understanding the implications of an institution taking up these challenges within the self-accepted framework of "stewardship." Then there is a cluster of studies that examines the internal dynamics of addressing the production mission and exploring the regulatory framework within which this would take place.

Three study elements make up the body of this work:

1. Develop conceptions of institutional stewardship and highly reliable operations as they might be expressed within LANL. The first concept is only minimally discussed in organizational literature; the second concept is more elaborated, drawing primarily on ten years of work conducted by the Berkeley High Reliability Organizations project of which La Porte was a leader. This element involves close reading of existing literature and the development of relevant organizational concepts in the event current literature does not provide them, as is the case here.

2. Become reasonably well acquainted with the work requirements and operating dynamics involved in handling hazardous nuclear and weapons related materials - those activities which would be carried out year after year for a number of work and management generations. The technical venues initially included work with the ARIES and MOX projects. Then, based in part on the learning in that phase, increasing our understanding of the complexities involved in pit production - plutonium and beryllium handling, and detonator production. This involves observation and informal interviews with work teams members, discussions with technical supervisors, and becoming familiar with management processes and program coordination. The effort to do this work depends on the number and variety of the groups that are involved with the production, support, coordination and safety management of the systems of interest. The more organizationally complex, the more intense the effort.

From an institutional or organizational research point of view, our work in the summer of 1999 afforded a good introduction both to some of the complexities of the weapons productions operations, and especially to a series of the organizational requisites and dilemmas that are emerging within the lab's present operating and program environment. This provided a strong dose of reality for these processes are remarkably complex technically and, as importantly, are carried out within an extraordinary organizational matrix of relationships among the Divisions and Groups that are directly responsible for maintaining the components fabrication and assembly processes.

3. Explicate the regulatory environment of the laboratory both for its defense and non-defense programs. While defense and non-defense activities formally have quite different sponsoring and regulatory overseers, both share facilities that draw the attention of a number of regulatory interests regardless of the mission. This regulatory environment — much more variegated than we expected — is a crucial aspect of the operating world into which both existing and newly designed technical systems would be deployed. Gaining a better understanding of these domains, and anticipating the ease or tensions associated with developing and deploying nuclear technologies involves "mapping" regulatory relationships within and outside the lab. This was based mainly on informal interviews and discussions with technical group and management leaders, those responsible for regulatory liaison, and members of external regulatory organizations who believe they can claim the attention of LANL management. An added aspect of this element was developing a way of rendered these relationships in computer graphic form for ease of analysis and impact of feedback.

Successfully engaging in this sort of work always depends on the cooperation and informal teaching of people in the organizations of interest. In our case, we were greatly assisted by many managers, and technical and support staff from a wide variety of units at LANL. Without their generosity and welcome, this multi-faceted project would have been truncated and fallen short of its promise. I am particularly indebted to the professionals of LANL for their reception of our students. Almost without exception, the three students involved with the work (two represented here as authors of these papers, another Andrew Koehler, now completing his Ph.D. with LANL support)[2] were received warmly and taught well by LANL staff. It has been an extraordinary experience for us all.

Of the many LANL staff, we especially thank these teachers. Those who have facilitated in the overall project and invaluably enhanced our understanding of Los Alamos as an institution were Rulon Linford, Warrren 'Pete' Miller, Paul Cunningham, Ed Arthur, Bruce Matthews, K.C. Kim, Jim Toevs, Sig Hecker, T. J. Trapp, Jim Porter, Karl Braithwaite, and Scott Gibbs, Harry Otway, Phil Thullen and Chick Keller. Others were generous in helping us understand particular aspects of our work. We acknowledge them in the notes for the relevant segments below. Special thanks to Sophie Vigil, who unfailingly helped us steer our way through LANL's often puzzling administrative processes and whose ebullient spirit gave a welcome lift to the everyday pressured dynamics of intense fieldwork. We all gained in her presence.

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[2] See "Design for a Hostile Environment: Technical Policy-making and System Creation." Diss., Graduate School of Public Policy, University of California, Berkeley, 2001.

Support staff on the UCB Berkeley campus greatly eased the process of dealing with the often surprising administrative processes of UCB and LANL, rather different entities both claiming important University of California heritage. Thanks especially to Richard Hill and Laurie Holland of the administrative staff of UCB's Environmental Engineering Health and Safety Laboratory, now the Institute for Environmental Science and Engineering for their work in sorting out contract puzzles. We also acknowledge the encouragement and good offices of Professor Bill Kastenberg, then Chair of the Department of Nuclear Engineering and the Director of the Center for Nuclear and Toxic Waste Management, in our earlier work and in facilitating our arrangements with UCB. (See also the full list of those to whom we talked and many of the laboratory and community processes from which we learned in a Methodological Afterward at the end of the full report.)

Todd R. La Porte

Berkeley, California

## Accessing Computer Enabled Sections of This Report

This bound report should be accompanied by a CD-ROM which contains digital copies of these papers as well as accompanying diagrams and programs described here.

These papers and the programs may also be accessed from the following URLs

http://int.lanl.gov/orgs/nmt/regexp/
http://socks.berkeley.edu:4050/regexp/

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# Institutional Elements for Long Term Stewardship in a Nuclear Age
**[Views from a "stewardee"]**

The LANL/UCB
Stewardship
Project

Final Repor

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Abstract: The metaphor of "stewardship" is increasingly being used to characterize the role of public institutions as they pursue the public's business. This paper explores the implications for institutions were attentive publics to take them at their word. For the domain of interest here, stewardship functions are directed to the management of intrinsically very hazardous materials and operations, in the interest both of the operators themselves and potentially for citizens in contact as well. This suggests a strong requirement for continuous, *highly reliable operations* stretching across many decades with the achievement of *institutional constancy* in a context of continuously high levels of *public trust and confidence*. These qualities tax the capabilities of organizations generally. They are particularly challenging for the institutions within the DOE network, the specific context here. The paper ends by outlining a series of studies carried out in the Los Alamos National Laboratory context which provide a better basis for understanding the character and magnitude of the effort needed to assure these conditions for the production missions of the laboratory.

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## Introduction[1]

Within the past decade, public agencies have increasingly appropriated the metaphor of "stewardship" to describe their relationship to the public, i.e., the concept of being entrusting with the management of the resources or other matters not their own. It is being used to characterize a wide sweep of functions, e.g., stewardship of environments and ecosystems, including land, forests, water, streams, air resources, and agriculture.[2] Now in the aftermath of the Cold War, the Department of Energy (DOE) and its contractors have also begun using the

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[1]This paper frames an overarching conceptualization on the operational and the political challenges that are associated with the technologies that the Los Alamos National Laboratory (LANL) employs to meeting its national mission. It is the first of six papers fulfilling the University of California, Berkeley (UCB) -- Los Alamos National Laboratory (LANL) contract on Stewardship and the Design of 'Future Friendly' Technologies: Avoiding Operational Strain in Nuclear Materials Management at Scale. (LANL/UCB Award # 120BG-0018-23 (1998-2000). The project's objective is to identify the organizational conditions associated with credible, publicly trusted institutional stewardship of nuclear materials over many management and worker generations, especially in the LANL context as the lab becomes of singular importance in maintaining the U.S. nuclear deterrence capability. This involves understanding both the operational requirements that will be needed in succeeding generations, i.e., the actual work of producing a modest number of weapons' components year after year, and the regulatory environment likely to characterize that future. Earlier, background work was enabled by the Center for Nuclear and Toxic Waste Management, University of California, Berkeley, and the Los Alamos National Laboratory (LA-UR 97-3227, UCB Contract LANL-C14550017-3Y-LAPORT-06/97. The views expressed herein are not necessarily those of these institutions.

This paper was assisted by comments from colleagues, K.C.Kim, Rulon Linford, Jonathan Medialia, and Paul Schulman. An early version of these arguments were presented in "Defining a Framework for the Nuclear Weapons Complex", for the Workshop on Land Use and DOE Sites: The Implications for Long Term Stewardship, sponsored by the Resources for the Future (RFF) and the Environmental Management Division, DOE. Washington, D.C., Jan. 16-17, 1997. The central question was "what kinds of institutions are needed to address the many challenges of long term stewardship at DOE sites". RFF, especially Kate Probst and Terry Davies, and the Office of Environmental Management's James Werner, Director of Strategic Planning and Analysis, catalyzed discussions about it. See "Long-Term Stewardship and the Nuclear Weapons Complex," Center for Risk Management, Resources for the Future, January 1997.

[2]See, for example, T. Sample, Land Stewardship in the Next Era of Conservation, 1991; Richard L. Knight and Peter B. Landres , (Eds.), Stewardship Across Boundaries, 1998; National Research Council, Science and Stewardship in the Antarctic,1993, and Toward a Scientific and Social Framework for Ecologically Based Stewardship of Federal Lands and Waters, 1996. From the Ecological Stewardship Workshop, U.S. Forest Service. [http://www.fs.fed.us/eco], DOD, Office of the Deputy Assistant Secretary of Defense for the Environment Defense [http://128.174.5.51/denix/Public/public.html], Legacy Resource Management Program Technical Earth Resources; Gerald L. Baliles, et al, Preserving the Chesapeake Bay : Lessons in the Political Reality of Natural Resource Stewardship, 1996; and a strong emphasis in the National Parks Service, Natural Resources Ecosystem-Based Stewardship program outlined on, [http://www.nature.nps.gov/partner/ecosystm.htm].

The concept has also been appropriated in the private sector as well. See for example, developments in "product stewardship," John D. Hamilton, ed., Ecological Assessment Polymers: Strategies for Product Stewardship and Regulatory Programs., Roger Sutcliffe, 1996; The Stewardship of Private Wealth : Managing Personal & Family Financial Assets, Sally S. Kleberg, Sally S. Kleber, 1997; The Buck Stops Here : Perspectives on Stewardship from Business and Professional Managers, Business Executives for Economic Justice, 1997. See more generally, Peter Block, Stewardship: Choosing Service over Self-Interest, 1997, arguing for the spirit of partnership and service in every business, government agency, and nonprofit institution.

The concept has long been used as an important defining aspect for the lives of Protestant denominations as church leaders orient their members to the care and gathering of financial and, more recently, environmental resources. See for example, Michael Katakis, Ed. Sacred Trusts : Essays on Stewardship and Responsibility,1993; Larry Burkett, Caretakers of God's Blessing : Using Our Resources Wisely (The Stewardship Series), 1996; and Calvin B. Dewitt, et al, Caring for Creation : Responsible Stewardship of God's Handiwork, 1998.

"stewardship" metaphor to reorient their evolving relationships with the American public.[3]

In the context of the nuclear enterprise, this covers an extraordinary range of functions: the long term monitoring of cleaned up mill tailing sites; the continued work to clean up production sites, such as Fernald, OH, and Rocky Flats, CO; the exceedingly complex, potentially insurmountable environmental challenges at the Hanford, WA, and the Nevada Weapons Test Site facilities; and potentially, the long term management of high level radioactive wastes at Yucca Mountain, NV, if on-going exploratory work there turns out to discover a site which is suitable for the formal approval of permanent disposal.[4] All these activities can be thought of as a kind of "battle-field clean-up", as we slowly recover from the damage done to our soil during WWII and the Cold War. In addition to these important monitoring challenges, there are also the much more active production-like, long term activities associated with managing the "build down" of the U.S. nuclear stockpile, especially the disposition of excess weapons grade plutonium, and maintaining a national nuclear deterrence capability for the foreseeable future termed "science based stockpile stewardship"[5] These are important, costly functions, and open to debate about the goals and means involved, and are sometimes seen as exporting undeniable operational and policy demands into the far social and political future.

This paper explores the potential implications for agencies and institutions were attentive publics to take the DOE and other institutions seriously in their claims to stewardship. *What obligations do institutions take on when the public*

[3] For a recent example see Department of Energy's (DOE) Environmental Management (EM), Long-Term Stewardship Study, Draft, October 2000, one of a number of reports dating back to 1995, see http://www.em.doe.gov/doclistb.html. See also "The Stewardship of Nuclear Weapons," Los Alamos Science, 21, 1993, for an early appropriation of this term at Los Alamos National Laboratory (LANL). It is featured prominently in LANL's long term planning documents. See the emergence of this concept in 1995 with LANL's, Institutional Plan: Science Severing Society, FY 1996-FY 2000, especially in its Overview section laying out a strategic vision derived from the core mission of "reducing the nulcear danger," highlighting "stockpile stewardship" as the first of five major program areas. See also the paper presented in1996 by LANL leaders, John Immele and Phil Goldstone to annual meeting of the American Physical Society, "Stewardship of the Nuclear Stockepile Under a Comprehensive Test Ban Treaty." Indeed, the notion of institutional stewardship has become a key basis for evaluating the performance of the labs managed by the University of California on behalf of DOE. (see Institutional Stewardship and Viability, in Appendix F, LANL, LLNL, Modification No.: M331 Supplemental Agreement to Contract No. W-7405-ENG-48.

[4] DOE, Environmental Management (EM), From Cleanup to Stewardship, A Companion Report to Accelerating Cleanup: Paths to Closure, October 1999; and Closure for the Seventh Generation, A Report from the Stewardship Committee of the State and Tribal Government Working Group, February 1999. See also Katherine N. Probst ,"Long-Term Stewardship and the Nuclear Weapons Complex: The Challenge Ahead." Resources for the Future, Washington, D.C., (Resources, 131, Spring 1998.)

[5] DOE, Office of Defense Programs (DP), Stockpile Stewardship Plan Overview, FY 2001, the most recent expression of this challenge for the nuclear weapons activities of DOE dating back to 1995. See Stockpile Stewardship and Management Program, Maintaining Confidence in the Safety and Reliability of the Enduring U.S. Nuclear Weapon Stockpile, May, 1995. These inform a relationship between DOE, LANL and Nuclear Commanders which until recently has been exercised predominantly within tight security arrangements. It has not been carried on with an eye to the broader

*comes to expect them to be "faithful stewards"?* While the specific context is the DOE complex, many of the challenges this institution and its contractors face in the next decades, the argument is equally salient to other institutions whose central work involves long term, highly hazardous materials and activities. After a short prefatory comment, the paper outlines the rudiments of institutional stewardship as a concept (especially long term stewardship in a nuclear age), then takes a preliminary look at conditions that are required to achieve it, and suggests those current conditions, in effect design constraints, that heighten the challenge for any agency and its contractors were they to pursue such an objective. I end by noting some of the research imperatives embedded in the remarkable intention seriously to take up the burden of institutional stewardship, and framing a series of studies carried out at Los Alamos National Laboratory which provides a better basis for understanding the character and magnitude of the effort needed to assure these conditions for the Laboratory's production missions.[6]

Initial considerations of institutional stewardship within DOE have been about the matters of land use and environmental legacies on many facilities associated with the production of nuclear weapons,[7] on the one hand, and the challenges of "stockpile stewardship," on the other.[8] The stakes are high enough in these domains, but the legacies of nuclear weapons and power, as well as other long lasting, intrinsically hazardous technologies, call us to consider the institutional design implications inherent in a stewardship role more broadly -- for government agencies and their contractors in an advanced industrial democracy. A systematic institutional effort toward effecting a sustained, faithful agency stewardship on behalf of our citizens regarding nuclear weapons facilities takes on added significance for it goes on in a context marbled with similar activities. There are similar initiatives in the chemical industry,[9] and recent efforts at Los Alamos and Lawrence Livermore National Laboratories regarding the

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public.

[6] I should like to acknowledge the remarkable cooperation, over the past two years, of the managers and staff of the Los Alamos National Laboratory, especially the Nuclear Materials Technology Division, and the Materials and Manufacturing Program Office, Nuclear Materials and Stockpile Management Directorate. This has been supplemented by work with portions of the Environment, Safety and Health Division, the Detonation Science and Technology Group, Dynamic Experimentation Division, and the Metallurgy Group, Materials Science and Technology Division. The men and women of the lab have been most welcoming and superb teachers of the ways of handling demanding materials in a highly regulated world.

[7] See note 5 above, and Katherine N. Probst, Carolyn A. Pilling and Karne T. Dunn, Cleaning Up the Nuclear Weapons Complex: Exploring New Approaches, Center for Risk Management, Discussion paper 96-25, Resources of the Future, July 1996.

[8]See Jonathan E. Medalia, Nuclear Weapons Stockpile Stewardship: Alternatives for Congress, CRS Report for Congress (96-11-F), Congressional Research Service, Library of Congress, Dec. 15, 1995.; and Jonathan E. Medalia, Nuclear Weapons Stockpile Stewardship: The Role of Livermore and Los Alamos National Laboratories, CRS Report for Congress (94-418 F), Congressional Research Service, Library of Congress, May 12, 1994.; and DOE, EM, Stockpile Stewardship and Management Program:…, op. cit.; and DOE, Office of Defense Programs, Next-Generation Manufacturing Document,1999; and Stockpile Stewardship and Management. Programmatic Environmental Impact Statement. Notice of Intent, Federal Register, June 14, 1995\: 31292.

[9]See Denise Kern, Product Stewardship Gets Dow's Vote, 40 (Chemical News:March 1990) ; Robert Luft,

stewardship (and management) of nuclear materials generally, including the continuing program of nuclear stockpile stewardship.[10] Thus, framing a perspective for the managing the environmental aftermath of the weapons production during WWII and the Cold War could contribute significantly to other initiatives responding to similar long term challenges. A perplexing aspect of DOE's challenge is the perceived need for the Department to maintain, at some *de minimus* level, the nation's nuclear deterrence capability for the foreseeable future. DOE is taken here as a reference case, so to say, for it oversees perhaps the widest range of "stewardship candidates" of major U.S. public institutions.

## I. Considering (Long Term) Institutional Stewardship

Our starting point is the brief, useful definition broached in 1997 for a workshop stimulated by the recognition that a number of sites and facilities used for the production of nuclear weapons either cannot be or are too costly to clean up so fully that the agency could, with good conscience, turn them over to local communities for unrestricted land use.[11] It this context:

> "Long term institutional stewardship refers to the set of strategies adopted and activities undertaken to protect current and future generations and the environment from exposure to hazards that remain on the sites in the nuclear weapons production complex after clean up has been completed."
>
> The comment goes on …(I)nstitutional controls to prevent the inappropriate land and ground water use; to maintain disposal facilities . . . to ensure continued containment of disposed wastes; to preserve institutional memory and communication mechanisms to keep future populations informed of site hazards; and long term surveillance and monitoring (*i.e., a guarding functions.*) *My addition.*

Put in question form: How can an agency or organization maintain, for the long term, control of functions necessary to address problems that will last for the long term?[12] Given the substantive areas in question, there is also a tacit expectation that stewardship activities may be required for the indefinite future, perhaps hundreds of years. This is a very tall design order.

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Environmental Stewardship: Its Good Business, N2 (11 Environmental Progress r: Nov. 1992); Gregory Bond, Manage Risk Through Product Stewardship Reviews, 84 (Chemical Engineering, January 1995), and Adam Stone, The Delicate Balance of Stewardship: The Case of the Chemical Industry's Response Care Program. Center for Nuclear and Toxic Waste Management, University of California, Berkeley, May 1996.

[10] See Nuclear Materials Stewardship Policy Review Workshop, Lawrence Livermore National Laboratory, Livermore, CA , October 27-29, 1996, esp. Thomas Issacs, "National Nuclear Materials Stewardship: A Possible Framework", and Robert Alverez, "Rethinking the Challenge: The Stewardship of Radioactive Materials."

[11] Long-Term Stewardship and the Nuclear Weapons Complex, Center for Risk Management, Resources for the Future, January 1997, p.1.

Let us attempt a fuller measure of the task that is set out. In addition to the familiar challenges of planning, resource estimation and management coordination (a discussion left for another time), we shall consider a broader perspective, along with a modest explication of the notion itself, which can provide rough objectives for more detailed institutional design profiles or specifications.

The challenge of long term management, when it is considered at all, has predominately been from the view of managers looking, so to say, from "the inside looking out." That is, managerial folk puzzling the questions of the magnitudes of the hazards and operational problems -- as seen primarily from the agency vantage -- that might warrant taking up such a remarkable discussion. It is clear that in things nuclear the magnitude of hazards is very considerable, and that "managing" many of these hazards will often require mainly passive monitoring, while others will include operating in a sustained, highly reliable fashion for many, many years.[13] These problems demand quite unusual efforts, even as there are some who contest the justice of the implicit costs and institutional efforts implied.[14]

An initial management point of view is understandable, given the sense of urgency many citizens and environmental leaders feel. **Let's get on with the job**! -- even as those involved must confront short term budget cycles, political instability, and the difficulties and frustrations of doing the public's business in the current problematics of advanced industrial society. Indeed, these would have to become important elements in considering institutional and technical design. But additional design concerns arise from another perspective -- one I wish to emphasize here -- that of able outsiders, members of the public who find themselves potentially in this stewardship relation.

These design concerns stem from the apparent *obligations taken on by institutions that assert a claim to become the dominant partner in a stewardship* (or a guardian) *relationship*. That is, what expectations are likely to be levied by the public and its spokespersons upon institutions claiming to be engaged in a stewardship relationship regarding its functions on behalf of current and future generations?

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12 Suggested by Jonathan Medialia.

13 US DOE, Estimating the Cold War Mortgage: The 1995 Baseline Environmental Management Report, 1995.

14 See for example, Arjun Makhijani and Scott Saleska, High Level Dollars, Low-Level Sense: A Critique of Present Policy for the Management of Long-lived Radioactive Waste and Discussion of an Alternative Approach. Takoma Park, MD: Institute for Energy and Environmental Research, 1992.

## An Excursion in Definition.

A first step to understanding these expectations requires tighter specification. What does "institutional stewardship" come to mean? A cryptic summary of the accepted meaning of stewardship per se reveals something of the depth of the challenge. Readers should listen, in their inner ear, for the institutional implications of these definitions which have been forged on the basis of individual or small group relationships in the past.

**Stewardship** involves a relationship between two or more parties such that one, the steward, "is entrusted (by another) with the management of property, finances or other affairs not his/her own", (that is, in the interest of someone or corporate entity that is not willing and/or capable of carrying on independently, as someone yet unborn, *my addition.*)[15]

It could include the function of **Guardian**; "One who guards or watches over something; … who is legally assigned to care of the person or property, esp. of an infant or minor (as in someone who does not have the capacity confidently to carry on independently, or for future generations my addition.) and/ or ..[Guard, v.t. 1)] To watch over or care for; protect; 3) To control or prevent exit or entry through. 4) To maintain cautious control over. 6) To take precautions; as followed by against. . . . .[16]"

Stewardship also connotes a **Fiduciary** (relationship) in which "One … holds something in trust; acting as a trustee, hold in trust."

Repeatedly, stewardship, guardianship, fiduciary, relationship rests *significantly on the underlying strength of trust in the person involved* -- to entrust, hold in trust. One person is trusting another to be, on their behalf, a faithful steward, a trustee.

Recall how interpersonal **Trust** is usually understood: It is "confident reliance on the integrity, honesty or justice of another, faith" (as one who is/maybe vulnerable, my addition.); again, something committed to one's care; or 3) (entrusted) The state or position of one who has received an important charge; and finally , for our purposes; 4)

[15]Funk and Wagnell, 661.
[16]Funk and Wagnell, 285.

confidence in the reliability of persons or things *without careful investigation*....[17]

However, trust in a steward is not a trust generalized to all activities; rather stewardship concerns attention to a specific, reasonably limited range or scope. But the *choice* of steward or guardian is bracketed by the vulnerable person's perception of a wide array of behaviors and actions that signal great integrity and trustworthiness of the steward chosen.

This short exercise in definition calls out the meanings of relationships that have been worked out , for good or ill, between individuals throughout the centuries. It is the relationship of persons, say parents, to someone whom they trust to be a faithful steward managing resources on behalf of their children, perhaps their grandchildren. It is usually a relationship carefully considered by the "stewardee" (or sometimes the courts on his/her behalf) with earnest regard for the welfare of those in a contingent future.

Yet these qualities are being sought (or claimed) in the relationships between public institutions and a society's citizens now and in future generations. It is an institution, a collective, that takes on a steward's role.[18] An expected evolution in such an extraordinary outcome would be that, after public debate, the nation's elected leadership, on behalf of the public, turns to an agency or perhaps proposes a new one, charging it with the grave function of the faithful management of a demanding, long term mission.

But, in the case at hand, the situation is reversed. It is the *agency* (DOE) that stakes a claim to become a steward on behalf of others in the society … with an ambiguous mandate, so to say. This stewardship relationship, then, would be different from the conventional in two ways: first, it must be worked out institutionally, through the engaged behavior of a collectively not just a single person; and second, the putative Steward initiates the claim to take up that role. This suggests an analytical expansion to intra-organizational perhaps inter-organizational behaviors. It is a wider range of considerations that is usually taken in such discussions and a review of what the claimant should be

[17] Trust, n. In addition to these meaning, it connotes: 2) Something committed to one's care. 3) (entrusted) The state or position of one who has received an important charge. 7) Law. a) The confidence, reposed in a person to whom the legal title to property is conveyed for the benefit of another. . . . (connotes fiduciary relationship.) b) Property held in trust [8,9 legal terms] 10) One who or that which is trusted. 11) Confident expectation; belief, hope. As to trust, v.t. 1) To have trust in, rely upon. 2) To commit to the care of another, entrust. 3) To commit something to the care of. 4) To allow to do something without fear of consequences. 5) To expect with confidence of which hope. 6) To believe. Or entrust (F&W, 212) v.t. 1) To give over (something) for care, safekeeping, or performance. 2) To place something in the care or trust of. Funk and Wagnell, 212.

[18] A short note on the meanings of "institution." This term is being used here in to include "institution as organization," "institution as agency," and "institution as formal legal arrangements" in the interest of a society's

obliged to do.

What, then, are able members of the public being asked to accept by this self-nominated public steward, whether it is DOE, DOD, EPA, their contractors, or some specifically established institution?

> **To entrust to this steward the obligation to manage often very hazardous activities requiring highly reliable operations for many (management and political) generations**.

The agent, in effect, is asserting that the public should entrust these matters to it -- apparently on the assumptions that:

- it (the agent, along with its contractors) can assure very skilled, highly reliable operations and exhibit institutional constancy for many generations -- in the face of unknown contingencies, and that
- it (along with its contractors) is worthy of such trust and confidence and will continue in that highly desirable condition for many years to come.

Public Trust and Confidence become the root bases for engaging in a such a stewardship relationship, a relationship in which technical operators in effect shoulder the obligation to perform at an extraordinarily high level year after year - that is to exhibit a steward's institutional trustworthiness. Put somewhat differently: The institutional design challenge is to structure institutional processes and incentives in such ways that they will assure: **highly reliable operations**, over the **very long term** in the context of continuously high levels of **public trust and confidence**.

I take these requisite design outcomes in order.[19] They are the challenges of:

1) establishing and maintaining highly reliable organizations (HROs),[20]

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governance, e.g., a legislature or courts.

[19] It is notable that there are only scant analytical bases for confident institutional design in each of these areas. For pointers to what is extant, see the references in notes 22-24. Subsequent discussion is drawn importantly from them. See an extended bibliography on each in the appendix.

[20] See T.R. La Porte, 1996. "High Reliability Organizations: Unlikely, Demanding and at Risk," Journal of Crisis and Contingency Management, 4,2 (June), 60-71; T.R. La Porte and P.M. Consolini, 1991 "Working in Practice but not in Theory: Theoretical Challenges of High Reliability Organizations," Journal of Public Administration Research and Theory, 1,1 (January), 19-47; and K. Roberts, 1989. "New Challenges to Organizational Research: High Reliability Organizations", Industrial Crisis Quarterly, 3, 111-125.

2) over times periods of at least five to ten management generations (say, 50 to100 years) which calls for extraordinary institutional constancy,[21] that is, organizational perseverance and faithful adherence to the mission and its operational imperatives, and
3) assuring organizational conditions and operations that indicate to potentially suspicious citizens that the program is continuously worthy of the public's trust.[22]

## 1. Stewardship and Highly Reliable Operations.

Systematically meeting the challenge of highly reliable operations in face of hazards has been demonstrated in enough to cases to gain a rough sense of the conditions which seem to associated with extraordinary performance. These include both internal processes and external relations. What can be said with some confidence? [23] What qualities do stewards claim they would exhibit?[24]

1) <u>Internal Processes</u>.[25]
   a) <u>Organizationally defined intention.</u> HROs exhibit a strong sense of mission and operational goals stressing both the objectives of providing ready capacity for production and service and equal commitment to reliability in operations backed up by a readiness to invest in reliability enhancing technology, processes and personnel resources. And, in cases such as our reference nuclear case, there is strongly re-enforced by a clear understanding that the technologies upon which the organizations depend are intrinsically hazardous in their design and potentially dangerous to human and other organisms. It is notable that for nuclear

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[21] See T.R. La Porte and A. Keller, 1996. "Assuring Institutional Constancy: Requisites for Managing Long-Lived Hazards" Public Administration Review, 56, 6 (November/December 1996), 535-544.

[22] See U.S. DOE 1993. Earning Public Trust and Confidence: Requisite for Managing Radioactive Waste. Report of the Task Force on Radioactive Waste Management, Secretary of Energy Advisory Board, (Nov.); and T.R. La Porte and D. Metlay 1996, "Facing a Deficit of Trust: Hazards and Institutional Trustworthiness," Public Administration Review, 56, 4 (July-Aug. 1996), 341-347.

[23] Highly reliable operations may become a keenly sought goal for situation which are not so dramatically hazardous in the physical sense, e.g., HRO operations in financial transactions, or in the performance of sophisticated computer chips or large software programs. See K.H. Roberts, K.H., and C. Libuser, C. (1993) "From Bhopal to banking: Organizational design can mitigate risk." Organizational Dynamics, 21, 15-26.) In these situations, motivation stems from fear of serious losses which that are seen as amounting to institutional not physical death.

[24] Caution should be taken in drawing generalized inferences from this discussion. These "findings" are based mainly on three types of organizations each with a limited number of cases, with bits from others (e.g., K. H. Roberts, (1993) "Some aspects of organizational cultures and strategies to manage them in reliability enhancing organizations." Journal of Managerial Issues, 5, 165-181). Though they operate in quite different institutional milieu, we cannot say they represent a systematic sample. No one now knows what the population of HROs might be.

[25] This section draws strongly on Roberts, K.H. (1990) "Some characteristics of high reliability organizations' Organization Science, 1(2), 160-177; op. cit.; Rochlin, 1993, op. cit.; P. R. Schulman, (1993). "Negotiated Order of Organizational Reliability," Administration and Society, 25, 3, (November), 356-372; La Porte and Consolini, op. cit.;

oriented institutions within the U.S., there is also high tacit agreement within the organizations and in the society at large about the seriousness of failure, and its potential costliness, as well as the value or benefits of what is being produced (in terms usually of a combination of economic, political or military outcomes.) This consensus is a crucial element underlying the achievement of high operational reliability, and has, until recently, increased the assurance of relatively sufficiently resources needed to carry out failure-preventing/ quality enhancing activities. It also serves to stiffen corporate or agency resolve to provide the organizational status and financial and personnel resources such activities require. But resolve is not enough. Evidence of cogent operations is equally crucial.

b) Reliability Enhancing Operations. These include the structural and operational dynamics that arise when extraordinary performance must be the rule of the day, re-enforced by an organizational culture of reliability, i.e., the norms and work ways of operations.[26] A dominant quality of organizations seeking to attain highly reliable operations is their intensive technical and social interdependence. Characterized by numerous specialized functions and coordination hierarchies, this prompt patterns of complexly related, tightly coupled technical and work processes which shape HROs social, structural, and decisional character.[27]

HROs' social character is, of course, typified by high technical/professional competence and technical knowledge of the system, and demonstrated high performance and awareness of the system's operating state.

(i) Extraordinary technical competence almost goes without saying. But it bears repeating because continuously attaining this quality requires close attention to recruiting, training, staff incentives, and ultimately the authority relations and decision processes among operating personnel who are, or should be, consummately skilled at what they do. This means there is a premium on recruiting members with extraordinary skills and/or an organizational capacity to develop them in situ via continuous training and an emphasis on reliable knowledge of the fundamentals of the operating system. Maintaining high levels of

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and Rochlin, La Porte and Roberts, op. cit.

[26] Weick, K.E. (1987) ‘‘Organizational culture as a source of high reliability,’’ California Management Review, 29, 112-127; Roberts, K.H. (1993) “Some aspects of organizational cultures and strategies to manage them in reliability enhancing organizations.” Journal of Managerial Issues, 5, 165-181.

[27] C. Perrow, Normal Accidents: Living With High-Risk Technologies, (1984) New York: Basic Books; K.H. Roberts, K.H. and G. Gargano, G. (1989) “Managing a high reliability organization: A case for interdependence,” in M.A. Von Glinow and S. Mohrmon, (Eds.) Managing complexity in high technology industries: Systems and people. New York: Oxford University Press, 147-159; La Porte and Consolini, op. cit.; Rochlin, 1993, op. cit.

competence, and professional commitment also means a combination of high organizational status and visibility for the activities that enhance reliability, and positions with ready access to senior management. This is illustrated in aircraft carrier operations where high ranking officers are assigned the position of Safety Officer reporting directly to carrier Captains.

(ii) HRO's also continuously achieve high levels of operational performance accompanied by stringent quality assurance (QA) measures in maintenance buttressed by procedural acuity.[28] Extensive performance data bases track and calibrate technical operations and provide an unambiguous description of the systems' operating state. These data inform reliability statistics, quality control processes, and accident modeling, and interpretations of system readiness from a variety of perspectives, and often provides the basis for competition between groups formally responsible for safety.[29]

HROs' operations are enabled by structural features characterized especially by flexibility and redundancy in pursuit of safety and performance, and overlapping or nested layers of authority relationships.

(iii) Operating complex technologies is not only often hazardous, it is also done within quite contingent environments. Effective performance calls for flexibility and 'organizational slack' (or reserve capacity) to insure safety and protect performance resilience. Such structural flexibility and redundance is evident in three ways: Key work processes are designed so that there are often parallel or overlapping activities that can provide backup in the case of overload or unit breakdown, and operational recombination in the face of surprise; operators and first line supervisors are trained for multiple jobs via systematic rotation; and jobs and work groups are devised in ways which limits the interdependence of incompatible functions.

(iv) Patterns of formal authority in large organizations are likely to be predominately hierarchical (though this may have as much an adjudicative functions as a directive ones).

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[28] Schulman, op. cit.; M. Bourrier, M. (1996) "Organizing Maintenance Work at Two American Nuclear Power Plants", Journal of Crisis and Contingency Management 4, 2 (June), 104-112.

29 T. R. La Porte, and C. Thomas (1994) “Regulatory Compliance and the Ethos of Quality Enhancement: Surprises in

And these patterns are present in HROs as well, to be seen most clearly in times of routine operations. But two other Anested or overlaid' authority patterns also evident - emerging in extraordinary times. Exhibited by the same participants who, during routine times, act out the roles of rank relations and bureaucrats, another pattern of collegial, skilled and functionally based authority relationships takes form as the tempo of operations increases. And, nested within or overlaid upon these two are yet another well practiced, almost scripted relationships that are activated during times of acute emergency. As these different situations arise, communication patterns and role relationships are altered to integrate the skills and experience apparently called for by the particular situation.

Within the context of HROs' structural properties, decision-making dynamics are flexible, dispersed among operational teams, and include rewards for the discovery of incipient error.

(v) Decision making within the shifting authority patterns, especially operating decisions, tends to be decentralized to the level where actions must be taken. Tactical decisions often develop on the basis of intense bargaining and/or collegial interaction among those whose contributions are needed to operate effectively or problem solve. Once determined, decisions are executed often very quickly with little chance for review or alteration.[30]

(vi) Due in part to the irreversibility of decisions once enacted, HROs put an unusual premium on increasing the likelihood that decisions will be based on the best information available, and that their internal technical and procedural processes, once put in motion, will not become the source of failure. This leads to more or less formalized efforts, continually to search for improvement via systematic gleaning of feedback, and the conduct of program and operational review. These are frequently conducted by internal groups formally charged with searching out sources of potential failure as well as improvements or changes in procedures to minimize the likelihood of failure. On occasion, there are several groups structured and rewarded in ways that puts them in competition with each other in

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Nuclear Power Plant Operations," Journal of Public Administration Research and Theory. 5, 4 (December): 250-295.
30 Roberts, 1992, op. cit.; Schulman, op. cit.

discovering potential error, and, due to their attachment to different levels of reporting levels of the management hierarchy, encourage the quick forwarding of information about potential error to higher authority.[31] Notably, these activities, due to their intrinsic blame putting potential, is often sought by upper management in a wide variety of organizations, but are rarely conducted with much enthusiasm. In response, HROs exhibit a quite unusual willingness to reward the discovery and reporting of error, without at the same time pre-emptorially assigning blame for its commission. This obtains even for the reporting of one's own error in operations and procedural adherence. The premise of such rewards is that it is better and more commendable for one to report an error immediately than to ignore or to cover it up.

c) Organizational Culture of Reliability.

Sustaining the structural supports to reliability and the processes which increase it are additional demands in the already intense lives of those who operate and manage large scale, advanced technical systems. Operating effectiveness calls for a level of personal engagement and attentive behavior that is unlikely merely on the basis of formal rules and economic employee contracts. It requires a much more fully engaged person responding to norms of individual and group relations which grow out of the particular demands and rewards of the hazardous systems involved.[32] For lack of a better concept to capture these phenomena, let us accept the slippery concept of "organizational culture" as a rough ordering notion.[33] A cultural of organizational reliability refers to the norms, shared perceptions, work ways and informal traditions that arise within the operating and overseeing groups closely involved with the systems of hazard.[34]

Recall that HROs, strive equally for high levels of production and safety.[35] HROs face the challenge of being reliable both as producers (many under all manner of demanding conditions) AND as safety providers

[31] La Porte and Thomas, op. cit.

[32] Weick, 1987, op.cit.; Roberts, 1993, op. cit.

[33] The concept of organizational culture is both attractive, for it captures sense that there are norms, values and "taken for granted" modes of behavior and perceptions that shape interpersonal and group relations. At the same time, the concept retains a reasonably high degree operational ambiguity, its use subject to stiff criticism (Ott, 1989; Roberts, 1989.; G. I. Rochlin, G. I. (forthcoming) ‘‘Highly Reliable Organizations: Past Research and Future Explorations,’’ in M. Bourrier, ed., Organization Approaches to Organizational Reliability, from a conference by the same name Department Technologies et Sciences de l’Homme, Universite de Technologies de Compiegne, Compiegne, France, Oct. 7,1999.

[34] Roberts, 1990, op. cit.; Rochlin and von Meier, op. cit.

[35] cf. Rochlin, 1993,op. cit.; Schulman, op.cit.

(under conditions of high production demands.) While most organizations combine vary degrees of production plus service/safety emphasizes, HROs have continuously to strike a balance; in times of routine safety wins out formally (though watchfulness is harder to sustain), in times of high tempo/surge this becomes reordered (though watchfulness is much more acute.) This suggests an organizational culture integrating the familiar norms of mission accomplishment and production with those of the so-called safety culture.[36]

Elements of the results are: operator/member elan; operator autonomy; and intrinsic tension between skilled operators and technical experts.

- Operating personnel evince an intense elan and strongly held expectations for themselves about the value of skilled performance. In the face of hazard, it takes on a kind of prideful wariness. There are often intense, peer group pressures to excel as a highly competitive team, and to cooperate with and assist each other in the face of high operating demands. This includes expectations of fulfilling responsibilities that often go well beyond formal role specifications. For example, there is a view that 'whoever spots a problem, owns it' until it is mitigated or solved in the interest of full, safe functioning. This sometime results in operators realizing that, in the face of unexpected contingencies, they may have to 'go illegal', i.e., to go against established, formal procedures if these SOPs appear to increase the difficulty of safely meeting the service demands place of the organization. Operator elan is re-enforced by clearly recognized peer group incentives that signal high status and respect, pride in one's team, emphasis on peer 'retention' and social discipline, and reward for contributing to quality enhancing, failure preventing activities.
- Hazardous operations are often time critical, as well as dependent on keen situational awareness, in situations where it becomes clear that speedy, decisive action must be taken, with little opportunity for assistance or approval from others. Partly as a result, HRO operators come to develop and insist upon a high degree of discretion, autonomy, and responsibility for activities 'on their watch'.[37] Often typified as being 'King of my turf,' this is seen as highly appropriate by both other operators and supervisors.
- But operator autonomy is often bought at a moderate price. Those HROs that have been studied all

[36] cf. Weick, 1987, op.cit.

[37] K.H. Roberts, D. M. Rousseau, and T.R. La Porte (1994) “The culture of high reliability: Quantitative and qualitative assessment aboard nuclear powered aircraft carriers.” Journal of High Technology Management Research. 5, 1 (Spring) 141-161.

> operated complex technical systems that put a premium on technical engineering knowledge as well as highly skilled operating knowledge and experience. These two types of skills are usually formally distinguished in the occupational roles designations within HROs. Each has a measure of status, each depends on the other for critical information in the face of potential system breakdown and recovery if problems cannot be contained. But in the operators eyes, they have the ultimate responsibility for safe effective operation. They also have an almost tactile sense of how the technical systems actually function in the organization's operating environments which is likely to be more situationally refined and intuitively more credible that the more abstract, cognitively based knowledge possessed by engineers. The result is an intrinsic tension between operators and technical experts, especially when operators judged technical experts to be distant from actual operations where there is considerable stress placed on tacit knowledge of system operations based on experience.[38]

These dominant work ways and attitudes about behavior at the operating levels of HROs, are prompted by working in operations that are closest to the hazards, and suggest the important affective nature of HRO operations. These patterns provide the basis for the expressive authority, and identitive compliance norms that sustain the close cooperation necessary when facing the challenges of unexpected high tempo/high surge situations with minimum internal harm to people and capital equipment. But HRO’s operate in the context of many interested outsiders: sponsors, clients, regulators, and surrounding neighborhoods. Relations with outside groups and institutions also play a crucial role.

2. External relationships.

HRO performance is clearly dependent on extraordinarily dense patterns of cooperative behavior within the organization. These are extensive, quite intense, and unusual both in terms of achieving continuous reliability and in higher costs. As such they are difficult to sustain in the absence of external re-enforcement. Continuous attention both to achieving organizational missions and to avoiding serious failures requires sustained interaction with elements in the external environment, not only to insure resources, but, as importantly, to support the internal management resolve to maintain the internal relations outlined above and to nurture HROs' culture of reliability. These characteristics are perhaps the most important of all the properties of HROs without which the

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[38] G .I. Rochlin, (1999) “Safe operations as a social construct,” Ergonomics, 42, 11, 1549-1560; G. I. Rochlin and A. von Meier. (1994) “Nuclear Power Operations: A Cross-Cultural Perspective,” Annual Review of Energy and the Environment. 19, 153-187.

rest are difficult to achieve and sustain. Generically termed, the 'Watchers,' they include externally situated, independent public bodies and stake holding interest groups, the processes assuring their presence and efficacy, and development of tools for the external monitoring in the interest of hazard evaluations.

Aggressive, knowledgeable 'watchers' increase the likelihood that reliability enhancing operations/investments will be seen as legitimate by corporate and regulatory actors, and the view that such costs should be incurred and that regulations and internal social demands should be allowed in the interest of safety. This may mean investing, on one hand, in the developing and training external review groups, and some instruments of behavioral surveillance, e.g., random drug tests, and, on the other, assuring that HRO leaders will be held quickly accountable for changes that could reduce reliability in service or safety.

These watching groups may be either formal or informal and are found both within the HRO's immediate institutional environment and outside it. It is crucial that there be clear institutional interests in highly reliable performance. This would be evident in strong super-ordinate institutional elements of the parent organization, such as Corporate or Command level officers (e.g., utility corporate headquarters, higher military command, Washington agency headquarters) and sometimes industrial association watchdogs (e.g., the nuclear industry's Institute for Nuclear Power Operators, INPO.[39]

At the same time, the strong presence of external stake holding groups assure attentiveness (if not occasional resentment.) These groups range from some quite formal public watchers, such as regulatory overseers (e.g., state PUCs, NRC, EPA, FEMA, and OSHA), and user, client groups, (e.g., instrument rated pilots using air traffic control services and Congress persons) to a wide sweep of 'public intervenors', (e.g., state, local governments, land use advocates, and citizen interest groups.) Finally, there is the important function played by professional peer bodies, and HRO alumni who represent operationally knowledgeable observers who are accorded respect both by other outsiders and by HRO operators themselves.

An abundance of external watchers seem crucial in attaining continuous, high reliably operations. Equally important in assuring their effectiveness in re-enforcing the culture of reliability are boundary spanning processes through which encouragement and constraints are exercised in the interest of product/safety reliability. Two types are evident. First, there are formally designated positions and/or groups who have oversight responsibilities. Two examples of formalized channels are the two or three Nuclear Regulatory Residents assigned to each nuclear power plant who have nearly complete access to power plant information, review meetings, etc., or the military liaison officers who are permanently assigned to air traffic control centers. Sometimes these boundary spanning activities are expressed in aircraft carriers operations via dual reporting requirements for nuclear engineering officers to

[39] T. Rees (1994) Hostages to each other. Chicago: University of Chicago Press.

report problems immediately, not only to the ship's Captain, but to a central nuclear affairs office at Naval Headquarters in Washington, as well.

Boundary spanning, and with it increased transparency, also occurs intermittently in the form of formal, periodic visits from 'check' or review groups that exercise powerful sanctions if the reviews do not measure up. These activities come in a number of forms, for examples phased inspections and training checks in aircraft carrier combat preparations, as well as the more familiar Inspector General reviews; and nuclear power utilities requirements to satisfy rigorous performance in responding to the NRC mandated, biannual activation of power plant emergency scenarios in which all the relevant local and state decision makers engage in a day long simulation leading to possible regional evacuation under the watchful eye of NRC and FEMA inspectors.[40]

Finally, external watchers, however will provided with avenues of effect, must have available full, credible, and current information about system performance. This almost goes without saying, but it is a requirement, often in the form of annual evaluations, hazard indices, statistical summaries noted above, and indicators of incipient harm and the early on-set of danger that become a basis for insightful reviews and public credibility (see below).

This is a formidable array of conditions for any organization to seek or sustain for the short term (see Table 1 near the end of the paper for this full array in combination with others discussed below ), to what degree would they suffice for the long term?

## 2. Assuring Institutional Constancy and Faithfulness in the Future.[41]

Many highly reliable organizations operate systems whose full range of positive and negative outcomes can be perceived more or less immediately. If there is full disclosure of failures as well as successes, organizational leaders can be rewarded or held accountable. But when operating systems are also capable of large scale and/or widely

[40] La Porte and Thomas, op. cit.

[41] This section draws from major portions of T.R. La Porte and A. Keller (1996) "Assuring Institutional Constancy: Requisite for Managing Long-Lived Hazards". Public Administration Review. 56, 6 (November/ December) 535-544. It is also strongly informed by my work at LANL exploring the organizational challenges posed for the laboratory by the missions of “science based stockpile stewardship (of nuclear weapons)”, “ nuclear materials stewardship,” and sometimes “environmental stewardship.” While the operations of the first two contrasted to the latter are very different, the challenges provoked by the longevity of the materials involved prompt very similar organizational puzzles. See also a similar rendering in T.R. La Porte. (1999) “Highly Reliable Operations and the Rigors of Sustained Legitimacy: Matters of Public Trust and Institutional Constancy,” presented to the workshop on “Organization Approaches to Organizational Reliability”, Department Technologies et Sciences de l’Homme,

distributed harm which may not occur or be detected for several generations, our familiar processes of accountability falter, and the public is rightly concerned that HROs and their regulatory overseers be worthy of the public's trust across these generations. Stewardship in the domains of interest here, especially the management of nuclear materials, can be expected to continue for at least a 50 to 100 years, perhaps centuries. This suggests a remarkably long period of *institutional constancy*, i.e., the faithful adherence to a mission and its operational imperatives in the face of a variety of social and institutional environmental changes. A requirement to take into account the trans-generational nature of nuclear systems presents particularly troublesome challenges for managers and for students of organization as we come to understand the nature of large scale systems and the longer term effects of their production technologies.[42] At the same time, it is the aspect of highly reliable operations about which the social sciences have the least to say. {Indeed, this is one of the most compelling reasons why the UCB/LANL project was initiated.}

As a partial remedy to this analytical deficit, I propose below a concept of "institutional constancy," and a suite of organizational conditions that become the foundation for sustained institutional stewardship, especially when they are achieved within the context of highly reliable operations noted above, and sustained public trust and confidence discussed in the next section. More formally, institutional constancy refers to "faithful, unchanging commitment to, and repeated attainment of performance, effects, or outcomes in accord with agreements by agents of an institution made at one time as expressed or experienced in a future time."[43] It includes assuring continued or improved performance in the spirit of the original agreement as new information, technology, or changed conditions develop. An organization exhibits constancy when, year after year, it achieves outcomes it agreed in the past to pursue.[44]

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Universite de Technologies de Compiegne, Compiegne, France, Oct. 7-8.

[42] Two of five conditions which increase the demands for constancy do so for they undermine our typical means of assuring accountability, and are sometimes characteristics of hazardous technical systems. They are: 1) when the information needed to provide unequivocal evidence of effects is so extensive and costly that the public comes to expect that it will not be forthcoming, and 2) if harmful effects occur, they are not likely to be known for some time into the future due to the intrinsic properties of the production processes and their operating environments. While our minds' eye turns quickly to public organizations, the argument applies with nearly as much force to the private sector in the U.S., especially those firms responding to the strong economic incentives for short term gain and deferral of costs. (See note x for a listing of the other three conditions.)

[43] T.R. La Porte and A. Keller, op. cit.

[44] Think, for example, of FAA's air traffic control operations, together with air carriers. They have consistently achieved high level of flight safety and traffic coordination in commercial aviation and flight operations at sea. And the nuclear navy has consistently achieved high levels of safety aboard nuclear submarines; and electrical utilities have achieved remarkably high levels of availability of electrical power. Great universities exhibit constancy in commitments to intellectual excellence generation after generation through producing very skilled undergraduates and professionals as well as path breaking research.

Conditions Encouraging Institutional Constancy.[45]

What little systematic examination of this remarkable intention there has been suggests that institutional constancy requires demonstrating to the public or its major opinion leaders that the HRO in question (an agency, public contractor or firm) can both be *trusted to keep its word* -- to be steadfast -- for a very long time into the future, and to show the capacity to *enact programs that are faithful to the original spirit of its commitments*.[46] The first set of conditions speaks to the assurance of continued political and institutional will, steadfastness in "keeping the faith," the second speaks to the organizational infrastructure of institutional constancy, i.e., the capacity to follow through for many years. I turn to these in order.

Institutional Purpose. Constancy is about future behavior and the organization must signal its collective resolve to persist in its agreements, especially with strong commitments to trusteeship and stewardship in the interests of future generations. Measures that re-enforce this perception are:

- The necessary formal, usually written goal of unswerving adherence to the spirit of the initial agreement or commitment; documents that can be used in the future to hold each generation's organizational leaders accountable for their actions.
- Strong, public articulation of commitments to constancy by high status figures within an agency or firm, calling especially on professional staff and key labor representatives to emphasize the importance of constancy. Coupled with formal declarations, consistent emphasis upon steadfastness within an organization re-enforces the otherwise difficult commitments of energy and public witness that is needed by key members of the technical staff and work force.
- Strong evidence of institutional norms and processes that nurture the resolve to persist across many work generations, including, in the public sector, elements in labor contracts that extend over several political generations.[47] When these exist, it binds workers and their leaders to the goals of the agency

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45 Note there are strong analytical and practical limitations to attaining institutional constancy over many generations, especially: a) weak analytical bases for confidently predicting the outcomes of institutional activities over long periods of time; b) limited means to re-enforce or reward generations of consistent behavior; and c) scanty knowledge about designing institutional relationships that improve rather than degrade the quality of action taking in the future that is faithful to the spirit of present commitments and agreements. Incentives to improve conditions which would assure constancy of institutional are scant. And so is interest in analysis which would improve our understanding of institutional and administrative design. Indeed, there is almost nothing insightful in the literature about increasing institutional inertia or constancy. It is still an analytical puzzle.

46 While these two qualities are closely related, one can imagine succeeding at one without achieving the other. A HRO might be able to persuade the public that it was firmly committed to certain objectives but actually turn out to be in no position to realize them. Conversely, a HRO could very well be situated, motivated, and structured to carry out its commitments for years to come, but be unable to convince the public of its steadfastness.

47 This point is akin to the arguments made classically by P. Selznick, Leadership in Administration. (1957) New York: Harper & Row, and J. Q. Wilson, Bureaucracy, op cit. 99-102, about the importance of institutional leadership and the character of the organization's sense of mission.

often transcending a number of management generations.

- Vigorous external re-enforcement from both regulatory agencies and "public watching" groups to assure that the institutions involved will not flag in attending to performance requirements from generation to generation. This would include the support for outside groups with regular formal involvement, and resources to foster their expectations and demands for consultation if the next generation of leaders waiver in their resolve. The optimum would be when these measures lead to laws, formal agreements, and foundation/non-governmental organization funding and infrastructure for continual encouragement and sanctions for "keeping the faith."

- The Infrastructure of Constancy: While strong motivation and earnestness are necessary, they alone do not carry the day. Other conditions should also be present to assure that actions can be carried out in realizing important commitments across multiple generations. These include:
- Administrative and technical capability and infrastructure needed to carry out activities that assure performance, along with agency/firm rewards and incentives for articulating and pursuing measures that enhance constancy and inter-generational fairness. These should include executive socialization and training processes to re-enforce commitment and perspectives. Such processes and resources are rarely provided in today's institutional environments which are characterized by quite short term, generation centric perspectives re-enforced by contemporary business and legislative cycles.
- In addition to assuring consistency in organizational culture, resources and activities needed to "transfer" or "pass on" the organization's critical operating, technical, and institutional knowledge from one work and management generation to the next is crucial. This includes systematic capture of critical skills and operating histories, as well as continuous training and evaluation of each generation's capabilities.
- Analytical supports to analysis and decision making that takes into account the interests of the future and enables work, such as "future impact analyzes," that attempts to clarify the effects of present action on future experience. This is likely to require at least a small cadre of highly skilled professionals, systems for rewarding their efforts and organizational and agency venues where their reflections will have a respected voice.
- And perhaps most importantly, evident and effective capacity to detect the early on-set of likely failures related to the activities that could threaten the future. This capacity should then be joined with a capacity to initiate a remedy, along with the assurance of remediation resources in the event failures should occur.[48]

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[48] See for example T. R. La Porte, and C. Thomas (1994) "Regulatory Compliance and the Ethos of Quality Enhancement: Surprises in Nuclear Power Plant Operations," Journal of Public Administration Research and Theory.

> Without a reasonably high degree of publicly aware capacity for early warning and pre-emptive remediation, the public is likely to remain skeptical, potentially suspicious, and ripe for mobilization into recalcitrant opposition.[49]

This suite of conditions under-girding a sense of institutional constancy is a pretty demanding and costly set. Considering developing them would be contingent upon their need. Three conditions (in addition to the two already mentioned) prompt a demand for constancy. It is sought by public and political movements when the work of the agency and organizations involve are seen a) as engaged in a large scale efforts whose activities may occur across broad spatial and temporal spans, and seem to pose potentially irreversible effects; b) when these effects are also seen as hazardous, (even if the likelihood of failure is small and accompanied by substantial gains for the program's prime beneficiaries); and c) if significant risks and their costs are likely to be borne by future generations who receive little benefit.

This third condition raises a particularly difficult dilemma. Should current populations endure costs today so that future populations will not have to?[50] Uncertainty about the knowledge and technological capacity of future generations exacerbates the problem. An optimistic view assumes that difficult problems of today will be more easily solved by future generations.[51] Skepticism about this, however, makes it an equivocal basis for proceeding with multi-generational programs. An inherent part of assuring constancy would be an agreed upon basis C an ethic C of how costs and benefits should be distributed across generations. This is especially true when operational effects extend far into the future, for it demands that generation after generation respond to new information and

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5, 4 (December): 250-295. Cf. K. Shrader-Frechette (1993) "Risk Methodology and Institution Bias", Research, in Social Problems and Public Policy. 5, 207-223; and L. Clarke (1993) "The Disqualification Heuristic: When Do Organizations Misperceive Risk?" Research in Social Problems and Public Policy. 5, 289-312, for discussions of the conditions that result in operator mis-perception of risk; conditions that would require strong antidotes if constancy is to be assured.

[49] This seems clearly the case in the political and legal travail experienced by the Department of Energy for a number of years. See U.S. DOE 1993. Earning Public Trust and Confidence: Requisite for Managing Radioactive Waste. Report of the Task Force on Radioactive Waste Management, Secretary of Energy Advisory Board, (Nov.).

[50] See, for example, R. M. Green (1980) "Inter-generational Distributive Justice and Environmental Responsibility," in E. D. Partridge, ed., Responsibilities to Future Generations: Environmental Ethics, Buffalo: Prometheus Books; R. Howarth (1991). "Inter-generational Competitive Equilibria Under Technological Uncertainty and an Exhaustible Resource Constraint," Journal of Environmental Economics and Management, 21: 225-243; B. Norton (1982). "Environmental Ethics and the Rights of Future Generations," Environmental Ethics, Winter : 319-338; and P. Wenz (1983). "Ethics, Energy Policy, and Future Generations." Environmental Ethics, 5: 195-209.

[51] For comment of how responsibility should be divided between generations that accounts for changes in knowledge, see, W. Halfele. (1990) "Energy from Nuclear Power," Scientific American. 263, 3 (September): 136-144; and C. Perrings (1991) "Reserved Rationality and the Precautionary Principle: Technological Change, Time and Uncertainty in Environmental Decision Making," in R. Costanza, ed., Ecological Economics: The Science and

changing value structures in coping with long-term effects.

This array of conditions, along with those associated with highly reliably operations, raises serious, unresolved operational, political and ethical questions. If an organization's program is seen to possess them in combination, *assurances of institutional constancy are likely to be demanded as a substitute for accountability.* In consequence, apprehensive publics seek assurances that these institutions will be uncompromising in the pursuit of highest quality operations through the relevant life times of the systems in question. This means that the quality of both external relations and internal operations should re-assure communities of interest and stakeholders that their views will be taken seriously and that organizational processes will result in immediate adjustment to potential error (also elements of HROs). When harmful effects may be visited upon future generations, our concern in this section, assurances of continuity or institutional constancy take on increasing importance.[52] Certainly leaders of some institutions are pressed to assure the public (especially able opinion leaders) that, as a condition of winning approval and resources to initiate or continue programs, their agencies and corporate contractors can credibly be expected to keep agreements and commitments with potentially affected communities far into the future.

These are very demanding conditions for organizational leaders to consider, much less actually to nurture, encourage and insist upon. (See Table 1 near the end of the paper listing them in combination with others discussed herein.) They are also conditions that call for a high degree of trust and confidence by the public in operating and overseeing institutions - a condition that is in increasingly short supply in contemporary American culture. We turn to this crucial matter below.

## 3. Institutional Trust and Confidence (Trustworthiness)

Operating beneficial, but hazardous technical systems intrinsically puts strain on the managing and sponsoring organizations. This is due both to the perceived levels of hazards and to the inevitable differentials in knowledge between technical operators and attentive members of the public. The public almost certainly feels vulnerable in the face of these differences and, if there is tendency to be suspicious of large institutions as well, this simply adds to the potential for distrust in the operators environment. If harm to the public due to operational missteps or mismanagement also extends far into the future (so that issues of constancy become salient), the demands for

Management of Sustainability. New York: Columbia University Press.

[52] While our mind's eye turns quickly to public organizations, the argument applies with nearly as much force to the private sector in the U.S., especially those firms responding to the strong economic incentives for short term gain and deferral of costs.

trustworthiness greatly increased. In effect the public is asked to trust those in charge and those who operate these systems.

In this context, it serves us to examine the meaning of institutional trust or public trust and confidence in institutions. Concepts subject to considerable rhetorical ambiguity (e.g., trust and confidence, legitimacy), La Porte and Metlay have proposed the following definitions for trust and confidence:[53]

1. Trust is the belief that those with whom one interacts (agencies, firms) will take your interests into account, even in situations where you are not in a position to recognize, evaluate and/or thwart a potentially negative course of action by "those trusted".
2. Confidence exits when the parties trusted (agencies, firms) are seen to be able to empathize with (know of) your interests, are competent to act on that knowledge, and will go to considerable lengths to keep their word.
3. Trustworthiness is a combination of trust and confidence.

To the degree *institutional trustworthiness* is a prime requisite for successful, long term stewardship, we can ask what institutional processes assure it. The challenge is formidable for, given these definitions above, many members of the public and stake holding groups, especially when they feel themselves to be vulnerable, do not believe that a number of U.S. institutions (including DOE and its contractors) have either the intent to take their interests into account, nor, if some of its members did, the competence/capability to act on it. This is an untenable position in advanced industrial democracy. *I urge the reader to reflect on the implications for managers and regulators if the conditions proposed below became imperative for the successful prosecution of agency and corporate missions.*

If the conditions that sustain or in some cases are to recover public trust and confidence are to be assured, upon what basis might they be developed, on what principles might they be designed? Processes intended to accomplish high <u>Public Trust and Confidence (PT&C)</u>, i.e., organizational and institutional properties that increasing the likelihood that able members of the public will regard an agency as worthy of their trust, are related: a) to interactions with external parties, and b) to a combination of internal organizational factors that make up a matrix of re-enforcing necessary conditions.[54]

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[53] Slightly revised from La Porte and Metlay, op. cit.; see also DOE 1993, op cit.

Interaction with External Parties

The central premise for designing external measures that evokes public trust and confidence is the following:

> When agencies (or firms) manage programs that could be seen as levying more potential harm than benefits upon citizens and communities, agency (or industry) leaders must give all groups of citizens and their representatives opportunities for involvement and must demonstrate fairness in negotiating the terms of their immediate relationship.[55]

To avoid arousing distrust (or reducing it), agencies or firms should commit themselves to conditions that address the need to involve stake holders in processes that assure them that they will be taken seriously, that their views will be visible to decision makers, and that there is recognition of the potential benefits and costs to stake holders associated with the technical operations in question. More precisely, six conditions (outlined below), if they can be achieved, reduce the grounds for suspicion. It is notable that, as distrust mounts, so does the importance of achieving **all** six conditions. If there is a surplus of trust, let us say, only the first condition is needed to maintain that relationship. These conditions are:

- Early and continuous involvement of stake holders advisory groups which are characterized by frequent contact, complete candor and rapid, full response to questions, etc.
- Timely carrying out of agreements unless modified through an open process established in advance;
- Consistent and respectful reaching out to state and community leaders and general public to inform, consult and collaborate with them about technical and operational aspects of agency (or firm) activities;
- Active, periodic presence of very high agency (and firm) leaders, visible and accessible to citizens at important agency field sites;
- Unmistakable agency (or firm) and program residential presence in the locality that contributes to community affairs and pays through appropriate mechanisms its fair share of the tax burden; and
- Assuring the availability of negotiated benefits to the community along with the resources to the affected host communities that might be needed to detect and respond to unexpected costs.

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[54]See La Porte and Metlay, op. cit.; and DOE 1993, op cit., for a more fully developed rationale for this argument.
[55] DOE, 1993, op. cit., 50.

These familiar external measures can be expected to reduce some sources of suspicion. But they go only some of the distance toward stimulating or recovering trust and confidence if the agency is facing a deficit of trust. If there is a reservoir of trust, so to speak, only consistent, candid interaction with stake holder advisory groups may be needed. But if the agency or organization faces even a modicum of distrust, then more effort is needed in elaborating relations with the social environment, certainly but questions of the *internal capacity* actually to manage hazardous systems emerge as well.[56]

Internal Operations

Why would turning to an agency's or firm's internal operating environment be important? What happens inside an organization takes on increasing salience for maintaining or recovering public trust and confidence when the success or failure of its technical operations cannot be determined quickly and unequivocally (as necessary for market based corrections), or more rarely for many years (as in the case of radioactive waste disposal programs, or the development and closing of mining operations) when success or failure cannot be judged until well after the life times of the programs' managerial and technical leadership.

> "This means that the quality of the decisions taken now or operations carried out in the near future cannot be judged on the basis of near term feedback, nor will there be any chance to reward or punish the leaders most responsible for the programs on the basis of its overall success or failure."[57]

Indeed, our legal system provides few ways of holding current decision-makers liable for failures they may have put in train, but are not discovered until well into the future. When this is the case, ones attention is re-directed to the organization's current competencies, and its operations and management, and its prospects for continuing into the future. In terms of design premises, this suggests that:

> Tasks should be carried out in ways that, when the public gains access to programs via improvements in external relations, they discover activities within the organization that increase institutional trustworthiness rather than decrease it.[58]

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[56] Indeed, the task force that first took up this problem spent over half its time (and 40 of its over 70 detailed recommendations) on matters of *internal processes* as well, DOE 1993, op. cit.

57 DOE, 1993, op. cit., 51.

Put another way, the maintenance or recovery of trust results, in part, when the more one knows about the agency or firm, the more confident one is that hazardous processes are and will continue to be done very well. Notably, this is the reverse of what most observers expect when they become fully familiar with large institutions, i.e., "the more you know, the worse it gets."

Then what internal conditions work to realize this unusual objective? Clearly, we would expect high competence all round. And this might be all that was necessary when there is already a surplus of trust. If this is not the case, or if one wanted to avoid slipping down the slope of public skepticism, we would also expect to see additional qualities that reassure. Thus internal operations should be designed to effect these internal measures germane to establishing or recovering public trust and confidence.[59]

- High professional and managerial competence and discipline in meeting technically realistic schedules.
- Pursue technical options whose consequences can be most clearly demonstrated to broad segments of the public.
- Processes of self-assessment that re-enforce activities permitting the agency to "get ahead of problems . . . before they are discovered by outsiders";
- Tough internal processes of reviewing and discovering actual operating activities that includes stake holders;
- Clear, institutionalized assignment of responsibility for protecting the internal viability of efforts to sustain public trust and confidence throughout the organization.

## 4. Concluding Reflections

Recall that the conditions of operations, planning and error responses summarized above take on special salience when agencies, operating organizations, or corporations claim the role as steward on behalf of society at large or a particular segment within it. In effect, the putative stewards are claiming that they can assure the perpetuation of the conditions associated with highly reliable operations, long term institutional constancy, and, under-girding these, continuous public trust and confidence.

[58] DOE, 1993, op. cit., 55f.
[59] DOE, 1993, op. cit., 56f.

Separately or in combination (as they are arrayed in Table 1), these are remarkable claims: an ensemble of conditions that *together* is very likely to be a necessary but not sufficient condition for the confident evolution of faithful institutional stewardship. While there are no single factor successes here, there can be single factors failures in achieving the foundations of faithful institutional stewardship. Indeed, it is likely that, for most organizations, it requires a new culture of awareness about the obligations and rigors of earning public trust and confidence.

The array of organizational conditions under-girding institutional stewardship present formidable operational conditions to put in place even if there were confident analytical bases to proceed, a more or less affluent, socially benign environment where there were whole hearted agreements about the urgency to do so, and clear priorities about the importance of spending national treasure in the process. But, of course, none of these are case. The perspective outlined here signals a wider, more demanding context than technical agencies and contractors have had to confront in the past. If these "institutional stewardship" requisites are necessary, it seems clear that past practices will not suffice, past assumptions about the benign public enthusiasms regarding technical work no longer hold, and, without energetic efforts to raise to the challenges of "institutional stewardship," the political legitimacy of our technical scientific institutions will be at risk.[60]

Frames of Research in the LANL context.

The analytical bases for designing and assuring institutional forms at substantial scale is limited at best, and there is scant work on institutional stewardship per se, very limited study of highly reliable organizations or on institutional trust and confidence, almost none on institutional constancy. A remedy to these important gaps in knowledge and understanding includes both analytical and experimental efforts to calibrate the dynamics of highly reliable operations, and especially probing the requisites for long term institutional constancy and trustworthiness.

More specifically, this means mounting organizational studies calibrating the degree to which present technical and operational directions in pursuit of environmental and nuclear materials management require high reliable organizations (HROs) and have long term effects, hence, produce a requirement for high levels of public trust and confidence (PT&C). We claim that the more the requirements for HRO, Institutional Constancy, and PT&C, the

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[60] T. R. La Porte (1994). Large Technical Systems, Institutional Surprises and Challenges to Political Legitimacy. Technology in Society (Fall) 269-288; slightly different version in Hans-Ulrich Derlien,Uta Gerhardt and Frtiz Scharpf, eds. (Systems Rationality and Partial Interests, trans. from German), Baden-Baden: Nomos

more demanding the stewardship function will be to establish and sustain. However, the conditions outlined above are quite rigorous, and there may be disputes about their respective relevance. Indeed, there is likely to be strong managerial reluctance to consider them seriously. But the stakes in a number of areas are very large, and there should be strong research efforts to ventilate and reduce our current uncertainties.

We take up parts of this challenge in the research reported here. It is broadly directed toward enhancing our understanding about extent to which technical operations and potential hazard to operators call for highly reliable operations and, for some technical systems, their implication for the long-term future. The work was conducted with the generous cooperation of the managers and staff of the Los Alamos National Laboratory, especially the Nuclear Materials Technology Division, and the Materials and Manufacturing Program Office, Nuclear Materials and Stockpile Management Directorate, the Detonation Science and Technology Group, Dynamic Experimentation Division, and the Metallurgy Group, Materials Science and Technology Division. This has been supplemented by support from and work on the regulatory environment within LANL with portions of the Environment, Safety and Health Division.

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Verlagsgellschaft, 433-452.

## Table 1. Properties of Institutional Stewardship

(+ if in a surplus of trust; ++ add if in deficit)

| **Internal Processes** | HRO | CONST | PT&C |
|---|---|---|---|
| * Strong sense of mission and operational goals, unswerving commitment | ✓ | ✓ | |
| * Public commitments by high-status agency leaders | ✓ | ✓ | |
| * Institutional norms that nurture commitments across many generations | | ✓ | |
| * Culture of reliability, w/norms of equal value of reliable production and safety | ✓ | | |
| * Extraordinary technical competence. | ✓ | | + |
| * High managerial competence and discipline in meeting …realistic schedules | | | + |
| * Pursue technical options clearly demonstrated to broad segments of the public | | | ++ |
| * Structural flexibility and redundance | ✓ | | |
| * Collegial, de-centralized authority patterns in the face of high tempo operations | ✓ | | |
| * Flexible decision.-making processes involving operating teams | ✓ | | |
| * Processes enabling continual search for improvement | ✓ | | |
| * Self-assessment to “get ahead of problems” before discovery by outsiders | | | ++ |
| * Processes that reward the discovery & reporting of error, even one’s own | ✓ | | |
| * Processes of review and discovery … that include stake holders | | | ++ |
| * Institutionalized responsibility and resources to protect these efforts thru out org | ✓ | | ++ |
| * Resources for “transferring” requisite technical/institutional knowledge across from one work & management generation to the next. | ✓ | | |
| * Analytical and resource support for “future impact analyzes” | | ✓ | |
| * Capacity to detect/remedy the early onset of likely failure that threatens the future, and assurance of remediation if failures occur. | | ✓ | |

| **External Relationships** | HRO | CONST | PT&C |
|---|---|---|---|
| * Strong superordinate institutional visibility within parent organization | ✓ | ✓ | + |
| * Strong presence of stake holding groups.(watchers) | ✓ | ✓ | ++ |
| * Mechanisms for “boundary spanning” processes btwn the unit & these watchers.” | | | ++ |
| * Venues for credible, current operational information available on a timely basis | | | ++ |
| * Early, continuous involvement of stake holders advisory groups w/freq. contact, candor and rapid, full response. | | | ++ |
| * Consistent/respectful reaching out to state and community leaders, and general public to inform, consult … about technical/operational agency activities | | | ++ |
| * Timely carrying out of agreements unless modified through an open process established in advance. | | | ++ |
| * Active, periodic presence of very high agency leaders, visible and accessible to citizens at important agency field sites. | | | ++ |
| * Unmistakable agency/program residential presence locally that contributes to community affairs and pays … its fair share of the tax burden. | | | ++ |
| * Negotiated benefits to the community with the resources that might be needed to detect and respond to unexpected costs. | | | ++ |

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# Sustained, highly reliable operations across multiple generations:

## Management challenges of assuring nuclear weapons components.

## (Troubles for the future?)

The LANL/UCB
Stewardship
Project

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Abstract: This paper examines the characteristics and dynamics of work teams at Los Alamos National Laboratory that are central to the production of nuclear and non-nuclear components for U.S. nuclear weapons. After a brief description of the institutional context of this work at LANL, the results of field observation and interviewing of five teams, parts of three groups (NMT-5, MST-6, DX-1), are summarized. Evidence from this work suggests that they resemble other organizations that have evolved effectively in the face of significant hazard to produce sustained, high reliably operations (HRO). The paper ends with a reflection on the pressures that may be building to increase the difficulty of sustaining these rare and valuable organizational assets over the coming generations.

University of California
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September 2000

**Final Report: UCB - LANL Institutional Stewardship Studies - 1998-2000**

## Introduction.

Los Alamos National Laboratory's (LANL) expanding role in the evolution of the U.S. nuclear enterprise poses remarkable technical and operational challenges. These include expanded responsibilities in confidently managing excess weapons plutonium, and for maintaining a "de minimus" nuclear deterrent capability for the foreseeable future. This entails a central role both in preparing excess plutonium for international inspection and subsequent use or disposal, and in assuring that the US maintains an effective, credible, significantly scaled down, nuclear deterrent capability. LANL and its University of California (UC) contract overseer are committed to continuing the past tradition of highest quality research and development, and to adding the skills and operational capacities required for producing the components needed in the reliable detonation of the remaining weapons in the nuclear stockpile.

While the technical issues associated with these missions are quite demanding, the institutional challenges are extraordinary. These missions require the development and sustained capacity to disassemble excess plutonium "pits," and to re-manufacture up to 20 plutonium "pit" assembles per year.[1] They also call for achieving results in areas where failures promise potentially serious environmental, social and political harm, and for assuring institutional qualities that result in highly reliable operations which inspire deepened public trust and confidence. The most significant aspect of these challenges arises from the indeterminate, but very likely long-term need to continue demonstrating such capacities.[2]

These are institutional imperatives for which only the slimmest of analytical bases exist to inform wise design. They are the primary sources of our research interests. Accordingly, our frame of reference is oriented less toward examining the Lab's considerable past accomplishments, than toward matters of its fitness for the future. In this paper, we seek to understand those teams, "in the trenches", whose work provides the physical capacity to produce the nuclear and non-nuclear components making up the "pit assemblies" -- one of several crucial capacities that must be available generation after generation. Based on interviews and observations, provisional descriptions of their current interactions and dynamics are summarized, and finally, their emerging

[1] As it will be used in this paper, "pits" refers to the complex device within a nuclear weapon containing plutonium and components deep inside the weapon which provides the initial forces necessary to release the energy from its uranium symbiont. The number of expected pits is derived from estimates of the necessary re-furbishing rate, the operational requirements continue high quality research and development, and the university reluctance to become large scale production managers. See especially the LANL white paper, "The Role of Component Fabrication at the Los Alamos National Laboratory in the Post Cold War Era," October 1999.
[2] See T. R. La Porte, "Institutional Strain and Precarious Values in Meeting Future Nuclear Challenges," Los Alamos National Laboratory report, LA-13515, March 1998, for an earlier reflection of this institutional development.

organizational situation is considered in terms of the challenges of realizing the conditions that nurture constancy of capacity.

For those interested, I include, in the Appendix, comments on the social science perspectives and methods upon which these observations are based. Points in the argument are noted where these become salient by a (Methods Note #) reference.

But before we consider the organizational capacities that could assure such fitness, several aspects of LANL's institutional and political context demand mention.

## A Glimpse of Context.

LANL's evolution is, of course, tightly linked to developments in the U.S. nuclear and policy communities. Two conditions emerging within the past decade that strongly shapes the longer-term imperatives of this (nuclear) institution.

First, much of the US's wide spread, extensive weapons production infrastructure has been closed, the complex shrunk in size and geography, if not in functions. Many of these functions have been concentrated predominately at LANL. The lab's and the University of California's responsibilities are heightened, their relative institutional importance has grown, and the political visibility of weapons activities is more concentrated. While the overall scale of the weapons system has diminished, institutional ground zero for supporters and for dissenters is much less diffuse. In following the University of California Regents' wish to support national security/defense, the University has been provided extraordinary resources and venues for very interesting science. Now it finds itself a more singular center of attention: an object of continuous interest from those who would turn to nuclear deterrents as a means of defense, and a target to those who fear the proliferation of those same devices.

Second, the U.S. has had a policy for a decade to abide by the provisions of the Comprehensive Test Ban Treaty (CTBT). This has meant that U.S. weaponeers no longer have an empirical basis to demonstrate to technical advisors and decision-makers of states tempted to use nuclear weapons as a means of political domination that the U.S. continues to have a ready capacity to deliver deterrent force. The result is that, in the absence of periodic, actual testing, the grounds from such demonstrations rest on the behavior of the people of the weapons labs and production complex – in the quality of their professional interactions with others whenever they leave work sites.[3] To re-enforce the perception of continued U.S. capacity, they should, in effect, behave in ways that suggest they are part of the world's best technical, production and management operations. Every aspect of lab and UC activities across the board should be seen as world class.

These two challenges produce an insistent demand for assuring operating conditions of high respect, openness and trust based on extraordinary competence in science, technology and operations, with strong capabilities for institutional defense in the face of policy contingency and predatory political environments. This is especially the case when these demands arise within an operating context of high hazard, with requirements for super-reliability, and sustained public trust and confidence for multiple generations. The result is an extraordinary array of institutional expectations; expectations that should be kept in mind as one reads the descriptions below.[4]

## On the Way to the Trenches.

One of the primary objectives of this LANL-UCB project was to identify those activities and processes that would be involved in a mature operation producing 10-20 pits/assemblies per year, that is, the state of the production complex, say, 3-5 years after initial 10-20 pit capacity level has been achieved. In effect, the analytical task is to estimate the character of a capacity under development ("ramping up" in local parlance), from a quite modest capability at present to sustained, highly rigorous small scale production activities which will go on for many generations.

Of surpassing institutional importance, these activities would be carried within a much larger and complex organizational setting of the nation's premier scientific organizations. LANL's traditional mission has been to produce highest quality research and development. This has been pursued within the some 13 technical Divisions that hold the primary scientific strength of the institution.[5] These range across an astonishing variety of areas, from the biological and environmental sciences, theoretical physics, computer and information sciences, chemistry, geology, materials sciences, nonproliferation and national security, mathematics, technology and environmental safety analysis, and a wide variety of engineering capabilities. Each Division has strong research capabilities – capabilities they intend to continue. In addition, they may have quite substantial facilities

[3] For a discussion of what this means for LANL see, John Immele and Phil Goldstone "Stewardship of the Nuclear Stockepile Under a Comprehensive Test BanTreaty," 1996, paper presented to annual meeting of the American Physical Society,

[4] I assume, for the purposes of this report, that most of its readers will have at least a passing acquaintance with the kinds of operations and the general pattern of work in this type of DOE facility. Therefore, I shan't belabor some aspects of LANL structure and processes that border on the exotic for many students of organization and management.

[5] In addition, there are three other Divisions that provide regulatory competence, and institutional business and operational services.

management responsibilities. Some Divisions also have had a limited production capability used to support the technical needs of experiments and test requirements, and periodically to provide services to other government missions and industrial needs.[6]

The weapons functions at LANL involve a number of technical areas: from the scientific questions associated with understanding weapons in ways that provide operational confidence without testing (science based stockpile stewardship program), to the monitoring of existing weapons to track their integrity as they age, (the dismantelment and surveillance program), and nuclear and non-nuclear component production.

In simplest terms, a production capability undergirding LANL's nuclear deterrence mission calls for the rigorous execution of these demanding steps:

> Preparing highly-refined nuclear and non-nuclear materials, casting these materials into the desired forms, machining them to exact specifications, then bringing a wide array of parts together for assembly.

Along the way there are intermediate steps of inspection and cleaning, all recorded to assure a careful record of the process. In schematic form, something like the sequence in Figure I.

Figure I. Schematic of Production Requirements

| | Materials Preparation | | Component Casting | | Precision Machining | | Component Assembly |
|---|---|---|---|---|---|---|---|
| Nuclear | O | → | + | → | + | ↘ | |
| | | | | | | | O |
| Non-nuclear | O | → | ++O | → | + | ↗ | |

Note: The pluses indicate the units I was able to observe and interview.

6 An additional aspect of LANL's internal dynamics is the network of program offices that provide formal interfaces with DOE's Washington, D.C., based Program Offices. These units are charged with coordinating Department-wide programs, overall work planning, and budget negotiations within the Department and with the Office of Management the Budget and Congress. I return to these dynamics near the end of the paper.

These functions call on production specialties in technical areas that still harbor a number of scientific surprises and technical challenges. And they are to be carried out within four of LANL's well-established technical Divisions each with strong research orientations and a history of extensive fabrication experience in their own right. They include:

| | | |
|---|---|---|
| Nuclear Materials Technology[7] | (NMT) | Nuclear components |
| Materials Science and Technology[8] | (MST) | Non-nuclear components |
| Dynamic Experimentation[9] | (DX) | |
| Engineering Sciences & Applications[10] | (ESA) | |

The hands-on work at LANL goes on in Groups of highly skilled technical specialists that make up the technical heart of these divisions. Formed into units of from 40 to 100 relatively highly educated technical staff members (TSMs) and experienced technicians, these groups and their work teams embody the sweep of technical knowledge and operating skills at the root of LANL's formidable scientific and technical contribution. These groups often provide complementary knowledge and analytical capabilities to each other in a kind of informal matrix of operations and services mixing predominately science oriented groups with technical and analytical units. For example, the Materials Science and Technology Division (MST) is made up of five (5) technical groups covering Metallurgy, Polymers and Coatings, Structure/property Relations, Condensed Matter and Thermal Physics, and Electronic and Electrochemical Materials. An Operational Support Group provides

[7] NMT Division provides strong capabilities to assist in maintaining a continuing weapons stockpile, disposing of excess plutonium and cleaning up legacy materials, and assuring core research and development competence in actinide and nuclear materials sciences and technologies. The Division has the responsibly of operating two nuclear facilities used for R&D and manufacturing and is developing the capabilities to manufacture certifiable nuclear "pits." Special thanks to Bruce Matthews, Dana Christensen (act), and Tim George, NMT Division's Directors during the term of our work there for their encouragement, support and insight.

[8] MST Division provides the core capacities in the materials science and technology base needed to maintain confidence in the safety and reliability of the nuclear weapons, and addressing a broad range of technical issues in energy, environment, infrastructure, and conventional defense, and laying the foundation for enhanced understanding and producing new materials. I am grateful to Division Director, Ross Lemons, for a useful discussion of MST's recent and current institutional challenges.

[9] DX Division has long experience in research, engineering, and experiments on high explosives and dynamic processes. Its weapons performance testing, science, engineering, and production projects support LANL's National and global security initiatives. Thanks to DX Division Director, Robert Day, for his interest and wide ranging discussion of the Division's evolution and its current challenges.

[10] ESA Division contributes to the stewardship of nuclear weapons through enhanced safety and reliability through stockpile surveillance, safety assessments, preservation and advanced warheads capabilities, ability to dismantle, rebuild and manufacture weapon components. Earle Marie Hanson, Division Director, and Luis Salazar offered cogent overviews of the Division.

services for running several complex facilities, of which one is capable of handling highly toxic materials. The MST Division also manages one major technology center and an extensive field laboratory.

These four divisions have a somewhat similar structure, with the fabrication and production functions often concentrated largely in one or two groups. It is these groups who have been called on to add small scale, rigorous "war reserve" quality manufacturing activities to their ongoing R&D functions. High quality fabrication capabilities in support of R&D often entail intriguing technical puzzles due to the uncertainties of development projects. Such production activities may be novel with fluid deadlines when there are expectations of surprise. Flexibility is a necessity, and the results are often professionally rewarding.

Assuming responsibility for even a limited number of "war reserve" (WR) quality components brings a different set of requirements.[11] The expected technical quality surely as high, but the manner of operations is significantly different. The objective is to produce exactly the same quality components time after time, with rigorous fidelity to design specifications that are spelled out in great detail. A premium is placed on demonstrating this achievement via highly formalized procedures, with detailed records for each component. Productions runs (campaigns) would be for a series of exactly reproduced nuclear and non-nuclear items, rigorous inspected, to earn a "diamond stamp" certifying its WR quality. All this to be done while meeting tight customer deadlines. Flexibility is not a desired characteristic. Rewards come from successfully meeting schedules with rigorous, unflagging quality.[12]

As LANL prepares for a greater relative role in components production, there have also been strong requirements to renovate, upgrade, and expand the facilities and mechanical infrastructure needed for production in facilities often opened over thirty years ago.

In this context, which groups are taking on the dual role of maintaining high quality research and development capacities and, at the same time, gearing up for the coming war reserve manufacturing regime? How are they presently situated? To what degree do they already exhibit interactions and dynamics that signal confidence in their "fitness to the future" that awaits them? (See Appendix, Methods Note 1.)

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[11] See General Accounting Office, Nuclear Weapons: Key Nuclear Weapons Component Issues Are Unresolved (Letter Report, 11/09/98, GAO/RCED-99-1), for a discussion of the operational challenges facing LANL in this enterprise.

[12] There is also a secondary confounding factor. Due to the enhanced visibility of this production function nationally, institutional notice of safety records, and worries about production capabilities become much greater. So does media attention and opportunity for political depredation.

The groups and teams involved are:

NMT – 5, Nuclear Weapons Component Technology, and the Plutonium (Pu) casting, Pu Machining and component assembly teams.[13]

MST – 6, Metallurgy, and its Mechanical Metallurgy, Machining and Foundry, Wielding and Joining teams, as well as the Beryllium (Be) Technology Facility with its teams for Plasma Spray and Be Machining. MST-6 personnel also join with NMT's assembly team.[14]

DX – 1, Detonation Science and Technology, with its Detonator Fabrication team.[15]

ESA– WMM, Materials and Manufacturing, with its Neutron Tube Target Tritium Loading team.[16]

The teams underlined above, ranging from three to six persons each, are those observed in operation and its members interviewed. They were selected in part due to their size. The largest teams in each group, they were more likely -- than individual technicians working more or less alone --to exhibit the social relations that often develop in units faced with the demands to operate very reliably in the face of high intrinsic hazard.[17] Due to the need to allocate scarce field observation time, single person functions, and analytical and quality assuring services carried on by groups within the Division itself and by groups from other Divisions drew less attention. (See Appendix, Methods Note 2.)

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[13] NMT-5 provides scientific and technical expertise for the stewardship and management of the plutonium components in the nuclear weapon stockpile, including pit surveillance, fabrication, assembly and engineering services to DOE's Defense Programs.

[14] MST-6 specializes in metallurgical engineering of non-radioactive metals and alloys with expertise in: alloy design and development, beryllium technology, corrosion and interfaces, electrochemistry, machining and foundry, mechanical metallurgy, mechanical testing, characterization, powder metallurgy, and welding and joining. Major programs include: fabrication of nuclear weapons components and prototypes, corrosion monitoring of weapons and accelerator components, and development of materials for the solid storage of hydrogen; and conventional defense work developing materials for kinetic energy penetrators, shaped charge liners, and explosively formed penetrators. Collaborative efforts continue with the aluminum industry on lightweight materials for transportation.

[15] DX-1 capabilities include "multi-point and multi-option detonators and cables, laser driven initiation, and secondary-explosive actuators, and fabrication of custom flexible circuits for other LANL organizations, DOE, DOD and industry."

[16] ESA– MM Weapons Manufacture supports LANL's program with precision, high quality metal and explosive components, plastics and composite materials and test assemblies, enhance the capabilities to produce components… and develop production fabrication and inspection technologies, advanced manufacturing techniques, material characterization and analysis to support stewardship of the nuclear stockpile. Neutron tube target loading has been added to other manufacturing functions.

[17] These fabrication teams are in work units that provide the support of administrative and facilities maintenance personnel often of equal size to the teams itself.

## Into the Trenches.

The hands-on work of research projects and/or the fabrication of nuclear and non-nuclear components for weapons goes on in spaces specially design to assure the safety of those who handle highly hazardous materials, e.g., plutonium, beryllium, and other explosive or toxic substances. Regardless of the specific task, a general pattern is evident. The men and women – in the trenches -- who work with these materials inhabit a world of specialized apparatus, safety devices and sensors, and sealed, radiation absorbing housing called “glove boxes.” Work is done by technicians and technical staff members (TSMs)[18] who are specially trained to handle these materials, their hands and arms frequently encased in thick protective gloves sealed at glove box openings as they reach in to carry on a wide range of tasks. And they are likely to work within facility-wide pressurized ventilation systems that are designed to protect them should a glove or glove box holding radioactive or toxic materials be breached. In addition, a variety of security barriers and measures provide an often close fitting cocoon of caution around them.

Research or production work sessions are planned carefully on the basis of work orders and the appropriate technical and safety procedures. Due to the radioactive or toxic nature of the materials, especially when it is in particulate form and can be inhaled, work teams are supported by Radiation Control Technicians (RCTs) or Industrial Hygienists (IHs). Their chief responsibilities are to review the proposed work to affirm that it is safely planned, and to be “on call” to respond immediately if decontamination remedies become needed. Fresh protective clothing is always worn for each shift. And other protective equipment, including air inhalation masks, is employed in particularly difficult situations. Frequent carefully monitored checks for contamination are mandatory, carried out via individual radiation dose counters (dosimeters), personal inhalators, and cleaning of exposed surfaces. Measurements are recorded, and there is an accounting made of every bit of special materials used or that becomes a waste form. These records are used to alert workers and management to potential health problems, or the potential loss of nuclear materials. The first of these occurs very infrequently; the latter almost never. Thus, the functions outlined here combine the need for demanding skills and for daily potential of exposure to high hazard.

[18] This is a distinction used through LANL. Technical Staff Members are relatively highly educated, scientifically trained specialists, most with MS degrees, many with Ph.D.s. Technicians, including the senior “lead techs”, are highly skilled workers, often with long experience in their craft. In the areas of interest to us, they include, plutonium, beryllium or explosives workers, as well as machining, wielding and metallurgy specialists.

Due to the nature of the mission, the work is endowed with a sense of considerable significance for those who are directly involved. It also draws sharp notice in the society from those who insist on the importance of nuclear weapons as a means of political and military security, and from those who are wary of the consequences of operating mistakes or wayward management for the health of workers, nearby citizens, and the natural environment. Neither group is willing to trust to the lab or to the contractor management the sole responsibility for security, for worker or citizen safety, or for the protection of the environment. The result is an extraordinary pattern of oversight and formal procedures and regulations.[19]

In such work situations of technical demand, hazard and scrutiny, how do those involved carry on? Are there similarities in the interactions and work dynamics among those whose skilled hands and risk taking provide a crucial components of U.S. deterrent capacity?

## Onto the Floor.

Addressing these questions calls for observation and acquaintance with the work teams, thus adding a social dimension to the formal descriptions in work package and project planning documents. The sections below give a sense of the teams' work places, the scale of activities, and the interaction patterns and dynamics of team work that speak to the demands of very skilled, high hazard work. These reflections are based on my observations of the several teams (spaced over a year's time), and they take on a more subjective, narrative tone. The experience was filled with surprise and an increasing appreciation for the demanding environment and extraordinary work dynamics that have evolved within these work teams. (See Appendix, Methods Note 3.)

Entering the world of the "weapons works," whether it supports R&D for surveillance or small batch production of Pu and non-nuclear components of WR/diamond stamp quality, brings one into an architecture and culture of watchfulness and careful operations. Each of the several work sites observed takes on particular characteristics, each its version of striving for very reliable, safe operations in proportion to the hazards and sensitivity of its production materials and technical specifications.

We go first to one of LANL's the most sensitive, highly secured sites, Technical Area 55 (TA-55). This triple fenced, patrolled and heavily guarded compound, managed by NMT, includes the massive Plutonium Facility 4

[19] See the papers by Stone and La Porte, and Egan and La Porte later in this report for a summary and comment on the some dozen regulatory domains that confront the lab and NMT especially. These include radiation protection, materials control and accounting, occupational health and safety, waste management, transportation, and an array of environmental protection regulations.

(PF-4), the only full-service, operational plutonium handling facility in the nation, and the work places of the NMT-5 teams who fabricate nuclear components.[20]

Subsequently, we turn to the team that produces the initiating high explosive detonators, and conclude with a discussion of those who produce the non-nuclear, crucial components including those requiring exotic beryllium metal.

"Life with the pits" - In the plutonium works.

The facilities and operations giving LANL a plutonium fabrication capability are managed by the Nuclear Materials Technology Division (NMT). This involves a sprawling array of activities covering plutonium and actinide research, chemical analysis, radioactive and toxic waste management, fissile materials management, materials safeguards and security, and radiation protection. These are carried out across two facilities complexes (TA-55 and the Chemical and Materials Research) both in the process of significant upgrading. The some 700 person Division has an annual budget nearing $150 million, divided about half and half for facilities upgrade and operations. The overall dynamics are importantly shaped by the inherent tensions between the planning and management challenges of large scale facilities construction and major equipment infrastructure development and the every day requirements for conducting research projects. Recent changes in the Division's somewhat ungainly organizational structure has moved it toward an unusual matrix arrangement which couple or link technical work activities with facilities management.

Within the general flux of weekly planning, adjusting schedules due to facilities contingencies and compromises in work processes, the weapons production related activities of Nuclear Weapons Component Technology Group (NMT-5), augmented by Actinide Chemistry (NMT-2), contribute to assuring the integrity of the plutonium components in the nuclear weapon stockpile.[21] This includes work in support of monitoring the conditions of aging pits (conducted by NMT-13's pit surveillance activity), as well as the fabrication and assembly of remanufactured ones.

[20] My thanks to Bruce Matthews, Tim George, (former and current Division Directors), K. C. Kim , Ken Courtney, Will Parson, Bill Zwick, Walt Stark, Jim Ostic, and Garry Eller for their sure guidance about the evolution and dynamics of this division. Special thanks as well to Gerd Rosenblatt, who shared with me the role of interested frequent visitor.

[21] My thanks to Joe Martz and Stevie Hale, past NMT-5 Group Leaders, for their effective briefing on NMT-5's functions and operating challenges, and to Doug Kautz, NMT-5's current Deputy Group Leader, for his very useful discussion of recent challenges the group is facing.

The technical work teams of NMT-5 receive highly refined (recycled) Pu from NMT-2, then assume the main responsibilities to make and assemble components into fresh pits. Supporting chemical testing and analytical services are provided by others, with assistance in integrated assembly of non-nuclear components from MST-6.

Key NMT-5 working teams who provide essential capabilities now and will be needed for many generations include casting of plutonium hemispheres, machining them to exact specifications, conducting inspections to assure that they are of war reserve quality, and finally assembling nuclear and non-nuclear components for a fully integrated, properly documented and certified pit. These were the teams I sought. I had the good fortune of coming to know the work of two teams – casting and machining. This took me into PF-4 and close to "life with the pits."

Passing through an access portal of TA-55, staffed by guards 24 hours a day, who preside over some half dozen checks that assure them that only fully cleared persons or well escorted visitors enter the razor fenced area, one finds the planning activity for the foundry and machining teams in nearby offices. With briefings completed, one proceeds toward an inner reach of Plutonium Facility 4 (PF-4). Its massive concrete wall and foundations buried deep underground are able to withstand strong earthquakes, wild fires, and direct terrorist assault. The facility supports life with a massive air filtering system occupying nearly the entire basement floor that cycles filtered air through the rooms and labs seven times a hour, providing the differentials in air pressures to assure worker safety.

After suiting up in protection gear - glasses, yellow overalls – at the outer entrance of PF-4, and again going through a security screen (with grilled doorways, armed guards, passes and clearance identification required), white booties are donned at an inner entrance. (These, along with the overalls, will be put in laundry bins upon exit.)

Down a long, wide hall, various kinds of monitoring and safety equipment here and there greet us. There is a continuous background hum of the air filters (similar to a large ship underway). The atmosphere is muted; talk and other workers are sparse.

In the Foundry.

Casting operations in the foundry are in one room, the machining team works in an adjacent room. The casting team is in one corner of a large, high ceiling room occupied by a variety of equipment. One sees an array of glove boxes, sometimes stacked three high. Personal radiation monitoring equipment on each one. More safety monitoring equipment. I recall the safety tests for a variety of audible alarm signals (for loss of air pressure differential, for the presence of gamma radiation, the fire in this room, in the wider facility.) A computer console at hand nearby: the "input for records" to a massive information support system.

No one else is in the room for this session. There is an unspoken readiness to get out of harm's way; and a sense that harm is always in the glove box, or just round the corner.

Three team members are already there. Two primary foundry technicians, one the lead tech, will be the key players. My guide, senior TSM John Huang, is overseeing the operation. A fourth man is watching/learning intently. There is good-natured banter, and a spontaneous effort from two of the techs to show me what will be happening. The session's work will go on within one glove box for the furnace to heat the plutonium, another for pouring the casting. They check to assure that a Radiation Control Technical (RCT) is close by. After checking the molds and talking through the process again, they are ready to begin.

There is a clear initial division of labor, more watchful cooperation between two people of nearly equal competence, rather than two with distinctive specialties. The lead tech closely follows the process. My guide occasionally interprets what is going on. The plutonium chunk due to be recast is being heated to its melting point. The team is keen to point out the progress along the way. (They make sure I move to a vantage to see into the glove boxed furnace.) As we wait, more to and fro among the team. Something of their histories comes out. Most have been on this team have worked with each other for some time. They can spell one another; have confidence in each others' skills.

The pouring sequence begins. A delicate technique comes into play, requiring close coordination among the pouring team members. About mid-way advice is given, one team member spells another, and the casting is made. Along the way, technical and procedural data are entered into the computer work station. The casting process is a reasonably labor intensive, hands-on operation; the team working steadily with a high temperature furnace, transferring molten plutonium to the casting apparatus, pouring the material with care to assure a flawless hemisphere. Things have gone well, the technique worked. They have a promising start. Now, to wait a bit for the casting to cool. They step back and review their work. An air of satisfaction enfolds the team. They are clearly proud of what they do.

As we wait, they gathered round. The techniques, they say, have been perfected over years of casting components for research and pit development projects. The process had been round a long time, it involves a feel of the apparatus, a sense of touch almost, as molten metal closed round the forms. Not everyone can do this, in fact not many are able to pick up the nuances, the art of plutonium casting. These skills are not, in their view, really appreciated by those distant from the foundry room, even for engineers and nuclear or material scientists who have a formal understanding of this material. And the teams delights in demonstrating to those few who could venture into these depths what their own skills require. Stories began to unfold about how they showed the over-confident, indeed, sometimes senior management, how hard the process actually is – to realize a flawless hemisphere, a “hemi” in local parlance. The spirit was one of proud production with a clear sense of the imperative of safe operations.

This was unexpectedly reflected in the conversation as it turned to the future. Research and development would go on, the lead tech was sure. The team could manage that demand now, maybe adding some WR production work along the way. After all, that sort of production is easier than the R&D work. There is less variation, repeating the same processes, and it is less interesting. The team would have to grow some to provide the capacity to do WR quality campaigns. There would be runs manufacturing a number of the same pit component. “Can’t stop in the middle of those”. Maybe 25% more, another two people perhaps would be needed. But there are “so few people who have experience in this type of work,” and when they recruit they have sought people who know the terrain, “who could be counted on, with experience.” Training could be done, but trainees are sometimes dangerous without realizing it.

At the same time, the prospects of doing WR quality work, while “not a big deal,” would require more equipment – equipment similar to the single pieces now available. The implications bothered the senior techs. There would be a need for furnaces, and casting and computer stations devoted to production, and another set for R&D. Research projects start and stop. Equipment is modified for special needs and modified again. “Can’t do that with production equipment.” They sensed a continuing source of disagreement and conflict. “We got flexibility now, I can see a time when production gets the highest priority. R&D will be strung out. You can interrupt that type of work. May never get it started again.”

Recruiting also came up as we talked about the flexibility of the existing team. It is a pretty small one for the range of technical skills their work calls for. The lead tech went through a rough review of both this range and those on the team who he had confidence in to provide them. One person here, two there, another able to meet special requirements. He worried that they were "pretty thin, sometimes we can't do the work right away when certain guys call in sick or gotta do training." In effect, this segment of weapons production capability was at a minimum sustainable level.

As data on the day's operation were being entered into materials accounting system,[22] I wondered how they treated situations when an error occurs. They thought about two types: when an error is made in the process – a technical or operating error; or when somebody makes a mistake in following procedures. The first kind they learn from. These generally arise in the course of doing sometime quite new or novel. It is a basis for technical learning. The other kind of error is more troubling. These can increase risk, they might lead to the rejection of the product on quality grounds. When these occur, there had been a kind of informal learning, local reassessment of the practices. More recently, such errors have become the focus of increased formalism of safety procedures and a growing apprehension about who would be blamed.[23]

This team had seen a number of changes already, and were anticipating more when the WR production requirements took hold. There wasn't opposition to doing production work. It is not as difficult, in their view, but it changes the character of things. "Lots more paper work!" "Researchers won't have it so good" was the somewhat regretful summary.

Machining the Result.

When a "hemi" is cast it emerges near to but not exactly as specified in size and shape to complete its function. Careful machining is needed. After being logged into the materials accounting system, rough "hemis" are moved through sealed passage ways and tunnels to a nearby machining room. Similar in look and architecture to the foundry, the room is filled with a variety of machine tools -- lathes, presses, grinders, computer controlled equipment – most of them encased in glove boxes, again, accompanied by safety devices, radiation detection sensors, and the muffled omnipresent sounds of massive ventilation systems. Radiation Control Technicians (RCTs) are on duty round the corner.

[22] LANL operates a massive nuclear material accounting and control system (MAAS) that tracks both the location and movement of radioactive materials down to the milligram. Daily reconciliation of the total amounts are conducted to assure the staff that no plutonium is unaccounted for in placement or quantity.

[23] In the past three years, a good deal of effort has been expended to increase the formal emphasis on safe work practices. Termed Integrated Safety Management (ISM), this strongly re-enforced program has been accompanied by more attention to standard operating practices, formal accounting and training. It has been paralleled in NMT by a new introduced complementary activity, "behavior based safety" processes which draw significantly on worker experience. See below for further discussion of this effort.

The machining team, with Steve Boggs as lead tech, is skilled in a wide range of special machining capabilities, chief among them is the machining of plutonium metal. Machining "hemi's" takes a somewhat smaller team than casting them, and the atmosphere is less intense, the hazard no longer amplified by molten material. Rather the task, assisted by numerically controlled lathes, requires extraordinary accuracy. Even very small mistakes can lead to product rejection. It calls on deep experience in the machinist's art, knowing the particulars of usually highly specialized machine tools and equipment, and a sense of how plutonium behaves in a variety of machining situations.

As the day's work commenced, the team met to go over the range of expected work. Its lead tech, also my guide, presided; the team leader, Patrick Rodriguez would arrive later. The fresh hemi produced the day before had been moved into the machine shop. This was to be the morning's major effort with several smaller jobs also on tap. The senior machinist who drew this "hemi" was looking forward to getting started. After the "hemi" has been "logged in," the work order was reviewed and the work began. Placing the "hemi" in proper position for exact machining is a crucial step, one made the more taxing by the intervening gloves and glove box setting. The contamination hazard here comes from even a small breach in the gloves due to wear or to leakage in the box's seals. And the risk is magnified by the potential that the sharp edges of the materials, the hand tools, or the corners of waste collection containers already contaminated could puncture the gloves themselves.

Veterans of glove box operations come to develop a kind of cautious dexterity, and subtle style of sparse hand and arm movements that limit their exposure to missteps, and at the same time, alert them of any tiny leak in the gloves. The man drawing this "hemi" noted that it took a good while, maybe two years, on different tasks "to get the hang of doing close work" inside a glove box, with moderately thick, and somewhat inflexible gloves running up past ones elbows. Gloved hand movements in the positioning this "hemi" were precise, setting the cutting tools to exactly the correct starting point. It was a moment of keen attention. Then a tension breaking sigh and out came the hands to be swiftly passed across the radiation counter at the right side of the glove box face; first the palms and then the backs of each hand.

In the midst of this concentrated effort, others of the team gathered round watching intently, following each move not make judgments nor look for flaws, but as other sets of eyes, ready, as one man did, to offer encouragement, a small alert to a possible consideration. Respect for the key man was evident.

The "hemi" and machine tool now set in place, the machining process began. What remained was to assure that all went as expected. Occasionally peering intently into the gloved boxed "hemi" and lathe, the process was pronounced satisfactory, colors and shapes emerged "as expected." An aura of modest accomplishment settled in as – over some minutes -- the refined shape was completed. He and most of the team had been engaged in plutonium and other R&D related machining atTA-55 for some time. "We have tackled some pretty tough problems and things have worked out." Others did they turn of the job I had just seen. There was tone of confidence when he said this if to say "and they would do as well as this one."

Milling work on a "hemis" and other components can go on in parallel, and two other continuing projects begun the week before ,discussed earlier that morning, were in progress across the room. All three jobs included attending to the challenge of reducing waste, in two cases, filings of machined plutonium. Each bit of Pu had to be scrupulously gathered up, weighted and logged in.[24] Recent emphasis on attempting to reduce the amounts of "waste" Pu had begun. I asked about this and a short conversation ensued about ideas to produce less stuff. This seemed to be difficult in machining operations, but a modest hunt was on.

Toward the end of the session, the team's leader Pat Rodrigez returned from a group management meeting, and the team now of six men assembled to de-brief the session. The discussion was informal and good humored. They seemed to have a respectful and easy relationship. The conversation turned toward future operations. As a team they thought a sustained War Reserve capability was nearly there, but that to do both R&D and production would need additional equipment replicating capacities they had in single machines but dedicated to production. Production was going to be a bit easier than R&D work, repeating demanding machining jobs but less uncertainty. And both the team leader and lead tech thought they'd need more people, maybe 25 percent more. But they worried about this. Experienced people were hard to find. "Lotsa competition out there." Like their foundry peers, they didn't want to face the risk of mistakes born of inexperience. "We're gonna have to do alotta training."

As we got ready to move to another part of the building, the lead tech continued this line of conversation. He was musing about the range of skills his people represented. "I got people who can cover every skill we need, but it's pretty thin. I know who's best in each area and can shift them around. But we are down to just a couple of people for most things, and down to one for some."

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[24] At the end of each day TA-55 wide accounting is made to locate and quantity every bit of Pu on-site. These numbers are compared with the figures from the prior day. Any discrepancy is treated as a **major** problem. In the very rare event

I was struck by the social tone of what I'd observed. The Foundry and Machining teams were teams in a deep sense. Members joined together by long experience seemed to have developed a mode of operations that blended wariness in the face of extreme hazard, trust in one another's technical or functional capabilities, and a kind of rough respect and comfort with each other. And they became quite engaged and animated in orienting this newcomer to their world. To my surprise, I found myself comparing them with teams of aircraft, "plane handlers" on the two aircraft carriers we had studied some years early.[25]

But there is more to providing components for nuclear pits than making the plutonium ones. What are other functions like? There are other teams to become acquainted with. Would I find similar patterns? It is time to move on.

The sense of massiveness and caution that stamps PF-4 returns as one leaves the primarily work rooms and proceeds (there is no other way of putting it) back to its interior guarded portal. Just before leaving any work room, one presents their hands, and booted feet to radiation detection devices, waiting for what seems an age it delivers its verdict, no contamination is detected. You are rewarded with a small beep and read out. Then through a husky door and into the hallway, now under more air pressure than the work room. A return walk to the entry area where ,in a defined space, one slips off the booties, deposits them into a laundry bin, and presents hands and feet to another radiation detection machine. Shoes and hands clean, you pass through a heavy set of double doors and into a transitional hallway where a whole body count radiation detection machines are poised to scan you from head toe. Again rewarded with a beep, you move through other spaces to surrender the temporary access card that you took in, and retrieve your I.D. badge. Then out through a narrow, heavily barred exit into the normally secured hall leading to the bins where your coveralls are deposited, your safety glasses stashed, and, if you are a visitors, your dosimeter is left for subsequent analysis.

When you emerge you have a sense of coming out of a quite particular world, where staff technical capabilities are excellent, and where the imperatives of careful operations in the face of both physical and national security hazards have been entwined in manageable norms and work ways. The visitor feels upon release to be fully vetted for contamination, and possible security negligence. A sense of relief and regard for those "plutonium

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that such a discovery is made, operations in the relevant units is suspended until the source of the discrepancy is pinned down. If the "lost" Pu is not found or accounted for a lab-wide search would be triggered.

[25] See especially, G. I. Rochlin, T.R La Porte, and K.H. Roberts, (1987) The self-designing high-reliability organization: Aircraft carrier flight operations at sea. Naval War College Review, 40(4), 76-90.

workers" upon whom the U.S. depends replaces the aura of mystery that operations like those within PF-4 and TA-55 almost necessarily evoke in outsiders.

"Life in the essential surround."

While plutonium components are central to nuclear weapons capability, the fully assembled pits are composed of many other essential components, a completed weapon of thousands of parts. These match the "hemis" in exactitude and often in fabrication complexity. Many of these "non-nuclear" components also have extraordinarily toxic, non-radioactive properties as well.

Among the many components made at LANL, those involving the high explosive detonator production team, a key part of Detonation Science and Technology Group (DX-1), in the Dynamic Experimental Division, and the foundry/machining and beryllium fabrications teams of the Metallurgy Group (MST-6), in the Materials Science and Technology Division afforded a good opportunity to understand the organizational dynamics producing non-nuclear components.

Working with explosives.

The engineers and technicians of DX-1 have a unique capacity to develop and produce devices that detonate a wide range of powerful explosives. No other unit in the U.S. has its specialized capabilities. DX-1's detonators and triggering cables and actuators are made to order for nuclear weapons, and for a variety of other non-nuclear armaments in service to the needs of other LANL groups, the DOE, the armed forces, and industry.

What is the facility like where nearly all the high explosive detonators for nuclear and other weapons systems are made for the U.S.? Like TA-55 and PF-4, it is also within a secure technical area, though with less formidable, less closely looming barriers. In one of several widely dispersed Technical Areas in the western sector of the lab, it joins a half dozen scattered facilities within a large area surrounded by a single fence. Guards are less heavily armed and check cars and I. D. badges at an entry gate a mile or so away from the facility. The long, low building housing DX-1 has a relatively newish look. One approaches, almost casually, to a "check-in" desk, with the obligatory sign-in book, where I.D. badges are checked again. Off to the right one sees a clean, well-lighted hall, and beyond a door into the spic and span clean rooms of the detonator fabrication team.

Earlier discussion with DX-1 leaders has effectively set the Group within the larger Division context.[26] Two aspects are instructive. First, DX-1 has had a long experience in combining R&D with limited production – in a past environment of relatively adequate resources. They work consistently to involve engineering and development activities with production requests and both the engineering staff (in evidence during interview sessions) and the production team felt they complemented each other. Second, the time of relatively adequate resources had come to an end and the Group was finding it harder and harder to maintain the flexibility needed to continue the range and continuity of work that was necessary to assure a steady technical and production capacity into the near term. These were to be matters that weighed importantly in their concerns about the future.

Entering the world of high explosive (HE) detonator production is in sharp contrast to the world closer to the pits themselves. HE detonators are intrinsically hazardous. While they are relatively small, precision devices, individually they pack a pretty powerful punch. Were one to explode in a production room, often containing a number of detonators, workers could be killed and very serious damage to the facility result. (Indeed, as a protective measure, fabrication rooms are designed with a thinner, less robust outer wall so that, in the very unlikely event of an explosion, structural damage will not effect the rest of the facility.) The result of a catastrophic mistake could be immediately fatal.

The explosive materials in uncompressed powder form are not particularly hazardous. They can be handled, with care to be sure, but without elaborate protective clothing or special ventilation systems. Nor do they call for special detection and decontamination processes. Neither are they as subject as Pu to the rigors of materials control and accountability, and there are fewer high classified aspects to these devises. Rather the work combines very precise shaping and compressing of materials with exact assembly of sophisticated electronic cables and actuators. This results in watchfulness in work processes, with somewhat less wariness and fewer safety procedures than one sees in PF-4.

The detonators developed and made by DX-1's production team are called on for in a number of R&D projects as explosives are used to test the character and adequacy of various materials, and for other experimental dynamics testing. They are also crucial components in initiating the high-speed sequence of events that trigger a nuclear explosion. The DX-1's production team has in the past provided detonators for all of the developmental "shots," nuclear tests at the Nevada Test Site (NTS). Each "shot" requires a number of detonators rigged to go

[26] My thanks especially to DX-1's Group Leader, Pruit Ginsberg, and team leaders for Development and Engineering,

off at precisely the same time detonating the high explosives surrounding the weapon's core so that a very strong imploding effect will result. For these developmental explosions, detonators rarely require the level of quality control that is associated with the many, many non-nuclear items that are finally assembled in a "war reserve" quality pit.

The evolution of the HE detonator team and its spaces reflect this history. It has mainly a R&D support function with occasional production demands for detonators that have not required formalized, extraordinary safety or quality control procedures. The team, led by Larry Lucero, combines both R& D and fabrication capabilities. The engineering section of some six TSMs, assembled for an initial conversation, is made up of production and process engineers, and specialists in statistical analysis and quality control. This section assembles and analyzes data on detonator performance for purposes of deeper understanding and design improvement. They have an interesting history of encountering novel explosive dynamics for analysis and, working hand-in-hand with the fabrication section, of addressing the challenges of assuring consistently produced precision detonators.

After we are briefed about the work in process, we move down a well-lighted hall to the production rooms. White coats are donned and one is ushered into an almost pleasant, modestly sized room. There are a number of computer supported work stations arrayed around the room at desk level. Sensitive weighing apparatus sits side-by-side with small machines for forming exact amounts and mixtures of explosive powder. When they are shaped in precise form, each emerging detonator is placed in a very robust container, and compressing under specific pressures for a variety of R&D and support to U.S. armed forces. On a table at one side, long lengths of electronic actuating cables are laid out. Beyond this room there is another with somewhat more complex manufacturing and recording systems where the war reserve quality detonators are made. Here information about each item is entered into computer based records, to be included in the data book that will accompany the pit to which these detonators will be attached.

The fabrication section is at work. It is made up of five engaging, shyly confident mature Hispanic women. Introductions are made by team leader Lucero. The section's leader has long experience with this unit, so have two other team members. They are skilled in a wide range of techniques, two of them are qualified for war reserve quality fabrication. The rest of the team are well along in an extended, informal training process.

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Derrick Montoya, and for Production, Larry Lucero. Lucero was to be my guide for engaging with the production team.

Lucero is clearly proud of this group. He recounts a bit of their qualifications. They exchange easy comments and there is a warmth I rarely notice at the lab. Indeed, there is an aura of a family operation, with comments by the section leader about how she is encouraging the less experienced, and an unexpected sense of respect and trust among this section. Body language, tone of verbal conversation signals confidence in the skills of each member and a quite sense of pride they seem to take in the jobs they do. There is also a hint that they think what they do is important, but probably not noticed much beyond DX-1 itself. "People think it's just production."

While actual fabrication is very much an individual matter, the section works in reasonably close quarters. Cross talk is quite possible and was evident as this team worked. Some of this was technical, comments about how the process was coming. Other bits were more diagnostic, commenting on the product, or the process of quality control. While I was not privy to lots of dialogue (all of it is subdued and they work steadily without a gush of conversation), the tenor of the language seemed at once to be functional, but as much to reassure, to support others in the conduct of demanding and possibly risky procedures.[27]

This sense was heightened when the room and work stations devoted to the war reserve (WR) production became the focus. In a separate room, adjacent to the team's central R&D work spaces, this room is more climate and security controlled. The WR detonators are subject to more rigorous, exact specifications than the already quite exacting procedures employed in the R&D devices. Each step, now carefully prescribed as to desired shape and compression pressures, is logged in on the computer work stations. In fabricating these detonators little is left to choice; exact repetition is the sine qua non. It is work that is becoming a central contribution to U.S. deterrent capability. It is also delicate and taxing, work that must be paced in the interest of reliability and safety. Others in the fabrication section clearly are keenly aware of its importance, and of the particular demands of this phase of the section's work. They took pains to demonstrate its discipline, and projected a sense of respect for its practitioners, those who are qualified to spend time in the WR room.

The overall production team also fulfills other functions, including microscopic inspection of test detonators and the cables that connect them to initial triggering devices. Together the level of production now needed can more or less be accommodated. Would this be the case when a fully engaged pit production regime becomes

[27] This impression, re-enforced by subsequent observations, suggests another dimension; one that could not be pursed in the course of this project. It is possible that there are systematic difference in group dynamics and capacities that stem in this case from the micro-cultural differences of an all female team contrasted to an all male one, on one hand, and, on the other, important contributions to group effectiveness that arise from the character of the Hispanic culture that characterizes a number of communities in LANL employment reach.

established? At expected levels of 20 pits per year, probably, was the intuitive sense. Qualifying several more fabrication team members would be necessary, and this was beginning to happen. I was reminded that WR detonator production was, after all less varied, more "routine." Once one learns the complex procedures and fabrication techniques, they don't change, and making each item takes less time.

Would commitments to maintain this level of WR quality production result in less support for the R&D work that is still to be done? Responses to this question were more equivocal. Probably, but the contingent character of R&D makes a confidence response more difficult. All of their past experience tells them that accurate estimates of the timing and level of effort involved in the interesting work of developing, designing and fabricating detonators for special purposes is intrinsically difficult. For effective development work, for example, tightly planned assigned time using existing equipment is likely to produce scheduling hassles, if routine production work has to be done with the same machines. There was a small concern that may be the steady demands of WR production might complicate other work.

Another unknown lurks in the growing spread of "formalization of procedures" then appearing in the nuclear materials areas of the lab. Prompted by increased environmental and safety regulatory scrutiny of the lab operations, the trend to demand more thorough documentary bases for procedural evaluation and work justification had yet not reached deeply into the DX Division. There was an apprehension that it might with unknown consequences for work practices and costs.

One comes away from an effort to learn from DX-1 and its fabrication team with a strong sense of the skills and dedication of its members, and the steady commitment to the quality of the produce and to the safety of its members. This should not be surprising. The group's record has been outstanding. What was somewhat unexpected (I had not idea what to expect at the outset) was the social dynamics that seemed to be integral to its present capabilities and would be central to continuing them. These relationships resulted in substantial delegation to the working teams themselves (something that was also the case in pit Pu production processes as well.) The fabrication team seemed quite evidently to have a quiet confidence in themselves and a sense of trust in their operations and respective skills. In concert with the engineering section, they were open to learning from surprises. I was struck, again, but the similarity – albeit in a very different context – to these we had observed in our work with "high reliability organizations."

I wondered, is there a pattern here? Would this sense of team cohesion and respect – a key characteristic of highly reliable operations -- be repeated?

Non-nuclear Symbiosis.

Between the initial trigger and a weapon's core, other non-nuclear components fill out the requisite mechanisms. A number of these can be made at LANL, some of the most important in the Metallurgy Group (MST-6) of the Materials Science and Technology Division. MST-6 specializes in metallurgical engineering of non-radioactive metals and alloys. It has evolved to encompass nearly the full range of technical skills and infrastructure necessary for highest quality metallurgical research, design, and small batch production. Made up of some 80 technical, support and administrative staff, it spans ten technical teams. Some specialize in alloy design, surface corrosion, electro-chemistry, mechanical and power metallurgy, testing, and characterization. Three larger teams are devoted to machining and foundry operations, beryllium technology work, and welding and joining. Of these three most intensive activities, I become familiar with the operation of the foundry and the beryllium plasma spraying team.[28]

The Metallurgy Group manages several facilities and a more complex range of activities than the other groups discussed in this paper. The group is large and variegated enough to warrant the management style of a small division. Relatively autonomous in its day-to-day activity, senior management seems to have nurtured a highly discretionary, de-centralized culture as well; one that is seen as appropriate for its present, mainly R&D mission. Technical management is clearly concentrated at the team level, with Group level coordination and oversight conducted much as it might in an academic engineering department. There is, of course, a stronger background presence of resource planning, the spill over of agency (DOE) budgetary dynamics, and information security processes.

The group's main working area (Sigma Site in local LANL parlance) is home to most of MST-6's work teams and spaces. Save for the surrounding single fence and small guarded access shack, it has the feel of a university lab. Halls are lined with research meeting notices and posters, only occasional evidence that classified work goes on amongst the various R&D projects. This relatively large heterogeneous group combines (mixes) strong development capabilities with extensive small batch production experience mainly in service to developmental

[28] I thank the Group's present and former leaders, Ray Dixon and Rich Mah, for their skill in introducing this stranger to their demanding and often singular technical and operating domains, and for their interest and generosity in opening this group and its teams to an outsider.

weapons and their testing. War Reserve quality work, at any sustained level, will be somewhat novel to younger staff.

Along with the "wielding and joining" team, the foundry/machining and the beryllium metal teams are the larger and potentially most involved teams in WR component production activities. While both teams clearly evince enthusiastic commitments to R&D, they are at somewhat different developmental stages. On the one hand, Foundry and Machining work is done in well-matured facilities with an array of specialized, one of a kind furnaces and equipment suitable for flexibly addressing novel development and research demands. And they work with a variety of materials. Development projects will be mixed with production in a sprawling, hands-on, industrial environment. On the other hand, the Group's decade long efforts to upgrade its beryllium technology programs has resulted in a new, substantially remodeled, state of the art Beryllium Technology Facility (BTF) designed to support sustained manufacturing of Beryllium components, as well as research and development on this highly hazardous metal. The BFT joins "Sigma site" as MST-6's two main facilities.

Of high temperature furnaces and molten metal.[29]

MST's foundry works occupy several large, barny, high ceiling rooms filled with a wide array of high temperature furnaces, mold making and casting apparatus, machining equipment, and massive overhead cranes. A bank of open offices line one side wall, protected from the potentially hazardous work area by a open ceiling interior wall. In each of three visits with the team, I was informally briefed on the variations of furnaces, from small conventional ones, to several very large, potentially volatile ones. These briefing, in effect, were also a safety orientation, outlining both the hazard and how they had processes to minimize the risk. In the midst of the main room is a clearly marked "clean area" calling for smocks and booties waiting at a station near the entry to this large inner work area. A hand and foot radiation counter was close by, so was an array of emergency response equipment.

Foundry Team Leader, Paul Dunn, briefed me on the team's work and its status as one the few fully capable metallurgy foundries of its type. Combined with their own machining capability, thus not dependent on others to provide this service, they have maintained a high degree of flexibility by avoiding both the time delay and the difficulties in design communications that afflict most other less completely supported foundries and component

[29] Many thanks to Foundry team leader, Paul Dunn, and technical staff members, Robert Aikin, Jr., and Deniece Korzekwa, and Phil Tubesing, for their patience, engagement, and effective instruction. The team's roster includes 14 people including administrative support personnel and some members devoted mainly to machining.

operations in the weapons complex. And some of the team's capabilities are unique to this facility. This accounts in part for the muted sense of technical excitement that suffuses discussions about the team's work, and its R&D accomplishments. "We're doing things here that could not be done in universities." At the same time, computer assisting technologies and processes have had to be retrofitted to equipment long in use. And universities often have better versions of some types of apparatus.

The team's work is planned at the beginning of each week in discussions with all seven of its members, four Anglo TSM's and three Hispanic technicians in an informal, hour long gathering in a small office on the foundry floor. Dunn presides over an easy, collegial discussion with a mix of administrative announcements, "there is increased attention to managing classified documents," and an up-date on the status of the four or five on-going projects calling on the relevant TSM and technicians. This is followed by discussions of new developments in the team's resource situation, contacts with other labs, and proposed projects. The projects the team thinks can begin within the week are assigned to the appropriate technician and his TSM supervisor. Often some time will be spent debriefing the technical results of an ongoing project, reporting surprises that are spotted from a particular casting. Ideas are suggested by the TSMs, discussions ensue, the somewhat taciturn techs are drawn in with good humor and clear respect. In side conversations, the TSMs describe their tech as very experienced, "they have seen a lot," and very capable, "we would have a hard time replacing these guys." There seems to be a kind of functional affection for them, with a pointed sense of their particular, often widely ranging skills.

The work style and quality of this team is seen as they engage each project. With their leader attending to external matters, the three other TSMs work closely together in analyzing the results of R&D projects, in drawing on sophisticated computer based data streams that chart the progress of an earlier casting technique, and in reviewing the extensive store of digitized photos that record each casting and its results. These discussions are animated, give and take, shifting from one TSM to another as the findings touch their respective areas of competence. They complement each other, teach each other and obviously respect each other's technical views. Seeing this team in action is to witness a small group of dedicated professionals and technicians with infectious enthusiasm for and independence in tackling the technical puzzles they take up. Planning for the next steps goes on, again, in a mood cooperation, joint problem solving, and engaged good humor. I sense I was seeing, for the first time, an archetypical expression of technical work in process that LANL professionals tout as the source of the lab's contributions and a key to its attractiveness to technically creative people.[30]

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[30] A passing note. My field observations in July, 2000, at MST-6 and Sigma Site, came in the context of continuing work in NMT and TA-55 as well, though my acquaintance with the teams of NMT-5 had come about a year early. The two locations presented very different social situations, and impact on the observer. Summer of 2000, TA-55 was deep in the

The spirit of experimentation continues as projects are carried out, molds reworked and installed in waiting furnaces, and often exotic alloys heated and cast in shapes to be used in explosives or weapons research. Techniques were being perfected for use in other DOE weapons facilities or by industry. Technical puzzles and unexpected results in a casting drew intense interest from the whole team gathered round the unveiling of work begun the day before - in this case, the casting of a cylinder with materials and a size pushing the envelope of what has been done in the past. The result has not been completely what they sought. Everyone contributed to the diagnosis, "see this discoloring around the side of the furnace," "look at that rough spot on the casting, must meaning an uneven distribution of cooling." The techs review the process they went through, and comment on what would have to be done if their collective analysis were right. One of the TSMs goes to the computer work station on a portable table near the apparatus and with fingers flying calls up the records of this project reviewing the distribution of temperatures, enters new data and calls for a digital picture of the casting. The next steps are proposed and a note is made for later debriefing. Surprises have been interesting, uncertainties the source of learning. Production demands seem very far away, the discipline of "war reserve" in another world.

I wonder how they will respond to the rigors of sustain production. The team thinks they can do it, the numbers of components needed will be well within their present capacity. There was one rueful comment, "Well, we'll have to space out research projects more than we do now." Will, I asked, the record keeping be much more than now? "Oh yeah, a lot." But no one there has done this sort of work. They don't have a good estimate. Turns out that between them -- they and the techs -- the team is only one or two deep in the types of skills needed to do what they do now. They think that maybe they will have to assign two techs to production, but they don't know yet. "Might need another tech and another TSM that knows about production processes." There is an undertone of apprehension.

The machining and foundry team seemed to be the most thoroughly R&D oriented of the several I visited. They are experts at their craft; they work as a collegial team of respected cooperative members; they operate informally with clear regard for the team's safety and with an unspoken acknowledgement of their respect

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throes of reacting to a series of draconian measures thrust upon it by DOE and Lab management. NMT was experiencing a safety stand down that had gone on in some of its units since March. In concert with far reaching computer and classified documents security measures, and uncertainties about the shape of the newly establish National Nuclear Security Administration and the possibility of a dramatic change in DOE's contract for lab management with the University of California, NMT management, technical staff and support personnel had begun to exhibit signs of deep dispiritedness, worry, and frustration. In contrast, the folks of MST-6, where work exciting to its TSMs continued with little outside attention, projected a sense of enthusiasm and elan. A day's time at NMT left one weary and mildly depressed. A day with MST left a bounce in one's step.

technical and operational skills. Process scheduling is flexible, contingent on the availability of often unusual materials and special equipment. Deadlines dissolve in the face of expected surprise. These qualities have resulted in very good work; they are also reasonably rare technical team characteristics. Many of them remind me of the dynamics of nuclear engineering in the early days of nuclear power plant development. I leave the foundry wondering to what degree the formal rigors of sustained WR production might erode these dynamics.

Other teams in MST-6 that will take up long term production work are those engaged in R&D and fabrication with Beryllium (Be) metal. We end this journey of exploration with the Beryllium Technology Facilities (BTF) folks and the plasma spray team as they prepared for full operational certification.[31]

Working with Beryllium[32].

The contained world of the beryllium works returns us to a venue of extraordinary caution and exotic materials. Beryllium metal has a variety of industrial and weapons uses. It is both very dense and quite hazardous in particulate form, and it is produced currently in the U.S. by only one mining firm, Brush Wellman, employing aging technology. There are no U.S. firms that have a strong fabrication capabilities. In addition to its uses in industrial processes, this metal is also important in the functioning of nuclear weapons. LANL has a commitment to provide up-to-date Beryllium R&D and fabrication capabilities for U.S. industry and in support of our nuclear deterrent capability.

The dynamics of work with beryllium are strongly effected by its hazard and MST Division's increasingly singular national role in working with this resource. In particulate form, if much of it is breathed or ingested by susceptible workers, it can result in a lingering, often fatal chronic beryllium disease (CBD). Some 119 workers have been diagnosed with CBD, many have died (far more than those killed by plutonium). The metal is not radioactive and, therefore, is much less detectable in work spaces. There is as yet no effective detector of air borne Be[33]. Emphasis on worker safety in industry and government labs has resulted in a thorough going re-evaluation of risks of all sorts. In the case of beryllium related work, this has meant a much greater awareness of its dangers and the measures that reduce them. There are at least three means of assuring extraordinarily clean working environments, including highly refined air filtering systems and pristine working conditions and

[31] At the time I was able to become acquainted with MST-6, the group was in the midst of conducting an Operational Readiness Review anticipating a similar DOE level review of the BTF which, if judged adequate, would enable the facility to commence beryllium processing operations.
[32] My thanks to Steve Abeln, BTF's manager, for his insights and orientation to the beryllium world. He amplified an initial introduction by Rich Mah, then MST-6 Group Leader, and one the lab's key beryllium experts.

clothing, great attention to processing and managing Be powders to avoid contamination, and strong emphases on industrial hygiene training and work procedures, including meticulous records on worker activities and potential exposure. This produces many of the same work practices and architectural features associated with plutonium work, through in the absence of immediate detection capabilities. One important variant: while beryllium does present some important weapons design and technical specification information sensitivities (and classification requirements), beryllium is not of itself – like Pu -- sensitive weapons material. Hence, many of the physical security fixtures of TA-55 – armed guards, materials accounting processes, and buildings designed to prevent malicious invasion -- are absent in the beryllium work.

At LANL this work goes on in the newly operational Beryllium Technology Facility (BTF). Renovated, upgraded and thoroughly vetted for the most effective safety, Industrial Hygiene, and operating "best practices" measures, the BTF is the best of its class, likely to be a model of its kind in the world.[34] Located in an "open area" of the lab's central Technical Area 3 (TA-3), it is deceptively modest, indeed, unassuming in size and presentation. A small suite of offices is accessible from an unmarked door on one side of the building. It is only when one advances toward the beryllium handing spaces themselves that the quality of design -- and potential hazard -- of the operation becomes vividly apparent. (See Appendix, Methods Note 4.)

Entry to the beryllium handling part of the facility is through a separate external door, with the familiar, badge swiping security entry lock, and one must be escorted. I'm with a team skilled in a particular technique for fabricating beryllium components.[35] They have briefed me on the activities they will be doing that week: a process they think most nearly demonstrate the dynamics of the work they will be doing. They will be going exactly through the sequence of complex tasks in operating the plasma spray process, with video cam in hand. The objective is to make a demonstration film to show what actually happens inside the BTF when it is in full operations. These video films, along with a full array of fixed video cameras through out the facility, and protective glass windows in the several workrooms with walls abutting the area just outside the handling areas themselves, are designed to provide substantial transparency of the work for safety and operational training purposes. It is also intended as a means of demonstrating the processes to outsiders. Once the facility is in operations, to minimize the risk of exposure, no unauthorized persons, including lab or DOE personnel, will be admitted.

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[33] It is notable that MST-6 has stimulated efforts to develop one through a recent contracts with the Schools of Public health, University of California, Los Angeles, and Berkeley.

[34] It has already drawn international interest, and is to be, in effect, a teacher to the beryllium world.

Inside, round a turn, in a narrow hall are spaces where personal safety equipment is stored, further along one picks up the protective full body overalls and glasses. One moves into a change room, with personal lockers and safety posters are here and there. There are shower rooms off to the right: each worker takes one at the end of his/her shift. Donning two protective suits for each worker, then gathering up booties, each person straddles a low bench in the Barrier Room separating the outside world from the clean one inside to put their booties on. Fully outfitted in protective clothing that will be laundered after each work session, staff members check into a small Industrial Hygiene (IH) Data room to log in their presence on a computer work station. Each team members picks up his full-face respirator from the room, checks that its air filter is operative and adequate. During this ritual, the team is warming up with cheerful banter and enthusiasm for their new work area. They have been together for a number of years, seen a lot, and, when asked, they note that there is no other team they know of with their skills. Indeed, Rich Castro, their leaders, finds himself serving on an international advisory committee that is setting standards of beryllium work world wide.

Making their way from the IH Data room along the side of a larger room being outfitted for manufacturing, we enter a small anti-room to the plasma spray area. Then through a heavy door into the beryllium workroom itself packed with equipment, a pressurized glove box and control panels, and the computer controls for machine tools. In one corner, there is yet another small, windowed interior room where beryllium and other metal powders are stored, awaiting. These spaces have just about enough room for three people to work without crowding each other. But it’s a close fit and intensifies the need for effective communications, now made the more tentative by the constant background sounds of an intense air filtering and ventilation system and the muffling effect of the
full face respirators. The solution has been to equip everyone with plug-in headsets and earphones. Plug-in stations are mounted here and there in both the main workroom and in the powder room.

The work processes (which were being filmed) call for extensive coordination, checking the progress in changing pressures and temperatures in the glove box. The team is in state of frequent communications, with checklists for nearly every procedure. As they go through the set-up and spray procedures, there is a steady stream of comments on how things are going. Surprises are considered, next steps modified with effective give and take. Each member seems to have particular experience, deferred to by the others. Their concentration is intense, especially when they work through the procedure for changing containers of beryllium powder. Crowded into the small powder room, there is a premium put on movements that absolutely minimizes the potential for

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[35] This is the Plasma Spray team of three TSMs, Rich Castro, its leader, Kendell Hollis, and Brian Bartram.

beryllium spills or contamination. A cleaning swipe of potentially exposed surfaces is done after each movement. Each step in the process is logged in, each step noted. They engage in a kind of industrial choreography, of closely coordinated movements framed with comments and encouragement.

It was, to my mild surprise, closely parallel to what we had seen in a much different setting -- the choreography of handling and maneuvering high performance aircraft on a carrier deck.

The tasks are complete, time to close out. Egress follows the reverse of entry. Deliberately, systems are shut down, checklists followed. Communications aids disengaged. One by one, the team members, make their way back through the rooms separating the hazard from the outside. Back to the IH Data Room, where respirators were checked again, logged in and readied for analysis of the filters in search of possible intake of beryllium particles. We return to the bench room, off with the booties, into the laundry bin, followed by the coveralls. Glasses returned to a storage rack. Hands washed, and, had this not been a demonstration run, showers would be taken as well. We swipe out the security badge reader, and retreat to the outer offices. The video tapes will be available there.

The project was nearly done, "we'll wait to see the tapes," but they think it has gone to their satisfaction. They sit back for a moment and reflect. They have been working together on this facility for sometime. It has passed rigorous evaluations thus far. They think it, along with the other spaces and expected equipment, are ready and will be able to handle the demand for R&D work as well as weapons' requirements. Indeed, they were beginning to look forward to engaging with industry; they knew of several industrial applications they'd like to try. And there was a quiet sense that, due to the nature of the beryllium industry in the U.S., their value was on the increase, not just for weapons research and support, but to become broad leaders in the beryllium field.

The tone and texture of the beryllium and foundry teams and the dynamics of MST-6 were the most the positive -- least fraught with an underlying sense of worry -- of the several units we have been describing. To be sure, both the teams expressed reservations about how their futures would unfold, but at the same time there was a sense of muted optimism.

They had not been confronted yet with mounting demands of war reserve production regimes, nor had they felt increasingly pressed by customer requirements. I wondered to what degree these pressures toward formalism, planning rather than exploration, and increased proportion of repetitious production would erode the roots of the respect and trust that seemed evident.

The MST-6 teams projected vividly the conditions of exploratory teamwork based on respect in the face of hazard. The other teams of NMT-5 and DX-1 portrayed with equal vividness the conditions of precision and reliability in the face of hazard. These dynamics have common characteristics, ones that, at first, took me aback. There were many of the characteristics that we had found typifying the working groups in much larger organizations operating hazardous technical systems often in turbulent and unpredictable environments. To discover them expressed consistently across the teams involved with R&D on nuclear weapons, teams that would soon be taking on a much greater production role was unexpected. When I embarked on this project, I had only the slightest notions about I would find. They did not include the discovery of existing pockets of what we have come to call High Reliability Organizations (HRO), as desirable as that might be given the hazardous and exacting nature of war reserve production.[36]

I turn now to a more general discussion of these units and the HRO characteristics. This is followed by a reflection on the challenges facing LANL in the event that they judge (as I do) that maintaining the remarkable pools of effectiveness will be central to the long term success of their expanded mission.

## Working Teams and The Elements of Highly Reliable Organizations (HRO).

This segment of the project has been devoted to increasing our understanding of the working dynamics presently expressed by the teams likely to be involved with War Reserve weapons component production at LANL over the coming years. At the outset of this paper, I attempted to identify many of these teams. We have examined five of them, perhaps half of those that are involved. In this sense, the coverage has been partial. It has also been based on subjective observation and interviewing. At the same time, the five teams present a pattern of characteristics hat span nuclear and non-nuclear production activities in three groups and divisions, across four facilities.

[36] Recall that in T.R. La Porte, “Institutional Elements for Long Term Stewardship in a Nuclear Age,” the paper preceding this one, argues that assuring HRO characteristics -- one of three such clusters of qualities -- is implied by the claim to stewardship offered by DOE and LANL in their management of nuclear weapons. This paper was framed well in advance of the field work reported above.

These following observations -- findings if you wish – should be treated as reasonably well founded hypotheses. On this basis, what could be expected?

**There is a good likelihood of a deeper, persisting pattern characterizing all the teams that will be involved with component production.**

Each team demonstrated at the time of observation a high technical and operating competence, if not a taste for schedule disciplined, formalized production. And they reflected a series of qualities that are associated with very effective, reliably performing teams who face highly hazardous conditions in changeful operation environments. These "high reliability organizations" (HRO) qualities are relatively rare in technical operating venues generally and seem particularly apt for LANL as the lab takes up increased production requirements. Table 1 below lists these qualities, along with a summary judgment of how nearly the nuclear and non-nuclear component produce teams expressed them at the time of the study. The reader may indeed have his/her own sense of how these teams are doing, and/or can estimate this from the short descriptions above.

Discussion. The qualities that are associated with highly reliable operations encompass internal processes focussed on unit goals, reliability enhancing practices, and a team culture of reliability. There are also important requisites for certain types of relationships with institutional sponsors and stake holders. In terms of the presence of these qualities in the five teams discussed here, three qualities or characteristics are unvaried in their strong intensity. Two of these set the attitudinal tone for everything else: commitment to achieve highly reliable operations, both in production and safety; and complementary organizational cultural norms stressing the equal value of reliable production and operational safety. While the observation is, I suppose, to be expected from able people who are proud of what they do and aware of the dangers inherent in their work, I was struck by how vividly they were expressed and observed.[37] Given these attitudes, it is then not a surprise to see they all the teams exhibited high technical competence as well; something that is absolutely essential in maintaining highly reliable operations through time.

A fourth quality - sustained, high technical performance – appeared at only a moderate level. The teams' performed very well – in keeping with their capabilities – but they had not experienced the capacities and

[37] These attitudes account, in part, for the equivocal response in some units to the recent lab wide effort to institute a formal, highly visible program of "Integrated Safety Management" (ISM in local parlance). Insisted upon by DOE and the University of California in the aftermath of a short string of safety incidents across the lab, the very public nature of the activity suggested inferentially that somehow these teams – facing hazards nearly everyday -- had NOT been taking personal safety into account.

sometimes the support to keep a sustained, steady pace of excellence. Part of this was due to the R&D nature of much of what they currently do. Much of this work comes in smaller project sized packages, some of it turns out to result in surprises that alter or bring the work to a stand still, but there are other structural reasons as well. Relations of some of these units with DOE, the source of funding, have been haphazard. And some of the teams are in situations where infrastructure improvements are required before sustained weapons component production activities can go forward. So they have achieved excellent performance, but it has not been sustained.

Table 1. HRO Qualities at the Weapons Component Working Level.[38]

(+s and –s indicate intensity of the characteristic: ++ strong indications to – largely absent; ? at risk)

| Characteristics of Highly Reliable Organizations (HROs) | Qualities of Technical Teams: Nuclear (TA-55) | Non-Nuclear (DX-1, MST-6) |
|---|---|---|
| Internal Processes | | |
| ** Strong sense of mission and operational goals, commitment to highly reliable operations, both in production and safety. | ++ | ++ |
| ** Reliability enhancing operations | | |
| * Extraordinary technical competence. | ++ | ++ |
| * Sustained, high technical performance. | + | + |
| * Structural flexibility and redundancy. | +/- | +/- |
| * Collegial, de-centralized authority patterns in the face of intense, high tempo operational demands. | ++ (?) | ++ |
| * Flexible decision-making processes involving operating teams. | ++ (?) | ++ |
| * Processes enabling continual search for improvement. | o | o/+ |
| * Processes that reward the discovery & reporting of errors, even one's own. | + (?) | + |
| * Strong teams based on respect and trust. | ++ (?) | ++ |
| ** Organizational culture of reliability, including norms that stress the equal value of reliable production and operational safety. | ++ | ++ |

[38] These qualities are outlined in chapter 1 above. For their elaboration see T.R. La Porte (1996) "High Reliability Organizations: Unlikely, Demanding and At Risk", Journal of Crisis and Contingency Management, 4, 2 (June 1996), 60-71; G. I. Rochlin, T.R. La Porte and K. H. Roberts (1987) "The Self- Designing High Reliability Organization: Aircraft Carrier Flight Operations At Sea." Naval War College Review, 90 (Autumn), 76-90.

Other operating practices and dynamics increase the teams' likelihood of demonstrating "grace under fire," and adjustments to surprise, both important aspects of operating well in a hazardous environment. Three of these have to do with team dynamics, others with discovery and improvement.

Clearly, each of the teams exhibited a suitable level of structural flexibility within the team and as they operate within their groups. The teams' structures were informal, with some capacity to shift skilled people here and there. But they are not robust. Critical skills are thinly distributed, and they lack the internal redundancy which provides the skill and experience depth that teams require for steady, reliable performance in the face of unpredictable overload, unexpected personnel absence, or emergency situations in the work place. The fragile staffing quality of teams is also worrisome when a longer time perspective is taken. These work teams (and other similar ones) are central to long term production capabilities. With only one or two members each representing critical skills, they are now ill placed to prepare the next generation. Members of an emerging generation are now in scant evidence. It is, of course, logically possible that the types of technical and operational skills needed for weapons component production and R&D support work would be readily available from future, wider ranging technical and industrial communities. If that were to be the case, then the present degree of apparent team fragility or brittleness is of small moment. If, however, this may not be the case, then at least careful analysis of its likelihood is called for. And, if it were to turn out to be unlikely (something now expected from those who are on the firing line), effective measures to introduce members of that future to technical and working requirements seems particularly in order.

In addition, two decision-making team and group characteristics are particularly important in achieving highly reliable operations in hazardous setting. They are both clearly evident in the teams we have observed. All of them were characterized by quite de-centralized authority relations as work processes grow in intense and tempo. This means that when intrinsically hazardous activities intensify, supervision and responses to operating demands are initiated at the work place without the requirement to seek approval from others. When this spirit of cooperation and discretion obtains, it allows for speedy responses to needed changing in cooperative action and, importantly, to surprises. Together with the capacity for flexible tasking, this enables those most experienced with particular problems seamlessly to move in and direct the activity without regard for formal position or status.

The other aspect of reliability enhancing processes, flexible decision-making involving operating teams, was also quite evident in this study. Though I did not report this in the small case descriptions above, there was invariably a good deal of team leader involvement with group leaders in developing work strategies, operating pace and direction of work. Rather than mainly taking direction from Division or DOE project offices, the teams often had the opportunity to bring their expertise to the table, so to say. This increases the likelihood of feedback from the working level, more realistic expectations, and team confidence in those who are instrumental in sending them "into harm's way."

Highly reliable operations also are associated with two processes of learning. These afford both the opportunity and legitimacy fully to understand the work processes and hazards involved as well as to identify sources of difficulties and reduce dangerous situations. The first, providing aggressive opportunities for continual improvement, obviously assists in assuring the other HRO characteristics of technical competence and performance. It also provides a foundation for team members of learn each other's competence and skills, to invest in team derived improvements about which they have confidence, and to re-enforce the bases for team members' trust in each other.

It is not a surprise that this characteristic is widely demonstrated throughout the working groups at the lab. After all, LANL's main claim on public resources stems precisely from an expectation of technical learning. At the same time, the constraints placed on the component producing teams by the prohibition of finally testing the assembled weapons appears to have reduced the intensity in searching for at least technical improvements in those teams most likely to confront the disciplined rigors of War Reserve production. This was already evident in the two teams I observed of NMT-5. To several of these team members, improvements in process and micro-component design were obvious, yet they knew they would be faced with anxious military customers if any changes in the basic fabrication processes were introduced. This was also evident to a lessor degree with the fabrication section of DX-1's detonator production team, though it was a problem for the engineers of the quality improvement section. Interestingly, neither of the MST-6 teams seemed to chaff under this constraint. Nor had either become involved, at the time I conducted the field work, with immediate demands to carry on War Reserve quality work at least at the intensity which would require a reasonably large proportion of technical staff time.[39]

[39] Recall the MST-6 teams was facing less relative involvement in war reserve production. They expected to continue to be engaged in a wider array of R&D as well as industrial activities than I sensed in either NMT-5 or DX-1. It is also possible that the onset of WR infrastructure development that was going on in NMT had not reached MST by the time I was working in MST-6. An alternative would be that MST-6 has in its recent past already dealt with the WR kinds of processes and had found them less limiting in terms of pursuing improvements and changes than other teams.

The other learning process has a different, more salient cast for hazardous operations than ones for which trial and error learning is a major mode of learning. When operating errors can result in grievous consequences, unit members tend to be very careful. But mistakes can happen, not due to neglect but to missteps, or not due to ignorance but to overload. How might highly reliable operating groups respond? One response is to seek means to identify small errors before they trigger large consequences. This includes "processes that reward the discovery and reporting of errors, even one's own." While such processes of encouragement and reward may be functional, they often run counter to organizational norms of harsh accountability measures that punish error making. In most such situations, operations are assumed to be sufficiently straight forward that mistakes are needless, and/or workers are assumed to be intrinsically negligent. This notwithstanding, in hazardous operations it is in the team's interest to avoid covering up errors and to learn from them so that such situations are not repeated. And, indeed, there is a modicum of exactly these dynamics in the teams I observed.

In most cases, this is an informal, unsystematic matter. Small mistakes were made, and acknowledged within the team. Sometimes they seemed to be discussed, other times they became an occasion for on-the-spot learning and "debugging." Only within the MST-6 setting, at least in my hearing, was the reporting of one's own error explicitly encouraged by group leadership. This came in the context of the matter of handling (or rather the mishandling) classified documents, where in the regular, weekly scheduled all-group meeting the group leader made a point of counseling his people to report to him or their team leaders situations that might be seen as document mishandling. This would be treated respectfully and without punishment. These sentiments were publicly re-enforced by other senior members of the group. It is worth noting here for the reader to be aware, first, of the unusual, and positive sensitivity to this relationship among those I talked with in these teams. It is also notable that realizing the benefits of error reporting requires a climate of substantial trust within the teams and in high supervisors and management. I turn now to the more general expression of work team trust and respect.

The four of the characteristics we have been discussing, when seen together, result in the work dynamics strongly associated with highly reliable operations. In a sense, their presence across the teams constituted one of the several surprises for me that came from this field work.[40] I reiterate them just below.

- Flexibility and cooperation of members within the work teams.

- De-centralized, authority relations that change to fit the challenges in the face of intense, high tempo operational demands.
- Flexible decision-making within the groups that involved operating teams.
- Norms that reward the discovery and reporting of errors, even one's own.

None of these qualities flourish in a team or group climate of worry about the skills or commitment of team members, nor of institutional distrust. The degree to which they were evident in each team of interest here is a clear indication of the more general sense that the weapons component production network could build upon "<u>strong teams whose dynamics are based on respect and trust.</u>" This represents a remarkable asset, one that is relatively rare in organizations generally. Whatever else happens in an organization, if it has such assets, they are to be protected, nurtured by whatever means the organization has. Relationships of trust take years to build, minutes to destroy, a generation to recover.

As far as one can tell on the basis of limited field work in a complex organization, a good number of the qualities associated with highly reliable operations were present in the summers of 1999 and 2000. I sensed that much of this was due to the ways group and division managers worked to absorb or anticipate external situations that could penetrate "to the floor," potentially disrupting the patterns of behavior I have summarized. Were the external environment to be more or less benign, I expect these patterns to persist. If, however, pressures from the LANL's external environment increase in ways that make it difficult to sustain relationships of high technical and operational respect and team trust, an erosion of these qualities could be expected.[41] In fact, such pressures were evident during the time of this study and account for the indications of "at risk" (see '?' in Table 1 above) for four HRO enhancing characteristics in the nuclear teams of NMT-5. I address this matter below.

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[40] A fifth, "processes that encourage a continual search for improvements," was less evident in some teams due, it seemed, to the constraints arising from a policy a testing ban in nuclear weapons' management.

[41] Along with adequate resources and amiable policy continuity, there are also several externally oriented organizational characteristics that increase the likelihood of highly reliable operations. They stem from the unusual difficulties most organizations have in maintaining the internal resolve and the expenditures implied by the internal characteristics discussed herein. While external relationships have not been a thrust of this portion of our work, we do have a subjective sense the degree to which the groups we learned from exhibit them. They are:

| <u>HRO Characteristics</u> | <u>Nuclear</u> (TA-55) | <u>Non-Nuclear</u> (DX-1, MST-6) |
|---|---|---|
| *External Relationships -- DOE // Outside* | <u>*D / O*</u> | <u>*D / O*</u> |
| ** External <u>"watching" elements</u>. | | |
| * Strong superordinate institutional visibility in parent organization [DOE]. | ++ / o | + / o |
| * Strong presence of stake holding groups. | o / - | o / - |
| ** Mechanisms for <u>"boundary spanning"</u> between the units and these "watchers." | ++ / - | + / - |
| ** <u>Venues for credible operational information</u> on a timely basis. | + / - | + / - |

While relating working team experience to management behavior and pressures from external sources were not the focus of this project, (though it could be for a subsequent one), the evolution of LANL as a national institutional resource involved interesting, sometimes, unsettling, currents that penetrated deeply into the organization. In the next section, I reflect on some of them with the question of their possible effects on maintaining and continuing the present mix of qualities that sustains the R&D, a s well as the emerging War Reserve quality production activities of those units involved in weapons component fabrication.[42]

## Reflections on the Present Context: Challenge to Institutional Constancy.

Recall that our interest in the challenges facing LANL has been prompted, not only by the immediate dynamics of introducing sustained production work into an ongoing R&D institution, but by the likelihood that this society will commit itself to assuring this function for an indeterminate number of generations. Recall also that the context of maintaining nuclear deterrents — within the parameters of the Comprehensive Test Ban Treaty – adds an intriguing twist. If an effective deterrence capacity is judged to be needed, this is to be done for generations without end -- a kind of "social forever" –and doing so limited by the prohibition to test fully assembled weapons. Testing was the most effective means of signaling to potential adversaries that we continued to have a capacity to mount a nuclear assault. In its absence, the basis for such a demonstration is the more subtle, institutionally demanding requisite to provide continual evidence that the professionals, technical staff and supporting organizational infrastructure is the best in the world. As I heard someone put it, "If you can't test, be the best."

When this project was proposed over three years ago, my expectations for this element, were to chart something of capacities present within LANL that seemed to be necessary to maintain the lab's value to the society for years to come. And, in this regard, we have been interested in those who work directly with demanding materials, engaged in processes and function "on the floor" making components. Indeed, on the basis of this preliminary study, we have gained a modest sense of what this might mean at the hands-on production team level.[43] These teams presently exhibit strong capabilities, and, while they are only thinly staffed, they also provide evidence of teams build on mutual respect and trust, and engaged in relationships strongly associated with safe, highly

[42] Many of the HRO and long term continuity challenges pertain to other nuclear weapons stewardship functions, such as the dismantelment and surveillance programs. I suspect systematic study would find a similar pattern of HRO enhancing behaviors and demands for these functions, as well
[43] For our purposes, we shall assume that our "sample" of perhaps half of the fabrication production teams likely to be involved reflect the patterns in all such production teams.

reliable operations. This represented a remarkable and unusual resource. Maintaining teams with these characteristics and able to support both R&D and small batch manufacturing from one generation to the next becomes a major management and program imperative.

I had expected, three years ago, then to propose whatever additional capabilities might be considered to assure "institutional constancy" and "public trust and confidence," for generations to come.[44] But so much has happened to LANL in the intervening years that this more or less straight forward approach is less warranted now for it was based on the tacit assumption that lab and UC management's would be in positions to reflect on these challenges, challenges I had reason to suppose they would be interested in addressing.

While the team characteristics I summarized originate from the interactions of those who continually face significant hazard, their development also requires at least tacit encouragement from immediate and institutional management. It is an interesting, perhaps crucial, question whether the institutional dynamics of the weapons laboratories will allow the efforts likely to be necessary to sustain HRO dynamics for a number of generations. I turn now to some of the characteristics of the lab environment that bears on this question.[45]

Given the importance of assuring the repeated generations of HRO capable work teams, to what degree do changes at LANL and have the potential of reaching down into the working teams in ways that re-enforce or inhibit effective work?

## Large trends in LANL's current development.

As these trends are outlined, keep in mind I am summarizing a sense of the institutional conditions that would affect the capacity of critical operating teams and groups to persist in providing highest quality working dynamics in the face of changes in planning, design and engineering opportunities, as these are accompanied by the distractions of facility operations, and regulatory formalism and the disciplines of national security. This discussion is intended not as body of conclusions, but rather as a rough frame reference the reader could use to estimate effects on the team and working dynamics vis-à-vis the qualities introduced above.

[44] Recall the conceptual discussion of these ideas is outlined in Chapter One of this final report, La Porte, "Institutional Elements for Long Term Stewardship in a Nuclear Age:..," op cit.

[45] The discussion of these characteristics is abbreviated in reference to the laboratory's institutional environment. I assume that readers of this report will e familiar with the LANL's organizational patterns. Extending this discussion to these matters was not envisioned at the outset of the contract. A treatment adequate for readers unfamiliar with the labs would require another paper of at least equal length. While such a discussion would, I think, be useful and enlightening

Four features of laboratory life are likely to challenge the institution in realizing its newly acquired challenge to assure generational continuity:

- An increasing proportion of WR component production to R&D in the relevant groups;
- Continued use of the Program and Line (Division) organizational structure as a means of coordinating Sponsor (DOE) demands and the maintenance of technical capabilities;
- Increasing pressures from institutional sponsors and overseers to tightly adhere to externally imposed customer demands, and accountability and regulatory stipulations; and
- An increasing range of regulatory coverage, with greater external visibility and rigor in the administration of regulations. (See chapters IV-VI below.)

As Production Increases.

As the mix of war reserve quality manufacturing increases in proportion to research and development work for the teams involved, the difficulties of daily operations are likely to increase as well. As we noted at the outset, the work requirements and social dynamics differ significantly. R&D activities embrace uncertainty and interesting surprises, WR production seeks unchanging predictability and formal discipline. Put in the context of a weapons component production mission, each type of activity is characterized by somewhat different organizational, operational and staffing factors. Table 2, contrasting R&D to Production activities, provides a compact summary of these varied characteristics. There has been much written about the variations in work processes comparing R&D with production requirements. The list in Table 2, derived from conversations with NMT staff, is a quite cogent expression of much of this institutional wisdom. I use it here, for it has particular salience in LANL's evolution where the language of its items is broadly understood. A review of this list, (without itemized discussion) suggests substantial, systematic differences in unit goals, the likely attitudes of staff, work practices, incentives sought, and external bases for evaluation. To accommodate either set, for R& D or for WR production, is demanding for teams and groups that would take on one or the other of these missions.

Let me invite the reader to put him/herself in the place of a team member, or better a team leader, or perhaps a group leader. Consider the mix of characteristics listed in Table 2. In whatever lab environment you wish to imagine, reflect on the dynamics you would anticipate when you attempted to accommodate both sets of

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for the communities that support and oversee the labs, and the academic field of organizational studies, it will have to await another time.

requirements. For those who find themselves asked to deal with a relatively equal mix of them, you might expect that it would provide a dicey matrix of pressures, potentials for uncomfortable trade-offs, and grounds for continual tension and possible conflict. Without considerable team and group leader skills, and an unusual level of Division management thoughtfulness, guidance, and forbearance, providing continually at the working level for an environment that sustains the qualities of confident, highly reliable operational actions becomes at least moderately problematic. But the currents within mixed mission teams go on in the context of other sources of support and strain.

Of Program and Line (Division) Distinctions.

Another source of support or complication in increasing the likelihood of continuity issues from the dynamics of the "program – division" relationships that characterize the exchanges between DOE and all their labs. Program Offices in DOE's Washington headquarters provide direction and resources for work to be done on one area or another. LANL is predominantly supported by the Defense Programs Office, a bureaucracy of various hues, that watches over the nation's nuclear weapons establishment.[46] Each laboratory accordingly has organized itself partially in terms of these DOE-HQ offices. LANL, for example, has a Nuclear Weapons Program Directorate, another for Threat Reduction, correlated with DOE's Nonproliferation programs. LANL further segments its Defense Program (DP) activities into those associated with the science underlying the maintenance of the U.S. weapons stockpile, the so called Science Based Stockpile Stewardship (SBSS) program, and the NW- Materials and Manufacturing programs, the segment of interest to us here.

Recall that the Divisions, i.e., NMT, MST, and DX Divisions in our case, are the institutional locus of technical and production capacity. These are, as we've noted, based on a rough disciplinary clusters whose leadership has a major responsibility for assuring the continuation of high technical quality – residing in the caliber of their technical and support staffs, and the infrastructure of technical work. Program Offices both in DOE HQ, and their derivatives regional offices in Albuquerque, and locally in Los Alamos, assume they can call on (and provide funding for) these technical resources in meeting program objectives that often require a combination of disciplines and capacities that span several Divisions. Program objectives are then factored into a series of

[46] Divided mainly between Research, Development and Simulation, and Military Applications and Stockpile Management, Program Offices span such areas as Defense Science, Advanced Simulation and Computing, Stockpile Assessment and Certification, along with Nuclear Weapons Surety, Nuclear Weapons Stockpile, and Emergency Operations.

**Table 2. Distinctions Typifying R&D activities and Production Dynamics:**

By Salient Functions involved in Weapons Component Work*

**R&D** ◄—— to ——► **Productio**

| R&D | | Production |
|---|---|---|
| | **Organizational** | |
| Mirco scale | | Macro multi-disciplinary |
| Local Experts | | Multi-organizational |
| | **Task Dynamics** | |
| High uncertainty | | Highly discipline |
| High autonomy | | Highly directed |
| Open information system | | Closed information system |
| | **Quality** | |
| 'Cutting edge' technology | | Mandated/specific regs. (QC-1) |
| Novelty | | Reproducible |
| | **Process** | |
| Publishing | | Documented formality |
| Professional exchange | | Marketing distribution |
| | **Risks** | |
| Small scale | | Large scale hazard |
| Chem/bio/safety/criticality | | Large inventory |
| | | Large #s of people |
| | | Long duration |
| | **Personnel/Securit y** | |
| Academic freedom | | Top secret (Q) cleared contingent |
| Engage internal collaboration | | Compartmentalized/need to know |
| Dissemination of information | | Controlled information |
| | **Incentives****| |
| Discretion,freedom to pose questions | | Rewards for meeting deadlines. |

* I am grateful to Jim Ostic, NMT Division planning office, for this useful summary. It is drawn from notes on a conversation concerning perspectives used at least tacitly to consider the dynamics of planning within NMT Division.

**Added by T. R. La Porte, suggested in a conversation with Vann Bynam.

"projects" tailored for some collection of groups' capabilities.[47] Funding is negotiated between DOE Offices and LANL's Program Offices for expenditure on projects executed by the Groups. These projects are assigned to someone in a group, and usually to a program staff member for coordination and informal oversight. Tension

[47] For example, the NW- Materials and Manufacturing programs, is divided into the project elements, for example: Pit Manufacturing; Nuclear Materials Management; Nuclear Component Readiness; Manufacturing Systems; and Nuclear Materials Storage Facility. Each has its own manager.

between Division and Groups leaders and Program Directors and Project Managers is an intended feature of the Program-Line organizational design, each set of roles checks the divergent propensities of the other.[48]

Anyone who has worked within such an arrangement knows that, indeed, tensions are inherent between those who are: 1) charged with maintaining top level technical capabilities, the "line" Divisions, and 2) those in the Lab's programs who are charged with coordinating, often negotiating in conjunction with Division and Group leaders, with DOE Program folks. This arrangement has a number of positive attributes, most of them evident in times of "adequate funding." Negotiated work is likely to allow both Group leaders and Program representatives to meet enough of their respective needs to make for a more or less harmonious relationship. Neither party achieving everything they'd hoped for but enough to signal project and program progress and technical achievement. In the terms sometimes used in describing the social relations of work, negotiators can find ways agreeably to distribute "relative deprivation," i.e., everyone gets some (more) of what they want, no one loses absolutely.

Continuing this mode of coordinating sponsor (DOE) demands with the maintenance of technical capabilities in more frugal times (as is the case at LANL) changes the dynamics considerably. Now compromises are struck that result in "absolution deprivation," i.e., those who gain may be seen as doing so at the absolute expense of other groups or programs. If DOE program needs remain more or less stable from year to year, then accommodations are often worked out. "You get advantages this year, I get them the next." But when DOE program objectives become ambiguous, and/or are shifted frequently or abruptly (as is now perceived by LANL leaders to be the case), and/or resources are diminishing or changed abruptly, then added pressures build up on the LANL program officers and on the group leaders. In the first instance, program representatives press for quick changes in group behavior sometimes without assurances that funds will actually be there during the time frame of the work needed. Group leaders, for their parts, scramble for funds to maintain coherence in their technical

[48] The terminology of Project management is used in another way within LANL as well. There are a number of very large construction projects going on in various locations across LANL's wide expanse. These represent new facilities dedicated to supporting various scientific aspects of Science Based Stockpile Stewardship (SBSS) that require sophisticated, complex often dangerous machinery, as well as the planned work to upgraded existing weapons production facilities. The progress of these large projects has been checkered and subject to much criticism by DOE and, for some projects, by Congress. In response, UC and LANL have recently established a "Project Management Division" with the intent of increasing lab skills in the management of such large, complex, time limited projects. Since they do not directly impinge on daily life in existing facilities, they are not an immediate source of pressure on work teams. As we see below, however, such mega-projects may come to have a distorting effect on many other activities within the institution. Of course, logically, when they are completed, they may also become the source of relief to the frustrations of crowding, limited equipment, etc. This is much to be hoped for, though rarely experienced, by many who are disadvantaged during the mega-project.

capacities, keep strong teams together, contributors satisfied, and facilities up-graded to support high quality performance.[49]

Over sustained periods of such funding and/or project equivocality, program negotiating and group management efforts intensify. This takes a number of forms, one is the tendency of some project leaders (representing DOE programs), perhaps understandably, to engage Group leaders directly in seeking to provide financial resources to assure progress on their particular projects. These may not be coordinated with other demands and needs at the Division-wide level, and, indeed, this works on occasion to undercut the influence of Division management coordinating efforts.[50] As this type of interaction wears on, the depth of resentment both parties (program and line people) feel toward each other grows. From the divisions' view, they are the "real workers," the program officers, are "bagmen" bringing in the cash from DOE DC. At the same time, program people see themselves as unappreciated protectors of the lab's integrity in the face of unjustified, unreasonable, and intrusive demands from Washington, and they view division and group leaders as sometimes petulant, short sighted technical people who have a limited sense of the incoherent behavior of and threats posed by DOE "program types."

In effect, this structural arrangements produces a kind of micro-"two cultures" dynamic. One in which there are intrinsic tensions. When they grow and become intensified, they can come to occupy important portions of group and team leaders' time and attention. If such tensions – conflicts is generally too strong a term -- are not managed gracefully, they introduce added strain within the teams themselves. Management's responsibilities in assuring a balance of views and perspectives, and in providing a decision-making environment to realize the benefits of this arrangement without slipping off this tight rope into situations of interpersonal conflict probably must stem from both the division and lab-wide management levels.

For NMT's part, where their capabilities and growing manufacturing mission draw significantly more program and project officer attention, it has responded recently in an interesting way. In the past, project managers were sited in facilities close to the seat of LANL's institutional power, the main administration buildings of TA-3, well removed from the particular setting of TA-55. Informal contacts were limited, communications were often

[49] This dynamic took on a strong form early in 2000 when some $5 million was withdrawn by DOE without changing the demands to continue work on the quite old Chemical Materials Research Building (CMR). The short fall was extracted from activities devoted to equipment upgrades for weapons component fabrication, and for other technical work (R&D). This precipitated increased efforts by project leaders to influence group leaders to attend to particular project needs.

[50] There is also a kind of parallel in reverse. LANL Program Managers have direct negotiating relations with counterparts in DOE HQ, and in the Regional Office. Division leaders sometimes perceive these managers, in an attempt to secure resources and satisfy unreasonable DOE demand, to agree to program arrangements that commit the Divisions and

intense via phones and email to be sure, but this truncated the interactions among project managers themselves, and between them and group and division people. In a way, each "side" was somewhat relived from having a refined sense of their effects on the other.

In an effort to redress this communication and perception situation, a number of the Nuclear Weapons Materials and Manufacturing Program elements have been moved to the Division Office of NMT. Managers for these program projects now have offices "cheek by jowl," so to say, with their division counter parts, some literally "next door," down a short hall from each other. Part of this arrangement includes the expectation that project managers, for the first time, regularly attend the bi-weekly NMT Division Management Team meetings. This brings those who are charged with the planning and resource budgeting for technical work to be done in cooperation with NMT's technical groups now in more continuous, close contact, and hence with greatly increased positive possibilities for exchange and informal coordination.[51]

All this brings members of each culture into continuous proximity. The hope is that this will provide a means for better, more tolerant understanding of each "side" about the other. If this occurs, it is reasoned, then each "partner" will take the other's problems and travail into account – and respectively change their unhelpful behaviors. There is, of course, another possibility, now that expectations for improvement have been raised. The constraints on "each side" may be sufficiently tight that the anticipated accommodation of "each side to the other" cannot take place. One result could be increases hostility, rather that its decline. To "know one another" can result in the discovery that the other is, in fact, so different and so apparently intractable that it calls for escalating resistance and continued pressures to change the overall arrangement.

The jury is still out regarding the evolution of these relationships within NMT. Those in the division operation arena have done a good deal of what they can do -- without changes in relationships "above" them, in the processes used by higher lab management and DOE program offices (and perhaps in DOE and Executive Budget Office modes of control.) Tensions evident at the group level that are affecting technical work team performance may be reduced. If it is not, or if it increases, this adds greater difficulties in maintaining and continuing the extraordinary HRO behaviors reported in the paper above.

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Groups to impossible levels of achievements given allowable budgets. If this happens, it is perceived by some Division leaders that they, rather than Program Mangers, are fingered as the source of failure.

[51] It is also notable in the past two years that NMT - partly in an effort to provide themselves with coordinating and planning information to avoid those tensions resulting from inadequate planning and the consequent disruptions of work processes for technical work teams -- has gone to considerable lengths to increase its internal capabilities in project planning, and other system integration capacity, e.g., an increased emphasis on developing an overall plan for managing the movement of nuclear materials around the facility and the lab.

## A Comment on Internal Dynamics.

In the two sections above, we have ventilated two broad circumstances that introduce systematic tensions into the dynamics of group life, and that could increase the pressures on the dynamics and social relationships of technical work teams: the inherent differences for technical teams to conduct significant levels of production as well as research and development work, and the dynamics of DOE's program-line arrangements of funding and coordinating technical activities. Unless managed gracefully, these tensions can disrupt the relationships noted in Table 2 that are central to continuing highly reliable operations (HRO) and erode the bases for trust and respect that are at their foundation.

These are important possibilities. Indeed, on the basis of field work reported here, I had the sense that the work teams of NMT had, by the summer 2000 sometime after I had observed them directly, begun to feel the consequences of these pressures. This accounts for the "at risk" indicator for a number of these relationships listed in Table 2. But this may not necessarily result in decreased capacity.

Dedicated people absorb interpersonal tensions and internalize the strain associated with attempting to work effectively in hazardous and increasingly unsatisfactory settings. This, of course, can go on and perhaps has gone on for sometime, but it does not contribute positively to a receipt for sustained operations across several generations.

How rapidly deterioration of HRO patterns and dynamics takes place is also a function of pressures on units from their institutional surround, both from their immediate organizational setting and from the more distant but potentially intrusive regulatory environment. Turning to the characteristics of LANL's external work, are there reasons to suppose that work team effectiveness is further at risk?

### Increasing pressures from institutional sponsors and overseers.[52]

LANL, and weapons production units in particular, have, in the past four years, experienced a sharp increase in the demands from DOE: to adhere much more tightly to requirements imposed by DOE Program Offices; to demonstrate more direct management accountability via increasing external reviews and management audits; and

[52] A note to the reader. Like other aspects of the portion of the paper, the discussion below is not called for by the contract to which this paper responds. Indeed, much of what I will introduce below emerged only during the past year. Offered in schematic form here is a set of less systematic observations which I urge you to take as informal hypotheses. If, upon more systematic review, they turn out to be verified, the prospects for confident operations in this and the next work generation would be importantly diminished.

to closely follow a widening range of regulatory stipulations levied by federal and state agencies. These pressures – substantial and burdensome changes as seen by the lab community -- are to be expected for an institution that is emerging from a context of war fighting to one of peaceful maintenance of an important national capacity. The former context allows for greater discretion in technical direction, an emphasis on programmatic effectiveness over economic efficiency, and an operational climate limiting information about internal activities. Each of these characteristics has changed: discretion of all types has declined; resources available for the program missions are much more dear; and a climate of expected openness has penetrated the cloisters of shadowed work within which the interior environments of trusted exclusivity and elan can flourish.

"On the ground" within LANL, these demands have been expressed as intensifying pressures to up-grade facilities in the face of relatively limited funds, to respond to increased waves of external safety and management reviews, and to dramatically tighten information security measures. To be effective, these changes would introduce processes and demands that could find their ways into the everyday lives of technical teams. Given observed highly reliable operations and team dynamics, what might be the sources of pressures or enabling effects?

** We have already noted the dynamics of an escalating proportion of production to R&D work sought by DOE's Defense Programs Office. In addition to increasing the intrinsic tension within work teams and groups, the weapons production mission precipitated within LANL increased priority to review and upgrade facilities (infrastructure) built a number of years ago so they could be brought up to contemporary production and safety standards. This process began some five years ago and goes on apace today. By everyone's account, it has been needed at the lab for some years as deferring maintenance on facilities has been a conscious budget strategy for DOE as times have become leaner.

These infrastructure reviews have been generally welcomed (in an "it's about time" sort of way). And the effort would have had a deep salutary effect on the LANL community's confidence that it could continue to keep its "world class" standing had this analysis been complemented by resources and increased skills in proportion to the depth of need. This has not been the case. One result has been to amplify the intrinsic tension between those who are charged with assuring a functional, safe physical environment, and those executing technical work within them.

Facilities up grades and equipment improvements necessary for war research production quality are quite expensive. Most LANL facilities have suffered from years of deferred maintenance. Many of them are well out of date with piping, values, safety systems, etc., often from twenty to thirty years old, with equipment that is far too limited for the production demands that are anticipated. They are approaching the ends of their useful lifetimes. And, in the meantime, facility standards themselves which had greatly increased in rigor and scope

This has meant sustained reevaluation of the cluster of facilities needed to provide the various technical capacities and services to handle, fabricate, analyze and control relatively high volumes of dangers materials. Indeed, one of the major project activities in full swing when the UCB-LANL team arrived was the Capacity Maintenance Improvement Project (to become CMIP, the acronym which quickly substituted for the project's full name – a name subsequently to be forgotten by almost all those who used it.) CMIP was an attempt to address the whole range of upgrades in one integrated project in order to realize the economies of scale. The project revealed an intricate pattern of functional requirements needed to enact a technical system characterized by closely coordinated movements of hazardous and sensitive materials, and unexpectedly high costs. It also exemplified a more general tendency that often reached down into day to day technical team operations. The costs of CMIP type capital improvements have been substantially more than DOE program offices have been willing to allocated to them. At the same time, there has been little relaxation of the pace of program deadlines (though these have been regularly missed.) The upshot has been that progress either in planning or in facilities improvement has required LANL program managers annually to systematically drained resources away from those needed to conduct technical work. As a result, the work teams, still largely conducting small R&D projects, found themselves engaged in more intermittent work, and worrying about the likelihood that they would face less flexibility in work arrangements and short falls in R&D capable equipment.[53]

Our CMIP prompted research project also revealed a tangled skein of organizational overseers and regulatory constraints arising from the practice of various DOE Programs Offices supported different R&D activities carried out in particular facilities.[54] In the past, the weapons related R&D work has been oriented toward relatively small scale projects conducted mainly within one facility. There have not strong needs for coordination between the managers these facilities. In the main, the funding for this work and the maintenance of each facility was likely to become the province of different Program Offices at DOE. While perhaps suitable for a mainly R&D regime, the result seem to be a tangle of multiple jurisdictions if these facilities and the technical capabilities must

[53] Recall the example cited in note 50 above.
[54] See the next paper, Stone and La Porte, "Revealing (micro) operational networks: Life in the emerging (down-scaled) post-cold war world of nuclear weapons", for one perspective of this nest of relationships.

be drawn together in the support of tightly integrated production related work. Indeed, the prospects of coordinating so many Programs Offices in the interest of an integrated production and materials control are daunting. If this is not accomplished, groups and work teams swept up in the production mission will be faced with apparently incoherent organizational structures with the many everyday conflicts that arise in such situations, conflicts added to those already intrinsic to the mixed missions they have accepted.

** Other sources of pressures on working team stem from greatly increased concern from DOE about the degree of industrial safety and information security within the lab and especially within the plutonium facilities. Responses to these concerns have resulted in a greatly heighten procedural formality and sense of wariness among technical staff.

Over the past three years there have been a series of four or five safety incidents ranging from automobile accidents and electrical accidents (some fatal, others resulting in very serious injury), with significant loss of workdays and large legal judgements against the lab.) There have also been several safety incidents within PF-4, the lab's main plutonium handling facility. These have prompted a good deal of press attention, great concern from DOE's Defense Nuclear Facility Safety Board (DNFSB),[55] and strong demands from DOE and, at their prompting, the University of California, Office of Laboratory Administration, for the lab to <u>institute measures intended to reduce safety incidents</u> to virtually zero.

This took the form within the two weapons' labs of a highly visible, formal program and emphasis on Integrated Safety Management (ISM), an explicit effort in training and constant reminder that workers and supervisors should be keenly aware of the situations they confront, their hazards and the means to mitigate them. Within the past three years, the language and rhetorical currents of "ISM" have found their way in to work spaces, lab policy, operational documents, and regulatory scripts.[56] Formal goals have been promulgated from top lab

[55] This is the small, quasi-independent regulatory agency within DOE (parallel in function to the Nuclear Regulatory Commission for civilian nuclear matters) that has a major presence within LANL.

[56] The effort mounted from the Lab Director's office has been vigorously pursued in a effort both to heighten general awareness, and to negotiate a program which has the endorsement of lab staff. (See Integrated Safety Management Description Document, LANL-98-2837, Rev. 3.1) This has meant the development within the lab of activities and a framework intended to inform DOE's understanding of these needs, as well as the oversight requirements of the UC contractor. The Lab's ISM program, reasonably well supported with resources, has been diffused throughout the lab and is signaled by the what is called locally, as The Five Step Process – now a ubiquitous mantra of the process for performing work used throughout the DOE complex to support the establishment, implementation, and assurance of safe work practices. The five steps? 1.Define Scope of Work; 2. Analyze Hazards; 3.Develop and Implement Controls ; 4. Perform Work; and 5.Ensure Performance (Each has a series of sub-steps and set comes with a circular logo joining 1 through 5.) The program importantly includes a Line Management Self-Assessment Program element. See the LANL ISM web home page: http://www.lanl.gov/orgs/ism/. I am grateful to Phil Thullen, for insights regarding the development and deployment of this activity.

management. Training session have been held, formal statistics of the past and current incidents have been compiled and returned to each unit, and tacit resistance confronted. Work procedures have been reviewed, and unit managers have been faced with questions about their relative compliance rates. Records are now being kept much more fully, check lists multiply, and sanctions are beginning to be applied. And the incidents of infractions (already quite low) are on the decline.

Quite recently within NMT, the drive for extraordinary levels of safety have taken a more urgent, indeed, coercive tone. An safety incident in March, 2000, involving the malfunction of a swedgelock fitting (a very common item assuring a tight connections between piping segments) occurred in which an experienced staff members was potentially contaminated with small amounts of Pu. This incident prompted an immediate, DOE directed shut down of facilities within which these values existed (nearly all the PF-4 workspaces), and a full blown, highly concentrated program of replacing all of the offending swedgelock fittings. As this effort unfolded, it was discovered that there were over 20,000 of these components, each one needing examination and possible replacement. In the process, some two thirds the way through this effort in July, another incident occurred, this time involving an experienced staff member and a misstep in following procedures – a misstep that was judged to have had the potential of putting others in the work team at risk.[57] Although at the time, over 12,000 of these components had been "changed out," the local, Los Alamos, and regional, Albuquerque, DOE offices greatly increased the pressures on NMT. Two results have been to bring at least three external teams of evaluators and advisors in to canvass the situation, and, more importantly for work team dynamics, the insistence by DOE that work monitoring processes of a specific sort be put in place. Local and regional DOE have required, as a condition for allowing any authorized work to be done at NMT and PF-4, that all work which may has even very modest hazardous aspects must be observed.

The requirement is framed in this paragraph from a letter to DOE from NMT's Division Director (supplemented by a clarifying section):

> "All work at TA-55, that is authorized by a formal work authorization document…, (a good deal of what goes on) will be continuously observed by a person knowledgeable of tasks being

[57] These two incidents, neither of them resulting in serious injury, signaled a need to continue emphasis on careful operational practices. Both of them have reasonably subtle aspects that I shall not to into here. (See, for example, the Occurrence Report #: ALO-LA-LANL-T-55-2000-0014, and letter from NMT Director Tim George to Davis Gurule, Area Manager, DOE/LAAO, MS A316, NMT-DO:(U)00-105, Administrative Requirements for Implementation of Interim Compensatory Actions in Ensure Safe Operations, July, 21, 2000). Suffice it to say, that for our purposes these incidents triggered intense, often aggressive responses from the DOE local and regional offices.

performed. For JCNNM (the craft contractor), it must be a JCNNM foreman. The safety observer/supervisor shall have no other duties. When the safety observer must leave the work, work must stop." (Together with this clarification by NMT's Safety Officer.) The safety observer does not necessarily need to have the same level of training as the person he or/she is observing, but must be knowledgeable. Knowledgeable means an understanding of the job or task being observed, hazards associated with the task and having read the appropriate work authorization document… required for performance of the job. Additionally, the safety observer must wear appropriate (personal protective clothing and equipment) to protect themselves during the observation process. From a letter by Tim George, NMT Division Director, to DOE, July 21, 2000.

This seems a direct response by DOE to a situation they have come to judge as beyond internal repair. A situation that calls for no infractions, even reported procedural ones ("zero tolerance" in local parlance), and even as the organization is attempting to mount a maximum effort to redress a long-term structural facilities problem. DOE appears to feel that improvements will not occur without extraordinary DOE intervention into the working level dynamics of the organization (even as the lab has gotten kudos from DOE for its ISM program).

This is an interesting, and unsettling, requirement from the perspective of technical work teams based on a relatively high levels of trust and respect. First, the assignment of someone with suitable knowledge about the content of each work authorization acts to nearly half the technical and skill resources actually available for often highly technical work. This in the face of a situation describe above of already very limited skill coverage. Second, introducing essentially a "watcher" without a particular function brooks the possibility of increased suspicion about the watcher, a decline in both technical respect and trust among team members. Third, such an imposition upon well functioning teams with what could be understood as mainly in the interest, not of the team nor of local management, but to protect the people in local and regional DOE who are also held responsible for management performance. From the view of the teams of PF-4, then circumstances have brought down upon them the wrath of DOE locals who have introduced apparently non-negotiable demands that are likely to have very erosive effects.[58]

[58] It is worth noting that at the time all this was happening, NMT was attempting to buttress the ISM theme by devoting resources to establishing a form of "behavior bases safety" (BBS) which is intended to evoke from the working level suggestions for work practices in the interest of improved safety. A key component of BBS is to encourage the self reporting of mistakes with the promise that these will be the basis for learning not punishment. The DOE intervention puts this effort in a position of considerable disadvantage.

** At the same time, over the past two years, <u>two highly publicized breaches of national information security</u> have brought great attention to the LANL and add another potential source of pressures on technical working teams.[59] Both incidents were surprises to LANL staff and management. They were in a sense unthinkable for most of the lab community. Reactions were immediate, earnest and, then, harsh. In summer, 1999, after the onset of the Wen Ho Lee investigation both on-site and in Washington, an internal climate of concern, then fear developed. It was said that early in the summer a senior weapons manager, exploded with something to the effect, "Anyone making a mistake, will be fired." Investigators from Washington were much in evidence. The lab and its communities were becoming objects of derision in the media, and to the chagrin of the lab, of ridicule in most late night talk shows. The willingness to take even small amounts of discretion, or bureaucratic risks in seeking flexibility declined. As the year worn on, internal formal procedures grew, areas of formerly open working spaces became closed, with the increase in approvals, scrutiny of badges, etc. Deeply buried grievances held by some minorities surfaced. Social relations had a much sharper edge.

The summer of 2000 brought other surprises. In May, the Cerro Grande wild fire burned a significant portion of old Los Alamos, swept through the lab, and disseminated huge swatches of the forest and mountains just to the west of LANL. The community lost over two hundred homes. Nearly every Lab unit had people who lost everything. In some units, up to ten percent of the unit was effected. The lab and the community had used up a good deal of their social reserve. Energies were low and a precarious recovery was beginning. The tapes were found missing. There was no time for graceful recovery.

The world again descended on LANL full force. More pummeling from Washington, more external investigators now from an agency which had managed to win, at best, the skepticism of the technical, at worst, its disdain. Now the management of all classified information became at issue. All units were to inventory exactly all such information under their stewardship. Accountability was raised to a continual topic. Those who had become responsible for any handling of classified information became increasingly anxious. A number asked to be transferred to non-classified duties. What had been a satisfying service to county, had become a liability. "Who knows," it was said, "how this would play out?" Fear continued to extend to and deepen for those who managed sensitive information. More procedures were introduced. Each time a person operated with classified information, someone else must be there. Heightened formalisms in security joined formalisms in the

[59] One only needs go to the annuals of the New York Times or Washington Post to see extensive reporting on the "Wen Ho Lee and National Security matter", or the episode of the "two missing hard drives" alleged to contain information on

interest of safety, and formalisms in the interest of meeting a host of regulations that have been pressed on the lab in the past four years.[60]

How far would the effects of increased formalism and fear seep into the everyday lives of highly reliable working teams, teams that are rooted in respect and trust? We could not tell in detail. We were not in a position to engage with the emerging changes systematically. Nor, indeed, was this an aspect of our work commitments. But it does not take great insight to expect that serious disruption is likely. This is a much more plausible hypothesis, so to say, than its reverse. It is in the interest of all those involved with nuclear research and production to gain a much better sense of the effects on the likely continuity of that scarcest of all social resources in complex organization – the elan and cohesion of skilled, high reliably operating teams.

What may be at stake here? Earlier in this paper, I summarized, in Table 1, the characteristics that are important in returning an unexpectedly high level of reliable operations in the face of demanding conditions. At the risk of being tiresome, let me repeat part of this list. In addition to high technical skills, reliably performing teams exhibit these qualities:

- Flexibility and cooperation of members within the work teams.
- De-centralized, authority relations that change to fit the challenges in the face of intense, high tempo operational demands.
- Flexible decision-making within the groups that involve operating teams.
- Norms that reward the discovery and reporting of errors, even one's own.
- Strong, fully functioning teams whose dynamics are based on respect and trust.

Table 1 indicates that all of these qualities were evident in the teams of NMT, MST, and DX Divisions at the time I observed them. There was, however, strong subjective indication that, as this year unfolded, four of these five qualities for the teams of NMT-5 have been put at risk (indicated with '?' in Table 1). As fear and formal team and personal accountability to rules that often do not evoke confidence increase, there is a decline in the conditions within the groups and divisions that allow for the qualities of shifting authority patterns, decision-

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nuclear weapons design. These are well known to LANL staff members and to those who will be reading this report. I shall not dwell on the details.

[60] See below Stone and La Porte, "Regulatory ecology: A visual and analytical approach to internal and external networks of regulatory actors at Los Alamos National Laboratory," that explicates the degree of complexity this trend has prompted.

making flexibility involving superordinate actors, and especially, the willingness to report errors of the team or of one's own doing.  The level of respect and trust characterizing such teams is threatened and may be lost.

While this may not have happened within the weapons producing teams, if it has a good deal will have been lost and immediate attention toward recovery is in order.  It would be a cogent management strategy to gain much more systematic insights into the changes that are likely to have occurred at the working levels as a consequence of the extraordinary turbulence LANL has encountered.[61]

Thus far, we have cataloged an increasingly complex array of pressures within LANL, prompted by demands from DOE, that reach deep within the operating groups and recently may have intruded into the dynamics of technical team operations themselves.  This array adds greatly to the challenges of group and team management usually led by senior technical staff members.  These leaders, while skilled in technical aspects of group projects, are likely to be relatively new in their experience of dealing with the dynamics of small or moderately sized organizations.  It is possible that they could gracefully adapt to the pressures I have suggested so far – especially if these were the only ones.  But anyone who has been following the world of controversial technical operations in the U.S. knows that there is another domain – the arena of governmental regulations -- from which additional pressures derive.  As we will see later in the report, this represents a substantial, confounding element in assuring the conditions that foster highly reliable operations across several generations.

On the Sweep of Regulatory Engagement.

A fourth major source of pressure on the coherence of technical work teams is the increasing range of regulatory coverage that has evolved within the past five years.  This has been accompanied by a trend toward much greater visibility of LANL activities as seen by external overseers and stakeholders, and demands for increased rigor in the administration of regulations.  Regulatory requirements have engulfed the lab, originating from DOE, especially the Defense Nuclear Facilities Safety Board, from the New Mexico Environmental Department, from the Department of Transportation, and a handful of other federal and other regulatory agencies or stake holding bodies.  These have grown rapidly and have come to make up important networks of constraint and demands for division and group leaders.

[61] Some insight in this vein is provided by Howard H. Baker, Jr. and Lee H. Hamilton, "Science and Security in the Service to the Nation: A review of the security incident involving classified hard drives at Los Alamos National Laboratory, Report to the President of the United States and the Secretary of Energy", September 2000.

In a sense, the activities prompted by these networks represent myriad "unfunded mandates", and draw resources and attention away from the business of managing the "tight rope walk" of every day team operations. This development represents a major management challenge for the lab. Its magnitude is seen in the extraordinary complexity of these networks. These networks and the dynamics that animate them are the foci of the second part of this report, in chapters IV-VI.[62] We will return to this important aspect of LANL's world later. Suffice it to say now, that these networks of constraint levy considerable additional pressure on those who would continue to assure a working environment of reliability and continuity.[63]

## Concluding reflections.

What might be made from these descriptive analyses? Our interests here have been to estimate the implications of a mission that requires extraordinary reliability in operations for many generations. We wondered what that actually meant, and whatever it might mean, how were LANL's weapons component production groups and technical work teams situated to realize these demands. What we found at the working level were teams already evincing many properties of organizations with highly reliable operations (HRO). This is a most interesting outcome. Such organizational properties are relatively rare; they are rooted in a relatively high degree of respect and trust among those nearest to the hazards. When this does evolve in other settings, it seems often to be in spite of formal organizational structures and control processes.[64] At the same time, the teams we observed have been reduced to near minimum size; they are quite fragile in scale and in the depth of technical and operating skills.

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[62] See especially the explication of the "regulatory explorer" a model of these networks developed by Adam Stone. See Stone and La Porte, "Regulatory Ecology:.." op. cit.

[63] There is yet another unsettling element in this mix that indirectly affects team cohesion, this is the question raised when the DOE-UC contract for lab management is re-negotiated usually every five years. Of keen interest to the technical staff, this relationship between the labs and UC has had the advantages of an institutional norm of independence, of the professional incentives associated with membership in of the world's primer academic institutions, and of a retirement system that provides comparatively very attractive benefits. It should be noted here that in the past five years this relationship has also come to include an increasingly rigorous process of evaluation and reporting to the UC Office of the President as the new stipulations of Appendix F of the contract requirement for rigorous self-assessment have been enforced. Recently, the wisdom of DOE--UC contract has been challenged in Congress and by members of the DOE executive. (It had already become a thorny issue for the UC faculty in each of the last two re-negotiating rounds, for quite different reasons.) In the aftermath of Congressional and DOE criticism of UC role in safety, security and project management, there has been considerable anxiety among senior lab technical staff about whether the contract would be renewed, and if not whether retirement benefits long expected would be forthcoming. It is informally alleged that were the contract to be terminated significant percentages of those senior staff and technicians who could now or could soon take retirement would do. The indirect affects on technical teams stems from the additional background source of uncertainty for many senior tech staff, and perhaps more importantly the hobbling effect of losing important elements of the institution's operating memory.

[64] La Porte, 1996, op cit.

This situation is not unusual for organizations undergoing change in a resource starved environment. However, LANL's emerging mission success calls for achieving "world class" status ("if you can't test, be the best") for the technical and operational quality and expertise involved. It also calls for maintaining this standing for many successive work and management generations. This frame of reference prompts another set of interests: to what degree do the circumstance of the lab re-enforce or erode the likelihood that what is (or was) there will be retained?

This leads to a reflection – beyond the scope of the contract – on the structural factors that we argued are characterizing LANL's institutional world. Each one signals important opportunities for enhanced support from DOE and/or protection from increasingly aggressive forces in LANL's institutional surround. Each one also poses often intrinsic operating tensions that could erode the basis for HRO teams. These factor are an increasing proportion of WR component production to R&D; a Program and Line (Division) organizational structure; mounting pressures to adhere tightly to externally imposed customer demands, and accountability requirements; and a wide range of regulatory requirements re-enforced by increasing external visibility and rigor in the administration of regulations. These suggest formidable dynamics that have the potential for severely eroding the basis for the necessary skills, capability, and commitment characteristic of effective technical team operations.

To the degree (subjective impressions) and/or subsequent work verifies the strength of these factors, what is the measure of the challenges before LANL and the weapons producing groups and their cognate program offices?

One answer is to posit, first, that the middle to upper level managers of any organization have the responsibility to assure the conditions for their work force that enable them to flourish. In their intermediate role between the organizational sponsors and the HRO team in the trenches, i.e., if HROs below, then what would one expect of managers so that teams could evolve?

Schematically, it might be as follows:

Managers would seek to:

1. Buffer groups from

    Policy instability,
    Spread of fear,
    Reprisals. -> Through mediating the cross currents of their environments.

2. Assure groups:

    Facilities,
    Financial resources,
    Discretion. -> For utilizing high quality operating capabilities.

3. Re-enforce conditions of

    Skills,
    Elan,
    Dissent. -> As the bases for team trust and respect.

In this spare form, the schematic takes on the tone of management training exhortations. Few managers will quarrel with the points noted above. But they will very likely feel a sense of fatigue in considering them. One suspects that they will not feel themselves free to act on many of these injunctions.

To do so would mean they have the capacity to adjust at least micro-policies from DOE program offices, to have the skills and resources to mediate the demands of their clients and sponsor, on one hand, and the stipulations of overseers, on the other. It would also mean that they are able to bend formal structures of authority to counter the effects of command hierarchies, and to encourage functional heterogeneous arrangements in the groups supported with resources to assure their integration. Finally, it would mean that they had the skills and capacity to reach within the groups and teams providing the leadership and the resources to assure their crucial capacities for the next generation.

But now at LANL, and I suspect at LLNL, these management capacities seem in limited supply. As a result, a good deal of cumulative institutional damage has been done over the past two to three years. One senses,

- Increased fear and suspicion at all levels.

- A collapse of discretionary, risking taking behavior across all functions.

- Widespread psychological fatigue and career exhaustion among senior managers and technical leaders, and recurring tensions, increasing the cumulative pressures on the elan of teams and dedicated staff, that adds to institutional fatigue.

- A decline in respect for management within the DOE, generally, within the University of California, within the Labs, and through management down to the Group level.

In the near term, some institutional changes may afford modest relief. The reorganization of DOE's nuclear institutions within the newly vested National Nuclear Security Administration is perceived to add some institutional weight toward redressing the balance. Recent DOE resolve to extend its contract with the University of California reduces one important source of uncertainty for senior technical staff members and managers. But uncertainty and distrust seems quite substantial now. Much is to be done within this generation so that later one's will experience at least no more travail than this one. While a necessary objective, in a world of "if you can't test, be the best", this seems well below the mark.

## Appendix. Methodological Notes.

Methods Note 1:

Time available for field observation was made relatively more scarce than in other types of organizations by the nature of the institution. Research on and production of weapons of mass destruction invariably involves information about technical specifications and processes that are judged to be highly sensitive, i.e., highly classified information. And the materials used are often of high intrinsic hazard. While organizational relationships themselves rarely draw a highly classified, "top secret" designation," conducting field research on organizational matters in these venues may call for being in locations and observing processes which inadvertently put the observer in the presence of such information, and in situations that could results in very serious injury, even if the probability is very low. Wariness about increasing the risk of compromising classified information is a common motif for managers of these activities, and for the institutions within which they work. So is management concern and a sense of responsibility for the safety of both workers and of those who visit them in the work place. This means that field researchers, as a condition of gaining access, should understand the security and safety processes all workers in such venues follow, and be willing to demonstrate this understanding - via systematic training. This includes understanding that escorts are required when visiting secure locations (in LANL's case both for security and for safety reasons), and the wish of managers to limit the exposure (in place and time spent) of visitors to potential hazard.

As a consequence of these dynamics, preparing for, negotiating and conducting on-site observations and interviewing is likely to be rather more involved than research activities in less demanding venues. This is the case even when those who are the objects of such research are quite willing (as LANL staff were) to be engaged with the project.

Finally, researchers in these settings require a security clearance to do this work in the first place. This meant that only the principal investigator would be involved in the weapons production related aspects of the UCB/LANL project, and, hence, limited the amount of observational energies available. Even if the graduate students involved with the project could have gotten sufficiently high security clearances, they face a remote but still too high a chance of finding their work "classified" and thus be unable to publish in the open literature. We chose not to subject them to this risk.

Methods Note 2.

The span of on-site work covered three summers, each allowing two months of field research. Intensive exposure in 1998 to the non-Defense Program (non-DP) activities of the ARIES and MOX projects afforded a chance to deepen my understanding of the broader organizational structures and dynamics of LANL's production arena.. My thanks especially to Jim Toevs, Brad Smith, Tim Nelson, and Steve McKee for their excellent orientation to the ARIES project. This project – a technically elegant reconfiguring of the plutonium components of nuclear pits in architecture and quantity so that this materials could be inspected by international bodies to assure that weapons grade materials had indeed been removed from the stock pile - had matured over the past three years. The MOX project also afforded a case that instructed us on the technical and operational complexities of nuclear related work. Thanks to Randy Erickson, Ken Chidester, Jon Buksa, and David Alberstein for their help. (See also the work of Andrew Koehler, Design for a Hostile Environment: Technical Policy-making and System Creation. Diss., Graduate School of Public Policy, University of California, Berkeley, 2001, that chronicles this evolution.)

These opportunities, along with a very valuable chance to observe the dismantelment of a pit in the surveillance program with the able briefing by Patrice Stevens, NMT-16, provided an introduction to the types of work in a glove box environment that is similar to weapons component fabrication processes. It also began to show me something of the operating requirements for conducting technical work that would be necessary for work generation after work generation.

The summer's work in 1999 began early in June just as the "security immersion" occurred, a result of reactions to the Wen Ho Lee matter. (See Wen Ho Lee and Los Alamos, for a collection of stories in the Washington Post about this matter at http://washingtonpost.com/wp-dyn/nation/ specials/nationalsecurity/chineseespionage /index.html.) A combination of the ensuing internal turmoil and my first concerted exposure to the weapons production activities themselves suggested much more complexity in operations than I had realized. And the lab's response to pressures on it to review and modify its security processes resulted in a slow down of all production related work. Expectations for what our project could be accomplished were adjusted as I discovered the unexpectedly wide range of groups and divisions cooperating in weapons activities. These are remarkably complex technically, and are carried out within an extraordinary organizational matrix of relationships among the relevant divisions and groups. Perhaps as importantly, they face an array of dilemmas that are emerging from the lab's present operating and program environment. These dynamics not withstanding, I was able to become acquainted with two teams in NMT Division and one in the DX Division.

Then, in summer 2000, further security and safety demands broke over the lab, especially upon NMT and TA-55 (the lab's major facility for handling plutonium). See Vernon Loeb, Two Hard Drives: Understanding Los

Alamos, Washington Post, Monday, September 4, 2000 , at http://www.washingtonpost.com/ac2/wp-dyn/A56002-2000Aug31, for a cogent overview of this case; and Howard H. Baker, Jr. and Lee H. Hamilton, Science and Security in the Service to the Nation: A review of the security incident involving classified hard drives at Los Alamos National Laboratory, Report to the President of the United States and the Secretary of Energy, September 2000; and safety report, March 6, 2000.) This further limited weapons production activity, bringing it nearly to a stand still. (In effect, there was no work activity to observe or learn from.) My field efforts shifted almost exclusively to the non-nuclear component elements.

These circumstances have resulted in only partial coverage, perhaps a bit more than half of the technical teams who will be involved in weapons production activities as they evolve at LANL. Missing are the teams that prepare materials for production per se, and, due to the suspension of production activities, summer 2000, there was no opportunity to observe the important assembly processes which brings together teams from both NMT and MST. Nor was I able to get a sense of the several intermediate analytical testing, inspections, cleaning, and other quality assuring activities mainly carried on by individuals.

Methods Note 3:

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Working with these teams followed a general pattern. After discussing the project with the Group leader and gaining his cooperation, observations and interviewing were done in work areas themselves. I briefed the team's senior technical staff members (TSM) and its "lead tech" about our study objectives. They in turn were effective in giving me an orientation to their team's operations, its members' roles and specialties, and their general work processes. This was supplemented, usual the next day, by a description of the specific work regime that was to be done during the time I would observe, e.g., the process of casting a metal form, the roles of the team members involved and their relationships to each other. In most cases, I was also able to sit in on the team's work planning session. Observations of work generally was over a two to three hour period during which I watched the process and talked to teams members about what was going on, how this process worked in the event of surprises, and how they learned from them. Often I continued the conversation with a subset of the team after the production run. In addition to reviewing what had gone on, this time was used to get a sense of their estimates of how adequate their current situation would be for including the work necessary to support a 10 to 20 pits per year production regime in the near future. (In addition to drawing on general organizational field research guidelines, we benefited from an earlier acquaintance with the non-defense program's ARIES project now managed by NMT-15. See note 2 above.)

Methods Note 4.

My introduction the beryllium operations came in the midst of a series of reviews in which the Group's effort to bring their new facility on-line were being evaluated. This included an Facility Operations Readiness Review conducted by an external panel assembled by MST, in advance of a similar review by a DOE delegation,. Earlier in the year, Steve Ablen, BTF's manager, had provided an effective orientation to the facility, its design conception, and, via a "walk-around" before the last detailed bits of internal construction had been completed, a sense of its lay-out. The window for such visits was closing for when actual beryllium handling began, only those "cleared" to handle it would be allowed into these spaces. Shortly after my summer's work with the plasma spray team, the window closed.

# Revealing (micro)operational networks:

## Life in the emerging (down-scaled) post cold war world of nuclear weapons

The LANL/UCB
*Stewardship*

*Project*

Final Report


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Abstract: The challenges facing a newly construed and downscaled nuclear weapons complex in the U.S. are explored in the context of weapons component fabrication activities. Using a multi-layered visualization of the geographical, operational, organizational, regulatory, and social characteristics of the program, a preliminary analysis of the program is made. Each layer adds data to the analysis of a tightly coupled, potentially hazardous mission as it is deployed in a new setting.



University of California
Berkeley, California
September 2000


**Final Report: UCB - LANL Institutional Stewardship Studies - 1998-2000**

## Preface

The work described in this paper was primarily completed in 1997 and 1998[1]. Since that time, major changes in the organization of Los Alamos have taken place and the project describe here, CMIP, no longer exists in the way in was conceived at that time. Some of these changes will be addressed in the third to last section of this paper: The Changing Face of CMIP. As a work of methodology, and as a description of evolving organizational networks and the lessons which can be learned by studying them, the paper is of the same value to researchers and managers despite the differences from the present organization. This research would not have been possible without the thoughtful assistance of Walt Stark of NMT, who led the CMIP project during the period of observation.

## Introduction.

The work we describe arises from a compelling, often unsettling exposure to a compact and puzzling world in transition — a key research instillation of the nuclear enterprise both in its weapons and nuclear power aspects, Los Alamos National Laboratory. The challenges this lab faces are of signal importance to the future … in ways that are both burdensome and instructive as we more fully appreciate the public management puzzles associated with operating large technical systems.

Our interest concerns one of the demanding analytical aspects involved in understanding the evolution of a system experiencing intense contraction and compression: how to describe the "organizational network effects" of concentrating, in a greatly reduced geographical area, many of the technical functions supporting a radically scaled-down nuclear weapons production and maintenance capability. Our work is in the initial stages and we touch only on some of the analytical challenges that have arisen. Along the way, we will also

[1] This report, an earlier version presented to the panel on "Network applications to science and technology policy," Association of Public and Management, Oct. 31, 1998, New York, NY, is one of six papers fulfilling the University of California, Berkeley (UCB) -- Los Alamos National Laboratory (LANL) contract on Stewardship and the Design of 'Future Friendly' Technologies: Avoiding Operational Strain in Nuclear Materials Management at Scale. The project's objective is to identify the organizational conditions associated with credible, publicly trusted institutional stewardship of nuclear materials over many management and worker generations, especially in the LANL context as the lab becomes of singular importance in maintaining the U.S. nuclear deterrence capability. This involves understanding both the operational requirements that will be needed in succeeding generations, i.e., the actual work of producing a modest number of weapons' components year after year, and the regulatory environment likely to characterize that future. This paper addresses an unexpected aspect of the matrix of relations that characterize much of LANL's weapons R and D and emerging production environment. The project has been supported by LANL/UCB Award # 120BG-0018-23 (1998-2000). Earlier, background work was enabled by the Center for Nuclear and Toxic Waste Management, University of California, Berkeley, and the Los Alamos National Laboratory (LA-UR 97-3227, UCB Contract LANL-C14550017-3Y-LAPORT-06/97.

offer glimpses of other extraordinary research surprises that stretch the adequacy of contemporary public management and organization theoretic formulations.

Our involvement began — cautiously — some three years ago with a two questions, “Can we (as a society) assume there will never be a ‘rogue state’ that will turn to nuclear weapons as a means of political domination?” Then a pause, “If we can’t make that assumption, what are the obligations of the United States and its weapons labs?”[2] The person who put the question was the senior program manager at LANL in charge of the Nuclear Materials and Stockpile Management program. It was the Program leading the Lab in addressing a recently expanded mission: that of *managing excess weapons plutonium* and *assuring the readiness of the plutonium components* for our rapidly declining stockpile. The issues, he thought, were novel. “Would we be interested?” We were … somewhat warily … intrigued. After a number of twists and turns, we began what has turned out to be a slowly evolving relationship…with an agreed upon expectation to explore the organizational dynamics and management challenges associated with the resolve to assure that the U.S. maintains a “de minimus ” nuclear deterrent capacity… without end and without testing.[3]

Two of LANL’s technical domains have engaged us (both are supported by DOE’s Defense Program):[4]

1. One emphasis, so called “threat reduction,” involves reducing the volume of weapons grade plutonium now in a useable form. The weapons stockpile is now much too large and its aging; no

[2]The question was put to a seminar of UCB’s informal Center for Nuclear and Toxic Waste Management, a loosely knit group that brings together faculty and students from nuclear engineering, public policy, material sciences, political science, and energy and resources. This unusual collection is constrained by a charter that insists the conversation should hold the technical and institutional aspects of large technical systems as co-equals analytically. An agreement apparently unique in such exchanges on universities in the U.S.

[3]An aside: This way of framing the question begs matters of whether having used the atomic bomb was needful or not...or whether the continued presence of this technology is a moral or wise thing. Rather, from an organizational point of view, what are the institutional implications for a society when it commits itself even tacitly to being one of the five or so countries that possesses the craft and capability of manufacturing and delivering nuclear weapons in support of a deterrence strategy .... maintaining that capacity in the rare but not impossible likelihood of its need in some probably distant future?

[4]A third effort associated with DOE’s Environmental Management program is also of interest to us but not addressed here. It is EM’s prolonged “battlefield clean up,” responding to the damage we endured on our own soil as a consequence of sustained industrial war fighting during the Second and Cold Wars. There are over a thousands sites involved, for example, Rocky Falts, CO, and Hanford, WA. The most dramatic is the punishment delivered to the Nevada Test Site; many of the some 900 nuclear explosions there were samples of a new batches of weapons, i.e., to assure military commanders that one of a new run would work, therefore, increased assurance that the whole batch would work.

fresh plutonium is being produced. Agreements of arms limitation have resulted in many weapons being declared as excess and therefore candidate to be accounted for via international inspection and disposition. This calls for two initial steps. First, to disassemble "excess weapons," altering the geometry and mass of their plutonium components (it's the shape and sizes of these spherical "pits" that are classified), so that these reconfigured plutonium ingots (nicknamed "pucks ," the resulting shape) can be inspected and temporarily stored. Second, the material is either categorized as waste and mixed with ceramics or glass for final disposal underground, or mixed with uranium oxide (MOX) and fabricated for use as fuel in specially designed electric power reactors. Due to the very substantial downsizing of the DOE's national nuclear complex, much of the developmental work on these activities is being done at LANL.

2. Another major technical emphasis is maintaining a highly credible weapons stockpile as a hedge against the future — an indefinite future in which it cannot be assumed that we will never be confronted with the need, however rare, to mount a nuclear threat to an unknown adversary who has turned to nuclear weapons for aggressive purposes.

   This is made more salient by the recognition that, as the nuclear means for generation electrical power spreads to south and southeast Asia and other parts of the world, the spent nuclear fuel so produced becomes, in effect, a plutonium mine.

One requirement for this so called "weapons stewardship," is to be able to tell whether the remaining weapons that we will be holding "at the ready" [stored in this conditions sometimes for decades] will work if they are called upon. The U.S. has foregone explosive testing as a means of assuring that remaining weapons will still be militarily viable. LANL and DOE have turned to, so called "science based stockpile stewardship," (SBSS) in search of a substitute means to do this testing. SBSS depends on major initiatives in the study of the basic structure of the materials involved and in the development of highly sophisticated computer based simulation of the behavior of the weapons, a kind of "virtual explosion" scheme as a surrogate for empirical testing. This is a quite fascinating subject gaining considerable notice in the domain of scientific research. But it presents few of the puzzles of operations and management that interest us here.

The other requirement — managing existing nuclear materials — does. It involves a cluster of demanding operating dynamics within the network of facilities that together contain the technical apparatus, specially designed work spaces, worker safe guards, and storing areas which are needed for handling plutonium (Pu) and other high dangerous materials used in the technical work of:

a) monitoring aging Pu pits for continuing technical integrity (pit surveillance), and
b) re-fabricating a small number of "pits" to insure that these critical parts of nuclear weapons meet the specifications associated with expected explosive yield (component readiness).

Furthermore, this complex (of technical and organizational networks) is nested within an agency and regulatory environmental that is replete with semi-integrated networks of legal rules, program sponsors, enforcement units, and stake holders of all stripes.

Understanding the organizational dynamics set in train by these circumstance (and inquiry into the adequacy of public organization and management theory) call persistently for detailed analyses of *internal technical developmental and producing networks*, and the networks characterizing the "technologies" surrounding *regulatory ecology*, so to say.

The key organizational domain in each of these networks is LANL's major division, the Nuclear Materials Technology Division (NMT) and its Program symbionts. NMT is embarking on an extraordinary organizational evolution as its technical staff and technician cadres take up the challenges of expanding the lab's "pit" disassembly, surveillance and rebuild capacity, and support contribute to several of the technical options for the safer disposition of excess weapons plutonium. This is coming to involve an expanded organizational domain and intensification of the technical functions and complexities demanded by the missions. And, due to the intrinsically hazardous nature of handling the radioactive materials intrinsic to these functions, they all demand very reliable, safe performance.

NMT's key facility in seeking such performance is Plutonium Facility 4 (PF-4), a large, unique, and highly secure facility with the extraordinarily complex infrastructure necessary to protect those who, for various reasons, wish to work with plutonium and other Actinides. And this work will be received into an operational and political environments of that is for more astringent than any time in the past.

The challenge is extraordinary in the degree to which the NMT must meet the most salient properties of institutional nuclear stewardship: high reliability in operations, and qualities that assure institutional constancy, and deepen public trust and confidence for many years to come, that is, already "fit for the future."

Given these constraints and goals, two basic research approaches, separately implemented but very closely linked, presented themselves: a micro-organizational and a macro-organizational one. On the micro side, a program of particular interest to us has been the Capability Maintenance and Improvement Project (CMIP) – a large scale project with interesting organizational and social characteristics[5]. On the macro side, we were interested in what might be called the regulatory ecology of the laboratory – that is, the entirety of the web of regulatory entities that interact with the lab. In this paper, we comment mainly on the micro-organizational, internal logistical nets that characteriz the emerging "pit rebuild" capacity. An additional paper in this report (Regulatory Ecology, Stone and La Porte) outlines the macro-problem described here.

## CMIP: Micro-Organizational Networks in Physical, Social, Organizational, and Regulatory Space

With the closure of the nation's major plutonium production facility at Rocky Flats, the requirement to maintain the ability to create new pits was moved to Los Alamos. Although not a production facility, LANL was expected to be able to produce up to 50 pits a year. In addition, the special requirement of no testing discussed earlier, meant that the Department of Defense demanded that the pits be produced through exactly the same process they were produced by before. This program has several unique characteristics which led us to study it in detail.

As a manufacturing process, CMIP requires a high degree of coupling between the various stages of production – both because of the inherent hazards of the material and because of the social requirements for materials accountability, control, and operations security. At the same time, the hazardous nature of the materials and the "no testing" requirements translate into demands for extremely highly reliable operations – operations which must not only be accident free but also nearly defect free in terms of production[6].

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[5] Recall that this paper was writted in 1997-1998 when CMIP was in being developed and before the reorganization of of the CMR and TA-55 Facilities.

[6] Much of the CMIP project is classified. In our research, information was sometimes adjusted for our ears and sometimes was not available. Fortunately, our interests were generally at a high enough level of abstraction that the

This manufacturing network and its unique requirements would be a challenging mission under ideal and isolated conditions. Unfortunately, the network was planned to exist within four loosely defined “spaces” which would further effect its operations as it would effect theirs. These spaces divide roughly into four categories: physical space, organizational space, regulatory space, and social space. These provide the settings and functions that shape overlapping networks of organizational relationships.

Physical Space:

Budget constraints forced the new pit production activities to be carried out in existing laboratory facilities. Thus, rather then creating a new production environment, these new activities will have to be carried out alongside existing research activities and, perhaps most importantly, will be spread across multiple facilities. Physically, six separate facilities in an 8 square mile area will be used in the production mission. Each time materials move between these facilities, they are subject to various transportation and accounting requirements, depending on the type of road (protected or open) in use. Interestingly, the various facilities do not represent a long-linked production line in which the component is moved from, for instance, production to finishing. Rather, the production process resembles an intensive, reciprocal operations in which data and materials from each of the facilities is integrated continuously into the production process. For example, assay of the pits is handled primarily at a building separate from the production facility, but this information is integrated into the production at various stages. We might liken the process to an intensive technology and perhaps the pit to a patient in an emergency room – though it also has the character of a long-linked production technology as well.

The physical space is further defined by two public roads which must be used to transport materials between the facilities, as well as the different levels of security at the different facilities. These classifications range from TA-55, a category 1 facility – the most secure type of facility in the Nuclear Weapons Complex – and the shops, which are only a moderately secure Class 2 facility.

specifics of production were not necessary.

Organizational Space:

These six facilities further exist in a thick and tangled matrix of organizations within the laboratory. Because each of these facilities serves different functional purposes and generally does separate research, each of them is controlled by a different division of the laboratory. Cross cutting those divisions are a variety of program offices which control funding and administration. In the case of the pit production, only one program office is in direct control of the activities, but at least six program offices are involved in operations at at least one of the facilities. Further cross cutting the lab, are the internal regulatory actors who will be covered in the next section.

Not surprisingly, each facility also has different norms and work habits, as well as different protocols for certain materials. The laboratory's history of self-regulation and independence has resulted in a system in which each division often creates its own requirements and operating procedures. Even in places where lab-wide operations are practiced or regulated in similar ways, there are varying levels of compliance with these regulations. As one high ranking internal regulator recently remarked, "when it comes to the lab, you don't have to do anything in any particular way."

Further complicating the organizational space are differences, both within the organizations and between them, regarding perceptions of task and work. For instance, the Chemical and Metallurgy Research Building (CMR), controlled by the Chemistry Science and Technology Division (CST), is populated by chemists doing significant amounts of primary research, in addition to providing key support in analytical chemistry to divisions and programs throughout the lab. At CMR, the perception of work is that it is primary research – that is, the employees of CMR generally see themselves as chemistry researchers. In contrast is the dual-perception at TA-55 and its Plutonium Facility PF-4 that work is both production and research. With both large research and technical/production staffs, TA-55 alternately resembles both a factory and an R&D facility, with elements of both cultures mixed in. A further contrast is the machine shops, which will support functions in the pit fabrication process which could be described as a production-support facility, with a culture probably not significantly different from any other machine shop in any large production environment.

Regulatory Space:

In addition to cross-cutting formal and informal modes of organization and contrasting work-norms and methods, the lab also must deal with organizational issues regarding regulation. Although the department of energy has historically been self-regulating, it would be incorrect to assume that this has translated into a relatively streamlined or perhaps even uninterested regulatory environment. In fact, the laboratory is perhaps one of the most oddly regulated facilities in the country – with a variety of cross-cutting regulatory systems with overlap, contradiction, and often infighting .

Detour: Regulatory Ecology, Unexpected Tangles

While our specific organizational and physical interests here are in the specifics of the CMIP program itself, our interests in the organization of regulation at the laboratory are more broad based, driven by a set of larger questions about the interface between design, organization, and regulation.

This set of questions grew out of discussions with top level managers and designers whom we would constantly pester with questions like: who are your regulators? With some small variation, the answers were almost always different and less than complete. With this as a driver, we wanted to find out who regulated the laboratory. As contrasted to the CMIP "plan view" of organizational relations, this task takes the perspective of an insider, "looking outward." Our approach was not to establish what regulations the lab operated under, but rather who "embodied" those regulations. Working from many different laboratory documents and dozens of interviews, we attempted to formalize the tacit knowledge of the people who might be termed "regulatory in-betweeners," – that is, those people at the laboratory who have responsibility for dealing directly with regulators.

Through this research, a complicated web of connections is being revealed. The results of this research are found in Paper IV in this series, Regulatory Ecology. So far, over 50 different regulatory bodies claim some type of control over the laboratory. Yet, the actual authorities of these various regulators is rarely formally outlined; rather a set of informal agreements and practices which have emerged over the years dominate the regulatory interactions.

For example, consider the issue of hazardous materials transportation at the laboratory. For non-nuclear materials, the lab is subject to normal DOT regulations of both the US DOT and the New Mexico DOT –

reasonably straightforward. For nuclear materials however, the DOE has agreed to abide by DOT regulations, but is not, in fact, directly subject to those regulations. DOT, in turn, defers to NRC for regulation of nuclear materials – though the NRC also lacks direct authority. However, the carriers themselves are subject to packaging requirements developed by NRC, DOT, and agreed to by DOE. However, these requirements are not universally implemented, resulting in different divisions of the laboratory implementing the requirements differently (as well as each of the US DOE facilities implementing the regulations differently as well). DOE shipping regulation is handled at the national level within the DOE, as well as coordinated by the DOE-Albuquerque Operations Office, which coordinates TRANS-COM – the Department’s nuclear materials transportation tracking and coordination system. These regulations are, in turn, filtered through LANL’s Business Operations Division 4 (BUS-4), which also handles inter-department mail and Federal Express shipments. Further, nuclear materials are subject to regulation due to radiation doses to workers and the public. These doses are regulated by an even more complicated web of actors, including US and NM OSHA, the DOE, the Radiation Protection Program Office, the New Mexico Environmental Department’s Oversight Bureau, and even influenced by international standards bodies like the IAEA. If we were to ask the question, who regulates transportation at the laboratory, clearly there is no straightforward response.

And transportation is by no means the most complicated of the various regulatory structures affecting the laboratory. Returning to the questions derived directly from the CMIP program, there are connections between each of the various activities, and these complicated embedded regulatory connections. It is convenient to think about the macro and micro approaches as bottom up and top down approaches. One begins with the entirety of the lab while the other begins at the level of a single technical system configuration. The results of both research agendas both meet in this regulatory space.

## Social Space

Of course, the lab is also accountable to and interacts with a variety of other external actors. In addition to the expected communities and local and state governments, the lab interacts with five major pueblos and a variety of international partners, environmental interest groups, and even a surprising number of pro-laboratory stakeholder groups. Because of the secrecy and security under which the lab operates, the public sees little of what goes on “behind the fence.” However, the physical layout and structure of systems has an effect on these views, due to the transportation of materials around the lab. These transports occur on public roads which are closed during the shipment process. Surrounded by armed guards, safe-secure transports move sensitive materials around the lab while cars pile up waiting for the main road to be reopened. The physical layout of the CMIP system will require significantly increased road closures due to the locations of the various facilities.

## Spaces and Networks

Each of these spaces implies a complicated network of actors and organizations, connected differently and dynamically depending on the nature of specific activities and subject to fluctuation over time. These four levels led us to adopt a network approach for use in describing these interactions.

In approaching the CMIP project, we began with the facilities involved. In Figures 1 and 2, we can see the basic facilities described in the first section. The primary facility is TA-55 – where most of the production and plutonium handling and processing is completed. A sixth facility, the shops, is located behind the CMR building. Although this constitutes the basic physical space of the production mission of CMIP, the physical space actually also encompasses the road to the Waste Isolation Pilot Project in Southern New Mexico - where the low level waste generated at Los Alamos will presumably eventually end up. In addition, the PANTEX facility in Amarillo Texas is the storage and disassembly facility for all existing weapons and thus forms one of the primary inputs and outputs for the weapons production process.

Overlaying a top level flow diagram between the facilities (Figure 3) we begin to get a sense for the number and character of connections between the facilities. The existence of this network, rather than linear connections between the facilities, suggests the intensive characteristics of the production mission described above. Looking at these connections, we also begin to get a sense for the large scale movement of materials implied by this production. The line from PF-4 to CMR for Assay of the Pits, for instance, could be used up to 4 times a week, with each shipment requiring a road closure and a safe secure transport of the materials. That line also crosses Upper Pajarito Road, a public road in frequent use by Los Alamos citizens, lab employees, and visitors to Bandelier National Monument.

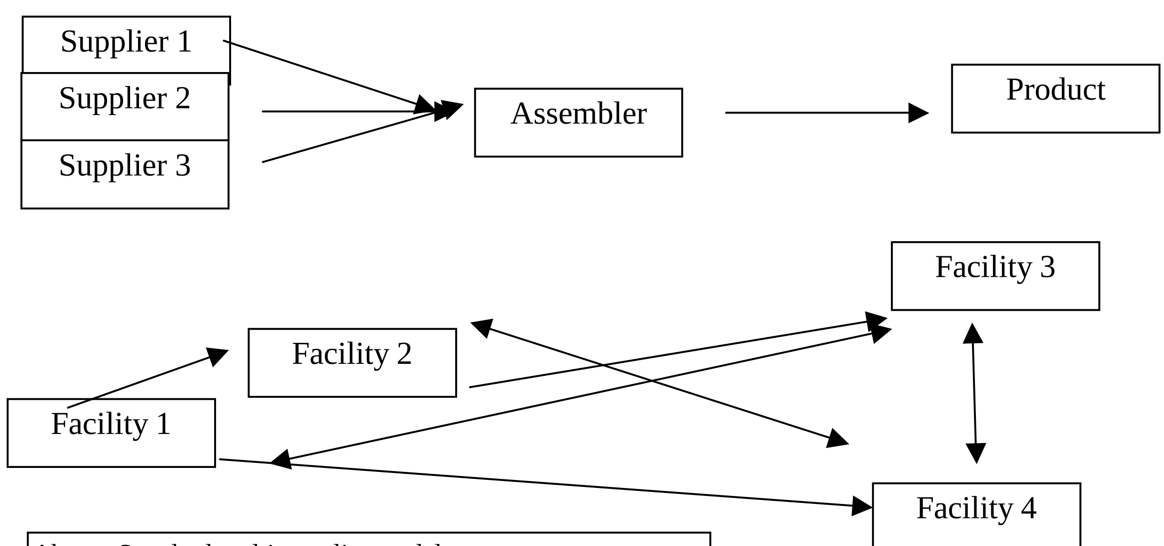
As we can see from superimposing the management map (Figure 4), while the connections between facilities are highly coupled and interwoven, the management of the laboratory is segmented along non-functional lines. Although a functional authority line exists in the form of the program office, many other management units have responsibility for various parts of the process, and employee loyalty has generally, in our experience, been seated with the division - not the program office. At the same time, norms, workhabits, and even safety standards differ between organizations - another set of differences implied by the "cones of responsiblity" shown on this diagram.

Finally, we can overlay regulatory networks as well (Figure 5). Returning to the notion of the diverging research agendas described earlier, the regulatory information is less well integrated with the specifics of the technical flow at this stage - though it will be better integrated in the future. Even given this, we can see that various regulatory actors have different interests in the different facilities. For instance, while the waste facility is highly regulated by the state, the state has very little oversight over the day to day operations at PF-4. We can also see the degree of overlap and competing claims to regulate that are implied in the production mission or in the buildings and services it will function in and utilize.

## Interesting Questions

Overall, these diagrams show a complicated and often conflicting set of connections implied by a deceptively simple mission assignment. Claims for authority flow in all directions and are numerous enough to present potentially significant challenges to the reliable operation of the system. At a minimum, the connections in this view seem to generate a number of interesting questions, two of which are explored below.

The first question suggested by the overlayed network diagrams is the extent to which the differences between functional and authority networks might translate into reliability issues. As diagrams 2, 3 and 4 show, the differences between the connections implied by the process and the connections in place for formal




Above: Standard multi-supplier model.
Below: Connected facility flow model.

**Diagram 0 - Two Models of Supply and Processing**

organization are quite stark. While such differences are similar to the ones experienced by any factory which receives parts from multiple suppliers, two basic differences are apparent. First, the flow of materials and information in CMIP is not one way, as we would expect it to be in the factory example.

This means that the level of communication and coordination required by the facilities is higher then those experienced in a standard production environment. Again, we return to the "intensive technology" analogy – while the operation has the final character of production, the process does not resemble a standard production operation.

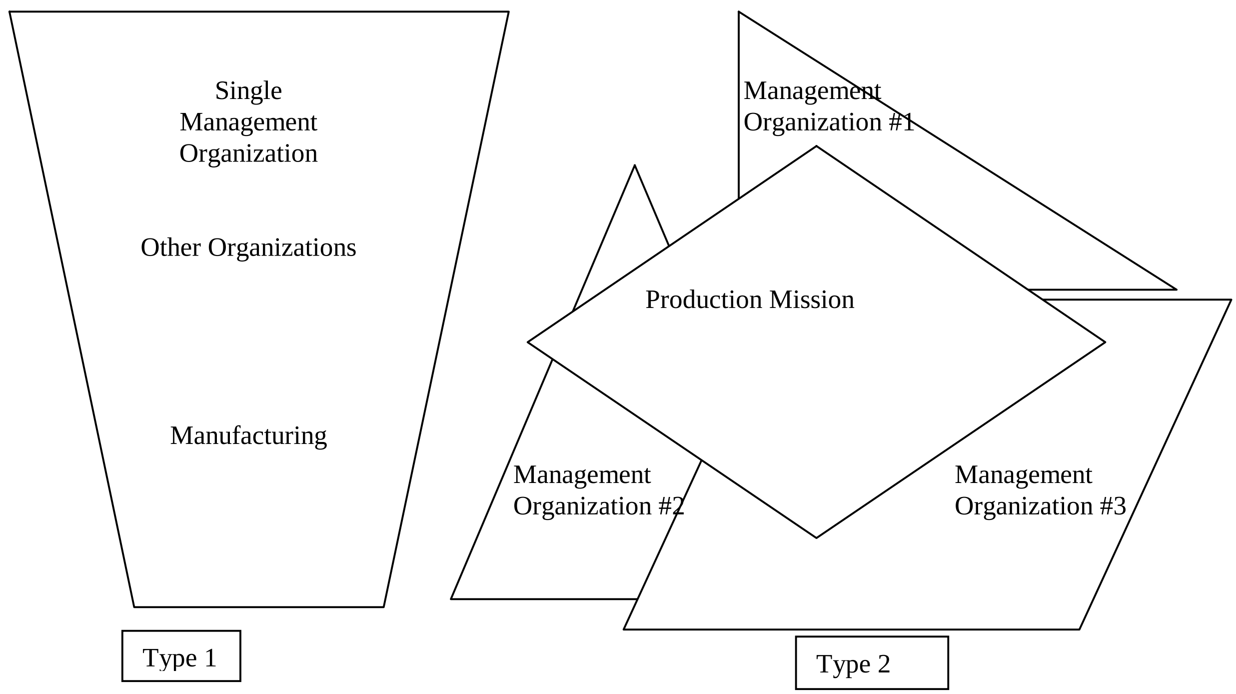
At the same time, CMIP also has the character of being somewhat tightly coupled. Although not as dangerous as a nuclear power plant, CMIP is producing extremely hazardous materials at relatively high operational speeds. The demands for coupledness are further increased by the organizational demands for materials accountability. Each material, as it moves between facilities, must be safeguarded and accounted for, increasing the level of communication necessary for reliable operations.

Together, these factors suggest that CMIP faces some interesting technical and organizational challenges in its quest for highly reliable operations. While this paper will not explore these constraints, this network analysis provides an analytically powerful window into these issues – further research is needed to formalize the hypotheses about reliability.

Another interesting question prompted by a graphical depiction of the CMIP networks is the extent to which overlapping and differential jurisdictions among organizations affects both the view regulators have of the system, and the view the public has of the system. Of course, both regulators and the public see the system through different filters, different not only from each other, but within each large group. Their views of the networks are affected by both the real and perceived networks as well as their necessarily partial view of the entire network of networks. Nevertheless, even without sampling each regulator's individual perception of the network or each stakeholder's perception, the graphical depiction allows us to ask the question: given the real network, from this actor's point of view, what does the network look like? In the case of CMIP, it looks like a quite complicated ball of twine indeed. This has implications for both regulators and the public.

One obvious question is: who is responsible for all this? In the regulatory frame: "who will I be able to trust to provide data." In the regulatory arena, research conducted at Los Alamos and with regulators in the Bay Area Air Quality Management District suggests that regulators prefer a singular point of responsibility and contact in their day to day operations. In the public frame: "who will be able to reassure me that the system is operating in my interests (or as near to my interests as possible)?" A simplified graphical approach to this line of questioning is presented below. In the Type 1 management structure on the left, a single management organization has hierarchical responsibility over other organizations and the actual operations of the project in

Two possible organizations of responsibility – hierarchical and overlapping. Perception may, of course, be more important that actual operations.




question. In the Type 2 management structure, one which mirrors the CMIP structure, multiple organizations exert claims of responsibility over the production mission. What does a Type 2 organization say to the outside world about its operations. One possibility is that it makes claims to have multiple layers of oversight, thus resulting in very reliable and well managed operations. Another possibility is that outsiders as well as those inside the organization are made uneasy about the lack of a single locus of responsibility. This graphical approach suggests questions about how the network is perceived and what connections and nodes might raise red-flags (or, alternately, raise confidence) in the institutions called upon to carry out these tasks.

## The Changing Landscape of CMIP

This research represents a snapshot of a program in development at a specific period in its history. Since it was initially completed, many things have changed in the regulatory environment. More formal and informal regulators occupy the regulatory space then did three years ago. At the same time, a major reorganization brought the TA-55 and CMR facilities under the same organization, a response in part to concerns about the interactions of the two facilities as expressed here, and in part, due to a series of near-accidents at the CMR facility. This change shows how internal and external, intentional and semi-random factors, may all enter into the changing nature of the organizational landscape.

In the intervening time, the program itself has also significantly changed – so much so that cross-program comparisons may by misleading. Nevertheless, judging from observations of the two facilities which came under centralized management, after a difficult period of integration, the two function more effectively as a team and the movement of materials between these two facilities has been improved. At the same time, while regulatory interactions are handled more centrally and in a more strategic manner by one division, the organization responsible for managing both divisions now feels regulatory pressure from those regulatory actors with more of a focus on TA-55, and those with more of a focus on CMR. The regulatory environment has thus become larger in some ways, and more managed in others.

Negotiations also are ongoing to build a single facility to handle the majority of the operations described here, at least in part for the reasons identified. The newly formed Nuclear National Security Administration may be instrumental in that process, but the outcome is uncertain.

The core of the methodological and analytic aspects of the problem remain unchanged however. From a methodological perspective, how might visual approaches assist in the analysis of complicated, potentially hazardous systems and how should those approaches be structured? From an analytic perspective, what important lessons can be learned about the ongoing operations of hazardous systems by thinking visually and analytically about what they will look like at deployment?

## Limitations and Roadblocks.

As this is a relatively new approach, there is little foundation in the literature for understanding the relationship between the functional and organizational networks. Is a mismatch between them actually a concern? Or is it a common and unconcerning feature of many organizations? As this research continues we hope to be framing these questions in such a way as to broaden this base of understanding.

Graphics Technology also represents a serious constraint. Ideally, these diagrams would be presented in 3-dimensions and with useful data embedded in colors and shapes in nodes and colors and forms of edges. In addition, we would like to be able to manipulate these networks in 3-dimensions and make changes to them on the fly, while viewing them in a 3-dimensional environment. Current technology we have encountered has not been up to the challenge. Molecular modeling programs we have used do not allow the flexibility we need to move nodes in 3-dimensional space while 3-d development tools cannot communicate in useful ways with the databases which contain the information. However, these tools do improve with time so we are hopeful that some of the features that we would like to see will appear over time.

Information availability is also a serious constraint in this type of research. In addition to the problems of classified data, the data available to create this visualizations had to be combined from many sources of interviews and flow charts to create the information visualized here. There is significant room for improvement however. Figure 5 shows the goal we would like to achieve in this type of research. It explicates the network down to the level of individual operations in the network. It would allow a researcher or manager to ask questions about how individual processes, or even steps in processes, interact with each other, and with the outside world. Charts like this might identify two steps of a process which were tightly coupled, but located at different facilities, under different management, and subject to different regulation. A finding like this might lead to questions about how operations and communications could be structured to better account for this situation.

One last feature of the final product we would like to see is the ability to share this data in an intelligible way with others – not just others in academia, but managers, stakeholders, and regulators as well. We have made excellent progress on this front using a program by Macromedia called Authorware. We used Authorware to create an interactive map of the various regulatory networks in the regulatory ecology project discussed earlier. While this research is also in progress, Authorware promises to be a valuable and easy to use tool in bringing data visualization to multiple interested parties[7].

## Some Tentative Conclusions

The goal of the CMIP program is to produce a de minimus nuclear capacity, certified to work, yet never tested - expected to function, but hopefully never to be used. This is a formidable technical and institutional challenge. A measure of its magnitude is found, in part, in terms of the goals or reach of the enterprise. In this case, the benchmark is set by the mission: it includes:

* An emphasis on a self conscious spirit of sustained institutional stewardship;
* Aiming to be the best of its kind in the world - not only within the lab, or in the U.S.;
* Equipping technical and operational professionals to demonstrate, via their interactions with professionals communities throughout the world, that the US retains an effective nuclear weapons deterrent capacity for the indefinite future[8];
* And, finally, achieving the conditions that supports the evolution of honored institutional stewardship across many generations.

These goals are unusual for technical organizations and programs, and as demanding a set of goals as ever to be proposed for the units involved. They are also completely apt for their evolving missions: establishing the organizational/technical basis for providing a "de minimus" nuclear deterrent without end .. and without test.

The challenge is also measured in the degree to which the existing organization already meets the most salient properties of institutional nuclear stewardship: <u>high reliability</u> in operations, and qualities that assure <u>institutional constancy</u>, and deepen <u>public trust and confidence</u> for many years to come, that is, already "fit for the future". Indeed, estimating the current "readiness" with regard to these properties has occupied much of our attention during our work at LANL (See especially the work of La Porte, Part II).

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[7] Copies of this rather expensive software package were provided free to us under a gift from Macromedia.
[8] As an aside, this emphasis follows from the shift of the "front lines" of the Cold War from the Nevada Test Site where the U.S. deterrent capability was repeatedly demonstrated via test explosions to the interactions of those say, 250 technical professionals round the world who know enough to argue with confidence to their political leaders that even without testing the U.S. technical community is so superior that one should not suppose that this country's capabilities are compromised.

The network approach to these issues has led us in several interesting directions in examining this situation. The ability to visualize the connections between the various organizations and technical domains has been a help not only in understanding this very complicated system, but in generating interesting analytical questions which rose organically from the graphical network approach. These tools have proved valueable in understanding the complex systems implied by large scale technologies and allow us to integrate the technical and functional networks in a unique way. But it is in the interesting questions about public trust and confidence and reliability that, among others, have shown us the usefulness, as well as the challenges, of employing these techniques in the domain of large, complicated technical systems.

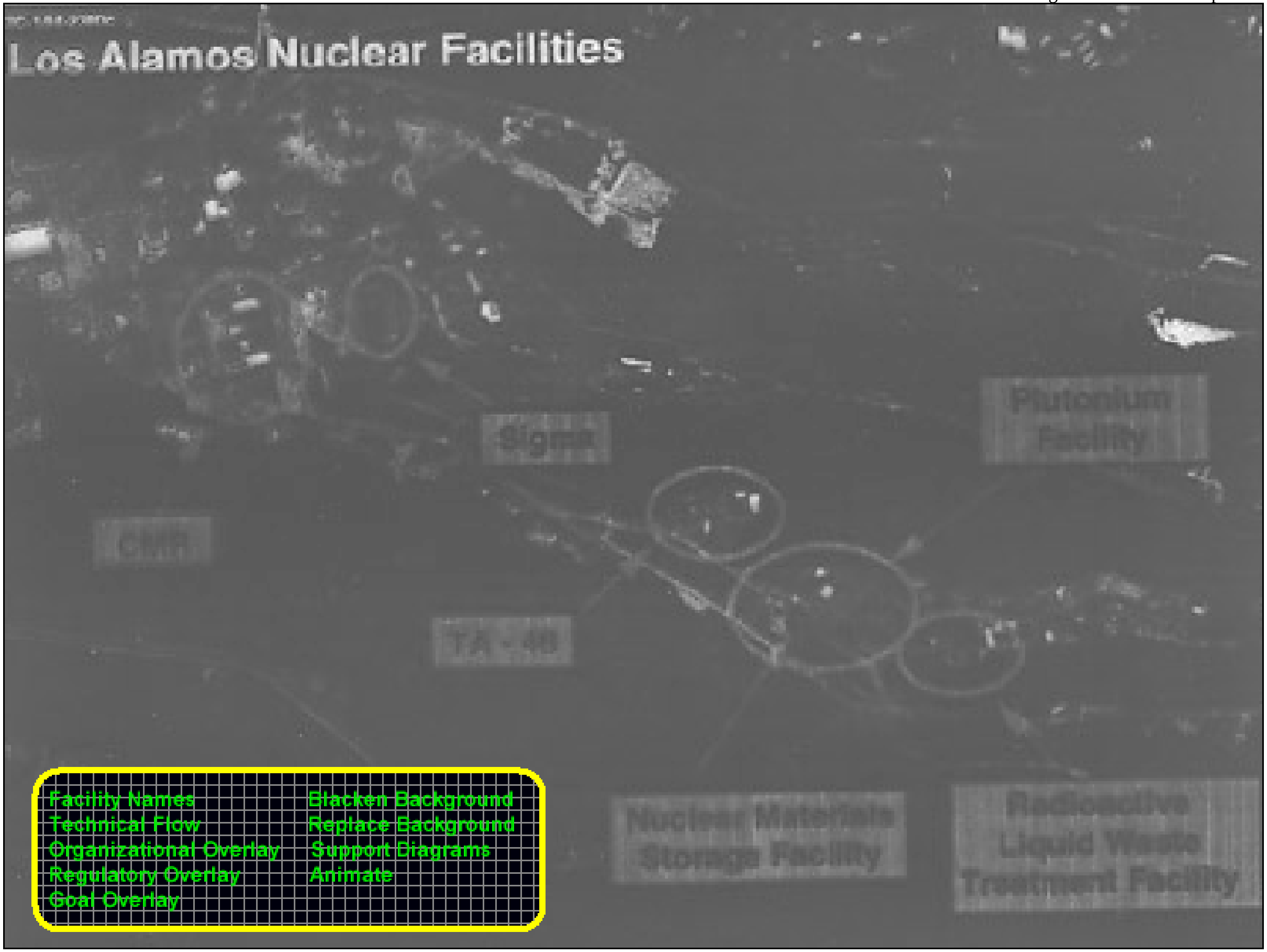


**Figure 1 - Satellite View of LANL Nuclear Facilities**

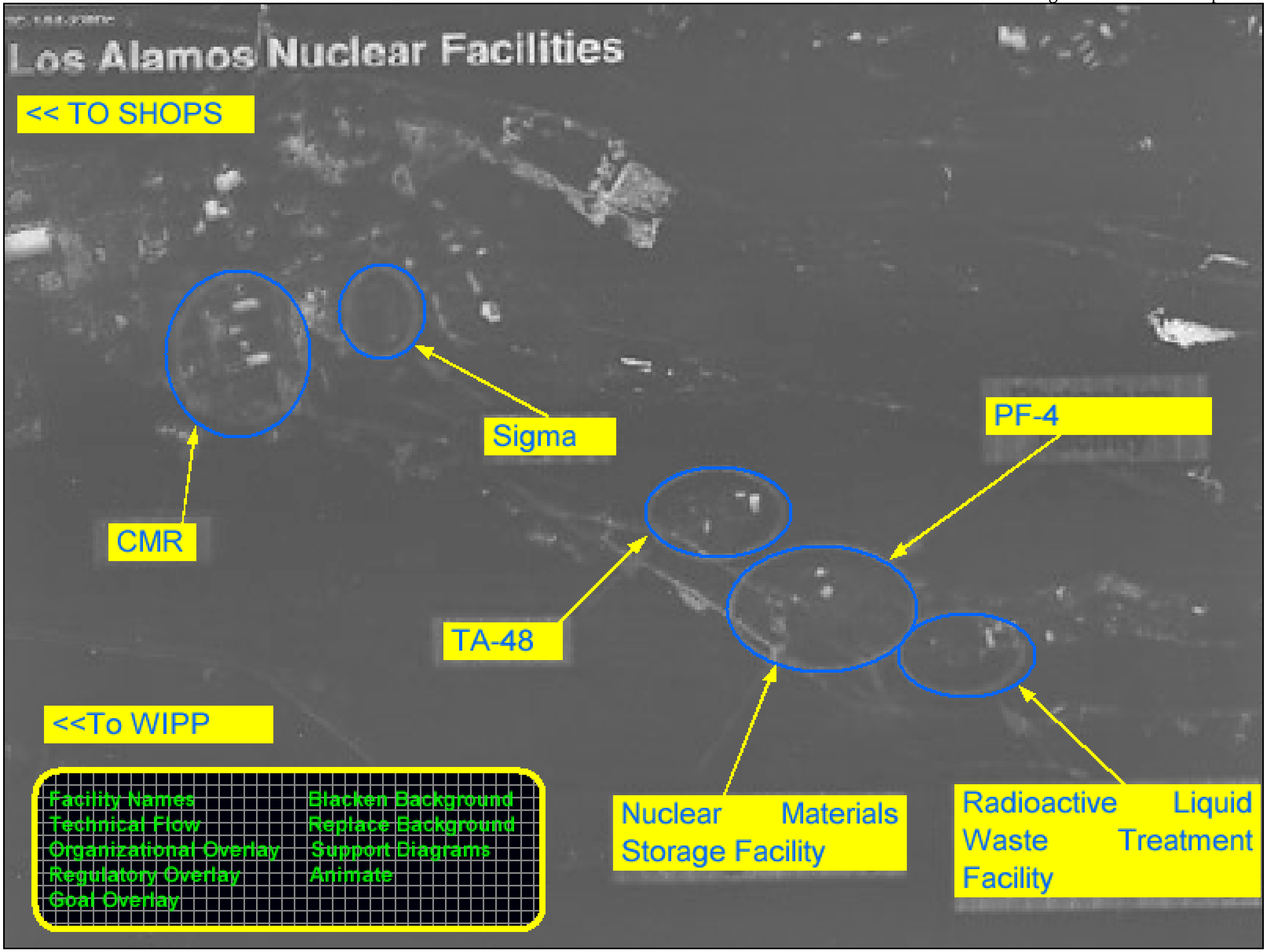


**Figure 2 - Satellite View with Facility Names Superimposed**

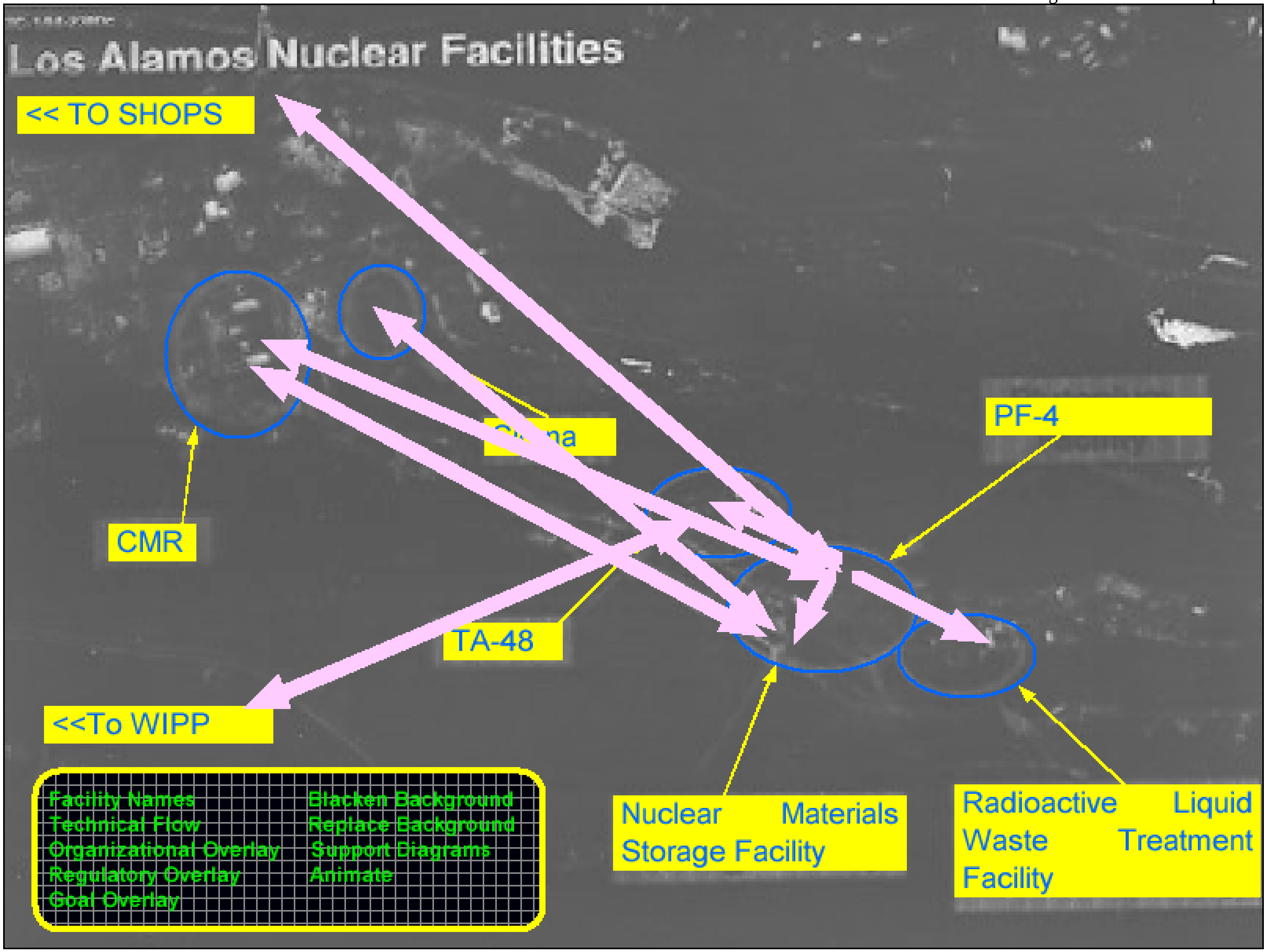


**Figure 3 - Technical Flows of Materials Between Facilities**

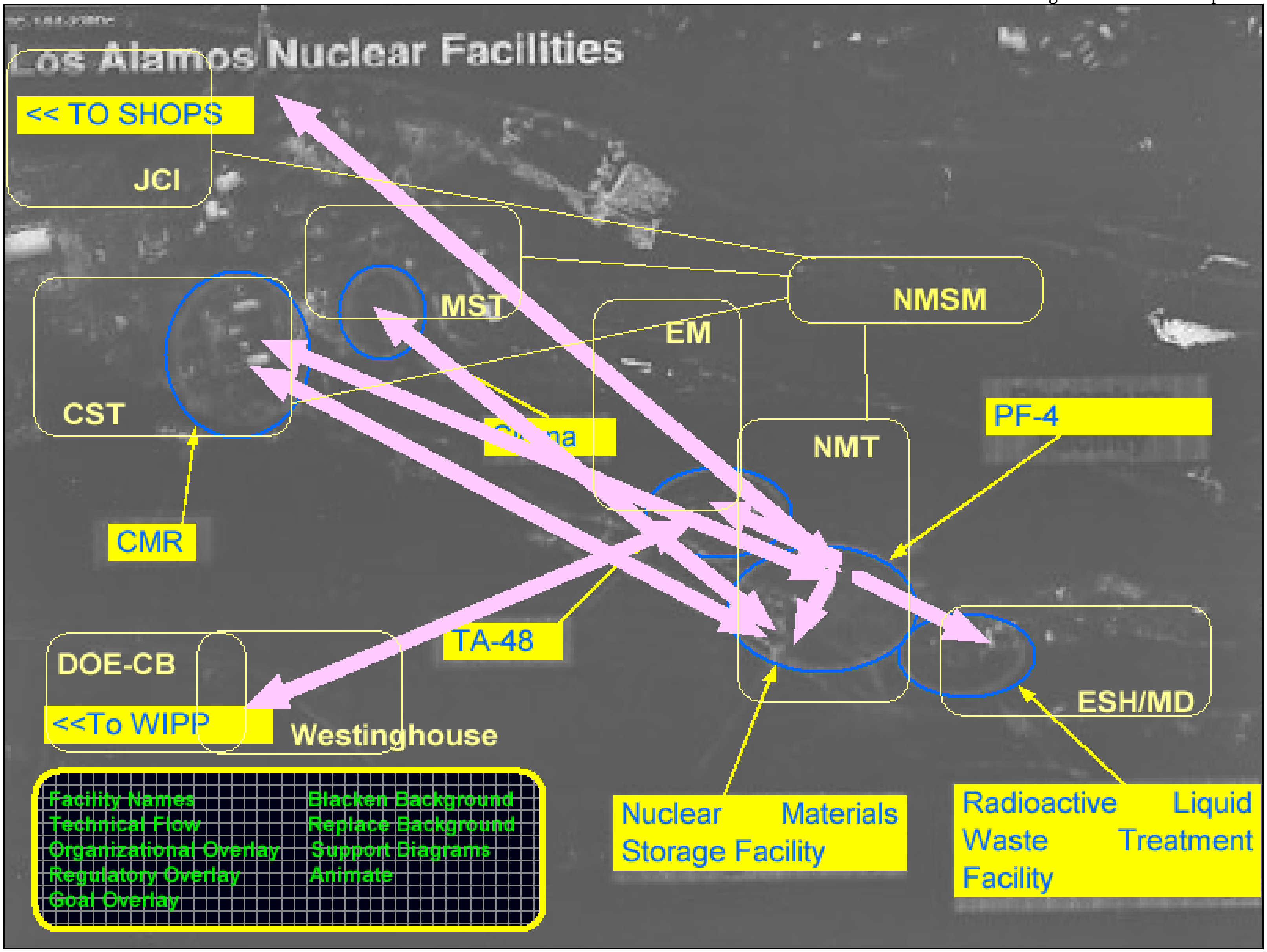


**Figure 4 - Management of Facilities Superimposed**

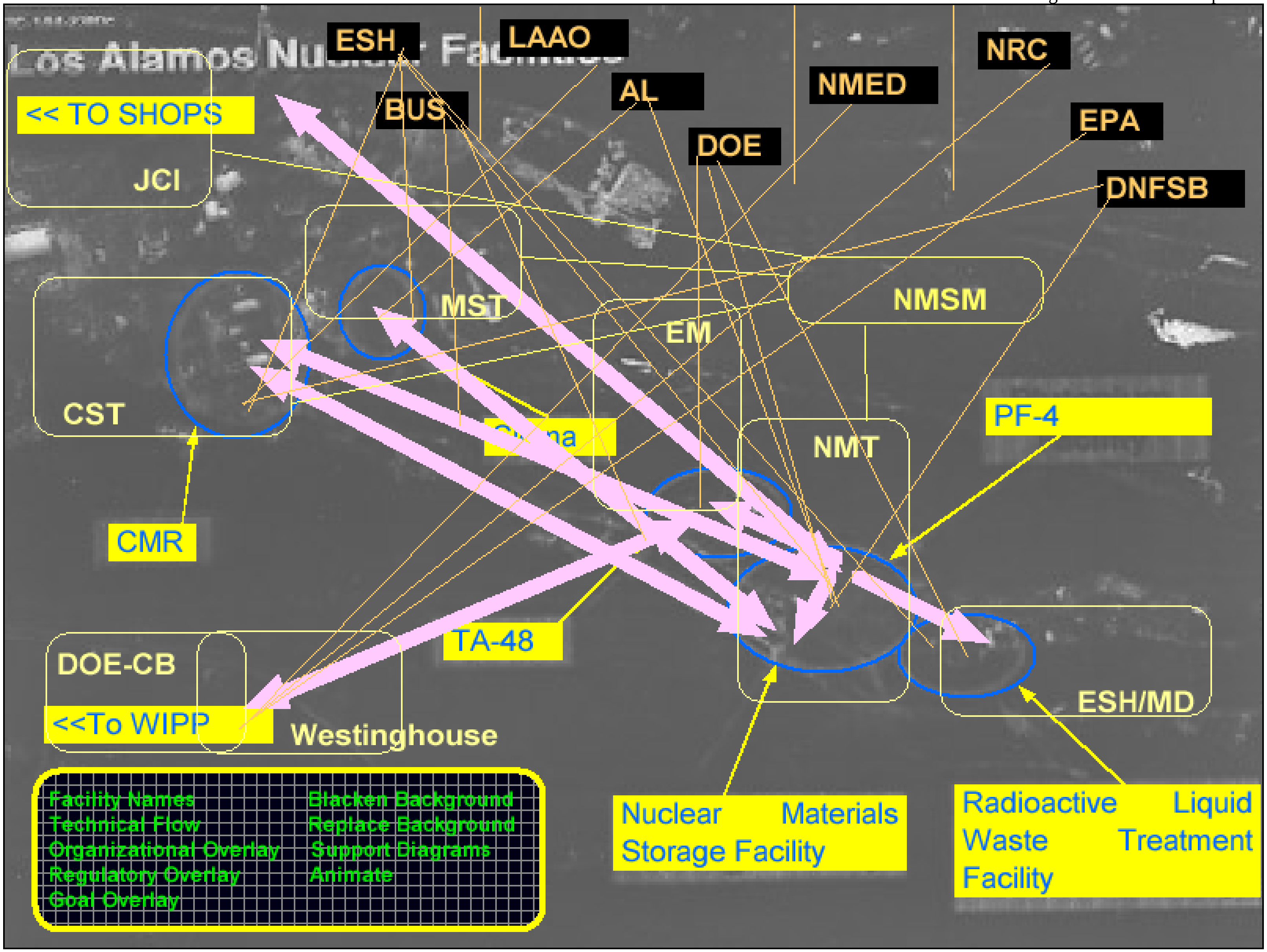


**Figure 5 - Regulation of Facilities Superimposed**

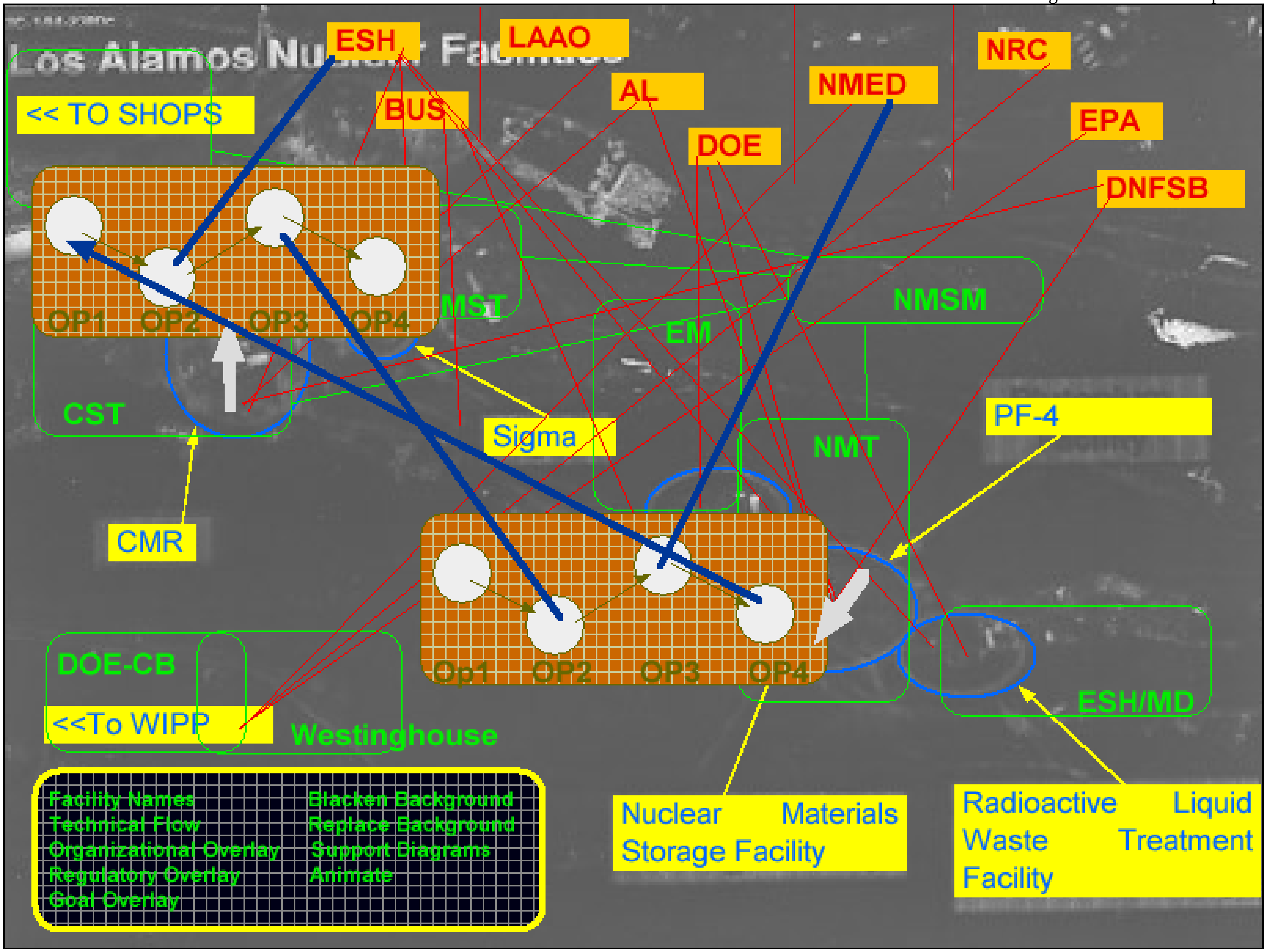


**Figure 6 – The Goal - Further Explication of the Network**

# Regulatory Ecology:

## A Visual and Analytical Approach To Internal and External Networks of Regulators

The LANL/UCB Stewardship Project

Final Repor

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Abstract: This paper seeks to outline an approach to mapping the regulatory surround of a complexly regulated organization –Los Alamos National Laboratory. Through interviews and reviews of documents, previously compartmentalized and tacit information about regulatory information was aggregated into a more encompassing visualization of the regulatory surround. The resulting work leads to new questions about the structure of organizations facing significant regulation, the prospects for reform in those organizations, and the prospects for adopting a strategic response to regulatory interventions in a multi-faceted and multi-dimensional regulatory environment.

University of California
Berkeley, California
September 2000

## **Introduction**[1]**:**

> "If they had to deal with what we have to deal with today, they never would have been able to build that bomb"
>
> -Anonymous LANL Manager

In the early days of Los Alamos, up through the time of the AEC, Los Alamos National Laboratory existed as a virtually unregulated research facility. This is hardly surprising given both its role in national security and the general regulatory climate in the US at the time. But over the last twenty years, regulation at LANL has increased dramatically both in scale and complexity. Regulation at Los Alamos has become so complex that few, if any, individuals at the laboratory have a strong sense of its scale.

Outside the laboratory, on the other hand, many stakeholders perceive that the laboratory is virtually unregulated. The idea that the laboratory answers to no one is a prominent one in our experience with stakeholder groups and others.

Finally, the regulatory environment has become so complex that both formal and informal regulators are often not aware of each other's roles. Overlapping and often contradictory

[1] This report is one of six papers fulfilling the University of California, Berkeley (UCB) -- Los Alamos National Laboratory (LANL) contract on Stewardship and the Design of 'Future Friendly' Technologies: Avoiding Operational Strain in Nuclear Materials Management at Scale. The project's objective is to identify the organizational conditions associated with credible, publicly trusted institutional stewardship of nuclear materials <u>over many management and worker generations,</u> especially in the LANL context as the lab becomes of singular importance in maintaining the U.S. nuclear deterrence capability. This involves understanding both the operational requirements that will be needed in succeeding generations, i.e., the actual work of producing a modest number of weapons' components year after year, and the regulatory environment likely to characterize that future. This paper addresses important aspects of that environment.
See also the work of Jude Egan in the next paper. The project has been supported by LANL/UCB Award # 120BG-0018-23 (1998-2000). Earlier, background work was enabled by the Center for Nuclear and Toxic Waste Management, University of California, Berkeley, and the Los Alamos National Laboratory (LA-UR 97-3227, UCB Contract LANL-C14550017-3Y-LAPORT-06/97.

regulatory requirements are the rule, even while many regulators perceive that no one actually watches the lab at all, possibly prompting more aggressive regulatory action on their part.

This situation presents a number of serious issues for the laboratory. These include: the relationship between internal regulators and internal line organizations, the interrelationships between various formal and informal regulators, the implications for cooperative and efficient regulation at the lab, and the implications for moving "beyond compliance" at Los Alamos. This paper will look broadly at the regulatory ecology of LANL and address and define these issues. The point of this paper is not to provide solutions to these problems or find fault with the environment, but rather to describe the scope and extent of this web, and some of the issues it represents.

## Regulatory Ecology: Research History

Our team's interest in the ecology of regulation at LANL was first suggested by our research on the Capability Maintenance and Improvement Project (CMIP), one of the first incarnations of the Plutonium Pit construction activities centered at TA-55. CMIP's interesting characteristic was, from our perspective, the disjoin between its necessarily tightly coupled component tasks, and the multiple dimensions of separateness enforced on those components by physical, organizational, and social barriers. This question forms the central subject of the paper: CMIP: Emerging micro-organizational networks in a post-cold war downscaled world (La Porte and Stone: 1998).

In attempting to understand how the organizationally and physically separate sites involved in CMIP would act in an "at-scale" setting, we looked at how these sites responded to and looked to different subsets of regulators in the environment. As our research in this area progressed, we came to see just how substantial the number and variety of regulators in the environment were, and decided to research this question further from another perspective.

## Methodology

While the approach of the CMIP research had been to take a production cycle and look bottom-up to see what the rest of the environment looked like, in looking at the regulatory world, we took a more top-down approach, attempting to catalog areas of regulation at LANL, and then the regulators who occupied each category. The following chart lists seventeen areas of regulation which were generated from interviews and documentary research at LANL.

**Table 1- Typology of Regulatory Domains Studied**

Materials-Based

- Materials Protection Control & Accountability
- Transportation
- Outcome/Production

Worker-Based

- Radiation Protection
- Occupational Health and Safety/Industrial Hygiene
- Human Resources / Labor Relations
- Security
- Fire Protection

Externally Based

- Cultural Resources
- Air Quality
- Water Quality
- Ecology
- Waste

This simple typology suggests thirteen domain in three broad and slightly overlapping categories. We sought to gather as much data as possible about each of these areas in order to build a nuanced understanding of each domain.

Our initial research assumption was that most of the data would already have been collected at the laboratory and that our work would aggregate it to show a more complete picture of the environment. The available data however, was not adequate to the task. Where information about regulators had been gathered, it was spotty and was confined to a single project or small area. No single source of data existed about regulators at the lab and no universal system for keeping track of this data existed in divisions or across divisions. Where attempts had been made to catalog regulatory data within a division or area, it often included only the most prominent regulators.

As such, research in this area required significant interviewing and documentary research to generate data which was initially thought to be already available. Interview data formed the primary basis of data gathering. Within each area we took a three tiered approach to attempting to exhaustively catalog the regulators who could make claims in this area.

1. Interview LANL regulatory liaisons (in-betweeners) and identify all possible regulatory actors for this area.
2. Interview LANL managers at multiple levels to identify all possible regulatory actors for this area (those that bypass the in-betweener and those that come through her/him)
3. Interview identified regulators to check connections downward and identify other possible actors in the regulatory environment both upwards and horizontally.

These three approaches are outlined in the following chart.

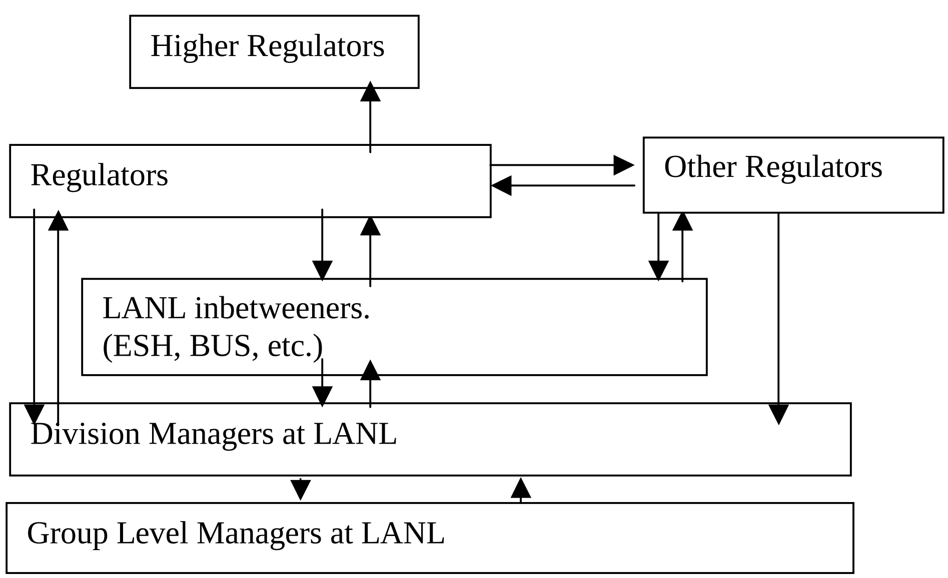



**Figure 0 - Layers of Research**

At each stage of interviewing and researching, respondents were asked to identify regulators they interacted with and the nature of this relationship. This produced three types of data: a list of regulatory entities, connections between those entities, and qualitative data about the character of those connections. The latter data is being used for research regarding the effects of technical and organizational design on regulatory behavior (see Stone, Lessons Learned from Design and Regulation at Los Alamos). The chart above also indicates how multiple checks for exhaustiveness exist in the research – at most levels, multiple actors are asked to reference other actor-classes to provide a more thorough picture of the regulatory environment.

As the data was collected, it was added to a visualization program we developed for this task. The program, dubbed "Regulatory Explorer[2]," has gone through many incarnations since we began its development three years ago. The guiding principle behind its development has been to provide an intuitive way to showcase the complexity of interactions between regulators and the laboratory as they vary across regulatory domains.

The regulators were recorded under categories which we developed early in this research. While the categories may not be completely exhaustive or mutually exclusive, they seem to usefully break down the various areas of regulatory scrutiny. The following screenshot from the Regulatory Explorer program shows the basic top-level categories of regulatory actors.

These top-level categories in turn, expand into a variety of categories and actors. In terms of the LANL area, we broke the laboratory down into several segments as outlined below.

As our initial interest was in the Nuclear Materials and Technology Division (NMT) at LANL, it became the basis of how we understood how different regulatory areas were expressed at the divisional level. NMT Division is particularly interesting because its nuclear role calls levels of regulation not experienced in other parts of the laboratory. The findings in this area will be discussed later, but it is important to note why these NMT groups appear with other internal regulatory actors.

[2] The program may be viewed on the CD-ROM which accompanies this report, or on the LANL Blue Network at http://int.lanl.gov/orgs/nmt/regexp/

Working from LANL internal regulatory groups and using the methods described earlier, we began to build a more complete picture of the regulatory environment. Dozens of in-depth interviews led to this picture as that data, combined with documentary sources, was integrated into the regulatory explorer.

This screenshot shows the “peeled away” version of the explorer’s main screen. In this view, the various regulatory areas are broken down into individual regulatory actors, and sometimes, into divisional actors within those larger regulatory actors as well. Generally speaking, we chose to call out sections of regulatory organizations only when interview respondents called them out directly, or made comparisons between various segments of the same organization.

From this point, we created network models between the actors that were involved in various regulatory domains. These models show the connections between the actors involved and how those connections manifest themselves in the laboratory network. The following screen shows the network of actors involved in the regulation of transportation at LANL. Each area of regulatory interest was detailed in this manner, showing the connections between the various actors involved in that domain.

This process was iterated for each of the 13 areas of regulation described above, though at the time of this writing, not all are complete. In all, hundreds of connections between 10’s of regulatory actors were documented.

## Regulatory Ecology: A Feeding Frenzy

Although the laboratory is a national security facility and has a history of self-regulation, it has transformed into a heavily and informally regulated entity, with many different types of regulatory actors involved in its operation.

Over 60 formal and informal regulators can make claims on the laboratory. Many of these actors have overlapping or at least very generally designated responsibilities and they vary dramatically along a number of different dimensions including attention, flexibility, formality, and others. For instance, regulators might be arrayed on a dimension of formal to informal.

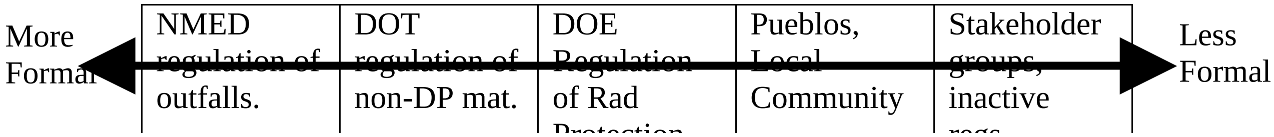



**Figure 1 - Formality of Regulatory Behavior**

In this context, we take formal and informal to refer to an overall judgment about the flexibility and consistency of the regulator in question. We could make such judgments more specific by arraying the character of discretion in finding of violations, discretion in application of penalties, and discretion in development of legal frameworks.

The fact that each regulatory area has formal and informal regulatory controls is only part of the story however. Each regulatory actor is also defined by having a large number of potentially overlapping regulators with different extensions into the organization.

**Table 2- Levels of Regulatory Actors**

| Level | Examples |
|---|---|
| Judicial | State and Federal Courts |
| Congressional | Defense Nuclear Facilities Safety Board (DNFSB), Members of Congress (MCs) |
| Federal Agency | DOE, EPA |
| State | New Mexico Environment Department (NMED), New Mexico Game and Fish (NMGF) |
| Local | Fire Department, L.A. Council |
| Stakeholder | National, State, and Local organized groups. |

The network is described by its nodes, the regulatory and LANL actors, and its edges, the lines of formal and informal authority that connect these actors. The content of these networks can be arrayed in terms of their complexity, measured both as a function of the number of nodes and edges, as well as the number of boundaries between LANL and the outside world. In the second case, two networks with equivalent numbers of nodes and edges, may be experienced very differently by the laboratory based on the number of edges which enter directly into different nodes of the laboratory, as opposed to the those that enter into a single, buffer, node and are then passed to other nodes in the network. This difference can be graphically depicted as follows:

As a reference point, consider a relatively simple network in the LANL regulatory space (Network – 4). Materials protection, control, and accountability regulation comes to LANL primarily through two segments of the DOE. It enter the laboratory at two points, both of which interact with eachother and with at least two of the actors. Both the total number of actors and the small number of organizations (two) that receive the external regulation, lend to the consideration of this as a simple network of regulation.

With only two internal points of connection with regulators, the network of MPCA connections is quite simple, but there is a network with even fewer numbers of regulatory interfaces involved. Consider the transportation network as a point of contrast (Network-5). With seven external regulators with claims, the network is more complicated in terms of regulatory actors. At the same time, it is evident from the diagram that although many actors are involved in transportation regulation, most of the network lines lead back to a central organization at LANL, Business Operations Division, Group 4 (BUS-4), the organization which coordinates transportation and mail services at LANL. As a regulatory inbetweener, BUS-4 does filter most of the transportation regulation into the lab's operating environment.

Although the number of regulatory interfaces may be small in this map, the domain is still a difficult one to get a handle on. Intra-lab transportation of hazardous materials, intra-lab transportation of radioactive materials, extra-lab transportation of hazardous materials, and extra-lab transportation of radioactive materials are all regulated in different ways and by slightly different sets of overlapping actors and regulations. For non-nuclear materials, the lab is subject to normal DOT regulations of both the US DOT and the New Mexico DOT – reasonably straightforward. For nuclear materials however, the DOE has agreed to abide by DOT regulations, but is not, in fact, directly subject to those regulations.

DOT, in turn, defers to NRC for regulation of nuclear materials – though the NRC also lacks direct authority. However, the carriers themselves are subject to packaging requirements developed by NRC, DOT, and agreed to by DOE. These requirements are not universally implemented though, resulting in different divisions of the laboratory implementing the requirements differently (as well as each of the US DOE facilities implementing the regulations differently as well).

DOE shipping regulation is handled at the national level within the DOE, as well as coordinated by the DOE-Albuquerque Operations Office, which coordinates TRANS-COM – the Department's nuclear materials transportation tracking and coordination system. These regulations are, in turn, filtered through Business Operations Division 4 (BUS-4), which also handles inter-department mail and Federal Express shipments. Further, nuclear materials are subject to regulation because of potential radiation doses to workers and the public.

These doses are regulated by an even more complicated web of actors, including US and NM OSHA, the DOE, the Radiation Protection Program Office, the New Mexico Environmental Department's Oversight Bureau, and even influenced by international standards bodies like the IAEA. If we were to ask the question, who regulates transportation at the laboratory, clearly there is no straightforward response.

In contrast, other areas are not nearly so centralized. Consider the case of Air Quality for instance (Network –6). Here, the external regulatory network not only interfaces directly with the regulatory buffer organization (ESH-17), most of the actors also interact directly with the box at the bottom right, facility managers. This box is not a single actor, but a collection of many actors around the laboratory who have ongoing interactions with external regulators in the air quality domain.

From a management perspective, this organizational design implies a less hierarchical approach to regulation, but also a potentially less coordinated one. At the same time, if one considers a regulatory connection edge in this diagram to be a view into the organization, then the air quality network maximizes external views into the organization as well. Again, this has many possible consequences and implies multiple different management approaches.

Network 7 represents the network for production-side regulation at LANL, with specific reference to the military-nuclear oversight and development role of the organizations at LANL directly connected to pit production and refabrication. This network records a large number of actors as well, with a large number of connections directly into the laboratory. Although generally not formal regulators in the same was as the NMED, the actors involved in the regulation of ongoing military operations are active and interested. Here, the line between formal and informal regulators begins to blur as a more client-centric regulatory structure appears. The regulatory nature of this relationship comes from the active and ongoing interest and observance of the client group. If the relationship were as simple as asking for a part and receiving it at the other end, this would not be a regulatory relationship. As the relationship instead involves ongoing discussion and observation as well as active connections between the client and the manufacturer, it takes on a regulatory character as well.

In the final basic network diagram, a more managed network is evident Network-8). While ESH-20 interacts with many actors in the environment, it also manages some of those interactions in a way which few other organizations at the lab have had the opportunity to do. The connections in the bottom left hand-corner between the various regulatory actors are in part created by the work of managers in ESH-20. Through the Jemez working group, these various regulators have been brought together into a more cohesive group and the transparency of the various actors and regulators in the mix was increased substantially

.

The final diagram (Network – 9)represents the overlay of eight of the seventeen regulatory arena networks we have identified and described in detail. This diagram represents the layered complexity of LANL's regulatory environment in a visually compelling fashion.

Here, all the major descriptors of the environment come into play: These eight networks serve as examples of the sort of variation this research has explored. Further exploration of the networks is available via the regulatory explorer itself. The program is available for download at http//int.lanl.gov/orgs/nmt/regexp/ and contains all the connections and actors documented in this research. Together, these connections form a complicated web. Returning to Network 9, notice that the networks follow very different paths through the hierarchy of actors. If these networks were similar, the movement from one section of the diagram to another would be similar across domains. However, as Network 9 shows, this is not the case.

Another way of looking at the data gathered through this network analysis is through more simple numerical representations. Here, some of the differences in terms of the character of external and internal interactions are captured in a form more suited to making comparisons between regulatory domains.

**Table 3 - EI Index of Selected Regulatory Domains**

| Domain | Total | Internal | External | EI Index (ratio of internal to external) |
|---|---|---|---|---|
| Ecology | 20 | 2 | 18 | .11 |
| Transportation | 9 | 2 | 7 | .28 |
| Radiation Protection | 14 | 6 | 8 | .75 |
| Air Quality | 27-47 | 10-30 | 17 | .58 – 1.76 |
| Production Cycle | 27 | 12 | 15 | .8 |
| MPCA | 6 | 2 | 4 | .5 |
| Waste | 11 | 2 | 9 | .22 |

This chart show the significant variability of two parts of the regulatory ecology problem. First, the number of actors varies dramatically across domains, leading to very different regulatory experiences at the boundary level. Second, the number of internal actors as compared to the number of external actors, also varies greatly. This variance is captured in the EI index at the far right. At the low end, Ecology has the small index of .11, indicating an environment which is externally weighted. At the high end, Air Quality reaches into +1 EI index range, or the high below 1 range, depending in the number of facility managers the observer considers to be directly involved with external regulators.

Of course, numbers of regulatory actors do not translate directly into the relative ease or difficulty of dealing with those actors, or the relative costs imposed by these actors. However, the character of the interaction and the way in which that interaction is experienced at the group level, is substantially different in domains with higher or lower EI indexes. Increased variability suggests less predictability and more surprises and would be expected to increase with the EI index, all other things being equal.

From these and other visualizations as well as quantitative analysis, we can begin to generate questions and hypothesis that arise from these representations. While all the implications have by no means been explored, the following areas seem fruitful for further research.

## Complexity in the Environment.

The lab's regulatory environment is exceptionally complicated and is defined by multiple overlapping actors at every level. This is true for many highly regulated organizations, but it appears to be especially descriptive at LANL and most likely arises from the lab's multiple personalities (University, National Security Facility, Research Facility, etc.). At the same time, the complexity of the lab's regulatory environment leads to division-level implementers often feeling besieged by regulation. Sometimes, the response to this is to attempt to ignore regulation completely, or to design programs to stay "under the radar" of regulatory entities.

In this environment, regulatory intervention becomes interpreted as a negative surprise. The intervention is often not known about in advance, is unwelcome when it comes, and often comes from an actor who was not even known about before the intervention came about. This type of intervention breeds mistrust and the desire to remain under "the regulatory radar", rather then embracing and working within a regulatory system. Regulatory surprises are bound to happen in any highly regulated operation, but LANL appears to be more susceptible than other facilities.

In part, this is because the lab's regulatory environment is sufficiently complex that few if any individuals at the lab have a sense of its scope or depth. Additionally, few resources exist to assist individuals in the lab context with preplanning for or implementing in this regulatory environment. Additional feelings of mistrust between virtually all the actors no doubt also contribute to these feelings.

The complexity of the regulatory environment makes it more difficult to manage the many regulatory streams the laboratory faces. This is especially true in the regulatory arenas that are both less centralized and more informal. The regulatory explorer can help to show the complexity of this environment in an intelligible way.

## Compartmentalized Tacit Knowledge

Individuals possess tacit knowledge about one or the other area of regulation at the lab, but very few individuals have the broad view of regulatory action at LANL. The knowledge is significantly more compartmentalized, however, then is the actual regulation and numerous examples of difficult regulatory situations have arisen because of this approach to regulation. This outcome is hardly surprising given the scope and history of regulation at Los Alamos. However, as the lab transitions to a more decentralized model of internal regulation, it will be interesting to see how this knowledge moves through the organization. This problem is addressed further below.

## Strategic Regulatory Action

The complexity of the lab's regulatory environment makes it harder to both actively and reactively manage the laboratory's regulatory environment. Reactive responses to regulatory issues, that is, responding to regulatory interventions after they happen, may be complicated by multiple actors and lack of centralization, but there are clearly areas in which the lab has successfully managed these interactions. Organizations such as the Laboratory Counsel Office become the key managers of these issues once a regulatory intervention occurs.

In terms of active management of regulatory areas however, the laboratory has had only occasional successes. The construction of the DARHT facility, for instance, eventually took into account many regulators and stakeholder groups and actively sought their input and consultation during the design and construction phases of the project. ESH-20, The Ecology Group, should also be noted for its efforts in managing many overlapping regulatory areas.

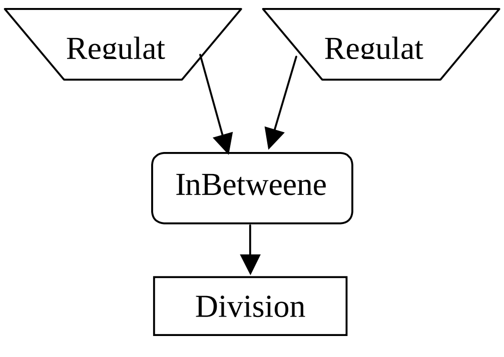
The active management of regulatory affairs is the subject of an additional paper by our research group, but it is useful to point out that the difficulties involved in thinking strategically about the regulatory environment increase substantially as the scale and complexity of that environment increase[3]. The potential for surprise increases as well as more actors must be accounted for in designing a regulatory strategy.

[3] Strategic Regulatory Action (Stone:2000)

The Laboratory's stated intention is to focus increasingly on this type of action in the coming years. At the same time, current changes to the lab's regulatory organization may also greatly effect the success of these attempts.

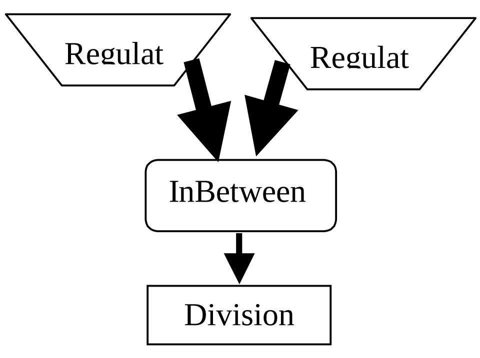
## Facing Changes in Regulatory Ecology

One of the features of the LANL regulatory environment that is in transition is the function and centrality of the regulatory inbetweener, in most cases, and ESH Division. Not only is this role in transition at LANL, it is also understood in very different ways by different actors within the system.




Type 1: Management

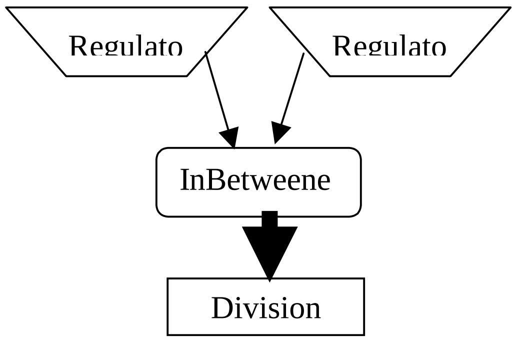
The Type 1 Diagram at left shows the outside management view of the ESH role. In this model view, manageable streams of regulation enter the Inbetweener and a manageable and implementable regulation emerges for laboratory use. At worst, the inbetweener simply combines the streams of regulation and at best, the inbetweener can also reduce the streams somewhat as the arrows in the Type 1 diagram indicate. This reduction would occur naturally from eliminating overlapping requirements and other basic tasks.




Type 2: Inbetweener View

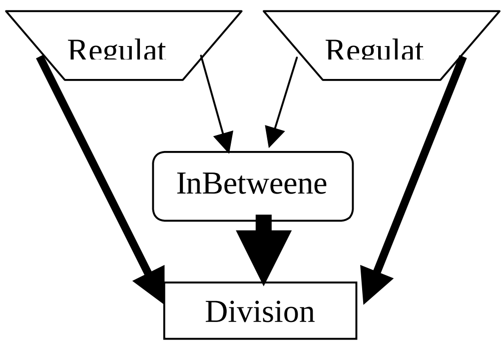
The Type 2 Diagram shows the system from the inbetweener perspective. From the inbetweener perspective, the regulatory streams are huge, sometimes nearly unmanageable, but the inbetweener expends significant effort to reduce those streams into manageable ones at the divisional level. While the stream reaching the Division is still large, it is merely a fraction of the actual extent of regulation in the view of the insiders.

In contrast, the divisional view at LANL is quite the reverse. Many divisional actors perceive that the inbetweener organizations actually function as amplifiers of the regulatory streams. This is expressed in the Type 3 diagram. In this view, the inbetweener becomes an enemy of efficient operations at the laboratory, slowing down operations and acting as inflexibly or more inflexibly then the regulators they are supposed to filter.



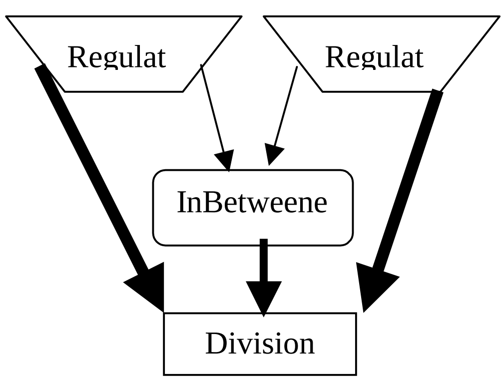

Type 3: Division View Basic

Finally, in the type 4 extended view, the inbetweener not only acts as an amplifier of the regulatory streams, it also fails to buffer the divisions from the regulators themselves. In this bottom-up view, a division faces regulatory streams both filtered and amplified through the inbetweener, as well as directly from the regulator itself. Indeed, this mode of operations has been actively sought after in certain circumstances where divisions have used the regulators themselves against the regulatory inbetweener.




Type 4: Division View

This research does not attempt to ascertain whether any of these models is more descriptive of the actual situation then another is. It simply presents these as distinctive views of the regulatory situation at LANL which appear to be dependant on the respondent's role in the network.




Type 5: Division View

The regulatory ecology visualization leads us to take seriously the idea that these individual models do exist and are themselves submerged in a complicated regulatory environment which looks different depending on where one sits in the network. Given this, it will be particularly interesting to see how the lab's current regulatory transitions take place. The laboratory appears to be about to embark on a dramatically different approach to its regulatory interactions, focusing on shifting responsibility for regulation to the divisional (line) level and reducing the authority and scope of the ESH divisions. Moving responsibility to the implementers is thought to localize accountability for regulatory action with the people responsible for the program, thus aligning their interests more usefully and reducing possible alignment problems with the inbetweener.

However, as we have seen, the lab's complex regulatory culture could create a variety of different outcomes. The divisions may not only face substantial regulatory pressure directly from the regulatory outsiders, they may also continue to face regulatory streams from internal organizations. At the same time, different divisions may find themselves more or less able to perform the buffering and boundary spanning roles previously performed by the regulatory inbetweeners. If this occurs, the lab will operate in a situation where each division faces different styles and complexities of regulation based on their abilities to navigate the regulatory environment, as much as on the technical characteristics of their organization.

Again, the point of this observation is not to find fault with the current system or the system the lab may transition to, rather, it is to point out how the current complexity of the lab's regulatory environment will effect the actual operations of the divisions in the coming months and years. Suffice to say, this type of visualization and the analyses upon which it is based, leads to a range of more general uses. These include:

- RegExplorer could be used to assist technical designers in thinking about the regulatory environment before implementing their systems.

- RegExplorer could be used to assist managers in understanding and managing the regulatory environment.

- RegExplorer could be used to show managers the level of complexity the inbetweeners face and how they restructure that complexity for the divisions.

- RegExplorer could be used to show regulators how various and diverse the character of regulation is at LANL.

- RegExplorer could be used to show higher-level DOE and other political actors how much regulation the laboratory faces, and the complexity of that challenge.

- RegExplorer could be used to show stakeholder groups how the lab's regulatory environment helps to check the lab's behavior in multiple ways.

- RegExplorer could be used as a basis to make much more formal analyses of the costs of regulation at LANL. If each edge is taken to represent a transaction cost of regulation, the costs could be quantified in a way not currently possible for the lab. LANL has little concept of what the total costs of regulation represent to the lab. The Explorer could assist in the making of those initial calculations.

## Methodological Findings

Perhaps the most important class of findings for this work have been methodological ones. This project takes seriously the idea that large-scale, complicated networks of organizations can be expressed in a fashion that exposes interesting things about the organizational network. This statement is not obvious and to our knowledge, an attempt to delineate an organizational network at this scale has never been attempted in a visual way.

Traditionally, organizational network analyses have focused on aggregate networks or on individual interactions. This type of research generally yields numerical descriptions of networks which are often an end point in and of themselves. Measures such as the venerable E-I index, a ratio of network connections within an organization to the ratio outside the organization may tell you useful things about an organization, but are not inherently visual in nature.

In contrast, the visualization approach to networks argues for the important role of the observer in understanding the network itself. The objective of visualization is, of course, to render the complicated simple by presenting large quantities of information in a more accessible manner. However, the visualization is not an end point. Instead, it becomes a tool useful to both practitioners and observers in better understanding the environment in which a given organization or group of organizations exists in. This approach draws both from the network applications literature and the techno-organizational approaches used by schools like Complexity Failures (Perrow:1984, Sagan:1993) and High Reliability Organizations (Rochlin:Bib, LaPorte:Bib, Roberts:1997, Roberts:1990 Schulman:Bib).

Creating a useful visualization for this problem has led to several interesting methodological issues. First, and most obvious, is that existing tools for creating network visualizations did not meet the needs of our research. These tools could not display a sufficient amount of information or offer sufficient interactivity to meet our needs. Thus, we were forced to develop our own tools for this process, a time-consuming and labor-intensive process, but one which has given us new insights into the functionality that such tools should contain.

Key features of our visualization which we believe are unique include the following:

1. Ability to create visual hierarchies of organizations. The regulatory explorer framework allows organizations to be visually represented as parents or daughters of other organizations. From an organizational analysis perspective, these connections are important to understanding the broader framework of the environment.
2. Ability to store additional data about nodes and edges. The regulatory explorer can store additional "pop-up" data for both the nodes (actors) and edges (connections) of the network. Because existing tools primarily focus on aggregate or mathematical representations, there is little room for observer data to be stored and accessed through the visualization. Regulatory explorer allows the observer or the practitioner to access additional information in both nodes and edges, allowing the observer greater insight into the nature of the connections and the network.
3. Multi-Network viewing. Existing visualization programs lack the ability to show multiple networks within the same set of actors. The regulatory explorer was designed to visualize differences between networks among the same actors. While existing programs could generate separate static displays of contrasting networks, the RegulatoryExplorer can do this dynamically.

Although the RegulatoryExplorer was designed for this purpose, it has several serious limitations. They arise from our own programming limitations and would require extensive time, expertise, and effort to remedy. Nevertheless, this project has shown our research team what the characteristics of the next generation of network visualization tools would need to be able to do. These features include:

1. Intelligent Database Storage. The RegulatoryExplorer's data are placed into the visualization manually as is data about interconnections and additional information about nodes and edges. The next generation tool would clearly need to draw its information from a database which would manage the large quantities of data more intelligently.
2. Multi-Angle Viewing. The RegulatoryExplorer visualized hierarchies in two dimensions, but our goal has always been to visualize these networks in three dimensions. With different hierarchical levels viewed on different planes of the visualization, it would be possible to see not only how different sectors interacted with each other (as the existing visualization allows) but also how different levels interact within each set of edges. New relationships with LANL researchers in the computer visualization project may lead to improved abilities in this regard. LANL is constructing a CAVE environment in which visualizations can be actively and immersively experienced in three dimensions. Through input devices like gloves, these environments can be actively explored in real time. The possibilities exist for attempting to do network visualization in this environment, with additional opportunities for learning in such a technically unique environment.
3. Walkthrough. An extension of the three dimensional viewing described above is the ability to view a network from multiple perspectives. In a three dimensional network depiction it should be possible to examine the connections from "shifting vantage points (LaPorte:1996)." That is, it would be possible to see the network from the different perspectives of its various members. This type of visualization could prompt questions such as: how does the regulatory environment look from the top and how does that differ from what it looks like from the bottom or the side. While the existing explorer can address these questions to some extent, a 3-dimensional visualization with the ability to change the view of the network would improve this capability significantly.

A third methodological issue concerns the level of effort implied by the decision to take network visualization seriously in this context. Our own expectations about this level of effort significantly underestimated its magnitude. Early on, we expected that both LANL and its regulatory actors would be able to provide detailed exhaustive data about the lab's regulatory environment. Indeed, our initial expectations were that we would simply act as an aggregator and visualizer of previously gathered data in this area.

Instead, we found that the data itself existed only tacitly and was distributed across many practitioners and managers within the organization. This made data collection significantly more time consuming, leading us to the interview process we described above and requiring extensive probing interviews rather then mere recitations. Often times, respondents would not immediately consider all the possible regulators and needed to be prodded to think about all the actors they interacted with in that regulatory domain.

The difficulties of both visualizing and gathering this data have led to useful lessons for researchers in this area as well as for practitioners at the laboratory who may wish to document this environment in the future.

## Summary and Next Steps.

The regulatory environment of LANL is complex and enormous in scope. This project has had three results which help to explain this environment in greater detail.

1. Direct Regulatory Findings. The final version of the LANL Regulatory Explorer, while not complete, could act as a useful tool for managers and designers in thinking about implementing new policies and technologies at LANL. The explorer currently contains enough information to assess the most important actors across various domains and could also act as a check for the tacit knowledge of internal regulators at the lab.
2. Proof of Concept for Regulatory Research at LANL. Perhaps more importantly for LANL, this research also serves as a demonstration and learning exercise regarding the usefulness and difficulties of this type of research at LANL. This research could be used as a model by which a more sustained effort at tracking the regulatory environment could be designed. This effort, in turn, could serve

the needs of the various groups at the laboratory as the regulatory environment continues to change and grow.

3. Methodological Findings for Social Science research on science and technology. This type of research is unique but by no means only applicable to LANL. Useful findings regarding the data gathering, management, and visual display of this information were garnered from this project. These findings will be used to improve this type of research in its next iterations and the tools developed here will hopefully serve as models for future network visualization tools in this area.

Overall, this research has shown that the complexity of the laboratory's regulatory environment is substantial. It is hoped that visualization approaches like the one detailed here will begin to render that environment both more specifically and in a more comprehensible fashion. From that point, actual lessons about regulatory strategies can begin to be evaluated.

## Appendix 1: Radiation Protection Map

The Radiation Protection Map shows those regulators primarily involved in the regulation of human radiation exposure. The map is notable in that multiple internal regulatory inbetweeners (ESH-2, 1, and 4) are coordinated by a central regulatory inbetweener (ESH-RPP). This office provides a centralized place for outside regulators to turn to for radiation issues, even though the office has little formal authority over the other internal regulatory groups. In the judgment of internal personnel, and two local regulators, this arrangement has been surprisingly effective from the point of view of providing outside regulators with a greater sense that there is someone to turn to for radiation issues, not many different people with overlapping responsibilities.

## Appendix 2: Digging Deeper Into the Radiation Network – ALARA

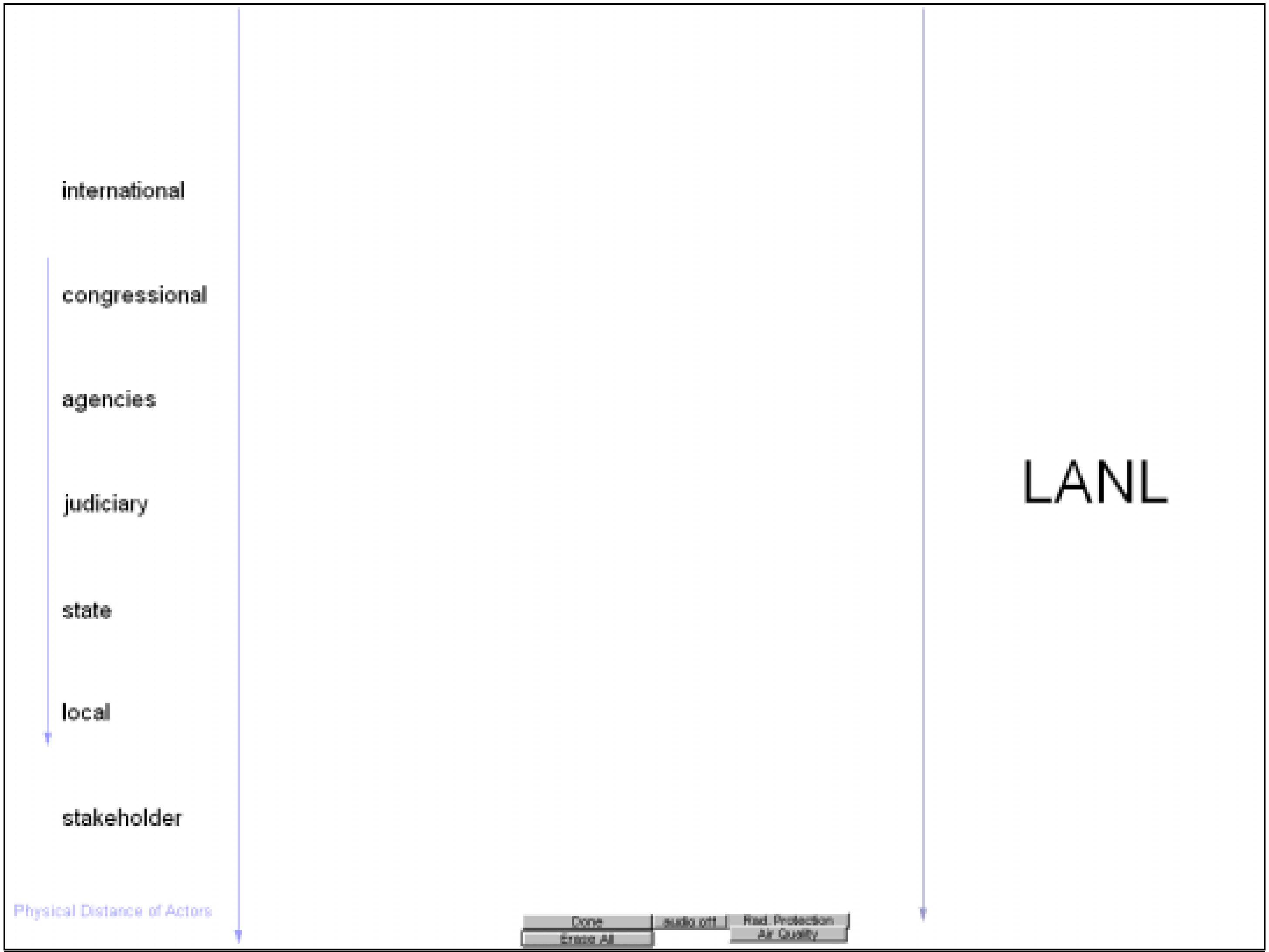
This map draws from the research of Jude Egan to show how visualization can also be used to trace the generation of complex individual regulations, through a regulatory network. This map shows the generation of the "As low as reasonably achievable" guideline and how it enters into the lab's regulatory environment. For further information on this development, consult Jude Egan's accompanying report.

## Appendix 3: Waste Networks

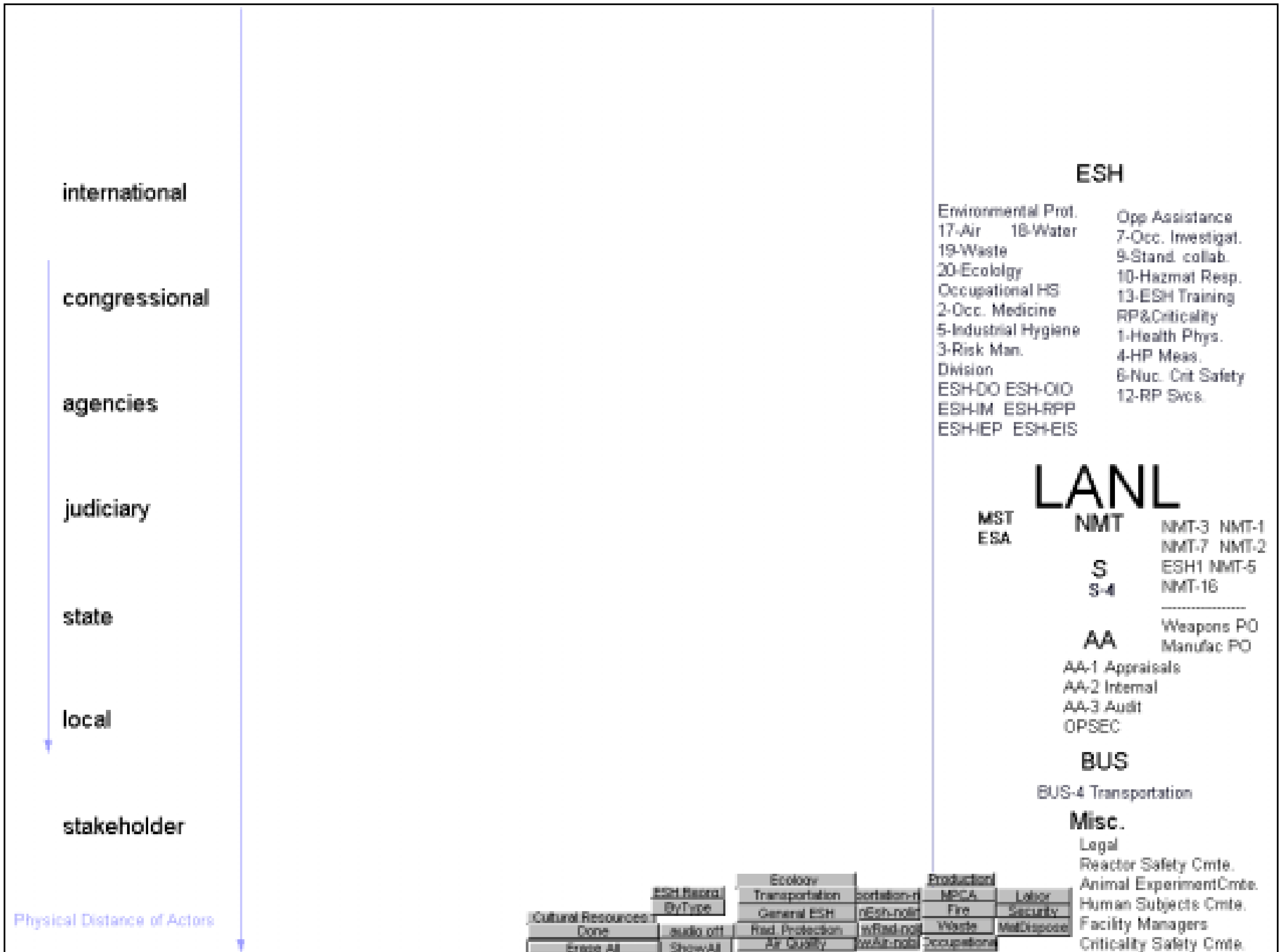
This map shows the actors involved in the regulation of hazardous waste generation (not restoration work) at LANL. This network is unique in that a single working division which also generates waste, maintains management over an important component of LANL's waste management strategies. Here, NMT-7 manages the liquid waste treatment facility and interacts directly with external and internal regulators. This map does not account for the work of FWO.

## Appendix 4: Satellite Accumulation Areas

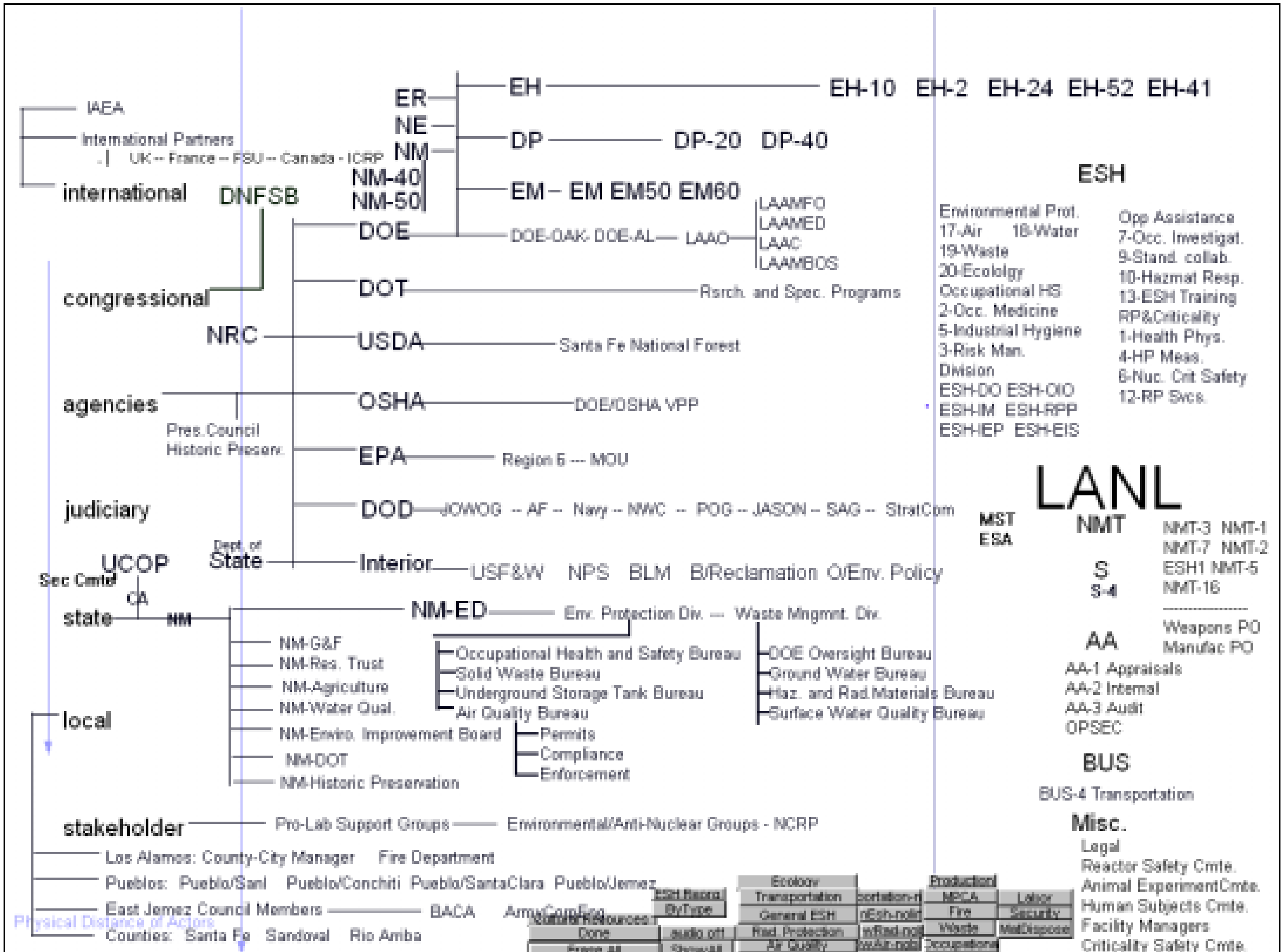
This map details the RCRA rule on Satellite Accumulation Areas in the same way that Appendix 2 details ALARA for radiation protection. Further information about this rule can be found in Jude Egan's work as well.



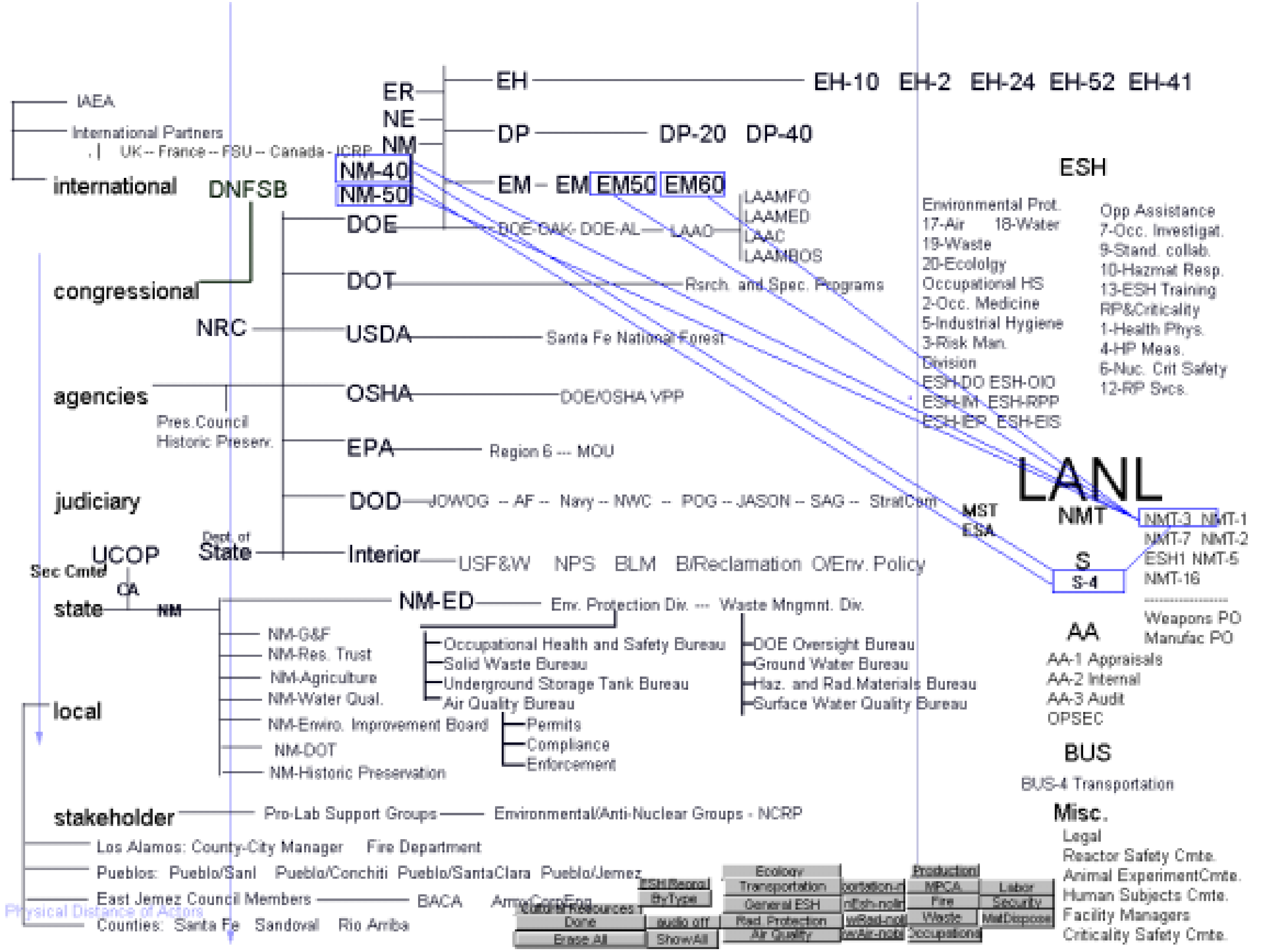

**Network 2 - Regulatory Hierarchies**



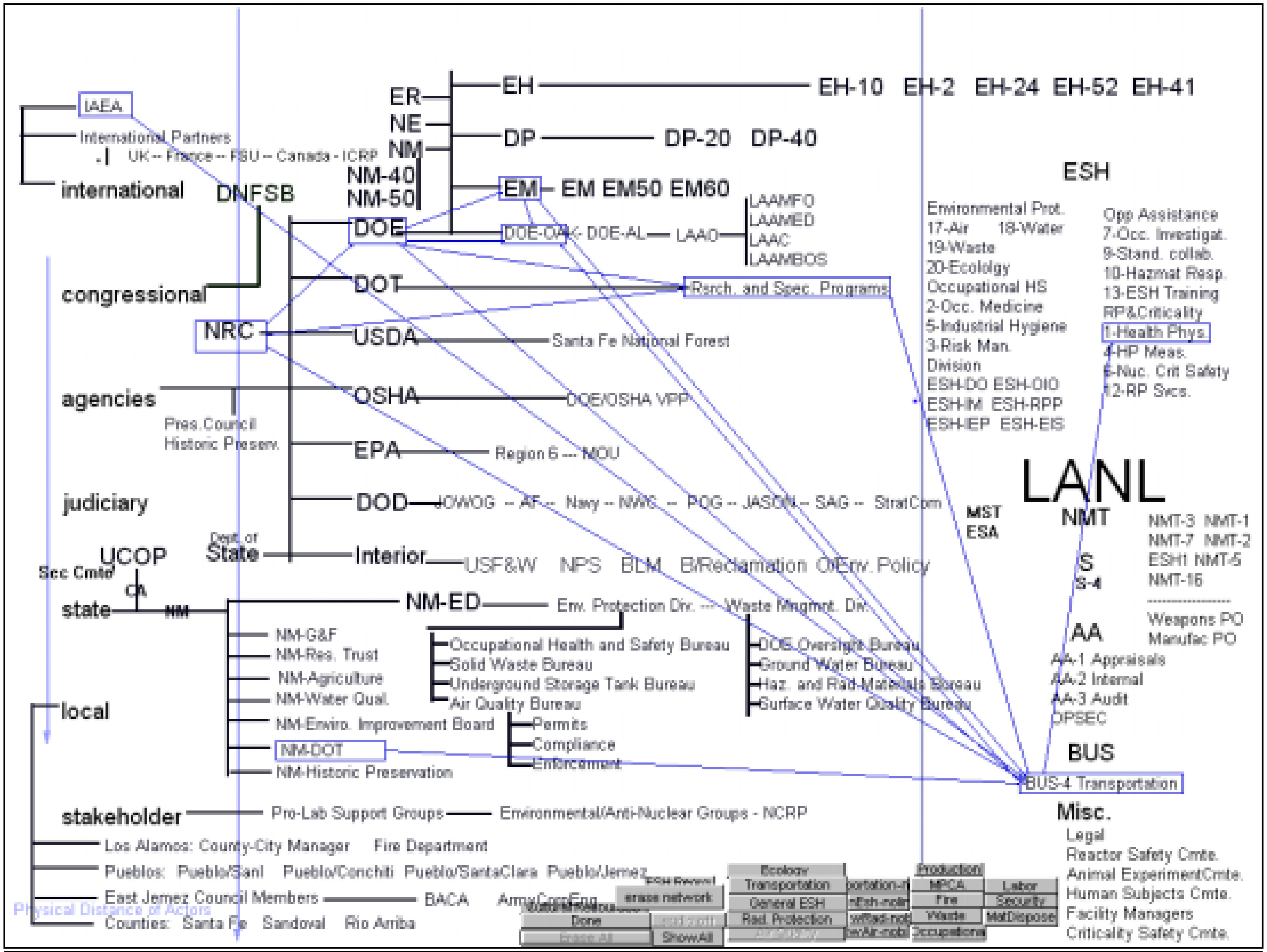

**Network 3 - LANL Expanded**



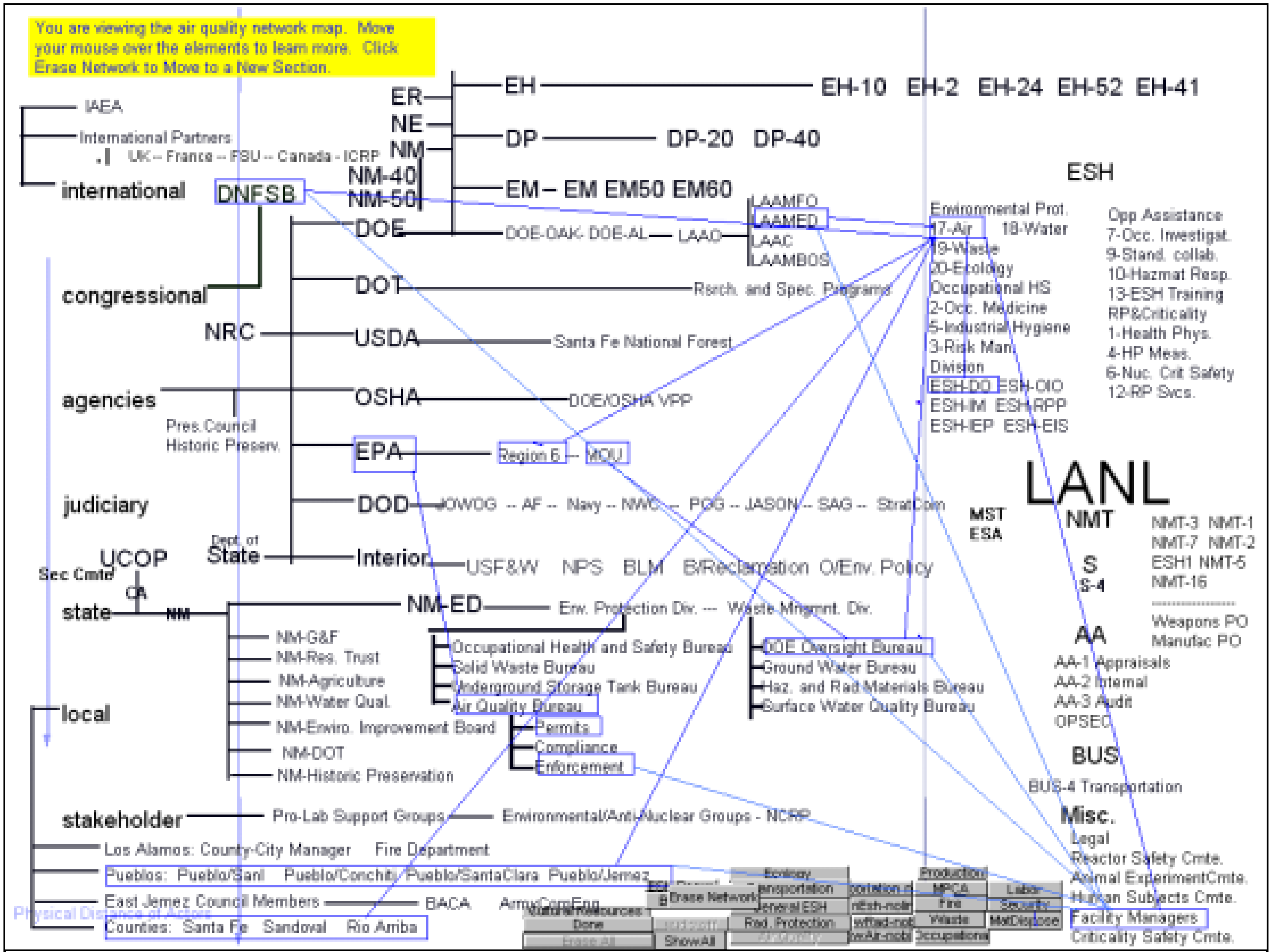

**Network 4 - The Regulatory World**



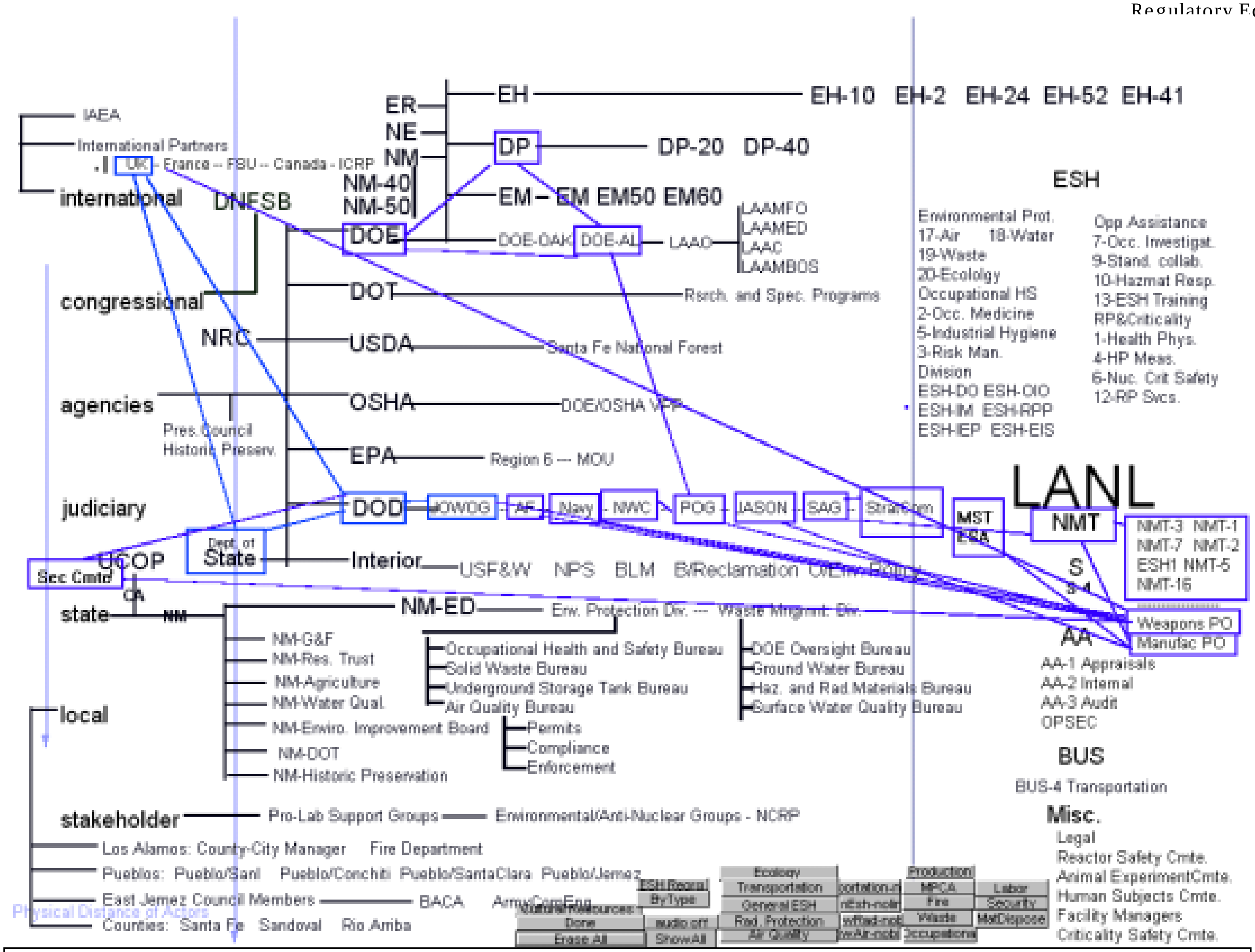

**Network 5 - A Simple Network (MPCA)**



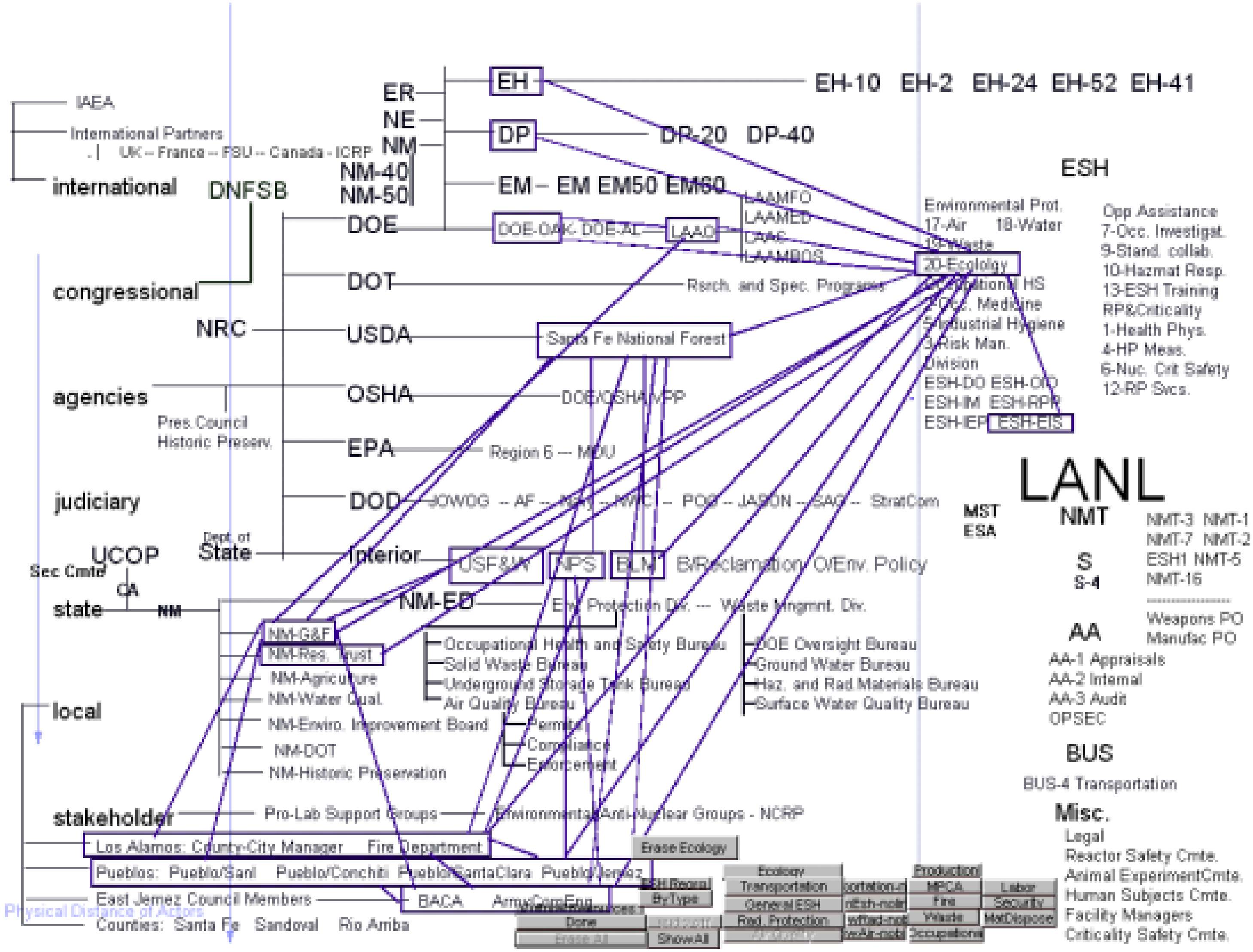

**Network 6 - A Single Boundary Network (Transportation)**



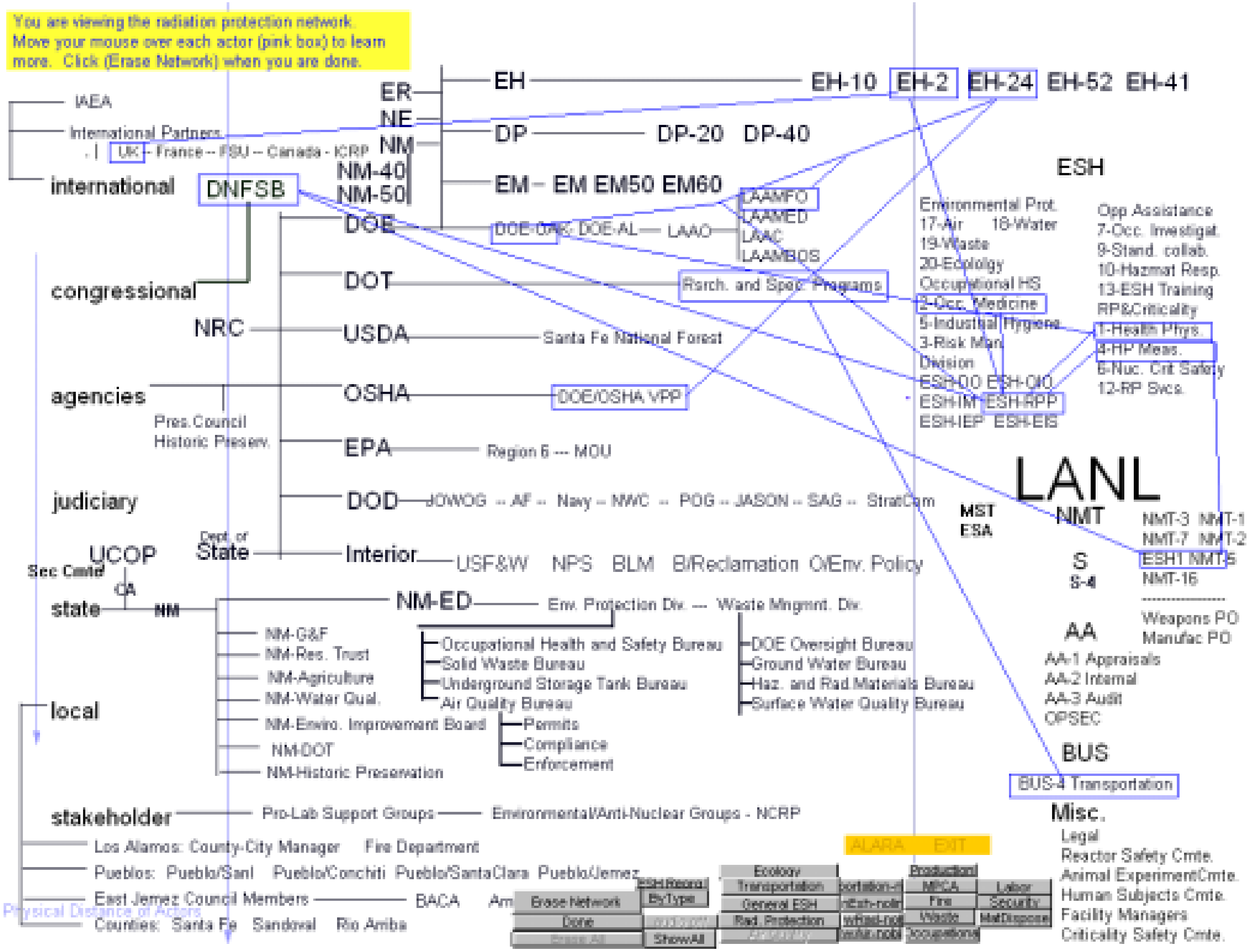

**Network 7 - A Multi-Boundary Network (Air Quality)**



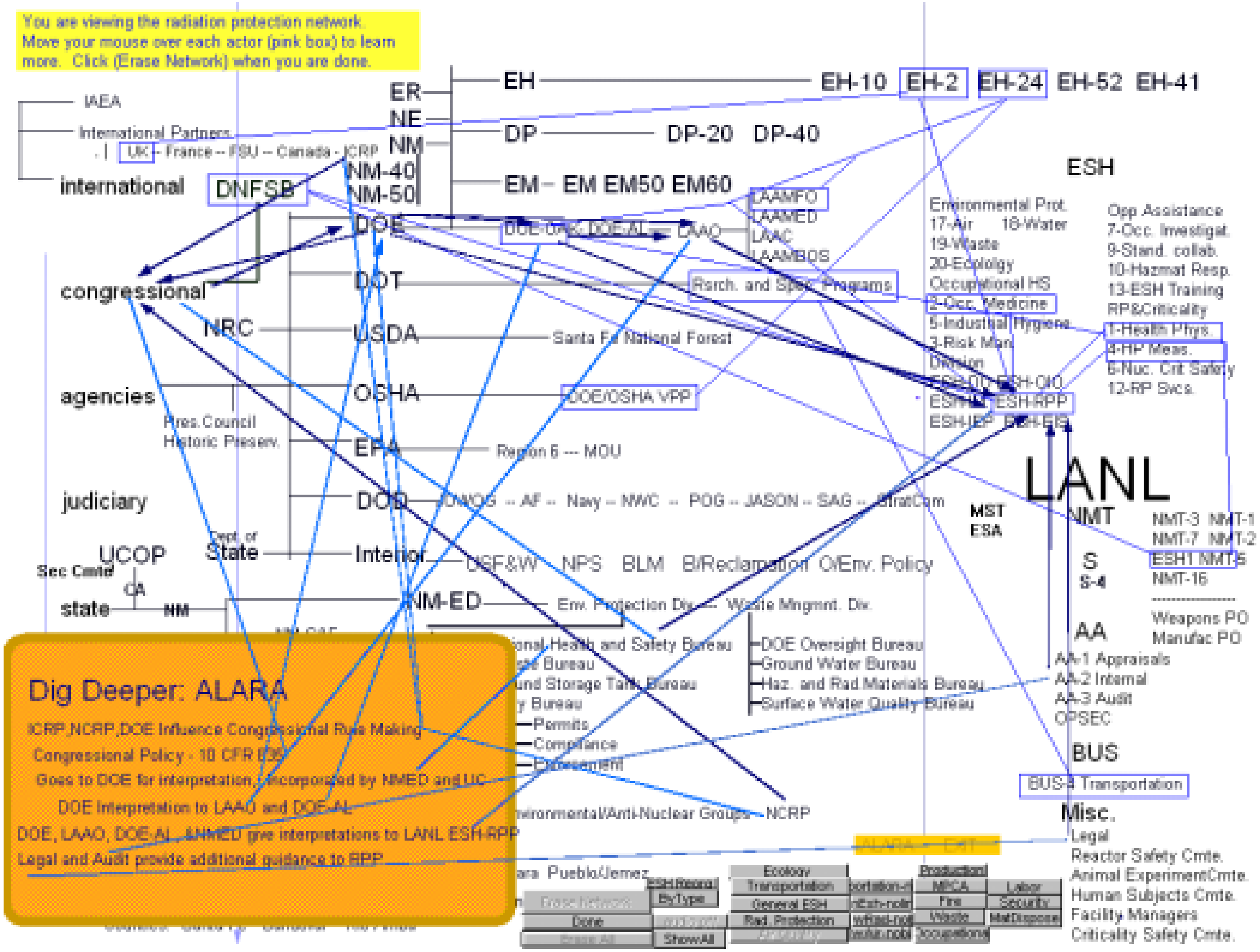

**Network 8 - A Multi-Boundary Complex Varied Network (Nuclear Production)**



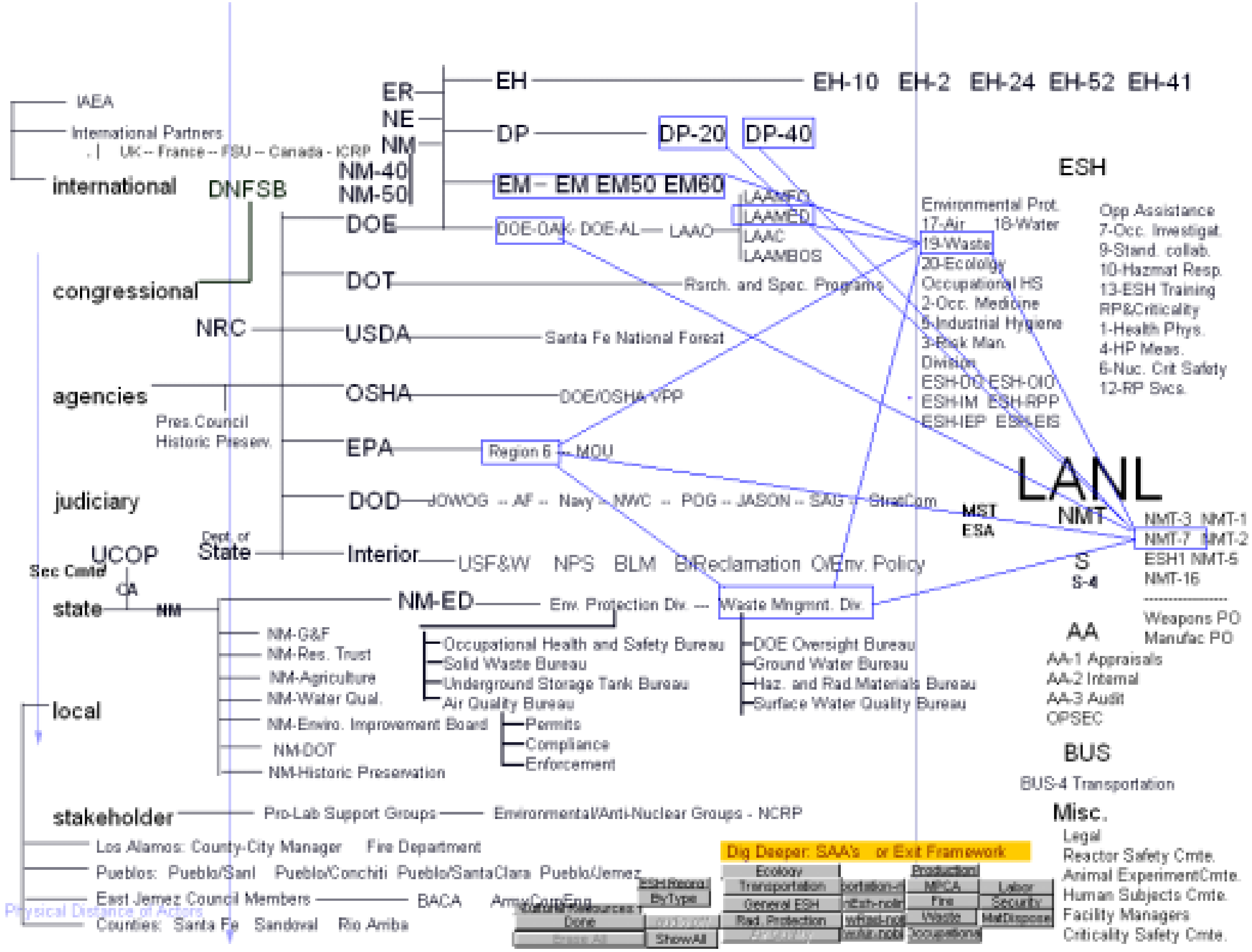

**Network 9 - A Managed Single Boundary Network (Ecology)**



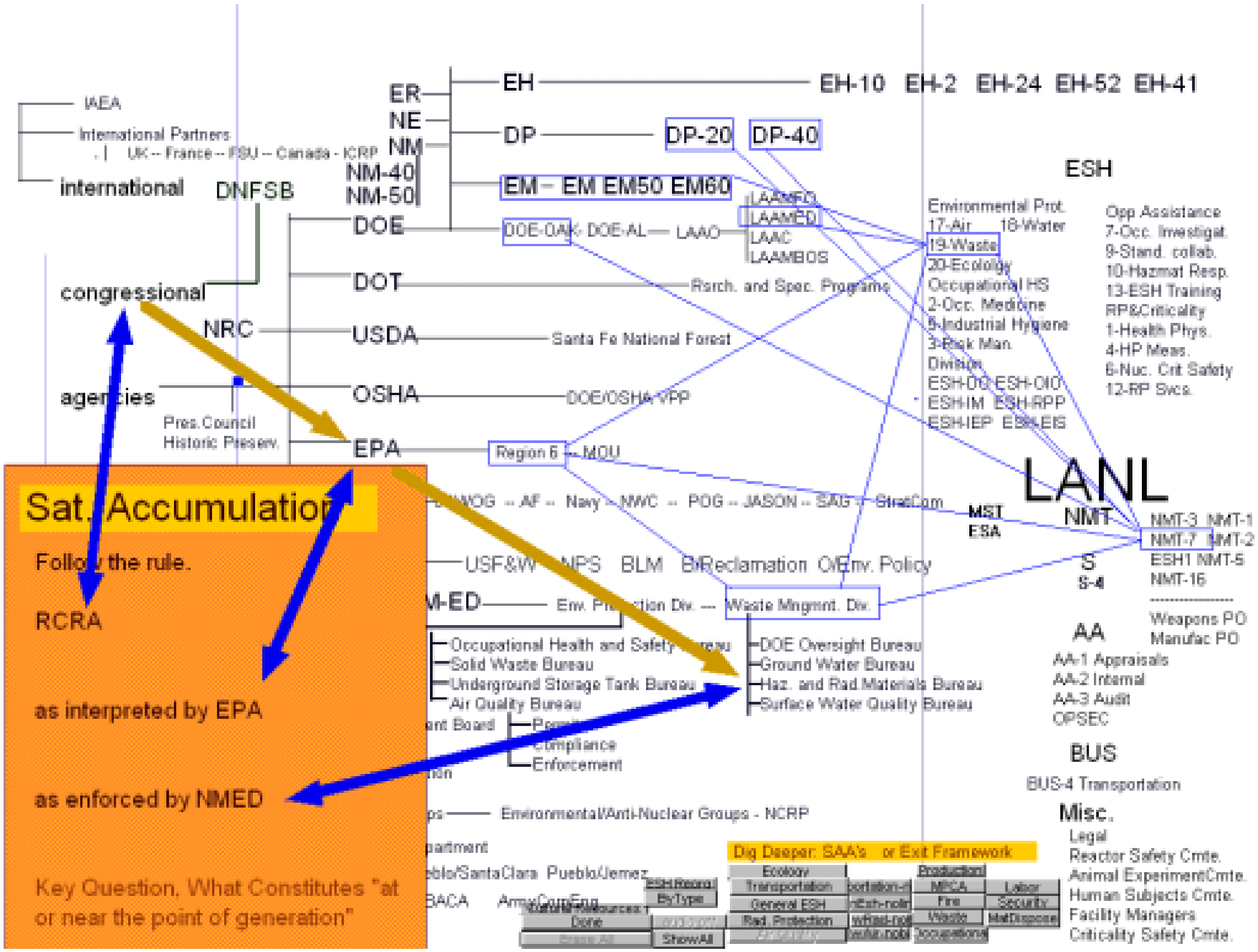

**Appendix 1 - Radiation Protection Map**



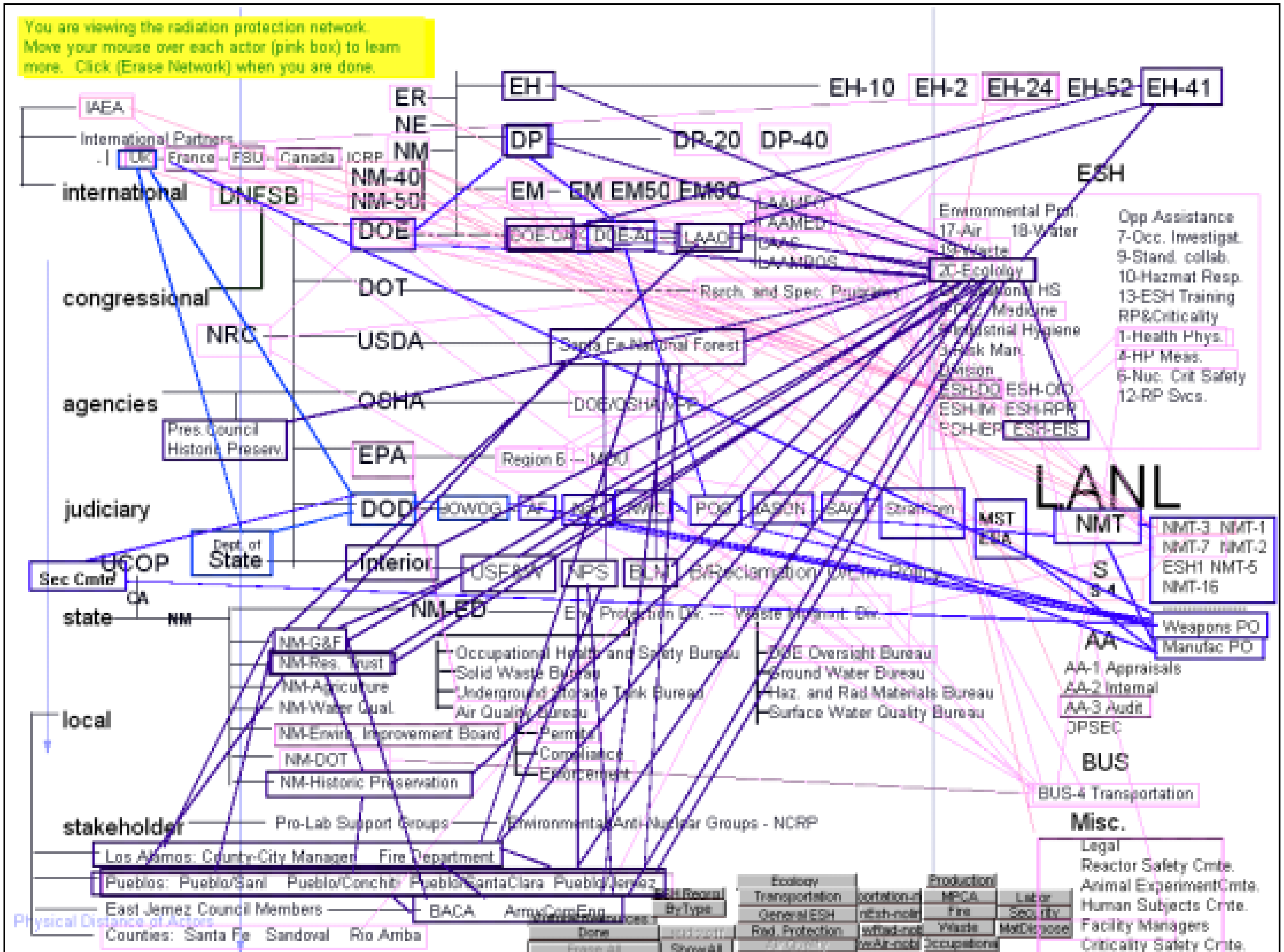
Appendix 2 - Digging Deeper into the Radiation Network, ALARA




Appendix 3 - Waste Networks




**Appendix 4 - Digging Deeper Into Waste - Sat. Accumulations**




**Network 10 - Overlapping, Comflicting, Complex, Varying Networks of Regulation**

# Technical Operations In the Shadow of the Law:

## Two Stories of Interpretation and Compliance at Los Alamos National Laboratory[1]

The LANL/UCB
Stewardship
Project

Final Report

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and Department of Political Science

Abstract. It has been noted that the dominant American legal culture is one of adversarialism. This is evidenced by the reliance on aggressive advocacy by lawyers on behalf of their clients, passive judges and "winner-take-all" judgements. Increasingly, in the regulation of high-risk operations, such as those conducted at Los Alamos National Laboratory, such adversarialism is quite apparent. This paper highlights two views of regulation. The traditional story of regulation (the "Simon Says" game) posits regulation as becoming more specific through regulatory interpretation. Another story that has grown out of interest group politics and pluralism theory (the "Telephone Game") shows that regulatory pronouncements do not always give guidance to those who are meant to implement them; that, in fact, regulations are often compromise agreements between politicians on behalf of constituents that are meant to be further specified by regulators. We explored the growing presence, and the adversarial nature, of the Telephone Game that may arise from the conflicting needs of the technical experts, who implement regulations, and the lawyers and politicians, who create it. Their backgrounds and training appear to instill in them different beliefs about the need for specificity/ambiguity in the wording of such regulations and thus lead to an inherent conflict. As evidence, the paper takes an unrepresentative sample of three regulations implemented at the Lab and follows them through the network of external and internal regulators to the Lab floor.

University of California
Berkeley, California
September 2000

## I. Introduction

To function, technical experts at Los Alamos National Laboratory must undertake a number of dangerous procedures, each of which involves some level of risk. A variety of federal, state and local regulations serve to mitigate the chance of accidents by requiring safety procedures, equipment and monitoring of Lab practices. Regulations are sets of general rules created by Congress to be interpreted and enforced by federal agency staffers. The rules are meant to give guidance to Lab officials and technical workers alike with regard to safe practices. However, there is an inherent conflict between those who enforce the rules and those who follow them in the level of specificity needed for compliance. The technical staffers at the Lab tend to prefer specific rules that give them guidance with regard to what is required by federal regulators. In many cases, the regulations have not attained a level of specificity great enough to ensure that they can be followed with confidence. Lab officials charge that interpretations of rules sometimes change from one year to the next or when there are personnel changes in the regulators' offices. The new interpretations allow regulators to cite the Lab for violating regulations, even if it had been in compliance during the previous inspection.

We outline two stories of regulation below: the Simon Says and the Telephone Game stories. The Simon Says story is the traditional view of regulation; Congress passes general rules that are interpreted specifically by technical agency experts and enforced by local regulators. The Telephone Game story holds that, though laws are general when they are passed, but that regulators' interpretations of them do not create specificity. Instead, the Telephone Game suggests that, often, regulators' interpretations conflict with one another in such a way as to make it difficult for Lab officials to comply with the requirements. Technical experts tend to prefer the Simon Says story of regulation because it gives them specific guidelines for conducting their work. Regulators may prefer the Telephone Game story of regulation because it grants them decision-making discretion. In addition, lawyers may prefer the Telephone Game story because their training teaches them that having room to make an interpretive argument is the best thing they can do for their clients.

## A. The Traditional or Simon Says Story

In a traditional regulatory approach to rule-making and compliance, one might expect to view a regulated entity as following a set of rules given to it in hierarchical fashion.[1] Rules stem from the top of the hierarchy, the *rule-makers*, and are followed below by the *rule-implementers*. The task of the rule-makers is to fashion rules that will create a preferred situation when implemented. The relationship between rule-makers and rule-implementers is such that the rule-makers give the limitations on how a thing can be done, or describe how it should be done, and rule-implementers work within these constraints to put them into practice. If rule-makers are government officials,[2] they will often have the authority either to enforce the law or to endow another organization with this power. The notion that the law is "an obligation backed by a sanction,"[3] is the pessimistic view that relies on the sanction to ensure compliance. That is, for regulators to be able to have an impact, they need to have an enforcement mechanism, and it is true that, in some regulatory instances, "the process is the punishment.[4]" Even where regulators choose not to impose sanctions on the offending organization, they can make operations time-consuming and difficult for the workers, simply by choosing to become more active as regulators.[5]

In order for rule-implementers to comply with regulations, two conditions have to be met. First, rule-makers have to be able to *exert authority* over those below them. That is, the hierarchy must be arranged in such a way that the rule-implementers will follow the dictates of those in authority to the best of their ability. As argued above, this can happen either through strong mechanisms for enforcing sanctions against non-compliant organizations[6] or through the threat of activating regulatory processes

[1] This is a standard "command and control" bureaucratic approach to management. Many writers including Fayol, Taylor and Max Weber have written on this subject.

[2] These rule-makers may not all be governmental organizations. In California, the Independent System Operator (CAISO) is a private corporation that regulates the electricity industry, the New York and Chicago Stock Exchanges are similarly private corporations with rule-making power. While the latter two have enforcement mechanisms, the CAISO is examining ways in which it might do the same.

[3] Cooter, Robert and Thomas Ulen, *Law and Economics*, Addison-Wesley Pub Co., 1999.

[4] Feeley, Malcolm, *The Process is the Punishment*, Russell Sage Foundation, 1992.

[5] In some instances at Los Alamos national Lab, the fear of activating an otherwise passive regulator is greater than the fear of being sanctioned by the organization she represents. An EPA regulator can significantly slow operations without imposing sanctions, by either issuing compliance orders or leaking information to citizens' groups who will then follow with lawsuits. {Joe Rochelle, 7/99,Catherine Thayer, 6/99}

[6] Cooter, Robert and Thomas Ulen. *Law & Economics*. (Third Edition), Addison-Wesley, 2000. 432-454. For this the Law and Economics literature on crime prevention can be of some use. The economic theory of crime and punishment views sanctions as prices to be paid for not complying with the law. Reductions in violations of the law are accomplished through increasing the price signals to the potential violator. That is, either the price of a violation is increased (i.e. the sanction/cost is raised) or enforcement is made more likely (i.e. the

or *administrative barriers*, that make operations difficult.[7] Second, the rule-makers must make sure that rules are *comprehensible* enough to the rule-implementers that they can be followed.[8] Within this second condition three additional conditions must be met. First, the rules must be clear and understandable to the people/organization to whom they are addressed. Second, the rules must be communicated to the people/organization in such a way as to be clear and understandable to them. Third, for the rules to be implemented, they must conform to standards of reasonability (i.e., financial, technical, social, etc.).[9]

This notion of hierarchy is the traditional idealized story or what I call the *Simon Says Story*. It describes the process of rule making by elected officials that, intuitively, seems the most democratic because it endows regulatory power in the hands of those officials elected by the people.[10] In the childhood game of Simon Says, the group of children elects one leader who then gives them commands. They are to follow his commands exactly (and only when he prefaces his statements by saying "Simon Says"). In the traditional story, it may simplify things to think of Simon as the elected officials who bring the public will into being. The group to whom Simon gives commands is then the rule-implementers. The implementers then take the rules they have been given and apply them to the specific environments in which they operate, thereby translating general rules into specific scenarios ("Simon Says radiation protection levels will be 'As Low As Reasonably Achievable'").

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probability of getting caught is increased). Also, Bardach, Eugene and Robert Kagan, Going By the Book. Temple University Press, 1982. 162-164.

[7] A remarkable instance of this occurred in 7/00 within the Nuclear Materials and Technology Division after a safety error resulted in the uprising of a massive "red tapism." Workers will always work in pairs, with one worker completing the work and the other watching over him. The amount of documentation of operations practices required for NMT workers was set to increase manifold. Some of the managers complained that they were already spending 70% of their time doing paperwork. {David Odland, 7/00} In this sense, such administrative barriers can be thought of as a type of sanction. Many different interviewees have pointed out that they would rather "stay under the radar" as much as possible to avoid regulatory intervention.

[8] Simon, Herbert. *Administrative Behavior* (4th Edition). Free Press, 1997. Chapter 8. Many of these ideas are drawn from the organizations literature regarding organizational communication. Essentially, communication is a two-way process: there is transmittal to a decision-making center of orders, information and advice and then there are transmittals of information from the center to other parts of the organization. If the regulatory process is viewed as a large organization, for which there are multiple decision-making centers, then the importance of comprehensibility of rules becomes more clear. An order, piece of information or advice must be understandable to those who are to both make decisions and enforce them.

[9] "Reasonability" has many potential connotations depending on the context in which it is used. What is technically "reasonable" might be a mixture of what is technically feasible and what is financially possible (see the "As Low As Reasonably Achievable" section below for more about this). In the legal context, what is "reasonable" might be what is expected of the average person/organization who engages in such practices. However, for these purposes, "reasonable orders" are those that can be followed within specified time frames.

[10] Hierarchies are, of course, anti-democratic, but governmental command and control structures place decision/rule makers who are responsible to voters or people who are responsible for voters for their decisions at the top of the pyramid. Those below them in the hierarchy simply implement the rules as given to them.

This calls to mind many of the questions associated with principal-agent theories of legislative-executive behavior. In theory, the executive agencies are extensions of the executive branch, each working to execute the laws. The laws are created by legislatures and handed to the executive for implementation. To that degree the executive branch becomes an agent of the legislative branch; it acts to carry out the mission put to it by the legislative/rule-making branch. However, the U.S. governmental system is not quite a principal-agent relationship because the executive branch is endowed with its own power to "check" the rule-making power of the legislative branch. Part of the power to "check" legislative power comes in how the executive executes the law. There is a further principal-agent dilemma raised in the executive-executive agency relationship, in which the President or one of his secretaries gives an order for how a piece of legislation is to be executed to the executive agency. The way the legislation is actually executed and whether or not the President may force executive agencies to execute in a certain manner has been called into question by the Unfunded Mandates Reform Act (UMRA) of 1995. This mandates cost benefit analysis in agencies for decisions regarding strategies for implementing rules and must show that it has undertaken this procedure if it is sued. The President may effectively use the Office of Management and Budget (OMB) to stop execution of the law in ways he does not like by refusing to allow funds to be disbursed. However, there are constitutional questions relating to the separation of powers doctrine that may arise in conjunction with the President's refusal to implement congressional proclamations.

For illustrative purposes, imagine Simon saying: "Simon Says touch the top of your head with the palm of your hand," the group does so in slightly different manners, but everyone essentially does the same thing. Now Simon says: "Simon Says: touch the ground." Each member of the group touches the ground in some manner; some sit, others lay, still others continue standing, one reaches down with her hand and still another does a handstand. Simon then says, "Everyone is out except the girl who touched the ground with her hand, because that is what I *meant* when I said 'touch the ground.' "Touch the ground" is the legal equivalent of a general rule, because it does not specify how to touch the ground, but leaves that decision to the implementer.[11]

If a legal snag is going to occur, it does so traditionally when there is an attempt to make general rules to apply specific situations. "Simon Says: keep spark producing instruments 35 feet or more away from

[11] In many instances, giving very detailed rules micro-manages the people who must follow them. This can be to such an extent that they are not allowed to make changes when each situation calls for them (e.g. the case of the speeder who is rushing to the hospital to save his child).

combustible materials,"[12] is a rule that requires knowledge of three things: a) what a spark producing instrument is, b) what a combustible material is and c) a tape measure. Since a) and b) are well-defined through common sense and c) requires a tool that is readily accessible to workers, the knowledge requirements required to implement it are quite homogeneous. The rule, "Simon Says: Satellite Accumulation Areas may accumulate…hazardous waste at or near any point of generation where wastes initially accumulate,"[13] requires knowledge of a) what waste is to be considered hazardous and b) what "at or near the point of generation" means. The first requires homogeneous knowledge, but the second requires knowledge that is more diverse. It may require policy interpretations, understandings of the laboratory's physical layout, the legislative history, or it may require a guess. Such a guess may leave the guesser in the same situation as the people who did not know exactly what Simon meant when he said, "touch the ground" in the example above.

## B. The Telephone Game Story

General laws, as passed by legislatures, are often unclear, imprecise instruments, tools that look more like political bargains than like clear policy-making directives, largely because they are the product of the group-struggle, or pluralist, political practice that has taken hold of the legislatures during the last half century.[14] Rarely do legislators have homogeneous goals when legislation is passed. More often, legislation is a product of compromise between actors with multiple and conflicting goals. In the economists' vision, votes are traded on issues less important to one particular legislator for votes on issues important to him or her. For pluralist political theorists concerned with minority rights, the idea of political compromise represents the highest form of government because it gives voice to interest groups who otherwise may have been left out of the political decision-making regime. This type of legislative decision-making stresses the process of governance as the highest form of the good, i.e., all people have a say in what the law will be, rather than the deontological view that a universally accepted "right" or "good" answer can be found.[15] Political compromise is the product of interest-group struggle.[16] The resulting imprecise rules promulgated through such struggle are the products of the bargains struck between groups with competing goals.[17]

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[12] 29 CFR 1910 251-252
[13] 40 CFR 262.34
[14] Shapiro, Martin, *Who Guards the Guardians? Judicial Control of Administration*, University of Georgia Press, 1988, p. 4-12.
[15] *Ibid.* Scientists and engineers, like moral theorists, may prefer to search for the "right" answer.
[16] "The process of making public policy consisted of groups competing with one another for what legislators, administrative agencies and courts has to offer." *Ibid.* p.5.
[17] *Ibid.* pp. 4-12.

Implementers are often hired with the idea that there is a clear-cut split between those who make policy and those with the technical know-how to make policy happen. Again, the early ideas of good administration placed technical decision-making power in the hands of those who had technical knowledge. The early idea of the "science of administration" involved the notion that experts could make technical decisions, immune from politics, in situations in which technical knowledge was required. Political decisions were to be separated from technical decisions and made by those who represented the will of the people.[18] Interest-group lobbying efforts have worked against this idea, showing that the separation of technical "facts" and the "values" held by those who interpret them is difficult.

Pluralist political theory views ideal policy-making efforts as the aggregation of group preferences, or rather, as the result of lobbying efforts by those affected by the policy to influence the wording and intent of the legislation.[19] An understanding of public policy and economics predicts that rules will always be made in favor of those most affected by them because they will be the ones exerting pressure on the legislature. In instances where burdens and benefits are focused on narrow interests, the resources spent on lobbying increases.[20] As lobbying increases, the need for political bargaining between individual legislators also increases, because they attempt to promote legislation that favors the lobbyist groups. Heavy lobbying on both sides creates incentives for legislation that allows lawmakers to tell both sides that they have won.[21] This tends not to lead to the promulgation of precise regulations by political decision-makers.

For some iterations of the law, such disagreement and compromise at the Congressional level leads to beneficial outcomes. In the case of social reform legislation, for example, one side pushes for greater reforms while the other tempers the possibility of future tyranny; the result is legislation that is forward-looking without being too risky. However, with regard to technology, since there is typically a fundamental conflict between safety or risk mitigation and production,[22] there is a need for regulation

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[18] Wilson, Woodrow, "The Science of Administration."

[19] Shapiro, op. cit. The "deliberation" requirement in U.S. administrative law is an example of this. For an administrative agency to set policy, it must listen to and take into account the preferences of those who are to be affected by the rules. Over time, the scope of those who would be affected (i.e. those who have a right to state their preferences in the rule-making forum and those who have standing to sue after the fact) has been greatly expanded by the courts.

[20] Eskridge Diagram reprinted in Cooter, Robert, *The Strategic Constitution*. Princeton University Press, 2000.

[21] For example, an auto emissions regulation that can be celebrated in Detroit by a pro-auto industry lawmaker as a "compromise bill" and a lawmaker in California who can refer to it as an "environmental victory." Another example is the addition of "pork barrel" *quid pro quo* riders on legislation pushed through to get a compromise on a crucial issue.

[22] Wenk, Ed, *The Double Helix: Technology and Democracy in the American Future.* Ablex, 1999.

to guide policy implementers to ensure that production motives do not create unnecessary externalities. Interest group struggle with regard to regulating technology, while often beneficial for lawyers—who prefer to be able to argue shades of gray on behalf of their clients—and legislators—who prefer to be able to tell their constituents that they voted the right way on all pieces of legislation—may create difficulties for scientists and engineers who are charged with the task of bringing such rules into practice.[23]

Of course, regulations are not always imprecise instruments. In some instances congress will pass legislation that is quite specific in its requirements. The regulations may require specified safety equipment, safe work practices, or measurable levels of released pollutants. These types of specific regulations require very little interpretation and, in that sense, are the closest to the Simon Says story of regulation. Since the Simon Says story of regulation relies on the notion that the pipeline between rule-promulgators and rule-implementers is direct, the creation of rules by Congress that include requirements direct links between the rule-promulgators and the rule-implementers.

However, since the power to enforce regulations, falls to the executive branch, even the most direct regulations must be promulgated as rules by an executive agency with the power to enforce them. This means that the remnants of the "science of administration" are still, to some degree, in effect. The rules promulgated by Congress are meant to have a wide focus and be made more specific so that technical and policy experts in administrative agencies and departments can enforce them. This specificity allows them to be implemented in industry. The Simon Says model expects regulation to move in the pattern below:

Congress → Executive Agency/Department → Regulated Entity

Under this, the Simon Says model of regulation, Congress acts as a general rule-maker, putting forth policy goals, e.g. the reduction of threat to worker safety, the reduction of environmental pollution, or the increase of national security. The Executive Agency or Department, often with the direction of the President, takes these policy goals and, with an understanding of technical issues, interprets them into policy directives that can be enforced by the executive body and implemented by the regulated entities. In that sense, the executive body is also a rule-maker, but it restates the congressional rules in such a

[23] {Joe Rochelle, LANL Counsel 7/10/99}

way that they can be both implemented and enforced. To do this effectively requires, as mentioned above, that the rules be *comprehensible* to the regulated entity; they must be clear, communicated, and reasonable.

Situations in which there are just two bodies—rule-makers and rule-implementers—are very rare. In the United States bureaucracy there is a third body: *rule-interpreters*. These people/institutions are not just rule-makers, but, rather, a hybrid body that does both makes rules and enforces them. Generally, they exist as "inbetweeners,"[24] liaisons between the enforcement agencies' headquarters and the regulated entities. In the case of the Department of Energy, such rule-interpreters exist in regional and local area offices closer to the locations of the regulated sites.[25] The regional DOE offices each have personnel who enforce rules promulgated by the DOE Secretary. If the rules are precise, as the Simon Says story warrants, each of the regulatory field offices will be in agreement. That is, if the Secretary says "35 feet from the spark producing instrument" each official needs only a measuring tape to know if the entity is in compliance. If the Secretary takes into account the differing requirements of each of the DOE laboratories and, thus, leaves specific interpretation of the rules he promulgates to the regional DOE offices responsible for the regulation, i.e. enforcement of rule implementation, he can promulgate more general directives himself. Before the regulated entity can implement regulations, each DOE office has the opportunity to interpret the directive and pass it on to the DOE regional office below it in the hierarchy. Since, each regional office has both rule-interpretation and rule-enforcement capabilities, each maintains its own interpretation of the rule and the right to enforce it. The idea behind this strategy is that each regional office has oversight over the regional office below it, i.e. DOE-HQ oversees DOE-ALB which oversees DOE-LAAO which oversees the onsite DOE officials. In practice, however, it means that each DOE office may regulate the Lab with its own particular interpretation.[26]

The passing of interpretations from one DOE office to the next, while each maintains its role as enforcer creates an "information hierarchy." These information hierarchies involve transaction-costs at each level; bits of distortion are added to interpretations as they move through an internal interpretive web from higher interpretive authority to lower. Rules are often endowed with the "personal stamps"

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[24] See Stone and La Porte, "Regulatory ecology: A visual and analytical approach to internal and external networks of regulatory actors at Los Alamos National Laboratory," above in this report for s discussion of the role and lab units "in between" regulators external to LANL and the group and work level operations.
[25] Los Alamos National Laboratory has DOE-Albuquerque (DOE-ALB), DOE-Los Alamos Area Office (DOE-AAO) and DOE-onsite officials as rule-interpreters/enforcers nearby.
[26] {John LaPointe, 7/11/00}

of each of the rule-interpreters because the values each official brings with him into the workplace reflect in the way he understands the meaning of each rule. Thus, it is difficult to separate administration from the values of each of the administrators.

The second story, then, is different than the Simon Says story. In the second story of regulation, rules are made by rule-makers, elected officials subject to an array of public opinions. This being the case, the rules, themselves, are made through the process of congressional and interest-group "pulling and hauling" described above, sometimes reaching a point of incomprehensibility when finalized.[27] Even if not incomprehensible, the congressional intent is largely shielded from those who are given the task of interpreting them,[28] and the rules bear the stamp of compromise deeply enough that there is plenty of room for executive agency or regulated entity interpretation.

These regulations are then passed to the executive agencies for enforcement. Agencies themselves are large and unwieldy organizations, populated by people with personal and political agendas. The people who work at these agencies are often experts in their fields. However, as most scientists are aware, expertise in any field does not necessarily insulate one from ones values, political or personal. Scientific objectivity may, however, provide a way of shielding oneself from claims that one is acting according to one's values and instead is "doing science" alone.[29]

Agency rule-interpreters pass regulations down to more agency rule-interpreters, often more localized bodies, who themselves pass regulations down to still another level of interpretation. The network is composed of regulatory actors responsible for more specific interpretations of rules as they are closer to the regulated entities.[30]

Each interpreter, if she doesn't change the rule with her own wording, will at least bring her values to her interpretation of it. Regulations that have undergone multiple interpretations will sometimes reach the regulated entity with multiple and conflicting interpretations accompanying them, any of which are

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[27] Incomprehensibility may come either from too much generality or specificity to the point of minutia. The Telecommunications Act of 1996, for example, is a document with more than 1200 pages.

[28] Berring, Robert. *Finding the Law.* 11th Edition. West/Wadsworth, 1999. Legislative histories are sometimes used to try to make sense of Congress' intent on a particular piece of legislation. Only sometimes do the legislative histories provide guidance on this matter. A debate is in progress in the Supreme Court about whether legislative histories can provide a sound basis for legal arguments about the congressional intent, and whether or not the "intent" should have any bearing on judicial interpretation.

[29] The Plutonium Futures 2000 Conference in Santa Fe July 10-13, 2000 was an attempt to focus on the science of plutonium rather than the politics of it. There, the discussion quickly moved to politics.

not promulgated in writing. The rule-enforcers at the most local level and the implementers at the highest level of the regulated entity's hierarchy attempt to decipher how to enforce and implement the rule respectively. High-levels of agreement about rule-interpretation can be difficult enough if the local DOE official and the Lab's internal regulators have an amiable relationship, but, if they have an adversarial relationship, as many times they do, it is more difficult still.[31]

This second story recalls the *Telephone Game*. In this child's game, one person thinks of a statement: "Pink Elephants run in circles." The phrase is whispered in the ear of the next person once. The second person then repeats the phrase to the third: "Think elephants in the circus." The third person hears what's been whispered in her ear and passes the phrase on again: "Sink elephants on the surface." The game goes on until the last person is asked to repeat the phrase as he heard it to the entire group: "A wink wonks in your face."

In the Telephone Game story of regulation, some promulgated rules are not *comprehensible* packages of information that can be processed and followed, something necessary for them to be implemented correctly. These rules begin with a need for interpretation and arrive at the implementation phase with many different interpretations. The lines of communication between regional offices of the executive agency or department, headquarters, the state regulators and the regulated entity, itself, are often difficult to follow. In order to enforce the rules effectively, especially in cases in which the knowledge requirements involve a great deal of complexity and the costs of non-performance could be catastrophic, regulators must make them comprehensible to implementers.

To be comprehensible, the rules must be 1) clear, 2) communicated and 3) reasonable. The Telephone Game distorts comprehensibility by distorting all three. Many rules do not gain clarity, if by clarity we mean specificity; in fact many of the rules are passed on from regional office to regional office without wording changes. Interpretations are thus kept private and personal by the regulator himself. The rules may be communicated but what is communicated does not come from a unified source. The regulated entity knows that any of the regional offices may send an official to ensure that the entity is implementing its particular interpretation. Many times, the official interpretation of the rule by each regional office is not made clear to the other offices, much less the regulated entity itself. If the

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[30] See Stone and La Porte, "Regulatory Ecology:..:, op. cit., for a discussion of regulations "passing through the network."

[31] Many of these relationships are bad, she said, because Lab personnel condescend to regulators because they feel they are incompetent. Regulators, understandably, take offense to this kind of treatment and negative relationships result. {Jennifer Pratt, July 17, 2000}

relationship between the regulated entity is adversarial, this is even less likely. Reasonability relies on the ability of the regulated entity to meet the technological, social or economic demands placed on it by regulators. Distant regulators not in close contact with the regulated entity may not have an adequate understanding of what is possible for the regulated entity to accomplish. Those closer to the entity, but in an adversarial relationship to it, may create unreasonable interpretations of the rules in order to make regulation less difficult. The entity, itself, may try to hide behind "unreasonability" as the basis for its noncompliance.

Implementers, both at the regulated entity and at the most local regional office of the executive agency interpret regulations that are often vague, either by design, as in legislation, or because the cost of the technical information needed to make them clear is prohibitively high. If the technological knowledge requirements to make a regulation comprehensible are highly complex or variable the final interpretation might be left to those who are considered the most expert in the field, e.g., actinide chemists may be the best people to decide how to make plutonium laboratories safe. They are also charged with attempting to unify personal values that are often heterogeneous and conflicting within the agency offices so that compliance and enforcement is possible. We see this, for example, in agencies in which there are many Carter-era environmentalists. With officials appointed during the Reagan-Bush years, there were extreme conflicts in interpretation of environmental regulations. Third, rule-implementers must contend with the organization itself, often a complex amalgamation of many work groups, technical staff and management that, while being a potential source of hazards, serves a government purpose. Los Alamos National Lab employs 12,000 people and conducts research on everything from geology and nuclear physics to atmospheric science and confronts an extraordinarily dense network of regulators who oversee its operations.[32] Fourth, coupled with the complexity of the organization are the technical requirements that may create conflict between the need for safety and the need to perform assigned tasks. Production is often in tension with safety, especially as new administrative safety and security measures may seem to take up as much as 70% of work time.[33] Each of these factors applies variously in cases of considerable complexity and multiple and conflicting values, as in things nuclear and other hazardous technical systems.

The Simon Says and Telephone Game stories offer very different versions of the regulatory process. Each acknowledges a rule giver at the top of a hierarchy of rule-interpreters and implementers, but from that point of agreement, the two differ widely about what happens to regulations as they go

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[32] See Stone and La Porte, "Regulatory Ecology:.." op. cit., for a dramatic description of the environment.

through the implementation process. This paper examines three regulations in order to cast some light on ways we might sort out the Simon Says story from the Telephone Game story. The point is not to say which one is the right way of perceiving the regulatory process, but to shed some light on the characteristics of each as they relate to Los Alamos National Lab. There are literally thousands of regulations with which the Laboratory comes into contact, each of which conforms to some degree to one story or the other. This paper is not meant to be an exhaustive study of these regulations, nor could it be, but rather a first cut at developing a typology of regulations that will better allow the Laboratory and its regulators to understand the regulatory environment in which it operates.

The sample regulations are non-representative by design. Two were chosen to show the characteristics of the Telephone Game and the other to begin to shed light on the Simon Says story. For the purposes of the paper, the Simon Says story regulation will be discussed first, though it came third of the three as a way of providing a control group for the research. Since Simon Says is the traditional story of regulation, we treated it as the null hypothesis, and were prepared to be surprised by any findings that might differ from it.

## II. LANL

### The Project

The project is a beginning step toward developing a way of classifying regulations as a function of the regulatory environment in which they are enforced, especially the ways of passing information from one level of the hierarchy to the next through the regulatory "inbetweeners" that make up the enforcement staff.[34] To our knowledge, the development of a typology for regulations that affect a given organization has not been attempted. Such a project entails a large amount of effort, especially with regard to an organization as heavily regulated as Los Alamos National Laboratory. This paper is an initial thrust into the development of regulatory fields, in this case, The numbers of regulations affecting the Laboratory could fill a large library. An attempt to study more than a small group would entail a much larger-scale project than that upon which we embarked, however, developing a typology for regulations may be possible using a smaller sample of regulations.

For LANL, an organization implementing many complex and extremely hazardous technical systems, the challenges of regulatory implementation stem from multiple sources. The Lab must interpret

[33] {John LaPointe, 7/12/00; Wu Chun-Feng, 6/7/00}

regulations in such a way as to make them comprehensible to the scientists and engineers who put them into practice. Senior officials in the lab will, ideally, make the regulations comprehensible by meeting regulators and clarifying the meanings of the rules. Lab divisions such as Environmental Safety and Health (ESH) will act as buffering agents, who interpret regulations to make them comprehensible for the implementers within the Lab.[35] If the agency's interpretation is not consistent between regional offices it will not be comprehensible to people in the Lab's internal buffering organizations.

Additionally, many interpretations turn on the values of the people who interpret them. Department of Energy employees are given interpretive discretion with regard to regulations. The degree to which the regulators are conservative in their interpretations may be influenced by the interpreter's feelings about the industry in which LANL is a participant[36]; the potential hazards, social, biological or environmental, created by the Lab; and the degree to which the relationship between the Lab personnel and the regulatory personnel is adversarial.[37] In addition, regulators may have conflicting views about the regulation. The Simon Says story notes that in any political hierarchy, the lower officials should implement the political values of the highest official, as he is represented by the head of the department or agency.

Additionally, LANL is a complex system with many component parts (Divisions andGroups) which function separately, while maintaining a connection to the higher body. The costs associated with information flow between divisions make it difficult to have a unified body of knowledge about regulations.[38] This makes for extraordinary complexity in the organization, especially that associated with the technical operating requirements and the many diverse technical safety hazards making it impossible to have a single way of implementing all regulations.[39]

LANL, with its diverse goals, operates within a wide variety of regulatory schemes. It can be regulated by at least 70 different bodies at the federal, state, and local levels, as well as the State of California

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[34] Stone and La Porte, "Regulatory Ecology:..:", op. cit.
[35] The Regulatory Explorer project, which runs parallel with this one, takes these internal Laboratory dynamics as part of its focal point. See Stone and La Porte, ibid,
[36] In the two day stand-down during Summer, 1999, one of the Lab's Directors made the point "Los Alamos National Lab's main business is making nuclear weapons."
[37] {Jennifer Pratt 7/17/00}
[38] LANL has begun trying to make regulations, both external and especially internal, available over its intranet system. www.lanl.gov/labview
[39] Impossible because some technical procedures require different methods of managing risk. The Lab, after a chlorine gas-related incident at Technical Area 55 on 7/11/00, has begun implementing safety procedures that can be implemented throughout the entire facility. These rules include documenting all activities and having a

through the contract it has with the University of California.[40] Many of its activities are classified as hazardous either to the environment or to human life. Since Lab employees work with and must dispose of hazardous materials, there are storage and transportation issues that involve the local and neighboring communities. The land surrounding the Lab has a National Park, several Indian Reservations and a major river, the Rio Grande, each of which involves oversight bodies and citizen groups. Furthermore, the Lab operates in an area in which citizen groups are highly politicized and sensitive to new developments, as well as, regular Lab activities.[41]

The scope of this initial foray into developing a method of classifying regulations and regulatory processes that accompany them is quite limited. The two stories of regulation are only meant to be markers, ways of sorting the regulations into two distinct but rough-cut groups. The next stages of the project will involve developing a more detailed regulatory typology.[42]

This project derives in part from the parallel Regulatory Explorer project, a nearly complete visual database of the 70 or more regulators who can exercise some claim over LANL, which details the complexity of the network of external regulators. Each of these regulators has the authority, even if it does not use it regularly, to affect the workings of the lab, and no one agency or department may claim greater authority than another.[43] The complexity of the Regulatory Explorer map is stunning with multiple cross-webs developing around particular regulations and regulatory areas. Agencies like the Department of Energy (DOE), the Department of Transportation (DOT) and the Environmental Protection Agency (EPA) and their many sub-branches (regional offices) may be responsible for interpreting and enforcing regulations. The number of potential enforcers creates an equal number of potential interpretations about which the implementers at the Lab must think. Each agency office may enforce its own interpretation of the regulation through its oversight power, while delegating enforcement to the regional office below it in the administrative hierarchy.

This project begins to create a "concordance" to the Regulatory Explorer that will allow distinguishing how the regulations are interpreted/enforced. We first wondered about the degree to which there

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safety observer for every potentially hazardous activity. These types of rules are possible to implement across the entire Lab network, but they are considered quite onerous by Lab workers.

[40] The goal of the Department of Defense, for example, is to receive a finished product, whereas the goal of Environmental Protection Agency is ensure that radioactive contaminants are not washed into the Rio Grande.

[41] Santa Fe, NM has no shortage of anti-nuclear and pro-environmental activists.

[42] See Appendix I, "Next Steps," below.

[43] The courts have traditionally held that national security "trumps" just about any other claim. In that sense, the DOD or even the DOE might be able to make a superior claim on the Lab were a conflict to arise.

would be agreement among the formal interpretations passed through the regulatory network in the form of written directives. Would the degree to which the Code of Federal Regulations contained ambiguous rules would make the implementers interpretations at the lab level more difficult? Would we find formal written changes in the regulation as it trickled down the levels? Would the language of the statutes change, i.e., was the DOE adding requirements not promulgated by the CFR? Given the dynamics suggested by Regulatory Explorer, we also wondered if we would find an array of regulatory agencies affecting and affected by each regulation.

## The Regulations Studied

The Lab does not have a location that houses all of the regulations, internal and external, nor a place where such information is readily accessible. In fact, though many employees know about the pieces of the regulatory environment that affect them, no one person knows or could know all of them. In a large organization, this is not surprising, however, it made it difficult to gather an estimate of the number of regulations in the Lab's environment.

With at least 70 regulators, the number of rules, interpretations, and agency orders as well as internal laboratory documents pertaining to implementation, is legion. Since the literature on regulation and organizations does not give a methodology for doing this type of research, we took an unrepresentative sample of three regulations: one that would require relatively homogeneous knowledge on the part of implementers (one that we thought might be seen as reasonably straight forward), and two that would require rather heterogeneous knowledge (perhaps more problematic in application.).[44]

The first regulation would form a basis for developing a typology of characteristics of regulations. The eventual goal was to create a regulatory schema that would parse out the characteristics of regulations that create higher risks of interpretive discrepancies. The first type of regulation would follow the Simon Says story of regulation, the one we took as the standard approach to regulation. We had to examine a surprisingly high number of regulations in order to find a statute with highly specific language and a homogenous knowledge requirement. One element of the developing typology suggests

[44] Documented below are the three regulations. The regulation that most closely parallels the Simon Says story of regulation is an OSHA Fire Protection Regulation 29 CFR 1910 Subpart Q (251-252) in which the regulation is quite specific in terms of what it requires. The two regulations that more closely resembled the Telephone Game story of regulation were the "As Low as Reasonably Achievable (ALARA)" Radiation Protection statute 10 CFR 835 and the Resource Conservation and Recovery Act "Satellite Accumulation Area (SAA)" statute 40 CFR 262.34. The latter two came as suggestoins from people who work in the Nuclear Materials and Technology (NMT) Division of the Lab. The first was much more difficult to come by, but was eventually suggested by a NMT consultant John LaPointe after a lengthy search.

that highly ambiguous rules prompt low-levels of agreement between regulators and implementers while high-levels of specificity create situations in which the rule-enforcers and rule-implementers have a high-level of agreement. Part of the essential task of this paper is to find out how to account for discrepancies between regulators' interpretations of the same statutory language.

This hypothesis suggests that in a regulation which follows the Simon Says story there would be a high-level of agreement between regulators at every interpretive level.[45] OSHA statute 29 CFR 1910.251-252 Fire Protection standards for "Welding, Cutting or Brazing" contains specific requirements in its wording such that the chance of interpretive discrepancies between regulatory interveners and rule-interpreters at the Lab is relatively low. It gives specific standards for fire protection facilities requirements and has also engendered a set of Lab-wide, internal procedures for producing sparks inside a building.[46]

We sought two other regulations to test our hypothesis regarding the dynamics of interpretation and implementation. These were chosen for the degree of heterogeneous knowledge required to implement them as a function of the degree of ambiguity they bear in their construction. Many Lab employees complained of the difficulty of interpreting regulations and pointed to the Telephone Game as the dominant regulatory story at LANL. A regulation had heterogeneous knowledge requirements for implementation and enforcement if it required knowledge of policy interpretation, organizational issues, technical details and economics, among others, to be complied with. Given this criterion, we asked people to suggest possibilities and chose to examine the "ALARA" radiation protection statute and the SAA environmental statute regulating the temporary storage of hazardous waste in Satellite Accumulation Areas.[47]

*Ambiguity* and *specificity* might be seen as two different ways of speaking of knowledge requirements. While ambiguity and specificity refer to the wording of the law itself, the terms *heterogeneous* and *homogeneous* refer to the quality of knowledge that must be present in those who read and implement the regulations. Heterogeneous knowledge requires not just knowledge of a wide-variety of factors that affect the implementation of a regulation (i.e. technical, policy, and environmental) but also, often,

[45] Furthermore, it would not be likely that there would be disagreement between Lab implementers and regulators. This disagreement could be at least partially measured by examining the number of violations for which the Lab is written up in a particular area.
[46] More on these internal compliance documents below.
[47] {These statutes were suggested by Bill Zwick of the Nuclear Materials and Technology Division and Denny Erickson of Environmental Safety and Health.}

requires communication between knowledge-holders who have a stake in the outcome. Homogeneous knowledge tends to be more straightforward, with knowledge requirements often limited to one type of field (i.e., technical, policy or environmental) and rarely requires communication between knowledge-holders beyond the regulation itself. Taking the ALARA and RCRA regulations as examples of heterogeneous knowledge requirements and the Fire Protection statute as an example of a homogeneous knowledge requirement allows us to begin to parse out what the differences between them might be.

Part of our goal was to develop a way of characterizing statutory language in such a way as to understand when Lab implementers and regulatory agents might be at risk of developing conflicting or difficult to implement rule interpretations. To do this requires the development of a typology that will aid in the classification of regulations and the risk of ambiguity that may develop from them.

The Regulations: OSHA Fire Protection, ALARA, and RCRA.

29 CFR 1910 Subpart Q (251-252) is a fire protection statute with two overall objectives: facility maintenance and life protection. This regulation carries in its wording something that made it attractive as a way of telling the Simon Says standard story of regulation for this project: specificity. Our hypothesis is that specificity makes a regulation intelligible to regulators and implementers alike and thus conforming to the Simon Says story of interpretive agreement. Recall that in this story the CFR would convey the exact meaning of the law to those who must implement it. The Telephone Game, by contrast, is a story of regulation that follows theories of interest-group politics that point out that regulations often have vague language that leaves room for a great deal of interpretation by regulators and implementers alike. The Telephone Game argues that the need to interpret such vague regulations at each regulatory level may create disagreement between regulators as to what compliance with the requirements entails.

Specificity in the regulation we expected to limit the likelihood that interpreters would be forced to give potentially disparate meanings to the law by introducing their interpretations of it. Fire protection codes in both the facilities and life safety areas are specific, with life safety is the most specific because building codes allow for variances depending on the more intrinsically ambiguous age and location of the building.[48] LANL buildings serve different purposes and in some instances the amount of cost outlay that would be required by facilities safety requirements would be so great that they have been

[48] {John LaPointe, 7/12/00}

effectively "grandfathered" into older fire protection statutes. Because of these potential causes for ambiguity of interpretation at the implementation stage, we focused on the OSHA statute.

ALARA is a statute that addresses the maximum levels of human exposure to radiation. It details the Lab's responsibility to mitigate the risk of exposure to workers and sets both a numerical baseline requirement (no more than 5 rems per year) and an adjustable standard that is meant to change with changing technology ("As Low as Reasonably Achievable"). "As Low As Reasonably Achievable" is a turn of phrase that is ambiguous enough to create the heterogeneous knowledge requirements that would produce disagreement between regulators' interpretations. Since Lab employees use radioactive materials on a daily basis, the Lab relies on well-defined exposure limits to be in compliance with regulations. As a radiation protection statute, the importance of its definition cannot be understated because it necessarily affects human life. Hence, we felt that the high level of ambiguity, the high degree of reliance and its overall importance for operations, made this a viable candidate for further study.

40 CFR 262.34[49] is a Resource Conservation Recovery Act (RCRA) statute governing Satellite Accumulation Areas (SAAs), areas where a limited volume of mixed hazardous and radioactive waste can be stored until it can be disposed. The regulation certifies facilities for temporary waste storage, up to 55 gallons of mixed hazardous or one quart of acutely hazardous waste, to be held before it is transported to either an approved holding facility or a 90 day temporary storage facility. The transportation of hazardous waste has become highly controversial and difficult due to state and federal transportation regulation. SAAs have become a necessity for the storage of waste, though the legislative history suggests that they were intended to be short-term holding facilities only.[50]

The location of SAAs, according to the regulation, shall be "at or near the point of generation," a turn of phrase that was, again, intrinsically ambiguous. Since the statute affects not only the immediate Lab environment and employee health, but also has the potential to affect the surrounding environment, it has the necessary importance to warrant further exploration.

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[49] (c)(1) "A generator may accumulate as much as 55 gallons of hazardous waste or one quart of acutely hazardous waste listed in Sec. 261.33(e) in containers at or near any point of generation where wastes initially accumulate, which is under the control of the operator of the process generating the waste…"

[50] Since the regulation makes no specific reference to the number of SAAs that may be in one location, the Lab has taken, in some instances, to putting two of them together in the same place. {Ellen Lauderbaugh, Chief RCRA lawyer as of 2000, 7/26/2000}

We began with the fire protection statute because it served as the control for the sample and was relatively "simple" to implement. We then examined the ALARA statute because its ambiguities seemed to be intended by its authors. It had been the subject of several lawsuits in several jurisdictions and would provide an interesting first cut at answering some of the questions we raised above. The SAA statute has not been so clearly litigated or well-defined. The ALARA statute has been the subject of numerous external challenges, while the SAA statute has largely been the subject of discussion between Lab implementers and state and federal regulators. In that sense, we chose to examine ALARA before the RCRA statute, in part, for its higher degree of "publicness," followed by the SAA statute.

### 1. *Fire Protection: The One That Works*

Fire protection surfaced as a candidate for further study after a prolonged search. We had begun the project by examining the two regulations that helped us develop the Telephone Game story of regulation. Low levels of agreement between regulators and implementers and heterogeneous knowledge requirements characterize those particular regulations. Since we initially expected to tell a story of regulation that involved high-levels of agreement between regulators and implementers, we sought a regulation that would have homogeneous knowledge requirements, to see if that could be "one that worked." We asked Lab employees if they could point us to a single regulation that is implemented with little interpretive struggle and yet is still "important" to Lab operations. Virtually all of the people we asked responded first with a derisive laugh and then commented that they could not think of even one that worked.[51] We had figured it would be easy to get several leads; we were wrong. After we had asked several people for suggestions and prompted their skepticism about after they had all scoffed at the possibility that there might be such a miracle regulation, we began to think that perhaps none of the regulations maintained high-levels of agreement between regulators and implementers. Again, we were wrong, but it took an offhanded remark by an NMT consultant to point us in the direction of the "life safety" section of the Fire Protection statue that governs the Lab.

What made 29 CFR1910.251-252 a statute that refers to "Cutting, Welding and Brazing," three activities that generate sparks and could cause combustible materials to ignite, attractive to us was the way the language in the congressional regulation only required homogenous knowledge for implementation. This OSHA statute refers more to the life protection issues than facilities. This was better from our perspective because facilities protection has the potential for reduced agreement levels.

[51] These comments were also often linked with winks and good luck wishes.

Much of the regulation of buildings is based on when they were originally built or modified. Thus, a building built before the regulation was passed would be grandfathered into older regulatory standards.[52]

29 CFR 1910.252 (a)(1)(i-iii) lists the general fire protection requirements with section (a)(2)(i-xv) containing special precautions that might be necessary when the activities fall within the scope of the general requirements. Section (a)(1)(i) states: "If the object to be welded or cut cannot be readily moved, all movable fire hazards in the vicinity shall be taken to a safe place." Section (a)(1)(ii): "If the object to be welded or cut cannot be moved and if all fire hazards cannot be removed, then guards shall be used to confine heat, sparks, and slag, and to protect immovable fire hazards." Section (a)(1)(iii): "If the requirements stated in paragraphs (a)(1)(i) and (a)(1)(ii) cannot be followed then welding and cutting shall not be performed." The rest of the statue defines the distance an object must be in order to be considered in a "safe place."

The statute requires a) that combustible material underneath the weld or cut or in cracks or holes in the walls be moved or that precautions shall be taken to ensure that no combustible material will be exposed to the spark;.[53] b) Fire extinguishing equipment "suitable" to the fire hazard shall be available for instant use;[54] c) Fire watchers are required whenever: 1) appreciable combustible material in the building or its contents is closer than 35 feet to the point of operation,[55] 2) appreciable combustible materials are more than 35 feet away but are easily ignited by sparks,[56] 3) wall or floor openings within a 35 foot radius expose combustible material in adjacent areas including concealed spaces in walls or floors[57] and 4) combustible materials are adjacent to the opposite side of metal partitions, walls, ceilings, or roofs and are likely to be ignited by conduction or radiation.[58] Fire watches, further, "shall be maintained for at least a half hour after completion of welding or cutting…."[59] Floors with combustible materials such as paper clippings, wood shavings or textile fibers on them shall be swept clean for a radius of 35 feet.[60]

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[52] A good example of this is a requirement that sprinklers be earthquake tolerant; in buildings where the walls themselves would not withstand an earthquake, there seems to be little reason to require fasteners that can withstand a major earthquake (they would be fastened to walls that would crumble).
{David Odland, NMT Consultant, 6/21/00}
[53]29 CFR 1910.252 (a)(2)(i)
[54] 29 CFR 1910.252 (a)(2)(ii)
[55] 29 CFR 1910.252 (a)(2)(iii)(A)(*1*)
[56] 29 CFR 1910.252 (a)(2)(iii)(A)(*2*)
[57] 29 CFR 1910.252 (a)(2)(iii)(A)(*3*)
[58]29 CFR 1910.252 (a)(2)(iii)(A)(*4*)
[59] 29 CFR 1910.252 (a)(2)(iii)(B)
[60] 29 CFR 1910.252 (a)(2)(v)

The portion of the statute on which we focus here is (a)(2)(vii) *relocation of combustibles*. "Where practicable, all combustibles shall be relocated at least 35 feet from the work site. Where relocation is impracticable, combustibles shall be protected with flameproofed covers or otherwise shielded with metal or asbestos guards or curtains." This kind of specificity is exhibited throughout the relevant portions of the statute cited here. The Simon Says story assumes that this should make the levels of agreement among implementers quite high.

The following steps describe how the Lab comes into compliance with the Fire Protection statute. First, interested parties lobby Congress for the standards they prefer and the language of the regulation is drafted and passed. The regulation is codified by Congress into the Code of Federal Regulations, which gives OSHA primary jurisdiction to oversee compliance. In this case, OSHA does not administer it directly but, rather, the DOE has said that it will uphold OSHA regulatory standards at the Lab, though it will be responsible for monitoring them itself.[61] Here, one of the key problems seen in the Telephone Game regulations, the problem of multiple and horizontal authorities, has been mitigated by dropping some of the regulators who might have had a claim the Lab would have been required to satisfy.

The DOE has appointed the LANL Fire Marshal as the "Authority Having Jurisdiction" (AHJ), meaning that in cases where there are discrepancies, or in which the rules are general, the Fire Marshal will have the ability to determine the meaning of the rule and how it will be implemented. The appointment of Jim Gordeaux as AHJ marks the first time in 50 years that the AHJ has been located on-site. The DOE can, at any time, challenge the AHJ's ruling through its chain of command[62] though it has never done so.

The Lab has also adopted 29 CFR 1910.251-2 in its Contract with the University of California, which means that the UC acts as a regulator in this instance. The Lab, thus, agrees to implement the fire safety precautionary measures both per federal law and per the agreement it has with its governing body. Part of the implementation program for UC Work Smart standards is the set of Lab Implementation Requirements (LIR). In this case, LIR 402-910-01.2 revised on April 21,1999 refers

[61] In general the Lab is not legally required to meet OSHA standards at all, but it has agreed to bind itself to them in both its contract with the University of California and in its own internal documents. {Jim Gordeaux, LANL Fire Marshall, 7/25/00}

[62] The fire protection organizations within DOE-LAAO, DOE-ALOO, DOE-HQ and, if necessary, the Secretary of Energy.

to fire protection explicitly. It is not, however, a document that leads to direct knowledge of applicable statutes. The LIR refers to National Fire Protection Association (NFPA) codes and says: "The fire protection program at LANL shall meet or exceed the codes and standards established by the NFPA and other referenced fire safety criteria [presumably 29 CFR 1910.251-2] as defined in the DOE/UC contract (described as Work Smart Standards), unless an explicit variance or exemption has been approved by the Fire Marshall." This LIR does little to clarify how the regulations are to be followed, though it describes the NFPA standards as trumps, meaning it will understand that, if the Lab meets NFPA standards, it will be in compliance with federal and local law.

"Buildings and structures designed and constructed to fully meet the requirements of NFPA – 101 The Life Safety Code shall be considered to have met the 'life safety' requirements of OSHA, 29 CFR 1910, and all other codes."[63] 29 CFR 1910 adopted the NFPA fire protection standards contained in "NFPA 101 – Life Safety" of 1972; since then there have been no additions to the OSHA requirements. The Lab, though it has bound itself to OSHA standards, continues to consider NFPA, in its most recently updated form,[64] the standard by which the Lab will be considered "in compliance" with its obligations to federal law.

In most cases, the NFPA standards have gotten more stringent over time. However, in a recent instance, the NFPA standards for fire alarms per capita were relaxed from one fire alarm for every ten people to one fire alarm for every fifty people. The AHJ has had to make a determination on whether to be in compliance with federal law or the NFPA standards.[65] The AHJ made a determination that the Lab would continue to abide by NFPA standards, even though they are less stringent than those required by the guiding OSHA statute. He could be overruled by any of the DOE branches that regulate fire protection at the Lab, though, in all likelihood, the fire protection engineers at the DOE would agree that NFPA 101 remains the standard by which the Lab is to be guided.[66] This marks one of the few instances where federal law has come into conflict with the NFPA document and remains and unresolved issue.

A document previous to LIR 402-910, Administrative Requirement (AR) 8-4 "Welding, Cutting and Other Spark-/Flame-producing Operations" is the controlling document for operations inside the lab. This document refers specifically to NFPA 51B and the OSHA 29 CFR 1910 Subpart Q document.

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[63] LIR 402-910-01.2
[64] The most recent update was in 1999
[65] This case is unresolved as of July 25, 2000 {Jim Gordeaux, 7/25/00}

While the LIR purports to be an implementation document, and a much more recent one than AR 8-4, it only advises in a general manner that the Lab is to incorporate the NFPA documents and 29 CFR 1910. The document spells out how a work crew can get a permit to practice a spark producing procedure.

In descriptive terms, the regulation carries the requirement that combustible materials be more than 35 feet away from the point of operation, or have a guard shielding them from sparks and that a firewatcher be present for thirty minutes after the activity has ceased. This regulation is then incorporated into AR 8-4, which requires that Form 1563 (ESH form 8-4A) Special Work Permit for Spark-/Flame-Producing Operations be filled out, unless the activities are covered by Standard Operating Procedures (SOPs) or are conducting in areas designed for such purposes. This might be described then, in a decision tree, as the regulation being covered by AR 8-4 and then sent to the technical workers. They are asked to make a decision: "are we welding, cutting, brazing or producing sparks in some way?" If yes, then they are to fill out Form 1563 which requires signatures from the: firewatcher, operator, operator's supervisor, facility manager, and the building manager. The activity may also require signatures from Health Physics Operations group (ESH-1), Industrial Hygiene and Safety Group (ESH-5), and the Emergency Management and Response/Fire Protection group (FSS-21), depending on special risks posed by the activity. For each there is a specific task assigned by AR 8-4. Variances may also be requested by submitting a variance request Form 1661 (LIR 301-00-02) to the Fire Marshall for approval. Once these forms are signed, operations may begin.

AR 8-4 specifies, in detail, the tasks of the operator's supervisor, the operator, the firewatcher, the area coordinator and the construction inspector for each instance. Incorporated are the 35 foot radius requirements for combustible materials and/or the need for fire guards to shield combustible materials from sparks. The firewatcher is to ensure that proper fire extinguishing equipment is available and at hand for use.

The relative homogeneity of knowledge required to implement this regulation began at its conception in the OSHA statute. Many of the requirements detailed by AR 8-4 are simply reiterations of 29 CFR 1910.251-2 and NFPA 51B, but they require less policy knowledge, or commitment to getting it than does the LIR that simply refers to 29 CFR 1910 and NFPA 51B without giving the specific information. Once the Special Work Permit (SWP) form is filled out with the appropriate signatures, the operator is

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[66] {Jim Gordeaux, 7/25/00}

given permission to proceed. There is no leeway when it comes to the operators' decision to seek out an SWP; if they are cutting, welding or brazing or otherwise producing sparks, they are required to get permission.[67]

Building managers are generally responsible for making decisions about spark-producing operations. The Fire Marshal only gets involved in decision-making when variances or SWPs are requested by the parties involved, or when the Lab is experiencing "extreme fire danger" conditions as occurred on May 5th, 2000 just before a wildfire swept through the Lab and the Los Alamos townsite. Under those conditions, all spark-producing operations require the Fire Marshal's signature. The "extreme fire danger" conditions mean that between 15-20 requests to engage in spark-producing activities cross the Fire marshal's desk each day. So long as the signatures from the building manager, the firewatcher and the operator are there, the document is usually signed off administratively, Under unusual circumstances, the Fire Marshal may investigate further but, in general, aside from annual, biannual or tri-annual inspections, the Fire Marshal's office leaves implementation to the building managers.[68]

*2. ALARA*

10 CFR 835[69] is a Radiation Protection statute that has a two-pronged limitation for human exposure to radiation, a formal numerical standard and the more ambiguous language of "As Low As Reasonably Achievable." On one hand, the No-Dose Threshold Limit requires that workers not be exposed to more than a total effective dose of 5 rems of radioactivity per year, a standard that is relatively easy for the Lab to meet. [70]

On its face, the 5 Rems requirement in 10 CFR 835 is a clear standard for the Lab to meet, though this level of dosage is higher than the expert bodies would prefer.[71] Most people with whom we spoke agreed that 5 rems of exposure standard is not much of a standard, since it is easily attainable. Most organizations would meet it regardless of the law.[72] Another, more ambiguous and possibly more

[67] {David Odland, 6/21/00}
[68] {Jim Gordeaux, 7/25/00}
[69] "Radiological work shall be conducted so that doses resulting from the work are as low as reasonably achievable (ALARA)." 10 CFR 835 101(c)
[70] Eisele and Wishau, Environmental Safety and Health - Radiation Protection Program Directors
[71] International Commission on Radiation Protection (ICRP) and the National Commission on Radiation Protection (NCRP), formal expert bodies that advise on national and international Radiation Protection standards. NCRP and ICRP documents.
[72] Though 5 rems per year is a clear standard, this doesn't avoid interpretive traps. Eisele pointed out this doesn't give any indication of how exposure is to be measured - 5 rems in gaseous form spread throughout a large room is quite different from 5 rems taken into the body in a liquid.

stringent standard was created alongside the 5 rem dosage limit. It acts in such a way as to apply a pressure on organizations to continuously reduce dosage risks to employees.

The second prong of 10 CFR 835's two-pronged approach to regulating dosage risk is called the As Low As Reasonably Achievable (ALARA) standard. Legislators anticipated that better technology would reduce the costs of mitigating risk while improving the benefits from such protection. The ALARA standard, as applied along with the No Dose Threshold Standard, implies that the Lab, and entities like it, should be getting better at protecting employees from exposure risks over time. The standard is, thus, *increased* to "reasonability"[73] in the second prong.

10 CFR 835's two prongs mean that, officially, the standard is: 5 rems per year *or* As Low As Reasonably Achievable, but there is no mention of which one takes primacy. In fact, it is not clear whether 5 rems per year on its own satisfies the "reasonability" standard without regard to context, even if a higher protective standard could be put in place at a somewhat greater cost to the organization, or whether ALARA requires that the "reasonability" goes beyond a simple application of the No-Dose Threshold Limit and looks to context for guidance.[74] Though the courts use context-based standards of reasonability in other circumstances such as tort liability and contract negotiation**,** courts are split on the interpretation of 10 CFR 835. Most have indicated that 5 rems alone is enough to satisfy requirements for radiation protection. The reasoning behind this in at least one court is that they do not want juries, made up of people without technical expertise in the field, to make decisions

[73] "Reasonability," for its part, is a legal fiction. It is the idea that there is a certain standard to which all people or organizations should be held accountable. It is the minimum duty of care one has to another and acts as a threshold which, if met, removes the party from being held liable for another's injury. However, the exact definition of it changes with regard to the particular actor and the particular context in which the actor is participating. Reasonability standards for corporations selling a good or service may be higher than those for individuals, simply because the organization has greater resources to devote to warranty protection than does the individual. Courts are often required to discover whether the reasonability standard has been met in private, tort actions to decide when a defendant has met his obligation to protect others from harm.

Courts employ a method of discovering the meaning of reasonability in a given situation in a way similar to the ideal regulatory point mentioned above, that is, they attempt to match available knowledge and information with possible actions. Read in this way, ALARA includes in 10 CFR 835 the understanding that, with the continual advances in protection technology and their reduction in cost over time, 5 rems will become a standard that allows the entity to supply *less* protection than the ideal regulatory level would require. That is, the marginal cost of providing another unit of safety at the 5 rems level (moving to, say 4.9 rems of dosage risk) will be much less than the benefit another unit of safety would provide.

It is possible to envision ALARA counteracting this problem by imagining a large weight pressing downward continuously, applying force on the reasonability standard. As technology makes dosage protection more cost-efficient, ALARA reduces the reasonability standard the organization must meet to not be held liable for harm resulting from dosage levels.

[74] "The ALARA principle is not a dose limit but an optimization process. Its objective is to maintain doses as far below the applicable requirements as is reasonably achievable, taking into account social, technical, economic, practical and public policy considerations." From LPR - 402-702.0

regarding technical reasonability.[75] In so doing, the courts have thus interpreted 10 CFR 835 to mean that the 5 rem No-Dose Threshold Limit satisfies standards for reasonability without the regard to context the "As Low as Reasonably Achievable" standard seems to require. This is a lower standard than would have been required of most organizations if the standard was a more ambiguous and context-based standard of reasonability.

*3. RCRA – the Satellite Accumulation Area Statute*

The New Mexico Environment Department (NMED), a state agency with a limited budget, administers the federal Resource Conservation and Recovery Act (RCRA). The State of New Mexico has adopted RCRA, the federal statute, by reference and, through the New Mexico Hazardous Waste Act and New Mexico Hazardous Waste Management Regulations, vests the sole power of enforcement in NMED. Between 1995 and 2000, the New Mexico State Legislature did not update its adoption of RCRA and continued to enforce the 1995 regulations, though the federal standards had changed in each of the intervening years. NMED regulators, however, did not know this and, in several instances, showed up at the Lab for inspections with rule books from the wrong year.[76] The agency is perennially underfunded and faces high employee turnover rates, which allows only for sort term institutional memory.

The Satellite Accumulation Area (SAA) portion of RCRA regulates temporary waste storage areas within the Lab. To be in compliance with the regulation, SAAs must be "at or near the point of generation [of the waste]" and "under the control of the operator of the process generating the waste." NMED regulators conduct yearly wall-to-wall inspections to monitor Lab performance with regard to the entire statute.[77]

This part of the Act that refers to SAAs was designed to allow for the on-site collection and storage of 55 gallons of mixed hazardous or one quart of acutely hazardous waste until volume limits have been

[75] CORCORAN V. NEW YORK POWER AUTHORITY 935 F.Supp. 376, *386 "…Adopting ALARA as part of the standard of care would put juries in charge of deciding the permissible levels of radiation exposure and, more generally, the adequacy of safety procedures at nuclear plants--issues that have explicitly been reserved to the federal government in general and the [Nuclear Regulatory Commission] specifically. "Adoption of a standard as vague as ALARA would give no real guidance to operators and would allow juries to fix the standard case by case and plant by plant.... Our holding protects the public and provides owners and operators of nuclear power plants with a definitive standard."

[76] {Lauderbaugh, 7/00}

[77] The statute is large and takes an entire state agency to enforce. The SAA portion of it is just one small section.

met. SAAs may be permanent, so long as the waste within them does not exceed volume limits.[78] If waste volume limits are exceeded, "the SAA operator has three calendar days to transfer the waste to a <90 day storage area or a treatment, storage, or disposal (TSD) facility (for example TA-54)."[79]

Though many types of waste are transported off-site, some, including nuclear waste, must be stored at Technical Area-54, the Lab's waste storage facility, because they are difficult to transport. The Lab transports the types of waste that are allowed by New Mexico state regulations, and Environmental Protection Agency and Department of Transportation policies,[80] though it has had serious difficulties in obtaining the authority to transport hazardous waste off-site. Moving waste off the generation site (even within the Lab itself) requires scheduling and road closures if the waste is acutely hazardous.[81]

SAAs were originally meant to be a temporary stopgap measure to alleviate waste transportation problems. They have become a sufficiently permanent solution that employees argue that the distance considered "at or near the point of generation" should be increased so usage can also be increased. The Lab cannot stop producing waste, and once it is produced, transportation problems limit disposal options, so SAAs have become not only permanent fixtures, but are growing in number as well.

The ambiguity of the language "…at or near the point of generation…" becomes important when seen in light of the increasing reliance on SAAs. LIR 404-00-03.0 provides the LANL guideline for SAA use,[82] but doesn't give very detailed information about the Lab's internal requirements.

LANL legal counsel argues that the New Mexico Environment Department's (NMED) interpretations of RCRA are subject to changes that seem to be evidenced merely on the basis of changing regulatory personnel. The lack of institutional memory resulting from personnel turnover means that what passed regulatory audit one year with one particular regulator may not pass the next. This sort of interpretive instability makes it difficult to know how to comply from one year to the next.

For example, In December 1999 the Lab received two SAA compliance orders from NMED. Though one stemmed from a 1997 audit and the other from a 1998 audit they varied on their interpretations of the language in the regulation. The compliance orders resulted from a conflict between National Fire

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[78] {Lauderbaugh, 7/26/00}
[79] LIR 404-00-03.0, effective date 12/16/96
[80] {Lauderbaugh, 7/26/00}
[81] {Lauderbaugh, 7/26/00}
[82] Environmental Safety and Health Division (ESH) Groups 13 and 19

Protection Association regulations as incorporated by OSHA and RCRA standards with regard to fire extinguisher location in an SAA. RCRA requires that fire extinguishers be "reasonably close" to waste storage facilities, while OSHA requires them to be >75 feet. The fire extinguisher at issue was not visible from the storage location, but it was in compliance with OSHA regulations and next to the door. NMED issued a compliance order to the Lab, which is repeat offender and therefore subject to large fines for such violations, for not having the extinguisher "reasonably close" to the waste. In 1997, the regulators found the fire extinguishers to be "reasonably close." In 1998, they did not. NMED alleged 30 violations carrying a fine of $845,990.[83]

Since LANL engineers and scientists cannot be sure how regulators will interpret the SAA regulations when they come to inspect the facility, and since LIR 404-00-03.0 is vague, Lab workers must either rely on their own interpretations of it or the ones LANL legal department suggests.[84] Interpreting an ambiguous legal phrase is resource-intensive, especially for scientists, but misinterpreting the regulation, and being found in violation, is also costly.[85] This creates a situation in which scientific resources must be committed to resolving legal questions. In addition, while the Legal and Environmental Safety and Health divisions attempt to clarify how particular SAAs may be used, Lab workers continue to store waste in them. In the face of ambiguity, one tactic may be for lawyers to advise a conservative interpretation of the statute and then try to argue for a more liberal one in court or before the regulatory agency.[86]

LANL Division and Group leaders who work with regulators perceive that the level of technical knowledge varies greatly from one NMED staff member to the next, reducing agreement between regulators.[87] Since there are so many possible violations and technical operations, NMED often uses the Lab as a training site for its junior regulators. Regulators are reluctant to commit to a written interpretive standard because doing so reduces their discretion. Not having a standard interpretation in writing may be a common practice among regulators, but when turnover is high, as at NMED, the lack of such interpretations in writing lead to the probability that they will change from year to year as newcomers take up the task.[88]

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[83] {Lauderbaugh, 7/26/00}
[84] {Rochelle, 7/10/99}
[85] See note 88 below.
[86] This is a somewhat traditional and pessimistic view of what lawyers do. {Rochelle, 7/99}
[87] {Pratt, 7/00}
[88] {Lauderbaugh, 7/26/00}

An underfunded NMED causes problems for the Lab because often the regulators arrive without adequate training or even adequate knowledge of the laws they are to enforce. Several times, NMED regulators arrived onsite for audits with a book of regulations to enforce from the wrong year. This leads to a reduced confidence in regulators' ability to enforce regulations with a high-degree of competence.

In 1999-2000, the Lab faced a challenge with regard to the renewal of the Lab's ten year RCRA permit. The permit was set to expire on November 8, 2000; the RCRA requirements that the regulated entity must reapply for a permit at least six months before the expiration date. The Lab applied for a new permit in January 1999, ten months before the permit was set to expire. The Lab had heard nothing from NMED by the expiration date. If the entity's application is complete and a new permit has not yet been issued, according to DOE, the permit is extended while awaiting approval. By July 26th, 2000, the Lab had still, not heard whether or not NMED had ruled on its RCRA permit. But something like a "catch-22" began to emerge. It was appraised that perhaps there was a question as to whether the application was "administratively incomplete." In discussion with NMED officials during Spring, 2000, the Lab was told that no permit could be issued because NMED did not have the personnel to write one. NMED petitioned the Lab to write its own permit, a state of affairs that brings to mind the potential for accusations of regulatory capture. The Legal Division was set to meet with NMED officials to decide if the Lab had a working RCRA permit at all, extended or not, during the first week of August 2000. Part of what was at issue here was the question as to whether or not the Lab could modify its pre-existing permit when it was extended, or "virtual," mode. There is neither case law nor statutory guidance on this question.[89]

The language referring to Satellite Accumulation Areas in the RCRA statute has several layers of ambiguity built into it. First, the language itself, on its face, carries two interpretive questions: "what is 'at or near the point of generation' and what is 'under the control of the operator of the process generating the waste?' However, the organization of the regulatory agency responsible for enforcing the regulation contributes to such ambiguity by having problems of its own: the process by which the state legislature adopts the federal statute and passes this information to its enforcers makes it difficult for them to know what the current rules are at any time. Lack of training and institutional memory within the agency further reduce the potential for interpretive standards the Lab and regulators may

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[89] {Lauderbaugh and Thayer, 7/26/00}

follow from year to year. These problems carry over into the existence of the permit itself, an issue that, eight months after it was set to expire, still had not been resolved.

The Telephone Game: ALARA and RCRA

In our initial foray we expected to find, in accordance with the Simon Says story, that regulations would be interpreted with considerable clarity and specificity by the time the Lab confronted it. Recall that the Simon Says story holds that regulations are general at the top of the administrative hierarchy and then interpreted with more specificity by the sub-agency regulators as the rules move from the top of the administrative hierarchy to the work floor.

The Simon Says story predicts that the regulation would follow a neat line through the regulatory agency's sub-divisions, each step growing clearer. Each sub-division is responsible for a more specific level of focus than the level above it. This responsibility is, in the case of the DOE, based on geographic area. The branch offices of the DOE are responsible for all the DOE regulated activities in their respective geographic areas. The Simon Says story notes that regulation becomes more concise and less ambiguous as it gets closer to implementation. It also holds that either, one regulatory agency can be responsible for the task of making the regulations intelligible for all the potentially regulated entities in its geographic area, or that multiple agencies would check one another through oversight, in order to keep potential mistakes to a minimum.

The Simon Says story of regulation takes the view that technical experts are benign, expecting them to implement policy without engaging in opportunistic behavior. The regulatory enforcers and the implementers at the regulated entity would be working on the same side, with the goal of achieving democratic stewardship of the nuclear stockpile. The ideal situation for regulatory implementation, according to the Simon Says story is that technical ambiguity is best left to be resolved by technical experts with knowledge of how to apply regulation specifically. Bardach and Kagan[90] and others argue that ambiguity in regulatory interpretations allows both regulators and implementers to govern such hazardous activity by consensus, reaching mutually agreeable implementation policies that create the safest possible environments.

We were surprised to find that regulation seemed rarely to followed the Simon Says story. In fact, as we interviewed people, it became clear from their reactions to our questions about the Simon Says story, that it was not their particular story. They reacted vigorously to the idea that regulation could be well defined and implemented in a strong hierarchical fashion. If anything, they claimed, regulation is implemented in a haphazard and ill-defined way that leaves lab workers without real guidance for compliance. As we continued to probe, they repeatedly told the Telephone Game story of regulation.

Recall that the Telephone Game story also envisions multiple agencies overseeing implementation, not to ensure that there are no mistakes, but as a way of solving the "capture"[91] problem.[92] If only one agency is responsible for the regulation in one specific industry the Telephone Game story predicts that the agency will tend to be captured by those it is regulating. Multiple agency oversight solves the regulatory capture problem and thus allows for greater regulation of the substances, practices or procedures that are dangerous, both to human life and to national security.

The Telephone Game story, unlike Simon Says, takes into account the possibility of opportunism by experts: by giving too much discretion to technical experts at the Lab, regulatory standards might be lost to opportunistic behavior. This would run the risk of allowing practices that are counter to the public interest. The same could be said of regulators, who by having too much discretion in rule interpretation and, especially in rule-enforcement, without adequately communicating their understandings of them, might lead to arbitrary enforcement procedures.[93]

Though the DOE is the sole federal regulator with regard to ALARA implementation through its Albequerque Operations Office (DOE-AL) and the Los Alamos Area Office (DOE-LAAO), NM state regulators also oversee enforcement on a state level. The University of California, through the Work Smart Standards (Appendix F) in the Lab's contract with it, provides yet another level of oversight. ALARA regulation seems to fall into the Telephone Game category because of the different offices that oversee it.

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[90] Bardach, Eugene, and Robert Kagan. *Going By The Book: the Poblem of Regulatory Unreasonableness*. Temple University Press, 1982. 44-45.

[91] A captured regulator is one who identifies strongly enough with the organization for which he is responsible that he often sides with it, rather than against it, when there is a conflict of interpretation.

[92] Bardach, Eugene, and Robert Kagan, op. cit.. See also, Shapiro, Martin. op. cit. ch. 1. This type of redundant oversight sacrifices overall regulatory efficiency. It may be more efficient for one agency to have expertise with regard to a regulation, however, the capture problem may pose a significant enough risk that overlapping departments would provide better safety coverage. By allowing overlapping authority, the capture problem is solved, but there may be other issues that arise, i.e. multiple interpretations and accountability, as well as, lack of a clear authority. This last point is a portion of what we are showing in this paper.

[93] Whether it is actually true that there is opportunism amongst regulators and Lab implementers, it certainly seems to be the case that both sides *think* the other side is being opportunistic. {Pratt, 7/00}

Further, contrary to the Simon Says expectation that the regulation would become more clear through time, implementation ALARA and the RCRA provision was confounded by the fact that the wording in the regulation did not change from the Code of Federal Regulations through the agency sub-divisions. By the time these rules arrive at the Lab level for implementation, they still carry within them the same ambiguity as when they were originally written. A possible explanation for this is the intention of their authors to impose on the Lab, and organizations like it, a constant pressure to improve the precautionary measures taken.

The Department of Energy is divided into a hierarchical structure with DOE-Headquarters (DOE-HQ) as the highest level. DOE Secretary Bill Richardson is responsible to the President in guiding Energy policy implementation and enforcement. DOE-HQ has more than 30 program offices that oversee different regulatory areas.[94] Not all of these program offices are responsible for Lab activity oversight, but such offices as the Office of Defense Programs (DP), Office of Environment, Safety, and Health (EH), Office of Management and Administration (MA), and Office of Nuclear Energy, Science, and Technology (NE) may make claims on the Lab. The DOE is then broken into operations offices that are closer to the sites it oversees. In the case of LANL and Sandia National Lab, DOE-Albuquerque Operations Office (DOE-ALOO) serves as the field organization with its primary mission being "stewardship and maintenance of the nation's nuclear weapons stockpile."[95] The Los Alamos Area Office of the DOE (DOE-LAAO) specializes in LANL oversight and carries out the mission of DOE-ALOO. There are also onsite regulators from DOE-LAAOO: LAAMFO, LAAMED, LAAC, and LAAMBOS.[96] Each of these branches of the DOE has specific oversight responsibilities for LANL.

Each office, formally, oversees each subordinate office that supports it in the field and the regulated entity itself. The result is that each office may make an enforcement claim on the Lab based on its own interpretation of the regulation. Ideally, if Simon Says were the guiding story, each organizational level would provide greater regulatory specificity to the organization that supports it. The documents would be in writing and would provide a "paper trail" for implementers at the Lab to use as guides for their projects.

We found, however, that instead of multiple regulators give multiple wordings of the regulations, each with greater specificity, we found that in cases like ALARA, the phrase "As low as reasonably

[94] http://www.doe.gov/people/peoppo.htm
[95] http://www.doeal.gov/Main/welcome.htm
[96] For a visual display of the DOE (and others) regulatory hierarchy see the Regulatory Explorer project.

achievable" 10 CFR 835 is not clarified by the Albuquerque Operations Office, Los Alamos Area Office or the onsite regulators. When it gets to the Lab's internal regulators at the Environmental Safety and Health division (ESH), it is interpreted in Lab Procedural Requirements (LPRs)[97], Lab Implementation Regulations (LIRs)[98] and Lab Implementation Guidelines (LIGs)[99], all formal internal regulations. These documents are an attempt by the Lab to guide scientists and engineers as well as Lab technical workers in how to implement safe working conditions. Since the Lab itself is divided into many Technical Divisions, each of these documents, which apply to the Lab in its entirety, must be general in focus. The workers at the Division (and their operating Group) levels then develop safe work practices and procedures specific to their sites.

The Telephone Game obscures regulatory meanings. This, in turn, creates uncertainty among implementers at LANL. How to interpret ambiguous turns of phrase is a cause of consternation for senior managers and technical staffers. They are forced to devote resources to making decisions about interpretations in the same ways as each of the external regulators has done, without knowing how each of the regulators above them have interpreted the law, and without adequate legal training to do so. While they may have learned how some of the regulators interpret the law, either through repeated contact or other informal conversations, there is no guarantee that interpretations will remain consistent between regulators and regulatory offices.

In interviews with those who confront the regulatory environment, we were told that they generally do not have much more to go on than the regulation from DOE-HQ and a history of oversight developed over time with specific regulators. This type of personality-driven regulation is a cause of increased uncertainty when the regulators with whom relationships have been developed leave the agency or start work in other departments. This leads to a strong case for the Telephone Game story of regulation where regulatory meanings are not communicated effectively enough to be complied with by those who work on the lab floor.

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[97] LPR 402-702.0 March 1998. [SAA – LPR 404-00-00.0]

[98] LIR 402-02-01.1 May 1998. This document is a little more specific about the way the Lab will handle ALARA issues. It outlines a graded approach to exposure risk with 5 person rems at the highest level and those who are at risk to receive less than 1 person rem at the lowest. It also gives a cost per rem scale with a recommendation of $2,000 per rem. [SAA-LIR 404-00-02.2 Appendix D – "At or near the point of generation"; LIR 404-00-05.1]

[99] LIG 300-00-01.0 September 24, 1999. This document refers to more general safe work practices than ALARA alone.

The Lab's contract overseer, the University of California Office of the President (UCOP), expects the Lab to check its interpretation with the DOE to ensure that LANL has a cohesive picture of the way in which the regulation will be interpreted or, if incoherence is discovered, that LANL could meet with regulators to work this out.[100] However, Lab staffers seem to do this only on rare occasions. One possible explanation is that Lab officials believe that this process does not create clarity and that LANL employees' efforts are not well-received by the UCOP because of the resources they must expend to try to negotiate it.[101]

Another possibility is that the legal department prefers ambiguity to specific standards because, while this may be difficult for engineers and scientists to attempt to implement, it provides them with some leeway in interpreting the regulation.[102] The way lawyers and technical staff conceive of rules suggests a fundamental difference between them. For a lawyer, a rule may be considered mutable from the moment it is drafted; every rule may be seen as an argument about what the rule might be. Settling on a specific interpretation of a rule, with complete agreement on both sides, binds lawyers from making further arguments on behalf of their client if the need should arise. By contrast, for a technical staff member, rules are guidelines or limits on the way in which something must be done. Agreement on meanings allows them to go about the business of implementing within an established framework that will not change in the future (and therefore, change the experiments they may run).

The challenge: implementers at the Lab interpret ambiguities in the law without guidance from the interpreters who have the responsibility to enforce the regulations. When the Lab staff attempts to comply with the regulatory standards, as they believe (or hope) the regulators understand them, both the Lab implementers and agency enforcers may hold different views of what compliance means. The Lab may be sending mixed signals to regulators with regard to what levels of interpretive congruency it wants. Lawyers may prefer ambiguity and technical staff may prefer specificity.

## Different Incentives for Technical Experts and Lawyers/Regulators Within

### LANL: A Look at the Two Stories of Interpretation

The presence of the Simon Says and Telephone Game stories and experience suggests that technical experts and lawyers may have quite different incentive structures based in the communities they

[100] {Howard Hatayama and Ken Groves, 12/7/99 at UCOP-Oakland}.
[101] Ibid.

inhabit. Whereas technical positions require precision and numerical standards, lawyers are encouraged to think in terms of the best argument and potential ambiguity.

For a technical expert, the Simon Says story of regulation is the preferred state of affairs because, not only are the rules clear and well-defined, but they are also consistently applied. This allows them both to tailor programs they are developing to be in compliance with regulatory standards and to plan for the way regulators will understand them in the future. A technical expert may view the world from the perspective of "engineering barriers," controls on what they do are limited by what is technically feasible. "Administrative barriers" are external controls that tell them how they may go about solving technical problems. If these two types of barriers are consistent over time, technical experts can devote resources to overcoming them. When the rules are inconsistently interpreted or are subject to change, devoting resources to a project that hinges on the interpretation of an ambiguous rule may end up being costly.

Lawyers are encouraged to argue shades of gray in the rules they are to interpret. A main function of the law school education is to teach that understandings of rules may vary over time and between specific situations, essentially linking lawyers to the Telephone Game story of regulation. Lawyers, as part of the oath they uphold, are to work on behalf of their clients to the best degree that they possibly can. Specificity in regulatory requirements can be seen as creating a "box" with defined parameters, within which they cannot make forceful legal arguments. In some instances, a lawyer may prefer ambiguity so that she can encourage her client to interpret rules conservatively, but still be able to make a strong argument for a more liberal reading.[103] Not doing this could lead to a claim of malpractice.

Law is, by nature, an adversarial discipline.[104] This adversarialness is the bedrock of making legal arguments on behalf of one's client. There are growing parts of the profession that revolve around mediation and dispute resolution, but for the most part, lawyers are the ones who argue the details of interpretation of the rules. These detailed arguments over linguistic rule-interpretations may lead to Telephone Game type situations.

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[102] {Joe Rochelle, 7/99}.
[103] {Joe Rochelle, 7/99}
[104] Kagan, Robert, "Adversarial Legalism and American Governance" from *The New Politics of Public Policy*, Lander and Levins (eds) Johns Hopkins University Press 1995. Malcolm Feeley, "The Adversary System."

This built-in adversarialness runs exactly counter to the needs and dictates of technical professions implementation. An engineer is a problem solver who often prefers to have been given a set of parameters within which to work. Whereas a lawyer prefers room within which to create space for argument, engineers and other technical workers prefer to know specifically what problems they are to solve. For an engineer, attempting to abide by a regulation in the face of ambiguity of interpretation created by the Telephone Game, essentially requires him or her to create a solution to an undefined problem. The benign view of technical implementers is that they are concerned with materials and processes rather than political bargains and thus prefer to know exactly what rules they are to follow when going about making decisions. For that reason, there is a strong tendency in technical experts to prefer the specific rules created by the strong regulatory hierarchies and consistent rule-interpretations that are formed by the Simon Says story.

A technical barrier is a specific scientific requirement that an engineer or other technical worker must overcome in order to solve a problem. Engineers at the Lab[105] prefer specificity in regulations because it allows them to know that the work they are doing conforms to the standards set for them to do it.[106]

This discussion of the needs of the different communities to which technical experts and lawyers/regulators belong is in a nascent stage, a first cut at understanding the different incentives for both groups and how those incentives might lead to implementation problems. Regulators are often technical experts who confront regulations through a legal lens. They are in the position of understanding that technical experts like themselves prefer specificity while attempting to maintain discretion in their offices. The existence of both the Telephone Game and Simon Says stories we have been outlining in this paper might actually be an example of these communities coming into conflict with one another. What seems like a problem of interpretation and implementation might actually be a challenge for regulators coming from the communities of technical designers and lawyers.

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[105] {Bill Zwick, NMT, 6/99}

[106] Rochelle argued that, though many of them claim to prefer such specificity, very few of them, employed by the Lab at least, have ever encountered it. At the Lab, he said, they are generally given a great deal of leeway in interpreting and implementing regulations. {Joe Rochelle, 7/99}

## NEXT STEPS

Comparing Regulations

We have thus far studied three regulations in detail. Two of these have pointed to the stories of regulatory discretion we call the Telephone Game. A third case points to the benign view of regulation involving an administrative hierarchy that creates more specificity in rules as they pass through it, the Simon Says story. We have also explored a possible explanation for the two different stories exists in the different incentive structures, educational backgrounds and needs of technical experts and lawyers.

We recognize that these three regulations are not a representative sample and their small number only allows the rough typology ( we have already created. But, by extension, we can imagine further ways of dividing regulations into more specific categories. A more comprehensive examination of a greater number and variety of regulations, will then enable us to test its validity. Below is a first cut at what such a typology might look like:

**Typology of Regs.**

| **The View from the Start** | **1.Specific** | **2. Specific** | **3. Specific** | **4. Fuzzy** | **5.Ambiguous** | **6.Ambiguous** |
|---|---|---|---|---|---|---|
| | | | | | | |
| **How it looks as it impacts the Lab** | **Specific** | **Ambiguous** | **Highly Amplified Specificity** | **Highly Amplified Amibiguity** | **Specific** | **Ambiguous** |
| **Story of Regulation it tells** | **Simon Says** | **Telephone Game** | **Simon Says** | **Telephone Game** | **Simon Says** | **Telephone Game** |

The first row takes the wording of the regulation on its face and is an attempt to examine it qualitatively to categorize its language as "specific," as in the Fire Protection statute, "fuzzy," as with the ALARA statute or "amobiguous," as with the SAA statute. This type of categorization can depend on a simple reading of the statutory requirements and the level of detail with which it outlines what compliance requires.

The second row involves a qualitative categorization of the statute after it has "passed through the network."[107] This will entail categorizing the view of the requirement as lab workers and lawyers comply with it. In some instances, the Simon Says story will have been called out and the wording will be specific with regard to the technical requirements for implementation. In others, even a relatively specific regulation will have become ambiguous while passing through the network. Many of the Lab's technical workers claim that both external and internal regulators (ESH and Legal) amplify the ambiguity of the rules by adding interpretations of them, rather than clarifying requirements. For the Simon Says story to be accurate, regulations should end up clear and specific after they have passed through the network, whereas, ambiguity, especially, highly amplified ambiguity will point to the existence of the Telephone Game story.

Next Step 1.

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In some ways, this can be seen as a project in risk analysis and mitigation. The typology could allow that Lab to quickly distinguish between regulations that have higher levels of agreement and thus lower implementation costs and those with lower levels and thus higher costs. Such a typology would also allow the Lab to better gauge its reaction to regulators (i.e. knowing when to fight an interpretation and knowing when to accept an interpretation). It may turn out that most regulations fall to one particular category or another; this will help the Lab reduce its costs by creating institutional response mechanisms rather than simply setting implementers adrift in the regulatory sea.

The next steps of the project require that it be defined in more detail. This will involve interviewing people about how the confront regulations and whether our categories are accurate descriptions. Initially, we will continue to study regulations, by reading the statutes, the regulatory interpretations, the internal interpretations and by interviewing people about how they are affected by them at the Lab.

[107] See Stone and La Porte, "Regulatory Ecology:..:, op. cit. , section on "Regulatory Inbetweeners" above.

This will allow us to begin to fill out the characteristics of each in order better to understand how such characteristics might affect Lab/regulator relationships.

The number of regulations facing LANL is, of course, quite considerable. It is not feasible, in early stages, to categorize all of the thousands of regulations that affect LANL. What is feasible now is to begin parsing out the characteristics of certain types of regulation and developing ways of generalization about such regulations and the relationships that develop around them. We expect that the typology emerging from this work will provide a way for the Lab to estimate the risks inherent in each regulation based on where it fits the typology. Some of the questions the typology could answer are addressed below in the rough two-category typology developed in this part of the project.

Next Step 2.

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*A "Simon Says" Reading of the "Telephone Game"*

In order to high light the phenomena found in the low-level of regulator/implementer agreement, Telephone Game-style regulations, we sought out regulations with a relatively high-levels of agreement between them. But most lab workers we interviewed agreed that low-levels of agreement between implementers and regulators are the norm. Undaunted by this, and unsure whether such sentiments were the result of cynicism or the riveted focus on the regulations that make their jobs more difficult, we persisted and eventually found the fire protection statute to use as the basis for our comparison regulation. But what was intriguing was the fact that most people to whom we spoke responded in the same way when asked. They would say they could not think of one. Then they would ask us to tell them if/when we found one. While these responses made our attempts to find smoothly administered regulations more difficult, it raised and interesting question. What was going on which resulted in such a thoroughly incredulous reaction?

<u>a. The Non-Cynical Investigator's First Hypothesis</u>

Why was it so difficult to find a comparison regulation? We framed the problem by posing the Simon Says story of regulation as the standard, thus accepting the idea that most regulations conform to it. But this was clearly at odds with the way Lab members perceived the situation. One reason why it is difficult for people to think of regulations that conform to this "standard" story is that the people who are responsible for regulatory interpretation are necessarily fixated on the regulations with which it is more difficult for them to work. That is, they spend most of their time working with the regulations which give them fits, i.e., about which agreement between interpreters is low. To work with low-agreement regulations requires heterogeneous knowledge among implementers. This suggests that implementers do not spend much time thinking about the possibly large number of regulations in which agreement levels are quite high. That is, people spend less time being self-conscious about the parts of their work that require less effort. The story the optimistic regulator (or the non-cynical investigator) might tell about the regulatory process is that the difficulties people have with regulatory interpretation are limited to specific situations and a small number of actual regulations. The problem, as implementers at the Lab see it, is that the regulations with low-agreement levels take up the largest proportion of Lab resources.

This hypothesis suggests that most regulations "work." That is, they can be interpreted and implemented without much disagreement over what they mean between people at the several interpretive levels. This conforms to the Simon Says story of regulation nicely because it entails a view of regulations, regulators and implementers who are all somewhat in agreement about the tasks to be accomplished.

If we were to accept the first story with regard to regulatory implementation, we would still want to ask if it is preferable to have implementers focus most of their attention on the implementation problems associated with regulations for which there is limited agreement. Some commentators argue that regulation is working at its best when potentially high-cost areas involve the most effort and thinking on the part of implementers/interpreters. The vast majority of issues, it is reasoned, are not high-cost and involve a relatively high level of agreement between implementers and regulators.[108] This type of system encourages efficiency because, in this case, Lab officials would not be spending needless time on regulations to which all parties involved agree on implementation procedures. With regard to potentially high-cost regulatory areas, or areas in which agreement between regulators and implementers is more difficult, implementers and regulators will spend more time attempting to ensure that they understand how the implementation should take place. This, Bardach and Kagan argue, is precisely how regulation should occur, because it does the best job of creating the efficient level of regulatory implementation and feedback to the regulators.[109]

[108] Bardach, Eugene, and Robert Kagan. *Going By the Book.*

It, of course, begs the question of when it is the right time to switch from implementing without disagreement and bringing disagreements to the fore. Once regulations have been put in place, regulators/Congress can get feedback either through the legal system or performance outcomes, though the latter may take several years to measure effectively. Since regulators have limited funds but show a willingness to be adversarial about how they enforce regulations, the regulated entity, in this case the Lab, will have the incentive to challenge many more regulations than necessary. If this happens, of course, efficiency gains would be lost.

b. <u>The Telephone Game and the Fire Protection Anomaly: Another Possible Answer.</u>

It is certainly plausible that the regulating the Lab might not conform to the Simon Says story at all. It may, in fact, be the case that the Lab contends with a regulatory environment that looks, for the most part, like the Telephone Game story. That would be the reason it is difficult to find regulations for which there is a great deal of agreement between regulators and implementers. They would indeed be quite rare. This seems to be the sentiment amongst people at the Lab whose jobs require them to think about regulatory implementation. People's sentiments are not always accurate; the fact that people feel this way could be more of an inherent cynicism in Lab workers, or a growing frustration with regulators, than an actual reflection of the truth. However, what if it were the truth?

One way of looking at this is to see the Simon Says story and the Telephone Game story as points on a spectrum.

←-------------------------------------------------------------------------------------→

Simon Says — Telephone Game

Homogeneous Know. Req. — Heterogeneous Know. Req.

The Simon Says story assumes that regulation should have a high-level of agreement, as to its intent, between regulators and implementers. Any disagreement, then, is really either the implementers trying to get away with not following the rules or the fact that regulators are overly aggressive in their pursuit of the regulated entity. The Telephone Game story says that virtually all regulations are vague and

[109] Bardach and Kagan. op. cit.

difficult to understand; that they are so by design because they are forged out of the "pulling and hauling" that goes on within congressional committees rather than being decided upon by teams of technical experts.

The purpose of searching for a regulation to which we might compare the more ambiguous regulations is to see if the actual practice falls somewhere in between either extreme. We had already found regulations that did not conform to the first story, so the task was to find out whether they are the exception or the rule. Then, it was important to find out whether the causes for this non-conformity to the first story are problems of institutional behavior/design or whether they stemmed from the regulatory safeguards that make the task of regulating more far difficult for all parties concerned.

This knowledge would help us figure out where the trouble areas are and may allow Lab employees to better devote resources to regulation. It may also allow them to develop a typology of regulatory risk, that is, a way of predicting when they can expect to be at a greater risk of regulatory disagreement and when they can expect to be in agreement. The idea of using a typology relies on the possibility that all regulations are neither exclusively the Simon Says or Telephone Game areas, but vary across this spectrum some characterized more by the Simon Says dynamics and others more in the Telephone Game situations. Further research in this project would require the development of a way of finding out the distribution of regulations arrayed between the stories and then describing them in greater detail.

Another aspect of this perspective leads to questions about whether the Lab can change the way the regulators interact with it by operating differently.[110] If the degree of disagreement or non-conformity between regulators' interpretations and the Lab implementers' interpretations could be measured, these could be examined to explore the conditions of agreement to see what the Lab or the regulators could do differently from an institutional perspective compared to situations with high disagreement. We might also consider the claim that the degree of adversarialness which exists between implementers and regulators could be importantly a function of the personalities of the people who occupy each

[110] See, Adam Stone, forthcoming 2001 (dissertation)

role.[111] It could also be related to the degree agency or lab division's employees understanding of the mission of their particular organization.[112]

By examining regulations with high-levels of agreement, we can start to parse out what might create it. We still will not have answered the question as to whether regulatory agreement or disagreement is the rule, but we will have a step toward understanding why some regulations seem to meet with little resistance on either side.

The search for a high-level of agreement in a particular regulation involved reading sections of the CFR for specificity. One of the key attributes of the low-level agreement statutes is the inherent vagueness built into them. Phrases like "As Low As Reasonably Achievable' and "At or near the point of generation" begin at the top of the hierarchy and are propagated throughout the DOE and Lab implementation route. Intuitively, it seems that greater specificity at the upper regulatory levels will lead to a higher-degree of agreement throughout the lower levels. Knowledge requirements for implementation will be more homogeneous and there will be less room for both regulators and implementers to insert their own interpretations.

While this may seem like an intuitively obvious point, we are impressed by how it has escaped discussions about regulatory relationships. If specificity leads to agreement, we may want more of it in appropriate cases. If specificity limits the ability of expert decision-makers to make decisions for which they are especially suited, we may want to rethink when and where specificity is better than vagueness and vice-versa. The work reported here suggest the utility of the proposed typology and examination of a wide sweep of regulatory seeking to estimate the risks the Lab faces with regard to various factors in the regulations themselves.

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[111] The degree of agreement with regard to the rule could be the result of personal amiability between the regulator and the Lab liaison. Rochelle seemed to think this was a possibility with regard to RCRA. {Rochelle, 7/99}

[112] That is, whether either the regulator or the Lab liaison/implementer believes it is his/her duty to adversarial with regard to the regulatory interpretation. For example, internal regulators within the Lab may believe that the Lab should read regulations conservatively in order to better protect the environment. They may believe that it is their role to ensure that the Lab does not pollute. Whereas, various units within the DOE may believe that Lab scientists have better access to the information and will defer to their judgment whenever possible *Chevron USA, inc. v. National Resources Defense Council, Inc.* 467 US 837 (1984)

# Strategic Regulatory Action

## A Framework for Analyzing Design and Regulation

The LANL/UCB
Stewardship
Project

Final Repor

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Abstract: This paper develops a framework for analyzing the connections between organizational and technical design choices, and regulatory behavior outcomes.

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## Introduction:

Los Alamos National Laboratory is one of the most highly regulated facilities in the country. The costs of regulation at Los Alamos are enormous and often unexpected. New facilities experience long delays in opening and existing facilities often face new and unique regulatory challenges. The laboratory's relationships with its regulators are complex, variable, and sometimes unsettling for those at LANL, in the regulatory agencies, and occasionally, in the surrounding communities (see Stone and La Porte, Regulatory Ecology:2000).

At the same time, strategic action on the part of the laboratory to manage this environment has not taken place in a coordinated manner. Throughout the laboratory, attempts have been made to deal in a more managed way with regulators, and these efforts have sometimes met with success. Nevertheless, to many managers and designers at the laboratory, the regulatory environment remains both frightening and mysterious; mysterious in the sense that it is seemingly unpredictable and frightening because of the shared knowledge of the delays and cancellations numerous projects have met with at the hands of this environment.

This paper will attempt to describe one aspect of the regulatory environment at Los Alamos: the interface between design and regulation. In the framework employed here, design refers to both technical and organizational design and its implications for ongoing management. From another perspective, this research attempts to develop a framework for analyzing the factors that influence regulatory behavior and fall under the direct or nearly direct control of the regulated entity. Although this paper's scope is limited to descriptive information and the development of an analytical framework for regulatee-based factors influencing regulatory behavior, the framework developed here provides a starting point for the analysis of strategic regulatory action – actions taken to influence the behavior and attitudes of individual regulators.

The research presented here is based on the analysis of the existing literatures on regulation and technological development and dozens of interviews with regulators, managers, and regulatory inbetweeners both at LANL and at other organizations facing similar regulatory environments. Based on the analysis of these sources, a framework was developed for the further analysis of these regulatory factors. This research represents the first and second steps towards the larger goal of understanding the downstream effects of technical and organizational changes on regulatory behavior.

## Pity the Poor Designer

Design is not a technically pre-determined activity, although much of social science and engineering has treated it as such. Neither, however, can it be reduced to an entirely socially constructed activity[1]. Engineering can be usefully thought of as a "translation activity" in which engineers work within a variety of constraints, technical, organizational, and social, in the process of design[2]. These factors can be functions of engineering norms or the culture of the specific organization involved in the design. These norms can be quite powerful, having effects on perceptions of operational safety and standard operating procedures[3].

This type of design has received attention from social scientists who see design activities as political activities with effects on worker empowerment and democratic action[4]. Design decisions, however, can also be made for more obvious reasons, such as ease of oversight or throughput at the expense of easier maintenance. Finally, some observers argue that technologies have their own logic which help to determine the specifics of their design and their deployment[5].

Historically, technical decisions have often played a small role in major technological deployments once an initial decision regarding a technology was made. Consider the case of nuclear power plants, which are based on a design chosen for civilian power primarily because of its successful history as a means of propulsion for nuclear submarines, despite the obvious and non-obvious differences in requirements for the two applications. Light water is only one possible means of cooling a plant. Canada, for instance, uses heavy water while experiments have been conducted with liquid metal, sodium, and others. Even the central way in which the reactor generates power (pressurized water system) is a design choice, not a foregone conclusion. For instance, the chief

[1] Pool, R. 1997. Beyond Engineering: How Society Shapes Technology. Oxford: Oxford University Press.
[2] Florman, Samuel C. The existential pleasures of engineering / Samuel C. Florman. New York : St. Martin's Press, c1976.
[3] Pool, R. 1997. Beyond Engineering: How Society Shapes Technology. Oxford: OxordUniversity Press.
[4] Noble, David F.America by design : science, technology, and the rise of corporate capitalism / by David F. Noble. 1st ed. New York : Knopf, 1977.
[5] Street, John, 1952-Politics and technology / John Street. New York : Guilford Press, c1992. Conduct of science series and Ellul, Jacques. The technological society / by Jacques Ellul ; translated from theFrench by John Wilkinson ; with an introduction by Robert ... New York : Vintage Books, 1964. Vintage books ; V390.

competitor, boiling water reactors, are now the standard for new plant construction by both GE and Westinghouse, the two remaining reactor manufacturers[6]. The decision to use the same technology that had been tried on nuclear submarines was not a technical one, but both a pragmatic and philosophical one. Pragmatism's close cousin "lock in" also may play a role in technical design, as possibly evidenced by the layout of the keyboard this was typed on[7].

Today, designers face a world determined by many factors other than the technical constraints of design. Managerial, financial, human resource, environmental, and regulatory factors all enter, in some way or another, into design activities. The extent to which these various factors are managed varies both between technical domains, and within them. In the nuclear domain for instance, the design environment varies dramatically between nuclear power plants and research laboratories like Los Alamos.

Regulation in particular, can be a source of confusion for designers. Regulatory responses to various operations appear to many designers to be almost random, and certainly not connected with any "real" risk implied by a large-scale technology. At Los Alamos, this confusion sometimes transcends into fear, as engineers and managers develop a shared lore about projects delayed or emaciated by regulatory surprise[8]. This fear, coupled with an inherently reactive approach to regulatory interventions, leaves designers feeling powerless and often resorting to a ostrich-like strategy. Projects are sometimes undertaken in ways designed precisely to avoid regulatory notice, as opposed to avoiding regulatory ire. One division was forced to stand down from work for four months, in part because of the mislabeling of an experiment as a demonstration, a strategy designed to avoid following procedures they found too arduous.

The result is a situation in which regulations harbor unknown fears and unpleasant surprises. Many designers have attempted to get internal regulatory actors and external regulatory actors to specify the regulatory environment in a way in which they can design for it. These requests are often met with no information, or information that they believe to be a "final answer" but which quickly

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[6] ibid Pool 1997
[7] Actually, although this is held up as the classic example, it's wrong on quite a few levels in the way it is usually described. As a general example of lock in, however, it is still valid, whether you believe that the DVORAK keyboard is more 'economically efficient' or not.
[8] Consider the Mixed Oxide Fuel Project at LANL, where managers and designers collectively decided to "fly under the radar" of the public and regulators to buffer themselves from regulatory surprise (Koehler:2000)

proves itself to be nothing of the kind. Designers crave requirement specificity in many circumstances, they see the requirements as a potential buffer. But, for reasons they cannot understand, uncertainty pervades these requirements and attempts to specify them further usually amount to little at all.

## Pity the Poor Regulator: Regulatory Theory, Adversarial Legalism, and Bureacracy

Pity the poor regulator. Depending on who you talk to, her job is either mind-numbingly boring or impossible – her training and abilities are substandard, and neither the people she regulates nor the citizens who rely on her regulation for their safety think she does a particularly good job.

One, possibly apocryphal, story of the mind-numbing side of regulation is that of the poultry inspector who examines the chickens before they are sent to slaughter. Apparently, the inspector is supposed to look for outward signs that the chicken is sick, or would otherwise represent a danger to the food supply. The average number of chickens expected to be found by a regulator in that regulator's work is one. Not one per year, but one during the entire work life on an inspector. And although chickens may not be as interesting as hazardous facilities, the story tells us something about the job of the regulator[9].

Although the US's initial foray with regulation began at the turn of the century in response to early consequences of the industrial revolution, it was not until the 1960's and 1970's that regulation of the form we now experience began to take hold. Bardach and Kagan speculate that this can be attributed both to an increase in the recognition of risks and a decrease in our tolerance of risks – led by pathbreaking work by Ralph Nader and Rachel Carson[10].

This new regulation is defined by a more legalistic approach then its predecessor. Where regulatory entities were often thought to be tools of the organizations they regulated and lacking both the power and will to effectively regulate, the new agencies of regulation were imbued with

[9] One could easily argue that chickens are more interesting then nuclear power plants – at least the poultry inspector can actually see the product and grasp the production process.

[10] Bardach, Eugene. Going by the book : the problem of regulatory unreasonableness / Eugene Bardach & Robert A. Kagan Philadelphia : Temple University Press, 1982 Kagan, Robert A.

more organizational and political power and were guarded against capture by a variety of formal and informal means. This is not to say that claims of capture were diminished – only that more formal processes, especially jurisprudential processes, were used to regulate agency behavior[11].

Observers of this new regulation are numerous, with significant attention paid to the way in which regulatory rules are written, the role of courts in the process, the macro-level behavior of agencies, and the costs of regulation generally. These focii are not surprising given the people who have studied these issues: political scientists, legal theorists, policy wonks, and economists. Perhaps because of this, very little attention has been given to the role and behavior of the inspector herself. The literature has primarily stopped short of studying the actual implementor of the rules and the observer of the regulated entities (see, for instance, Frankel:1994). The primary exception is Bardach and Kagan's Going By The Book. Other notable exceptions include the evolutionary game theory work of Scholz and the works of Ayres and Braithwaite among others. These will be discussed further below[12].

The observers of regulatory behavior have been interested primarily in whether both regulator and agency act in a fundamentally cooperative-accommodative or adversarial-legalistic manner. Various attempts to create multidimensional axis of this behavior have been useful, but for our purposes, a simple cooperative to adversarial axis should suffice.

Agencies are seen to differ in the extent to which they act cooperatively with the regulated entity – assisting them with compliance and perhaps acting leniently when good firms make small accidental mistakes in compliance. The cooperative inspector would be expected to take mitigating circumstances into account when citing violations and would be expected to work closely with the entity to achieve compliance. By the same token, the flexible-cooperative agency might act comparatively harshly against a "bad apple" firm – one with a history of repeated or intentional violations of the law.

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[11] Harris, Richard A., 1951-. The politics of regulatory change : a tale of two agencies / , Richard A. Harris, Sidney M. Milkis. New York : Oxford University Press, 1989. xii, 331 p. ; 22 cm. And Shapiro, Martin M.. The Supreme Court and administrative agencies, [by] Martin Shapiro. New York, Free Press [1968]

[12] AYRES I; BRAITHWAITE J. TRIPARTISM - REGULATORY CAPTURE AND EMPOWERMENT. LAW AND SOCIAL INQUIRY-JOURNAL OF THE AMERICAN BAR FOUNDATION, 1991 SUMMER, V16 N3:435-496.

In contrast, a constrained-adversarial regulator would be expected to treat all firms and violations similarly. A small overlooked violation by a "good apple" firm would be treated in the same way as a violation by a perpetual violator. The regulator and regulatee are not in cooperation to find the best means of meeting the regulation – here the model is adversarial-legal – the agency may well be unwilling to even provide guidance to the regulated entity in gray areas of the law.

These are obviously sharp characterizations which collapse several characteristics of these behaviors – however, they are illustrative of the general behaviors we associate with each archetype of regulation.

In trying to understand what accounts for differences in the way regulators behave, observers have noted the importance of several types of factors. Factors affecting legalistic enforcement can generally be divided into two categories, socio-political and task-environmental. While the former has received significant attention and is no doubt responsible for the sea-changes we have witnessed in regulation since the 1960's, the latter is also important and has been talked about only infrequently.

We need not dwell on the socio-political factors here, except to say that they are numerous and are probably more influential in terms of the overall character of regulation then any task-environmental factors – at least on the agency level. At the margins, however, task environment factors may have quite a bit of influence over the behavior of what we might term "street level regulators," those individuals who actually do the observation and work of regulation.

These task environment factors have, as was noted, been given very little attention by researchers, especially in the details of what constitutes "visibility of violations to complaintants." Perhaps because regulators generally have to deal with what they see, the literature shows a sort of instrumentalist bias towards technical issues. That is to say, the extent to which individual technical configurations are overlooked may represent a general feeling that technical configurations are givens in the world of regulation.

Slightly modified from: Factors Affecting Regulatory Style, Kagan:1996 .

- Socio-Poltical Factors:
- Legal Design Factors
- Stringency of regulatory mission
- Legal Powers

- Political Environment Factors
- Strength and aggressiveness of proregulation interests
- Preferences of political authorities, as influenced by:
- Recent catastrophes or scandals
- Economically urgent projects subject to regulation
- Political controversy over enforcement style
- Electoral shifts/changes in regulatory leadership
- Budget cutbacks
- Resistance by regulated governmental entities
- Leadership factors
- Reactive vs. strong minded regulatory leaders. If strong:
- Leader's policy beliefs
- Beliefs concerning enforcement style
- Degree of staff professionalism

Task Environment Factors
- **Visibility of Violations**
- **Frequency of interaction with regulated entities**
- **Visibility of violations to complaintants**
- **Regulated entities' willingness to comply**
- **Size and Sophistication of regulated entities**
- **Cost of compliance/economic resilience**
- **Seriousness of risks to be prevented.**

Where attention has been paid to individual technical problems, the focus has been on technology-forcing regulation and on the legislation of specific technical measures[13]. This type of thinking appears frequently in the debates between those who argue for a "radical technology forcing" approach at one extreme, and a best-available technology or economic based regulatory scheme on the other Unfortunately, neither of these types of studies are particularly useful in organizing our thinking about technical decisionmaking and the ongoing regulation of different technical alternatives. This is because the framework takes the regulation as the changeable variable, rather then the technology itself.

Of those non-technical factors that have been studied, one

[13] See, for instance, the debates between radical technology forcing and available technology critics. Also Melnick, R. Shep, 1951- Regulation and the courts : the case of the Clean Air Act / R. Shep Melnick. Washington, D.C. : Brookings Institution, c1983.

stands out as especially well documented. Frequency of interaction between regulator and regulatee has been examined in numerous studies and seen to positively affect the degree of cooperation between the two entities. Three explanations, neither mutually exclusive nor collectively exhaustive, exist for this effect.

First, traditional capture theory argues that frequency of interaction creates opportunities for regulated interests to capture the interests of regulators - either through legal (social) or illegal (financial) means[14]. The modern practice of rotating regulators in some agencies is a specific response to this problem.

Second, game theoretic approaches suggest that frequent interaction allows firms and regulators to play iterated, mutually beneficial games. By adopting a tit for tat or modified tit for tat strategy, regulators and regulatees can achieve optimum amounts of cooperative behavior while still dishing out severe punishments to bad apple firms.

Finally, some observers have suggested that the same factors which might lead to capture on the one hand, may also lead to cooperation on the other. This tomato – tomato argument has, as its premise, the idea that an enhanced understanding of the specific constraints, skills, and conditions of a regulated enterprise will in turn help the regulator to behave in a more cooperative fashion, or at least avoid instances of extreme regulatory unreasonableness.

This argument, implied by several observers but spelled out more explicitly by Bardach and Kagan, has important implications for this research project. The dimension of frequency of interaction actually collapses a set of factors we might suppose would constitute some of the advantages of interaction. For instance, frequency might be a proxy for level of understanding of the specifics of the technical system. Frequency might also be a proxy for level of understanding about the organization and how it operates, or about the various external and internal factors which impact operations and perhaps compliance. Viewed in this way, frequency of interaction is a proxy for a variety of factors which relate to what might be called the "comprehension factor."

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[14] Ibit Ayres and Braithwaite, 1991

Two other factors which are often mentioned are the level of technical sophistication of the regulators and the visibility of violations. The latter is the most technically oriented of the factors which have been observed, but even here, there is little in the literature that might be considered guidance for a designer wishing to create a more regulatorily-friendly technology. The basic concept of both, however, is both intuitive and appealing. Bardach and Kagan note:

> A friendly, congenial manner, however is only one aspect of being effective and persuasive. One critical ingredient is the capacity to be reasonable, to diminish serious from nonserious violations, and to invest effort in the former. This capacity seems closely related to technical competence – an ability to provide technically persuasive explanations for regulatory requirements and to understand how the regulations affect production or managerial functions. Lack of technical competence is a likely corollary of legalistic enforcement[15].

One side of technical competence is clearly in the hands of regulators, the obvious prescription is to hire and train more competent ones. But another, overlooked side of this, is the technical one; the ability of a design decision to improve the technical competence and knowledge of a regulator.

In the same way, visibility of violations is essentially a comprehension factor. Technologies differ in the extent to which they relay information about various aspects of their operations. Design decisions can have enormous impacts of the flow and character of that information. Consider the decision not to utilize sensors to establish coolant level in the core in early nuclear power plants. This decision was based on calculations regarding the risks of adding the sensors and the likelihood of the core coolant emptying

Seriousness of risks is an intuitive but somewhat difficult factor to evaluate. Returning to the earlier discussion of the risk literature, it is not clear what exactly is meant by seriousness of risks. From a technical or actuarial perspective, seriousness of risk may be relatively straightforward (though perhaps still difficult to calculate). Economic analysis adds the dimension of utility to these considerations, but it is not until social and cultural considerations are included in the discussion of

[15] ibid Bardach and Kagan, 108

"seriousness of risk" that we begin to fully comprehend this topic.

This is especially important in the context of regulatory costs, where real risks may have little bearing on the relative intensity of regulation. For instance, Liquid Natural Gas shipments are highly dangerous but only moderately regulated, whereas low level nuclear waste shipments are regulated by a cast of thousands despite the more moderate harm an accident would cause.

Presumably, the same factors which influence public perception of risks and rewards also influence the attentions of regulators but we currently have no data to support such a hypothesis. Even if we did, the risk literature is still sufficiently underdeveloped that clear help in figuring out the characteristics of systems which alter risk perceptions is not available. In terms of this perception, Freudenburg notes:

> Two particularly significant aspects of social amplification of risk have received little attention to date, however. The first is that human and social processes can lead to the attenuation of risk estimates as well as to their amplification; the second is that the problems can exist among experts as well as among the general public (Freidenbug: 1992).

These two points are useful to us in thinking about regulatory perception. First, changes in the environment (social, organizational, and technical) can have the effects of both attenuating and amplifying human perceptions of risk. Second, even trained personnel, such as those responsible for regulation, are subject to both types of fluctuation in their perceptions.

We have now reordered part of the category of task environment variables above into a larger more encompassing notion of technical comprehension. The literature provides us with a good basis to see various examples of comprehension factors we should look for in trying to understand the role of technical design as it relates to regulatory behavior. It also offers a powerful framework by which to judge regulatory behavior – the adversarial cooperative one described above.

We leave this discussion with one last important point: the job of the regulator is hard. In an interview with one Bay Area Air Quality Management Regulator, we heard stories of verbal threats, thrown tools, and, in one instance, a gun. Regulators customarily perform searches and seizures of private property without a warrant[16]. Even if they were to do their jobs perfectly, they would face animosity among the regulated.

However, doing their jobs perfectly is far from easy. Regulators face a variety of systems and operations whose operators are almost always more knowledgeable about the process then are the regulators. This makes hiding violations often a relatively easy task. Regulators are usually paid less and trained less well then the people they regulate. This results in "don't know whether to cry or laugh" scenarios such as the one which takes place at Los Alamos National Laboratory where very effective and talented regulators are almost always hired away from the state by the laboratory at double or triple the wages. Those who don't get hired away often harbor resentment against the laboratory because they were denied jobs there. Although extreme, this example is instructive – regulators often can find more lucrative private sector work and many are lured away.

Even those who are both competent and stay face an uphill and difficult job – resentment by the regulatee and the knowledge that even simple violations may end up tied up in legal battles for years. Add to this the mind-numbing aspects of certain regulatory jobs such as the poulty inspector described above. In theory, we trust regulators to guard our safety but in reality, they can do little more then help try to keep the regulated enterprise in line.

## Pity the Poor Policymaker and Manager: (policy literature on hazardous systems and LTS theory)

Technical systems do not come into being as solely technological creatures. They have organizational, technical, and institutional symbionts. Each technical decision and system implies networks of interconnections. The more complicated and hazardous the system, the more these connections may be relied upon for the safety of operations.

The difficulties of operating complicated and dangerous systems have been apparent for some time. Our earliest large scale technological missions, for instance, demanded new forms of social organization of an unprecedented scale. It has been argued that the Apollo project represented one

[16] ibid Bardach and Kagan

of the earliest examples of this. Apollo implied a technocratic and elite-driven mode of management and operations. No longer was decentralized research and control an option, the scale of operations had surpassed the normal democratic mode and moved into an altogether more powerful one[17].

But it was not until the Three Mile Island accident that our notions of risk in technical systems really began to take hold. Even early environmental watersheds such as love canal are often seen as more environmental then technological disasters. Perrow's classic, Normal Accidents, is the seminal work of the difficulties and dangers of running high risk, high hazard technical systems. Perrow argues, in much more complicated and nuanced terms then will be used here, that these systems are defined by both their complexity and their tight coupling. Together these present an internal contradiction: a need for centralized knowledge of the myriad of interacting factors in the system, while at the same demanding decentralized decisionmaking in response to quickly changing conditions. Under these circumstances, Perrow argues there can be no best response. We must then consider major accidents to be a normal part of the operation of these technologies[18].

Berkeley researchers Todd La Porte, Gene Rochlin, and Karlene Roberts (and others), through their observations of several of these type of systems, developed a school of thinking known as high reliability organizations. This work looks at the operations of very high performance organizations in these situations and observes the unique factors which are thought to assist in that remarkable performance. While some take Perrow and the HRO researchers to be in conflict, others argue that the HRO writings are really a companion to Perrow's work, showing the incredible demands implied by operating these systems reliably.

Both theories suggest the scale of difficulty involved in the safe and reliable operation of large technical systems in modern society. The technical challenges however are only one part of the political equation. Risk and risk perception also represent major components of the way in which society approaches these technologies.

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[17] McDougall, Walter A., 1946- The heavens and the earth : a political history of the space age / Walter A. McDougall. New York : Basic Books, c1985.
[18] Perrow, Charles. Normal accidents : living with high-risk technologies / Charles Perrow. New York : Basic Books, c1984.

Risk, in the traditional sense, is the magnitude of hazard multiplied by the probability of that hazard. This sense, however, is of limited use to those who study reactions to risk. Perceived risk seems to be much more important to behavior. Needless to say, it is a much more difficult thing to generalize about.

Significant attention has been paid in the literature to different understandings of risk, both regarding the significance of different hazards and the way in which people value different potential risks[19]. Ortwin Renn provides an excellent classification scheme in which the literature on risk is divided into actuarial, economic, psychological, sociological, and cultural approaches[20].

Of these, the psychological, sociological, and cultural approaches are most interesting from the perspective of this research. These three approaches share a focus on perceived risk and, in the case of the latter two, the socially constructed and influenced aspects of that perceived risk:

> Cultural reason does not deny the role of technical reason; it simply extends it. The former branches out, while the latter branches in. Cultural rationality does not separate the context from the content of risk analysis. Technical rationality operates as if it can act independently of popular culture in constructing the risk analysis, whereas cultural rationality seeks technical knowledge but incorporates it within a broader decision framework[21].

Technical reason and probabilistic risk assessment are connected with the technical characteristics of systems, but regulatory behavior also serves as a bridge between public perception and technological reality. LANL's Harry Otway describes his understanding of the role of technology in risk studies:

> In searching through the psychology literature I was struck by the similarity between attitudes toward risk and what was beginning to be called "risk

[19] For a cogent discussion, see Poole:1997
[20] Cross-cultural risk perception : a survey of empirical studies / edited by Ortwin Renn, Bernd Rohrmann. Dordrecht ; Boston : Kluwer, c2000.
[21] Krimsky, Sheldon. Environmental hazards : communicating risks as a social process / Sheldon Krimsky, Alonzo Plough. Dover, Mass. : Auburn House, c1988.

> perception." After much thought, it seemed that the relevant issues was not risk per se, but attitudes toward the technology associated with that risk. Obviously, it is the technology as a whole that is ultimately accepted, not its risks in abstract isolation[22].

This thinking germinates two thoughts for the research at hand. First, on a regulatory rather then social level, what is the relationship between technical choice and risk perception? And, on a secondary level, what is the character of the regulatory role as explainer and certifier of technical deployments. To the extent that risks of technologies are perceived by citizens, presumably, faith in their overseers and operators must be intimately bound up in any conception of risk[23].

It is also important to distinguish between what might be called intrinsically hazardous and operationally hazardous activities. Intrinsically hazardous activities, those that present hazards not related to human activity, include earthquakes, hurricanes, and other natural disasters. The scope and scale of these hazards is very large, comparable – at least in recent experience – to the hazards experienced from human generated hazards. Organizationally hazardous activities generate hazards from their improper operation. It is not the technology itself, but the failure to operate it in a reliable fashion, that generates the hazard directly. This distinction is an important one for our work because it draws the focus to the organizational locus of the hazard and away from the technology itself. Citizens willingly accept many intrinsic hazards (consider the seven million people living in the Bay Area), while they are loathe to accept organizational hazards that pale in comparison.

It is not necessary that we examine all of these various risk perspectives in this context, only that we take from the literature the idea that real and perceived risks are not always the same. This is important as we approach the regulation of technical systems from the policy and large technical systems perspectives. We will also return to the first question above as we begin to talk about the regulatory task environment in subsequent sections.

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[22] In Renn, ibid

[23] For instance, I have a lot of faith in the designers and regulators of automobiles and I think most people do. Cars rarely explode or catastrophically fail. Yet they clearly have that potential. A great example of faith placed in regulators and designers, but not in operators. I certainly don't trust that my neglect of my automobile will help to prevent its explosion.

Nuclear engineers are fond of pointing out that the real risks of nuclear power pale in comparison to those of chemical plants, the transportation of liquid natural gas, or, for that matter, driving your car. While these numbers may be debatable, society clearly feels more strongly about some of these hazards then others. Whatever it is that results in certain activities having very high perceived risks, the outcome is usually the same – calls for stopping the activity and, barring that, increased regulation of it.

Some observers have suggested that the successes of environmentalism can primarily be attributed to our growing awareness of the risks of environmental damage, but also to a growing intolerance for the perceived hazards themselves. Again, the result is calls for governmental intervention to protect the environment and by extension, ourselves.

Yet, as in the case of regulatory literature, the policy literature on hazardous systems and environmental concerns has routinely ignored the work of the actual regulator herself. This is not surprising, we would expect this literature to be primarily concerned with the meta-level policy issues. It is, however, troubling in the sense that this literature is more concerned with the specifics of technical alternatives and still has ignored the effect those choices have on ongoing regulation.

Another type of instrumentalist bias is in evidence here, with overtones of our politics-administration dichotomy problems in the U.S. Significant attention is paid to the specific legal aspects of regulation while little attention is paid to the act of regulating. Questions such as "how are tradeable air permits really enforced?" and "what would this type of technological regulation really entail at the street level?" rarely surface in policy discussion.

Overall, this group of literatures leaves us with concerns over the reliability of large hazardous systems and very little confidence in those who carry them out. At the same time, the routes of that research, traced to organization theory, provide us with a framework for understanding some of the work of regulators which is implicit in the regulatory literature described in the previous section. We are left with concerns about the dangers of these systems and the difficulties of both operating and regulating them.

At the crossover between the regulatory and policy literatures is the tiny but fascinating literature on private regulation. At least two industries, the nuclear and chemical industries, have attempted different forms of self-regulation, both with varying degrees of success. The successes and failures of the nuclear industry have been documented in Reess' book "Hostages of Each Other." Rees argues that the nuclear industry was led to effective communitarian regulation, despite what one might guess about the effectiveness of self-regulation, because of the perception that one mistake at one plant might have grave effects on the entirety of the nuclear industry (e.g. Three Mile Island)[24].

In the chemical industry, the Responsible Care/Chemical Stewardship approach has been successful not only in terms of inter-company cooperation, but also in showing regulators that the industry was committed to improving itself and the environment. Although the responsible care project has had many stumbling blocks, it has proven to be an effective tool in improving the perceived trustworthiness of the industry.

Attempts such as these show how the regulated entity can make a difference in terms of the way they approach regulation, potentially changing the nature of the regulatory relationship at the same time. Although Rees does not find evidence of the latter for the nuclear industry, there is some evidence that Responsible Care has been effectively used as a lever to forestall increasingly legalistic regulation of the chemical industry.

## Thinking About Regulation From A Design Perspective

In summary, the job of the regulator is hard, but her behavior appears to be connected to a number of social and task-related factors. Some of these factors are under the partial control of the regulatee, allowing for the possibility of exercising some control of the regulatory environment. At the same time, the job of the technical designer is also hard. It is filled with uncertainties about the design environment, and in many cases, substantial and reasonable fears about regulatory interventions. Technical design is often treated as a given in these circumstances, when it actually has flexibilities which are not often accounted for. Even when the designer tries to account for the

[24] Rees, Joseph V. Hostages of each other : the transformation of nuclear safety since Three Mile Island / Jospeh V. Rees. Chicago : University of Chicago Press, 1994

regulatory environment, the results are often not as positive as the designer hopes for, perhaps in part because the assumptions that each group makes about the other, may not have strong basis in reality. Before examining this in detail, it is first necessary to lay out the baseline regulatory environment at LANL.

## The Regulatory Environment at LANL

LANL's regulatory relations are numerous and complicated (see additional reports Stone and La Porte, La Porte, Egan). Blanket statements are difficult to make about regulatory behavior as the diversity of its regulators continues to increase. This is an important lesson in and of itself: regulatory outcomes are variable and, from a practitioner standpoint, need to be framed by the data available on individual regulators.

Nevertheless, there are five key characteristics of the regulatory environment which frame this analysis:

1. The Lab's Regulatory Environment is made up of complex, varying, overlapping, and conflicting networks of regulators and regulations: The accompanying research paper on the regulatory environment at LANL lays out 13 regulatory arenas which connect 60-odd regulators in the environment. The networks of connections in the regulatory environment are complex, varying both across time and across domains, overlapping between functional areas and between regulatory groups, and occasionally conflicting both within and between regulatory arenas. The impacts of this are further outlined in the next section.

2. The Lab treats most regulation as an afterthought to the design and ongoing management/operations of technical systems: Regulation is simply not a key factor in technical or organizational design at LANL. The Lab responds primarily in a reactive fashion to the regulatory world. Where proactive action is taken, it is not part of a larger strategy of strategic regulatory action: There are individuals and organizations at LANL that take a proactive view of the regulatory environment, however, these actions occur within the context of individual projects. There is little that connects these projects into a larger

vision of strategic regulatory thinking at LANL. Interviews with management-level regulatory inbetweeners and management at the working division level, bear out the frustration with a lack of lab-wide direction on regulatory concerns.

3. Many individuals at LANL perceive their regulatory peers to be significantly less technically qualified then their LANL peers. In dozens of interviews, regulators express their frustration with their perception that their LANL colleagues do not treat them as competent actors. At the same time, many LANL managers and others express frustration with what they perceive as less than technically adept behavior on the part of regulators. This disconnect has been mentioned in virtually every interview with both LANL's internal and external regulatory actors.

4. On the whole, LANL's relationship with its regulators is both adversarial and legalistic: the relationship is adversarial in the sense that regulators are usually assumed (often correctly) to be the adversary as opposed to a partner. The environment is legalistic in that the lab usually resorts to legal recourse against the regulators, leading to a constrained and heavily legalistic relationship between LANL and its regulators.

## The Task Environment

These factors will be discussed in further detail in the section on barriers to adoption. For now, it is important to understand that the regulatory environment is complicated and multi-dimensional and implies significant costs for the laboratory. From this point, we can begin to develop a typology of factors influencing regulatory behavior. This initial typology is laid out in Figure 4 below.

The figure begins with the basic breakdown between organizational and technical task environment factors. The factors described in each area are, of course, highly interconnected, but for purposes of analysis, it makes sense to separate those that are connected directly with management and those that are more clearly related to technical design. One interesting distinction between organizational and technical design in this context is the relative ease, in many cases, with which the organizational design can be manipulated over time, as contrasted with the more fixed nature of technical design.

**OrgSimilarity**
Similarity of Structure to Others in regulator's view

**OrgCompetence**
Relative competence of organization members

**OrgResource**
Resources available to do job.

**OrgTrust**
Do they want to do the right thing?

**OrgConfidence**
Can they pull it off?

**OrgHide**
Ability or likelihood of organization hiding information

**OrgTransparency**
Relative transparency of organization to regulator

**OrgConstrain**
How constrained is the organization

**TechSimilarity**
Similarity of technical implementation to others in regulator's view.

**TechQuality**
Quality of technical implementation - multifactorial

**TechHide**
Ability to hide problems behind technical deployment (intentional)

**TechError**
Likelihood of error.

**TechVisibility**
Visibility of error

**TechGrasp**
Intuitiveness of system to regulator

**TechTransparency**
Intuitiveness of component parts to regulator

**TechMaintain**
Level of technical maintenance.


*Preliminary list of factors influencing regulatory behavior.*
This list describes the technical and organizational components of design which frame the research on task environment drivers of regulatory behavior. The central arrow is designed to show how technical factors also drive the organizational factors, and vice versa. These are not independent variables.

The chart above lays out the framework which was generated from the analysis of dozens of interviews, stories, and documents produced at LANL and from comparative research with other regulators and other organizations operating in hazardous environments. This research is still a work in progress, but this framework provides a new opportunity to begin to analyze the concept of strategy as it related to regulatory action in a more systematic way.

This is organic theory in that the framework arises from the data gathering process, but then can be used to explain and categorize the ongoing data gathering in a more specified and more useful manner. Each organization facing regulation experiences each of these factors differently. It should be noted that in looking at this framework that the task environment factor does not necessarily imply a clear scalar and vector towards improved regulatory relations. It would be incorrect to assume that simply increasing the amount of each of these factors below would automatically improve a regulatory relationship. These are descriptive categorizations, not, at this point, prescriptions.

This next section of this report begins to develop more fully the chart on the preceding page. Each area of regulatory effect will be defined and then analyzed given the research completed to date. Organizational factors will be examined first as they provide a basis for understanding the technical factors in an organizational context. The technical factors cannot be fully separated from the organizational factors and since the organization provides the primary window in to the technology, those factors seem foundational to our analysis.

Organizational Factors

- OrgSimilarity: The similarity between one organizational design and another was the second most mentioned organizational aspect in interviews of regulatory inbetweeneers at Los Alamos. In general, statements in this area fell into two areas – statements about the distinctive type of organization at LANL and the problems it engendered for regulators, and statements about regulators adjusting to these odd organizational forms. In one case, the regulatory domain had come under fire for its component parts of the regulation being too separate in the organization. A reorganization of sorts was attempted to make LANL look more like the other DOE nuclear facilities but took the form of an informal reorganization. One person close to the reorganization noted the success of the it, "{the regulator} says, 'we don't know why it works, but it seems to."

- OrgCompetence: The perception of the competence of the people in the organization being regulated appears to be a very important factor in regulatory behavior outcomes. Unfortunately, the perception of organizational competence can have surprising effects on regulatory outcomes. At LANL, the employees are considered by the lab and often by external regulators, to be very competent, often, they are considered to be more technically competent then the regulators themselves. The result is that some regulators have expressed shock and dismay at the errors committed by these smart people – imbuing potentially accidental situations with a degree of intentionality reserved for those who really know their stuff. Consider this chilling comment from a state regulator:

> Those people up there are the best in the world at what they do. They have the resources to do it right, if they don't do it, I assume they've made the calculation and decided not to do it right on purpose (1996).

Being organizationally top-notch has both an upside and a downside. The ability to project organizational competence is, of course, not necessarily related to the actual task of being competent – a factor which can work to decrease or increase the ire of regulators.

- OrgResource: Regulators base their impressions of regulatees in part on their perception of the resources available to do the job correctly. Once again, LANL is perceived as a place of nearly unlimited resources, but the regulatory outcome can be slightly perverse. An air quality regulator in San Francisco explained that mom and pop gas stations always got more regulatory leeway and cooperation than the big franchises because the regulator understood that they had neither the resources or the expertise to do the job. In contrast, LANL is perceived as so resource-rich that its regulators often see its shortcomings as functions of intention rather then constraint. LANL is indeed a place of significant resource constraints

– just because one program has money does not mean that another has any resources at all. A common complaint is that the regulators of the lab cannot be convinced that this is true. One LANL manager observed, "they sit there with us and say 'move the money to this other project' or 'get this project done first' but we can't just move the money around like that – we go to jail for doing things like that (2000)." A lab IT person who had the opportunity to work with a state regulator and the lab on a database project made a similar observation: "they think we can do whatever we want and that we have all the money in the world – when people here talked about constraints, you could see the {regulators} chuckling." It is perverse to think that LANL might get more leeway if it was more incompetent, but that is not the most pressing lesson that should be learned in this area. Although more data is required, it seems clear that relatively abundant organizational resources hold organizations to a higher regulatory standard than those with limited resources.

- OrgTrust: Faith that the organization wants to "do the right thing" is perhaps the most important and elusive of the organizational categories. In some ways, it is a meta-category, capturing many aspects of the other organizational and technical capabilities under one catchall category. The point here is to separate these other factors from the general question as to whether the regulated organization is a "good apple" in the language of Bardach and Kagan. Good apples, those organizations who are trying to be good but occasionally slip up, both should and do receive greater leeway then bad apples. LANL faces a classic public trust problem in this area – the number of bad apples at Los Alamos has declined from something approaching 100% in the early 1990's to something approaching 0% in the year 2000 (at least in the perception of one manager), but LANL is still living down a legacy of negative bad apples with its regulators. As regulators change jobs and move from place to place, both hard data and organizational lore are passed from regulator to regulator. The perception of faith in an organization may last years past the initial incidents which caused the mistrust, and years more then the people who first experienced or observed them. This, of course, frustrates and dismays those who work within the improving regulated organization. "Why don't they see that I'm trying to do the right thing?" is a common question posed by managers at LANL. This frustration may grow exponentially as the organization continues to be treated like a "bad apple," years after its original offenses against the trust of regulators.

- OrgConfidence: This is perhaps the most hidden of the factors involved in organizational task environment perceptions, the confidence factor. A regulator would have to have strong knowledge of an organization to judge whether they could pull off a strong implementation of a corrective or compliance measure. For regulators and pseudo-regulators though, it is possibly the most insidious of factors, eating away at the credibility of an organization when it makes claims to its regulators. In the last section of this paper, the skills of the implementor will be discussed in further detail, but one quote from a Department of Energy official is telling, "I think they want to do the right thing almost all the time, I just don't have any faith that they can do it (2000)."

- OrgHide: Is the nature of the regulated organization to hide things, or to come clean about them? Does the regulator perceive that the larger organization encourages the reporting of error from individuals inside it, and does the regulator perceive that those individuals will act in a forthright manner towards the regulator. OrgHide is distinguished from OrgTrust in that OrgHide refers to the perceived likelihood that the organization will hide information if they make an error whereas as OrgTrust refers to a more general perception of a desire to "do the right thing." At LANL, these questions are among the most central to the regulatory relationship. LANL is a place of both secrets and secrecy. LANL's regulators, almost universally, do not see the lab as a place that is forthright and sharing with regulators. One state regulator's quote is instructive: "they kept telling us for years that there was no problem with the water, then all of a sudden, there's all this contamination – and it turns out they've been sitting on this data for six months, every time we think they're becoming more honest – something like this happens (1999)."

- OrgTransp: Organizational transparency is, in a nutshell, the understanding an outside regulator has about the organizational structure of the regulated firm or group. Responsibility and accountability are two key factors mentioned by regulators, but the larger factor is a simple understanding of how the organization functions. In a multi-faceted and complex organization like LANL, this poses severe and ongoing problems for regulators. External regulators of LANL constantly explain that they are at a loss to understand how the internal structures of the organization work and express dismay when an organization they thought was responsible for one activity claims not to be responsible for it at all. This presents a serious roadblock to the kind of generalized transparency this research concerns. This impact will be addressed in the next section on barriers.

- OrgConstrain: Organizational constraints, the limiting factors influencing the ongoing operations of the organization deploying the technical system, are tied into both resources and implementation. As above, a regulator must have a strong sense about an organization to really understand its constraint level. As indicated under resources, constraints may be a double edged sword. A regulator is more likely to give leeway to an organization facing significant constraints, but at the same time, the regulator may have more faith in an organization that has good intentions, and few constraints on achieving them. Although the comment was made more about public trust and confidence then about external regulators, one senior lab manager's comment is instructive, "they don't understand that other people tell us what we can and cannot do." Indeed they do not, but many times LANL managers believe that these constraints are somehow obvious to external actors. First, this is rarely true and the lab rarely acts to make these outside constraints clear to other actors. Second, it may not matter that much. As far as the public is concerned, the idea that LANL suffers from being regulated by DOE is nonsense – it is all one organization. The same holds true for some external regulators as well.

## Technical Factors

- TechSim – Recognizable technical implementations are a recurring theme in both regulatory and internal regulatory actors. Regulated entities are often judged against their peers, and technical choices made in one facility may impact the regulatory conditions of another. At Los Alamos, this plays out in inter-facility and intra-facility manners. In the inter-facility instance, a regulator sees two different technical implementations at two different facilities doing similar work at LANL. Even if one is no better or worse than the other, it often becomes a source of contention. This has commonly played out in areas of LANL that use administrative as well as engineered safeguards for radiation protection. Where engineered safeguards have been implemented, often a regulator has concentrated on why administrative safeguards are used in other locations. The same thing plays out across similar facilities. At LANL, Sandia and Los Alamos often do similar things differently. Regulators, especially those close to the process, often cite these differences in discussions about how design impacts their work. While not noted specifically in any data from LANL managers, this factor would seem to be very important.

- TechQual: The quality of a technical implementation has a good deal of impact on regulators, but it is often understood by engineers as having a much larger impact then regulators seem to feel it does. Elegance in design and implementation is a strong component of what drives many engineers, but it is rarely cited by regulators in their discussions of design. It is certainly possible that the impact of this is underappreciated by regulators – perhaps it has a sort of hidden impact on their behavior.

- TechError: The likelihood of error in a specific technical implementation clearly has an impact on regulators. How prone to error is a specific system and how do those errors interact with variables in TechHide and TechVis?

- TechVis: From an unintentional perspective, this category addresses the transparency of errors when they occur. In a nutshell: how likely is it that both the operator and the regulator will see an error if it happens. Realtime monitoring technologies such as NewNet at LANL create very visible errors to study. TechVis encompasses both the clarity and speed of feedback.

- TechHide - The ability to hide problems behind a specific technology is one aspect of transparency that was mentioned rarely in interviews. In this framework, TechHide refers to the ability of a technology to allow for easy intentional misleading of external observers. Does a specific technical implementation make is easier or harder to fool a regulator into believing an organization is in compliance?

- TechGrasp: Understanding how a system works is an important aspect of regulation. Too often, regulators use proxies for regulating when systems are not understood as whole. Managers find these proxies frustrating, prompting comments such as, "why should they ding me for record keeping, can't they see how well the system works." Technical choices change the way people understand systems. Some systems are easy to grasp immediately while others are much more difficult to understand.

- TechTransp: Transparency captures many aspects of this framework. Here, the focus is on how the component parts of the system appear to the regulator. A favorite example comes from a new Biological Safety Level 3 facility which recently came online at Harvard University. Between each negative pressure room is a clear tube with a ping pong ball in it above the door. The ping pong ball sits on whichever side of the door the pressure is lower on (following the direction of airflow). Here, a component of a larger biological safety system is represented in a uniquely transparent way – and the transparency is of a form that even the least technically competent observer can immediately grasp its meaning. It is used, of course, in addition to the technical controls and gauges which monitor the pressure of the various laboratories in the facility, but it serves as a transparent and simple feedback device which has obvious and useful meanings.

- TechMaintain: A technical implementation is only as good as its maintenance. The maintenance of systems and facilities plays an important role in regulatory behavior. Sometimes, this maintenance is "under the hood" and sometimes it is quite cosmetic. At a nuclear power station in California, the dark cement floors were painted light gray and then coated with a shiny lacquer. Liquid of any kind shows up very obviously against the floor. The amount of liquid spilled or leaking, in this case, a proxy for maintenance level, is obvious to anyone who walks through the plant. This sort of second level transparency feeds into perceptions of competence and maintenance.

These factors together represent a first attempt at structuring the task environment variables related to regulatory behavior. The framework is not set-in stone but is useful in analyzing how regulatory behaviors play out in different situations as those situations are modified by and constructed by the regulated entity. Unfortunately, in the context of LANL, these actions are often difficult to undertake. The next section begins to address some of the constraints facing an organization that decided to take seriously the idea of managing its regulatory environment in proactive fashion. Ongoing regulation is a dynamic system with many variables effecting its ongoing operations. Taking as its basis the framework laid out above, this represents a short list of things which make manipulation of these variables more or less difficult.

## Factors Which Make Strategic Regulatory Action Less Likely/More Difficult

LANL is a highly regulated, complex facility with a history of self-regulation and secretiveness. These factors, detailed in the description of LANL regulatory environment above, present many obstacles to the implementation of the sort of analysis described above. While the framework presented here is really an analytical one, it has implementable lessons for those who manage and design large technical systems. This framework presents the opportunity to structure a research agenda to more fully develop these implementable lessons. However, although these lessons are not fully developed now, the framework presents the opportunity to consider what sorts of constraints would face the organization that decided to develop and implement these lessons. A short list of those lessons from the LANL perspective follows:

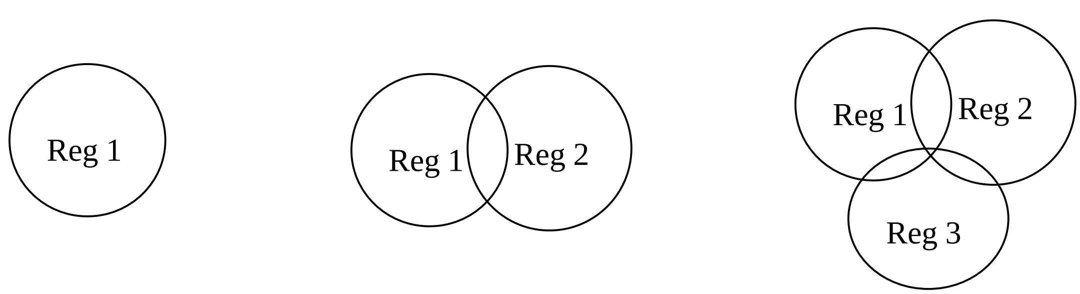
1. Conflicting, Overlapping Networks of Regulation

LANL exists in a complicated web of regulatory actors, with overlapping and sometimes conflicting responsibilities, both within and across regulatory domains. Within a single domain like air quality, multiple regulators may attempt to apply different standards or different interpretations of the same standard while each lays a claim to direct regulation of the lab. Across domains, multiple regulators may make claims in clear conflict with each ohter. For instance, different parts of DOE regulate radiation exposure and security, but the ALARA (as low as reasonably achievable) rules and the two man rule for security areas may come in to conflict on a regular basis. In the first type, it is possible to imagine finding a source of arbitration between two regulators or regulations within a domain – it is not easy, but it is at least conceivable. In the second case, it is even less likely with different regulatory groups claiming expertise over different domains, and little common ground on which to base a compromise between them.

These regulatory networks significantly affect the ability of LANL to manage its regulatory environment in at least three ways. First, the shifting patterns of the regulatory landscape make a baseline ground for action difficult to find. In the chemical industry's experience with Responsible Care, a reliable baseline of regulation turned out to be a hidden and unknown critical component of the success of their efforts at moving "beyond compliance." In the mid 1990's with a deregulation-based Republican Congress in power, this regulatory baseline began to decline and the coalition that held together the responsible Care project was nearly destroyed. Several medium sized players found that exploiting lower standards in the new regulatory environment allowed a much greater return then their beyond compliance activities had in the context of a stronger regulatory system. Baselines at Los Alamos are constantly in flux, in large part due to the multiple layers of regulation LANL is subject to.

Second, the "surprises" of multiple regulators may cause even the most ambitious laboratory entrepreneurs to lose hope in the possibility of gaining greater control over the environment. Many internal inbetweeners at the lab have worked hard to establish a relationship and agreement with one regulatory organization, only to find that another one comes and criticizes it for a misinterpretation of their rules. This is particularly the case with the more mission-flexible regulators such as DNFSB, in contrast to a more mission-constrained regulator such as NMED.

Finally, and most importantly, the demands of strategic management of a regulatory



environment increase far faster then the number of regulatory actors, as their numbers increase. One regulator may present many difficulties for dealing strategically with it, but two regulators present not only their own unique demands, but the challenges associated with finding a common ground for strategic action within which the regulated actor might operate.

The diagram above represent the same concept graphically. Each circle represent a sphere of interpretation by a single regulator. In the first, the entire area of the interpretation represents a possible common ground from which strategic regulatory action could be launched. In the second, that ground is reduced to the overlap between the spheres of interpretation of two regulatory actors. Finally, in the third case, with three regulatory actors, that sphere of action is reduced farther still.

2. Secrecy

Nearly every regulator at the lab, even those with DOE, regards the lab's current secrecy, and its legacy of secrecy, as a serious barrier to cooperative regulation. Many things at LANL are and should be secret, but this still represents a serious constraint on the ability of LANL to behave in a transparent fashion. For at least one regulator, this takes on a more nuanced criticisms:

> It's not just secrets, it's secretiveness. Especially with people from the weapons side… We wish they were very open, we want them to tell us how it really is…. Openess is the way, you accept the problem and you show us what's really happening.

At least on a perceptual level, this regulator draws the distinction between things which are secret, and a general attitude towards secretiveness – an attitude which is mentioned by many regulators as "plaguing" the laboratory.

3. Compartmentalization – Absence of "one lab"

Speaking of "the laboratory" is, in most cases, inherently flawed. At best, there are perhaps twenty laboratories worth giving independent thought to at Los Alamos, and at worst, perhaps every working group at the lab might be thought of as its own laboratory. In the absence of central coordination or command of regulatory compliance, efforts at taking strategic action to manage regulators is inherently more difficult. This is further exacerbated by independent understandings and agreements made by different subsections of the laboratory and their regulators, and by a lack of communication among these parts on regulatory issues.

At the same time, regulators often perceive the laboratory as one laboratory, with resources and communication between its parts. Although they may identify parts of the lab which are better and worse then others, the perception is often that the laboratory does something, not an individual or group within it.

On the other hand, the laboratory also has the possibility of learning from multiple "laboratories of regulation." There are possible lessons to be learned from all over LANL which would be helpful in pursuing a more coordinated strategy for dealing with and managing regulation.

Suffice to say, the shared responsibility for regulation at every level of LANL has both strong and weak points in terms of the lab's regulatory performance. One particularly weak point however, is the absence of an overall strategy for regulatory compliance and management. In addition, because of the compartmentalization of regulatory responsibility, no one group in the laboratory perceives itself as having responsibility for regulatory management – and indeed, no one group does.

4. Perceptions of Internal Los Alamos Regulators, Roles of Same

At LANL, regulatory interpretation and implementation is carried out in large part by regulatory-inbetweeners – groups such as the environmental, safety, and health groups and others which both interpret and enforce the regulations internally at LANL. Another major issue has to do with regulatory perception of the lab as having few if any resource constraints. They see a group of people who are very well funded by their standards, and exceedingly well paid and trained. Regulators thus often see Los Alamos as a place unfettered by money or personnel constraints. Incidents of "inability to move funds to that project" have been greeted with exclamations of frustration from regulators. These individuals are not inside the organization and do not know the constraints it operates under. Unfortunately, no one at the lab has made a substantial effort to inform them. Even this, however, might not be enough. This perception on the part of the regulators may not be particularly changeable.

Consider this very telling quote from a regional regulator:

> They have the best chance of anyone in the country, they have the people to be at 100% on everything. The must have the resources to show that it doesn't make sense for them to exert the energy to move to beyond compliance (1078:1998)

Regulators see the lab as a place of expertise and abundant resources. Its behavior, on the other hand, often appears to be very constrained. From that, regulators often judge that the lab is choosing to move slowly or ineptly, when much of their action is limited by draconian rules and resource constraints. This subject is also covered in further detail in the accompanying Regulatory Ecology paper.

5. Conflicting Norms

Engineering norms and regulatory norms often do not mesh well. The elegance of design is not necessarily a factor in regulatory behavior. At the same time, engineers' desires for specific requirements to meet regulations are often not matched by similar desired on the part of managers or regulators. From a managerial perspective, consider one LANL manager's comment:

> We know that 6 months is too long (to characterize waste) and we know that 2 weeks isn't enough time, but we can't ask the question to the regulators, because God knows what the answer would be (104/6.99)

Specificity is clearly not always a good thing from the perspective of managers. From the regulatory perspective, being specific means going out on a limb to say that something will meet a regulation. This is not as straightforward as it sounds, regulators change and regulations are interpreted differently over time. Further, an individual regulator usually does not have the authority to specify what constitutes compliance, even if he or she believes they do at the time they make the statement. Specificity is a constant problem for managers and others at Los Alamos, a topic developed in Jude Egan's accompanying report.

6. Costs not understood / Costs not priority.

LANL does not know what the total costs of regulation are to the lab, nor does it know how those costs are distributed nor how many of those costs could be reduced or, perhaps, need to be increased. Neither the accounting nor metrics exist for such a calculation. LANL doesn't really even know how many regulators it deals with, much less what the costs of regulation are to it. These costs are distributed and are experienced variously by people with responsibility for a regulation, groups, divisions, and even individual scientists and projects. One senior manager at LANL suggests this explanation for the lack of understanding of costs when asked about attempts to manage those costs more effectively:

> Intuitively, you would think it's more costly in time, in dollars, and in [safety] [to behave in an uncoordinated way], but on the other hand, it's distributed, so no one really cares because no one is effected enough to do anything about it (1998 – safety inserted to hide the regulatory area under discussion with interviewee).

7. Arrogance

LANL is often accused of arrogance, sometimes appropriately. In analyzing the role it plays , it is perhaps better to term it "perception of competence." In the regulatory arena, this plays out in two ways. First, the lab's people usually see themselves as significantly more qualified then their regulatory peers. Second, internal arrogance about the best practice for a specific regulatory compliance often leads to many approaches to the same problem. In the first instance, the result is often a talking down to individuals who come in from both the State and Federal governments. A perverse situation develops in which LANL hires away the best of the state regulators, leaving behind not merely ones who are perceived to be less qualified, but also those who were rejected from employment at the Lab and may harbor very negative feelings towards it. In the second and more serious case, internal perceptions of best practice differ markedly from one group or division to another. The perception that each group's interpretation of the rule and solution to it are the best, further detracts from the sense of "one lab" with a unitary responsibility for regulatory compliance.

## Beyond Compliance?

Beyond compliance has become a popular phrase in regulatory circles, as companies around the world work to improve their regulatory performance. It is heard around the lab, both from managers and from regulators. Moving beyond compliance is indeed an excellent goal for the laboratory, but exceeding standards does not necessarily translate into improved regulatory relations. Merely tightening one's own standards does not, in and of itself, achieve the sorts of goals laid out in the preceding sections.

It is important to keep this in mind, because the results could otherwise be frustrating. Early experiments at beyond compliance at LANL could lead to the belief that exceeding standards did nothing to improve regulatory relationships. Unfortunately, this would be the wrong lesson to learn from the experience. The real conclusion is that exceeding standards alone may not be enough to positively impact regulatory relationships. A strategy and an understanding of the regulatory environment and factors influencing regulatory behavior are both necessary to achieve this goal.

The framework laid out in this paper suggests the larger set of issues which are necessary to consider before attempting to improve relationships with regulators. They concentrate on how regulators see what happens inside your organization in general terms, but this poses one last topic of concern that must be considered.

## Rethinking Good Apples

Transparency, of technologies, of motives, of organizations, is the theme of the framework laid out above. The advantage of transparency is that your regulator sees you for what you are. The disadvantage of transparency is that your regulator sees you for what you are.

When the regulator begins to understand the organization he or she is brought into in a more specific and specialized manner, the danger, of course, is that he or she finds out what you didn't want them to know. At LANL, the question was posed to managers, "how would you behave if you, knowing what you do about the lab, were put into the position of regulator." Most of the managers this question was put to laugh initially, and as often as not, this laughter has the ring of fear to it. While most individuals at LANL feel that the people here are very bright and have good intentions, the general feeling is that, as often as not, the perversities of the organization and operations of LANL would make most of the managers here very skeptical regulators.

Opening one's organization up to the outside world, whether it be to clients, competitors, stakeholders, or regulators, is a demanding task fraught with potential problems. However, it is also an action which can yield great benefits – especially if the openness is a managed and considered one, rather than one which is haphazard and disorganized.

## Conclusion

This paper develops an initial framework that can be used to add structure to discussions and thinking about regulatory strategy. Its focus is on those factors that influence regulatory behavior which are under the direct control of the regulated entity. These factors are both organizational and technical in nature, but at their core, they are all about transparency and the creation of understanding. Most organizations feel that the behavior of regulators is out of their control. The point of this exercise is to develop a language and theoretical bases for understanding the extent to which this belief is and is not true in organizational practice. From that analytical point, there exists the potential for a new understanding of regulation in the technical and managerial context.

# Methodological Afterward: Project Team Field Research Activities 1998-2000

The LANL/UCB
**Stewardship**
**Project**

Final Report

Todd R. La Porte
**Principal Investigator**
**Center for Nuclear and Toxic Waste and**
**Department of Political Science**

## Methodological Afterward. Project Team Field Research Activities - 1998, 1999, 2000.

Activities providing the data and insights noted above included a) intensive interviewing and observation of some **185 people** a number several times, and b) a series of events and regular institutional processes.

**A. Members of the team interviewed** the following: (In all some 100)

Unless otherwise noted, all activities were conducted by the P.I. (L)
Team interviews (including GRAs Stone and Egan) are indicated by ##.
Solo work by other team members, GRAs Stone and Egan, indicated by #S and #E respectively.

| Function - Interviewees | Field Researcher: By Year 98 | 99 | 00 |
|---|---|---|---|
| **UC Lab administration** (Dealing with overall organizational and regulatory matters.) | | | |
| UCOP Vice Provost for Research Robert Shelton | L | | |
| Laboratory-University Relations, Rulon Linford, Assoc. Vice Provost, Research* | L | L | L |
| ES&H oversight, Howard Hatayama, Dir* | | ## | #S |
| Lab Oversight Rick Notini | | | #S |
| Lab Oversight Ken Groves | | | #S |
| **Regulatory Surround** | | | |
| Defense Nuclear Facilities Safety Board (DNFSB) Albert Jordan, Program Director; | L | | |
| Group Leader Nuclear Weapons, James McConnell | L | | |
| Technical Specialist, Farid Bamdad, | L | | |
| Nuclear Regulatory Commission (NRC), | | | |
| Assist. to Commissioner Neils Diaz, Anthony H. Hsia | L | | |
| **DOE Proper** | | | |
| NEPA Compliance & Outreach (MOX project) David Nulton, Director | | | L |
| DOE-LAAO Overseer Jimmy Harris | | #S,E | |
| **LANL Lab programs and administration.** | | | |
| Laboratory Director, John Browne | L | | |
| Former laboratory Diector, Sig Hecker (ret 10/97)] | L | L.#S | L |
| Special Assistant to Director, Pete Miller | L | L | L,#S |
| former Assistant Lab Director Science & Technology | | | |
| Governmental Relations, Karl Braithwaite | L | L,#S | L,#S |
| Assistant to Director Harry Otway | L | L | L,#S |
| Integrated Safety Management, Phil Thullen | L | L#S | L,#S |
| Deputy Director, Business Administration and Outreach | | | |
| Human Resources (HR), Helga Christoferson, Dir | | | L |
| Quality Improvement Off., Bill Wadt | | | L,#S |
| Assoc. Director - Strategies and Supporting Research | | | |
| Science Technology Base:(STB) & LDRD, Allen Sattelberger | L | L | |
| University Relations/UC S&T Council, Jim Porter | L | L | L |
| Public Affairs Office (PAO)- Sylvia J. Brucchi | | L | |
| Public Affairs, Gustafson, John | | #S | #S |
| Energy and Sustainable Systems Prog, | | | |
| Nuclear Fuel Cycle, Edward Arthur, Prog. (Nuclear vision) | L | ## | L,#S |
| ATW, Deborah Bennett, Prog. Dev, (See TSA-10/MOX 99) | | | |
| Assoc. Director for Science and Technology, Wm. Press | L | | |
| Special Assistant to Assist. Dir. for Science and Technology, George Kwei | L | L | L |
| Assoc. Director for Threat Reduction - John D. Immele, Assoc. Director | | L | |
| Chief of Staff, Mary Ann Yates | | L | |
| CISA (MOX and Russian Nuclear Cities) Jim Toevs, | L | L | L |
| Assoc. Director for Operations, Richard J Burick, | | | L.#S |
| Spec. Assist , Tom Gunderson,. | | #S | L.#S |
| Fire Marshall, Jim Gordeaux (Regulatory Game) | | | #E |

| | 98 | 99 | 00 |
|---|---|---|---|
| Assoc. Director - Nuclear Weapons Programs, Steve Younger (Surveillance, Rebuild) | L | | |
| Special Assistant, Phil Goldstone | | | L |
| Weapons Safety Studies, George F. Hurley | | | L |
| Dpt ALab Dir. NW Sci.-based stockpile stewardship, Jazz Mercer-Smith | L | | |
| Dpt ALab Dir NW Stockpile Systems ,Carolyn Mangeng | | L | |
| Nuc. Materials & Stockpile Management NMSM >98 Paul Cunningham, Dir | L | L | |
| Nuclear Weapons - Materials & Manufacturing (NW-MM), Prog. Dir. Scott Gibbs | L | L | L |
| Program Assistant, Micheline Devaur | | ## | L |
| Nuclear Component Readiness, T.(Turner) J. Trapp | L | L | L,#S |
| Systems integration, Kim Martin | | L | |
| Weapons requirements development, Bob Spenser (w/TSA-7) | | L | |
| Risk & Safety Management, John Kindinger (w/TSA-11) | | L | |
| Nuclear Materials Program, Joel Williams | L | L,#S | L |
| MAAS, Tresa Yarbro (w/NMT-3) | | L,#S | |

**Division Operations** (Those involved with handling plutonium and NW components)

| | 98 | 99 | 00 |
|---|---|---|---|
| Nuclear Materials Technology Div.(TA-55) | | | |
| NMT Technical Review Comm. Chairs, | | | |
| Susan Wood; Dir. Savannah River Technology Center (00) | | L | L |
| Ned Wogman, Assoc. Dir. National Security Prog. Pacific Northwest Lab. (8,99) | L | L | L |
| Division. Director, Bruce Matthews (98, 99) | L | L | L |
| Division. Director ,Tim George (2000) (see below, Power sources) | | | L |
| Act. Dir. Director, Dana Christensen, 99 | L | L,#S | |
| Chief Scientist, K.C. Kim | ## | ## | ## |
| Seaborg Institute, David Clark, | L | L,#S | L |
| Chief of Staff, Will Parsons (98,99) | ## | ## | ## |
| Patrick Trujillo, (00) | | | L,#S |
| Bus/Finance, David Williams | | ## | L,#S |
| Facilities/space mngt , Bob Quinlan | | L | L |
| Pit Manufacturing, Vann Bynum | | L | L |
| NW work force, Brett Kniss | L | | |
| Stabilization & Disposition, Randy Erickson, [Re: ARIES/MOX] | L | L | L |
| Planning and Schedules, Jim Ostic (see TSA 98) | | L | L |
| IPP NMT-DO Integration (Bechtel/LA) Dennis Smith | | | L |
| Tech Modeling Pit processes (TSA-7) Mark Burnside | | | L |
| Systems Integration, Ken Courtney | L,#S | ## | ## |
| Systems planning, Beth Joseph | L,#S | ## | |
| Consultant, Gerd Rosenblatt | L | ## | L |
| Consultant Thomas Hill | L | ## | L |
| Consultant/ Mentor: David Odland | | | ## |
| Consultant/ Mentor :John LaPointe | | | ## |
| Waste Minimumization, Sam Pillay | L | L | L |
| Performance Assurance, Safety & Training, Bill Zwick (98, 99) | L | ## | L,#E |
| Issues Management ,Jennifer Pratt | L | L,#E | L,#E |
| Training, Todd Conklin | | | L |
| Regulation and Diversity, Dwight Herrera | | L | |
| Organization Operations, Carmella Romero | | | #S |
| | | | |
| Dep. Dir. Operation , Karl Stadhammer, | | | L |
| Actinide Chemistry (NMT-2) Joel Williams, Grp Ldr (see NMT Proj 00) | L | L | |
| Deputy Grp, Steven Schreiber, L | | L | |
| Process analysis (NMT-2) Sammi Owens | | L | |
| Nuclear Materials Information Management, (NMT-3) Patrick Brug, Grp Ldr | | L,#S | |
| Deputy Grp Ldr, | | L#S | |
| Nuclear Material Management & Control, (NMT-4) Dennis Brand, Grp Ldr. | L | L | |
| MASS analysis, Tresa F Yarbro | | L | |

| | 98 | 99 | 00 |
|---|---|---|---|
| Vault supervisor, Cindy Mills, | | L | |
| Non-Destructive Assay Lab, Sandy Hildner, (Pure Pu assay) | | L | |
| Weapons Technology, ( NMT-5) Stevie Hale (98) Mark Dinehart, Grp Ldr. (99) | L | L | |
| Deputy. Grp Ldr. Doug Kautz (Proj.Ldr.Pit Surveillance) | | | L |
| 1994-1 R&D; Chair, NMT Technical Advisory Comm., Gary Eller | L | L | L |
| UK Advisor (John) David Hird | | L | L |
| Pit work Scheduler, Steve McKelvey | | L | |
| Plutonium Casting, John Huang (Team Ldr) | | L | |
| Lead Technician, Kenny Vigil (And team of four) | | L | |
| Plutonium Machining, Pat Rodrigez (Team Ldr) | | L | |
| Lead Technician, Steve Boggs (And team of four) | | L | |
| Advanced Tech R&D (NMT-6), Larry Avens,Grp Ldr . | L | L | |
| ARIES Program Proj, Tim Nelson (98,99) | L | L | |
| 1994-1 R&D (ARIES, 99) Steve McKee | L | L | |
| 1994-1 R&D/ Chjr Div Tech Adv. Comm., Gary Eller | L | L | L |
| ARIES Brad Smith (98,99) | L | L,#S | |
| MOX Stan Zygmunt (CST-18) | L | L,#S | |
| Waste Management & Environ.Compliance, (NMT-7), Jim Balkey, Grp Ldr | L | | L |
| Deputy Dir Environ.Compliance ,Ron Wieneke | L | L | |
| Regulatory aspects, Mark Robinson | | L,#E | #E |
| TA-55 Facil. Management, (NMT-8) Deidra Yearwood | | L.#E | |
| Facilities Management, TA-55, Tom Blum | | | #E |
| Power Sources, (NMT-9) Tim George, Grp Ldr (98,99) | L | L | L |
| MOX fabrication team, Ken Chidester (w/Alberstein & Buska w/TSA-10 see below) | L | L | |
| Industrial Q.A. (MOX vs Ur feed), Amy Ecclesine | | L | |
| Chemistry, Metallurgy, & Materials (NMT-11) (CMIP) Walt Stark, Dpt Grp Ldr | L | L,#S | L |
| Weapons Certification, Rueben Gutierrez | | L | |
| Pit-Disassembly & Surveillance Technology (NMT-15) Tim Nelson | L | L | |
| Pit Surrveillance, Patrice Stevens Team Ldr | L | | |
| NMT/CMR Rad Protection (ESH assigned) Paul Hoover, | L | L | |
| Health Physics Team Bob Stokes (ESH-1) Team Ldr. | | L | |
| Dave Wannigman, Proj. Ldr. Target Zero | | L | |
| | | | |
| Materials Science Technology (MST-DO) Ross Lenoms, Div. Dir. | | | L |
| MST-6 Richard Mah. Grp Ldr (99) | | L | |
| Grp Ldr. Ray Dixon (Subsequent observation, Jan. 2000, three technical teams) | | L | L |
| Metalurgy, Duncan Hammon, Team ldr | | | L |
| Beryllium Technical Facility, Steve Abeln, Team ldr | | | L |
| Be Plasma Spray team, Rich Castro, Team ldr | | | L |
| Kendell Hollis - | | | L |
| Brian Bartram - | | | L |
| Foundry team, Paul Dunn, Team ldr | | | L |
| Phil Tubesing | | | L |
| Deniece Korzekwa | | | L |
| Robt. Aikin Jr | | | L |
| | | | |
| Dynamic Experimentation (DX-DO), Robert Day, Div Dir. | | L | |
| Jay Dallman, Chief of Staff. | | L | |
| Paul Cunningham, (Special Assistant) ) | | | |
| Detonation Science and Technology, (DX-1) Pruit Ginsberg, Grp Ldr | | L | |
| Development & Engineering., Derrick Montoya, Team Ldr | | L | |
| (Discussion with engineering team of five) | | L | |
| Production, Larry Lucero, Team Ldr | | L | |
| (Observed production team of five staff) | | L | |
| | | | |
| Eng. Sciences & Applications (ESA-DO) Earle Marie Hanson, Dir. | | L | |
| Luis Salazar, Design Agency (DA) Representative. | | L | |

| | 98 | 99 | 00 |
|---|---|---|---|
| Assembly process. Laura McNamara , w/Archives and History Programs | | ## | |
| <u>Technical Systems Assessment</u> (TSA) Anal & Assess Div. | | | |
| Nuclear Futures, Systems Engineering & Integration (TSA-3) Bob Krakowski, | L,#S | L | L |
| Technology Modeling and Analysis (TSA-7) Terry Helms Gp Ldr | L | | L |
| CMIP analysis, Nelson DeMuth Nuc.System Team Leader | L | | |
| Enterprise Model/Pu modelling, Jim Ostic (see NMY above 99, 00) | L,#S | | |
| Production force, Al Valentine (LA TechAssoc) | | L | |
| Nuclear Design &Analysis (TSA-10) -Deborah Bennett, Grp Ldr (See ATW above) | | L | |
| Allen Neuls (Dep. Gr. Dir) | | L | |
| DOE/NRC regulatory relationships, Charles R. Bell | | L | |
| Nuclear Materials Disposition (MOX) Team, John Buksa, See above NMT 9 | L | L | |
| MOX Program, David Alberstein | | L | |
| Probablistic Risk and Hazard Assessment (TSA-11) Desmond Stack, Dep. Grp Ldr. | | | L |

**Regulatory Reconnaissance.**

| | 98 | 99 | 00 |
|---|---|---|---|
| State of New Mexico, Environmental Department | | | |
| Water Quality, Steve Yanicak | | #S | #S |
| Air Quality, Ralfe Ford | | #S | |
| LANL/UC Responders | | | |
| UC-ESH Panel Members | | L,#S | |
| Audit Office, Ivan Wachler (AA-2) (Regulatory Nets/Games) | | #S&E | #S&E |
| <u>Legal Office</u> | | | |
| Environmental Regulation, (RCRA) Ellen Louderbough, | | | L,#E |
| Environmental Paralegal, (RCRA) Catherine Thayer | | ## | L,#E |
| Senior Staff (RCRA) Joe Rochelle | | ## | |
| Environment, Safety and Health Div (ES&H), Dennis Erickson, Dir | | ## | L,#S |
| Chief Scientist, Wayne Hansen | | L,#S | #S |
| Dpty Dir. Lee McAtee | | | #S |
| Chief of Staff, John Fox | | L,#S | L,#S |
| Institutional Performance Cynthia Blackwell | | | #S |
| Radiation Protection, Joe Graf, Prog Mngr. | | L,#S | L,#S |
| Program SiteWide EIS, Doris Garvey | | L,#S | L.#S |
| ALARA, Bill Eisele (Regulatory Game) | | ## | #E |
| Operational Integration Off. Robbie Robertson (Regulatory Game) | | | #E |
| Regulatory Nets, Jimmy Harris | | #S | |
| Regulatory Nets, John Rogers | | #S | |
| Regulatory Game, Filbert Romero | | | #E |
| Regulatory Game, Rick Breke, ESH -7 | | | #E |
| Regulatory Nets - Ecology, (ESH-20) Diana Webb | L | L,#S | |
| L,#S | | | |
| Citizen Outreach, John Bartlit | | | ## |
| Other: | | | |
| LANL Volunteer Activity - On Common Ground: Chick Keller, Dir. IGPP L | L | L | L,#E |
| LANL Contractor, Kandace Favorite (Regulatory Nets) | | | #S |
| Public Attitudes, Hank Jenkins-Smith - UNM-ABQ | | #S | |
| <u>Informal Lab contacts</u>. | | | |
| Computer Sciences, Wu Chen Feng | | | #E |
| Design (X) Division, Jeff Johnson | | | #E |
| " Jeff Favorite | | | #S |

41 (~185) (summed up there are nearly 190 difference people interviewed with a sizeable number attending informal feedback and discussion session concerning the findings of this work.)

In addition, presentations were made to a variety of groups interested in our work. These include:

Adam Stone presented his work on "Regulatory Strategy and Regulatory Ecology," August 2000 to:

14 Members of S Site Safety Meeting from ESA and DX
40 Members of the Operations Working Group
45 Members of the NMT All Managers Meeting

Todd La Porte and the UCB team (Stone, Egan and Koehler) lead a seminar on elements of public trust and confidence in the LANL environment, ES&H seminar series, July 2000.

**b) Learning Events within and in connection with LANL**.

During the summers' field work, team members observed a number of LANL events and organizational processes from which we learned a good deal about the informal and social currents at the lab and in the community.

The signal event for this learning, Summer 99, was participation in the LANL "Security Immersion," in mid-June. This two day event was in direct response to great concern from the DOE Secretary's Office about the implications of the Wen Ho Lee espionage matter. It involved a two day "stand down" from regular work and the required attendance at a series of security briefs, history and attempts to fashion responses tailored to the specific of each Division. All members of the team participated. Covering all those who regularly were involved in lab work, the implementation of this effort required widely dispersed gathering both on-site and in Los Alamos proper. Team members were distributed across various locations, some within secure areas, others in facilities where uncleared employees and summer students experienced the briefings. This unexpected development provided extraordinary windows for understanding the effects of the changes in the Lab's and DOE's social and political world upon the daily lives of highly skilled technical professionals, and younger aspiring scientists and engineers.

A similar experience came in summer, 2000, in the lab's response to the "missing disk" episode within the X-4 group. Again this included a security stand down - one day of briefings and review of procedures within NMT. All team members took part.

Other organizational processes included: (itemized by team member.)

# <u>Todd LaPorte</u>

* NMT Division Technical Review [3 day annual meeting] (98,99,00)

* Managers= Stand up meetings [Daily, early in the day - 10+] (98,99,00)

* Attended NMT Division Management Team meetings. Provided opportunity to observe dynamics of NMT management at a time of high demand. (98,99,00)

* Attended all NMT management meeting as the Division responded to pressures to review and tighten security measures. (99, 00)

* Attended a program review for the Defense Programs with special emphasis on NMT's role. (98)

* Attended multiple meetings of the NMT-French team of MOX designers in their attempt to development cooperative relationships. (99)

* Attended a management planning session of senior management, the Dynamic Experimentation Division (DX). (99)

* Aftermath of the Cerro Grande Wild fire, (00) including Public Outreach Meetings, Historical Society Sponsored Cerro Grande Meeting; and Sierra Club debriefing on the fire.

# Adam Stone

* Attended several ESH Division Managers Meetings (00)

* A multi-day tour of the Nevada Test Site and Yucca Mountain Project (along with Andrew Koehler a former team member who has become a LANL GRA) to gain a perspective on other sites within the complex. Talked with long-time veterans of the NTS and researchers at YMP about both technical and socio-institutional issues. Provided a unique opportunity to experience some of the pre-test-ban aspects of weapons complex life. (99)

* Observed efforts to integrate behavior-based safety program at LANL including conducting informal interviews with persons who completed the early training program. (99)

* Attended and observed (along with Andrew Koehler) the bio-release meetings at LANL over the summer including the major public meeting in White Rock, and post-decision meetings with UC-ESH. Conducted conversations with key LANL-PA employees responsible for the conduct of the meeting. (99)

* Attended and observed (along with Andrew Koehler) the Peace Action protest at LANL, and the peace action meetings in Albuquerque including planning and strategy sessions and acted as an observer of the peace action protest in Los Alamos and at the laboratory. Discussed conduct of both LANL and protestors with many top-level individuals at LANL. (99)

* Attended and observed LANL/DOE protest demonstration in Los Alamos, and at the laboratory. Discussed conduct of both LANL and protestors with some top-level individuals at LANL. (00)

* Talked about recent developments in the LANL public sphere with UNM public-opinion researcher Hank Jenkins-Smith. Also discussed new developments with individuals from the LANL-PA office. (99)

* Observed aftermath of the Cerro Grande Wild fire, including: (00)
  - Public Outreach Planning Meetings, Cerro Grande Fire
  - Public Outreach Meetings, Cerro Grande Fire
  - Modeling Development Meetings, Cerro Grande Fire
  - Multi-Media Coverage, Cerro Grande Fire
  - Historical Society Sponsored Cerro Grande Meeting