HOMELAND AIR DEFENSE

FINAL BRIEFING REPORT

Executive Summary

DEFENSE SCIENCE BOARD

OFFICE OF THE UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

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: Final Report of the Defense Science Board (DSB) Task Force on Homeland Air Defense

I am pleased to forward the final briefing report of the DSB Task Force on Homeland Air Defense, co-chaired by Dr. Mark Maybury and Mr. Mark Russell. Defending the U.S. homeland from air and missile threats is a critical element of the DoD's increased focus on homeland defense. After a long period of neglect, the Department must renew its efforts to deter and defeat air and missile attacks against domestic critical and military infrastructure.

As this report makes clear, the air and missile threat to the homeland is real and growing. More capable defenses will deter aggression by reducing adversary confidence in attacks against the U.S. homeland and will increase resilience should deterrence fail—ensuring that attacks against critical targets will not disrupt the flow of forces and materiel abroad in defense of our allies and national security interests.

The recommendations included in this report provide actionable plans for quickly and affordably standing up improved air defenses for critical targets. The recommendations also provide a new framework—the Strategic Aerospace Guard Environment, or SAGE II—for creating adaptable, scalable, and affordable air defenses for the homeland that evolve as threats and technologies change.

I fully endorse the findings and recommendations detailed in this report and urge the Department to quickly implement both the rapid response component and the SAGE II framework developed by the task force. Doing so will have benefits beyond defending the U.S. homeland, though that in and of itself would be sufficient. It will also ensure that our forward-deployed forces can rely on receiving capabilities and reinforcements, enhancing deterrence, reassuring allies, and strengthening the U.S. position globally as it competes in the current dynamic security environment.

Eric D. Evans

Dr. Eric Evans
Chairman, DSB

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DEFENSE SCIENCE BOARD

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

MEMORANDUM TO THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Final Report of the Defense Science Board (DSB) Task Force on Homeland Air Defense

Attached is the final briefing report of the Defense Science Board Task Force on Homeland Air Defense. The task force was asked to consider the most effective science, technology, capability, systemic, and operational vectors to address advancing air and missile threats against the U.S. homeland and develop an architectural solution to meet the challenge.

After reviewing the threat landscape, current U.S. homeland air defense capabilities, and the state of relevant technologies (both matured and emerging), the task force concluded that it is essential and feasible to quickly and affordably provide vital protection for critical homeland targets. Furthermore, the task force determined that an adaptable, scalable, and affordable framework that is constantly evolving to meet future threats will be necessary for long-term success. The proposed homeland air defense framework—the Strategic Aerospace Guard Environment, or SAGE II—offers a path for organizing this whole-of-government effort and incorporating new capabilities in an affordable and interoperable way.

The task force report details via an actionable path forward how protecting the homeland from air and missile threats now and into the future is necessary, achievable, and affordable. The recommendations proposed herein do *not* include a massive reorganization, nor the procurement of expensive and stovepiped capabilities. Instead, they emphasize affordability, interoperability, and scalability as new capabilities feed into SAGE II.

We urge the Department to review the task force's proposals and to quickly implement them. This is a critical need that can be met now, addressing clear and present threats and laying the groundwork for adapting successfully to future ones. Our adversaries recognize the value of defending their airspaces. It is time for the United States to do the same.

Dr. Mark Maybury
Co-Chair

Mr. Mark Russell
Co-Chair

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DSB Final Report on Homeland Air Defense

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DSB Final Report on Homeland Air Defense
Executive Summary

Scope of Study

The Defense Science Board Task Force on Homeland Air Defense (HAD) was tasked with assessing the science, technology, capability, system, and operational vectors necessary to defend the U.S. homeland from air and missile threats in an increasingly aggressive security environment. Strategic competitors and adversaries are acquiring the capabilities to hold targets at risk, posing a threat to American lives, economic interests, and critical infrastructure. The *2022 National Defense Strategy* identifies defense of the homeland as the DoD's top priority, necessitating a reassessment of U.S. air defense capabilities to ensure the ability to deter, defeat, and recover from air and missile threats—all while remaining below the nuclear threshold.

Following its fact finding, this task force proposed both short- and long-term solutions to meet the homeland air defense challenge. The former are recommendations for using existing capabilities to protect critical targets. The latter is a framework for a future adaptable, scalable, and affordable HAD capability to guide R&D and acquisition plans. Adopting these recommendations will better position the DoD to deter against and, if necessary, defeat airborne threats to the U.S. homeland.

Status Quo

The current airborne threat environment encompasses a broad array of threats and targets, ranging from small, covertly launched drones, to cruise missiles launched from submarines or aircraft, to hypersonic missiles and glide vehicles. The complexity of this possibility space—as well as the sheer number of potential targets—has been exacerbated by the lack of clear and consistent HAD priorities from relevant agencies within the U.S. government. Additionally, domestic capabilities to detect, track, and target airborne threats in a congested environment have been underfunded to varying degrees for decades, necessitating a modernization effort.

Addressing Current Needs

To address some of the threats facing the homeland today, the task force suggests that affordable steps can be taken that leverage existing capabilities to provide coverage for selected sites. Large, complicated, multi-year acquisition programs for homeland air defense are not necessary in the short-term. Networking extant capabilities together will provide increased defense at comparatively high speeds and low cost, as well as a degree of flexibility that enables protection of key sites in response to developing threat scenarios.

Meeting Future Threats

Modern defenses will inevitably become obsolete against advanced threats no matter the skill and ingenuity with which they are combined. To ensure that the United States is prepared to develop its HAD capabilities accordingly, the task force devised the Strategic Aerospace Guard

Environment (SAGE II), a framework for future development inspired by the Cold War's Semi-Automatic Ground Environment (SAGE). Initially developed throughout the 1950s, SAGE leveraged the development of real-time computing and digital radar data transmission to synthesize radar coverage of over 12,000 miles of U.S. coastline.

SAGE II offers an adaptable, scalable, and affordable framework for homeland air defense that incorporates emerging technological innovations to ensure all-domain awareness, assured tracking, secure command and control, and affordable engagements. These technologies include (but are not limited to) artificial intelligence/machine learning (AI/ML), multi-statics, directed energy, proliferated LEO constellations, and multimodal seekers, as supported by advances in big data analytics and digital engineering. When incorporated together (i.e., a JADC2-style framework linking sensors and shooters), these capabilities enable detection, tracking, and interception of a broad range of threats at an advantageous exchange ratio.

SAGE II will also integrate left-of-launch information across a spectrum of sources to predict threats and inform possible responses for delaying, disrupting, or denying impending attacks. As decision timelines are tightened by integration of AI/ML and physically faster threats, awareness that extends beyond traditional radar range will become increasingly necessary to perform the HAD mission.

This proposed framework takes advantage of technologies that are already being developed throughout the DoD, the intelligence community, and other organs of the U.S. government, reducing R&D costs to affordable levels when compared to exquisite, tailor-made missile defense systems. The networked skeleton of the framework allows for incorporating new systems and capabilities as technology progresses, especially when they are developed with interconnectivity.

Conclusion

The current security environment necessitates a homeland air defense capability that is adaptable, scalable, and affordable to provide long-term defense against competitor and adversary threats. Updating current defenses in the interim period will minimize the window of opportunity that could potentially be exploited by adversaries with modern capabilities. Maximizing defensive potential will also involve the Department of State, the Department of Homeland Security, and other federal agencies and departments, as well as international allies and partners. The short-term HAD architecture and the long-term SAGE II framework proposed by this task force offer a realistic and actionable set of recommendations that should be implemented by the DoD to ensure that the nation is defended from air and missile threats now and into the future.

For the full classified version of this report, please contact the Defense Science Board office.

Appendix A: Task Force Terms of Reference

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

RESEARCH
AND ENGINEERING

OCT 3 0 2019

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference – Defense Science Board Task Force on Homeland Air Defense

Increasing adversarial capability and capacity challenge the United States to provide homeland air defense for our nation. Proliferation of enemy weapon systems with global reach dictate that the United States can no longer presume domestic sanctuary. Affordable defensive coverage across broad domestic areas of the continental United States is a challenge. New technologies and architectures to sense, track, and interdict threats promise new solutions to this problem.

The Defense Science Board Task Force on Homeland Air Defense will consider the most effective science, technology, capability, system, and operational vectors to maintain superiority beyond the next decade in the face of advancing threats from the surface, subsurface, air, space, and cyberspace. The goal of the Task Force is to develop recommendations regarding an architectural solution to this challenge for consideration by the Deputy Secretary of Defense and the Under Secretary of Defense for Research and Engineering. These considerations should include:

Objectives: What is the nature of homeland air defense now, in 2025, and in 2035? What priority offensive and defensive requirements are essential to ensure air defense from land, sea, air, space, and cyberspace threats across a range of scenarios?

Threat: What capability gaps must be addressed for air defense in 2025, 2030, and 2035 considering projected adversary full-spectrum threats to include capabilities (e.g., platforms and payloads); tactics, techniques, and procedures; vulnerabilities; and increasing speed, precision, and lethality?

Technology and Systems: How do we ensure comprehensive, affordable, scalable, and sustainable capabilities to counter a persistent peer adversary? What technologies provide advantage (e.g., railguns, directed energy, cruise missiles, hypersonics, autonomous vehicle swarms)? How can speed of innovation, acquisition, and fielding be achieved to sustain an air defense advantage over time? What is the most effective mix of offense and defense of systems and integrated capabilities? What effective and affordable capabilities are domestically deployable to respond to regional threats?

Strategy and Operations: How can air defense objectives be best accomplished? What innovative concepts of operation (e.g., autonomous swarms, human-machine teaming) will yield the greatest benefit? What is the most effective system strategy for evolving and ensuring resilience and superiority in an increasingly contested operational environment? What strategies best ensure superiority over the long term to deny adversaries access?

Deterrence: What are the most attractive cost–benefit options to persistently impose costs and deter adversaries?

This study will be sponsored by me as the Under Secretary of Defense for Research and Engineering, who is authorized to act upon the advice and recommendations of the Board. Dr. Mark Maybury and Mr. Mark Russell will serve as co-Chairmen of the study. Mr. David Moreau will serve as the Executive Secretary. Mr. Kevin Doxey will serve as the Defense Science Board Secretariat.

The task force members are granted access to those Department of Defense (DoD) officials and data necessary for the appropriate conduct of their study. The Under Secretary of Defense for Research and Engineering will serve as the DoD decision-maker for the matter under consideration and will coordinate decision-making as appropriate with other stakeholders identified by the study's findings and recommendations. The nominal start date of the study period will be within three months of signing this Terms of Reference, and the study period will be between 9-12 months. The final report will be completed within six months from the end of the study period. Extensions for unforeseen circumstances will be handled accordingly.

The study will operate in accordance with the provisions of Public Law 92-463, "Federal Advisory Committee Act," and DoD Instruction 5105.04, "DoD Federal Advisory Committee Management Program." It is not anticipated that this study will need to go into any "particular matters" within the meaning of title 18, United States Code, section 208, nor will it cause any members to be placed in the position of action as a procurement official.

Michael D. Griffin

Appendix B: Task Force Membership

Chairs

Dr. Mark Maybury
Stanley Black & Decker

Mr. Mark Russell
Raytheon Technologies

Members

Mr. Paul Bailey
Raytheon Technologies

Gen Michael Carns (USAF, Ret.)
Private Consultant

Dr. Eric Evans
MIT Lincoln Laboratory

Dr. Jack Fleischman
MIT Lincoln Laboratory

Dr. Ronald Kerber
Advanced Technology International

Dr. Paul Nielsen
Software Engineering Institute, Carnegie Mellon University

Dr. Eric Reinke
Northrop Grumman

Dr. David Van Wie
Johns Hopkins University Applied Physics Laboratory

Mr. Lee Venturino
First Principles

Dr. Marc Viera
MIT Lincoln Laboratory

Government Advisors

Mr. Jan Ithier
NORAD and USNORTHCOM

Col Eric Morgan, USAF
Missile Defense Agency

Dr. Richard Joseph
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Ms. Susan Spencer
Missile Defense Agency

Executive Secretary and Designated Federal Officer

Mr. David Moreau
Defense Science Board

Defense Science Board Secretariat

Mr. Kevin Doxey
DSB Executive Director

Study Support

Mr. Ari Kattan
SAIC

Mr. Paul Normolle
SAIC

Appendix C: Briefings Received

10-11 February 2020

MDA Briefing
Missile Defense Agency

N&NC Why Briefing
NORAD and USNORTHCOM

Cruise Missile Defense of the Homeland
RAND Corporation

30 March 2020

Former DASD for Nuclear and Missile Defense Policy Perspective
Lawrence Livermore National Laboratory

C3 and Escalation Discussion
Carnegie Endowment for International Peace

21st Century Missile Defense
Center for Strategic and International Studies

15 April 2020

The Role of Allies in Homeland Air Defense
Brookings Institution

MDA Cruise Missile Defense Briefing
Missile Defense Agency

DHS Perspective
U.S. Department of Homeland Security

4 May 2020

JIAMDO Perspective
Joint Integrated Air and Missile Defense Organization

AFC Perspective
Army Futures Command

15 June 2020

Hypersonics
RAND Corporation

Lessons from RAND Air Base Resiliency Study
RAND Corporation

24 September 2020

NASIC Threat Briefing: Cruise Missiles and Ballistic Missiles
National Air and Space Intelligence Center

DARPA Briefings: Glide Breaker, Blackjack, Mosaic Warfare, and Marconi
Defense Advanced Research Projects Agency

N&NC HAD, From Why to How
NORAD and USNORTHCOM

Appendix D: Acronyms and Abbreviated Terms

A2/AD	anti-access/area denial
ADS-B	Automatic Dependent Surveillance-Broadcast
AFC	Army Futures Command
AFRL	Air Force Research Laboratory
AI/ML	artificial intelligence/machine learning
AMRAAM	advanced medium-range air-to-air missile
AOI	area of interest
ARSR	Air Route Surveillance Radar
ASA(ALT)	Assistant Secretary of the Army (Acquisition, Logistics, and Technology)
ASAT	anti-satellite weapon
ATC	air traffic control
AWACS	airborne warning and control system
BLOS	beyond line of sight
BMD	ballistic missile defense
C2	command and control
C3	command, control, and communications
CAL	critical asset list
CBP	Customs and Border Control
CCTV	closed-circuit television
CMCC	Common Mission Control Center
CMD	cruise missile defense
CCMD	combatant command
COMINT	communications intelligence
CONOPS	concept of operations
CONUS	continental United States
DAL	defended asset list
DARPA	Defense Advanced Research Projects Agency

DASD	Deputy Assistant Secretary of Defense
dBsm	decibels per square meter
dBW	decibel watt
DevSecOps	development, security, and operations
DHS	Department of Homeland Security
DIA	Defense Intelligence Agency
DOS	Department of State
DOT	Department of Transportation
ECM	electronic countermeasures
ELINT	electronic intelligence
EO/IR	electro-optical/infrared
ERSA	Enhanced Regional Situational Awareness
FAA	Federal Aviation Administration
FFRDC	Federally Funded Research and Development Center
ft	Feet
GCHQ	Government Communications Headquarters
GCI	ground controlled intercept
HAD	Homeland Air Defense
HCM	hypersonic cruise missile
HCOC	International Code of Conduct against Ballistic Missile Proliferation
HGV	hypersonic glide vehicle
I&W	indications and warning
IADS	integrated air defense system
IAMD	integrated air and missile defense
IBCS	IAMD Battle Command System
IFF	Identification friend or foe
IMINT	imagery intelligence
IoT	internet of things
IRBM	intermediate-range ballistic missile

ISR	intelligence, surveillance, and reconnaissance
JADC2	Joint All-Domain Command and Control
JAIC	Joint Artificial Intelligence Center
JIAMDO	Joint Integrated Air and Missile Defense Organization
kft	kilofeet
km	kilometer
LaWS	Laser Weapon System
LEO	low-Earth orbit
LOS	line of sight
MDA	Missile Defense Agency
MFIX	Maneuver and Fires Integrated Experiment
MOTSU	Military Ocean Terminal Sunny Point
MRBM	medium-range ballistic missile
MTCR	Missile Technology Control Regime
N&NC	NORAD and USNORTHCOM
NASAMS	Norwegian Advanced Surface to Air Missile System
NASIC	National Air and Space Intelligence Center
NCR	National Capital Region
NLCC	National Leadership Command Capability
nmi	nautical mile
NORAD	North American Aerospace Defense Command
NTM	national technical means
OTHR	over-the-horizon radar
PAC-2	Patriot Advanced Capability 2
PAC-3	Patriot Advanced Capability 3
PLAAF	People's Liberation Army Air Force
PLAN	People's Liberation Army Navy
P-LEO	proliferated low-Earth orbit
PNT	positioning, navigation, and timing

PrSM	Precision Strike Missile
R&D	research and development
RCAF	Royal Canadian Air Force
RF	radio frequency
SAF/AQ	Assistant Secretary of the Air Force (Acquisition, Technology, and Logistics)
SAGE	Semi-Automatic Ground Environment
SAGE II	Strategic Aerospace Guard Environment
SAM	surface-to-air missile
SAR	synthetic aperture radar
SENSR	Spectrum Efficient National Surveillance Radar
SIGINT	signals intelligence
THOR	Tactical High Power Microwave Operational Responder
TTPs	tactics, techniques, and procedures
UAS	unmanned aerial system
UAV	unmanned aerial vehicle
UHF	ultra high frequency
UHF-DTV	ultra high frequency-digital television
USD(A&S)	Under Secretary of Defense for Acquisition and Sustainment
USD(P)	Under Secretary of Defense for Policy
USD(R&E)	Under Secretary of Defense for Research and Engineering
USINDOPACOM	United States Indo-Pacific Command
USNORTHCOM	United States Northern Command
VHF	very high frequency