Large Complex Project Success:

Have we institutionalized the wrong lessons?[1]

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"Not everything that matters can be measured, and not everything that can be measured matters." Albert Einstein

This paper builds on my beliefs that the prevailing theory of project management has failed us with respect to large complex projects. I have written extensively on this including highlighting that the assumptions of Gantt and Fayol fall short at scale and complexity. In this paper I examine the successes that underpin modern project management theory and seek to understand how the resulting approach to project management has failed to deliver comparable successes with regularity. As I explored these questions, I sought to understand the unique characteristics of the Atlas and Polaris missile programs; the subsequent institutionalization of the perceived success factors; and importantly, did perception and reality align. In other words, have we made an incomplete set of assumptions and institutionalized them?

As I move through this paper I will look separately at Atlas and Polaris through a management lens. The technical richness of the history of the development of these two missiles provided context as I extensively researched these programs, but that engineering accomplishment is not the focus of this paper.

Having outlined each of these programs from a management perspective I will turn to the institutionalization of elements of these programs within the Department of Defense (DOD) largely at the impetus of then Secretary of Defense Robert McNamara. Finally, I will offer some comments on the further institutionalism of modern project management by the Project Management Institute, flowing in large part from the growing adoption of the institutionalized DOD practices or variants of them.

My review will be critical at times, but it is not intended as criticism but rather an attempt to maybe uncover some of the real drivers of Atlas and Polaris success. And perhaps more completely learn the lessons of these outstanding project management achievements.

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Atlas

Convair developed an innovative concept for an ICBM in the early 1950's that utilized a pressurized tank as an integral part of the rocket structure. Left unpressurized the rocket would collapse under its own weight. Later in 1953, the Teapot Committee led by Dr. John van Neuman of Princeton Institute for Advanced Study recommended:

- **Special (dedicated) Air Force managing group** (WDD was the result of this recommendation)
- **Special technical assistant group to serve as system integrator** (a new term) to help AF make tough technical decisions and trade-offs. The system integrator concept originated in a prior (1952) committee (Millikan Committee) which looked at Convair's response to AF RFP (January 1951 study). This recommendation, in part, also arose from concerns about whether Convair could handle the whole job

We see in the Teapot Committee a recognition of importance of a dedicated, empowered owner organization supported in a way that addresses and compensates for owner weaknesses.

The Western Development Division (WDD) was established by the Air Force in 1954 to lead development and installation. WDD organizational and management innovations included:

- Focus on minimizing development time
- Streamlining process for approving large financial commitments (They recognized importance of cash flow to contractors, something many of today's owners have lost sight of.)

Their efforts were successful with Atlas being operational in October 1959, within two months of the target date set by the Air Force and Convair in 1954. The first full Atlas squadron went operational in 1960.

The Atlas development and deployment project required:

- Designing a missile, solving a myriad of engineering problems, including those associated with Atlas's unique structural design (incorporating fuel tanks as part of the structure) which would collapse under its own weight if not pressurized.
    - Speed of turning concepts into a deployed capability
    - More expensive and more significant engineering feat than even the Manhattan Project

- Concurrently, creating the necessary infrastructure to fabricate, test, support and launch the missile
    - **"Concurrency"** was the adopted management approach (This was later baked into Polaris following the joint Air Force/Navy effort to develop Jupiter (also liquid fueled) for submarines.)
- Deploying it as a Soviet deterrent
    - Within five years the first four SAC Atlas missile squadrons were operational.

Convair had to address three key management challenges:

- Securing the necessary funding. This required working the halls of Washington, especially the key committees.
- Standing up a dedicated project organization with all the necessary organizational infrastructure
- Technically proving and finalizing their innovative design

WDD's management plan for the Atlas program included:

- WDD leading with strong management processes and focus on interface management.
- Air Force holding contracts with several major Associate Contractors and Ramo-Wooldridge (RW) (later TRW) serving as system integrator as envisioned by Teapot Committee (technical decisions and tradeoffs). RW was excluded from bidding on hardware work associated with Atlas.
- Use of systems integrator removed necessity of Air Force adding necessary technical resources on their staff. Early elements of a PMO function can be seen in the system integrator role. The role was passive not active (problem solving or directive).
- Convair as airframe and integrating contractor (install and integrate all hardware). Other Associate Contractors included rocket engines, guidance, ground-based computer support and nose cone other than the weapon itself (supplied by government).
- WDD coordinated other government elements such as the US Army Corps of Engineers (USACE) which had a lead role in Atlas base development.
- Concept of Joint Occupancy Date (JOD) (USACE and Convair both on site) and Beneficial Occupancy Date (BOD) when USACE was done.

For its part, the Convair management structure and key characteristics included:

- Single Project Manager (PM) with authority over the project. This was driven by Air Force but was not how airplanes were built at the time and represented a significant management change. (Functional leadership to project leadership). Authority meant control of people and money. This increased staff requirements in some areas with an added cost and risked diluting expertise in other areas.
- Rapid growth in organization that the project required resulted in broad spans of control (flat organization; 15 direct reports to Project Manager and 55 next level supervisors.
- Heavy emphasis on communication; frequent meetings and clear direction.
- Focus on configuration and change control
  - Changes limited to mandatory changes. Improvement changes were not permitted because of the importance of schedule. Scope tightly controlled. (Focus on needs versus wants).
  - Senior Configuration Control Board (SCCB) reviewed all proposed changes and either accepted or rejected. Impacts on other elements of the design (cascading impacts) and schedule were assessed before SCCB review. The seniority of the group acted as a filter on the changes brought forward. The SCCR met two to three times a week to support the project pace. This approach underscored the value of timely decisive decision making.
- Early single-item activities were not subject to heavy cost control, but later stage repetitive activities were. The importance of getting the right solution first was recognized.
- Logistics, scheduling and control were essential to feed testing program and then into the production lines. This created a concomitant requirement on strong configuration control.

WDD required that technical manuals instruct how to operate and troubleshoot any situation. Repair and checking were covered. The technical manuals improved over time to reflect all configuration changes which was highly useful. This underscored the importance of configuration control (40,000 parts). Both WDD and Convair recognized that you can't foresee or control all technical problems that might arise but you need to ensure the fixes will do what they are supposed to and do not create new problems. Similarly, writing specifications familiarized staff with the equipment being incorporated into the design.

Recognizing the risks associated with the development of Atlas, the Air Force maintained optionality by funding Titan as a backup to Atlas. Ultimately Atlas replaced by the ten warhead (MIRV) Peacekeeper missile. This notion of optionality is recurring as we look at Atlas and Polaris.

The early days of Atlas did not use PERT and PERT/Cost (which were just under development as part of Polaris) with these becoming DOD requirements later. Even then Atlas escaped rigorous application in order to meet originally projected dates. This is a key point. PERT did not contribute to Atlas success.

Why did Atlas succeed?

Atlas success was driven by:

- Sound planning by experienced Air Force personnel at the outset of the program
- Strong top-level management support
- Dedication of otherwise ordinary people, with strong individual motivation.
- Recognition that the handling of failure is an important element of project success. Failures are inevitable but confidence is built in the contractor and owner (including system integrator) by how you worked and solved problems.
- Technical strength of decision makers
    - Great attention to engineering, manufacturing and operational detail
    - Required given concurrent design approach both in missile design but also with supporting facilities such as Atlas bases
- Versatility enabling new mission tasks (Mercury; missions to Mars, Jupiter, Pluto; classified missions). Later versions of Atlas are still used today.

Atlas, like Polaris, was a schedule driven program. In the scheduling of Atlas, the stair-step activation approach initially envisioned was unable to take full advantage of leapfrog staff deployment because of the number of sites being delivered at the same time. Also, during Atlas development (and similarly in Polaris) schedule accelerated because of changes in external environment (Soviet Sputnik; H-bomb and missile advances).

Atlas contracts were initially cost plus % fee (now illegal). The procurement environment changed fundamentally when McNamara became DOD Secretary.
Atlas was not all about success, it also had its failures. These included:

- Soviets first developed an ICBM; first tested it successfully; first converted it for space use
- Bureaucratic delays impacted Atlas (slowed decision making)
- Proliferation of committees and divided responsibilities further added to delays and inefficiencies
- Excessive waste and duplication even for a crash program

Atlas was structured and operated very differently than Polaris as we will see in the next section. Later on, we will lay out some of the common elements of success which may provide some insight into what really drives large complex project success.

Polaris

The origin of Polaris goes back to that point in time when the Navy stopped a joint venture with the Air Force to modify a liquid fueled Jupiter missile. It then received the go ahead to develop an entirely new solid fueled missile for use on submarines. (December 1956)[2].

Less than four years later the first test firing from a submarine was on July 20, 1960. By the end of the year two Fleet Ballistic Missile (FBM) submarines were on patrol and another dozen at various stages of outfitting or construction. Like Atlas, Polaris was schedule driven.

The program had strong congressional support for reasons we will shortly see such that congressional support provided budgets in excess of Presidential budgets.

A word is warranted on program leadership since the nuclear Navy is most often associated with Admiral Rickover. Admiral Rickover was responsible for nuclear propulsion but not missiles. Polaris from inception through development was led by Vice Admiral William Raborn, an aviator who had served in the Bureau of Ordnance. He led Polaris until 1962.

Polaris was a success. Key achievements included:

- Deployed several years ahead of the original Fleet Ballistic Missile (FBM) schedule
- No cost overruns
- Met strategic mission objectives
- Special Projects Office (SPO) recognized as one of the most effective agencies within the government

Success Factors included (Note elements of Owner Readiness):

- Clearly defined, agreed to and constantly articulated strategic outcome
    - Focus on schedule to meet threat (deployable system)
- Skill at bureaucratic politics
    - Translating an initial joint participation with Air Force into separate program with ultimate support from Air Force in exchange for supporting

[2] The FBM was supported outside regular Navy allocations during the initial joint effort with Army. Jupiter S (solid fueled version of Jupiter) gives way to a new designed from scratch Polaris.

assignment of the land-based ICBM mission (over 200 miles) to the Air Force
    - Internal Navy organizational resistance to both SPO and the realization that older technologies that many in Navy were tied to would be made obsolete. Organizations as well as people seek stability.
    - DOD use of systems analysis in 1960's recognized the nuclear triad of bombers, land-based and sea-based missiles. This reduced head-to-head competition between the Air Force and Navy. Previously though, direct competition drove sharpening of missions and assessments of strengths and weaknesses.
    - Recognizing the full range of external organizations (White House; Congressional Committees; DOD, Navy and other governmental organizational elements) and working with them to minimize problems.
    - Understood that the **power of priorities** lay more with the reputation of the organization (for accomplishment) than in the direct use of the power.

The Special Projects Office (SPO) employed four bureaucratic strategies that contributed to Polaris success:

- **Differentiation** – establishing unchallengeable claims on critical resources by creating a belief that no other program will satisfy strategic needs and objectives better. Greatest risks are development of a business-as-usual complacency or skepticism in long duration programs. (Note: Any governmental program focused on climate change will face this challenge). Conventional thinking and conventional action could not be tolerated. A consistent message was "Think big or get out." Evangelistic messaging is a key element of a differentiation strategy and involves continuous, broad communication of a simple message, why this program is important to you. Differentiation did isolate FBM from the rest of the Navy, ultimately limiting the ability of the Navy to support it when challenged from the outside.
- **Co-optation** – absorbs new elements into its leadership or policy structure either by actually sharing power or just the burdens of power. An example was how TVA allowed the American Farm Bureau Federation (AFBF) to determine agricultural policies to overcome opposition to government ownership of electric power. AFBF's soil conservation groups created a base of local support. For Polaris there was always a task and money for any Navy element that expressed any interest in helping develop the weapon system. Support from the science community was particularly important after WW II.
- **Moderation** – building long term support for program by sacrificing short-term gains. This was accomplished by supporting some immediate objective without disrupting the program. This approach assured that animosity to the program did

not accumulate. Contributions from other Naval and governmental units was always recognized especially in testimony to Congress (Shared Success).

- **Managerial innovation** – focused on achieving the desired autonomy that SPO sought in this highly complex and risky program by introducing management tools and practices that appear to provide a high level of unique project management competence. The goal was to sustain decentalization of execution and a high degree of independence by building confidence in its management abilities both within government and broader industry, and the general public more broadly. Various innovative management techniques were developed to reinforce this image of managerial competence. **Later, despite its misgivings about the managerial value of several of the innovations, the SPO needed to maintain its reputation, a core bureaucratic strategy it deployed.**

Differentiation and co-option created and sustained demand for the FBM until the nuclear triad strategy formally emerged. Moderation and managerial innovation served to protect the program from outside interference.

Polaris employed dedicated, single-purpose organizations:

- New, dedicated organization, Special Projects Office (SPO), was established to manage the program. Basic objective of proponents was to gain organizational autonomy to deploy FBM submarines in shortest possible time. Subobjectives included attracting a broad base of support yet prevent interference from those very parties providing support. Use of aerospace contractors for R&D and management support provided a private sector base of support and reduced reliance on other governmental organizations. Initially this was necessitated by personnel limitations imposed on SPO. **The establishment of the SPO was in some ways more consequential for the Navy than even the FBM program aiding in a shift from a purely functional organization by introducing a project element**, providing an alternative model for weapon system procurement. Further, SPO expanded the definition of a weapon system to include testing, training and fleet support. **The focus shifted from control of organizational inputs to a strong output and delivery focus**. Key points:
    - Organizational independence was a crucial factor in Polaris success. It must be continuously earned, and effective bureaucratic strategies employed.
    - SPO had control of nearly all technical and financial resources it required. This allowed it to manage uncertainty that all complex organizations face, reducing environmental forces that could affect the program
    - All priority programs should have sufficient authority to stand autonomous

- Associate contractors were encouraged to create comparable dedicated project organizations (We saw this with Convair on Atlas). Steering group meetings gave contractors the ability to speak to the Admiral without any filters. Many large complex programs suffer as owner side project staff act to "shield" executives from bad news.
- SPO did not use a single prime contractor instead providing system integration themselves. This evolved from the initial arrangement with the Army which when it ended the Navy found itself providing guidance to what were a series of FBM specific subcontractors that had been engaged under a prime contractor in the Jupiter program. The technical branches in SPO had developed strong ties with FBM contractors that were not easily changed.
    - This eliminated reliance on the technical judgement of just one firm
    - Sustained influence of government experts in the design of a strategic deterrent
    - Encouraged effective performance for fear of losing work to a competitor
- Temptation to centralize control in face of uncertainties was avoided in favor of delegation of authority.

Regular oversight of FBM program including SPO performance was undertaken by the head of FBM:

- Chief Scientist and Engineering Consultant reported to FBM head on program development and opportunities
- Special advisory committee of technical naval personnel to independently review important technical decisions and test results
- Weekly Management Meetings with focus on interdependencies among technologies and schedules
- Management by walking (traveling) about including major contractor facilities

Optionality was obtained in several ways:

- Separate initial contracts on developing a solid fuel propulsion design (Lockheed and Aeroject)
- Removal of guidance responsibilities from missile contractor's direct control building on a new concept developed at MIT
- Use of a number of competing organizations to generate alternative designs at the subsystem level. Technical alternatives were not just from one organization or filtered by lead Associate Contractor of each subsystem.
    - Eleven different methods of ejecting missile from submerged submarine were simultaneously studied.

- Decentralization and use of competing contractors created optional proposals in boundary areas. **Competition was viewed as a management strategy** to put a fire under competing contractors in critical areas.
  - Rocket motor competition led to innovations in motor case construction, thrust vector controls and propellant mixtures
  - Guidance gyros/inertial guidance equipment competition was crucial to meeting accelerated deployment schedules
  - Fire control computer competition resulted in an improved product at a reduced price
  - Ability to absorb higher initial costs, which many programs lack, was essential
  - Decentralization gave authority to act to those closest to the problems, but competition assured the core central staff would be aware of critical decisions
- **Performance goals were also a controllable variable** (fallback strategies)
  - Progressive improvement was recognized; relieved need to be perfect
  - Avoided premature commitment to any performance goal
- An approach guided by **disciplined flexibility** was followed
- Optionality increased the probability of obtaining the best system in a given time

Authority and budget were matched as SPO prepared a total FBM budget including for elements of work that would be performed in other Navy bureaus.

- Navy Management Fund (NMF) allowed SPO to control Polaris funds, a demonstration of its power, despite the fact they were allocated under various appropriation categories. The ability to use the fund was terminated at the end of FY 68, SPO's first loss of a bureaucratic fight and a sign of its waning power as fear of a Soviet missile attack diminished.

Emphasis on technical challenge:

- First Technical Director of Special Projects Office, then Captain Levering Smith, a naval officer with experience in missile research, later becomes head of entire program after Raborn and Galantin in 1965. Technical strength of Navy management team contrasts with Air Force reliance on RW as systems integrator. Technical Director formulated technical goals and the main direction of the various development efforts. This directive ability was fully retained by the Technical Director.
- Creation of a Chief Engineer position on the Technical Director staff to monitor system interfaces.
  - Tight physical constraints demanded strong configuration control

- System performance requirements were established by the Technical Director in conjunction with relevant technical experts. This assured realism and buy-in.
- Associate Contractors made decisions affecting technical details of subsystems. Those closest to the problem (workface) were in the best position to overcome the challenges.
- Designed with technology required at time of deployment versus currently available technology. Technology was not an objective of the program but rather a path to deployment.
- Backup projects were performed in areas of major uncertainty.
- System designs were frozen and controlled but subsystem improvements were ok if they didn't impact the deployment schedule.
- Interface specifications were fixed early and tightly monitored and controlled.
- Technology tasks that did not directly contribute to deployment were avoided.
- Focus on overall system reliability was supported by rigorous quality control.

Given the total system focus of Polaris it opted to use two crews that maximized time within range of targets and reduced the number of submarines required to achieve desired coverage and mission objectives. This was developed in response to Air Force criticisms. (FBM's invulnerability caused Air Force to rethink force protection plans and operating models.) The result was asset maximization.

In support of one of its four core bureaucratic strategies Polaris pioneered several managerial techniques:

- **Outcomes focus** (Navy ballistic missile capability) versus an output focus (hardware)
- Integrated management control system that **focused decision making** on program costs in relationship to program performance.
- **Full system life cycle** (hardware; support facilities to maintain an operational unit in combat readiness) focus through design of program packages. SPO became the point where maintenance, equipment design, crew morale and procedures were analyzed even after the FBM squadrons were assigned to various fleet elements.
- **Program Evaluation and Review Technique (PERT)** – schedule/time focused. Later called PERT-Time. Original concept of the Program Evaluation and Research Task (original name for PERT) was to describe the optimum relationship among time, cost and performance. Three weeks after the team started development, in early 1958, cost and performance were dropped reflecting post-Sputnik (October 4, 1957) realities. **Disciplined planning focused attention on interdependencies and resource requirements.**
- **PERT/COST** – extension to include costs (1961)

- **Reliability Management Index (RMI)** – note incorporation of life-cycle performance from initiation of program. Did not gain the traction of PERT and PERT/COST. Focused on hardware reliability to predict longevity of missile components. Initiated in 1961 it included an elaborate system to ensure components met design specifications and that discrepancies could be traced (material and component traceability).
- Concept of **project management**
- **Program management center**
- **Program Management Plans** (PMP) – hierarchal structure in which each plan is tied to another. Describe tasks, responsibilities, time-related milestones and sequence of accomplishments, end products (outputs) and their components specified,
- **Weekly program review meetings**
- **Managerial graphics**

Many of these managerial techniques became **contractual requirements imposed by DOD, despite SPO's own private misgivings. Perception was institutionalized and some of the factors that contributed to Polaris's strong foundations and success were lost in the adoption of a readily convenient perception.** SPO became synonymous with progressive management.

SPO also enthusiastically adopted the Line of Balance concept developed outside the program. LOB compared current output against planned output. Used effectively in hardware procurement. In 1963 a System for Projection and Analysis (SPAN) was added which focused on submarine deployments and availability of equipment for overhauls and aided in assessing target coverage, training and resupply.

After 1960, the Office of the Secretary of Defense took on a more dominant role in establishing program requirements. The political backing Polaris had obtained limited Secretary of Defense Robert McNamara to preventing the growth of the planned fleet from 41 to 45 submarines. **SPO's reputation for managerial effectiveness further inoculated it from Secretary McNamara as he dealt with cost and schedule overruns affecting other major weapons programs. The bureaucratic strategies paid dividends.** Later with the implementation of McNamara's Program Planning and Budgeting System and overall growth of the defense budget driven by the Vietnam War, FBM's unique burden on its sponsoring service was reduced.

SPO was more involved with the technical details than the Air Force (WDD) but not as much as Space Technology Laboratory (STL), the successor to RW.

Management Myth

PERT and the other management techniques described above had little to do with the effectiveness of the effort to develop Polaris

- Not applied at scale until after deployment of initial FBM submarines
    - In 1960 only small portion of FBM was on the system and the first test firing from a submarine occurred the middle of that year
- In early phase of program
    - They were applied but did not work
    - Applied and worked but for different purpose than officially described

Myth of effectiveness was created by SPO and had value as a **bureaucratic strategy**

- Senior DOD (Assistant Secretary) and Navy (Chief of Naval Operations) believed SPO had never missed a scheduled commitment and always caught impending errors. Neither perception was true. Management innovation contributed little to the technical effort.
- The further away from SPO the bigger the myth
- Management philosophy did not match management practice (British Admiralty assessment)
- Techniques that actually guided Polaris were ignored since they didn't conform to the advertised theories that derived from Polaris. **This was project management's real loss.**

PERT, a computer-based system, was the beneficiary of a general management malaise and a willingness to accept silver bullets. PERT was in reality a dull object in a shiny package and its perception as successful acted to limit other management development efforts.

Management success did not rest with invention of new management methods but with:

- SPO's ability to apply policies without interference
- SPO self-confidence to apply them and follow through
- Disciplined flexibility exercised by SPO

Polaris' ability to meet self-generated estimates stemmed from its advantage of overwhelming and dependable political support.

- Honest, accurate estimates by SPO and its contractors were possible because of the degree of reliable political support the program enjoyed. Recognition that estimates would be accepted drove realism in estimates.

- As program progressed it became evident that required resources would be provided.
- Each program acceleration was matched with increased resources to overcome technical obstacles created by acceleration
- Program requested and received significant contingency appropriations, ultimately turning over $700 million to other Navy projects.

Independent evaluation did not become truly independent until 1968.

The Management Center was not where real time status was found. Rather, **frequent communication** by telephone or face-to-face meetings often away from the main office fulfilled the real intent of the Management Center.

While weekly management meetings worked well, problem identification or changed status were communicated in real time. Senior management was not surprised by weekly reports. While weekly management meetings were an important communication tool, they filled an even more important role of **re-aligning and recommitting the team to the mission outcome**.

Program Management Plans (PMP) served the program well after the initial phase where objectives were still evolving (outcome of FBM deployment did not change although its schedule did). In the early phase the PMP could not keep up with the program's changing scope and direction. Clarity was required before the PMP's became effective. On-site planning and coordination meetings substituted for the lack of PMP clarity and timeliness in the early program phases. Again, communication was key.

PERT time estimates suffered from:

- Engineering optimism bias on technical capabilities
- Optimism bias on future resource availability

FBM management myths around their management innovations became models for government and industry. In the process we lost an opportunity to model the true drivers of success. DOD and Navy project management efforts in the early 1960's did not model FBM but rather adopted the Air Force view of staff coordination of activities performed by functionally specialized line organizations.

Techniques that really guided Polaris

If there is myth, there must also be reality. So, the question becomes what were the management techniques that really guided Polaris? A half-dozen broad techniques that proved effective on Polaris can be summed up as follows:

- **Effective bureaucratic strategy** encompassing differentiation, cooptation, moderation and managerial innovation (of which PERT was just one element)
- **Quality of leadership** provided by technical director
    - Recognition of the complexity of the technical effort
    - Progress through a multitude of small steps and not a dramatic leap
    - Synchronized development of multiple different technologies
- Organizational structure
    - **Centralized control by SPO** eliminated need for large number of coordinating committees
        - Provided considerable executive authority to a single self-contained entity rather than as a combined operation of multiple general-purpose departments of the Navy
    - **Decentralized and competitive within SPO**
        - Subunit initiative encouraged
        - Range of alternatives for every major decision (See Box 1 for comparison of Air Force and Navy procurement philosophy)
        - Provided self-regulating control
        - Responsibility was held at the lowest possible level and **"managed by exception"**

Box 1
Procurement philosophy

Air Force
- Selected source early in procurement process
- Worked with selected firm to produce acceptable design
- Concurrency

Navy
- Nail down acceptable design before selecting source
- Fewer surprises during development phase

- **Esprit de corps**
    - Continuous rededication to program goals kept an organization that could easily fly apart because of decentalization and competitiveness, unified and focused
    - Visible personal commitment by program leadership to delivering the program outcome modeled behavior for the team
    - Strategic outcome was made personal (protect your family)

- Personal relationships including between SPO and contractors were encouraged
- **Importance of informal structures and behaviors** cannot be overstated
- Integration of all factors affecting technical performance and operational deployment
  - First comprehensive **systems approach** (later adopted in most major weapons system programs). See Box 2 for a comparison of Atlas and Polaris systems approaches.

Box 2
Atlas and Polaris System Engineering

General systems engineering

- Deals with overall integration of the system
- Design trade-offs between subsystems
- Integration of different combinations of system values into a coherent system
- Interface definition
- Subsystem analysis
- Testing supervision (subsystems)
- Assurance that objectives are met in an economical and timely way

Systems Engineering

- Trade-offs between various system performance parameters (range versus weight)

Technical direction

- Process of reviewing contractor's work
- Exchange of information on progress and problems
- Future work planning
- Better ways to achieve objectives
- Choice among alternative designs
- Modification of contractor's technical efforts in any manner

Program	**Atlas**	**Polaris**
General Systems Engineering	STL (formerly RW)	SPO/Associate Contractors (shared)
Systems Engineering	STL/Associate Contractors (shared)	SPO
Technical Direction	STL (WDD – limited)	SPO (with input from Associate Contractors). SPO dominated because of use of multiple competing organizations at subsystem level.
Detailed Design	Associate Contractors	Associate Contractors

- Effective **strategy to overcome barriers to synchronized technology development**. These included:
  - Synergism – subsystem solutions could be detrimental to the larger system (launch efficiency vs. crew safety)

  - Uncertainty in rate of technological progress and sequence of development. Selection of subsystem options becomes critical.
  - Organizational legacy from the joint Air Force/Navy Jupiter project created independence from central control in the program's technical branches
  - Accelerated and expanding schedules
    - Initial deployment was scheduled for 1963 (pre-Sputnik)
    - Post-Sputnik schedule was moved up to 1960
    - Number of boats grew measurably from the initial fleet of six boats to forty-one

Changed Environment for Polaris

Polaris was delivered at a time of rapidly changing contexts and environments. At least four types of environmental change were experienced by Polaris through deployment in the 1960's after Robert McNamara became Secretary of Defense:

- **Structural**
  - Shift of initiative and power to Secretary of Defense, enabled by ambiguity in 1947 National Security Act. This occurred primarily after Secretary McNamara arrived on the scene.
  - Centralization of power and consolidation into two newly established support units (Defense Supply Agency; Defense Intelligence Agency)
  - Centralization limits subunit initiative and innovation and restricts competition
  - Through McNamara's tenure FBM moved progressively deeper into the Navy organization, no longer reporting to the Secretary of the Navy
    - The organizational independence it enjoyed, and which was crucial to its success was eroded
  - Disciplined hierarchy suppresses the **information needed to cope with uncertainty**.
- **Contractual**
  - DOD shift from cost plus fixed fee to incentive type contracts which were used together with fixed-price contracts in later versions of Polaris after prototypes were procured under a cost-plus fixed fee basis.
    - Incentive contracts heighten awareness of cost of change but in development projects you can never sufficiently address system integration at the time of contract. Incentive contracts will require modification to fully address interfaces, creating paperwork and contractor profits.
    - Communication becomes more formal and as a consequence slower.

        - Incentive contracts ignore bureaucratic and political conditions that may change over the project lifetime. They depend on fixed targets which ignore the realities of externalities.
    - Polaris avoided most new DOD procurement rules until the Poseidon missile was seriously considered in 1964. Even then it received dispensation from some procurement rules such that the entire development did not have to be open to competition. Only the motor contract was based on competition with other major subsystems being sole-source awards.
        - Incentive contracts used by FBM considered multiple factors such as performance, cost and schedule. Overweighting of performance ensured contractor compliance with SPO needs and the power of performance over cost was now codified in the contracts.
- **Program**
    - FBM focus shifted to Polaris sustainment and logistics, not as challenging or interesting as initial Polaris development
    - Subsequent shift to Poseidon lacked mission clarity and acceptance. Changed strategic emphasis was further clouded by introduction of new MIRV technology.
    - Team commitment suffered from lack of articulation and agreement on strategic objectives. The question of what was to be accomplished was not uniformly answerable.
- **Political**
    - Changed threat perceptions; cost and schedule overruns taking more defense resources; and success of FBM and continued perception of invulnerability
        - Uncertain of strategic need of Poseidon
        - Fearful of Poseidon's impact
            - Potential uncertainty and adversarial instability MIRV's introduce
    - The exceptional has now become routine creating political vulnerability for FBM
    - Bureaucratization was the result of policy changes, DOD reorganization and FBM maturity
        - McNamara's changes limited room for political maneuvering forcing changes in SPO operations

PERT

PERT was first developed and deployed in the Polaris program as part of one of their four bureaucratic strategies, management innovation. Subsequently, PERT was first made public in 1958. PERT became the symbol, perhaps undeservingly, of the management innovations of the Polaris program. So, what was PERT and what were its characteristics

PERT Characteristics

- Graphic network showing interrelationship of steps to develop a specific output
- Three time estimates – most optimistic, most likely, most pessimistic
- Calculated probability distribution of "expected time" to complete an activity
- Identification of critical path (longest expected time) – calculated using a beta function
  - Beta function selected for mathematical convenience only and was not shown to describe the distribution of activity times in research and development
- PERT focused on time since it was the main constraint at the time, not cost
- Later shift to single time estimate
  - Eliminated direct input from the workface (bench engineers) which was valuable even though optimistic
  - Prevented probability modeling of results
  - Shifted focus to a schedule to be met rather than the probability of meeting it
- PERT/COST developed at later stage (1961) by including accounting information
- PERT system was costly to operate

Who were PERT users and how did it initially develop?

SPO claimed PERT took two years off schedule; part of management innovation strategy and as a result SPO became synonymous with progressive management.

Contractors were initially PERT opponents, resisting even when it was mandated. Original system data was not used by them in managing their efforts. Yet the myth persisted. The Air Force thought PERT to be almost worthless but was pressured to follow the Navy lead introducing "improved" versions of PERT of which Program Evaluation Procedure (PEP) was the most prominent. Within government eight PERT systems were in use by 1962 and it became a DOD contract requirement.

PERT was an important element of the management innovation strategy SPO employed. SPO became synonymous with progressive management. PERT allowed SPO to focus management on solution of technical problems instead of continuous justification of the program and its decisions. Astutely, SPO recognized that management systems could have political as well as operational benefits. Pizzaz helped continue to sell the program and the SPO approach.

SPO understood the need for large scale programs that are subject to external review to develop management strategies and techniques that provide early warning and control deviations from plan. Importantly PERT provided a requirement for disciplined planning which benefitted the project even more than PERT itself. With the arrival of Secretary McNamara PERT and managerial innovation were frozen as of 1961 (Developed 1956 – 1961) based on its perceived value rather than how it actually was used and performed. This institutionalization of the wrong insights and lessons to be learned from Atlas and Polaris in some ways still haunts project management today.

Robert Strange McNamara

Robert Strange McNamara was selected as Secretary of Defense by President Kennedy. He had been promoted to president of Ford when 1961 models went on sale but resigned eight weeks later to become Secretary of Defense. He was alternately known as a Whiz Kid; technocrat; "an IBM machine with legs" (Barry Goldwater). It is important to understand Secretary McNamara and both his management and defense legacy as we understand how the real lessons of Atlas and Polaris were missed and attention focused just on numbers and the shiny new tools such as PERT.

Management legacy

Robert McNamara's management legacy is a mix of positives and negatives. His beliefs, actions and their varied consequences follow and built on his personal mantras of maximize efficiency and get the data:

- Process more important than product
- Statistical analysis improved logistical efficiency and mission planning (Positive)
- Had sense of social responsibility (seat belts at Ford, sold safety; poverty reduction as World Bank president) (Positive)
- Value of an outsider providing analytical clarity (himself)
- Asked, what are goals; what constraints do we face; what is most efficient way to allocate resources to achieve objectives? Recognized importance of objectives (Positive)
    - Often lost sight of objective over procedures (Negative)
- Data that was hard to quantify was overlooked. (Negative)
- Failure to insist on the impartiality of data (Negative and in conflict with his belief of an outsider providing analytical clarity)
- Undervaluation of people skills missed the fact that people are not purely rational actors (Negative)
    - People exhibit systematic bias in judgements
- Failure to recognize that organizational processes have their own dynamic that can lead to flawed decision making (Negative; we saw this with Vietnam)

  - Escalating commitment to a failing strategy
  - Silencing of dissenting views
- Did not recognize value of emotional intelligence (Negative)
  - Managed data not people
  - Ignored delegation, flexibility and informal communication
    - Did not recognize that authority did not flow from position but rather willingness of others to accept direction as authoritative
  - Did not develop esprit de corps, shared purpose and vision, or team spirit
- Recognized (later) the need to probe assumptions (Positive, but maybe too late)
- Over centralization of decision making (Negative)
  - Accomplishing anything under schedule pressure required taking the project out of the system. The system he developed was over-organized, over-manned and resulted in over-spending and under-accomplishment (Deputy Secretary of Defense David Packard, co-founder of Hewlett-Packard)
  - Paralysis by analysis
  - Not interested in what had to happen after a decision was made
- Not a people person (Negative)
  - Failed to recognize that logical solutions still required people to implement them
  - Formalized communication system even with top aides stifled creativity and initiative
  - Inability to delegate prevented him from institutionalizing management principles he held as ideal
  - Not sensitive to stakeholders (Congress, military)
- Willingness to probe his own shortcomings later in life (positive)

Defense Legacy

McNamara's management legacy cannot be looked at in a vacuum. It is important to understand his defense legacy as well. In that regard there are both positives and negatives and he can be credited with the following:

- Institution of system analysis in public policy (Positive)
  - Broadest possible context
  - Reduction of complex problem to component parts for better understanding (Mixed)
- Planning, Programming and Budgeting System (Positive)
  - Considered defense in context of national needs
  - Considered needs and costs together
  - Focus on top level alternatives (strategic tradeoffs)

- Analysis at top policy levels
- Future costs of current decisions considered (Positive)
- Transparent analysis and data but so complex that conclusions could not be challenged (Negative)
- Reality – focus on minutia distracted from high level policy considerations (Negative)

- Replaced doctrine of massive retaliation with one of flexible response (Positive)
    - Proportionality
    - Avoid escalation
- Improved DOD alignment using PPBS as a tool (Positive)
    - Aligned strategy, plans and programs with budget
    - Gave impetus to service unification
    - Gave Secretary detailed knowledge of departmental workings
    - Gave Secretary control over composition and missions of armed services (Negative, micro-management)
        - Decisions that previously would be viewed through a military lens were now viewed through a cost-effectiveness one
- Program definition protected against committing large sums of money until project fully defined (Positive, in most instances but would have precluded Atlas and Polaris)
- Procurement process on large weapons systems brought military and bidders closer together and narrowed differences between two bids (Mixed)
    - Incentive vs. CPFF gave government more leverage in remedying deficient performance but was not fail-safe in resolving issues between contractors; was undermined by active military involvement in development and production phases; and any intermediate acceptances might be perceived as waivers of some deficiencies
- Misapplied elements of systems thinking (Negative)
    - Emphasized specified systems (do this, this way at this time) versus system specifications (achieve what we want in terms of specifications, anyway you want)
- Vietnam debacle – failed to recognize limitations of advanced equipment and doctrines when confronted by highly motivated people using unconventional tactics. (Have we learned this lesson yet?)
    - Could not subject chaos of war to empirical control
    - Tentative because of uncertainty
- Failure to defend controversial decisions (Negative; projected arrogance)

In summary McNamara's management style:

- Prevented discussion of real issues
- Not interested in finding out truth
- Encourages institutional bullshit that drives out the frank discussion of truths to deal with complexity

So we have seen two successful projects, Atlas and Polaris, held up as modern management marvels without a contemporaneous recognition of the factors that contributed to their success and a further inability to make that critical examination less a management myth which was essential to SPO be punctured in the process. The myth fit into the personal mantras of a new Secretary of Defense and were readily institutionalized together with control mechanisms that benefited McNamara and DOD during his initial years in the role. Over the balance of his tenure as Secretary their limitations became more evident but by then they were more broadly embraced in industry with further institutionalization being driven through the formation of a professional association dedicated to project management.

Project Management Institute

Founded in 1969, the Project Management Institute (PMI) was a professional extension of the project management trend that emerged from the 1960's explosion of project management in the defense industries and its principle, primarily aerospace, contractors. This was driven by the Navy development of PERT in 1958 and requiring it in 1959 to be used by all Polaris contractors and its broader mandate in DOD and NASA in 1962.

This focus on project management built on the real achievements of the Atlas and Polaris programs but more so on the perceived reasons for their success. These perceptions were largely accelerated and institutionalized by Secretary McNamara despite concerns that existed both in the Air Force and Navy organizations responsible for these successful programs. In effect Polaris's strategy of management innovation had served it too well. In some ways the project management underpinnings of PMI did not track back to the successful project elements of Atlas and Polaris.

This is not intended as an indictment of PMI and the professionalism that they have brought to the field of project management but rather may help explain why conventional project management methods regularly fall short on large complex projects. Traditional project management methods focus heavily on hindsight but may be limiting when dealing with complex projects. The systems thinking that was core to Atlas and Polaris success was replaced by initial perceptions of one management tool that in complexity has limited utility. Projects are increasingly complex, uncertain, constrained and non-linear.

In Atlas and Polaris, we saw that:

- project management was accomplished without the benefit or constraints of a normative set of techniques such as those laid out in various bodies of knowledge
- sense making and questioning were key rather than simple reliance on measurable facts (Later, during Vietnam, key factors did not lend themselves to ready measurement were all but ignored)
- delegation and broad effective communication delivered results that close surveillance and limited discretion have failed to
- tasks were neither discrete or well bounded, a fundamental assumption in modern project management with roots back to Gantt and decomposition of work
- uncertainty both with respect to what was required for success and the tasks to deliver it were ever present contrasting with a view of low uncertainty of requirements and tasks
- top-down decomposition of the total transformation effort and even the project's requirements was not possible except in the broadest sense
- integration was perhaps even more important than analysis
- emphasis on integrating and controlling often outweighed planning

So, what were the real lessons in success we should learn from Atlas and Polaris and which lessons were unique to large complex government programs.

Common Elements of Success

The following table highlights key contributors to success of the Atlas and Polaris program with areas of importance and high commonality between the two programs highlighted and accounting for half of the elements of success.

These common elements of success can be grouped into three broad categories:

- Owner readiness
- Flow of project
- Stakeholder engagement

Specifically, the common (highlighted) elements would be grouped as follows:

- Owner readiness
    - Owner organization – dedicated, empowered
    - Strategic objective – outcomes-focused and schedule-driven
    - Management support – strongly present and recognized the importance of a reputation of performance in sustaining support

 - Process for financial commitments – streamlined with available to contingency and supportive of contractor cash flows
 - Leadership – high quality and stable
 - Esprit-de-corps – aligned, committed ordinary people doing extraordinary things
 - Technical strength of decision makers – essential in any development, engineering and construction program
 - Management processes – these had required strength and recognized the challenges that would be faced by introducing new organizational concepts and developing and deploying new management innovations
 - PMO – providing independent technical advice and oversight to program executives
 - Risk management – based on optionality at both the system and sub-system level
 - Failure (Expectation) Management – both Atlas and Polaris suffered multiple failures during missile development. This risk had been communicated and a fail forward strategy let each program demonstrate continued improvement
- Flow of project
  - Communication – recognized as key to successful management of complex flows in these programs
  - Informal structures and behaviors – essential with dealing with project pace and complexity. Formal processes would retard timely actions and decisiveness
  - Management approach – recognized the need and importance of concurrency, a characteristic in many large complex projects
  - Interface management – essential in all complex projects but even more so give the strategy of concurrency deployed
  - Configuration control - essential in all complex projects but even more so give the strategy of concurrency deployed. Also recognized that missiles would evolve, with subsequent generations of each likely once initial capabilities has been deployed
- Stakeholder engagement
  - Political/stakeholder engagement – ranging from walking the halls to program inoculation through a series of well thought out bureaucratic strategies

Common Elements of Success Atlas & Polaris		
	Atlas	**Polaris**
Owner's Organization	Dedicated, empowered (WDD)	Dedicated, empowered (FBM)
		Organizational independence
Organizational Control	Control through coordinating committees	Centralized control
Planning	Experienced owner personnel	Experienced owner personnel
External environment	Unstable; rapidly changing	Unstable; rapidly changing
Strategic Objectives	Outcomes Focused; Schedule Driven	Outcomes Focused; Schedule Driven
		Clearly defined, agreed to, constantly articulated
		Performance goals were a controllable variable
Management Support	Strong top-level management support	Recognized power of priorities rested with reputation
		Regular engagement of top-management with Associate Contractors (C-suite access)
Communication Processes	Key to success	Key to success
Process for financial commitments	Streamlined	Navy Management Fund (facilitated combination of multiple appropriation items)
Owner Project Management Organization	Program Management Oversight (RW)	Program Management (SPO)
		Decentralization of Authority (Disciplined flexibility)
		Weekly Project Management Meetings

Common Elements of Success Atlas & Polaris		
Leadership	High quality	High quality
Project staffing	Ordinary people with strong individual motivation	Esprit-de-corps
Informal structures and behaviors	Extremely important	Extremely important
Management Approach	Concurrency	Concurrency
Failure Management	Recognition that the handling of failure is an important element of project success. Fail forward.	Recognition that the handling of failure is an important element of project success. Fail forward. Emphasizing reliability through testing and quality control to achieve required reliability.
Technical Strength of Decision Makers	WDD/RW + Convair Very High	SPO + Associate Contractors Very High
Political/Stakeholder Engagement	Walked the halls of Washington	Well-developed bureaucratic strategies
		Recognized and engaged (primarily governmental)
Management Processes	Strong	Strong; Management Innovation a core strategy
	Reliant on strong communication; frequent meetings; clear direction	Reliant on strong communication; frequent meetings; output and delivery focus
System Integrator	RW (passive oversight); Convair (missile integration)	SPO (active)
Technical Direction	RW (passive)	SPO (active)
Sub-system technical decisions	Associate Contractors (closest to workface)	Associate Contractors (closest to workface)
Interface Management	Strong WDD Focus	Strong SPO focus (Weekly management meetings focused on interdependencies)
PMO	Early elements in system integrator role (RW)	FBM use of Chief Scientist and Engineering Consultant

Common Elements of Success Atlas & Polaris		
Schedule Innovation	Joint Occupancy Date (JOD)	PERT
Organizational Transformation	Functional to project leadership	Functional to project leadership
Organization Shape	Flat; broad spans of control	
Scope Control	Tight (needs vs. wants)	Emergent at early stage given system level performance tradeoffs
Configuration Control	Strong	Strong; physical limits of missile size
Project control	Clear direction	Output and delivery focus versus input control
Estimates	Weak initial estimates; heavy cost control on repetitive activities	Recognition they would be accepted drove realism
		Funded contingency
Risk Management Strategy	Optionality (Backup missile concept)	Optionality (Backup projects performed in areas of major uncertainty)
		Optionality (Competition of suppliers)
Life Cycle Focus	Limited to complete operating system	Extended into operational phase

Measures of success in government programs

- Absence of criticism
- Based on natural-systems model, the organization/program behaves as an adaptive social organism seeking to survive in an uncertain and potentially hostile environment
- Held up as a model of success (FBM in general and Polaris in particular)
  - PERT was effective politically
- Politics is a systemic requirement, independent of program imperatives
  - Success requires skills in bureaucratic politics

Recognize that conflict between programmatic success and bureaucratic success grows as programs near completion.

Summary

Atlas and Polaris demonstrate that we are capable of delivering large complex programs, programs that had much to potentially do with our survival as a nation. They demonstrate when there is a will there is a way. They underscore what engineers and scientists can accomplish when given the freedom and support required to solve significant problems and meet significant challenges.

Atlas and Polaris also highlight a need to not become trapped by over limiting views of effective project management in a world with ever emergent challenges and complexity. An environment where uncertainty can dominate. The importance of a comprehensive system view cannot be understated. Neither can the importance of challenging assumptions and perceptions.

The stories of Atlas and Polaris are captivating and the research into their histories, building on the works of others, was most rewarding.

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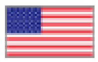

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