Stitching the Patchwork Quilt:

Integrating the Diverse Literatures Relevant to Complex Product Innovation in a Government Monospony

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***Abstract*—This paper reviews the economic, political science/strategic, business and operational literatures on complex product innovation in government markets. It categorizes their insights in terms of the sources of innovation they identify – civilian leadership, bureaucratic politics, new technologies and user innovations – to illustrate the overlap among the disciplinary insights. It argues that past studies have over emphasized innovations generated by idiosyncratic events; if useful prescriptions are to be developed, the process of *normal* complex product innovation in monopsony markets must be examined. To this end, the paper suggests several priorities for future work.**

I. Introduction

Innovation is widely recognized as an important driver of economic growth and efficiency across multiple disciplines.[1] However, despite significant scholarly attention by economists, sociologists, business and military strategists, psychologists and technical historians among others, there remains limited consensus, among the disciplines, as to what innovation is and how it should be best encouraged. Part of the problem is that the dynamics of innovation appear to be strongly related to the environment in which innovation occurs[1] [2, 3] and the choice of the "unit" of innovation.[2] [4, 5] Since the choice of these parameters – context and product unit – often relates to the domain interests of the investigator, multiple seemingly contradictory explanations have emerged. For example, individual characteristics and the structure of organizational relationships have both been shown to be primary drivers of innovation [6]. Similarly, von Hippel's emphasis on lead users as a important source of innovation [7, 8] contradicts the notion that innovation is catalyzed by visionary leaders in positions to enact change from the top-down [9]. In fact "*factors found to be important for innovation in one study are found to be considerably less important, not important at all, or even inversely important in another study. This phenomenon occurs with relentless regularity*." p. 700 [10] Another study found that of 38 propositions about innovation identified by academics in the field, they disagreed on 34 of them. Of the four that they did not disagree about, none had received more than limited peer review.[11] Rather than being contradictory, it is likely that different studies are accurately observing different pieces of an extremely complex phenomenon [12]. If a consistent system-level picture is to emerge, attention must be given to the ways in which insights from the various innovation disciplines complement each other.

One area where this is particularly important is in government acquisition of complex technological products as in the defense and space sector, with fighter aircraft, tanks, submarines, and spacecraft. With an expectation for each system to be vastly superior to its predecessor, and with only a single viable customer in most cases, much of the technology development burden falls to the government. [13, 14] As a result, complex organizational systems have been put in place, with the goal of catalyzing breakthroughs relevant to complex product innovation.[15] Within the umbrella of the department of defense, there are basic science research labs, technology development centers, advanced test facilities, formal project teams, mechanisms to incorporate operational needs etc. Thus, insights regarding the differences between environments that foster entrepreneurial behavior and structured incremental change [16], or how incentive structures are best designed to encourage innovation [17] may be equally as relevant as the more traditional insights derived from "grand historical narratives, operational histories, or bureaucratic-political case studies," characteristic of military innovation studies. [18] The goal of this paper is twofold. First, it seeks to identify areas where insights from the non-defense sector literature are most relevant to increasing our understanding of the government acquisition structure. Second, it will explore the utility of the government acquisition process as a framework for integrating a wide range of innovation insights. To do this, the paper begins by surveying the literature on enabling innovation; categorizing the diverse literatures in terms of the mechanisms they identify. Analyzes the competing theories to identify gaps and overlaps in their explanations. Finally, it outlines a set of key strategies for future investigation, with proposed strategies for addressing many of them.

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[1] (Nelson 1993) examines differences across national innovation systems; while (Rothwell and Zegveld 1994) illustrate the impact of differing economic conditions over American history)

[2] (Utterback and Abernathy 1975) focus on the basic production unit in their investigation, while (Henderson and Clark 1990) derive insights on the relationship of architectural and component linkages by examining a more complex "unit" of innovation.

II. Innovation Mechanisms in Complex Organizational Structures

In one of the earliest essays explicitly on the topic of military innovation, Morison (1966),[3] a historian, recounts the tail of how one major innovation – continuous-aim firing – was introduced into the US Navy. The *innovation* involved two main alterations to the then standard cannons aboard Naval ships: 1) the gear ratio in the cannon elevator gear was modified to allow the gunman to compensate for the roll of the ship and thus keep the gun pointing at the target throughout the firing process; and 2) a telescope sight was mounted independently from the recoil of the barrel so that the gunman could use the sight while firing, without getting the eye piece jammed into his eye. While neither alteration was particularly novel, their implementation fundamentally changed "gunfire at sea" from an imperfect art to a repeatable science; kill rates improved by 3000% over six years. Yet, despite demonstrated improvements, widespread adoption was not even initiated until five years of effort by one maverick Navy lieutenant culminated in the solicitation of a directive from then President Roosevelt.

In addition to spinning a fascinating story, Morison's account introduces many of the multiple, interrelated, drivers and challenges of innovating in complex bureaucratic organizations. These include: i) the development of new, enabling, technologies; ii) changes in operating procedures; iii) insight from the operators/users of the product; iv) championing by a maverick officer within the bureaucracy; v) staunch resistance from bureaucratic decision makers; and vi) intervention by civilian leadership. While not intended to represent an exhaustive list, the mechanisms identified in Morison's "gunfire at sea" do span the majority of innovation theories put forward in the plethora of studies published in the years since. Thus, these broad categories of innovation mechanisms are used to organize the explanations offered in the military innovation literature, and the business theories that inform them.

A. Civilian Leadership

One commonly held innovation mechanism is that of intervention by (external) civilian leadership. The concept is that bureaucratic organizations are designed to resist change [9] and require a '*kick in the pants'* from outside if major change is to occur [19]. This type of intervention has typically been motivated by fear (e.g., the ramp up of missile development following WWII)[20], prestige as an instrument of foreign policy (e.g., the moon race, and to a certain extent the International Space Station (ISS) [21, 22]), out of necessity during times of military engagement (e.g., the Manhattan Project), or sometimes idle interest (e.g., Morison's gunfire at sea). Following the unparalleled success of the crash programs of the 1950s and 60s, many extracted the lesson that innovation in government programs must proceed in giant capability leaps as directed by strong civilian leadership and concentrated funding allocations. [21] However, while catalytic geopolitical events have at times spurred incredible levels of technological innovation, detailed historical analyses have revealed a more nuanced story.

Perhaps the best known, and most well studied, example of civilian intervention as a source of government innovation is *JFK's moon* mission. Politically, the moon project was an implement of foreign policy; a technological stunt designed to restore national prestige following the bay of pigs fiasco and Yuri Gagarin's first flight.[23] Nonetheless, Kennedy's inspiring words [4] (and the appropriations they entailed) mobilized the nation towards an extremely ambitious, yet clearly defined, technological goal. However, the popular perception of the Apollo program as a byproduct of JFK's vision is overly simplistic. Firstly, Kennedy's speech, no matter how compelling, could not have overcome technological infeasibility. In fact, project Apollo formally traces its origins back to recommendations made in April 1959 by the Goett Committee, a NASA Research Steering Committee. In the words of Logsdon (1970):

> Operating pretty much in a political vacuum in terms of policy guidance, and basing their choice on what constituted a rational technical program of manned space flight development, NASA planners chose a lunar landing objective fully two years before President Kennedy announced his choice of the lunar landing as a national goal. [5] p. 18

When Kennedy decided that a spectacular space achievement was required to reaffirm American superiority in the ongoing Communist-Capitalist power struggle, he asked, first and foremost:

> Do we have a chance of beating the Soviets by putting a laboratory in space, or by a trip around the moon, or by a rocket to land on the moon, or by a rocket to go to the moon and back with a man. Is there any other space program that promises dramatic results in which we could win? [24]

While Kennedy's primary motivation was clearly political, the above quotation reveals his understanding of the necessity for a technically feasible solution as well. He was not about to bet the reputation of the country on an engineering "pipe

[3] Based on a lecture initially presented in 1950

[4] "First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth." JFK, special address to congress on urgent national needs May 25, 1961

[5] A version of NASA's long-range plan, which included the lunar goal, was first presented to Congress as early as 1960. By mid-1959 the Space Task Group[5] (STG) began to generate guidelines for the development of an advanced space vehicle that would eventually take men to the moon. As plans solidified, it became clear that rocket lift capabilities were going to be a key constraint to the success of the mission. As a result, in December 1959, the Silverstein Committee made the bold decision to develop upper stage engines that employed the higher-thrust, yet at the time untested, combination of liquid hydrogen and liquid oxygen. According to Logsdon (1970), if the fuel decision had not been made at that time, experts would not have vouched for the feasibility of a lunar landing to Kennedy in 1961. By February 1961, the Low committee concluded that "*no invention or breakthrough is believed to be required to insure the over-all feasibility of safe lunar flight.*"[5] Of all the pre-Kennedy decision moon work, the Low committee conclusion was critical.

dream." When Kennedy said "*we should go to the moon*," his message was directed at Congress (and the nation) with NASA's blessing, not vice versa. Much of the engineering groundwork had already been laid. This is an important point that when ignored in subsequent projects yielded disastrous implications. For example, the Apollo model has been applied to Johnson's "great society" initiatives, the war on cancer and the Space Defense Initiative (SDI)[25] all of which failed, because among other issues, breakthroughs were required and not achieved.

Second, in addition to the need for technically attainable visions, a very particular set of circumstances are required in order to afford the executive office that level of power.[6] In their edited book "Spaceflight and the Myth of Presidential Leadership," Launius and McCurdy (1997) argued that the Imperial power enjoyed by Eisenhower, Kennedy and to a lesser extent Johnson and Nixon was a historical anomaly rather than a trend. Even if a contemporary president were to become enamored with space exploration, it is unlikely that congress would consent to stable funding on the order of magnitude required for space development projects. This projection has been born out, to a certain extent, by the failure of President George H. W. Bush's Space Exploration Initiative (SEI, 1989) and President George W. Bush's Vision for Space Exploration (VSE, 2004) to catalyze a second Apollo era. While part of the limitation of the later visions was certainly a failure to appreciate the enormity of the proposed technology challenge – sustained mission to mars – and the level of funding it would require,[7] one cannot discount the importance that fear and competition played in the success of to the Moon plan.

B. Bureaucratic Politics

Another class of explanation for what drives innovation in government projects, stems from analyses of the bureaucratic politics of large government organizations. Starting from the assumption that bureaucracies are *normally* resistant to change, one to three detailed historical case studies, of instances where radically new technologies were implemented, are typically performed to identify the key enabling *difference*. From this body of literature – largely concentrated in the disciplines of strategic studies and military history – four core explanatory dynamics have emerged. Namely, competition among services for shared resources; preservation of organizational culture; the heroic efforts of a maverick; and the conceptualization of a new way of war.

1) Competition

The concept behind the inter-service rivalry model is that military services within a state are constantly competing for the same scarce resources. In order to maintain their budget (and by implication importance) they tend to propose solutions to capability gaps which reinforce their existing expertise. The emergence of new mission areas is seen as an opportunity to expand their purview, and thus hotly contested among the services.[18] This dynamic has been observed several times in history including the first satellite launch (Vanguard v.s. Project Orbiter [8])[22], the creation of NASA, [9] or the development of nuclear missiles (Jupiter v.s. Thor; Polaris v.s. Minuteman)[27, 28]. When present, this competition has been shown to break down bureaucratic barriers which normally stifle innovation.

The seminal work in this area is due to Sapolsky's (1972) examination of the Navy's Polaris submarine-launched missile system development. He argues that competition with the Air Force's Minuteman created momentum within the Navy that enabled project managers to assemble resources and talent more efficiently than on other programs. The implication is that bureaucracies can operate efficiently (the Polaris system was delivered on time and on budget) if expansion aspirations overcome bureaucratic obstacles. Unfortunately, while this dynamic may have dominated in the case of Polaris, the numbers of potentially contestable mission areas are limited. Further, the notion that resource scarcity would motivate bureaucracies to change their behavior so as to protect their existing stake, or expand their purview to retain resources has not been validated in the few empirical studies. For example, Posen (1994) reports that a study of 94 public health agencies found "surprisingly but unequivocally" that changes in resource availability had on average no impact on proportional innovation. [29]

2) Culture

The premise behind the organizational culture model is relatively intuitive. Agencies, like individuals, develop organizational identities overtime. When innovations reinforce that identity, they are readily accepted. When they go against it, adoption and implementation are much more difficult. For example, the USAF is smitten by technology, particularly piloted flying machines.[30] As such, they will readily adopt the newest development in fixed wing aircraft. However, despite the enormous promise of recent Unmanned Arial Vehicle (UAV) development, the Air Force is resistant to a change that might reduce the important role of pilots in military engagements. [10] Ironically, the Army has been the recent sponsor of Joint Capability Technology Demonstrations (JCTD) involving UAVs since their cultural interest in air support is tied to its existence, not the mode of implementation. Similarly, since helicopters (although flying machines) do not

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[6] Richard Neustadt laid out 5 conditions that must prevail if a president's order is to be readily obeyed by his bureaucratic subordinates: 1) president must be clearly involved in the decision; 2) unambiguous order; 3) widely publicized; 4) men who receive the order must have be able to act on it; and 5) "authority to issue"[26] R. Neustadt, *Presidential Power*. New York: John Wiley, 1980. P.16. It seems that sufficiently unstable geopolitical conditions can generate such conditions, but that is hardly a dynamic to wish for.

[7] Proposals for SEI ranged from $200 to $500 Billion

[8] In fact, Vanguard was chosen for non technical reasons associated with the need to divorce the launch from military efforts. However, the expedience with which the German Rocket Team followed through as soon as they were given the go-ahead can be attributed, at least in part, to the pride associated with competition.

[9] Weather the new space agency should be a division within NACA (the National Advisory Committee for Aeronautics) or DoD and within DoD, which service?

[10] Similarly, contrary to technical reasoning, a window was put in the Mercury capsule to disprove the reality that astronaut (pilots) were merely "spam in a can."

fall under the cultural identity of the Air Force, they too were initially implemented by the Army.[31]

Although this mode of explanation is a good predictor of relative resistance to change, it provides limited insight as to how cultural biases can be overcome. Given that radical innovations tend to destroy existing competence, combating cultural biases is an important issue. One historical strategy has been to create a new agency when confronted with a truly new functional area. Consider the evolution of the US military. The original US "Department of War" was an army. The Navy was created in 1798, when the battle theater moved for the first time to the "high seas" to combat Barbary Coast pirates. The Air Force was finally formally designated a separate branch under the unifying Office of the Secretary of Defense (OSD) in 1947, a full thirty years after aircraft were first used in combat.[32] Once space emerged as the next frontier in the 1950s, the familiar debate returned, however this time it transcended the bounds of the military. In fact NASA was created as an evolution of – but fully separate entity from – the National Advisory Committee for Aeronautics (NACA), as a civilian, research oriented front to the US Space effort.[22] It has been said that project Apollo succeeded because NASA was a new agency, unencumbered by cultural baggage. More recently though, NASA has struggled to perform, because it has been unable to adapt to the new role of space as ancillary policy.[21]

3) *Maverick + Civilian*

The maverick and civilian model of government innovation, like many of the bureaucratic models, presumes that organizations won't change unless forced. Since the conditions for a President to be successful as the forcing agent are extremely hard to meet vis-à-vis innovation [26], Posen (1984) argues that the existence of a military maverick can facilitate matters. This is an appealing notion. A maverick – an isolated, masterless man who has rejected the authority of his superiors – single handedly combats the stogy bureaucracy. Classic examples of mavericks include Billy Mitchell (winged defense) and Hyman Rickover (nuclear navy) in the American Military [9], Percy Scott (innovation: continuous-aim firing; alliance: President Roosevelt) [7], or John Houbolt (Lunar Orbit Rendezvous) of NASA [22]. However, Rosen (1994) argues that the very characteristics that make a maverick, limit his effectiveness. In fact, according to Rosen (1994) closer examination reveals that many of the so-called maverick change-makers were either a) not in fact mavericks, or b) less effective than they are credited for [28, 33]. This is not to say that military change does not often require the persistence of an individual or small group. Posen merely believes that those individuals emerge and suceed through a more complex mechanism (described below).

4) *New Order*

In his book, "*Winning the Next War*" Rosen (1994) examines 21 cases of military innovation initiated during peacetime, wartime and purely technology enabled. Compared to the other major works in the field which tend to focus on one or at most three cases, Rosen's 21 are quite extensive. Throughout the book, he raises counter examples to existing theories (some of which are highlighted above) and settles on the conclusion that individuals may not be able to change, but visionaries are capable of recognizing when it's time to make way for the next generation of officer. Thus, Posen (1994) argues that major innovations (e.g., the transitions to Amphibious warfare 1905-1940, Carrier Aviation 1918-1943 and Helicopter Airmobility 1944-1965) occurred when senior military officers with traditional credentials, reacting, not to intelligence about the enemy, but to a structural change in the security environment, acted to create new promotion pathways for junior officers practicing this "new way of war."

This model is evocative of the concept of creative destruction espoused by [34]. Where Schumpeter argues that long term economic growth can only be sustained through the entry of innovative entrepreneurs and the necessary value destruction of established (monopolistic) companies, Rosen contends that military productivity is sustained by the *changing of the guards*; entrenched officers give way to new talent. The key conceptual difference between these two models is that Schumpeter's creative destruction is initiated by entrant firms seeking to gain market position; conversely, Posen's revitalization is initiated from the top, with senior officers choosing to step aside. Since rigid military hierarchies inhibit natural restorative forces to act, change often requires a deliberate action from the top.

C. *New Technologies*

In the broader innovation literature, significant effort has been directed towards understanding how new inventions are conceived of. From the point of view of the firm, being the one to come up with the new capability is extremely important. Conversely, from the point of view of the government buyer, the particulars of who originated the innovation is immaterial; only that the new capability is developed. Although technology enablers are critical precursors to radical new system development, many government agencies are relatively satisfied assuming deterministic average yields on R&D spending. [insert some references] However, the business literature has produced considerable evidence that different organizational environments promote different kinds of innovation [16]. Also that system level innovation requires knowledge creation at multiple levels of the product hierarchy (i.e., knowledge of the components and their linkages) [5]. Combined, these insights suggest that more than just encouraging innovation in general government policies must foster a mix of organizational environments and incentives. The literature on new technologies as a driver of government innovation takes two main forms. First, there are historical cases illustrating how a particular technology enabled the development of a new class of systems. Second, studies that examine the role of government acquisition policies in promoting innovation.

1) *Technology Enablers*

One classic example of innovation resulting from the "critical technology enabler" status of one component is the integrated circuit (IC) and the Apollo guidance computer. This case was studied thoroughly by Mindell (2008), although not in the context of innovation. When project Apollo was initially conceived, it was known that the guidance computer would represent an extreme technical challenge, but since the technology was so immature, the extent to which it was a technological risk did not surface until many years after the original contract.[11] As design requirements solidified over the course of the program, the designers were confronted with power, size, mass and reliability requirements which, combined, seemed unmeetable. Faced with this conundrum, and given the must-succeed nature of project Apollo, the design team made the bold decision to evaluate the potential use of integrated circuits (ICs) in lieu of the then standard core transistor circuits. Despite obvious advantages, [12] this proposition seemed extremely risky given the lack of maturity in IC technology. At the time, the technology was only 3 years old.[35] Not only was the availability of reliability data limited, at the time, but production quantities were also low and corresponding prices excessively high. In fact, by 1963, circuits used in the Apollo prototype construction accounted for 60% of the national production.[35] There are two lessons to be drawn from this case vis-à-vis enabling technologies. First, had ICs not been invented in the late 50s, technical hurdles associated with the Apollo computer may have proven insurmountable. Second, had the level of ambition in the Apollo requirements not prompted a necessary design risk to be taken, which, as an unintended bi-product, subsidized an emerging IC market, commercialization of IC technology would likely have happened much slower if at all.

Similar dynamics, whereby the enabling properties of an immature and/or controversial technology force government agencies to break down bureaucratic barriers, have played out in other areas (e.g., nuclear propulsion for submarines and spacecraft has enabled extremely long missions.)

However, nearly opposite to the critical enabler perspective, in an oft sited DoD sponsored study, Sherwin and Isenson (1967) found that the major leaps in performance between subsequent generations of military systems, where attributable to many (on the order of 100s of) small innovations as opposed to any single major development. Project Hindsight reviewed the history of 20 major US military CTIGM programs and identified 710 discrete events which contributed to the observed performance improvements. 95% percent of all events were developed with the aid of government funding, which they interpreted to represent a "clear understanding of DoD need." [13] This phenomenon is not surprising, given that the project team is more likely to be aware (and have access to) developments internal to the military organization. Also, that developments sponsored by the DoD are more relevant (and traceable) to next generation military developments. Finally, government patronage of relevant R&D is thought to be necessary, given its status as a monopsony buyer.[14, 36]

It is worth noting that the finding that most innovations occur internal to the military establishment is in direct contradiction of the generally accepted premise that new ideas come from outside.[16, 34, 37] However, the more subtle takeaway, that while radical innovations like ICs may be initiated from "outside," there can be a role for the government too, in subsidizing early-stage risk.

2) Structural Enablers

The structure of the acquisition process is explicitly designed to enable the development of new capabilities. As conceived in the early sixties, there are three main phases: (1) the government's decision to initiate a weapons program; (2) the selection of the contractor to carry out the program; (3) the implementation of the program through development and production. [36] This process embodies a deterministic view of technology development, believing that most weapons innovations were incremental and that the role of the acquisition system was to infuse updated capabilities into subsequent developments as desired. This philosophy is well captured by Peck and Scherer (1962):

> Weapons technology has been advancing in a more or less evolutionary way, with relatively few truly dramatic "breakthroughs." […] the step-by-step evolution of weapons technology has been such that one can seldom attribute a particular innovation solely to a specific individual or group. […] Weapon system ideas are seldom inspired by a single technical advance. Rather, the perceived feasibility or desirability of a particular type of system generally tends to increase gradually with the accretion of numerous technical advances. Sometimes it may be possible to identify the one marginal advance which eliminated a critical bottleneck, providing the impetus for a full scale system development decision. But more frequently, the exact margin between feasibility or desirability and their converses is difficult to discern. p. 277

Although the philosophy of *planned innovation* through coordinated systems acquisition was compelling, its naïvety was revealed through acquisition challenges.[38] The current instantiation of the DoD Acquisition process employs a two-tiered organizational structure, separating (1) research and development and (2) formal acquisition programs. [15] Recognizing the importance of incentivizing technology development in advance of system acquisition, multiple strategies have been attempted. These have included COTS, seed-funding models being explored by the Operationally Responsive Space (ORS) program office and prizes (*e.g.*, Ansari X-Prize). The idea in each of these is to help sustain a market rather than subsidize the development of a particular technology (*i.e.*, generate sell side initiative, not just capability development). While none of these strategies have proved entirely effective, they make important steps towards the mix of structures and incentives suggested by the business literature. There is an opportunity here for insights from the business innovation literature to inform acquisition policy.

D. Users as Innovators

An important challenge associated with innovating in the government acquisition context lies in identifying the intersection of what is possible and what is useful.[15] In the

[11] The Apollo guidance computer was officially awarded, as a sole source contract to the MIT instrumentation lab (IL), a mere 67 days after Kennedy announced the lunar goal. In the contract, a computer was requested which would "*provide a general on-board guidance capability for the various earth-orbital and cislunar missions*."

[12] The performance per mass characteristics of ICs made the specifications meetable.

current DoD acquisition process, this is nominally accomplished through a series of “gap analyses” performed as part of the Joint Capabilities Integration and Development System (JCIDS). However, in practice the complexity of integrating the needs of such a disaggregated buyer as the US government leads to significant shortcomings in JCIDS’ realization.

One critical aspect of prioritizing “next” acquisitions is in soliciting and integrating inputs from the operational arm of the DoD – the user warfighter. While it is relatively well accepted that a warfighter has a unique understanding of the impact of performance tradeoffs on operational utility, and should thus be consulted to help refine needs; the extent to which a warfighter can contribute to the capability generation side of the innovation process is less well understood. When von Hippel’s theory of lead-user innovation [13] [39] is extended to the acquisition context, warfighters are often identified as analogous to lead users because self-preservation is the highest possible incentive to innovate.[40] A commonly cited example illustrating the ability of warfighters to innovate under adversity is the High-Mobility Multipurpose Wheeled Vehicle (HMMWV). Among many HMMWV capability improvements attributed to warfighter ingenuity is the Self-Protection Adaptive Roller Kit (SPARK), which was initially improvised by members of the U.S. Army 3rd Infantry Division in 2006, and is now standard issue in Iraq on three mobile platforms.[41] It’s worth noting that several iterations of research and development were completed between the gap-filler improvisation and the deployment of the significantly more effective operational SPARK.[41]

To date, much of the empirical research on lead-user innovation has centered on systems that are either software intensive (e.g., personal computer – Computer Aided Design software,[42] Online public access library software[43]) or personal-use expert systems (e.g., canyoning, sailplaning, boarder cross and para-cyclists’ equipment[44]). While some of the findings from these studies may be generalizable to government acquisition systems, key differences make the analogy suspect. Specifically, the cost of changing military systems is prohibitive, [14] warfighter culture emphasizes acceptance of the status quo and uniformity of equipment, and individual warfighters do not necessarily have the required knowledge to make substantial changes to the systems they use. Despite all these caveats, the question is not whether any warfighters adapt their equipment to better address emerging threats – they have done and will continue to. The more interesting questions centre on the kinds of innovations that warfighters capable of generating; or whether all warfighters – faced with an emergent threat – innovate equally (or are there distinguishable “lead-warfighters”?). In addition to adding to and refining lead-user innovation theory as it applies to complex products developed in government enterprises, this line of investigation has the potential to lead to an improved approach to collecting and interpreting warfighter input into the acquisition process.

[13] which asserts that users who (1) face needs in advance of the market at-large and (2) are positioned to benefit significantly by obtaining a solution to those needs, represent an important source of innovative product concepts

[14] Developed over multiple years and designed to last for a decade or more, transition costs measure in the billions.

III. Priorities for Further Research

In a review paper on innovation and diffusion of technology in industry, published in Science in 1974 [1], Utterback concludes with the following critique of the literature at large:

> Case studies may continue to be a source of ideas and hypotheses for further research, but do not appear to offer a means for deeper understanding of the innovation process. The retrospective nature of nearly all of the sources discussed probably means that the process has been viewed as much more rational and well-ordered than it is in fact. […]More serious problems are raised by the distinctly non-representative nature of the samples used. There are few cases in which the contributions of more than one organization, or details of interactions over a significant period of time, are discussed. p. 626

Nearly the same statement can be made about the state of the military innovation research today. While the broader innovation literature has since heeded Utterback’s advice, leveraging historical quasi-experiments to investigate the impact of policy interventions over extended periods of time and expanding the unit of analysis to consider entire sectors and even countries, the military innovation literature remains focused on riche descriptions of successful innovations. And, although detailed historical cases have provided important insights into the bureaucratic innovation process, the tendency to focus on highly successful cases limits their generalizability. For example, one of the common findings of many of the studies is that particular sets of exogenous influences can create sufficient urgency to overcome “normal” bureaucratic barriers. Such a conclusion fails to appreciate the rationale for installing those barriers in the first place. Lindsay [45] articulates the tension between the need for strategic control and the need to deviate from standard operating procedures. However, if the observation that radical innovation occurs when institutional barriers are broken down leads to the conclusion that bureaucratic processes should be minimized, the system itself may break.

Broader-based studies like Project Hindsight [13] offer some greater potential for generalizability, however the research methods they employ – for example, asking members of the project team to trace the origin of new components – are heavily biased towards the results they yield (that developments sponsored by the DoD are yield the majority of new technology used in future systems) since the project team is both more likely to be aware of (and have access to) developments internal to the military organization. Unfortunately, a less biased approach which traced the innovations farther back than the program which “militarized” it may be impossible due to limited access to, and existence of, the required data. Nonetheless, continued analysis of “normal” government innovations (i.e., major capability improvements between generations vice the invention of a new way of war) will yield insights more relevant to acquisition policy.

To this end, the role of government acquisition policy in generating enabling technologies remains relatively poorly understood and merits further investigation. Conceptually, since a government acquisition agency is effectively a monopsonist buyer, its purchases determine the demand profile of the market for that class of product (i.e., reconnaissance satellites). [36] As a result, there is limited incentive for government contractors to invest in R&D outside the explicit requests of the government. [14] Thus, an important policy question underlies the frequency and mix of government contracts. Conventional wisdom within the acquisition community dictates the need for a two tiered acquisition process – separating technology development from formal system level acquisition [46-48]. Additionally, there is a grown consensus that increasing the frequency of new space system developments will revitalize a stagnating industrial base. [15, 49, 50] However, these propositions are based on personal experience, albeit extensive, rather than systematic research. Studies on innovation dynamics in competitive markets (c.f. [16, 37]) provide some insight, but there remains a need to understand the fundamental trade-off associated with contract size and frequency in monopsony markets. As the computational capacity for computer experiments continues to increase, there is an opportunity to investigate theoretical alternatives in a simulated environment.

The topic of user innovation in the military context also represents an exciting area for future work. With the current emphasis on responsiveness and space support to the warfighter within the DoD acquisition community, characterizing the role that users/operators can/do/should play in the innovation process is particularly relevant. While it is relatively well accepted that a warfighter has the best understanding of the impact of performance tradeoffs on operational utility, and should thus be consulted to help refine needs (to be translated into requirements); the extent to which a warfighter can contribute technical solutions is less well understood. Based on user innovation theory, one might expect that if, in an ever changing environment most products will be out-of-date by the time they are deployed, and that users are motivated to make the available products work for them, then they will find ways to adapt the products to better fulfill their needs. However unlike in the domains traditionally studied by user innovation scholars (i.e., open source software and expert systems) warfighters may not have the knowledge and technical capabilities required to make meaningful capability contributions. Work in this area has potential to both inform acquisition policy by identifying how warfighters can most productively contribute to the innovation process, and also add another dimension to lead-user innovation theory through the analysis of problems involving more complex technical systems in a disaggregated knowledge environment.

IV. References

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