

Ground Demonstration of Autonomous Robotic Laser Beam Welding for In-Space Servicing, Assembly, and Manufacturing

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Abstract—In-space servicing, assembly, and manufacturing (ISAM) missions require robotic systems that can perform precise joining and repair tasks despite communication latency, thermal variation, diverse lighting conditions, uncertain workpiece geometry, and limited crew intervention. This work presents the Lunar Assembly and Servicing by Autonomous Robotics (LASAR) system, a ground demonstration of autonomous robotic laser beam welding and additive manufacturing capabilities relevant to future ISAM missions. LASAR integrates PickNik MoveIt Pro with the Rocket Lab Robotics xLink robotic arm. Both technologies are also used by NASA's Fly Foundational Robots mission, establishing a direct connection between terrestrial ISAM testing and future orbital robotic operations. The autonomy architecture combines model-based motion planning, collision-aware trajectory execution, autonomous seam detection, visual servoing for weld-tool alignment, coordinated laser and robot control, and supervisory remote operations. Operators at NASA Johnson Space Center (JSC) remotely commanded experiments performed at NASA Marshall Space Flight Center (MSFC). Thermal-vacuum tests evaluated robotic welding at extreme temperatures from approximately -40°C to 55°C , while additional tests incorporated a wire-feed mechanism for additive deposition and weld repair. The demonstrations advance perception-guided manipulation, remote operations, and in-space welding capabilities needed for scalable ISAM infrastructure.

Index Terms—ISAM, robotic welding, Fly Foundational Robots, visual servoing, thermal vacuum

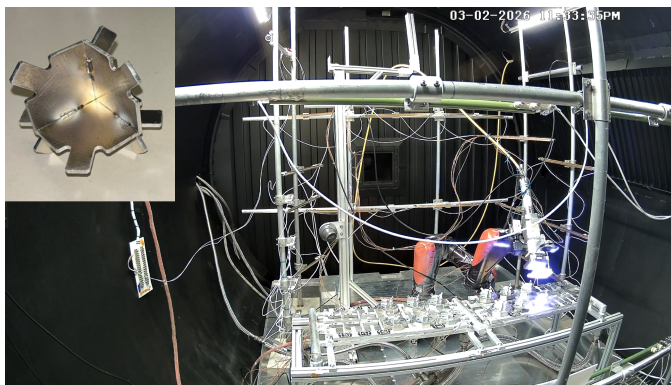


Fig. 1. The xLink robotic arm performing autonomous laser beam welding during LASAR thermal-vacuum testing over a temperature range of approximately -40°C to 55°C . (Inset) Example welded structure requiring three precise welds along orthogonal seams.

I. SYSTEM AND DEMONSTRATION

LASAR evaluates the integrated robotic capabilities needed to construct, modify, and repair structures after launch. The

LASAR system includes the Rocket Lab Robotics xLink arm¹, the Laserline LDM40-4000 laser generator², and OTS-5 laser optics³. A RealSense D405 camera⁴ provides perception of weld locations, while a Baumer camera⁵ supports visual servoing for weld-tool alignment. PickNik MoveIt Pro⁶ coordinates task sequencing, collision-aware planning, Cartesian tool motion, process-command interfaces, and operator supervision. Vision-based seam detection estimates the weld location and orientation, while visual servoing reduces residual tool-alignment error caused by workpiece-placement uncertainty, nondeterministic robot motion, calibration error, and thermal distortion.

The system was exercised through a three-center collaboration among NASA Johnson Space Center (JSC), Marshall Space Flight Center (MSFC), and Langley Research Center (LaRC), including geographically distributed operations between JSC and MSFC. Autonomous sequences included work-site observation, seam localization, tool alignment, approach planning, laser activation, seam traversal, laser deactivation, and retreat. Thermal-vacuum trials assessed the integrated robot, sensors, software, and welding process. Complementary experiments incorporated a wire-feed mechanism to investigate additive filler deposition.

The principal contribution is an end-to-end demonstration combining flight-relevant robotic hardware and software with autonomous seam localization, precision alignment, thermal-vacuum welding, additive deposition, and remote ground operations. The work provides ground-based risk reduction for Fly Foundational Robots capabilities, including reusable autonomy, precise manipulation, and supervised robotic execution.

¹<https://motivss.com/products-capabilities/robotics/xlink/>

²<https://www.laserline.com/en-int/products/high-power-diode-lasers/ldm-series/>

³<https://www.laserline.com/en-int/products/processing-optics/modular-ots-optics/welding-optics/>

⁴<https://www.realsenseai.com/products/stereo-depth-camera-d405/>

⁵<https://www.baumer.com/int/en/p/36661>

⁶<https://picknik.ai/pro/>