Operational Acceptance and Employment of the Space Surveillance Telescope in 2022

Jonathan Hutfilz
Space Systems Command

ABSTRACT

On March 5 2020, the Space Surveillance Telescope (SST) obtained first light from its new home near Exmouth in Western Australia. Since then, SST, weather permitting, has been viewing the southern hemisphere sky collecting data on bright and dim objects passing within its field of view. These incredible collections have included tens of thousands of objects never before seen. In addition, SST has found space objects that had been previously lost in public space catalogs as well as discovered dozens of potentially hazardous natural objects. SST's unique location, combined with its ability to see dim objects enhances the ability of the space surveillance network (SSN) to improve detection, safety of flight, separation, conjunction assessment, and proximity operations. As the barriers for entry to space lower, more and more actors have gained access. This trend will lead to the emergence of greater congestion and competition. The number of earth-orbiting objects will continue to grow while the size of the objects will decrease through advances in technology, requiring sensors to provide higher sensitivity, resolution, and capacity. SST has inherently shifted from traditional tasked-based operations to search-based operations while the system's unique capability is able to meet the requirements for detecting and tracking deep space objects. SST marches towards operational acceptance into the space surveillance network. After a rigorous testing regime, SST will provide capabilities improving detection and characterization of space activities.

1. INTRODUCTION

The Space Surveillance Telescope is one of the world's most exquisite space domain awareness sensors, capable of searching (in seconds) an area the size of either the U.S. or Australia, surveying one-quarter of the sky several times each night. The number of earth-orbiting objects will continue to grow while the size of those objects shrinks. Effective catalog maintenance requires sensors with high sensitivity, resolution and capacity. The Space Surveillance Telescope is the first operational sensor of its kind, and is ready to effectively monitoring the growing population of man-made objects in deep space. In doing so, it will fill a critical gap in the Space Surveillance Network's (SSN) coverage of the skies above Earth. Under DARPA's leadership, SST was developed by the Massachusetts Institute of Technology Lincoln Laboratory and fielded at Whites Sands Missile Range in New Mexico. The design includes a 3.6-meter diameter aperture matched to an f/1 optical prescription, and a unique camera composed of 96 million pixels positioned along a curved surface. L3 Technologies, Brashear Division, now part of L3 Harris, designed and built the telescope. Lincoln Laboratory designed and built the camera.

To satisfy the 2013 agreement between the U.S. and Australia's defense departments, an international collaboration was forged between two separate Program Offices, one assigned to the U.S. Space Force and the other to Australia's Defence Department. This led to a decision to relocate the SST from New Mexico to Exmouth, Western Australia. Through closely-integrated but separate acquisition activities conducted by both System Program Offices, the transformation of SST began. Over a 9-month period in 2017, SST was slowly disassembled in New Mexico, allowing for documentation of procedures, inspection and repair of components and assessment of improvements required so that SST could eventually meet reliability and SSN operational standards. 232 tons of SST hardware were shipped over 14,000 miles in 17 crates, safely arriving in Australia. Australia designed and constructed a marvelous facility for SST, fit for the purpose of maintaining high operational availability of this new sensor. Finally, the re-assembly of SST commenced in parallel with completion of that facility's construction. The U.S. Chief of Space Operations, General Jay Raymond, publicly announced that the re-built SST achieved "first light" in Australia in March of 2020.

Traditionally legacy SSN sensors were task-based. DARPA's foresight into the deep space object surveillance needs recognized the value for search-based operations. SST shifts the paradigm from traditional tasking to this new concept of operations. While SST can accept and respond to legacy-based taskings, its bread-and-butter is searching the southern hemisphere several times a night. The SST is providing the capability to resolve and discriminate space objects and debris in the southern hemisphere to accurately assess space events and make informed decisions in response. SST's unique location combined with its ability to see dim objects enhances the ability of the network to improve detection, safety of flight, separation, conjunction assessment, and proximity operations. Both the U.S. and Australia recognize that space systems are part of the national infrastructure, and their national defensive and economic security are dependent upon the free use of space. As the barriers for entry to space lower, more and more actors have gained access. This trend will lead to the emergence of greater congestion and competition. The number of earth-orbiting objects will continue to grow while the size of the objects will decrease through advances in technology, requiring sensors to provide higher sensitivity, resolution, and capacity. SST with its unique capabilities is able to meet these requirements for deep space objects.

Figure 1. Space Surveillance Telescope Site near Exmouth, Western Australia (photo courtesy of Australia DoD)

SST will operate in an autonomous search mode with little or no direct tasking, allowing SST to operate as a synoptic survey sensor detecting and tracking viewable objects, which pass within its field of view. SST operators can schedule preset synoptic search patterns for future observation periods. The SST system will autonomously detect, track, and characterize space objects while still responding to the traditional legacy tasking mode of operations. However, SST through its synoptic search, is expected to satisfy legacy taskings that would have been issued by the command and control centers for resident space object catalog maintenance.

2. THREATS

"China has claimed the destroying or capturing satellites and other sensors would make it difficult for the US and allied militaries to use precision guided weapons. Russia perceives the U.S. dependence on space as its Achilles' heel…therefore, Russia is pursuing counterspace systems to neutralize or deny U.S. space-based services both military and commercial as a means of offsetting the proceeds U.S. military advantage." [1] Furthermore, both China and Russia have already demonstrated their capabilities of rendezvous and proximity operations in multiple orbits. As technology advances, it is easy to make the leap CubeSat sized RSOs will continue to proliferate in various orbits that could contain hostile intent toward U.S. and allied assets. It does not take the next Ray Bradbury to imagine these small, maneuverable, hard to detect CubeSats could be outfitted with kinetic weapons or other capabilities to disrupt U.S. and allied satellite operations.

U.S. policy is that any hostile act in space is considered an act of war. That act, however, must be attributable. Without rock solid evidence it is unlikely to be acted upon, therefore, each one of the potentially weaponized CubeSats (the threat) must be identified, characterized, track, and monitor – foundational space domain awareness –

to provide indications and warnings of threats to command and control facilities. While not a CubeSat, in January 2022, the Chinese Shijian-21 satellite docked with their Beidou-2 navigation satellite and removed it from geostationary orbit. While this was a peaceful maneuver, it not hard to make the leap to its use as a potential weapon, leading the US Space Command Commander to testify in front of Congress, that Chinese satellites like SJ-21 and others “could be used in a future system for grappling other satellites” [2].

3. CAPABILITES

The number of earth-orbiting CubeSat’s will continue to grow while requiring sensors to provide higher sensitivity, resolution, and capacity. SST, with its unique detection capabilities combined with rapid wide field surveillance is able to meet the real-time support requirements for offensive and defensive counter space operations in deep space. SST provides highly accurate metric data that helps identify and maintain custody of small objects and reduces misidentification, while enabling intelligence production centers to develop, monitor, and maintain space orders of battle, which are a critical component of counter space operations planning and execution.

SST was precisely designed to address this challenging task by combining fast search rates with a large field of view. Traditional or legacy SSN electro-optical systems offered only a narrow field of view, which one can liken to looking at space through a soda straw. SST brings a windshield perspective, and with it, high search rate that scans the sky about the size of the U.S. in seconds. SST’s capability to scan the sky multiple times a night provides the necessary timeliness for real-time support to counter space operations.

The primary technology enabling the wide field of view are the curved charge-coupled-device imagers. SST has a mosaic of 12 curved imagers that matches the telescope’s inherent Petzval curvature. This invention was critical in SST keeping its wide field of view. Typically, traditional cameras forces optical system designers to introduce complex lens and mirror arrangements to make the field of view flat. This introduces additional components and creates additional optical irregularities. Curving the focal plane enables the SST to use simplified set of secondary optics while maintaining a point spread function around one arc second over the entire field of view.

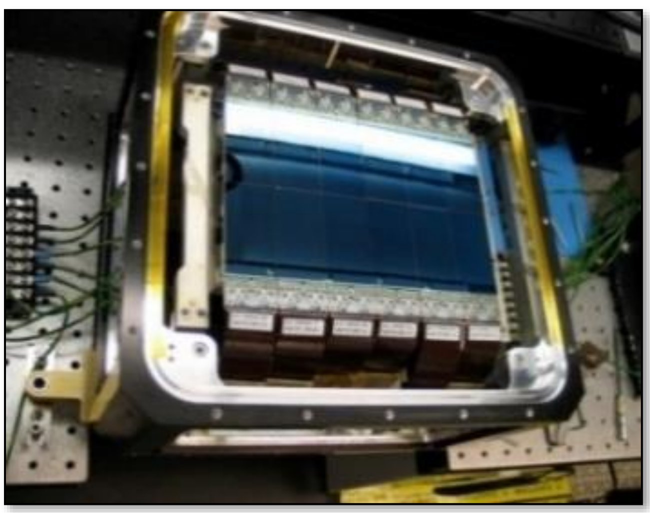

Figure 2. SST Curved Focal Surface Array (Photo courtesy of MIT LL)

SST’s innovative camera design, with a 5.44-meter radius of curvature, allows for a short, compact focal length. SST mirrors are some of the steepest aspherical curvatures created and allow the telescope to have the fastest optics of its aperture class. These features combine, along with a fast and nimble telescope mount, to provide an order of magnitude improvement in space domain awareness versus legacy or traditional sensors.

But what do all these technological advances really mean for the mission and to for domain awareness? Well, from June of 2020 through November 2021, SST utilizing its search and processing techniques discovered over 20,000 new, unique objects; over 14,500 of these objects were seen on multiple occasions. In addition, over the same period, SST discovered over 200 new asteroids in its normal space domain awareness mode of operations. These asteroids range in size from 26 centimeters to 13.5 meters in size. Furthermore, SST has rediscovered objects with multi-day periods:

Name	Date Rediscovered	Date Last Recorded
Vela 10	2021:082	1984:131
Vela 1	2021:084	2021:080
Vela 5	2021:114	2021:055
Vela 7	2021:127	2021:123
TESS	2021:175	Predictions only
GEOTAIL	2021:176	2021:166
SOLRAD 11A/B PKM	2021:190	2021:046
Vela 8	2021:214	2021:107
Vela 6	2021:258	2021:165
Lucy (49328)	2021-093A	2021:289 (insertion)
Vela 11	2021:312	2021:024
Vela 12	2021:314	2021:021

Overall, SST has collected more than 7.3-million observations since June 2020.

4. FUTURE WORK

Cislunar or beyond geosynchronous/geostationary orbit (xGEO) is the next phase of space domain awareness. There are areas for experimentation and development for Earth ground-based electro-optical systems and use for cislunar observations. The amount of traffic to the Moon as well as the lunar surface is expected to increase greatly over the next decade. The same way that Earth orbits are monitored, the DoD needs to be able to monitor space objects past the geostationary orbit to ensure the safe operations and attribute threat actions in that regime. Serendipitously, SST discovered Chang'e 5 after its lunar slingshot maneuver. While this is a great first step in understanding the potential, more is needed such as specific cislunar search patterns, managing moonshine on sensitive electronics, processing algorithms, and the development of a coordinate system for reporting.

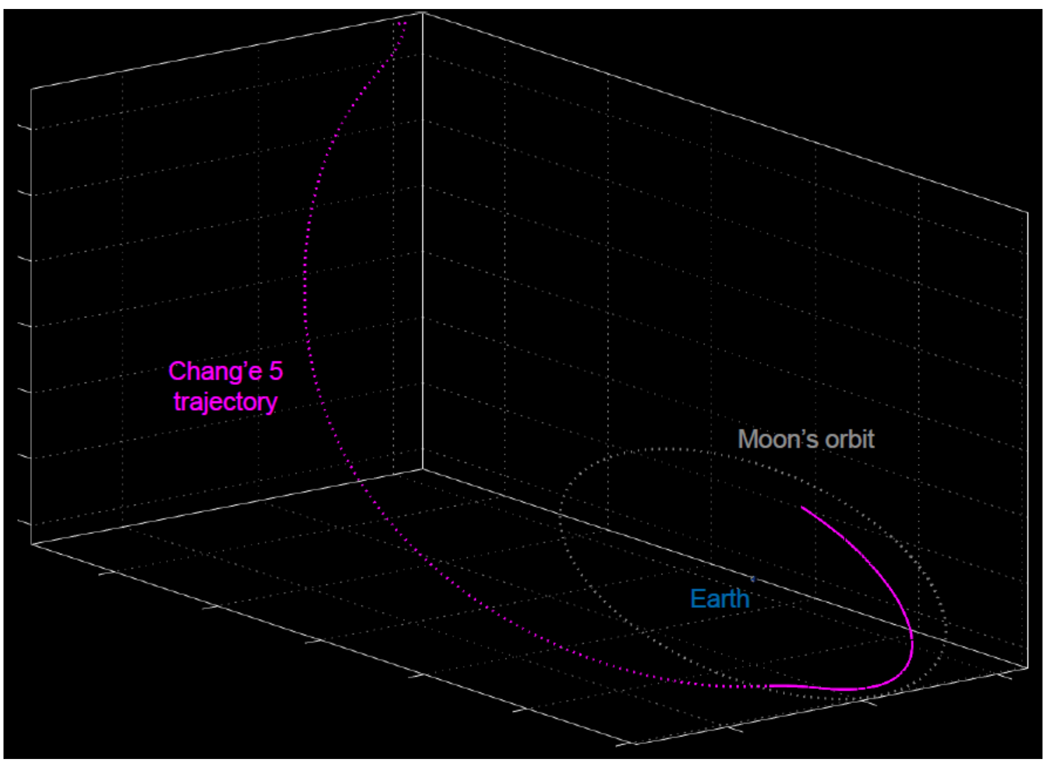

Figure 3. Chang'e 5 Orbit (courtesy of MIT LL)

5. CONCLUSION

SST is the most exquisite, ground-based optical telescope in the U.S. Space Surveillance Network family of systems. SST is designed for synoptic survey of deep space, collecting data on all viewable objects in that region whether or not the object has been previously cataloged. Developed by the Defense Advanced Research Projects Agency (DARPA) with Massachusetts Institute of Technology Lincoln Laboratory serving as DARPA's lead integrator for the design and system integration, SST is capable of rapid uncued search, detection, and tracking of dim objects in deep space. In 2006, Headquarters Air Force Space Command (AFSPC) signed a memorandum of agreement with DARPA to evaluate the military utility of the SST prototype with the intent that AFSPC would operationalize the prototype in New Mexico. However, in 2010, the U.S. Secretary of Defense and the Australian Minister for Defence signed a Statement of Principles establishing a space domain awareness partnership to investigate the potential for jointly establishing and operating SDA facilities in Australia. Then in 2013, the two defense leaders furthered the international partnership in mutual SDA capabilities by signing a memorandum of understanding to relocate, demonstrate, and operationalize SST in Australia. It is imperative for the U.S. and Australia partnership to have the capability to resolve and discriminate space objects and debris to accurately assess space events and make informed decisions in response. The successful relocation and operational acceptance of SST will provide capabilities to effectively improve detection and characterization of space activities; improve orbital safety of flight during maneuver, separation, conjunction assessment, and proximity operations; and improve SDA support to counter-space operations. In addition to relocating and operationalizing the system, the Royal Australian Air Force will operate and maintain the telescope. AFPSC, now Space Operations Command, a field command under the U.S. Space Force, charged the Space Systems Command, specifically the Acquisition Delta - Space Domain Awareness, with the task of transitioning the DARPA prototype system to an operational sensor, implementing SST in Australia, and creating an enduring and lasting sensor for many, many years to come.

6. REFERENCES

[1] Defense Intelligence Agency. *2022 Challenges to Security in Space. Space Reliance in an Era of Competition and Expansion.* https://www.dia.mil/Portals/110/Documents/News/Military_Power_Publications/Challenges_Security_Space_2022.pdf accessed 7 May 2022

[2] B. Tingley. *A Chinese Satellite Just Grappled Another And Pulled It Out Of Orbit*, 27 January 2022. The Drive. https://www.thedrive.com/the-war-zone/44054/a-chinese-satellite-just-grappled-another-and-pulled-it-out-of-orbit accessed 4 June 2022

An author's personal thanks to the Massachusetts Institute of Technology's Lincoln Laboratory Space Surveillance Telescope team who created numerous data points in this paper under DARPA, USAF, and now USSF sponsorship. This work is not possible without their support and dedication.