Marshall Space Flight Center Technology Capabilities for Use in Space Situational Awareness Activities

Larry Gagliano[1], Todd MacLeod[2], and Mary Hovater[3]

[1]NASA/MSFC, Mail Code ST03 Huntsville, Alabama, United States; larry.gagliano@nasa.gov
[2]NASA/MSFC, Mail Code ES10, Huntsville, Alabama, United States;
[3]NASA/MSFC, Mail Code CS02, Huntsville, Alabama, United States

ABSTRACT

NASA's Marshall Space Flight Center is working to improve space situational awareness through technical innovation, collaboration, and cooperation with U.S. Government agencies and the global space community. NASA has long-standing guidelines for assessing space objects. Specifically, Marshall has the capabilities, facilities, and expertise to address the challenges that space objects, such as new-Earth objects (NEO) or Orbital debris, pose to space assets. Marshall performs research, integrated information, matures technologies, and enhances science to bring together a diverse portfolio of products and services of interest for Space situational awareness (SSA), which can be accessed through partnerships with Marshall.

Marshall's Integrated Space Situational Awareness and Asset Management (ISSAAM) three-pronged approach brings together vital information and in-depth tools working simultaneously toward examining the complex problems encountered in SSA. These technology prongs are database/analyses/visualization, detection/tracking, and mitigation/removal. Marshall has many technologies under these prongs in current use and/or development that could offer solutions to problems outside the NASA arena. Marshall provides solutions for complex issues with in-depth capabilities, a broad range of experience, and unique expertise, all available in one convenient location.

1. BACKGROUND

Seeing the increasing need for technologies across all aspects of space situational awareness (SSA), and playing off its long standing work in orbital debris testing and modeling for spacecraft, Marshall evaluated how current technology developments could be useful for SSA. A small team was assembled and the technologies grouped into three areas: database/analyses/visualization, detection/tracking, and mitigation/removal. This paper provides information on Marshall capabilities and a few technologies that are in development.

2. DATABASE/ANALYSES/VISUALIZATION

2.1 Space Asset Management Database

Effective space asset management is one key to addressing the ever-growing issue of space congestion. It is imperative that agencies around the world have access to data regarding the numerous active assets and pieces of space junk currently tracked in orbit around the Earth. At the center of this issue is the effective management of data related to orbiting objects. As the population of tracked objects grows, so too should the data management structure used to catalog technical specifications, orbital information, and metadata related to those populations.

Marshall Space Flight Center's Space Asset Management Database (SAM-D) effectively catalogs a broad set of data related to known objects in space by ingesting information from a variety of databases and processing that data into useful technical information. Using the universal North American Aerospace Defense Command (NORAD) number as a unique identifier, the SAM-D processes two-line element data into orbital characteristics and cross-references this technical data with metadata related to functional status, country of ownership, and application category. The SAM-D began as an Excel spreadsheet and was later upgraded to an Access database. While SAM-D performs its task very well (see sample in fig 1), it is limited by its current platform and is unavailable outside of the local user base. Further, while modeling and simulation (M&S) can be powerful tools to exploit the information contained in SAM-D, the current system does not allow proper integration options for combining the data with both legacy and new M&S tools.

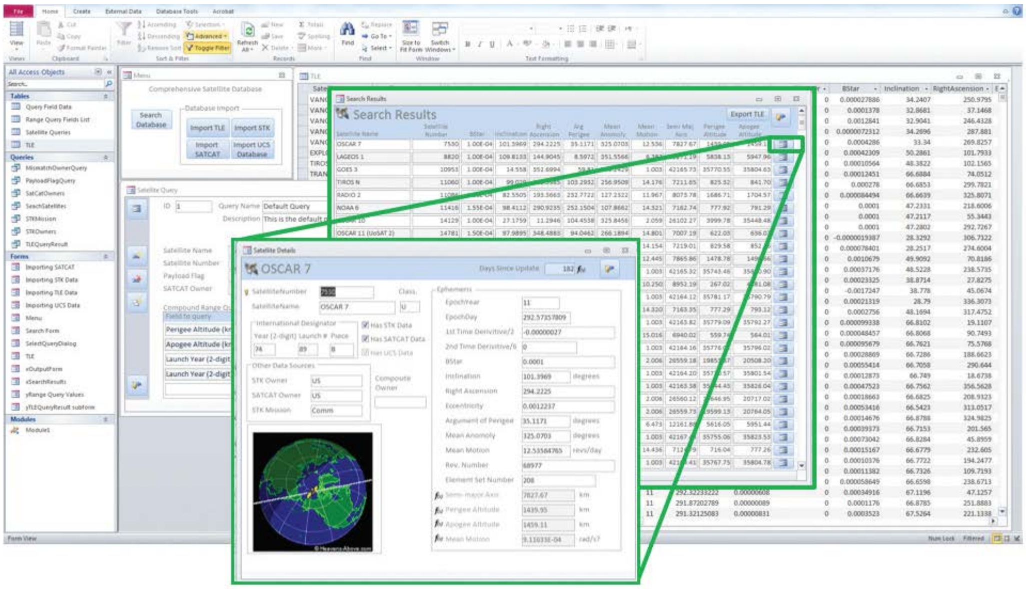

Fig 1. Sample of data review in SAM-D.

2.2 Meteoroid Environment Office

The Meteoroid Environment Office (MEO), based at Marshall, is the NASA organization responsible for meteoroid environments pertaining to spacecraft engineering and operations. The MEO leads NASA technical work on the meteoroid environment and coordinates the existing meteoroid expertise at NASA centers. MEO's objective is to understand the flux and the associated risk of meteoroids impacting spacecraft traveling in and beyond Earth's orbit. Meteoroids impacting spacecraft are a quantifiable risk as they can puncture pressurized volumes (i.e. space station modules, propellant tanks) or destroy components (i.e. engines, electronics).

2.3 Meteoroid Environment Model

Given a state vector, the Meteoroid Environment Model (MEM) outputs mass-limited or penetrating fluxes and average impact speeds and distributions on the surfaces of a cube-like structure with the ram face oriented along the spacecraft velocity. Some of the revolutionary aspects of MEM are: a) identification of the sporadic radiants with real sources of meteoroids, such as comets, b) a physics-based approach which yields accurate fluxes and directionality for interplanetary spacecraft anywhere from .2 AU to 2 AU, and c) velocity distributions obtained from theory and validated against observation.

2.4 Smooth Particle Hydrodynamics Code

Smooth Particle Hydrodynamic Code (SPHC) is a software code that can handle one-, two-, or three-dimensional versions of a problem to support high-velocity impact simulation/modeling. It accommodates any material for which a specified set of properties is known, using any of ten equations of state and seven material strength models. SPHC has flexible geometric modeling capabilities, allowing it to simulate a wide range of articles. Impacts can be modeled at any speed below ≈50 km/s using initial temperatures, densities, porosities, and user-specified internal pressures. Complex objects can be built up from simple geometric constructs, then duplicated and moved as desired in the simulation space.

2.5 Space Environmental Effects Testing

The Space Environments Effects (SEE) Testing team studies material behaviors in the space environment. Laboratory capabilities include simulation of orbital atomic oxygen, ultraviolet radiation, electron and proton radiation, plasma, thermal vacuum, and meteoroid and space debris impacts. Also, the team has conducted on orbit testing for several years on the Materials on the International Space Station Experiment (Fig. 2).

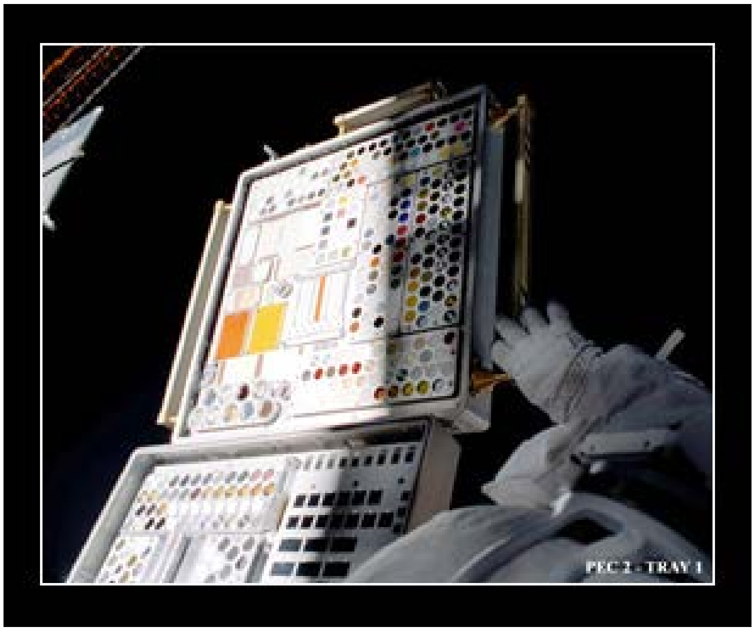

Fig 2. Materials on the International Space Station Experiment (MISSE).

2.6 Natural Environments Research and Analysis

This group leads the development of natural environment definition for both terrestrial and planetary missions including: ionizing radiation, plasmas, meteoroids, neutral thermosphere, thermal environment, and solar activity forecasting. They also do environments data reduction and analysis and environments model development.

3. DETECTION/TRACKING

3.1 Automated Lunar and Meteor Observatory (ALaMO)

Marshall has two observatory domes, a 15-meter tower with a roll-off roof, and an operations center with laboratory space. The telescopes are equipped with computerized mounts so that observations can be controlled from the operations center.

3.2 Small Orbital Debris Detection, Acquisition and Tracking (SODDAT)

This conceptual technology demonstration spacecraft was developed to address the challenges of in-situ small orbital debris environment classification including debris observability and instrument requirements for small debris observation.

3.3 Space Situational Awareness Sensor Suite Experiment (SSASSE)

This sensor will fly on NASA's Small Orbital Debris Detection, Acquisition, and Tracking (SODDAT), a conceptual technology demonstration spacecraft. By combining off-the-shelf digital video technology, telescope lenses, and advanced video image Field Programmable Gate Array processing, Marshall is building a breadboard for a passive orbital tracking camera that can track faint objects (including small debris, satellites, rocket bodies, and NEOs) at ranges of tens to hundreds of kilometers and speeds in excess of 15 km/sec.

3.4 Orbital Debris Stereo Tracking Camera Development

A pair of intensified megapixel cameras with ruggedized telephoto lens will see the sun glint off of small objects (coin-sized) in low-Earth orbit (LEO) at tens of kilometers. When pointed parallel to the orbital velocity vector, objects following or approaching the International Space Station can be differentiated from the moving star-field background with simple pixel and spot processing in real-time. Stereo cameras provide ranging and redundancy. Fig 3 shows an artist rendering of the SODAT with these cameras. On Orbit cameras can directly measure debris flux and see smaller objects than ground radar.

Camera objectives are to evaluate its performance in LEO for real-time object detection and ranging. It is also intended to generate orbital object tracking data to compare to state of the art radar data and debris models.

Fig 3. Artist concept of the Stereo camera system on the Small Orbital Debris Active Removal (SODAR) craft.

3.5 High-Fidelity Dynamics Star Field Simulator

This technology is a unique capability developed in conjunction with Texas A&M University that is now in testing. It has a high-resolution, large, monochrome display and a custom collimator capable of projecting realistic star images with simple orbital debris spots (down to star magnitude 11–12) into a passive orbital tracking camera with simulated real-time angular motions of the vehicle mounted sensor. The simulator can be expanded for multiple sensors, real-time vehicle pointing inputs, more complex orbital debris images, and is adaptable to other sensor optics, missions, and installed sensor testing.

4. MITIGATION/REMOVAL

4.1 Marshall Active Debris Removal and Transportation Architecture Study (MADR-TAS)

Under this task, Marshall studies large debris/objects and how to effectively remove them in the most affordable manner. Marshall investigates the best transportation methods to reduce the threat of a LEO orbital debris conjunction. In addition, the study helps to determine what Resident Space Objects (RSOs) pose the largest threat to worsening the lower-Earth orbit orbital debris environment.

4.2 Electrostatic Gripper Technology Development

Developing specialized Electro-Static grippers (commercially used in semiconductor manufacturing and package handling) allows gentle and secure capture, soft docking, and handling of a wide variety of materials and shapes (such as upper-stages, satellites, arrays, and possibly asteroids) without requiring physical features or cavities for a pincher or probe or using harpoons or nets. Fig 4 shows a photo of one of the grippers used in the lab. Combined with new rigid boom mechanisms or small agile chaser vehicles, flexible, high speed Electro-Static Grippers enable compliant capture of spinning objects starting from a safe stand-off distance. Electroadhesion (EA) can enable lightweight, ultra-low-power, compliant attachment in space by using an electrostatic force to adhere similar and dissimilar surfaces. A typical EA-enabled device is composed of compliant space-rated materials, such as copper-clad polyimide encapsulated by polymers. Attachment is induced by strong electrostatic forces between any substrate material, such as an exterior satellite panel and a compliant EA gripper pad surface.

When alternate positive and negative charges are induced in adjacent planar electrodes in an EA surface, the electric fields set up opposite charges on the substrate and cause an electrostatic adhesion between the electrodes and the induced charges on the substrate. Since the electrodes and the polymer are compliant and can conform to uneven or rough surfaces, the electrodes can remain intimately close to the entire surface, enabling high clamping pressures. Clamping pressures of more than 3 N/cm^2 in shear can be achieved on a variety of substrates with ultra-low holding power consumption (measured values are less than 20 microW/Newton weight held). A single EA surface geometry can be used to clamp both dielectric and conductive substrates, with slightly different physical mechanisms. Furthermore, EA clamping requires no normal force be placed on the substrate, as conventional docking requires. Internally funded research and development has demonstrated that EA can function effectively in space, even in the presence of strong ultraviolet radiation, atomic oxygen, and free electrons. We created a test setup in an existing vacuum chamber to simulate LEO conditions. An EA mechanism was fabricated and installed in the chamber, instrumented, operated in a vacuum, and subjected to ultraviolet photons and free electrons generated by an in-chamber multipactor electron emitter.

Extensions to EA that can add value include proximity and contact sensing and transverse motion or rotation, both of which could enhance docking or assembly applications. Possible next steps include development of targeted applications for ground investigation or on-orbit subsystem performance demonstrations using low cost access to space such as CubeSats.

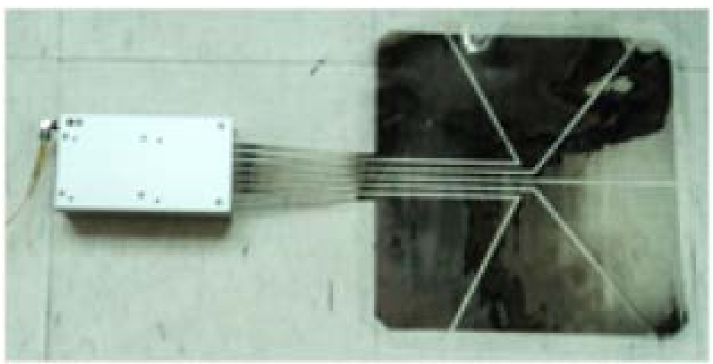

Fig 4. Electrostatic gripper.

4.3 Small Orbital Debris Active Removal (SODAR)

This architectural study investigated the overall effectiveness of removing small orbital debris from LEO using a satellite-based, non-weapons class, low-power laser. The results found that a spacecraft with an integrated forward-firing laser is capable of reducing the small orbital debris flux within a 60 to 100 km orbital shell by a significant amount within the one spacecraft’s operational lifetime.

4.4 Material Ablation De-orbit Experiments

Marshall is working with industry and academia to study the use of laser ablation to de-orbit small debris using the **Electrostatic Levitation Laboratory** (see fig 5). This concept is being considered for addition to the SODDAT in conjunction with the SSASSE. It would detect, track, and heat debris with a laser, changing its trajectory to lead to de-orbit.

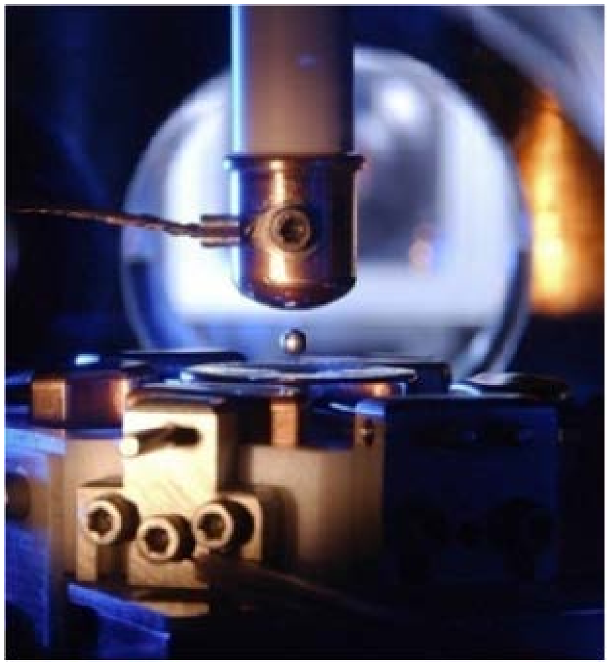

Fig 5. Levitated sample in Marshall's Electrostatic Levitation Laboratory.

5.0 Conclusion

While this paper highlights many of the technology developments and capabilities Marshall has to offer with respect to SSA, there are many more useful capabilities. Marshall's goal for this paper is to help make the SSA community aware of potential help that could be found for current issues. ISSAAM is regularly working with possible partners and collaborators in SSA to assist them to connect with the right areas at Marshall to develop unique solutions to their needs.