The Weldinator: Autonomous Precision Welding System Repair

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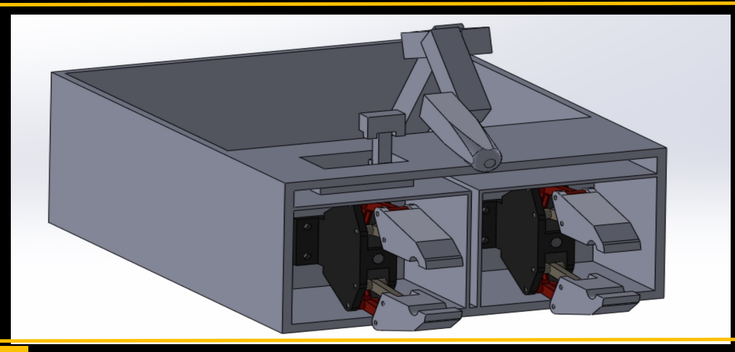
Project Objective

As space missions grow longer and more complex, infrastructure maintenance and in-space assembly are becoming essential. The Weldinator is a robotic payload designed to perform impulse laser welding on quarter inch stainless steel wire to create infrastructure in space autonomously. Our system address this by supporting the assembly, repair, and reinforcement of metal structures in space which will help extend satellite lifespans and reduce reliance on Earth based prefabrication.



System Level Requirements & Constraints

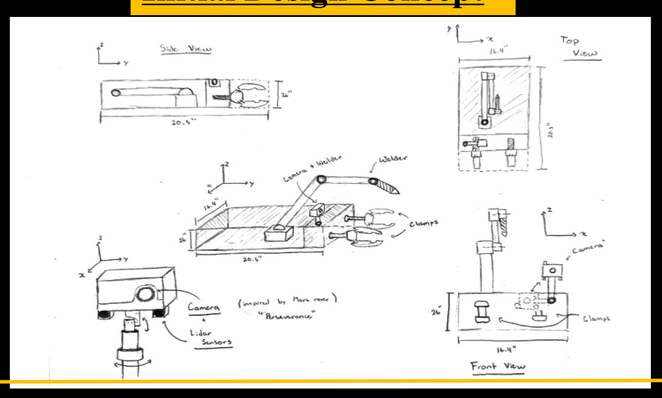
- Payload Volume: 17" x 16.4" x 27"
- Mass: ≤ 70 kg
- Energy Storage: 10.2 Ah battery, 444W max system draw
- Environment: Vacuum, microgravity, –157° C to +121° C
- Material Welded: 316 Stainless Steel
- Melting Point: ~1650 K
- Surface Temp: Can range from –270° C (shadow) to +120° C (sun)

Project Goals

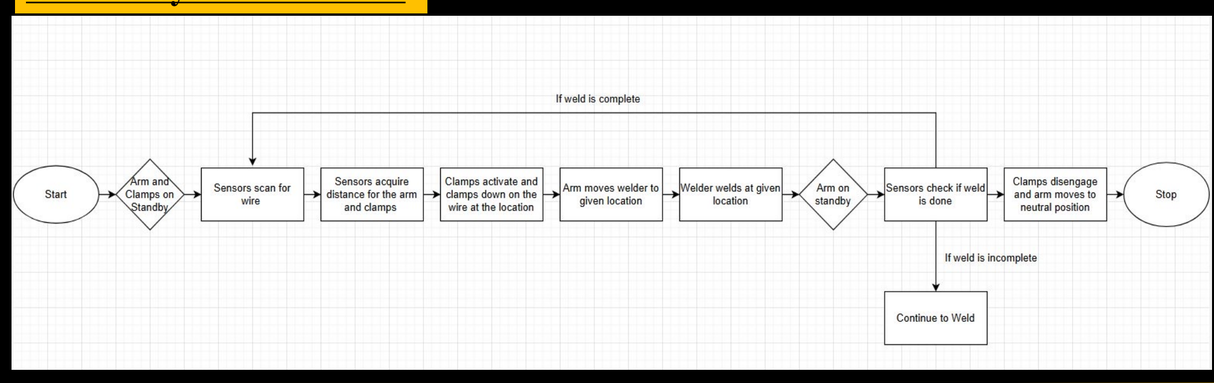
The Weldinator will autonomously weld ¼-inch stainless steel structures in Low Earth Orbit (LEO). The system is designed to:

- Operate within space-qualified environmental and power constraints.
- Require minimal human intervention after launch.
- Support In-Space Assembly and Manufacturing (ISAM) missions.
- Fit inside the X-Sat Venus-class bus payload envelope.
- Function using real-time sensor data and onboard feedback systems

Initial Design Concept



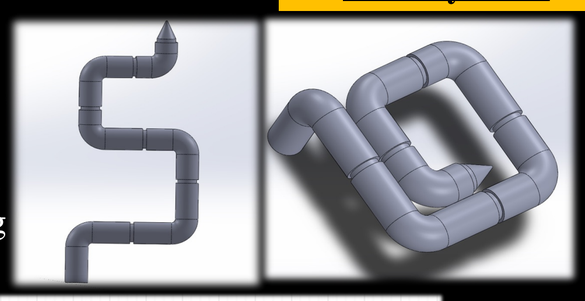
Overall System Function

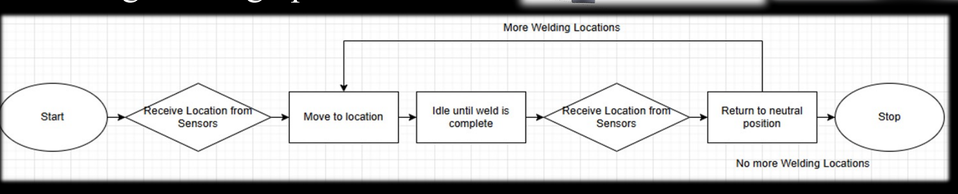


Core Systems

Robotic Arm

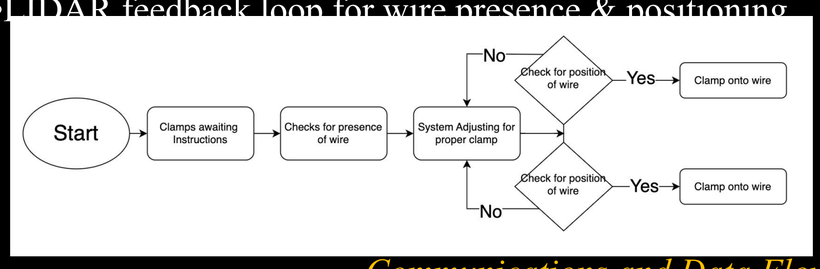
- 6 Degrees of Freedom, 22 kg
- Foldable for compact stowage
- 125–150 W power consumption
- Designed for precise positioning during welding operations

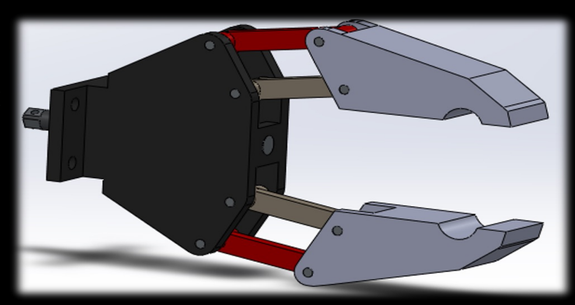




Stabilization Clamps

- T6-6061 Aluminum with space-grade solid Teflon lubricant
- Clamps onto wire or structure for secure welding base
- LIDAR feedback loop for wire presence & positioning

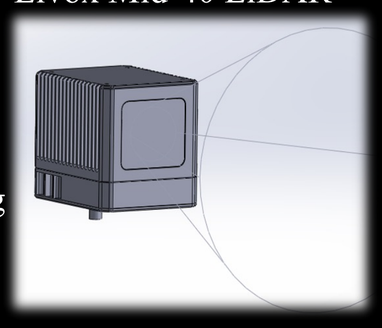




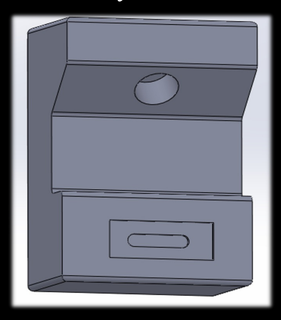
Sensors

- SmartRay ECCO X100 Vision Sensor
  - 100 mm FOV, 20 kHz scan rate, 1 Gbps data rate
- Livox Mid-40 LiDAR
  - 38.4° FOV, 2cm precision, 100k pts/sec
- Used for positioning, alignment, and weld monitoring

Livox Mid-40 LiDAR

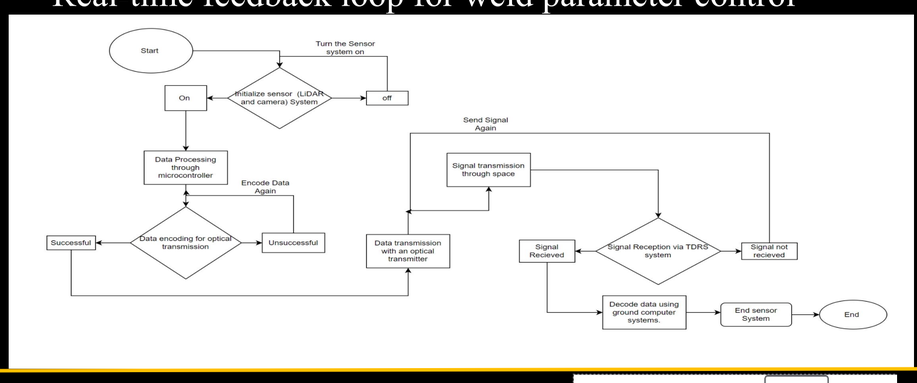


SmartRay ECCO X100



Communications and Data Flow

- Primary: Optical data transfer via Model 922-SFP transceiver
- Backup: RF via 922-DSL modem
- Bandwidth: 100–200 Mbps average, peaks up to 1 Gbps
- Real-time feedback loop for weld parameter control



Welding Module

- Impulse Laser Welding
  - 8.5 kW peak, 2ms pulse duration
  - Weld depth: ~2mm per pulse
- Low thermal spread makes it ideal for use in delicate space structures.

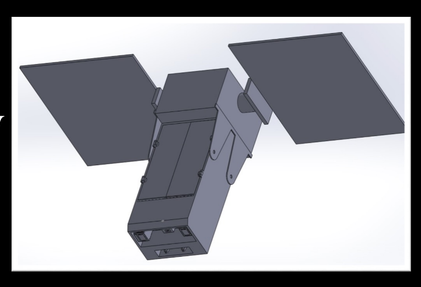
Operations

Pre-Launch

- Full environmental testing (thermal, vacuum, vibration)
- The payload was folded and loaded into the Atlas V 401 launch vehicle.

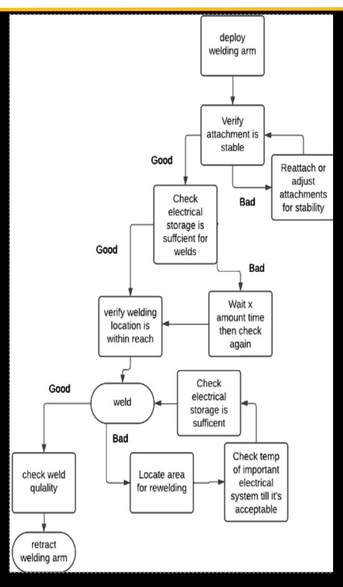
Deployment & Activation

- Launch to GTO → orbital insertion.
- Deployment of solar arrays, sensors, and comms
- System checks and autonomous startup



Welding Operation

- Sensors lock onto the target wire.
- Clamps stabilize material
- Arm positions welder for multi-pass laser welding
- Vision sensors + comms loop monitor results
- Optical data is sent to the ground for evaluation.
- A fallback RF channel is used if the optical link fails.



Trade Studies

- Welding: Impulse laser selected over MIG, TIG, and Electron Beam for energy efficiency, precision, and low heat spread
- Mobility: Robotic arm chosen over spider-bot, snake-bot, and free-flyers for its balance of TRL, accuracy, and energy use
- Sensors: Mid-size vision and compact LiDAR for resolution-to-weight optimization

Conclusion

The Weldinator is a semi to fully-autonomous, precision welding payload engineered for on-orbit construction and repair. Designed to fit within a compact 17" x 16.4" x 27" envelope and stay under 70 kg, it meets strict space and power constraints with a maximum draw of 444W. Its impulse laser module, delivering 8.5 kW peak pulses, enables deep, clean welds with minimal thermal spread—ideal for delicate in-space structures. The system combines a 6-degree-of-freedom robotic arm with SmartRay ECCO X100 vision sensor in-line weld detection and Livox Mid-40 LiDAR sensor to create mapping for which the Weldinator will be able to navigate itself. Stability during operation is maintained through T6-6061 aluminum clamps using solid Teflon lubrication, ensuring reliability in the vacuum and thermal extremes of Low Earth Orbit.

A robust dual-channel communication system transmits live telemetry and sensor data via a high-speed optical link, with RF fallback to ensure uninterrupted feedback and command flow. Built with rad-hard components, thermal shielding, and energy-efficient control systems, the Weldinator is capable of supporting In-Space Assembly and Manufacturing (ISAM) initiatives while extending the lifespan of orbital assets. Ultimately, this payload represents a critical step toward sustainable, autonomous infrastructure development in space, reducing dependency on Earth-based servicing and advancing the future of long-duration missions.