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OFFICE OF THE SECRETARY OF DEFENSE

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DEFENSE
SCIENCE BOARD

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

SUBJECT: Final Report of the Defense Science Board Summer Study on Technology
Superiority

I am pleased to forward the final products of the 2022 Defense Science Board Summer Study on Technology Superiority. This study explored concepts, capabilities, and strategies to enhance the military technological advantage of the United States. The ability of America's strategic competitors and adversaries to utilize advanced technology threatens our national security and necessitates the development of new operational concepts, increased cooperation among stakeholders, and rapid employment of emerging science and technology capabilities. The study examined the fourteen critical technology areas identified by the Under Secretary of Defense for Research and Engineering (USD(R&E)) including microelectronics, quantum science, FutureG, advanced computing and software, biotechnology, renewable energy generation and storage, directed energy, hypersonics, and space technology.

The report provides key recommendations for the Department of Defense (DoD) with actionable steps for USD(R&E) to further research, science, technology, engineering, and innovation across the critical technology areas. All recommendations highlight the importance of DoD's technology strategy in strengthening the overall technological superiority of the United States. I fully endorse the findings and recommendations in this report and urge their careful consideration and adoption.

A handwritten signature in black ink, reading "Eric D. Evans".

Dr. Eric D. Evans
Chair, Defense Science Board

Executive Summary

The Defense Science Board (DSB) Summer Study on Technology Superiority examined concepts, capabilities, and strategies that may enhance the military technological advantage of the United States. The study reviewed the fourteen critical technology areas identified by the Under Secretary of Defense for Research and Engineering (USD(R&E)) and emphasized the areas of microelectronics, quantum science, FutureG, advanced computing and software, biotechnology, renewable energy generation and storage, directed energy, hypersonics, and space technology. The study also considered the strategic value of the global innovations ecosystem, the need for cooperation across government, industry, academia, and foreign partners, and the urgency to integrate all elements of national power to ensure the enduring technological superiority of the United States. The following overview highlights key findings of the study by critical technology area.

Microelectronics

Microelectronics are fundamental to all Department of Defense (DoD) systems and missions. To maintain access to state-of-the-art microelectronics, the DoD should work closely with the commercial industry to better understand and leverage emerging products, security best practices, and production workflows. The DoD should focus funding efforts on captive manufacturing facilities, particularly for strategic radiation hardened (rad-hard) components and high-power analog electronics. The DoD should also continuously test and perform vulnerability analysis of commercial-off-the-shelf intercommunications systems in use in DoD systems. Finally, given that nearly all innovation in microelectronics occurs as a result of commercial research, the DoD should rapidly integrate the fruit of that commercial research using 3D interconnect and software customization, rather than relying on bespoke hardware.

Quantum Science

Quantum sensing for DoD-motivated problems is beginning to mature and promising prototypes have been developed for timing, communications, and navigation. Quantum communications, on the other hand, is still immature, and quantum key distribution is unlikely to lead to benefits for the DoD. For promising quantum science applications, the DoD should focus on maturation of underlying devices and technologies (e.g., lasers, optics, materials), system engineering, and manufacturing processes.

FutureG

FutureG communications include short-haul communications which will largely be informed by commercial developments and long-haul communications that include both space and air components. Current DoD 5th generation mobile network (5G) emphases are on enterprise applications of 5G, where FutureG must increase focus on operational and tactical applications. For short-haul communications, the DoD should continue to work closely with commercial

industry early in development cycles to leverage standard commercial parts and networks, while also conducting rigorous evaluations of security vulnerabilities in emerging products and architectures.

Advanced Computing and Software

A set of topics were explored under the computing and software umbrella, ranging from architecture design to workforce strategies. Recommendations included the development of strategies that leverage lightweight architectures, such as those pioneered by layered internet protocol strategies, to enable pervasive interoperability. The DoD should also leverage commercial developments in artificial intelligence (AI), especially Generative AI. A set of specific applications are recommended, including rapid code development and decision support. Finally, strategies were offered to expand the base of potential software developers available to support DoD efforts, including those that are classified.

Biotechnology

Biotechnology is a rapidly evolving area of development for the DoD. The applications are vast and can include biology in the service of manufacturing, including specialized materials; however, this study focused on biodefense, which has become much more complex due to advancements in biotechnology. The COVID-19 pandemic offered a real-world example of the potential impact of complex, unwarned bio-events. This study explored the needs and opportunities for developing and deploying the threat-independent biodefenses needed in light of the biotechnology revolution currently underway, emphasizing both bio-surveillance and countermeasures.

Renewable Energy

Fuel logistics pose a significant challenge for overseas operations against a near-peer adversary; however, opportunities exist to minimize risk and enable joint force freedom of operation. In particular, this study emphasized and provided recommendations for developing locally sourced synthetic fuels as well as pre-deployed energy assets including nuclear micro-reactors and high-capacity batteries. In addition, it is noted that DoD applications would benefit from targeted investments in very high discharge batteries which are uncommon in the commercial world. The DoD should explore viable alternative synthetic fuels (e.g., hydrogen-based) which can be used in theater at comparable or reduced price and at operationally relevant capacities.

Directed Energy, Hypersonics, and Space Technology

Significant opportunities exist to enhance the DoD's warfighting posture through the development and deployment of technologies and capabilities in directed energy (e.g., lasers and high-power microwaves), hypersonics, and space systems. Further information is provided in the classified report.

Innovation Ecosystem

The innovation ecosystem in the United States is fueled by a free and open society and economic system and is admired globally. Furthermore, the United States has the strategic advantage of having a very broad base of innovative global partners. Together, the global innovation ecosystem that the United States can leverage holds the promise of being a key enduring strategic advantage over the decades to come. Myriad efforts exist to nourish and better leverage our ecosystem, but some are insufficient, not cohered, and not part of a broad strategy to maximize this strategic advantage. The DoD should develop and launch an innovation ecosystem campaign aimed at expanding this strategic advantage in the near, mid, and far term.

Terms of Reference



RESEARCH
AND ENGINEERING

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Department of Defense
OFFICE OF PREPUBLICATION AND SECURITY REVIEW

MEMORANDUM FOR CHAIR, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference – Defense Science Board Summer Study on Technology Superiority

American military technological dominance is no longer assured as strategic competitors to the United States have greater access to state-of-the-art technologies than ever before. The employment of such technologies by adversaries and competitors can disrupt America's interests and threaten our national security. The challenges are diverse and complex, ranging from sophisticated cyber-attacks to supply chain risks, and from defending against hypersonic missiles to responding to biological threats. These demands call for new operational concepts, increasingly joint operations, and quickly operationalizing and fielding emerging science and technology capabilities.

The objective of the Defense Science Board's (DSB) Summer Study on Technology Superiority ("the Summer Study") is to recommend concepts, capabilities, and strategies that may enhance the military technological advantage of the United States, where these recommendations may inform the National Defense Science and Technology strategy for the Department of Defense (DoD or "the Department"), which will be spearheaded by the Under Secretary of Defense for Research and Engineering (USD(R&E)). In conducting this Summer Study, the DSB should examine the fourteen critical technology areas identified in the USD(R&E)'s Technology Vision for an Era of Competition ("the Technology Vision") and provide options for the Department to champion associated research, science, technology, engineering, and innovation in these domains. The DSB should identify opportunities for cooperation in these domains among the Government, the Defense Industrial Base, academia, Federally Funded Research and Development Centers, University Affiliated Research Centers, small businesses, new entrants and startups, international partners, and even with competitors. The goal is to understand the global race for technological advantage and ensure that the DoD's technology strategy will strengthen the technological superiority of the United States.

Through the Summer Study terms of reference, I am tasking the DSB to provide a report on findings and recommendations for a detailed technology strategy which encompasses each of the fourteen areas covered in the USD(R&E) Technology Vision. The DSB report and recommended strategies should take into consideration the following:

- Prioritizing near-term asymmetric capabilities;
- Identifying areas where current programs underway can be better leveraged to support the mission;

- Highlighting rapid development needs – to include opportunities for technology demonstration within Combatant Command operational exercises and/or Rapid Defense Experimentation Reserve (RDER) investment;
- Assessing current efforts – and opportunities – for cooperating with industry, academia, and foreign allies and partners to advance the state-of-the-art, explore creative applications of new concepts, enhance agility in development, and rapidly operationalize in these fields; and
- Such other matters as the Secretary or I consider appropriate.

The DSB's findings, observations, and recommendations will be thoroughly discussed and deliberated on in a properly noticed and public meeting subject to the Federal Advisory Committee Act (5 United States Code (U.S.C.), Appendix) and Government in the Sunshine Act (5 U.S.C. § 552b) requirements. The DSB will provide its findings and recommendations to the USD(R&E) as the Sponsor of the DSB. The start date of the study period will be 30 days from the signing of this Summer Study Terms of Reference (ToR). In no event will the duration of the Summer Study exceed 24 months from the start date.

In support of this ToR and the work conducted in response to it, the DSB has my full support to meet with Department leaders. DSB staff, on behalf of DSB, may request the Office of the Secretary of Defense and DoD Component Heads to timely furnish any requested information, assistance, or access to personnel to the DSB. All requests shall be consistent with applicable laws, applicable security classifications, DoDI 5105.04, "Department of Defense Federal Advisory Committee Management Program," and this ToR. As special government employee members of a DoD federal advisory committee, DSB members will not be given any access to DoD networks, to include DoD email systems.

Once material is provided to the DSB, it becomes a permanent part of the DSB's records. All data/information provided is subject to public inspection unless the originating Component office properly marks the data/information with the appropriate classification and Freedom of Information Act (5 U.S.C. § 552) exemption categories before the data/information is released to the DSB.

The DSB will operate in accordance with the provisions of the Federal Advisory Committee Act, the Government in the Sunshine Act, and other applicable federal statutes, regulations, and policy. Individual DSB members do not have the authority to make decisions or recommendations on behalf of the DSB nor report directly to any Federal representative. The members of the DSB are subject to certain Federal ethics laws governing conflicts of interest, including 18 U.S.C. § 208, and the Standards of Ethical Conduct regulations in 5 Code of Federal Regulations Part 2635.



Heidi Shyu

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Acronyms and Abbreviations

5G	5th Generation Mobile Network
AI	Artificial Intelligence
DoD	Department of Defense
DSB	Defense Science Board
USD(R&E)	Under Secretary of Defense (Research and Engineering)