STRATEGIC MANAGEMENT OF NAVY R&D LABORATORIES: AN APPLICATION OF COMPLEXITY THEORY

DIRECTOR OF NAVY LABORATORIES CASE STUDY

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ABSTRACT

As part of an on-going process of centralizing control of government science and technology (S&T) after World War II, in 1966 the Navy went through a major reorganization that was intended to centralize the strategic management of the Navy laboratory system. This centralization was to be accomplished by placing the major Navy research and development activities in a single systems command – the Naval Material Command - and establishing the position of Director of Navy Laboratories. Organizational studies and reorganizations continued for the next 25 years until the Naval Material Command and the Director of Navy Laboratories were disestablished in 1985 and 1991, respectively. This dissertation is, in part, an historical study of the Navy from 1946 to 1966 that focuses on the bureaus and laboratories. It summarizes the organizational changes related to strategic management and planning of science and technology. The 1966 reorganization was a critical event because it created the first formal Navy laboratory system. It is proposed that the 1966 reorganization was not successful in centralizing the strategic management of the Navy laboratory system.

Classical organization theory offers an explanation of this failure. What can complexity theory add? The overarching contribution is in recognizing that a "Navy Laboratory System" existed before one was formally established in 1966. This argument is developed by considering two specific aspects of complexity theory.

First, there is the notion that strategic management of the laboratory system resulted from the complex interactions of the smaller units that comprise the system (rather than the result of organization and process choices by senior leadership). Second, there is the theory that an organization will exhibit different behaviors at different times or in different parts of the organization at the same time. This translates into the idea that at particular times and places, the formal structure was dominant in strategic management, but at other times the "emergent" organization was dominant. In fact, if power law theory is applicable, then the periods of stability (where the formal structure was dominant) ought to be more prevalent than the turbulent periods where the emergent organization was dominant in strategic management.

This case is made by describing agent-based models of the Navy laboratory system at two points in time and using them to identify the expected performance characteristics of the system. Historical and organizational artifacts are then used to make the case that the postulated system existed.

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LIST OF ABBREVIATIONS

ACNO	Assistant Chief of Naval Operations
ASN	Assistant Secretary of the Navy
ASN (Air)	Assistant Secretary of the Navy for Air
ASN (R&D)	Assistant Secretary of the Navy for Research and Development
ASN (RDA)	Assistant Secretary of the Navy for Research, Development, and Acquisition)
BOB	Bureau of the Budget
BRAC	Base Realignment and Closure
BuAer	Bureau of Aeronautics
BuMed	Bureau of Medicine
BuOrd	Bureau of Ordnance
BuPers	Bureau of Personnel
BuShips	Bureau of Ships
BuWeps	Bureau of Naval Weapons
CEO	Chief Executive Officer
CND	Chief of Naval Development
CNM	Chief of Naval Material
CNM (D)	Chief of Naval Material (Development)
CNO	Chief of Naval Operations
CNR	Chief of Naval Research
COC	chain of command

CSC	Civil Service Commission
DCNM (D)	Deputy Chief of Naval Material (Development)
DCNO	Deputy Chief of Naval Operations
DCNO (D)	Deputy Chief of Naval Operations (Development)
DDR&E	Director of Defense Research and Engineering
DLO	Department Laboratory Organization
DLP	Director of Laboratory Programs
DNL	Director of Navy Laboratories
DOD	Department of Defense
DSB	Defense Science Board
DTMB	David Taylor Model Basin
DTNSRDC	David Taylor Naval Ship Research and Development Center
FCRC	Federal Contract Research Centers
GAO	General Accounting Office
GPRA	Government Performance and Results Act
IED	Independent Exploratory Development
IR	Independent Research
IR/IED	Independent Research and Independent Exploratory Development
MILCON	Military Construction Program
NACA	National Advisory Committee for Aeronautics
NAEC	Naval Air Engineering Center
NASL	Naval Applied Science Laboratory
NAVAIR	Naval Air Systems Command

NAVELEX	Naval Electronics Systems Command
NAVFAC	Naval Facilities Command
NAVMAT	Naval Material Command
NAVORD	Naval Ordnance Systems Command
NAVSHIP	Naval Ship Systems Command
NAVSUP	Naval Supply Command
NCCCLC	Naval Command, Control, and Communications Laboratory Center
NCEL	Naval Civil Engineering Laboratory
NCSL	Naval Coastal System Laboratory
NEL	Naval Electronics Laboratory
NHC	Naval Historical Center
NIF	Naval Industrial Funding
NMARC	Navy-Marine Corps Acquisition Review Committee
NMDL	Naval Mine Defense Laboratory
NME	National Military Establishment
NMEL	Naval Marine Engineering Laboratory
NMSE	Naval Material Support Establishment
NOL	Naval Ordnance Laboratory
NORC	Naval Ordnance Research Calculator
NOSC	Naval Ocean Systems Center
NOTS	Naval Ordnance Test Station
NPG	Naval Proving Grounds
NRDL	Naval Radiological Defense Laboratory

NRDRB	Navy R&D Review Board
NRL	Naval Research Laboratory
NSF	Naval Science Foundation
NSRDC	Navy Ship Research and Development Center
NSWC	Naval Surface Weapons Center
NUSC	Naval Underwater Systems Center
NUSL	Naval Underwater Sound Laboratory
NUWC	Naval Undersea Warfare Center
NUWRES	Naval Underwater Research and Engineering Station
NWC	Naval Weapons Center
NWL	Naval Weapons Laboratory
ONM	Office of Naval Material
ONR	Office of Naval Research
OPNAV	Chief of Naval Operations staff
ORI	Office of Research and Invention
OSD	Office of the Secretary of Defense
OTA	Office of Technology Assessment
PE	Program Element
PEO	Program Executive Officer
PM	Program Manager
PPBS	Planning, Programming, and Budgeting System
R&D	Research and Development
RDB	Research Development Board

RDT&E	Research, Development, Test and Evaluation
REFLEX	Resources Flexibility
RMS	Resource Management Systems
S&T	Science and Technology
SECNAV	Secretary of the Navy
SLBM	Submarine Launched Ballistic Missile
SPO	Special Projects Office
SUPSHIPS	Supervisor of Shipbuilding
SYSCOM	Systems Command
T&E	Test and Evaluation
WNY	Washington Navy Yard
WOL	White Oak Laboratory
WSDO	Weapons System Development Organization
WWII	World War II

CHAPTER 1

THE PROBLEM AND ITS SETTING

Introduction

As part of an on-going process of centralizing control of government science and technology (S&T) after World War II, in 1966 the Navy went through a major reorganization that was intended to centralize the strategic management of the Navy laboratory system. There is evidence that the 1966 reorganization did not achieve this objective.

Classical organization theory offers an explanation of this failure. This dissertation proposes to use complexity theory to enhance the explanation. The case is made by describing agent-based models of the Navy laboratory system at two points in time and using them to identify the expected performance characteristics of the system. Historical and organizational artifacts are then used to make the case that the postulated system existed.

It is appropriate to study the historical background before examining the basics of complexity theory and using them to describe the required agent-based models of the Navy laboratory system. This short history will provide the context for the historical and organizational artifacts used to make the case for the explanatory power of complexity theory.

History of the Navy Laboratory System

The Navy laboratory system underwent a number of organizational and process changes in the 1950s and 1960s. These changes, which reflected evolving views within the Department of Defense (DOD), addressed both the proper role of the laboratories and the strategic management of government science and technology. Many of these organizational and process changes reflect a move to greater centralization of strategic management. However, there was not unanimity of opinion on either the role of laboratories or on their strategic management. For example, some theorists[1] argue that decentralized authority is appropriate for this type of organization. Based on this and the historical legacy in the different elements of the laboratory system, it is reasonable to question the actual effect of the formal changes.

Complexity theory provides a theoretical basis for studying the question: Was the strategic management structure of the Navy laboratory system the result of organizational and process choices by the senior leadership of the Department of the Navy or did it emerge from the complex interactions of the smaller units that comprised the system? This chapter will briefly discuss the background of the question. Later, the theoretical basis that underlies this line of research will be addressed.

The laboratory system can trace its origins back to the establishment of the Naval Torpedo Station in Newport, Rhode Island in 1869. Certain aspects of the laboratory system can be related back to the earlier engineering activities at the Washington (D.C.) Navy Yard and even to the naval shipyards. Throughout this early history, the Navy's

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[1] See, for example, Perrow's technology typology for classifying organizations based on coupling (loose or tight) and interaction (linear or complex). He notes that decentralized authority is desirable in "loose-complex" organizations, such as those that perform research and development. (in *Complex Organizations*, 1986)

Research, Development, Test and Evaluation (RDT&E) establishments were aligned organizationally with three bureaus: Bureau of Ordnance (BuOrd), Bureau of Ships (BuShips), and Bureau of Aeronautics (BuAer). The bureaus, which reported to the Secretary of the Navy's office through a uniformed bureau chief, represented the material procurement side of the Navy's bilinear structure. The operational forces – the other side of the organization – reported to the Chief of Naval Operations (CNO).

The federal government, and the military departments in particular, have a somewhat limited history in science and technology.[2] The emphasis in the Navy has been on weapons development based on testing and engineering or, put another way, on the production or acquisition of the required weapons or ships. Interest in basic and applied science developed, for the most part, during World War II. Hence, Navy RDT&E establishments that predate World War II were often of one type and those that developed during the war years were of another type. For example, the BuOrd activities at Dahlgren and Indian Head and the BuShips activity at Carderock all have their origins at the Washington Navy Yard and were primarily testing or production facilities.

In contrast, other activities put a greater emphasis on research, such as the Naval Ordnance Laboratory at White Oak, which had its primary growth during World War II, and the Naval Ordnance Test Station at China Lake, which developed from a California Polytechnic Institute laboratory during the war years. In the end, the bureau laboratories concentrated on the support of system development and acquisition and did very little basic research. Most of the basic research was performed by the Naval Research

[2] The U.S Constitution (Article I, Section 8) gives Congress the power to "promote the progress of science" by protecting patents and to regulate standards for weights and measures. These and agricultural research characterize government science for the first 150 years of the republic.

Laboratory under the control (after World War II) of the Office of Naval Research. Further, BuOrd establishments, since they worked in areas where there was little or no commercial market, differed from those in BuAer and BuShips. This was manifest in the relationships between the laboratories and the bureaus (and in the assignments the laboratories received) and between the laboratories and non-governmental institutions.

The organization of the military and the nature of government science and technology and research and development came under review after World War II. By the late 1950s and early 1960s, there was a great deal of interest developing around the Navy's RDT&E organizations. Much of this interest can be characterized, in retrospect, as concern with the strategic management of the laboratory system. To one degree or another, this concern has persisted for the last four decades. Over the years there have been a variety of forces – that changed over time – that shaped the problem of strategic management of the Navy laboratory system. The solution, however, has taken the same general form – reorganization.

Historically, reorganization and process changes were intended to change the control or planning (i.e., the strategic management) of science and technology in the Navy laboratory system. This history raises questions that this research proposes to address. Did different parts of the Navy misunderstand or disagree as to what the business of the laboratories should be? One example of this can be found in the different views of government science. The bureaus, for example, believed that the laboratory role was to support the development or acquisition of systems that met the needs of the operating forces and, specifically, to apply technology to improve the capabilities of existing systems. Others viewed the laboratory role in terms of performing basic and applied research in order to provide the advanced technology that could be used by industry or the Navy to solve emerging or future operational problems.[3] This position was represented in the Navy by the Assistant Secretary of the Navy (Research and Development), the Office of Naval Research, and some elements within the bureau laboratories.

If there was a difference of opinion as to the proper role of Navy laboratories and their strategic management, then did the resulting reorganization actions really change how the organization did business and, in particular, did they change the strategic management processes? Did real change (i.e., in the way the laboratories did business) occur or, when change happened, was it an emergent process rather than the result of those formal changes (at least for the most part)?

The primary research hypothesis is that the evolution of the strategic management of the Navy laboratory organization can be better explained using complexity theory than by the processes and structure of the formal organization. The hypothesis will be tested through a case study of the establishment of the Director of Navy Laboratories (DNL). Langton (Marion 1999) observed that "large structure … emerges from the interaction of small units." It is postulated that the structure for strategic management of the Navy

[3] This is debated by Carl Kaysen and Paul W. Cherington in *Defense, Science, and Public Policy* (Edwin Mansfield, Editor, 1968). The basic distinction can be expressed in terms of the time required to incorporate technology – short when improving existing systems and long if meeting emerging or future needs. Edward Luttwak (*Strategy*, 1987) provides another way of expressing this idea. He talks about two "styles of war" (*attrition* and *relational-maneuver*) that nations tend toward. These styles also affect "peace time" strategy and, importantly, R&D and acquisition. Winning under an attrition strategy is "mathematically" determined - the one with the most and best systems wins. Hence, there is motivation to develop/acquire the most and the best systems. This usually translates into a slow development (time is not an issue) and an expensive one. A relational-maneuver strategy requires matching the threat and exploiting weaknesses. The requirements for new systems are that they match the threat and be available quickly (before the threat changes). Hence, development must be fast and not affect any of the ancillary systems. In other words, the emphasis is on changes to existing systems rather on starting from scratch.

R&D laboratory system emerged from the interaction of the individual laboratories as they pursued their own visions of the interests of the Navy. This organizational decision-making process, which is an example of local rationality (Cyert and March 1992), is anticipated by complexity theory.

The DNL was established in 1966 to provide strategic management of the Navy laboratory system. It was disestablished in 1991. Its establishment offers the opportunity to study this issue – which was preeminent: the emergent organization or the formal structural solution?

Development of the Bureaus

There is a literature of military administrative, organizational, and programmatic histories. The literature includes both published histories and official studies and reports. The official studies provide most of the specific information related to the management and organization of Navy research and development. Of particular interest to this research is the subset that deals with the organizational development of Navy research and development laboratories. This history provides the setting for this research.

At its founding the Navy was very small and equipped mostly for coastal operations. During the Jefferson administration (in 1806), for example, there were fewer than 250 officers and approximately 900 seamen in the Navy (Cunningham 1978). The Navy Department was the smallest in Washington, D.C. with a staff that consisted only of the Secretary and Accountant of the Navy and 12 clerks (Cunningham 1978). The military officers controlled activities at sea and civilians administered the shore establishment. The Navy Department administered six shipyards. The responsibility for superintending these yards was combined with that of the Naval Agent in all of these yards except Boston. The Naval Agents were responsible for "the building, fitting, and supplying of a naval force" (Cunningham 1978). The situation changed after the War of 1812.

A review of the Navy's performance during the war identified a need for more professional staff and for an organizational change. Consequently, the Board of Naval Commissioners was established in 1815 and assigned duties relating "to the building, repairing, and equipping of ships and superintending of Navy Yards" (Franke 1959). This change was justified by the increase in the size and scope of the business not by an increase in its complexity. In fact, there was very little "invention" evident in the Navy since most shipbuilding was still done by craftsmen and most guns were of European origin or design. This organizational change marked the first sign of the bilinear organization that characterized the Navy well into the 20th century.

The Commissioner organization proved to be inadequate due to a lack of technical skills to address the more complex and expanding technical problems that were developing. It was replaced by the Bureau system. Five bureaus were established in 1842: Yards and Docks; Construction, Equipment, and Repair; Provisions and Clothing; Ordnance and Hydrography; and Medicine and Surgery (Furer 1959). The number and nature of the bureaus changed on several occasions (e.g., after the Civil War and several times between 1900 and 1959) but the system lasted until 1966.

This same period saw the development of the test and engineering stations and activities that were the forerunners of the current Navy laboratory system. Among the earliest of these was the Experimental Test Battery established by Lt. John A. Dahlgren at the Washington Navy Yard in 1847. Dahlgren was also named Head of Ordnance

Matters at the Navy Yard. These particular developments were motivated by the ordnance weaknesses revealed in the War with Mexico and, especially, by a gun explosion that killed the Secretary of the Navy and the Secretary of State as they attended a shipboard demonstration (Peck 1949).

In the remaining years of the century, other engineering and test stations were established and were usually associated with one of the bureaus. This included, for example, the Naval Torpedo Station in Newport, Rhode Island (1869), the Naval Gun Factory (1886) and the Experimental Model Basin (1898) at the Washington Navy Yard, and the Naval Powder Factory at Indian Head, Maryland (1890). The trend continued through World War II. By the time of the establishment of the Director of Navy Laboratories in 1966, there were 15 Navy laboratories associated with the bureaus.

Changing the Organization

Throughout this period (1842-1966), the Navy was characterized by a bilinear organization – the "users" of the weapons and systems and the "developers and acquirers" of these systems. The users were the operating forces that after 1915 reported to the Secretary of the Navy through the Chief of Naval Operations (CNO). The developers and acquirers were the bureaus whose Chief, a flag officer, reported to the Secretary. The science and technology system in the Navy can also be characterized as bilinear in nature. In this case, the two components are foundational (or basic) research and systems development (including applied research). In the post-World War II Navy, basic research was the responsibility of the Office of Naval Research (ONR) and the Naval Research Laboratory. Systems development with the associated applied research was performed by the bureau laboratories. One point of contention was the relationship between the two components. ONR (in a position represented by Vannevar Bush) viewed the overall process as linear – development was preceded by applied research and basic research. This implied that management of the entire process (preferably by ONR) was required. The bureaus, being more interested in developing and improving systems, were less concerned with basic research than with technology that was available to be applied to the systems under their cognizance.

This led to issues of funding and control of the research agenda. One result was the establishment of an organization to plan and budget for research in the Department of Defense – the Assistant Secretary of Defense (Research and Engineering) in 1957 and the Director of Defense Research and Engineering (DDR&E) in 1958. The services followed suit. In the same year, the Assistant Secretary of the Navy (Research and Development) replaced the Assistant Secretary of the Navy (Air) for planning research in the Navy.

These changes set the stage for a series of studies that changed the face of the Navy laboratory system. These studies, which addressed elements of the strategic management of Navy research (although that term does not appear to have been used): control, budget, staffing, and facilities, are described below. They provide a more specific context for this research project.

Undersecretary of the Navy William Franke released a study of Navy organization (Department of the Navy 1959) that recommended that the bilinear structure of the Navy be retained. The committee observed that there was confusion concerning the responsibility for the development of certain systems, such as missiles.   They proposed to solve this by combining the Bureau of Ordnance and Bureau of Aeronautics to form the Bureau of Naval Weapons. They anticipated that this would also eliminate the need for additional independent program offices such as the one set up to develop Polaris.

The Task 97, or Fubini, report (Department of Defense 1961) noted several problems with DOD laboratories: low morale, non-competitive salaries, substandard physical plants, and difficulties with executive management due to dual leadership (civilian and military) and lack of technical qualifications. The report recommended that the laboratories be placed under the control of the service Assistant Secretaries for Research and Development and that there be a single laboratory director and changes to improve the Military Construction (MILCON) process (under the service Assistant Secretaries). They also proposed an increase in salaries for laboratory directors and government scientists and engineers.

President John F. Kennedy directed the Bureau of the Budget to review government contracting for research and development (Bureau of the Budget 1962). The Bell Report noted that some 80 percent of federally funded research and development (R&D) was done through non-Federal institutions and that it was in the national interest to continue to rely heavily on these institutions. Nevertheless, there were government roles in R&D that could not be abdicated and there were concerns that needed to be addressed – maintaining the technical competence required to manage non-government R&D and performing R&D directly. The study recommended that scientist's salaries be increased as well as opportunities for more interesting work assignments and professional development. It was also proposed that laboratory directors be given more direct responsibility for personnel and facility issues. This was echoed by the Furnas Report (Office of Director, Defense Research and Engineering 1962). This Defense Science

Board (DSB) report additionally recommended programs that allow government scientists to spend a sabbatical period in industry or university laboratories (and vice versa) while it cautioned against strengthening government laboratories at the expense of not for profit and industry laboratories.

Rear Admiral Rawson Bennett wrote a report (Department of the Navy 1962) that reviewed the management of Navy R&D. He noted a number of problems: fragmentation of executive responsibility on the developer/acquirer side of the bilinear organization, lack of a long range plan for R&D, difficulty of transitioning from ideas to development, and a shortage of "truly expert personnel, both military and civilian." He also observed that it is difficult to maintain an adequate technological base through basic R&D given the greater attraction of development. He made recommendations concerning organization both outside and within the bureaus: formation of a "supra-bureau" level executive, Chief of Naval Logistics; consolidation of all R&D guidance under the Deputy CNO for Development; and realignment of some bureau responsibilities. He also offered some proposals for addressing problems that he perceived with personnel, facilities, and funding.

In 1963, the Secretary of the Navy established the Naval Material Support Establishment (NMSE) and assigned overall responsibility for coordination of the material bureaus to the Chief of Naval Material (CNM). This organization continued the bilinear structure because the CNM reported to the Secretary independently of the CNO (Booz, Allen, and Hamilton 1976).

The Director of Navy Laboratories (DNL)

Chalmers Sherwin, Deputy Director Defense Research & Engineering, made proposals for changing the management and operation of in-house DOD and Navy laboratories that led to the establishment of the Director of Navy Laboratories (Sherwin 1964a,b). In his DOD study he proposed that a Weapons System Development Organization (WSDO) be formed to manage most applied research and development programs and test and evaluation centers. He also proposed a Department Laboratory Organization (DLO), under civilian leadership, to manage all basic research and to perform in-house research and exploratory and advanced development. The head of each DLO (called the Director of Navy Laboratories in the Department of the Navy) was to report to the service Assistant Secretary for Research and Development. His proposal would implement many of the recommendations of the Bell Report.

The Sherwin proposal for the Navy applied the fundamentals of his DOD plan and proposed the establishment of the Director of Navy Laboratories. The DNL would report to the Assistant Secretary of the Navy (Research and Development) and the nine principal Navy R&D laboratories would be subordinate to him. The Navy concurred with many of Sherwin's observations but disagreed with his organizational proposal. The Navy responded with studies by RADM J.K. Leydon (1964) and the Assistant Secretary of the Navy (R&D), Robert Morse (1965). Both studies argued for the traditional bilinear organization and for keeping R&D closely linked to production, procurement, and maintenance (i.e., no organizational barrier between research and system development). Both advocated a review of policies and processes concerned with personnel, military construction, and financial management. Morse proposed to keep the principal laboratories linked to the bureaus and to establish a DNL coequal to the Chief of Naval Research (CNR) and Chief of Naval Development (CND). The DNL, reporting to the Assistant Secretary, would be responsible for long-range planning for personnel and facilities. He also proposed to change the budget structure and programming procedures to provide block funding to the laboratories.

The Assistant Secretary of the Navy chartered a review of all in-house research, development, test and evaluation (RDT&E) activities by Dr. William P. Raney (Department of the Navy 1965). Raney's task force identified nine major Navy capabilities and proposed that an RDT&E activity be established for each. These RDT&E activities were to be formed through an examination of existing activities leading to decisions about consolidation, relocation, or elimination of some of them. Raney's report makes a number of such specific recommendations.

These studies culminated in two actions. First, in August 1965 it was decided that the four material bureaus would be abolished within a year and replaced by Systems Commands. In 1966, it was further decided to replace the Naval Material Support Establishment with the Naval Material Command (NAVMAT) and to assign the CNM to report to the CNO (Carlisle 1993b). This marked the end of the bilinear structure in Navy R&D. The major Navy laboratories were to report to the CNM rather than to the systems commands that succeeded the bureaus.

Second, in December of 1965 Secretary of the Navy Instruction 5430.77 established the Director of Navy Laboratories. The DNL was to report to the Assistant Secretary and was to also act as the Director of Laboratory Programs (DLP) in the Office of Naval Material. He was assigned responsibility for the in-house Independent Research

(IR), Independent Exploratory Development (IED) programs, the in-house exploratory development technology programs, and the associated funding. He was also given authority to control the RDT&E MILCON program and the distribution of civilian personnel, to establish laboratory requirements and policies, and to direct long range planning for RDT&E resources. It is interesting to note that the first person asked to be the DNL, Dr. Gregory Hartmann (Technical Director of the Naval Ordnance Laboratory), turned it down. He described the DNL/DLP position as "awkward and perhaps untenable" and was convinced that the DNL had little real responsibility and authority over the laboratories (Smaldone 1977). (Note that the budget controlled by the DNL was typically 3 to 5 percent of a laboratory's budget. The balance came from the systems commands.)

Organizational and process changes continued after the establishment of the DNL. In 1966, the Director of Defense Research and Engineering (DDR&E), John Foster, asked Dr. Leonard Sheingold to lead a Defense Science Board study of in-house laboratories. The DSB proposed that the laboratories be reorganized into weapons centers. Soon after the DDR&E directed that the Navy initiate planning to establish weapons systems development centers, the CNM approved a plan for their establishment. Implementation of the plan in July 1967 started a process of reorganization that moved the Navy from 15 principle laboratories to 6 weapons centers over a period of some 7 years.

There were important changes to laboratory processes in the late 1960s and early 1970s. As late as 1967, the laboratory financial systems were as disparate as their management histories. The Department of Defense initiated Resource Management

Systems (RMS) in the late 1960s. The Navy converted all of the CNM laboratories to Naval Industrial Funding (NIF) in 1969. NIF had been introduced in the Naval Research Laboratory and Naval Ordnance Laboratory as early as 1953 (and earlier in the shipyards). While this process aided financial management in the laboratories, they never realized its full benefits due to limits on the availability of funding, personnel ceilings, and procedural rules (Booz, Allen, and Hamilton 1976).

A second major change was the implementation of Project REFLEX (Resources Flexibility). In 1967, in response to a Civil Service Commission study of in-house laboratories, Project REFLEX was initiated to test the feasibility of removing controls on staffing levels at the laboratories in favor of fiscal controls. The 3-year experiment in the CNM laboratories ran from 1970 to 1973. Despite favorable reviews by the GAO and the DNL, it was allowed to expire.

Continued Change

The previous sections describe the history and evolution of the Navy laboratory system through the period of interest in this research. The changes did not stop there however. The laboratories – both Defense and Navy – continued to be studied throughout the 1970s. The Task Group on Defense In-House Laboratories and the second DNL, Dr. Joel Lawson, identified a number of laboratory problems that needed to be addressed. They included the lack of clarity in roles and systems for which each laboratory has responsibility, conflict between the sponsors of established programs and the purveyors of new ideas – the laboratories, insufficient discretionary funds under the direct control of the laboratory directors, and the lack of full utilization of laboratory expertise and resources (Office of Director, Defense Research and Engineering 1971; DNL 1971a,b).

There was continued concern about competition between the laboratories. The Office of the Director, Defense Research and Engineering and the Secretary of the Navy sponsored studies of laboratory missions and operations. The Hollingsworth study recommended a recasting of the laboratory mission statements and a requirement that sponsors assign work and funding to the laboratories in strict accordance with their missions. This was intended to reduce the laboratory competition for funds that NIF motivates (as well as the resulting mission overlap) (Hollingsworth 1974). The Navy-Marine Corps Acquisition Review Committee (NMARC) suggested that the Navy needed to reaffirm the bilinear structure of Navy R&D (Department of the Navy 1975). They proposed to do this by assigning the CNM more responsibility for the management of development funding under the supervision of the Assistant Secretary of the Navy (R&D).

Most of the studies in the 16 years from 1960 to 1976 that addressed the in-house Navy laboratories supported a policy of coordination of research under the Secretary of the Navy, added levels of review and oversight to the R&D process, and added more complex financial accounting systems. The most recent studies (e.g., Hollingsworth and NMARC) raised the concern that the changes had created as many problems as they had remedied. In addition, there was a growing concern about the technology base and the ability of the Navy to integrate the efforts of the systems commands to develop ships and airplanes. During the Carter and Reagan presidencies the emphasis shifted to a concern with the bureaucratic (and, hence, inefficient) processes of government and privatization.

As part of this, it was appropriate to also consider the specification of required in-house facilities and capabilities (Office of the Undersecretary of Defense for Research and Engineering 1980).

Decline of the DNL

By 1985 there was increasing Congressional and press criticism of Navy procurement practices. There was also a view that there was duplication and excessive management layers in the Defense and Navy R&D system. When the CNM, Admiral Steven White, resigned in March 1985, Secretary of the Navy John Lehman took the opportunity to disestablish the Naval Material Command and, thereby, reduce a level of management in the procurement system. The Naval Electronic Systems Command was changed to the Space and Naval Warfare Systems Command at the same time. The DNL and Navy laboratories were assigned to the Office of Naval Research. The Chief of Naval Research reported to the Assistant Secretary of the Navy (Research, Engineering, and Systems). The systems commands would report directly to the Office of the CNO. These moves were intended to reduce the number of management levels, streamline communications, and improve the development of systems. They were also supposed to preserve the independence of the laboratories. It was felt that the laboratories might cease to exist and would get caught up in solving short-term problems if they reported directly to the systems commands (Carlisle 1993b).

This organizational change only lasted 10 months. In February 1986, the DNL and the laboratories were placed under the managerial control of the Space and Naval Warfare Systems Command. There was concern expressed by the other systems commands at the prospect of “their” laboratories being placed under the management control of another systems command. Some believed that the purpose of the reorganization was to reduce the involvement of the laboratories in development activities.

As a result of the Goldwater-Nichols Defense Reorganization Act of 1986 and Defense Department reorganization studies, a major reorganization of Defense R&D was undertaken. Two important changes were the increased role of the operating forces in setting requirements and the establishment of the Program Executive Officer (PEO) structure. The PEOs were to be responsible for system acquisition and reported to the newly constituted Assistant Secretary of the Navy (Research, Development, and Acquisition) (ASN (RDA)). The intent was to move control of major acquisition programs from the systems commands to the ASN (RDA). The laboratories maintained their independence from the systems commands although one thing did not change – most laboratory funding came from activities other than the one that exercised management control.

The significance of this funding process to the management of the laboratories was confirmed by a major study of Navy Industrial Funding by Coopers and Lybrand (1986). The study concluded that the individual laboratories were well managed but found that the ONR laboratories only controlled about 25 percent of the Navy's RDT&E appropriation. Further, the laboratories expended just 7 percent of their funding on technology base (about one-half of that out-of-house) and seemed to be evolving into contracting centers. The Defense Science Board (1987, 1988) and the Office of Technology Assessment (1989) continued to study how effective DOD was in managing and maintaining the defense technology base. They all raised some concerns and made several recommendations including moving towards consolidation of laboratories under DOD aegis (OTA, 1989) and creating new executive positions in DOD and the services to provide oversight and guidance for science and technology programs.

The last phase of the DNL period began with an increased focus on base closure. This brought attention to the Navy laboratories, including both the organization and their roles. The Navy Base Structure submitted its report to the Defense Base Closure and Realignment Commission in 1990. Its recommendations formed the basis for the commission's approach to Base Realignment and Closure (BRAC), as required by Public Law 101-510.[4] The recommendations outlined a significant realignment of the Navy laboratory system – 4 megacenters were to be established and, in the process, 10 activities were recommended for closure and consolidation into other activities. Additionally, 16 others were marked for realignment (Department of the Navy 1991). A Federal Advisory Commission (1991) also favored the warfare center concept and recommended that it be implemented in January 1992. This commission was concerned about the possible loss of laboratory identity and the disruption of the workforce. Consequently, it also recommended that the warfare centers be part of the DOD Laboratory Demonstration Program. These proposals were implemented in January 1992 and the major Navy R&D centers were joined to form the megacenters and were attached

[4] As the Cold War came to an end, Congress perceived a need to close unneeded military bases. The only way that they saw to overcome the opposition of members to closing individual bases was to entrust the process to an independent commission – the Defense Base Closure and Realignment Commission (known as the BRAC Commission). The BRAC Commission was created by statute in 1988 to develop and recommend a slate of candidates for closing. The slate could only be approved or disapproved in its entirety by the President and Congress. The Defense Base Closure and Realignment Act of 1990 (Public Law 101-510) retained the Commission but modified the process so that the Department of Defense developed recommendations that were reviewed by the BRAC Commission. As before, the final list could only be approved or disapproved in its entirety by the President and Congress. The Act authorized rounds of base closure in 1991, 1993, and 1995.

to the appropriate systems command (e.g., the Naval Surface Warfare Center was established as part of the Naval Sea Systems Command). At the same time, the Director of Navy Laboratories Office was disestablished.

In summary, this review has addressed the studies performed over a 30-year period that led to the establishment of the DNL, its modification, and its abolishment. The studies have not stopped however. Throughout the 1990s the BRAC process continued and there were a collection of studies that addressed efficiency (e.g., the reinvention studies and standardization of business systems and processes), the costs and effectiveness of the Defense laboratory structure, contracting out and privatization, and consolidation and realignment. The systems commands have each taken a different approach to organizing and managing their programs and their associated laboratories.

CHAPTER 2

OVERVIEW OF THEORETICAL FOUNDATION

Introduction

There are three primary conceptual literatures that must be reviewed: complexity theory, strategic management, and organization theory (especially as related to complexity theory and strategic management). These conceptual literatures will be used as the basis for examining and understanding the structure and processes used for strategic management of the Navy laboratory system in the period leading up the establishment of the Director of Navy Laboratories.

There is also a significant literature of Navy laboratory institutional histories, including reorganization studies and proposals. The latter literature (and the DNL papers in the Naval Historical Center Operational Archives) provides much of the source information that is the basis of this research. Science policy and strategic management literatures are of secondary importance because they contribute to an understanding of management and organizational issues.

This chapter will first consider how the research objective and the primary conceptual literatures – strategic management, complexity theory, and organizations – are related. Each literature will be considered individually and then in conjunction with the others. At the conclusion of this chapter, the elements of interest in each of the conceptual literatures are put into a framework that will be used to structure the project.

Complexity Theory

Introduction

In this review, some of the fundamentals of complexity theory are outlined and some of the ways (mostly metaphorical) that they have been applied to organization and management theory are highlighted. This research specifically focuses on certain elements of complexity theory: the four behavior classes defined by Wolfram and others (including Langton) and the power law distribution that is characteristic of complexity. In particular, the characteristics of the behavior classes will be related to the assumptions associated with each of the elements of strategic planning.

It has been observed that the distribution of many events (by their intensity) follows a power law – there are many low intensity events and few high intensity ones. This distribution has been observed in many social events, including, for example, the distribution of museums by city size, the size and frequency of cities, the physical size of species, and the extinction of species.[5] This suggests that there may be a similar distribution of the changes that affect strategic management. This distribution may also apply to changes or improvements in the business and processes of an organization – there are many more minor changes than major ones.[6]

Stephen Wolfram defines four behavior classes for complex systems: Class 1 - death, Class 2 - static, Class 3 - chaos, and Class 4 - "edge of chaos." It has been postulated that most organizations exhibit Class 4 (or "edge of chaos") behavior.[7] One characteristic of that behavior class is that the level of turbulence varies from low (near

[5] See, for example, Marion (1999) and Kauffman (1993).
[6] Phelan (1995) suggests that the power law distribution applies to business systems.
[7] See Marion (1999), Phelan (1995), and Stacey (1996)

Class 2) to high (near Class 3). The degree of turbulence in the system may also follow a power law distribution – there are many more periods of low turbulence than of high turbulence. The strategic management of such organizations should vary accordingly. One might expect, for example, to see evidence of emergent organization or management processes in periods of relatively high turbulence and, conversely, more linear processes in times of low turbulence. Even in periods of relatively high turbulence there are always "islands" of stability. The processes applied to the elements of strategic management are clearly different (i.e., more rational) in these areas of stability than in more turbulent areas. This leads to consideration of the notion that there are portions of an organization or some of its processes that will exhibit stable (i.e., linear) characteristics and others that will not. Again, specific aspects of strategic management will vary accordingly.

There is a growing complexity literature. Its origins can be found in the natural and physical sciences in the work, for example, of Stuart Kauffman, John Holland, Christopher Langton, Yaneer Bar-Yam, and Ilya Prigogine. More recently, the literature has grown to include works in other fields – popular science (Casti, Coveny and Highfield, Lewin, and Waldrop); social sciences (Marion, Michaels, and Jervis); and management (Kiel, Wheatley, Youngblood, and Sanders). The scientific literature will be reviewed here; the literature at the intersection of complexity and organization theory will be addressed later in this chapter.

For many, their first exposure to the dynamics of complex systems was with chaos theory (and specifically with Gleick (1987)). Chaos also became a popular buzzword in the management literature. Complexity was popularized by Lewin (1992) and Waldrop (1992) and is represented in the popular management literature (McMaster

1996; Youngblood 1997). What is the difference between chaos and complexity? Some argue that chaos is a general theory of non-linear dynamics and that complexity is a subset of chaos. Others argue the opposite. Still others see chaos and complexity as two sides of the same coin. Marion (1999) makes the case that complexity and chaos are different, although they exhibit some similar characteristics.

Chaos and complexity theorists both claim that the dynamics of most systems are not adequately represented by a linear relationship (i.e., if the system input A is increased by δ, then output B changes proportionally). Systems can be thought of as complex webs of nonlinear feedback loops (Stacey 1995). These complex adaptive systems evolve from simplicity to greater complexity in response to increased environmental complexity (Michaels 1995). Systems may also exhibit complex change in response to simple causes. These complex changes, or bifurcations, may be so significant that they represent a disjunctive state change in the system (Kronenberg 1995) or it may appear as if the system has crossed an invisible boundary (Marion 1999).

The behavior of nonlinear feedback systems can be described in terms of a number of attractors, or patterns into which behavior ultimately settles. These attractors generally take one of three forms: (1) stable equilibrium attractors in which behavior is repeated over time in a regular and predictable manner, with small deviations quickly damped away by negative feedback; (2) unstable attractors created by positive feedback that exhibit no discernable pattern; and (3) chaotic attractors that occur as nonlinear feedback systems that pass from stable to unstable states, and in which small changes may be amplified into qualitatively different patterns. The third form of attractor represents bounded instability, or chaos, and the result is that long-term future behavior is totally unpredictable in specific terms, but occurs within recognizable, irregular patterns as the system is driven by both negative and positive feedback.

Chaos tends to focus on mechanical systems (such as weather) that respond sensitively and unpredictably to minute changes in system inputs. The classic example was given by Lorenz – the motion of a butterfly's wings in China affecting the weather in New York. Chaos theory has been found to be better suited to application to physical systems, such as weather and fluid turbulence, that are mathematically deterministic but whose descriptive equations cannot be solved.

Complexity theory has been developed in an attempt to better represent systems that are adaptive and deliberative (or, in other words, that carry information about themselves). It is described (Marion 1999) as "layering chaos on top of more traditional theories of stability." An important characteristic of complexity is that as a balance is struck between stability and chaos, organization emerges from the interaction of the elements of the complex system. Complex adaptive systems, thus, consist of a number of components ("agents") that interact with each other according to rules (usually simple ones) in order to improve their individual behavior and, consequently, that of the system they comprise.

Applications of Complexity Theory

The first applications were to biological processes such as evolution. Langton, for example, used a game invented by John von Neumann called "cellular automata" to model self-reproduction. In its simplest form, this game is played on a checkerboard whose squares (or cells) are "alive" or "dead." (As an aside, if this is thought of as a system of lights, then alive means that the light is on and dead, it is off.) The state of the board is randomly initialized (i.e., each cell is randomly made alive or dead) and a set of simple rules is used to determine their state at each succeeding step in the game. Typical rules might be:

(1) A cell is alive if two or three of the contiguous eight cells are alive.
(2) A cell is dead (from exposure) if fewer than two of the contiguous cells are alive.
(3) A cell is dead (over-crowding) if more than three of the contiguous cells are alive.

If this game is played, emergent behavior is observed. Some groups of cells will fall into a repeating on/off pattern, other groups will grow and contract, and some will freeze in one state and show no activity.

Von Neumann's original version of the game assigned one of a possible 29 values to each cell rather than the binary version described above. Langton used a version developed by another researcher that assumed only eight states and, further, only allowed each cell to interact with four others – those above, below, and to the left and right of the cell (Marion 1999; Waldrop 1992; Coveny and Highfield 1995). He also added a control by specifying the probability that a given cell would be alive in the next step. He discovered that when this parameter (which he called lambda) was set low (around 0.17, i.e., a 17 percent probability that the cell will be alive in the next step), then the system froze – there was no activity. Stephen Wolfram referred to this as Type 1 stability. When he increased lambda to 0.19 then he saw periodic order (also called Type 2 stability). The system repeatedly swung through several states much like the periodic motion of a pendulum. When lambda was set to a high value (say, 0.45), then chaotic order (Type 3) was the result. There were frequent and random changes in the state of the system. Langton found another form of order between Type 2 and Type 3. When lambda is set to a value between 0.2 and 0.4 (he used λ=0.273), he observed order that was dynamic but which seemed predictable. He referred to this as the "edge of chaos" and argues that it is there that one finds biological evolution (Waldrop 1992; Lewin 1992). Waldrop (1992) and Stacey (1996) argue that organizations that are in this state (i.e., at the "edge of chaos") are dynamic organizations that display self-organization and the ability to learn and adapt. This concept will be developed further and applied to the organizational case studies that are the basis of this research.

Stuart Kauffman used a similar model to show the formation of structure at the edge of chaos and the relationship to the size of the network (Marion 1999; Kauffman 1995). In his model, networks settle into a number of attractors (or repetitive behaviors) that define the system. There is a "basin of attraction" associated with each attractor. A basin of attraction is a zone (in phase space) around an attractor within which a point is drawn to the attractor. This concept is represented schematically in Figure 2-1. On the figure, each state is represented as a bold point. The state space is broken down into several cycles, or attractors, represented as circles. Each initial state eventually will end up in one of these cycles (the arrows show the direction of the flow). The totality of states that evolve towards a given cycle is the basin of attraction of that cycle.

The basin can also be thought of as a buffer zone around an attractor. If the basin is large, then a perturbation will usually cause an attractor to return to its original state. If the basin is small, a perturbation will cause the attractor to change to another type of attractor. This stability concept can be illustrated by consideration of the stability modes of a pencil. If one end of a pencil that is lying on its side on a table is lifted and released, the pencil returns to its original state as long as the tip is lifted through less than 90 degrees. This is equivalent to a large basin of attraction. If, on the other hand, the top of an unsharpened pencil that is standing on end is moved to the side and released, the pencil will fall over unless the perturbation is very slight.

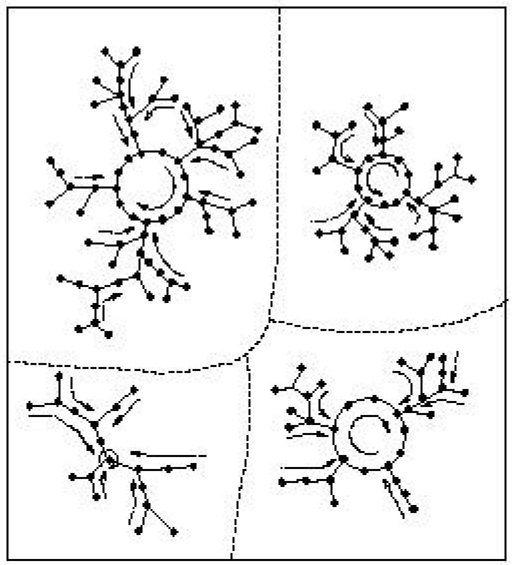

Figure 2-1: Representation of Attractors and Basins of Attraction

Kauffman's model consisted of a network with a number of nodes (N), each of which assumes one of two values "1" (on, if the node is represented by a light) or "0" (off). Further, he describes the complexity of the network by specifying the number of nodes that can affect the state of each individual node (K), i.e., that are connected to it. The state of each node is determined by the state of the other nodes that can affect it if applied through a specified rule. He defines two Boolean rules – an OR rule and an AND rule. The OR rule turns a node on if any of the connected nodes are on. The AND rule turns a node on only if all of the connected nodes are on. He initializes the network by randomly setting each node either on or off and assigning it one of the two rules to govern its behavior.

If this system is run with all nodes (say, N=100,000) affected by all the others (or, K=N), then some 36,000 attractors result. These attractors are large, move around the parameter space, and have small basins of attraction. Thus, perturbations can cause attractors to mutate to any of the other types of attractors in the system. If the number of interactions is reduced (i.e., K is smaller), then the behavior of the system changes dramatically. For example, if K is greater than 5, the system is as previously described (the attractors are large and large in number and low in stability, i.e., have small basins of attraction). If K=1, the attractors are fixed and unchanging. Each attractor is isolated from all of the others and, as a result, its dynamics have no affect on any other attractor. Kauffman found that if K=2, then the number of attractors is approximately the square root of the number of nodes (or, 316 if N=100,000). Further, each attractor was relatively small and tended to have large basins of attraction and, thus, had limited connections to each other. The system was sufficiently stable to retain its form, but dynamic enough to change. This, then, was self-organization at the "edge of chaos."

This is illustrated on Figure 2-2 for a Boolean network with N = 13 and K = 3. The 2^{13} (= 8192) states in the state space organize into 15 basins. The individual states in each basin are represented by the individual symbols. The number of states in each basin is: 68, 984, 784, 1300, 264, 76, 316, 120, 64, 120, 256, 2724, 604, 84, and 428.

Application to Organizations

Kauffman (1995) introduces two other concepts – fitness landscapes and patches – that are helpful when complexity is applied to organizations. A fitness landscape can be visualized as a mountain range. (Mathematically, it can be thought of as a plot of the function $Z = f(X,Y)$.) An example of a fitness landscape is given in Figure 2-3. The highest peak is the optimum value (Z) of the particular function. The lower valued peaks are the local optima described in the following paragraph.

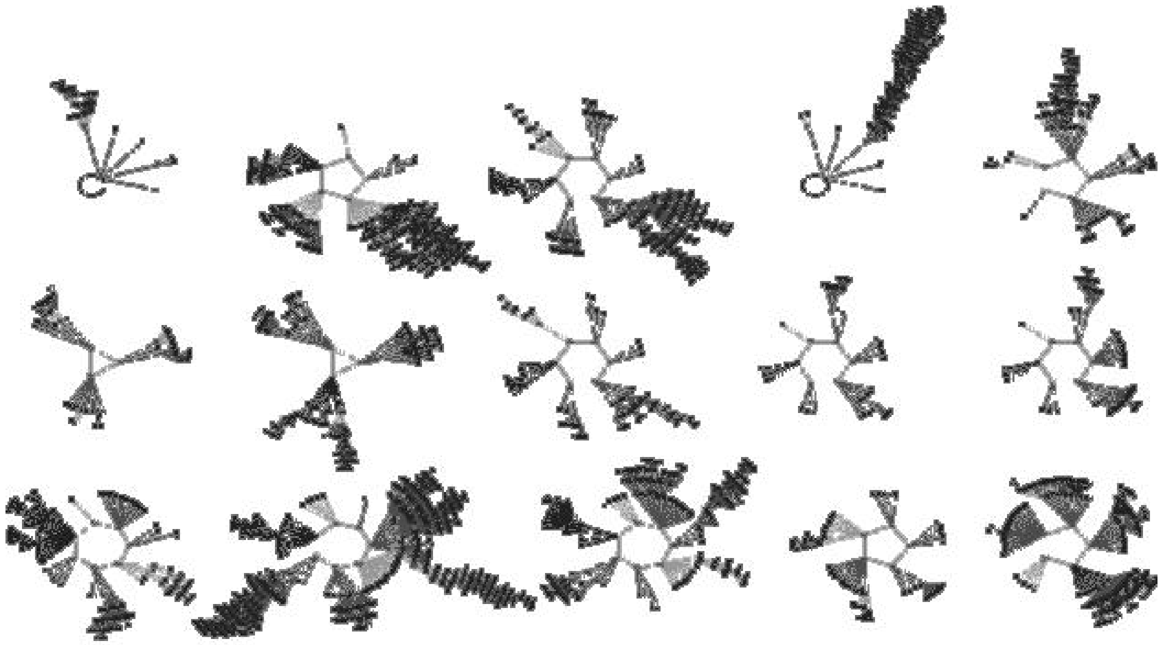

Figure 2-2: The Basin Of Attraction Field Of A Random Boolean Network (N=13, K=3)

Kauffman constructs a fitness landscape using an extension of the process previously described. For example, if there are N genes, each of which can assume one of two values and are linked to K other genes through Boolean rules, then each gene can combine to form K^N different genomes. If each gene in each genome is randomly assigned a fitness value between 0 and 1, then the mean fitness of each genome is computed as the mean of the fitness of the included genes. The genomes represent the peaks on the landscape with heights equal to the computed fitness values. The highest peak represents the optimal location (or the maximum value of Z). Lower peaks represent local optima – good locations, the best in that vicinity, but not the best.

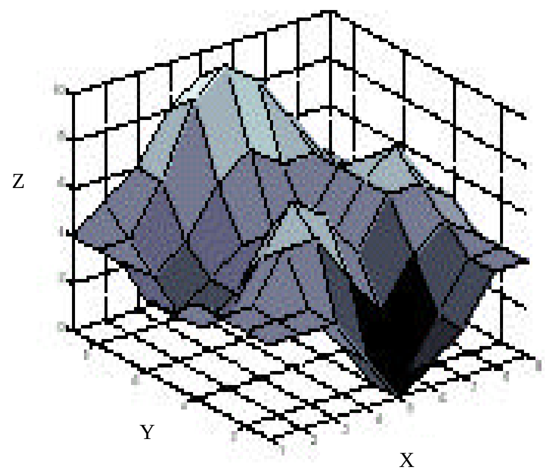

Figure 2-3: Fitness Landscape (Example)

Metaphorically, a system searches for the optimum as it undergoes the process of self-organization. A concern (as it is with any mathematical optimization process) is that the structure will settle on one of the local optima and be unable to continue to evolve to the optimum. Real physical systems have a natural way to escape from local optima – they randomly move in the wrong direction (caused by thermal vibration).

Organizational structure also has to provide the means to move from one peak to another. Kauffman (1995) proposes patches as a way to do this. The patch process involves dividing a hard, conflict-laden task into a quilt of non-overlapping patches. Optimization occurs within each patch and, because of the coupling between patches, the problems in the neighboring patches are changed. The patches cooperatively evolve ("coevolve") to an optimal solution for the overall task. Kauffman's experience is that the number of patches is critical. If there are too few patches (for the roughness of the landscape), the system can settle on local optima and freeze up. If there are too many patches, then their coevolution becomes chaotic (the so-called "Red Queen" effect [8]) and the system never converges on any solution. If the number of patches is appropriate, the coevolving system lies at a phase transition between order and chaos.

The patch analogy can also be applied to understand organizations. The open system perspective in organizational theory is concerned with matching the complexity of the organization to that of the environment.[9] For example, the situation where there are too many patches is analogous to the case of an organization whose structure is more complex than its environment. The open perspective includes both the possibility that the organization and environment can be intentionally matched (the *open-rational* perspective) and that they are matched through an evolutionary process (the *open-natural* perspective).[10]

To summarize, this review has introduced some of the concepts of complexity found in the scientific literature. Kauffman (1995), among others, has begun to apply these concepts to the social sciences, including organization theory. The following section will address the intersection of the organization and complexity theory literatures.

Organization and Complexity Theory

A conceptual framework for assessing organizational effectiveness

The new sciences of nonlinear systems dynamics - chaos, complexity and self-

[8] This effect, which is a state of unbounded coevolution, gets its name from the Red Queen in Lewis Carroll's *Through the Looking Glass* (1872) who described Wonderland as a place that "… takes all the running you can do to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that."

[9] Contingency theory and bounded rationality, which are discussed later in this chapter, are examples of the application of the patch analogy to organizations. There is also a biological analogue – the "Law of Requisite Variety" – that states that in order to achieve control, the variety of actions a control system is able to execute must be at least as great as the variety of environmental perturbations that need to be compensated.

[10] These organizational perspectives are discussed in more detail later in this chapter.

organization - offer a conceptual framework for understanding organizational performance and effectiveness in the face of changing environments. This perspective focuses on the internal characteristics of organizations and how these characteristics shape, and are shaped by, their environment. When this conceptual framework is applied to organizational effectiveness, it considers the actions of two stakeholder groups—managers, who primarily act through the formal organization, but who also act through the informal organization, and workers, who create and act through the informal organization. Rather than defining what makes an organization effective, this perspective defines the conditions under which an organization can or will exhibit adaptive behavior that is effective in meeting the challenges of a changing environment.

Organizations can be thought of as complex webs of nonlinear feedback loops (Stacey 1995). These complex adaptive systems evolve from simplicity to greater complexity in response to increased environmental complexity (Michaels 1995). The behavior of nonlinear feedback systems can be described in terms of a number of attractors, or patterns into which behavior ultimately settles. These attractors generally take one of three forms: (1) stable equilibrium, (2) unstable, and (3) chaotic.

The dominant lens through which theorists and practitioners currently view organizational functioning is the linear, stable equilibrium perspective. In this perspective, effective organizations are those that are attracted to stability and within which it is possible to identify links between cause and effect. Managers set up stable equilibrium attractors when they design formal negative feedback control mechanisms that consist of centralized hierarchical structures, reporting procedures, policies and rules, and plans and budgets; in short, when they set up the formal organization. The formal organization structure sets the boundaries, or the holding environment of the organization, but it is always in tension with the informal structures that pull toward decentralization and individualism. It is this tension that generates the chaotic state, and it is this state in which new patterns of behavior emerge without prior shared intention. This framework recognizes that effective organizations are those that are pushed far from equilibrium to the edge of chaos and that exhibit spontaneous self-organization and emergent adaptive behavior and processes.

If an organization can be sustained at the edge of chaos, in the phase transition between stability and instability, it has the potential to be creative, to change, and to become an effective organization. The long-term outcomes of a creative changeable system emerge from the nonlinear system behavior, and they do so through a process of self-organization (Stacey 1995). In organizations, a self-organizing system is one that people spontaneously create, and where organization members acquire information, learn, conduct political activity, and change the system of which they are a part. The informal part of any organization is a self-organizing system. From a nonlinear systems perspective, the processes we would expect to be key in bringing about innovative change—those processes that would make an organization effective—would be networking, associations of an alternating cooperative and competitive sort, and learning communities of practice (Stacey, 1995).

Theoretical grounding

The new sciences of chaos and complexity offer a theoretical grounding for understanding organizations as nonlinear, self-organizing systems. Human organizations are networks of people where the connections between them take the form of nonlinear feedback loops. Chaos is a deterministic, nonlinear process characterized by extreme sensitivity to initial conditions; changes in initial conditions do not necessarily elicit a proportional change in an effected variable; it may result in no response or a disproportionately large or small response. Small changes in initial conditions, for example, can be amplified in a system and have an enormous influence on the long-term behavior of the system.

Chaos theory is the study of complex, nonlinear dynamic systems. Complexity refers to the interaction of many components in a system, giving rise to properties at higher levels that are not found in any of the individual components. Complexity theory attempts to identify the rules governing the emergence of system structure and order. The concepts and ideas that have come out of the work on chaos and complexity offer useful new ways of thinking about the dynamics of organizations, including the dynamics of organizational effectiveness.

Lissack (1999) applies the concepts of complexity to organization theory. In particular, he relates Kauffman's fitness landscapes and patch process (and other complexity metaphors) to possible applications in organizations. Patches, for example, can be compared to matching the complexity of the organization to the environment it faces. Fitness landscapes have implications for processes used to search for improvement strategies (e.g., when fitness is average, search is best carried out far away across the space of possibilities). Likewise, as fitness increases, the fittest variants are found ever closer to the current location in the space of possibilities. Consideration of Figure 2-3 helps to understand these assertions. An organization that differs significantly from its optimal condition (in structure and processes) can be said to be located far from the fitness peak on the fitness landscape. In that case, the search area for the optimum must extend across the space of possibilities. Conversely, as an organization approaches the fitness peak, the space of possibilities that must be searched continues to shrink. In other words, one would not expect to see major changes to organizational structure or processes. This highlights the danger that an organization will settle on local optima and not continue to evolve to the true optimum.

McKelvey (1999) is concerned that the application of complexity theory to organizations will not move past the metaphorical stage. He also notes that complexity is the latest in a long line of management fads. McKelvey, as well as Stacey (1996), observe that the only way that complexity will move past metaphor or fad is if it changes the research agenda in organizational theory. McKelvey proposes a focus on *organizational microstates* and a union with model-centered organizational modeling. He defines microstates as "discrete random behavioral process events," defines several options (i.e., decisions and information), and settles on organizational processes as being the most appropriate. The research agenda centers on (1) testing whether the theory predicts the empirical behavior of the model, and (2) "comparing the isomorphism of the model's idealized structure/processes against … the total relevant 'real-world' phenomena" (McKelvey 1999).

Stacey (1996) identifies the fundamental research questions as: (1) "How does the process of spontaneous self-organization actually operate in organizations to produce emergent strategies;" (2) "What is the process of creative destruction that does this;" (3) "What part do the mess and disorder we observe in organizational processes play in creative outcomes;" and, (4) "What does an organization do to influence the parameters that determine whether or not it occupies the creative space?"

Definition of organizational effectiveness

From the perspective of the new sciences, organizational effectiveness has more to do with processes and conditions than outcomes. The conceptual framework focuses on recognizing the nonlinear, informal systems that inevitably arise in organizations. It is these processes that will create an effective organization, rather than the stable, formal processes that are based on negative feedback and that pull the organization back to equilibrium. Organizations are systems that have both positive and negative feedback loops. While the negative feedback loops tend to maintain stability, positive feedback loops bring disturbances, amplifications, and change. Positive feedback pulls the organization away from equilibrium and sets the stage for a system dynamic that allows adaptive reorganization. Effective organizations recognize the value of positive feedback loops. Likewise, they recognize the risk of destabilization that is inherent in a strong positive feedback loop and the role of negative feedback in maintaining stability in a changing organization. The effective organization also engages the environment as a source of information and opportunity, not as something from which it must protect itself. Effective organizations are structured around their core competencies and are capable of maintaining sensitivity to their environment (Wheatley 1994). At the same time, effective organizations change their environments as they evolve toward a better fit.

Criteria used to evaluate effectiveness

Kiel (1994) has examined the problem of improving the effectiveness of public organizations in the face of pressures to improve performance and quality of service.

Goldstein (1994) has used the concepts of self-organization and nonlinear systems theory as a consultant to understand and manage organizational change. James (1996) presents practical approaches for applying chaos theory to organizational decision-making and strategic thinking. The criteria for understanding effectiveness that are common to the application of chaos and complexity are found at the intersection of organizational change behavior and environmental uncertainty.

Within the framework of nonlinear systems, particularly self-organization, effective organizations recognize the nonlinear nature of many organizational processes, take advantage of random or unexpected events, and exploit the system's innate potential to change, grow, and develop. Stated in operational terms, criteria for assessing effectiveness within this conceptual framework are really designed to measure the extent to which an organization has positioned itself to benefit from the processes of self-organization.

Stacey (1995) points out one cautionary note for researchers using the nonlinear systems perspective to understand organizational behavior. The conceptual framework would hypothesize that formal plans and programs to change and renew organizations to make them effective will usually fail. When organizations do show innovative and creative changes, the framework hypothesizes that it will be as a result of spontaneous self-organization within an informal system. Because the result of such self-organization is patterned, it will be possible to construct an "official" account of what happened that makes it look as if the adaptive change was the result of prior intentions and plans. This retrospective sense making of organizational effectiveness will construct a linear cause and effect version of events in which management forms intentions and then implements them. The researcher working within the nonlinear systems perspective must look for the complex systems interpretation in which self-organizing processes produce emergent outcomes.

Strategic Management

Introduction

There are several aspects of strategic management that are of particular interest. The first of these areas is concerned with the historical aspects of strategic management. One can identify four historic phases of the literature of strategic planning – budgeting and control; long-range planning; strategic planning; and, finally, strategic management. Each reflects underlying assumptions about the environment and the future – whether or not they were repeatable, predictable, or controllable. A related concern is the differences in strategic management between public and private organizations. TenDam (1986) and Rainey, Backoff, and Levine (1976) provide frameworks that help to characterize strategic management in public organizations. These differences can be generally described by reference to two concepts – market and politics. The concept of a "market" is not the same in the private and public sectors. The public environment, the freedom to define a vision, and the selection of strategies have a political component not present in the private sector. The first category in the Nutt-Backoff-Levine framework includes *environmental* factors: market, constraints, and political influence. Their second major category is *transactional* factors: coerciveness, scope of impact, public scrutiny, and ownership. The last category contains *organizational process* factors: goals, authority limits, performance expectations, and incentives.

A typical definition of strategic management (such as from Fred David, 1997) identifies a number of processes that comprise strategic management. These include establishing an organizational vision, budget, personnel, and investments (e.g., facilities, equipment, and discretionary). These business-like elements, modified by the market and political differences described by Nutt, Backoff, and Levine, are used to characterize the strategic management processes of the Navy laboratories and to frame the analysis of the evolution of the Navy laboratories and to place the DNL establishment decision in context.

The evolution of planning has been traced through four phases (Hensey, 1997). The first phase, budgeting and control, was coincident with the beginning of the scientific management period. The underlying assumption was that the past, for the most part, repeated itself. The long range-planning phase began in the 1950s. Some consider this the origin of strategic management and trace it to1954 when Drucker's *The Practice of Management* was published. The basic assumption supporting long-range planning is that past trends will generally continue. Starting in the 1960s, and for some 20 years, strategic management was viewed as a linear, sequential process and, as a result, the emphasis in business was on strategic planning. This third phase was characterized by the feeling that the future can be predicted to the required degree and that the environment (i.e., trends and forces) is predictable or controllable. The fourth and latest period – strategic management – began in the mid-1980s in response to a belief that the traditional planning cycles are not compatible with rapid and unpredictable changes. The abolishment of the strategic planning structure at General Electric (by CEO Jack Welch) in 1983 is often cited to mark the beginning of the strategic management period.

Public organizations have followed a somewhat parallel path. At the turn of the century the New York Bureau of Municipal Research was formed. Its studies (and those of groups like it in other cities) led to the establishment of budget processes and, at the federal level, the Bureau of the Budget (BOB) (McSwite 1997). The development of budgeting systems such as the Planning, Programming, and Budgeting System (PPBS) in the 1960s is an example of long range planning in government. Strategic planning in government agencies began in the 1970s and continues to the present (Bryson and Roehring 1988; Baker 1990a,b; Berry 1994; Berry and Wechsler 1995). The Government Performance and Results Act (GPRA) of 1992 requires strategic planning by government agencies. Strategic management of public organizations has been written about since the late 1980s (see, for example, earlier editions of Nutt and Backoff and Koteen) and there are examples of its implementation at all levels of government.

Strategic Management Process

Strategic management is a process that integrates all business functions in order to achieve organizational success. Throughout the literature there is a reasonable degree of consensus on a model of the process. The representation in Figure 2-4 is from David (1997). It has three components: strategy formulation, strategy implementation, and strategy evaluation. The strategy formulation phase is concerned with determining the future direction of the organization. This determination usually requires an evaluation of the external and internal situation in terms of external opportunities and threats and organizational strengths and weaknesses. This component also includes the specification of the mission and vision of the organization and long-range objectives. It should be noted that in the strategic planning of the 1960s and 1970s long range might have meant a decade or more. In the modern strategic management model, the long-range view

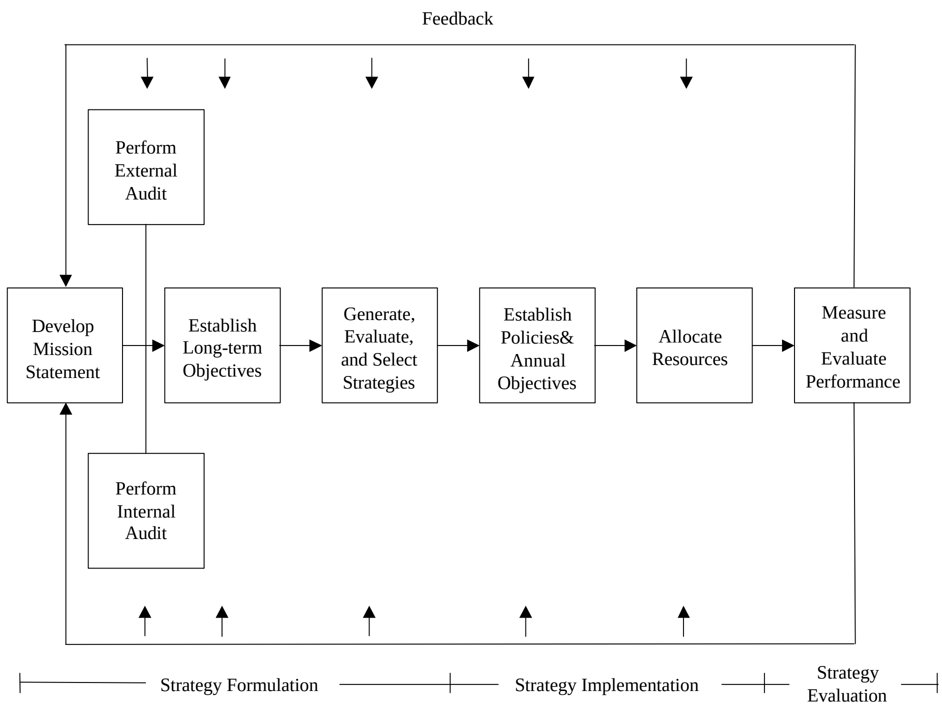

Figure 2-4. Typical Strategic Planning Process

is represented by the mission and the vision of the organization. Long range, in the current process, is anything over 1 year. Strategic planning, as previously noted, assumed that the future was knowable to the necessary degree and that any changes to the assumptions could be made within the planning cycle. Strategic management captures the very long-range intent in a concise vision and focuses on nearer term objectives.

The second component is strategy implementation. In this phase, the strategies selected to achieve the long-range objectives are translated into annual objectives and implementing structure changes, policies and actions, including allocation of resources. The final component of strategic management, strategy evaluation, is concerned with the measurement and review of progress and feedback to the other elements of the process.

As the arrows on the perimeter indicate, this feedback could be back to the beginning of the process in order to start the next iteration or to any of the intervening steps in the process in order to make midcourse corrections.

Henry Mintzberg (1994a,b,c) takes issue with this representation of the strategic management process. He believes that strategic management is not the linear sequential process that the figure indicates. He views the entire process as "strategy formation" with many of the steps being performed in parallel with continuous feedback loops. He suggests that organizational strategies are a combination of those planned in a formal process and those that evolve through the decisions made and actions taken at all levels of management. In his discussion of the process, Mintzberg (1994a) places greater value on determining a strategic vision that is accepted and understood throughout the organization. This vision is the framework within which managers make the decisions that define the emerging strategies. The organization's strategic plan is, in essence, the collection of emergent strategies, each of which is a result of individual decisions.

One of the more important assumptions implicit in strategic management is the rapid and unpredictable nature of the external environment. As noted, this leads to a process with a shorter-range view, greater sensitivity to the environment, and an opportunity for more frequent modifications to strategies and their implementation. It also leads to a need to move the responsibility for execution of the process beyond senior leadership or a corporate planning staff to include all levels of the organization (Bryne 1996; Galagan 1997; Campbell and Alexander 1997).

Floyd and Wooldridge (1997) studied the importance of the role of middle managers. Their findings are consistent with Mintzberg's theory of emerging strategies and with Thompson's description of middle managers as "boundary spanners" (Thompson 1967). A more recent trend – that is clearly an extension of the idea of involvement of all levels of management – is towards a thinking organization (Hamel 1996; Christensen 1997).

There is some disagreement as to the degree to which the strategic management process developed for business is applicable to public institutions. Some (such as Koteen 1997) accept that the processes generally apply to both the private and public sector. Others (such as Nutt and Backoff 1992) take the publicness of the organization into consideration. Public and private organizations as ideal types seldom exist. Most organizations, public or private, have elements of both.

Understanding each of these views of strategic planning and strategic management is critical to understanding the organizational approaches prescribed by the various studies that led to the formation of the Director of Navy Laboratories office and the subsequent changes to it.

Organization Theory and Strategy

The first step in understanding how organization theory explains the relationship (and its changes) between structure and strategy that is described in this short history of the Navy laboratory history is to define strategy. Hatch (1997) describes strategy (from the organizational theorist's point of view) as the link between organization and environment through which influence and information pass. This link can be viewed as having various uses. Scott (1998) describes four - *cognitive* (to guide decision makers), *cathetic* (to motivate), *symbolic* (to establish an institutional view), and *justification* (for post-decisional sensemaking). He also suggests that these different uses for organizational goals and strategies can be associated with different theoretical perspectives in organizational theory.

Organizational Theory

Scott (1998) proposes a layered framework for categorizing models of organizational theory. He starts with system level perspectives and, in particular, with whether or not the environment is considered as part of the system. Specifically, does the theorist assume a closed or an open system? A closed system approach implies that the theorist focuses inside the organization and, at most, may include the immediate external environment as part of that system. An open system theorist emphasizes the interaction between the organization and the environment.

Boulding classifies systems by their level of complexity and offers nine types. Open system organizational theorists describe systems at level 3 or 4 in Boulding's typology (in Scott, 1998)

Scott's framework then further subdivides both major categories into rational and natural system models. Rational systems treat organizations as machine-like while natural systems are more like organisms. Kronenberg (1995) has summarized the characteristics of each. The rational or machine approach views organizations as social objects, created for a purpose, that can be evaluated according to the standards applied to machines (efficiency and effectiveness), are controllable, and predictable. The natural or organism perspective, on the other hand, conceptualizes organizations as something that, while created for a purpose, have acquired a life of their own. The organization is viewed as being embedded in multiple complex environments and as having a less hierarchal authority and decision-making structure. It relies heavily on equilibrium assumptions, namely, that learning is intended to return the system to an equilibrium state.

This layered framework provides four perspectives – *closed-rational*, *closed-natural*, *open-rational*, and *open-natural* – that Scott suggests fit the chronological development of organization theory. Scott does not suggest that any one perspective is correct; rather, he asserts that each offers valuable insights. Others (such as Mintzberg and Perrow) suggest that the utility of a particular perspective can be associated with the complexity of the organizational structure and the environment. Thompson proposes that different levels of a given organization (he describes the *technical*, *managerial*, and *institutional* levels) may be best described by different perspectives. Others would suggest that the perspective most applicable to a given organization might change over time – as the organization changes. Using Scott's rough chronology, one would note that the organizational discussions in the Navy laboratory system that are of interest here were taking place at the same time that the shift from closed to open systems was occurring in organizational theory. Specifically, Scott observes that the shift that was occurring was to an *open-rational* system perspective.

Each perspective suggests particular views of organizational strategy. It may be instructive to review these and then relate the organizational views of both structure and strategy to the Navy laboratory history. At the conclusion of this brief discussion, it should be possible to move to a discussion that proposes areas where complexity theory can provide additional insight and to specifically identify a small number of variables from organizational theory that can be juxtaposed with complexity theory.

Strategy

Each organizational perspective brings with it a particular view of strategy. The closed systems approach, in general, focuses attention on developing strategies for managing the organization's relationship with the environment. The closed-rational view specifically sees strategy as normative and as a process of designing the organization to achieve a predefined purpose.

Chandler (1998) is an example of a rational theorist. He segregates operational and strategic decisions and reserves the latter for executives. He views organizational strategy from the perspective of a multi-division (*M-form*) organizational structure and as a hierarchal, top-down process. Specifically, the corporate level (the highest in the hierarchy) decides on the business or product lines to be in and on shaping and segmenting the organizational structure to best match the environment. Typical corporate-level strategies would address diversification, reorganization, divestiture of business lines, and downsizing.

The major divisions (which may be either product or geographically determined) focus on the business-level strategies that typically address market-related and organizational development issues. These strategies are typically developed to support the corporate strategies and, hence, follow the development of the upper level strategies. There is often coordination of strategies across levels as well as reporting upward. At all levels, organizational resources are allocated to implement strategies. In a large organization, the division-level strategies will have both corporate- and business-level elements. In smaller, less diverse organizations, the separation of corporate- and business-level strategy development may be more pure. In any case, there is a fundamental assumption about the predictability and controllability of the system.

The closed-natural perspective has the same basic view but adds a level of complexity in opening up the possibility of a more complex environment and an organizational structure (formal and informal) to match it. It also recognizes that there can be a diversity of organizational goals as well as structure other than that formally described on the organizational charts that plays a role in the development and implementation of strategies and goals. Additionally, it begins to allow for what Mintzberg refers to as *emergent* (unplanned in the formal sense) and *realized* (based on actual behavior) strategies in addition to the *intended* (planned) ones. The natural systems view also acknowledges that strategies can have cathetic or symbolic uses as well as being used to guide decision-makers. In the end, however, this perspective still focuses on the organization's internal arrangements.

The open systems approach takes a fundamentally different perspective and focuses on the interaction between the organization and the environment. The rational model of open systems more fully acknowledges the complexity of the interaction between the environment and the organization and the impracticality of a completely hierarchal approach to strategy. This led to the ideas of bounded rationality and contingency theory. The rational perspective is still organizationally based and, hence, the top-level strategic issues revolve around matching the organization to the environment. The basic approach is to create closed system compartments within the organization and to develop strategies for sealing and buffering the compartments. If this were successful, then strategy development within the closed compartments would be much as described above. The main difference is in the decentralization of the process. As before, focus is still on *intended* strategies and the primary use of strategy would be to guide the distributed decision-makers.

The natural model of open systems views the organization from the perspective of the environment. The population ecology approach, for example, views organizations much as one would view biological systems - the environment has the power to select from a group of competitors the organization that best serves its needs (typically based on economy and technology). Institutional theory acknowledges that the social demands (e.g., values) of the environment also affect the selection and adaptation of organizations by the environment. This perspective moves more strongly to the view of organizational strategy and goals as motivational and symbolic and may be used to retrospectively justify organizational actions. Emergent and realized (as opposed to planned) strategies are characteristic of this perspective.

Relating Strategy and Organization

It was previously suggested that none of the organizational perspectives that were described should be considered more correct than any of the others.   Rather, each offers valuable insights and may be useful to understanding different organizations or the same organization at different times. Likewise, each organizational perspective offers different insights into strategic management. What criteria can be used to judge the utility of each perspective in understanding the relationship between organizational structure and strategic management?

Mintzberg (in Hatch) and Hatch (1997) propose basing that judgment on an assessment of the complexity of the organizational environment and its rate of change and, thereby, characterize the environment as of low, moderate, or high uncertainty. This is shown in Figure 2-5. For example, in a low complexity, slowly changing (e.g., low uncertainty) environment the rational perspectives (in either a closed or open system model) of strategic management and organization theory provide insights. Increases in either complexity or rate of change increase the uncertainty in the environment and, consequently, diminish the utility of the rational model.

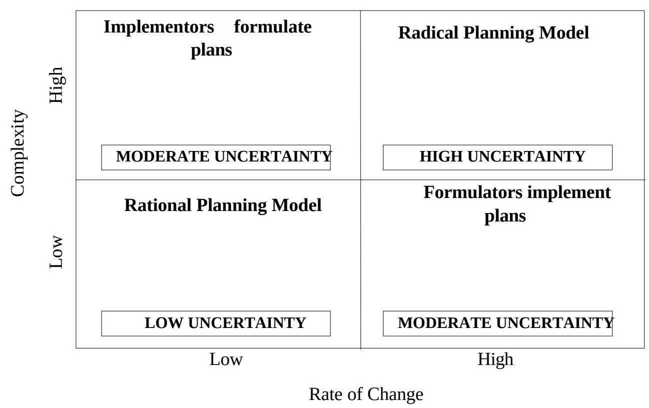

Figure 2-5: Mintzberg-Hatch Framework

Hatch proposes an information perspective, which relates directly to strategic management, that can be mapped onto this framework (Figure 2-6). This perspective relates the availability of information and the amount required to the strategic management approach that is appropriate to the organizational environment. For example, in a low uncertainty environment, the needed information is known and available. As the uncertainty increases, the amount or type of available data is inappropriate or, perhaps, the required data are not known.

Perrow (1986) provides a framework for characterizing organizations (and identifying the most appropriate form of organization and control – centralized or

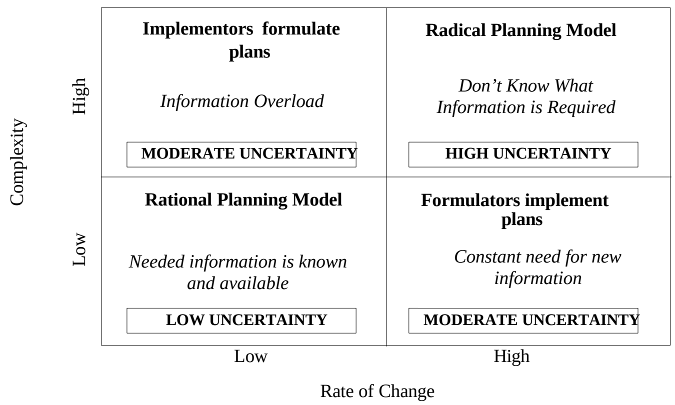

Figure 2-6: Mintzberg-Hatch Framework with Information Perspective

decentralized) based on the complexity of their organizational interaction and the tightness of organizational coupling. This framework is shown in Figure 2-7.

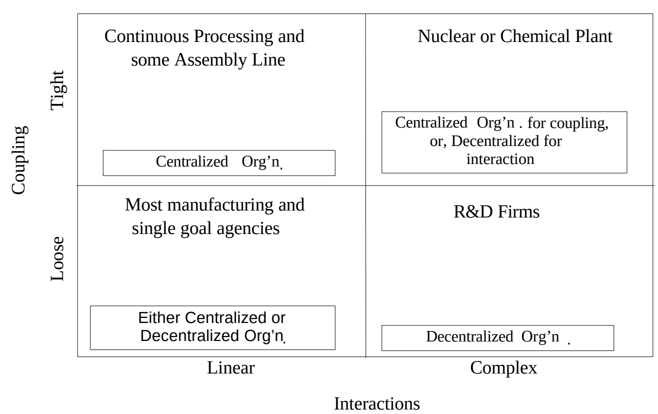

Figure 2-7: Perrow Framework

Organizational interaction refers to the number and nature of the connections between the elements of the organization. For example, assembly line production is linear – each organizational element (in this case, a station of the assembly line) is only connected to the stations that precede and follow it – and additive – the process only flows in a single direction. By contrast, the elements of a research and development firm, indeed any transformational activity, are complexly connected with many known and unknown feedback loops.

Coupling refers to how quickly and explosively a change in one element of an organization is felt in another. A change in one element of a tightly coupled organization, such as a nuclear plant, propagates quickly through other elements of the organization. A manufacturing and a research and development organization, however, are both loosely coupled and a change in an element of either affects other elements slowly if at all.

The rational perspective provides insights into organizations that are characterized by linear interaction and tight coupling and which are suited to centralized control. As organizational interaction becomes more complex and the coupling is looser, a decentralized organization becomes appropriate and the rational model has less explanatory power. This framework, as does Mintzberg-Hatch, relates the nature of the appropriate form of control (i.e., centralized or decentralized) and, hence the management and planning, to organizational characteristics.

Both frameworks are used to analyze the formal organization and management of the Navy bureaus and laboratories in Chapter 5. They provide one basis for explaining some of the differences between the different bureaus and their subordinate laboratories.

CHAPTER 3

METHODOLOGY

Introduction

This research project was designed and conducted as a case study of the Director of Navy Laboratories (DNL) Office and its effectiveness in the strategic management of the Navy research and development laboratory system. A review of the government studies and organizational histories shows that the strategic management of Navy research (and specifically of the laboratory system responsible for the government portion of the research) has been of concern for at least four decades. History also shows that the usual approach to ensuring or enhancing strategic management in the Navy has been through application of an organizational solution. The primary research hypothesis is that the evolution of the strategic management of the Navy laboratory organization can be explained more fully using complexity theory rather than by the processes and structure of the formal organization alone.

These concepts will be used more than metaphorically. The general approach is to give definition to organizations and environment in order to characterize them using an agent-based model with an appropriate rule set. The objective, of course, is to relate the characterization and the rules to the nature of strategic management. More specifically, the objective is to identify how the organization performs the processes of strategic management and utilize complexity theory as the conceptual basis for understanding how it changed (or stayed the same) when faced with change. This approach illustrates the "footprints" of complexity as exemplified by behavior classes and the islands of stability within the organization. The Navy laboratories before and around the establishment of the DNL are the basis of this examination to test the primary research hypothesis.

As discussed earlier, complexity theory states, in general terms, that large structure organization emerges from the interaction of small units as they pursue their individual interests and vision. Accordingly, it is postulated that the strategic management structure of the Navy laboratory system resulted more from the actions of the individual laboratories than from the structure imposed by the various reorganizations of the management system. The validity of this proposal is evaluated by considering the individual processes that comprise strategic management – budget, personnel, and investments (facilities, equipment, and discretionary) – and how they were performed, i.e., by the formal organization (as it was at a given point in time) or by an emergent organization. In addition, this research considers how the organization reacted to change.

Organization

The previous sections describe an approach to this research that characterizes strategic management in public organizations and uses some elements of complexity theory to examine the strategic management of Navy science and technology. The description in the previous chapter identifies several characteristics of complexity theory including agent-based models, behavior classes, and power law distributions that point to a need to characterize organizations in a way that supports the application of these concepts to a description and analysis of strategic management.

A view of an organization as a collection of analytically differentiated systems – authority, control, information, and technology – provides one dimension of a framework that can be used to describe how the strategic management processes are performed (see description above).[11] The second dimension of the organizational description is a vertical one that categorizes the organization at different levels within the hierarchal structure of the Department of the Navy. The Navy laboratory system has multiple levels, from the individual laboratory to the Secretary of the Navy. Evaluating the effect of reorganization on strategic management requires a vehicle for considering the multiple aspects of the organization – the environment each faced (and the level of turbulence), the applicability of the organizational solution, and the alternate approaches that emerged. The analysis must also consider the changes that occurred and the organizational responses, both formal and emergent.

This requires the development of a model that allows for the representation of both the formal and emergent organizations and the environment that affects each. The approach is to develop formal organizational charts to depict the official system and relationships and an agent-based model that supports identification and analysis of the emergent system and processes. This also requires the development of rules that governed agent behavior at each level of the model. It should be highlighted that since this research emphasizes strategic management, the rules focus on the organizational behavior and elements and processes that comprise strategic management - budget, personnel, and investments (facilities, equipment, and discretionary).

Next, complexity theory is applied in order to develop an understanding of the evolution of the strategic management of the Navy laboratory system. The previous discussion highlights some of the features of complexity theory. How can these be applied to test the research hypothesis? Ideally, one would gather temporal data and

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[11] This organizational model is from Kronenberg (1973).

subject it to mathematical analysis.[12] For example, one might produce a time-based response plot and infer the behavior class (per Wolfram) that describes the style. A more mathematically rigorous approach would be to use the temporal data to construct Poincaré (or phase space) plots to examine the nature of the attractor at work in the system. The empirical data in a system such as this will not be as nice (or regular) as in a physical system, but there are methods for doing this analysis with incomplete or irregularly spaced (in time) sets of data. Again, this would point to a particular behavior class for the system. Finally, one might compute the Lyapunov exponent to examine the correlation dimension. This is a measure of the average convergence or divergence of the data. These techniques require a large number of data points over an extended period of time. There is a problem with applying these techniques to data from social systems because it is difficult to acquire the necessary number of data points.

There appear to be two alternative approaches to applying complexity theory to this problem. First, one might look at the characteristics of the organization and judge where (i.e., in which behavior class) they place the organization. A second approach would be to look for the "footprints" of complexity. These footprints include things like a power law distribution of changes in response to perturbations of the system and the nature of the system response to perturbations. The nature of the response says something about the organizational "fitness landscape" (to use Kauffman's term)[13] and, hence, the number of attractors and the sizes of their basins of attraction. For example, rapid and frequent changes, which are characteristic of a system with many attractors

[12] More detailed information on these methods is available, for example, in Bar-Yam (1992), Nicolis and Prigogine (1989), Kauffman (1993), and Marion (1999).
[13] This concept is described in some detail in Chapter 2.

with small basins of attraction, indicate a chaotic system. At the other extreme, an absence of change is indicative of a system whose attractors are isolated from each other. Such a system will be fixed and unchanging. Of particular interest is the system response to major change. Marion describes such change (which he calls “catastrophic”) as “substantive change in structure, behavior, or level of fitness.” Such changes occur when systems elaborate their structure or when they change what they do or how they do it.

Thus, the final issue relative to research design is to select the points in time at which the organization will be described and analyzed. The historical discussion of the development of the Navy laboratory system highlights four important years: 1960, 1963, 1966, and 1973. The significance of these dates will be briefly discussed and the selection of the time on which this analysis focuses will be explained.

By 1960 several important changes had been made to the laboratory structure and processes that had been in place since World War II. These included the creation of the Assistant Secretary of the Navy (Research and Development) to manage a consolidated budget line for Navy Research and Development (R&D), and the establishment of the Bureau of Naval Weapons (BuWeps) from the Bureau of Ordnance (BuOrd) and the Bureau of Aeronautics (BuAer). In 1963, the Secretary of the Navy created the "Naval Material Support Establishment" to be headed by the Chief of Naval Material (CNM) with the responsibility to coordinate among the bureaus. In 1966, the bureaus were disestablished and split into systems commands that reported to the Secretary of the Navy through the CNM and the Chief of Naval Operations (CNO). The principal R&D laboratories reported to the CNM independently of the systems commands. The DNL (who was also the Director of Laboratory Programs for the CNM) was established and given the responsibility for coordinating and planning the activities of the laboratories. Between 1966 and 1973, the 15 laboratories in the Naval Material Command were reorganized into 7 functional centers, and process changes had been implemented for both financial and personnel systems.

The events in 1966 are the primary focus of the research and the analysis will focus on modeling the laboratory strategic management system before and after the establishment of the DNL. Some attention will be given other periods in the discussion of the system and processes because they provide historical context.

Agent-based Models

A clear understanding of agent-based models is required in order to appreciate the research methodology. Simply put, such a model represents the structure of a system by populations of agents. These agents, which are defined by their location in the system, capabilities, and memory, are assumed to obey simple rules and are motivated to improve their individual behavior. This application of local rationality has the result of improving the behavior of the entire system.

What is required to define an agent and an agent-based system? Agents are defined by their (1) location, (2) roles, (3) allowable actions or strategies, and by (4) the nature of their interactions with other agents and the environment. "Allowable actions" and "nature of their interactions" are other ways of saying that the agents follow specific rules. Agents are also part of a larger context. Axelrod & Cohen (1999) observe:

> Agents, of a variety of types, use their strategies, in patterned interaction, with each other and with artifacts. Performance measures on the resulting events drive the selection of agents and/or strategies through processes of error-prone copying and recombination, thus changing the frequencies of the types within the system.

Axelrod and Cohen also define the larger framework of a complex adaptive system as comprising populations, systems, types, and strategies. Agents are considered to be in the same population if they could employ the same strategy. Populations have structure, which provides the means for strategies to move (and sometimes change). Systems usually include more than one population and all of their strategies, artifacts, and environmental factors. The different types of agents are generally defined by detectable features of the agents in the population. Other variations may exist in a population and not be recognized as types by the agents themselves. In fact, the distinguishing features of types are usually imperfect indicators of the actual differences in actions among agents. Strategy can imply either deliberate choice or a pattern of response that pursues a goal with little or no deliberation.

Specifying an agent's location in a complex system places it in a structure and defines its relationship to other agents in the system and to the environment. The location can be further refined by grouping agents into populations. A population of agents is roughly defined by the idea that its members could employ the same strategy. There may be additional structure within a population. The structure of a population can be defined either exogenously or endogeneously. The model that is developed for this analysis has been done exogenously – by someone on the outside – from an examination of historical evidence. It is necessary, however, to be aware of the structure defined by the agents in the system (endogeneously) since their understanding of the system likely affected the actions they took and how they interacted with each other.

The discussion of the roles and allowable actions of the agents is focused on those areas that are specifically associated with strategic management – the budget, personnel, and investment (facilities, equipment, and discretionary) processes and how and by whom they were performed. This is discussed more in Chapters 6 and 7 when the models are defined in detail. This discussion distinguishes between the allowable actions, external effects, constraints, and activation that characterized the different levels of the Navy organization. A key to doing this is in defining the rules at the different levels – both the constraints and those that governed agent behavior.

Axelrod and Cohen (1999) propose 3 concepts that are useful when defining interaction between agents: proximity, activation, and space. In general terms, the closer the proximity of agents (when combined with space), the greater the interaction. Proximity, in this case, may be physical, organizational, friendship, or community. Space can be either physical or conceptual. Physical space is defined as the relative location of agents in geographical space or time. Conceptual space refers to locating agents in a set of categories structured to produce interaction. In either case, "nearby" agents tend to interact. Activation addresses how the interaction is triggered and controlled. Activation may be "externally clocked" (e.g., to budget or planning cycles) or internal as a response to a current event. Interaction is typically activated by a combination of both. Internal activation is generally associated with decentralization and is usually considered a good thing. This issue is addressed more in a later discussion of organizational categorization.

Another key issue is whether the interaction is intense or diffuse. Intense interactions are concentrated in a few pairs and, conversely, diffuse interactions are more spread out. Intense interactions are usually associated with exploitation (i.e., a lack of exploration) while diffuse interactions are associated with exploration. Both can lead to problems, such as premature convergence or external boiling, if a proper balance is not maintained. Premature convergence, a problem usually associated with intense interactions, is a loss of variability in strategies or agent types too quickly. External boiling describes a system in perpetual change. Axelrod and Cohen note that “extinction happens.” In other words, the process of exploration and exploitation can lead to organizations performing worse rather than better and, in some cases, to the disappearance of all examples of a particular type of agent or strategy. Axelrod and Cohen also assert that “edge of chaos” systems structure the diffuseness of their interactions to balance exploration and exploitation and, thus, to avoid both of the problems defined above. Systems that achieve and maintain this balance are more likely to survive than those that do not.

The first step in applying this approach to the analysis of the stated problem is to define two models – pre- and post-establishment of the DNL. The principles described above are applied to define the environment, populations, and agents. This leads to a specific definition of the structure of the laboratory population and the individual agents, including internal and external interactions. This is used to describe the key relationships in the model.

The critical step in the analysis conducted in this research project is to use specific historical citations to substantiate the rules and interactions. Likewise, historical data are used to draw comparisons of organizational behavior before and after the key event – the establishment of the DNL – and to evaluate the roles of the official and emergent systems. Careful consideration of the roles of the two systems is used to identify the “footprints” of complexity, namely, behavior classes and islands of stability. The structure, diffuseness of interaction, and the nature of activation provide the evidence.

The analysis shows that at certain times and in certain parts of the system the official system was dominant. Likewise, there are signs that the emergent system was dominant in other times and places.

Frameworks for Analysis

The agent-based models are used to analyze the strategic management of the Navy laboratories before and after the 1966 reorganization to consider how complexity theory can add to an understanding of the contributions of the emergent system. Robert R. Maxfield (in Alberts and Czerwinski 1997) provides a framework for analyzing an agent-based model of the emergent system.

Maxfield describes strategic thinking in an organization facing a complex foresight horizon and proposes two strategic practices they should follow: *populating the world* and *fostering generative relationships*. "Populating the world is a process of discourse to construct and interpret a representation of the external environment – who and what are the agents and artifacts that constitute the world, what are their relationships, and how are they changing." He also defines fostering generative relationships as "an attempt to secure a position in the world which will enable the organization to recognize and influence emergent opportunities." Based on its understanding of its external environment, the organization invests resources in existing relationships or to establish relationships – that have generative potential – with new agents.

The generative potential of a relationship can be assessed by considering the degree to which several preconditions are met. Maxfield defines these preconditions as follows:

(1) Aligned directness – The participants have a compatible orientation of their activities.
(2) Heterogeneity – The participants differ in key respects, e.g., competencies or access to agents.
(3) Mutual directness – A recurring pattern of interactions.
(4) Permissions – Matched authorizations from their respective organizations for engagement.
(5) Action opportunities – Opportunity to engage in joint actions.

The relationships of the agents in the system and the rules they follow are defined when the model of the system is developed. Maxfield's framework, and especially his preconditions, can be used to explore the nature of these relationships in more detail. The last step in assessing the utility of a particular model is to examine the applicability of the proposed rules for agent behavior and their role in the strategic management of the Navy laboratory system.

Rosenau (in Alberts and Czerwinski 1997) specifies that agents that self organize their behavior must be related to each other sufficiently to form recurrent patterns. The preconditions for generative relationships also provide a process for establishing the nature of the relationships between these agents (i.e., the laboratories, in this research) and between the agents and other elements of their environment.

Why is Maxfield's framework applicable to this analysis? Stacey (1995) observes that an organization that can be sustained at the edge of chaos has the potential to be creative. Such a system is self-organizing and can be described as a learning organization. A learning organization is "continuously invented, shaped, and modified in the light of feedback from the environment." (Scott 1998) The highest level of Maxfield's framework defines two strategic practices characteristic of such a learning organization – developing an organizational representation of the environment and gathering external information to augment and modify the representation. The Navy laboratory system fits the definitions from Stacey and Scott and, hence, this level of the Maxfield framework is appropriate for analyzing its emergent behavior.

Scott defines two aspects of environments – technical and institutional – that have often been viewed as separate perspectives. The technical perspective focuses on the systems that support production, e.g., the processes for acquiring resources, capital, and markets. The institutional aspect is concerned with the cultural and symbolic factors that affect organizations. Scott asserts that organizations have both technical and institutional foundations and controls and their relative importance has more to do with the nature of the specific organization. In the case of the Navy laboratories and, in particular, at the level of analysis adopted for this research, it is appropriate to focus on the technical perspective of the organizational environment.

From the technical perspective, the organizational environment can be viewed as either a stock of resources or as a source of information. Those stressing the former view consider the resources required from others and the degree to which the organization is dependent upon them. Those focusing on the informational aspects of the environment address the degree of uncertainty confronting the organization. Lawrence and Lorsch (as given in Scott) and Thompson (1967) take this latter perspective and define numerous dimensions of uncertainty: degree of stability-variability, threat-security, homogeneity-heterogeneity, interconnectedness-isolation, and coordination-noncoordination.

If one analyzed the potential of an external relationship using the resource view of the environment, one would evaluate the resources required by the organization for its production process and, specifically, what is lacking and the degree to which a potential source can satisfy the need. Applying the information perspective (and the uncertainty dimensions given above) leads to other evaluation criteria concerned with the nature of the relationship, such as the degree of connectedness (e.g., a pattern of interaction and opportunities to work together) and the degree to which both bring different (but complementary) competencies and views of the environment to the relationship.

The institutional perspective adds other elements to the analysis. Considering the political, social, and cultural systems that comprise this perspective leads one to consider the compatibility of the orientations of the organization and the external environmental agent and the degree to which they are free to work together.

Taken together, the technical and institutional perspectives of the organizational environment can be used to specify a number of criteria that can be used to evaluate external relationships. The previous discussion shows that the Maxfield preconditions for assessing the generative potential of relationships are a logical outgrowth of both of these perspectives.

Finally, it is necessary to make similar comparisons across the reorganization event in order to make the case that the patterns of performance of both the formal and emergent systems persisted. Stacey *et al* (2000) argue that transformation is another characteristic of complex systems behavior, an idea that is consistent with the notion that an organization at the edge of chaos has the potential to be creative and change (Marion 1999; Stacey 1995). As noted previously, systems may also exhibit complex change – transformation – in response to simple causes. These complex changes, or bifurcations, may be so significant that they represent a disjunctive state change in the system (Kronenberg 1995) or it may appear as if the system has crossed an invisible boundary (Marion 1999). This research treats the reorganization of 1966 as such a bifurcating event. The second comparison, therefore, is whether and how the laboratory system was transformed by this event.

Model for Analysis

This research uses the individual Navy laboratories as the unit of analysis. Agent-based models for the Navy laboratory systems (pre- and post-1966) are developed and applied as the basis for using complexity theory to add fullness to the explanation of the evolution of the strategic management of the Navy laboratory system. The Navy laboratory system is defined as a population within the larger defense research and development system. Additionally, behavior variations between the laboratories are addressed as part of an analysis of the balance between the dominance of the formal and emergent strategic management systems.

Agents are defined by their location, roles, allowable actions or strategies, and the nature of their interactions with other agents and the environment. The location of the agents, their roles, and the details of their interactions with other agents in the system and with their environment are developed in detail when the pre-1966 and post-1966 Navy laboratory systems are analyzed. Allowable actions of the laboratory agents can take many forms depending on the behavior of interest. In this instance, the specific behaviors of interest are related to strategic management and, thus, the set of actions potentially available to agents is defined with that in mind.

Referring back to the review of strategic management in the previous chapter, we find that strategic management is a process that is intended to integrate all business functions in order to achieve organization success. Typically, the actions associated with strategic management will be concerned with budget, personnel, and investments (facilities, equipment, and discretionary).

The set of allowable actions adopted for this analysis, which is a compilation from the literature in the field of strategic management, is as follows:

- Set/change future direction (i.e., mission, vision, product areas, …)
- Allocation of resources
- Develop/acquire resources (funding, capability, equipment, facilities, …)
- Add/drop personnel
- Alter reporting structure ("who reports to whom")
- Alter task structure ("who does what").

In a hierarchal organization (such as the Navy) strategic decisions may be made at each level of the organization. The difference may be that the decisions are associated with the strategic management of that organizational level rather than of the organization as a whole (although the upper levels of the organization form part of the context of the level under consideration). Remember, however, that one of the basic assumptions of agent-based models is that the decisions of these organizational elements (or agents) are locally rational but generally have the effect of improving system outcomes. When the agent-based models are developed, it is necessary to clearly identify agent actions when analyzing the system.

One element comprising the nature of an interaction is specification of the information that may be passed between agents. Again, we focus specifically on information associated with strategic management and identify the types of information that are characteristic of the actions listed above. The following types of information are used in the analysis of the Navy laboratory system:

- Vision
- View of future Navy needs
- Mission

- Goals/objectives/requirements
- Tasking
- Funding
- Direction
- Personnel ceiling (number, grade level)
- Resource allocations (facilities, equipment)

It is important to note that these do not represent unique pieces of information. An agent, for example, may hold a "View of future Navy needs" that differs from that of other agents and from others in their environment (or in the larger defense research and development system). It is necessary to clearly identify what information is being passed when the system model is defined.

Sources of Data

There are several sources of data available to support this analysis. A very important source of data for the proposed research is the laboratory archival collection at the Naval Historical Center (NHC) at the Washington (D.C.) Navy Yard. Much of the organizational history can be found in the collection of laboratory reorganization studies in the NHC operational archives. The reorganization studies in the period leading up to the establishment of the DNL and information related to reorganizations that occurred during the life of the DNL are of particular interest. There are also extensive DNL files in the archives that are a source of information concerning both the DNL and major laboratory management processes. Organizational histories of the individual laboratories are a source of additional information.

Finally, this research relies on a collection of oral histories and interviews that have been conducted with many of the key individuals associated with the history of the Navy laboratories.

This collection, formerly the Archives of the Director of Navy Laboratories (DNL), is a rich source for the seminal and landmark reports in the organizational history of the Navy laboratory system. It also provides insight into the interactions within the laboratory system through direct sources, such as DNL and laboratory reports and correspondence. Analysis of this material and the near-contemporaneous observations of key individuals in their oral histories and interviews provide the historical and organizational artifacts that are needed to support this research.

CHAPTER 4

ORGANIZATIONAL HISTORY

Introduction

As part of an on-going process of centralizing control of government science and technology (S&T) after World War II, the Navy went through a major reorganization in 1966 that was intended to centralize the strategic management of the Navy laboratory system. The following organizational history of the Navy (focusing on the bureaus and laboratories) from 1946 to 1966 summarizes the changes related to strategic management and planning of science and technology. This history concludes with the proposition that in the 1966 reorganization, the Navy was not successful in centralizing strategic management of the Navy laboratory system.

Review of Organizational History

Early History

The Franke Board report argued that the basic principles of decentralized organization had been followed from the beginning (1798) in the Navy. This may be somewhat of an overstatement, but is largely true. That report also made a big issue of the "bilinear" organization of the Navy, which was also a long-time tradition. The bilinear organization basically separated the operating forces and their control from the organizations that developed or acquired ships, weapons, and supplies. This stems from the establishment of the bureau system in 1842 and was said to be required because the technical knowledge required for development and acquisition was different from that required to operate forces. Decentralization in operations was consistent with early strategy and use of navy forces. The practice was to station individual warships to protect ports and for ships to operate individually on the open seas. The small size of the Navy Department, lack of communication, and long periods of independent operation required decentralized control and led to the development of that culture in the officer corps.

This began to change in the late 19th century and is reflected in Mahan's writings. Strategy changed to emphasize operating as a fleet rather than as individual ships. This led to more centralized control – both within the fleet and above the fleet level. Communication technology began to support that. Mahan (and his followers) also advocated a more centralized command structure in general and, in particular, for a central office charged with planning and preparing overall Navy strategy and fleet operations. Decentralization was also reflected in the bureau system. Authority in the identified areas was distributed to bureau chiefs. The only common level across bureaus and between the bureaus and the operating forces was the Secretary of the Navy (SECNAV). In practice, they operated as independent entities. This changed slowly in the 20th century (sped along by World War II and the establishment of the Department of Defense) until they were abolished in 1966.

The bureaus were the biggest opponents to centralization and because most senior navy leadership (on the General Board or as Chief of Naval Operations) had served as bureau chiefs, early organizational changes had little effect on decentralization. There was political opposition to the "General Staff" concept in addition to the general opposition of the naval officer corps. The political concern was that a strong General

Staff (e.g., the German model) threatened the supremacy of civilian leadership over the military. When the Chief of Naval Operations (CNO) position was established in 1915, it was principally as one (of a number) of advisors to the Secretary of the Navy and to exercise control over the operating forces.

Chapter 1 contains a review of the various studies of the organizational structure and management of the Navy laboratory system after World War II. These studies lay the groundwork for understanding the changes that were made to the system in the first two postwar decades. Since this research is concerned with the relationship between structural change and strategic management, it is appropriate to review the evolution of organization structure and management processes, such as planning, budgeting, and program execution, in the Departments of Defense and Navy during this same time period.

Organizational Changes in the Navy

Before World War II the bureaus were the dominant force in the Navy for planning, budgeting, and program execution. The General Board was established in 1900 to do overall navy planning, but never achieved that goal. Board members were senior navy officers, most of who had served as bureau chiefs, and had little interest in trying to centralize power outside of the bureaus. The result was that, at best, the General Board helped to coordinate activities across bureaus.

Congress authorized the CNO position in 1915. The CNO reported to the Secretary of the Navy and, in practice, had little or no control over the bureaus or the budget. Vincent Davis (1967) notes several reasons for this. As with the members of the General Board, most CNOs had previously served as bureau chiefs and had little interest in reducing the authority of the chiefs. Second, the CNO was placed in a relatively weak organizational position (under the Secretary of the Navy) and was not given much staff. Finally, Davis notes that the dominant cultural belief among navy officers was opposition to centralization of authority. All of the senior officers – including the CNO and General Board – shared that belief and made no attempts to undercut it. In fact, that belief persisted until well into the 1960s. Davis opines that the Gates Board Report (1954) and the Franke Board Report (1959), which are discussed below, were largely attempts to preserve the decentralized navy organization in the face of DOD organizational changes (in 1953 and 1958). These organizational changes tended to centralize authority in the Office of the Secretary of Defense. In any case, Davis observes that the organizational changes that occurred (in the Navy) in 1954 and 1959 were minimal. The same could be said about the Dillon Report and organizational changes in 1962.

Research and Development (R&D) was very low on the Navy agenda in most of the first half of the 20th century. For example, there was no navy R&D budget line before World War II and, by some estimates (see Vincent Davis, *The Admiral's Lobby*), Navy R&D expenditures in 1940 totaled about 1 percent of the navy budget (or $9M). Even though the Naval Research Laboratory was established in 1923, it was located in a bureau in its early years and was somewhat ineffectual. The emphasis on R&D changed significantly during World War II. Science, and civilian scientists, played a major part in the war effort. In fact, the Navy established a Coordinator of Research position during this time (which was intended to be a civilian with a military assistant). These positions became the Assistant Secretary of the Navy for Research and Development and the Deputy CNO for Development in the organizational changes after World War II. The establishment of the Office of Naval Research (ONR) changed the relationship between the Navy and university researchers.

Shortly before the end of World War II, in the summer of 1945, Secretary of the Navy James V. Forrestal began to prepare the Navy for the postwar world and, specifically, for the expected pressure for reorganization and, perhaps, service unification. In order to prepare the Navy to plan and work more closely with the other services, Forrestal had to increase the power and prestige of the Secretary's office and decrease that of the CNO. President Harry S. Truman, in Executive Order 9635 (29 September 1945), gave a revised statement of the CNO's power, divided the supervisory power over the material bureaus between the secretary and the CNO, and created a new office, which reported to the secretary, to coordinate scientific research. Navy General Order 230 (12 January 1946), implementing some of the recommendations of a board chaired by Under Secretary of the Navy Artemis L. Gates, gave the CNO staff ("OPNAV") the responsibility for producing operational requirements. While not all of the naval officers agreed with Forrestal, most had to approve of his successful defense against service unification (Hone 1989).

The powers of the CNO were identified in General Order Number 5 (10 February 1947). These included "planning and forecasting the needs of the Operating Forces," "issuing statements of these requirements … to the bureaus," and "reviewing and evaluating the progress of the bureaus." A year later, Public Law 432 gave the CNO the authority to "coordinate and direct the efforts of the bureaus and offices of the Navy Department as may be necessary to effectuate availability and distribution of the personnel and material required where and when they are needed." .

Dwight D. Eisenhower's platform called for defense reorganization and, in particular, to increase the power of the Secretary of Defense over the military departments. Among the early reforms was the replacement of the Joint Chiefs of Staffs (and service chiefs) with the service secretaries in the chain of command from the President to the unified and specified commanders. Secretary of the Navy Robert B. Anderson, in response to the president's reorganization plan, appointed Under Secretary of the Navy Thomas S. Gates to head a special board to study the Navy organization (Carlisle 1993a).

The board reviewed the applicable general orders that allocated authority and responsibility within the department: General Order Number 5 (administration of the department), Number 9 (organization of the operating forces), and Number 19 (shore activities). They acknowledged and affirmed the basic structure of the Naval Establishment as a divided, decentralized organization (with dual chain of command) of the Navy Department and its bureaus, the operating forces, and the shore support facilities (Hone 1989). For example, the bureaus reported to the Secretary but were required to satisfy the requirements for weapons, training, and personnel set by OPNAV. An important change recommended by the board was the assignment of the responsibility for policy, management, and control of R&D to the Assistant Secretary of the Navy for Air.

Later changes in DOD included the establishment of the position of Assistant Secretary of Defense (Research and Engineering) in 1957 and Director of Defense Research and Engineering (DDR&E) in 1958. The services followed suit and, in the

Navy, the ASN (Air) was disestablished and replaced by the ASN (Research and Development) for the management of the newly established Navy RDT&E appropriation.

There was an evolution of the Navy organization associated with requirements planning. In 1947, the New Development Board was established as the OPNAV focal point for R&D requirements and budget review. The board was later renamed the Navy R&D Review Board and the Chief of Naval Research was made a member. In 1950, the Law Board recommended, and the CNO created, the New Development and Operational Evaluation Division under the Deputy CNO (Operations) to coordinate operational requirements. The Libby Board recommended in 1956 that the division be replaced by the Assistant CNO for Research and Development under the Deputy CNO (Fleet Operations and Readiness). Two years later, a change was made so that the Assistant CNO reported directly to the Vice CNO (Booz, Allen and Hamilton 1976).

In 1959, the OPNAV R&D function was elevated by the establishment of the Deputy CNO (Development) to coordinate the RDT&E program (as recommended by the Franke Board). CNO staff planning was done by the Long Range Objectives Group and the CNO Advisory Board. The Deputy CNOs prepared program plans – consistent with OPNAV guidance from the Advisory Board – that were forwarded to the material bureaus. The actual link between the bureaus and the Deputy CNOs was a group of officers called "program coordinators." As detailed in Chapter 1, the bureau structure was changed in 1959, followed by the establishment of the Chief of Naval Material and the Naval Material Support Establishment (1963), and the Naval Material Command and the Director of Naval Laboratories (1966). All of these changed the relationship between OPNAV and the bureaus (or systems commands) and R&D planning.

Planning Processes

Early in the era (ca. 1946), requirements from OPNAV warfare desks[14] and the Operational Readiness Division were transmitted to the Deputy CNO for Logistics, who established the project in the appropriate bureau. In 1948, after R&D responsibility had been assigned to OPNAV and the New Development Board had been established, the Navy Planning System was instituted. Under this process three requirements documents were developed: (1) Planning Objectives (by OPNAV), (2) Operational Requirements (OPNAV), and (3) Research Requirements. Bureau chiefs had the authority to plan and initiate R&D programs to meet the material needs of the fleet. OPNAV coordinated the R&D program using annual budget reviews by the Navy R&D Review Board (NRDRB). It was the responsibility of the bureau chiefs to justify their budget to the Bureau of the Budget and to Congress. The Office of the Secretary of Defense (OSD), through the Research Development Board (RDB), influenced R&D planning and specified the format of several standard reports (Booz, Allen and Hamilton 1976).

There were several changes to the planning processes implemented in the mid-1950s. The New Development and Operations Division in OPNAV introduced the "Development Characteristics" document that was more specific than the Operational Requirements document. The Assistant CNO for R&D established the requirement for Technical Development Plans, CNO Weapons (Support) systems concepts, and annual program guidelines. The most lasting change was the Technical Development Plan

[14] The bureaus and CNO staff were organized along functional lines (e.g., testing or science and technology), by platform type (i.e., class of ship or type of aircraft), or by warfare area (e.g., air warfare or mine warfare). These organizational elements, which were responsible for planning, budgeting, and oversight in their particular area, were referred to as "desks." The person who was in charge of the desk, usually a naval officer, was called the "desk officer."

(TDP). This required the bureaus to provide a formal plan describing what they proposed to accomplish and how.

There were additional changes between 1958 and 1962. A separate program category was created for exploratory development in 1959 and exploratory development requirements were issued. In 1961 the OSD introduced the Planning, Programming, and Budgeting System (PPBS) and changed the Research, Development, Test and Engineering (RDT&E) program structure to include six program categories: Research, Exploratory Development, Advanced Development, Engineering Development, Management and Support, and Operational Systems Development. Between 1960 and 1962, DDR&E imposed a variety of new reporting requirements, including TDPs and program lists. The Deputy CNO (Development) revised navy RDT&E program planning in 1962 to bring it in line with the OSD structure.

R&D Budget Process

In the immediate post-World War II years, the Navy R&D budget process was bureau oriented (as might be inferred from the previous description of the planning process). R&D was a set of disaggregated line items funded within the context of the overall bureau program. R&D (except for the "Research, Navy" line for ONR) was not a separate item in either the budget or the appropriations. Budgets were prepared by the bureaus and justified to the BOB and Congress by the bureau chiefs. The chief also had broad reprogramming authority within a blanket appropriation for his bureau. Subsequent changes, associated with the establishment of the Office of the Secretary of Defense (OSD) and the National Military Establishment (NME) by the National Security Act of 1947, theoretically consolidated the budget defense. In reality, it imposed little management control and the service secretaries could appeal decisions to the Office of the President.

The National Security Act of 1949 established stronger OSD controls by establishing comptrollers in OSD and in the military departments and instituted an integrated budget review. The Navy comptroller, who was in the Assistant Secretary of the Navy (Air) office, followed suit and had an integrated review of the Navy budget. The budget structure was changed in 1951 to be based on program objectives under the standard 21 appropriate titles structured along bureau management responsibility lines. Note that R&D was a standard subheading in nine of these titles. It is significant that although the bureaus were not mentioned by name, the bureau chiefs were still required to justify the budget. In 1953 the first DOD-wide budget classification system was established (with activities aggregated by major cost categories, such as R&D).

The organizational changes made between 1953 and 1960, which were described earlier, were accompanied by changes in the budgeting processes. For example, the "Research, Navy" line and bureau R&D were consolidated into a single line – "R&D, Navy" – and management responsibility was assigned to Assistant Secretary of the Navy (Air) and later to ONR. This was expanded to "RDT&E, Navy" in 1958 to align with the DDR&E push for standardized titles. This was standardized across all military departments in 1960. The establishment of PPBS led to greater centralization at the OSD level. Under this program, budgets and plans were aggregated into major program packages, such as R&D. These program packages were broken into program elements, which was the level at which DDR&E exercised control. Navy R&D program managers, for example, prepared data and estimates by program element for aggregation and review (in major program packages) by DDR&E. These same elements structured the allocation to Navy offices. (Carlisle 1993a)

The increased centralization in the OSD was highlighted by the resignations of the Chief and Deputy Chief of BuShips in October 1965 "… in protest against the increasing centralization of authority in the Defense Department" (New York Times, 10/28/65). The two officers were particularly concerned about the power of the comptroller's office, which they viewed as McNamara's primary means for exercising budgetary control over the military departments. It was also observed that "[i]n recent years, however, the bureau's authority has been curtailed by several management reorganizations … . A little over a year ago, for example, an Office of Naval Material was created to supervise the bureaus and there was widespread speculation that this was but a first step towards abolishing the bureaus."

It is important to highlight the extent of bureau freedom relative to the budget process through much of this period. For example, in the early 1950s the Bureau of Ordnance authorized some of its laboratories to "tax" programs to produce discretionary funds to be applied to in-house foundational research. This became Navy-wide practice in the 1960s when the IR/IED program was created. As previously noted, the laboratories also had some ability to reprogram other funding, as did the bureau.

Program Execution

Through the first half of this era (until about 1955) the basis for research was the "competent individual." Under this model, there was a significant level of freedom at the project level (and below) in basic and applied research. ONR and the bureaus worked to achieve a program that was balanced in a number of dimensions, including by discipline, government/non-government, and across specific laboratories. Technology programs were more focused, but until the late 1950s, there was a great degree of bureau independence. The bureaus were guided in this complex and unstructured process by their responsibility and authority to meet fleet needs.

Execution of full-scale development programs was under the cognizance of the bureaus once OPNAV decided to pursue them. Planning and control was delegated to project officers and engineers, who were sometimes assisted by bureau laboratories in the performance of their technical direction role. As noted previously, the roles assigned to laboratories and the relationship between the bureau and its laboratories varied from bureau to bureau. For example, the Bureau of Ordnance (BuOrd) tended to use its laboratories in the technical direction process more than the other bureaus.

Beginning in 1955 (and continuing for at least the next 20 years), bureau control of system development eroded. This began with the establishment of program managers within the bureaus and then by the Assistant Secretary of the Navy for Research and Development and the Chief of Naval Material. These program managers had less regard for bureau traditions and laboratory prerogatives and, consequently, the laboratory share of funding for advanced engineering and operational systems development declined from 37 to 28 percent from 1965 to 1973 (Carlisle 1993a).

Summary

As World War II was ending, an important debate over the role of the federal government in science was beginning. World War II resulted in a major change in the role of the federal government in research and development – from virtually no involvement to patronage of research and development. During the war years, four major activities – the Office of Scientific Research and Development (OSRD), War Department, Navy Department, and the National Advisory Committee on Aeronautics – were involved in research activity in support of national defense. Each organization operated independently, they performed research in different ways – government laboratories and arsenals, industry – and they were not always on friendly terms. There was also conflict between the military and the civilians. The civilian scientists and administrators had disdain for the strict military protocol and for those who had made their careers in government or the military rather than in academia. The military was very protective of their roles in developing military policy and strategy and viewed civilian involvement as interference. What was the actual contribution of basic research to national defense? The military officers praised the contribution of science to the war effort, but were usually talking about technology when they said that (Sapolsky 1990).

The post-World War II debate revolved around several issues: (1) the appropriate size of the federal science budget (and, namely, should it be less than it was during the war), (2) centralized or distributed planning and funding of research by the federal government, (3) the proper role of the military in government science, (4) the government's focus – basic research or technology, and (5) the government's role – performer or patron. The debate extended to the Navy Department as well. In May 1945, Secretary of Defense James V. Forrestal established the Office of Research and Invention (ORI), which was headed by a naval officer but reported to the Secretary. This move and the subsequent discussion associated with the establishment of the National Military Establishment highlighted the disagreement within the Navy over control of the planning and budget for science. The uniformed Navy wanted control placed with a

Deputy CNO while the civilian side (and, in particular, the Secretary of the Navy) desired civilian control. The bureau chiefs, as expected, preferred to maintain control of their own research programs. The Secretary of the Navy prevailed. The ORI was renamed the Office of Naval Research (ONR) and assigned to the Assistant SECNAV (Air) and, later, to the new Assistant SECNAV for Research and Development.

As noted above, OPNAV was given preference in the establishment of military requirements. Early in the era the bureaus and OPNAV shared responsibility for planning. Specifically, OPNAV set requirements, established a program and developed an overall budget for the bureaus. The bureau chiefs were responsible for the detailed planning and execution and budget justification to the Bureau of the Budget and Congress. They also had freedom in planning R&D and in reprogramming funds within fairly broad limits. The bureaus shared this freedom with their laboratories to varying degrees. BuOrd gave its laboratories the most freedom.

All of the organizational, process, and budget changes that were made in the next 20 years had the effect of centralizing control of planning and budgeting for basic research and exploratory research at the Navy level and at the DOD level. Control of development remained with the bureaus, although it began to erode in the late 1950s with the development of the first program offices. As noted previously, this erosion accelerated with the establishment of the Chief of Naval Material.

Finally, this chapter presented a review of management processes in the Departments of Defense and Navy to complement the history of organizational structure changes given in Chapter 1. An analysis of these organizational developments, using the frameworks and concepts developed in Chapters 2 and 3, is the subject of the next chapter.

CHAPTER 5

APPLICATION TO NAVY LABORATORY HISTORY

Introduction

Consider three phases of laboratory history: before 1963, 1963-66, and after 1966. Organizational charts covering 1946 through 1966 are given in Figures 5-1 through 5-4. In the first phase (before 1963), the laboratories "belonged" to the bureaus. The bureau chiefs reported directly to the Secretary of the Navy (SECNAV), as did the Chief of Naval Operations (CNO). This "bilinear" organizational form dated back to 1842. The number and nature of the material bureaus changed in 1959 (as they had other times). Before 1959, the bureaus of interest were the Bureau of Ships (BuShips), Bureau of Ordnance (BuOrd), and Bureau of Aeronautics (BuAer). In 1959, BuOrd and BuAer were combined to form the Bureau of Naval Weapons (BuWeps). (Note: In the pre-1966 context, the term "laboratories" is used to refer to the fifteen major Research, Development, Test and Evaluation (RDT&E) activities, as identified in the reorganization studies of the 1960's. There were other field activities that also belonged to the bureaus, but they were different in their nature and mission from the other fifteen.)

In the second phase, the Chief of Naval Material (as head of the "Naval Material Support Establishment (NMSE)") was interposed between the bureau chiefs and the Secretary of the Navy. As before, the laboratories belonged to the bureaus. The main reason for the establishment of the Chief of Naval Material (CNM) was to provide

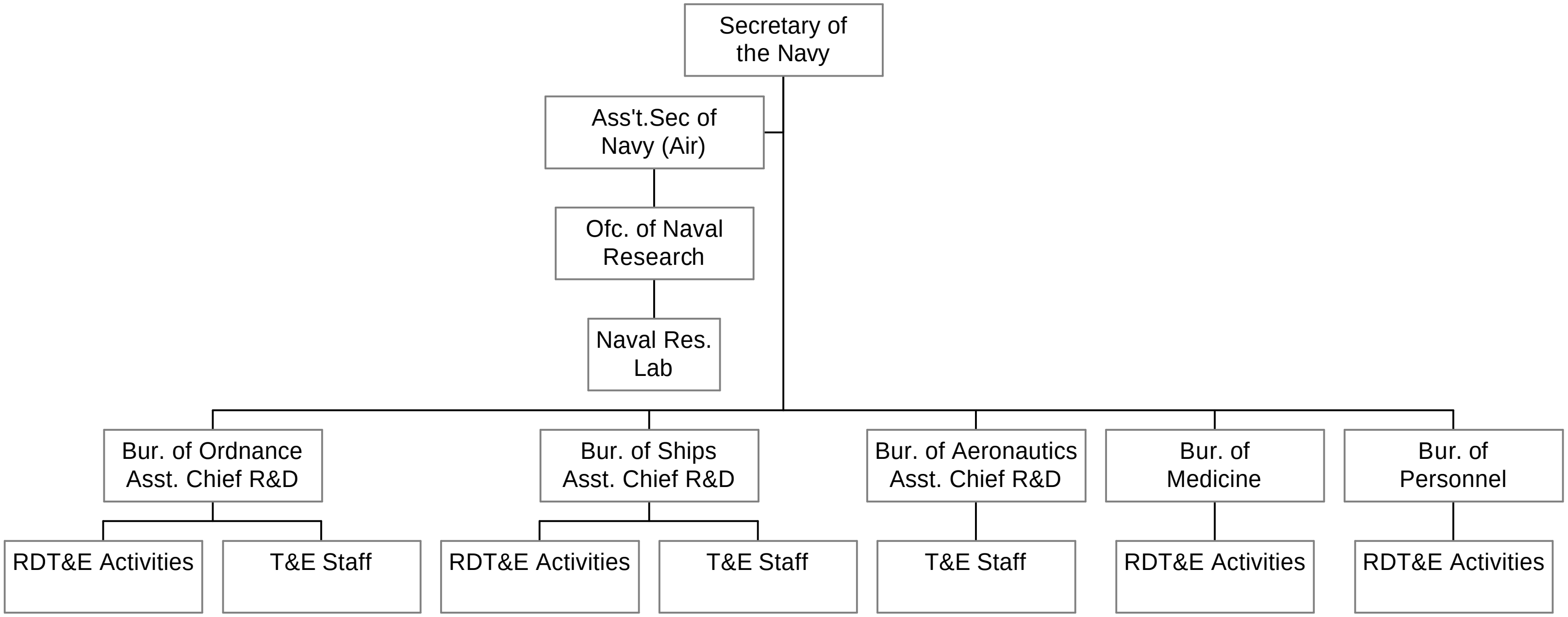
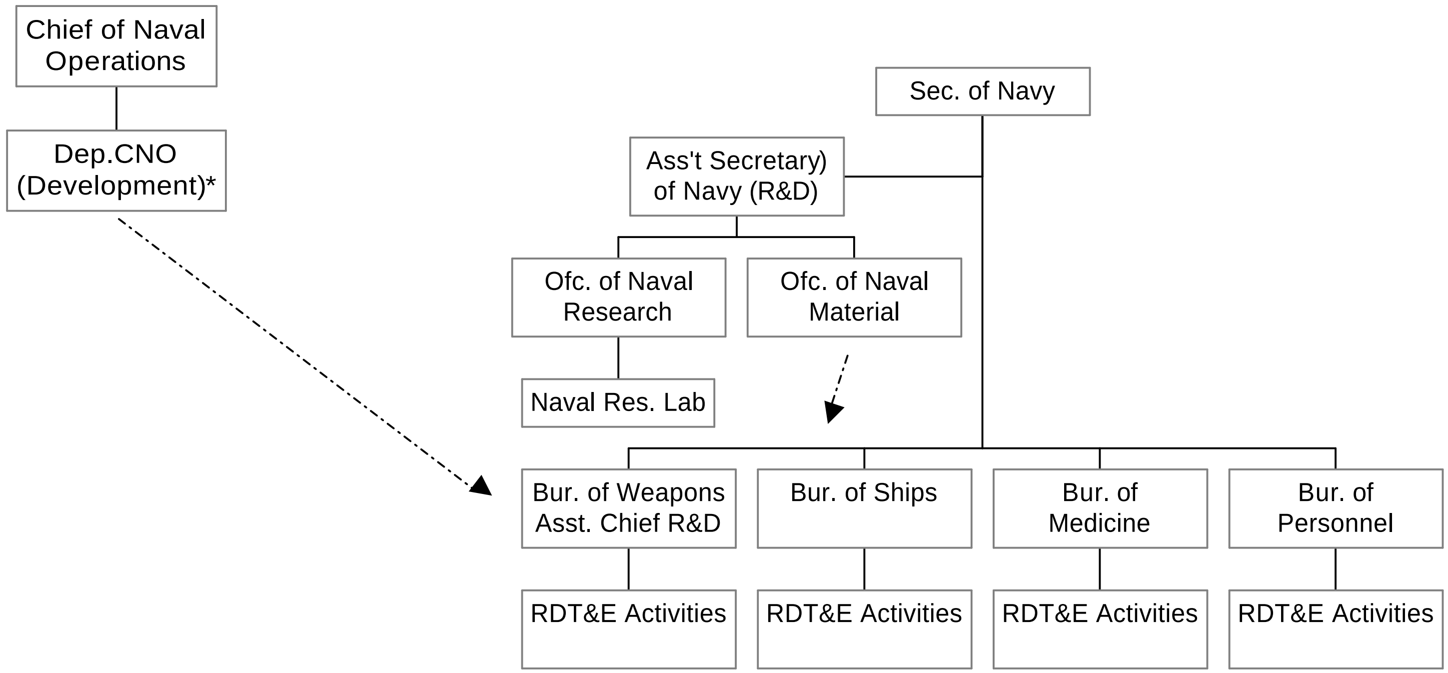


Figure 5-1: Navy Organization – 1946



*Also, Dep. CNOs and Ass’t. CNOs for fleet operations, planning, platforms, …

Figure 5-2: Navy Organization – 1959

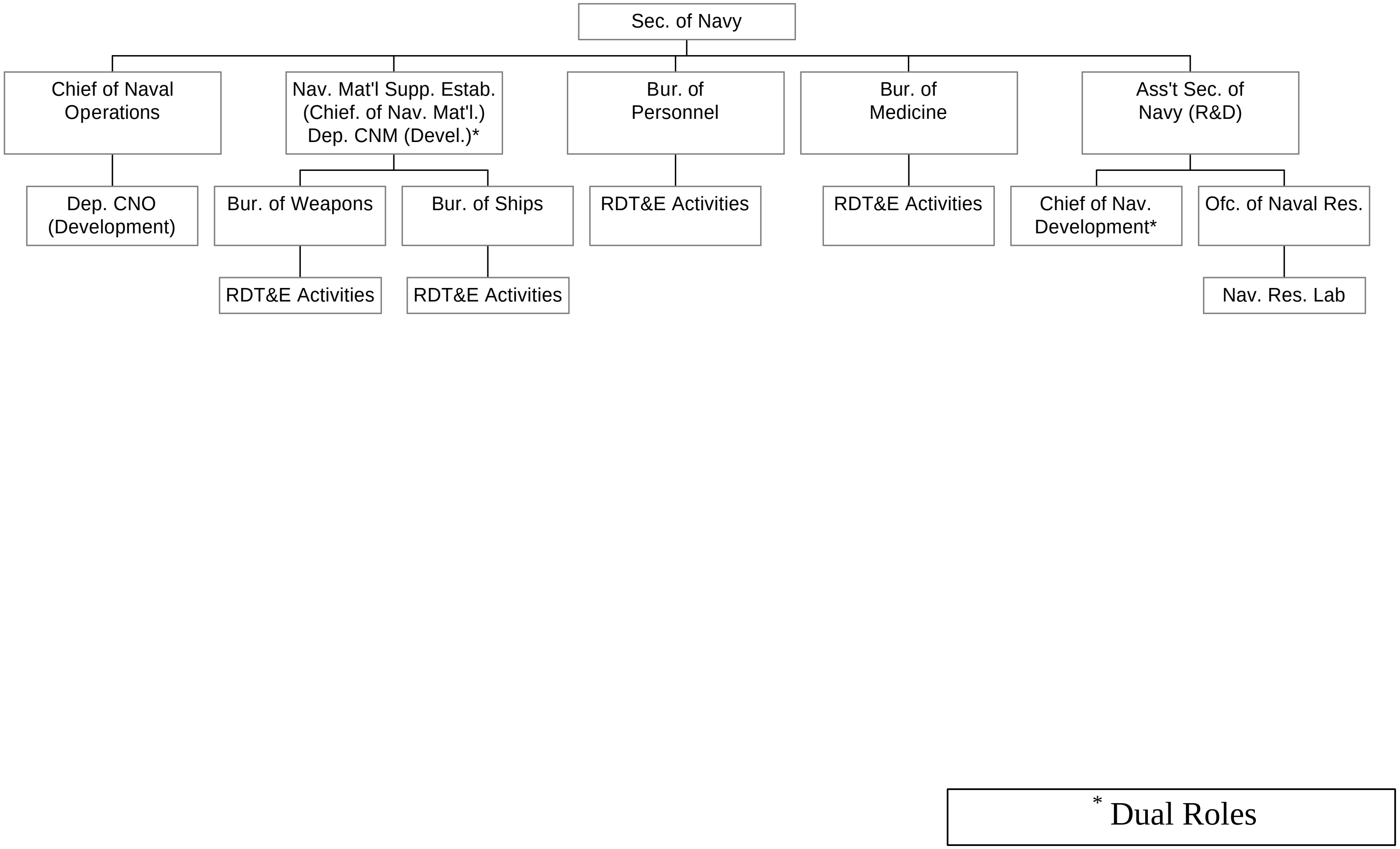


Figure 5-3: Navy Organization – 1964

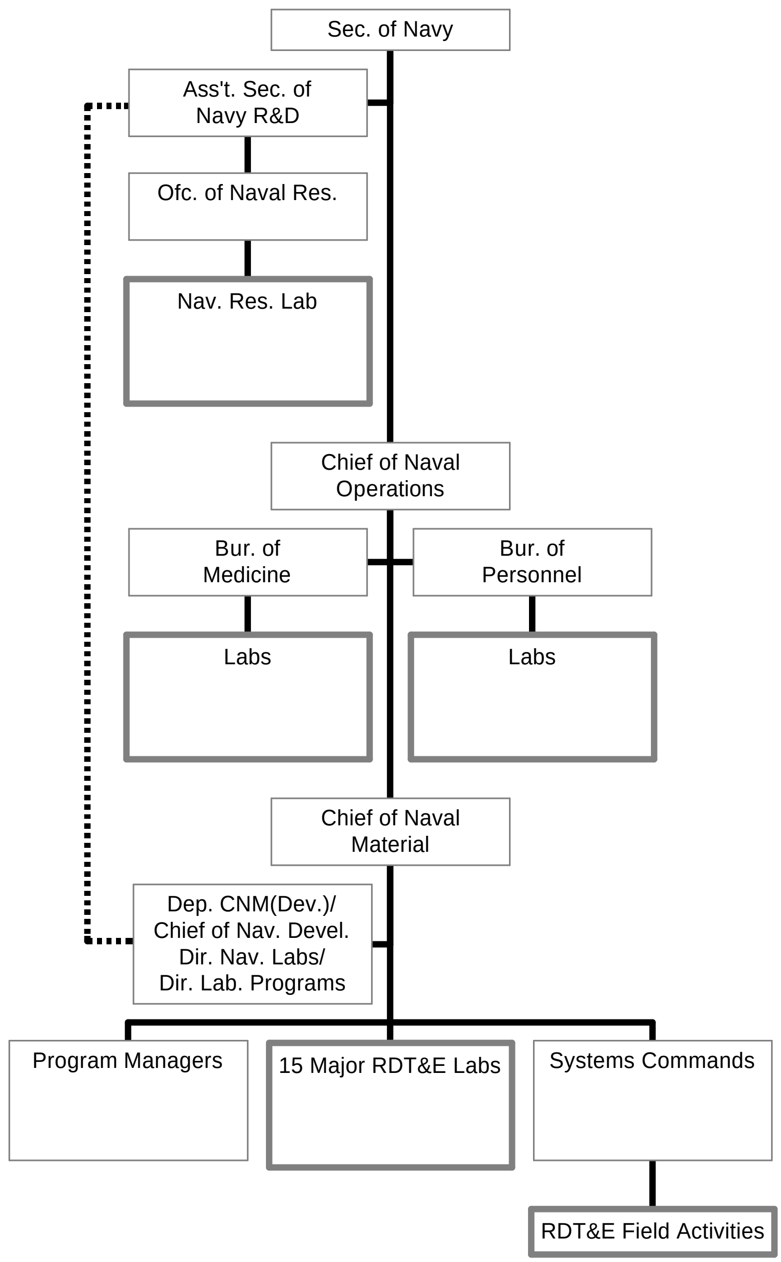


Figure 5-4: Navy Organization – 1966

coordination for systems development across the bureaus at a level below Secretary of the Navy. It was a reaction, in part, to the establishment of program offices outside of the bureaus. (Note: Bernard calls the establishment of program offices outside of the "normal" organizational structure one sign that the organizational structure has become dysfunctional.) Some (see Galantin quoted in MacDonald, 1966) also believed that between the establishment of program offices and the CNM (and especially through movement of some bureau staff to CNM and program offices staffs), the authority of the bureaus was undermined and they were diminished as the "paramount corpus of technology know-how."

In the third phase, the bureaus were disestablished and six systems commands were created. The systems commands were part of the Naval Material Command (NAVMAT) and reported to the CNM. The laboratories were separated from the bureaus and reported directly to CNM. A Director of Navy Laboratories/Director of Laboratory Programs (DNL/DLP) position was created on CNM staff and was responsible for the laboratories. There were also program offices that reported to CNM that had responsibility for the development of specific systems that cut across the systems commands.

As the Navy structure changed, so did the associated management processes and systems. The following sections will describe the management of Navy research and development in each era.

Management in the Bureau Era

The bureaus worked with the CNO Staff (“OPNAV”) to define requirements in the pre-1966 era. The idea was that OPNAV (representing the "user") would know fleet requirements and the bureaus would know the state of technology. The bureau chiefs prepared their own budgets and presented them to the Secretary of the Navy and defended them to Congress. After the late 1950s the research and development (R&D) budget (primarily for foundational or basic research) was rolled up by the Office of Naval Research (ONR) for the Assistant Secretary of the Navy for Research and Development. Much of this work and funding was outside of bureau control; however, there was usually a small amount of funding available for the bureaus. Most of the in-house funding went to the Naval Research Laboratory (NRL), which was ONR's laboratory. The bureaus, on the other hand, were in control of the work and funding for applied research and development. Hence, their "research" interest was usually directed at the application of research to upgrade existing systems or in the development of new systems. In short, there was no centralized "Navy Laboratory System." Instead, there were several – in each bureau and in ONR.

Each bureau had different requirements for research and for its laboratories. BuAer, for example, tended to focus its laboratories on test and evaluation (T&E) because there was a thriving aircraft industry and the National Advisory Committee for Aeronautics (NACA) for research and development. Their field activities provided the major facilities to test aircraft (and fly off competing concepts). BuOrd laboratories did both R&D and T&E because there was little industrial capability for research and development of ordnance. Some of the BuOrd laboratories had a research function. Other field activities primarily provided test and acceptance facilities. BuShips was a little of both as well as production. The BuShips laboratories provided T&E facilities (such as the model basin) that were also used for research in hull shapes and other areas.

This facility (by Public Law) served the same function for the commercial shipbuilding industry. BuShips, through its Supervisors of Shipbuilding and the Navy Shipyards, was also directly involved in managing production (in this case, shipbuilding).

Laboratories generally received funding from "desks"[15] in the bureau with which they were associated. In BuOrd, for example, the Naval Ordnance Laboratory (NOL) received science and technology (S&T) funding from a desk concerned with research while the Naval Proving Grounds (NPG) at Dahlgren (later the Naval Weapons Laboratory, NWL) received its funding (primarily T&E) from another desk. Funding might also be received from desks responsible for specific systems or from program offices outside of the bureaus that were responsible for major system development efforts (for example, the Special Project Office (SPO) for Polaris). Note that when BuWeps was formed from BuOrd and BuAer, the funding process did not really change. The laboratories still went to the same individuals on the same desks; the old BuAer and BuOrd pieces still existed and operated much as they did before the reorganization (McLean, Oral History 1974).

Within BuOrd, allowance was made for certain laboratories to "tax" the funding it received (up to a specified maximum) to create a discretionary fund that its Technical Director could use to fund research efforts of his choosing. When this was first proposed BuOrd anticipated "… that a maximum of 20 percent of the total yearly project money budgeted for the Naval Ordnance Laboratory can be made available for this allotment, of which not less than one-half should be assigned for fundamental research" (Chief, BuOrd 12 June 1950). Edward S. Lamar reported, in a Naval Air Systems Command

[15] This term is discussed in Chapter 4.

memorandum (dated 25 January 1968), that this process started in BuOrd in 1950 and foundational research was funded as a percentage of total research and development (R&D) funds authorized to each of three stations: Naval Ordnance Test Station – 10 percent, Naval Ordnance Laboratory – 10 percent, and Naval Proving Ground – 5 percent. In 1953, foundational research was a line item in the R&D budget for seven BuOrd laboratories and by 1955 it was being distributed to laboratories in proportion to the number of professional technical personnel at each station.

The Bureau of Ships (BuShips) started a similar program in 1956 (Chief, BuShips 10 October 1956). Funding for foundational research was budgeted for each laboratory based on laboratory proposals to BuShips. The Bureau of Aeronautics (BuAer) established their program at some field stations in 1958. The BuOrd and BuAer programs were merged when the bureaus were combined to form the Bureau of Naval Weapons (BuWeps) in 1959. Reporting by the laboratory directors to the parent bureau was very informal until BuWeps established a formal process in 1963 to satisfy a Secretary of Defense requirement. The Chief Scientist of BuWeps provided an annual report to the Assistant Secretary of the Navy (Research and Development (Lamar 25 January 1968). This program was formalized for all laboratories in the early 1960s with the establishment of the Independent Research/ Independent Exploratory Development, or IR/IED, program.

The laboratories also had some flexibility in "reprogramming" their funding as long as they accomplished what they were tasked to do. Examples may be shown of laboratories using their discretionary funds (or reprogramming funds received for other purposes) to pursue research and development, even in areas outside of their mission (and even their bureau's mission). The development of the Sidewinder missile by the Naval Ordnance Test Station at China Lake is one example. In general, the laboratories received most of their funding from the bureau that they belonged to, but had some capability to fund discretionary action.

Management in the NMSE Era (1963-66)

Generally, the management processes continued to work much as they had in the earlier phase. Each laboratory still belonged to a bureau and received funding in much the same way as before. There was, however, a process in place to provide discretionary funds to laboratories (IR/IED). The feeling was expressed (see MacDonald and Galantin) that the new organizational structure had weakened the ability of the bureau chiefs to do their jobs. This was specifically attributed to the creation of the Naval Material Support Establishment (NMSE) and, in particular, to the creation of the Chief of Naval Material (CNM) to coordinate among the bureaus. Galantin notes that the CNM staff was created by moving people from the bureaus with the result that the bureaus were weakened. The bureaus were further weakened when people were transferred to staff the program offices. There was still no centralized "Navy Laboratory System" other than the weak system that was implied by the NMSE structure. This, Galantin felt, was a source of major weakness in the functional management of the NMSE.

It was noted in the earlier organizational history that there was a continuing effort to centralize planning in the Department of Defense (DOD) and in the services. The more centralized budget control began to affect the freedom that the bureaus had traditionally enjoyed. The creation of additional program offices and the establishment of the NMSE and CNM both exacerbated this. The resignation of the Chief of BuShips and his deputy in October1965 was to protest the growing centralization of authority in the Defense Department.

Management in the DNL Era (Post-1966)

The reorganization in 1966 is described as having eliminated the bilinear system since the Chief of Naval Operations was placed directly in the laboratory chain of command. In the new organization the CNM reported to the Secretary of the Navy (SECNAV) through the CNO. Research and development was managed through a separate organizational line to the Assistant SECNAV for Research and Development (and then to the Secretary of the Navy). The 15 major RDT&E activities became part of the Navy Material Command (NAVMAT) and reported to the CNM rather than to the systems commands that replaced the bureaus. The laboratories reported to the Assistant SECNAV for R&D through the Director of Navy Laboratories/ Director of Laboratory Programs (DNL/DLP), who was on the CNM staff.[16] This created the first centralized Navy Laboratory System. Other field activities (e.g., the engineering activities) reported directly to the systems commands as they had to the bureaus.

Most laboratory funding came from the systems commands and the program offices. R&D funds (including IR/IED), which were controlled by the ASN (R&D) and planned for the laboratories by DNL, were a minimal part (typically no more than 5-10 percent) of most laboratories' funding. The DNL/DLP position was set up in NAVMAT to manage the Navy Laboratory System. In theory, the DNL/DLP controlled R&D funding, military construction (MILCON) planning and funding, personnel ceilings,

[16] The DNL/DLP was a member of the CNM staff. As DNL, he reported directly to the Assistant SECNAV for R&D regarding certain research programs and funding. As DLP, he was responsible for managing the laboratories that were part of the Naval Material Command.

represented the laboratories to the systems commands and the secretariat in resource discussions, and directed workload balancing between laboratories and the assignment of responsibilities. Later on, the DNL established a long range planning process for the laboratory system.

Organizational Analysis

Overview

Chandler (a rational theorist) provides a model for analyzing the formal Navy R&D structure. Chandler's *M-form* organization is an example of a multi-division hierarchal model that provides a way to characterize the different expectations for strategy at each organizational level. With this model the Secretary of the Navy (and staff) represents corporate-level management, the bureaus are product- or business-specific divisions, and ONR is the corporate research organization. Similarly, the CNO staff (OPNAV) might be seen as the "corporate planning staff." This representation clearly seems to be applicable to certain parts of the OPNAV organization, specifically the warfare desks and Deputy CNOs who were responsible for planning and coordinating budget reviews. All in all, however, this is a reasonable way to describe the organization and the expectations for strategy that result (see Chandler and Burgelman and Sayles). If this hierarchal model is extended to the individual bureaus, then it leads to similar expectations relative to the relationship between the bureau and its laboratories and engineering stations. This plays out differently with each bureau based on the nature of its "business."

Further, this representation supports the view that the leaders of the organization subscribed to a *closed-rational* perspective on organizational theory. (Note that one might argue that BuOrd moved towards a *closed-natural* perspective with regard to research, if not necessarily for system development. This would appear to be less true of the other bureaus and with BuAer in particular.) The models for planning and strategy that were developed fit well with this perspective. This was certainly the case with basic research. Technology (defined as applied research for application to system development) was more complex – through the late 1950s at least – since authority for planning was devolved to the individual bureaus. The higher-level control, in theory, came through the specification of bureau missions and areas of responsibility and responsibility for their overall budgets.

Understanding the Navy Laboratory System

When using organization theory to gain understanding of the changes in strategic management of the Navy laboratory system, it is helpful to start with the post-World War II organizational structure of the Navy acquisition system. As noted previously, it had a strong resemblance to the *M-form* organization described by Chandler. The Secretary of the Navy (SECNAV) was the head of an organization comprising three product-specific divisions – the material bureaus: Bureau of Ships (BuShips), Bureau of Ordnance (BuOrd), and Bureau of Aeronautics (BuAer) – and a "corporate" R&D division: the ONR and NRL, headed by the Assistant SECNAV for Air. The CNO staff (OPNAV) provided corporate leadership in the development of requirements. Each bureau had product-specific elements and a "division-level" R&D function. In short, the organizational structure was a classical hierarchal one. Did the Navy planning process fit this organizational model?

Burgelman and Sayles (1986) differentiate between the roles of corporate R&D and division R&D. Corporate R&D focuses on building knowledge in general and on developing new products or business areas. Division-level R&D activities focus mostly on the application of technology to maintaining and improving existing products (or weapon systems in the case of the bureaus). Basic research will be a very small percentage of the work in bureau level R&D. The executive role (SECNAV) is to specify the areas in which activity is to be performed – the general research areas for R&D and product lines (and corresponding organizational structure) for the organization in general. This sounds very much like a rational planning and management process. In fact, formal planning (requirements-setting) processes were implemented in OPNAV in the years following World War II (as previously described) with the intention that the development and acquisition processes would be driven from the top down. More specifically, the Navy acquisition and development system was viewed and operated as a *closed-rational* system.

In reality, the bureau chiefs retained significant authority over systems development in their area of responsibility and for their budget - both its development and its execution. The bureaus had both a voice in the high level planning by OPNAV and the power to operate somewhat independently in planning their own research initiatives and in the systems they developed or acquired. There were other laboratory management efforts, such as the Laboratory Management Council, that provided still more opportunities for planning at the bureau level. In the next decade or so, shortcomings in the system began to surface. Specifically, the development of some new weapons (such as guided missiles) did not easily fit into the existing bureau structure.[17] In addition, there was a push at the DOD level for centralized control of the R&D planning process. Organizational changes were made to gain control outside of the bureaus in order to address both of these issues. Navy R&D budget elements were established and control of them was centralized under the new ASN (R&D). Likewise, the Office of Naval Material (ONM) and some program offices were established under the Assistant SECNAV for R&D to provide coordination of activities between bureaus. Finally, BuOrd and BuAer were combined to form the Bureau of Naval Weapons (BuWeps). Each of these steps to provide means for formal control and restructuring to meet changing business needs is consistent with viewing the system from a *closed-rational* perspective.

This same perspective appears to have informed the reorganizations that followed in 1964 (establishment of Naval Material Support Establishment and the Chief of Naval Material, CNM) and 1966 (disestablishment of the bureaus, establishment of the Naval Material Command above the laboratories and the systems commands, and creation of the DNL/DLP to manage the laboratories). These reorganizations were part of a continuing, but never fully successful, effort to gain the management control over the organization that the structure implied (and that would be consistent with the *closed-rational* view). This can be argued at either the bureau (or systems command) level or a

[17] The roles of the Navy bureaus were focused either on platforms (i.e., ships for BuShip and aircraft for BuAer), weapons (BuOrd), or functions (BuPers or BuMed). Guided missiles did not fit this model cleanly. BuAer chose to consider guided missiles as "aircraft" while BuOrd considered them weapons. They also disagreed on the technical solution – jet powered missiles such as Regulus or ballistic missiles. (Armacost, 1969) This mirrored the larger disagreement between the Air Force and the Army in the late 1940s and 1950s. The Air Force viewed missiles as an extension of their strategic bombardment mission while the Army considered them an extension of artillery. (Beard, 1976; Armacost, 1969)

higher level (either the Secretary of the Navy or Assistant SECNAV level). The focus in this research is at the bureau (or systems command) level.

The organizational charts clearly indicate that there was no formal laboratory system prior to 1966. Similarly, the 1966 organizational chart illustrates the intended laboratory system under the Chief of Navy Material. Various studies (see Chapter 1 for examples) clearly hint that the laboratories were separated into commonly recognized groups such as the “15 major RDT&E activities” and “engineering stations.” These groups, which were acknowledged by the 1966 reorganization, cut across bureau lines and had more to do with capability and the types of work performed than with size. A closer look shows that there were also important subgroups. For example, not all of the 15 major RDT&E activities were equal. Some had a larger S&T component and others were more inclined to applied research or test and evaluation.

Categorizing the Navy Laboratories

As discussed in Chapter 2, Charles Perrow (1986) provides a framework for mapping organizations based on the complexity of their organizational interaction and the tightness of the organizational coupling. Also described in Chapter 2 is the Henry Mintzberg framework for categorizing organizations (and applicable modes of strategic management) based on the complexity of the organizational environment and its rate of change. One could begin to define the pre-existing laboratory system by using these frameworks to characterize the bureau laboratories. It is important to recognize that there were differences between laboratories within a given bureau and, hence, categorizing at the bureau level is only a first step. It is suggested here that the bureaus can be located in Perrow’s framework as shown in Figure 5-5.

As previously described, the BuOrd laboratories performed a variety of tasks from basic research to production because there was little or no commercial source for their products. Thus, the BuOrd laboratories might be placed in the "loose-complex" quadrant. The BuAer laboratories were largely for test and evaluation since the aircraft industry and NACA were sources for research, development, and production. Thus,

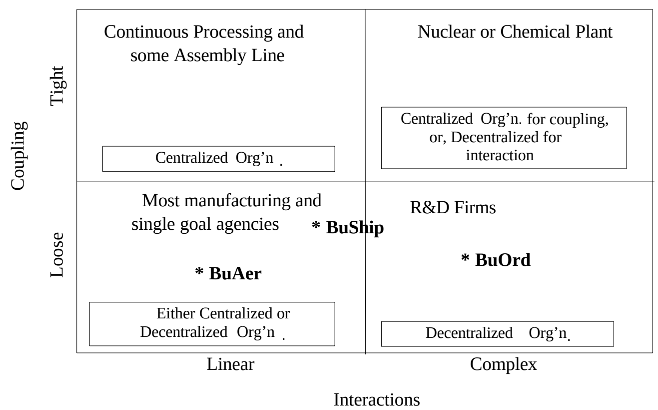


Figure 5-5: Classification of Bureaus with Perrow Framework

while the products (aircraft) were complex, it seems appropriate to place BuAer in the "loose-linear" quadrant. The BuShips laboratories ran the gamut from industrial (namely, shipbuilding) to research and they are placed on the boundary between the two quadrants. Perrow notes that organizations located in the "loose-linear" quadrant could reasonably choose either a centralized or decentralized organization (although, in his experience, most opt for a centralized organization). Organizations in the "loose-complex" quadrant should always choose a decentralized structure. The complexity of the environment requires it and the looseness of the internal coupling allows it.

Likewise, the bureau laboratories can be loosely located in the Mintzberg framework (Figure 5-6), which offers additional insights into the nature of strategic management that was appropriate. Locating the BuAer laboratory in the low complexity – low rate of change quadrant is consistent with both a centralized organization and use of a rational planning model. On the other hand, BuOrd, because it operated in a moderate uncertainty environment, would benefit from a planning process that is compatible with a decentralized organization. In other words, a process that makes the most of the numerous interactions with the complex environment.

If an information perspective (as associated with Hatch in Chapter 2) is overlaid on the Mintzberg framework, one finds that typically the information needed for rational planning by a centralized organization is available to organizations in a low uncertainty environment (the low-low quadrant). (See Figure 5-6.) Organizations in the moderate uncertainty environment (the high-low quadrant), on the other hand, run the risk of having information overload. Planning in that environment is dominated by emergent strategies rather than those produced by a rational planning model. In other words, strategies should result from a process that allows participation by the decentralized elements of the organization that are in closest touch with the different aspects of the environment.

These frameworks, taken together or separately, provide one basis for explaining the differences in organizational structure and strategic management of the Navy laboratories by bureau. It is apparent that the bureaus cover the spectrum from a centralized, rational system/process to a decentralized one. The planning process associated with the decentralized system would be as suggested by *open system* theorists. If this categorization were taken a step further, it would be clear that the individual laboratories within the Bureaus (especially those in BuOrd and BuShips) are not

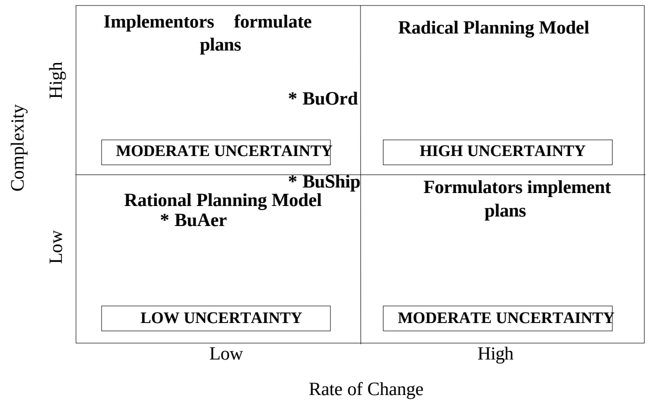


Figure 5-6: Classification of Bureaus with Mintzberg-Hatch Framework

adequately represented by locating the entire bureau within the Perrow and Mintzberg frameworks. Instead, individual laboratories within a given Bureau may be spread across multiple quadrants.

In BuOrd, for example, laboratories with a greater focus on science and technology (such as the Naval Ordnance Laboratory and the Naval Ordnance Test Station) will be located in Perrow's "loose-complex" quadrant and Mintzberg's "high-low" quadrant. Other BuOrd laboratories (e.g., NPG) might be more appropriately located in (or closer to) the "loose-linear" and "low-low" quadrants. The same distinctions can be made with the BuShips laboratories. To a significant degree, the 15 major RDT&E activities tend to fall into one category and the engineering and test stations into another. Even when 1 of the 15 activities is more appropriately part of the other group (based on the general nature of its work), it was considered 1 of the 15 on the basis of the diversity of its work and its size.

The 15 major RDT&E activities were viewed as being different from the engineering stations and, as the use of the two frameworks show, were different. It is reasonable to view the 15 activities as a vestigial laboratory system. Developments such as the Laboratory Management Council were indicators of this system and provided a forum for planning across laboratories within BuOrd. This Council eventually was extended to include laboratories from the other bureaus. This analysis also provides a useful way to point out the shortcomings in the 1966 reorganization relative to the strategic management of the laboratories.

In short, the 1966 reorganization recognized the distinctions between the 15 major RDT&E activities and the engineering and test stations, but then assumed that all of the 15 activities were alike. Specifically, it was assumed that they were primarily S&T activities and could be "managed" by a Director of Navy Laboratories/Director of Laboratory Programs (DNL/DLP) who controlled the S&T budget. (It was noted earlier that this reorganization was the lineal descendent of a series of reorganizations and management changes – dating back to the late 1940s – that were intended to provide hierarchal control of S&T planning and budgets at the service and DOD levels.) The previous discussion (using the Perrow and Mintzberg frameworks) highlights two problems with this assumption. First, the bureaus and laboratories were not alike and, second, even if they all had been S&T activities, then centralized, rational planning and control was not appropriate. Both of these observations provide the basis for explaining the ineffectiveness of the DNL/DLP in the strategic management of the laboratories. They come up short, however, in providing a description of the "real" laboratory system and how it functioned.

Summary

An approach to developing this description that has been discussed by a number of organizational theorists is to consider the formal, informal, and non-formal structures within the organization. One might extend this argument to cover the bureaus and laboratories and propose informal structures that cross organizational boundaries and which supplement the formal structures described by organizational charts.

The environment surrounding the laboratories (and, in particular, their adaptation to it) was an important element in the strategic management of the laboratories. A perspective reflecting that would be useful in identifying the "real" strategic management system – the one that existed long before 1966 and persisted through the reorganizations. Using either a rational or natural open systems perspective to analyze the organization would do that. The bounded rationality and contingency theories that are part of the *open-rational* family of models are particularly useful in this regard.

Neither of these approaches provides a complete explanation however. Kronenberg (1995), for example, has observed that the *organic* (or *natural*) model is still based on an assumption of equilibrium. The authority structure and method of decision-making are less hierarchal and more collegial when the *organic* model is applied; however, the basic system is assumed to be self-equilibrating (i.e., resistant to transformation). In addition, both approaches tend to look at the system laboratory by laboratory and focus on the relationship between the individual laboratory and its specific environment. The result, therefore, is to conclude that, in practice, there was no laboratory system. The only exception to that is found in the limited control that the

1966 reorganization gave the DNL/DLP over the laboratories' S&T funding, personnel ceilings, and construction budgets.

How Does Complexity Add to the Explanation?

The previous chapters have described the changes in the strategic management of Navy laboratories and shown how organization and management theory can provide an explanation for them. Complexity theory can complement or expand this understanding by adding additional layers of explanation and, specifically, by demonstrating that a Navy laboratory system had emerged before it was formally established in 1966.

Other theorists bridge the gap between classical organization theory and complexity. Bromiley and Weissinger-Baylon have each applied the "garbage can" approach to planning in large organizations (specifically to defense R&D and naval warfare, respectively). Bromiley has described decision-making within a hierarchal system from both a top down and a bottom up perspective. He proposes that decision making at each level of the hierarchy follows the garbage can model and, consequently, more is involved than what is passed from level to level within the organization. His conclusion is that the proper approach to defense R&D planning combines elements of both the top down and bottom up systems. More specifically, the higher levels of the hierarchy should focus on total funding for the lower levels and should pass down a limited set of problems and solutions to be addressed using that funding. The lower levels of the organization should have sufficient discretion to define additional problems and to develop and apply their own solutions. The result is an organizational "tool box" of solutions that are ready to be applied when problems emerge.

Edward Luttwak defines two "styles of war" – *attrition* and *relational-maneuver*. These are defined in detail in Chapter 1. If technology is to be applied, especially in the *relational-maneuver* case, then the long lead-time associated with development must be shortened. Bromiley claims that this is an advantage to his approach to R&D planning. Burgelman and Sayles' views on "bootleg" research address a similar issue (i.e., research performed by an organizational entity that is not the “official” research element and without formal research funding). Bromiley and Burgelman and Sayles begin to establish a link between organization theory and complexity in the area of strategic management. They do this by acknowledging activity by a structure that is outside of and somewhat independent of organizational control. Can we take the next step and characterize the Navy laboratory “system” (across all of the material bureaus) as a complex system to aid in understanding the strategy process?

Complexity theory can add to our understanding of the strategic management of the Navy laboratory system. The overarching contribution is in recognizing that there was a "Navy Laboratory System" before one was formally established in 1966. There were concrete signs (such as the Laboratory Management Council), but complexity theory takes the explanation to another level. There are two specific aspects of complexity theory of interest. First, there is the notion that strategic management of the laboratory system is the result of the complex interactions of the smaller units (agents) that comprise the system (rather than the result of organization and process choices by senior leadership). Second, there is the idea that an organization will exhibit different behaviors at different times (per Wolfram's behavior classes) or in different parts of the organization at the same time ("islands of stability").

The following chapters present agent-based models for the pre-1966 and post-1966 Navy laboratory systems and use them as the basis for using complexity theory to add fullness to the explanation of the evolution of strategic management of the Navy laboratory system. Additionally, behavior variations of the individual laboratories are addressed as part of an analysis of the balance between the dominance of the formal and emergent strategic management systems.

CHAPTER 6

ANALYSIS OF THE PRE-1966 NAVY LABORATORY SYSTEM

Modeling the Laboratory System

Formal Organization and Processes

As we examine the formal organization and processes in the pre-1966 Navy laboratory system, it is important to consider that the system was undergoing evolutionary changes throughout the post-World War II years. These changes are represented here at three discrete points in time – 1946, 1959, and 1964. The formal organization and strategic management processes in the three pre-1966 Navy laboratory systems are described in some detail in Chapter 5.

There were some common threads throughout the period, mostly centered on the traditional bilinear organization and the bureaus. Many of the changes reflected a move in the DOD towards centralization in the planning and budgeting for research and development. Throughout the period, the laboratories were each associated organizationally with a particular bureau. Direction and most of the laboratory's funding came from that one bureau. When a laboratory accepted tasking from another bureau it was with the approval of the parent bureau. As the discussion in the earlier chapters highlights, one change in this time period was in the number of material bureaus. The reorganization in 1959 merged the Bureaus of Ordnance (BuOrd) and Aeronautics (BuAer) to form the Bureau of Naval Weapons (BuWeps). A significant change came with the creation of the Naval Material Support Establishment (NMSE), headed by the

Chief of Naval Material (CNM), to coordinate the activities of BuWeps and Bureau of Ships (BuShips) for the Secretary of the Navy. The CNM was specifically responsible for coordinating the bureau efforts in the development and acquisition of systems that required the cooperation of both. This was a reaction to the establishment of program managers for major systems (such as the Special Project Office for Polaris) and to ensure that additional programs would not be required. Neither the merger of the bureaus nor the establishment of program managers had an effect on the relationship between the laboratories and the bureaus.

The other changes in this period were designed to centralize the management of R&D and to respond to organizational changes in DOD. Prior to the 1959 reorganization, the Assistant Secretary of the Navy for Air had the responsibility for integrating the research and development (R&D) budget for the Navy, the pieces of which were largely determined by the bureaus and the Office of Naval Research (for basic or foundational research). The centralization established common funding lines for R&D and gave the new Assistant Secretary of the Navy for Research and Development more control in the development of the R&D (and, later, for the combined Research, Development, Test, and Evaluation) budget and its review. Centralization, in this context, implies top down control of the R&D program rather than the more bottom up process of integration. In general terms, the basic research budget was controlled by the Office of Naval Research (with some allocated to the bureaus) and the more applied research was controlled by the bureaus.

The processes that were in place to perform the strategic management functions listed above are addressed, in general, in Chapter 5. Most of these functions were the responsibility of the bureaus for things (and laboratories) within their area of responsibility. Setting future direction, development (and justification) of bureau budgets, and allocation of resources (to laboratories or elsewhere) were the purview of the bureaus. Planning took place in a context set by the CNO staff.

By 1955, the Chief of Naval Operations (CNO) staff ("OPNAV") had begun long range force planning and linked it to programming – the process by which operational requirements for new systems were translated into development goals for the bureaus (Hone, 1989). The process involved the development of two plans, Long Range Requirements (10-15 years) and Long Range Objectives (i.e., the goals for fulfilling the requirements), which were based on projected Navy missions and force requirements. These plans, in turn, were used to develop guidelines for use by the Deputy Chiefs of Naval Operations (DCNOs) as they produced operational requirements and program objectives that were constrained fiscally and by general force requirements. The DCNOs (who were key links between OPNAV and the bureaus and the fleet) forwarded requirements to the bureaus where detailed program plans and cost estimates were prepared. The process described in OPNAV Instruction 3900.8 (dated 17 January 1966) makes it clear that the bureau roles in this process were to develop exploratory development requirements based on the general operational requirements, execute the exploratory development program, propose technical solutions, and plan and execute a technical development program.

This is not to say that concepts and proposals did not originate in the laboratories or that the laboratories had no control over their strategic management. The Chief of the Bureau of Ordnance (in a memorandum dated 12 June 1950) described the process by which the Naval Ordnance Laboratory could apply a mark-up to their project funding in order to apply up to 20 percent of the their annual budget to discretionary use. Its use was controlled by the laboratory Technical Director subject only to the restriction that at least one half of the funds were to be used for foundational research. This was soon extended to other BuOrd laboratories although the allotted percentage varied by laboratory (i.e., the Naval Ordnance Test Station and the Naval Ordnance Laboratory were allowed 10 percent each, but the Naval Proving Ground was only allowed 5 percent) (Lamar, 25 January 1968). Foundational research was a line item in the research and development budgets of seven BuOrd laboratories and stations in 1953. In 1955, funding for foundational research was distributed to BuOrd laboratories and stations in proportion to the number of technical professional personnel at the activity. The use of these funds was at the discretion of the Technical Director of the activity with no formal requirement for reporting to the bureau.

The Chief of the Bureau of Ships established a similar program for the BuShips laboratories in 1956 (Chief, Bureau of Ships, 10 October 1956). In this case, the funding was part of the laboratory budget and was allocated on the basis of proposals from the laboratories to the Bureau of Ships. Dr. Edward Lamar, BuWeps Chief Scientist, observed: "It is my impression that the Bureau of Ships was not as permissive in their dealings with the laboratories as was BuOrd first and later the BuWeps." The Bureau of Aeronautics program was started, on a limited basis, in 1958. The program was expanded when the Bureau of Naval Weapons was created in 1959. Secretary of Defense McNamara extended the concept across the Defense Department in 1961. While the budget was for "work judged by the laboratory director to be of promise or importance without need of prior approval or review by higher authorities," a formal review of results was mandated (Secretary of Defense, 14 October 1961). Bureau reports to the Assistant Secretary of the Navy (Research and Development), which satisfied McNamara's reporting requirement, indicate that the amount of foundational research funding varied by laboratory. In short, laboratories with a large research and development budget tended to have more foundational research funds. Conversely, test and evaluation activities had less use for foundational research funds. Since the allocation was typically a percentage of an activity's budget, larger organizations received more discretionary funds.

Some laboratories were under a modified version of industrial funding and had some flexibility in reprogramming funds. A report on the management of Navy RDT&E programs (summarized in Marchese letter of 6 August 1987) observed that "… occasionally money appropriated for use in one area is used to fund work in a different area. In particular, the boundaries between RDT&E and ship building and operations and maintenance are not being strictly observed." This process was formalized (with controls) by the Naval Material Command in 1969.

Laboratory management approaches also varied in the bureaus. Again, the BuOrd laboratories generally were given more flexibility. One significant difference was in the equality of position of the civilian Technical Director and the uniformed Commanding Officer. The BuAer organizational structure was a more traditional military hierarchy and this was replicated in its laboratories with technical military officers at all levels. Direction and control were more centralized at the bureau level and the laboratories were run in a quasi-military fashion. The Bureau of Ships (BuShips) also had a centralized management approach. Carlisle (1998) noted that it was not until the late 1950s that BuShips first named civilian technical directors at its laboratories. Prior to that time, the commanding officers were in charge. Capt. W.M. Nicholson (Commanding Officer of the Naval Ship Engineering Center) described the difference between Air Force and Navy laboratories:

> In our Navy laboratories, at least those associated with the old Bureau of Ships, the direction of the scientific efforts of the laboratory has been in the hands of the Commanding Officer. In the particular case of the David Taylor Model Basin, this has been especially true because of the special technical qualifications and direct involvement of our officers in technical programs. (Letter to Dr. G.W. Johnson, 27 May 1966)

The *Bureau of Ships Journal* (June 1965) noted that the responsibilities of the Assistant Chief (of BuShips) for Research and Development included "… planning the Bureau's long range RDT&E program … regardless of source of funding, … establishing fields of endeavor and managing program aspects of BuShips laboratories."

These differences were, in part, a consequence of the nature of the work assigned to the laboratories by the different bureaus (i.e., test and evaluation or research and development) and the resulting differences in the nature of the laboratory work force. Price (1965), for example, notes that one characteristic of research and development organizations is that the ratio of scientific to non-scientific personnel that comprise their staff tends toward one to one. The Office for Laboratory Management of the Office of DDR&E reports on "DOD In-House RDT&E Activities for 1966 through 1970 show several trends. The old BuOrd and BuShips laboratories tended to have many more civilian employees than military personnel and approximately the same number of technical professionals as non-professionals. The old BuAer activities tended to have many more military personnel than civilian employees and many more non-professional than technical professional employees. These differences are also reflected in the amount of foundational research performed in the laboratories.

In short, the laboratories – especially in the Bureau of Ordnance – had some limited control over their strategic management. They worked with the appropriate "desks" in the bureaus to obtain their funding and were responsible to the bureaus for technical review of their work and financial practices. Control of tasking and funding varied with bureau also. BuOrd was more directly responsible for planning, assigning specific tasking to the laboratories, and providing technical oversight. Control of laboratories was through industrial funding and technical review. BuShips, on the other hand, leaned towards block funding with control of assigned projects (and their priority) through schedules. Wright (May 1959) describes the BuShips control of its laboratories "through distribution of personnel ceiling, obligational authority, and facilities approval." Laboratories did little (usually none) of their own contracting, which was, instead, done by regional centers. While their missions and organizational structure were subject to approval by the parent bureau and they were limited in their ability to create high-grade positions, they retained the ability to manage their work and to make personnel decisions.

Agent-Based Model

An agent-based model of the Navy laboratory system (before the reorganization of 1966) is illustrated by Figure 6-1. The model specifically addresses the system in 1964. The primary differences between this and possible models for the earlier times are suggested by the previous discussion. The figure shows all of the agents in the larger Navy system grouped into populations (or collections of agents that employ similar

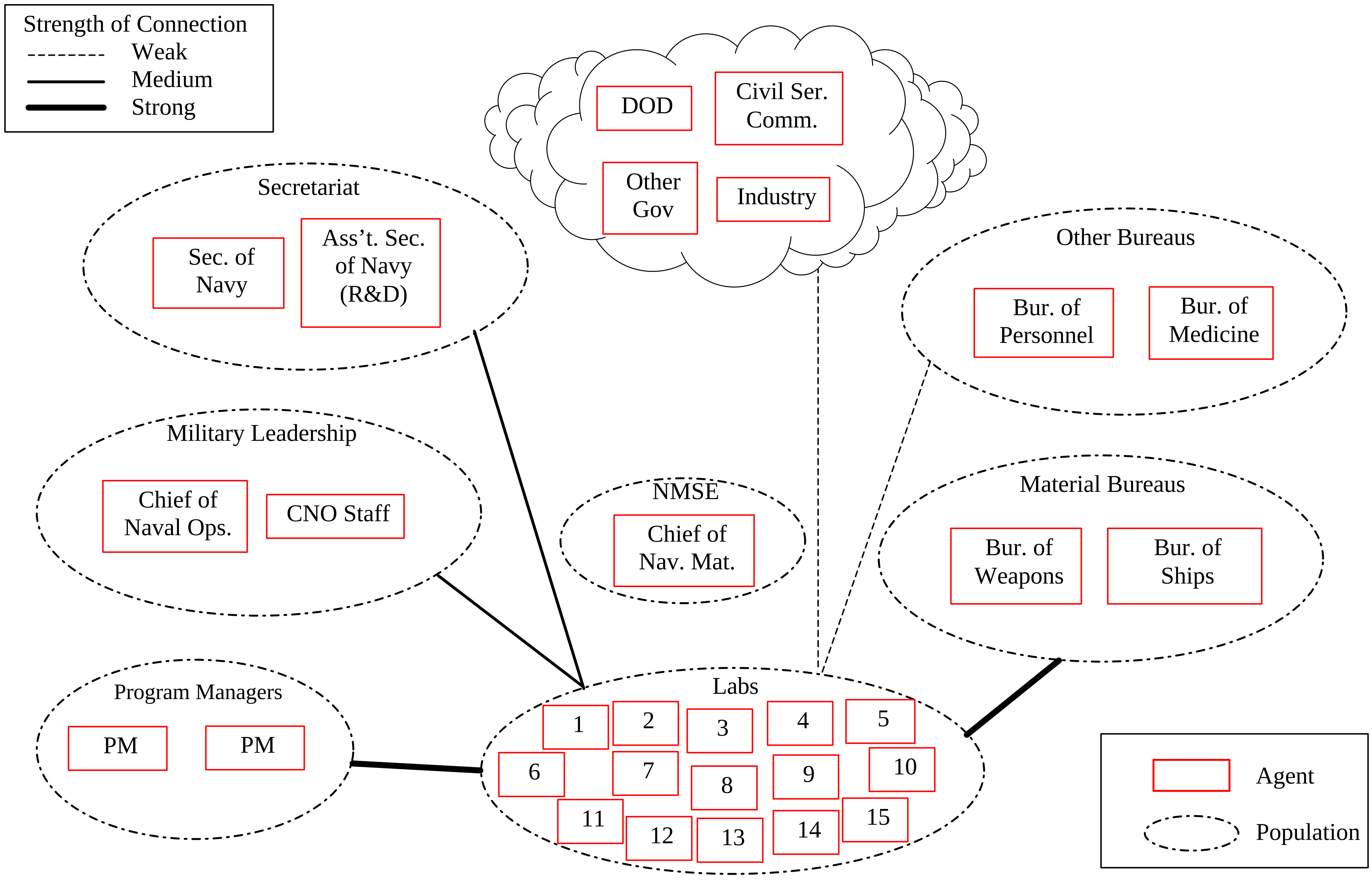


Figure 6-1: Agent-Based Model (Pre-1966)

strategies or rules). This research focuses on the population of agents called "Laboratories" and the interaction among them and with outside populations/agents. The strength of the various relationships in the system (in the strategic management of the laboratories) was assessed based on an interpretation of historical and organizational artifacts. Relationship strength is indicated by the width of the lines that connect pairs of agents on the figure. The following discussion addresses the elements of the system that are most strongly involved in the strategic management of the laboratories – the agents. Specifically, it excludes the populations labeled "Other bureaus" (i.e., the non-material bureaus whose effects on laboratory strategic management were indirect) and "Other" (with agents far enough removed from the laboratories that they form part of the larger context or environment).

To do this, it is necessary to define the agents in the system and the nature of their interactions. This requires (according to Axelrod and Cohen) specifying the agent's location in the system, its rules, allowable actions or roles, and the nature of its interactions with the other agents. The figure (and the organizational chart in the previous chapter) indicates the organizational location of the various elements in the system. The next step in defining the system is to address the roles of the components of the system and the nature of the connections between them. The following discussion of "roles" will focus on the allowable actions regarding strategic management and will lead to a definition of a set of rules that the laboratories followed, as inferred from indications of behavior and the written record.

The roles of the agents of the pre-1966 system – emphasizing allowable actions regarding strategic management of the laboratory system – can be summarized as follows:

Assistant Secretary of the Navy (R&D): Formerly ASN (Air). Authorized the research and development program and had overall management responsibility for the in-house laboratory complex. Acted through the Bureau Chiefs.

Chief of Naval Operations (and CNO Staff): Defined Navy needs and requirements; managed system acquisition; and provided support for the operating forces.

Chief of Naval Material: Coordinated in-house support of system acquisition and development through the bureaus, program managers, and laboratories. Planned exploratory development program for bureaus and laboratories with Deputy Chief of Naval Material (Development).

Bureaus: Directed the acquisition and development of systems required by the Navy; coordinated with the CNO staff in the development of Navy requirements and program planning; and allocated funding either to appropriate laboratories or other sources to support acquisition and development. Provided technical and administrative oversight of in-house laboratories.

Program Managers: Directed the acquisition, development, and support of systems for the Navy through the material bureaus (and, sometimes, directly with laboratories). First program manager (Special Project Office for Polaris) reported directly to Secretary of the Navy. Later program managers reported to CNM.

Laboratories: Supported parent bureau and program managers in the acquisition and development of systems; invested discretionary funds based on own view of future needs and planning; made staffing decisions based on needs (within the limits set in policy); advocated for military construction (MILCON) planning and funding; and coordinated and collaborated with other laboratories (collectively and individually) as required.

The interactions between the agents[18] can also be defined as followed:

Chief of Naval Material – Secretariat: The chain of command for the bureaus (and, thus, the laboratories) was through the CNM to the Secretary of the Navy. As such, one would expect to see vision and a view of Navy needs conveyed from the secretariat as well as specific information concerning R&D goals and objectives, tasking, and funding.

Chief of Naval Material – Military Leadership: The CNM and the CNO both reported to the Secretary of the Navy. The DCNM (D) also served as Deputy CNO (Development). The CNM (and the bureaus) worked with the CNO to develop Navy requirements. The CNO passed a vision, a view of Navy needs, goals, objectives, and requirements to the system bureaus and the program managers (often through the CNM).

Chief of Naval Material – Material Bureaus (individually and as a population): The CNM was responsible for coordinating the activities of the bureaus as required to develop or acquire systems for the Navy. One would expect to see the CNM transfer a vision and view of Navy needs as well as more concrete information such as their goals, objectives, and requirements to the bureaus.

[18] These definitions address interactions between agents in the same population and in different populations. In the latter case, the heading will contain the name of the population (as shown on Figure 6-1) but the definition will address the agents that comprise the population.

Military Leadership – Program Managers: Resource sponsors on the CNO staff (OPNAV) worked directly with the program managers to define system requirements for development and acquisition. In this role, vision and a view of Navy needs as well as specific information, such as goals, objectives, requirements, tasking, and funding would be passed to the bureaus. Some of this (namely, tasking and funding) would bypass the chain of command. The program managers were responsible for reporting project status up the chain of command through regular management meetings and reports.

Military Leadership – Material Bureaus: Elements of the CNO staff (OPNAV) worked directly with the bureaus (bypassing CNM and program managers) to define system requirements for development and acquisition. In this role, vision and a view of Navy needs as well as specific information, such as goals, objectives, requirements, tasking, and funding would be passed to the bureaus. Some of this (namely, tasking and funding) would bypass the chain of command.

Military Leadership – Secretariat: As discussed previously, the CNO (and staff) was primarily responsible for setting requirements. Research priorities and budget coordination were the responsibility of the ASN (R&D). Both reported to the Secretary of the Navy. Information passed both ways to support the definition of system and research requirements needed for development and acquisition programs and to produce (and defend) Navy budgets.

Program Managers – Material Bureaus (individually and as a population: The program managers were responsible for working through the bureaus for the development and acquisition of systems for the Navy. This included coordinating the activities of multiple bureaus, as required. In this role, vision and a view of Navy needs as well as specific information, such as goals, objectives, requirements, tasking, and funding would be passed to the bureaus.

Material Bureaus – Laboratories: The bureaus provided funding and technical direction to their laboratories to support the development and acquisition of weapon systems and platforms for the Navy. Bureaus provided critical direction and review of policies and administration of their laboratories. The bureaus would provide policies, tasking, funding, and review. The laboratories developed and presented proposals for work to the bureaus.

Military Leadership – Laboratories: The laboratory chain of command went through the bureaus to the CNM. The laboratories (usually through their senior technical leaders) also had direct relationships with the CNO staff (OPNAV) for the development of Navy requirements. These relationships bypassed the chain of command (and, in the minds of some, were used to circumvent bureau prerogatives). Vision and a view of Navy needs would be passed through these interactions.

Secretariat – Laboratories: The laboratory chain of command went through the bureaus and CNM to the Secretary of the Navy. Vision, view of Navy needs, and more direct guidance concerning laboratory roles and laboratory - industry balance would be passed. The laboratories (usually though their senior technical leaders) also had direct relationships with the ASN (R&D) on research needs. These relationships bypassed the chain of command.

Program Managers – Laboratories: The laboratory chain of command typically went through the bureaus to the program managers. There were also direct connections (for technical direction and oversight) that bypassed the chain of command.

Laboratory – Laboratory (multiple): These relationships varied with each pair of laboratories; some were historic rivals while others had little or no technical or mission overlap. All competed for MILCON funding and staffing resources (namely, for a share of the overall personnel ceiling). The laboratory technical directors met regularly with the Chief Scientist of the Office of Naval Research for planning and coordination. There were also laboratory-to-laboratory exchanges for coordination and collaboration. Virtually all laboratory funding came from the parent bureau. Hence, there was often competition between the laboratories that reported to the same bureau for this tasking and funding. Sometimes this competition grew out of laboratory mission overlaps; sometimes a laboratory would compete where it had applicable technical capability regardless of its assigned mission.

The preceding discussion has considered the entire Navy R&D system and serves to locate the laboratory population in it. In the description of the laboratory-to-laboratory connection, it also began to describe the complex adaptive system that is the focus of this research. The next step is to define that particular system in more detail. This will be done by specifying the connections in more detail and by giving the rules they followed for strategic management.

During this time period the following laboratories composed the Navy laboratory system (Booz Allen and Hamilton, Inc. 1976):

Bureau of Ships (BuShips)

- David Taylor Model Basin, Carderock, Maryland
- Experimental Dive Unit, Washington Navy Yard (WNY)
- Engineering Experimental Station, Annapolis, Maryland
- Naval Boiler and Turbine Laboratory, Philadelphia Navy Yard
- U.S. Navy Underwater Sound Laboratory, New London, Connecticut
- Naval Electronics Laboratory, San Diego, California
- U.S. Navy Materials Laboratory, Brooklyn Navy Yard

- Industrial Testing Laboratory, Philadelphia Navy Yard
- U.S. Navy Metals Laboratory, Munhall, Pennsylvania
- Navy Radiological Defense Laboratory, San Francisco, California
- Naval Mine Countermeasures Station, Panama City, Florida

Bureau of Aeronautics (BuAer)
- Naval Air Material Center, Philadelphia, Pennsylvania
- Naval Air Experimental Station, Philadelphia, Pennsylvania
- Naval Air Modification Unit, Johnsville, Pennsylvania
- Naval Auxiliary Air Station, Weston Field, Pennsylvania
- Naval Aircraft Factory, Philadelphia, Pennsylvania
- Naval Air Station, Patuxent River, Maryland
- Naval Air Missile Test Center, Point Mugu, California

Bureau of Ordnance (BuOrd)
- Naval Proving Ground, Dahlgren, Virginia
- Naval Powder Factory, Indian Head, Maryland
- U.S. Naval Ordnance Test Station, Inyokern, California
- Naval Ordnance Test Station, Pasadena, California*
- Navy Ordnance Laboratory, WNY (later, White Oak, Maryland)
- Explosives Investigation Laboratory, Indian Head, Maryland and Port Townsend, Washington
- Naval Torpedo Station, Newport, Rhode Island, Keyport, Washington, and Alexandria, Virginia
- Ordnance Aerophysics Laboratory, Daingerfield, Texas
- Ordnance Research Laboratory, State College, Pennsylvania*
- Naval Ordnance Development Unit, Silver Spring, Maryland*
- Applied Physics Laboratory, Seattle Washington*
- Naval Aviation Ordnance Test Unit, Solomons, Maryland
- Demolitions Research Unit, Fort Pierce, Florida
- Allegany Ballistics Laboratory, Cumberland, Maryland*

(* Indicates that the laboratory was government owned, contractor operated)

Understanding in more detail how the laboratories operated independently and cooperatively will help in the formulation of the rules that governed laboratory behavior regarding strategic management as agents in a complex adaptive system.

The Naval Ordnance Laboratory (Washington Navy Yard and White Oak, Maryland) developed a set of Operating Principles in 1947. The principles, which were approved by the Chief of the Bureau of Ordnance, remained in effect throughout this period with only minimal modifications. The NOL principles (Table 6.1) provide insight into the organization's formulation of the rules. The Naval Ordnance Test Station at China Lake developed operational principles in 1947 that echoed these ideas. The 1955 version of the NOTS principles are given in Table 6-2.

Table 6-1. – NOL Operating Principles (1 February 1961)

1. The Naval Ordnance Laboratory is a primary research and development activity of the Bureau of Naval Weapons, responsible to that Bureau for its funds, its operations, and its results.
2. The mission of the Naval Ordnance Laboratory, briefly, is to originate and analyze new ideas in ordnance, and to advance them by research, development, test and evaluation, under the direction of the Bureau of Naval Weapons.
3. It is essential that there be a positive, integrated program which the laboratory has a share in planning.
4. To accomplish results, adequate facilities and funds and superior professional personnel are mandatory.
5. Superior military and civilian professional personnel are alike essential, each with adequate authority and responsibility, each supplementing the other.
6. It is the responsibility of the professional civilian staff to produce technical accomplishments in research, development, design, test and supporting activities.
7. It is the primary responsibility of the technical armed services officers attached to the Laboratory to assist and advise the civilian technical staff on matters relating to the development of ordnance material designed to meet service requirements and operating conditions.
8. The Commander is responsible to the Chief of the Bureau of Naval Weapons for all phases of operation of the Laboratory.
9. The Technical Director, a civilian, is responsible to the Commander for all the technical work of the Laboratory.
10. The Commander and the Technical Director are jointly responsible for the effective and economical internal functioning of the Laboratory.
11. The civilian heads of all technical activities are responsible to the Technical Director through the appropriate line organization.
12. The primary function of the service departments is to aid in supplying the needs of the technical staff for accomplishing the work specified by the Technical Director.
13. The Naval Ordnance Laboratory is an integral part of the Naval establishment. Its staff members, military and civilian, are equally a part of that establishment. Every effort will be made to provide opportunities for professional advancement and recognition, to the end that all hands will be proud that they are part of the Navy. (Smaldone 1977)

Table 6-2. – NOTS Operating Principles (1955)

1. The Naval Ordnance Test Station is a primary research, development, and test activity of the Bureau of Ordnance, and is responsible to that Bureau for the administration of assigned funds, conduct of operations, and the accomplishment of the Mission.
2. The Mission of the Station is to support the Bureau of Ordnance by originating and analyzing new ideas in ordnance, and by advancing them through research, development, experimental production, test, and evaluation, and by assisting in introducing the resultant weapons and techniques into production and service use.
3. The program of the station is planned jointly by the Bureau of Ordnance and the Station, and is fully integrated and positively directed toward accomplishing the Mission.
4. The Commander, a senior naval officer, is responsible to the Chief of the Bureau of Ordnance for all phases of operation of the Station.
5. The Technical Director, a recognized civilian scientist or engineer, is responsible to the Commander for all the Technical work of the Station.
6. The Commander and the Technical Director are jointly responsible to the Chief of the Bureau for the effective and economical internal functioning of the Station.
7. The heads of all technical activities are responsible to the Technical Director through the appropriate line organization.
8. The primary function of all groups at the Station is to further the technical program, and all departments participate according to their responsibilities in accomplishing the Station Mission.
9. It is the responsibility of the professional staff to produce superior technical accomplishments in research, development, design, experimental production, test, and evaluation of weapons systems.
10. It is the primary responsibility of the technical officers of the armed services attached to the Station to advise the civilian technical staff on matters relating to the development of ordnance material designed to meet service requirements and operating conditions.
11. To accomplish the mission superior military and civilian professional personnel are essential, each with proper authority and responsibility, each supplementing the other, and they must be supported by adequate facilities and funds.
12. The Naval Ordnance Test Station is an integral part of the Naval Establishment. Its staff members, military and civilian, are equally a part of that establishment. Every effort is made to provide opportunities for professional advancement and recognition, to the end that all will be proud that they are a part of the Navy.

The NOL and NOTS principles both emphasize the importance of the role of the laboratory in planning its program, the roles of the Commander and the Technical Director, the technical role of the civilian staff, and the role of the “technical armed service officers" to advise the civilian staff on fleet requirements and operating conditions. The principles specifically relate to the elements of strategic management when they emphasize the importance of personnel, facilities, and funding.

NOL principle 9, supported by numbers 11 and 12 (and, likewise, NOTS principles 5 and 7), highlights an important feature of the BuOrd laboratories (that was not reproduced at laboratories in the other bureaus) – the preeminence of the civilian Technical Director in technical matters. Admiral M.F. Schoeffel, head of the Bureau of Ordnance, summarized this when he said (in 1951, as quoted in Westrum 1999)

> … the Bureau decided to operate these installations [NOL and NOTS] on the principle that the technical activities would be conducted and directed by professional civilian scientific and engineering personnel, and that the role of the military personnel would be that of providing the necessary knowledge of operating conditions plus the administration required to make the laboratory a part of the Naval establishment in the broadest sense.

The "operating principles" of the Bureau of Ships (regarding their laboratories) can be inferred from several sources. Captain E.A. Wright, Commanding Officer and Director of the David Taylor Model Basin, gives some characteristics of a successful naval engineering organization such the Bureau of Ships (BuShips). These include Naval officers of unsurpassed technical competence and an understanding of fleet needs, a civilian staff of minimum size and the highest quality, and management control and command of naval shipyards, naval laboratories, and other field activities. The <u>Bureau of Ships Journal</u> (June 1965) defines the responsibilities of the Assistant Chief (of BuShips) for Research and Development as including "establishing the fields of endeavor and managing program aspects of BuShips laboratories." Carlisle (1998) notes that prior to 1959 the Commander was in charge of technical programs at BuShips laboratories such as the David Taylor Model Basin. Civilian control of the technical laboratories did not begin until BuShips named the first Technical Directors at its laboratories. These all point to a greater degree of military control of the laboratories and management centralization at the bureau level than was characteristic of BuOrd and its laboratories.

Operating Principle 2, short statements of the NOL and NOTS missions, makes the point that originating and developing “new ideas in ordnance” was a responsibility of the laboratory. Even though, as Principle 1 (NOL and NOTS) says, funding comes from the parent bureau, many of the ideas came from the laboratory and were “sold” to project officers (“desk men”) in the bureau. Baile (1991) gives a description of the philosophy of Dr. Russell Lyddane, Technical Director of the Naval Proving Ground (Dahlgren) from 1956 to 1964 that makes a similar point:

> … we had to send people up to the bureau and beat on the doors of individual project officers who had programs to sponsor and convince them that this was the way of the future. … It took the entire senior staff an awful lot of time in Washington to get this thing moving. And, of course, the more you get it moving, the more you demonstrate that you can perform, the more funds you get, the more people you can hire, the more solid an organization you can build, the more results you can produce, provided you don’t make the kind of error that some other Navy laboratories made. They played a great deal of ‘scientist versus naval officer.’ … We always took the attitude that the Fleet was, after all, our customer, and if you are going to stay in business, you’d better worry about and respect your customer.

As noted, the laboratories were funded almost exclusively by their parent bureau. Some bureaus approached this in a “paternalistic” manner and very specifically tasked, funded, and reviewed the work of the laboratory. Others (and in particular BuOrd) allowed their laboratories more discretion both in proposing tasks to the bureau and in using (and “reprogramming”) project funding from the bureau to perform laboratory-generated research. BuShips tended to provide block funding to their laboratories and the bureaus assigned projects throughout the year. Even so, civilian department heads at the

David Taylor Model Basin worked directly with desk officers in BuShips to propose tasks (Carlisle 1998).

Laboratories were assigned missions in specific primary areas based on bureau affiliation and their historical development. In many cases, the areas were broad and the laboratories determined their missions "post facto" or, in other words, based on what they were funded or chose to work on. This led, over time, to overlap and duplication in laboratory missions and to competition between them. Other laboratories had a different experience. Booz, Allen, and Hamilton (1976) described the stability that resulted from bureau control of laboratory work assignments and funding as well as the negative consequences. A bureau desire for control in order to ensure that laboratories provided the required support often turned the laboratories into "job shops" for their bureaus. Baile (1991) associates this tendency with narrowly defined laboratory missions. Joel Lawson, the second Director of Navy Laboratories, traced it back to World War II (Lawson 1971). When John Foster (Director of Defense Research and Engineering) forwarded the Glass Report, which proposed greater delegation to laboratory directors as the solution to the management problems in defense laboratories, he observed that the formation of program managers and special program offices has left little but job shop work for the laboratories to do (Hilyer, Speech 1977).

Booz, Allen, and Hamilton (1976) describe the other extreme in bureau control as the "unfettered freedom" that enables scientific progress. While the true condition was most often found between these extremes, there are also examples of laboratories making a conscious decision to fundamentally redirect their mission (and convince their bureau and others in the Navy of the change). Baile (1991) describes the efforts of Lyddane (and others) in the 1950s and 1960s to change the Naval Proving Ground (NPG) from its traditional role as a test station for guns and ammunition to a more broadly based role in weapons technology. The choice that was made by the individual laboratories said a lot about their view of their role in strategic management.

The previous discussion hinted at the differences in management approach of each of the bureaus. These differences also had an effect on laboratory strategic management. This can be demonstrated by consideration of the elements of strategic management – control, budget, staffing, and facilities. The BuOrd laboratories were civilian run – in technical areas – with a Naval line officer (rather than a technical one) as Commanding Officer. The BuShips and BuAer laboratories, at least until late in this period, were run by Naval officers, even in technical areas. Nearly all of the laboratories operated under a modified industrial financial system. This type of funding system did not allow laboratories to maintain a working capital fund and laboratories could receive funding either on a project basis or as an allotment. Funding of the core functions required to operate the laboratory came as separate budget line from the bureau. The differences in the laboratories, by bureau, were addressed earlier in this chapter. The Bureau of Ordnance authorized discretionary funding (generated by "taxing" project funds) for foundational research at its laboratories beginning in the early 1950s. The Bureau of Ships and Bureau of Aeronautics did not take this step until later in that decade and, then, only at selected activities. All laboratories were responsible to their parent bureau regarding staffing levels and facilities.

BuShips laboratories responded to a strong central organization in the bureau and had specific missions (Abrams, Oral History 1983). As noted above, they received block funding from BuShips and were assigned projects throughout the year. As a result, they were very responsive to BuShips, which had the job of managing laboratory priorities (typically by assigning completion dates for the projects). BuAer had much different expectations of their laboratories (as evidenced by their use of Naval officers in laboratory management). They were primarily test and evaluation laboratories and BuAer looked to the aircraft industry and the National Advisory Committee for Aeronautics (NACA) for concepts and research and development.

Given this, how should the connections between the laboratories be represented in the agent-based model? In many respects the laboratories were competitors. Certain laboratories with common interests or competencies competed for funding from their parent bureau or to acquire specialized equipment. Niemann (1982) describes the competition between the Naval Proving Ground and the Naval Ordnance Laboratory for the Navy's first mainframe computer, the Naval Ordnance Research Calculator, in the early 1950s. He suggests that the Bureau of Ordnance encouraged the competition to ensure that the Navy obtained the most capable computer possible from IBM. There are also examples where laboratories stretched their mission into areas that were the responsibility of other bureaus or laboratories. For example, Westrum tells how the Naval Ordnance Test Station developed the Sidewinder air-to-air missile, which was outside of their mission, by using discretionary and redirected funds, test equipment from other programs, and unpaid work after hours and on weekends. All of the laboratories competed with each other for a share of the facility and equipment budgets. While the laboratories competed, they also collaborated with each other – either in their own interest or at the urging of the bureau.

The previous discussion leads to a formulation of the rules for strategic management that laboratory-agents follow in the model of the laboratory system. The review of the operational principles and the actions and practices of laboratory leadership highlights several themes that relate to the elements of strategic management – control, budget, staff, and facilities. The laboratories were motivated to operate in an efficient and effective manner to maximize the funding that could be applied to the technical projects. Laboratory missions were not viewed as hard limits on action and laboratory directors acted to meet Navy needs (i.e., to support the fleet) and in their laboratory's interests. Likewise, the laboratories proposed projects to their parent bureau and applied available or discretionary funds and existing facilities to their own projects.

This is summarized by the following rules:

(1) Accept funding based on laboratory judgment of value to the Navy and laboratory regardless of laboratory mission.
(2) Make the plans and decisions necessary to run the laboratory in an economical and efficient manner.
(3) Define the concepts and systems required by the Navy and begin to work on them
(4) Do not let bureaucratic rules impede doing the right thing for the Navy.

These rules will be part of the comparison of the formal and emergent systems in the post-1966 Navy research and development environment.

Comparison

The formal system and processes have been described and an agent-based model was developed to describe the emergent system that existed before the reorganization in 1966. It now remains to answer the question of which was dominant or, more accurately, when and under what conditions each system was dominant. The first step is to evaluate the formal systems and processes and to provide an assessment of whether or when they provided for the strategic management of the laboratory system. In particular, given the description above, how can we summarize the effectiveness of the formal system in the strategic management of the Navy laboratory system? Recall the allowable strategic management actions outlined above. Were these actions that the bureaus took? If so, were there times when they could not?

While there were organizational elements above the bureaus that potentially played a part in the strategic management of the laboratories, the discussion very quickly focuses on the bureaus. This is partly due to the fact that the bureaus were the immediate organizational superiors to the laboratories. It is, perhaps, due more to the fact that the bureaus were largely independent actors throughout this period. Before 1964 the bureaus reported directly to the Secretary of the Navy and had virtually complete control over their areas of responsibility. They prepared their own budgets and defended them before Congress, when necessary. Bureaus worked with the CNO staff to set requirements; but the bureau was in control after the CNO decided to develop a weapon, aircraft, or ship.

The independence of the bureaus and their inability to cooperate led to the establishment of independent program offices, the merger of the Bureaus of Ordnance and Aeronautics, and to the creation of the Naval Material Support Establishment headed by the Chief of Naval Material (CNM) in 1964. Sapolsky (1972) makes this point in his description of the formation of the Special Project Office for Polaris:

> Their intention in creating the Special Projects Office, however, was only to settle a difficult jurisdictional dispute [between BuOrd and BuAer] not to reorganize the Navy.

It was expected that this would be a temporary and rare deviation from the Navy's standard organization for the procurement of weapons. Instead, it became an alternative organizational model. This point was reiterated by the Franke study in its discussion of the confusion concerning the responsibility for missile development in the Navy. The Franke study recommended combining BuOrd and BuAer to form the Bureau of Naval Weapons and assumed that would eliminate the need for independent program offices. That did not prove to be the case as program offices proliferated through the 1960s.

Bennett (1962) and Sherwin (1964) pointed out the absence of a means for control and integration across bureau lines other than the Secretary of the Navy himself. They proposed organizational solutions that led to the creation of the Naval Material Support Establishment (NMSE) and the Chief of Naval Material. The CNM, who was placed organizationally between the bureaus (and program managers) and the Secretary of the Navy, was expected to coordinate the activities of the bureaus in system development and acquisition. Did it work?

Bernard Smith, Technical Director of the Naval Weapons Laboratory (NWL), thought that the idea of a single voice (and advocate) for the bureaus and laboratories was a good idea (Oral History 1974). Smith felt that it did not work because the first CNMs were weak and did not understand their role or power. Specifically, he was of the opinion that the CNMs did not understand the need for starting projects that would not be completed during their 3-year tours (which encompasses most projects of any significance).

Dr. William P. Raney, Special Assistant to the Assistant Secretary of the Navy for Research and Development and Chief Scientist in the Office of Naval Research, thought that the bureaus “knew they had to admit that there was a level of authority above them but they didn’t pay much attention” (Oral History 1980). On the other hand, Vice

Admiral I.J. Galantin, CNM in 1965 and one of the key actors in the 1966 reorganization, thought that the power of the bureau chiefs had been weakened “because some of their key people went into my staff and other key personnel later went into the project staffs” (in MacDonald 1966). He also felt that there were other major organizational weaknesses in the functional management of the command. This is compatible with the opinion that the 1966 reorganization was motivated, at least in part, by the feeling in the Department of Defense and Congress that the bureaus could not manage (Rexroth, Oral History 1980). In short, focusing on the bureaus when considering the strategic management of the laboratories is justified. Booz, Allen and Hamilton (1976) assert that laboratory management was, for all practical purposes, the unique responsibility of the bureaus. Further, laboratory management was decentralized and policies and practices varied across bureaus in order to meet their disparate needs. Hence, the following discussion will highlight differences between the bureaus (as suggested by their categorization using the Perrow and Mintzberg frameworks).

A number of actions that are elements of strategic management are listed in Chapter 3. These guide our evaluation of the formal systems and processes. We’ll first consider the role of the bureaus in setting the future direction of the laboratories. This was certainly the case for some bureaus and their laboratories. The degree to which it was done in other cases is arguable. There was a feeling that laboratories could take one of two paths – develop and move towards areas of special competence or become a “job shop” for the parent bureau. The case was previously made that the Bureau of Ships and the Bureau of Aeronautics were different than the Bureau of Ordnance in this regard.

The BuShips laboratories had a strong central organization and specific missions. They were seen as being very responsive to BuShips, but as not responding well to groups outside of their chain of command (Abrams, Oral History 1983). William McLean observed that the BuShips laboratories received block funding from BuShips and were assigned projects by the desk officers in the bureau. They were seen as being used to, and needing, bureau guidance (Smith, Oral History 1974). Likewise, the BuAer laboratories were viewed as being part of a larger organization that was staffed by military officers at all levels. Research and development was subordinate to testing and the laboratories were part of the larger team (rather than given any technical authority) (Booz, Allen and Hamilton, 1976).

The Bureau of Ordnance and its laboratories had a different relationship. While there was an expectation that the bureaus "ran" the laboratories (and processes were in place to ensure that), there were a variety of other processes that gave their laboratories significant freedom in determining their future direction. This is highlighted in the NOL White Oak operating principles that were accepted by BuOrd (e.g., the need that there be "…a positive integrated program which the laboratory has a share in planning"). Laboratory missions were sufficiently broad that they overlapped and "mission creep" and inter-laboratory competition resulted. The ability to redirect funds, which was viewed as the Technical Director's right by Smith (1999) and McLean (in Westrum 1999), and the availability of discretionary funding provided a means for a laboratory to pursue their own view of their future direction. The redefinition of the NWL mission by Lyddane and Smith in the 1950s and 1960s (described above), which was opposed by elements of BuOrd (Baile, 1991) provides an example of this. Rear Admiral E.A.

Ruckner, Assistant Chief of the Bureau of Ordnance and, later, Deputy CNO (Development), was of the opinion that laboratory independence varied with the type of work they performed (Oral History 1974). He thought that the bureaus gave the laboratories greater freedom during exploratory development, but increased their control as a system moved closer to production.

Resource development and allocation is also an element of strategic management. In virtually all cases, laboratory funding came from the parent bureau. Before a laboratory worked for another bureau, the bureaus discussed it and agreed beforehand. BuShips gave its laboratories block funding and assigned projects. This led to the assignment of too many tasks for a laboratory to complete and, hence, priorities were managed by establishing a schedule (Hartmann, Oral History 1974). In BuOrd, laboratories obtained funding from desk officers in the parent bureau. Bernard Smith, Technical Director of the Naval Weapons Laboratory and Bureau of Weapons Chief Scientist (1961-63), observed that desk officers had freedom to operate within an assigned budget (Smith, Oral History 1974). NOL White Oak, for example, worked with the research and development desk while NWL worked with one of the production desks. The bureau developed exploratory development programs in cooperation with the DCNO (Development) and funding was provided to the laboratories for execution (Smith, Oral History 1974).

The "Advisory Group to the Assistant Secretary of the Navy, Research and Development (ASN (R&D)) in Laboratory Matters" was established by Secretary of the Navy Instruction 5420.158 (2 January 1964). This group was to provide information on laboratory matters and to be a forum to discuss questions of laboratory management. The members of this committee included representatives of the Chief of Naval Operations, the Chief of Naval Material, and each bureau. It was chaired by a representative of the ASN (R&D). The first Chairman was Dr. William P. Raney (Special Assistant to the ASN (R&D)).

Secretary of Navy Instruction 3900.13A ("Management of Navy Research and Development Laboratories") required the bureaus to have an office that acted as staff to the senior leaders in the bureau, served as a focal point for laboratory matters, and discharged the bureau's responsibilities to its laboratories. Each bureau was represented in Raney's monthly meetings by their Office of Laboratory Management. Raney said that the group met to discuss manpower levels, problems with workload planning and balancing, funding, and other practical things (Raney, Oral History 1980). Captain Bernard Towle, Laboratory Management officer for the Bureau of Naval Weapons, observed that Raney's group considered issues such as resource allocation and the military construction program, but not internal bureau management (Towle, Oral History 1974).

The bureau Laboratory Management Office's job was to see that the bureau laboratories kept a balance between their tasks, bureau resources, and laboratory capabilities. Technical guidance was the responsibility of other parts of the bureau (Towle, Oral History 1974). Bernard Smith (NWL Technical Director), however, observed that technical guidance from the bureaus was generally poor and ignored by the laboratories (Oral History 1974). He also observed that "a smart lab guy would make the bureau guy look good."

The bureaus had other processes for controlling the laboratories. The Inspector General would inspect a laboratory every 2 years, comptrollers would do fiscal and program appraisals, and the desk officers would do program appraisals based on plans and schedules (Smith, Oral History 1974). The bureaus generally felt that they had to protect their laboratories and, interestingly, the research and development desk would defend the laboratory during internal appraisals (Smith, Oral History 1974). Howard Smith, Special Assistant to the Assistant Secretary of the Navy for Research and Development, expressed the view that the bureaus had *de facto* control of the laboratories because they controlled the budget (Oral History 1980).

Additional strategic management actions are altering the reporting structure and the task structure. The bureaus clearly had control over the bureaucratic processes such as mission definition and task assignment for their laboratories. Laboratory organization was also subject to bureau review and approval. (Smaldone describes this process and changes in the NOL White Oak organization in some detail.) Selection of civilian leaders of the laboratory was also the responsibility of the bureau. The bureau (often through its Laboratory Management Council) attempted to perform workload balancing across its laboratories. This is summarized in Baile (1991):

> The bureau chiefs exercised virtually exclusive authority, responsibility, and management control over the laboratories. Tasking and communications were directly aided by the short hierarchy, and the bureaus coveted the subordinate position of the laboratories.

In summary, the discussion to this point has highlighted the role of the formal organization and processes in the strategic management of the laboratory system and, in particular, the areas in which they came up short. What does the proposed agent-based model of the emergent system add?

Robert R. Maxfield (in Alberts and Czerwinski 1997) provides a framework for considering this question. He describes strategic thinking in an organization facing a complex foresight horizon and proposes two strategic practices they should follow: *populating the world* and *fostering generative relationships*. These practices and the preconditions for assessing the generative potential of a relationship – aligned directness, heterogeneity, mutual directness, permissions, and action opportunities – are discussed in Chapter 3. The Maxfield framework is used to explore the relationships of the agents in the system in more detail.

The last step in assessing the utility of this model is to examine the applicability of the proposed rules for agent behavior and their role in the strategic management of the Navy laboratory system. Rosenau (in Alberts and Czerwinski 1997) specifies that agents that self organize their behavior must be related to each other sufficiently to form recurrent patterns. The preconditions for generative relationships provide a process for establishing the nature of the relationships between these agents (i.e., the laboratories) and between the agents and other elements of their environment.

The first preconditions to be considered in examining the nature of these relationships are "aligned directness" – the compatibility of their orientation – and "heterogeneity." The previous discussion has shown how management approach and organization differentiates the three material bureaus. The case can also be made that the laboratories within a given bureau were compatible in orientation.

In a general sense, this is demonstrated by the common elements of the operating principles at NOL White Oak and NOTS China Lake and Lyddane's management principles at NWL. Likewise, the different principles in BuShips and BuAer show that their laboratories formed two other aligned groups. BuShips had a strong central organization and the laboratories focused on specific missions related to ship research, development, and testing. They received funding, guidance, and direction from BuShips. Although all of the BuShips laboratories were involved in testing in some fashion, they have been described as "heterogeneous" (Booz, Allen and Hamilton, 1976). In particular, the David Taylor Model Basin performed research in addition to military and civilian hull testing and in this regard, at least, there were similarities with the BuOrd laboratories.

BuAer and its laboratories had a fundamentally different orientation than either BuOrd or BuShips. The BuAer laboratories focused on test and engineering rather than on research and development and depended on the civilian aeronautical complex, both industrial and the National Advisory Committee for Aeronautics (NACA). It also had a quasi-military organization with technical Navy officers in positions at all levels of the organization (Hartmann, Oral History 1974). The Chief Scientist in BuOrd laboratories was in a senior line management position responsible for the technical direction of the laboratory. It was a staff position in the BuAer laboratories. These differences were reflected in both their operating principles and the way in which the laboratories interacted with the bureau.

We will next consider whether or not the relationships between the laboratories exhibited a pattern of interactions, or "mutual directness." Dr. Emmanuel Piori, Chief Scientist in the Office of Naval Research, instituted an inter-laboratory and cross-bureau Senior Scientist Council in the early 1950s (Booz, Allen and Hamilton 1976). Civilian laboratory directors met two or three times a year to exchange views and information. Hartmann credits this council with the establishment of discretionary funding for foundational research in BuOrd laboratories (Oral History 1974). A few years later the Council stopped meeting due to its increased membership and formality (Hartmann, Oral History 1974) and its focus on administrative matters more than on program and management matters (Booz, Allen and Hamilton 1976). The Laboratory Management Office in each bureau (as described above) was another form of interaction for the laboratories and the bureaus. Capt. Bernard Towle, a BuWeps Laboratory Management Officer, felt that the Laboratory Management Office worked better than the Director of Navy Laboratories (DNL) because it was not in technical competition with the laboratory and was not the Technical Director's boss (Oral History 1974).

There was also informal interaction, especially when laboratory capabilities were complementary and teaming was mutually beneficial. There was another kind of interaction – competition – that was also common. While competition was not an explicit part of the documented operating principles, there are enough examples of competitive individual and organization behavior to show that it was an accepted practice. Hartmann noted that by the late 1950s the laboratories could compete (Oral History 1974). He also observed that "it was pretty uncontrolled and there was a concern that everyone was trying to do everyone else's business." Examples of this are discussed in Westrum (1999) – the development of air-launched missiles at NOTS China Lake in competition with BuAer concepts – and in Niemann (1982) – competition between NWL and NOL White Oak for the Naval Ordnance Research Calculator (NORC), the Navy's mainframe computer.

Another precondition for a generative relationship is that both organizations have permission to engage. In what sense did the laboratory agents have permission to engage with each other? Within BuOrd, this permission was implicit in the creation of discretionary funding sources for some of its laboratories in the late 1940s – the "Foundational Research Fund" – and its extension to other BuOrd research and development activities in 1956 (Booz, Allen and Hamilton 1976). At a minimum, it was inevitable when discretionary funding was combined with operational principles that encouraged laboratories to what they thought was best for the Navy. Niemann (1982) describes how the Bureau of Ordnance encouraged competition between NPG and NOL for the Naval Ordnance Research Calculator in order to get the best product from IBM. Some of the BuOrd laboratories (such as NOL White Oak) operated under a modified version of industrial funding beginning in the mid-1950s. Much of the tasking was self-generated by the laboratories (often through the interaction of the laboratory and BuOrd) and it reflected the interests of the Technical Director (Booz, Allen and Hamilton 1976).

These practices were less common in BuShips and BuAer, although most laboratories operated under a modified industrial system for funding and discretionary funding for foundational research was adopted in the late 1950s. Under the modified industrial system, the bureau could fund a laboratory project by project or in a block with tasks assigned by the bureau throughout the year. The latter approach was characteristic of BuShips. When BuOrd and BuAer merged to form the Bureau of Naval Weapons (BuWeps), a centralized laboratory management office was established to control manpower ceilings and the appointment of officers to its field activities. A less successful attempt was made to rationalize resource allocation, review overall laboratory programming, and coordinate workloads (Booz, Allen and Hamilton 1976). However, from NOTS it did not appear that there was any difference – the parts (BuOrd and

BuAer) and processes were still separate and the laboratory went to the same person for funding (Smith, Oral History 1974).

Finally, a generative relationship requires that there be action opportunities. The defense budget held constant through the 1950s with growth in the early 1960s (in constant year dollars). At the same time, Defense research, development, testing, and evaluation funding increased steadily (if slowly) through the 1950s with a marked increase in 1960. Significant increases also occurred in military procurements, especially in missiles and aircraft, during this period (Jones 1999). Federally funded research and development for national defense increased steadily through the 1950s and early 1960s. In fact, the 1963 budget was more than twice that in 1957 (in constant 1991 dollars) (National Science Foundation 1997).

The view that the laboratory agent relationships satisfy Maxfield's preconditions for generative potential has been presented. The laboratories each had internal planning staffs or functions that facilitated the process of discourse to establish a local representation of the external environment. Bureau processes, such the Senior Scientist Council, provided vehicles for discourse to establish a laboratory system-level representation of the external environment. The BuOrd practice of assigning Navy line officers to the laboratories was intended to bring knowledge of the needs and practices of the operating forces to laboratory scientists and management.

The case has been made that the BuOrd laboratories, if not the others, possessed the attributes of agents in a complex adaptive system. Having said that, it is important to remember the nature of the interaction of agents in a complex system. Agents are independent actors that apply a shared set of rules to their knowledge of the environment.

This does not imply negotiated action or overt agreement among the actors. Instead, the overarching requirement for interaction is for the agents to share a relatively consistent representation of the external environment and an understanding of the state of the other agents in the system. The first of these is facilitated by the availability of DOD and Navy planning documents and budgets. Individual laboratories will, of course, develop their own unique representation of this environment by adding their own observations and information. The second dimension – understanding the state of the other agents – means, in the case at hand, understanding the elements of strategic management of the other agents. These types of information, which were defined previously, are the kinds of data that were discussed by the Laboratory Management Council (e.g., personnel ceiling, MILCON and equipment allocation) and in Senior Scientist and Laboratory Director meetings, documented by the agents in their planning documents and annual reports to the bureau Laboratory Management Office, or which could be inferred from their actions.

The previous discussion describes the nature of the interactions among the agents and identifies the sources of information available to them. Did they follow the rules that were postulated earlier when they used this information? Evidence shows that they did in the BuOrd laboratories. The actions of the technical directors McLean, Lyddane, and Smith in pursuing tasking and funding within the bureau are examples of the effect of the NOL and NOTS operating principles on management approach. The actions at NOTS in the development of Sidewinder (Westrum 1999) and at NWL in supporting the Polaris Special Project Office (Gates, 1995) are examples of a laboratory going outside of its mission, as understood by the parent bureau. Bureau processes that provided discretionary funding and the modified industrial funding process that allowed redirection of funding by the laboratory director enabled this freedom.

The law that established the David Taylor Model Basin in 1896 provides that "experiments may be made … for private shipbuilders, who shall defray the costs of material and of labor per diem employees of such experiments" (Carlisle 1998). A later version of this law (Public Law 568 of 6 May 1936) specified that this be done "under such regulations as the Secretary of the Navy may from time to time prescribe." This gave them the means to exercise some local control over tasking. Between 1945 and 1970, for example, model powering experiments were performed for more than 150 merchant ship hull designs for the Maritime Administration, many leading ship builders, ship owners, and design offices. This declined after 1970 along with the U.S. shipbuilding industry (Carlisle 1998).

There are also examples of laboratories deciding to change their mission and taking the steps to make it happen. The Naval Ordnance Test Station at China Lake evolved, over a number of years, from an ordnance development and test and evaluation site focusing primarily on ship-launched missiles for BuOrd to become a developer of air-launched missiles. Successive Technical Directors, Lyddane and Smith, combined, over a period of time, to build on efforts begun by their predecessor, Dr. Charles Bramble, to move NWL from being a test site for guns and ammunition to a role as a "full spectrum laboratory" (Baile, 1991). This same capacity was demonstrated by the David Taylor Model Basin in BuShips (if not in other laboratories there or in BuAer).

During this period, personnel ceilings were set by the bureaus, which enabled laboratory-to-laboratory balancing by bureau Laboratory Management Offices. At the same time, the Bureau of Ordnance led the way with innovative processes for funding: the Foundational Research Fund (in the late 1940s), allowing laboratory directors to "tax" projects to obtain discretionary funding (1950s), and the use of modified industrial funding in some of their laboratories. Smith (Oral History 1974) observed that the bureaus tried to run the laboratories but were not able to because the laboratories controlled the equipment and the people. It was also the case that many tasks were generated from the bottom up working informally with the bureaus (Smith, Oral History 1974). One element of this was by the "smart lab guy" who "made the bureau guy look good" (Smith, Oral History 1974).

Taken together, these near-contemporaneous observations support the conclusion that some of the laboratories were free to perform the actions that comprise strategic management. It is also apparent that in many cases, the formal system allowed the laboratories to provide elements of the strategic management function for themselves. It is also clear that the substructure in the laboratory system is important, as implied by the categorization of the laboratories using the Perrow and Mintzberg frameworks. The former BuOrd, BuAer, and BuShips laboratories had distinct management approaches and are in different populations, as defined by Axelrod and Cohen's requirement – they employ different strategies.

This categorization is also critical in accurately describing the agent-based model of the laboratory system before the 1966 reorganization. The individual BuOrd laboratories most fully displayed the attributes of agents in a complex adaptive system (appropriate interactions, a shared representation of the external environment, and a common set of rules that governed their actions concerning strategic management).

Elements of the BuShips laboratories displayed many of these attributes – namely, the research functions in the David Taylor Model Basin. Other BuShips laboratories and the BuAer laboratories did not display many of these attributes.

This is not inconsistent with the proposition that complexity theory provides additional explanation for the organizational changes in the Navy laboratory system. In fact, it supports the proposal (in Chapter 5) that the Perrow and Mintzberg frameworks help identify the types of organizations that one would expect to demonstrate these attributes and which, in fact, require them for high levels of organizational performance.

CHAPTER 7

ANALYSIS OF THE POST-1966 NAVY LABORATORY SYSTEM

Modeling the Laboratory System

Formal Organization and Processes

The formal organization and strategic management processes in the post-1966 Navy laboratory system are described in some detail in Chapter 5. The reorganization in 1966 created the first formal Navy laboratory system. Key elements include the establishment of the Director of Navy Laboratories/Director of Laboratory Programs (DNL/DLP) to manage the 15 major research, development, test, and evaluation (RDT&E) activities that were moved from the bureaus (which were disestablished). The bureaus were replaced by five systems commands that had the responsibility for systems development and acquisition. This responsibility was shared with several major program managers. Each of these elements reported to the Chief of Naval Operations through the Chief of Naval Material (CNM).

The DNL also managed research and development funding and, in that capacity, reported to the ASN for Research and Development (ASN (R&D)). The DNL responsibility (as DLP) for managing the CNM laboratories included controlling research and development (R&D) funding[19], military construction (MILCON) planning and funding, personnel ceilings, directing workload balancing between the laboratories, and

[19] This specifically refers to the "Research and Development, Navy" budget category. Most of these funds were allocated to universities and the Naval Research Laboratory.

assigning responsibilities. The DNL also represented the laboratories to the systems commands and the secretariat. It should be noted that the R&D funding controlled by the DNL was typically no more than 5 to 10 percent of the annual laboratory budget. The Deputy Chief of Naval Material (Development) (DCM (D)) in coordination with the DNL and the ASN (R&D) controlled exploratory development planning and funds. The DCNM (D) had cognizance over the exploratory development funds allocated to the CNM by the ASN (R&D) as well as that allocated to the systems commands. Significant laboratory funding came from the systems commands and program managers – as it had from the bureaus (and program offices) before the reorganization.

The processes that were in place to perform the strategic management functions listed above are addressed, in general, in Chapter 5. There are also several instructions that assign the responsibility for these functions. Secretary of the Navy Instruction 5430.67 assigned the responsibility to the Chief of Naval Operations (CNO) for planning and preparing Navy research and development requirements and program objectives (U.S. General Accounting Office June 1967). The Deputy Chief of Naval Operations for Development (DCNO (D)) was assigned responsibility for establishing standard management procedures for planning, programming, and appraising research and development. Secretary of the Navy Instruction 3900.13B ("Management of Navy Research and Development Resources and Installations") named the Director of Navy Laboratories/Director of Laboratory Programs (DNL/DLP) as the ""headquarters Manager" and, hence, responsible to the laboratories for mission definition, guidance and assistance in the establishment of an appropriate technical program and the maintenance of their technical competence, and prosecution of a program to provide adequate support in terms of funds, manpower, and facilities. The laboratories were responsible for the establishment of a technical program and schedule, assembly of a staff, and identification of the resources required to prosecute their technical program.

The Secretary of the Navy Instruction that established the DNL (SECNAV INST 5430.77, dated 20 December 1965) specified that the DNL was responsible for: (1) the in-house exploratory development program, (2) the application of programmed funds as well as for assuring optimum responsiveness of the Navy laboratories to their sponsors, (3) the establishment of the military construction (MILCON) program for the laboratories, (4) determining the distribution of civilian personnel (by total number and number of high-grade level positions) in the laboratories, and (5) directing and coordinating the long-range planning of RDT&E resources. If these responsibilities are compared with the list of strategic management actions allowed agents in an agent-based model, it is apparent that the DNL was intended to provide for the strategic management of the laboratory system.

At the same time, the individual laboratories were given the ability to address some aspects of their own strategic management – within the limits imposed by the DNL. For example, specific hiring (and firing) decisions were the prerogative of the laboratory and so, as a result, was the ability to shape the capabilities of the workforce. In 1967, this flexibility was increased when Project REFLEX extended relief from DNL imposed personnel ceilings to several laboratories (in favor of fiscal controls) during a 3-year demonstration period.

The individual laboratories also had flexibility in acquiring funding. Since the laboratories were “industrially funded” when Resource Management System improvements were implemented in 1969 (and as early as 1953 for some of the former Bureau of Ordnance field activities), they had the ability (and necessity) to accept funding from a variety of sources, including any of the system commands and program managers. In theory, prescribed laboratory missions and DNL workload-balancing actions limited this flexibility. Secretary of the Navy Instruction 3900.13B specifies that the laboratory mission serves as a guide for the generation of the laboratory's technical program, to identify the principle objectives in which the laboratory is expected to excel, and as a basis for future improvement and development. This was less of an issue in practice because laboratory missions and capabilities tended to overlap and because some laboratories were not constrained by their mission.

A U.S. Civil Service Commission report on management problems in Department of Defense laboratories (27 December 1967) was based, in part, on interviews with several Navy laboratories. The Naval Research Laboratory, the Naval Weapons Laboratory (NWL), and the Naval Ordnance Laboratory (NOL) generally agreed that they were given sufficient control over manpower, funds, and mission assignment. They also felt that they exercised considerable control of which projects were accepted or rejected. The Naval Ship Research and Development Center (NSRDC) did not share this view. The report concluded:

> Presumably, the difference in their experiences resulted from the fact that local staff organizations that administer manpower and personnel management activities are usually organizationally controlled by naval laboratory commanders.

The Assistant Secretary of the Navy (Research and Development) response to the Civil Service Commission report (27 April 1968) said:

> … Navy laboratories are assigned a broad mission, which is further defined by a more detailed statement of functions. Within this framework, the laboratories are

> intentionally given broad flexibility in the determination of the amount and type of workload to be undertaken within available resources.

This practice is documented in the individual laboratory reports to the Director of Navy Laboratories/Director of Laboratory Programs from 1966 to 1969. It is difficult to produce accurate laboratory budgets and manpower levels that can be compared from year to year because the ongoing laboratory reorganization and consolidation added and subtracted field sites from the laboratories each year. In general, however, many laboratory budgets were growing, as were manpower levels. The variability in the sources of laboratory funding (as given by the percentage of funding that they received from within the Naval Material Command (NAVMAT)) indicates that some laboratories were less constrained than others. The NSRDC, for example, regularly received at least 85 percent of its funding from NAVMAT sources. The Naval Ordnance Laboratory received 65-70 percent of its funding from NAVMAT activities. On the other hand, the Naval Ordnance Test Station (China Lake), Naval Air Development Center, and Naval Underwater Research and Engineering Station each received only 45-55 percent of its funding from within NAVMAT.

The laboratories had the ability to plan and direct performance of tasks although the ability to do their own contracting was a new capability for many of them. Earlier, most laboratory contracting was done by the bureaus or through regional centers. Some of the BuOrd laboratories (such as NOL White Oak) were granted some contracting authority a decade earlier.

In short, the individual laboratories had limited control over some of the key processes of strategic management. The DNL controlled other aspects of strategic management of the individual laboratories (e.g., MILCON) and imposed constraints and processes intended to ensure consistency and a system-level view.

Agent-Based Model

An agent-based model of the Navy laboratory system in 1966 is given in Figure 7-1. This illustrates all of the agents in the larger Navy system grouped into populations (or collections of agents that employ similar strategies). This research focuses on the population of agents called "Laboratories" and the interaction among them and with outside populations/agents. The strength of the various relationships in the system (in the strategic management of the laboratories) was assessed based on an interpretation of historical and organizational artifacts. Relationship strength is indicated by the width of the lines that connect pairs of agents on the figure. The following discussion addresses the elements of the system that are most strongly involved in the strategic management of the laboratories. Specifically, it excludes the populations labeled "Other SYSCOMS" (i.e., the non-material systems commands whose effects were indirect) and "Other" (with agents far enough removed from the laboratories that they form part of the larger context or environment).

To do this, it is necessary to define the agents in the system and the nature of their interactions. This requires (according to Axelrod and Cohen) specifying the agent's location in the system, its rules, allowable actions or strategies, and the nature of its interactions with the other agents. The figure (and the organizational chart in the previous chapter) indicates the organizational location of the various elements in the system. The next step in defining the system is to address the roles of the components of the system and the nature of the connections between them. The discussion of "roles"

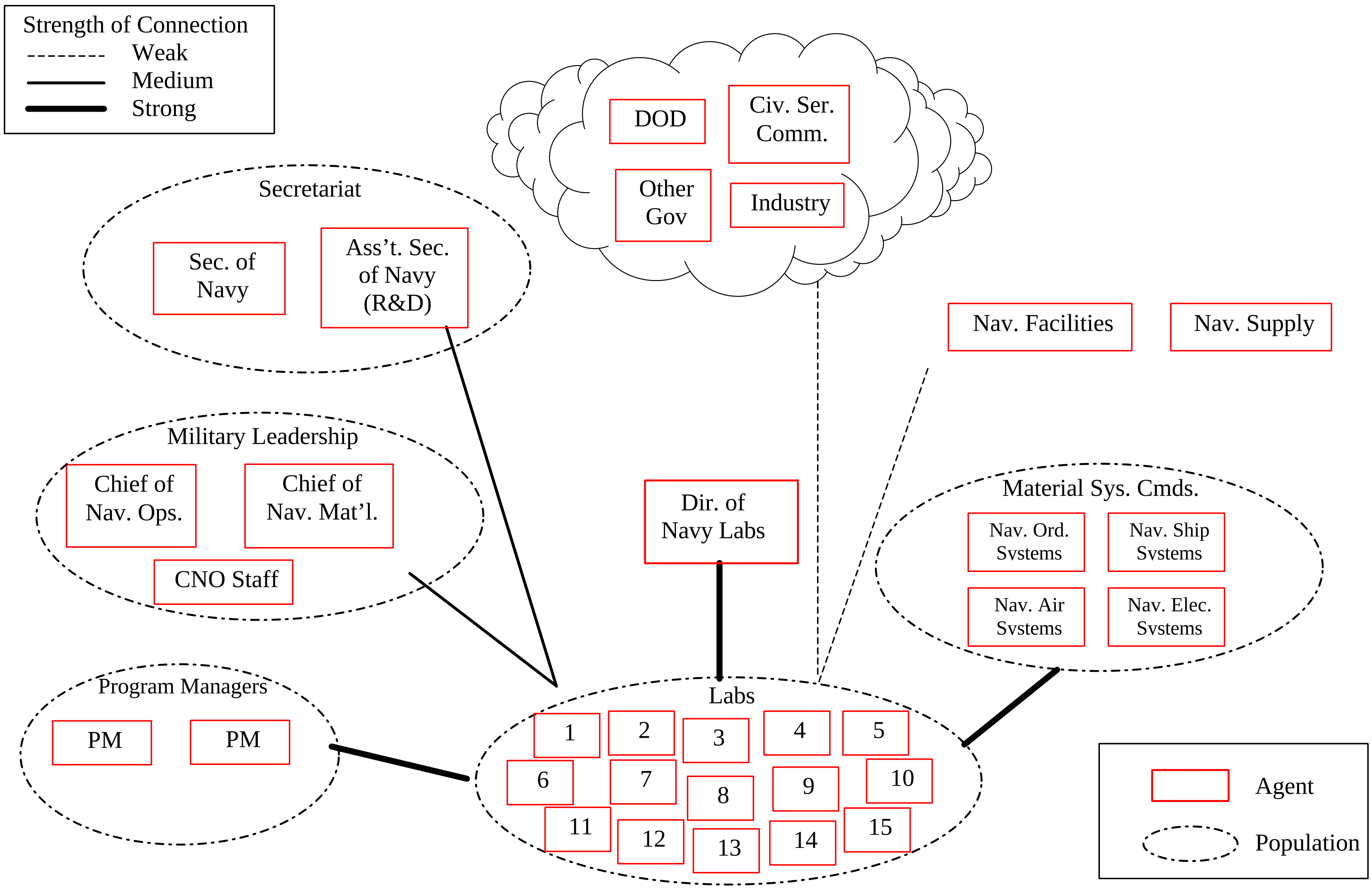


Figure 7-1: Agent-Based Model (1966)

focuses on the allowable actions regarding strategic management and will lead to a proposed set of rules that the laboratories followed.

The roles of the components of the 1966 system – emphasizing allowable actions regarding strategic management of the laboratory system – can be summarized as followed:

Assistant Secretary of the Navy (R&D): Planned and managed the R&D program and budget for the Navy and coordinated with the Chief of Naval Operations (and staff), the Director of Navy Laboratories, the system commands, and others outside the Navy to do this.

Chief of Naval Operations (and CNO Staff): Defined Navy needs and research and development requirements; managed system acquisition; and provided support for the operating forces.

Chief of Naval Material: Coordinated in-house support of system acquisition and development through the systems commands, program managers, DNL/DLP, and laboratories.

Director of Navy Laboratories/Director of Laboratory Programs: As DNL, advocated for laboratories with the ASN (R&D) regarding R&D, and participated in R&D planning. As DLP, represented the NAVMAT laboratories with the system commands (and in the coordination of efforts in support of the system commands and program managers), defined and implemented policy regarding laboratory staffing levels, allocated IR/IED funds to the laboratories, advocated for military construction (MILCON) planning and funding, and led laboratory planning processes.

System Commands (SYSCOMs): Directed the acquisition and development of weapon systems or platforms required by the Navy (either through or in support of NAVMAT program managers); coordinated with the CNO staff in the development of Navy requirements and program planning; and allocated funding either to appropriate laboratories or other sources to support acquisition and development.

Program Managers: Directed the acquisition, development, and support of weapon systems or platforms for the Navy through the systems commands and directly with laboratories for planning and execution of work assignments and to exercise technical and financial control of those assignments; coordinated with the resource sponsors on the CNO staff (i.e., the Deputy CNOs); reported status to CNM and CNO staff.

Laboratories: Supported the system commands and program managers in the acquisition and development of systems; invested discretionary funds based on own view of future needs and planning; made proposals for IR/IED to DNL; made staffing decisions based on needs (within the limits set in policy); advocated for MILCON; coordinated and collaborated with other laboratories (collectively with DNL and individually) as required.

The connections between the components can also be defined as follows:

Director of Navy Laboratories – Secretariat: The DNL represented the laboratories in planning for R&D and advocated for Navy laboratories. The secretariat (namely, the ASN (R&D)) was the focal point for R&D planning and budgets. As such, one would expect to see vision and a view of Navy needs conveyed from the secretariat as well as specific information concerning R&D goals and objectives, tasking, and funding.

Director of Navy Laboratories – Military Leadership: The chain of command for the DNL (and, thus, the laboratories was through the Chief of Naval Material (CNM) to the Chief of Naval Operations (CNO). The CNO passed a vision, a view of Navy needs, goals, objectives, and requirements, and direction and funding (through the CNM) to the system commands and the program managers.

Director of Navy Laboratories – System Commands (individually and as group): The DNL represented the laboratories to the systems commands for the purpose of understanding their needs to ensure that the laboratories provided the required capabilities. Or in other words, so that he could properly set personnel ceilings, plan the MILCON program, and plan for the development of the laboratories and to support planning of the R&D program. The DNL also coordinated laboratory support for the system commands to ensure workload balancing and collaboration. One would expect to see the system commands transfer a vision and view of Navy needs as well as more concrete information such as their goals, objectives, and requirements.

Director of Navy Laboratories – Laboratories (individually and as group): As noted previously, the DNL (and also as DLP) was in the laboratory chain of command, both to the military leadership and to the secretariat. The DNL/DLP defined individual laboratory missions and personnel ceilings. He defined the MILCON program for the laboratory system and defined and allocated research funding (IR/IED) to the laboratories. He (and his staff), in regular coordination meetings with laboratory Technical Directors, planned for the future. The DNL/DLP passed a vision and view of

Navy needs. He also relayed more specific information and direction: individual laboratory mission, MILCON, personnel ceilings, and funding and tasking for basic research.

Military Leadership – Program Managers: The chain of command went through the CNM to the CNO. Resource sponsors on the CNO staff (OPNAV) worked directly with the program managers to define system requirements for development and acquisition. In this role, vision and a view of Navy needs as well as specific information, such as goals, objectives, requirements, tasking, and funding would be passed to the systems commands. Some of this (namely, tasking and funding) would bypass the chain of command. The program managers were responsible for reporting project status up the chain of command through regular management meetings and reports.

Military Leadership – System Commands: The military chain of command for the system commands went through the CNM to the CNO. Elements of the CNO staff (OPNAV) worked directly with the system commands (bypassing CNM and program managers) to define system requirements for development and acquisition. In this role, vision and a view of Navy needs as well as specific information, such as goals, objectives, requirements, tasking, and funding would be passed to the systems commands. Some of this (namely tasking and funding) would bypass the chain of command.

Military Leadership – Secretariat: As discussed previously, the CNO (and staff) was primarily responsible for setting requirements. Research priorities and budget coordination were the responsibility of the ASN (R&D). Both reported to the Secretary of the Navy. Information passed both ways to support the definition of system and research requirements needed for development and acquisition programs and to produce (and defend) Navy budgets.

Program Managers – Systems Commands: The program managers were responsible for working through the systems commands for the development and acquisition of systems for the Navy. This included coordinating the activities of multiple systems commands, as required. In this role, vision and a view of Navy needs as well as specific information, such as goals, objectives, requirements, tasking, and funding would be passed to the systems commands.

System Commands – Laboratories: The system commands provided funding and technical direction to the laboratories (often outside the chain of command) to support the development and acquisition of weapon systems and platforms for the Navy. It is important to note that as much as 90 to 95 percent of a laboratory's funding would come from one or more of the system commands (or program managers). Individual laboratories had long-time relationships with the bureaus that were the forerunners of the system commands and, hence, relationships were often stronger between those laboratory-system command pairs than others.

Military Leadership – Laboratories: The laboratory chain of command went through the DNL/DLP to the CNM and CNO. Vision, view of Navy needs, and more direct guidance concerning laboratory roles and laboratory-industry balance would be passed. The laboratories (usually though their senior technical leaders) also had direct relationships with the CNO staff (OPNAV) for the development of Navy requirements. These relationships bypassed the chain of command (and, in the minds of some, were used to circumvent DNL/DLP prerogatives).

Secretariat – Laboratories: The laboratory chain of command went through the DNL/DLP to the ASN (R&D). Vision, view of Navy needs, and more direct guidance concerning laboratory roles and laboratory-industry balance would be passed. The laboratories (usually though their senior technical leaders) also had direct relationships with the ASN (R&D) on research needs. These relationships bypassed the chain of command (and, in the minds of some, were used to circumvent DNL/DLP prerogatives).

Program Managers – Laboratories: The laboratory chain of command typically went through the systems commands to the program managers. There were also direct connections (for technical direction and oversight) that bypassed the chain of command. The laboratory provided financial reports, funding plans, and schedules to the program managers.

Laboratory – Laboratory (multiple): These relationships varied with each pair of laboratories; some were historic rivals while others had little or no technical or mission overlap. All competed for MILCON funding and staffing resources (namely, for a share of the overall personnel ceiling). The DNL/DLP and laboratory technical directors met regularly for planning and coordination. Laboratory-to-laboratory exchanges were also conducted for coordination and collaboration. As noted previously, most laboratory funding came from the systems commands and program managers. Hence, laboratories often competed for this tasking and funding (some combinations more than others). Sometimes this competition grew out of laboratory mission overlaps; sometimes a laboratory would compete where it had applicable technical capability regardless of its assigned mission.

In conclusion, the preceding discussion has considered the entire Navy R&D system and serves to locate the laboratory population in it. In the description of the laboratory-to-laboratory connection, it also began to describe the complex adaptive system that is the focus of this research. The next step is to define that particular system more completely. This will be done by specifying the connections in more detail and by giving the rules they followed for strategic management.

A good place to start the definition of the laboratory system is by identifying the 15 laboratories that became part of the Naval Material Command with the reorganization in 1966:[20]

- David W. Taylor Model Basin (Carderock, Maryland)
- Naval Air Development Center (Johnsville, Pennsylvania)
- Naval Air Engineering Center (Philadelphia, Pennsylvania)
- Naval Applied Science Laboratory (Brooklyn, New York)
- Naval Civil Engineering Laboratory (Port Hueneme, California)
- Naval Ordnance Laboratory (Corona, California)
- Naval Ordnance Laboratory (White Oak, Maryland)
- Naval Ordnance Test Station (China Lake, California)
- Naval Radiological Defense Laboratory (San Francisco, California)
- Naval Underwater Weapons Research and Engineering Station (Newport, Rhode Island)
- Naval Weapons Laboratory (Dahlgren, Virginia)
- Naval Electronics Laboratory (San Diego, California)

[20] At the same time that the 1966 reorganization was being planned and implemented, a second phase of reorganization was being prepared. The emphasis of this phase was on combining the laboratories in such a way that a "critical mass" of expertise could be formed in key mission areas so that the laboratories would be capable of system-level development (rather than only device-level development). This process took 10 years (1966-75) to complete. Some argue that only the first of these centers was developed for mission-related reasons and the rest were done for political reasons or to reduce the number of laboratories. In short, David Taylor, NMEL, and NMDL were combined to form the David Taylor Naval Ship Research and Development Center (1966); NEL became the Naval Command, Control, and Communications Laboratory Center (1967); NOTS and NOL Corona became the Naval Warfare Center (1967); the Pasadena Annex of NOTS became the Naval Undersea Warfare Center (1967); NUWRES and NUSL combined to form the Naval Underwater Systems Center (1970): and NWL and NOL White Oak formed the Naval Surface Weapons Center (1975). In relatively short order, the former NMDL was separated from DTNSRDC and became the Naval Coastal System Laboratory (1972) and NCCCLC and NUWC were combined to create the Naval Ocean Systems Center (1974). Other laboratories were closed – NASL (1970) and NRDL (1969) – or transferred to systems commands – NAEC to NAVAIR (1967) and NCEL to the Naval Facilities Command (1975). This history may raise questions of "extinction" of agents in the case of certain laboratories.

- Navy Marine Engineering Laboratory (Annapolis, Maryland)
- Navy Mine Defense Laboratory (Panama City, Florida)
- Navy Underwater Sound Laboratory (New London, Connecticut)

Understanding in more detail how the laboratories operated internally and with the other laboratories helps to complete the definition of the laboratory system because it describes the connections and leads to the formulation of the rules that governed laboratory behavior as agents in a complex adaptive system.

The Naval Ordnance Laboratory (White Oak) developed a set of "operating principles" soon after World War II and had them signed by the Chief of the Bureau of Ordnance. They modified these principles periodically over the following two decades – mainly to reflect new organizational relationships (e.g., changing BuOrd to Bureau of Naval Weapons). They were modified more substantially in 1966. This version of the principles is given in Figure 7-1.

The Naval Ordnance Test Station at China Lake developed operational principles that echoed these ideas. They were considered to be their "founding ideals" and were based on several concepts, including an integrated military-civilian team, creativity and flexibility in technical programs, taking calculated, productive risk in technical programs, and laboratory initiative in determining requirements (NWC 1974). The principles given in Table 7-2 are from the 1971 version (by which time they had become the Naval Weapons Center).

The NOL and NWC principles both emphasize the importance of the role of the laboratory in planning its program, the roles of the Commander and the Technical Director, the pre-eminent role of technically qualified civilians (compared to military officers) in making technical and scientific decisions, and the role of the "technical armed

Table 7-1. – NOL Operating Principles (26 February 1966)

1. The Naval Ordnance Laboratory is a primary research and development activity of the Chief of Naval Material, responsible to him for its funds, its operations, and its results.
2. The mission of the Naval Ordnance Laboratory, briefly, is to originate and analyze new ideas in ordnance, and to advance them by research, development, test, and evaluation, under the direction of the Chief of Naval Material.
3. It is essential for the Laboratory to plan a positive integrated program subject to review by the Chief of Naval Material.
4. To accomplish results, adequate facilities and funds and superior professional personnel are mandatory.
5. Superior military and civilian professional personnel are alike essential, each with adequate authority and responsibility, each supplementing the others.
6. It is the responsibility of the professional civilian staff to produce technical accomplishments in research, development, design, test, and supporting activities.
7. It is the primary responsibility of the technical armed services officers attached to the Laboratory to assist and advise the civilian technical staff on matters relating to the development of naval material designed to meet service requirements and operating conditions.
8. The Commander, a Naval Officer, is responsible to the Chief of Naval Material for appropriate operation of the Laboratory. He will delegate line authority and responsibility to the Technical Director for the technical programs.
9. The Technical Director, a civilian, is responsible to the Director of Laboratory Programs for implementing technical guidance affecting the laboratory.
10. The Commander and Technical Director are responsible to the Director of Laboratory Programs for policy matters affecting the Laboratory and for inter-laboratory relations.
11. The Commander and Technical Director, jointly, have management responsibility to Sponsors for the acceptance and conduct of tasks.
12. The Commander and Technical Director are jointly responsible for the effective and economical internal functioning of the Laboratory.
13. The civilian heads of all technical organizations are responsible to the Technical Director through the appropriate line organization.
14. The primary function of the service departments is to aid in supplying the needs of the technical staff for accomplishing the work specified by the Technical Director.
15. The Naval Ordnance Laboratory is an integral part of the Naval establishment. Its staff members, military and civilian, are equally a part of that establishment. Every effort will be made to provide opportunities for professional advancement and recognition, to the end that all hands will be proud that they are a part of the Navy. (Smaldone 1977)

service officers" to advise the civilian staff on fleet requirements and operating conditions. Principle 11 (NOL) is especially important since it explicitly identifies the laboratory responsibility for accepting work (rather than the CNM or DNL/DLP). That

Table 7-2. – NWC Operating Principles (1971)

1. The Naval Weapons Center is a primary research, development, and test activity of the Naval Material Command. The Commander, Naval Weapons Center, is responsible to the Chief of Naval Material for the administering assigned funds, conducting operations, and the accomplishing the mission of the Center.
2. The Mission of the Naval Weapons Center is to originate and analyze new ideas in weapons systems and related fields of science and technology; to advance them through research, development, experimental production, test, and evaluation; and to assist in introducing the resultant weapons systems and technology into production and service use.
3. The technical program of the Center is planned jointly by the Chief of Naval Material and the Commander, Naval Weapons Center and is integrated and positively directed toward accomplishing the mission.
4. To accomplish the mission, superior military and civilian are essential, each with proper authority and responsibility, each complementing the other, and each supported by adequate facilities and funds.
5. The Commander, a senior naval officer, is responsible to the Chief of Naval Material for all phases of operation of the Station. He delegates line authority to the Technical Director for the technical program.
6. The Commander and the Technical Director are jointly responsible to the Director of Navy Laboratories for policy matters affecting the Center and interlaboratory relations, and for the effective and economical internal functioning of the Center in accomplishing its mission.
7. The Technical Director, a recognized civilian scientist or engineer, is responsible to the Director of Laboratory Programs for implementing technical guidance affecting the Center.
8. The Deputy Technical Director and Deputy Commander are jointly responsible to the Commander and Technical Director for directing and integrating the work of all departments in accomplishing the mission.
9. The Heads of Departments are responsible to the Deputy Technical Director and the Deputy Commander for providing leadership in their respective programs in supporting and accomplishing the mission.
10. The primary function of all groups of the Center is to further the technical program. All departments participate according to their responsibilities in accomplishing the mission of the Center.
11. The responsibility of the professional staff is to produce superior technical accomplishments in research, development, design, experimental production, test, and evaluation of weapons systems.
12. The primary responsibility of the technical officers of the armed services attached to the Center is to assist and advise the civilian technical staff on matters relating to the development of naval material designed to meet service requirements and operating conditions.
13. The Naval Weapons Center is an integral part of the Naval Establishment. Its personnel, military and civilian, are equally a part of that establishment. Every effort is made to provide opportunities for professional advancement and recognition, to the end that all will be proud that they are a part of the Navy.

and the industrial funding of the laboratories opened the way for internal strategic management (see NOL Principles 3 and 12) and for competition with the other laboratories. NWC Principles 3 and 6 make somewhat the same point albeit in a weaker form. Principles 10 (NOL) and 6 (NWC) acknowledge the role of the DNL/DLP in setting policy concerning interlaboratory relations. The principles specifically relate to the elements of strategic management when they emphasize the importance of personnel, facilities, and funding. Consideration of some typical laboratory approaches to the elements of strategic management follow.

Naval Industrial Funding and the reorganization required that the laboratories be innovative in finding sources of funding outside of their traditional Navy sponsors. Successful laboratories balanced a pioneering spirit with the discipline not to stray far from their usual kinds of tasking or their organizational competencies. China Lake was clear on the importance of independent planning and action. The Technical Director, William McLean, considered the China Lake role to be to define the concepts that were needed and to make the first moves toward their solution. McLean is also quoted (in Westrum) as saying:

> Being able to choose its own problems, the things that really needed to be done, as well as those passed down from above, was essential to make China Lake a successful laboratory.

The NWL Technical Director, Bernard Smith (1999), said much the same thing about the Naval Weapons Laboratory in the late 1960s:

> Those who would emerge as leaders in the future would have to make judgments on the value of the assignments, whether or not they were suitable for the Navy or the laboratory, and if not, propose better ways to use the Navy's resources at Dahlgren. Guts would be required to turn down improper assignments no matter how safe and comfortable and to pioneer into areas of pressing Navy needs, untouched because of high risk and lack of vision.

He also observed “Good labs ignore mission statements and follow ideas they develop” (Oral History 1974).

Funding these tasks (with only limited discretionary funds available) was an important part of the strategic management process of the laboratories. Their view of the importance of laboratory independence carried over and shaped the China Lake approach to funding work on the problems they chose. Namely, the rules took a backseat to intelligent action and if they could not be ignored, they could be bent.

> “All money is green and it all comes from the taxpayer” was a common China Lake phrase. (Westrum 1999)

The leadership passed this on as part of the institutional culture. Hack Wilson (Associate Technical Director to William McLean) “… gave … valuable lessons about operating in the government system … he was very careful to be sure he understood how far he could stretch the rules about shifting money around without being vulnerable to being sent to prison” (Westrum 1999). Diverting chapel construction funds (temporarily) to pay for a launcher for testing the Lark missile is an example of how far rules could be bent.

This view also could (and did) lead to competition between the laboratories. The China Lake view, exemplified by Bill McLean, was that competition between laboratories, or groups of laboratories, was critical to the research process and should be encouraged because competing approaches would lead to a better solution. Similarly, he had no concerns about a laboratory coming up with a solution to a problem that “belonged” to another laboratory. The Sidewinder missile developed at China Lake is an example of this philosophy.

Bernard Smith echoed this view in his management philosophy:

> Means of warfare change and shift. We must look at all aspects: underwater, surface, air, etc. We should not have mission-oriented labs, but several general purpose labs and allow them to take assignments in any warfare area, from any [systems command]. History shows that the best ideas come from labs that don't have that particular area in their mission. (Baile 1991)

Howie Wilcox, Sidewinder project manager under McLean sums up the China Lake (and typical laboratory) view of competition and the process for obtaining tasking from sponsors:

> They thought of us as the Huns descending on Washington out of the west to run off with all of the plums. I think there was a certain 'robber baron' character to the way [China Lake] operated, because our philosophy basically was: if you can run faster than the next guy, you get the job. (Westrum 1999)

Clearly, one representation of the connections between the laboratories in the agent-based model is as competitors. Certain laboratories with common interests or competencies competed for funding from sponsors. Since they no longer "belonged" to a specific systems command, they were free to market to any system command. At the same time, the systems commands were not obligated to favor their previous laboratories over others … and some did not. All of the laboratories competed with each other for a share of the MILCON budget, the personnel allocation, and the DNL and DCNM (D) research funding. While the laboratories competed, they also collaborated with each other – either in their own interest or at the urging of a sponsor.

The previous discussion leads to a formulation of the rules for strategic management that laboratory-agents follow in the model of the laboratory system. The review of the operational principles, the actions and practices of laboratory leadership, and the processes implemented by the DNL/DLP highlights several themes that relate to the elements of strategic management – control, budget, staff, and facilities. The laboratories were motivated to operate in an efficient and effective manner to maximize the funding that could be applied to the technical projects. Laboratory missions were not viewed as hard limits on action and many laboratory directors acted to meet Navy needs (i.e., to support the fleet) and in their laboratory's interests. Likewise, the laboratories proposed projects to a variety of sponsors, including systems commands and program offices, and applied available or discretionary funds and existing facilities to their own projects.

This is summarized by the following rules:

(1) Accept funding based on laboratory judgment of value to the Navy and laboratory regardless of laboratory mission.
(2) Make the plans and decisions necessary to run the laboratory in an economical and efficient manner.
(3) Define the concepts and systems required by the Navy and begin to work on them.
(4) Do not let bureaucratic rules impede doing the right thing for the Navy.

These rules will be part of the comparison of the formal and emergent systems in the post-1966 Navy research and development environment.

Comparison

The formal system and processes have been described and an agent-based model was developed to describe the emergent system. It now remains to answer the question of which was dominant or, more accurately, when and under what conditions each system was dominant. The first step in answering this question is to evaluate the formal systems and processes and to provide an assessment of whether or when they provided for the strategic management of the laboratory system.

As might be expected, the success of the DNL is the subject of much disagreement. Some would argue that the office was successful – at least in some aspects of strategic management – while others disagree. Some believe that it could have been successful and place the blame for its failure at the feet of the first two Directors – Gerald Johnson and Joel Lawson. Still others contend that the DNL was never intended to be successful. Each of these views must be examined to form a complete evaluation of the performance of the DNL.

Allen Himes, Associate DNL to James Probus and long time member of the Bureau of Weapons and DNL staffs, suggested that the DNL made certain things better (Oral History 1978). He specifically said that the DNL saved facility funds, resulted in less duplication of effort (by the laboratories), and that in general, the laboratories were better off than if they were under the systems commands (where there would have been operational competition with, for example, the shipyards). Joel Lawson, DNL from 1968-74, noted that the reorganization and the DNL were successful in moving the laboratories to working on major projects rather than being "job shops" for the systems commands (Oral History 1975). He also indicated his belief that the DNL/DLP was successful in its limited role – advocate/salesman for laboratories and control of the Independent Research/Independent Exploratory Development (IR/IED) program. Bernard Smith (Oral History 1974) felt that the success of the reorganization came from the fact that it freed the laboratories from the systems commands and, while "[l]abs were forced to do more of their own thinking to have long term survival," it allowed them to accept suitable work and reject useless work. He attributes the success of the laboratories "more to the insights of the top officers in the Navy than to the existence of the office of the DNL" (Letter to author 2000).

The more widespread view is that the DNL/DLP was not successful, due either to circumstances, the performance of the first Directors, or the intent of the designers. Bernard Towle, Associate DNL, felt that the DNL Charter added up to real power, authority, and money. However, some key things were never implemented and, in his view, the "machine" never worked (Oral History 1974). He specifically noted that the DNL never got control of exploratory development and did not have ultimate control over some of the elements of strategic management that were of the most interest to the laboratories – personnel ceilings and military construction, and that DNL direction had little effect on the systems commands. He also noted that, in any case, the Vietnam War precluded control over personnel ceilings and MILCON by the DNL. Howard Law, Associate DNL in the 1980s, noted that several things happened that reduced the role of the DNL: (1) Federal Contract Research Centers (FCRC) were not placed under the DNL, (2) test and evaluation organizations were excluded (and left under the control of the systems commands), and (3) exploratory development was removed from DNL control (to the Office of Naval Research and the CNM (D)) (Oral History 1983).

Others also expressed these sentiments. Dr. John Adkins, Assistant Chief Scientist in the Office of Naval Research, declared "… that sort of thing was just not workable" and that the DNL/DLP was one person with two hats "… and with neither hat did he have any authority to do anything about anything" (Oral History 1981). Vice Admiral H.G. Bowen, Deputy Chief of Naval Operations (Development), when asked what the practical effect of the establishment of the DNL was on him as DCNO (D) said: "I didn't even get a ripple out of it … as far as I was concerned, it was another administrative centralization …". James Colvard (Oral History 1980) posited that "[t]hey didn't give him control of enough resources to amount to much; he has always had to manage by dint of his personality and persuasion because the labs are industrially funded activities with 90 percent of their money from the system commands." Similarly, A.B. Christman, Historian of Navy Laboratories and the Naval Weapons Center, said the "… DNL supposedly has controls which they do not in fact have since the dollars mainly control who does what, rather than the real control lying with directives" (Oral History 1980). Joel Lawson, the second DNL, observed that planning was a problem because funding comes from system commands and project managers and is a long process that is not easily changed once established since it takes on the "aura of gospel" (Director of Navy Laboratories 25 May 1971).

Gregory Hartmann, Technical Director NOL White Oak, was offered the job as first Director of Navy Laboratories. He declined saying that he viewed the DNL as basically a laboratory management office but without the power to balance workload and that it had no say in funding and inadequate staff (Oral History 1974). The validity of his observation is supported by Naval Material Command Instruction 5450.8 (dated 27 June 1967), which specified that

> Systems commanders, project managers, and other sponsors of laboratory work shall have direct and full access to laboratories for planning and execution of work assignments and exercise technical and financial control thereof.

Howard Smith, Assistant DNL to both Gerald Johnson and Joel Lawson, said, "… when our office was created, we perceived ourselves to have certain powers, which in fact we did not have. We started out to gain these powers, which in fact we could not gain" (Oral History 1980). Towle felt that the DNL concept was wrong and required a superman who all of the laboratory Technical Directors would accept as their superior on technical issues. In a similar vein, Howard Smith observed, "… it was going to go downhill anyway. J. Lawson or Jesus Christ would have been in the same position; one would have stretched it out longer than the other."

Others felt that the failure of the DNL/DLP could be placed at the feet of the first two Directors, Gerald Johnson (1966-68) and Joel Lawson (1968-74). Bernard Towle's assessment was that Gerald Johnson would not use CNM channels (where his power was) and, consequently, had little CNM cooperation or support (Oral History 1974). He also felt that Johnson tried to have his own policy and, consequently, was viewed as technical competition by the laboratories. Neither did he use the mechanisms he had at his disposal to coordinate with the laboratory Technical Directors. Rear Admiral E.A. Ruckner, Assistant Chief of the Bureau of Ordnance and, later, DCNO (D), thought that the establishment of the DNL "could have been a pretty decent move, but turned out to be a pretty horrible thing" (Oral History 1974). He thought that the DNL could have ensured a stable workload for the laboratories working through the systems commands and the Chief of Naval Development, but it did not. He places the blame on Johnson who, he believes, tried to build an empire not closely related to Navy problems and, in so doing, "got off on the wrong foot and never got straightened out." Dr. William P. Raney, Special Assistant to the ASN (R&D), observed that Johnson did not have any patience for the "bureaucratic niceties" that can make or break an organization. "He raised issues, fought the fight, but didn't tend to bureaucratic details and was unwilling to bargain with and accommodate the people he needed to work with" (Oral History 1980).

While Joel Lawson was more willing and able to do the "practical politicking" required, he was forced to operate at a lower level than what Johnson sought. He was considered to be better at practical things, such as manpower and facilities (Raney, Oral History 1980). Bernard Smith expressed the opinion that Lawson did not show any innovative management. He particularly disagreed with Lawson's approach to MILCON – he preferred to allocate it to laboratories to help them get work rather than to laboratories that had tasking and needed additional facilities (Oral History 1974). Howard Smith (Oral History 1980) believed that Lawson perceived his job as managing everything, which was a serious mistake. Instead of working at the higher levels where his stature was required, he was "piddling around with projects that didn't matter anyway." He also observed that Lawson thought that the DNL's job was to be the laboratories' representative in Washington, which was impossible because laboratory interests were too diverse.

Others held the view that the DNL position was never intended to be successful. Chalmers Sherwin proposed a reorganization of all defense and service laboratories in 1964 (see Chapter 1). He made a parallel proposal for an implementation of his proposal in the Navy. Raney (Oral History 1980) believed that the DNL was a compromise "that looked like it responded to Sherwin but didn't do violence to a key part of the ongoing Navy function." He also said "It was in many ways cosmetic; we knew it couldn't work as well as Sherwin and I wanted it to work, but there seemed to be some chance to get some good out of it." Ruckner (Oral History 1974) describes the creation of the DNL as a "delaying action to a DDR&E [Sherwin] move to take the labs away from the services."

The uniformed Navy favored placing the DNL under the uniformed CNM if there had to be one (Howard White, Oral History 1980). James Probus, DNL from 1974-80, felt that the final form of the DNL was a compromise between Admiral Galantin (CNM) and Robert Morse (ASN (R&D)). He was specifically referring to the organizational structure that placed the DNL under the CNM and also required him to report to the ASN (R&D) (Oral History 1983). He also observed that no CNM – starting with Galantin – has been happy with the arrangement given the implicit split loyalties. Colvard (Oral History 1980) said that "… the major thing that the DNL was set up for was [to effect a] compromise between the ASN (R&D) and the blue-suit Navy. I don't think either one of them wanted it to be a powerful position … and they got exactly what they wanted."

A number of actions that are elements of strategic management are listed in Chapter 3. These guide our evaluation of the formal systems and processes as we summarize the effectiveness of the DNL in the strategic management of the Navy laboratory system. Were these actions that the DNL took? If so, were there times when they could not take those actions?

Consider the role of the DNL in setting the future direction of the laboratories. A case can be made that it was not done effectively. Initially, the Director had only limited support from the CNM or the systems commands. For example, the DNL was supposed to provide laboratory support for the Naval Material Command (NAVMAT) program managers. Howard White, Special Assistant to the Assistant Secretary of the Navy for Research and Development, believed that this did not work because the CNM forced the program managers to work through the systems commands (Oral History 1980).

Before the establishment of the DNL the laboratories and their parent bureaus were required to jointly plan laboratory programs and budgets. Secretary of the Navy Instruction 3900.13A (dated 1 November 1963) requires the laboratory and its parent bureau to prepare a five year plan for the technical and fiscal programs of the laboratory.

The Bureau of Weapons established a process in which each laboratory would prepare a five-year budget plan based on a five-year program plan. The bureau held annual planning conferences with all of its field activities to discuss the plans and reach agreement on programs, personnel, and funding levels. Likewise, the Bureau of Ships held an annual "R&D Council" meeting with its laboratories to discuss business practices and processes, technical programs, and personnel issues.

Naval Material Command (NAVMAT) Instruction 5430.26, which established the DNL, specifies that the DNL is responsible for directing and coordinating the Naval Material Command research, development, test, and evaluation (RDT&E) resources. A revision of NAVMAT Instruction 3900.13A directs the laboratories to work with the DNL/DLP to produce laboratory five year plans. Joel Lawson, the second DNL, acknowledged, in his plan to improve the Navy laboratories, that planning was a problem because laboratory funding comes from the systems commands. The Sproul Committee report (2 March 1974) observed that there was no long range plan for Navy field activities and laboratories and concluded that the resource split between the Chief of Naval Material and the systems commands reduces mission focus and inhibits planning. A Naval Material Command survey in 1976 requested information about long range planning in its laboratories. The responses indicate that the level of laboratory planning varied from well established to minimal. The David Taylor Model Basin produced its first consolidated five-year RDT&E plan in 1965. The Naval Weapons Laboratory published a plan that reviewed the external environment, discussed the laboratory mission, and proposed changes in its organization and technical program (NWL 1968). The NAVMAT survey was part of a process to develop a formal long-range planning process (Hughes 23 December 1975). A formal planning process was not implemented in the DNL until 1976 although Lawson took some steps in that direction (Himes, Oral History 1983).

As noted previously, the DNL lacked the authority or control to enforce its plans or direction on either the laboratories or the systems commands. The laboratories ultimately realized that they had greater leeway than under the bureau system. The former Bureau of Ordnance laboratories were always the most independent and adapted to it more easily than the former Bureau of Ships laboratories, which required more detailed direction and were less willing to start new ideas (Abrams, Oral History 1983; Lawson, Oral History 1975). The instruction that established the DNL (NAVMAT Instruction 5430.26) specified that the DNL is to direct and coordinate the planning of Naval Material research, development, test, and evaluation resources, but did not give him the power to do it. The management policies and command relationships for the Navy laboratories (NAVMAT Instruction 5450.8) give the systems commands and project managers direct and full access to the laboratories for the planning and execution of work assignments. Likewise, NAVMAT Instruction 3910.13A assigns the responsibility for planning and management of exploratory development to the systems commands and the laboratory. The DNL used the power of persuasion – its only real power – to shape and communicate the vision that connected the systems commands and the laboratory and to coordinate laboratory activities to support the systems commands. In the end, it could be said that the DNL worked for the systems commands and the laboratories rather than vice versa (Probus, Oral History 1983).

Resource development and allocation is also an element of strategic management. The funding issue was discussed in some detail above, but, in short, the DNL controlled a very small part (5 to 10 percent) of the laboratory funding. According to Dr. John Adkins, Assistant Chief Scientist in the Office of Naval Research in the 1960s, the DNL/DLP did not have authority "about things that are meaningful to the laboratory – personnel ceiling, MILCON, procurement authority … for labs" (Oral History 1981). The DNL tried to control other resources – manpower and facilities. The first problem that was addressed – successfully – was the freeze on promotions to the GS-14 and GS-15 levels. DNL control of the MILCON process was limited by circumstances: the funding level was greatly limited by the cost of the Vietnam War. This authority was executed by Lawson, if not always to the satisfaction of the laboratories. Although the total laboratory manpower ceiling was set at a higher level, the DNL could allocate individual limits to the laboratories. When Project REFLEX was started at three demonstration laboratories in 1967, this control was passed to those laboratories for the duration of the project.

Strategic management actions also include altering the reporting structure and the task structure. The DNL had control over the bureaucratic processes such as laboratory mission definition and had a role in selecting individuals to fill high-level laboratory positions, such as Technical Director and Commanding Officer (Frosch, Oral History 1981; Himes, Oral History 1983). Efforts were also made to perform workload balancing and to represent the laboratories with the systems commands when there were manpower issues (by identifying work that would not be done). Neither was particularly effective (Lawson, Oral History 1975). In many ways, workload balancing and manpower followed the funding decisions that were made by the systems commands and the laboratories and that were largely beyond DNL control or influence. The DNL, however, did represent laboratory interests in the consolidation efforts that began in 1966 – with some success. With the exception of the few laboratories that were closed, there were few changes as the DNL strove to protect Navy capability (Lawson, Oral History 1975). In fact, the beginning of the end for Lawson as DNL may well have been his involvement (and defense of the laboratories) in later closure activities (Himes, Oral History 1978).

Summarizing, the discussion, to this point, has highlighted the role of the formal organization and processes in the strategic management of the laboratory system by the Director of Navy Laboratories and, in particular, the areas in which it came up short.

Robert R. Maxfield (in Alberts and Czerwinski 1997) provides a framework for considering what the proposed agent-based model of the emergent system adds. He describes strategic thinking in an organization facing a complex foresight horizon and proposes two strategic practices they should follow: *populating the world* and *fostering generative relationships*. These practices and the preconditions for assessing the generative potential of a relationship – aligned directness, heterogeneity, mutual directness, permissions, and action opportunities – are discussed in Chapter 3. The Maxfield framework is used to explore the relationships of the agents in the system in more detail.

The last step in assessing the utility of this model is to examine the applicability of the proposed rules for agent behavior and their role in the strategic management of the Navy laboratory system. Rosenau (in Alberts and Czerwinski, 1997) specifies that agents that self-organize their behavior must be related to each other sufficiently to form recurrent patterns. The preconditions for generative relationships provide a process for establishing the nature of the relationships between these agents (i.e., the laboratories) and between the agents and other elements of their environment.

The first preconditions to be considered in examining the nature of the relationships between the agents are “aligned directness” – the compatibility of their orientation – and “heterogeneity.” In a general sense, the common threads in the operating principles at NOL White Oak and NOTS China Lake illustrate the compatibility of the former Bureau of Ordnance laboratories.

> … to operate these installations on the principle that the technical activities would be conducted and directed by professional civilian scientific and engineering personnel, and that the role of the military personnel would be that of providing the necessary knowledge of operating conditions plus the administration required to make the laboratory a part of the Naval establishment in the broadest sense.” (Westrum, 1999)

The Technical Directors at NOTS and NWL (William McLean and Bernard Smith) both made a point of encouraging laboratory freedom to select areas of work. Ron Westrum (Personnel Communication 1999) observed that “… White Oak was supposedly also set up to be creative like China Lake …”. The reorganization freed them up to pursue work that suited both their capabilities and their view of Navy needs.

Likewise, the former Bureau of Ships and Bureau of Aeronautics laboratories formed two other aligned groups. The BuShips laboratories focused on ship research and development and, hence, had one major sponsor after the reorganization – Naval Ship Systems Command. They had a strong central organization (Abrams, Oral History 1983) with the technical director acting as a chief scientist and subordinate to the military leadership (Himes, Oral History 1978). The Naval Air Systems Command laboratories had a mission that focused more on test and evaluation than research and development and a quasi-military organization with technical Navy officers at all levels (Hartmann, Oral History 1974). The Chief Scientist was a staff position rather than a line management position (Himes, Oral History 1978).

The previous discussion highlights the heterogeneity displayed by the major groups of laboratories. The mission statements of the former BuOrd laboratories indicate the heterogeneity in the capabilities of these laboratories. In general terms, NOL White Oak's traditional areas of competence were ordnance research, mines, and torpedoes. NOTS competence was missiles (originally only surface launched) and NWL was guns, ordnance, and computers. In 1971, Joel Lawson issued two DNL reports ("A Plan for Improving the Effectiveness and Utilization of the Navy's In-House Labs" and "How Can the Laboratories Best Serve the Navy") that opened the "mission exclusivity" battles. His goal was to reduce the overlap between the laboratories and to tie their missions to the traditional Navy warfare areas. (Anspacher et al 2000) This move towards mission exclusivity, to the degree that it was successful, would increase the heterogeneity of the laboratory agents.

Consider whether or not the relationships between the laboratories exhibited a pattern of interactions, or "mutual directness." There were DNL-established forums for laboratory interaction. One such group was the "Inter-Laboratory Committee on Personnel Administration." This group – a personnel organization that crossed laboratory lines – addressed issues, beginning with freeing up the GS-14 and GS-15 freeze in place at the time of the reorganization. The DNL also coordinated quarterly meetings of the laboratory technical directors and commanding officers. Colvard (Oral History 1980) expressed the view that these meetings were for information exchange and never solved anything. The minutes of the August 1966 meeting indicate that more than 70 commanders and senior civilians (from 39 laboratories, including university laboratories and Federally Funded Research and Development Centers) met to exchange ideas concerning policy and operations and for the rapid dissemination of information on non-routine, non-recurring events (Navy Laboratory Directors Council August 1966).   Joel Lawson (Oral History 1975) noted that these meetings began to consider missions in 1968 or 1969. He felt that they got too large and "came unglued" and were largely considered ineffective (Colvard, Oral History 1980; Lawson, Oral History 1975).

There were also formal processes that required or resulted in laboratory interaction. Examples include the allocation of Independent Research and Independent Exploratory Development (IR/IED) funds and personnel ceilings to the laboratories. The DNL also required regular reports from each laboratory and held technical reviews of the efforts funded by the DNL IR/IED program. Beginning in 1966, the DNL/DLP required each laboratory to produce an annual report that addressed funding expectations and staffing requirements for three years, a discussion of funding sources, and a description of the laboratory, remotes sites, and facilities. The first report contained laboratory funding and staffing profiles back to the mid-1950s.

In addition to the meetings for information exchange and the formal processes for laboratory interaction, there were also informal interactions, especially in the cases where capabilities were complementary and teaming was mutually beneficial. As noted earlier, there was another kind of interaction – competition. This could occur when, as McLean and Bernard Smith noted, a laboratory had a good idea – in another laboratory's mission area. Since laboratories often had overlapping capabilities, it also resulted when the reorganization broke down the traditional laboratory-bureau linkages.

Another precondition for a generative relationship is that both organizations have permission to engage. In what sense did the laboratory agents have permission to engage with each other? Laboratory consolidation and the drive by the DNL for mission exclusivity can be taken either way. On the one hand, the intended effect might be to reduce the opportunity and need for engagement. Another view is that, exclusivity aside; large system development required a diversity of technical capabilities and testing and evaluation sites and, often, the interaction of multiple laboratories. Joel Lawson, the second Director of Navy Laboratories, was of the opinion that placing the laboratories under the CNM better enabled them to work together on major projects (Oral History 1975). In a general sense, formal processes, such as industrial funding, and Project REFLEX – for the demonstration laboratories – gave implicit permission for engagement.

Finally, a generative relationship requires that there be action opportunities. Lawson (Oral History 1975) felt that the laboratories always had funding for more work than they had available manpower. Bernard Smith (1999), for example, notes that the NWL budget increased from $24 million to $50 million between 1964 and 1968 and doubled again in the next 4 years. The annual laboratory reports to the DNL/DLP describe similar growth at other laboratories. Even though some of the growth is attributable to reorganizations and mergers, several of the laboratories grew by at least 50 percent between 1964 and 1970. One indication of the number of opportunities is given by the growth of the Defense and Navy budgets during this period. The defense budget experienced a peak in 1968 and, while it decreased in real dollars over the next decade, this was due in large part to the reduction in spending on the war in Vietnam. (Jones 1999; Korb 1979) During this same period, defense research and defense spending was nearly constant. (National Science Foundation 1997) While the Navy budget held relatively constant at around 30 percent of the DOD budget, ship construction and aircraft procurement budgets were increasing and a number of major acquisition programs were beginning.

In summary, the view that the laboratory agent relationships satisfy Maxfield's preconditions for generative potential has been presented. The laboratories each had internal planning staffs or functions that facilitated the process of discourse to establish a local representation of the external environment. DNL processes such as the laboratory technical director/commanding officer meetings and the DNL planning process that developed later provided vehicles for discourse to establish a laboratory system-level representation of the external environment. The DNL also established programs such as the Vietnam Laboratory Assistance Program (that later became the Navy Science Advisor Program) that placed scientists and engineers in the field with the operating forces. This program, which was not well received by all of the systems commands (Bernard Smith, Oral History 1974), provided additional information to help the laboratories represent their external environment.

In short, the case has been made that the laboratories possessed the attributes of agents in a complex adaptive system. Having said that, it is important to remember the nature of the interaction of agents in a complex system. Agents are independent actors that apply a shared set of rules to their knowledge of the environment. This does not imply negotiated action or overt agreement among the actors. Instead, the overarching requirement for interaction is for the agents to share a relatively consistent representation of the external environment and an understanding of the state of the other agents in the system. The first of these is facilitated in a government laboratory system by the availability of DOD and Navy planning documents and budgets. Individual laboratories will, of course, develop their own unique representation of this environment by adding their own observations and information. The second dimension – understanding the state of the other agents – means, in the case at hand, understanding the elements of strategic management of the other agents. These types of information, which were defined previously, are the kinds of data that were collected by the DNL (e.g., personnel ceiling, MILCON, and equipment allocation), documented by the agents in their planning documents, or which could be inferred from their actions.

The previous discussion describes the nature of the interactions among the agents and identifies the sources of information available to them. Did they follow the rules that were postulated earlier when they used this information? Evidence shows that they did. McLean and Bernard Smith – Technical Directors of NOTS and NWL, respectively – have already been cited as emphasizing a culture of independence at their laboratories. Smith, in fact, brought senior managers from NOTS to NWL in the late 1960s in order to strengthen this aspect of laboratory culture (Smith, 1999). This included acceptance or rejection of tasking, pursuing good ideas for the Navy regardless of whether they fell outside of the formal laboratory mission area, and utilizing available discretionary funding and reprogramming other funding within the limits of the industrial funding process.

There are also examples of laboratories deciding to change their mission and taking the steps to make it happen:

> During the mid-1960s, the NWL at Dahlgren decided to evolve from a primarily test and evaluation establishment, to an R&D laboratory … the Dahlgren top management was using its energy to establish itself in technical mission areas that had no clear in-house Navy laboratory competition by "pounding the pavement" visiting the NAVORD Program Managers. (Anspacher, 2000)

This is spelled out in the report by an internal "Mission Analysis Panel" that presents their assessment of the external environment and the laboratory's organizational and technical strengths and recommendations for change. They specifically propose a new NWL mission and attendant changes in the laboratory organization and technical programs (NWL 1968). A similar case can be made for the Naval Weapons Center (former NOTS) at China Lake. They evolved, over a number of years, from an ordnance development and test and evaluation site focusing primarily on ship-launched missiles for BuOrd to a primary developer of air-launched missiles in support of the Naval Air Systems Command.

Project REFLEX gave increased control over the personnel processes to the demonstration laboratories. Smith (Oral History 1974) observed that industrial funding had the same effect as REFLEX – it moved management to the local level – and "legalized what was already done in various places" such as NWL and NOTS. McLean (Oral History 1974) was of the opinion that industrial funding increased laboratory freedom but that other capabilities were going away – the ability to transfer funds between funding categories and to start work using funds from the revolving fund (of the industrial fund). The policy for laboratory acceptance of funds is defined in Naval Material Command Instruction 7000.13. This policy requires the laboratories to propose a time-phased funding plan to their sponsor and to prepare a monthly Fiscal Management Report that addresses funds available and the laboratory performance plan for the balance of the year. McLean's observation is confirmed by the policy: "'Banking' of sponsor's funds and overcommitment of manpower must be avoided."

Project REFLEX, while it lasted, was good for the pilot laboratories because it attempted to eliminate personnel controls and operate laboratories on the basis of funding (Colvard, Oral History 1976). Lawson (Oral History 1975) felt that laboratory management benefited from REFLEX, in part because it came at a time when manpower ceilings were tight but funding was available. He also thought that it caused laboratory management to pay more attention to the linkage between manpower and funding when they accepted work. The Comptroller General (21 June 1974) prepared a report to the Congress on Project REFLEX. It concluded that management was better able to match manpower to overall laboratory goals, address long-term implications, and plan more effectively. The report quoted Navy laboratory officials as saying

> "… before Project REFLEX, there was no real planning of manpower requirements because of the frustrations and time involved in obtaining staff increases."

Even though they observed that civilian and military personnel only increased by 13 percent while funding increased by 54 percent, there was no basis for evaluating productivity. They recommended that the project be continued in order to develop and apply appropriate criteria to evaluate productivity.

The DNL evaluation of Project REFLEX (summarized in a letter from Joseph Marchese to Howard Law) recommended that the program be extended to all Naval Material Laboratories and that they be managed by fiscal controls only. They based this on their conclusions that the laboratories were better able to balance funding and manpower, they were more sensitive to cost, their planning processes were more realistic, and their sense of responsibility and accomplishment were heightened.

How were laboratory strategic management actions viewed from the outside? Dr. William P. Raney, Special Assistant to ASN (R&D), observed that the systems commands were "unhappy and noisy" and threatened not to fund the laboratories (Oral History 1980). Raney noted that situation lasted for 3-4 years until the systems commands realized that they did not get better performance from contractors. Some individuals, specifically Rear Admiral Arthur Gralla (first Commander of Naval Ordnance Systems Command) opposed the reorganization and tried to "punish" the laboratories by only sending funding to the engineering stations at Indian Head and Louisville that remained part of the Naval Ordnance Systems Command (NAVORD) (instead of NOL White Oak and NWL) (Hartmann, Oral History 1974; Smith, Oral History 1974). John Rexroth, who had long service in BuOrd, BuWeps, and NAVAIR, noted that the Naval Air Systems Command (NAVAIR) increasingly turned to industry for concepts rather than to the laboratories (Oral History 1980).

Even though his attempt to withhold funding was not successful (the required capability did not exist at the NAVORD stations), Gralla persisted in this belief. He felt that laboratories should be part of a system command and receive budget and task assignments exclusively from it (Oral History 1980). He also held the view that laboratory technical directors should be subordinate to commanding officers. John Rexroth expressed this same view (Oral History 1980). He felt that it was difficult to get the laboratories to be responsive and that since the laboratories could do research of their own devising; there was a risk that it would not be coupled to naval systems (Oral History 1980).

Likewise, the “lump funding” of exploratory development to the laboratories by the CNM (D), especially when coupled with the power to aggregate (and control) the exploratory development funding allocated to the systems commands, was not viewed favorably by the systems commands (Rexroth, Oral History 1980; Smith, Oral History 1974). The Naval Material Command (NAVMAT) policy on the governance of exploratory development funding is given in NAVMAT Instruction 3910.13A. Even though the policy gave the systems commands the responsibility for establishing Task Area Objectives to guide laboratory proposals and the system commands and laboratories were required to meet annually to develop and consider the overall research and development plan, the laboratories were given some flexibility. The laboratories were free to propose any project and they were given a limited ability to reprogram funds in order to best fulfill objectives. They were not allowed to move funds between program elements or to reduce funding to a subproject by more than 20 percent without approval.

Project REFLEX was not extended beyond its demonstration period. Colvard (Oral History 1976) was of the opinion that the Office of the Secretary of Defense (OSD) when faced with the choice of either applying it across the board (including to shipyards and depots) or not at all, chose the latter. McLean felt that REFLEX was not extended because “everyone [i.e., those who would have control otherwise – DDR&E, CNO, CNM, and Bureau of Personnel] felt that it gave the laboratories too much freedom” (Oral History 1974).

Taken together, these documents, reports, and near-contemporaneous observations support the conclusion that the laboratories were free to perform the actions that comprise strategic management (and were perceived that way by others external to the laboratory system). It is also apparent that, for the most part, the formal system was unable to provide the strategic management function for the laboratory system. Finally, the individual laboratories displayed the attributes of agents in a complex adaptive system (appropriate interactions, a shared representation of the external environment, and a common set of rules that governed their actions concerning strategic management). It is also clear that the substructure in the laboratory system implied by the categorization of the laboratories using the Perrow and Mintzberg frameworks is important. The former BuOrd, BuAer, and BuShips laboratories had distinct management cultures that persisted through the reorganization and they are in different populations, as defined by Axelrod and Cohen's requirements – they employ different strategies.

The success of this approach can also be demonstrated by laboratory performance in the subsequent years. The Naval Ship Research and Development Center continued development of technology for advanced ship classes, in ship signature measurement and silencing, and materials (Carlisle 1998). The Naval Weapons Laboratory, as it evolved into the Naval Surface Warfare Center, increased its involvement in major systems development and acquisition with the submarine launched ballistic missile (SLBM), the AEGIS system, and the STANDARD Missile (Baile 1991; Gates 1995; Hughey 1995). The Naval Weapons Center at China Lake continued to increase its involvement with Sidewinder upgrades and other air-to-air and air-to-ground missiles (Westrum 1999). Other laboratories were not as fortunate.

There is another characteristic of complex adaptive systems (described in Chapter 3) that has not been specifically discussed – extinction of agents. While it will not be considered here, it is worth noting that "extinction" is an allowable strategic management action ("altering reporting or task structure"). Some of that was done as part of the reorganization process and subsequent laboratory consolidation (see footnote 17). Of more interest is what happened to the Naval Ordnance Laboratory in White Oak. NOL (White Oak) had long been considered an important site for ordnance-related science and technology and, arguably, was the pre-eminent laboratory in the Bureau of Ordnance. On several occasions, its Technical Director (Dr. Gregory Hartmann) proposed that NWL and the Mine Development Laboratory in Panama City, Florida be combined with NOL to form the Navy's East Coast research and development center (Smith 1999; Smaldone 1977). The laboratory consolidation process and the mission battles of the late-1960s left NOL without the required linkage to a specific Navy warfare area and "czar" in the Office of the CNO. By 1974, the decision was made to combine NOL with NWL – under NWL leadership. This can be viewed as an example of a strategic management action "made" by the laboratory system:

> However, as the external environment changed and this system of development was deemed too expensive by some, the breech between the CNM, the DNL, and the military sponsor and the WOL's [White Oak Laboratory] management became wider. The political winds had blown in a sea change which the WOL leaders fought, attempting to maintain the same responsibilities and conduct business the same way … because we had been so successful using this methodology. Consequently, by the late 1960s WOL found itself in the position of a decreased mission area, out of "sync" with the weapons/warfare theology for the R&D centers, and with erosion of support among the naval officers in the Naval Ordnance Systems Command and the Naval Material Command. (Anspacher et al, 2000)

Now that the utility of the agent-based model has been shown in each era, the next step is to compare the formal systems and models from the two time periods in order to examine the proposition that the emergent system persisted.

CHAPTER 8

PERSISTENCE AND TRANSFORMATION

The performance of the formal and emergent systems in the strategic management of the Navy laboratory system in the periods before and after the 1966 reorganization has been discussed. The next step is to make similar comparisons across the reorganization. The first comparison will determine the extent to which the patterns observed before 1966 persisted after the reorganization. Persistence supports the case for the role of the emergent systems. Stacy *et al* (2000) argue that transformation is another characteristic of complex systems behavior by an organization. The second comparison, therefore, is whether and how the laboratory system was transformed by the bifurcating event that was the 1966 reorganization[21].

Persistence

The laboratory system before and after 1966 has been described in some detail previously. Comparison across the reorganization is aided by summarizing these descriptions. The key elements of the summary description are the structure of the system (e.g., subsystem structure), the number of agents, and the number and strength connections between the agents. The context for these characterizations is, of course, the strategic management of the laboratory system.

The laboratory system before 1966 is characterized by three subsystems (or populations) associated with the three material bureaus: Bureau of Ordnance (BuOrd),

[21] The concept of a bifurcating event is discussed in detail in Chapter 2.

Bureau of Ships (BuShips), and Bureau of Aeronautics (BuAer). Recall that Axelrod and Cohen (1999) define agents as being in the same population if they could employ the same strategy. The three populations in the pre-1966 system are strongly characterized by the differences in the relationship with their parent bureau (and especially in the degree of management freedom accorded the individual laboratory), the type of tasks required of the laboratory, and the nature of organizational structure (and in particular the relationship between the civilian and military leadership).

As discussed in the previous chapter, the BuOrd laboratories, in general if not equally for all laboratories, were accorded significant management freedom and the civilian leadership was given a dominant role in the planning and management of technical activity. The BuAer laboratories were mostly expected to perform test and evaluation tasks and were given less freedom of action by BuAer. They were an element of a larger system development effort and were part of a quasi-military hierarchy that supported more centralized management. Smith (Oral History 1974) argued that these fundamental differences between the BuOrd and BuAer laboratories persisted even after the two were combined to form the Bureau of Naval Weapons (BuWeps). The BuShips laboratories displayed some of the characteristics of both the BuOrd and BuAer laboratories but were different from them. The BuShips field activities ran the gamut from research and development to test and evaluation and to production (the shipyards). Management was more centralized in the bureau and certain flexibilities that were common in BuOrd laboratories (e.g., discretionary funding) were not available until late in the period.

In short, the pre-1966 system can be considered as comprising three subsystems. The connections between the laboratories within a given subsystem were moderate to strong (varying with pairs of laboratories). The connections between the BuOrd laboratories were generally stronger than was the case within the other subsystems (even if the connections were often driven by competition). The connections between the individual laboratories in BuAer and BuShips were typically stronger with the parent bureau than with each other (which is consistent with the demonstrated dominance of the formal system in those cases). The connections between the subsystems were generally weak except in specific cases (such as in the competition between BuOrd and BuAer for leadership in guided missile development). The relative weakness of the connection, even in that case, is demonstrated by the establishment of a program office for Polaris development outside of the bureau structure.

The system after 1966 was the result of two changes: the reorganization that abolished the bureaus in favor of systems commands and placed the 15 major research, development, test, and evaluation laboratories under the new Director of Navy Laboratories (DNL), and the subsequent moves to combine laboratories to form larger warfare centers. As described previously, one result was that this subset of former bureau field activities formed a Navy laboratory system as part of the formal organization. New processes extended many of the management capabilities previously available to the BuOrd laboratories to all of the DNL laboratories. The establishment of the DNL, in theory at least, also strengthened the connections between the laboratories.

The discussion in the previous chapter makes the point that the laboratories continued to display the characteristics they developed when they were part of their former bureaus. The former BuOrd laboratories, being more accustomed to management freedom at the local level, exercised a greater level of control over their strategic management. The Naval Weapons Center (previously the Naval Ordnance Test Station, China Lake, California) used the freedom to obtain tasking (and funding) from the Naval Air Systems Command (NAVAIR) to develop air-launched systems – which it had been doing using discretionary and reprogrammed funds – in addition to its traditional ordnance tasks. The Naval Weapons Laboratory (NWL) continued its evolution from a gun and ammunition test station to a more well rounded research and development laboratory by pursuing tasking from sources other than its historical BuOrd ones. This was not true of all former BuOrd laboratories. The Naval Ordnance Laboratory (NOL, White Oak, Maryland) was one that did not successfully adapt and its role was reduced; it was eventually combined with NWL.

The former BuAer and BuShips laboratories, in the short term, found it harder to change their manner of operation. This was due, in part, to their organizational structure, the nature of their tasking, and the fact that their funding sources tended to be the same as they were before the reorganization. Certain parts of the organization (namely, the research elements of the David Taylor Model Basin) adapted more readily.

The Navy laboratory system continued to be characterized by three subsystems – organized by their former bureau affiliations. Typically, the connections between the BuOrd laboratories continued to be the strongest, in part because of the similarity of their operational principles, capabilities, and strategies. The connections between the laboratories in the other subsystems remained weaker than those in the former BuOrd laboratory subsystem. The connections between the subsystems were also weak except for special cases such as connections between NWC and some elements of the former BuAer subsystem. It can be said that the emergent system persisted throughout the reorganization of 1966.

Transformation

Kronenberg (1995) noted that the organic (or natural) perspective conceptualizes organizations as having acquired a life of their own and as embedded in multiple complex environments. While this implies decentralization and freedom in decision-making, Kronenberg points out that there is also an underlying equilibrium assumption, i.e., that learning is intended to return the system to an equilibrium state. Stacey, Griffin, and Shaw (2000) say much the same thing.

Stacy *et al* propose five causal frameworks for thinking about organizational change and stability based on teleological (or final) cause: (1) Secular Natural Law Teleology, (2) Rationalist Teleology, (3) Formative Teleology, (4) Transformative Teleology, and (5) Adaptionist Teleology.

The first three, which assume movement towards a known future state, represent the current dominant discourse on the management of organizations. They all make common assumptions about causality and the management role and encompass all of the theories discussed in Chapter 2. Consistent with Kronenberg's comment on natural perspectives, they also all make an equilibrium assumption. The last two frameworks assume movement towards an unknown (but perhaps recognizable) future.

The Formative, Transformative, and Adaptionist Teleologies differ from the first two since they focus on self-organization rather than human action in organizational design and control. The Formative Teleology assumes that the purpose of self-organization is movement towards a known future. Adaptionist Teleology lines up with the view of complexity that focuses on selection and movement (through a weak form of self-organization) to a stable state of adaptation to the environment. Stacy *et al* place scientists such as Murray Gell-Mann in the Adaptionist Teleology that they describe as a form of "neo-Darwinism." Of the three, only the Transformative Teleology allows for novel organizational developments.

Put another way, complexity theory has been applied to the other frameworks, but if the emergence of novel developments is not allowed, then the only result is that the language of complexity is being applied to "rephrase" the current organizational theories.

The second basis for comparison across the 1966 reorganization is whether or how the Navy laboratory system was transformed. What would be signs of transformation? Kauffman's fitness landscape metaphor for describing changes in the system can be used to identify these signs. (Fitness landscapes are discussed in more detail in Chapter 2.) The roughness of a fitness landscape at any point in time is determined by the number and strength of the connections between the agents in each subsystem and between the subsystems. Note that a fitness landscape is a temporal construct and not a representation of something external to the system. The roughness of the landscape and the changes in it are a reflection of the strength of the internal dynamics of the system. In a simple system (i.e., one with no subsystems), for example, the higher the number of connections (K), the more rugged the landscape; and the internal system dynamics are characterized by multiple conflicting constraints on agents. The dynamics of such a system result in a constantly changing fitness landscape and agents that are continually searching for fitness peaks. Agents that get trapped on a low peak in this unstable system will be candidates for extinction when compared with more successful agents.

A simple system with a low number of connections has a relatively smooth fitness landscape that changes slowly and is, therefore, very stable. The landscape has a small number of distinct peaks and, as a result, it is easy for competitors to settle on the same survival strategy, which makes them subject to waves of destruction. A critical level of connection exists at which the system is neither too stable nor unstable and the chances of survival are the greatest.

In a more complicated system, the number of subsystems and the connections between them is critical. Systems with few subsystems (S) and connections (C) between them and a high number of connections between agents within the subsystems are stable. Conversely, a system with high S and C and low K is characterized by a rapidly and constantly changing landscape and is a system that evolves chaotically. As before, there is a critical point between these extremes – the edge of chaos – where systems evolve in a self-organizing way. Power law assumptions about extinction (few large ones and more numerous small ones) are valid at the edge of chaos (see Chapter 2).

This highlights the notion that the dynamics of any subsystem are not determined solely by its internal dynamics but also by the size of the larger system and the connections between it and the other subsystems. It also raises questions about causality and, in particular, about the effect that managers can have on the choice of strategic direction for their organization.

In summary, the signs of transformation will be found in the dynamics of the system and subsystems. A second consideration is the effects of management decisions at both the system and subsystem level and the extent to which the power law or "islands of stability" metaphors apply.

Transformation might take several forms. At the highest level it could be a change in the number of subsystems in the system or in the number or strength of the connections between them. It might be a change in the composition of a subsystem, i.e., in the number or nature of the agents that populate the subsystem or in the connections between the agents in a subsystem. Extinction and formation of agents are also examples of transformation.

The detailed description in the previous chapter makes the case that there was little transformation evident at the system level after the 1966 reorganization. For the most part, the three subsystems that characterized the system before the reorganization continued to be dominant after the reorganization. In general, the differences between the nature of the work performed by the laboratories and the management approaches in each subsystem did not foster new or strengthened connections between the subsystems. Further, in the BuAer and BuShips subsystems the sponsors of laboratory tasking and funding remained the same when the bureaus became the Naval Air Systems Command (NAVAIR) and the Naval Ship Systems Command (NAVSHIP) in the reorganization.

This is not to say that there were no changes in the system. The Naval Weapons Center (NWC) at China Lake, which was part of the BuOrd subsystem, continued to increase its attention on air-launched missiles given the freedom to pursue tasking from NAVAIR. The result was a strengthened connection between one agent in the BuOrd subsystem – NWC – and those in the BuAer subsystem. Some of the process changes that accompanied the establishment of the DNL were intended to have the effect of strengthening the connections between the subsystems. It is more accurate to say that those changes were intended to break down the subsystems by developing or strengthening the connections between the individual laboratories that made up the new Navy laboratory system. The limited success of those efforts was also described in the previous chapter.

More evidence was shown of transformation at the subsystem and agent levels than at the system level. As noted previously, the connection between NWC and the BuAer subsystem strengthened after the reorganization. In fact, there appears to be support for the argument that at a later time (beyond the scope of this research) NWC became part of the BuAer subsystem. There were also organizational changes that affected individual laboratories. Several of the 15 laboratories that formed the Navy laboratory system in 1966 were disestablished or merged with other laboratories relatively quickly after the reorganization. In some cases, such as the Naval Applied Science Laboratory (NASL) and the Naval Radiological Defense Laboratory (NRDL), this was attributed to the reduced need for their capabilities.

The merger of laboratories to form critical masses of expertise in a few warfare centers account for other changes. Moving the residual capability of NASL and NRDL to the David Taylor Model Basin (DTMB) and NOL (White Oak), respectively, obviously changed the subsystem dynamics and the ability of DTMB and NOL to respond to changes in their environment. It is arguable, however, whether the creation of a critical mass was always successful. One specific example is the merger of the Naval Mine Defense Laboratory with the David Taylor Model Basin and the Navy Marine

Engineering Laboratory. Within a very few years, NMDL was separated from the other two and reestablished as an independent laboratory.

The subsystem and agent changes just described resulted, to a significant degree, from identifiable actions taken in one of the two phases of the reorganization. Were there changes that were the result of either subsystem or agent actions? The NWC actions that were a continuation of an earlier (i.e., pre-1966) strategic decision to focus on the development of air-launched weapons serve as an example. Similarly, the Naval Weapons Laboratory (NWL) took steps to change its mission and capabilities before the reorganization. In many ways, the changes in processes (e.g., industrial funding and Project REFLEX) and reduced dependence on a single bureau for funding allowed this effort to come to fruition after the reorganization when NWL became the Naval Surface Warfare Center in the mid-1970s.

The same can be said of the David Taylor Naval Ship Research and Development Center (DTNSRDC). Even though the primary source of funding was still the same (NAVSHIP), separation (in a management sense) from the shipyards and the addition of new technical expertise (from, for example, NASL) enabled a growth (in work years and diversity) in the research efforts at DTNSRDC. At the time of the reorganization, DTMB performed some 80 work years of discretionary research as part of the Independent Research/Independent Exploratory Development program (Carlisle 1998). In the early 1970s this grew significantly and expanded into areas such as vertical takeoff and landing aircraft, helicopter rotors, ship signature reduction, and new classes of ships (such as hydrofoils, surface effects ships, and air cushion landing craft). In some important ways this laboratory changed its basic nature after the 1966 reorganization – from a focus on test and evaluation to emphasizing research and development.

There are examples of “extinction” that were not the direct result of actions related to the reorganization. The argument was made in the previous chapter that the Naval Ordnance Laboratory (NOL) in White Oak is such a case. Anspacher *et al* (2000) argue that NOL did not adjust to the changes in its environment in the late 1960s and early 1970s. In particular, the leadership did not deal effectively with the changes in the NOL status compared to other laboratories (Smaldone 1977) or in laboratory missions, in general. By 1975, NOL was merged with NWL to form NSWC (with leadership in Dahlgren) and the White Oak Laboratory eventually closed in the Base Realignment and Closure (BRAC) actions of the 1990s.

Another such example is NWC in China Lake. Rear Admiral Rowland Freeman, NWC commander, made major changes to the Principles of Operation in 1974 and did away with them altogether in 1976. Freeman came from the Bureau of Aeronautics and believed in a line organization with the military in charge of the civilians. He also believed, in accordance with the BuAer approach of having their contractors do weapons development, that NWC should get out of research and development and into systems management. The China Lake Museum Foundation videotape (1993) “Secret City: A History of the Navy at China Lake” describes how the changes in process (notably civilian housing on the base) and the changing relationship with its primary sponsor (NAVAIR) has caused the laboratory to decline as a force in Navy research and development. Westrum (1999) makes much the same point when he quotes a 1988 interview with Leroy Riggs (former acting technical director):

> I remember when I went to Mike Lab. It was only eight months old and it was a *laboratory*. I mean you could walk down every one of those wings, and you would have high-pressure gas, air, vacuum, several kinds of power, and battleship linoleum floor. … You go up there now, and *mail clerks* have carpets. And you walk down any of those wings, and every wing, except for Chem wing and the Physics wing, … every single one of them has had all the laboratory equipment taken out. There is no fancy power, no gas, no vacuum. They are offices, carpeted offices, with people shuffling papers.

Westrum concludes his history of Sidewinder by observing that it is an open question as to whether China Lake will survive.

The preceding discussion shows that there was transformation in the Navy laboratory system that resulted from the actions and interactions of the agents in the system. It also makes the point that major extinctions were very rare. Indeed, the cases that resulted from actions of the individual agents (specifically, NOL) began during the time of interest but did not reach a conclusion until much later. The cases where agents transformed themselves over a period of time are more common. It was also argued that the dominance of the formal system in the strategic management of the laboratory system continued in the BuAer and BuShips subsystems. The agents in the BuOrd subsystem, on the other hand, were already accustomed to a relatively high level of freedom relative to their individual strategic management and, in general, adapted to the new processes and environment.

Stacy *et* al (2000) assert in their description of Transformative Teleology that creative change comes from individual interactions rather than management decision or control. This research has used the laboratory as the unit of analysis not the individuals that comprise it and, in so doing, has asserted that the actions and interaction of the agents (laboratories) were the creative force in the strategic management of the Navy laboratory system. However, "management" decisions were made as part of the reorganization (and subsequent events). What effect, if any, did they have on the transformation of the Navy laboratory system?

This discussion and the preceding chapters describe how the reorganization in 1966 led to changes in processes and the establishment of the Director of Navy Laboratories. The previous chapters have a lengthy discussion of how the DNL generally failed in its efforts to manage and control the laboratory system. On the other hand, there was also discussion of how the reorganization (and the subsequent steps to form a few large warfare centers by consolidating laboratories) provided opportunities for subsystems and, especially, individual agents (or laboratories) to transform themselves. The separation (in a management sense) of DTMB from the shipyards and the closure of NASL and the transfer of personnel to DTMB allowed the new DTNSRDC to increase its focus on research.

The extension of processes such as industrial funding to more laboratories and the personnel management demonstration (through Project REFLEX) in certain laboratories provided additional “tools” for laboratories inclined towards local strategic management. The consolidation of laboratories to form warfare centers capable of managing large programs did not have that effect in the short term since the systems commands and Naval Material Command program managers were not willing to concede that level of control. On the other hand, some laboratories did take significant technical leadership roles in major programs a few years later. NSWC leadership in the development of the AEGIS air defense system beginning later in the 1970s is one such example. Naval Weapons Laboratory (which merged with the Naval Ordnance Laboratory to form NSWC) planning documents suggest that this development was the result of both the actions of the individual agent/laboratory and management decisions by the Naval Material Command. (Naval Weapons Laboratory 1968)

This research has also identified some negative examples. The case can be made that the decline of NOL resulted both from its failure to adapt to a changing situation and to NAVMAT-level management decisions in the late 1960s. For example, when it became important that a laboratory's mission be aligned with a specific Navy warfare area, NOL's mission was left more generic and did not specifically align with any warfare area. The example of the decline of NWC has more to do with local management decisions, although a close organizational alignment with NAVAIR was a contributory factor.

Stacey *et al* observe that one implication of Transformative Teleology is a recognition that there are limitations on the ability of managers to design, plan and control for maximal or optimal outcomes. While they focus on the actions and interaction of individuals within organizations, this research has used the laboratory as the unit of analysis for assessing the strategic management of the Navy laboratory system. The previous discussion leads to the conclusion that NAVMAT- or DNL-level management decisions that were intended to exercise control over the agents in the laboratory system generally proved to be unsuccessful. Organizational and process changes that modified the environment of the laboratories in the system were much more likely to have an effect on the strategic management of the laboratory system that resulted from the actions and interactions of the individual agents. Whether the transformative effect was positive or negative depended to a significant degree on the choices made by the individual laboratories. In either case, evidence of transformation exists, especially at the individual laboratory level. The transformative actions of some of the individual laboratories preceded the reorganization of 1966 but were strengthened by the resulting organizational or process changes. In other cases, the transformation was a more direct result of the reorganization.

In summary, the patterns of strategic management of the Navy laboratory system that were evident before 1966 persisted after the reorganization. It is also apparent that transformation resulted from the bifurcating event that was the reorganization.

CHAPTER 9

CONCLUSIONS

The first formal Navy laboratory system was established by the 1966 reorganization that established the Navy Material Command and the Director of Navy Laboratories. That was the latest in a series of reorganizations intended to centralize control of the budgeting, planning, and execution of research and development in the Navy. The changes in organization and process that were described previously mirrored and supported similar changes in the Department of Defense. It was proposed that these changes were intended to improve the strategic management of the Navy laboratory system. It is clear from history that the 1966 reorganization and, in particular, the DNL were not successful regarding the strategic management of the Navy laboratory system. The application of complexity theory also supplements the classical organization theory based explanation of this failure.

This research shows that complexity theory adds additional layers of explanation to an understanding of the strategic management of the Navy laboratory system, as it existed both before and after the 1966 reorganization. Specifically, it shows, using the elements of complex adaptive systems and agent-based models, that a Navy laboratory system existed before it was formally established in 1966 and, further, that it persisted in much the same form after the reorganization. It does this by describing agent-based models of the Navy laboratory system before and after 1966 and uses them to analyze the performance of the formal and emergent systems in the strategic management of the

Navy laboratory system. Complexity theory also leads to an expectation that a bifurcation event – such as the 1966 reorganization – will lead to transformation of the system. This research supports that theory by showing how the Navy laboratory system transformed as it persisted. The role that management action played in this transformation is also addressed. In short, while laboratory system management had an effect, much of the transformation resulted from the actions of the individual agents (i.e., laboratories).

The research highlights the subsystems in the Navy laboratory system and the different roles that the formal and emergent systems played in each. One subsystem in particular – the former Bureau of Ordnance laboratories – demonstrated more of the self-organizing behavior and transformation anticipated by complex adaptive system theory. The differences in the three subsystems and the relatively weak connections between them (coupled with the moderate number of connections within the subsystems) resulted in a relatively stable system overall. In the end, the conclusion is that, as expected, both the formal and emergent systems played a role and, in accordance with power law theory, the “islands of stability” (where the formal system was dominant) were prevalent.

The issue of strategic management of the navy laboratories is once again a concern and many of the issues being raised are similar to those studied periodically for the last 40 years. The alternative solutions being proposed are also similar to those recommended and adopted in the past – a reorganization of the system. One alternative proposes a return to something that resembles the bureau structure that was abolished in 1966. This proposal appears to retain what was previously perceived to be the weakest part of the structure (a strong link to a single systems command). An alternative proposal would restore what some feel was the strongest part of the organizational structure that existed after 1966 – independence from the systems commands through a link to the “producer’ side of the Navy – the secretariat. While these organizational solutions are clearly different, they both result from emphasizing the roles of the formal structure and processes in strategic management. The historical study of the Navy laboratory system, that provides the foundation for this research, can also contribute to the current discussion of laboratory reorganization.

This research argues that what is needed instead is a new view of strategic management and, in particular, of the form it has taken in the Navy laboratory system and how it is related to organizational structure. The research contributes to that by developing a description and an understanding of the strategic management of the Navy laboratory system and, specifically, of the role of the Director of Navy Laboratories in strategic management at one point in time.   Complexity theory, which has its origins in the physical sciences, provides an alternative basis for understanding. It holds promise both to help to understand the history of organizational change of Navy research and development laboratories and for evaluating the current organizational alternatives. McKelvey (1999) and Stacey (1996) note that if complexity theory is to be more than a fad or a metaphor, then the research agenda in organizational theory must change to include it. Consequently, a secondary outcome of this research is a contribution to the conceptual literatures, namely the application of complexity theory to organizational analysis.

Directions for Further Research

The Director of Navy Laboratories (DNL) was the organizational solution implemented in 1966 to address a perceived strategic management problem with Navy laboratories. The DNL, which was disestablished in 1991, provides an opportunity to apply complexity theory in order to understand the evolution of an organization over its entire life span – from birth to death. This research used the founding years to develop an approach that can be used for additional research in the development of the Navy laboratory system and to analyze possible changes to it. One possible extension of this research is to analyze of the evolution of the DNL during the 1980s and its eventual disestablishment. Another extension of this work is to link complexity theory and organizational learning. This has been proposed in the literature and the Navy laboratory system may provide a suitable case study. This research, as well as that proposed above, uses the individual laboratory as the unit of analysis.

Stacey, Griffin, and Shaw (2000) suggest that a more suitable unit of analysis of Transformative Teleology is the individual and relationships between individuals. In the end, Transformative Teleology posits that novel change in organizations results from the interaction of individuals and, consequently, challenges the assumption that managers, in groups or individually, can choose the future direction of the organization. This opens up additional avenues for analysis of this case study or the transformation of Navy laboratories in general. In particular, studying the development of the individual laboratories in the context of the overall Navy laboratory system may provide insight into the assumptions in Transformative Teleology as applied to a public organization.

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