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About the Authors

Adam Jay Harrison is a Visiting Distinguished Research Fellow at the National Defense University. Dr. Bharat Rao is an Associate Professor at New York University. Dr. Bala Mulloth is an Assistant Professor at the University of Virginia.

Key Points

- The U.S. Department of Defense (DOD) is looking at new ways to spur entrepreneurship and innovation among its stakeholders and related constituencies.
- We recommend creating a platform within the DOD focused on developing the Human and Relational Capital components of the innovation ecosystem such as the MD5 National Security Technology Accelerator, an initiative that develops innovators and human-centered networks that create high-tech "ventures" relevant to national security.
- The proposed ecosystem would not only facilitate the development of high-tech ventures in the national security interest, but also educate and build networks of innovators and entrepreneurs, both inside and outside of DOD, who would be equipped with the incentives, expertise, know-how, and resources required to continuously develop, commercialize, or apply technology relevant to military needs.
- A competency framework for developing such an ecosystem that would encourage venture-led, dual-use products that provide a sustainable, competitive advantage for the DOD and the national economy is presented and discussed.

Developing an Innovation-Based Ecosystem at the U.S. Department of Defense: Challenges and Opportunities

by Adam Jay Harrison, Bharat Rao, and Bala Mulloth

In today's knowledge-based global society, economic wealth, resources, information, and power are widely distributed, contributing to the emergence of new sources of disruptive innovation. While the importance of technology to military competitiveness is a broadly accepted fact, the role that the Department of Defense (DOD) plays in catalyzing the emergence of technology-based products with broad social and economic impact is somewhat less recognized. Enrico Moretti, Claudia Steinwender, and John Van Reenen identified a strong correlation between defense research and development (R&D) investment and private R&D outputs.[1] Moreover, many of the foundational general purpose technologies that drive the global high-tech economy—such as interchangeable parts and mass production, aircraft, nuclear energy, semiconductors, the Internet, and space technology—are either direct offshoots of, or strongly linked to, military procurement activities.[2] Mirko Draca attributed a sharp increase in U.S. corporate research and development spending in the 1980s to high DOD technology investment during the administration of President Ronald Reagan.[3] Draca likewise showed a corresponding deceleration in private research and development coincident with the post–Cold War defense drawdown under Presidents George H.W. Bush and Bill Clinton. Efforts such as the Defense Innovation Initiative, launched in 2014 by then–Secretary of Defense Chuck Hagel, combined with projected defense spending increases of $500 billion to $1 trillion in the administration of President Donald Trump, will reinforce the positive correlation between DOD and commercial high-tech industry and increasingly expose

the defense research and development enterprise to the tumult of creative destruction in the civilian sector.[4]

The world has entered a period of hyper-innovation in which the military-industrial complex and commercial industry alike are subject to continuous business process and technology disruption. Ray Kurzweil described this phenomenon, where technology evolution "advances [at least] exponentially" driven by "human ingenuity combined with ever changing market conditions," as the Law of Accelerating Returns.[5] Within this context, succeeding generations of technologies interact in a multiplicative manner to produce a cascading flow of future innovations. Individuals and small teams, enabled by the proliferation of emerging, creative technologies, play an increasingly significant role in accelerating innovation. For example, Chris Anderson linked the diversification of the consumer media marketplace to the democratization of the tools of digital content production and distribution.[6] Klaus Schwab defined the shift from traditional forms of industry-led research and development to more local-scale, entrepreneur-led forms as the "Fourth Industrial Revolution."[7] According to this paradigm, talent, more than capital, represents the critical factor of innovation, where people "connected by mobile devices, with unprecedented processing power, storage capacity, and access to knowledge" disrupt entire industries as well as traditional power relationships in society.

a military example underscoring the impact of disruptive innovation instigated by networks of individuals and based on rapid, iterative product development cycles is the improvised explosive device threat that manifested in Iraq and Afghanistan beginning in 2003

In the future, businesses and militaries that rely on technology for competitive advantage will depend on the cultivation of people who continuously invent, reinvent, and apply value-creating technology interventions. To the extent that individual and small-team actors outside of the traditional corporate context are not constrained by sunk costs, legacy markets, and organizational inertia, they can efficiently explore the technology-application decision space. This phenomenon is enabled by the aforementioned democratization of technology associated with the widespread expansion of knowledge and creative tools.[8] Clayton Christensen defined "disruptive innovation" as the discovery of new products that disrupt markets and the firms that lead those markets.[9] Eric Ries identified entrepreneur-led startups that target emerging or underserved markets as a key source of disruptive innovation.[10] Within this context, startups develop minimally viable products, observe the customer response to these products, and deploy subsequent generations of products in rapid succession until an optimum value proposition is achieved.

A military example underscoring the impact of disruptive innovation instigated by networks of individuals and based on rapid, iterative product development cycles is the improvised explosive device (IED) threat that manifested in Iraq and Afghanistan beginning in 2003.[11] Anthony Cordesman, Charles Loi, and Vivek Kocharlakota, based on the compilation of U.S. Government data, found that IEDs were responsible for the majority of coalition combat fatalities in Afghanistan and Iraq.[12] Costing on the order of 10s to 100s of dollars per device to manufacture, IEDs, as the name implies, are improvised from materials on hand augmented with electronic triggers re-purposed from consumer electronics. While opinions vary, it is generally accepted that the main challenges posed by IEDs are lack of standardization, which complicates countermeasures, and an accelerated product development cycle that measures in weeks to months. In the cases of Iraq and Afghanistan, almost as soon as the U.S. military deployed a threat-specific IED countermeasure through traditional development channels, new

IED variants would appear on the battlefield rendering the countermeasure obsolete.[13] James Revill has identified specific factors related to the nature of IEDs that have contributed to the diffusion and disruptive adaptation of the technology.[14] Peter Singer and others have concluded that the Pentagon spent $60 to $100 billion on various counter-IED capabilities since 2003, an investment that has funded such products as Mine Resistant Ambush Protected (MRAP) vehicles, radio-controlled IED jamming devices, and a host of IED detection systems.[15] By contrast, the manufacturing of IED components, underwritten primarily by diversified commercial markets and adapted for use by networks of individuals in direct contact with the application space, benefit from economies of scale as well as rapid product development and improvement cycles. This competitive asymmetry means that America's nonstate adversaries can produce IEDs at a small fraction of the cost and time associated with the U.S. military's development of countermeasures.

Unlike previous generations, where the competitive advantage associated with a technology breakthrough was measured in years or even decades, technology obsolescence, driven by factors such as Moore's Law (that is, the doubling of the number of transistors in a dense integrated circuit every 2 years), is accelerating at faster and faster rates. This trend implies that organizations in the future will increasingly benefit from the ability to rapidly, cost effectively, and continuously recognize value-creating applications of technology ahead of the competition. This model of competition, derived from the theories of military strategist John Boyd,[16] is based on the idea of executing key decisions ahead of one's adversary—a concept adapted by Steve Blank to the process of startup business creation in a method called Lean Startup.[17] The shift from technology invention—where product development is closely coupled to a prescribed future application (that is, if A then B)—to technology innovation—where product development and potential applications co-evolve in rapid, recursive cycles (that is, if A then N)—has major economic and security implications. Successfully competing in the new technology environment requires a major shift in framing the entrepreneurial mindset. The individual innovator becomes not just the vehicle for the development of technology means, but also the agent for the exploration of technology ends.

Early 19th-century military philosopher and strategist Carl von Clausewitz famously wrote on a concept he referred to as "military genius"—the qualities of mind enabling a military professional to recognize and exploit opportunity from the chaos of conflict. A Prussian officer who served during the march of post-revolutionary France across Europe, Clausewitz idealized Napoleon as the archetypal military genius who combined a competitive, martial spirit with elements of character and modern scientific reasoning to devastating effect. Importantly, Clausewitz recognized that developing military genius in a systematic and deliberate manner was an impossibility; however, nations could influence the underlying cultural, intellectual, and social conditions that tend to promote the emergence of military genius.[18] Fast forward to the current era and the qualities that Clausewitz attributed to the military genius are much in evidence in the new class of entrepreneurial innovators disrupting industries and changing the global economy. Today's technology and business innovators are adept at recognizing gaps and opportunities (that is, signals) amidst the chaos of the competitive environment (that is, noise) and moving quickly and efficiently to seize the momentum with new

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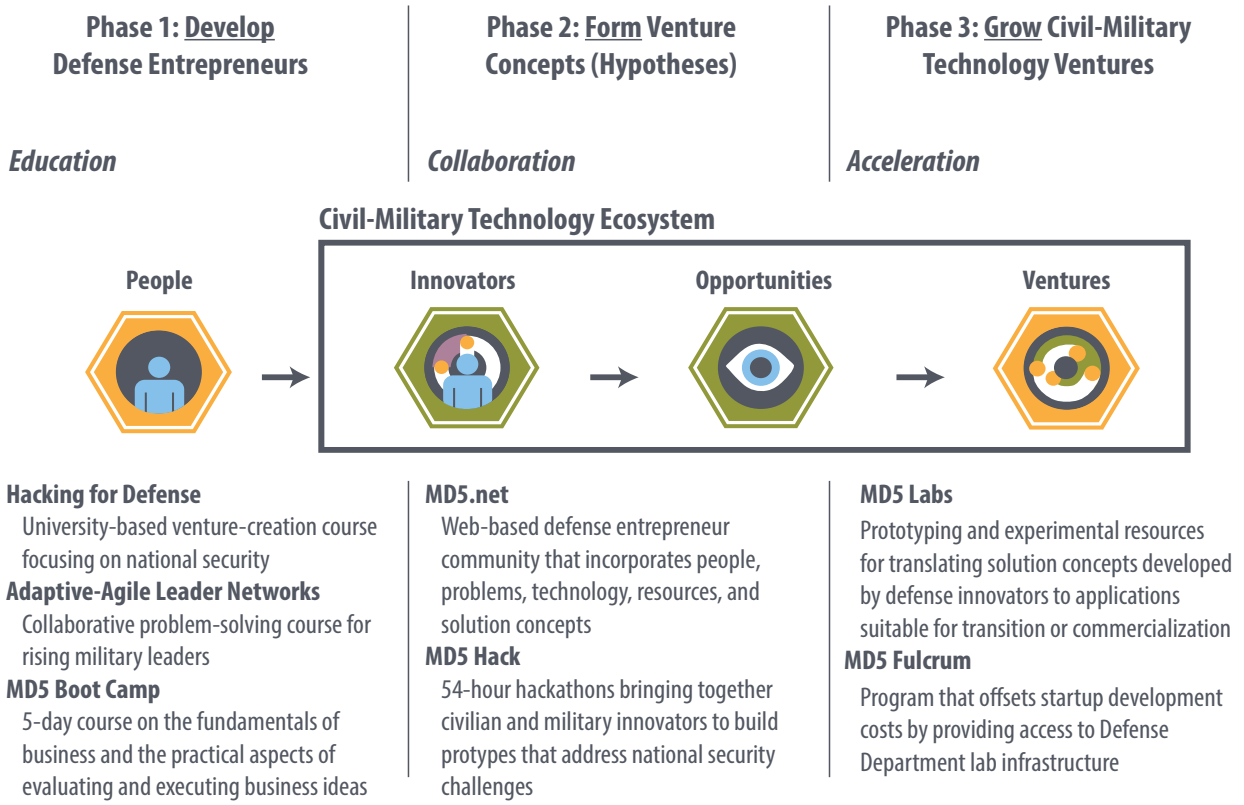
products and services. Such agents of change emerge because of and in response to environmental conditions present in innovation ecosystems—a combination of economic assets, networking assets, and physical assets that facilitates the transfer and application of knowledge and associated technology value creation.[19]

Given the prominent, if not decisive, role that technology plays in the modern economic and security landscape, the cultivation of entrepreneurial innovators who can rapidly, cost effectively, and continuously recognize the value-creating applications of technology in a national security context is an imperative. To this end, the development of a robust innovation ecosystem that promotes the development of entrepreneurs in relation to the DOD represents a unique and timely opportunity to gain and sustain a competitive military advantage. In the current global security environment, the government can no longer function as a "coach on the sidelines," content to set innovation strategies and call initiatives into action. Instead, it must play a leading role in executing the collective strategies of education, innovation, and entrepreneurship. In short, a successful DOD innovation enterprise must eschew a purely bureaucratic role and "lead by example" by becoming more entrepreneurial.

Within this context, the MD5 National Security Technology Accelerator (MD5) initiative was created to catalyze entrepreneur-led venture creation relevant to national security. Established in 2016 at the U. S. National Defense University, MD5 promotes the development of an entrepreneurial national security workforce that drives emergent innovation opportunities by a) providing academic programming on topics related to science and technology, entrepreneurship, and innovation; b) establishing a technology and knowledge transfer platform to facilitate new venture creation; and c) creating business accelerator services to encourage DOD employees and their peers in academia and industry to create startups based on emerging technology-market opportunities relevant to national security. Figure 1 provides an overview

Figure 1. MD5 Overview



of MD5 and its programs; the broader impacts are described in a later section of this paper.

Why Focus on Innovation?

Innovation is a complex and multifaceted topic. Scholars have studied many aspects of the subject and have delineated the differences between types of innovation (for example, radical vs. incremental innovation or product vs. process innovation).[20] Scholars also noted that technological innovation takes place in different settings (for example, large corporations, entrepreneurial start-ups and growing enterprises, government-funded basic R&D environments, and large-scale, macro-level endeavors), and that innovation operates somewhat differently in each of these venues.[21] Today, innovation vis-à-vis the accelerated development of new technologies to solve problems is a crucial strategic weapon in corporate and government arsenals—a fact that has been accompanied by an upsurge in the study of disruptive innovation in recent years.[22]

Entrepreneurship is a major engine of noted economist Joseph Schumpeter's dynamism of "creative destruction." Schumpeter described creative destruction as an economy-wide process, which "incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one."[23] The dynamism of modern market-based economies and the firms that thrive in these economies is attributed to the process of creative destruction; however, this process can also be seen at work in the contemporary national security landscape. Today, a new class of innovators is emerging within the military and expanding the boundaries of the traditional defense industrial base. These public entrepreneurs watch for opportunities, make decisions "under uncertainty, and then meld the factors of change in sticky [that is, locally commercialized] ways."[24] According to B.J. Armstrong, defense entrepreneurs create networks with the aim of organizing internal and external stakeholders to tackle problems related to staffing, organization structure, and training of the military enterprise.[25] To bring such entrepreneurs to action, mission-oriented investments in science and technology are required.[26] "Mission-oriented" policies target the development of particular technologies that address a given societal challenge, for instance "putting a man on the moon," in the case of the Apollo Program. Dominique Foray, David Mowery, and Richard Nelson further argued that a Manhattan Project or Apollo Program model is inappropriate for confronting new challenges such as climate change and that the focus now should not be about developing a single "silver bullet." In the case of complex, heterogeneous challenges, solutions are more likely to result from a web of interaction among different institutional actors working together to develop multiple technologies.[27]

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Several disruptive trends have accelerated the rise of new models of innovation in recent decades, including flexible Intellectual Property (IP) policies, university-industry collaborations, micro-entrepreneurs, venturing, distributed innovation in global locations, open innovation, etc. Further, there has been a perceptible shift away from the single organization as a core source of technological innovation and a move toward using networks and leveraging external ecosystems to enhance innovation. This ecosystem emphasis in technological innovation and technology management is a growing trend and presents firms in an ever-increasing number of sectors with significant opportunities and challenges.[28] New networks of innovation and changing mindsets among people have a distinctive impact on "re-perceiving" many of the enormous and urgent challenges such as climate

change, oil depletion, water scarcity, global warming, and ever-increasing environmental pollution into opportunities to "leverage the power of markets and business to have transformative, system wide impacts."[29]

One notable development in this area is the concept of Open Innovation, which is an innovation model whereby ideas and technologies at various stages of development are allowed to flow in and out of proprietary R&D pipelines.[30] According to Henry Chesbrough, Wim Vanhaverbeke, and Joel West, "open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for the external use of innovations, respectively."[31] Open Innovation theorists have also recognized the importance of customer involvement in the overall innovation processes.[32] In fact, users are increasingly regarded not as just passive adopters of innovations, but as developers of their own innovations, which producers can imitate. Users, for example, regularly modify their current machines, equipment, and software to better satisfy process needs.[33] Firms may benefit from their customers' ideas and innovations by proactive market research, by providing tools for user experimentation, or by making products based on the designs of customers and evaluating what may be learned from user-created designs. Some have argued that open research methods that encourage information flows from the commercial sector to the military sector and from global supply centers to domestic supply centers would be a good approach for enhancing the strength of military R&D.[34]

the emergence of advanced, potentially disruptive technology derived from the civilian high-tech sector poses an orthogonal threat to the traditional technology superiority of the U.S. military

Andrew Hunter and Ryan Crotty described a secular trend where R&D spending outside the United States and in commercial (nongovernment, nondefense) industry is eclipsing traditional sources of R&D investment.[35] To the extent that the DOD does not maintain proprietary access to technology stemming from the global, commercial R&D marketplace, the emergence of advanced, potentially disruptive technology derived from the civilian high-tech sector poses an orthogonal threat to the traditional technology superiority of the U.S. military. Mitigating this threat requires the military to simultaneously optimize internal R&D activities—which Hunter and Crotty defined as *inside-direct* (that is, internal R&D corresponding to an explicit military demand signal) and *inside-indirect* (that is, internal R&D corresponding to an implicit or speculative military demand signal)—and to increase exposure to external R&D activities relevant to the military.[36] In this context, external R&D activities are defined as *outside-direct* (that is, external R&D corresponding to an explicit military demand signal) and *outside-indirect* (that is, external R&D developed for the commercial market with applicability to military applications). With the center of gravity for R&D shifting to the commercial marketplace, Jay Stowsky identified "spin-on" as a strategy to provide the military with leading-edge technology initially developed to satisfy commercial market demand (that is, outside-direct and outside-indirect). A complementary strategy, "spin-off," involves the military taking advantage of economies of scale associated with commercial markets that are much larger than organic military markets. The spin-off strategy enables the military to shift technology production costs to commercial industry and capitalize on lower per-unit costs.[37]

Capitalizing on "spin-off" and "spin-on" opportunities requires that needed information and problem-solving capabilities be brought together. Eric Von Hippel wrote that information regarding technologies and potential applications is often difficult to acquire, transfer, and use in a new context, making it tacit or "sticky."[38] Significant physical, cultural, and regulatory barriers between the defense and civilian R&D communities exacerbate the challenge of sticky information transfer across industry lines.[39] When information required for

innovation-related problem-solving is concentrated, there are fewer opportunities to internalize (that is, spin-on) or externalize (that is, spin-off) the development of new technologies and associated applications. Von Hippel identified multiple behaviors to reduce the friction of sticky information transfer, including iteration between complementary information nodes, partitioning of problems, and investments.[40]

Given the complex and multifaceted nature of innovation, it is clear to observers and researchers that the underlying set of linkages among individuals, institutions, and other stakeholders can be a critical determinant to the eventual success or failure of the group—whether or not there is a thriving innovation ecosystem.

What Is an Innovation Ecosystem?

Although the concept of an innovation ecosystem has only begun to attract attention as a framework for policymakers in recent years, the core concepts of the term are rooted in the theory of innovation, particularly the theories of Schumpeter. His views on innovation-related technological changes and entrepreneurship as drivers for economic growth became the basis for innovation policy in many regions.[41] In his opinion, innovations resulted not from rational thinking, but from a creative process led by entrepreneurs.[42] Thus, entrepreneurial efforts are necessary to bring innovations to market. A vast array of theories and concepts havebeen employed to explore the entrepreneurship phenomenon.[43] Several studies have focused on units of analysis, theoretical perspectives, and methodologies related to entrepreneurship.[44] In addition to studying new firm development, exploration and exploitation of opportunities, and entrepreneurial behavior of existing firms, entrepreneurship research also examines institutional approaches.[45] At the same time, researchers have evaluated the differences in innovation systems in different territories, with the conclusion that every country and region has its own innovation system that reflects particular institutional elements.[46] For example, Douglass North has correlated innovation development to national or regional "adaptive efficiency" (that is, the rate at which institutions are able to change).[47]

The term *ecosystem* is drawn from the term *ecology* defined by the *Concise Oxford Dictionary* as a "branch of biology dealing with living organisms' habits, modes of life, and relations to their surroundings." Similarly, the "innovation ecosystem" refers to all the organizations that interact with each other to produce some given level of innovation in an economy and the relation of that complex to the influences surrounding it. An innovation ecosystem is the term used to describe the large number and diverse nature of participants and resources that are necessary for innovation. In this context, the actors involved in creating an innovation ecosystem would include the material resources (for example, funds, equipment, facilities) and the human capital (for example, students, faculty, staff, industry researchers, industry representatives) that make up the institutional entities participating in the ecosystem (for example, universities, colleges of engineering, business schools, business firms, venture capitalists, industry-university research institutes, federal or industry-supported Centers of Excellence, state or local economic development and business assistance organizations, funding agencies, policymakers).[48]

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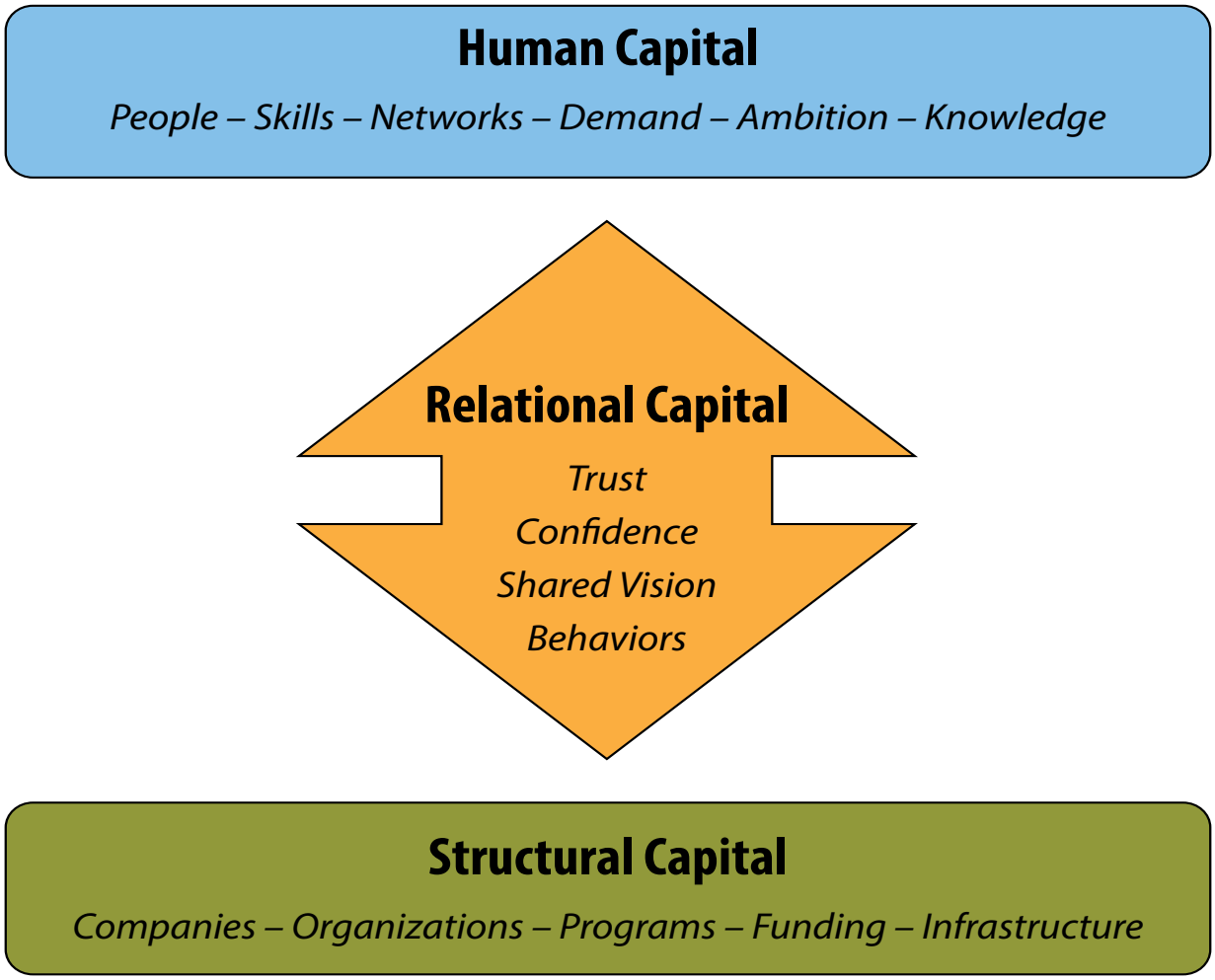
Figure 2 depicts the principles that underpin the role and value of interactions and relationships within the innovation ecosystem.[49]

In figure 2, Structural Capital refers to the companies, organizations, programming, funding, and infrastructure projects that support and develop innovation activity in geographic or sectoral settings. The Relational

Figure 2. Interactions and Relationships Within the Innovation Ecosystem



Capital and Human Capital aspects draw attention to the wider and more intangible, qualitative, and subtle, but important, interactions and relationships that affect innovation. We believe that all three factors play an important role in developing an innovation ecosystem and are interconnected.

Per a report by Meirion Thomas, successful innovation ecosystems are typically characterized by an active knowledge economy comprised of strong public-private partnerships between academia, government, and business, which are all together supported by robust and flexible public policy mechanisms.[50] Successful innovation ecosystems also need a culture of innovation based on interaction and openness to new opportunities and change. The firms within a geographically concentrated cluster share common technologies, skills, knowledge, inputs, consumers, and institutions, facilitating agglomeration across complementary and related industries. A strong cluster environment enhances growth at the region-industry level by facilitating operational efficiency and raising the returns to business expansion, capital investment, and innovation, thereby increasing job creation and productivity.[51] Thus an effective innovation ecosystem enables entrepreneurs, companies, universities, research organizations, investors, and government agencies to interact effectively to maximize the economic impact and potential of their research and innovation. Others have also argued that the presence of a cluster of related industries in a location will foster entrepreneurship by lowering the cost of starting a business, enhancing opportunities for innova-

tion, and enabling better access to a more diverse range of inputs and complementary products.[52] The collocation of companies, customers, suppliers, and other institutions also increases the perception of innovation opportunities while amplifying the pressure to innovate.[53] Since entrepreneurs are essential agents of innovation, a strong cluster environment should foster entrepreneurial activity.

There appear to be two key features that suggest the importance for developing an innovation-based ecosystem at the DOD as a vehicle for the value-maximizing behaviors associated with the efficient transfer of tacit knowledge and resulting *inside-indirect*, *outside-direct*, and *outside-indirect* R&D activities. These features include:

- Flexibility: the innovation ecosystem is dynamic and flexible, allowing new entrants to become part of the ecosystem with minimal entry barriers, while allowing other parts of the ecosystem to fade and leave active involvement.
- Openness: the innovation ecosystem is an open system that is not concerned with its structures, but is, rather, focused on the range and quality of interactions within and between the structures in the ecosystem.

The degree of flexibility and dynamism, the openness of the ecosystem, and the extent and quality of its interactions and relationships will provide important evidence of the health of the innovation ecosystem and the contribution that the innovation ecosystem can potentially make to the organization and its innovation performance. To help understand the innovation ecosystem, it is useful to identify the key stakeholders, participants, and contributors as a basis for later discussion around key interactions and relationships and, crucially, the engagement and interaction of innovative individuals, networks, and companies in the innovation ecosystem.

Framework for Innovation Ecosystem Development

The DOD has recently embarked on a series of initiatives designed to capitalize on the innovation outputs of the non-defense high-tech industry to offset what military leaders and national security experts agree is the accelerating, systemic erosion of the U.S. military-technology edge.[54] Such efforts, while necessary, only address a fraction of the benefit to national security of a more comprehensive partnership between the military and the commercial marketplace. The DOD needs the commercial marketplace not just as a source of advanced technology (that is, outside-direct and outside-indirect), but also as a partner in the commercialization (for example, maturation, validation, production) of military-relevant Intellectual Property (IP).

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The transfer of IP and know-how from the DOD to the civilian world has resulted in some of the most transformative technologies of the modern era. For instance, the Internet, a technology initially developed with funding from the Advanced Research Projects Agency (ARPA, now the Defense Advanced Research Projects Agency or DARPA), is credited with contributing over $1.5 trillion to the global economy each year.[55] In the past, the primary beneficiary of military-to-civilian technology transfer or spin-off was assumed to be the commercial marketplace; today's reality is considerably different. As the Global Positioning System (GPS) and numerous other examples attest, the military stands to gain an equal share of the benefit from outflows of technology. Revenues from technology licenses can be reinvested in DOD laboratory operations, partially mitigating the impact of

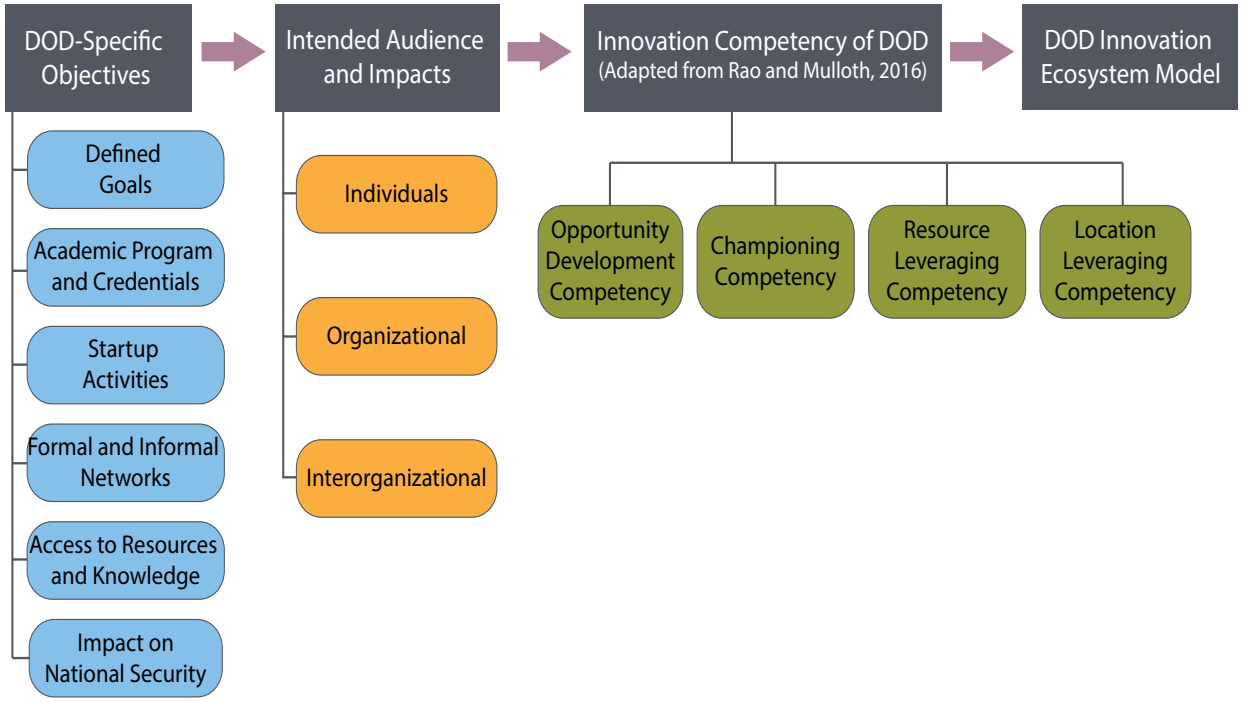
stagnating defense R&D budgets; economies of scale associated with the adoption of nonsensitive, military-relevant technology by commercial markets can reduce the DOD's cost burden for sustaining and scaling products; and commercial partners operating in parallel, nondefense markets can assume or even accelerate the development of DOD-derived IP for future civilian and military applications. Perhaps most importantly, prominently positioning the DOD as part of the commercial technology value chain provides a powerful mechanism to attract, grow, and retain innovators who would not otherwise consider careers in defense. Taking advantage of such opportunities, however, requires an efficient mechanism to facilitate the placement and incubation of military technology with commercial (or consumer) potential.

Ventures are one such mechanism. A venture-focused strategy that expands the range of useful applications for DOD-developed inventions, prototypes novel business models and processes, and provides a channel to partner with the nondefense high-tech community, is essential for the United States to maintain and extend its military-technology advantage. Such a strategy involves three aspects: a) attracting and developing innovators, entrepreneurs, and partners both inside and outside of the DOD who are ready, willing, and able to externalize defense-derived technology or otherwise incubate military-relevant technology in the commercial marketplace; b) furnishing programs and resources that allow these stakeholders to efficiently identify and connect the building blocks associated with venture creation (technologies, problems or market gaps, sales channels, enabling resources, etc.) and to collaborate in the formation of venture concepts and teams; and c) providing resources to mature, nascent ventures for success in commercial and defense markets. To this end, on July 1, 2015, New York University (NYU) initiated a study effort incorporating inputs from noted scholars, business leaders, technologists, and defense practitioners to explore key issues and practical recommendations regarding implementation of a National Security Technology Accelerator (NSTA)—a platform of education and resources designed to catalyze formation of a rich venture ecosystem that complements the traditional military-industrial base by expanding opportunities for innovators and entrepreneurs to commercialize military-relevant R&D from traditional and nontraditional sources. Study activities focused on surveying academic, government, and industry best practices for educating, connecting, and enabling an innovative national workforce that builds technology ventures relevant to the U.S. military. Based on the findings of the NYU study, the DOD officially launched the MD5 National Security Technology Accelerator (MD5) on October 14, 2016.

The DOD maintains and operates over one hundred major research laboratories, University Affiliated Research Centers, and Federally Funded Research and Development Centers that span the widest possible range of technology areas. The DOD laboratory enterprise is augmented by a massive technology test and evaluation infrastructure that consists of 24 sites and covers some 18,000 square miles of land and 180,000 square miles of airspace. In the aggregate, the laboratory enterprise along with the defense industrial base underwrites tens of thousands of scientists, researchers, and technical staff in government, academia, and industry and executes over $70 billion in R&D funding per year. This legacy DOD R&D complex constitutes the Structural Capital component of a DOD innovation ecosystem.

The mission of emerging efforts like MD5 is to develop complementary Relational Capital (that is, trust, confidence, shared vision, and behaviors) and Human Capital (that is, people, skills, networks, demand, ambition, and knowledge) components to leverage, augment, and optimize the available Structural Capital elements to do the following: a) increase access to technological innovations in the commercial and global economy; b) reduce the cost and time to field defense systems and improvements thereto; c) introduce innovative, cost-effective business practices to the DOD; and d), grow a culture of innovation that is a reflection of the rapidly changing operational and technological environments confronting the American military. To accomplish its

Figure 3. DOD Innovation Ecosystem Development Framework



mission, MD5 executes three portfolios of activities as depicted in figure 3: Education, Collaboration, and Acceleration. MD5 Education programs provide the academic and values-based resources to develop innovators and entrepreneurs prepared to solve defense problems throughout their careers; MD5 Collaboration programs enable extended communities of collaborators to network, self-organize, and collaborate in the selection and refinement of value-creating projects; and MD5 Acceleration programs provide resources to build, test, and refine solutions relevant to the national security enterprise.

Development of a viable innovation ecosystem aligned with the interests of the DOD requires a systemic process. The first step in this process is to identify the objectives of such a DOD innovation platform, including factors such as defined goals, academic programs and credentials as indicated in figure 3. The second step is to analyze these identified objectives across the targeted audience at the individual, organizational, and inter-organizational levels. The third step involves exploring the innovation competency of the DOD with respect to the university entrepreneurial competency model.[56] The four specific entrepreneurial competencies are:

- Opportunity development competency: the need to develop a viable business (or mission) opportunity
- Championing competency: the need for championing individuals who provide meaning and energy to the entrepreneurial process
- Resource-leveraging competency: the need to access the resources necessary to develop the new venture
- Location-leveraging competency: the need to locate the new venture in the right ecosystem and support infrastructure.

The above four competencies provide the basis of a useful analytical framework as they highlight how different factors could play varying roles in the development of the DOD's innovation competency.

Opportunity Development Competency. The ability of seeing a potential opportunity for value creation and developing it into a viable business or project is a cognitive act with different individuals playing different roles

throughout the entrepreneurial process.[57] Indeed, the perception of an opportunity is related to the knowledge and experience of the individual and this "opportunity recognition capacity" has been found to be the most important factor in the individual's engagement in new ventures.[58]

Championing Competency. In the case of entrepreneurs, the individual motivation could be related to a range of factors such as technology diffusion, technology development, financial gain, public service, and peer motivations.[59] Within the DOD setting, support from peers, managers and senior leaders, technology transfer office staff, and people in external networks is often critical, particularly in early stages.[60] The role of these champions is to provide emotional meaning and energy to the venture process and, in so doing, procure the commitment of others to the new venture.[61] As an example, it has been argued that organizations such as DARPA should empower their program managers to develop explicit social networks connecting researchers. Such networks would enable the program managers to have expanded access to the research community in order to surface emerging R&D themes that correspond to military requirements.[62]

the mission of emerging efforts like MD5 is to develop complementary Relational Capital (that is, trust, con dence, shared vision, and behaviors) and Human Capital (that is, people, skills, networks, demand, ambition, and knowledge) components to leverage, augment, and optimize the available Structural Capital elements

Resource-Leveraging Competency. Several different resources, such as human capital, financial capital, physical assets, technological resources, and organizational resources, are essential for building a new startup venture. It has also been mentioned that, very often, the intangible "soft" resources are more useful than tangible resources, especially during the early stage of venture development.[63] Successful creation of a new venture depends on the ability both to assemble and to organize resources.[64] The likelihood of launching viable spin-offs (and spin-ons) increases as researchers have access to more financial resources, Intellectual Property assets, knowledge assets in the fields of computer sciences and engineering, knowledge expertise in application fields, social capital assets, and resources of large research universities.[65]

Location-Leveraging Competency. A significant debate is underway regarding the role of the regional economic environment in shaping differences in the rate of regional entrepreneurship and overall economic performance.[66] A strong cluster environment surrounding a particular region-industry enhances the incentives and potential for entrepreneurship. New ventures greatly benefit from the locational advantage of the cluster where the new venture is located.[67] David Brannon noted that new ventures are imprinted with characteristics that fit the specific environment in which they were founded.[68] The internal and external characteristics at founding have long-term effects on the development, survival, and performance of new ventures.[69] Studies also indicate that the perceived viability to act entrepreneurially is to a high degree influenced by the local environment. Individuals who are trained or currently work in a setting where entrepreneurial behavior is encouraged are more likely to become entrepreneurs themselves.[70] However, if the culture and environment do not actively support entrepreneurship, potential entrepreneurs are discouraged.[71] The role of the local work environment is particularly important in the DOD context because these ventures are usually developed by teams where several persons play an active championing role.[72]

Discussion

Based on our literature review, we recommend creating a platform within the DOD focused on developing the Human and Relational Capital components of the innovation ecosystem. Such a platform would include an

organization such as MD5 that leverages human-centered networks. Such an initiative would encourage venture-led, dual-use products that provide a sustainable, competitive advantage for the DOD and the national economy. Given the size and complexity of the DOD, a coordinated strategy that fosters civil-military industry collaboration is more likely to be successful than a strategy that focuses narrowly on the DOD. Specifically, we emphasize using several different criteria, including social and technical metrics, for developing and evaluating the innovation ecosystem. Furthermore, each of the four competencies identified in the framework will need to be explored in more detail within the context of the DOD. Accordingly, in the next stage of our research, we will interviewkey decisionmakers and stakeholders in academia, industry, and relevant departments at the DOD to determine current thinking related to entrepreneurship and innovation-related activities and best practices. A representative sample of respondents will be selected in the following categories: current and former DOD uniformed and civilian leaders; DOD and foreign military innovators; DOD principal investigators and researchers; DOD educators; civilian innovation scholars and thought leaders; venture capitalists; defense industry leaders; commercial high-tech industry leaders; and congressional stakeholders.

The research approach used will be qualitative in nature using evidence based on interpretative interviews and direct observations. The qualitative method is expected to give us a rich and deep interpretation of the organization being studied.[73] The inductive approach will build on existing concepts in research on innovation ecosystems while exploring for new strategies, processes, and relationships.[74] We will explore models that can deliver a broad range of innovation-related activities across organizational boundaries and develop multiple project scenarios that will put our key literature findings into practice. We will report our findings in a subsequent paper and recommend key characteristics that the Department of Defense would need to develop with regard to the identified competencies.

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