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Would Admiral Rickover's Method Still Work in Today's Complex Acquisition and S&T Landscape?

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Would Admiral Rickover's Method Still Work in Today's Complex Acquisition and S&T Landscape?

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Abstract

The easy access of advanced and capable microelectronics has lowered the barrier for technologists to participate in fields that were traditionally secluded for state actors, the consequences of which have inspired the public to focus its resources to compete without boundaries and at great speeds. Over the last several decades, technology innovation has moved from being defense-led research to commercial-led research, resulting in the ubiquitous presence of advanced sensing, signal processing, and amplifying technologies which have placed large stresses on defense systems. The demand for transitioning advanced technologies for the defense environment has surpassed the capacity of what the traditional acquisition and science and technology (S&T) communities can provide. This paper addresses some of the S&T challenges that ADM Rickover faced when transitioning the nuclear reactor technology, discusses the impacts of the Goldwater-Nichols Act and the current landscape, provides suggestions for contracting and reforms needed, and provides some lessons from history and applies it to present times.

Current Speed of Technology

In the past, there were huge technical and capital barriers for acquiring parts and integrating them into large systems to perform tasks that require resources from a government or a modern-day wealthy aristocrat. Hence the Department of Defense (DoD) only had to be concerned with large nation states in technological competition. However, the speed at which technology moves today, from an idea to the marketplace, has increased drastically due to advancements in additive manufacturing, advanced modeling software, microelectronics, and access to private capital. Over the last several decades, technology innovation has moved from being defense-led research to commercial-led research, resulting in the ubiquitous presence of advanced sensing, signal processing, and amplifying technologies which have placed large stresses on defense systems.

For example, today, the arrival of software defined radios (SDRs) have wrought havoc on the Electronic Warfare community. Advanced waveform generation can be done through a USB-based, small-form-factor waveform generator that can be purchased for $2,000 at Signal

Hound. An SDR that can be purchased for under $1,000 on Amazon can be configured to interact with an arbitrary waveform generator to broadcast any type of waveform for any application (communication, radar, etc.). A small USB-based SDR (Figure 1) can be purchased for a few hundred dollars. On plugging an antenna into it, one can receive the radio frequency (RF) to generate a very decent waterfall diagram or even to perform time-difference-of-arrival (TDOA) calculations, if one combines multiple SDRs. Moreover, any developer can create an application to display the calculations.

Often these SDRs are regularly updated in firmware and software as fast the market can deliver them. There is a growing community of SDR users filled with hobbyists and people from academia, industry, and government. These SDRs are getting more and more capable every year with no evidence of slowing down in the advancements of microelectronics and signal processing. Furthermore, the sharing of code on platforms like GitHub has significantly increased the speed of development in signal analysis for classification, signal modulation for communication and sensing, just to name a few. Many software developments are then tested in realistic environments through experiments by users around the world. This activity is a type of crowd-source development that might move the technology at speeds that have never been seen before. Combining an SDR with current advancements in artificial intelligence (AI) and machine learning (ML) may lead to an explosion of advanced concepts and capabilities in this domain. The current development speeds of technologies such as this are alarming.

Will our current legal structure and defense acquisition framework be ready to handle what lies ahead in the 21st century?

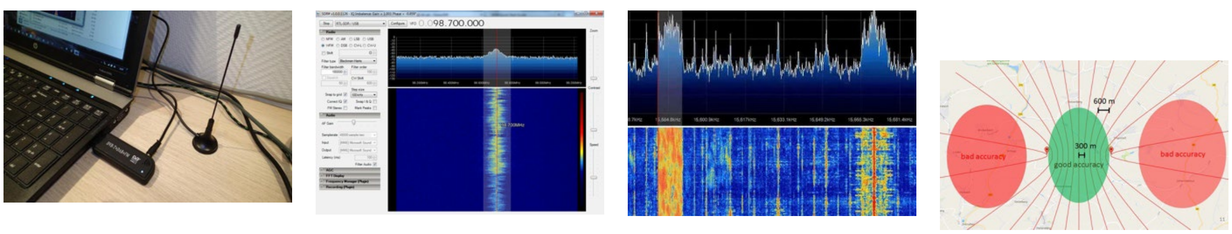

Figure 1. Current Market SDR Capability

Large Innovative Technology has Large Consequences

One day a disgruntled commanding officer of a nuclear submarine wrote a letter to ADM Rickover, stating that if nuclear propulsion was so harsh in its demands, the navy would do well to find another propulsion system. “Rickover, tossing the letter aside for a moment remarked that technology brings its own discipline, a truth he was not sure society understood. What he meant was quite simple: the stronger the forces of nature harnessed by a technology, the more discipline was needed by those who design, build, operate, and maintain the products of technology” (Duncan, 1990).

ADM Rickover realized that the more revolutionary and more powerful a technology becomes, it needs to be controlled by the highest discipline exercised by a strong technical group, which itself was the product due to this discipline. He realized as early as 1946 that nuclear technology came with an immense responsibility and that to incorporate nuclear technology in the fleet could not be done through the normal navy or industrial organization (Duncan, 1990, p. 279). If a technology was so critical that a failure would lead to catastrophe, then having the “discipline of technology” becomes paramount, and the criticality is proportional to consequences of the failed technology.

It should be of no surprise that a technology which has a massive impact would also come with the greatest critics and inertia. The level of difficulty and effort to advance a technology to a program of record increases nonlinearly. A technology not only has to overcome technical challenges, but it also must overcome political challenges. The more impactful a technology becomes, the more important the politics and storytelling are.

ADM Rickover not only acquired Congressional support despite the pushback from the Naval bureaucracy, but he also took great care in recruiting, training, and creating the conditions under which people were able to perform at their best potential. He protected his people from the red tape and viciously guarded his time. He would assume full responsibility for what he would consider political and was zealous in protecting his people from any distractions. He maintained that discipline and kept the highest standards for himself and the organization that he ran (Duncan, 1990). The higher the impact the technology had for the fleet, the more disciplined and the more persistent he had to be in order to transition the technology.

Department of Defense S&T Lexicon

Figure 2. Technology Readiness Level—Budget Activity Map

Figure 2 comes from the DoD 500 Acquisition Guidebook and shows the mapping between a Budget Activity (BA), which is a type of the Research, Development, Test & Evaluation (RDT&E) funds, and the Technology Readiness Level (TRL). A TRL assesses the readiness of the technology in question. Both terms are used when assessing a technology and are shared lexicon across the services.

A Short Survey of Atomic Physics

Figure 3 is a short survey of scientific accomplishments in atomic physics. Since it is impractical to cover the immense amount of major discovery and work done in this area, only a few discoveries are selected to provide an overall appreciation of how much basic research (6.1) and applied research (6.2) had to be done for ADM Rickover to make that first naval nuclear reactor. He rested on the shoulders of giants who made gargantuan scientific contributions. He leveraged their findings and applied his engineering prowess, grit, and resilience to design and develop the prototype of the Navy’s first nuclear-powered submarine.

Henry Cavendish’s discovery of the hydrogen atom to Enrico Fermi’s first controlled nuclear chain reaction are shown in Figure 3. The list of discoveries in Figure 3 is not meant to be an exhaustive but rather is intended to give the reader an appreciation of what level of discoveries was needed before the nuclear reactor became possible. By attempting to categorize scientific discoveries, the discussion of advancements in Atomic Physics can be made in the DoD framework. The demarcation from 6.1 to 6.2 was made on the basis that the activities in physics were starting to shift from trying to gain the fundamental knowledge of the atom to a more applied exploration of the atom. After Henry Cavendish’s discovery of the hydrogen atom in 1766, more than 130 years elapsed before J. J. Thompson’s discovery of the electron in 1897. Generations of physicists and mathematicians had to develop the mathematical tools to explain the physical world that they were observing. From 1897 onwards into the twentieth century, scientists were starting to use the knowledge that they had gained to applications by performing experiments, developing theories to explain the experiments, and then developing the mathematical tools to predict and explain the nature of the atom reliably. These efforts crossed into the 6.2 world and were filled with numerous scientific ventures as the world became fascinated with the unseen world.

Figure 3. Survey of Atomic Physics

Heinrich Hertz was discovering the photoelectric effect, and Albert Einstein explained its phenomenon using the concept of quanta of light, which later was influential in the development of quantum theory. Ernest Rutherford discovered the alpha and beta particles emitted by uranium. Niels Bohr presented the quantum model of the atom, and Arnold Sommerfeld built on that by replacing circular orbits with elliptical orbits. Robert Millikan defined the fundamental unit of an electric charge. Louie de Broglie suggested that electrons would have wave-like properties in addition to particle-like behaviors. Werner Heisenberg, Max Born, and Pascual Jordan developed the quantum matrix mechanics. Erwin Schrödinger improved the work showing that the wave and matrix formulations of quantum theory were mathematically equivalent. Max Born then showed the probabilistic nature of the wavefunctions. A collaboration between Max Born and Robert Oppenheimer introduced the Born-Oppenheimer approximation. Subsequently, a series of major discoveries of coordinated scientific work led to Eugene Wigner to develop the theory of neutron absorption by the atomic nuclei, which then led to Enrico Fermi making the first controlled nuclear chain reaction in 1942. It was this broad coordination across international lines and research interests among scientists that allowed for Robert Oppenheimer to know how to put the team together who would understand the known physics at the time to develop the fission bomb for the Manhattan Project.

The takeaway is that it took 45 years to make the first controlled nuclear reaction after J. J. Thompson's discovery of the atom, which itself was based on the previous 130 years of 6.1 research on theoretical fundamentals. During those 45 years of very productive scientific coordination and endeavors to 6.2 research, no one could have predicted having the entire world at war. Fortuitously, the products of investments in 6.1 and 6.2 were in place, so that the development of the first atomic bomb was possible. From the first controlled nuclear chain reaction in 1942, which would be considered 6.3 by the current DoD definition, to the test of the first fully functional nuclear bomb in 1945 was three years. By placing immense national resources, the working prototype of an atomic bomb crossed over to 6.4 in three years. For the reactor, it would take 15 years from 1942 to 1957 until the first working civilian nuclear reactor became fully operational at the Shipping Port Atomic Power Station. ADM Rickover understood the what impact this technology would have for the Navy.

ADM Rickover made the case to Chief of Naval Operations ADM Chester Nimitz, who understood what this technology would bring to the Navy and made a strong case to the Secretary of the Navy (SECNAV) John L Sullivan. ADM Rickover received his charter and worked with the scientists at the Oak Ridge Laboratory to develop the nuclear reactor. The USS *Nautilus* (SSN-571) completed its epic journey submerged through the North Pole in 1958 with the newly developed reactor. From Enrico's demonstration in 1942 at the 6.3 level to the fully operational submarine commissioned in 1954 at the 6.5+ level took 12 years. It was a valiant, political effort to cross the "valley of death"[1] to a fully operational submarine. And the nuclear submarine catapulted the United States to a significant technology advantage over her adversary, so far ahead that the Soviet Union would end up playing catch-up for the rest of the Cold War. Furthermore, because of this technological breakthrough in nuclear propulsion, the United States still holds this key advantage in nuclear propulsion against any near peer adversaries.

Challenges Faced by Rickover

"Nothing worthwhile can be accomplished without determination. In the early days of nuclear power, for example, getting approval to build the first nuclear submarine—the Nautilus—was almost as difficult as designing and building it. Many in the Navy opposed building a nuclear submarine." –ADM Rickover

The Cold War was in full swing, and the United States had a great advantage with the large technology gap provided by forward submarine forces that were persistent and quiet, with powerful propulsion. For strategic arms to work well, the ships had to have the ability to have long on-station times. The Manhattan Project proved that a controlled chain reaction could be achieved, and the proof of concept was demonstrated with a working prototype. However, the engineering journey needed to be done for ship propulsion, which still needed the development of reactor fuel with long life and high integrity. To accomplish that, materials that could withstand

[1] The "valley of death" in research refers to the challenging phase where promising technologies or ideas struggle to transition from initial research to commercialization due to funding gaps, regulatory hurdles, and other factors.

intense and prolonged radiation, the development of coolant to remove heat quickly from the system, and a long list of other capabilities were needed.

Although ADM Rickover knew nothing about the Manhattan Project, he was mesmerized by its achievement. At the Oak Ridge Laboratory, he followed many key scientists, some of them many decades younger than him. He would listen to their explanations of complex atomic physics and would study the equations on the blackboard. It was a humbling experience for him as he did not have this background. He was thoroughly impressed by their command of the technical knowledge, but he had issues. For example, at the outset of the nuclear propulsion program, he discovered, to his dismay, that the scientists on whom he was so keen had no awareness of the principles and standards of safety and reliability. For ADM Rickover, it was a disappointment, but the lesson to be taken here is that the scientists who are trying to solve 6.1/6.2 problems are not trained to be engineers. They are trying to understand the fundamental physics, not engineering a critical system to be used in a real-world environment. Consequently, the Daniel reactor project was never built (Duncan, 1990, p. 192).

ADM Rickover had to start over and implement an arduous program of study, interviewing, and learning. He realized that there had to be a change in mindset. He wasn't against science or scientists. But he learned that "scientific truth was not engineering truth." The worldview and approaches were different. One was about discovery, and the other was about engineering a practical working system. Since the 6.2/6.3 work had stopped, it was time to learn from the scientists and transfer that knowledge to seasoned engineers who would apply the necessary rigors to design and engineer a safe and effective reactor plant. It was time to bring in industry—Bettis Atomic Lab under Westinghouse Electric Company was selected to start designing and building the reactor. The takeaway is: in order to transition, the science should stop and the engineering must begin.

ADM Rickover also had internal Navy inertia. The Navy was concerned about competing against the other services in delivering strategic arms against the Soviet Union. They did not understand the novel technology of the reactor and were pushing back against ADM Rickover. But about the same time, the Soviet Union's ADM Gorshkov was pushing hard towards a nuclear hegemony with the submarines to create an uncomfortable technology gap with the United States. This gap never did materialize because ADM Rickover drove the nuclear reactor technology into being through his grit and vision. The Navy leadership was focused on nuclear weaponry, not in developing nuclear engines. According to Captain Edward L. Beach in 1947, the Navy was focused on countering the U.S. Air Force's claim that only the long-range bombers could deliver nuclear weapons. The Navy felt that it would lose its mission to the Air Force. This sort of fierce inter-service rivalry would be addressed decades later by the Goldwater-Nichols Act, as the inter-service rivalry had led to serious failures in military operations.

Therefore, the Navy focused all its resources into the development of nuclear weapons for aircraft carriers. Developing a nuclear submarine was very much a secondary objective. ADM Rickover was faced with the largest resistance and criticism coming from the Navy as he understood what this technology would bring to the Navy, and how the nuclear-powered Navy could alter the tide of the Cold War. The demonstration of the nuclear reactor and its ability to provide propulsion, giving the Navy a submarine fleet that could be persistent on station around the world was clear, but that was not interesting to the Navy. Though the reactor technology had crossed over to 6.4, the novel reactor technology required a champion. ADM Rickover found an advocate in ADM Chester Nimitz, which incurred the ire of the Naval leadership.

Even after his victory, ADM Rickover had to "defend" the nuclear reactor technology from the Navy, as the expenses of building ships and submarines using this propulsion technology were significant and the operating and maintenance instructions of the reactor were extremely strict. Although the completed journey of the USS *Nautilus* clearly showed the importance of nuclear propulsion, with the reactor technology at TRL 9, the future was not certain until it received the support of Congress. The compelling story was to make all surface and submarines powered by a nuclear reactor. This approach was costly, but the value was clearly there. However, there was a new competing radar technology for surface ships called AEGIS which would provide air defense against Soviet threats. This new important technology impacted the agenda of making the Navy be powered by nuclear reactors. It was too expensive to build both an AEGIS system and a reactor on surface ships. The choices were two AEGIS ships with no reactors or one AEGIS ship with a nuclear reactor. From the budgeting point of view, it was better to have two AEGIS ships (Duncan, 1990).

Having a technology achieve maturity is insufficient for a transition to a fielded system. Transition requires an unrelenting champion. Once reactor technology crossed over to 6.4, transitioning it became, as Rickover would put it, “political;” that is, the difficult problems of scheduling, budgets, stakeholder adoption, etc., needed to be overcome. Those problems were not technical in nature, but they were needed for the continued movement of the technology through the bureaucratic system. ADM Rickover had many challenges, but he did not face the legislative and regulatory burdens that many current innovators face when transitioning novel technology.

A New World Under the Goldwater-Nichols DoD Reorganization Act of 1986

The Goldwater-Nichols Department of Defense Reorganization Act of 1986 was signed into law on October 1, 1986. The chairman of the Joint-Chiefs-of-Staff General (David C. Jones) started the process to push for reforms in the DoD, but the House Armed Services Committee did not have much interest. However, through Senators Barry Goldwater and Samuel Nunn, the Senate Armed Services Committee pushed for the legislation to make major reforms within the DoD (Locher, 2002). National leaders understood that a reform was needed within the DoD as there were fierce rivalries among the services that led to technology duplications. President Ronald Reagan requested the Packard Commission in 1985 to perform a study to provide recommendations to reform the DoD, which fed into the creation of the Goldwater-Nichols Act. The legislation was to reduce inter-service rivalries and address many of the inter-service problems. The Packard Commission addressed serious acquisition problems where systems were acquired within the services that were not able to interoperate. The Goldwater-Nichols Act was a response to series of military failures and discovery of much fraud and waste. The need for the legislation became apparent after series of joint operation failures, such as: (1) the SS *Mayaguz* incident during the Fall of Saigon, where a joint rescue mission resulted in casualties from lack of coordination: (2) Operation Urgent Fury in October 1983 in Grenada, where there were significant joint cooperation issues between the Army and Navy; and (3) Desert One, a 1980 Iranian Hostage Rescue mission that ended with various aborted missions leading to fatal accidents from lack of joint cooperation.

The legislation created the following significant changes (Bond et al., 2016).

- Clear military chain of command from operational commanders (i.e., combatant commanders) through the Secretary of Defense (SECDEF) to the President.
- Service Chiefs are responsible for training and equipping forces, while explicitly clear that they were not in the operational military chain of command.
- Chairman of the Joint Chiefs of Staff (JCS) was elevated above the other service chiefs, being the military advisor to the President.
    - Creation of the Vice Chair position.

- Required military personnel entering strategic leadership roles to have experience working with their counterparts from other services.
- Creation of an organization for the services to collaborate when developing capability requirements and acquisition programs, thereby reducing redundant procurement programs. This established the position, Undersecretary of Defense for Acquisition.

The legislation created the Undersecretary of Defense for Acquisition [USD (A)] and consequently created the Program Executive Offices (PEOs) for the services. It also created the Vice Chairman of the Joint Chiefs of Staff, a position that presided over the Joint Requirements Oversight Council (JROC). The Vice Chairman also held the Vice Chair position for the Defense Acquisition Board (Locher, 2002). This law made significant changes in the military. The service chiefs were no longer involved in military operations but rather in the training and equipping of the services, and consequently, they controlled the requirements process which is defined by Joint Capabilities Integration and Development System (JCIDS). The creation of the program offices for the acquisition of the capabilities for each service fell under the service secretaries to the Undersecretary of Defense. This consequential legislation impacted three DoD processes—Planning, Programming, Budgeting and Execution (PPBE); the Defense Acquisition System (DAS), which is defined by the DoD Instruction 5000 series; and JCIDS. The law directed services to share technology and development efforts through the USD (A). The intention was to streamline what the services were doing so that duplication would be reduced while increasing procurement efficiency (Locher, 2002). This law was further amplified through the Defense Acquisition Workforce Improvement Act (DAWIA), the Weapons Systems Acquisition Reform Act (WSARA), and the National Defense Authorization Act of 1987.

The impacts were consequential. The entity that did the asking of the technology was now separate from the entity acquiring the technology. Not only did the entity asking for the technology have the ability to ask for a capability, but it could also get to direct the “how” through the JCIDS process. In a 1974 talk, ADM Rickover made some comments that it was not wise for the military staff to dictate the “how”. He cited a few examples in history where this did not end with good outcomes. His position was that the CNO and his staff were trained military experts not technical experts. They would not know how to dictate the “how” and would then have to expand the staff in order to perform this task. The CNO and his staff would be distracted to be executing on the acquisition mission where he believed that that should be the function of the SECNAV while leaving the warfighting doctrine and warfighting to the CNO (Rickover, 1974). The legislation removed that capability. The actual warfighting was to be done through the combatant commands. The legislation created the senior acquisition executive who was answerable to the service secretary, and the requirements process rested in the hands of the service chiefs. The service chiefs get to play a technical role to drive the acquisition function from the service secretaries.

Consequently, the JCIDS process supported the JROC and the Chairman of the JCS by identifying, assessing, validating, and prioritizing joint military capability requirements. It was meant to be a transparent process that allowed for the JROC to balance the demands of the military.

Thirty years later, the DoD is still struggling with trying to transition important technologies to the warfighters. The late Senator John McCain, Chairman of the Senate Arms Services Committee, said in 2015, “It was about 30 years ago that Goldwater-Nichols was enacted, and the one thing we are committed to is a thorough and complete review of Goldwater-Nichols Act” (McCain & Thornberry, 2015). The law is designed for the Cold War, which was a contest between the two superpowers under stated agreed-upon rules, but is it sufficient for the 21st century?

The JCIDS process involved the service chiefs in the technical direction of their requested technology; while the service secretaries became more involved in acquisition at much higher TRLs, restricting themselves largely to budget, schedule, and performance. The result over time has been that the technologists who once lived under the SECNAV were less needed and demands for technical people within the CNO and OPNAV increased, burdening the CNO with more tasks. The different chains of command and authorities, along with the distributed nature of requirements and acquisitions, have diluted the responsible party of making the technology to transition.

Technology does not understand organizational structure, nor does it care about the laws that command it to comply. Technology only understands physical laws and obeys only the demands of nature. By requiring those who ask and those who acquire to be separate personalities, it became necessary that the two entities must find a delicate balance, further constrained by the budgeting process of PPBE. Consequently, the action officer and the requirement officer in the POM process of the PPBE must agree with the current leadership visions and policies. And since those positions are transient in nature, the technology that has been in demand under one leadership could shift to different priorities. Therefore, the desire to take on higher risks to write requirements for novel technologies has been curtailed by the demand to comply with the current vision of the leadership.

In the 1980s, the findings of the Packard Commission showed that reforms were needed in the DoD, and the Goldwater-Nichols Act was hailed as the most significant legislation that changed the way the DoD operated. The creation of the Undersecretary of Defense for Acquisition and the corresponding Senior Acquisition Executives changed the way the DoD controls and manages procurement. And this in turn made a significant impact on the S&T community who attempts to transition innovative technology to the warfighter. ADM Rickover did not have to navigate through this new landscape.

PPBE Process

The PPBE process is the process by which the DoD acquires its funds to execute within its charter. To acquire the funds from Congress, various policy and procedural documents are associated with preparing, submitting, and defending the annual Program Objective Memorandum (POM) submission. The POM process is calendar driven and is often myopic in nature; that is, the POM addresses only the budgeting cycle. Innovations require longer cycles and a long steady plan. Much of the woes in S&T can be traced back to the long-term nature of doing research and development and the short-term nature of the budget cycles.

The Action Officers (AO) that serve the CNO in putting the POM together must understand that the POM belongs to the CNO and must align to the CNO's visions and priorities and must help deliver the POM to the Secretary of the Navy. An AO is generally not seasoned in the PPBE process and often requires going through two POM cycles to become effective or to acquire a "journeyman" understanding of being a requirements officer (RO; Blickstein et al., 2016). Because of the transience of the CNO, the priorities continue to change, and many S&T programs were cancelled on the whim of the CNO. In order to advance bleeding edge technology, there needs to be stability and continuity. ADM Rickover would often quip that he had to protect the nuclear reactor power program from the Navy (Duncan, 1990). The technical challenges of the technology do not change. However, with every new POM cycle, the technology that is being developed must bend to the demands of the changes set by each new CNO.

Figure 4 is an illustrative way to understand the value propositions of innovation and technology. The left side indicates the basic and applied research areas. On the right of the 6.4 line are the engineering and development areas. The innovation vectors on the side represent the level of novelty. The technology velocity vector represents how quickly the technology moves. On the left in the basic and applied research world, the technology moves slowly as the methods of science are applied towards exploration and understanding. The technology vector on the right is high because it is an engineering problem, resulting in a prototype using sound engineering principles. The technology moves quickly, and systems are built. The performers are different in the 6.1/6.2 space and the 6.4+ space. Typically, academia and service laboratories are involved in basic research, and industry is on the right side of the diagram.

There is a tendency to move towards areas of high-technology velocity areas. The stakeholders prefer the technologies binned in the 6.4+ areas. The products are polished, and the delivery times usually can fit into a POM cycle. The impact of the technology would be acceptable but not outstanding. The opportunities for technology to surprise or leap far ahead of the competitors as ADM Rickover did with the nuclear reactor would not be realized under the current paradigm. To realize groundbreaking technologies, a more holistic approach is required, and PPBE, JCIDS, and DAS must be strongly aligned.

JCIDS

When researchers are developing new innovative ideas, there is a heavy emphasis to transition the technology. The technology should map to a capability gap, or it could address an urgent needs statement. But what is not usually clear is how the innovation makes an impact at the warfare level while it is still on the left side of 6.3 line. The JCIDS process generates requirements. More in-depth mission engineering tools are needed that can connect the technology to the mission, which can be shared with the researchers developing the technology. According to Freeman, mission engineering involves forecasting the performance of future capabilities to inform future requirements and acquisition priorities (Freeman et al, 2024).

For future successful S&T transitions to the warfighter, the author feels that there needs to be a focus on the warfighting doctrine of tomorrow that would create the warfighter needs and that those needs need to be translated to technical problems that scientists and engineers can solve. Presently, OUSD R&E describes mission engineering in a five-part process:

1. Frame the mission problem
2. Characterize the mission (e.g., mission sets)
3. Model the mission architectures
4. Perform analysis and evaluate tradeoff
5. Document results and recommendation

Figure 4. Transition Under the DoD S&T Framework

The mission engineering tools should be advanced and developed in all warfare areas to identify the key capability gaps. In their paper, Freeman et al. also discussed an AI integrated strategy. The advantages are well articulated in the paper, and there is no doubt that a more effective way to generate warfighting requirements and technical requirements is needed.

Many technologies that have been developed sit on shelves today because of the lack of adoption by the warfighters. Much of these woes can be traced back to untraceable requirements (i.e., the warfighters did not “ask” for them). Many advanced concepts and innovations do make it to 6.3 through stakeholder interests, but the difficulty in crossing the “Valley of Death” is two-fold: the lack of funding and a lack of compelling narrative to make the jump. Often, the warfighters may not know how to ask for innovative technologies or merely do not want to ask for them (change the status quo). The success of ADM Rickover was his ability to communicate a compelling narrative on how the nuclear reactor mattered for the Navy to key stakeholders. Naval nuclear reactors came into being not because of the Navy, but despite it. When ADM Rickover got naval nuclear reactors to 6.4+, the value of the nuclear reactor was instantly apparent when the USS *Nautilus* completed its journey through the North Pole. The champion must be able to visualize this reality and to articulate this message when the innovation is still at 6.3. The transition process comes with high risks, and the champion needs to be able to assess and accept those risks, to build a phenomenal team, and to maintain the incredible “discipline” required to mature the technology.

Novel Technology Adoption Requires a Champion

The nuclear reactor was not the only technology that came with bureaucratic inertia. In its infancy, radar technology proved to be extremely critical during World War II. It was a primary contributor for the Germans losing the air campaign in the Battle of Britain. The Royal Air Force was able to detect and engage the Luftwaffe and contributed to the victory of the battle. After World War II, the world shifted to a Cold War which was a quiet war between the United States and the Soviet Union. The fierce competition between the two nations led to the development of the phased array radar concept around 1949, and there were many proponents of the concepts. For example, MIT Lincoln Laboratory started developing the phased array around 1958 (Fenn et al., 2000).

Figure 5 shows an artist's concept of the phased arrays that were being developed in the nation's laboratories, post-World War II. From the early concept to the development of the phased array was 10 years, spanning from late 6.2 to 6.3. The phased array concept was not easily adopted, and it came with fierce resistance from key radar figures at the time such as Merrill Skolnik, with as many critics as advocates. Although it may not be a debatable item today, the technology was at a crossroad of being stored away in a warehouse or being transitioned as part of an advanced radar system.

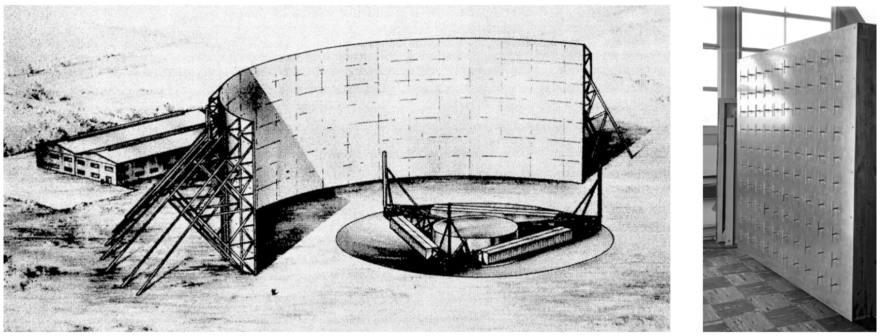

Figure 5. (Left) 1950s Era Hybrid Phased Array Radar Combining Mechanical and Electrical Steering. (Right) An Early L-band Dipole Phased-Array Test Bed Developed by the Sperry Rand Corporation, Used in the Lincoln Laboratory Array Investigation During the 1960s
(Fenn et al., 2000)

The transition of the phased array was not clear and had similar transition challenges as did ADM Rickover with the nuclear reactor. Getting the technology across the "Valley of Death" required a champion. Getting it over the 6.3 line to a full system required both the technical and political maneuvering as was the case for ADM Rickover with the Navy reactors. The Navy, at the time, required an advanced air defense shield, and RADM Frederic S. Withington delivered a report to the SECNAV on May 15, 1965, recommending five major items—(1) a phased array S-Band radar to search and track air targets, (2) six slaved X-band radars for illumination and fire control, (3) a digital control system compatible with the Naval Tactical Data System, (4) a standard missile that could be directed in flight, and (5) a dual rail-launcher. With this report, the case for the phased array radars was set in stone, and a prime was selected to develop the radar, despite the fierce resistance of the technology and the lower TRL at the time this report was made to the secretariat.

Understanding the impact that the phased array would have, RADM Wayne E. Meyer had a slogan "AEGIS at sea" in 1971 (Meyer, 2008). His mindset was "build a little, test a little, learn a lot." He was committed to pushing this high-risk 6.3 technology over the "Valley of Death" to 6.4 and beyond. Since the phased array was novel, many engineering challenges needed to be retired. For example, developing the phase shifters and the amplifiers that combined the power out of each array were highly technical, high-risk challenges. In 1975, RADM Meyer became the founding Program Manager for the AEGIS Shipbuilding Office (PMS-400), and he implemented rigorous system engineering discipline throughout the organization and was into the program details in much the same way that ADM Rickover was for the nuclear reactor program. In his later years, he attributes much of the transition of the AEGIS radar program to the people that he was able to muster to execute the program.

In his 2008 interview, a year before his passing, RADM Meyer stated that there were many engineering challenges and many critics of the AEGIS program. The costs of these systems were too high, and it was not clear that the funds would be there to execute the program. What he realized then was that if he had the right people, the development could be done in a cost-effective way. The engineering challenges and the cost challenges were so risky that he had to either abandon the program or he and his team needed to be all in, even to the point of complete and utter failure. When he created the team, he had some criteria. First, he did not want anyone other than those who would volunteer into the program. He did not want critics. He wanted believers of the phased array system. Second, he wanted people who were willing to risk their careers if they failed. People had to rise to the occasion or sink with the ship. There was no middle ground. He needed people with the right attitude.

At Moorestown, he had his sailors and officers come in through the front door of the facility. They had to come in uniform as living examples for why the engineers were building the radar components. Lockheed Martin's slogan even today says, "We never forget who we are working for." He wanted to make sure that everyone is working towards a common goal. If the AEGIS program failed, he knew the Navy was going to come after them. Failure was not an option for him.

Technology that would revolutionize the warfighter and significantly catapult the capabilities of the warfighter ahead of their adversaries requires the kind of commitment to the programs that ADMs Rickover and Meyer had for the program. However, technology does not understand bureaucracies or man-made laws. It only obeys its underpinning physical laws. The realization of the technology needs to have the same commitment and energy from the engineers that make them. Crossing the 6.4 threshold requires overcoming the technical challenges that come with such technology. Furthermore, advancement beyond 6.4 requires a champion, who needs to understand the nuances of the PPBE, JCIDS, and DAS processes and to navigate the technology through politics and bureaucracy. The more significant the technology, the more committed and risk taking the champion needs to be.

Alignment of PPBE, JCIDS, and DAS

A proposed strategy for transitioning game-changing technology is to align the business processes of PPBE, JCIDS, and DAS. Figure 6 is a Venn Diagram of these three business processes. In the intersection is the war doctrine, technical requirements, capacity requirements, S&T, acquisition, retirement prioritization, correctly resourcing the requirements, and steady and reliable execution of the budget.

When researchers try to determine what novel technologies to develop, they operate from their own worldview and try to align that with the potential sponsor. The difficulty is that if the technology is too novel, the potential sponsor has no requirement or use case for it. Even if a sponsor is deeply technical and understands a technology, the employment of the technology becomes a problem. Lost opportunities occur because researchers do not understand what capabilities the warfighter truly needs. Researchers have technically deep skills, but they typically do not have the background to understand how a technology could be used in an operational environment.

Figure 6. Aligning Business Processes

The war doctrine on how we are going to fight the future war needs to be articulated properly, which in turn needs to be translated to technical requirements that the scientists and engineers can understand. The technical requirements would then need to be checked with capacity requirement. How many do we need? This was ADM Rickover's dilemma. Should the entire surface and submarine Navy have gone with nuclear propulsion? If not, how many ships should have nuclear propulsion? The capacity requirements should be mapped back to the war doctrine. Then there should be a requirement prioritization. n the PPBE and JCIDS processes, the requirements owner should prioritize the requirements and appropriately resource them.

The S&T organizations can ingest the requirements and distribute them to their performers for providing high-risk solutions, and the acquisition entities, whose mission is to field the technology, would tamper and manage those risks when transitioning the technology, resulting in more stable and reliable systems. Doing so requires strong discipline across the entities with clear communication and well understood expectations.

Defense Contracting Strategy

Choosing the right contracting strategy has significant impact in the movement of the technology along the maturation levels. Figure 7 shows the various FAR and non-FAR based contracting strategies from the Defense Acquisition University (DAU). Normally, the Broad Agency Announcement (BAA) has been used for basic and applied research. A BAA is an announcement for potential performers, but once published, dialogue is not encouraged. Among the contracting strategies, the Commercial Solutions Opening (CSO) may be a good strategy to use for 6.3–6.4+ work. CSO is a merit-based market-driven source-selection strategy for soliciting commercial solutions that align with the government's requirements. Like other traditional commercial solicitations, it involves competitive methods. Multiple potential performers submit their proposals to address solicited requirements; however, its focus is to attract businesses and institutions that are not the traditional partners with the U.S. government. CSO was authorized by Section 879 of the FY17 National Defense Authorization Act (NDAA).

Section 803 of the FY22 NDAA codifies CSO authority in 10 U.S.C. Section 3458, where "Commercial Solutions Opening (CSO) is a non-Federal Acquisition Regulation (FAR) based solicitation authority for acquiring innovative and commercial solutions."

CSO differs from other contracting approaches such as the Other Transaction Authority (OTA), which is often regarded as the flexible approach in engaging industry partners for research, technology development, and prototype projects. OTA is a legally binding agreement, whereas CSO functions as a solicitation method aimed at acquiring available commercial products. The emphasis for an CSO is to have a solicitation that leads to a contract award as a fixed-price contract or an Other Transaction (OT) agreement. CSO can lead to an OT contract or FAR-based fixed-price contract.

CSO can be a FAR-based contract or opt out to be non-FAR-based, which allows degrees of freedom in the procurement strategies (Defense Acquisition University, 2025). Its purpose is to reduce the barrier of entry for many participants not accustomed to the defense market through simpler contract terms, a streamlined application process, fast-track evaluation timelines for solutions briefs, normally within 30 calendar days of topic closure, and generous negotiable intellectual property rights. The strength of a CSO is that the evaluation is based on merit and on how a solution best solves the problem, rather than on a competitive forum for choosing a "winner."

The CSO approach provides a great way of soliciting higher TRL technology to be matched with technology that has been developed by the government with the cost reliability of fixed-price contracts that would lead to a prototype and production. CSO could be a way to move at commercial speeds, since the process is straightforward. A problem statement is provided, and the potential performer can present a white paper, which is a minimal effort for the vendor compared to the traditional government solicitation methods. The government evaluates the proposal on merit instead of comparing with competitors' proposals. Subsequent to the evaluation, the 2nd stage is an interactive phase, where the vendor provides information on its higher TRL technology with an appropriate cost estimate and the government elaborates on the use case. The 3rd and final stage involve the government generating a statement of work and negotiating prices and terms before reaching a prototype OT agreement or a fixed-price FAR agreement. CSO requires dialogues unlike other contractual processes.

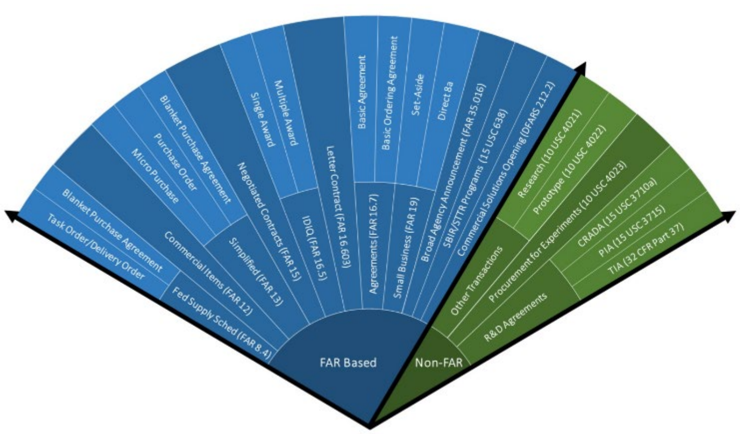

Figure 7. Defense Contracting Cone
(Defense Acquisition University, 2025)

Figure 8. A Potential Contracting Strategy for transition

In Figure 8, the traditional methods of grants and BAAs can be used for a 6.1–6.3 level of effort. They could be accomplished through grants or the service laboratories. These vehicles can be coordinated efforts between academia and government laboratories. If an innovation has reached a certain level of maturity, a service laboratory could shepherd the innovation under an appropriate venue to 6.3. At this point, there would be an industry collaboration to move the innovation forward. If an innovation cannot follow the traditional transition path, the idea is to provide a more relaxed Intellectual Property (IP) strategy. This strategy may involve using an OT or a CSO in the contracting approach, allowing the performers to own the IP and further the technology through commercial or government investments. Doing this may help build the industrialization of the U.S. commercial sector to take on tough DoD challenges.

RCA was able to take on the original AEGIS radar work in the 1970s because the core structure was present to develop the phased array. RCA’s long-term production work in the commercial sector was ready to take on the highly risky technical venture of creating AEGIS. The gap between 6.3 and 6.4 is the “Valley of Death,” and the available funds for moving the multitude of requisite technologies across it are limited. Developing a licensing strategy or IP strategy to allow private equities to be involved may help many of the technology investments to bridge this gap with efficacious results at commercial speeds.

Goldwater-Nichols Act Revisited?

The current speeds at which technology advances have placed severe stress on defense acquisition systems. By the time a solution is acquired and placed in the hands of the warfighters, the solution has often become obsolete. The machinery that runs the DoD’s acquisition is highly stressed to deliver capability on time. Some temporary workarounds and waivers exist for getting technology through the rigorous JCIDS, DAS (DoD 5000), and PPBE processes, but they are insufficient.

These processes are a result of the Goldwater-Nichols Act of 1986 and its derivative laws and regulations. The legislation fixed many joint problems that existed prior to 1986. The

Act's solution to joint problems was to create the combatant commands with operational control of the joint forces. By doing so, the service chiefs started to pick up or share roles that the service secretaries used to hold. The service chiefs hold the JCIDS process, and the service secretaries hold the DAS process; they both interact with the PPBE process.

Consequently, the size of a service chief's staff like the CNO's OPNAV has grown to execute the roles and responsibilities that it inherited (Rickover, 1974). Furthermore, with the CNO's staff being transient, there is little continuity over time. New action officers must re-learn already established lessons. What was an exciting new technology program loses its air in the sails when a new CNO shifts the sail. The PEOs under the service secretaries are limited to the type of technologies that they can acquire. When novel technologies must navigate through such uncertainties and instability, only a precious few can transition unless they are championed by the grit and commitment of the likes of ADMs Rickover and Meyer. But even for them, reproducing their results within the current DoD framework might not be possible. It is not clear whether the current framework with all the program management tools would have permitted the provisions of the nuclear reactor budget to pass; the cost analysis might have killed the program.

In light of current challenges and national leaders speaking of acquisition reforms, it may be time to stand up a commission analogous to that of the Packard Commission to look into the impact of the Goldwater-Nichols Act and to take a serious look at the current construct to see if it is optimized to deliver technology. Joint operational failures in the second half of the 20th century resulted in a commission that led to the Goldwater-Nichols Act. Perhaps the many acquisition failures could result in another commission.

A good example of a joint acquisition problem is the F-35 program. Requirements creep and management can be traced back to service-driven priorities (Air Force, Navy, Marines). The service chiefs were pushing for their own capabilities but not necessarily looking at the trade-offs. The GAO's 2021 report on the F-35 flagged poor coordination among service leaders and acquisition officials, with costs ballooning to more than $1.1 trillion. Had this been pre-Goldwater-Nichols, the service secretaries would have had more leverage to temper the service chief's ambitions.

Conclusion

Developing highly complicated technology is a difficult and complex process. There must be a relentless and rigorous pursuit of it. There is an adage that ADM Rickover would say at his public speaking engagements. People, not organizations, make things happen. The responsibility and roles must be placed on the right people.

Francis Duncan writes of the Discipline of Technology in his biography of ADM Rickover:

> Many times he tried to express this thought: "Technology knows no rank"; "Technology will not yield to leadership"; "Technology will not obey an order"; and "You can't argue with technology."
>
> The aphorisms might have little direct meaning for a manufacturer of many everyday products, or for most people doing paperwork in offices, but to men developing products at the forefront of an advanced technology they cannot be so easily set aside. The success of the naval nuclear reactor means that the organization must adapt to the technology, and not the technology to the organization. . . . The discipline of technology raises moral and ethical questions. Technological development undertaken as a profit-making venture can bring about circumstances involving ethical considerations when goals slip far beyond their schedules and when cost estimates soar far over budget. The operation of highly complex machinery without proper maintenance and timing can also

raise similar questions. The discipline of technology can make sad reading in the balance sheet and in the annual report to the stockholders. But so can newspaper headlines about accidents caused by the poor design of a component or the faulty training of the operator.

Rickover was convinced that the discipline of technology was essential to the survival of society. He thought it unfortunate that those who benefited most from technology usually accepted its benefits without question, indeed almost as a right. No force penetrated more deeply into a society than technology nor was more active in transforming it. Yet the dangers of technology and its flawed products raised serious questions. A society based on technology but alienated from it was dangerously divided. . . . But more important, the discipline of technology conferred upon an individual the greatest challenge of all—acceptance of responsibility. . . . Unless you can point your finger at the man who is responsible when something goes wrong, then you have never had anyone really responsible. (Duncan, 1990, pp. 293–294)

Laws can change. New regulations can be passed. Technology will be indifferent to laws and managerial systems. To develop complex novel technologies, responsibility must be placed on the right leaders who have the vision and the commitment to carrying through to the end. It is not enough to be a great researcher or technologist. To have transitions of major types, it requires the "discipline of technology," and some of the takeaway from ADM Rickover are:

1. The 6.1 and 6.2 investments must be made for groundbreaking technology. The reactor was realized due to more than a century of basic and applied research. Though the timelines are long, the opportunities for great technologies can be realized.
2. In order to transition, engineering with rigor must be done once the science is understood.
3. Technology requires an unrelenting champion with a compelling story.
4. Warfighters and technologists need to be engaged with minimal bureaucracy in between.
5. Clearly defined responsibilities and roles are needed.
6. Commitment.
7. Create a work force that is agile, committed, and risk-taking with minimal "distractions."

When interviewed by Paul Stillwell in 2008, RADM Meyer was in the twilight of his life and passed the following year at age 83. Of all the things that he could have discussed (cross-field amplifiers, waveguides, array construction, etc.), he chose to talk most about the people who built the AEGIS radar, because he felt that people not organizations get things done. The people were there because they wanted to be there, and they were willing to take the program to its finish even at the risk of their own careers (Meyer, 2008). The riskiest technology requires the greatest sacrifices.

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