Use of a Commercial GEO Servicing Vehicle for Space Domain Awareness Data Collection

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ABSTRACT

SpaceLogistics, a Northrop Grumman Company, will soon take the groundbreaking step of utilizing a commercial, space-based platform for the collection of SDA data for USG and other approved customers. With the MEV-1 and MEV-2 vehicles, currently providing life extension for customers in the GEO belt, SpaceLogistics has established both the feasibility of commercial on-orbit servicing and the performance of a visible spectrum sensor for SDA detection and tracking capabilities. The upcoming Mission Robotic Vehicle (MRV) will be SpaceLogistics second generation of rendezvous and docking technology replacing the basic docking mechanism with DARPA's RSGS general purpose robotic capability. The primary commercial mission of this MRV is the installation of life-extending Mission Extension Pods (MEPs). During the frequent periods the MRV will spend transiting between Client Vehicles (CVs), the sensor suite which provides rendezvous capability can easily be re-tasked in an SDA capacity. Supported by MEV mission data, this paper will explore the performance of the MRV sensor suite in this application, and demonstrate ways data from MRV can supplement and extend the capabilities of a larger Space Traffic Management (STM) system.

1. INTRODUCTION

In February 2020, SpaceLogistics Mission Extension Vehicle 1 (MEV-1) made history by becoming the first commercial vehicle to dock near GEO orbit and is to this day continuing to provide life extension services to the Intelsat 901 (IS-901) satellite. This achievement was rapidly succeeded by the MEV-2 / IS-10-02 docking in an active GEO slot in April 2021, showcasing a robust commercial mission extension capability that is the culmination of over a decade of development work by SpaceLogistics' prime contractor, Northrop Grumman Space Systems (NG).

Building on the proven MEV system design, Space Logistics and NG have partnered with DARPA and the US Naval Research Lab (NRL) on the DARPA RSGS program to deploy and demonstrate new advanced technologies in the GEO environment. The upcoming Mission Robotic Vehicle (MRV), scheduled for launch in 2024, will carry highly dexterous DARPA-developed robotic manipulators and new sensor systems, enabling MRV to provide an even wider range of servicing, inspection, and monitoring capabilities for commercial and governmental clients in/near GEO.

A recurring mission for MRV will be rendezvous, capture, and installation of SpaceLogistics Mission Extension Pods (MEPs) to customer vehicles. MEPs are compact, propulsion augmentation devices which are launched using cost effective commercial ride-sharing opportunities and operate as free-fliers until reaching GEO. After capture by MRV and installation onto a client vehicle, a MEP provides 6 years of extended GEO stationkeeping capability for its host.

While MRV will rendezvous with dozens of clients over its 10+ year mission life, its active rendezvous, proximity operations, and docking (RPOD) sequences are relatively brief bursts of activity punctuating quiescent periods devoted to activities such as phasing between GEO slots. During these drift phases, the MRV RPO sensor system is available for secondary mission tasking.

With a rapidly evolving threat profile affecting all operators of vehicles in the GEO environment, Space Domain Awareness (SDA) capabilities are more important to industry and government than ever. The use of MRV as a commercial GEO-stationed sensing platform represents a unique capability, augmenting ground-based sources of data that are primarily used to monitor this regime. It is the intent of SpaceLogistics to make MRV tasking and data collection available to USG and USG-approved Space Traffic Management (STM) data suppliers, providing an invaluable operational capability for this critical mission.

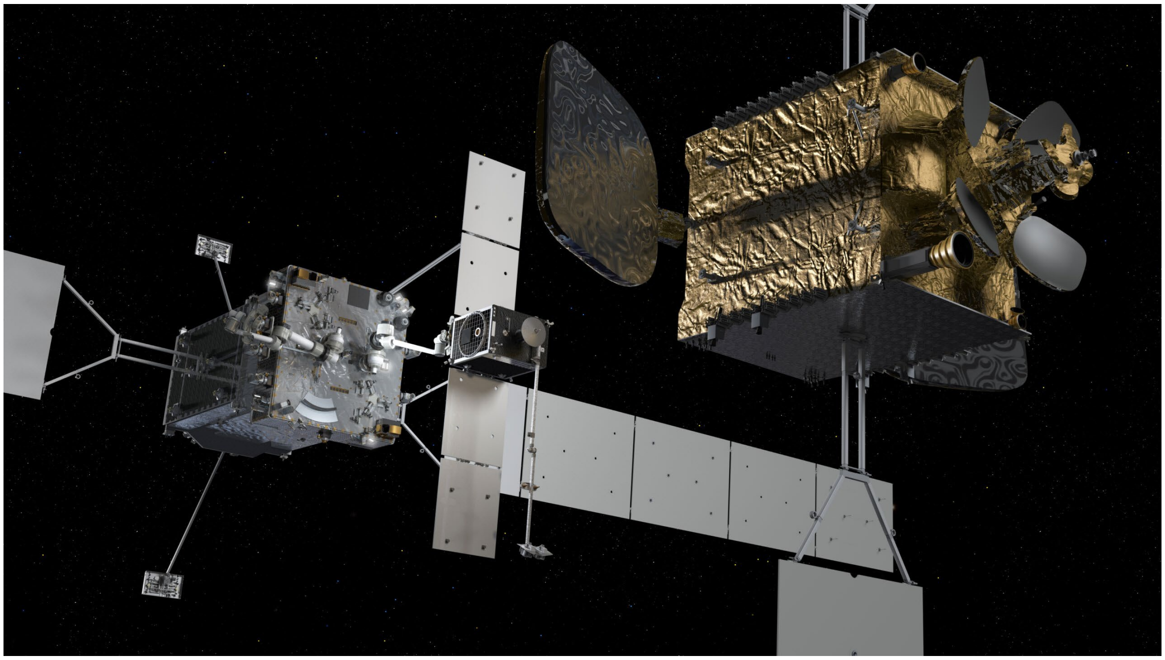

Fig. 1. Rendering of MRV in the process of installing a MEP to a customer vehicle.

2. MRV VISIBLE SENSOR SYSTEM

Designed for both long-range CV tracking and zero-range, high-precision robotic operations, MRV sports a suite of 21 individual cameras. For the purposes of this paper, we will focus only on the visible spectrum sensing capabilities which provide detection and tracking of unresolved resident space objects (RSOs) at extreme ranges, and which would be ideal for data collection in support of SDA/STM.

Long range detection and tracking for MRV is provided by a pair of Malin ECAM-P50 cameras. Implementing a 1" format global-shutter focal plane coupled to a low distortion rad-hard optic, each 22mm EFL P50 is capable of imaging a 32 x 25 deg swathe of the sky in each captured frame. Sharing proven components with heritage cameras on Mars 2020, RRM3, and other successful missions, the ECAM-P50 will provide reliable and powerful data collection for RPOD and SDA operations.

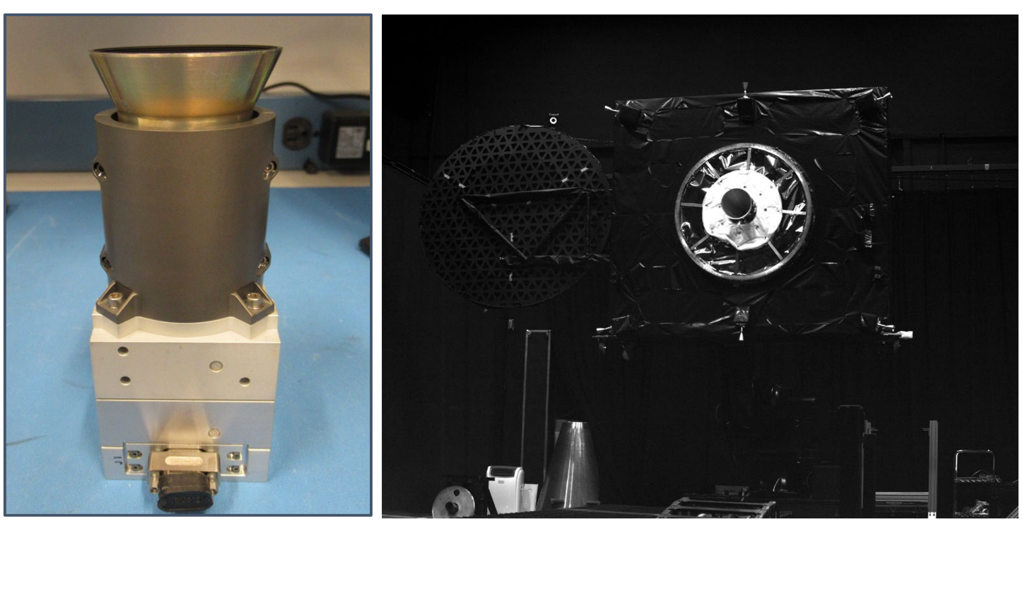

Fig. 2. Left: ECAM-P50 engineering model in NG lab. Right: ECAM-P50 ground test image of NG RPOD lab CV mockup.

3. MRV LONG RANGE DETECTION PERFORMANCE

On several occasions during MEV-1 and MEV-2 RPOD and other calibration operations, observational data was collected which incidentally contained RSOs in addition to the customer CV. See Fig. 3 below, captured by MEV-2. While MEV-2 orbited IS-10-02 as part of terminal approach, this image was captured looking down the GEO belt, and shows a resolved IS-10-02 in the foreground, with unresolved non-star RSOs present in the frame.

These serendipitous captures qualitatively demonstrated the capability of MEV-derived systems to capture data useful for SDA/STM purposes, and also allowed NG to validate the analytical models used for evaluating camera performance for these applications with extensive on-orbit data.

Fig. 3. MEV-2 VSS images during approach to 10-02, looking down the GEO belt. Three non-star objects are clearly visible in the background.

As part of the MRV development effort, these validated models were used to evaluate the performance of the upgraded MRV sensor suite for a dedicated SDA data collection tasking.

For this application, if no post-processing of image data were to be implemented, a 13 dB SNR represents a high confidence of detection of an RSO in a single image frame. Therefore, this threshold is highlighted on the plots below.

However, it is important to note that the raw MRV sensor data will be available to USG and other approved customers, providing an opportunity to implement their own heritage post-processing techniques for the purposes of signature enhancement, tracking, and other purposes. For this reason, all performance estimates shown here should be considered extremely conservative, and the full signature SNR vs. Apparent Magnitude or RSO range are shown for end user evaluation.

Fig. 4 shows the relationship between apparent magnitude of an RSO and the signature SNR of the unresolved object for a single image capture. As stated above, a 13 dB threshold (corresponding to a magnitude 6.4 RSO) is shown for reference, but represents only a very conservative level of detection.

Fig. 5 shows the signature SNR vs. range to RSOs of various sizes. For the purposes of this estimate, simulated RSOs of the enumerated sizes are modeled as 20% Lambertian, and lit by the Sun. Even with the same conservative 13 dB threshold, the MRV is able to detect small (1 m^2) RSOs out to ~600 km; medium RSOs (2 m^2) out to ~1200 km, and large RSOs (3m2) out to ~1800km.

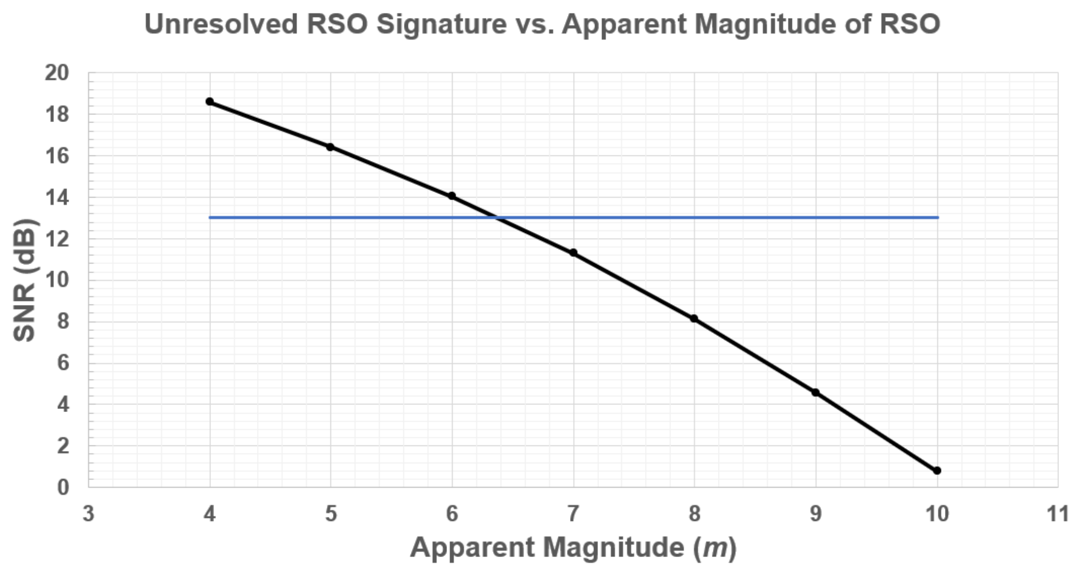

Fig. 4. Detection SNR of the MRV long range visible camera system vs. Apparent Magnitude of an RSO. 13 dB conservative detection threshold shown for reference.

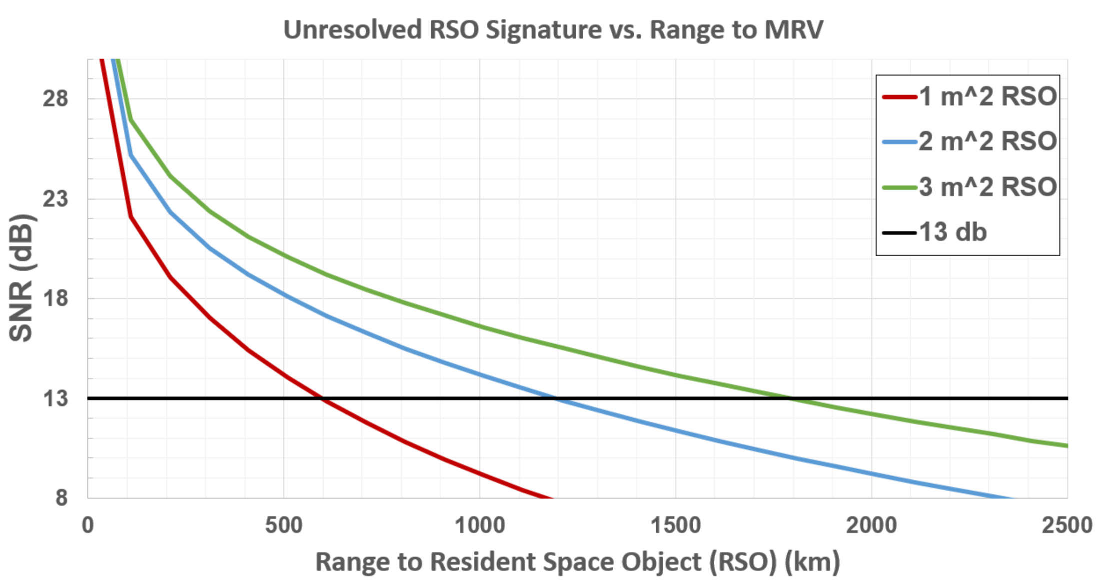

Fig. 5. Range to RSOs of various sizes vs. Signature. 13 dB conservative detection threshold shown for reference.

4. MRV CONOPS AND TASKING

One of the primary missions for MRV is to rendezvous with and capture free flying SpaceLogistics Mission Extension Pods (MEPs), then phase to a customer vehicle and install the MEP to provide life extension. It is expected that the MRV will be occupied with performing this operation four to five times a year, and continue throughout the MRV 10+ year mission life. Each MEP rendezvous and installation sequence is expected to take no longer than four weeks of dedicated event sequencing, leaving the majority of the MRV time on orbit available for secondary missions.

It is expected that, as a commercial space-based SDA platform, the ability of MRV to observe the neighborhood of the GEO belt and provide this data in response to commercial tasking will be in high demand.

MRV will be a powerful supplemental source of data to existing ground-based SDA networks. MRV sensors do not have to contend with weather-based outages, and are observing from within the GEO belt itself, allowing a high concentration of data in the region of highest operational interest. Moreover, MRV generally observes other GEO residents from the in-track axis, orthogonal to the ground, maximizing precision in the direction in which ground-based passive sensors are the weakest.

For data collection tasking, MRV supports multiple methodologies. The MRV attitude control system is capable of precise vehicle pointing for fixed-vector observations, and is also capable of performing rastered scan patterns to cover wider areas of interest. Multiple exposures can be captured at specified attitudes or at each point in a search pattern, to allow increased sensitivity and detection range via ground processing of the resulting data.

The MRV utilizes an onboard GPS receiver to maintain knowledge its own ephemeris without resorting to ground ranging, and the GPS receiver also provides a precision time reference. Vehicle attitude knowledge is maintained at all times via high precision star trackers. This vehicle state information is provided as metadata with captured SDA images, along with standard camera configuration parameters, for ingestion into customer systems and correlation with other sources of observational data.

5. CONCLUSIONS

The SpaceLogistics Mission Robotic Vehicle (MRV) builds on the demonstrated success of the MEV-1 and MEV-2 vehicles. With the DARPA RSGS payload, MRV will demonstrate advanced robotics in GEO for the first time and brings significant new offerings to the table for the space domain awareness (SDA) mission. SpaceLogistics will offer the unique capabilities enabled by MRV to redefine once again how the commercial market can support both servicing and SDA mission needs.

As a commercial SDA platform which is able to provide observations from within the GEO regime itself, data collected by MRV sensors will serve as a powerful supplement to existing detection and tracking networks for USG and other approved customers.

6. ACKNOWLEDGEMENTS

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