Engineers ready innovative robotic servicing of geosynchronous satellites payload for launch

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Members of the U.S. Naval Research Laboratory's Robotic Servicing of Geosynchronous Satellites (RSGS) team prepare flight Robotic Arm System (RAS) #1 for thermal vacuum (TVAC) testing in Washington, D.C. June 16, 2022. TVAC testing exposes flight hardware to a vacuum environment and cycles over a wide range of temperatures to ensure the hardware will survive the harsh environment of space. Credit: U.S. Navy/Sarah Peterson

Engineers at the U.S. Naval Research Laboratory's (NRL) Naval Center for Space Technology (NCST) recently completed robotic payload component level testing for the Defense Advanced Research Projects Agency (DARPA) Robotic Servicing of Geosynchronous Satellites (RSGS) program.

Once on-orbit, the RSGS robotic servicing vehicle will inspect and service satellites in Geosynchronous Earth Orbit (GEO), where hundreds of satellites provide communications, weather monitoring, support national security missions, and other vital functions.

The RSGS program is a public-private partnership between DARPA and Northrop Grumman's SpaceLogistics subsidiary, with NRL developing the robotic servicing payload.

"This partnership will enable revolutionary servicing capabilities to commercial and government users for visual diagnostics, upgrades, orbit adjustment, and satellite repairs," Bernie Kelm, Superintendent of the Spacecraft Engineering Division, NCST, said. "As the robotic payload developer, we designed this innovative set of spaceflight hardware and software that will advance national capabilities in satellite servicing."

The RSGS payload includes flight hardware components, robotic control algorithms, multiple highly customized electronics designs, and flight software running on five single-board computers. NRL also specified and procured two dexterous seven-degree-of-freedom robotic arms, outfitting them with control electronics, cameras, lights, and a robotic tool changer.

Additionally, NRL developed the robotic tool to grapple customer satellites via their standard launch vehicle interface and procured another tool to capture resupply elements that are compatible with DARPA's Payload Orbital Delivery (POD) design standard.

"Our diverse team of NCST engineers has focused their efforts on the robotic payload for the RSGS Program for the last seven years," William Vincent, NRL's RSGS program manager, said. "The Robotic Payload is one of NRL's most complicated payload developments ever."

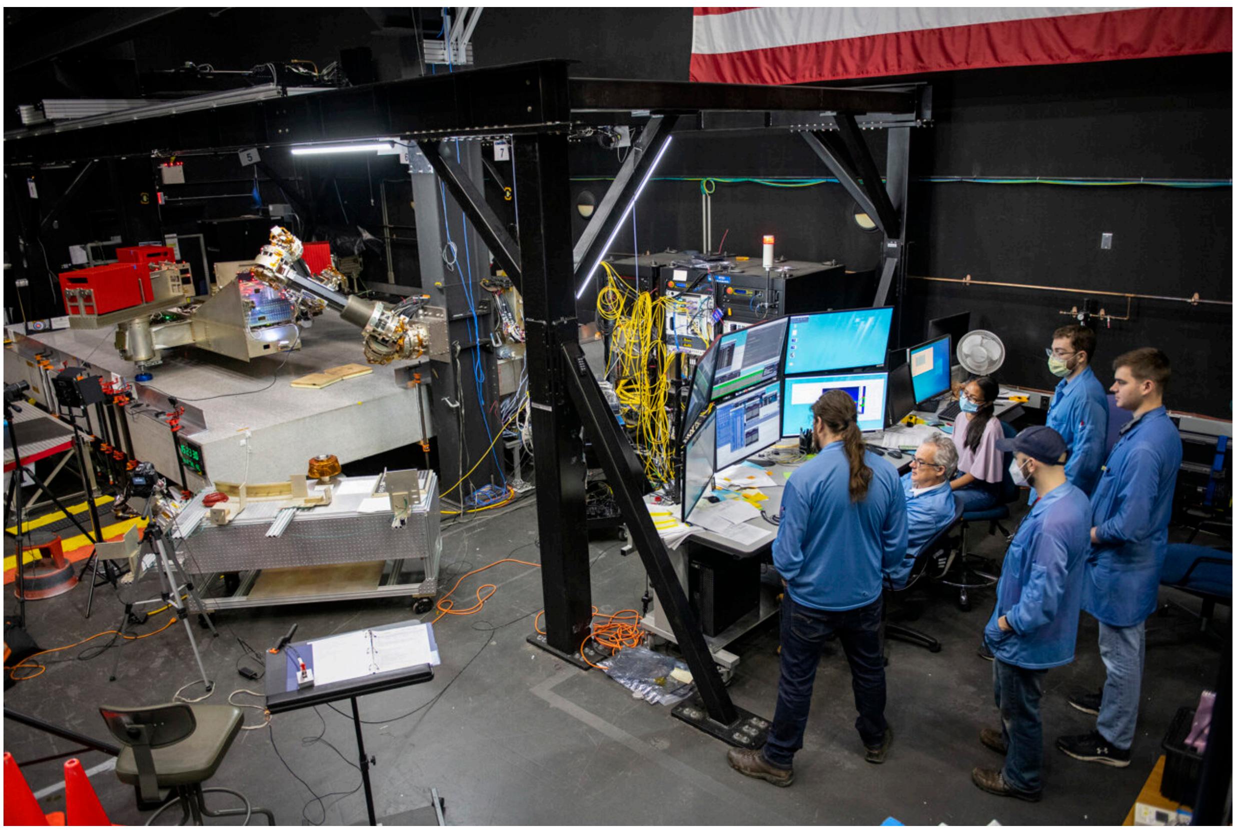
NRL engineers developed multiple power and control avionics running on a distributed SpaceWire network to support an extended duration mission to control all the sensors and actuators in a robust and redundant manner. NRL procured panchromatic and color cameras, alongside designing LED lighting units to provide situational awareness during robotic activities.

"Our algorithms team developed machine vision, position control, collision avoidance, and compliance control algorithms that support robotics control and enable autonomous grapple capabilities," Vincent said. "The algorithms are implemented in flight software which also provides all of the command-and-control functionality for the payload and provides control interfaces to the spacecraft bus."

Robotic motions require special planning to ensure safe spacecraft operations. NRL has developed the Integrated Robotic Workstation (IRW) to accomplish just that. The IRW supports mission planning for the development of new mission activities. Once a mission is planned, the IRW supports screening activities to prescreen all robotic motion commands in a payload simulator to verify command loads before they are sent.

Finally, using NRL's Neptune ground control software, the IRW commands all robotic payload activities and displays and trends payload telemetry during operations. To execute this effort, a skilled systems engineering team spent years performing system analyses, documenting requirements and interfaces, and generating a robust verification and validation plan.

"The engineers worked closely with the integration and test teams to ensure the system meets all requirements as it comes together for component, subsystem, and payload level testing," Vincent said. "Once complete, the robotic payload will enable the wide range of missions envisioned and future missions not yet imagined."



The U.S. Naval Research Laboratory's Robotic Servicing of Geosynchronous Satellites (RSGS) Integration and Test team analyzes data collected from contact dynamic testing on the robotic test bed in Washington, D.C. June 16, 2022. Contact dynamic testing allows the team to charaterize how the payload will behave when servicing client spacecraft. Credit: U.S. Navy/Sarah Peterson

The RSGS team recently completed environmental testing of the first of two flight robotic arm systems. This included simulating the launch environment in NRL's vibration lab, simulating both the vacuum and extreme temperature ranges of space in NRL's thermal vacuum (TVAC) Chamber, and ensuring electromagnetic interference (EMI) functionality in EMI chamber testing.

During TVAC testing, the robotic arm system demonstrated performance over temperatures representing actual on-orbit conditions. Under the harsh temperature and vacuum conditions of space, the robot arm performed a variety of operations including running pre-planned robotic calibration movements, tool actuation, and camera and light functions.

The second robotic arm system is integrated with a separate testbed that has the entire flight avionics suite. It is currently going through motion performance testing.

This fall, the second arm system will complete environmental testing. Robotic performance testing to demonstrate and verify robotic algorithms' function is underway in the Robotics Testbed (RTB) at NRL's Space Robotics Laboratory. The RTB consists of a non-spaceflight version of the flight robotic arm system and avionics hardware running flight software. This high-fidelity robotics testbed allows ground verification of many system-level robotic performance characteristics for the RSGS payload.

Compliance Control algorithm characterization and Marman Ring Detector algorithm performance characterization have been completed. Contact dynamics testing in the RTB is underway, which uses a sled floating on a thin layer of air to simulate the arm contacting client space vehicles ranging in mass from 75—3,000kg (165—6,613lbs.). Grapple, articulation, and release testing is scheduled later this summer.

The flight software team is preparing to start qualification testing. Testing takes place in a software testbed with a real-time dynamic simulation that generates simulated robot arm pose inputs for the robotic control algorithms and dynamic imagery for input into machine vision algorithms. This testbed allows the NRL team to test the flight algorithms with realistic control loops to fully verify the system thoroughly before launch.

"The systems engineering and verification efforts required by RSGS are extensive," Amy Hurley, NRL's Lead Systems Engineer, said. "It is amazing to see years of systems engineering and a strong verification and validation plan come together successfully."

Provided by Naval Research Laboratory

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