U.S. GOVERNMENT ACCOUNTABILITY OFFICE

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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 [Note 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

Enclosure I: Briefing Slides titled "Space Situational Awareness Efforts and Planned Budgets".

[Refer to the additional PDF in this PDF portfolio.]

Enclosure II: Space Situational Awareness Sensors

	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; Vardø, 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	Mechanical radar; Produces near-Earth

	Defense Test Site (RTS), ARPA Lincoln C-band Observables Radar (ALCOR); Kwajalein Atoll, Marshall Islands	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

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

Space Situational Awareness Planned Budgets (Dollars in millions)

Operations and Payroll:

		FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
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**
Air Force Space Command: 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**
Air Force Space Command: 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**

		FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
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**

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Total Air Force Space Command operations	472.1	513.5	500.3	504.2	487.0	488.9
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:

		FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Air Force Space Command	**Upgrade to dedicated sensors [Note A]**	11.4	20.1	8.6	0.0	0.0	0.0
	Upgrade to collateral sensors [Note B]	34.6	68.5	42.3	41.5	39.1	39.8
	Upgrades to DSC2-D [Note 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**
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 [Note 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**

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Total Air Force Space Command upgrades	60.8	95.9	57.9	53.4	51.4	52.4
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:

		FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
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**
Air Force Space Command: Space Based Space Surveillance Follow On		**0.0**	**31.5**	**50.6**	**130.2**	**151.3**	**154.0**
Air Force Space Command: Weather Systems Follow-on Energetic Charged Particle sensor		**1.7**	**2.3**	**6.7**	**0.0**	**0.0**	**0.0**
Air Force Space Command: Operationally Responsive Space project #5		**21.0**	**6.1**	**3.8**	**0.0**	**0.0**	**0.0**
Air Force Space Command: 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**

		FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
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**

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Total Air Force Space Command new sensors and Systems	296.2	365.7	322.5	253.1	258.3	260.7
Total DARPA new sensors and systems	28.9	24.7	25.0	15.0	5.1	0.0
Air Force Weather new sensor networks [Note E]	3.0	3.1	3.1	4.2	4.4	4.5
Total New Sensors and Systems	**328.1**	**393.5**	**350.7**	**272.2**	**267.7**	**265.2**

Total Space Situational Awareness:

	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Total Operations and Payroll	604.0	661.3	651.4	656.5	642.8	646.2
Total Upgrades to Sensors and Systems	64.5	113.3	71.7	66.5	64.2	65.3
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**

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

Note A: Dedicated sensors included are the Eglin sensor and Ground Based-Electro-Optical Deep Space Surveillance sensors (Diego Garcia, Maui, and Socorro).

Note 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).

Note C: DSC2-D is the operations system for the secondary Joint Space Operations Center in Dalhgren, Virginia.

Note D: Air Force Weather sensor networks included are the Solar Telescope Network and the Solar Optical Observing Network.

Note 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.

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