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THE PRC STATE & DEFENSE LABORATORY SYSTEM: AN OVERVIEW

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Abbreviations

AECC	Aero Engine Corporation of China
AVIC	Aviation Industry Corporation of China
CAS	Chinese Academy of Sciences
CAEP	Chinese Academy of Engineering Physics
CASC	China Aerospace Science and Technology Corporation
CASIC	China Aerospace Science and Industry Corporation
CETC	China Electronics Technology Group Corporation
CMC	Central Military Commission
CNNC	China National Nuclear Corporation
CSSC	China State Shipbuilding Corporation
COSTIND	Commission for Science, Technology and Industry for National Defense
DSTKL	Defense Science and Technology Key Laboratory
EDD	Equipment Development Department
FYP	Five-Year Plan
GNC	Guidance, Navigation and/or Control
MIIT	Ministry of Industry and Information Technology
MOST	Ministry of Science and Technology
NDRC	National Development and Reform Commission
NL	National Laboratories
NIS	National innovation systems
STI	Science, technology, and innovation
SASTIND	State Administration for Science, Technology and Industry for National Defense

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Introduction

China's 14th Five-Year Plan (FYP) (2021-2025) highlighted the reorganization and development of China's laboratory system, a core component of its National Innovation Systems (NIS),[i] as a top policy priority for the next five years and beyond. With "self-sufficiency and self-made success in science and technology" [科技自立自强] as the overarching goals, Chinese policymakers are attempting to reorganize and reinvigorate state-level research and development platforms and facilities, the infrastructure which enables transformative scientific discoveries and breakthroughs in critical technologies.[ii] The 14th FYP made the integration and optimization of the nation's S&T infrastructure and resources a priority, specifically the restructuring of the national laboratory system [实验室体系].

Despite a wide body of research on China's scientific progress, the laboratory system remains a less understood component of China's S&T ecosystem in the English literature. While lists of these labs have been compiled and some preliminary research performed to categorize them,[iii] the exact number and inner workings of these labs remain in many ways poorly understood. This opacity not only leads to gaps in our knowledge of Chinese defense research, but in many cases has allowed these labs to fly under the radar, leading to cases of close interaction, and even cooperation, between Chinese defense labs and U.S. and allied academic institutions.

This paper is intended to address some of these knowledge gaps. Organized into two parts, the first part provides a brief overview of China's state and defense research laboratory system and examines how the various laboratory designations interrelate after 30 years of development. It explains, for example, how the Defense Science and Technology Key Laboratories (DSTKLs) [国防科技重点实验室] fit into China's current S&T infrastructure ecosystem and their relations to some of the other important categories of labs such as National Laboratories and State Key Laboratories. It also explains how the Military-Civil Fusion strategy facilitates interactions between DSTKLs and other parts of NIS and how this system might evolve during the 14th FYP period.

The second part presents initial key findings from the authors' research into the DSTKLs, a segment of the PRC lab system crucial to understanding China's defense research priorities. The analysis builds on a database of defense research labs and other major scientific research facilities, compiled by BluePath Labs, with key details about each lab's research foci, real-world applications of that research, funding, facilities and equipment, domestic and international collaborations, leadership, and notable affiliated scholars, among other things.[iv] The analysis presented here represents an initial step in gaining visibility into these understudied defense research labs.

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i The Chinese STI community began to research and adopt the concept of 'National Innovation Systems,' first proposed by the OECD in 1997, in the early 2000s. The 2006 Medium to Long-term Plan for the Development of Science and Technology (2006-2020) defined NIS as a social system led by the government that gives full play to the role of the market in allocating resources, and one in which all types of STI actors are closely linked and interacts effectively. For more on the current state of the NIS, see Section 3.1 in Alex Stone, "China's Model of Science: Rationale, Players, Issues," CASI, 2022.

ii Beginning in the mid-2010s, a variety of existing national-level laboratories and other science and engineering centers and facilities have been reorganized or reclassified under the new umbrella category 'national STI bases' [国家科技创新基地], a core component of the 'National Innovation Systems.'

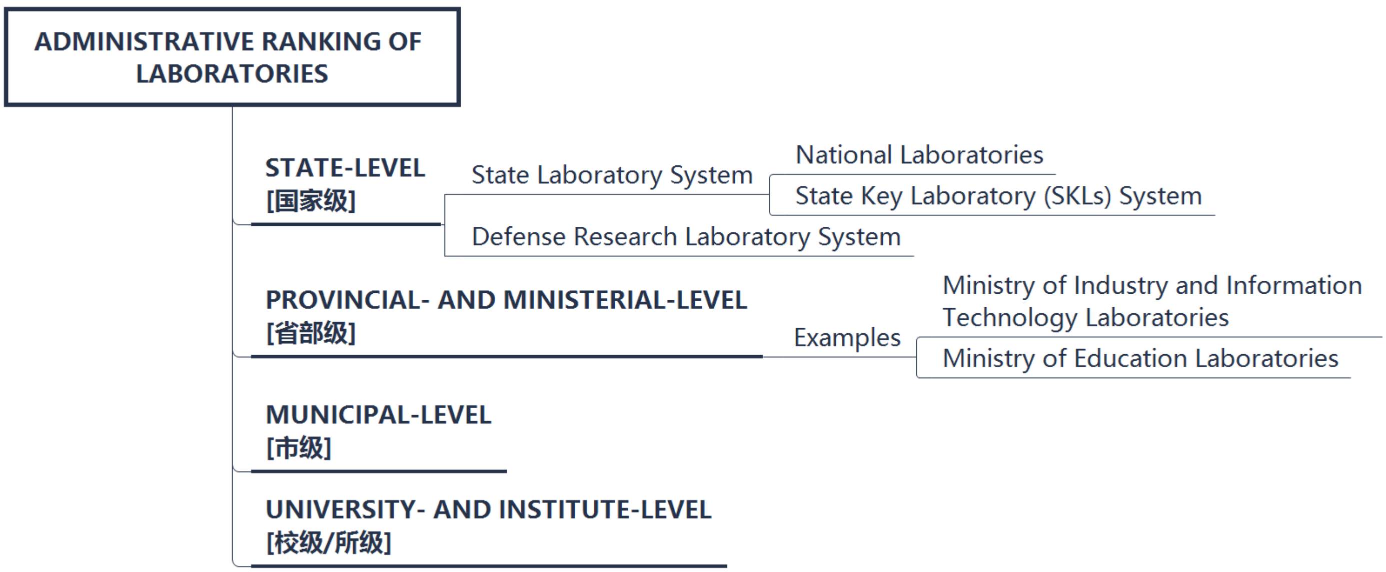
iii For example, see "Defence laboratories," ASPI, accessed August 2021, https://unitracker.aspi.org.au/defence-laboratories/

iv Please contact CASI for details about access to this data.

Overview of the State and Defense Laboratory System

Over the past 30 years, China has developed a vast and complex laboratory system. From an analytical standpoint, at present, laboratories generally fall into one of several categories according to their administrative rankings. They include, in descending order: state-level laboratories[国家级], provincial and ministerial-level laboratories [省部级], municipal-level laboratories [市级], and university/institute level laboratories [校级/所级] (See fig.1)[1]. Among them, the laboratories at the state level are the nation's oldest and also the most important platforms of innovation, where the most strategic and cutting-edge research takes place. They are an integral part of the 'National Strategic S&T Enterprise'[国家战略科技力量].[v] These labs are the 'crown jewels' of China's National Innovation Systems which the 14th Five Year Plan has stressed for prioritized development.

Figure 1



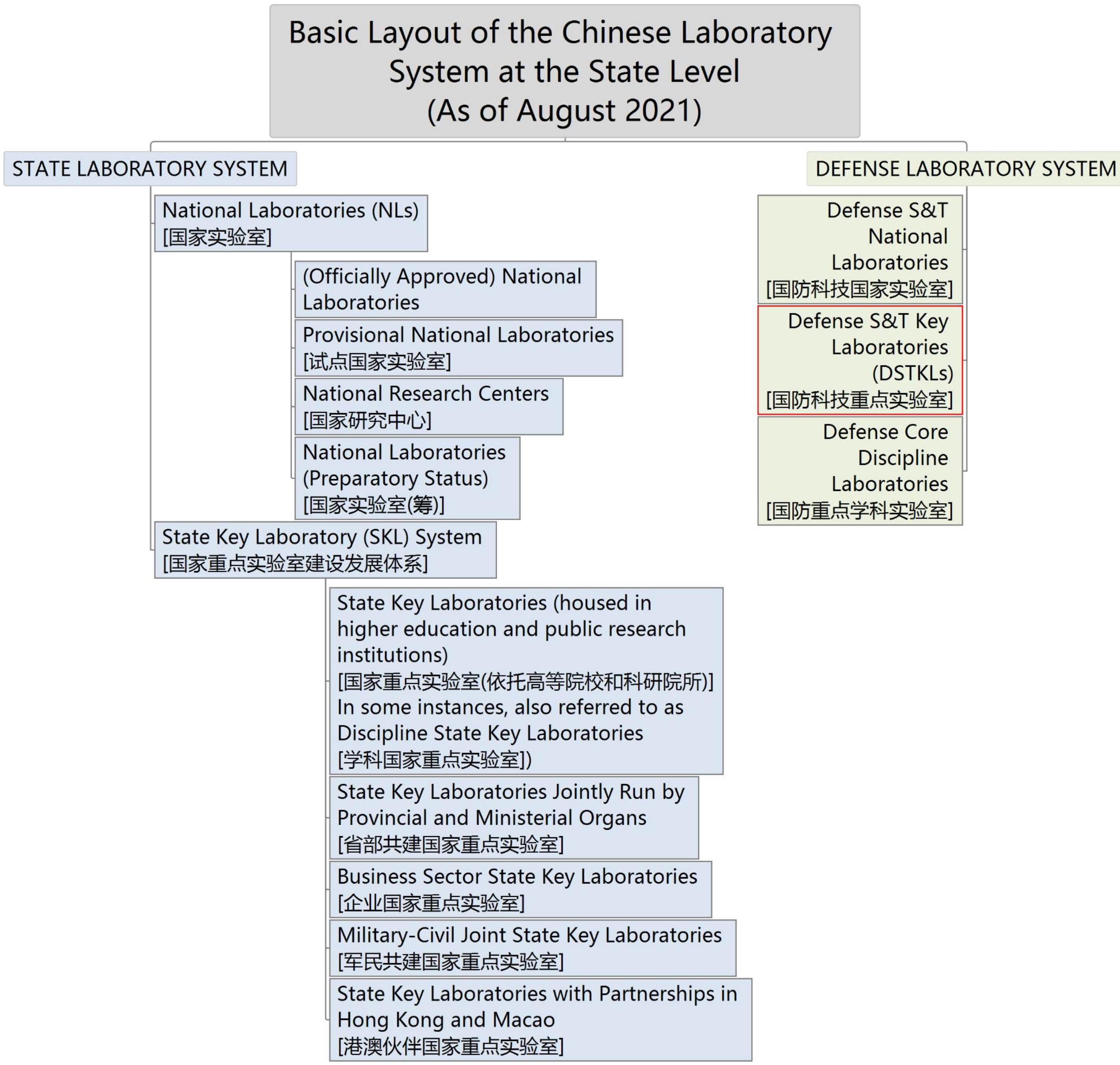
The state-level laboratories, the focus of the authors' research and this paper, can be divided into two laboratory systems:

1. The state (or civilian) laboratory system with oversight from the Ministry of Science and Technology (MOST);
2. The defense research laboratory system managed by the State Administration for Science, Technology and Industry for National Defense (SASTIND) and (likely) the Central Military Commission Equipment Development Department (CMC EDD).

v For more on the National Strategic S&T Enterprise, see Section 3.1 in Alex Stone, "China's Model of Science: Rationale, Players, Issues," CASI, 2022.

Figure 2 illustrates the two parallel systems and their various sub-categories. The DSTKLs surveyed and analyzed in Section 2 are highlighted in red.

Figure 2



The State Laboratory System

The state laboratory system mostly includes a handful of National Laboratories (NL) [国家实验室] and the state key laboratory (SKL)[国家重点实验室]system, which comprises at least seven sub-systems with a total of around 700 labs.

National Laboratories[国家实验室]

National Laboratories (NLs) are envisioned as the nation's highest-level scientific research and innovation platforms that reflect national intentions, carry out strategic missions, and represent the highest achievement of Chinese science. First launched in 2000 to conduct cross-disciplinary research, China is in the middle of a complete revamping of its NL system, whose number is in the single digits. As part of these reforms, several NLs previously in preparatory status [筹] have been downgraded to what is called 'National Research Centers.' As a result, there are currently four officially approved National Laboratories and one provisional.

These are:

- Synchrotron Radiation National Laboratory (Hefei) [同步辐射国家实验室]
- Electron Positron Collider National Laboratory (Beijing) [正负电子对撞机国家实验室]
- Beijing Tandem Accelerator Nuclear Physics National Laboratory (Beijing) [北京串列加速器核物理国家实验室]
- Lanzhou Heavy Ion Accelerator National Laboratory (housed at the Heavy Ion Research Facility in Lanzhou)[兰州重离子加速器国家实验室]
- (Provisional) National laboratory for Marine Science and Technology (Qingdao) [青岛海洋科学与技术国家实验室]

Some sources suggest that during this round of restructuring, some of the existing NLs might also be downgraded to make room for new ones in more cutting-edge areas of research. Policymakers have announced plans under the 14th FYP Period (2021-2025) to build more NLs in the areas of quantum information, photonics and micro-nanoelectronics, network communications, artificial intelligence, biomedicine, modern energy systems, etc.[2] The 14th FYP stressed the need to speed up the development of the 'strategic S&T enterprise' led by national laboratories.[3] Chinese leader Xi Jinping has also called on NLs to closely follow global S&T development trends and yield more strategic, critical, and major scientific and technological achievements, in order to form a "highly effective national laboratory system with Chinese characteristics along with the state key laboratories."[4]

State Key Laboratories [国家重点实验室]

SKLs were launched in 1984 with administrative oversight from the then State Development Planning Commission [国家发展计划委员会].[5] A total of 155 SKLs were established between 1984 and 1997, most of which were housed at research institutions such as the Chinese Academy of Sciences (CAS), universities, and various state ministries.[6] Among this group were also laboratories undertaking research in national defense science and technology. MOST took over their supervision [宏观管理] during the organizational reform in 1998 and gradually increased the number of SKLs housed in higher education and research institutes, while at the same time removing some labs with obsolete research areas from the SKL category. MOST expanded the SKL program in 2003 to establish SKLs in the central and western regions and other regions with weak scientific research infrastructure, and again in 2006 to develop SKLs in the business sector.[7] Under the push for deepening military-civil integration in the mid-2010s, the SKL system was further expanded to include a group of military-civil joint SKLs [军民共建国家重点实验室]. Deputy Minister of Science and Technology Huang Wei [黄卫] revealed at a 2017 press conference that there were a total of 17 SKLs under this designation, conducting research that supports national R&D programs such as those for manned space flight, lunar exploration, and second-generation navigation systems.[8]

The number of SKLs is constantly changing due to the fact that each lab must be evaluated by MOST at least once every five years to determine its categorization. While it is difficult to ascertain the exact number of labs currently in operation, according to policy directives issued by MOST and the Ministry of Finance in 2018, the plan was to maintain around 700 SKLs in operation by 2020.[9] MOST has not made publicly available its data and official analysis of the SKLs since 2016; however, according to some estimates, China is about 150 labs short of its 700 mark, with the shortfall mostly coming from business sector SKLs.[10]

Figure 3

Lab Categories	Estimates as of May 2020[11]	Goal set by MOST
(Officially Approved) National Laboratories	4	N/A
Provisional National Laboratories	1	
National Research Centers	6	
National Laboratories (Preparatory Status)	9	
Discipline-specific, Military-civil Joint, and Hong Kong-Macao Partnered SKLs	298	300
SKLs (Business Sector)	174	270
SKLs jointly run by Provincial and Ministerial Organs	50	70
Total	**542**	**700**

The Defense Research Laboratory System

Understandably, there is less information available about the defense research laboratory system. When it comes to the organization of this system, the plan, according to interviews conducted with COSTIND officials in 2007, was to develop three types of defense research labs: Defense S&T National Laboratories [国防科技国家实验室], Defense S&T Key Laboratories [国防科技重点实验室], and Defense Core Discipline Laboratories [国防重点学科实验室].[12] SASTIND policies put out in the mid-2010s confirm that this classification still applies. [13]

Defense S&T National Laboratories [国防科技国家实验室]

Mirroring the design of the state laboratory system, the Defense S&T National Laboratories, which would be fairly limited in number, were envisioned as national-leading innovation centers conducting strategic, advanced, inter-disciplinary research into defense and dual-use technologies.[14] Even though COSTIND officials announced plans to launch this series of labs in 2007, descriptions of these labs were still framed in aspirational terms in policy documents issued in the late 2010s. For example, policy measures issued by SASTIND in June 2016 indicated *intentions* [谋划设立] to build Defense S&T National Laboratories, but no further details were provided.[15]Although policymakers have been planning for the development of NLs since the early 2000s, it appears that the overall layout and research directions of the NL system have yet to be finalized, and no Defense S&T National Laboratories appear to exist at this time.

Defense S&T Key Laboratories [国防科技重点实验室]

In the early 1990s, following the creation of the SKLs, the former Commission for Science, Technology and Industry for National Defense (COSTIND) launched a program to build up a separate group of state-level key laboratories designed to target national defense S&T development needs with access to stable and more substantial government funding.[16] Subsequently, some former SKLs engaged in defense research were transferred into this new category, called the Defense S&T Key Laboratories (DSTKLs) [国防科技重点实验室]. These labs were overseen by COSTIND until 2008, when SASTIND and the PLA General Armaments Department (now the CMC Equipment Development Department) took over during the 2008 central government administrative reforms. This movement of individual labs between categories is the first of several issues that can obfuscate their current status and role.

The number of DSTKLs has also fluctuated depending on the sources. According to a book published in 2019 by the Party Central School which documented the major achievements of the PRC since its founding in 1949, COSTIND approved a total of 55 DSTKLs, with 35 of these housed in higher education and 20 in research institutions.[17] A different source, citing data from a since-deleted page on an official central government website, listed 60 DSTKLs.[18] Preliminary research has not yet revealed if there is any degree of overlap between the DSTKL category and the SKL category.

The first phase of this project began with a review of the initial public list of 60 DSTKLs. Subtracting duplicates and labs that have since been downgraded in status left a sample of 56 labs. In addition, further research revealed 45 more labs which have, at some point, used the "Defense S&T Key Lab" moniker, leading to confusion about what actually constitutes a DSTKL. As mentioned earlier, some of the ambiguity regarding these labs' status is due to their complicated organizational history. Some degree of this confusion may also be the result of deliberate obfuscation, as labs oftentimes will attempt to obscure their military nature, especially when collaborating with foreign partners (see Section 2 for details).

Defense Core Discipline Laboratories [国防重点学科实验室]

Defense Core Discipline Laboratories, as the name suggests, are established in universities with a strong track record of academic performance and highly qualified faculty in disciplines related to defense basic science and frontier technologies. For example, according to its website, Nanjing University of Science and Technology's [南京理工大学] application to establish the Intelligent Ammunition Technology Defense Core Discipline Laboratory [智能弹药技术国防重点学科实验室] was approved because the university ran four PhD programs in the areas of "Weapon Science and Technology," "Instrument Science and Technology," "Aerospace Science and Technology," and "Mechanical Engineering." Defense Core Discipline Laboratories are concentrated in the seven universities affiliated with the Ministry of Industry and Information Technology (MIIT), also known as the Seven Sons of Defense [国防七子], military universities and research academies, and other top research universities under the Ministry of Education.

Based on the surveyed sources it is difficult to ascertain whether Defense S&T Discipline Laboratories overlap to any degree with DSTKLs. There is evidence to suggest that these labs are not state-level labs by their administrative ranking. For example, the Intelligent Ammunition Technology Defense Core Discipline Laboratory notes on its webpage that it is a provincial- and ministerial-level laboratory.[19]

Placing the Laboratory System Inside the National Innovation Systems

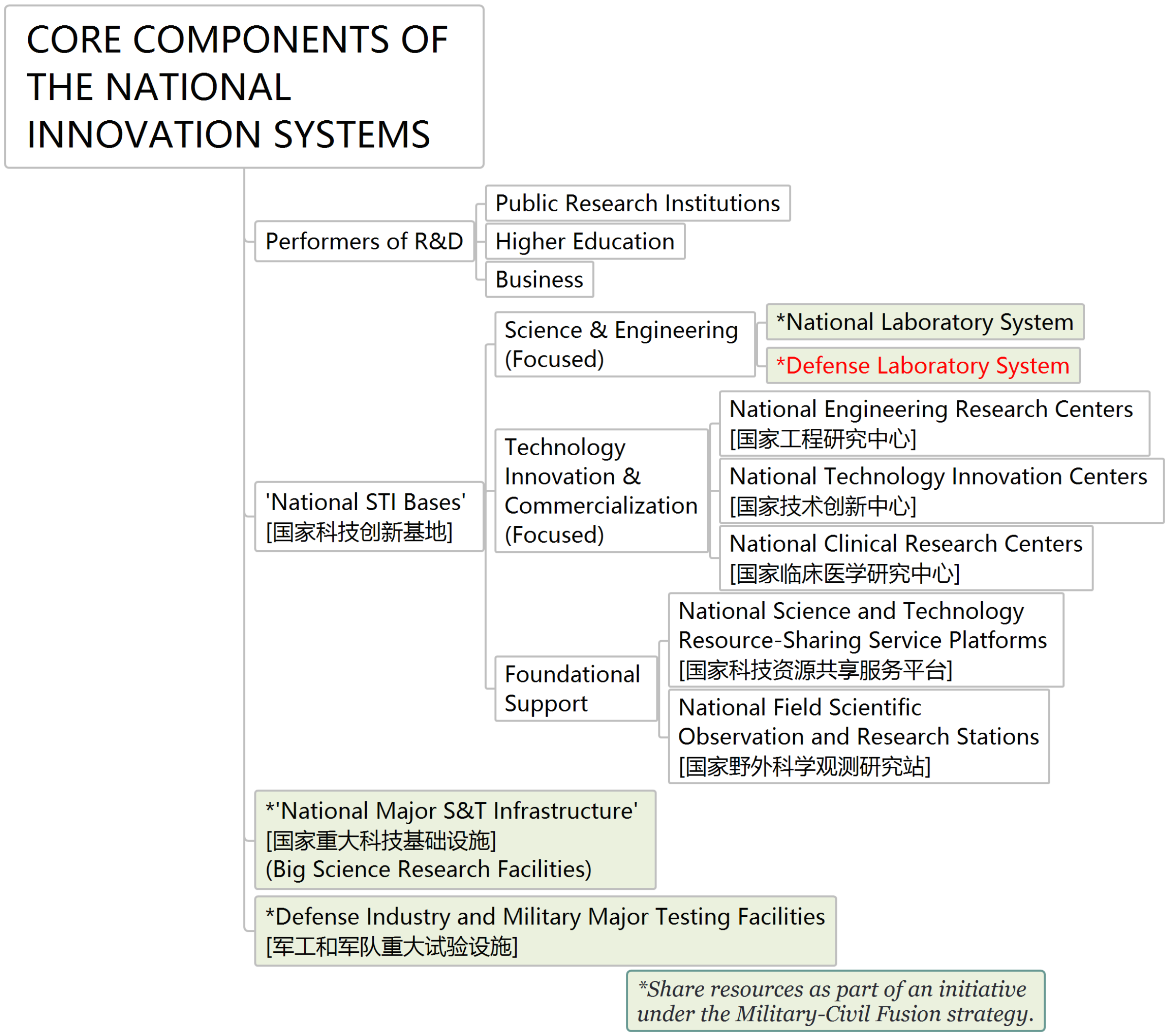
Since the mid-2010s, MOST has been leading the efforts to reclassify and reorganize existing labs and facilities, including the various state-level labs, into three main categories of 'National STI Bases' (see fig.4). State-level labs are classified as 'Science and Engineering-focused National STI Bases' [科学工程类国家科技创新基地], and comprise one of three main categories.

Figure 4

National STI Bases[20]		
Types of National STI Bases	**Core Components**	**Mandate**
Science and Engineering [科学与工程研究]	• NLs • SKLs • DSTKLs	Carry out strategic, cutting-edge, and forward-looking research and development activities centered on strategic, national objectives.
Technology Innovation and Commercialization [技术创新与成果转化]	• National Engineering Research Centers [国家工程研究中心] • National Technology Innovation Centers [国家技术创新中心] • National Clinical Research Centers [国家临床医学研究中心]	Carry out research and development on cross-sector and engineering technologies to support economic and social development.
Foundational Support [基础支撑与条件保障]	• National Science and Technology Resource-Sharing Service Platforms [国家科技资源共享服务平台] • National Field Scientific Observation and Research Stations [国家野外科学观测研究站]	Discover the laws of nature, catalogue field research data, and provide resource-sharing services that benefit the public.

Chinese STI policymakers have taken a systematic approach towards the arrangement of the nation's S&T infrastructure and are in the process of reshaping the layout and research direction of these platforms. The three types of 'National STI Bases' are a core component of China's overall "National Innovation Systems' [国家科技创新体系] for scientific research, alongside traditional R&D institutions and other critical research, development and testing facilities (See fig.5).

Figure 5



Finally, the integration of these platforms, particularly through the sharing of resources between civilian and defense platforms, is an important part of the Military-Civil Fusion strategy. In June 2018, MOST, the National Development and Reform Commission (NDRC), SASTIND, and the CMC EDD announced measures to promote resource sharing[vi] across a wide range of national scientific research facilities, including the hundreds of SKLs, dozens of DSTKLs, major military and defense industry test facilities [军工和军队重大试验设施], and the over 60 facilities designated as "national major scientific and technological infrastructure" [国家重大科技基础设施] (marked in green in fig.5).[vii21] State key labs and national defense S&T labs are encouraged to strengthen "two-way opening"[双向开放] and "effective integration" [有效集成]. This initiative closely binds military and civillian research institutions, making differentiation difficult and complicating the efforts of U.S. companies, research institutions, and regulatory agencies trying to prevent intellectual property and advanced technology from being transferred to the PLA.

vi Here "resources" include facilities, scientific instruments, data, experimental materials, etc.

vii Our database also includes profiles of the over 60 big science research facilities designated as "national major scientific and technological infrastructure."

Defense S&T Key Laboratories

As explained in the previous section, China has developed a vast and complex laboratory system over the past 30 years, among which the SKLs and DSTKLs are the two most well-defined categories of labs with the longest development history and significance. Given their centrality to defense R&D, DSTKLs were a logical starting point for understanding this complex system. For each DSTKL, known aliases, research foci, real-world applications of that research, funding, facilities and equipment, domestic and international collaborations, and leadership and notable affiliated scholars were compiled into a database. As mentioned earlier, after accounting for duplicates and labs that have since been downgraded in status, a sample of 56 labs remained.

In the course of this research, it quickly became apparent that the online list which formed the basis of the survey appeared to be lacking a significant number of relevant labs. To date, at least 45 additional labs which have at some point used the "Defense S&T Key Lab" moniker have been discovered. Part of the confusion stems from the seeming lack of rigor with which these labs are labeled in public sources. A single lab can be designated as a "Defense S&T Key Lab" [国防科技重点实验室], a "Defense Key Lab" [国防重点实验室], a "State Key Lab" [国家重点实验室], a "State-level Key Lab" [国家级重点实验室], or simply a "Key Lab" [重点实验室], depending on the source. These titles are used seemingly interchangeably, leading to substantial confusion as to what Labs are actually DSTKLs. Further, despite the fact that MOST has clear rules regarding translation of names into English,[viii] these rules do not appear to be followed strictly.

As an example, the images below show two different names used by one DSTKL working on radar signal processing at Xidian University [西安电子科技大学]. Despite describing the same lab, both the English and Chinese names are different in the two images. Note that neither English name uses the word *defense*, even though the Chinese in the top image includes the characters for defense.

Figure 6

Figure 7

This confusion may be at least partially by design, as labs oftentimes will attempt to obscure their military nature, especially when collaborating with foreign partners. Notably, the "Defense" part of their name is almost never translated into English. Online evidence suggests that U.S. and other Western research institutions fre-

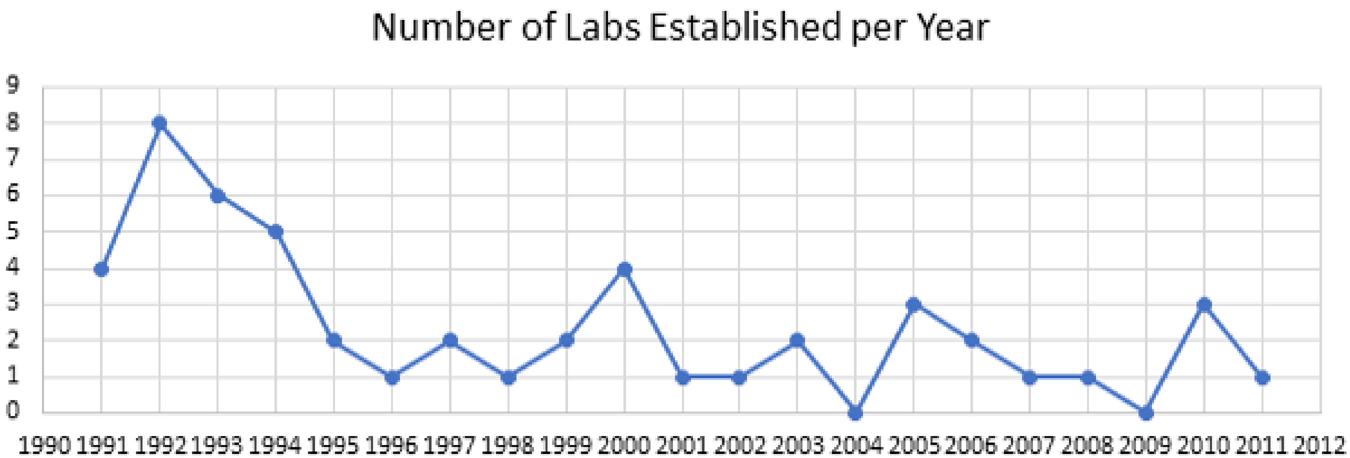
viii According to MOST, labs in the key laboratory series should be uniformly translated into "State Key Laboratory of ___ (Organization Name)." Such as: State Key Laboratory of Silicon Materials (Zhejiang University).

quently collaborate with these defense labs, including on potentially sensitive research topics such as underwater sensor networks,[22] radar signal processing,[23] and advanced materials,[24] among many other things. Many of these labs have had or continue to have ongoing connections with some of the U.S.'s top research universities, including Princeton,[25] MIT,[26] and Stanford University,[27] and American experts have attended and presented at conferences hosted by these labs on topics such as space propulsion,[28] underwater acoustics,[29] and aircraft thermal dynamics[30](notably, the latter hosted by a defense lab likely conducting research on the PLA's future H-20 stealth bomber).[31]

Number of Labs Established Per Year

A founding date was found for 50 of the 59[ix] DSTKLs surveyed in the initial list. The first batch of labs, at least 12 in total, was established by COSTIND and the PLA General Armaments Department between 1991 and 1992. At least 11 more labs were established in 1993 and 1994. Following this initial spate, between 1995 and 2011 (the last year in which a lab in this survey was definitively established), labs were established at a mostly consistent rate of around 1-2 per year. Four were established in 2000, and none were established in 2004 or 2009. The newest lab on the list passed its final inspection and gained approval in 2018, but a founding date was unable to be ascertained.

Figure 8



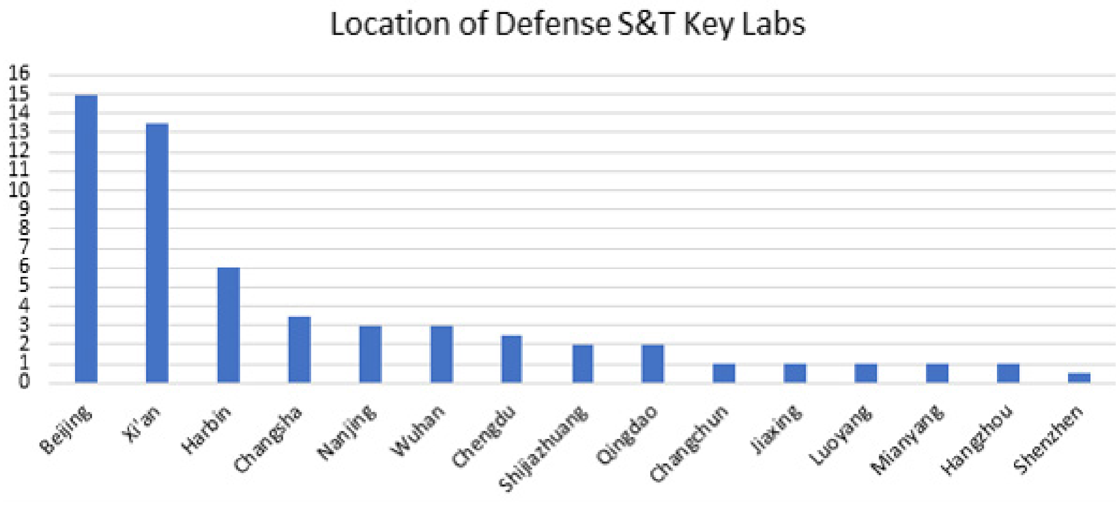
Location of Defense S&T Key Labs

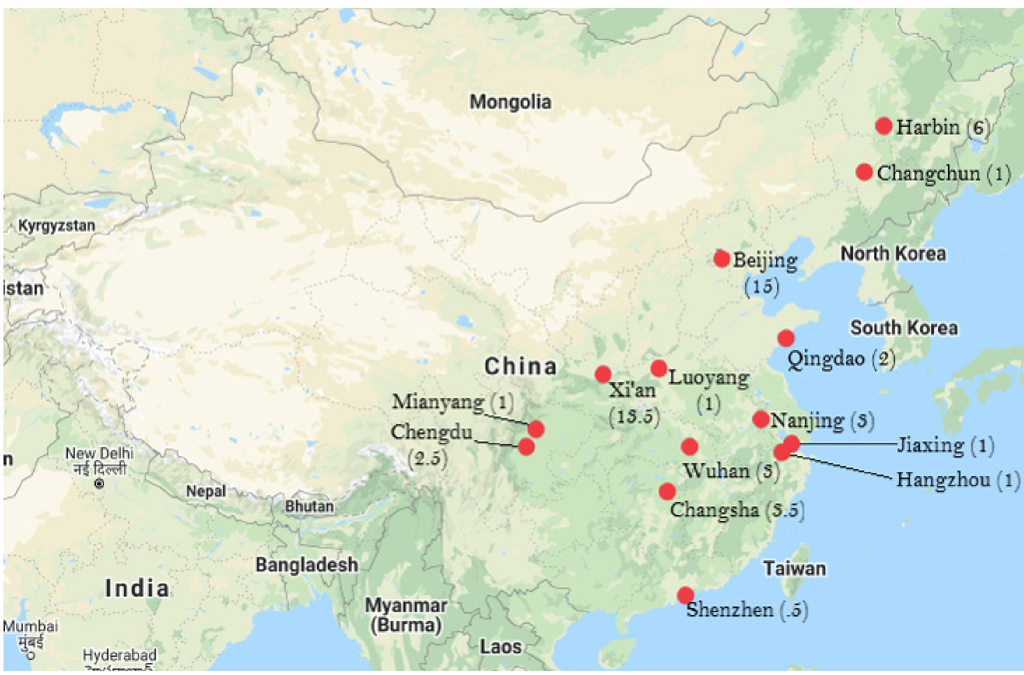
Over half of the labs surveyed are clustered in three cities: Beijing, Xi'an, and Harbin. It is no coincidence that these three cities are home to five of the "Seven Sons of National Defense," a group of seven research universities which produce a disproportionate amount of the PRC's military research and workforce. Beijing is the home to the largest number of labs, with 15 in total, including labs managed by Beihang University and Beijing Institute of Technology, as well as a large number of major research institutions for state-owned conglomerates such as CETC, AVIC, AECC, CASC, CASIC, and CNNC. Xi'an has the second greatest number of labs with 13.5,[x] including labs under Northwestern Polytechnical University, Xidian University, and the PLA Air Force Engineering University, as well as at least two Norinco research institutes. Harbin is third, with six labs, all under Harbin Engineering University or Harbin Institute of Technology. Smaller numbers of labs are widely distributed across 12 additional cities.

ix Including three Labs which are no longer classified as Defense S&T Key Labs

x Labs which have co-equal headquarters in two cities, typically the result of partnerships between universities and SOEs or PLA institutions, were counted as .5 for each city

Figure 9

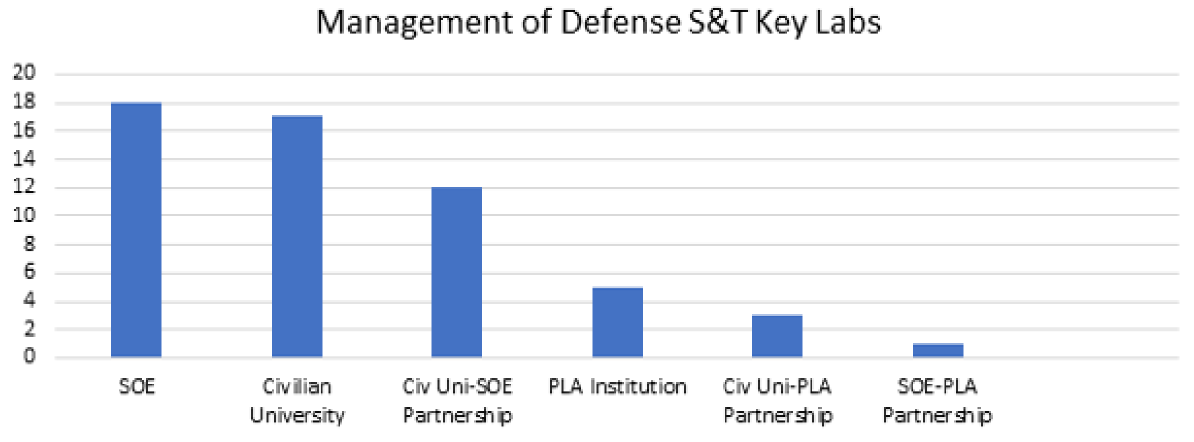




Management of Defense S&T Key Labs

Of the 56 current DSTKLs surveyed, 18 were managed exclusively by state-owned enterprises, while 17 were managed exclusively by civilian universities. A further 12 were co-managed by civilian universities and state-owned enterprises. Five Labs were managed by PLA research institutions or service universities. Smaller numbers were managed by partnerships between the PLA and civilian universities (3) or the PLA and state-owned enterprises (1).

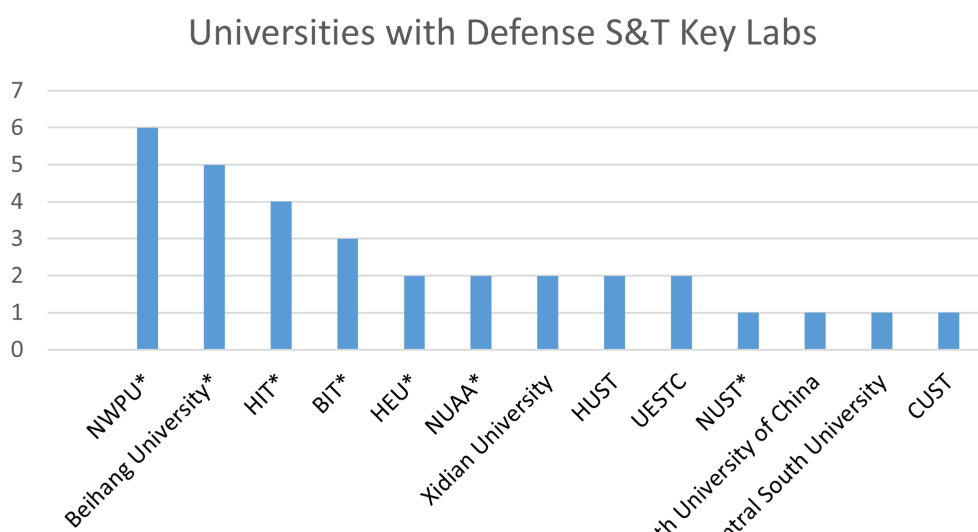
Figure 10



Universities with Defense S&T Key Labs

Unsurprisingly, the "Seven Sons of National Defense" are well represented amongst the civilian universities assigned DSTKLs. Northwestern Polytechnical University in Xi'an leads with six labs, while Beihang University has five, Harbin Institute of Technology has four, Beijing Institute of Technology has three, Harbin Engineering University and Nanjing University of Aeronautics and Astronautics have two each, and Nanjing University of Science and Technology has one. In total, 23 of the 32 Defense S&T Key Labs assigned to civilian universities are under one of the Seven Sons, with nine under other universities.

Figure 11



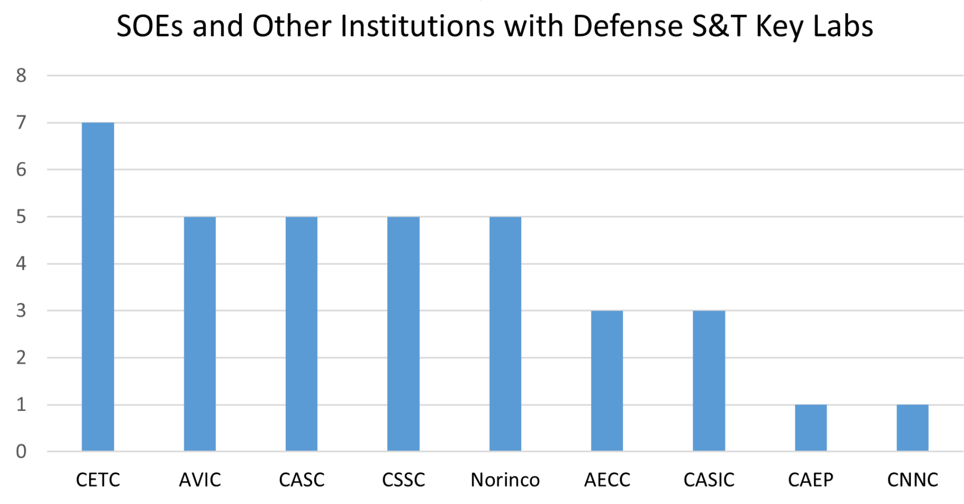
**One of the 'Seven Sons of National Defense'*

SOEs and Other Institutions with Defense S&T Key Labs

The list of DSTKLs assigned to state-owned enterprises is dominated by, and fairly evenly distributed between, the PRC's largest defense conglomerates. China Electronics Technology Group Corporation (CETC), which produces a wide range of high-tech military products including radars, communications systems, guidance systems, and other electronics, leads with seven labs. Aviation Industry Corporation of China (AVIC), the PRC's largest military aviation conglomerate and producer of most of the PLA's military aircraft and helicopters, has been assigned five labs, while Aero Engine Corporation of China (AECC), the

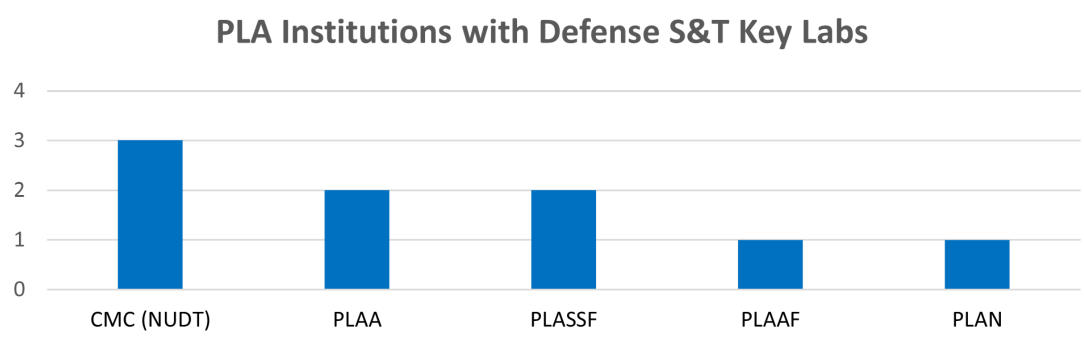
PRC's second largest military aviation conglomerate, has been assigned another three. China Aerospace Science and Technology Corporation (CASC) and China Aerospace Science and Industry Corporation (CASIC), the PRC's two major space conglomerates, are responsible for the PRC's military satellites, ballistic missiles, and other aerospace products, and have been assigned five and three labs, respectively. China State Shipbuilding Corporation (CSSC), the PRC's largest ship-building conglomerate and builder of all of the PLAN's warships, has been assigned five labs. China Ordnance Industries Group Corporation, also known as Norinco, is responsible for a range of products including military vehicles, armor, and munitions, and has been assigned five labs. The Chinese Academy of Engineering Physics (CAEP)[xi] and the China National Nuclear Corporation (CNNC), the two leading entities responsible for the PRC's nuclear weapons program, have each been assigned one lab.

Figure 12



Of the PLA institutions which have DSTKLs, the Central Military Commission has the most with at least three (via the subordinate National University of Defense Technology). The PLA Army and PLA Strategic Support Force each have two, and the PLA Navy and PLA Air Force each have one. According to some sources, the PLA Rocket Force (PLARF) may also oversee two DSTKLs,[32] although these are not among the initial list of surveyed labs.

Figure 13



Defense S&T Key Lab Research Areas

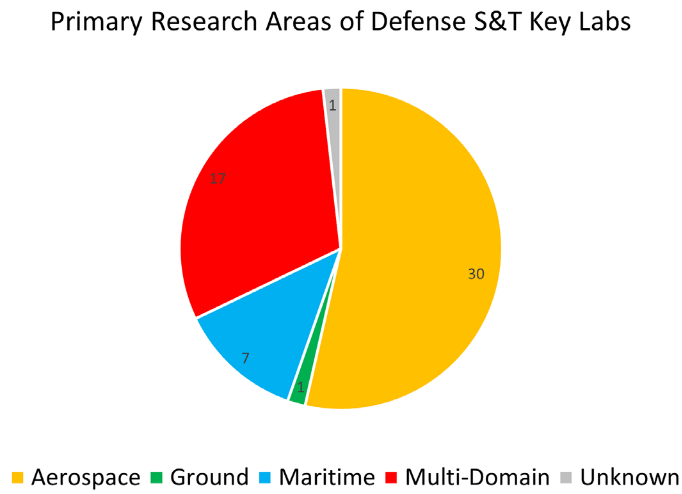
Finally, data on the research foci of the 56 surveyed labs was compiled. These have been broken down into area focus (aerospace, maritime, ground), equipment focus (aircraft, UAVs, missiles, etc.), and "functional" focus (acoustics, electromagnetics, propulsion, etc.). These were also brokem down into a "primary" focus and "secondary" foci, to show both the number of labs primarily focusing on a specific area as well as all labs conducting at least some research in that area. While these categorizations will inevitably be somewhat subjective and limited

xi CAEP, unlike the other entities listed here, is not a state-owned enterprise, but a state research institution for China's nuclear weapons program and other research related to nuclear physics.

by what information is publicly available, these breakdowns provide insight into what the PRC has chosen to prioritize in its defense research.

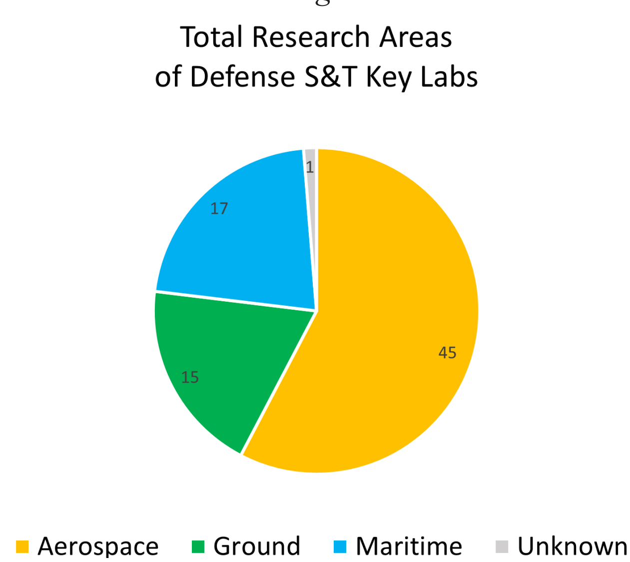
Of the labs surveyed, over half are primarily concerned with military aerospace research. The preponderance of aerospace research can be explained by the fact that many of the most challenging and important technologies for future warfare, including those related to spaceflight and rocketry, ballistic missiles, aircraft propulsion, and UAVs, are in the aerospace sector, and it is thus not surprising that the PRC is allocating significant resources in this direction. 17 labs conduct research into multiple areas, with no single area dominant. Ground warfare plays a less significant role in the research landscape, with only one lab primarily devoted to ground warfare, although a larger number conduct research relevant to ground warfare in a secondary role or as one of multiple research areas (see below).

Figure 14



When looking not just at the primary research area but at secondary research areas as well, at least 45 of the 56 labs conduct at least some aerospace-related research. Both maritime and ground warfare are also better represented, with at least 17 labs conducting some research into maritime warfare, and at least 15 conducting some research into ground warfare.

Figure 15

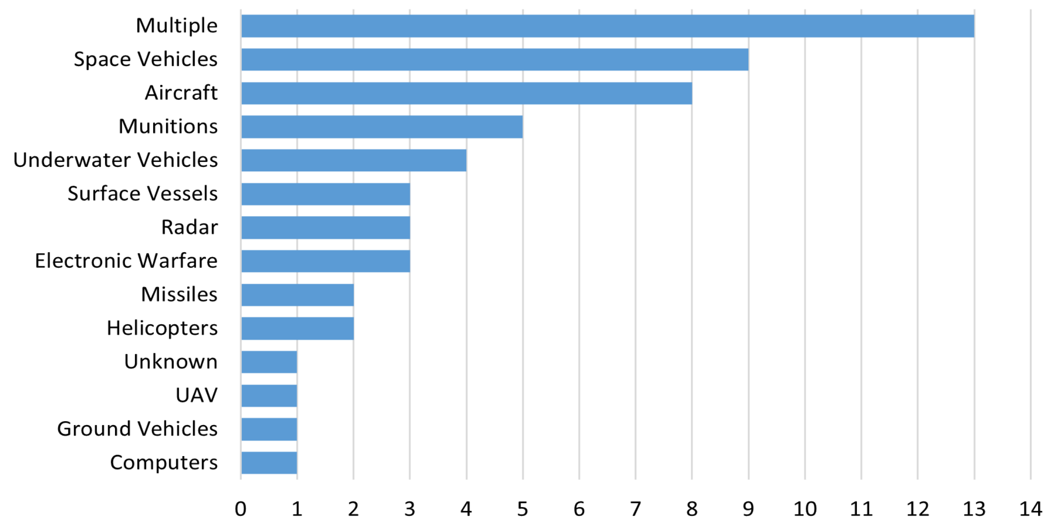


Defense S&T Laboratory Research Foci

As expected, given the preponderance of labs focused on aerospace, research related to space vehicles (including satellites, manned spaceflight, etc.) and aircraft make up the two largest equipment research areas, with nine and eight labs devoted to these two areas, respectively. Smaller numbers of aerospace labs are focused on helicopters (2) or UAVs (1). Maritime research is primarily focused on underwater vehicles (4) and surface vessels (3). One lab conducts research into ground vehicles. Additional labs are primarily dedicated to research of equipment with multi-domain applicability, including munitions (5), radar (3), electronic warfare (3), missiles (2), and computers (1).

Figure 16

Primary Equipment Researched by Defense S&T Key Labs

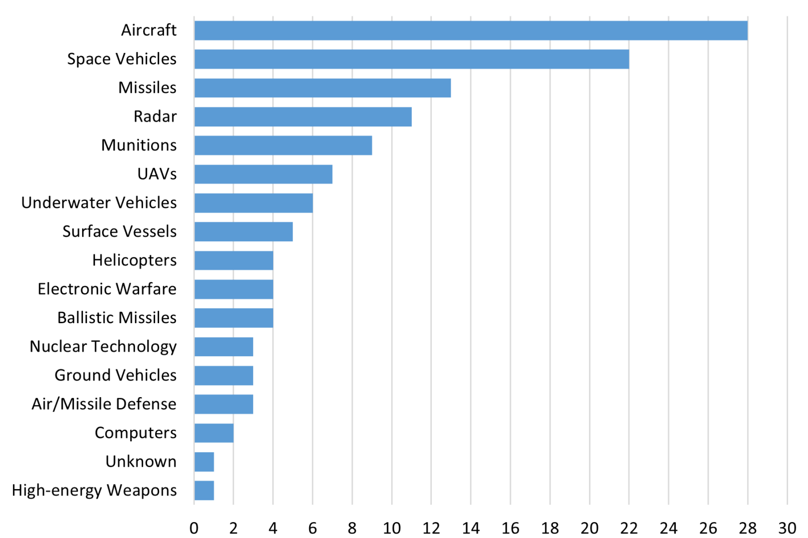


Equipment Development Foci

When looking not just at the primary equipment but *all* equipment researched by each lab, aircraft and space vehicles remain dominant, with at least 28 and 22 labs, respectively, conducting some research in these areas. At least seven labs conduct some research into UAVs, and at least four into helicopters. At least 13 labs conduct some research into (non-ballistic) missiles, and four more into ballistic missiles (although given the dual-use nature of space launch research, this number could in fact be significantly higher). Maritime and ground warfare technologies are better represented, with at least six labs conducting research into underwater vehicles, five into surface vessels, and three into ground vehicles. At least 11 conduct some research related to radar technology, nine into munitions, four into EW, and two into computers. A number of other areas also appear here as secondary research interests, including nuclear technologies (3), air and/or missile defense (3), and high-energy weapons (1).

Figure 17

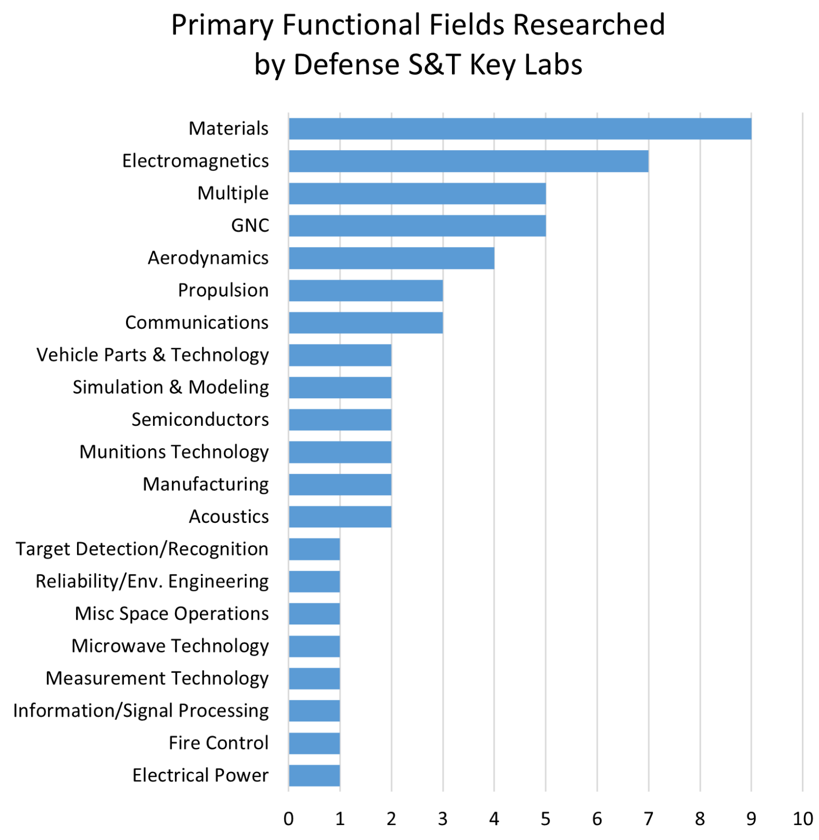
Total Equipment Researched by Defense S&T Key Labs



Primary Functional Fields Researched

Looking at the primary functional research areas of each lab, research into advanced materials is the single largest area of focus, with nine dedicated labs. Research into electromagnetic technologies is second, with seven labs, and research into guidance, navigation, and/or control (GNC) technologies, typically for either aerospace or underwater vehicles, is third, with five labs.

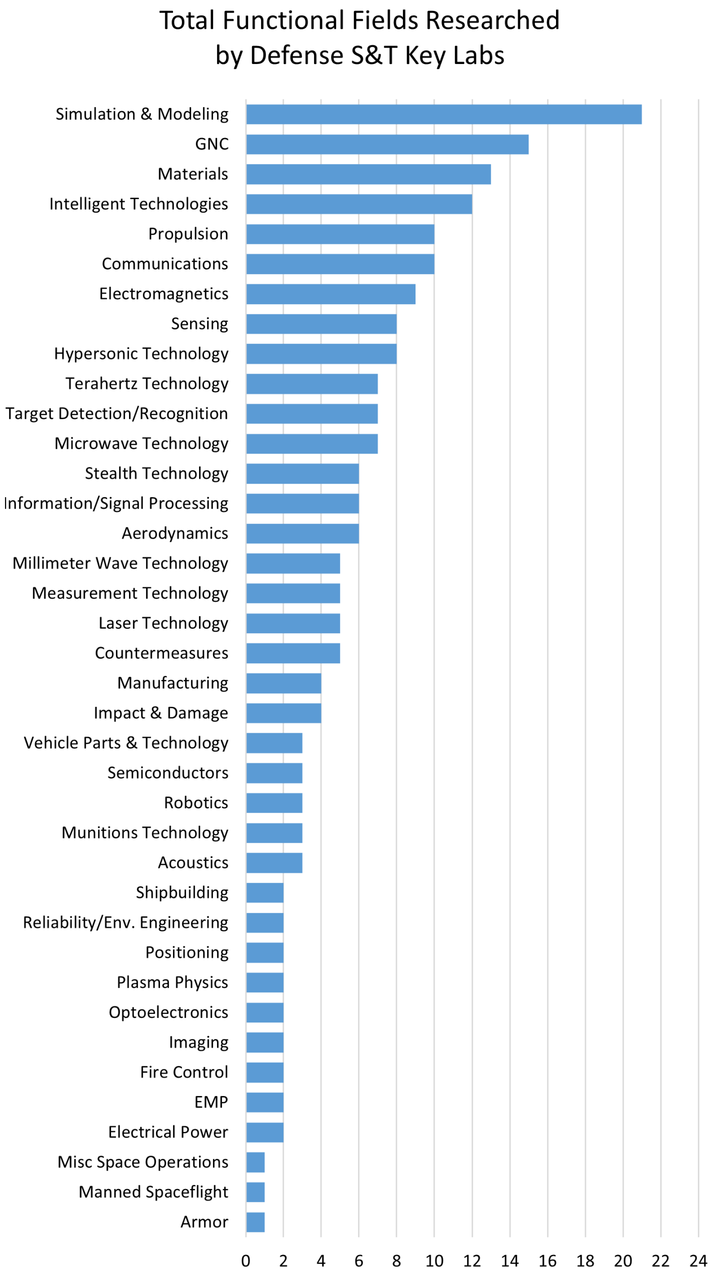
Figure 18



Total Functional Fields Researched

When looking at *all* significant research conducted by these labs, it was found that at least 21 discuss conducting simulation & modeling work. Recent advances in simulation and modeling capabilities have the potential to significantly reduce the time and expense of testing new defense technologies, and it is thus unsurprising to see the PRC's defense labs incorporating it into their research. GNC and advanced materials also remain important areas of focus, with at least 15 and 13 labs each. There was also significant research into cutting edge, future warfare technologies such as artificial intelligence, machine learning, and robotics, with at least 15 combined labs conducting research in these areas, hypersonic technologies, with at least eight labs, stealth and anti-stealth technologies, with at least six labs, and semiconductors, with at least three labs. Further, significant research into various portions of the electromagnetic spectrum for a wide range of uses is clearly apparent, including advanced next-gen radars, communications, and ISR, with at least seven labs studying microwave or terahertz technologies, and five studying millimeter wave technologies.

Figure 19



The above statistics provide some initial insight into the priorities and research direction of China's most important defense labs. They suggest a strong emphasis on cutting-edge air and space technologies, as well as the necessary supporting technologies for aerospace dominance, such as advanced materials, GNC, propulsion, stealth, and hypersonic technologies. It also reveals increasing emphasis on the kinds of technologies, such as those related to AI/ML and the electromagnetic spectrum, that are central to the PLA's goal of transforming itself into an "intelligentized" force relying on superior technology to conduct network-centric warfare and complex system-of-systems operations.

This initial data is the first step in a larger effort to create a searchable database of China's military science, technology, and industrial infrastructure. Given that senior Chinese leaders have identified the development of China's STI infrastructure as a top policy priority for the 14th FYP period, it is highly likely that these labs will only further increase in importance. China's STI policymakers recognize that China's tech ambitions require first-class infrastructure and facilities to be achieved. These labs are intended to be the incubators of the new breakthroughs necessary for China to reduce its reliance on foreign technologies, spark domestic innovation, and dominate the battlefields of the future.

Appendix 1: List of Relevant Institutions

Aero Engine Corporation of China (AECC) [中国航空发动机集团]

Aviation Industry Corporation of China (AVIC) [中国航空工业集团]

Beihang University [北京航空航天大学]

Beijing Institute of Technology (BIT) [北京理工大学]

Central South University (CSU) [中南大学]

Changchun University of Science and Technology (CUST) [长春理工大学]

China Aerospace Science and Industry Corporation (CASIC) [中国航天科工集团]

China Aerospace Science and Technology Corporation (CASC) [中国航天科技集团]

China Electronics Technology Group Corporation (CETC) [中国电子科技集团]

China National Nuclear Corporation (CNNC) [中国核工业集团公司]

China State Shipbuilding Corporation (CSSC) [中国船舶集团]

Chinese Academy of Engineering Physics (CAEP) [中国工程物理研究院]

Harbin Engineering University (HEU) [哈尔滨工程大学]

Harbin Institute of Technology (HIT) [哈尔滨工业大学]

Huazhong University of Science and Technology [华中科技大学]

Nanjing University of Aeronautics and Astronautics (NUAA) [南京航空航天大学]

Nanjing University of Science and Technology (NUST) [南京理工大学]

North University of China (NUC) [中北大学]

Northwestern Polytechnical University (NWPU) [西北工业大学]

Xidian University [西安电子科技大学]

University of Electronic Science and Technology of China (UESTC) [电子科技大学]

Appendix 2: LIst of Image Sources

Page	Img. No.	Source
No.12	Fig. 6	"Image Gallery: Defense S&T Key Labs," accessed August 2021, https://baike.baidu.com/pic/%E5%9B%BD%E9%98%B2%E7%A7%91%E6%8A%80%E9%87%8D%E7%82%B9%E5%AE%9E%E9%AA%8C%E5%AE%A4/6851098/0/d68b65cb2ed1f856bf09e645?fr=lemma&ct=single#aid=0&pic=d68b65cb2ed-1f856bf09e645
No.12	Fig. 7	"State Key Laboratory of Radar Signal Processing, Xidian University," xidian.edu.cn, accessed August 2021, https://rsp.xidian.edu.cn/index.html

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