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A Paradigm Shift for How DOD Funds People to Drive Innovation Through Entrepreneurial Science

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A Paradigm Shift for How DOD Funds People to Drive Innovation Through Entrepreneurial Science

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Abstract

The Department of Defense (DoD) funds approximately $2.7 billion in basic science annually (American Association for the Advancement of Science, 2020) that generates many high impact innovations from graduate students working in university laboratories. However, the traditional academic path does not train these developing scientists on the process of technology transition and transfer (T3). This paper describes current ecosystem bottlenecks and explores lessons learned for DoD T3 from a novel doctoral program driven with a venture science pedagogy (Campbell, 2024) as well as a complementary entrepreneurial research fellowship. Best practices from these programs can inform the DoD's extramural funding arms, e.g., the Army Research Office, Air Force Office of Scientific Research, and Office of Naval Research, etc., how to optimize their academic scientific investments and their student programs to enhance T3 and impact the acquisition workforce.

Background and Problem Statement

In World War II, the United States created its most innovative engines. After the war Vannevar Bush articulated a peacetime mission for accelerated progress, creating the National Science Foundation (NSF) and DARPA. Today that mission is not being communicated to the 50,000 science, technology, engineering, and math (STEM) PhD scholars trained in the United States, every year. If 1% of this talent base was activated to operationalize their research towards the commercial markets, the United States would see an additional 500 high impact science companies formed every year. The DoD funds more than $3 billion of basic research in universities every year (National Center for Science and Engineering Statistics, 2022) and less than 10% of that focuses on multidisciplinary, convergent science, e.g., MURI (DoD, 2024). DARPA deploys an additional amount of nearly $2 billion every year towards fundamental research. These resources are more than sufficient to repeatedly convert 1% of U.S. STEM PhD scholars into the engineers of our nation's next breakthroughs and to lay the foundations for a "moonshot nation" (Bahcall, 2019). Greater mission impact could be delivered if the DoD has efficient mechanisms to harvest talent and breakthroughs from federal basic science investments.

What is preventing DoD from accessing this talent and opportunity? Three key gaps have developed over the past 50 years, creating a chasm between invention and capability. The United States is not training student inventors in the process of commercialization even though they are often the best positioned to lead this work. Meanwhile, industry has superior market knowledge but seeks short term returns rather than long term investments and relies on academia for the next generation of inventions. At the same time, career academics are pursuing novelty, publications, and grant funding and often overlook the market potential of their intellectual property (IP). Furthermore, some of the legacy sectors in the United States have established defenses to block innovation.

STEM PhD programs simply no longer train for the careers that students will eventually pursue. With limited faculty positions available, the percentage of graduates going into industry continues to increase, however, coursework at universities has not evolved to position these graduates to understand and develop technology in the context of market needs. There are some programs addressing this gap. NSF's Innovation Corps (i-Corp) captures technical talent across the university system, introducing customer discovery skills into the front of the talent pipeline, i.e., starting in undergraduate education. Programs like Activate Entrepreneurial Research Fellows (ERF) and Breakthrough Energy Fellows support postdoctoral talent, nucleating startups when they are ready to spin out. NobleReach Foundation is also clearly demonstrating the value of DARPA-inspired talent development. Both the Graduate Intern and Senior Fellows programs at NobleReach Foundation could be served by a PhD training program dedicated to deep tech moonshots.

The ARPA innovation ecosystem is a key source of talent but its reliance on research professors as Program Directors has been criticized by Bill Bonvillian, one of the architects of ARPA-E (Bonvillian, 2021). The key criticism is that while university laboratories supply the scientific workforce, they are not designed to train its entrepreneurs or managers about how to run DARPA programs. Science-based entrepreneurship, unlike that based on software (e.g., "lean start-up methodology"), depends more on forward-looking analyses of sector-scale opportunities than on customer development. Through specialized venture-building environments, hundreds of new tech stars could pour out of labs every year, giving their regions a fairer share of U.S. innovation.

Innovation incentive structures are not aligned across academia and industry. Historically, large corporations provided much of the runway for U.S. innovation. Before 1970, firms like DuPont, Xerox, and AT&T prized basic research, but changing stakeholder composition and increased competition led to drastic R&D cuts (Arora et al., 2019). Since then, the sharpened divide between academia (research) and industry (development) has been slowing the U.S. economy. Despite increases in total spending on higher education R&D (6x; National Center for Science and Engineering Statistics, 2020), trained PhDs (2x), and research publications (7x; Arora et al., 2019), more product innovations now rely on acquiring inventions from universities, and small firms (nearly 50% in the manufacturing sector; Arora et al., 2017). However, market entry is not a priority for university researchers. Industry rewards the commercial utility of inventions, but academia rewards novelty—which is why academics are 23% less likely to file for a patent than industry for the same discovery (Bikard, 2018). This mismatch in incentives blocks market launch.

While conflicting national, industrial, and institutional incentives limit our growth, competitors are gaining a strategic upper hand. As an International Trade Administration official told Congress in a hearing on the Chinese threat to American competitiveness, “China, by controlling America’s revenue stream, also controls America’s ability to earn income and fund R&D” (Nikakhtar, 2020). In the United States, complex established legacy sectors (CELS) operate within well-defended technological, economic, and political paradigms rooted in incentives, price structures, expert communities, political support, university curricula, and career paths built over decades. With these defenses, incumbent firms and their aging technologies “resist any change that threatens their business models” (Weiss & Bonvillian, 2011). These defenses result in hidden market imperfections like network dependence and non-appropriability—wherein customers benefit more than investors—that keep university spin-offs out of CELS. Thus, the training gap and incentives problem upstream, and market imperfections downstream, are major barriers to our innovation system’s productivity and scope.

Manufacturing economies like China and India build innovation into all sectors and have productivity growth rates two to three times that of the United States (Weiss & Bonvillian, 2011). While reshoring manufacturing is necessary to rescue domestic supply chains, it is not sufficient. China is turning its trade deal revenues into innovation and productivity gains which cannot be reshored—through massive investment in state-owned-enterprises, e.g., LinkDoc (Sturman, 2018) and Jinko Solar (JinkoSolar Holding Co., Ltd., 2020). This structure is why the International Trade Administration emphasizes that a “second essential component of a reshoring strategy is incentivizing inward investments in domestic manufacturing and R&D activities” (Nikakhtar, 2020).

The training gap, incentives problem, and market failures must be solved simultaneously. This necessary alignment was a key insight of Nobel Laureate Economist Paul Romer, in his analysis of the National Defense Education Act’s Title V PhD Fellowship which led to the creation of the fields of electrical engineering and chemical engineering (Romer, 2020). Very similar dynamics were in play when ARPA created the first computer science PhD. These programs leveraged a common playbook which led to the modern-day industries of Energy Resilience and AI, yielding trillions of dollars of economic growth.

More unique to the DoD is the acquisition gap. The DoD is distinct in that it funds full stake product development to turn technologies into capabilities that serve the warfighter. However, the path for startups to be part of their solution set has been encumbered by entrenched prime contractors holding needed relationships and contracts for procurements. This system leaves startups with two paths to selling to the military. In the first, a startup would partner with a prime who then captures most of the value of the product. This economic structure often prevents a startup from raising the private capital it needs to realize the full potential of the technology and to drive pricing down. Alternatively, the startup can scale on the commercial market first, then come back to sell to the DoD. This model is served by DIU and has been successful at delivering new capabilities to the DoD. However, either of these paths increases the time it takes to get new solutions to the warfighter. Tighter integration between startups and the DoD stakeholders could help align incentives earlier in their commercialization journey, unlock follow-on funding, and provide a new path to talent and capability acquisition for the DoD.

Examples of Success

New models are needed to attract and capture talent and innovation into the defense industrial base. Fortunately, the best practices have emerged from some notable programs that specifically serve STEM talent, more specifically the Venture Science Doctorate (VSD) and the Activate Entrepreneurial Research Fellowship (ERF). Their design, best practices, and existing programs can be leveraged to meet the goal of harvesting basic science breakthroughs to create a next generation workforce to serve warfighter needs.

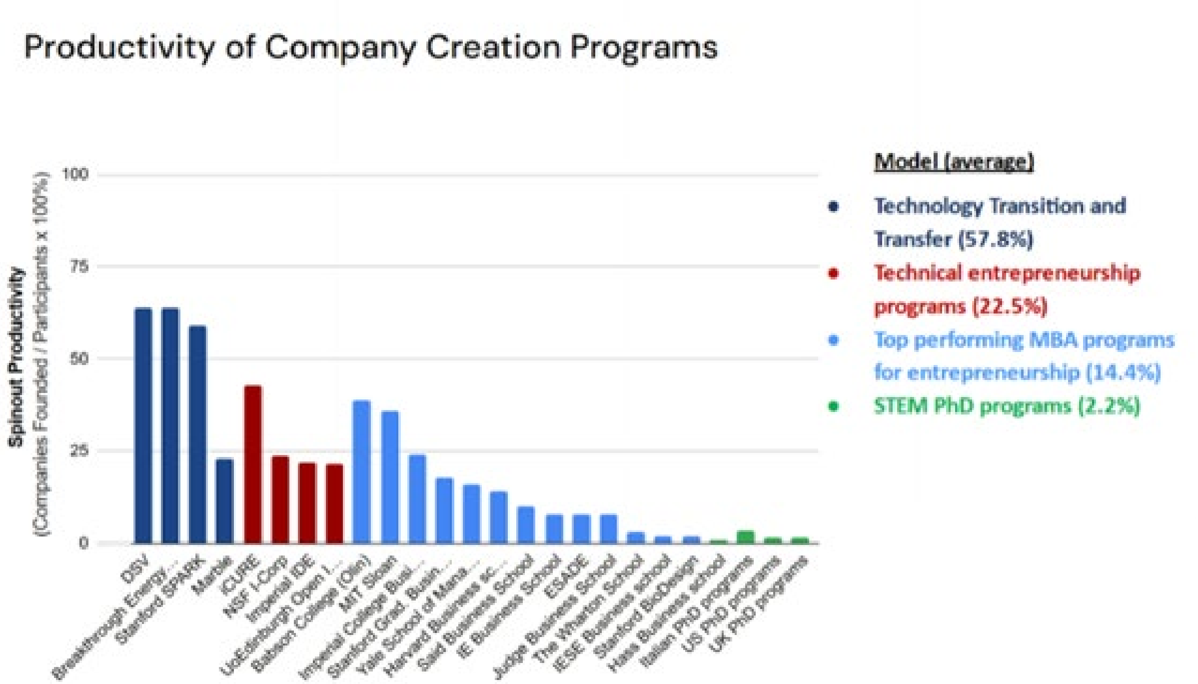
According to Paul Romer, a playbook for modern industry creation is a user-led, industrial, interdisciplinary, portable, scalable, three-year PhD fellowship. The VSD is such a program and updates these design constraints with the addition of i) accessing a broad base of talent and ii) venture-led innovation. The industrial, user-led and interdisciplinary aspects are combined to most rapidly establish new industries, instead of waiting decades for new industries to emerge from basic research.

The VSD is a PhD in moonshots and has been recognized in Forbes magazine as a frontier vehicle for the generation of high impact energy resilience at scale, alongside programs established by the DOE and Bill Gates. It has been endorsed by the Ministry of Education, Trade, and Industry in Japan as international best practice in workforce development, alongside programs of IBM and Mitsubishi Electric. Now with the support of Germany's ARPA (SPRIND), The VSD is well poised to repeat this success story across Europe as Germany's Federal Government has announced its intention to build 150 ventures, through this breakthrough PhD program, by 2029.

In the VSD, every scholar focuses on the process of generating a breakthrough. This three-year PhD fellowship gives scholars a framework for defining "currently impossible outcomes" for society and generating approaches that make those outcomes possible. Year 1 VSD PhD candidates dedicate to inventing and the developing skills and attitudes of elite deep tech founders. In Year 2 they generate proof-of-concept data and a policy white paper summarizing constraints in the innovation ecosystem which are slowing founders down. In Year 3 they build a working prototype, hire co-founders, and engage with several investors around milestones which they must meet to scale up commercially from the prototype. All this activity has financial sustainability as a requirement for success.

A portfolio approach to invention proceeds R&D. A research methodology called "scoping" combines scientific and market research to map the space of possible technology prototypes and business models to find optimal combinations. When a prototype fails, hypotheses adapt through a "Living Lab" approach which draws technologies from disparate fields and protocols from many research laboratories. Deep Science Ventures has partnered with more than 30 universities and national research assets worldwide, including Cornell Tech, The Helmholtz Association, GlaxoSmithKline, and CGIAR—the world's largest agricultural research network. With more than 100 physical sites, inventors can combine technology components across research disciplines to solve an important problem. Mastering "scoping" arms founders with a mindset that prioritizes impact over ideas and a framework for pivoting post-incorporation in response to market pressures. Composing ventures in a "Living Lab" enables pre-commercial coordination. Where technologies like photovoltaic panels took more than 100 years to emerge, now technologies that represent a step-change for an industry can be forecasted and their missing components built in parallel.

Although public procurement has contributed to the launch of the VSD, corporate and philanthropic dollars have too. As a fully accredited college, Deep Science Ventures has established the program, takes equity in, and thereby invests in companies formed. Deep Science Ventures is on a 10-year mission to generate 1,000 ventures per year—only possible if the companies it builds achieve significant returns on investment. By focusing on improving and making advances in the emerging field of venture creation, Deep Science Ventures have created one of the world's first commercialization co-pilots, Elman, which accelerates patent searching, invention, techno-economic analysis, and co-founder recruitment. "Venture Scientists" on the program have already used Elman to dive deep into new fields in materials science and achieve postdoctoral level mastery of the key technical and commercial considerations for their technology in just two months. In the hands of advanced users, Elman can digest an important problem, explore and rank commercially viable solutions, and suggest a team with the right skills mix in a day.



Dedicated T3 programs consistently achieve better outcomes than MBAs and translational research programs. The average conversion of participants to founders across the top MBA programs was 14.4%, with technical entrepreneurship programs having a 22.5% conversion rate. For T3 programs such as DSV's and Activate, which almost exclusively draw on PhDs and postdoctoral fellows, conversion rates are 64% and 100% respectively. T3 programs average 2-times more efficient company formation than technical entrepreneurship programs and are 20-times more efficient than STEM PhD programs. We believe a hybrid program can maximize conversion, at scale, through PhD education.

Complementary to VSD, the Activate ERF, supports scientists turned founders once they are ready to create a company and fully spin out after a traditional STEM PhD. Since 2015, Activate pioneered and scaled nationally the ERF, initially in partnership with the DOE and the Cyclotron Road Division of Lawrence Berkeley National Laboratory. The DOE has since formalized ERFs as Lab-Embedded Entrepreneurship Program (LEEP) and expanded it to other national laboratories. Activate also continued to scale the program, including a node at MIT Lincoln Laboratory, as well as other facilities across the country. Activate operates five ERF programs today.

The high touch fellowship was created to fill a very specific opportunity and resource gap. Entrepreneurs building new hardware-based businesses face unique obstacles when commercializing research and development breakthroughs. In particular, the business faces risk across four key dimensions: technology, team, market, and finance. All startups face financing risk—how can I convince someone to fund my vision? Software companies face a lot of market risk—who will use it, then buy it, and what will they pay? Pharma startups face a lot of technical risk—will this drug be effective and pass clinical trials—but almost no market risk because the product can command multi-billion dollar revenue per year with monopoly status. Hardware startups face both technology and market risk, making their journey even more challenging. This specific barrier is what leaves many academic inventions sitting on the shelf.

Key components of the Activate Fellowship

Table 1. Activate Fellowship

Activate Fellowship: What Makes Us Unique	
Two-year living stipend of $100k/year along with health insurance, travel and education stipend, and relocation support	Fellows are personally financially supported and able to commit full-time to commercializing their technology
Specializing in early-stage technology readiness levels (1-4)	Encourages pivots and early learning cycles to help increase chances of success
Concierge service providing access to a diverse community of peers and advisors, including over 500 hard tech venture capital investors and over 50 corporate partners	Provides risk-free opportunities for guidance, collaboration, education, and follow-on funding across a network of investors, corporations, other entrepreneurs, academics, government, mentors, and advisors
100% support: Activates takes **zero equity**	Offers support and resources without diluting fellows' ownership or diminishing their incentive
$100K R&D stipend and access to lab equipment and dedicated facilities with exclusive rights to their own intellectual property	Seed funding and research support helps budding entrepreneurs advance their technology
Additional pre-seed capital to advance fellow businesses	At least $75K in additional capital through Activate's flexible capital partnership program helps advance their business
Intensive in-person and virtual weekly classes and professional development services, with full-time, personal mentorship	Custom-built program develops scientists into commercial business founders

While most entrepreneurial programs work with existing companies to accelerate their success, Activate, like VSD, comes in at the earliest stage in the entrepreneurial journey to support scientists and engineers as they transition from lab to startup, when the risk of startup failure is at its highest and available funding at its lowest (Hermann, 2022). Many fellows apply to Activate while still in the final year of their PhDs, incorporate once they are accepted into the fellowship, and would not have formed companies without the ERF support. By investing in teams that are too early for accelerator programs, Activate brings to market high-risk technologies that have the potential for impact on a massive scale, bridging a critical gap in the U.S. innovation ecosystem. The fellowship enables a "zero-to-one" journey that transforms proto-companies from an idea to a first product, and Activate does not take equity in exchange for this support.

The Role of Graceful Pivots in Deep Tech Company Progression

Activate Fellows work at the cutting edge of science and engineering, developing technologies that have the potential to transform industries and address global challenges. Early-stage innovation is inherently unpredictable, and the path from concept to impact is rarely linear. Fellows often face evolving technical hurdles, shifting market dynamics, and changing customer needs—all of which require them to pivot. Whether refining their technology for a new application, rethinking their business model, or targeting an entirely different market, Fellows must stay agile and responsive. Activate's program is designed to support this flexibility, providing the time, resources, and mentorship that empower Fellows to make strategic pivots without compromising their long-term vision. This ability to adapt is crucial to maximizing the chances of success in bringing groundbreaking technologies out of the lab and into the world. Fellows are selected in part based on their open-mindedness, ability to learn, and adaptability because these capabilities are essential for any successful founder.

Activate is uniquely structured to help Fellows navigate the uncertain and often non-linear journey of deep tech commercialization, including making strategic pivots when necessary. First, Fellows receive up to two years of non-dilutive funding and a living stipend, which provides a critical financial runway to explore different technical pathways or market applications without immediate pressure to generate revenue or raise external capital. This funding frees Fellows to focus on problem-solving and iteration, not just pitching to investors.

Additionally, Activate offers tailored entrepreneurial training and one-on-one mentorship from their Managing Director who is a seasoned entrepreneur themselves. Along with other advisors, the Managing Director helps Fellows stress-test assumptions, evaluate market feedback, and explore alternative commercialization strategies when their original plans prove challenging. Fellows receive training on product-market fit frameworks as well as the soft skills needed to learn the most about a market. The program's flexible milestone planning process encourages Fellows to revisit and revise their technical and business goals regularly, ensuring their project evolves based on real-world insights. Activate's broad network of industry partners, potential customers, and investors also plays a vital role—facilitating early market validation and providing critical feedback loops that often trigger informed pivots toward higher-value opportunities.

Together, these resources create a supportive environment for thoughtful experimentation, enabling Fellows to pivot confidently—whether that means refining a core technology, shifting customer segments, or even reimagining their entire business model—while staying true to their long-term mission.

Activate believes that scientists can make fantastic entrepreneurs and are the most qualified to lead their companies through all the market learning cycles and pivots. The Activate ERF equips science entrepreneurs with the new mindsets and skills needed to navigate the complex journey of bringing transformative technologies to market. Fellows develop as rigorous, data-driven leaders, continuously seeking high-impact advice and investing in their own growth to make informed decisions—even with imperfect information. They cultivate resilience and adaptability, balancing optimism with healthy skepticism to sustain both themselves and their companies through inevitable challenges. Activate fosters a deep commitment to customer-centric problem solving, guiding Fellows to define clear value propositions and deliver impactful commercial products. By capturing and leveraging a broad network of resources, Fellows reduce risk and accelerate progress, acquiring funding that aligns with their mission, values, and stage of development. The program emphasizes the importance of strong teams, encouraging Fellows to build intentional, mission-driven cultures rooted in trust and collaboration. Through this comprehensive approach, Activate empowers entrepreneurs to pair technical excellence with entrepreneurial acumen, dramatically increasing their potential for long-term success and impact.

While every startup's journey is unique, typical outcomes of the program include one or more pivots, an industry-ready prototype or minimal viable product, specs for that prototype, beachhead market definition with initial customer engagement, follow-on funding raised ($5.3 million, on average which equals 13 months of runway, on average), advisors (three, on average), majority ownership of their companies, and defined next steps for product development and manufacturing milestones. Ninety-six percent of Activate companies are still operating today, but intentional “no-gos” also occur. Activate considers “no-go” decisions an important indicator of success, demonstrating that fellows have learned leadership skills and made a deliberate choice more quickly (than they otherwise might have) that there was not a clear path to market.

Since 2015, 249 Activate Fellows have created 197 science-based companies, some of which will go on to change the world. These companies have collectively raised $4 billion in follow-on funding, mostly in private capital. This amount translates to more than 50x leverage on every dollar spent to support the fellowships. Activate companies have created more than 2,800 jobs and earned more than $71 million in revenue. During the fellowship, companies raise an average of $5.3 million. Another leading measure of success is that 96% of Fellow companies are still active.

Results

The analyses in this manuscript indicate that a notable venture builder in the United Kingdom has led to 50 companies in just eight years with a half a billion dollar valuation and is now scaling through the VSD. Similarly, results of Activate’s ERF indicate that in a similar eight year time frame, Fellows created nearly 200 companies which went on to raise nearly $4 billion. We derive recommendations for adopting lessons learned based on these analyses.

Recommendations on Adoption of VSD

Although several U.S. agencies offer various PhD fellowships, none are venture focused. A DoD-sponsored VSD program represents an attractive opportunity to explore hundreds more advanced technology avenues in parallel, every year. Generating more founders within the defense workforce will lead to more dual use technologies, a larger ecosystem of deep tech human resources, and technologies that can contribute to the continuous transformation process (Rainey, 2024). By focusing on founder-type recruitment, learning engineering for elite deep tech founder development, and venture capital fundraising, the VSD can enable the DoD to generate immediate, direct returns on university R&D investment. Doctoral training is the gateway into the deep tech workforce but admissions favor highly individualistic achievement styles and academic career ambitions, biasing against effective deep tech founders. There is a great opportunity to adapt some portion of the resources that go into existing degree funding programs and pivot them to focus on developing advanced synergistic technologies in parallel, and growing the number of technology experts that the DoD can draw on by growing the dual use economy. The VSD can also generate more ambitious talent for follow on programs like a DoD-sponsored ERF.

Recommendations on Adoption of ERF

By adopting the ERF model as other federal agencies, such as DOE, NSF, and NIST, have, DoD-sponsored Activate fellowships could further the DoD’s mission by directing this talent and their product development to meet military needs. At the same time, the model captures private capital to accelerate the growth of these companies. The cohort-based model also means that the DoD as an engaged partner could access and inform the business model of all relevant fellows in the cohort regardless of their actual sponsor, quite literally having a multiplicative effect of shaping early company trajectories. This approach enables the DoD to capture talent and technology emanating from other federal agency’s basic science investments. Fellows certainly choose their own path in product development and customer acquisition, but are informed and influenced by the stakeholders to whom they have access.

Imagine if the acquisition process was demystified for them and they had access to DoD product roadmaps with defined technology insertion points. Fellows would not only be prime candidates to receive R&D and prototype funding, but also build relationships that equip them to build for future requirements.

Discussion

We report on the success of the VSD and ERF to demonstrate how DoD agencies could enhance T3 of fundamental science across the academic/government nexus using best practices of VSD and ERF. By smoothing transitions across early Technology Readiness Levels (TRLs) working across the DOE, academia, industry, and the DoD, these practices improve the probability of private capital capture for promising technology, leveraging highly trained technical personnel, lab infrastructure, and adjacent market demands to catalyze an industrial base. Collectively, they enhance the availability and adequacy of external (venture) funding—poised with a strong track record of returning a 50X multiple to initial government investments, such as the $25 million appropriated for the LEEP. Just as the Naval Postgraduate School (NPS) has played a notable role in technology transitions from experimentation to operational use of autonomous systems, its proximity to Silicon Valley and being a use-inspired military research institution position NPS as a strong hub for instantiating the DoD's VSD programs and ERF. Tighter connection and synergy between DoD-funded venture science PhD students and their ERF can enhance T3 through collaboration among defense, industry, private capital, and academia—most importantly accessing financiers with their capital stacks that are ever more targeting deep tech.

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