AN/FSY-3 SPACE FENCE SYSTEM – SENSOR SITE ONE / OPERATIONS CENTER INTEGRATION STATUS AND SENSOR SITE TWO PLANNED CAPABILITY [1]

Gregory P. Fonder
Lockheed Martin, Rotary and Mission Systems, Moorestown, NJ
Peter J. Hack
Lockheed Martin, Rotary and Mission Systems, Moorestown, NJ
Matthew R. Hughes
Lockheed Martin, Rotary and Mission Systems, Moorestown, NJ

1. ABSTRACT

This paper covers two topics related to Space Fence System development: Sensor Site One / Operations Center construction and integration status including risk reduction integration and test efforts at the Moorestown, NJ Integrated Test Bed (ITB); and the planned capability of Sensor Site Two.

The AN/FSY-3 Space Fence System is a ground-based system of S-band radars integrated with an Operations Center designed to greatly enhance the Air Force Space Surveillance network. The radar architecture is based on Digital Beam-forming. This capability permits tremendous user-defined flexibility to customize volume surveillance and track sectors instantaneously without impacting routine surveillance functions. Space Fence provides unprecedented sensitivity, coverage and tracking accuracy, and contributes to key mission threads with the ability to detect, track and catalog small objects in LEO, MEO and GEO. The system is net-centric and will seamlessly integrate into the existing Space Surveillance Network, providing services to external users—such as JSpOC—and coordinating handoffs to other SSN sites.

Sensor Site One construction on the Kwajalein Atoll is in progress and nearing completion. The Operations Center in Huntsville, Alabama has been configured and will be integrated with Sensor Site One in the coming months. System hardware, firmware, and software is undergoing integration testing at the Mooretown, NJ ITB and will be deployed at Sensor Site One and the Operations Center. The preliminary design for Sensor Site Two is complete and will provide critical coverage, timeliness, and operational flexibility to the overall system.

2. INTRODUCTION *(Derived from [1])*

The U.S. Air Force (USAF) is developing the AN/FSY-3 Space Fence System (SFS) as part of its Space Surveillance Network (SSN) to provide unprecedented space object detection sensitivity, coverage and tracking accuracy. The Space Fence Program was initiated by the USAF in 2005 to develop a system of geographically dispersed S-Band phased array radars which provide 24/7 un-cued capability to find, fix, and track small objects in Low Earth Orbit (LEO). After several trade studies, the concept was expanded to increase flexible sensor coverage across the LEO, Medium Earth Orbit (MEO), Geosynchronous Earth Orbit (GEO) regimes while simultaneously supporting cued search requests. The system replaces the now decommissioned very-high frequency (VHF) USAF Space Surveillance System (AFSSS). In June 2014, the Lockheed Martin industry team was awarded the contract for the Engineering, Manufacturing, Development, Production and Deployment (EMDPD) of the SFS. Two Space Fence sensor sites are planned; sensor site #1 in the Kwajalein Atoll and sensor site #2 in Western Australia as shown in Fig. 1. A Space Fence Operations Control Center (SOC) is co-located with the Reagan Test Site (RTS) Operations Center in Huntsville, AL (ROC-H). The current Program of Record (PoR) is 85% complete with first track on-island expected by the end of 2017.

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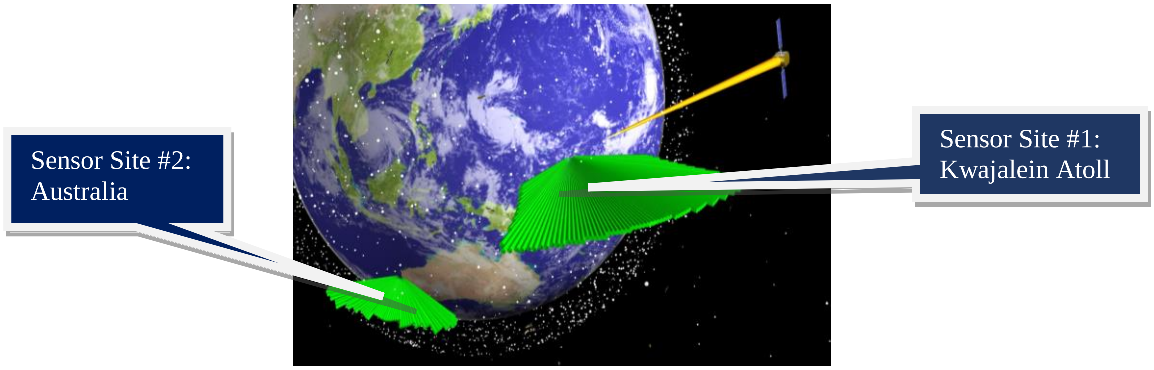

Fig. 1. Space Fence System Sensor Sites

Lockheed Martin's Space Fence System solution is a result of extensive cost-schedule-performance studies conducted during multiple concept and design phases. The design was shaped by the need for flexible sensor coverage and affordability through use of digital array technology that employs element-level Digital Beam Forming (DBF) and is capable of many independent beams to support simultaneous functions. The design leverages Gallium Nitride (GaN) high power amplifier technology for use in the transmit array to provide high power long pulses needed for space operations and high efficiency for low operating costs. The radar is matched with a commercial off-the-shelf (COTS)-based, net-centric enabled Mission Processing Suite. Mission Processing forms observations from radar measurements, monitors space events and provides internally and externally available data services.

The Space Fence design includes two minimally-manned radar sites with complementary coverage and the Space Fence Operations Center (see Fig. 2). Each radar site features closely-spaced, but separate, transmit and receive arrays that are mission-optimized for high availability and low lifetime support costs, including prime power. Coverage is optimized to provide assured coverage at Initial Operational Capability (IOC) down to 800 km altitude with the Kwajalein Atoll site and improved lower altitude assured coverage to 550 km at Full Operational Capability (FOC) with the addition of the Australian site. Both sites provide cued tasking support to all altitudes including GEO. The SFS is net-centric (interconnected by the Global Information Grid (GIG), more recently referred to as the Department of Defense Information Network (DoDIN)) and will seamlessly integrate into the existing SSN, providing services to external users—such as the Joint Space Operations Center (JSpOC)—and coordinating handoffs to other net-centric SSN sites.

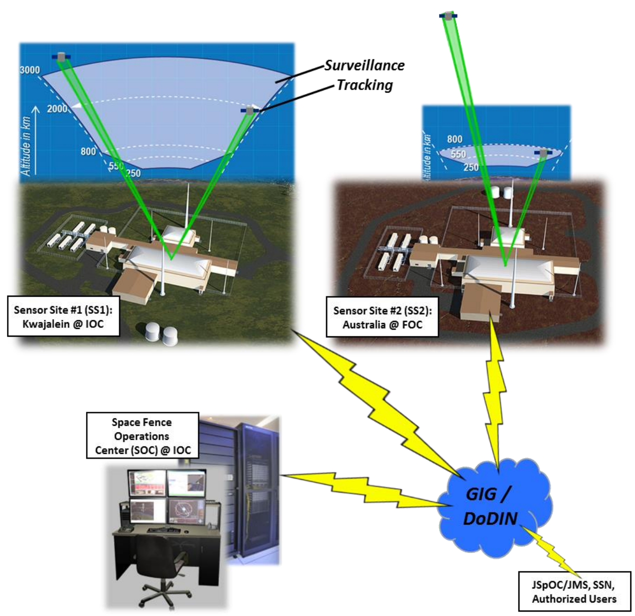

Fig. 2. Space Fence System Architecture and Coverage

The layout of a sensor site is depicted in Fig. 3. The system architecture permits tremendous user-defined flexibility to customize volume surveillance and track sectors instantaneously without impacting routine surveillance functions. Arrays are built with scalable building block sections and Line Replaceable Units (LRUs). Array electronics can be serviced from beneath while arrays are operating, permitting high system availability as shown in Fig 4. Liquid cooling enables high performance and reliability. Radar control, signal and data processing, and Mission Processing are hosted on COTS processing systems within the operations building. A portion of this processing is dedicated to automating many of the SFS functions, such as space object observation generation and system status monitoring.

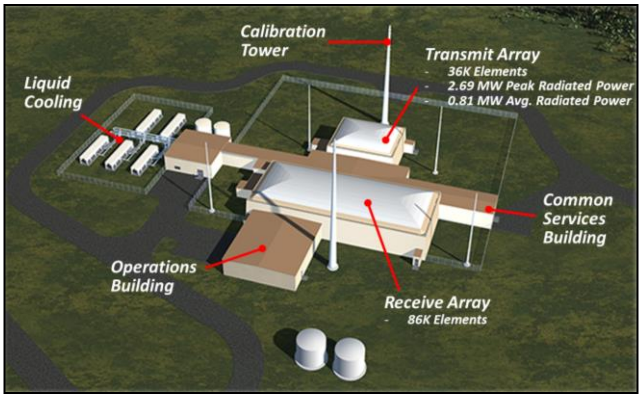

Fig. 3. Space Fence Sensor Site Overview

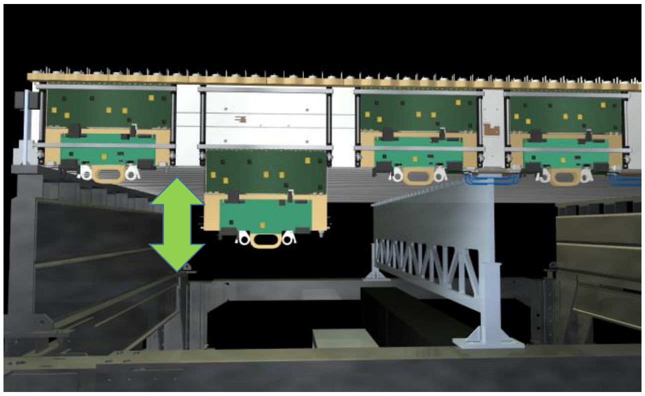

Fig. 4. Array Electronics Serviceable From Beneath Array While Operating for High Availability

Use of element-level DBF permits Space Fence to maintain persistent surveillance while tracking hundreds of simultaneous objects detected in the fence. The system automatically manages resources by performing long-arc tracks on Un-Correlated Targets (UCT) to support accurate initial orbit determination (IOD) (See Fig. 5).

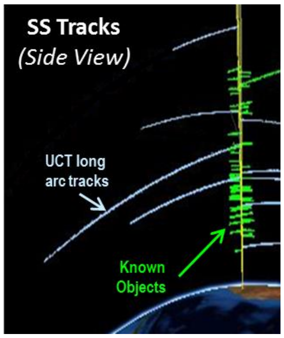

Fig. 5. Element-Level DBF Enables Long Arc Tracking Simultaneously With Un-cued Surveillance

For high-interest objects, a "mini-fence" can be electronically constructed to gather more track data, focusing radar resources specifically on that object, providing more timely and accurate information. Scheduling of the mini-fences is automated and based on orbital algorithms and system parameters. System resource control automatically adjusts the number of beams and range extents to cover the required volume of the mini-fences. Use of element-level DBF allows Space Fence to support cued tasks without interrupting un-cued surveillance.

The SFS, and in particular Mission Processing, provides efficient sensor control, automated data processing and operator friendly interfaces that enable the operator to focus on the mission instead of the volume of data typically available from a large sensor system.

To ensure risk to on-island integration is mitigated, Lockheed Martin utilizes its Integration Test Bed (ITB), a scaled prototype based in Moorestown, NJ that contains the radar and mission production hardware, software, and firmware. The ITB has been operational and tracking objects since January 2016. In fact, the system's performance has been verified and validated against In-Plant Contractor Test (CT) at the ITB during system-level requirements testing with the USAF. Moreover, this paper will also include the benefits of a future Sensor Site 2, which include further accuracy, timeliness, custody, and resiliency. The second sensor site FOC is achievable as early as 2021.

3. PROGRAM STATUS

The Space Fence Program has made significant progress over the three years since Contract Award completing 85% of the Program to-date. Radar prime mission equipment (PME) installation began at Sensor Site 1 in April 2017. The equipment included power cabinets, radar column assemblies, and radiator tiles, among others. First track of an orbiting object is expected by the end of 2017. The system will then track (un-cued) objects to the size of a softball (~9.7cm diameter) with full fence and marble-sized (~1cm diameter) with mini fences. The Space Fence Operations Center (SOC) hardware installation in Huntsville, AL has been completed as well. Space Fence Program is on-track to an early 2019 Initial Operational Capability (IOC).

4. SENSOR SITE 1 AND SOC PROGRESS

The construction on-island has been occurring since the initial breaking of ground in October 2015. The foundations and ring walls have been poured and the majority of concrete work is complete. The electronically transparent radomes for the Transmit and Receive buildings have been installed, which facilitates the inside of the buildings to be environmentally controlled (see Fig. 6). The remaining work includes outfitting the miscellaneous mechanical, electrical, and plumbing (MEP) work at the Sensor Site and Power Plant Annex.

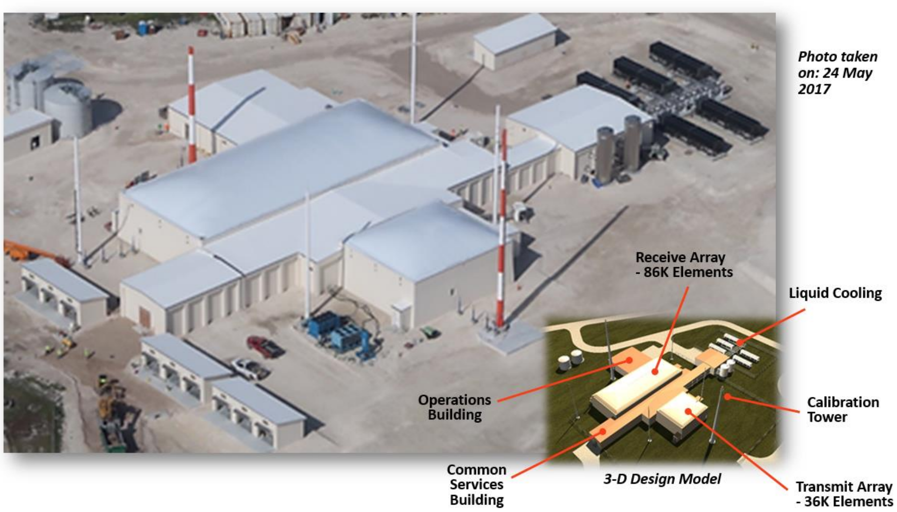

Fig. 6. Sensor Site 1 as of May 24, 2017 Compared to Initial Artist Rendering

The SOC, located at the ROC-H, completed the hardware installation and culminated in a ribbon cutting in October 2016 (see Fig. 7). Initial system checkout including hardware and software testing were performed as well. The SOC integrates data and status from Sensor Site 1 and future Sensor Sites. It also enables remote operation of Space Fence sensor sites. The SOC is equipped with multiple workstations, racks of servers, and a conference room (see Fig. 8).

Fig. 7. SOC Ribbon Cutting Event in Huntsville

Photo: USASMDC/ARSTRAT Public Affairs

Fig. 8. SOC Conference Room and Workstation

5. INTEGRATION TEST BED (ITB): RADAR FACILITY OVERVIEW

The ITB, which is located in Moorestown, NJ, is a scaled-down end-to-end system with end-item cabinets, electronics, and antenna support structure (see Fig. 9). Its used to mitigate risk to on-island integration and test through form/fit checks as well as hardware, software, and firmware integration and test. The ITB is used for requirements verification and performance testing at all specification levels. It also serves as a platform to facilitate operator training, maintainability demonstrations, and remote resolution support of sensor site integration issues. Lastly, it allows the team to perform extended operational test on live targets of opportunity.

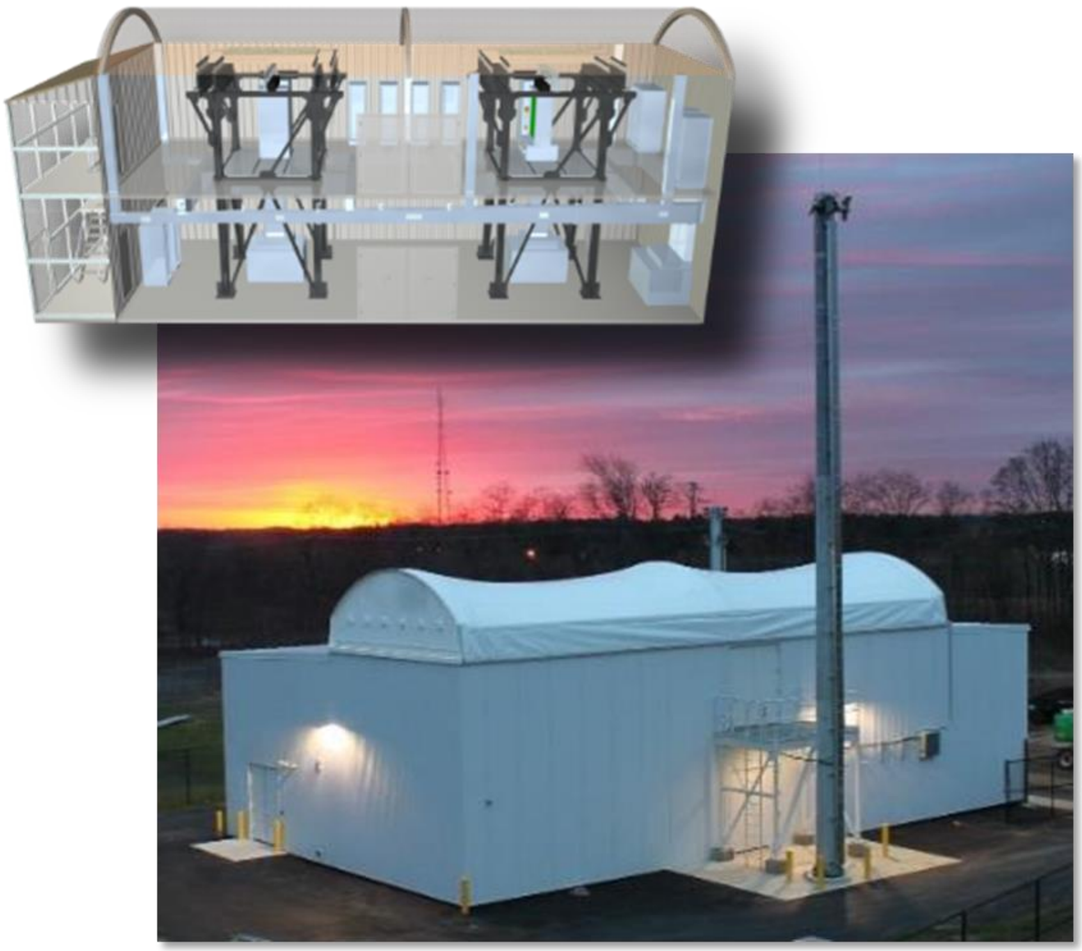

Fig. 9. Integration Test Bed in Moorestown, NJ – Operational Since January 2016

Further, the ITB enables the team to verify key system tenets such as scalability, calibration, digital beamforming, accuracy, and simultaneity (see Fig. 10). The team demonstrates the scalability of the overall system by being able to track resident space objects (RSOs) at various array sizes. The team can demonstrate element-level calibration techniques to expected thresholds. The ITB has a test tower that is used to verify DBF by measuring beam patterns. In doing so, Lockheed Martin can prove that angle accuracy using DBF outperforms traditional monopulse methods. There are thousands of simultaneous beams collected for concurrent large volume surveillance plus track on hundreds of objects. Through its multi-mission performance, the ITB has tracked well over 1,000 different RSOs utilizing its surveillance, cued search, and track operations concurrently.

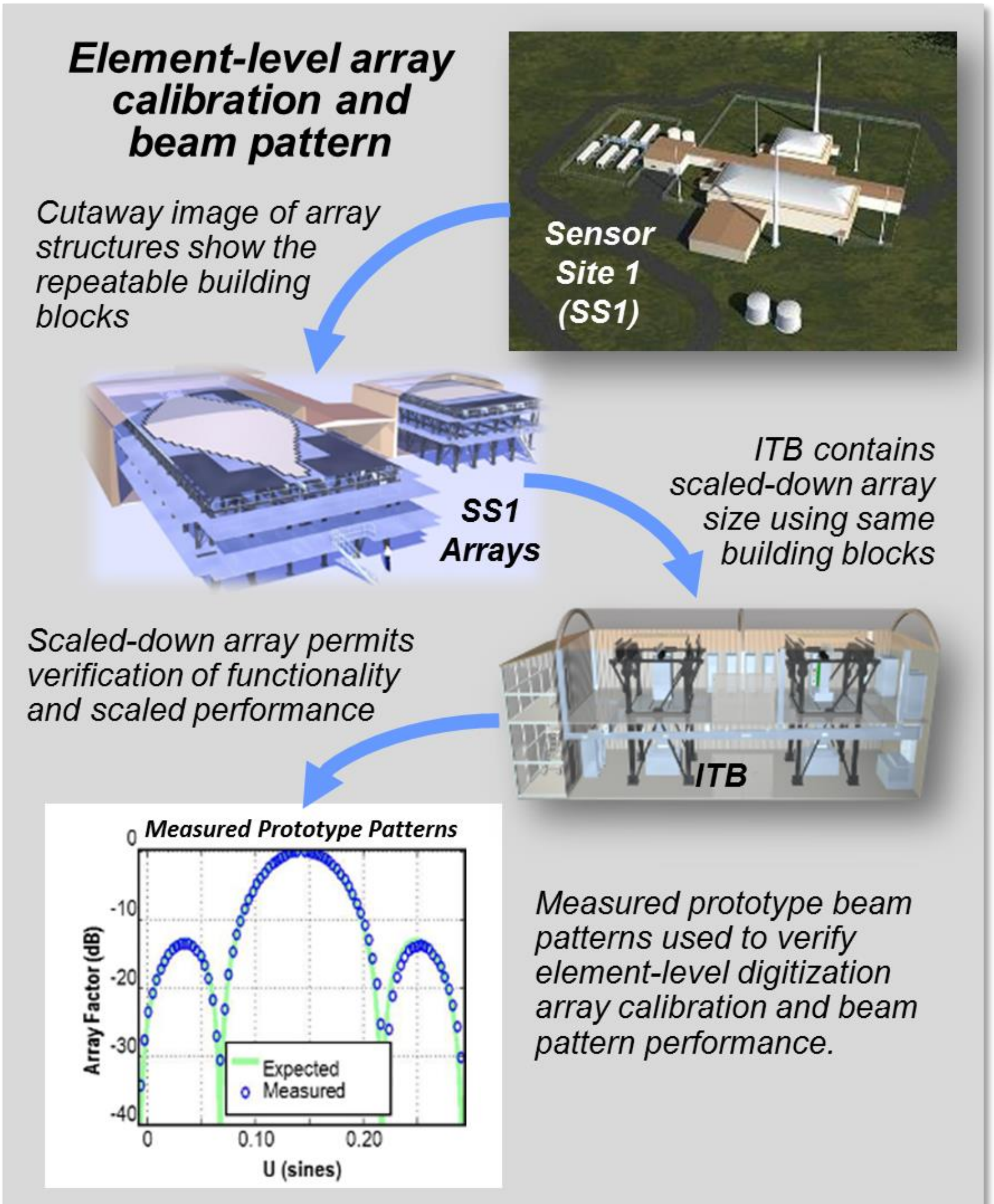

Fig. 10. Key Tenets Verified Using the Integration Test Bed

The ITB enables operational testing in advance of Sensor Site 1. There are various highlights at the system level (see Fig 11). Some of the highlights in requirements verification include greater than 90% of all requirements verified CONUS and over 60% of the system-level requirements verified CONUS. This reduces cost and schedule spent on-island. The team has been working through Verification, Validation, and Accreditation (VV&A) where so far the ITB scaled array size performance has been verified and the team is in the process of validating the ITB models for scaled site size predicted performance. Other highlights include operational risk reduction as the team utilizes ITB as a mini operational site and demonstrates organic and networked command and control (C2) capabilities.

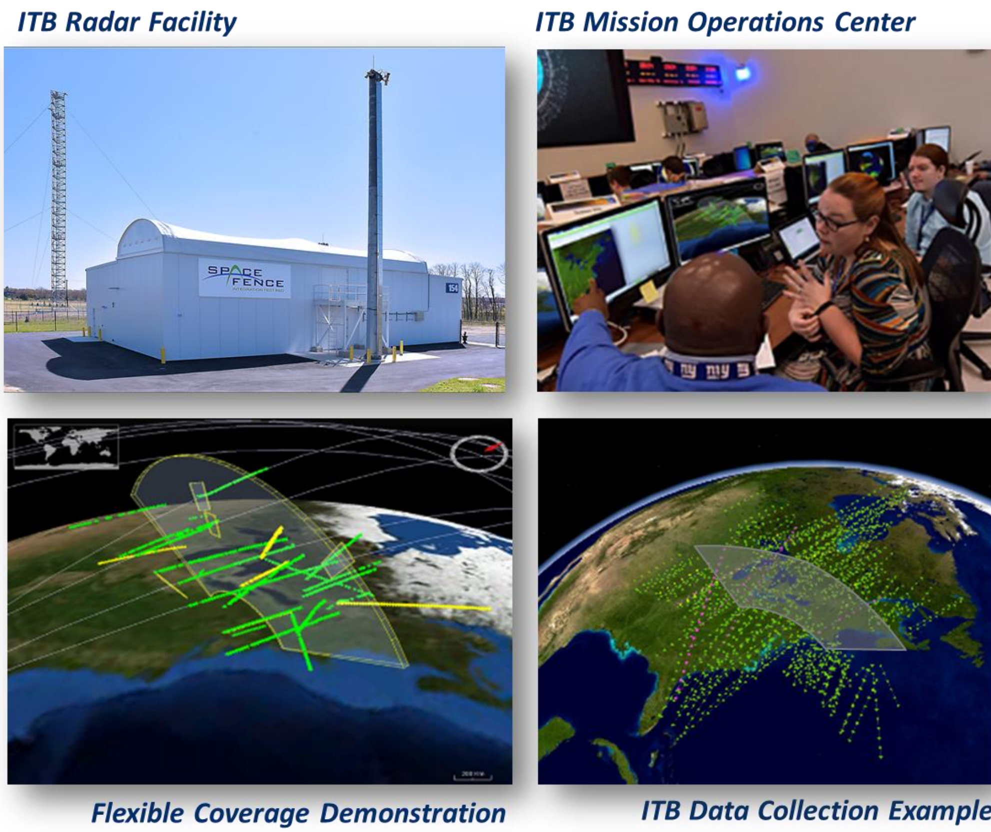

Fig. 11. Integration Test Bed System Level Testing Highlights

6. SENSOR SITE 2 BENEFITS

The second Sensor Site is an unexercised option on the current contract for planned employment on the Harold E. Holt Naval Communication Station near Exmouth, Western Australia (see Fig 12). It will provide geographic diversity from Sensor Site 1, improve RSO positional accuracy, decrease on-orbit event detection timeliness, and enable greater custody through increased revisit rates. By having a second site, it increases the tracking opportunities per day as well the opportunities on low attitude objects. Further, it increases southern hemisphere coverage and enhances coverage in Deep Space. Lastly, Sensor Site 2 provides a backup for Sensor Site 1 and facilitates future mission CONOPS. It improves Space Surveillance Network (SSN) resilience, balances mission load, and enables either site to focus on SSA while the other performs dedicated tasking. The second sensor site FOC is achievable as early as 2021.

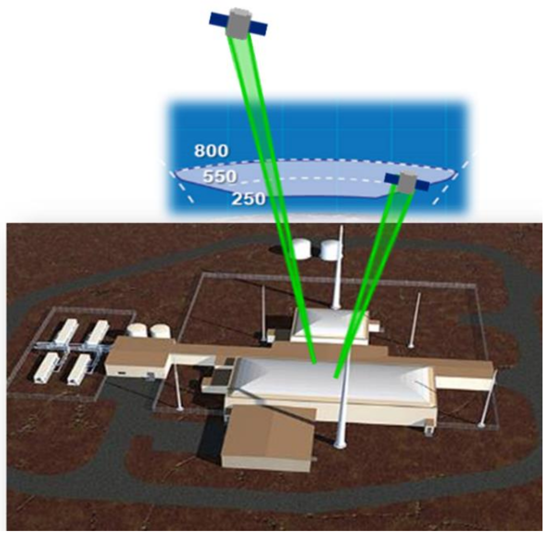

Fig. 12. Sensor Site 2 is Planned for Western Australia and Will Increase the SSN's Capability

7. SUMMARY

Sensor Site 1 construction on the Kwajalein Atoll is in progress and nearing completion. The Operations Center in Huntsville, Alabama has been configured and will be integrated with Sensor Site One in the coming months. The Space Fence Program has made significant progress to-date and is over 85% complete with a first track expected by the end of 2017. System hardware, firmware, and software is undergoing integration testing at the Mooretown, NJ ITB and will be deployed at Sensor Site One and the Operations Center. The use of the ITB continues to reduce risk to Sensor Site integration and has been operational and tracking targets since January 2016. Its system performance has been verified and validated against In-Plant Contractor Test where 60% of system-level requirements were tested. The future Sensor Site 2 is required to fully achieve near term critical SSA mission needs. It will provide critical coverage, timeliness, and operational flexibility to the overall system and could be operational by 2021. The Space Fence Program is on-track for an early 2019 IOC.

8. REFERENCES

1. Peter J. Hack, Ken Carbaugh, Kameron J. Simon, "Automated Space Surveillance Using The AN/FSY-3 Space Fence System", Advanced Maui Optical and Space Surveillance Technologies Conference Proceedings, September 2016.