DEFENSE SCIENCE BOARD

Commercial Provision of Navigation Signals for Operational Use

Executive Summary

OCTOBER 2024

PNT
PHASE II

DEFENSE SCIENCE BOARD

OFFICE OF THE SECRETARY OF DEFENSE
3140 DEFENSE PENTAGON
WASHINGTON, DC 20301–3140

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

SUBJECT: Defense Science Board (DSB) Report on Commercial Provision of Navigation Signals for Operational Use

I am pleased to forward the final report of the DSB study on *Commercial Provision of Navigation Signals for Operational Use.* After the recent DSB study on *Position, Navigation, and Timing (PNT) Control*, a follow-on study was conducted to examine whether commercial services could be used to fill the needs it identified, either as a short-term gap filler or a continuous complement to the Global Positioning System (GPS).

This study focused on commercial PNT services that could be purchased by the DoD, including mature offerings and those that are still in relatively nascent stages of development. Through examination of public materials, briefings from commercial entities, and consultation with government stakeholders, the study found that disconnects remain between military needs and drivers of commercial success in terms of how heavily different attributes are prioritized (accuracy, jamming resistance, hardening, hostile use, etc.). Although these misalignments can potentially be resolved through further investment, there are risks to creating services wholly dependent on DoD as a customer. This should be approached carefully to ensure the advantages of purchasing commercial services are maintained.

The findings, observations, and recommendations were presented to the full DSB, and were approved after thorough discussion and deliberation. I fully endorse all the study's recommendations and urge their careful consideration and adoption.

Eric D. Evans

Dr. Eric D. Evans
Chair, Defense Science Board

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DEFENSE SCIENCE BOARD

OFFICE OF THE SECRETARY OF DEFENSE
3140 DEFENSE PENTAGON
WASHINGTON, DC 20301–3140

MEMORANDUM FOR THE CHAIR, DEFENSE SCIENCE BOARD

SUBJECT: Report of the Defense Science Board (DSB) Permanent Subcommittee on Strategic Options Study on Commercial Provision of Navigation Signals for Operational Use

The final briefing report (an annotated briefing) of the Permanent Subcommittee on Strategic Options Study on *Commercial Provision of Navigation Signals for Operational Use* was approved by the Defense Science Board (DSB). This follow-on study to the Board's previous work on position, navigation, and timing (PNT) control addressed commercial satellite navigation (SATNAV) services that could be purchased as-is or with minimal changes to meet DoD needs. As in the PNT Control study, recommendations were made to improve the long-term health and viability of the Global Positioning System (GPS) constellation via commercial space strategies.

To understand the current commercial PNT service space, the study created a taxonomy that describes systems as dedicated SATNAV (where companies launch and operate satellites for PNT purposes), SATCOM-derived SATNAV (in which PNT is extracted from extant communication services), or hosted SATNAV (where other systems or signals have been modified specifically to provide PNT). The study then compared these categorized current and near-future services against DoD needs to determine whether any were suitable in challenging environments. No perfect fits were identified due to technical tradeoffs that focus on commercial viability, although many companies expressed willingness to work with the Department going forward.

As this market is still evolving, the study recommends that the DoD adopt a consumer mindset where it evaluates and responds to commercial offerings rather than trying to drive the market. However, to ensure that DoD does not miss important opportunities, the study also recommends establishing a commercial PNT purchasing function to engage with the market and represent its interests. Integrating new SATNAV signals will never be painless given the Department's use of legacy equipment and other constraints, but steps can be taken now to prepare DoD for a future where many such signals are available and offer potential benefits for military operations.

J. D. Shields

Mr. James D. Shields
Study Co-chair

Daniel Hastings

Dr. Daniel E. Hastings
Study Co-chair

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Executive Summary

On January 12, 2024, the Under Secretary of Defense for Research and Engineering (USD(R&E)) tasked the Defense Science Board to follow its recent *Position, Navigation, and Timing (PNT) Control* study (hereafter referred to as the Phase 1 study) with a study on *Commercial Provision of Navigation Signals for Operational Use* (the Phase 2 study), examining the potential for commercial satellite navigation (SATNAV) services to meet DoD PNT needs. Key questions in the terms of reference (Appendix A) include whether SATNAV signals broadcasted from low Earth orbit (LEO) can meet DoD needs, what additional equipment will be necessary to receive and process them, what models of engagement with the commercial sector are likely to produce favorable results, and what threats to such services can be anticipated.

The Phase 2 study drew on participants from public and private sectors, federally funded research and development centers, and national labs, whose work was informed by a team of government advisors from relevant offices. Members spent six months receiving briefings from industry and government, supplemented by information already received during the Phase 1 study, which informed its findings and recommendations.

Classes of Commercial PNT Services

The Phase 2 study also drew from the recent DSB study on *Commercial Space System Access and Integrity* to establish its scope, which is compared against past efforts in the graphic below.

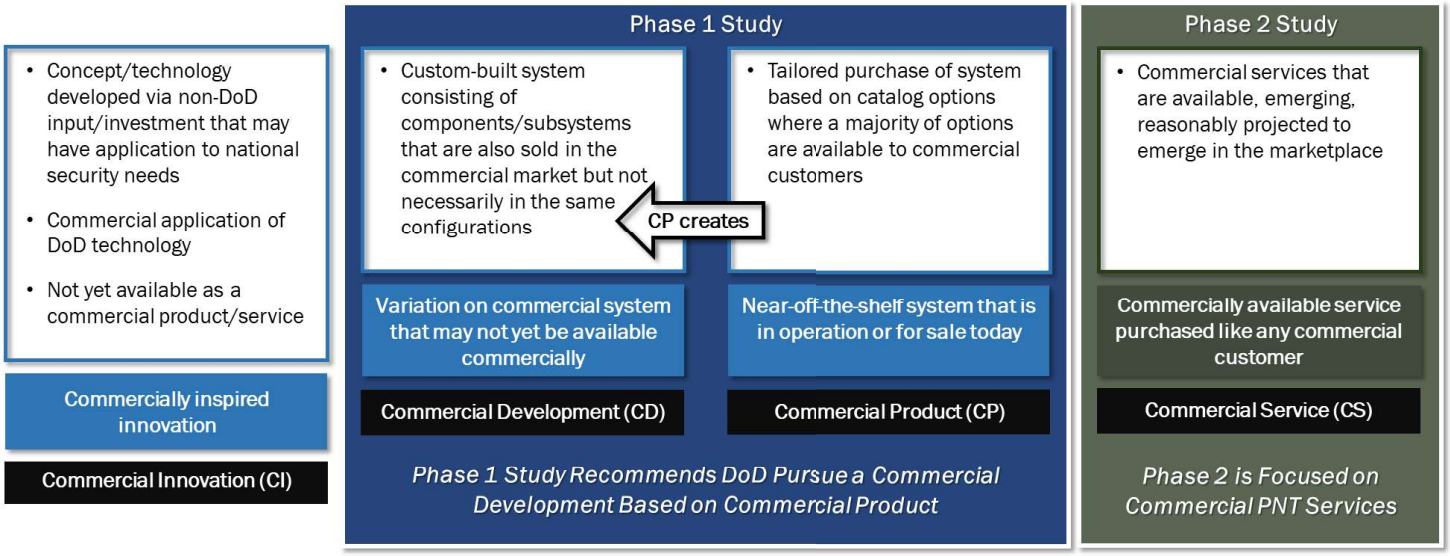

Figure 1: Commercial Space Provides Spectrum of Opportunities

Topics such as government funds being used to create alternative, military-only services from commercial entities (commercial product and commercial development) were covered in the Phase 1 study and played a significant role in its recommendations for updating the Global Positioning System (GPS). As such, the Phase 2 study focused on the commercial services end of the spectrum, where independent markets support PNT services that the government can engage with as a customer without being the driver of development or the sole user ensuring long-term viability.

In considering this topic, the study identified three categories of commercial PNT services:

1. **Dedicated SATNAV**. Systems developed and operated primarily to provide positioning and timing.

2. **SATCOM-derived SATNAV**. Communications systems that allow user devices to extract positioning and timing data from their unmodified signals.
3. **Hosted SATNAV**. Commercial services whose functions are different than SATNAV but also provide signals designed for PNT regardless of whether the hosting involves changes to satellites or ground segments, or whether these changes are hardware- or software-based.

The study did not focus on terrestrial PNT options due to the tasking in the terms of reference and issues that were examined during the Phase 1 study.

Misalignment of DoD Needs and Commercial Drivers

In considering types of commercial services, the Phase 2 study also examined alignment and misalignment of focus and capabilities between companies offering such services to commercial customers and DoD PNT requirements. Generally, commercial SATNAV aims to augment GPS by providing very high levels of positioning accuracy or by providing PNT in environments with challenging geometries and signal environments (either natural or artificial). These goals drive specific design decisions in terms of both satellites and receivers that may not be easy to shift.

In contrast, the Department seeks resilience in actively hostile environments, the ability to receive signals on both modern and legacy platforms without extensive integration efforts, and to avoid becoming financially or technically beholden to a service with uncertain longevity. As determined by the Phase 1 study, the spectrum diversity of multiple SATNAV systems offers some benefits but is not a panacea for jamming. There are additional considerations that are unlikely to be addressed by commercial services without DoD investment.

Although some of these areas can be aligned via either CD or CP as defined above, the study concluded that it is unlikely for a commercial service to naturally develop that meets all DoD needs while remaining commercially viable. As commercial SATNAV services appear in the marketplace, the DoD will need to evaluate their offerings to determine how many of its requirements can be met for specific platform/mission pairings.

Integration and User Equipment

Integration and user equipment will pose challenges no matter what commercial SATNAV services the DoD purchases. Many companies consider themselves to be in the "signals" business rather than in "chips" or "equipment," meaning at least one additional party will be necessary for any widespread effort to make existing systems (modern or legacy) able to navigate using new signals. Platforms with sufficient size, weight, and power margins may be able to use software-defined radios (SDRs) implemented within a Modular Open System Approach (MOSA) framework to alleviate some integration challenges, but even then, may require hardware adjustments where antennas and other analog equipment differ.

Recommendations

Relative to commercial PNT services, DoD must adopt a "consumer" attitude; namely, monitor the market and be agile as an adopter/adapter as needed. Moving too fast risks distorting the market before it has fully evolved, potentially cutting useful developments short.[1]

[1] This should not be taken to encompass commercial space strategies overall. DSB continues to strongly advocate for DoD to develop high-power RMP/M-code GPS IIIF-Lite satellites using new commercial approaches rather than wait for the commercial market to independently fill PNT needs.

To ensure DoD does not miss important opportunities because of its "consumer" attitude, a commercial PNT purchasing function should be established by the Under Secretary of Defense for Acquisition and Sustainment with the mission to develop budget and funding strategies for commercial PNT, define and articulate military PNT needs externally, advocate internally for architecture flexibility, and assess business models and viability risks of commercial services. This function should also select one or more SATCOM-derived PNT vendors to be a pathfinder for integration of alternate/complementary PNT onto a relevant DoD platform to better understand implementation challenges.

Finally, robust MOSA and/or SDR development efforts should be undertaken to enable adoption and integration of commercial PNT services when sufficiently mature.

Conclusion

Although there is great enthusiasm for the commercial space sector, not all missions are equally situated for a transition toward it. As global navigation satellite systems offer free and ubiquitous PNT, commercial SATNAV services will need to find niches to become profitable; these niches may not align well with the DoD's own specific needs. Purchasing decisions should not be taken lightly given the integration hurdles posed by adopting commercial SATNAV. The Department must carefully determine which companies it can rely upon over the long term, what qualities and dependencies each service entails, and which investments can produce additional capability without distorting commercial viability.

Appendix A. Terms of Reference

UNDER SECRETARY OF DEFENSE
3030 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

RESEARCH
AND ENGINEERING

12 JAN 2024

MEMORANDUM FOR CHAIR, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference –Defense Science Board Permanent Subcommittee on Strategic Options Study on Commercial Provision of Navigation Signals for Operational Use

Modern battlefields in Syria, Ukraine, and elsewhere have demonstrated that the Global Positioning System (GPS) is critical but that additional capabilities may be necessary to fulfill position, navigation, and timing (PNT) needs for the Department of Defense during future conflicts in challenging environments. The recent Defense Science Board (DSB) *Task Force on PNT Control* study found that GPS modernization has encountered a series of delays to completing necessary upgrades on its space, control, and user segments. The DSB also issued a series of recommendations, based on innovations in space launch and satellite design, that, if implemented, will accelerate operational capabilities.

Additionally, the recent DSB *Task Force on Commercial Space System Access and Integrity* study found that it is feasible for certain DoD missions to be conducted via commercial satellites. There continues to be much discussion of broadcasting PNT signals as secondary payloads from highly proliferated constellations in low- or medium-Earth orbit as well as dedicated commercial PNT signals-as-a-service initiatives that may have the potential to supplement GPS if technical and logistical challenges can be overcome.

The DSB, working through its *Permanent Subcommittee on Strategic Options* ("the Permanent Subcommittee"), is directed to conduct a study to consider the topic of commercial provision of navigation signals for operational use. The study should include the benefits of commercial constellations broadcasting PNT signals for DoD operational usage. The evaluation of these commercial alternatives must consider issues including security, technical viability, resilience, and industrial capacity. Through this process, the study should answer the following questions:

- Are PNT signals broadcast from low-Earth orbit feasible for military purposes in environments where jamming and spoofing are prevalent? What advantages and risks would such a constellation entail? What threats to these services can be anticipated and how might they be mitigated? Can military GPS user equipment effectively use these signals?

- What models of engagement with the commercial sector are likely to produce technical success and ensured availability at affordable costs? Will commercial PNT services develop without significant government funding? Consider both the military and civil uses of PNT that make GPS so invaluable.

- How can modern launch capacity be leveraged to deploy PNT capabilities as needed?

- What additional infrastructure is needed to broadcast, control, and receive signals from commercial PNT satellites in different orbits?

The Permanent Subcommittee findings, observations, and recommendations will be presented to the full DSB for its thorough, open discussion and deliberation at a properly noticed and public meeting, unless it must be closed in accordance with one or more of the exemptions found in subsection 552b(c) of title 5, United States Code (U.S.C.). The DSB will provide its findings and recommendations to USD(R&E) as the Sponsor of the DSB. The nominal start date of the study period for this terms of reference (ToR) will be within 30 days of when this ToR is signed. In no event will the duration of the study exceed 12 months from the start date of meetings to development of the final briefing/report.

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

Once material is provided to the DSB and the Permanent Subcommittee, it becomes a permanent part of the DSB's records. All data and information provided is subject to public inspection unless the originating Component office properly marks the data or information with the appropriate classification and Freedom of Information Act exemption categories before the data or information is released to the DSB and the Permanent Subcommittee. The DSB has physical storage capability and electronic storage and communications capability on both unclassified and classified networks to support receipt of material up to the TS/SCI level.

The DSB and the Permanent Subcommittee will operate in conformity with and pursuant to the DSB charter; chapter 10 of title 5, U.S.C.; subsection 552b(c) of title 5, U.S.C.; and other applicable federal statutes, regulations, and policy. Individual DSB and Permanent Subcommittee members and the Permanent Subcommittee as a whole do not have the authority to make decisions or provide recommendations on behalf of the DSB nor report directly to any Federal representative. The members of the Permanent Subcommittee and the DSB are subject to certain Federal ethics laws, including section 208 of title 18, U.S.C., governing conflicts of interest and the Standards of Ethical Conduct regulations in 5 Code of Federal Regulations, Part 2635.

Heidi Shyu

cc:
DoD Advisory Committee Management Officer

Appendix B. DSB Membership

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Mr. Michael Appelbaum

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Dr. Kimberly Budil

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Mr. Fred Dixon

Adm William Fallon, USN (ret.)

Ms. Laetitia de Cayeux

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Dr. Robert Grossman

Dr. Daniel Hastings

Dr. Ayanna Howard

Dr. Evelyn Hu

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Dr. John Manferdelli

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Dr. Reshma Shetty

Dr. Alfred Spector

Dr. Vincent Tang

Dr. Dorota Temple

Dr. Jan Tighe

Dr. Bradford Tousley

Dr. David Van Wie

Ms. Mandy Vaughn

Dr. Dinesh Verma

Dr. Steven Walker

Dr. Robert Wisnieff

Appendix C. Subcommittee Membership

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Mr. D. Marshall Brenizer	Mr. Tony Kourepenis
Dr. Willem de Vries	Mr. Edward Powers
Dr. Brent Grime	Dr. J. Scott Stadler
Dr. Paul Kaminski	Ms. Mandy Vaughn
Dr. Thomas Karr	

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Mr. Paul Manz, *JPEO AA*	Mr. Paul Manz, *JPEO AA*
Dr. Christopher Erickson, *SAF/SQ*	Dr. Sonya "Lethal" McMullen, *DoD CIO*
Mr. Ivan Franklin, *USA*	Mr. Brian Stutz, *JNWC*
Col Matthew Garvin, *USAF*	Mr. Michael Trzeciak, *USA*

DSB Secretariat	
Ms. Elizabeth Kowalski, Designated Federal Officer	Mr. Sean Hagerty, Alternate DFO

SAIC Study Support	
Mr. Paul Normolle	Mr. Mark Brophy

Appendix D. Briefings Received

Meeting 1 (21-22 March 2024)

TrustPoint Perspective
TrustPoint GPS

Constellation Backbone Technology
Aalyria

A2PNT in LEO
Program Executive Office for Command, Control, Communications, Computers, and Intelligence

Meeting 2 (10-11 April 2024)

Xona Perspective
Xona Space Systems

STL Service
Iridium Communications

Meeting 3 (1-2 May 2024)

Infrastructure and Standards Dependencies
National Geospatial-Intelligence Agency

Viasat Perspective
Viasat

Commercial PNT Roadmap
OUSD(R&E)

Starshield Perspective
SpaceX

Meeting 4 (28 May 2024)

Commercial PNT Business Models
BryceTech

Meeting 5 (27 June 2024)

Project Kuiper Perspective
Amazon

NAVSYS Perspective
NAVSYS Corporation

Parsons Perspective
Parsons Corporation

Threat Briefing
National Space Intelligence Center

Appendix E. Acronym List

CD	commercial development
CP	commercial product
CI	commercial innovation
CIO	Chief Information Officer
DoD	Department of Defense
DSB	Defense Science Board
GPS	Global Positioning System
JNWC	Joint Navigation Warfare Center
JPEO AA	Joint Program Executive Office Armaments & Ammunition
LEO	low Earth orbit
MOSA	Modular Open System Approach
PNT	position, navigation, and timing
SAF/SQ	Office of the Assistant Secretary of the Air Force for Space Acquisition and Integration
SATNAV	satellite navigation
SDR	software-defined radio
USA	United States Army
USAF	United States Air Force
USD(R&E)	Under Secretary of Defense for Research and Engineering
USG	United States Government


Defense Science Board
DSB
Department of Defense