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Roles and Tasks of India's Defence R&D vis-a-vis USA's RDT&E

A Preliminary Analysis

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A top ideologue for the defence industry, defence acquisition process, indigenous defence development and self-sufficiency, **Vice Admiral Raman Puri**,PVSM,AVSM,VSM (Retd.) is a former Commander-in-Chief of Eastern Naval Command and Chief of the Integrated Defence Staff. He is also a Distinguished
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Roles and Tasks of India's Defence R&D vis-a-vis USA's RDT & E: A Preliminary Analysis

DRDO's R&D Structure

While developing a range of products for the Armed Forces - covering electronics, sensors, weapons, missiles, armored vehicles, combat vehicles, aircrafts, unmanned systems, advanced computing systems and advanced materials – India's Defence Research & Development Organization (DRDO) has been applying multi-disciplinary engineering, technology and scientific methods. DRDO's strength has helped achieving higher levels of technological maturity and self-reliance in some of the critical Defence systems and technologies such as strategic systems, air defense systems, radars, sonars, aircrafts, airborne early warning & Control (AEW&C), underwater weapons, electronic warfare (EW) systems, guns, tanks and armoured vehicles. DRDO's policies are also helping towards building a robust industry-academia interaction framework and a greater Defence research & development (R&D) and ecosystem in the country.

In this context, an analysis of the USA Defense R&D activities by the various Laboratories and Centers and Budget allocations has been being carried out to help evolve greater clarity among the stakeholders. Mapping of R&D activities in DOD's R&D Framework is also done to clarify on certain misconceptions on the roles and tasks of DRDO & the often-stated comparisons to DARPA. Some of the important conclusions which can be drawn based on of this analysis are as addressed in the following parts.

DRDO's Comparison with the USA's Defence R&D Structure and its DARPA (Defence Advanced Research Projects Agency)

There is a wide perception that USA's Defence R&D which includes DARPA is primarily executed by Industry, but this is mostly not the case. There is a large network of Defence R&D Laboratories (Lab) and Centres headed by Under Secretary of Defence (Research and Engineering or R&E) driving the projects for Army, Navy and Air force. US Defense (R&E) steers the Defence research in various domains to meet the modernization priorities of the Armed Forces with advanced and futuristic technologies. Indian Defence R&D setup is on similar lines in which DRDO comprising of Labs working in diverse domains

execute projects through various Director Generals heading clusters of Labs for all the three services with the help of industry participation in various phases of execution. The US Defense (R&E) moves to making prototypes through industry by Advanced Technology Demonstrators (ATD) and Advanced Concept Technology Demonstrators (ACTD) which take projects from Technology Readiness Level (TRL)-3/4 to TRL-7. DRDO similarly engages to produce prototypes in Mission or Technology Development Mode, in some cases through the Development-cum-Production Partner Mode.

Roles and Tasks of US Defence (R&E) in USA's Department of Defence (DoD) setup are similar to Secretary Defence Department R&D (DDR&D) and Chairman DRDO, albeit with lesser number of laboratories, manpower and budget which naturally limit the scope of R&D activities of the DRDO. In the present USA DoD's R&D framework, US Defence (R&E) is supervising all defense research and engineering, technology development, technology transition, appropriate prototyping activities, experimentation and developmental testing activities and programs, and unifying defense research and engineering efforts across DoD. Office of US Defence (R&D) also oversees the functioning of agencies such as Defense Advanced Research Projects Agency (DARPA), the Defense Innovation Unit, the Missile Defense Agency, and the Space Development Agency (SDA). In the Indian context, role and responsibilities of Secretary DDR&D is aligned to US Defence (R&E) wherein DRDO, Aeronautical Development Agency (ADA), Defence Institute of Advanced Technology (DIAT) and other agencies report to the Secretary DDR&D, which is part of the Ministry of Defence headed by Raksha Mantri. This is similar to US Defence (R&E) reporting to Secretary of Defence in the USA DoD's organizational structure.

Spectrum of Defense R&D activities in USA varies from environmental science, life sciences, missile, aero, space, electronics, computing, modeling and simulation, armaments etc. Significant numbers of laboratories are working in Life Science domain helping towards support to soldiers enhancing their combat effectiveness in the operational scenarios. A significant number of Defense Laboratories and Centers in Naval domain also focus on Naval Medical and Naval Submarine Medical Research. A total of approximately 86 Defense Labs, R&D and Technology Centers including headquarters and offices work towards executing the projects of the Army in multiple spectrums of warfare and technologies. Similarly, a total of approximately 90 Defense Labs, R&D Centers and Technology Centers work towards executing the projects of Navy while approximately 25 Defense Labs, R&D Centers and Technology Centers work towards executing the projects of Air Force. There are a total of 12 Federally Funded Research and Development Centers (FFRDC) also placed under the US Defence (R&E), to work on sponsored projects by different agencies such as Army, Navy, Air force, Office of the Secretary of Defense and the National Security Agency. In the Indian context, the DRDO - with a base of 43 Defence Laboratories, five Young Scientists' Laboratories, the ADA, the DIAT and 10 Centres of Excellence at leading academic institutes - is on fast track to network the academia and industry as per the present Government's priorities towards achieving self-reliance in defence systems and technologies.

USA's Defense Laboratories and Centers are focusing on some of the essential research programs to the Army's modernization priorities. On similar lines, the projects and programs being executed by DRDO, ADA and other agencies under Secretary DDR&D are to meet the modernization priorities of Indian Armed Forces. These fall in the bracket of its 5-yr and 10-yr plans. In this context, the DRDO's R&D activities are more or less in the same technology directions of that of the USA, although DRDO programmes and projects need to be strengthened by more manpower to meet the spectrum of futuristic defense projects.

Missile and Space Defence is one of the priority areas of USA's DoD. USA's Space and Missile Defense Technical Center provides technologies to meet today's requirements as well as the future needs in directed energy, space, cyberspace, hypersonic and integrated air and missile defense. DRDO's Missile Complex consisting of a cluster of Laboratories have initiated many programs and accomplished successes in these advanced technology domains. DRDO has started involving its Development-cum-Production Partners (DcPP) during design and development phases for smooth transition of the skill sets and technologies to industries. These initiatives will help towards meeting the mandate of the Government in building a defense industrial base in the country and exports of defense equipment. USA's Missile Defence Agency under US Defence (R&D) can be aligned with the roles and tasks of DRDO's air Defence and missile programmes. Some of the important ongoing technology programs of the Missile Defence Agency (MDA) include: Terminal High Altitude Area Defence (THAAD) and Patriot Missile Defence Systems, Arrow-3 Interceptors and Hypersonic Missile Defence Program. Space- and ground-based Battle Management, Command, Control, and Communications (BMC3) software capabilities for the National Defense Space Architecture (NDSA) and 'Satellite Swarm' for tracking Hypersonic Missiles are some of the priority technology programs of the SDA.

Role of US's DARPA is primarily to execute Advanced R&D through academia, industry and other R&D Centres which is just a miniscule part approximately 3-4 percent of Defence R&D Budget, though it amounts to 3-3.5 billion dollars and in the entire setup doesn't directly make any final product for Defence . However, share of funding to the industry for executing the DARPA projects is approximately 62 percent out of its allocations whereas the share of DARPA's funding to universities, colleges and intramural are approximately 18 percent and 11 percent respectively. In the DRDO set-up, activities under Director General (Technology Management) although much smaller in size and budget allocations, can be aligned with the activities of DARPA. DRDO's Directorate of Futuristic Technology Management (DFTM) have set up number of Centres of Excellence (CoE) at premier academic institutes of the country working on advanced technologies. This is akin to the US's FFRDCs which are sponsored by one or more US government departments and agencies; DARPA funding to FFRDC is approximately four percent of its budgetary allocations. One of the DRDO's CoE's, the Joint Advanced Technology Centre (JATC) at IIT Delhi, has undertaken multidisciplinary directed basic and applied research in the identified research verticals such as Advanced Ballistics, Special Structures and Protection Technologies (ABSSP), Advanced Electromagnetic Devices and Terahertz Technologies (EMDTERA), Brain Computer Interface and Brain Machine Intelligence (BRAIN-CIAMI), Photonic Technologies, Plasmonics and Quantum Photonics (P2QP), and Smart and Intelligent Textile Technologies (SITEX). Similarly, other centers have taken focused projects under other domains. DRDO's Technology Development Fund Scheme encourages participation of public and private industries, especially the Micro, Small & Medium Enterprises (MSME) and 'Start-ups', so as to create an eco-system for enhancing cutting-edge technology capabilities for defence application.

Majority of DARPA's projects on Advanced Technologies are getting executed by the industry. DRDO too involves industry as DcPP partners. This is important in DRDO's context, since Indian industry is in the gearing up phase for taking up large scale defence development programs. Many good products are being produced by the industry and being delivered and maintained, however multi-disciplinary and complex defence technologies requiring programmes and project management remains within domain of DRDO. In order to encourage industry to embrace large and complex technology-based product development, technical handholding is as important as government investment in the projects. upcoming technology-based products like hypersonic vehicle programs, glide vehicles and anti- hypersonic defence

require intensive design, development, experimentation and testing in multiple areas like aerodynamics, aeronautics, scramjet engines, materials and precision control actuation for mission control. Similarly modern fighter aircrafts and modern armored systems will require intense scientific and technological work before industry can take it forward.

USA's Research, development, Test & Evaluation (RDT&E) budget allocations shown that majority of the budgets are allocated for major systems and operational systems development followed by advanced technology development. These programmes are structured by the DoD(S&T) to accelerate movement of technologies through the continuation to maturity through Advanced Technology Demonstrators (ATDs) and Advanced Concept Technology Demonstrators (ACTDs). The DRDO takes up mission mode projects and delivers them as prototypes in development-cum-production partner mode and also technology development projects wherein also in some cases the industry is engaged in the development-cum-production partner mode to produce the prototypes often through many interactions.

Allocations for the funds for basic and applied research are three and six percent of total RDT&E budget. In the Indian context, DRDO is the lead agency for RDT&E, meeting the requirement as projected by the Armed Forces (through the long-term plans and qualitative requirements) and the budget allocations priorities are aligned with the USA's funding patterns. DARPA's budget allocation as stated above is approximately 3-4 percent of total RDT&E Budget of the DoD. Majority of the DARPA's budget allocations are for applied research (41 percent) and advanced technology development (42 percent).

Details of the USA's Defence R&D framework and its mapping with India's Defence R&D framework is provided at Appendix I. USA's defence budget distribution and its Defence R&D priorities are provided at Appendices II and III respectively.

Inferences

Inferences from the analysis of the US Defence (R&E)'s structure, roles and priorities vis-à-vis the DRDO are listed in the following paragraphs.

1. Structurally in its roles and responsibilities DRDO is well aligned with US Defence (R&E). Tasks of the US Defence (R&E) in USA's DoD set up are similar to Secretary DDR&D and Chairman DRDO. In present US Department of Defence's R&D framework, US Defence (R&E) supervises all defence research and engineering, technology development, technology transition, appropriate prototyping activities, unifying the Defence R&E efforts across the DoD. US Defence (R&E) also oversees the functions of agencies such as DARPA, Defence Innovation Unit, Missile Defence Agency and Space Defence Agency. The organization chart of the office of US Defence (R&E) is provided at Appendix I.

2. Both secretary DDR&D and US Defence (R&D) report to their respective Defence Ministers, viz. Raksha Mantri and Secretary Defence respectively.

3. The spectrums of Defence R&D activities in USA are similar to those of DRDO though obviously of a lesser scope. A total of approximately 200 Defence Laboratories, R&D and Technology Centres including the Offices execute various projects for the three services. A significant number of defence laboratories are in the life sciences. Federally funded R&D Centres for sponsored projects from services and the National Security Agency are placed under US Defence (R&E). In the Indian context, DRDO has a base of 43 Defence Laboratories, five Young Scientists Laboratories, ADA and

DIAT, and 10 Centres of Excellence at leading academic institutes.

4. At Appendix II, a mapping of USA and DARPA R&D technology domains of Defence Laboratories and Centres is done with the R&D activities and missions of the DRDO. It is however noteworthy that the scope of DRDO's charter is limited by the resources in terms of manpower, equipment and computing infrastructure which are much lesser than that of US Defence R&D Laboratories and this aspect is directly related to the funding which is less than 10 percent of US Defence (R&D). There are many areas, where DRDO does not have dedicated unit to do the necessary R&D. There are many areas which are not sufficiently invested in like international research collaborations, life cycle assessment, technology centres and technology think tanks. The bold and italicized text in the ''Capabilities' column pertaining to US Defence Labs indicates the particular area where DRDO's R&D is not being undertaken in full-fledged manner. Considering the resources, especially manpower and the funding available, similar research in various domains to encourage domain specificity is not possible in the case of DRDO. Extensive R&D is conducted on health and operational efficiency of personnel for different arms of armed forces. There are many areas which DRDO should take up R&D in addition to existing technology development and system development projects and scale the roadmap with the help of much more funding. Special focus should be on advanced research on most technologies, and extensive funding need to be provided for research and its usage in the existing and next generation systems.

5. R&D activities of Missile Defence Agency under US Defence (R&D) are aligned to that of Programme 'Air Defence' or AD in DRDO set-up. Design and development of advanced ballistic missile interceptors, long range detection and tracking radars and battle management command, control and communications systems are technology R&D priorities of Missile Defence Agency. In similar lines DRDO's Programme AD has developed PDV exo-atmospheric interceptors and Advanced Air Defence (AAD) endo-atmospheric Ballistic Missile Defence (BMD) interceptors, and demonstrated its capability during multiple successful flight trials. Programme 'AD' is working on AD-1 endo-atmospheric interceptor and AD-2 exo-atmospheric interceptor as a part of Phase-2 of Ballistic Missile Defence Programme. Labs in missile complex along with other labs are working in mission mode to deliver the products meeting the Armed forces present and future needs in directed Energy, cyberspace, hypersonic, air and missile domains similar to USA's space and missile Defence Technical Center. UA Defence R&D priorities and activities of Defence Laboratories, DARPA, Missile Defence Agency and Space Defence Agency are provided at Appendix III.

6. Role of DARPA under US (R&D) is primarily to execute Advanced R&D through academia, industry and other R&D Centres with a funding which is approximately 3-4 percent of Defence R&D budget allocations. DARPA funding to universities and colleges, intramural research and industry are 18, 11 and 62 percent of its budget allocations. In the similar lines, Director General (Technology Management) under chairman DRDO sponsors R&D activities at premier universities and institutes and also through Centres of Excellence established at these academic institutes. DRDO's Technology Development Fund scheme encourages participation of public and private industries, especially MSMEs and Start-ups, so as to create an eco-system for enhancing cutting edge technology capability for defence application.

7. In the USA DoD R&D setup, their Industry sponsors Defence R&D activities at FFRDC which come under the purview of US (R&D). On similar lines, in India, Defence R&D fund allocations for r efforts towards building Defence R&D ecosystems with the academia and industry should

come under purview of Secretary DDR&D. The scope of the Technology Development Fund (TDF) should be extended to enable some critical technologies, components and subsystems within a funding support of say 50 crores from the current funding limit of 10 crores to promote interaction with industry as in the case of DARPA though the latter has an order of magnitude higher funding available for the purpose.

8. USA DoD budget estimate for RDT&E in FY 2021 is approximately 100 billion US Dollars. Allocation is approximately 3 percent for basic research and 6 percent for applied research. These Defence R&D research activities get performed largely at academia and correspond to Technology Readiness Levels of 1 to 2/3. However, major share of the funds allocated for RDT&E activities are for Advanced Technology Development, Major Systems Development and Operational Systems Development which correspond to 7, 47 and 37 percent of total budget allocations. On the similar lines, majority of the budget allocations of DRDO are for major systems and technology development in Technology or Mission Mode Projects. Budget allocations of 25 percent of Defence R&D funding to industries from within current DRDO allocations, which is less than 4 percent of US (R&D) fund allocation, will hamper the advanced technology development priorities of DRDO; therefore, it requires a review. Details of US DoD funding allocations along with funding distribution of RDT&E and DARPA are provided at Appendix IV.

9. Human Resources: From above analysis the alignment between the roles, mission and tasks of US (R&D) & DRDO is clearly established. While large differential in the resource availability in terms of finance, infrastructure and scope of R&D undertaken is unavoidable, an area current concern for the DRDO is the situation of human resources. It is worth noting that the total scientists in US (R&D) structure is approximately one lakh with about 40,000 deployed directly in laboratories and the balance in the many centers and agencies under US (R&D). Comparatively DRDO sanctioned manpower is less than 10 percent and even here there are sanctioning and perception issues. This aspect is explained below:-

   a. With emphasis on *Atamanirbharta,* the challenges in the field of R&D for fundamental research to technology development, system engineering and system development will only increase and this apart from other factors will require appropriate human resource polices. Piecemeal small sanctions to meet some critical project needs in the last decade is today having deleterious impact on the national Defence R&D capability. Build-up of DRDO with decades of effort is likely to suffer a crippling effect as a number of experienced scientists and even supporting technical staff have either retired or are on verge of retiring. This has led to a voids and an inverted pyramid structure. The base of Scientists B & C who provide the backbone and energy to the system are now in minuscule numbers. Further experienced leadership needed for project and laboratory management and mentoring of the young scientists have either retired or will retire in significant numbers in the next four to five years.

   b. It may further be mentioned that the mode in which it is possible to secure *Atmanirbharta* in the foreseeable future is through the development-cum-production partner mode with the DRDO. Efforts in the past at 'Mark 1', and then transfer of technology, system design and development effort to the industry is mostly unlikely to succeed in complex systems, as has been our past experience since 2009. Therefore, it is important to take corrective measures to address the manpower situation in DRDO.

c. While the reasons for this current manpower situation is partly attributable to DRDO itself, the situation as mentioned above needs to be addressed urgently and out-of-the-box measures are required to be taken. For this, immediate phased recruitment of good quality scientists in specific disciplines and policy changes to laterally induct scientists at different levels are needed. Also, here is the need to retain scientists heading major technology development and mission mode projects beyond their current retiring age of 60. Golden handshake and early retirement to those whose performance is not up to the mark may be examined.

d. Further, laboratories should be able to deploy Junior Research Fellows (JRF) on contract in much larger numbers. Apart from their availability, these JRF working on advanced cutting-edge technologies would be an asset to the nation at large and would contribute to the scientific skill development efforts so necessary for *Aatamanirbharta*. Provision should also exist for promising JRFs to be absorbed by the DRDO after their contract period is over. Human capital is the most valuable asset for the nation and specificallyso for an R&D organization like DRDO. Government may also like to review this one-size-fit-all policies being applied to the scientists across the board.

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Appendix I: DOD's R&D Framework

Under Secretary of Defence (Research &Engineering) under DoD of USA is supervising all defense research and engineering, technology development, technology transition, appropriate prototyping activities, experimentation, and developmental testing activities and programs, and unifying defense research and engineering efforts across DOD. US (R&D) is also serving as the principal advisor to the Secretary of Defense (Secretary DDR&D in Indian MoD setup) on all research, engineering, and technology development activities and programs in DOD. US (R&D) is also the Chief Technical Advisor to the Joint Requirements Oversight Council (JROC), whose equivalent here would be the SCAPCC with the intent of assisting DOD "in taking full advantage of technological possibilities, on-ramping new technologies into military operations, and identifying new, affordable, and effective means of achieving military ends. The Organization chart of the office of US (R&D) is shown below in Fig.1.

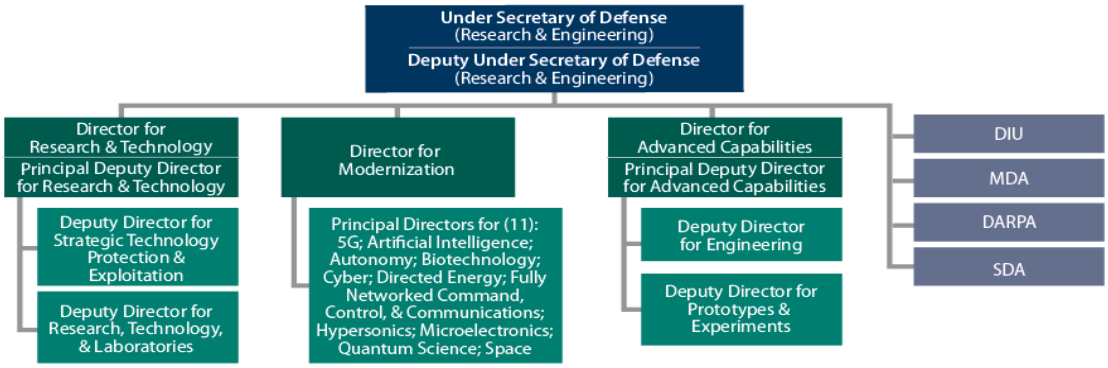


Fig.1 Organization chart of the office of US (R&D)

Source: Adapted from Attachment 1, Department of Defense, Memorandum from Deputy Secretary of Defense on Establishment of the Office of US (R&D) and the Office of the USD (A&S), July 13, 2018; and https://www.cto.mil/leadership/, accessed on December 20, 2021.

Notes: DIU = Defense Innovation Unit; MDA = Missile Defense Agency; DARPA = Defense Advanced Research Projects Agency; SDA = Space Developmental Agency

Roles and tasks of the components of the Office of US (R&D) are discussed briefly in the following sub-sections.

A. Director for Research and Technology

Director for Research and Technology is responsible for setting the strategic technical direction and investment, integrating laboratory infrastructure, and providing stewardship of the technical community. Director of Defense Research and Engineering for Research and Technology leads the Department's work to create DOD's technology advantage. DDR&E (R&T) also:

- Oversees the Department's entire Science and Technology portfolio
- Advocates for the Department's S&T workforce and laboratory infrastructure.
- Oversees the Department's Federally Funded Research and Development Centers (FFRDC)

and University Affiliated Research Centers (UARC)

- Helps to cultivate the next generation of S&T professionals for the Department.
- Advises on the Department's critical technology protection policy
- Oversees the health of the Defense technical industrial base

B. Director for Advanced Capabilities

Director for Advanced Capabilities is responsible for prototyping and experimentation that is designed to increase understanding of a technology and its capabilities, drive down technical risk, and incorporate war-fighter feedback to ensure concepts that transition to acquisition address the needed capability, and are timely and affordable. The closest equivalent in case of the DRDO would be the Cluster DGs who heads cluster of Labs for design, development and demonstration of various Technology Development (TD) and Mission Mode (MM) Projects with close interactions with Academia and Industry.

C. Director for Modernization

Director for Modernization is responsible for managing the capability analysis and investments for the modernization priorities outlined in the National Defense Strategy. The modernization priorities include 5G; artificial intelligence; autonomy; biotechnology; cyber; directed energy; fully networked command, control, and communications; hypersonic; microelectronics; quantum science; and space.

D. Other agencies under US (R&D)

The other agencies such as Defense Advanced Research Projects Agency, the Defense Innovation Unit, the Missile Defense Agency, and the Space Development Agency also report to the US (R&D).

α) **Defence Innovation Unit**

Technological innovation is central to future economic prosperity and national security. DIU seeks to provide examples of how government, businesses, and academia can work together more effectively to maintain competitiveness today and lay the foundation for future advances. DIU aims to move from problem identification to prototype contract award in 60–90 days whereas the traditional DoD contracting process often takes more than 18 months.

β) **Missile Defence Agency**

The Missile Defense Agency (MDA) is a research, development, and acquisition agency within the Department of Defense under Office of US (R&D). MDA mission is to develop and deploy a layered Missile Defence System to defend from missile attacks in all phases of flight.

χ) **Defence Advanced Research Projects Agency**

DARPA explicitly reaches for transformational change instead of incremental advances. But it does not perform its engineering alchemy in isolation. It works within an innovation ecosystem that includes academic, corporate and governmental partners, with a constant focus on the

Nation's military Services, which work with DARPA to create new strategic opportunities and novel tactical options. For decades, this vibrant, interlocking ecosystem of diverse collaborators has proven to be a nurturing environment for the intense creativity that DARPA is designed to cultivate. DARPA is a relatively flat organization consisting of the Director's Office; six technical program offices; the Adaptive Execution Office; the Aerospace Projects Office; the Strategic Resources Office; and the Mission Services Office. DARPA comprises approximately 220 government employees in six technical offices, including nearly 100program managers, who together oversee about 250 research and development programs. This agency works under US (R&D) and its budget is only about 3-4 percent of the total Defence R&D budget of USA's DOD.

δ) **Space Defence Agency**

SDA under Office of US (R&D) aims to provide responsive and resilient space capabilities and support of the Joint Force and as part of the Joint All Domain Command and Control (JADC2) - increasing war-fighters' lethality, maneuverability, and survivability.

E. US (R&D) and USD (A&S) Relationship

Role of the Under Secretary (Acquisition & Sustainment) is to enable the delivery and sustainment of Secure, Resilient, and Preeminent capabilities to the War-fighter and International partners quickly and cost effectively. Details of the roles and tasks of USD (A&S) can be separately studied.

Appendix II: DOD's R&D Framework USA: Defense Laboratories and Centers; and mapping with Missions and Labs of DRDO

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
Engineer Research and Development Centre (ERDC) Engineer Research and Development Centre is the premier research and development centre to discover, develop, and deliver innovative solutions to the nation's toughest challenges in military engineering, installations and operational environments, civil works, geospatial research and engineering, and engineering resilient systems.	1. ERDC CERL: Construction Engineering Research Laboratory, Champaign, IL, USA 2. ERDC CHL: Coastal and Hydraulics Laboratory Headquarters, Vicksburg, MS, USA 3. ERDC CRREL: Cold Regions Research and Engineering Laboratory Headquarters, Hanover, NH, USA 4. ERDC EL: Environmental Laboratory Headquarters, Vicksburg, MS, USA 5. ERDC GRL: Geospatial Research Laboratory, Alexandria, VA, USA 6. ERDC GSL: Geotechnical and Structures Laboratory Headquarters, Vicksburg, MS, USA 7. ERDC ITL: Information Technology Laboratory, Vicksburg, MS, USA	1. War fighter Support – geospatial information; system development; operational support; **force protection; and force projection and sustainment** 2. Installations-transformation; operations; and environmental issues 3. ***Environment – remediation & restoration; land planning, stewardship & management; threatened & endangered species; and cultural resources*** 4. ***Water Resources – infrastructure, water resources, environmental issues, and navigation; and flood control and storm damage reduction*** 5. Information Technology – informatics; geospatial technologies; computational services; ***high-performance computing applications***	1. **Defence Geoinformatics Research Establishment (DGRE)** geospatial information system for operational planning and military intelligence, cutting edge engineering solutions for ensuring safe movement of troops in all kind of terrain with a focus on avalanche and landslides 2. **Defence Institute of High Altitude Research (DIHAR)** R&D into cold arid agro-animal technologies 3. **Centre for Fire, Explosive and Environment Safety (CFEES)** R&D in Fire Science & Engineering, Explosive and Environment
Combat Capability Development Command (CCDC) CCDC ensures the dominance of Army capabilities by creating, integrating and delivering technology-enabled solutions to soldiers. **Eight Cross-sectional Teams were created to address the six modernization priorities.** 1. Long-Range Precision Fires 2. Next Generation of Combat Vehicles 3. ***Future Vertical Lift Platforms*** 4. Army Network 5. Air and Missile Defense Capabilities 6. Soldier Lethality- shooting, moving, communicating, protecting and sustaining. Improving Body Armor, sensors, Radios, and load-bearing exoskeletons.	1. CCDC ARL: CCDC Army Research Laboratory, Adelphi, MD, USA ARL is the Army's principal extramuralbasic research agency in the engineering, physical, information and life sciences; developing and exploiting innovative advances to ensure the Nation's	CCDC ARL performs threat-based ***foundational research for technologies that are disruptive and unique to the Army.*** It also serves as AFC's interface to the worldwide academy community for foundational research through its expansive collaborative network and expanding national S&T ecosystem. ***The laboratory stays ahead of the threat, developing long-term projections of future military technology.*** Technical capabilities are as follows. 1. Extramural Basic Research 2. Computational Sciences 3. Materials Research 4. Sciences-for-Manoeuvre 5. Information Sciences 6. ***Sciences for Lethality and Protection*** 7. ***Human Sciences*** 8. Assessment &Analysis 9. Advanced Computing & Big Data 10. ***Agile Manufacturing*** 11. ***Synthetic Biology***	Long term projects of future military technology and creating ecosystems for foundational research by academia and expanding national S&T ecosystem may fall into the domain area of Director General (Technology Management). DG (TM) sponsors research projects through Directorate of ER&IPR, Research boards and advanced centre of excellence established at premier institutes. Directorate of Technology Development Fund under DG(TM) sponsors industry for prototyping of the specific technologies/ systems/ subsystems.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	2. CCDC AC: CCDC Armaments Center, Picatinny Arsenal, NJ, USA CCDC Armaments Center is the primary source for armaments and munition research, development and engineering.	Focus areas of CCDC AC are as follows. 1. Lethality 2. ***Integrated, Multi-Mission Armament Systems*** 3. Smart Sights 4. Pyrotechnics 5. ***Battlefield Digitization & Software*** 6. Precision Armaments 7. Environmental Technologies 8. Networked Lethality 9. ***Defense Against Unmanned Systems*** 10. ***Counter Terrorism Technologies*** 11. ***Homeland Defence Technologies*** 12. Advanced Materials / Nanotechnologies 13. Novel Power & Energy Systems for Weapons & Munitions 14. ***Armaments Manufacturing Science Technologies*** 15. Reliability & Predictability Technology 16. Modelling & Simulation of Armament Systems 17. Integrated Armaments Systems 18. Advanced Energetics & Warheads 19. Autonomous Systems 20. ***Armament Software & Sustainment Engineering Technologies*** 21. ***Ammo Logistics System Technologies***	Missions of some of the DRDO Labs mapped to CCDC Armaments are as follows. **1. Armament Research & Development Establishment (ARDE)** Conventional armament systems and related technologies. **2. High Energy Materials Research Laboratory (HEMRL)** Technologies related to High Explosives, Propellants and Pyrotechnics **3. Advanced Centre for Energetic Materials** Technologies related to solid rocket propellants **4. Proof and Experimental Establishment** Test, evaluation and proof of various types of Armament stores.
	3. CCDC AvMC: CCDC Aviation and Missile Center, Huntsville, AL, USA CCDC Aviation and Missile Center is the Army's focal point for providing research, development and engineering technology and services for aviation and missile platforms across the life cycle.	Mission of CCDC Aviation and Missile Centre are to develop, integrate, demonstrate, and sustain aviation and missile systems capabilities to support modernization priorities and improve readiness. Capabilities of Software, Simulation, Systems Engineering and Integration Directorate 1. Hardware-In-the-Loop Models & Simulations for Aviation & Missile Systems 2. Conduct Performance and Effectiveness Evaluations for Aviation & Missile Systems	R&D activities and missions of CCDC Aviation and Missile Centre of USA can be mapped with R&D activities of some of the labs under Director General (Missiles &Strategic systems) and Director General (Aero). Missions of DRDO Labs in Aviation and Missile domain are as follows. 1. **Defence Research and Development Laboratory (DRDL)** Systems and technologies for missile based weapon systems deployable from underwater, sea, land and air based platforms.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
		3. Design and Develop Virtual Prototyping 4. Facilities for User Evaluations of Aviation & Missile Applications 5. Define and Develop Modeling& Simulation Methods & Technologies for DoD Applications 6. Computer Hardware/Software Technology 7. Independent Verification and Validation 8. Software Flight Safety/ Airworthiness Assessments 9. Software Development & Sustainment 10. ***Cyber and Protective Technology Development*** 11. ***Interoperability Engineering and Test*** 12. ***Software Fielding/New Equipment Training*** 13. Software Configuration and Data Management 14. Software Quality Engineering 15. Hardware Design, Fabrication & Integration (Prototype Integration Facility) 16. Systems Engineering 17. ***Multidiscipline Acquisition and Project Engineering Leadership*** **Capabilities of Technology Development Directorate** 1. Design & Assessment 2. ***Intelligent Teaming*** 3. Avionics & Architectures 4. ***Air Launched Effects*** 5. ***Power Generation & Management*** 6. ***Drives, Structures & Rotors*** 7. ***Human Systems Interface*** 8. ***Survivability & Vulnerability*** 9. Vehicle Management & Control 10. Experimental/Computational Aeromechanics 11. Acoustics 12. Flight Test 13. Prototyping 14. Missile Seekers, Guidance, Navigation & Control	2. **Research Centre Imarat** Guided missile systems for the Armed forces by developing the frontier technologies, multidisciplinary competence and avant-garde infrastructure leading to self-reliance. 3. **Advanced Systems Laboratory** Technologies required for design and development of missile systems, Long Range Missile systems. 4. **Aeronautical Development Establishment (ADE)** Unmanned Air Vehicles and Aeronautical Systems 5. **Terminal Ballistic Research Laboratory** • Technologies and products related to warheads • State of the art diagnostic facilities for test and evaluation of armaments systems. 6. **Integrated Test Range, Chandipur, Balasore** • To achieve excellence in service quality and reliability • To develop best test facilities and become a World Class Test Range 7. **Aeronautical Test Range** Aeronautical Test Range (ATR) for testing of unmanned air systems 8. **National Aerospace Laboratories** CSIR-NAL is a high-technology oriented institution focusing on advanced disciplines in aerospace. It has several advanced test facilities, and many of them are recognized as National Facilities. Wind tunnel facilities at NAL are being utilised by some of the laboratories in Aero and Missile clusters for aerodynamic data generation.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
		15. Missile Materials & Structures 16. Missile Propulsion, Warhead Integration & Fuzing 17. Air Defence Sensors (Seekers & Radar) & Fire Control **Capabilities of Systems Readiness Directorate** 1. Airworthiness Engineering • Systems Engineering • Aeromechanics • Propulsion • Structures & Materials • Mission Equipment • Maintenance Engineering 2. ***Sustainment Engineering*** 3. Lifecycle Engineering Support for Product Performance • Test & Evaluation • Production Engineering • Configuration & Data Management • ***Logistics Engineering*** • ***Industrial Base Assurance*** • ***Manufacturing Science & Technology*** • ***Reliability & Maintainability Engineering*** • Quality Assurance	9. **Aeronautical Development agency** ADA, under Department of Defence R&D is the nodal agency for the design and development of LCA. HAL is the principal partner in LCA Programme with participation of DRDO and CSIR Laboratories, Public & Private sector industries and academic institutions.
	4. CCDC C5ISR: CCDC Command, Control, Communications, Cyber, Intelligence, Surveillance, and Reconnaissance Centre, Aberdeen Proving Ground, MD, USA CCDC C5ISR is an applied research and advanced technology development centre under the U.S. Army Combat Capabilities Development Command.	Mission of CCDC C5ISR is to enable the networked war-fighter by discovering, developing and rapidly delivering innovative technologies that enable decisive lethality through information dominance in Multi-domain operations. Technology priority areas of this centre are as follows. 1. Mission Command 2. Tactical and Deployed Power 3. ***Tactical Cyberspace Operations*** 4. Electronic Warfare 5. Intelligence, Surveillance, • Reconnaissance and Targeting • Network 6. Prioritize Position Navigation and Timing(PNT) R&D activities of CCDC C5ISR Night Vision and Electronic Sensors Directorates are as follows. • Electro-Optics Systems and Components	R&D activities of some of the labs of the mapped with R&D activities of CCDC C5ISR Labs are as follows. 1. **Centre for Artificial Intelligence & Robotics (CAIR)** Intelligent Systems, Information Processing Systems, Tactical Command Control & Communication Systems and Security Solutions. 2. **Scientific Analysis Group** Tools and techniques based on contemporary Mathematics, Computer Science and Electronics & Communication for Analysis of Security and IT products. 3. **Defence Electronics Research Laboratory (DLRL)** Electronic Warfare systems covering radar and communication frequency bands for the Indian Army, Air-force and Navy.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
		• Thermal Imaging • Low Energy Lasers • Aided/ Automatic Target Recognition • ***Tactical Augmented Reality*** • Sensor Fusion and Interoperability • Sensor Integration into Manned & Unmanned, Land and Airborne Platforms • ***Soldier Sensors*** • ***Humanitarian Demining*** • Mine Detection & Neutralization • Modelling, Simulation, Analysis and Virtual Prototyping C5ISR – Center, Research and Technology Integration (RTI) Directorate is responsible for the advancement of Science and Technology (S&T) in the C5ISR centre's technical competencies: Networking, Cyber, Electro-optic Infrared, Knowledge Management, Power and Energy and Radio Frequency.	4. **Defence Electronics Application Laboratory (DEAL)** Software Based Radios, Anti-Jam Data Links, Secure Satcom Systems, Millimeter Wave Communication & Surveillance Systems 5. **Instruments Research & Development Establishment (IRDE)** Night vision devices and thermal imagers, compact laser based instruments, Integrated electro-optical surveillance and fire control systems, photonics. 6. **Electronics and Radar Development Establishment (LRDE)** Radar systems meeting the current and futuristic requirements of Services and Paramilitary Forces, keeping in view the emerging threat and EW scenario. 7. **Centre for Air Borne Systems (CABS)** Technologies and Infrastructure for building efficient and cost-effective Airborne Surveillance Systems. 8. **Aerial Delivery Research and Development Establishment (ADRDE)** Entire range of Parachutes and Lighter-than-Air Systems
	5. CCDC CBC: CCDC Chemical Biological Center, Aberdeen Proving Ground, MD, USA The centre develops technology in the areas of detection, protection, and decontamination and provides support over the entire lifecycle -- from basic research through technology development, engineering design, equipment evaluation, product support, sustainment, field operations and disposal.	The DEVCOM Chemical Biological Center develops technologies such as protective masks and respiratory systems; biological agent detectors and warning devices; and decontamination systems to protect both Soldiers on the battlefield and civilians here at home. Technical areas of various branches under CCDC CBC are as follows. **Aerosol Sciences Branch** • ***Wind tunnel and chamber characterization of aerosol inlet and collector performance for point detection systems*** • Characterization of output quantity, particle size distribution, and biological viability from aerosol sources, • ***Theoretical physics of optical properties of aerosol particles, especially methods for inversion of optical data to determine particle size, shape, index of refraction, and internal structure.***	9. **Institute of Nuclear Medicine and Allied Sciences (INMAS)** Biomedical and clinical research with reference to radiation, neurocognitive imaging and CBRN research, development of radio protectors, development of diagnostic and therapeutic approaches using non-invasive imaging techniques, neuro-cognitive and endocrine functional assessment of human body.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
		BioSciences Division • Growth and purification of biological agents to include pilot scale fermentation up to 75 liters • Chemical and biological agent enzymatic and vaporous hydrogen peroxide decontamination • ***Detection by immunological, genetic, or physical means*** • **CB System Integration branch** • ***Improving CB detection, warning, and situational awareness by fusing data from CB and non-CB sensors.*** **Chemistry Branch** • Synthesis and purification of CW agents • Physical properties of toxic chemicals • Demilitarization of CW agents • Chemical Analysis **Decontamination Sciences Branch** • ***Analytical equipment for quantification and identification of chemical agents and reaction products (LC-MS-MS, GC platforms with MS and MS-MS, and FID detectors)*** **Laser Standoff Detection Branch** • ***Design, develop, and test active laser standoff detection hardware, software, and algorithms.*** **Chemical Biological (CB) Protection** • ***Full spectrum chemical test laboratories with capability to evaluate novel air purification media (sorbents, catalysts, etc) and processes involving temperature, pressure, relative humidity, flow and chemical reaction.*** • ***Modelling capability focused on component and full-scale integration into military platforms.*** **Modelling, Simulation & Analysis** • ***Analytical planning and execution support to include: study plans, design of experiments (DoE), conduct of simulation experiments, and statistical analysis for both internally generated and customer provided data.***	10. **Defence Research Development Establishment (DRDE)** Technologies and products for chem.-bio Defence and establish state-of-the-art repository and test and evaluation facilities for developed products. 11. **Defence Laboratory Jodhpur** Multispectral Camouflage and Low Observable Technologies, solutions to Desert related problems, and develop nuclear radiation sensor technologies and applications and applications of radioisotopes.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
		• ***Using simulation codes that portray CBRN operations, threats, sensors and limited protective equipment in a distributed environment (CB Sim Suite); and smoke and obscurants in standalone versions (Smoke System Performance Model (SSPM) and Sensor-Obscurant*** • ***Engagement Simulation (SOES)).*** • ***Performing simulations in both unclassified and classified modes using in-house computing and SIPRNET resources.*** • ***Developing new or adapting existing M&S tools with in-house or support contractor personnel.*** Obscurants- Smoke & Target Defeat Branch • ***Aerodynamic testing and analysis using wind tunnels (subsonic, transonic and supersonic)*** • ***Aerosol wind tunnel – collector characterization*** • Technology feasibility demonstration • Skunkworks atmosphere • ***Fully instrumented aerosol test chambers to measure the performance of materials and equipment in the Ultraviolet, visible, infrared, and Millimeter Ware Radar regions of the spectrum*** Toxicology program • Biomarker/dose-metric methods research to quantify the internal dose of chemical warfare agents • PBPK (physiological based pharmacokinetic) model research to improve cross species and route extrapolation for human risk assessment. • Safe agent generation for inhalation and contact exposure experiments.	

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	• ***CCDC DAC: CCDC Data and Analysis Center, Adelphi, MD, USA*** The center provides agile, timely and integrated analytical products for item/ system level performance and effectiveness, vulnerability/ lethality, and human systems integration, enabling Army Futures Command to conduct streamlined decision processes that are underpinned by sound evidence-based analysis.	The DEVCOM DAC has a vast array of capabilities, including ***integrated analysis from concept to fielding***, ***cyber and electronic warfare vulnerability and resiliency,*** kinetic lethality and vulnerability, ***authoritative models and data for modernization decisions, Soldier-centered performance design impacts*** and weaponeering tools for multi-domain operations.	**Institute for Systems Studies and Analyses** Systems analysis and decision support in application areas of Sensors and Weapons, Electronic Combat, Land and Naval Combat, Air-to-Air Combat and Air Defence for effective use by DRDO and Services for Design, Mission Planning, Tactics development and Training.
	6. CCDC GVSC: CCDC Ground Vehicle Systems Center, Warren, MI, USA CCDC SC: CCDC Soldier Center, Natick, MA, USA The Centre leads several Army science, technology, research, and development efforts collaborating with the Army's combat developers to ensure that it fields robust equipment that meets aggressive cost, schedule and performance standards.	The organization drives the state-of-the-art in ground vehicle robotics and autonomy, survivability, power and mobility, intelligent systems, manoeuvre support, and sustainment. GVSC researches, develops, engineers and integrates advanced technology into ground systems and support equipment, from smaller, lighter, more mobile platforms to the largest of the Army's ground vehicles, while developing enhanced lightweight armour for better ballistics protection, ***enhanced fuels and lubricants, and water supply and waste water treatment capabilities***. Focus areas of CCDC GVSC are as follows. • Autonomous Systems • Ground Vehicle Robotics • Vehicle Power and Mobility • Vehicle Electronics Architecture • ***Advanced Manufacturing*** • ***Ground Vehicle Survivability and Protection*** • Advanced Modelling, Simulation & Software • ***Vehicle Sustainment Engineering*** • ***Force Projection Technology*** • ***Experimental Prototyping***	1. **Combat Vehicles Research and Development Establishments (CVRDE)** Tracked armament vehicles and specialist, technological capabilities in critical areas including test and evaluation of Combat system. 2. **Research and Development Establishment (Engineers)** • Mobility and Counter-Mobility Systems • Field Defence and CBRN Collective Protection Systems • Launch Systems for Weapons and Unmanned Aerial Vehicles • Advanced Products using Composite Materials • Robotics and Unmanned Systems • Micro Electro-Mechanical Systems • Specialized Power Systems and Solutions • Specialized Engineering Equipment and Solutions. 3. **Vehicle Research and Development Establishments (VRDE)** Research, Development, Trials and Evaluation of : • Specialist Vehicles & Launchers for Strategic Missile Program. • Combat and Combat Support Vehicles – Wheeled. • Combat and Combat Support Vehicles - Light Tracked (Up to 25t GVW). • Engines for UAVs (Rotary and Reciprocating). • Unmanned Aerial (From 10 kg to 150 kg AUW) and Unmanned Ground Vehicles.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	7. CCDC SC: CCDC Soldier Center, Natick, MA, USA The centre's world-class scientists, engineers and equipment designers provide American forces with a wide range of field feeding and life support systems, clothing, precision airdrop systems, and ballistic, chemical, and laser protection systems.	The DEVCOM Soldier Center has created new fabrics, developed food rations to improve Soldier performance and enhanced Soldier shelters for the maximum protection. It maximizes the Warrior's survivability, sustainability, mobility, combat effectiveness and quality of life by treating the Soldier as a complete system. Some of the core technology domains are as follows. 1. Advanced/ Multifunctional Materials 2. Biomechanics 3. Cognitive &Behavioral Sciences 4. Food Science 5. Geographic/ Precision Guided Systems 6. Soldier Performance Optimization 7. ***Biological Technology*** 8. ***Neuro-cognition***	R&D activities of some of the DRDO labs and DRDO Young Scientists' Laboratory can be mapped to Advanced/ Multifunctional Materials domains of CCDC Soldier Center are as follows. 1. **DYSL-SM** Smart material technology solutions, accelerated materials development, micro-robotics and stealth technologies. 2. **Defence Materials and Stores Research and Development Establishment (DMSRDE)** • Advanced engineering polymers, elastomers and multi-performance composites for Defence applications • Lightweight, ultra-high performance polymers and composite materials for making Personal Protective Gears • Smart polymer, fibre and fabrics for wide range strategic applications like NBC, stealth, extreme cold, fire resistant & ballistic protection etc. • Nano-materials for fabrication of micro/ nano-electronic devices, sensors and new 2nd generation materials 3. **Physiology & Allied Sciences (DIPAS)** Optimization of human performance in different occupational environment conditions using physiological, biochemical, nutritional and ergonomic approach. 4. **Defence Food Research Laboratory (DFRL)** Research and Development in the field of Defence Food Science and Technology. 5. **Defence Institute of Defence Bioengineering and Electro- medical Technology (DEBEL)** State-of-art life support and biomedical systems and devices.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
			6. **Defence Institute of Bio-Energy Research (DIBER)** Bio-resource and bio-energy technologies for Defence use. 7. **Defence Institute of Psychological Research (DIPR)** Psychological support to the armed forces in selection, training, effective man-machine interface and motivation to enhance mental health and operational efficiency of the armed forces. 8. **Institute of Nuclear Medicine and Allied Sciences (INMAS)** Biomedical and clinical research with reference to radiation, neurocognitive imaging and CBRN research. Development of radio protectors, development of diagnostic and therapeutic approaches using non-invasive imaging techniques, neurocognitive and endocrine functional assessment of human body.
Space and Missile Defence	1. SMDTC: U.S. Army Space and Missile Defence Technical Center, Huntsville, AL, USA USASMDC Technical Center provides technologies to meet today's requirements and future needs in directed energy, space, cyberspace, hypersonic and integrated air and missile Defence .	essential tasks: executing science and technology, research and development, and test and evaluation; managing and operating the Ronald Reagan Ballistic Missile Defence Test Site; and conducting space operations and space domain awareness. The Technical Center contributes to the success of the warfighter and joint force in four major areas: 1. Directed energy, System Integration, Atmospheric Characterization, Beam Control, Laser Lethality, and High Power Microwave Effects Labs 2. Tactical responsive space and high altitude ***Environmental Testing,*** Payload Demonstration, and Assured Position, Navigation, and Timing Labs The Technical Center focuses on three Test and evaluation, and 3. Hypersonic and strategic weapons ***Aerophysics,*** Hypersonic System Integration, and ***Aero thermal Integration Labs***	1. **Centre for High Energy Systems and Sciences (CHESS)** Directed Energy Weapons (DEW) based on High Power Lasers (HPL) and high power electromagnetic (HPEM) leading to self-reliance. 2. **Defence Research and Development Laboratory** Aligned with R&D activities with U.S. army Space and Missile Defence Technical Centre, DRDL's HSTDV project focuses on development of technologies for Hypersonic weapons. 3. **Programme 'AD'/ RCI** DRDO's Programme 'AD' has demonstrated Ballistic Missile Defence capability in a number of flight trials. It has also achieved technological milestone by demonstrating Anti- satellite capability. 4. **Advanced Systems Laboratory** Missile systems, launcher systems for satellites

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
		Planned upgrades in R&D facilities • ***First end-to-end systems integration lab for directed energy*** • ***Up gradation and*** • ***Refurbishment of Aero-physics Research Facility*** • Directed energy range • Expansion of the directed energy lab and add space and hypersonic labs. • ***Fabrication lab, a collaboration lab and a shared computer resource lab.*** • Ongoing Technology Demonstration Projects • Kestrel Eye Visible Imagery Nan satellite Technology Demonstration • High Energy Laser Tactical Vehicle Demonstrator • Mobile Experimental High Energy Laser • Multi Mission High Energy Laser • Solid State Laser Testbed • ***25K Transportable Target Launcher -Economical Target***	5. **Defence strategic Projects** Sensor payloads for satellites
Army Medical Research	1. ARI: U.S. Army Research Institute for the Behavioural and Social Sciences, Fort Belvoir, VA, USA	1. ***Develop innovative measures, methods, and models to maximize personnel and unit readiness of the Future Army.*** 2. ***Develop fundamental theories and investigate new domain areas in behavioural and social sciences with high potential impact on Army issues.*** 3. Conduct scientific assessments and provide behavioural and social science advice to human resource authorities and to inform human resource policies.	1. **Defence Institute of Psychological Research (DIPR)** Psychological support to the armed forces in selection, training, effective man-machine interface and motivation to enhance mental health and operational efficiency of the armed forces.
	2. USAMRMC: U.S. Army Medical Research and Materiel Command, Fort Detrick, MD, USA	1. Responsibility for medical research, development, and acquisition and medical logistics management.	1. **Defence Institute of Physiology & Allied Sciences (DIPAS)** Optimization of human performance in different occupational environmental conditions using physiological, biochemical, nutritional and ergonomic approach.
	3. USAARL: U.S. Army Aero medical Research Laboratory, Fort Rucker, AL, USA	1. ***Research and development on health hazards of Army aviation, tactical combat vehicles, selected weapons systems, and airborne operations.*** 2. ***Assesses the health hazards from noise, acceleration, impact, and visual demands of these systems and defines measures to offset hazards.***	

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	4. USACEHR: U.S. Army Center for Environmental Health Research, Fort Detrick, MD, USA	***1. Improving risk assessment methods and developing bio-monitoring technologies for military environment health hazards***	1. **Centre for Fire, Explosive and Environment Safety (CFEES)** Fire Science & Engineering, Explosive and Environment Safety 2. **Defence Research Laboratory, Tezpur** Technologies for promoting health and hygiene in hot, humid and high-altitude environments and judicious utilization of local resources for benefit of the armed forces.
	5. USAISR: U.S. Army Institute of Surgical Research, San Antonio, TX, USA	***Lead research laboratory for improving the care of combat casualties. The Institute follows a rigorous process for analyzing patterns of Injury and the burden of disease to determine where research can be conducted in order to positively impact care.***	-
	6. USAMRICD: U.S. Army Medical Research Institute of Chemical Defence , Aberdeen Proving Ground, MD, USA	The U.S. Army Medical Research Institute of Chemical Defence (USAMRICD) is the DoD's lead Laboratory for the medical chemical Defence research and medical management of chemical casualties.	1. **Defence Research Development Establishment (DRDE)** Technologies and products for chem.-bio Defence , state-of-the-art repository and test and evaluation facilities for developed products.
	7. USAMRIID: U.S. Army Medical Research Institute of Infectious Disease, Frederick, MD, USA	Core mission is to protect the warfighter from biological threats; Also investigates disease outbreaks and threats to public health.	
	8. USARIEM: U.S. Army Research Institute of Environmental Medicine, Natick, MA, USA	The United States Army Research Institute of Environmental Medicine (USARIEM) is the U.S Army's main institution and facility for military environmental medicine and exercise physiology research.	1. **Defence Institute of Physiology & Allied Sciences (DIPAS)** Optimization of human performance in different occupational environmental conditions using physiological, biochemical, nutritional and ergonomic approach
	9. WRAIR: Walter Reed Army Institute of Research, Silver Spring, MD, USA	WRAIR, part of the U.S. Army Medical Research and Development Command (USAMRDC) under the Army Futures Command (AFC), is committed to ***developing and advancing effective solutions—such as vaccines, monoclonal antibodies, therapeutics and diagnostics—to counter HIV and other infectious disease threats.*** MHRP reinforces the priorities of the AFC which include a focus on the development of products to improve the performance and readiness of our forces.	1. **Institute of Nuclear Medicine and Allied Sciences (INMAS)** Biomedical and clinical research with reference to radiation, neurocognitive imaging and CBRN research, development of radio protectors, development of diagnostic and therapeutic approaches using non-invasive imaging techniques, neuro-cognitive and endocrine functional assessment of human body.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	10. USAMRD-AFRIMS: U.S. Army Medical Research Directorate – Armed Forces Research Institute of Medical Sciences, Bangkok, Thailand	The mission of the US Army Medical Directorate of the Armed Forces Research Institute of Medical Sciences (USAMD-AFRIMS) is to optimize soldier lethality and mission effectiveness by developing ***solutions to infectious diseases capability gaps through product development and surveillance*** research in Asia.	-
	11. USAMRD-G: U.S. Army Medical Research Directorate – Georgia, Tbilisi, Georgia	USAMRD-Georgia was established in 2014 in Tbilisi, Georgia with a mission to build Georgian scientific and medical capacity, ***monitor disease threats with a particular focus on antibiotic resistance***, and use its laboratory facilities to support U.S. and allied forces deployed within U.S. European Command.	-
	12. USAMRD-K: U.S. Army Medical Research Directorate – Kenya, Nairobi, Kenya	USAMRD-A works with partner research sites across sub-Saharan Africa and its activities are known in many local communities as the Walter Reed Program. They collaborate with host governments and communities to advance research on endemic diseases such as malaria and HIV, and to help identify and ***develop countermeasures for emerging infectious disease threats such as Ebola and Lassa*** fever.	-
	13. USAMRD-W: U.S. Army Medical Research Directorate – West, Joint Base Lewis-McChord, WA, USA		-
Army International Technology Center	1. USAITCA: U.S. Army International Technology Center – Atlantic, Regional Center, London, United Kingdom 2. USAITCAM: U.S. Army International Technology Center – Americas, Regional Center, Santiago, Chile 3. USAITCP: U.S. Army International Technology Center – Pacific, Regional Center, Tokyo, Japan	***The Army's International Technology Centers seek the most innovative solutions possible through foreign partnerships.***	-
Domain- NAVY	**Defense Laboratories and Centers**	**Capabilities- primary technical areas/ Missions**	
1. Naval Air	1. NAVAIR: Naval Air Systems Command, Patuxent River, MD, USA	Naval Air Station Patuxent River in St. Mary's County, Md., is home to NAVAIR Headquarters, affiliated Program Executive Officers, and the Naval Air Warfare Center Aircraft Division. Conducting over 200,000 air operations annually, NAS Pax River hosts more than 50 tenants including three services, federal agencies and private industry.	Navy Operational domain In the Indian Defence R&D setup, DRDO steers design and development of Defence systems and technologies for all the three services- Army, Navy and Air Force.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	2. NAWCAD: Naval Air Warfare Center Aircraft Division – Lakehurst, Lakehurst, NJ, USA 3. NAWCAD: Naval Air Warfare Center Aircraft Division – Patuxent River, Patuxent River, MD, USA	Naval Air Warfare Center Aircraft Division delivers aircraft, avionics, air-launched weapons, electronic warfare systems, cruise missiles, unmanned aerial vehicles, launch and arresting gear, training equipment and facilities, and airpower to support the research and development, engineering, and test and evaluation of all Navy and Marine Corps air vehicle systems.	
	4. NAWCTSD: Naval Air Warfare Center Training Systems Division, Orlando, FL, USA	Navy centre for research, development, test and evaluation, acquisition and product support of training systems, to provide Inter-service coordination and training systems support for the Army, Marine Corps and Air Force.	
	5. NAWCWD: Naval Air Warfare Center Weapons Division – China Lake, China Lake, CA, USA 6. NAWCWD: Naval Air Warfare Center Weapons Division – Point Mugu, Point Mugu, CA, USA	Naval Air Warfare Center Weapons Division is an organization within Naval Air Systems Command dedicated to maintaining a centre of excellence in weapons development for the Department of the Navy. NAWCWD primarily operates in two Southern California locations: China Lake and Point Mugu.	
2. Naval Medical Research	1. NMRC: Naval Medical Research Center, Silver Spring, MD, USA	The laboratory's mission is to conduct health and medical research, development, testing, evaluation, and surveillance to enhance deployment readiness of DoD personnel worldwide. NMRC is a premier research organization with the vision of world-class, operationally relevant health and medical research solutions.	Naval Health domain- In DRDO Defence R&D setup, there is no specific Laboratory to meet the naval health requirements.
	2. NAMRU-D: Naval Medical Research Unit - Dayton, Dayton, OH, USA		
	3. NAMRU-SA: Naval Medical Research Unit - San Antonio, San Antonio, TX, USA	NAMRU-SA's mission is to conduct gap driven combat casualty care, craniofacial, and directed energy research to improve survival, operational readiness, and safety of Department of Defense personnel engaged in routine and expeditionary operations.	
	4. NHRC: Naval Health Research Center, San Diego, CA, USA	The Naval Health Research Center (NHRC) manages and executes expeditionary operational medical research, development and test and evaluation programs for the Naval Medical Research Command, Silver Spring, MD, Navy Medicine Support Command, Jacksonville, FL and the Navy Bureau of Medicine and Surgery.	

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	5. NSMRL: Naval Submarine Medical Research Laboratory, Groton, CT, USA	The Naval Submarine Medical Research Laboratory (NSMRL) is located on the New London Submarine Base in Groton, Connecticut. The laboratory's mission is to protect the health and enhance the performance of our War Fighters through focused submarine, diving, and surface research solutions.	USA's Naval medical research collaborations with other countries. Not concerned with us.
	6. NAMRU-2: Naval Medical Research Unit No. 2, Phnom Penh, Cambodia	NAMRU-2 is a subordinate command of the Naval Medical Research Center, Forest Glen, Maryland (GEIS, 2000e). NAMRU-2 is distinguished by its extremely close working relationships with Indonesian public health institutions. Projects are jointly developed and implemented with Indonesian public health officials.	
	7. NAMRU-3: Naval Medical Research Unit No. 3, Cairo, Egypt 8. NAMRU-3: Naval Medical Research Unit No. 3 - Ghana Detachment, Accra, Ghana	Naval Medical Research Unit 3 (NAMRU-3), is the largest U.S. military medical research facility operating overseas and one of the largest medical research laboratories in the North Africa-Middle East region.	
	9. NAMRU-6: Naval Medical Research Unit No. 6, Lima, Peru 10. NAMRU-6: Naval Medical Research Unit No. 6 - Iquitos Detachment, Iquitos, Peru	NAMRU-6 was founded in Lima and Iquitos, Peru in 1983 through an agreement between the Surgeon Generals of the Peruvian and U.S. navies, with the concurrence of the U.S. Department of State and the Peruvian Ministry of Foreign Affairs Global influenza surveillance has emerged as the major effort of DoDGEIS with the appearance of H5N1 strains in SE Asia, Europe and Africa.	
	11. NMRC-A: Naval Medical Research Center - Asia, Singapore, Singapore	NMRC-Asia/NAMRU2-PP operates in the United States Pacific Command (PACOM) and is under the authority of the respective country entities under U.S. Embassies in Singapore, Cambodia, and Thailand. NMRC-A is currently headquartered in Sembawang Terminal, Singapore, from where the leadership, administrative, logistic, and financial management teams operate. NMRC-A maintains liaison officers at the U.S. Embassy in Singapore and at the Armed Forces Research Institute of Medical Sciences in Bangkok, Thailand.	
3. Naval Research Laboratory/ Office of Naval Research	1. NRL: Naval Research Laboratory, Washington, DC, USA	NRL conducts cutting edge research and technology development to keep the United States Navy and Marine Corps the most advanced in the world. NRL's scientists and engineers conduct basic and applied research across a wide spectrum of scientific disciplines for both **immediate and long-range national Defence needs.** NRL's research is primarily sponsored by government agencies including the Office of **Naval Research, Naval Systems Commands and Warfare Centers, Air Force, Army, DARPA, Department of Energy, and NASA.**	1. **Naval Science & Technological Laboratory (NSTL)** Torpedoes, Mines, Targets, Decoys, Fire Control Systems, Autonomous Underwater Vehicles(AUV), test facilities 2. **Naval Physical & Oceanographic Laboratory** Sonar systems for naval applications, technologies for underwater surveillance, study of ocean environment and underwater materials.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
4. Office of Naval Research	1. ONR: Office of Naval Research, Arlington, VA, USA 2. ONRG: Office of Naval Research Global Headquarters, London, United Kingdom 3. ONRG: Office of Naval Research Global, Prague, Czech Republic 4. ONRG: Office of Naval Research Global, Santiago, Chile 5. ONRG: Office of Naval Research Global, São Paulo, Brazil 6. ONRG: Office of Naval Research Global, Singapore, Singapore	The Office of Naval Research has been a pioneer in the public support of science and technology research that benefits both the naval services and the nation. From investments in the earliest computers to spearheading seminal research in deep sea exploration to cultivating ground breaking efforts in solid-state electronics and countless other innovations, ONR has been shaping the Navy and Marine Corps — and the world around us — for seven decades and counting.	3. **Naval Materials Research Laboratory (NMRL)** • Air Independent Propulsion (AIP) system for Naval Submarine and Fuel Cell technologies • Scientific solutions for all categories of materials and related technologies for Indian Navy. • Research projects on strategic materials for Indian Navy.
5. Naval Warfare Centre	1. NAVFAC EXWC: Naval Facilities Engineering and Expeditionary Warfare Center, Port Hueneme, CA, USA	NSWC PHD focuses its technical capabilities on Next Generation In-Service Engineering, which involves direct connectivity to the fleet on a global ***basis and the immediate availability of around-the-clock access to products, services and fleet-support capabilities. Next Generation In-Service Engineering supports predictive system failure, remote diagnostics and corrective action via real-time networked communications.***	
	2. NAVSEA: Naval Sea Systems Command Warfare Centers, Washington, DC, USA	NAVSEA Warfare Centre comprises of the Naval Surface Warfare Center (NSWC) and the Naval Undersea Warfare Center (NUWC)	
	3. NSWC: Naval Surface Warfare Center Headquarters, Washington, DC, USA	NSWC cohesively and seamlessly operates the Navy's full spectrum research, development, test and evaluation, engineering, and fleet support centres for offensive and defensive systems associated with surface warfare and related areas of joint, homeland and national Defence systems from the sea.	
	4. NSWC Carderock Division, Bethesda, MD, USA	NSWC Carderock Division is the full-spectrum research and development, test and evaluation, engineering, and fleet support organization for the Navy's ships, submarines, military watercraft, and unmanned vehicles with insight into new concepts and diverse technologies for the Navy fleet of the 21st Century. NSWC Carderock Division's expertise spans from naval architecture and marine engineering, to electrical and mechanical engineering, to computer engineering and physics. ***Thrust Areas*** • ***Ship, Submarine, and Unmanned Vehicle Design and Integrity*** • ***Advanced Manufacturing*** • ***Digital Strategy*** • ***Signature Management*** • ***Unmanned Mobility Systems***	Naval Science & Technological Laboratory (NSTL) Torpedoes, underwater targets and decoys, ship fire control systems and underwater mines

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	5. NSWC Corona Division, Norco, CA, USA	NSWC Corona Division is home to three premier national laboratory and assessment centres: the Joint Warfare Assessment Lab (JWAL); the Measurement Science and Technology Lab; and the Daugherty Memorial Assessment Center (DMAC). Along with the renowned "Corona Engineers," these state-of-the-art facilities enable NSWC Corona Division to fulfil its unique mission for the Navy. The JWAL and DMAC are at the core of NSWC Corona Division's integrated approach to warfare assessment, and the Measurement Science and Technology Lab is where NSWC ***Corona Division researches and establishes the metrology and calibration standards and procedures for the Navy and Marine Corps.*** Technical capabilities and unique expertise - ranging from ***missile Defence assessment to range and test instrumentation to setting measurement standards - enable Corona to support in-service and emerging weapons and combat systems for key customers*** in critical areas:	
	6. NSWC Crane Division, Crane, IN, USA	NSWC Crane Division's total focus is to support the warfighter by leveraging its technical capabilities for the rapidly changing combat environment. Anchored by technical expertise, a strong work ethic and total lifecycle leadership, NSWC Crane Division's personnel and preeminent facilities set the standard for excellence in acquisition, engineering and sustainment. NSWC Crane Division's electronic warfare (EW) mission area provides innovative, leading-edge, technical solutions for military actions that use ***electromagnetic energy to control the electromagnetic spectrum. This includes destroying an adversary's combat capability, gathering intelligence data and ensuring friendly use of the electromagnetic spectrum. NSWC Crane Division's technical solutions are employed across air, ground, maritime domains for the joint and coalition forces.***	
	7. NSWC Dahlgren Division, Dahlgren, VA, USA	Provide research, development, test and evaluation, analysis, systems engineering, integration and certification of complex naval warfare systems related to surface warfare, strategic systems, combat and weapons systems associated with surface warfare. Provide system integration and certification for weapons, combat systems and warfare systems. Execute other responsibilities as assigned by the Commander, Naval Surface Warfare Center.	

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
		Thrust Areas • ***Building on our core, target and prioritize technical opportunities in the following strategic thrusts:*** • ***Lead electric weapons design, development and integration.*** • ***Institutionalize mission engineering and analysis.*** • ***Incorporate cyber warfare engineering in our naval systems.***	
	8. NSWC IHEODTD: Indian Head Explosive Ordnance Disposal Technology Division, Indian Head, MD,USA	Provide ***research, development, engineering, manufacturing, test, evaluation and in-service support of energetic systems and energetic materials for ordnance, warheads, propulsion systems, pyrotechnic devices, Cartridge Actuated Devices and Propellant Actuated Devices (CAD/ PADs). Packaging, handling, storage, and transportation; gun systems and special weapons for Navy, joint forces and the nation. Develop and deliver EOD technology, knowledge, tools and equipment and their life cycle support*** through an expeditionary work force which meets the needs of DoD, combatant commanders and foreign and interagency partners. Support the Executive Manager for EOD technology and training. Execute other responsibilities as assigned by the Commander, Naval Surface Warfare Center.	1. **Centre for Fire, Explosive and Environment Safety (CFEES)** One of the missions of CFEES is R&D in Explosive and Environment Safety. R&D activities of NSWC IHEODTD can be aligned with CFEES in Indian Defence R&D setup. 2. **High Energy Materials Research Laboratory (HEMRL)** Technologies related to High Explosives, Propellants and Pyrotechnics
	9. NSWC Panama City Division, Panama City, FL, USA	The mission of Naval Surface Warfare Center Panama City Division is to conduct research, development, test and evaluation, in-service support of ***mine warfare systems, mines, naval special warfare systems, diving and life support systems, amphibious/expeditionary manoeuvre warfare systems, other missions that occur primarily in coastal (littoral) regions*** and to execute other responsibilities as assigned by Commander, Naval Surface Warfare Center.	-
	10. NSWC Philadelphia Division, Philadelphia, PA, USA	NSWC Philadelphia Division provides ***research, development, test and evaluation, acquisition support, engineering, systems integration, in-service engineering and fleet support with cybersecurity, comprehensive logistics, and life-cycle savings through commonality for surface and undersea vehicle machinery, ship systems, equipment and material.***	-
	11. NSWC Port Hueneme Division, Port Hueneme, CA, USA	NSWC PHD focuses its technical capabilities on Next Generation In-Service Engineering, which involves direct connectivity to the fleet on a global basis and the immediate availability of around-the-clock access to products, services and fleet-support capabilities. Next Generation In-Service Engineering supports ***predictive system failure, remote diagnostics and corrective action via real-time networked communications.***	-

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	12. NUWC: Naval Undersea Warfare Center Headquarters, Newport, RI, USA	NUWC Newport Division provides research, development, test and evaluation, engineering, analysis, and assessment, and fleet support capabilities for submarines, autonomous underwater systems, and offensive and defensive undersea weapon systems, and stewards existing and emerging technologies in support of undersea warfare. Executes other responsibilities as assigned by the Commander, Naval Undersea Warfare Center.	-
	13. NUWC Keyport Division, Keyport, WA, USA	Provide advanced technical capabilities for test and evaluation, in-service engineering, maintenance and industrial base support, fleet material readiness, obsolescence management and logistics support for undersea warfare. Execute other responsibilities as assigned by the Commander, Naval Undersea Warfare Center.	**Naval logistics-**
	14. NUWC Newport Division, Newport, RI, USA	NUWC Newport Division provides research, development, test and evaluation, engineering, analysis, and assessment, and fleet support capabilities for submarines, autonomous underwater systems, and offensive and defensive undersea weapon systems, and stewards existing and emerging technologies in support of undersea warfare. Executes other responsibilities as assigned by the Commander, Naval Undersea Warfare Center.	-
	15. NIWC Atlantic: Naval Information Warfare Center Atlantic Headquarters, Hanahan, SC, USA		
	16. NIWC Pacific: Naval Information Warfare Center Pacific Headquarters, San Diego, CA, USA		
Domain- Air Force	**Defense Laboratories and Centers**	**Capabilities- primary technical areas/ Missions**	
Air Force Research Laboratory (AFRL)	1. AFRL: Air Force Research Laboratory Headquarters, Dayton, OH, USA	AFRL leads the discovery, development and delivery of war- fighting technologies for our air, space and cyberspace forces.	
	2. AFRL AFOSR: Air Force Office of Scientific Research, Arlington, VA, USA 3. AFOSR SOARD: Southern Office of Aerospace Research and Development, Santiago, Chile 4. AFOSR EOARD: European Office of Aerospace Research and Development, London, United Kingdom 5. AFOSR AOARD: Asian Office of Aerospace Research and Development, Tokyo, Japan	AFOSR continues to expand the horizon of scientific knowledge through its leadership and management of the Air Force's ***basic research*** program. As a vital component of the Air Force Research Laboratory (AFRL), AFOSR's mission is to support ***Air Force goals of control and maximum utilization of air, space, and cyberspace.*** AFOSR accomplishes its mission by investing in basic research efforts for the Air Force in relevant scientific areas. Central to AFOSR's strategy is the transfer of the fruits of basic research to industry, the suppliers of Air Force acquisitions; to the academic community which can lead the way to still more accomplishments, and to the other directorate of AFRL that carry the responsibility for applied and development research leading to acquisition.	DRDO's Directorate of ER & IPR sponsors academia for research in all the Defence domains. DRDO's Aeronautics Research and Development Board (ARDB) encourage and fund basic and applied research specific to aeronautical systems.

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	6. AFRL RD: Directed Energy Directorate, Albuquerque, NM, USA	The Air Force Research Laboratory Directed Energy Directorate is the Department of the Air Force's Center of Expertise for directed energy and Optical technologies. Located at Kirtland Air Force Base, New Mexico, the Directorate develops and transitions technologies in four core technical competencies: laser systems, high power electromagnetic, weapons modelling and simulation, and directed energy and electro-optics for space superiority.	**Centre for High Energy Systems and Sciences (CHESS)** Directed Energy Weapons (DEW) based on High Power Lasers (HPL) and high power electromagnetic (HPEM) **Instruments Research and Development Establishment (IRDE)** Night Vision Devices, Thermal Imagers, Laser Based Instruments, Integrated Electro-optical Surveillance and Fire Control Systems
	7. AFRL RI: Information Directorate, Rome, NY, USA	The Information Directorate is the Air Force's and nation's premier research organization for Command, Control, Communications, Computers, and Intelligence (C4I) and Cyber technologies. The directorate explores, prototypes, and demonstrates high-impact, affordable and game-changing Technologies. These technologies transform data into information and subsequently knowledge for decision makers to command and control forces. This knowledge gives our air, space and cyberspace forces the competitive advantage needed to protect and defend the Nations.	**C4ISR and Cyber domain** There are programme/ project specific C4ISR systems as a part of major weapon systems and air Defence systems.
	8. AFRL RQ: Aerospace Systems Directorate, Dayton, OH, USA	The Aerospace Systems Directorate brings together world-class facilities including ***a fuels research facility***, structural testing labs, compressor research facility, rocket testing facilities, supersonic and subsonic wind tunnels, flight simulation lab, and many other cutting-edge research labs.	**Gas Turbine Research Establishment** Advance aero engine technology, affordable aero gas turbine engine systems and their derivatives for the Defence forces. **High Energy Materials Research Laboratory (HEMRL)** Technologies related to High Explosives, Propellants and Pyrotechnics
	9. AFRL RV: Space Vehicles Directorate, Albuquerque, NM, USA	Develop and transition innovative high-payoff space technologies supporting the war-fighter. Supports intelligence, surveillance and reconnaissance, defensive space control, space situational awareness, responsive space and all areas of small satellite development.	Space situational awareness domain
	10. AFRL RW: Munitions Directorate, Eglin AFB, FL, USA	The Air Force Research Laboratory Munitions Directorate (RW) is responsible for developing superior weapons technologies that are effective and affordable for our warfighter. Provides the technologies that will enable war-fighters to win in all domains, and actively looks at new technologies to stay ahead in a rapidly advancing tech driven world.	**Defence Research and Development Laboratory** Systems and technologies for missile based weapon systems **Research centre Imarat** Guided Missile Systems, Avionics

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	11. AFRL RX: Materials & Manufacturing Directorate, Dayton, OH, USA	The Air Force Research Laboratory's Materials and Manufacturing Directorate develops materials, processes, and advanced manufacturing technologies for aircraft, spacecraft, missiles, rockets, and ground-based systems and their ***structural, electronic and optical components***. Air Force product centers, logistic centers, and operating commands rely on the directorate's expertise in materials, non-destructive inspection, systems support, and advanced manufacturing methods to solve system, expeditionary deployment, and operational challenges.	**Defence Metallurgical Research Laboratory (DMRL)** Development of innovative materials and process technologies, related product engineering, supports research in the fundamental and applied aspects of materials. **Instruments Research & Development Establishment (IRDE)** Night vision devices and thermal imagers, compact laser-based instruments, Integrated electro-optical surveillance and fire control systems, photonics **Solid State Physics Laboratory (SSPL)** Semiconductor materials and electronic devices/ components for Optoelectronics/ microwave/ sensor applications
	12. AFRL RY: Sensors Directorate, Dayton, OH, USA	The Air Force Research Laboratory's Sensors Directorate mission is to lead the discovery and development of future capabilities, providing ***integrated Intelligence, Surveillance, and Reconnaissance (ISR), combat identification, and spectrum warfare effects.***	**Centre for Air Borne Systems (CABS)** Technologies and Infrastructure for building efficient and cost-effective Airborne Surveillance Systems. **Centre for Artificial Intelligence & Robotics (CAIR)** Intelligent Systems, Information Processing Systems, Tactical Command Control & Communication Systems and Security Solutions. **Defence Electronics Research Laboratory (DLRL)** Electronic Warfare systems covering radar and frequency bands
	13. AFRL 711 HPW: 711th Human Performance Wing, Dayton, OH, USA	The 711th Human Performance Wing (711 HPW) is a unique combination the Airman Systems Directorate (RH) and the US Air Force School of Aerospace Medicine (USAFSAM). The synergies of combining the ideas, resources and technologies of these units position the 711 HPW as a world leader in the study and advancement of human performance.	**Defence Institute of Psychological Research (DIPR)** Psychological support to the armed forces in selection, training, effective man-machine interface **Defence Institute of Physiology & Allied Sciences (DIPAS)** Optimization of human performance in different occupational environment conditions using physiological, biochemical, nutritional and ergonomic approach **Defence Bioengineering and Electro- medical Technology** State-of-art life support and biomedical systems and devices.

Defence Labs for ARMY projects	**Defence Laboratories and Centers**	**Capabilities- Primary Technical Areas/ Missions**	**Mapping with DRDO Labs and their Missions**
Joint Warfare Analysis Centre	1. JWAC: Joint Warfare Analysis Center, Dahlgren, VA, USA	***JWAC's mission is to provide combatant commands, Joint Staff, and other customers with effects-based analysis and precision targeting options for selected networks and nodes in order to carry out the national security and military strategies of the United States during peace, crisis, and war.***	
Sponsored R&D at FFRDCs	**Federally Funded Research and Development Centers (FFRDCs)**	**Capabilities- primary technical areas/ Missions**	**Mapping with DRDO Labs and their Missions**
Sponsored by the Army	1. RAND Arroyo Center, Santa Monica, CA, USA	RAND Arroyo Centre's mission is to: • ***Conduct objective analytic research on major policy concerns, with an emphasis on mid- to long-term policy issues*** • Help the Army improve effectiveness and efficiency • Provide short-term assistance on urgent problems • Be a catalyst for needed change	-
Sponsored by the Navy	1. CNA: Center for Naval Analyses, Arlington, VA, USA	• **Systems, Tactics and Force Development**-*Quantitative analyses of weapons, sensors, networks and systems- and the tactics for mission success.* • **Resources and Force Readiness**- Economics analysis helping military leaders making their people, budgets and assets more effective and efficient to maximize readiness. • **Data science**-*Predictive analytics and machine learning for optimized outcome and performance.* • **Strategy, Policy, Plans and Programs**- Decisions and strategies critical to national security. • **Operations Research, Scientific analysis**	Partially gets mapped to System analysis and modelling cluster
Sponsored by the Air Force	1. RAND Project Air Force, Santa Monica, CA, USA	RAND Project Air Force conducts objective, analytic research on major policy issues, helping the USAF to improve effectiveness and efficiency.	-
	2. The Aerospace Corporation, El Segundo, CA, USA	Technical guidance and advice on all aspects of space missions to military, civil, and commercial customers.	-
Sponsored by the Office of the Secretary of Défense:	1. CMU SEI: Software Engineering Institute at Carnegie Mellon University, Pittsburgh, PA, USA	Research on complex software engineering, cyber security, and AI engineering problem; create and test innovative technologies; and transition maturity solutions into practice.	-
	2. IDA: Institute for Défense Analyses, Alexandria, VA, USA	The Institute for Defence Analyses administers three federally funded research and development centres- the Systems and Analyses, the Science and Technology Policy Institute, and the Centre for Communications and Computing in addressing national security issues.	Partially gets mapped to System analysis and modelling cluster

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	3. MIT Lincoln Laboratory, Lexington, MA, USA	**Advanced Technology Groups**- Advanced imagers technology, laser technology and applications, quantum computing, Microsystems, RF technology and chemical sensors. **Air, Missile, and Maritime Defence Technology Groups**- Advanced sensor systems and test beds, advanced undersea systems and technology, integrated missile Defence technology, interceptor and sensor technology **Biotechnology and Human systems**- advance Defence s against biological and chemical threats **Tools for Cyber Defence and Human Language Processing**- Advanced hardware, software, and algorithms for processing datasets from a range of sources, including speech, imagery, text, and network traffic.	-
	4. MITRE National Security Engineering Center, Bedford, MA, USA 5. MITRE National Security Engineering Center, McLean, VA, USA	Systems engineering, modelling and simulation, ***acquisition strategy***, and management, enterprise engineering, information technology, and cyber security.	-
	6. RAND National Defense Research Institute, Santa Monica, CA, USA	Defence Research and Analysis • Acquisitions and Technology Policy • Forces and Resources Policy • International Security and Defence Policy • Analysis for Navy and Marine Forces	-
Sponsored by the National Security Agency	1. IDA: Communications and Computing, Center for Computing Science, Bowie, MD, USA	High performance computing for cryptography, network security and related cyber issues, signal processing, emerging mathematics and algorithms techniques for analyzing extremely complex data sets.	**Scientific Analysis Group** • Cryptology and Information security • Tools and techniques based on contemporary mathematics, computer science and Electronics & Communications for Analysis of Security and IT products
	2. IDA: Communications and Computing, Centers for Communication Research, Princeton, NJ, USA	Mathematical, statistical, and computational research in support of national security in the fields of cryptology, signal processing, network security, and related disciplines.	
Sponsored Research at Universities	**University Affiliated Research Centres (UARC)**	**Capabilities- primary technical areas/ Missions**	**Ongoing Research/ R&D Priorities**
Sponsored by the Army	1. GTRI: Georgia Tech Research Institute, Atlanta, GA, USA	-	-
	2. MIT ISN: Massachusetts Institute of Technology Institute for Soldier Nanotechnologies, Cambridge, MA, USA	-	-
	3. UCSB ICB: University of California, Santa Barbara Institute for Collaborative Biotechnologies, Santa Barbara, CA, USA	Biologically inspired, revolutionary technological innovations in systems and synthetic biology, bio-enabled materials, and cognitive neuroscience	-

Defence Labs for ARMY projects	Defence Laboratories and Centers	Capabilities- Primary Technical Areas/ Missions	Mapping with DRDO Labs and their Missions
	4. USC ICT: University of Southern California Institute for Creative Technologies, Playa Vista, CA, USA	***Synthetic training environment, stress resilience in virtual environments, Science and Technology Futures Initiative, War games***	-
Sponsored by the Navy	1. JHU APL: Johns Hopkins University Applied Physics Lab, Laurel, MD, USA	***Air and Missile Defence , Cyber Operations, National Security Analysis, Precision Strike, Strategic Deterrence***	-
	2. PSU ARL: Pennsylvania State University Applied Research Lab, State College, PA, USA	Communications, information and navigation, Fluid dynamics and acoustics, materials and manufacturing, undersea systems	-
	3. UH ARL: University of Hawaii Applied Research Lab, Honolulu, HI, USA	Sensor development, remote sensing, renewable energy.	-
	4. UT ARL: University of Texas Applied Research Lab, Austin, TX, USA	***Underwater acoustic research,*** sonar system design, underwater mechanical and optical system design, and electromagnetic systems research, ***unmanned and remotely operated underwater vehicles***	-
	5. UW APL: University of Washington Applied Physics Lab, Seattle, WA, USA	*Multi- Sensor Tow body, Wave Energy Converter for UUV Recharge*	-
Sponsored by the Office of the Secretary of Defense/ US (R&D)/ DDR&E (AC)	1. SIT SERC: Stevens Institute of Technology Systems Engineering Research Center, Hoboken, NJ,USA	***Trusted systems, systems Engineering and Systems Management Transformation, Human capital Development***	-
	2. UA GDNP: University of Alaska Geophysical Detection of Nuclear Proliferation, Fairbanks, AK, USA	Instrumentation and monitoring, Geophysical measurement and signature intelligence	-
	3. UM ARL-IS: University of Maryland Applied Research Lab for Intelligence and Security, College	***Integrate social and behavioural sciences, AI, and computing for new Human domain applied research and development capabilities***	-
	4. Sponsored by the Missile Defense Agency: USU SDL: Utah State University Space Dynamics Lab, North Logan, UT, USA	-	-
Sponsored by STRATCOM (Strategic Communication)	1. NU NSRI: University of Nebraska National Strategic Research Institute, Omaha, NE, USA	Enable deterrence of, preparedness for and response to strategic national security threats across multiple domains through research and support.	-

Appendix III: USA DOD's Defence R&D Priorities

A. **DOD's Defence Laboratories and Centres**

Details of the R&D activities of these Labs and centers are analyzed. Following information can be derived based on the analysis of their R&D and Technology Priority areas.

a) **Six Modernization Priorities**

- Long-Range Precision Fires
- Next Generation of Combat Vehicles
- Future Vertical Lift Platforms
- Army Network
- Air and Missile Defense Capabilities
- Soldier Lethality-shooting, moving, communicating, protecting and sustaining. Improving Body Armor, sensors, Radios, and load-bearing exoskeletons.

Eight Cross-sectional Teams were created to address six modernization priorities

b) **Essential Research Programs for Army's Modernization**

For Mid to Far Requirements

- AI for Maneuver and Mobility
- Human Autonomy Teaming
- Long Range Distributed & Cooperative Engagements
- Convergence of Lethality, Protection and Autonomy to Dominate Ground Combat
- Versatile Tactical Power and Propulsion
- Foundational Research for EW in Multi-Domain Operations
- Quantum PNT
- Physics of Soldier Protection to Defeat Evolving Threats
- Science of Additive Manufacturing for Modular Munitions
- Transformational Synthetic Biology for Military Environments

c) **Space and Missile Defence**

Ongoing Technology Demonstration Projects

- Kestrel Eye Visible Imagery Nan satellite Technology Demonstration

- High Energy Laser Tactical Vehicle Demonstrator
- Mobile Experimental High Energy Laser
- Multi Mission High Energy Laser
- Solid State Laser Testbed
- 25K Transportable Target Launcher
- Economical Target

d) **Army Medical Research**

- Military infectious diseases; combat casualty care; military operational medicine; medical chemical and biological defense; and clinical and rehabilitative medicine.
- Research on the bio-effects of laser systems, medical defense against chemical agents, impact of continuous Operations on individual and crew performance, development of improved means of patient evacuation
- Test and evaluation of medical equipment used in aero medical evacuation

e) **Electronics Science & Technology**

- Research and development in quantum information science and technology; nano-electronics; surface and interface sciences; electronics material growth, characterization, and processing; theoretical and computational electronics and electromagnetic; power electronics; microwave, millimeter-wave, and sub millimeter-wave solid-state and vacuum electronics technologies; optoelectronics; photovoltaic; radiation effects.
- Plasma Physics, Radar, Tactical Electronic Warfare

f) **Naval Research**

- Research in autonomous systems, intelligent autonomy, human-autonomous system interaction and collaboration, sensor systems, power and energy systems, networking and communications, and platforms
- Advanced Ground and Amphibious Platforms; Advanced Modeling and Simulation for Training and Analysis, Advanced Power and Energy for Undersea Applications
- Anti-Submarine Warfare, Assured Cyber Effects, Artificial Intelligence/Machine Learning
- Auditory Neuroscience & Performance
- Augmented Reality for Advanced Maintenance Training
- Bio-inspired Autonomous Systems, Bio-inspired Signature Management
- Biological and Physiological Monitoring and Modeling, Cognitive Neuroscience of Perception

and Attention, Cognitive Science for Human Machine Teaming

- Command and Control
- Communications and Networking
- Computational Methods for Decision Making – Automated Image Understanding, Large Scale Distributed Decision-making, Resource Optimization
- Cooperative Autonomous Swarm Technology (CAST)
- Directed Energy Weapons: CDEW and High Energy Lasers, High Power Microwaves
- High-Temperature Technologies for Naval Applications
- Human Interaction with Autonomous Systems
- Human Performance, Training and Education
- Hypersonic Aerothermodynamics, High-Speed Propulsion and Materials
- Innovative Naval Prototype
- Jet Noise Reduction
- Live, Virtual and Constructive (LVC) and Adaptive Training technologies
- Materials & Processes for Additive Manufacturing
- Materials for Thermal & Chemical Extremes, Metamaterials, Nano-engineered Materials
- Synthetic Biology for Naval Applications
- Tactical AI for Marine Corps
- Thermal Science and Engineering
- Undersea Medicine & Performance
- Undersea Signal Processing
- Undersea Weapons
- Underwater Signatures (Electromagnetic): Sea basing Logistics and Amphibious Craft
- Unmanned Surface Vehicle and Small Combatant Craft

g) **Air Force Research Laboratory**

- Scramjet engines, alternative fuels, unmanned vehicles, hypersonic vehicles, collision avoidance and aircraft energy optimization

h) **DARPA's Advanced Research and Technology Priorities**

Some of the advanced technology development programs undertaken by DARPA's Strategic and Tactical Offices are as follows.

- Creating Cross-Domain Kill Webs in Real Time
- Alpha Dogfight Trials Foreshadow Future of Human-Machine Symbiosis
- Secure Handhelds on Assured Resilient networks at the tactical Edge
- Adapting Cross-Domain Kill-Webs (ACK)
- Aerial Dragnet
- Air Combat Evolution (ACE)
- COnstructive Machine-learning Battles with Adversary Tactics (COMBAT)
- Context Reasoning for Autonomous Teaming (CREATE)
- CONverged Collaborative Elements for RF Task Operations (CONCERTO)
- Cross-Domain Maritime Surveillance and Targeting (CDMaST)
- Dynamic Network Adaptation for Mission Optimization (DyNAMO)
- DARPA'S Hypersonic Air-breathing Weapon Concept (HAWC) Achieves Successful Flight
- Team CERBERUS and Team Dynamo Win DARPA Subterranean Challenge Final Event
- Blackjack Program Successfully Deploys Two Mandrake 2 Satellites
- Advanced Full Range Engine (AFRE)
- Aircrew Labor In-Cockpit Automation System (ALIAS)
- Blackjack
- Consortium for Execution of Rendezvous and Servicing Operations (CONFERS)
- Control of Revolutionary Aircraft with Novel Effectors (CRANE)
- Demonstration Rocket for Agile Cislunar Operations (DRACO)
- Glide Breaker
- Gremlins

i) **Missile Defence Agency (MDA) Programs**

MDA's current technology program priorities are as follows.

- Test Integration of THAAD and Patriot Missile Defense Systems
- Arrow 3 Interceptor
- Fielding of the Long Range Discrimination Radar
- Hypersonic Missile Defence Program- Glide Phase Interceptor
- Deployment of Tiny Satellites with Potential Big Impact on Missile Defense Development
- Hypersonic and Ballistic Tracking Space Sensor (HBTSS) program

j) **Space Defence Agency (SDA) Programs**

- Space- and ground-based Battle Management, Command, Control, and Communications (BMC3) software capabilities for the National Defense Space Architecture (NDSA)
- Tranche 1 Tracking Layer to Address Conventional and Advanced Missile Threats
- Experimental infrared sensor into orbit
- Satellite Swarm for tracking Hypersonic Missiles

Appendix IV: USA Defence Budget

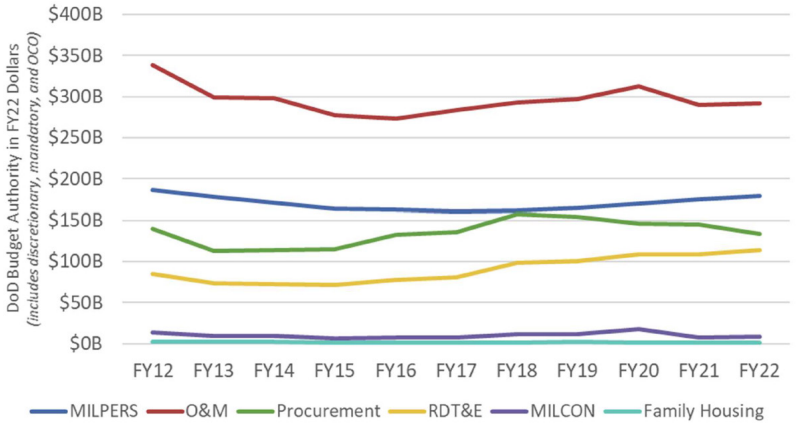
Total budget for national Defence in FY 2022 comes to $768 billion

- Total of $753 billion in discretionary funding for national Defence
  - $715 billion for the Department of Defence (DoD)
  - $10 billion in funding for Defence -related activities in other parts of government
  - $28 billion for Defence -related atomic energy activities to support the maintenance and modernization of nuclear warheads and bombs, the development and maintenance of nuclear reactors for Navy aircraft carriers and submarines, and the labs and infrastructure that support these activities.
- Total of $15.5 billion in mandatory funding for national Defence
  - $13 billion in DoD mandatory funding in FY 2022
  - $2.5 billion in other national Defence mandatory funding

The discretionary DoD budget for FY 2022 represents a 1.6 percent increase above the level enacted for FY 2021, but it represents a slight decline of 0.2 percent when adjusted for inflation. (Assumes inflation will be 1.8 percent between FY 2021 and FY 2022.)

FY	Total budget for national Defence
2023	USD 773 billion fiscal year 2023 Defense Budget Request
2022	USD 768
2021	754
2020	774
2019	745

Figure 1: DoD Budget by Title



Source: Office of the Undersecretary of Defense, *National Defense Budget Estimates for FY 2022* (Washington, DC: DoD, August 2021), Table 6-8, https://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2022/FY22_Green_Book.pdf.

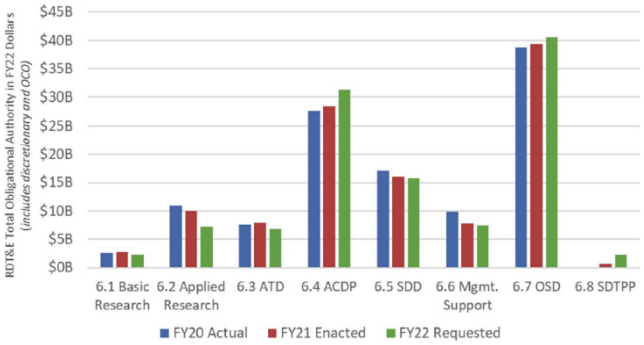
A. RDT&E Funding

The mission of the Department of Defense is to provide "the military forces needed to deter war and ensure the nation's security." Congress supports research and development activities at DOD primarily through the department's Research, Development, Test, and Evaluation (RDT&E) funding. These funds support the development of the nation's future military hardware and software and the science and technology base upon which those products rely.

Table 1. DOD RDT&E Budget Activity Codes

Code	Description
6.1	Basic Research
6.2	Applied Research
6.3	Advanced Technology Development
6.4	Advanced Component Development and Prototypes
6.5	System Development and Demonstration
6.6	RDT&E Management Support
6.7	Operational System Development

Figure 2: RDT&E by Budget Activity



RDT&E funding in FY 2022 grows by 4.4 percent in real terms and $6.7 billion in nominal dollars compared to FY 2021. However, $1.25 billion of this increase is for a new mandatory RDT&E funding line entitled "Prepare Americans for Future Pandemics." Without this funding line, the overall growth in discretionary RDT&E is 3.2 percent.

Science and Technology (S&T) funding (6.1, 6.2, and 6.3) is down 20 percent in real terms compared to the FY 2021 enacted level.

Funding for system development and demonstration (6.5) and management support (6.6) also decline in real terms by 1.7 and 4.9 percent, respectively.

Funding for advanced component development and prototypes (6.4) sees the largest increase in FY 2022, growing 9.6 percent in real terms, or $3.3 billion in nominal dollars.

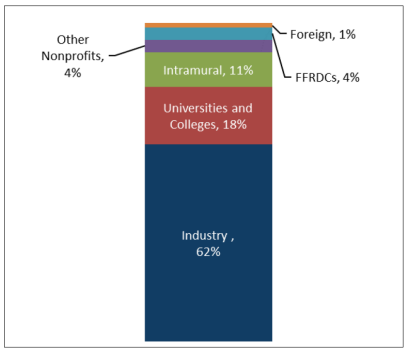
This is driven mainly by proposed increases in some major acquisition programs, including the Air Force's Ground Based Strategic Deterrent (GBSD) and Next Generation Air Dominance (NGAD) programs, the Navy's Conventional Prompt Strike program, and the Army's Future Vertical Lift program.

Funding for operational system development (6.7) is up 3.3 percent in real terms, and nearly all of this increase is in classified funding lines that do not publicly report their activities.

B. DARPA Appropriations and Funding Trends

Nearly all of DARPA's funding falls under the categories of basic research (6.1), applied research (6.2), and advanced technology development (6.3). Funding for the 6.1 to 6.3 program elements is referred to by DOD as the science and technology (S&T) budget. DOD's S&T budget is often singled out by analysts and others for additional scrutiny, as it is viewed as an investment in the

foundational knowledge needed to develop future military systems. DARPA's remaining funding falls within the 6.6 budget activity code for management support, which includes personnel salaries and benefits as well as costs associated with travel, supplies, equipment, and office space.



As stated previously, DARPA does not directly perform R&D, but supports R&D through contracts with various R&D performers which include universities and industry. As illustrated by Figure 1, DARPA primarily supports R&D performed by industry. Specifically, in FY2020, 62percent ($2.3 billion) of DARPA's R&D was performed by industry, 18percent ($668 million) by universities and colleges, 11percent ($396 million) by intramural R&D performers (e.g., federal laboratories), 4percent ($146 million) by other nonprofits, 4percent ($136 million) by Federally Funded Research and Development Centers (FFRDCs), and 1percent ($53 million) by foreign entities.

Figure 3. DARPA Funding by Character of Work, FY1996-FY2021
Obligational authority, in millions of constant FY2021 dollars

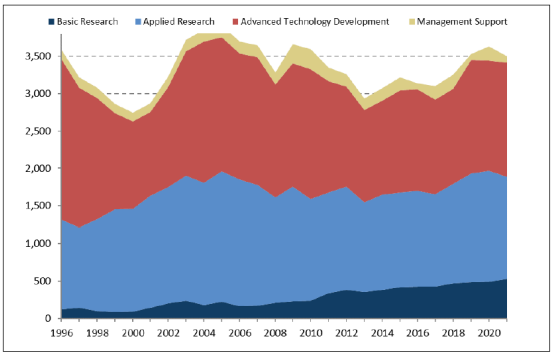
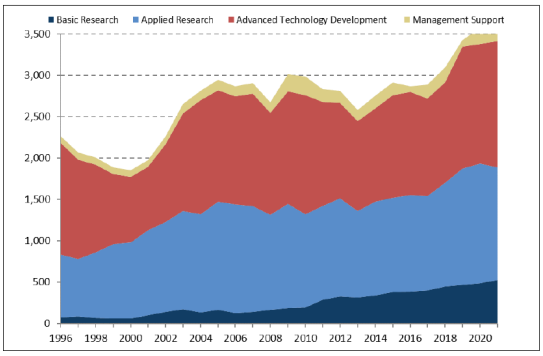


Figure 2. DARPA Funding by Character of Work, FY1996-FY2021
Obligational authority, in millions of current dollars



Source: CRS analysis of data from Department of Defense, *Research, Development, Test, and Evaluation Programs (R-1)*, FY1998-2022.

Notes: CRS used the earliest of the three fiscal years of data (actual expenditures) provided in each R-1. For example, the FY2017 funding levels are from the FY2019 R-1. For FY2021, CRS used the enacted level.

Figure 2 and Figure 3 show DARPA funding trends from FY1996 to FY2021 by character of work (i.e., basic research, applied research, advanced technology development, and management support) in current and constant FY2021 dollars (adjusted for inflation), respectively. In current dollars, overall funding for DARPA has increased by 54.2percent from $2.27 billion in FY1996 to $3.50 billion in FY2021, a compound annual growth rate (CAGR) of 1.7percent (Figure 2). In FY2021 constant dollars, DARPA funding has decreased by 2.4percent, from $3.59 billion in FY1996 to $3.50 billion in FY2021. DARPA funding has averaged $3.34 billion between FY1996 and FY2021 with fluctuations over time (Figure 3). Specifically, funding for the agency decreased by 23percent between FY1996 and FY2000 in constant dollars, but then increased by 43percent to its highest level in FY2005. Since FY2005, DARPA funding has declined by 11percent (Figure 3).

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