Space Systems Center Special Programs Advanced Technology Integration Future Space Domain Awareness Hosted Payloads

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CONFERENCE PAPER

This paper provided an overview of the Space Systems Center (SSC) Enterprise Corps Advanced Technology Integration Space Domain Awareness Hosted Payload (HP) efforts. SSC/ECZGZ is developing a future hosted payload architectures leveraging technology from the QZSS-Hosted Payload (QZSS-HP) program to minimize costs and maximize Space Domain Awareness (SDA) capabilities. In addition this capability can be integrated on commercial, Government, and international space vehicles to allow for additional collaboration and United States (U.S.) partnerships.

1. SPACE BASED SDA UNITED STATES SPACE FORCE NEED

The United States Space Force (USSF) has identified a need for evolutionary space based SDA sensors to augment current and planned systems by providing frequent, timely, assured volume revisit. This capability will allow for proliferation of the Geosynchronous (GEO) belt with sensors on any available platform while minimizing sensor and operational costs and focusing on capable solutions for SDA. As hosted payloads, these sensors should support a scalable architecture that can extend coverage as hosting opportunities arise. The SSC Portfolio Architect and USSF emphasis for small satellite and low cost payload capabilities has driven future focus to affordable and highly capable solutions for SDA. This includes alternative solutions for hosting capabilities on commercial, international and US Government satellites. A hosted payload architecture can provide high-interest object custody, enable change detection, and Indications and Warning (I&W) for GEO. The goal of proliferating SDA sensors on any space based platform as needed for continuous search, detect & identification of objects within payload Field of View.

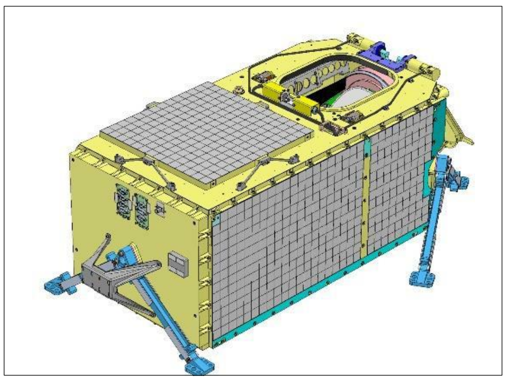
2. LEVERAING QZSS HP PROGRAM

The SSC Development Corps Directorate, with the assistance of the Enterprise Corps Space Domain Awareness Programs Division, is working with MIT/Lincoln Laboratories to develop a hosted payload that will fly on Japan's Quasi Zenith Satellite (QZS) 6 and 7. The main objective of the program is to demonstrate a successful space partnership between the U.S. and Japan while achieving SDA utility. This program will set the stage for future collaborations between other international and/or commercial partners in the future. The two payloads' capability will provide autonomous, space-based optical sensors for timely, rapid revisit of critical assets in GEO. It also will allow for sensor diversity and provide the Space Surveillance Network (SSN) complementary viewing angles over the INDOPACOM region of interest. Stakeholders include: OSD Space Policy, SSC/DC, SSC/ECZGZ, SSC/ZAP, HQ USSF, PACAF, SAF/IA, SAF/AQ, SAF/GCI, SPACECOM, PACOM, U.S. Embassy Tokyo.

"The Quasi Zenith Satellite System Hosted Payload (QZSS-HP) is a Space Systems Center (SSC) Pacesetter program with an objective of demonstrating a successful US-Japan partnership. Because the United States and Japan have similar interests in space security, particularly for space assets over the western Pacific, a partnership arose in which the United States would provide sensors to be hosted on board regional navigation satellites that Japan is developing. These satellites will join an existing constellation, the Quasi-Zenith Satellite System (QZSS), which works with the U.S. GPS constellation to enhance navigation and timing services for users in Japan and the western Pacific. "This program will allow the United States to monitor satellite behavior within the GEO belt over a very interesting part of the world.

The data collected by these platforms will be utilized operationally by the National Space Defense Center and National Air and Space Intelligence Center, and will also be used to further develop and support several ongoing data processing and analytics efforts at the Laboratory," says Mark Huber, a technical staff member in Lincoln Laboratory's Space Systems and Technology Division. "It is also a pathfinder in several ways. The U.S. team is blueprinting methods to allow data sharing between the United States and Japan" (*MIT LL website, 12 Aug 2020, Cleared for Open Publication 29 Oct 2020, Office of Prepublication and Security Review*).

"Because of the Japanese satellites' collocation within the GEO belt, they would have a very narrow view of other satellites in the belt. To enable a larger overall field of regard, a two-axis scan mirror was added to the design to improve mission utility with the same basic system from the QZSS-HP program." (*MIT LL website, 12 Aug 2020, Cleared for Open Publication 29 Oct 2020, Office of Prepublication and Security Review*).



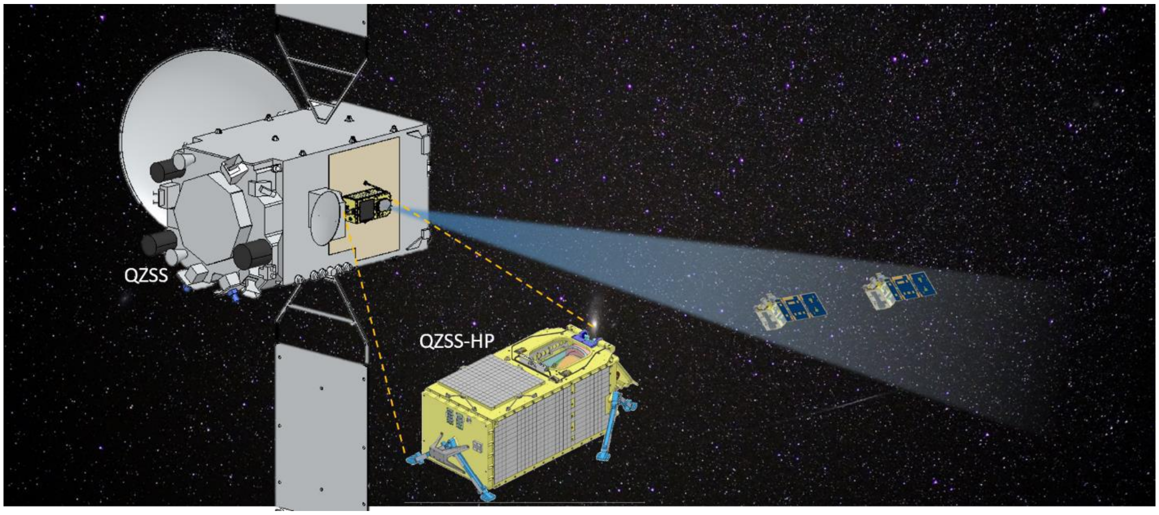
QZSS-HP size is 45 × 31 × 19 inches,

with a mass of 154 pounds (MIT LL website, 12 Aug 2020, Cleared for Open Publication 29 Oct 2020, Office of Prepublication and Security Review

The QZSS-HP "leverages ORS-5 technologies to provide a rapid development and delivery sensor system that has signification onboard Space Situational Awareness data processing capabilities" (MIT/LL 2020 Annual Report).

Although the key QZSS-HP objective is to demonstrate the successful partnership with Japan, the aim is to also provide mission utility from the payloads while ensuring affordability. The U.S. must ensure that the payload design and integration does not perturb Japan's QZSS launch schedule, does not drive significant changes to the current spacecraft design, and that the U.S. payload will "do no harm" to the host spacecraft during the host's design life.

This strategic partnership between the United States and Japan allows for SDA resilience through disaggregation and proliferation. In the MIT Lincoln Laboratory (MIT-LL) article (1), *Lincoln Laboratory is designing a payload to integrate on Japanese Satellites*, published on November 16, 2020, it describes "cost-effective ways for nations to broaden coverage of the space environment". QZSS-HP is the first step at leveraging technology from previous SDA efforts and creating a resilient capability to reduce costs while growing the space based architecture in GEO.

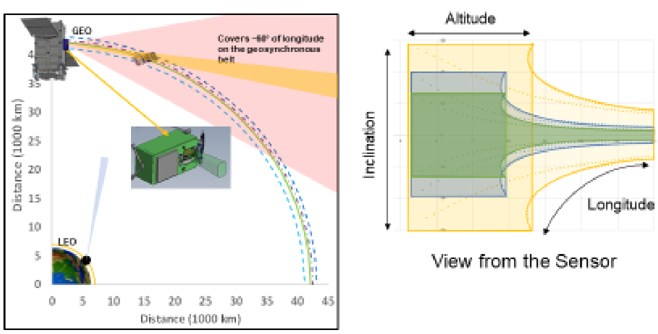


Deployed into the geosynchronous belt, the Japanese satellite QZSS, which carries an optical payload (QZSS-HP) developed by Lincoln Laboratory, will monitor objects in that region of space (MIT LL website, 12 Aug 2020, Cleared for Open Publication 29 Oct 2020, Office of Prepublication and Security Review

3. SPACE BASED SDA HP REQUIREMENTS

GEO-based optical sensors augment the Space Surveillance Network (SSN) by allowing load-shedding from other sensors to increase revisit times over important regions of interest. Future resilient architectures are key to augmenting programs such as the Space Based Space Surveillance (SBSS) Follow-On, Geosynchronous Space Situational Awareness Program (GSSAP), and our ground SDA infrastructure.

- This effort will identify, develop, and demonstrate concepts for low-cost (goal RE<$10M), low size, weight, and power (SWaP) hosted space-based sensors to improve Space Domain Awareness (SDA) of the GEO belt
  - Hosted Payload to be mounted with an East or West view of the GEO belt



Key Requirements	
Longitude	10-60°
Inclination	±7-15°
Altitude	±500-1000 km
Volume Revisit Rate	15-30 min
Sensitivity	30-100 cm Min Detectable Object
Size	1.0m x 0.5m x 0.5m
Weight	100 kg
Power	200 W
Host Provided Downlink Data Rate	10-100 kbps (constant contact)

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4. FILLING THE GAP

Effective space domain awareness relies upon a network of dedicated and contributing sensors providing various types of information (e.g. positional, behavioral, operational) on space objects across a full spectrum of phenomenologies (e.g. UV, visible, NIR, LWIR, RF). The USSF has previously invested in space based optical sensors for performing SDA functions from LEO (i.e. SBSS, ORS-5). These previous investments were motivated by the need for increased persistence of coverage of RSO's in GEO over what ground based observatories can provide. By moving from ground to LEO, exclusion from the Sun was significantly reduced. This effort extends these previous activities. Providing GEO-based hosted payloads enables a regional capability to cover the local noontime. Coordinating hosted payloads with ground-based or other space-based sensors enable a 24 hour persistent coverage of the GEO belt, negating the effects of solar exclusion. This effort provides coverage of this critical time of day while also providing measurements from a diverse vantage point, increasing the utility of other optical measurements made by existing sensors.

The approach considered allows for a scalable constellation to meet regional or global requirements to GEO SDA.

5. SDA HP DEVELOPMENT

SSC/ECZGZ is in concept development and preliminary design reviews of the future SDA hosted payload system. The ongoing QZSS-HP development aims to deliver an initial hosted SDA capability, but is limited by unique constraints of the host (most notably uplink and downlink data rates), thermal challenges, and a significant solar exclusion gap.

The concept payload in development will be suitable for hosting on a variety of spacecraft. The USSF has assumed that the host is in a GEO orbit at 0° inclination and provides the payload a clear field of regard in either the ram or anti-ram direction. The payload is being designed to be thermally isolated from the host spacecraft and will be mounted on the east or west panel of the host spacecraft. Because of unknowns at this time in regards to the host spacecraft, the program office made reasonable assumptions based on the current QZSS-HP system experience associated with hosting. As a general guide, payload size, weight and power (SWaP) (including the HPIU and encryption unit) would be less than the following:

- 100 kg
- 1.0 m x 0.5 m x 0.5 m
- 200 Watts

Host data uplink and downlink availability may vary. Data and power interface to the host will be through a USSF-provided Hosted Payload Interface Unit (HPIU). Additionally, the USSF is providing an encryption/decryption device for data security.

Based on a system mounting using either the host's east or west panel, the USSF SDA HP concept will be thermally isolated from the host, and our concept design documents any additional assumptions related to the host interface as it affects the thermal design. Our concept design makes reasonable assumptions related to the mechanical interface for this hosting location.

6. SDA HP OPERATIONAL CONSTRUCT

The SDA HPs will operate in a non-tasked manner, executing search-based SDA operations of the GEO belt, within the sensor's field-of-regard (FOR). The sensors will operate autonomously and require minimal commanding, with the exception of potential commands during anomaly resolution or emergency operations, as well as limited, non-time-sensitive commands to narrow or adjust scan coverage areas within pre-defined system limits.

The operational construct for the hosted payload is for the SDA sensors to be mounted on either the east or west face of a host spacecraft in a GEO orbit with an unobstructed field of regard down the GEO belt. The sensors will operate in a non-tasked manner, executing search-based SDA operations of the GEO belt, within the sensor's field-of-regard (FOR). While scanning through a predefined search volume, the sensors will collect SDA data on all GEO objects that fall within the sensors' minimum sensitivity threshold. The sensors will operate autonomously and require minimal commanding, with the exception of potential commands during anomaly resolution or emergency operations, as well as limited, non-time-sensitive commands to narrow or adjust scan coverage areas within pre-defined system limits.

The system will consist of a space segment (the hosted payload capable of flying on varied hosts) and a supporting ground segment at a U.S. Payload Ops Control Center (POCC). Command and Control (C2) of the spacecraft bus will be performed by the host, while C2 of the payload will be done at the POCC.

Encrypted data will flow between the POCC and the payload through an existing link segment that is part of the host spacecraft architecture. The payload ground segment development will include a nominal interface that can be tailored for any particular selected link segment. The USSF will provide encryption and long-haul communications on the ground as well as a Hosted Payload Interface Unit (HPIU) to provide power conditioning and a communication path (including data encryption/decryption) between the payload and the host spacecraft.

The SDA data will flow near real-time to be further processed at the POCC for correlation of the observations. The processed SDA data will be published net-centrically to the Unified Data Library and be of sufficient quality to augment the SSN. Data collected by the payload will support the Commercial Space Operations Center (CSpOC) and National Space Defense Center (NSDC) operations as a dedicated SSN sensor.

7. ACQUISITION PLANS

Current discussions are underway to find the next host spacecraft for SDA HP production units in the FY25 and beyond timeframe. Memorandums of Agreements and bi-lateral agreements with international partners take time for negotiation and approval, so discussions are underway with interested parties through the SSC SDA International Liaison Branch and the SMC Chief Partnership Office. SSC/ECZGZ is developing the cost/schedule for integration of these HP's on potential partners. In addition, the SSC Development Corps QZSS-HP program office is developing the Interface Control Documents needed for the SDA data. Current QZSS-HP schedule delivers the first proto-qualified unit in FY23 with additional units delivered in the following years.

8. FUTURE INTERNATIONAL AND COMMERCIAL PARTNERSHIPS

The SDA HP program is building relationships with our international and commercial partner community. Using international resources and partnerships, the SDA HP program will allow for future collaboration globally and allow for us to meet the future challenges in space through proliferation of cheaper small payloads on available platforms. The U.S. has a history with space based SDA partnerships such as the Canadian Sapphire program and now Japan's QZSS-HP program. The USSF will continue to see many future opportunities for leveraging our international and commercial partners through data sharing agreements and host satellite capabilities.

SMC is currently available for future discussions on hosting capabilities and our asking several questions of available hosts.

1. What are your goals for a partnership?
2. What timeframe (year) is the capability needed?
3. Will this effort be a dedicated satellite or hosted payload?
4. Where will the satellite/hosted payload be built?
5. What orbit and phenomenology is needed? Electro optical sensor, Weather sensor, Proximity sensor, Images or Metric observations
6. What is the risk posture for the effort: new technology or proven technology?
7. Where will the hosted payload/satellite be operated? (example: U.S. SOC or host nation)
8. Where is the data going? (example: CSPOC, host nation)

Once an available host is determined, the USSF will begin partnership planning, policy, and agreements.

7. CONCLUSION

The SDA HP capability is providing an exciting opportunity for international and commercial partnerships and collaboration in the near future. The USSF is leading the charge in providing an industry base for affordable, resilient HP capability for expanded SDA coverage. By developing modular host-agnostic (int'l, Govt, commercial) EO payloads and associated ground architecture, SSC/ECZGZ is crafting a future affordable architecture to provide timely GEO search and revisit capabilities. The current activities leverage existing HP designs/technology reuse and catalyze industry production and innovation. Having a diverse SDA network of hosted payloads that can be flown on any satellite bus will complement the existing SDA architecture and allow for future cost savings and partnerships.

9. REFERENCES

1- https://www.ll.mit.edu/news/lincoln-laboratory-designing-payload-integrate-japanese-satellites

2- US/Japan Quasi Zenith Satellite System – Hosted Payload Program Development, MIT LL SCC Presentation, dated September 2021