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Strategic Acquisition of Navy Unmanned Systems: Analysis and Options

12 July 2012

by

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Abstract

The U.S. Navy (USN) and U.S. Department of Defense (DoD) have many emerging robotics needs and potentialities. However, although the U.S. is strong in defense robotics—in particular in Unmanned Aerial Systems (UAS) -- recent reports have identified fundamental weaknesses in the broader U.S. robotics innovation system in which defense robotics is embedded. Since the potential scale of commercial robotics is far greater than military robotics over the long run, the U.S. needs to develop a stronger national robotics innovation system to support the long-term development of defense robotics and help make the nation more secure. Traditionally, the policy response to such needs has involved stimulating the supply side. This report identifies robust local U.S. demand for robotics as a critical element in developing a thriving U.S. robotics innovation system. Therefore, while some DoD acquisition strategies attend to industry development via supply-side elements (such as research and development support for major suppliers, Small Business Innovation Research initiatives, etc.), I suggest that these initiatives must be complemented with a set of pro–demand-side acquisition strategies. This report outlines the rationale for including a demand-side approach in DoD robotics acquisition policy, a set of appropriate strategies, and a framework for implementation.

Keywords: DoD emerging robotics needs, defense robotics, pro-demand side acquisition strategies

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About the Author

Professor Nick Dew has spent the past ten years studying innovation and entrepreneurship. In this specialty he has published over 25 peer-reviewed journal articles, several book chapters, and an award-winning coauthored textbook on entrepreneurship.

Over the same period he has also studied and published several articles on DoD logistics matters, including the role of RFID in the supply chain, and his PhD dissertation which analyzed the creation of the now ubiquitous EPC (Electronic Product Code). His other areas of research have included studies of the PSC industry (Private Security Contractors), innovation initiatives in the Navy, and technology transfer activities at DARPA.

Professor Dew has a Ph.D. and MBA from the University of Virginia. Before entering academia, he spent eight years working internationally in the oil industry. His past research has been funded by OSD, ONR and DARPA.

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I. Introduction

> National Security is founded on a Robust Innovation System … A Robust Innovation System will help make the Nation Militarily and Economically Secure. Robust Defense Spending alone will not make the Nation more Innovative, thus, ultimately Less Secure. (Charles Wessner, Director of Technology and Innovation, National Research Council, 2004, slide 58).

The U.S. Navy (USN) and Department of Defense (DoD) has many emerging robotics needs (“FY2009–2034 Unmanned Systems,” 2009; “The Navy UUV Master Plan,” 2004; Button, Kamp, Curtin, & Dryden, 2009). This paper examines questions that lie at the interface between the DoD’s robotics requirements and initiatives and the acquisition policies that enable and sustain them. My focus is on how the DoD might use strategic acquisition to optimally harness technical development in the naval robotics space. In this report I will provide a framework that supports future acquisition policies in DoD robotics. The report starts with the premise that a broader range of acquisition policies might be employed strategically by the DoD to get more of what it needs out of the robotics industry. While there is ample research on public policy tools available, in general, to nurture industries and plenty of research on the impact of defense spending, in general (including specifically on defense research and development R&D spending), there is much less work on how particular acquisition tactics can be directly employed by the DoD to nurture industry segments that are important to it (Birkler et al., 2003). In addition, while supply-side support via R&D spending has been studied in the past, the role of demand-side policies (and therefore the acquisition policy tools) has been largely overlooked. Yet demand is a key driver of innovation in industries (Edler & Georghiou, 2007) and—in my view—has significant potential to impact how the nascent and rapidly developing defense robotics industry might evolve in the future. This is an important issue: by acting strategically now, our acquisition policies might be geared to enable demand-side factors that may help the defense robotics industry to develop along paths that are advantageous to the DoD in the future.

Of course, robotics is a classic “dual-use” technology, meaning that its fundamental facets are shared between military and civilian/commercial uses. This report takes as its context the Computing Community Consortium (CCC) 2009 robotics report, a recent synopsis of the U.S. national robotics industry that identified significant weaknesses in the robotics sector (CCC, 2009). That report notes that “Led by Japan, Korea, and the European Union, the rest of the world has recognized the irrefutable need to advance robotics technology and have made research investment commitments totaling over $1 billion; the U.S. investment in robotics technology, outside unmanned systems for defense purposes, remains practically non-existing” (CCC, 2009). Recognizing the nation’s shortfalls, President Obama announced a $70 million kick-start investment in robotics R&D on June 24, 2011, called the National Robotics Initiative (NRI). Since the one bright spot and area of strength for U.S. robotics has been military robotics—in particular, unmanned aerial systems (UAS)—one may wonder why this matters. The fact is that Department of Defense (DoD) robotics spend alone is not enough to fuel a flourishing national robotics industry over the longer term because it is posed to be rapidly overtaken by commercial spending on robotics on a global scale. Yet research on national prosperity has identified that leadership in particular technologies has been a crucial element contributing to national well-being in the past. Such leadership has both direct and indirect effects: direct when it involves leadership in industry sectors such as aerospace that are intimately connected with developing and fielding military capabilities; and indirect because national wealth is a significant predictor of military prowess in general. According to recent work summarized by Cimoli, Dosi, and Stiglitiz (2009),

> In fact in each epoch there appear to be technologies whose domain of application are so wide and their role so crucial that the pattern of technical change of each country depends to a large extent on the technical capabilities in mastering production/imitation/innovation in such crucial knowledge areas (e.g., in the past, mechanical engineering, electricity and electrical devices, and nowadays also information technologies) … Thus, these core technologies shape the overall absolute advantages/disadvantages of each country.

In the future, robotics is likely to be one of the core technologies fuelling economic prosperity, and therefore a key industry in which the U.S., needs to be a major participant (Brynjolfsson and McAfee, 2012; CCC, 2009; Markoff, 2012).

A. Commercial R&D Spend Dwarfs Pentagon Spend

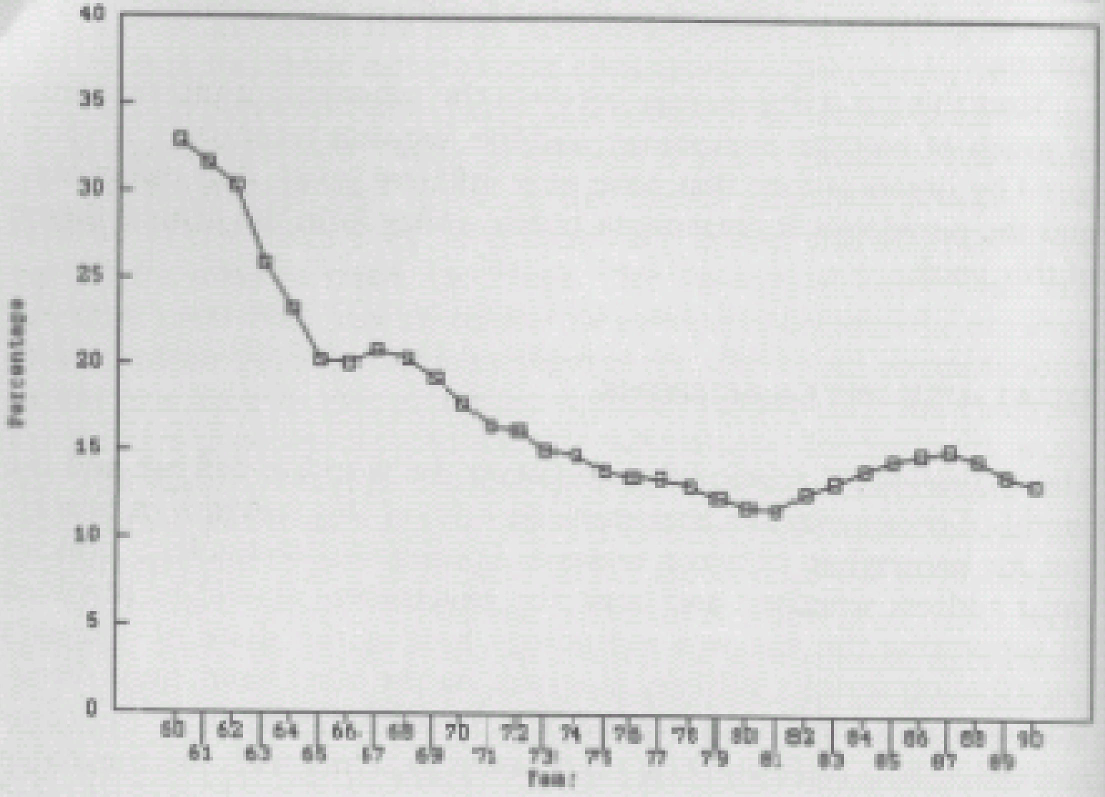
An important contextual element for understanding why demand-side strategies make sense for the DoD is the wider pattern of research and development (R&D) spend globally. It is well known that after peaking in the 1950s, the Pentagon’s share of global R&D spend has steadily decreased (see Figure 1) to the point where today, the Pentagon’s R&D spend is dwarfed by commercial R&D spend that occurs on a global basis. In a provocative presentation, Wessner (2004) argued that the Pentagon’s R&D spending is one of the central innovation myths that exist about the U.S. defense establishment and that the Pentagon has not nearly the clout it had in the 1950s and 1960s to influence the direction of R&D activities (contra Hooks, 1990). In a similar vein of argument, Alic, Branscomb, Brooks, Carter, and Epstein (1992) criticized another Pentagon myth, what they call the “spin-off” model of technology transfer from the military to the commercial sector, which—with a few notable exceptions mainly funded by DARPA (GPS, the Internet)—has been swamped by the amount of “spin-in” from the commercial sector to defense. Summarizing the issues highlighted in this paragraph, the 2011 UK Ministry of Defense Joint Doctrine Note (MOD JDN) on UAS concludes that

> The changes in world economies over the last 2 decades mean that the military sector is now dwarfed by the economic size and power of the commercial sector. Except perhaps for space, new developments in military systems are therefore likely to come from specialized development of commercial systems rather than vice versa. It is to the commercial sector that we must look for the delivery of future disruptive technology.

To this data must be added several factors that further mitigate in favor of spin-in as the predominant basis for future military R&D, rather than spin-out. First, military robotics needs are too specific to drive R&D in the robotics industry as a whole; instead, military robotics needs and their requisite R&D support are just one of many segments of the broader robotics industry. Second, robotics differs from some past technologies in which Pentagon R&D played a prominent role in technology evolution because it has not grown up with the kind of extreme dependence on military R&D that has characterized sectors such as aircraft development. Instead, the cutting-edge robotics research is more dispersed globally and less dependent on military orders, with many of its key developments going on in commercial sectors such as medical robotics. Third, one can argue that in robotics, all of the major technological pieces are now basically in place and what exceptions there are—for example, needs for lightweight, long-life power sources in many applications—are not robotic-specific technologies. Once again, this means that the technology development issues are dispersed across other industrial sectors and are not specific to the military.

All of the preceding factors suggest in favor of a view of robotics industry development that over the long run is dominated by the commercial sector rather than military R&D support or requirements. Robotics is a classic dual-use technology in which it is likely that military robotics development will be paced and driven by developments in the commercial sector owing to growth in the market size of that sector relative to the military robotics market. This suggests that the future of military robotics lies in spin-in of Commercial Off The Shelf (COTS) technologies rather than spin-out (i.e., the military leveraging commercial R&D for military needs).

FIGURE 1-1:
U.S. Defense Share of OECD R&D, 1960–1990



Source: Data were provided by the Division of Scientific, Technological, and Industrial Indicators, Directorate for Science, Technology and Industry, Organization for Economic Co-operation and Development. See Chapter 4, especially Figure 4-2 and footnote 12.

Figure 1. U.S. Defense Share of Organization of Economic Development (OECD) R&D 10 1960–1990
(Alic et al., 1992)

B. Misconceptions about the Relative Efficacy of Policy Tools: R&D vs. Demand

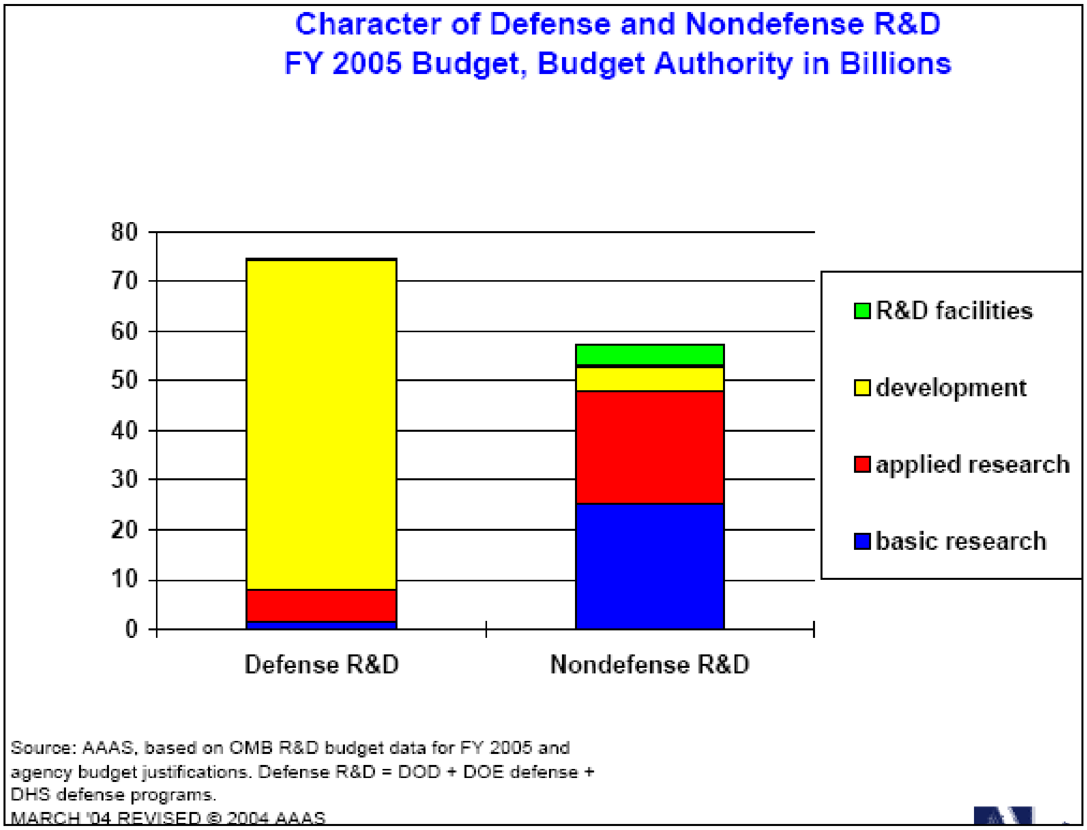
As well as the influence of these important trends in R&D spend (as highlighted in Figure 1) on the robotics industry, one might add that past analyses of major technology trends tend to perpetuate an important misconception about how innovation occurs and how innovation is turned into military value (Bhide, 2006). The misconception is that leadership in R&D is the same as leadership in innovation—in particular that upstream “R” (research) is the primary mechanism underpinning the emergence of innovative new technologies with genuine military utility. This misconception is part of a system of very sticky beliefs about R&D that have been criticized as “techno-fetishism” (Ostry & Nelson, 1995). Within the R&D world generally, such techno-fetishism has resulted in a gross over-estimation of the relative value of R (research) as compared to D (development), i.e. of upstream research compared to downstream development. Economic studies have contributed to the perpetuation of this misconception by using patent counts as their primary measure of innovation, which, by representing innovation in terms of patents, clearly helps perpetuate the myth that innovation is the prodigal son of upstream research spending, despite the fact that patent counts have been roundly criticized as a measure of innovation in a wide range of research.

In fact, R&D subsidies either in the form of incentives (tax breaks) or direct grants are only one of four major categories of public policy that effect innovativeness (Geroski, 1990), with the other incentives being regulations (e.g., laws and standards), infrastructure investments (e.g., in the educational system), and public acquisition. Of these incentives, direct public acquisition (e.g., demand) appears to be by far the most potent tool of public policy and one that has been wielded particularly effectively in the defense business but also in other areas such as energy innovation. Latent or emergent demand that goes beyond the capabilities of current technology is a significant factor stimulating producers to invest in innovation. In fact, changing user needs are frequently cited as one of the top factors in creating incentives for innovation, across a wide range of industries (BDL, 2003). Empirical evidence bears out this claim. For example, in one well-known study that examined the genesis of 50 industrial clusters, public procurement was a “very big” or “major” factor in 50% of these developments. By comparison, R&D subsidies made a very big or major impact on only four clusters out of 50 (a mere 8%; Rothwell & Zegveld, 1981). Combined with other evidence, this led Geroski (1990) to conclude that “[P]rocurement policy is, in general, a far more efficient instrument to use in stimulating innovation than any of a wide range of frequently used R&D subsides” (p. 183).

Techno-fetishists also underestimate the extent to which the *D* (development) in R&D may better explain technological leadership and why this is so. Yet keen observers of military history, such as Max Boot in his 2008 study of several centuries of military technological change, seem to be well aware of the real drivers of military innovation. Boot (2008) concluded as follows:

> The way to gain a military advantage, therefore, is not necessarily to be the first to produce a new tool or weapon. It is to figure out better than anyone else how to utilize a widely available tool or weapon.

This downstream development of innovation—figuring out better than anyone else how to utilize new technology—has several important characteristics that are worth highlighting. First among these is that innovation occurs in concert with users, for innovation is the process of customizing technology into something of genuine utility for users. As highlighted by Rosenberg (1976) and since emphasized in so many studies of innovation, customizing new technology into innovations of genuine utility involves extensive interaction between technology developers and technology users, with the result that innovation tends to be a gradual and complex process of problem solving that uses significant resources. The phenomenon described by Rosenberg is highlighted by the Pentagon’s own R&D budget (see Figure 2), with its preponderance of D spending.



Source: AAAS, based on OMB R&D budget data for FY 2005 and agency budget justifications. Defense R&D = DOD + DOE defense + DHS defense programs.
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Figure 2. Character of Defense and Nondefense R&D FY2005 Budget, Budget Authority in Billions
(Wessner, 2004, slide 8)

A second important characteristic of downstream innovation is that it generally involves recombinations of extant technologies rather than the incorporation of de novo technology (Schumpeter, 1976). Upon investigation, it is customary to find that nearly every technology called new and radical has a much longer history than realized upon first inspection and that the dominant processes in innovation are the application of technologies to solve (new) problems usually by some kind of combination with other pre-existing technologies. Again, the emphasis belongs on the downstream work of adapting technologies to solve user problems or serve some need/desire of value.

A third important factor in downstream innovation is the relative locational "stickiness" of the process compared to upstream invention (von Hippel, 1994).

Because the customization process depends heavily on long, drawn-out processes of developer-user interaction, downstream innovation is locationally constrained in ways that patents (the prototypical manifestation of upstream innovation) are not. Therefore, downstream innovation is less mobile than upstream innovation. In military terms, this means that downstream D is less threatened by the imitative designs of rival countries than upstream R. This becomes all the more important when one considers which type of innovation—upstream R or downstream D—creates the most value.

Economists frame the issue of value capture from innovation as one of who captures the surplus, or profits, from new technologies. On the one hand, a consumer surplus is available from utilizing a new technology; on the other hand, there is the surplus captured by the inventors of new technologies. Several economic studies have examined this issue, and all concluded that the vast bulk of value from innovation is captured by users, not producers of innovation. In other words, the majority of the value from innovating is captured downstream, not upstream. In Nordhaus' 2004 study, which measures the division of this surplus, Nordhaus concluded that

> [O]nly a miniscule fraction of the social returns from technological advances over the 1948-2001 period was captured by producers, indicating that most of the benefits of technological change are passed on to consumers rather than captured by producers.

In Nordhaus' study, *miniscule* was 4%. In other words, per Max Boot (2008),leadership in applying a new tool (or weapon)—which flows from downstream D—is the key to capturing value from innovations and is not at all the same thing as being the first to invent and possess a new technology (upstream R), which by comparison typically yields much less return.

The upshot of all of this is that not only is military R&D not the place to look for robotics innovation going forward but neither is R&D the place to look for innovation more generally. Instead, the focus needs to shift to demand as the factor on which the majority of robotics innovation will depend. This means that there is an important mismatch between mindshare occupied by R&D and mindshare occupied by demand as tools of innovation policy (Edler & Georghiou, 2007). The Pentagon's actual R&D budget reflects a lot more D than R, as it should. But the way we conceptualize and talk about the relative importance of R&D does not reflect either the Pentagon's actual behavior or what we know more generally about the importance of downstream demand in the innovation process. A necessary first step in getting our approach to policy-making right is to recognize this mismatch between policy talk and reality and build our strategies for influencing industry development around the reality of downstream demand as the vehicle of industry development, rather than the current gross overemphasis on upstream research. Ultimately, a crucial key to having a U.S. military robotics capability par excellence is that the U.S. military robotics business dwells in a robust national robotics industry, which will only exist if it is powered by domestic demand for robotics systems, because most of the value capture from innovations occurs via downstream adaptation of innovations to meet specific local demand. This is the major reason that defense acquisition strategy has an important role in the overall *policy mix* for the U.S. robotics innovation system—because demand, embodied in direct acquisition, is arguably by far the most important tool for driving innovation (Geroski, 1990; summarized in Figure 3).

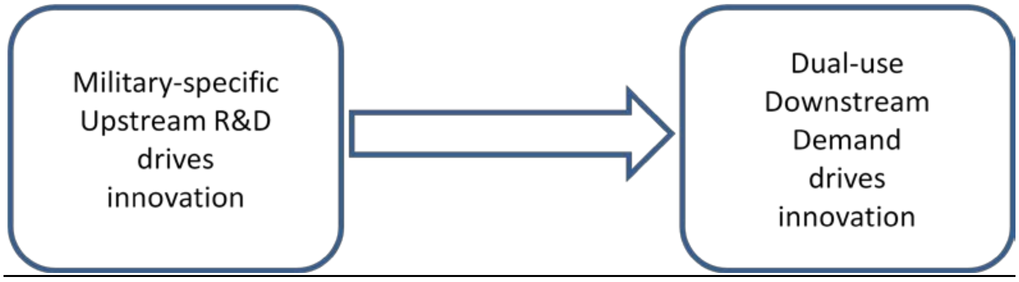

Figure 3. Shifting Mindsets About the Drivers of Innovation

C. The DoD Needs a Demand-Side Strategy for Robotics

From the proceeding arguments, we can see that an R&D strategy alone is insufficient to support a dynamic U.S. robotics innovation system over the long run, per the Obama kick-start. What has to be realized is that, ultimately, R&D dollars are paid for out of the pockets of users, that is, on the basis of (future) demand for the products and services that the R&D prospectively will make available. Robust domestic demand for robotics therefore provides the shared resources to pay for R&D that needs to be undertaken on the supply side. What the DoD needs is a large number of user partners sharing its R&D load, thus making its R&D dollars stretch much further via scale economies and synergistic R&D. Because the largest part of this spend is actually D, and this happens further downstream in connection with user needs, innovation won't happen unless user communities are significantly involved, which requires them to see the promise and practical application of robotics technologies to business problems that they care about solving. This makes user demand the bottleneck in robotics industry development, not supply. If the DoD wants to influence the long-run trajectory of the U.S. robotics innovation system (for its own gain), its acquisition strategy should therefore make use of demand-side policy tools. What is needed is the facilitation of a demand environment that is innovation friendly. To achieve this innovation friendliness, one of the primary tools that the DoD has available is acquisition strategy.

The overall goal of this aspect of acquisition strategy can be summarized simply: helping the U.S. to maintain/become the world's lead market in air, marine, and utility robotics by accelerating the diffusion of these technologies in the U.S.

Any goals that the DoD adopts must be implemented in a complex, policy environment with several other federal actors (e.g., FBI, CIA, Department of Homeland Security (DHS), the Coastguard) that have an active interest in developing the robotics industry, plus many other actors (e.g., state and local law enforcement, commercial industries such as oil and agriculture, industry associations such as the Association for Unmanned Vehicle Systems [AUVSI]) that together constitute a complex and fragmented system that collectively provides a “policy mix” for the robotics industry (Flanagan, Uyarra, & Laranja, 2011). The argument developed in this paper is that it is important to focus on what is missing from the policy mix influencing the development of the robotics industry at present. In general, the demand-side of the innovation policy mix has been sorely neglected in the recent past, both in policy circles and in the research domain (Geroski, 1990). In an effort to revive it, recent research by Edler and Georghiou (2007) defined demand-side policy tools as follows:

> [D]emand-based innovation policies are defined as the set of public measures to articulate, increase demand for innovations and/or improve conditions for the uptake of innovations in order to spur innovation and their diffusion into the marketplace. (p. 952)

Part of my argument is that the DoD has limited resources and is subject to various administrative constraints that curtail its ability to do all that might be desirable to influence the directions of the robotics industry in the near and longer term. Recognizing this makes it all the more important for the DoD to pursue some specific targets via its acquisition strategy, rather than going after many targets at once. As we will see when we study the robotics industry (or innovation system, as I will call it) in more detail, it therefore makes a great deal of sense for the DoD entities to pursue key bottlenecks in robotics industry development, vice targeting areas that are not constraining the industry’s progress. The conclusion that the DoD should focus its efforts on supporting demand for commercial marine and aviation robotics in the U.S. will initially seem like a strange strategy since external outreach by the DoD is almost always via supporting R&D on the supply-side. But the supply-side is not the bottleneck in robotics development; what is weak in the U.S. is the demand-side. Therefore, there is a role for a demand-side strategy by the DoD in order to help push the development of the U.S. military robotics industry. The rest of this report proceeds as follows.

The next section (Section 2) of the paper explains the logic for highlighting demand-side aspects of the robotics industry as part of a more systematic analysis of the global robotics innovation system.

Section 3 proposes several demand-side policy tools that could be used as part of the DoD's portfolio of R&D activities and acquisition practices.

Section 4 rounds out the report by suggesting an implementation framework for these policy tools that recognizes the unique DoD environment in which implementation has to take place and incorporates proposals for evaluating the effectiveness of what is done.

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II. The U.S. National Robotics Innovation System

A. The "Innovation Systems" Framework: A Brief Overview

There is a long tradition of researching industries both in economics (Industrial organization—"IO" studies) and in sociology (population ecology studies). To a large extent, these studies focus on that which is easiest to see in industries, which is the body of suppliers: the supply-side of an industry. However, the limitations of these approaches have become apparent: they are largely static, neglect many of the actors involved in industries, and have a limited ability to explain innovativeness (Organisation for Economic Co-operation and Development [OECD], 2011). Starting in the 1980s, a new stream of thought called the Innovation Systems approach emerged (Freeman, 1987), which grew out of the perception that traditional industry studies were, in fact, hiding as much as they were illuminating by missing or underemphasizing some of the most crucial elements and aspects of industries. Some of these studies evolved from studying national systems of innovation, where it was very apparent in countries such as Japan (Freeman, 1987) that a much wider and more varied system of actors were intimately involved in innovative activity (Nelson & Rosenberg, 1993). Other studies emerged as studies of technology systems, set on a global stage unbounded by geographic factors. Researchers further outlined a sectoral systems approach and problem-focused approaches (Metcalfe & Tether, 2003). As of the present time, the innovation systems approach has become the received wisdom in many economic policy-making circles. (See the 2003 RAND report [Birkler et al.] to the U.S. Congress for a useful example and the 2011 OECD report for an overview of national innovation systems.) Freeman (1987) provides a reasonable consensus definition of this approach: a national system of innovation is "[T]he network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies."

Two elements distinguish the innovation systems approach to studying industries. First, the cast of actors included in this approach is considered larger and more varied than in traditional industry studies. Innovation system studies highlight all the actors involved in an industry, many of which play subtle roles. Examples include the role of

- government bodies, such as Japan's MITI, which is explicitly charged with industrial policy, or regulatory bodies, such as consumer standards authorities, which shape markets;
- public or private standards bodies, which cover technology compatibility issues, and independent quality assessment agencies (e.g., in automobiles J. D. Power);
- industry consortia of various kinds, such as those involving shared R&D, supplier groups, or user groups;
- educational institutions, such as universities, providing fundamental and applied research as well as training for industry-specific occupations;
- public research institutes;
- producers of products and services;
- secondary suppliers and intermediaries, such as service firms, sales and marketing channels, and contractors that provide services to the system; and
- users.

Together with emphasizing the large number and variety of actors populating an innovation system (the components of the system), innovation system research emphasizes a second important factor, which is the nature of the linkages between the components of the system. What is important is the web of activities connecting players in the system. In particular, researchers draw attention to the interactive nature of innovation systems—one where interaction between users and producers increases the performance of products and services produced in the system by compound user-producer learning over time. Much of this performance improvement happens via patterns of networked one-to-one user-producer interactions, particularly when technically competent users, often with very specific demands, interact with technically competent suppliers with specific skills in designing products and services. These interactions generate iterative cycles of learning and mutual adaptation that increase the competence and capability of the overall system.

Third, I should also mention that the conception of innovation systems takes for granted that they are dynamic, that is, evolving over time. New players arrive and are incorporated into the system, bringing with them new resources of knowledge for problem solving. At the same time, defunct players may drop out of the system and their knowledge may be discarded (Metcalfe & Tether, 2003).

Yet despite the inclusion of demand in innovation systems research in theory, there is still a lack of demand-side orientation in innovation policy as it is practiced. Why? Quite probably because demand is the least visible, most intangible aspect of innovation systems. In Figure 4 below we incorporate demand side players into our illustration of the U.S. robotics innovation system. As shown by Porter's *The Competitive Advantage of Nations* (1990), domestic demand conditions are a crucial factor in the performance of innovation systems. It is to this issue that I turn next.

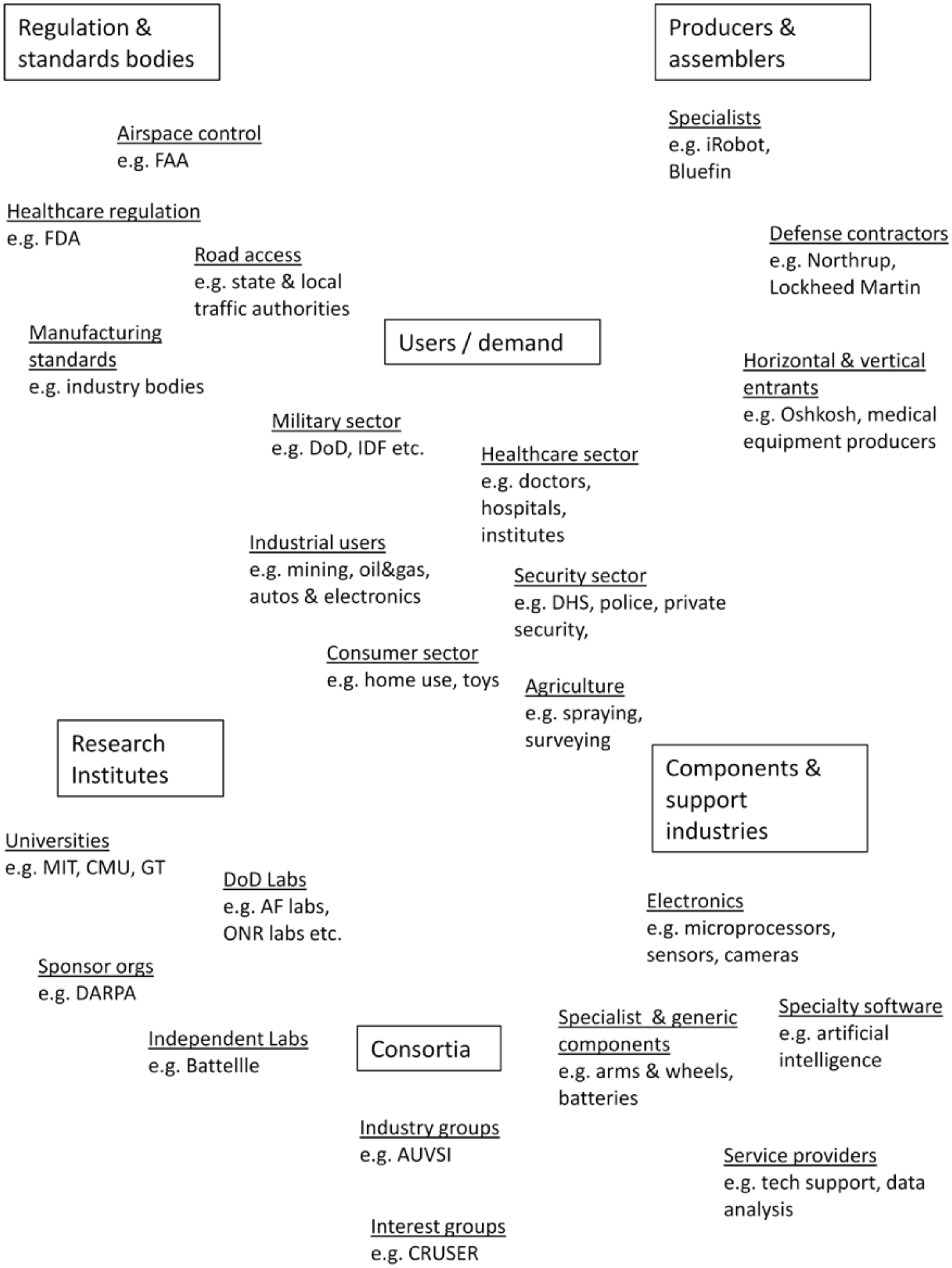

Figure 4. The U.S. Robotics Innovation System, Illustrated (Linkages not Shown)

B. The Porter "Diamond" Framework

Among research on innovation systems, Porter's (1990) work on national competitiveness stands out with regard to its emphasis on demand-side factors. Porter's work is based on a large set of case studies drawn from 10 countries and 100 internationally competitive industries that was undertaken in the 1980s. Porter's basic premise was that the long-term international competitive success of firms was a product of their innovativeness. Porter looked for companies that were globally successful in export markets and then traced the national context in which they were embedded. Analysis of the cases revealed that four generic factors working together as a system constituted the context for successful exporters. Porter called these factors the "Diamond" (see Figure 5):

- Factor conditions: refer to national factors of production such as skilled labor.
- Related and supporting industries: refer to the presence of internationally competitive supplier industries.
- Domestic rivalry: refers to the national governance of competition and the amount of rivalry between firms.
- Demand conditions: refer to the nature of domestic demand for firms' goods.

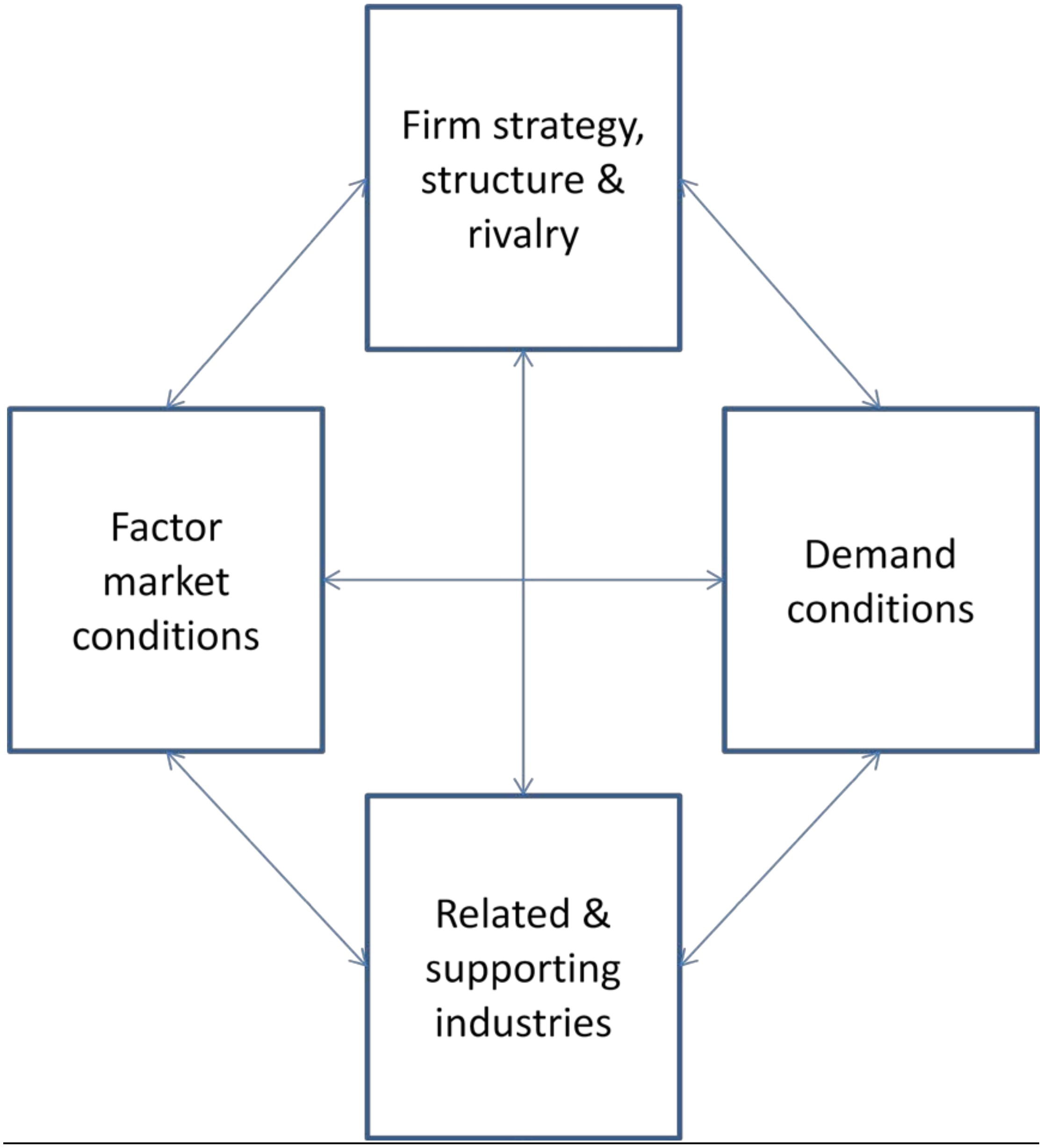

Figure 5. Porter Diamond Model

One of Porter’s key conclusions was that the location of demand in innovation systems remains important and, specifically, that the quality of domestic demand is a key factor in driving firms to innovate in a national system (Porter, 1990). The observation and reasoning here is that there are various ways in which national innovation systems depend on sophisticated users for a key part of their vitality. Examples include: the role of Finnish customers’ demand for sophisticated mobile phones in the rise of Finland’s telecommunications sector (in particular, Nokia); the role of sophisticated local demand in the New York, Paris, and Milan fashion clusters; and the role of DoD demand for UAS for prosecuting the War on Terror (WoT) in the development of a local (mainly Southern Californian) cadre of competitive suppliers of these systems.

While Porter’s claim that “location matters” for demand is well known, the explanation for this pattern is less well understood. The key to the location-specificity of demand—that is, the claim that the location of demand matters—is that the information required for solving problems (e.g., customer needs for improvements to a product) must be brought together with the capability to solve the problem (e.g., skilled producers with the ability to engender a solution). In other words, the location of the intense interactions between users and producers that is required for the process of customizing innovations is driven by the “stickiness” of information (von Hippel, 1994). If information could be transferred at little cost, then the problem-solving activities that lead to refined innovations could be located anywhere. However, empirical work on the stickiness of information suggests quite the opposite: for instance, Teece’s (1977) study of 26 international technology transfer projects showed that information transfer costs averaged 19% of the project costs, ranging from 2% to 59% depending on the nature of the technology transferred. When information is costly to transfer, problem-solving activity will tend to occur where the information is stuck. There are several reasons why the kind of information used in innovation is often sticky:

1. Much of the relevant information for problem solving is very specific and particular. This information is private to users, may be difficult to describe, and thus resists being made explicit (and therefore more easily transferable) and instead remains implicit or “tacit” in nature.
2. To generate a solution to a problem may require very large amounts of information about the problem to be transferred from users to producers, including a lot of information about the exact context in which the problem occurs. For example, problem solving in a sophisticated military aircraft may require a great deal of information transfer.

3. Information may be sticky because it requires high absorbative capacity on the part of the senders and the receivers, that is, the producer has to possess or acquire the requisite information and knowledge to be able to use the user's information.

4. Problem solving is dynamic, that is, the information required is updated in iterative cycles of problem-solving activity.

In the Porter Diamond, the key characteristic of local demand highlighted is its sophistication. Porter (1990) argued that lead users and markets are important for prodding producers to improve their product offerings and innovate. Here, the local market has a disproportionate effect on firms' perceptions of what users want more generally, and can often serve as "bellweathers" of emerging customer demands, thus giving producers an earlier picture of where the market is heading (Porter, 1990; Edler & Georghiou, 2007). Other local demand conditions that may be important include (i) the size of the local market, which may enable producers to develop economies of scale; (ii) the diversity of local demand (how fragmented the local market is), which may lead producers to develop sophisticated offerings responding to a wide variety of market needs; and (iii) how well-formed and well-articulated local demand is, which may enable producers to have a better "read" on the market's signals (Geroski, 2003).

C. The Role of "Venturesome" Users in Innovation Systems

A further crucial characteristic of local demand is the venturesomeness of users (Bhide, 2006). By venturesome, I mean the willingness of users to experiment with new products and services. For example, the DoD has a long history of willingness to be a venturesome user of new technologies, UAS included. However, while the venturesomeness of producers (for example, their entrepreneurship) is frequently highlighted as a key element of the vitality of innovation systems and whole economies, the venturesomeness of users—which is equally important for the innovativeness of a system—has been largely ignored. Yet clearly one needs both venturesome producers and venturesome adopters (users) to drive the vibrancy of an innovation system.

Understanding why user venturesomeness is necessary requires a closer look at the nature of adopting innovations. For several reasons, I see that considerable risk-taking is required on the part of users seeking to adopt an innovation. These reasons can be summarized as follows (Bhide, 2008):

- One cause of risk is whether the innovation will work as it is supposed to, meeting minimal standards, and whether it will work well. Upon longer-term use there is the question of whether it will keep working well or, as in the case of the Lockheed C5, need very expensive unanticipated repairs to its wings. Long-term use might also reveal issues relating to human safety (asbestos) that creates unforeseen operating expenses or environmental pollution (CFCs) or disposal costs (nuclear waste) that were not initially accounted for. Indeed, the novelty of innovations implies that incalculable costs are involved in their application. Given how problematic it is to predict the performance of innovations, it comes as no surprise that innovations "bite back" with some regularity, imposing unforeseen private and social costs because their consequences prove to be different than those they were designed to have. With consumer goods, business-to-business goods, and most certainly military goods, there are numerous examples of innovations biting back, for example, Agent Orange in Vietnam and depleted uranium in Gulf War I.

- Another cause of risk for users is whether an innovation will attract a critical mass of other users. This risk is particularly large for goods that exhibit bandwagon effects driven by network externalities or the presence of complementary goods that create lock-in effects for winners, such as that experienced in computing with Microsoft Windows. However, failure to attract a critical mass of users is also risky when there are significant economies of scale or learning effects for a product, since in the absence of a critical mass, these scale and learning effects do not transpire as predicted. One could argue that this is the case for marine robotics, where the absence of a critical mass of users keeps the USN’s marine robotics very expensive as compared to UAS, for example, where scale (and therefore learning effects) are more evident (Button et al., 2009).

- A third cause of risk to users is uncertainty about the value of an innovation in relation to its price. To be frank, this issue is already a conspicuous one in the economics of military artifacts because it goes without saying that evaluating the worth of many military products and services is extremely difficult, and ultimately, these decisions are made in the mind’s eye of the most senior commanders in the armed Services. What, for example, is an F-22 really worth compared to its price? What are 188 of them worth compared to what the program cost? Behavioral researchers have argued that “[P]eople don’t have clue theorists about the value of things they have never experienced” (Bhide, 2008) and that because of the unmeasurable/unquantifiable nature of their valuations, they cannot form objective estimates about the worthwhile-ness of adopting many innovations. Similarly, if the F22 is never deployed in competitive combat, we will never know its true worth. Instead of valuation, users really on their venturesomeness, that is, their willingness to experiment with and try out new stuff.

- Lastly, the uncertainty about the costs of implementing innovations imposes risks and therefore requires venturesomeness on the part of users. Owing to several factors such as organizational inertia and barriers to innovation (Dew, 2010), innovations often suffer from frictional costs in the implementation process. Given that innovations frequently don’t perform as planned, deriving utility from them requires considerable user problem solving and learning by doing, none of which can be accurately costed ahead of time. Indeed, one of the overwhelming facts about innovations is just how much time, treasure, and talent is expended in the pursuit of implementing them (Denning & Dunham, 2010). In the UAS domain, good examples include UAS crashes in the history of the U.S. Air Force (USAF; Gertler, 2012), which illustrate the non-trivial costs of learning to master this new technology. It also illustrates the irony of deploying UAS on the basis of expectations of lower manpower requirements: in fact UAS exhibit surprising total cost of ownership challenges owing to their high consumption of manpower, to both operate them and to analyze the huge amounts of data they collect.

A good understanding of the need for venturesomeness among users is a prerequisite for appreciating what kinds of actions the DoD might take to accelerate the diffusion of air, marine, and utility robotics in the U.S. Based on rational diffusion theory, prospective adopters will evaluate the balance of pros and cons from adopting an innovation: if the risk of downsides can be reduced, then the payoff to adoption improves and I would expect adoption rates to increase (all other things being equal). Therefore, if it is in the DoD’s long-term interests to strengthen the U.S. robotics innovation system by increasing domestic demand for robotics from all sectors of the economy, then figuring out how—at the margin—to reduce the necessity for user venturesomeness becomes the cornerstone for such strategies.

D. CI and Defense Demand Complementarity

My argument so far has been that the U.S. needs to develop a stronger national robotics innovation system to support the long-run development of defense robotics that will help make the nation more secure. My review of innovation systems has highlighted the following: first, that the systems perspective is helpful because it draws our attention equally to all the diverse actors—and the interactions between the actors—in an industry such as robotics, thus helping us not to overlook the core role of users and demand in the system; second, that the characteristics of demand—in particular, sophisticated domestic users that demand high performance—is an important aspect of a vibrant national innovation system; and third, that user venturesomeness is prerequisite for the uptake of innovative goods offered by producers in the system. Now I turn to a fourth element of demand that is relevant for dual-use goods such as robotics, which is the complementary nature of commercial and military demand for robotics.

I start with what the U.S. defense establishment contributes to the nature of demand within innovation systems.

First, the business of defense has performance needs that often go beyond the requirements of commercial or consumer systems. This has sometimes been referred to as “gold plating” defense equipment, but the need for such elevated performance is obvious: first, to possess equipment that performs distinctly better than that possessed by nations hostile to the U.S. (arms race logic); second, by doing so, to reduce the risks of engaging in combat for U.S. military personnel (casualty reduction aims); and third, one might add a deterrent component, which is to intimidate hostile entities and thus dissuade them from aggressive acts, by them observing the U.S. commitment to equipment that is significantly better than their own. While it is hard to estimate the cost of wars avoided, it would seem that a degree of gold plating is more than worth it in order to avoid a major conflict.

The second way in which defense contributes to demand is by playing the role of lead user, engaging in experimentation and in pioneering and piloting new technologies. In this regard, the DoD has a long history of being a venturesome user of new technology, par excellence. While the list of pioneered technologies is a very long one, Hooks' (1990) case study of the genesis of the microelectronics industry provided a particularly good example of the DoD as a lead user that prodded and pushed producers to improve their product offerings (Porter, 1990). The recent wars in Iraq and Afghanistan provide numerous similar examples.

Third, the DoD contributes to the nature of demand via its large-scale Programs of Record (PORs) that provide a source of relatively stable, long-term demand commitments for innovative goods. These often stretch over many years, as with Lockheed C-130 production (at over 50 years, the longest continuous production of a military aircraft) or the prospective multi-decade commitment to the highly innovative F-35.

Commercial businesses contribute different characteristics to the nature of demand within innovation systems than those contributed by the DoD. However, in many ways, these elements are complementary to what the DoD brings to the table.

First, commercial businesses have a cost focus that overrides other requirements. If commercial firms cannot make money using an innovation, then they have no reason to pursue it. As I have already discussed, while there is a distinct need for firms to be venturesome because of the difficulties in estimating the value of innovations and their costs of implementation, the cost focus of firms, at minimum, puts significant pressure on producers to attend to costs in a material way if they want to win business with customers.

Second, the potential size of most commercial markets ultimately dwarfs the size of defense markets, which means that commercial demand holds the promise of larger economies of scale and bigger learning effects in production that defense markets do not.

Third, commercial markets have a broader variety of needs than in military markets, simply because there are many more users (a function of scale, again). This often creates technology niches that support the survival of a broader variety of producers in an industry than many military markets exhibit (Birkler et al., 2003). Moreover, whereas the DoD sometimes commits to long production runs of innovative technologies to meet demand, commercial markets (and, even more so, consumer markets) tend to operate on shorter timescales. Commercial and consumer markets therefore exhibit market dynamics that demand ongoing processes of incessant innovation from the supply base as producers are forced to compete to adapt their designs with the latest technology to meet emerging user needs.

Fourth, and finally, the incentive structure of commercial demand also tends to support the inclusion of disruptive innovation more speedily than military demand does (Christensen, 1997). Again, the reason for this may have to do with demand variety in the commercial space. By its nature, disruptive innovation tends to creep in at the margins of markets, starting with users and uses that are outside the mainstream. For instance, Christensen (1997) found that new generations of disk drives were not competitive against current generations, so these disk drives found their first uses in applications outside the mainstream. However, if their trajectory of improvement is faster than mainstream technologies, eventually disruptive technologies catch up with mainstream performance requirements, invade that market space, and disrupt conventional technologies. Such dynamics have played out with ease in a wide variety of commercial products and services. However, as Max Boot (2008) reminds us, the processes for adopting disruptive technologies in the military are somewhat different because one does not have as much demand variety inside one nation that stimulates these dynamic processes. National militaries have a history of resisting and rejecting promising disruptive technologies. Instead, disruptive technology dynamics often play out across nations and are seen eventually in combat clashes between nations.

Thus, defense and commercial markets in many ways represent the ying and yang of demand characteristics in innovation systems: they are different, but they complement each other. Defense users often have very high end needs (for good reason), whereas commercial users are much more focused on cost. Defense supports long production runs of what are often—at the beginning of production—highly innovative technologies, whereas the commercial sector holds the ultimate promise of larger scale and lower costs, albeit accompanied by a wider variety of more rapidly changing demands. Defense fulfills the lead user role par excellence and is widely experienced with handling immature innovations, but the structure of demand in the commercial sector supports the emergence of disruptive innovations more readily than the military sector does. This complementarity adds strength (as well as complexity) to systems of innovation for dual-use technologies and, from a policy standpoint, is an opportunity to be leveraged.

E. Binding Constraints on Industry Growth

Next, I want to consider what is probably the hardest part of the argument for demand-side intervention in the U.S. robotics industry: the notion of focusing on the *binding constraints* on industry innovation. The notion of binding constraints derives from economic growth theory—in recent times, via the work of Rodrik (2008)—but more broadly draws on the Hirschmanian tradition in growth economics. According to Naude (2011),

> By binding constraints I mean constraints on economic growth and development which, if relieved, would have a more significant impact on promoting growth and development than other constraints. Binding constraints, as long as they remain in place, would hinder growth, even if other possible constraints or determinants of growth are addressed.

In operations management, this would be called this a “bottleneck” on innovation, and the premise is that by removing a bottleneck, one can have a larger impact on the innovation—in this case—within an industry than by applying effort to several variables at once or by using a shotgun approach. In turn, the idea of attacking binding constraints is based on the further premise that while we can describe the general features of industries using the innovation systems model, industries develop in a contingent fashion and therefore differ in their opportunity sets and constraints at any given point in their development. The notion of uneven development is well established in research on industry growth: Schumpeter (1976), for instance, spoke of "discrete rushes" in development; there is also the development blocks approach, which similarly highlights a disequilibrium concept of industry development. In fact, everything we know about industry development from the Schumpeterian tradition of evolutionary economics suggests that systems evolve via disequilibriums and that they are best thought of as being in a constant state of disequilibrium. Development is therefore uneven, which means there are opportunities to make a larger impact on development of a system if you know where to push it at particular points in time; in other words, if you know where the bottlenecks are, one can develop strategies to tackle these leverage points. This is attractive from a policy perspective because organizations such as the DoD do not have unlimited resources, so it makes sense to focus their scarce capacity directly on alleviating key bottlenecks on innovation, in the hope of generating the biggest bang for their buck (Rodrik, 2008, pp. 56-57). This beats using a wish list of desirable strategies to improve an industry's innovativeness, where many actions on this list will not address the most binding constraints and therefore will not have much impact on innovation.

Rodrik (2008, p. 57) suggests that this method of focusing on binding constraints can be portrayed as a decision tree (see Figure 5). We start by framing the overall problem: "Why is the US robotics innovation system weak?" (CCC, 2009). We then trace the probable causes, organized by the theoretical elements we have laid out so far, such as the elements of innovation systems highlighted in the Porter Diamond and the elements of user venturesomeness highlighted by Bhide. The idea is to uncover the most important bottlenecks that are constraining the innovativeness of the system: Is it a case of A or B or C? As we move down the branches of the decision tree, we are discarding candidates for the key bottleneck on industry innovation. Once we identify the candidate imposing the most constraint, then we can strategize about how to relax or remove that candidate factor.

In the case of the U.S .robotics innovation system, my analysis suggests that demand-side factors (specifically, lack of discovery of viable, profitable uses for robotics, and unknown implementation costs) are the leading bottleneck candidates that are weakening the U.S. robotics innovation system or, at minimum, that these factors are as strong a candidate as any other factor in the decision tree. Also notable is the relative weakness of U.S. firm rivalry in non-defense sectors, perhaps owing to the relatively low number of U.S. firms specializing in non-defense robotics (relatively low numbers compared to global competitors such as Japan and Europe, that is) and potentially because of some defense-sector crowding-out effects (e.g., the attractiveness of the U.S. defense sector, with its strong demand and well-supported R&D, has potentially drawn U.S. resources away from other, non-defense robotics businesses).

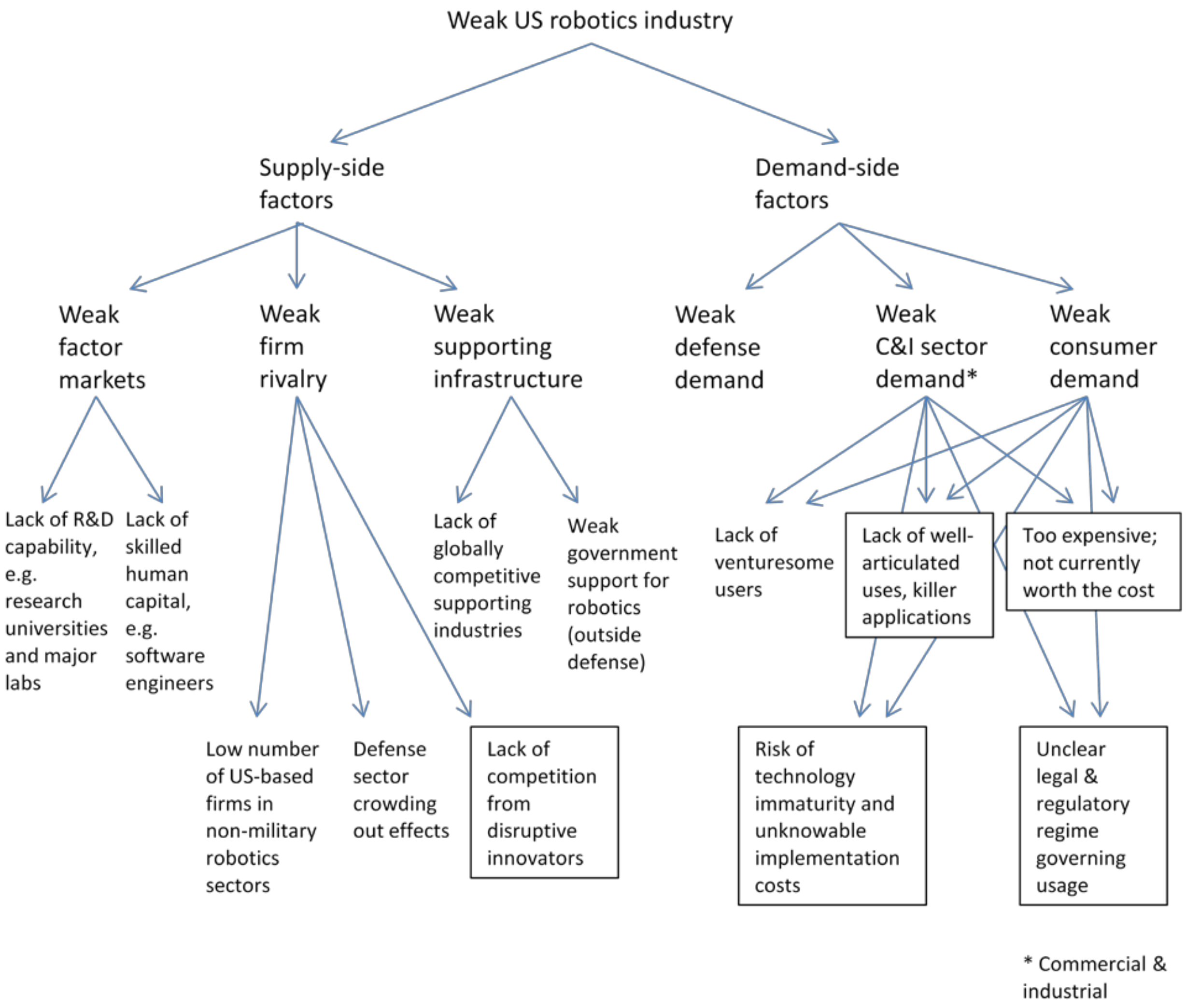

Figure 6. Binding Constraints Decision Tree Analysis (Shown in Boxes)

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III. Demand-Side Support Mechanisms Available to the DoD

A. Summary of Mechanisms

Based on my binding constraints analysis in Figure 6, in my assessment, there are five prime candidates (each indicated with a boxed edge) that may be constraining the U.S. robotics industry from flourishing. Four of these candidates are clearly on the demand-side, being drivers of weak commercial and industrial (C&I) and weak consumer demand for robotics systems. A fifth—lack of competition from disruptive innovators—is an aspect of weak rivalry among U.S. firms in some sectors of the robotics industry but also has distinctive demand-side aspects and can be influenced by DoD acquisition strategies, so I will include it in my analysis and address here how it might be mitigated.

In my estimation, the presence of these constraint candidates creates scope for policy intervention of some kind on the demand side (in my case, via DoD acquisition strategies) in order to alleviate, mitigate, and/or manage these constraints, so that improvements can be made in the uptake of unmanned systems in the U.S. domestic market. Innovation systems theory suggests that such interventions will lead to the long-term strengthening of the U.S. robotics system, with benefits for the DoD.

The four demand-side constraints are as follows:

1. <u>Lack of well-articulated uses, killer applications</u>: This may be a function of producers knowing less about user needs than is desirable and users that may not yet be aware of what bleeding-edge robotics are capable of.
    - Appropriate strategies for addressing this issue involve the DoD demonstrating well-defined user demands that provide examples of robotics functionality and value.

2. Too expensive, not currently worth the cost: For many cost-sensitive commercial and consumer applications, it may be that current robotics offerings are perceived as too expensive to be worth implementing.
    - Appropriate strategies for addressing this issue will address cooperative and catalytic acquisition strategies that promise enough volume to enable producers to make significant cost reductions via economies of scale and learning effects.
3. Risk of technology immaturity and unknown implementation costs: Users may also wonder if robotics technology is mature enough to work as promised in their applications and what the implementation costs will really look like.
    - Appropriate strategies for addressing this issue will reduce the information discovery costs for the private sector by sharing information about DoD experiences, where possible.
4. Unclear legal and regulatory regime governing usage: Unmanned systems pose many safety challenges in cluttered people-populated environments, a prominent example being the integration of unmanned systems into federal air space.
    - Appropriate strategies for addressing this issue will involve the DoD participation in accelerating a comprehensive package of institutional reforms that will present clear “rules of the game” for unmanned systems usage and foster technology standards where they are necessary.
5. Lack of competition from disruptive innovators: A key issue in innovation is the incentive structure for the emergence of new, disruptive models for unmanned systems. Often, these disruptive models are not technology-driven per se but involve a recombination of operational practices, financial models, and technological adoption.
    - Appropriate strategies for addressing this issue will include the alternative acquisition strategies to traditional major acquisition programs for unmanned systems.

In the subsequent sections, I address each of the acquisition strategy options in more detail. Throughout, my efforts are guided by the latest research on demand-side policy tools that have proven efficient and effective in the past for other technologies and innovation systems (Edler & Georghiou, 2007).

B. Demand Definition: Demonstrating Well-Articulated Uses and Killer Applications

A large part of the opportunity for DoD demand-side strategies can be explained by information asymmetries between potential users of robotics systems and producers of these systems. For one thing, users often lack information and knowledge about what robotics systems are available and what the systems can—or could potentially—do for them, that is, the majority of potential robotics users are busy carrying out their daily tasks and therefore frequently are not invested in understanding what bleeding-edge robotics are capable of. Second, producers often lack information and knowledge about what users want, need, and are willing to pay for. This is despite the fact that changing user needs for the future are one of the top factors in creating opportunity for innovation (BDL, 2003). This is connected to a third problem, which is that the costs of resolving these producer-user information asymmetries can be very high. Economists refer to these as the transaction costs of coordinating the market. From the producer perspective, demand is scattered; producers have to locate users that might have a need for robotics if only they knew more about them without the benefit of understanding what the user's privately known needs are or how the user's own articulation of those needs might unfold over time as users learn about the most valuable applications of robotics. Here, the innovation system fails because of poor interaction between users and producers, which results in producers being unable to read what are very noisy market signals (what Geroski [2003] calls the problem of "inchoate" demand), whereas what producers really need are user demands defined concretely enough that they can reasonably try to meet them. In turn, this results in inefficiencies in R&D investments, which are inevitably made on the basis of producer perceptions of noisy demand. The result can be a vicious cycle where the transaction costs of user-producer coordination hold the market in a "bad" equilibrium where both sides of the market miss the potentialities of a technology, while a better equilibrium might be readily attainable were the information asymmetry issues to be overcome.

Experience shows that public sector acquisition policies may sometimes play a key role in resolving some of the information asymmetry problems that haunt user-producer interactions, as described previously (Rothwell, 1984). The key here is vicarious learning by private-sector users from the demonstrated uses of robotics by others, with UAS usage in the WoT being an excellent example of how this process works. Such demonstration effects are well known from innovation diffusion research to be a key factor in the uptake of innovations (Rogers, 1995). The two major wars have provided an extensive, varied, and tough testing and proving ground for UAS usage, enough of which has been observable to the private sector. By providing a critical mass of observable UAS usage, the DoD has provided a focal point for broader robotics usage and development (Rosenberg, 1976; Metcalfe & Tether, 2003). The information spillovers, both intentional and unintentional, from these programs have considerably raised public awareness of the functionalities and potential value of UAS, with “Predator” drones in particular becoming virtually the icon of the WoT, thus entering the U.S. public psyche and providing a “taster” of robotics potentialities (see, for example, Newsweek, 2008). Strong military demand for UAS, with news stories reporting insatiable demand by operational commanders for UAS assets and Congress authorizing significant future UAS procurement (Gertler, 2012), has added further credibility to claims that this particular kind of robotics system has made the leap to becoming a mainstream technology. UAS has many potential applications, from police work to agricultural spraying to real estate sales. As suggested by signaling theory, nothing communicates to the private sector the potential for UAS usage better than demonstrated applications and concrete future orders for the technology by the DoD. These orders often address military-specific values and goals, such as reducing the risk of military casualties. Importantly, the demonstration value of DoD UAS usage does not have to encompass specific private-sector needs in order to be of value in informing the broader market of UAS viability. There just has to be enough overlap between defense and private-sector demands that private-sector observers can benefit from the demonstration effects of military usage, and there is evidence that such overlaps often do exist early in the life of major innovations (Geroski, 1990).

Thus, my overall message is that the demonstration role of DoD usage of UAS is instrumental in overcoming information asymmetry problems in the private sector. The DoD “show and tell” about UAS has been occurring on a large scale over the past 10 years. Other DoD initiatives such as the DARPA Mojave Desert robotics Grand Challenge 2005 have also played an important role, in that case broadening user awareness to the rapidly accelerating capabilities of terrestrial unmanned systems (UMS). Going forward, from an acquisition and procurement strategy perspective, one issue is for the DoD to acknowledge the role that our activities have played in the vicarious learning of private-sector robotics users, much of which is just now beginning to become evident, and realizing the potential that mobilizing private-sector demand may have in catalyzing the evolution of the U.S. national robotics innovation system. The DoD should not smother these information flows as the WoT winds down in Afghanistan; indeed, they need to replace them in order to keep information about robotics flowing into the private sector. This is particularly the case for Unmanned Underwater Venhicles (UUVs), where much less information is publically available (see Button et al., 2009. I will take up the tension between needs for secrecy and public information release in more detail in Section 3.4 on information sharing). The truth is that despite Bill Gates’ well-known 2006 article, we are really a long way from a robot in every home. In large part, this is because awareness of the potential uses for robotics systems are only now beginning to diffuse; in many instances, users are just beginning to figure out how to apply robotics. What private-sector demand exists is still in market niches, and we are a long way from a pan-robotics market. I have argued that DoD usage of UAS has been one of the major factors in accelerating what pan-robotics awareness there is among users. A lot of perception changes have yet to take place among users, but the DoD should not overlook the feedback between these positive perceptions and the nation’s interests in building a robust U.S.-based robotics industry.

C. Cooperative/Catalytic Acquisition: Addressing High Costs of Innovations

Cooperative/catalytic acquisition involves procurement by the DoD not only to fulfill mission needs but also to stimulate demand in the private sector and/or by other federal/state/local actors. The idea is very similar to consortia buying, but in this instance, with the DoD acting as the consortia procurement lead. Acquisition can be of one of two kinds. Cooperative acquisition involves the DoD and private/state/local/other federal sectors bundling their demand to jointly buy innovative robotics offerings. Catalytic acquisition involves pass-through procurements that are made by the DoD but are ultimately used 100% by others. Both types of approaches have been tried in the past, including the U.S. Experimental Technology Incentives Program in the 1970s (Rothwell, 1984) and a major program that successfully accelerated the diffusion of energy-efficient technologies in Sweden in the 1990s (Neji, 1999).

Cooperative/catalytic acquisition can be effective in accelerating demand and the diffusion of innovations for a number of reasons. First, because it bundles and consolidates demand that may otherwise be scattered around the market, it helps overcome some of the information asymmetry issues I mentioned in Section 3.2 by providing a clear, well-articulated demand to producers. Second, the bundling of demand creates a critical mass of users and thus has the potential to create bandwagon effects, which can be very effective in getting private demand moving and in shifting the market into a dynamic state that is receptive to both current and future innovations. Several consequences occur, as follows:

- Demand bundling via cooperative/catalytic acquisition may enable producers and users to invest in economies of scale facilities, thus lowering the costs of innovations.
- Bundling may enable learning-curve effects to be gained, again lowering innovation costs and enabling the expectation of cheaper costs in the future.

- Bundling reduces user risks of getting stuck on the wrong technology (see Section 2.3) because the technology they chose failed to attract a critical mass of other users.

One notable example of just how effective cooperative acquisition can be comes from the emergence of very-low-cost radio frequency identification (RFID) tags since 2000 (Dew & Read, 2007). Prior to the Millennium, the RFID market was typified by a "chicken-and-egg" problem in which users did not adopt the technology in sufficient numbers because it was too expensive, with vendors in turn unable to produce RFID tags in the volumes necessary to make it cheaper. A range of organizations recognized that this problem might be solvable but none, acting on their own, could coordinate the activity of enough players in the system to get a collective shift to occur in the marketplace. A consortium of potential RFID users formed the Auto ID Center at MIT to overcome these issues by developing a wireless bar coding system called the electronic product code (EPC). A key consortium member—Walmart—developed an ingenious catalytic acquisition strategy by mandating that their top suppliers adopt the EPC on a particular timetable. This automatically forced Walmart's largest suppliers to start procuring EPC tags to attach to any shipment designated for Walmart, generating overnight demand for hundreds of millions of highly innovative, low-cost RFID tags. This was a manifest "visible hand" coordination of demand for innovation. But what was also interesting was the "invisible hand" response, since subsequent to Walmart's mandate, the DoD announced its own mandates to suppliers, on precisely the same timetable as Walmart (the top 100 suppliers starting in January 2005, with the rest on a planned timetable thereafter), that is, it coordinated procurement on the heels of Walmart's strategy. Other members of the Auto ID Center, such as Metro of Germany, and Tesco in the UK, followed with similar mandates. The result was a large-scale, indirect, catalytic acquisition strategy for tags, with Auto ID Center members getting their suppliers to make collectively massive procurement of the novel EPC tags.

Based on this example, one can imagine several other actors with demand-side profiles for robotics that the DoD could potentially collaborate with for cooperative/catalytic acquisition strategies. Within the security domain, the interest of many actors in UAS is already becoming evident. Examples of state and local police forces already using some UAS have been reported, as have some examples of UAS outsourcing by DHS to private security companies (PSCs). It is not hard to imagine that the collective demands for UAS of these various state/federal/local/private security entities might be bundled in order to give a significant demand-side kick-start to the UAS industry to take it well beyond its current DoD-focused development by diffusing UAS technology among a much wider range of security operators. A second area where cooperative acquisition may have potential is utility robotics. The DoD employ some of the most expensive military manpower in the world and therefore have strong incentives to invest in substitution of mundane but labor-intensive tasks (e.g., cleaning) with utility robots. The U.S. private sector and various public-sector entities share these incentives in many instances. However, the utility robotics market remains (with the exception of iRobot's vacuum cleaners) woefully underdeveloped and much in need of a demand-side kick-start that the DoD might contribute.

D. Information Sharing: Addressing the Costs and Risks of New Technology Implementation

Despite demonstration effects and cooperative acquisition, prospective UMS users still may not know enough about a specific robotics system to make a decision about adopting it, owing to lack of information about the costs and risks associated with adopting the new system. Prospective adopters know that they will only learn what a robotics system *really* costs to implement, and what its risk profile looks like, by actually trying the technology. This is why user venturesomeness is a key part of the adoption picture for any new technology. Therefore, the goal of my third suggested DoD acquisition strategy is to reduce the discovery costs and risks of UMS adoption for other users by information sharing. Prospective adopters can then learn some information from public sources (e.g., the experiences of other users), thus leveraging information that is already available within the system of users instead of bearing the cost of learning this information privately. As outlined in Section 2.3, users face four significant issues as they make adoption choices: How well will the technology work? Will there be a critical mass of other users? What is its value to me in relation to its price? And, what are the costs of implementing it? A pool of common knowledge within an innovation system that addresses these issues reduces some of the information deficits plaguing prospective robotics users, thus lowering adoption costs and risks and allowing the industry to grow via faster adoption than would otherwise be possible.

One method of creating common knowledge is for the DoD to proactively share information about their experiences adopting various UMS with the prospective user community. Of course, such sharing has to be done with care in order to protect sensitive information and knowledge. What kinds of information can be shared varies with the recipient: sharing DoD experiences with DHS is obviously different than sharing with local emergency responders (e.g., fire) or private-sector users. However, although there is a clear tension with DoD imperatives for secrecy with respect to the technical details of some of its UMS programs, the vast majority of the information that is useful to other prospective adopters of robotics systems is of a much more pedestrian kind, involving key "lessons learned" from DoD experiences adopting unmanned systems. A variety of government agencies already report some aspects of this information, for example, USAF UAS crash test data demonstrating the learning curve compared to manned aircraft; the exact number of UAS in operation; aggregate hours flown (Gertler, 2012). What would make more sense is for such sharing to be done deliberately and consistently with an eye to the beneficial effects of information spillovers on the adoption of UAS by other users, rather than as a by-product of some other goal. Probably the primary method of sharing involves one-to-many modes of reporting, for example, sharing information at public conferences with AUVSI consortia members and issuing written reports. Much of this reporting could take the form of soft, qualitative, lessons learned–type reporting on DoD experiences adopting UMS that does not involve the release of any sensitive technical information but is highly informative to other users who are trying to make up their minds about the costs and benefits of adopting a specific UMS. A second form that information sharing might take involves one-to-one interactions and two-way sharing by offering a variety of “open door” arrangements for prospective UMS adopters to learn from DoD experiences with robotics. Here again, the point is that the DoD may have lessons learned to trade with DHS, for example. But it may also benefit over the long run from carefully informing a much wider range of prospective public- and private-sector UMS adopters about its experiences.

Another opportunity to create public knowledge about the costs and risks of adopting UMS is via private-sector information spillovers. There is a clear incentive for the DoD to encourage information spillovers between other players in the U.S. robotics innovation system. Several mechanisms might be used to encourage such spillovers. One is producer joint ventures and alliances. For example, the typical DARPA program structure might involve two or three teams—sometimes industry teams, sometimes university-industry teams—competing to create the best design. Such processes tend to create more opportunities for a rich set of information spillovers, including to users, especially when the program is of a more downstream “development” nature, as many recent DARPA programs have been.

Lastly, the DoD might also consider engaging in some joint adoption projects with other users. Some examples of partnering already exist, for example, the NPS partners with MBARI (Monterey Bay Acquarium Research Institute) on marine robotics. However, these relationships are more research oriented and less adoption driven. While research relationships are to be encouraged, so are implementation-driven projects, where the goal is learning and discovering the costs and risks of implementing a major robotics initiative so that these costs and risks can be reduced in future implementations. One key to these processes is that they activate interactions between the DoD, other users, producers, and others in the robotics innovation system, with the end goal being the discovery and distribution of new information relating to operational usage of a particular UMS. The most appropriate focus for such partnering on projects is obviously applications that are not of a sensitive nature, for example, *back office* apps such as supply chain efficiency initiatives, or crisis response within the U.S. For example, opportunities exist to partner with other federal agencies (e.g., DHS), state and local authorities (e.g., emergency responders), and private-sector players (e.g., PSCs) on the application of robotics systems in domestic crisis situations. Another example of a back office application is warehouse robotics where the DoD might partner with its major contractors such as Kellogg, Brown & Root (KBR) (see Kiva, 2012, for examples of some remarkable efficiency gains being achieved in the online retailing business). Other examples might be medical robotics, where the DoD has leading-edge needs, and security robots, for example, augmenting perimeter security of CONUS bases, which have many commonalties with perimeter security needs among other public-sector agencies as well as in the private sector. Here again, the goals for robotics usage are mainly about developing usage models that are better and more efficient than current alternatives (cost saving via labor substitution) and do not involve the sharing of proprietary and sensitive technical information, per se.

E. Regulation: Helping Establish “Rules of the Game” for Public Robotics Usage

The question of what the rules of the game will look like for robotics usage in public spaces remains a key issue in the industry. Uncertainty about the regulatory regime governing robotics usage clearly holds back users from making investments in adoption. This is because of the risk that the way they plan to use robotics could be unfavorably impacted by future regulations. Regulatory uncertainty also holds back producers from investing in designing new robotics systems until the regulatory regime is clear, so they know what constraints their design has to successfully meet. In contrast, a well-defined set of regulations around usage helps users define and articulate economical ways to use robotics and helps producers to design with confidence, both of which promotes adoption. Because robotics is a fast-evolving technology, a key issue is to establish a regulatory regime governing usage that is flexible enough to leave scope for users and producers to take advantage of future advances in the state of the art.

Among many economists, sociologists, and political scientists, there is widespread agreement on the importance of regulation of various kinds, which is usually studied under the label of *institutions*. For example, many argue that the institutional setup in a country is one of the leading factors affecting its long-run development, if not *the* leading factor (Rodrik, 2008). Part of the reason for this is that good institutions are a key factor that allows countries to invest in new technologies. Some of these institutions are formal rules of the game in the sense that they are legally enforced by the state. Other institutions are of a softer, informal nature and represent socially acceptable norms for ways of doing things. Together, these formal and informal sets of rules define how technologies can be used by constraining their operation to particular allowable circumstances, thus defining the incentive structure for adoption. For instance, autonomous automobiles are currently regulated off public highways in every country in the world, but specific usage (under 400 feet) of public airspace by commercial UAS users is beginning to be allowed in the U.S. by the Federal Aviation Authority (FAA) (Lacher & Maroney, 2012). In addition the Nevada state legislature has signaled the beginnings of the integration of UMS on the roads by asking its Department of Motor Vehicles to draft regulations for autonomous vehicle usage (Brynjolfsson and McAfee, 2012). The aforementioned demonstration effect of UAS, specifically Predator drones, in combat operations has informally “normed” the U.S. public to UAS usage, in contrast to autonomous autos where social acceptance still appears lower. All other things being equal, the fact that the formal and informal institutional playing field favors UAS over autonomous autos is expected to have a significant impact on the uptake of these respective innovations in the marketplace, until the law and norms change.

A key question is where DoD acquisition strategy plays in regulatory issues. Two factors stand out. First, the DoD is a vital part of the overall emerging policy mix governing robotics usage, in large part owing to its role as a lead user in robotics. Because it has been at the bleeding edge of much robotics adoption, the DoD has had to develop its own internal (formal) regulations and (informal) policies on UMS operations via learning by doing and experience with operating these systems. These regulations and policies are gradually embodied in the specific UMS technologies that the DoD acquires from industry and over time become part and parcel of the specifications demanded by the DoD. Because their own regulations and policies are prototypes that may be adopted by other private/state/federal/local-sector UMS users, the DoD have some influence over the regulations adopted in the wider market. In short, MILSPECS (United States defense standard) of various kinds have accompanied the diffusion of technologies in the past, and we might anticipate that this could also be the case to some extent in robotics. A case in point is the evolution of informal norms around acceptable UMS usage. One critical area in this regard is UMS autonomy, which is a regulatory frontier where DoD experiences may have considerable value. For example, the development of decision rules in combat UMS that involve life and death choices may spill over to other domains, such as autonomous autos' need to prevent road traffic accidents or to choose which accident to have when no safe choice is available. Here again, robotics technology and the social rule set will evolve together and the DoD's early user experiences with these issues make it likely that they will play a role in shaping the norms for safe behavior among robots that are later applied to other use domains. Therefore, the choices that the DoD makes in its acquisitions of robotics are likely to have spillover effects on the evolution of formal and informal regulation in the rest of the robotics space.

A second place that DoD acquisition strategy plays in regulatory issues is that the DoD are significant stakeholders in regulations promoted by other federal agencies, for example, the FAA. This raises interagency coordination issues, and with an important seat at this table, the DoD has the opportunity to accelerate or retard the FAA's progress on regulations. Currently, the FAA issues permits for UAS usage, with about 300 operator permits issued so far (each permit may permit multiple UAS to be flown) that allow the holders to fly in specific geographic areas outside airspace designated for commercial, business, and private planes. From the perspective of encouraging adoption of and promoting the U.S. robotics innovation system, it makes sense for the DoD to do whatever it can to see the new FAA regulations instituted in a timely fashion. Also, because the DoD has a hand in which regulations get adopted, they also have some influence over the incentive structure that FAA regulations create. An example is the FAA's NextGen (Next Generation Air Transportation System), which uses GPS technology and promises to allow numerous cost savings for aircraft operators, such as more efficient routing, less delays, and more economical landing approaches. Specific regulations on UMS usage, which are currently being negotiated for 2014, will likewise constrain and enable the efficiency of UAS; therefore, the DoD has a hand in negotiating how attractive the use environment will be for other UAS adopters. Moreover, these regulations are likely to affect regulation in other UMS domains, that is, terrestrial and marine environments, because what works well in the air domain will likely get carried over to other domains where the DoD operates. Once again, wherever DoD policy affects terrestrial and marine UMS regulation, it generally makes sense for the DoD to adopt policies that accelerate the institutions necessary for usage to become widespread, in order to support the U.S. as a lead market in robotics adoption.

F. Unorthodox Acquisition Strategies: Addressing a Lack of Disruptive Competition

Although not designed to directly address private-sector competition issues, I have suggested already that military acquisition strategies clearly enter the broader policy mix for innovation systems (see Section 1.4). This occurs largely through acquisition choices, rather than R&D subsidies. For example, Geroski (1990) concluded that second-sourcing policies by the DoD have had the effect of encouraging competition and stimulating the rapid diffusion of innovations in U.S.

markets, much more so than in the UK, where second sourcing is rare by the UK Ministry of Defence (MoD). The DoD’s policy of acquiring via the Small Business Innovation Research (SBIR) program has also had competitive effects on the diffusion of innovations by encouraging the entry of small, entrepreneurial firms with new ideas into the defense industrial base. Therefore, I think it is reasonable to suppose that the DoD’s acquisition strategies already do have important indirect effects on the competitive structure of some industries.

As I have shown, a key factor in developing robust innovation systems is competition among producers (see Section 2.1). Broadly speaking, the economic incentive structure for competition can be framed as encompassing two kinds of incentives: neoclassical and Schumpeterian. By neoclassical, I mean addressing issues such as the contestability of markets by keeping barriers to entry low. This enables more firms to enter the marketplace. The resulting competition pushes down costs via competitive learning and investment, encourages entrepreneurial effort to discover how to apply a technology to new market segments, and incents marketing and promotion efforts to encourage technology diffusion, all of which build demand for a market. These actions may be critical in enabling some national innovation systems to flourish, because price advantages via lower costs are often at the heart of global lead market advantages (Beise, 2004). The Schumpeterian approach to competitive incentives is different but no less important. It involves seeing innovation as the prime competitive weapon and thus aims at incenting innovative effort—in particular, disruptive innovation (see Section 2.4). Here, the incentive system is the threat of disruption, which provides a strong mechanism for encouraging existing players with more conventional technology to invest in staying competitive, under threat of being disrupted by emerging technologies, usually with initially lower-end performance. Thriving innovation systems are built out of technologies at different stages of development, with emerging technologies constantly putting pressure on more established offerings in the marketplace by threatening to take market share from them. This is the heart of the Schumpeterian model of innovation.

This leads me to conclude that the DoD has an incentive to encourage—where possible—the emergence of disruptive technologies in the U.S. robotics innovation system, because these currently nascent technologies of today may be the alternatives on which the DoD will be drawing tomorrow. The point here is to use acquisition strategy adroitly in order to build real options for COTS technologies that might be spun in to the DoD at some point in the future. These spin-ins provide improved technology options for the future. Indirectly, the emergence of disruptive COTS technology also incents competition among the DoD's current robotics supplier base.

While several unorthodox acquisition mechanisms can be employed to achieve these goals, one example of a creative approach has been the use of leasing arrangements by the USN for UAS assets, specifically leasing the Insitu ScanEagle ("ScanEagle") system. This approach is very instructive for a number of reasons. For one, the ScanEagle was originally designed and developed as a tool for the fishing industry in order to make the detection of fish in the open sea more efficient. It is therefore an example of COTS technology spun in to the DoD (primarily the Marines), although it has also been used by other DoD services, internationally, and in commercial industry. Next, the USN's contract with ScanEagle involves an operating lease in which the USN, in effect, buys delivered pixels from ScanEagle. Thus the USN uses a dual-track procurement approach whereby it buys service from Insitu on a company-owned, company-operated (COCO) contract, at the same time that it chooses government-owned, government-operated (GOGO) arrangements elsewhere. The COCO contract has proved important in ScanEagle's case, owing to the disruptive nature of the technology. According to company representatives, ScanEagle was conceived from the get-go as a disruptive design that would be cheap and start with relatively low performance but would leverage the progressive improvements in electronics allowed by Moore's Law to rapidly improve over time. The firm has now logged over 80 major design improvements in five years (>1 per month), which are 100% self funded. Importantly, this striking rate of performance improvement is only possible because of the COCO contract, which keeps ScanEagle outside the DoD program management system where, according to company representatives, the DoD's system would have inevitably slowed down ScanEagle's improvement rate.

I hazard several conclusions from this example. First, the COCO leasing arrangement is a perfect example of using a dual-track approach in which an unorthodox acquisition strategy is used at the margin, while conventional approaches (GOGO) are maintained for the vast majority of DoD acquisitions. Second, this unorthodox leasing arrangement for the ScanEagle works precisely because it produces orthodox competitive incentives, namely, giving the supplier an incentive to continuously innovate in order to save costs (which they benefit from) and increase volumes (by offering their customers a better product for the same leasing price). Third, the leasing approach is an excellent example of the DoD engaging selectively with COTS innovations that fulfill mission requirements but at the same time fuel competition in the COTS market by providing competitive incentives for the rapid improvement of a disruptive technology.

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IV. Implementation Framework

A. Implementing a Change in Mindset in the DoD

In this final section of the report, I focus on issues regarding the implementation of the policy tools so far outlined by recognizing the unique DoD environment in which implementation has to take place. As is well-known in research on the strategic management of organizations, and from organization theory, the implementation of new directions for an organization creates significant challenges. In short, policies that look like good ideas on paper often fail at the implementation stage because of the barriers to putting them in place in practice (for a prior study of these issues in the USN, see Dew, 2010). Therefore, in this section of the report, I consider some key factors effecting the implementation of the demand-side strategies for DoD robotics that I have identified.

There are two broad categories of issues regarding implementation that we will consider: the first involves *sensitizing* acquisition professionals within the DoD to the role that their decisions about acquisition might have in innovation outcomes; the second involves enabling the coordination of efforts across different organizational elements within the DoD (Edler & Georghiou, 2007).

The first element of sensitizing acquisition professionals involves creating an enhanced mindset that the DoD’s acquisition choices can make an important difference in the evolution of the U.S. robotics innovation system. Here, the need for some changes in the practices of acquisition professionals rests on changes in informal factors, such as the basic mindset or cognitive assumptions made in the domain. A prominent issue is the aforementioned assumption that supporting innovation classically occurs via intervention on the supply-side, that is, that R&D support is the major route to increased robotics innovation. I described this earlier as technofetishism (see Section 1.3). Changing the deeply held assumption favoring technology creation will be challenging owing to various factors that lead to cognitive inertia in organizations and therefore requires quite significant education and leadership of cultural change among acquisition professionals . Such needs occur in the context of calls already made for the significant upgrading of human capital in the acquisition workforce (Gansler, 2007). However, human capital upgrading also represents a natural opportunity to incorporate the demand-side perspective into the future education requirements for acquisition professionals. A movement within management research known as evidence-based management (EBM) may also be important here. EBM is designed to re-focus education on what really matters (based on empirical evidence) in a domain, rather than what has been traditionally thought to matter. And the facts about demand-side impacts on innovation speak for themselves, as seen in the following examples:

- A major survey by BDL (2003) found that 50% of innovations implemented by firms were driven by new user demands and only 12% by new technological developments.
- A survey of all innovations commercialized in Finland from 1984 to 1998 found that 48% of innovations were driven by public policy or procurement.
- A well-known study of innovation commercialization in the 1970s (Rothwell, 1984) concluded that over the long term, public acquisition triggered more innovation than R&D subsidies did.
- Detailed research on the evolution of individual industries further substantiates broader claims about the role of demand in industry evolution. In the case of the RFID industry in prior work, I found that demand-side factors were the leading cause of industry development from the late 1990s onwards, including alliances between the DoD and Walmart (Dew & Read, 2007).
- In a review article, Geroski (1990) was led to the conclusion that acquisition policy is a far more refined instrument for generating innovation than R&D subsidies, despite the latter's more frequent use.

Overall, then, these results support the implementation of training and education and culture change within the DoD that sensitizes acquisition professionals to the importance of their robotics-related acquisition strategies for innovation in the robotics space, as well as beyond.

A second issue involves enabling efforts to be coordinated across different DoD organizational elements. A formal organizational response is needed that builds on changes in the informal organizational mindset, highlighted previously. The core issue is that in a complex, highly differentiated organization such as the DoD, various organization elements (including some outside the DoD, e.g., in Congress) share some responsibility for how the acquisition budget gets spent and that together, these elements collectively provide a policy mix for innovation (Flanagan et al., 2011). In order to coordinate these elements, first and foremost what is needed is official policy regarding the explicit incorporation of innovation goals into acquisitions that involve robotics, which is rapidly becoming many of the major acquisition programs as well as many other general procurement contracts. To use the example again of warehouse robotics, acquisition strategy can be used to incent our logistics contractors to accelerate the adoption of robotics systems into DoD support operations. Or, to incorporate driverless vehicles into convoys, more rapidly, etc. To achieve the kind of cross-departmental coordination that is needed to result in consistent policy across many different acquisition domains inevitably means that goals for innovation will have to be pushed down from a sufficiently high level in DoD organizations. Only with transparent goals and continuous high-level signals of support for these goals will the various commands with a hand in acquisition choices “get on board” and actually implement the various policy tools for promoting robotics innovation that I have talked about.

B. Implementing a Multidimensional Evaluation Process

Innovation policy at the level of national economies often encompasses broad and undefined objectives, although the general purpose is increased competitiveness. However, for the DoD there is a need to be more explicit about the contributions of demand-side strategies toward military efficiency and effectiveness, that is, toward the DoD’s explicit security goals. This means that the evaluation of the impacts of strategies is key (Edler et al., 2012). Since innovation evaluation to date has focused on supply-side metrics, in this section, I will briefly spell out a framework for measuring innovation impacts on the demand side.

My prior work on evaluation metrics for DARPA (Dew, 2011) led me to undertake a comprehensive study of research on the evaluation of technology transition, much of which is relevant for the present study. A key takeaway from this research was that a multidimensional approach to evaluation is necessary for any kind of technology diffusion, owing to the multiplicity of the impacts and outcomes, and different assessment according to who does the assessing:

> Success means different things to different people. An architect may consider success in terms of aesthetic appearance, an engineer in terms of technical competence, an accountant in terms of dollars spent under budget, a human resources manager in terms of employee satisfaction. Chief executive officers rate their success in the stock market. (Freeman & Beale, 1992, p. 8; Shenhar, Dvir, Levy, & Maltz, 2001)

In short, “one size does not fit all” in the world of evaluation. What is critical is embracing the need for multiple dimensions of measurement in order to avoid getting caught in some specific “mis-measurement” trap. This has led to the introduction of multidimensional frameworks for the assessment of success, one of the most useful of which can be adapted from Shenhar et al. (2001), summarized in Figure 7.

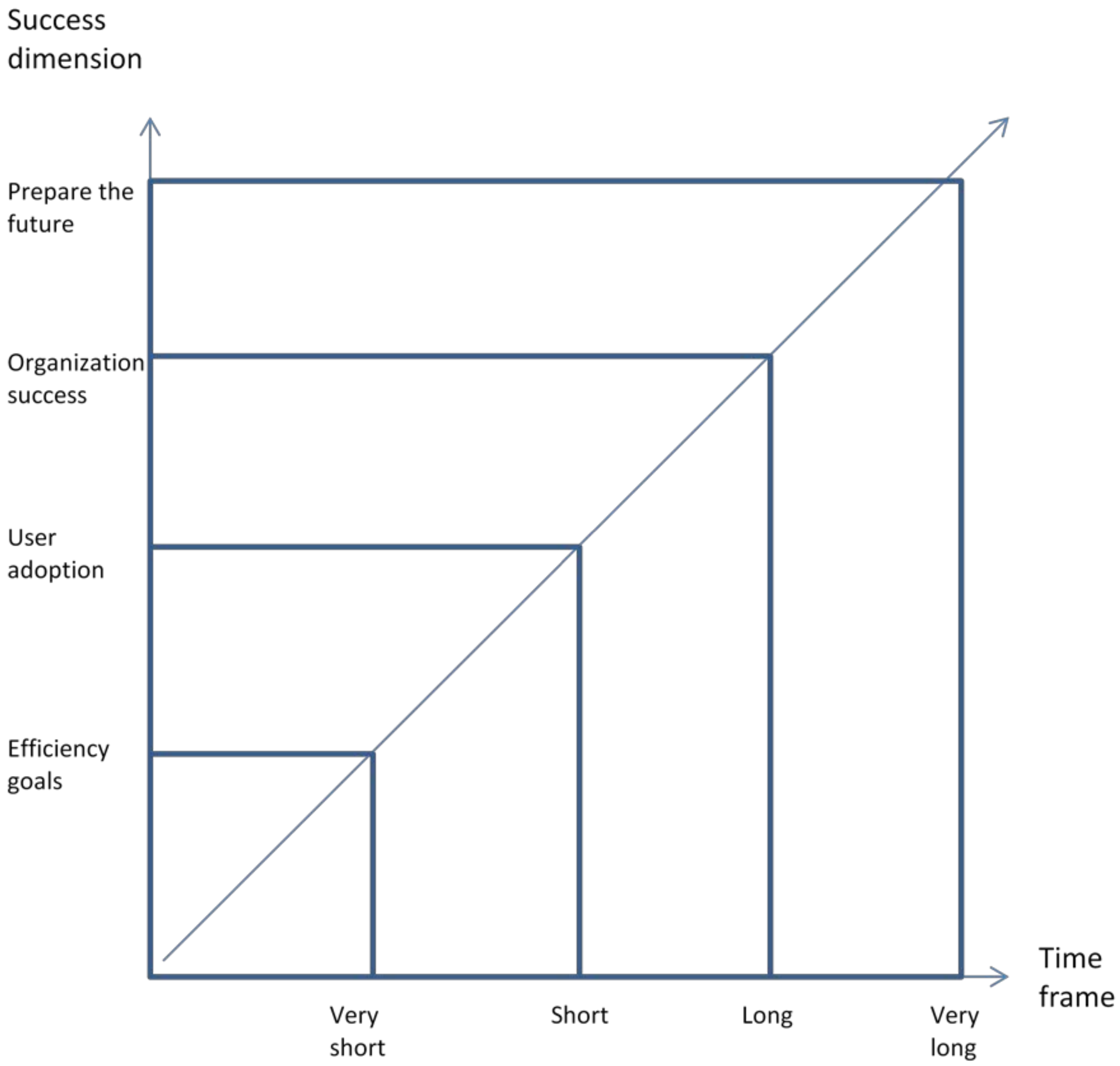

Figure 7. Multidimensional Framework for Evaluating Success of Demand-Side Acquisition Policies

The idea illuminated by Figure 7 is that different dimensions of success are important across different time spans. In the short term, the emphasis is on whether specific goals were met (on budget, on time, on spec). Beyond this, the question of market development is key, that is, did the demand-side policies implemented lead to the objectives highlighted in Section 1.4: to help the U.S. maintain/become the world leader in air, marine, and utility robotics by accelerating the diffusion of these technologies in the U.S. market? However, if these objectives are met, then they should lead to further measurable results, including many organizational success stories and new organizational foundings within the U.S. robotics innovation system. Finally, one might gauge success in terms of the overall performance of the U.S. robotics innovation system over the long run, measured in terms of its capacity and capabilities. Following, I develop each of these areas on measurement in more detail:

1. Efficiency measures focus on whether the initiative met its targets by being on budget, on time, and on spec goals, that is, the initiative met the constraints that were initially specified for it. These are the traditional measures of project success that can be naturally applied to any acquisition strategy or intervention that is used. For example, cooperative/catalytic acquisition initiatives can be evaluated on such a basis, as can impact assessments of legal regime evolution and usage standards.

2. The impact on users of unmanned systems is a key measure of success for strategic initiatives aimed at diffusing robotics in the U.S., for the long-term benefit of the DoD. Market development indicators are important metrics here because they indicate that other users are buying and adopting the technology and therefore are a key indication that demand-side influence is working. Other specific metrics that are useful are measures of changes in procurement behavior of users. Measuring the development of competencies of users is also useful since highly competent robotics users are more demanding of suppliers, thus enhancing the robotics innovation system.

3. Organization success is a third measure for evaluating the impact of DoD demand-side strategies. The relevant metrics are those that capture the success of organizations comprising the U.S. robotics innovation system, which might encompass their global market share, profitability, and growth. The presence and impact of disruptive innovators in the U.S. robotics innovation system are other metrics worth tracking.

4. Lastly, my evaluation framework highlights that success is also a function of how prepared you are for the future. The idea is to capture metrics that indicate how much the capacity and capability of the U.S. robotics innovation system as a whole has been enhanced. Measures such as patenting activity, number and innovativeness of new designs under development, number of engineers, and network relations with organizations globally might all be useful indications of such capacity and capability enhancements.

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- Acquiring Combat Capability via Public-Private Partnerships (PPPs)
- BCA: Contractor vs. Organic Growth
- Defense Industry Consolidation
- EU-US Defense Industrial Relationships
- Knowledge Value Added (KVA) + Real Options (RO) Applied to Shipyard Planning Processes
- Managing the Services Supply Chain
- MOSA Contracting Implications
- Portfolio Optimization via KVA + RO
- Private Military Sector
- Software Requirements for OA
- Spiral Development
- Strategy for Defense Acquisition Research
- The Software, Hardware Asset Reuse Enterprise (SHARE) repository

Contract Management

- Commodity Sourcing Strategies
- Contracting Government Procurement Functions
- Contractors in 21st-century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting, Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

Financial Management

- Acquisitions via Leasing: MPS case
- Budget Scoring
- Budgeting for Capabilities-based Planning
- Capital Budgeting for the DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-term Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness

- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public-Private Partnership
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