Mission Operations, Cubed: NASA Marshall Operations Support for SmallSats

Darren S. Wallace, Sam Digesu, Clifton Jones, Geoff Lochmaier, David Hitt
NASA Marshall Space Flight Center
Huntsville, AL, 35812
darren.s.wallace@nasa.gov

ABSTRACT

SmallSats have come a long way since the Huntsville Operations Support Center (HOSC) at NASA's Marshall Space Flight Center supported its first "minisatellite" mission in 2010. And just as SmallSats themselves have evolved in those 12 years, so too has the HOSC's mission support for SmallSats. Marshall Space Flight Center has a long history with payload and mission operations, including support for the Apollo missions to the moon, the Space Shuttle program, and 21 years of continuous around-the-clock science operations support for research aboard the International Space Station. Today, the HOSC is a multi-tenant facility, supporting not only ISS, but also NASA's Commercial Crew program, the Space Launch System, the Hubble and Chandra observatories and others – including multiple SmallSat missions. Two SmallSat solar sail missions will be among those taking advantage of the HOSC's resources for planning, training for and executing mission operations – the Near Earth Asteroid (NEA) Scout and Solar Cruiser missions. One of 10 6U CubeSats manifest on the Artemis I launch of NASA's Space Launch System rocket this year, NEA Scout's three-year mission will be supported through a more traditional operations concept, with a dedicated Flight Controller staff operating within the HOSC. Scheduled to launch as part of the Interstellar Mapping and Acceleration Probe (IMAP) in February 2025, Solar Cruiser's 11-month mission will take a next-generation approach to operations by utilizing a multi-mission flight controller concept, as well as Marshall's Telescience Resource Kit (TreK). TreK provides a suite of software applications and libraries that allow the Mission Operations Center to serve as an in-house ground system which incorporates remote and automation capability options for engineers and scientists. This presentation will compare the approaches the HOSC will use to support these two missions as a way of demonstrating the array of options NASA MSFC offers for operations support for CubeSat and SmallSat missions.

INTRODUCTION

With experience with mission operations that predates human spaceflight and an initial experience providing operations support for a SmallSat spacecraft a dozen years ago, the Huntsville Operations Support Center (HOSC) at NASA's Marshall Space Flight Center [Figure 1}provides multiple options for support for SmallSat developers. The HOSC offers expertise and facilities to help developers plan for, train for and fly their missions.

Two upcoming solar sail SmallSat missions – the NEA Scout asteroid mission and Solar Cruiser technology demonstrator – will both be operated from the HOSC. The differing operations approaches that will be taken for these two missions exemplify the range of services the HOSC offers.

HUNTSVILLE OPERATIONS SUPPORT CENTER

Based at NASA's Marshall Space Flight Center in Huntsville, Alabama, the Huntsville Operations Support Center is a multi-mission facility offering capabilities to support payload and mission developers to plan for, train for and operate a wide variety of missions, including SmallSats.

Figure 1: The Huntsville Operations Support Center

The HOSC is a multi-mission facility providing a secure and centralized gateway services and communication infrastructure capable of distributing data (and video and voice channels) anywhere in the

world, and offers highly-configurable advanced systems and services to allow remote users to access mission operations data 24 hours a day, 7 days a week, 365 days a year. The HOSC offers both expertise and facilities for supporting all phases of missions, including planning, testing, simulation, prelaunch, launch, and flight operations.

Today, the HOSC is perhaps best known for its Payload Operations Integration Center [Figure 2], which has been providing around-the-clock science operations support for astronauts aboard the International Space Station since 2001. The POIC serves as the primary science command post for the ISS, connecting astronauts and researchers, and coordinating with international partners from Europe, Japan and Canada as well as commercial partners. The POIC also houses an ISS Laboratory Training Complex, which provides a hands-on training environment for ISS science operations, as well as simulation rooms to prepare for space station expeditions.

Figure 2: The Payload Operations Integration Center

Other current "anchor tenants" of the HOSC include NASA's Commercial Crew program and Space Launch System (SLS) program, for which the facility and its team provide engineering support for launches. [Figure 3] For SLS, the HOSC serves as the SLS Engineering Support Center (SESC) where engineers will support final integration, test, launch countdown, and powered flight. Most recently the HOSC and SESC supported the Wet Dress Rehearsal testing in preparation for the vehicle's first launch on Artemis I. The HOSC is also currently preparing for lunar science utilization to support new systems being developed for the Artemis program, including the lunar Gateway platform and a future lunar surface habitat.

Figure 3: Commercial Crew control room

The HOSC is operated by Marshall's Payload and Mission Operations Division (PMOD), within the Center's Human Exploration, Development, and Operations Office. For each mission supported from the HOSC, PMOD assigns an Operations Dirctor, to lead mission operations integration and execution. Marshall's Payload and Crew Ops Office provides trained Flight Controllers (FCs) who will execute the spacecraft contacts, perform commanding, and respond to anomalies. The FC will also lead and coordinate the mission planning process and build and validate the command sequences. PMOD will provide a Ground System lead that will ensure the HOSC is ready to meet mission execution needs. Mission ground systems are hosted in the Mission Operations Center withing the HOSC. PMOD has responsibility for development, installation, integration, testing, and maintenance of the MOC and for coordinating interface testing and data flow exercises with ground antenna networks (like NASA's Deep Space Network). PMOD provides the Telescience Resource Kit (TReK), a ground system software used for flight operations and execution in the MOC.

The roots of the HOSC predate Marshall, going back to operations support for the first U.S. satellite launches by the Army Ballistic Missile Agency, which provided the foundation for Marshall Space Flight Center. During the Apollo program, the HOSC provided operations support for the Saturn launch vehicles and for the Marshall-developed lunar rover. The HOSC provided science mission support for the Skylab space station in 1973-74, and later for Spacelab missions flown on the Space Shuttle (as well as engineering support for Shuttle launches), prior to becoming ISS science central more than two decades ago.

The HOSC provided its first operations support for a SmallSat mission in 2010 with the FASTSAT mission [Figure 4]. FASTSAT, or Fast, Affordable, Science and Technology Satellite, was an under-400-pound

SmallSat carrying six technology and atmospheric science payloads developed at NASA Marshall as a demonstration of the opportunities presented by a small spacecraft to build, deploy and operate a science and technology flight mission at lower costs than previously possible leveraging off-the-shelf hardware. FASTSAT was designed, developed and tested over the course of 14 months at Marshall in partnership with the Von Braun Center for Science & Innovation, Dynetics, and the Department of Defense's Space Test Program (STP), prior to a rideshare launch on the DOD's STP-26 launch on November 20, 2010. The HOSC provided operations support for FASTSAT for two years.

Figure 4: FASTSAT

FASTSAT marked another milestone that would prove to be a precursor for future HOSC endeavors. The FASTSAT microsatellite deployed a free-flying nanosatellite, NanoSail-D, which was the first solar sail NASA deployed in Earth orbit.

Today, the HOSC is preparing to support two more solar-sail small satellite missions, NEA Scout and Solar Cruiser.

NEA SCOUT

One of 10 CubeSat spacecraft flying as secondary payloads on the first launch of the SLS rocket, Artemis I, the Near-Earth Asteroid Scout (NEA Scout) is a 6U CubeSat that will deploy a solar sail to fly by and return data from an asteroid. [Figure 5, 6]

Designed and developed by NASA Marshall and the Jet Propulsion Laboratory in Pasadena, California, under NASA's Advanced Exploration Systems program, NEA Scout will deploy from its shoebox-size spacecraft a solar sail measuring 86 square meters (925 square feet). The sail is made from a very thin aluminum polymer and will deploy using stainless steel booms. The large, highly reflective sail will use sunlight to generate useful thrust by reflecting solar photons. The mission will further demonstrate solar sails as a highly efficient means for a spacecraft to be propelled indefinitely in space, reach and maintain novel orbits otherwise inaccessible, and to conduct orbital plane changes more efficiently than spacecraft using conventional chemical propulsion. Vehicles with solar sails are capable of achieving remarkable speeds, potentially enabling rapid exploration of the outer solar system.

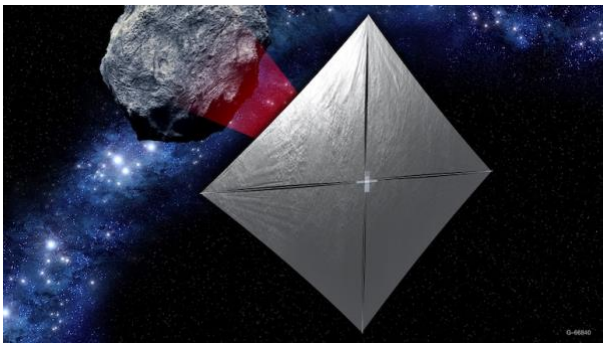

Figure 5: NEA Scout

Figure 6: NEA Scout during testing at NASA Marshall

NEA Scout and the nine other CubeSats will launch on Artemis I in the Orion Stage Adapter connecting the SLS upper stage with the Orion crew vehicle. Following Orion separation, the CubeSats will begin deploying in the lunar vicinity. NEA Scout will use cold-gas thrusters for initial maneuvers prior to deploying its sail and beginning an approximately two-year to fly within 1 kilometer of a target asteroid around 150 million kilometers from Earth. Upon reaching its destination, NEA Scout will become the first interplanetary CubeSat to image and characterize a near-Earth asteroid, using an on-board camera with a resolution as high as 10 centimeters per pixel to take images that will help determine physical properties like shape and volume, rotation, debris/dust field, and regolith characteristics of the asteroid. The spacecraft will reduce the image file sizes via on-board processing

to speed their downlink time to Earth. The HOSC will provide mission operations support for the full two-three year duration of the NEA Scout mission.

SOLAR CRUISER

Scheduled for launch in 2025, Solar Cruiser will incorporate new technologies for a solar sail demonstration that could enable game-changing new science mission profiles in the future. [Figure 7]

Sponsored by the Solar Terrestrial Probes Program of NASA's Heliophysics Division and developed by Marshall Space Flight Center, Solar Cruiser will deploy the largest solar sail ever flown – a four-quadrant 1,653 square meter solar sail 2.5 microns thick, thinner than a human hair. The sail will be deploying four lightweight composite booms, each almost 30 meters long and embedded with thin photovoltaic film to demonstrate a new method of power generation. The sail itself is made of a thin-film polyimide coated with aluminum. That polyimide – clear polymer 1, or CP1 – was developed over two decades ago and flown on FASTSAT's NanoSail-D nanosat.

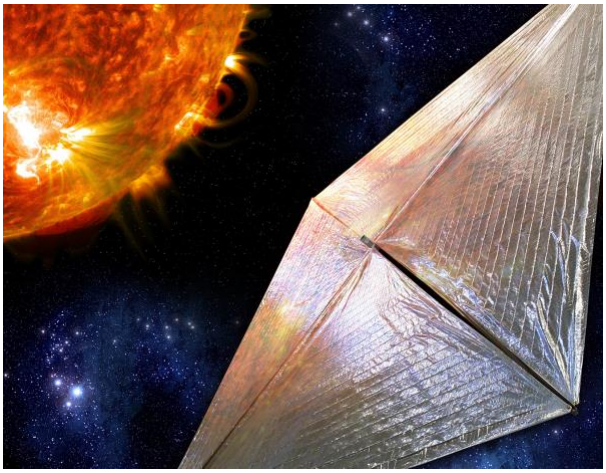

Figure 7: Solar Cruiser

On its almost-11-month mission, Solar Cruiser will demonstrate the capability of solar sail propulsion to enable spacecraft to collect observations from vantage points difficult for spacecraft with conventional propulsion systems to reach and sustain. Specifically, Solar Cruiser will maintain a position sunward of Sun-Earth Lagrange point L1. The spacecraft will demonstrate technologies that will enable future missions to improve space-weather monitoring, prediction, and science.

In addition to Marshall, the Solar Cruiser team includes Ball Aerospace, Redwire, and subcontractor NeXolve. Solar Cruiser will launch as a secondary payload along with NASA's Interstellar Mapping and Acceleration Probe (IMAP) mission on a SpaceX Falcon 9 vehicle no earlier than February 2025.

NEA SCOUT AND SOLAR CRUISER OPERATIONS SUPPORT

Marshall's Payload and Mission Operations Division has responsibility for leading, planning, and executing mission operations for both the NEA Scout and Solar Cruiser missions.

While there will be multiple similarities in the manner in which PMOD provides operations support for the two missions from the HOSC, there are also significant differences that reflect the range of capabilities PMOD and the HOSC offer for SmallSat mission operations.

For both of the missions, a Flight Control Team is assigned, with the number customized to the needs of the mission. That team includes a Mission Operations Lead who provides operations preparation support during development, and will certify as a Spacecraft Operations Director (SOD) prior to launch. The SOD will lead and coordinate the mission planning process and the creation and validation of command sequences, and has the responsibility for overseeing the training for all operations and support personnel.

The rest of the Flight Control Teams consist of certified Flight Controllers, who execute communications with the spacecraft, perform commanding, assist in planning, and respond to real-time anomalies. To minimize the resources needed for mission operations, the team is staffed with multimission flight controllers who receive core training to support multiple missions, augmented by any specific needed training for a particular mission; allowing them to potentially operate multiple missions at the same time. This reduces the footprint of personnel needed and cuts the training timeline associated for mission operations and thus reduces costs to the projects.

Working with the Flight Control Team, a Ground Systems lead ensures that the HOSC is equipped and ready to meet mission execution needs.

The Mission Operations Centers for each of the two missions will be located in configurable control rooms in the HOSC. The rooms support an Internet Voice Distribution System (IVoDS) voice loop system. Workstations in the configurable control rooms connect to a shared virtual server farm running data processing, distribution, commanding services and storage systems used by various missions. Firewalls and front-end servers provide secure access to mission data at remote locations. The HOSC itself is on an uninterrupted power supply with diesel generator backup power and

is staffed 24/7 by facilities personnel in support of various programs and projects.

Mission Operations Systems (MOS) execution activities begin at launch and continues until decommissioning is performed. This includes all ground activities necessary to manage the sailcraft throughout the mission, including uplinking commands, sequences, and files; downlinking and archiving telemetry; troubleshooting and correcting anomalies; performing data analysis and trending on the sailcraft subsystem telemetry; determining and updating the flight trajectory.

Just as NEA Scout itself was developed as a collaboration between NASA Marshall and JPL, operations of the mission will likewise be a partnership between the two locations. Leveraging JPL's Advanced Multimission Operation System (AMMOS), NEA Scout operations will use as its ground system the AMMOS Multimission Data Processing and Control System (AMPCS) to command and monitor the spacecraft. JPL will also lead mission design and navigation and science objectives for NEA Scout.

Solar Cruiser is being designed as an independent mission utilizing Marshall resources for the ground system, mission design and navigation, and establishment of mission objectives. Command and Control of Solar Cruiser is achieved via Marshall's Telescience Resource Kit (TReK). TReK is a suite of software applications that is used to monitor and control the sailcraft. TReK provides the Flight Control Team the capability to receive, process, record, playback, forward, and display data (ground-based data or telemetry data). TReK's command capabilities include support for creating, modifying, storing, and uplinking a variety of command products such as commands, command files, command loads, and command sequences. TReK software has two decades of heritage, supporting payloads on the International Space Station and having been used for FASTSAT.

During the last six months of the NEA Scout mission, PMOD will attempt to demonstrate a new Automated Spacelink Connectivity concept. Assuming a successful demonstration, this new automation approach will be implemented for multiple mission phases of Solar Cruiser and would be available for future missions.

Solar Cruiser operations will be the first MSFC project that will utilize a tailored Communication Security (COMSEC) approach to meet NASA Space Systems Protection Standard as outlined in the newly established NASA-STD-1006, providing additional security for spacecraft communications.

CONCLUSION

Marshall's Huntsville Operations Support Center and Payload and Mission Operations Division have a long decades-spanning heritage of operations and mission success, ranging from some of the largest missions in spaceflight history to some of the smaller.

Just as SmallSats are pushing an evolution in mission design and architecture, PMOD is pursuing an evolution in mission operations, continuously seeking ways to implement new technologies and approaches designed to offer flexible, configurable services that are tailored to customer needs and reduce operations cost and complexity.

A variety of capabilities are available for every stage of development and flight, including planning for the operations stage, training mission personnel, and conducting flight operations during the mission.