U.S. GOVERNMENT ACCOUNTABILITY OFFICE

441 G St. N.W.
Washington, DC 20548

October 8, 2015

The Honorable John McCain
Chairman
The Honorable Jack Reed
Ranking Member
Committee on Armed Services
United States Senate

Space Situational Awareness: Status of Efforts and Planned Budgets

Space systems provide capabilities essential for a broad array of functions and objectives, including U.S. national security, commerce and economic growth, transportation safety, and homeland security. These systems are increasingly vulnerable to a variety of threats, both intentional and unintentional—ranging from adversary attacks such as antisatellite weapons, signal jamming, and cyber attacks, to environmental threats such as electromagnetic radiation from the Sun and collisions with other objects. The government relies primarily on the Department of Defense (DOD) and the Intelligence Community to provide Space Situational Awareness (SSA)—the current and predictive knowledge and characterization of space objects and the operational environment upon which space operations depend—to provide critical data for planning, operating, and protecting space assets and to inform government and military operations. According to DOD, as space has become more congested and contested, the SSA mission focus has expanded from awareness of the location and movement of space objects to also include assessments of their capabilities and intent to provide battlespace awareness for protecting U.S. and allies' people and assets. For example, in addition to allowing satellite operators to predict and avoid radio frequency interference and potential collisions with other space objects, SSA information could be used to determine the cause of space system failures—such as environmental effects, unintentional interference, or adversary attacks—better enabling decision makers to determine appropriate responses.

In a report accompanying a bill for the National Defense Authorization Act for Fiscal Year 2015, the Senate Armed Services Committee included a provision for GAO to estimate the cost of SSA efforts over the next five fiscal years.[1] This report formally transmits updated information we provided in a briefing to the committee on July 8, 2015, to meet our reporting requirement. We have updated the briefing to reflect current data on SSA workloads and to incorporate additional agency technical comments that we received since that time. See enclosure I: *Space Situational Awareness Efforts and Planned Budgets Information Presented to the Senate Armed Services Committee*. This report addresses the following: (1) What are the government's current and planned SSA-related research and development, procurement, and operations efforts? (2) What is the planned budget for these efforts for fiscal years 2015 through 2020?

[1]S. Rep. No. 113-176, at 235 (2014).

To determine the governments' current and planned SSA-related efforts, we obtained and reviewed relevant program documentation, such as program budget requests and status briefings, as well as policy and planning documents. We also obtained overviews of the efforts from, and discussed the status of the efforts that were expected to take place in the next 5 fiscal years, with DOD officials from the offices of the Under Secretary of Defense for Acquisition, Technology and Logistics; Under Secretary of Defense for Intelligence; Chief Information Officer; DOD Executive Agent for Space Staff; U.S. Strategic Command and its Joint Space Operations Center; Secretary of the Air Force for Acquisition; Air Force Space Command and its Space and Missile Systems Center; Operationally Responsive Space; Assistant Secretary of the Army for Acquisitions, Logistics, and Technology; Army Space and Missile Defense Command and its Reagan Test Site; Space and Naval Warfare Systems Center Pacific; Navy Military Sealift Command; Defense Intelligence Agency; Defense Advanced Research Projects Agency; and National Reconnaissance Office. We also met with officials from the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA). The full range of assets available to DOD for SSA include both classified and unclassified assets; however, this review covers only the unclassified efforts as they represent those primarily involved in SSA.

To identify the planned budget for the SSA efforts, we obtained and analyzed the operations and maintenance, research and development, and procurement budget requests for fiscal years 2015 through 2020 from the above offices and organizations. From these data, we compiled the budgets for the SSA core efforts to the extent practicable. We discussed the sources of the cost data with the offices and organizations listed above and determined that the data were sufficiently reliable for the purposes of this report.

We conducted this performance audit from December 2014 to October 2015 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

In summary, SSA data is obtained and processed using a variety of sensors and systems—satellites, ground-based radars, and optical telescopes. According to DOD, a potential of 375 sensors and systems are available to contribute to SSA across the commercial, civil, military, and intelligence communities. Currently, the primary sensors used are a core group of 8 dedicated and 18 multiple mission sensors (see enclosure II for a list of these sensors). While DOD provides most of these sensors and systems, other entities—such as NASA, NOAA, the intelligence community, and commercial companies—also provide data used for SSA. For much of the core group of sensors, DOD is leveraging assets by using sensors that perform other missions as their primary functions, such as sensors used for missile defense and missile warning. U.S. Strategic Command's Joint Space Operations Center (JSpOC) is responsible for analyzing the data provided by the sensors and processing it into useable SSA information. For example, in 2014 JSpOC provided 671,727 collision warnings to satellite operators to alert them of a potential need to move their satellites to avoid a collision with another space object.

To support and sustain its SSA efforts over the next 5 years and to meet the expanded mission focus of SSA, DOD plans to relocate sensor systems, develop and field several additional sensors and systems, conduct technology development, and upgrade some of its current sensors. For example:

- The Air Force's Space Fence program, which is developing one or more ground-based radars designed to track space objects that are smaller than those identified by current sensors, is currently scheduled to begin operations in 2019;
- The Air Force's JSpOC Mission System (JMS) program, which is developing and fielding a new space command and control system designed to maintain the catalog of space object information, is also developing new capabilities, such as providing real-time alerts of jamming and other hostile actions toward U.S. sensors;
- The Air Force Weather group's Next Generation Ionosonde (NEXION) program, which is developing a series of ground-based radars to provide data on the ionosphere for SSA and other space weather analyses, is currently installing radars and is expected to be complete in fiscal year 2022; and
- The Defense Advanced Research Projects Agency's Hallmark program is investigating technology to support real-time SSA and decision-making tools.

Based on data reported by the agencies, the government's planned budget for SSA core efforts—DOD, NASA, and NOAA operations of sensors, upgrades, and new developments—averages about $1.0 billion per year for fiscal years 2015 through 2020. Table 1 summarizes the budget for SSA core efforts over the next several years.

Table 1: Budget for Space Situational Awareness Core Efforts—Fiscal Years 2015 to 2020 (in millions of then-year dollars)

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Operations and Payroll	604.0	661.3	651.4	656.5	642.8	646.2
New Sensors and Systems	328.1	393.5	350.7	272.2	267.7	265.2
Upgrades to Sensors and Systems	64.5	113.3	71.7	66.5	64.2	65.3
Total[a]	**996.5**	**1,168.0**	**1,073.7**	**995.2**	**974.7**	**976.7**

Source: DOD, NASA, and NOAA data; GAO presentation. | GAO-16-6R

Note: [a]Values may not add to totals because of rounding.

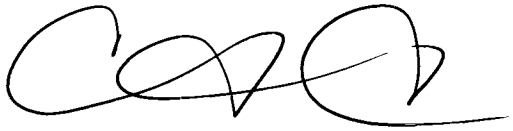
The budget for SSA operations and payroll averages about 63 percent of the core budget during fiscal years 2015 through 2020. In addition, the government is planning to invest about $1.8 billion in new sensors and systems over the next several fiscal years. For a more detailed breakdown of the planned budgets identified for the SSA core efforts, see enclosure III. Compiling a more complete SSA budget beyond the core efforts is challenging because the SSA mission involves assets from multiple agencies and organizations, and a comprehensive budget is not maintained. In addition, since SSA is not the primary mission for most of the sensors that perform this mission, their SSA efforts are not tracked because these sensors would continue to operate even if the SSA mission did not exist. For example, the Missile Defense Agency has not determined what percentage of its budget for operating its missile defense sensors, which averages about $538 million per year over the next several years, would be allocated to the SSA mission.

Agency Comments

We are not making recommendations in this report. We provided a draft of this report to DOD, NASA, and NOAA for comment. These agencies provided technical comments that were incorporated as appropriate in the final report.

We are sending copies of this report to the appropriate congressional committees; the Secretary of Defense, the Administrator of NASA, and the Director of NOAA. This report will also be available at no charge on our website at http://www.gao.gov.

Should you or your staff have questions concerning this report me at (202) 512-4841 or at chaplainc@gao.gov.Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report are Rich Horiuchi, Assistant Director; R. Eli DeVan; Jean Lee; and Alyssa Weir.



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Enclosures – 3

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Space Situational Awareness Efforts and Planned Budgets

Information Presented to the Senate Armed Services Committee

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Introduction

- As the space domain has become more congested, the potential for intentional and unintentional threats to space system assets has increased. To mitigate these threats, the Department of Defense (DOD) has undertaken a variety of initiatives to enhance its network of sensors and systems to provide space situational awareness (SSA)—the current and predictive knowledge and characterization of space objects and the operational environment upon which space operations depend.
- This briefing was in response to a report accompanying a bill for the National Defense Authorization Act for Fiscal Year 2015 that included a Senate Armed Services Committee provision for GAO to identify the government's current and planned SSA efforts and the corresponding budgets for fiscal years 2015 through 2020.[1]

[1]S. Rep. No. 113-176, at 235 (2014).

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Objectives

This briefing addresses the following questions:

1) What are the government's current and planned SSA-related research and development, procurement, and operations efforts?
2) What is the planned budget for these efforts for fiscal years 2015 through 2020?

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Summary

GAO found:

1) SSA data collection, data processing, and operations are performed primarily by DOD using a variety of sensors and systems, most of which serve multiple missions. DOD is also developing new sensors and replacing its SSA information system to enhance operational capabilities as the SSA mission focus expands from providing only awareness of space objects to providing "battlespace" awareness in support of military operations. The National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and other entities also provide data that supports the SSA mission.

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Summary *(continued)*

2) The budget for core SSA efforts averages about $1.0 billion per year for fiscal years 2015 through 2020. Compiling a budget for all SSA-related efforts is a challenge because many of the sensors that support the SSA mission do not have it as their primary mission, and DOD does not track their SSA-related efforts in a manner that would provide such data. Additionally, these sensors would continue to operate for their primary missions, even if they did not provide data for the SSA mission.

Background

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Background: Expansion of SSA Focus

- Prior focus—Space Awareness
  - awareness of space objects within or near the Earth's orbit and their movements; and spaceflight safety for U.S. assets and people.
- Current focus—Battlespace Awareness
  - awareness of space objects within or near the Earth's orbit and their movements, capabilities, and intent; spaceflight safety for U.S. and other countries' assets and people; and protection from potential threats to U.S. and allies' assets and people.

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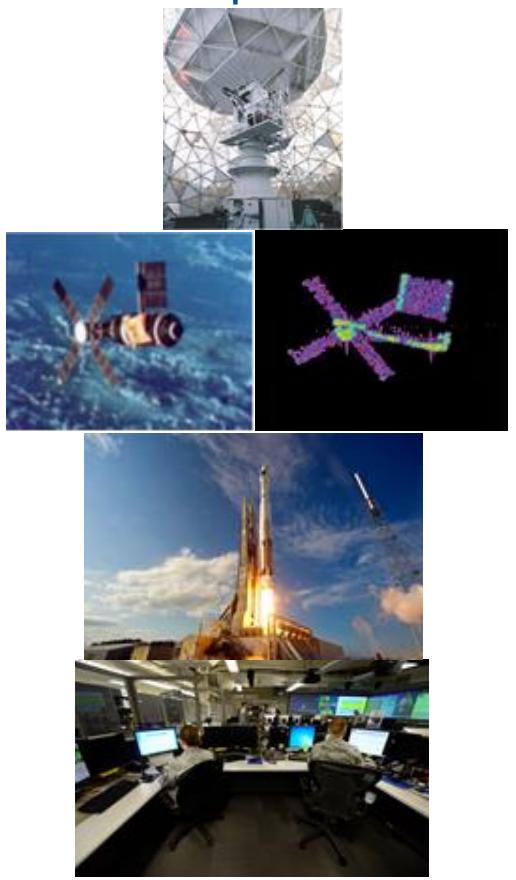
Background: Four Functions of SSA

1) **Detect, Track, and Identify:** Search, discover, and track space objects, and monitor events to distinguish between objects and their type and use;
2) **Characterize**: Determine strategy, tactics, intent, and activity—including characteristics, operating parameters and threats—of space objects;
3) **Threat Warning and Assessment**: Predict and differentiate between potential or actual attacks on or from space objects; predict space weather and space system anomalies and their potential impact; provide timely status of forces; and
4) **Data Integration and Exploitation:** Correlate and integrate multi-source data into a single common operating picture; provide decision-level SSA information to the combatant commands.

Figure 1: Space Situational Awareness Sensors and Operations Center



Source: Air Force, NASA, and Pat Corkey, United Launch Alliance (launch photo)

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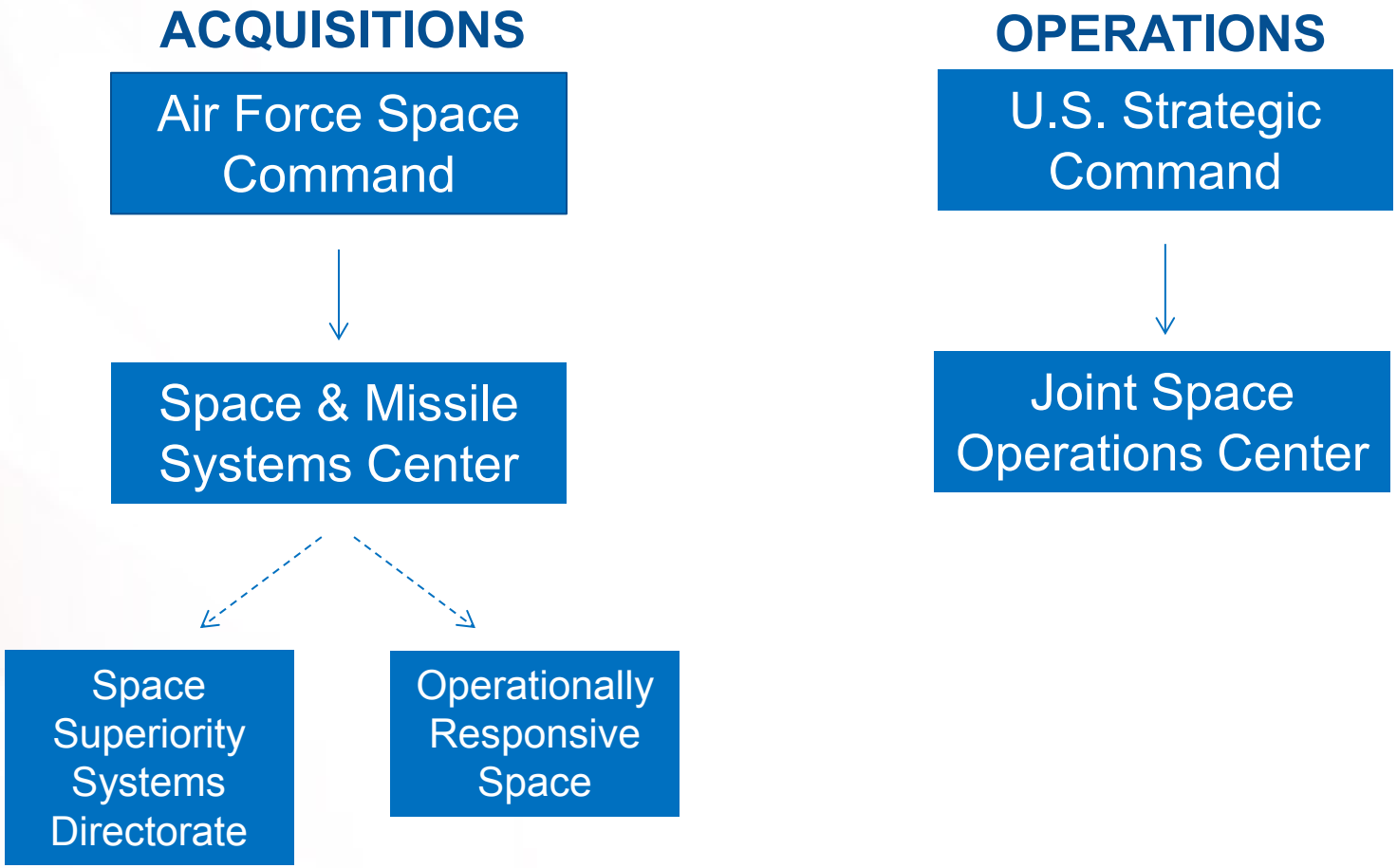
Background: Primary SSA Organizations

Figure 2: Primary Space Situational Awareness Organizations



Source: DOD data, GAO presentation.

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Background: Primary Stakeholders Involved in SSA

Figure 3: Primary Stakeholders Involved in Space Situational Awareness

DOD

Office of the Secretary of Defense
Under Secretary of Defense for Acquisition, Technology, and Logistics
Under Secretary of Defense for Intelligence
Under Secretary of Defense for Policy
Defense Advanced Research Projects Agency
Defense Special Missile and Astronautics Center
Director of Cost Assessment and Program Evaluation
Director of Operational Test and Evaluation
Joint Chiefs of Staff
Executive Agent for Space
Office of the Secretary of the Air Force
U.S. Strategic Command
Joint Functional Component Command for Space
Joint Forces Command
U.S. Pacific Command
U.S. European Command
U.S. Central Command
Office of the Chief of Naval Operations
14th Air Force
Air Force Materiel Command
Air Force Intelligence, Surveillance and Reconnaissance Agency
Air Force Research Laboratory
Air Force Space Command
Air Force Technical Applications Center
Missile Defense Agency
Army Space and Missile Defense Command
Space and Missile Systems Center
U.S. Marine Corps, Plans, Policies and Operations

Intelligence community

Office of the Director of National Intelligence
Central Intelligence Agency
National Air and Space Intelligence Center
Defense Intelligence Agency
National Geospatial-Intelligence Agency
National Reconnaissance Office
National Security Agency

Civilian community

Department of Commerce
Department of Energy
Department of State
Department of Transportation
Federal Aviation Administration
National Oceanic and Atmospheric Administration
National Aeronautics and Space Administration
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
Massachusetts Institute of Technology, Lincoln Laboratory
Sandia National Laboratories
Johns Hopkins University Applied Physics Laboratory

Commercial and foreign entities

Satellite operators
Satellite developers
Foreign government space agencies

Source: GAO analysis of DOD documentation. | GAO-16-6R.

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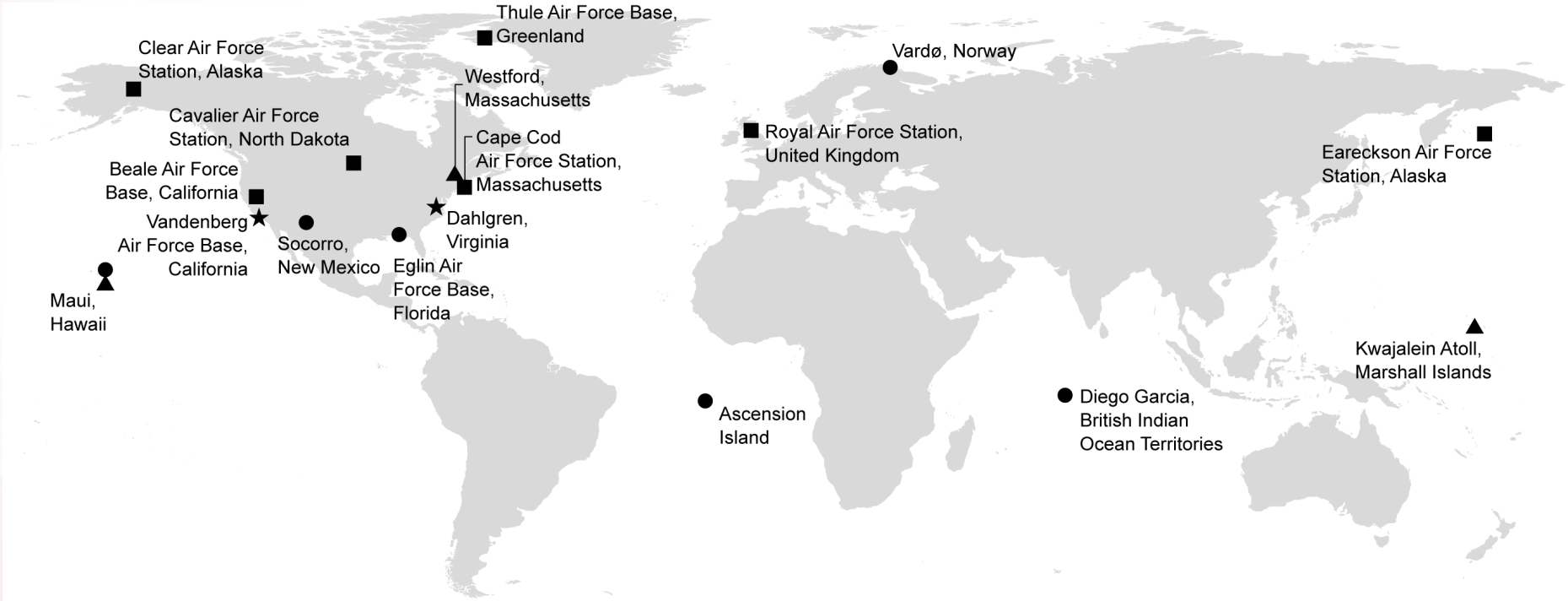
Background: SSA Sensors

- According to DOD, a potential of 375 sensors and systems are available for SSA across the commercial, civil, military, and intelligence communities.
- Sensors include satellites, optical telescopes, and radar systems.
  - Most sensors used for SSA serve multiple missions—including SSA, missile warning, and missile defense; and
  - Ground-based sensors are located around the world to provide a global picture.

Background: Locations of SSA Primary Ground Sensors and Operation Centers

Figure 4: Space Situational Awareness Primary Ground Sensors and Operations Centers



Source: GAO analysis of DOD data (data), Map Resources (map). | GAO-16-6R

Objective 1: Current SSA Efforts

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Objective 1: Current SSA Efforts

- Space observations are collected using a core group of 8 dedicated and 18 multiple-mission sensors, most of which are operated by DOD.
- SSA data currently provided by other agencies:
  - Missile Defense Agency—data on space objects observed by ballistic missile warning and defense sensors;
  - National Oceanic and Atmospheric Administration—data on near-Earth space weather and solar events; and
  - National Aeronautics and Space Administration—data on naturally-occurring objects that will come near the Earth and natural space debris, and data for space weather analyses.
- Multiple efforts are ongoing or planned to sustain and upgrade current sensors and develop new sensors and systems to enhance SSA capabilities in each of its four functional areas.

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Objective 1: Detection, Tracking, and Identification Efforts

- Two sensors are being moved to Australia to enhance view of objects in the southern hemisphere and deep space.
  - Space Surveillance Telescope (SST)—Ground-based optical telescope to provide data on small objects as far as the geosynchronous belt; move expected in fiscal year 2016 and expected operational in fiscal year 2019; and
  - C-Band Radar—Ground-based radar to detect and track objects in low Earth orbit; move completed December 2014 and expected operational in 2016.

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Objective 1: Detection, Tracking, and Identification Efforts *(continued)*

- Five new sensor systems are planned or in development to enhance SSA data collection:
  - **Operationally Responsive Space 5 (ORS-5)—**Satellite to provide data on space objects as far as the geosynchronous belt; critical design review planned for September 2015 and launch expected May 2017;
  - **Space Fence—**Ground-based radars to detect and track objects in low and medium Earth orbit; first radar expected to be operational in 2019;
  - **Space Based Space Surveillance (SBSS) Follow On**—Satellite system to provide data on space objects as far as the geosynchronous belt; request for proposals expected May 2016 and launch targeted for fiscal year 2021;
  - **Weather Systems Follow-on (WSF) Energetic Charged Particle (ECP) Sensor**—Satellite sensor to provide space weather data for SSA; WSF ECP prototypes delivery expected in fiscal year 2018; and
  - **Next Generation Ionosonde (NEXION)**—Ground-based radars to provide data on the particles that make up the ionosphere for SSA and other space weather analyses; installations underway and expected complete in fiscal year 2022.

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Objective 1: Characterization Efforts

- Joint Space Operations Center Mission System (JMS) is being developed to provide increased SSA catalog and other capabilities.
  - Increment 2 provides mission functionality with enhanced cataloging functions—expected to be fully operational by December 2016.[2]
- Number of space objects to be catalogued and characterized is expected to increase when new sensors come on line that are to identify and track smaller objects.
  - In 2014:
    - Reviewed 320,000 satellite observations per day; and
    - Maintained catalog with about 22,000 space objects.

[2]Increment 2 adds onto the system infrastructure and new data display tools of Increment 1, which was fully deployed in April 2013.

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Objective 1: Threat Warning and Assessment Efforts

- Analysis workloads increasing with added JMS capabilities and are expected to continue increasing as more objects are cataloged and tracked
  - In 2014:
    - 671,727 possible collision warning notifications to satellite owner/operators; and
    - 93 space launches (52 foreign and 41 domestic) planned, executed, and tracked.
- Air Force Weather Wing is updating its Space Weather Analysis and Forecasting System to enhance its capabilities.

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Objective 1: Data Integration and Exploitation Efforts

- Analysis workloads changing as SSA focus expands to provide battlespace awareness information.
  - JMS Increment 3 to add real-time alerts of jamming and other hostile actions—requests money starting in fiscal year 2016 and policy issues remain to be resolved to provide allied countries with access; and
  - Defense Advanced Research Projects Agency (DARPA) Hallmark program investigating technology to support more real-time SSA and decision-making tools.

Objective 2: SSA Planned Budget

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Objective 2: SSA Planned Budget —SSA Core Efforts

- The SSA budget identified for its core efforts—DOD, NASA, and NOAA operations of their sensors, upgrades, and new developments—averages about $1.0 billion per year during fiscal years 2015 through 2020.

Table 1: Space Situational Awareness Core Efforts—Fiscal Years 2015 through 2020 (in millions of then-year dollars)

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Operations and payroll for dedicated, collateral, and contributing sensors	604.0	661.3	651.4	656.5	642.8	646.2
Upgrades to sensors and systems	64.5	113.3	71.7	66.5	64.2	65.3
New sensors and systems	328.1	393.5	350.7	272.2	267.7	265.2
Total[a]	**996.5**	**1,168.0**	**1,073.7**	**995.2**	**974.7**	**976.7**

Note: [a]Values may not add to totals because of rounding.
Source: DOD, NASA, and NOAA data, GAO presentation.

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Objective 2: SSA Planned Budget —SSA Core Efforts *(continued)*

- Compiling a budget for all SSA-related efforts is a challenge because many assets that support the SSA mission do not have it as their primary mission.
  - DOD is not required to and does not track the budgets specific to its SSA efforts for multiple-mission systems, and it does not estimate what percentage would be allocated to SSA.
    - For example, some portion of the ballistic missile defense sensors budget, which averages about $538 million per fiscal year over the next few years, supports SSA, but DOD does not track the efforts of multi-mission sensors in a manner that would provide such data.
  - SSA-related efforts performed using intelligence community sensor systems are also not included in the core SSA budget because those efforts and their budgets are classified.

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Objective 2: SSA Planned Budget —SSA Operations

- Air Force Space Command's portion of the SSA mission operations over the next several fiscal years averages about $494 million per year.

Table 2: Air Force Space Command Space Situational Awareness Operations —Fiscal Years 2015 through 2020 (in millions of then-year dollars)

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Dedicated sensors operations and payroll	160.8	158.2	151.5	147.4	160.4	166.5
Collateral sensors operations and payroll[a]	277.6	294.4	293.3	302.3	272.9	277.5
Joint Space Operations Center operations and payroll	33.6	61.0	55.6	54.5	53.6	44.8
Total[b]	**472.1**	**513.5**	**500.3**	**504.2**	**487.0**	**488.9**

Notes: [a]Budget amounts for collateral sensors operations and payroll are incomplete as they include only the amounts currently provided by the Air Force under agreement with the operating organizations. The operational organizations' budget was not provided.
[b]Values may not add to totals because of rounding.
Source: DOD data, GAO presentation.

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Objective 2: SSA Planned Budget —SSA Operations *(continued)*

- Air Force Weather Wing SSA operations budget is $18 million for fiscal year 2015 and then holds steady at about $17 million through fiscal year 2020.

Table 3: Air Force Weather Wing Space Situational Awareness Operations —Fiscal Years 2015 through 2020 (in millions of then-year dollars)

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Payroll	7.1	7.1	7.1	7.1	7.1	7.1
Space Weather Analysis and Forecast System operations	4.2	2.2	2.4	2.7	2.9	3.2
Sensor operations	5.3	5.7	5.4	5.4	5.0	5.2
Data Sharing Program	1.5	1.6	1.6	1.6	1.6	1.7
Total[a]	**18.1**	**16.5**	**16.5**	**16.8**	**16.7**	**17.2**

Note: [a]Values may not add to totals because of rounding.
Source: DOD data, GAO presentation.

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Objective 2: SSA Planned Budget —SSA Operations *(continued)*

- Army Space and Missile System Defense Center SSA operations of its four contributing sensors is expected to increase from about $18 million in fiscal year 2015 to over $31 million in fiscal year 2020.

Table 4: Army Space Situational Awareness Operations—Fiscal Years 2015 through 2020 (in millions of then-year dollars)

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Sensors operations	18.2	20.9	25.3	26.6	30.3	31.3

Source: DOD data, GAO presentation.

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Objective 2: SSA Planned Budget —SSA Operations *(continued)*

- Missile Defense Agency (MDA) SSA mission operations are not tracked separately in its budgets.
  - The combined research, procurement, and operations budgets for the ballistic missile defense sensors average about $538 million per year from fiscal years 2015 through 2020.
  - MDA data from its missile defense sensors is provided for SSA; since SSA is not the primary mission, MDA is not required to and does not track a budget for its SSA efforts.
  - MDA has not determined what percentage of its missile defense budget would be allocated to the SSA mission.

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Objective 2: SSA Planned Budget —SSA Operations *(continued)*

- NASA's SSA mission operations are about $85 million in fiscal year 2015, are expected to increase to $97 million in fiscal year 2016, and remain steady at around $95 million through fiscal year 2020. NOAA's are about $11 million in fiscal year 2015, are expected to increase to almost $14 million in fiscal year 2016, and remain steady through fiscal year 2020.

Table 5: Non-DOD Entities' Space Situational Awareness Operations—Fiscal Years 2015 through 2020 (in millions of then-year dollars)

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
NASA	84.6	96.7	95.6	95.3	95.3	95.3
NOAA	11.0	13.6	13.6	13.6	13.6	13.6
Total	**95.6**	**110.3**	**109.2**	**108.9**	**108.9**	**108.9**

Source: NASA and NOAA data, GAO presentation.

Objective 2: SSA Planned Budget —Sensors and Systems Upgrades

- Air Force Space Command and the Air Force Weather Wing have several upgrades planned for their SSA sensors and mission systems that combined total over $445 million over fiscal years 2015 through 2020.

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Objective 2: SSA Planned Budget —Sensors and Systems Upgrades *(continued)*

Table 6: Upgrades to Space Situational Awareness Sensors and Systems —Fiscal Years 2015 through 2020 (in millions of then-year dollars)

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Upgrades to dedicated sensors[a]	11.4	20.1	8.6	0.0	0.0	0.0
Upgrades to collateral sensors[b]	34.6	68.5	42.3	41.5	39.1	39.8
Moves of dedicated sensors[c]	2.3	2.4	0.0	0.0	0.0	0.0
Joint Space Operations Center Mission System refreshers	0.0	0.0	0.0	11.9	12.3	12.6
Distributed Space Command and Control---Dahlgren (DSC2-D) mission system[d]	4.8	0.0	0.0	0.0	0.0	0.0
Space Weather Analysis and Forecast System	3.8	14.2	12.3	12.2	12.7	13.0
Upgrades to weather sensor networks[e]	0.0	3.1	1.5	0.8	0.0	0.0
Other SSA operation systems	7.7	4.9	7.0	0.0	0.0	0.0
Total[f]	**64.5**	**113.3**	**71.7**	**66.5**	**64.2**	**65.3**

Notes: [a]Dedicated sensors included are the Eglin sensor and Ground Based-Electro-Optical Deep Space Surveillance sensors (Diego Garcia, Maui, and Socorro).
[b]Collateral sensors included are the Ballistic Missile Early Warning System sensors (Clear, Flyingdales, and Thule), Cobra Dane, and the Submarine Launched Ballistic Missile sensors (Beale and Cape Cod). Upgrades to these collateral sensors also benefit the sensors' work for other missions.
[c]Sensors being moved are the Space Surveillance Telescope and the C-Band Radar.
[d]DSC2-D is the operations system for the secondary Joint Space Operations Center in Dalhgren, Virginia.
[e]Weather sensor networks included are the Solar Telescope Network and the Solar Optical Observing Network.
[f]Values may not add to totals because of rounding.
Source: DOD data, GAO presentation.

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Objective 2: SSA Planned Budget —New Sensors and Systems

- Air Force Space Command is planning to invest a total of about $1.8 billion during fiscal years 2015 through 2020 towards developing four new SSA sensors and systems and replacing the Joint Space Operations Center's mission system.

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Objective 2: SSA Planned Budget —New Sensors and Systems *(continued)*

Table 7: Air Force Space Command New Space Situational Awareness Sensors and Systems—Fiscal Years 2015 through 2020 (in millions of then-year dollars)

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Space Fence[a]	190.2	243.9	196.0	68.5	51.7	50.6
Weather Systems Follow-on Energetic Charged Particle sensor[b]	1.7	2.3	6.7	0.0	0.0	0.0
Space-Based Surveillance System Follow On[c]	0.0	31.5	50.6	130.2	151.3	154.0
Operationally Responsive Space 5[d]	21.0	6.1	3.8	0.0	0.0	0.0
Joint Space Operations Center Mission System—Increment 2	83.3	69.5	0.0	0.0	0.0	0.0
Joint Space Operations Center Mission System—Increment 3	0.0	12.4	65.4	54.4	55.3	56.1
Total[e]	**296.2**	**365.7**	**322.5**	**253.1**	**258.3**	**260.7**

Notes: [a]Space Fence program is developing ground-based radars to detect and track objects in low and medium Earth orbit.
[b]Weather Systems Follow-on effort is developing an Energetic Charged Particle sensor that is to provide space weather data.
[c]Space-Based Surveillance System Follow On program is developing a satellite system to provide data on space objects in the geosynchronous belt.
[d]Operationally Responsive Space 5 program is developing a satellite to provide data on space objects in the geosynchronous belt.
[e]Values may not add to totals because of rounding.
Source: DOD data, GAO presentation.

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Objective 2: SSA Planned Budget —New Sensors and Systems *(continued)*

- Air Force Weather Wing is planning on investing about $22 million during fiscal years 2015 through 2020 towards developing a new SSA sensor.

Table 8: Air Force Weather Wing New Space Situational Awareness Sensor—Fiscal Years 2015 through 2020 (in millions of then-year dollars)

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Next Generation Ionosonde[a]	3.0	3.1	3.1	4.2	4.4	4.5

Notes: [a]Next Generation Ionosonde program is developing ground-based radars to provide data on the particles that make up the ionosphere for space weather analyses.
Source: DOD data, GAO presentation.

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Objective 2: SSA Planned Budget —New Sensors and Systems *(continued)*

- Defense Advanced Research Projects Agency (DARPA) is planning on investing a total of almost $99 million during fiscal years 2015 through 2020 towards developing several new SSA sensors and systems.

Table 9: Defense Advanced Research Projects Agency New Space Situational Awareness Sensors and Systems—Fiscal Years 2015 through 2020

(in millions of then-year dollars)

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Space Surveillance Telescope[a]	9.0	9.0	0.0	0.0	0.0	0.0
Space Domain Awareness projects for mission systems	19.9	5.7	0.0	0.0	0.0	0.0
Hallmark program[b]	0.0	10.0	25.0	15.0	5.1	0.0
Total	**28.9**	**24.7**	**25.0**	**15.0**	**5.1**	**0.0**

Notes: [a]Space Surveillance Telescope provides data on space objects and debris. It is currently being moved to Australia.
[b]Hallmark program is investigating technology to support more real-time SSA and decision-making tools.
Source: DOD data, GAO presentation.

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Scope and Methodology

To identify the current and planned SSA research and development, procurement, and operations efforts underway across DOD:

- We obtained and reviewed relevant program documentation regarding current and planned SSA efforts.
- We interviewed DOD, Air Force, Army, and Navy acquisition and space program officials and other organizations' officials to obtain an overview of current SSA operations, the status of ongoing development efforts, and planned efforts expected to begin in the next five years.
- Our observations provide information on the unclassified efforts and budget for SSA efforts. We are continuing work to identify the classified efforts and will report on those efforts separately.

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Scope and Methodology *(continued)*

To identify the planned budget for these current and planned SSA efforts:

- We obtained budget data for the SSA efforts for fiscal years 2015 through 2020 from each of these organizations, where available, and compiled the data into a picture of the budget for the core SSA efforts. Data for efforts performed using intelligence sensor systems are not included because those efforts and their budgets are classified.
- We interviewed DOD, Air Force, Army, and Navy acquisition and space program officials and other organizations' officials to discuss the tracking of money and budgets for SSA efforts, including those that use sensors and systems that perform multiple missions.

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Scope and Methodology *(continued)*

We met with and obtained information from the following organizations:

- Office of the Secretary of Defense
  - Under Secretary of Defense for Acquisition, Technology and Logistics, Washington, District of Columbia
  - Under Secretary of Defense for Intelligence, Washington, District of Columbia
  - Chief Information Officer, Alexandria, Virginia
  - DOD Executive Agent for Space Staff, Washington, District of Columbia
- U.S. Strategic Command
  - U.S. Strategic Command, Omaha, Nebraska
  - Joint Space Operations Center, Vandenberg AFB, CA
- Air Force
  - Office of the Secretary of the Air Force, Acquisition, Washington, District of Columbia
  - Air Force Space Command, Colorado Springs, Colorado
  - Space and Missile Systems Center, Los Angeles, California
  - Operationally Responsive Space, Kirtland AFB, New Mexico

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Scope and Methodology *(continued)*

- Army
  - Office of the Assistant Secretary of the Army for Acquisitions, Logistics, and Technology, Washington, District of Columbia
  - Space and Missile Defense Command, Huntsville, Alabama
  - Reagan Test Site, Kwajalein Atoll, Marshall Islands
- Navy
  - Military Sealift Command Pacific, Point Loma, California
  - Space and Naval Warfare Systems Center Pacific, San Diego, California
- Other organizations
  - Defense Intelligence Agency, Anacostia, Maryland
  - Defense Advanced Research Projects Agency, Arlington, Virginia
  - National Aeronautics and Space Administration, Washington, District of Columbia
  - National Oceanic and Atmospheric Administration, Washington, District of Columbia
  - National Reconnaissance Office, Chantilly, Virginia

Sensor name and location	Sensor type and description
Dedicated support for space situational awareness	
Ascension; Ascension Island, south Atlantic Ocean	Mechanical radar; Provides near-Earth metric tracking and radar cross section (RCS) measurements
Eglin; Eglin Air Force Base, Florida	Phased Array Radar; Primary sensor for near-Earth metric tracking; also provides RCS measurements and limited deep-space metric tracking
Ground-based Electro-Optical Deep Space System (GEODSS); Diego Garcia, British Indian Ocean Territories; Maui, Hawaii; and Socorro, New Mexico	Electro-optical telescopes at each site; Primary sensor for deep-space metric tracking; also provides optical space object identification (SOI) data
Globus II; Vardo, Norway	Mechanical Radar; Provides near-Earth metric tracking and deep-space wideband images
Space Based Space Surveillance (SBSS); Space	Optical sensing satellite; Provides both metric observations and photometric SOI data
Advanced Technology Risk Reduction (ATRR); Space	(classified)
Collateral support for space situational awareness	
Ballistic Missile Early Warning System (BMEWS); Clear Air Force Station, Alaska; Thule Air Force Base, Greenland; and Royal Air Force Station, Flyingdales, United Kingdom	Phased Array Radar at each site – Primarily for Missile Warning; Provides near-Earth metric tracking and RCS measurements
Cavalier; Cavalier Air Force Station, North Dakota	Phased Array Radar – Primarily for tactical warning and attack assessment of sea-launched and intercontinental ballistic missiles; Provides near-Earth metric tracking and RCS measurements
Cobra Dane; Eareckson Air Force Station, Alaska	Phased Array Radar– Primarily for missile defense; Provides near-Earth metric tracking and RCS measurements
PAVE Phased Array Warning System (PAVE PAWS); Cape Cod Air Force Station, Massachusetts and Beale Air Force Base, California	Phased Array Radar – Provides missile warning and space surveillance data; Provides near-Earth metric tracking and RCS measurements
Contributing support for space situational awareness	
Lincoln Space Surveillance System (LSSC) Haystack, Haystack Auxiliary, Millstone; Westford, Massachusetts	Mechanical radar; Produces near-Earth and deep-space wideband images and RCS measurements
Maui Space Surveillance System (MSSS) – Advanced Electro Optical System (AEOS), Optical Supercomputing Site (AMOS), RAVEN; Maui, Hawaii	Electro-optical telescopes (5); Produces deep-space metric tracking and photometric SOI, and near-Earth optical images
Ronald Reagan Ballistic Missile Defense Test Site (RTS), ARPA Lincoln C-band Observables Radar (ALCOR); Kwajalein Atoll, Marshall Islands	Mechanical radar; Produces near-Earth wideband images and RCS measurements
RTS, ARPA Long-range Tracking And Instrumentation Radar (ALTAIR); Kwajalein Atoll, Marshall Islands	Mechanical radar; Earth and deep-space metric tracking and RCS measurements
RTS, Millimeter Wave (MMW); Kwajalein Atoll, Marshall Islands	Mechanical radar; Produces near-Earth wideband images and RCS measurements
RTS, Target Resolution and Discrimination Experiment (TRADEX); Kwajalein Atoll, Marshall Islands	Mechanical radar; Produces near-Earth and deep-space metric tracking and RCS measurements
SAPPHIRE (Canadian); Space	Space-based optical telescope

Source: DOD data, GAO presentation. | GAO-16-6R

Space Situational Awareness Planned Budgets (dollars in millions)	Fiscal Year 2015	2016	2017	2018	2019	2020
Operations and Payroll						
Air Force Space Command						
Dedicated sensors						
Sensor operations	148.7	145.8	138.8	134.4	147.2	153.0
Civilian pay	7.3	7.8	8.1	8.3	8.5	8.7
Military payroll and retirement health	4.8	4.6	4.6	4.7	4.7	4.8
Total dedicated sensors operations	***160.8***	***158.2***	***151.5***	***147.4***	***160.4***	***166.5***
Collateral sensors						
Sensor operations	254.4	272.1	270.9	279.3	249.6	253.8
Military payroll and retirement health	23.2	22.3	22.4	23.0	23.3	23.7
Total collateral sensors operations	***277.6***	***294.4***	***293.3***	***302.3***	***272.9***	***277.5***
Joint Space Operations Center (JSpOC)						
JSpOC Mission System (JMS) operations	6.2	27.2	38.4	37.1	33.3	24.2
Space operations	7.0	6.9	6.9	7.0	7.0	7.0
Payroll	18.5	8.4	0.7	2.8	5.5	5.6
Operations support	1.9	16.9	9.5	7.6	7.8	8.0
Other procurement	0.0	1.6	0.0	0.0	0.0	0.0
Total JSpOC operations	***33.6***	***61.0***	***55.6***	***54.5***	***53.6***	***44.8***
Total Air Force Space Command operations	**472.1**	**513.5**	**500.3**	**504.2**	**487.0**	**488.9**
Air Force Weather Wing						
Payroll	7.1	7.1	7.1	7.1	7.1	7.1
Space Weather Analysis and Forecast System operations	4.2	2.2	2.4	2.7	2.9	3.2
Weather sensors operations	5.3	5.7	5.4	5.4	5.0	5.2
Data Sharing Program	1.5	1.6	1.6	1.6	1.6	1.7
Total Air Force Weather Wing operations	**18.1**	**16.5**	**16.5**	**16.8**	**16.7**	**17.2**
Army—Reagan Test Site sensors operations	**18.2**	**20.9**	**25.3**	**26.6**	**30.3**	**31.3**
National Aeronautics and Space Administration (NASA) operations	**84.6**	**96.7**	**95.6**	**95.3**	**95.3**	**95.3**
National Oceanic and Atmospheric Administration (NOAA) operations	**11.0**	**13.6**	**13.6**	**13.6**	**13.6**	**13.6**
Total Operations and Payroll	**604.0**	**661.3**	**651.4**	**656.5**	**642.8**	**646.2**
Upgrades to Sensors and Systems						
Air Force Space Command						
Upgrade to dedicated sensors[a]	11.4	20.1	8.6	0.0	0.0	0.0
Upgrades to collateral sensors[b]	34.6	68.5	42.3	41.5	39.1	39.8
Upgrades to DSC2-D[c]	4.8	0.0	0.0	0.0	0.0	0.0
Other Space Situational Awareness systems upgrades	7.7	4.9	7.0	0.0	0.0	0.0
JMS future upgrades	0.0	0.0	0.0	11.9	12.3	12.6
Move of C-Band Radar	2.3	2.4	0.0	0.0	0.0	0.0
Total Air Force Space Command upgrades	**60.8**	**95.9**	**57.9**	**53.4**	**51.4**	**52.4**

Enclosure III: Space Situational Awareness Planned Budgets—Fiscal Years 2015 to 2020

Space Situational Awareness Planned Budgets (dollars in millions)	Fiscal Year 2015	2016	2017	2018	2019	2020
Air Force Weather						
Upgrades to Space Weather Analysis and Forecast System	3.8	14.2	12.3	12.2	12.7	13.0
Upgrades to sensors[d]	0.0	3.1	1.5	0.8	0.0	0.0
Total Air Force Weather upgrades	**3.8**	**17.3**	**13.8**	**13.0**	**12.7**	**13.0**
Total upgrades to sensors and systems	**64.5**	**113.3**	**71.7**	**66.5**	**64.2**	**65.3**
New Sensors and Systems						
Air Force Space Command						
Space Fence						
Research, Development, Test, and Evaluation	190.2	243.9	196.0	68.5	5.3	0.0
Procurement	0.0	0.0	0.0	0.0	46.3	50.6
Total Space Fence	***190.2***	***243.9***	***196.0***	***68.5***	***51.7***	***50.6***
Space Based Space Surveillance Follow On	0.0	31.5	50.6	130.2	151.3	154.0
Weather Systems Follow-on Energetic Charged Particle sensor	1.7	2.3	6.7	0.0	0.0	0.0
Operationally Responsive Space project #5	21.0	6.1	3.8	0.0	0.0	0.0
JSpOC Mission System Increment 2						
Research, Development, Test, and Evaluation	73.8	69.5	0.0	0.0	0.0	0.0
Reprogrammed Air Force funding	9.5	0.0	0.0	0.0	0.0	0.0
Total JSpOC Mission System Increment 2	***83.3***	***69.5***	***0.0***	***0.0***	***0.0***	***0.0***
JSpOC Mission System Increment 3	0.0	12.4	65.4	54.4	55.3	56.1
Total Air Force Space Command new sensors and systems	**296.2**	**365.7**	**322.5**	**253.1**	**258.3**	**260.7**
Air Force Weather new sensor networks[e]	**3.0**	**3.1**	**3.1**	**4.2**	**4.4**	**4.5**
Defense Advanced Research Projects Agency (DARPA)						
Space Surveillance Telescope	9.0	9.0	0.0	0.0	0.0	0.0
Space Domain Awareness projects	19.9	5.7	0.0	0.0	0.0	0.0
Hallmark program	0.0	10.0	25.0	15.0	5.1	0.0
Total DARPA new sensors and systems	**28.9**	**24.7**	**25.0**	**15.0**	**5.1**	**0.0**
Total new sensors and systems	**328.1**	**393.5**	**350.7**	**272.2**	**267.7**	**265.2**
Total Space Situational Awareness	**996.5**	**1,168.0**	**1,073.7**	**995.2**	**974.7**	**976.7**

Notes: [a]Dedicated sensors included are the Eglin sensor and Ground Based-Electro-Optical Deep Space Surveillance sensors (Diego Garcia, Maui, and Socorro).
[b]Collateral sensors included are the Ballistic Missile Early Warning System sensors (Clear, Flyingdales, and Thule), Cobra Dane, and the Submarine Launched Ballistic Missile sensors (Beale and Cape Cod).
[c]DSC2-D is the operations system for the secondary Joint Space Operations Center in Dalhgren, Virginia.
[d]Air Force Weather sensor networks included are the Solar Telescope Network and the Solar Optical Observing Network.
[e]Air Force Weather Next generation Ionosonde program is developing ground-based radars to provide data on the particles that make up the ionosphere for space weather analyses.

Source: DOD, NASA, and NOAA data, GAO presentation. | GAO-16-6R

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