Preliminary Design Review(PDR)

Cosmic Challenge/Client: The Aerospace Corporation

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Project Constraints

Main Goal: Design a payload, to be hosted about the BCT X-Sat Venus Class bus, that will demonstrate a chain of 3 or more operations that provide an on-orbit, autonomous ISAM capability.

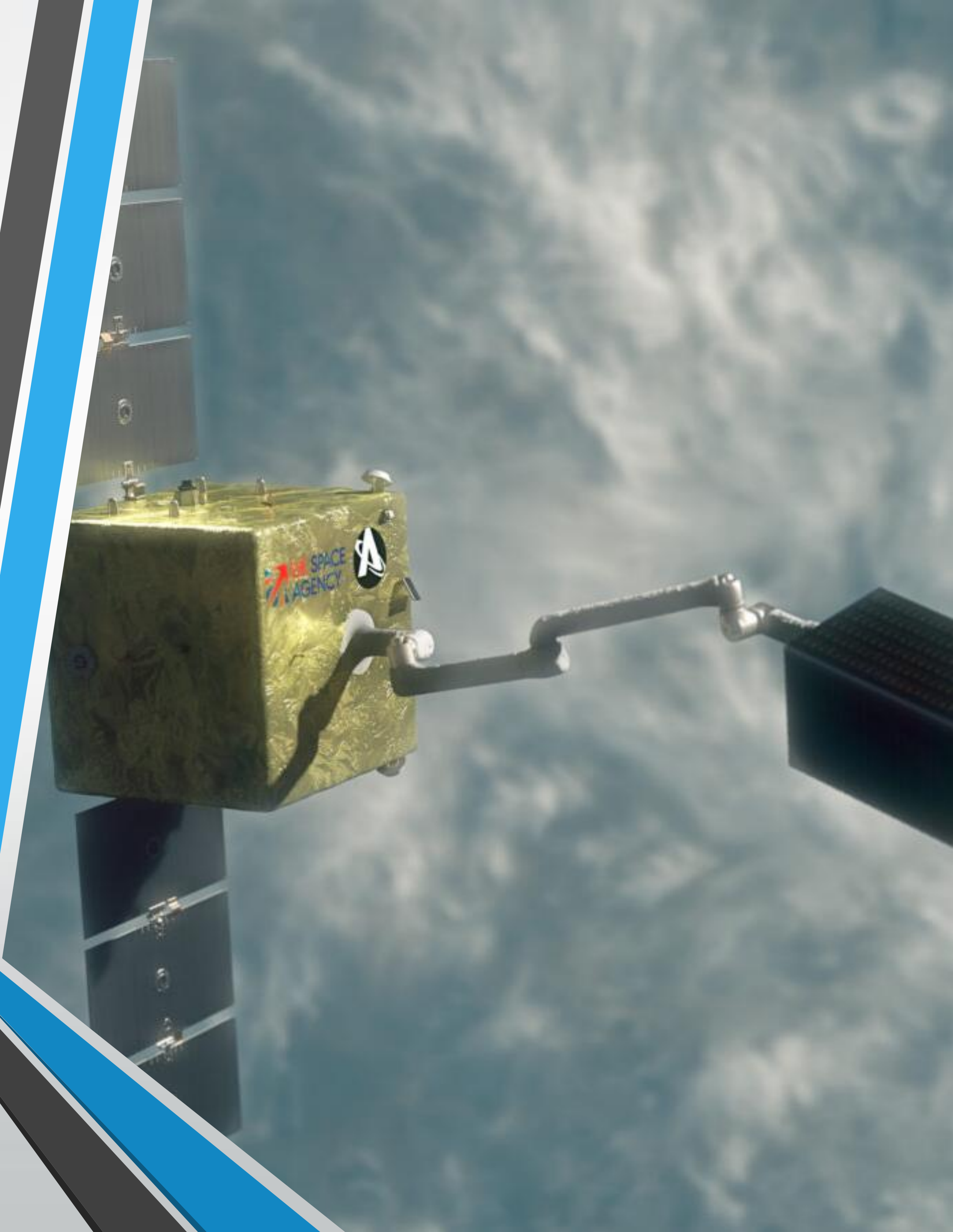
Constraints:

- Power: Two Solar Arrays(444W)
- Energy Storage: 10.2 Amp-Hour
- Mass: 70kg or 154 lbs
- Volume: 20.5” X 16.4” X 26”
- Fully Autonomous
- 3 or more Functions
- Must provide an ISAM capability

- Vacuum
- No gravity
- Wide temperature range (-157-121C)
- Micrometeoors

Potential objectives

- Welding brackets to aid in successfully deploying deployable
- To locate and analyze the situation to determine if the robot needs to act to repair the satellites fuselage
- "COSMIC" mission from astroscale our bot/machine can be used on this satellite



Aluminum 6061-T6

- Extremely heat treatable aluminum alloy, contains silicon and magnesium
- Mechanical and corrosion resistance properties
- Ultimate Tensile Strength = 310 MPa
- Tensile Yield Strength = 276 MPa
- Melting Point = 582-652 Celsius

Aluminum 7075-T6

- Contains high level of zinc in composition
- Has average corrosion and high fatigue resistance
- Compares to the strength of steel
- Ultimate Tensile Strength = 572 MPa
- Tensile Yield Strength = 503 MPa
- Melting Point = 477 – 635 Celsius

Materials (Trade-Study)

Criteria	Aluminum 6061-T6	Aluminum 7075-T6
E.O.W	Melting Point = 582-652 Celsius	Melting Point = 477 – 635 Celsius
S	UTS= 310 MPa TYS= 276 MPa	UTS= 572 MPa TYS= 503 MPa
C.E.S	Material common on: ISS (Fuselage) Apollo Spacecraft The Skylab	Material common on: Structural Skins for ISS

Summary – Trade Studies

Aluminum 6061-T6 has been selected

Material Requirements

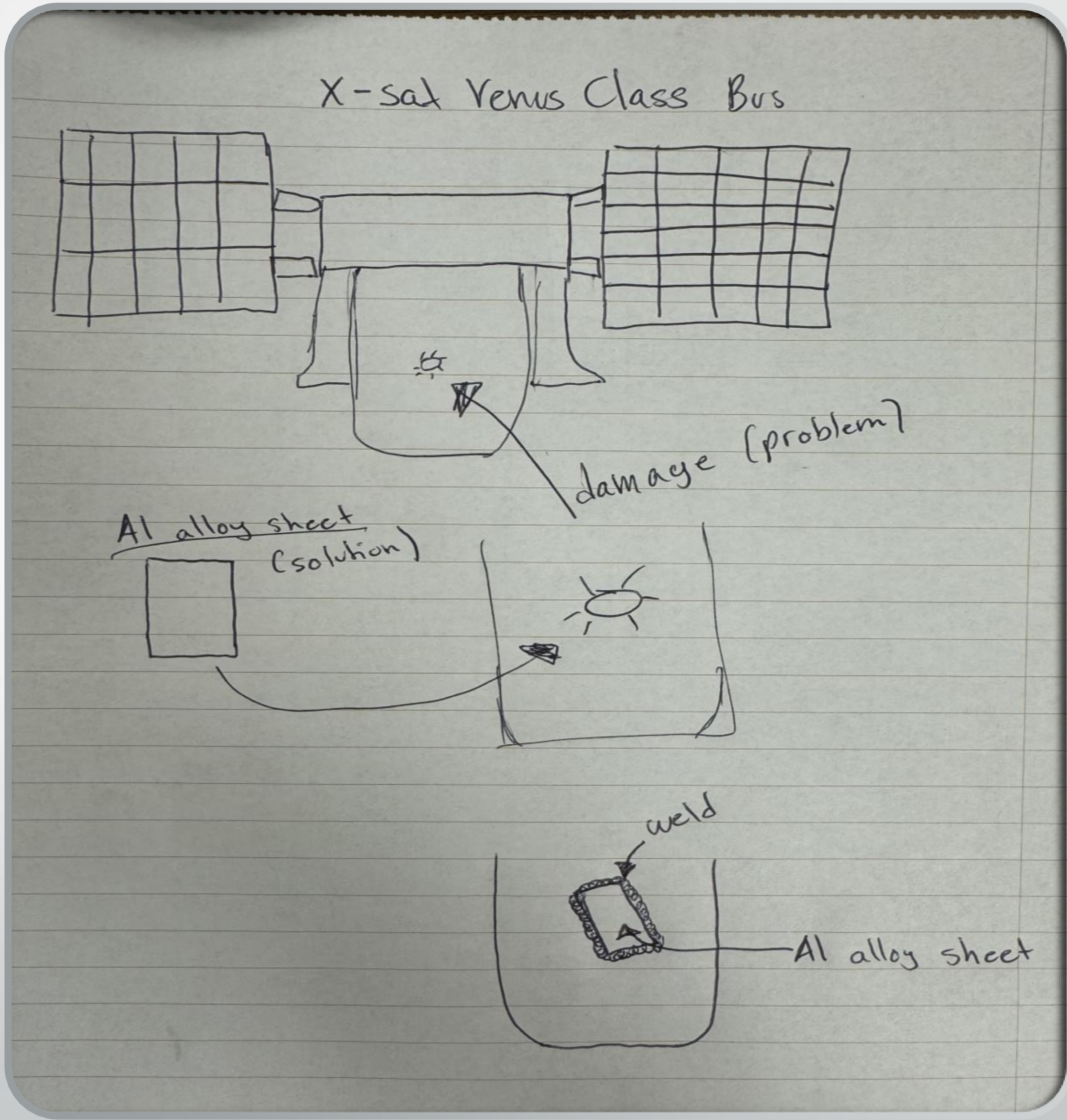
- Requirement 1: ease of weldability for the material, the melting point of the material will be determined
- Requirement 2: Must be lightweight and excellent material properties
- Requirement 3: Compatibility with existing systems for repair on existing systems

Example: Welding a Patch

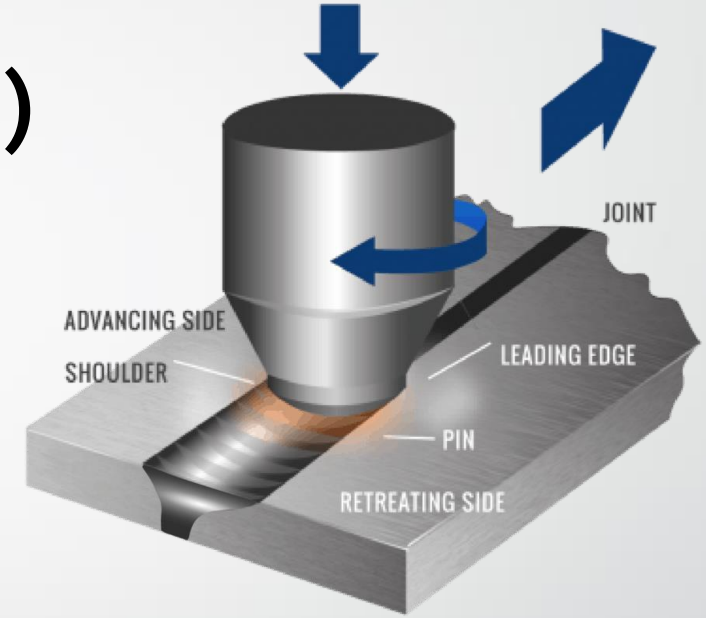
- By repairing damaged satellite by applying sheet of aluminum over damaged area.

- The material that has been researched is aluminum 6061
  - Good mechanical properties
  - Good for welding
  - Very common material used for making satellites
  - Lightweight and strong

- Our weld would take place around the sheet of metal onto the satellite to protect from further damage from micrometeoroids and radiation



Friction Stir Welding(Pros)



- Versatile can weld a variety of materials
- No consumables or waste bi-product
- Consistent and repeatable process

Friction Stir Welding(Cons)

Gaps: Since there is no filler material so gaps will need to be controlled

Workpiece: The head/tip wears out and will need to be replaced

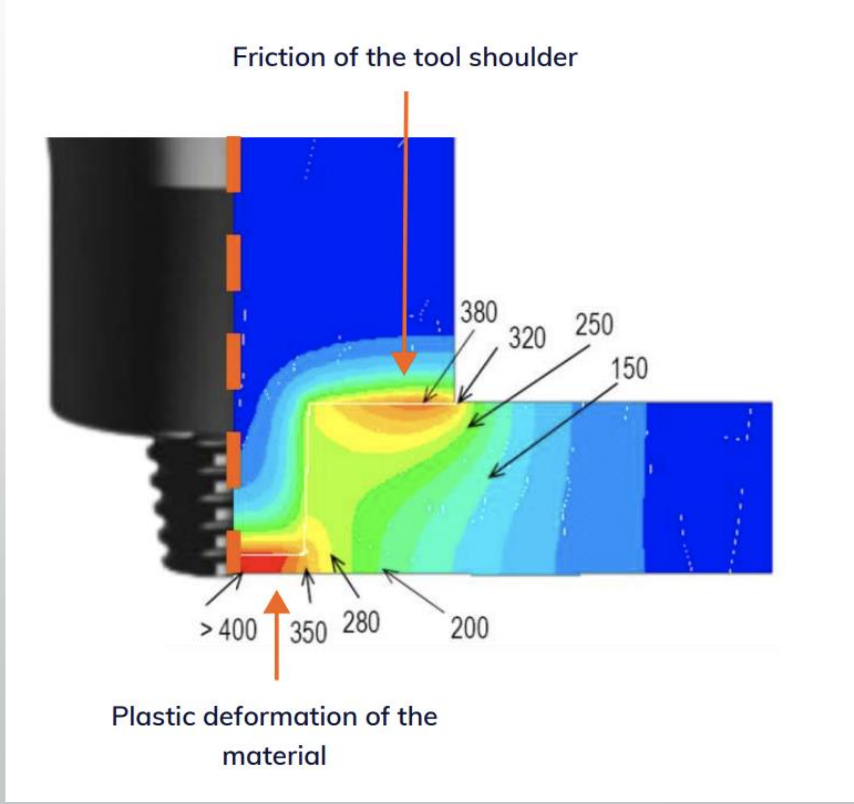
Size: typically, machines that exist are big and bulky

Power: Multiple Power consumption varies heavily on the thickness of the weld

Friction Stir Welding (Specs)

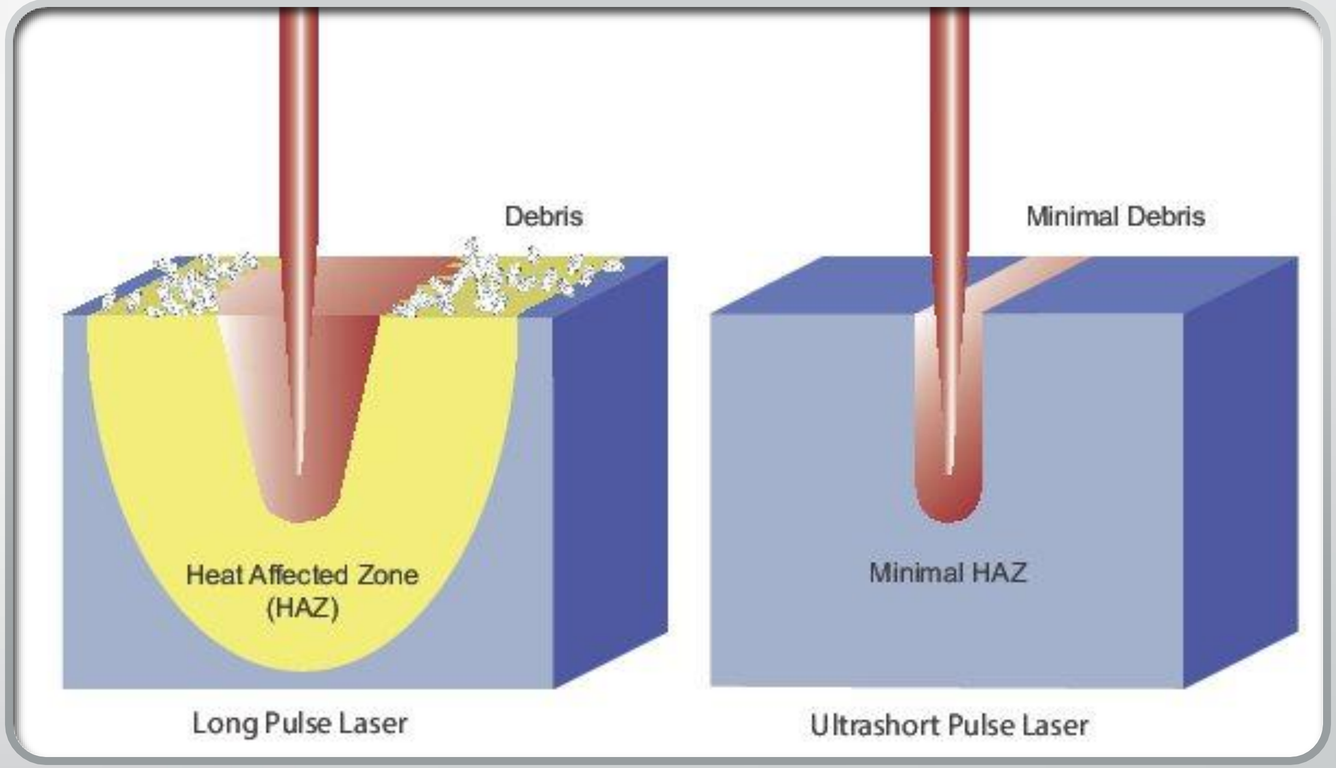
For 2 mm in thickness

- Power consumption- 100 watts over 15 seconds
- Operating temperature- ~450 C
- Down force- ~4082Newtons
- Travel force- ~890 Newtons
- RPM- 850 RPM
- Spindle- 300 watts at 2.8 Nm of torque
- Weld speed- 100mm/min



Pulse Laser Beam Welding(Pros)

- High Peak Power: allows for welding of reflective material and achieving deep penetration
- Minimal heat input: short pulse durations minimizes heat entering the part
- Precision: offers great precision compared to traditional welding methods
- Versatility: Suitable for a wide range of materials



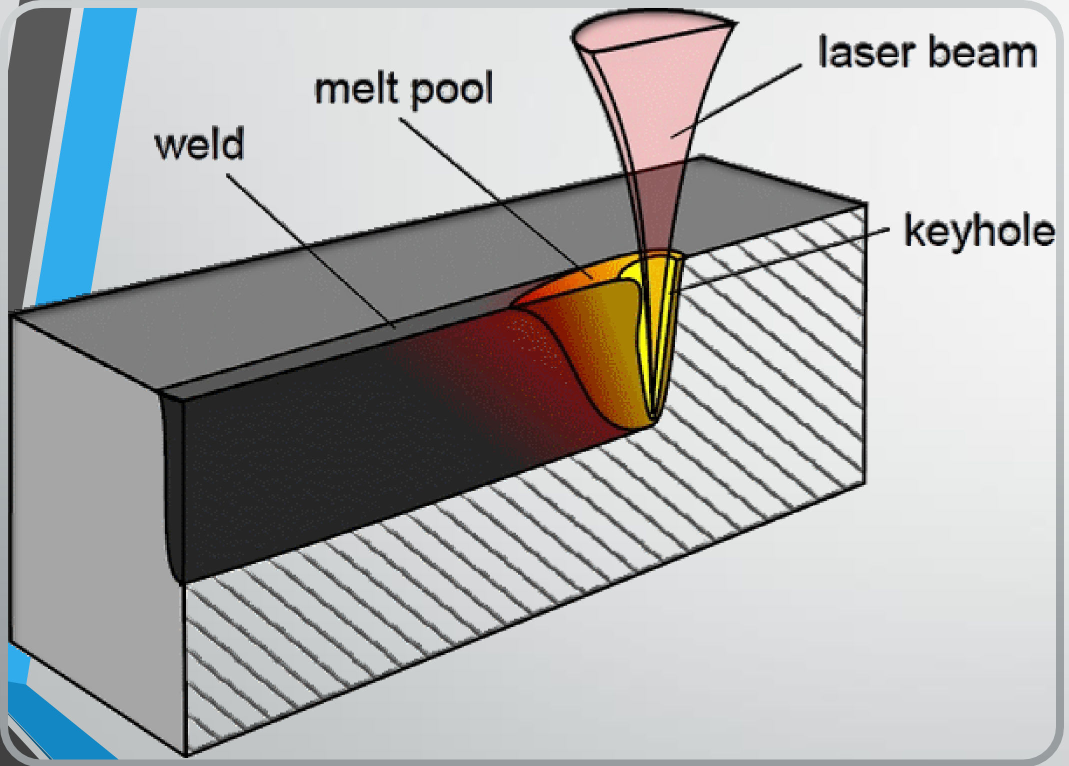
Pulse Laser Beam Welding (Cons)

- Power Limitations: While capable of higher peak powers the average power is typically lower than continuous wave lasers, potentially limiting penetration depth for some materials
- Limited Continuous Welding: Overlapping spot welds are required which isn't as efficient as continuous welding
- Positioning Requirements: Weldment must be precisely positioned within the focal range of the laser beam
- Heat dissipation/ transfer is limited to radiation in a vacuum

Pulse Laser Beam Welding (Specs)

- Maximum Mean Power: 400 W
- Pulse Duration: 0.2-20 ms a longer pulse duration results in a deeper weld
- Pulse Frequency:0-100Hz
- Spot Diameter: 0.2-3mm
- Welding Speed: 1.6-10 mm/s
- Weld Penetration is influenced by Spot Diameter and Welding Speed
- Material thickness varies because of the parameters like welding speed and spot diameter but will use 0.5-3mm thickness

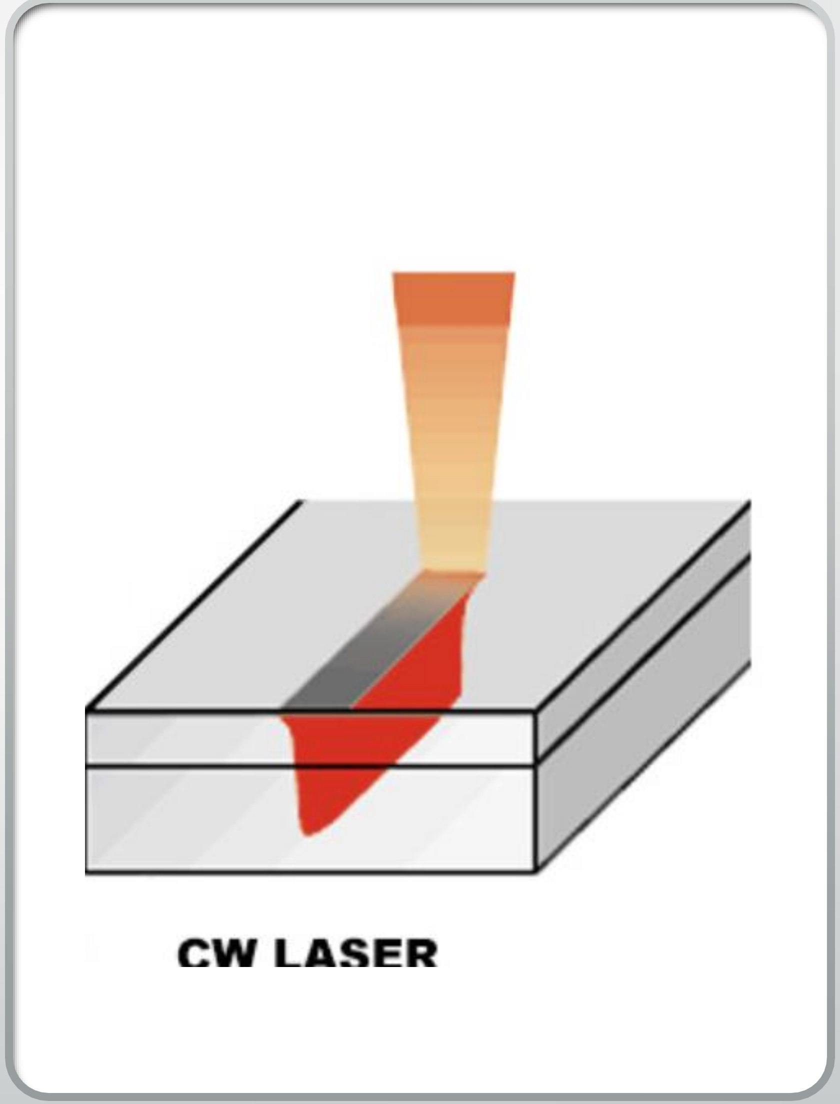
Continuous Laser Welding Pros



- Power Requirement: Min(220w) Max(1000+ w) We'll use around 300w or less
- Material thickness: Because of the low wattage we'd use between 1-5mm
- High Welding Speed: CW laser welding offers a continuous beam that allows for high-speed welding, which is beneficial for large volume or rapid production needs.
- Consistent Energy Delivery: The continuous nature of the beam provides stable energy delivery, resulting in consistent and reliable welds.
- Deep Penetration: CW lasers can achieve deep weld penetration, which is useful for thick materials that require strong joints.
- Minimal Heat Affected Zone: The focused energy delivery minimizes the heat affected zone around the weld, reducing thermal distortion and preserving the properties of the base materials.
- Versatility: CW laser welding can be applied to a variety of materials including metals and thermoplastics, enhancing its utility across different industrial sectors.

Continuous Laser Welding Cons

- High Power Consumption: Operating at continuous high-power levels can be energy-intensive, which may not be cost-effective for all applications.
- Potential for Excessive Heat Buildup: Continuous energy output can lead to excessive heat buildup, potentially affecting the microstructure of the material being welded.
- Limited Control Overheat Input: Unlike pulsed laser welding, CW laser welding offers less control overheat input, which can be a disadvantage when welding heat-sensitive materials.
- Safety Considerations: The intense and continuous laser beam requires stringent safety measures to protect operators from potential harm, including burns and eye damage.



Continuous Laser Welding Specs

- Power Requirement: Min(100w) Max(1000+ w) We'll use around 300w or less
- Material thickness: Because of the low wattage we'd use between 1-5mm
- Feed Rate: 25-100 inch per min
- Penetration: 0.060 inches
- Beam Width: 0.5mm
- Frequency: 20-50khz
- Power adjustment range (%): 10-100
- Beam Quality(M2): 1.1-2.7bpp

On-Orbit Repair (System Trade Summary)

Specs	FSW	Pulse Welding	Continuous Welding
Power (W)	5kW-20kW	400 W	220-1000+ W
Feasibility	Unlikely due to power consumption	Possible. Make it efficient	Highly unlikely due to power consumption
Material Thickness Penetration	2mm	Depends on spot diameter and welding speed(0.5-3mm thickness)	1.5 mm
Quality of Weld	Good if power wasn't an issue	Good for thin materials	Bad due to lack of heat for fusion
Limitations	Power consumption, thermal management	Avg power is lower than other methods, limiting penetration depth	Potential for excessive heat buildup

Summary- System Requirements

Pulse Laser Welding has been selected

Functional Requirements

- Requirement 1: Be able to locate damaged location
- Requirement 2: Be able to relocate material to weld location
- Requirement 3: Be able to weld a piece of metal to satellite structure

Ultrasonic Pros and cons

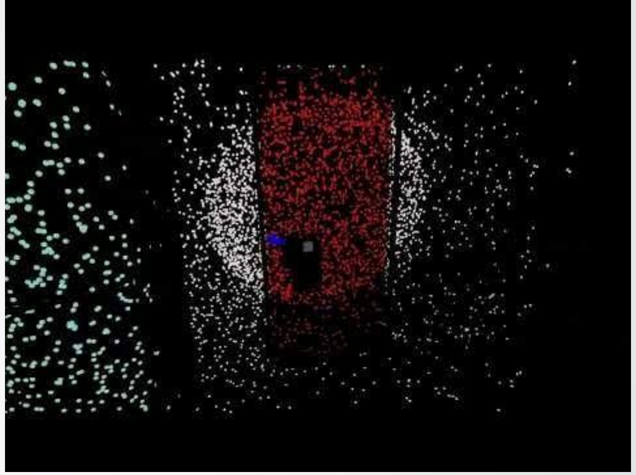
- Pros:
- Cost-effective: Ultrasonic sensors are relatively inexpensive compared to LiDAR sensors.
- Simple design: They are easy to use, install, and maintain.
- Works in darkness and transparent environments: Ultrasonic sensors can operate in low-light or completely dark conditions and detect transparent objects like glass.
- Wide range of materials detected: Effective for detecting various materials (e.g., metals, liquids, and solids).
- Durability: They are robust and can withstand harsh environments like dust, moisture, or vibrations.
- Doesn't allow dust/dirt particles to disrupt imagery

- Cons:
- Limited range: Ultrasonic sensors have a shorter detection range, usually a few meters at most.
- Slow response time: The speed of sound propagation limits their responsiveness.
- Environmental interference: Performance can degrade in extreme temperature variations or low-pressure conditions, such as those in space.
- Accuracy limitations: Not as precise as LiDAR for measuring distances or mapping.
- Beam width: The sensor’s wide beam can lead to inaccurate readings in cluttered environments.

Ultrasonic specs

- Range:
  - Typical: 0.02 m to 10 m
  - Maximum: ~15 m (depending on the model)
- Accuracy: ±1% to ±3% of the measured distance (lower precision compared to LiDAR)
- Operating Frequency: Typical: 20 kHz to 80 kHz
- Response Time: 50 ms to 200 ms (relatively slow)
- Field of View: Wide beam angle: ~15° to 45°
- Power Consumption: Low: Typically 10–50 mW
- Temperature Range: -20°C to 70°C (may degrade in extreme conditions like space)
- Weight: A few grams to ~50 g
- Environmental Sensitivity: Affected by temperature and air pressure (not suitable for vacuum environments like space)

LiDAR



Pros:

- High precision: LiDAR offers extremely accurate distance measurements and detailed mapping.
- Longer range: It can detect objects at much greater distances, often exceeding 100 meters.
- Fast response time: LiDAR operates at the speed of light, making it much faster than ultrasonic sensors.
- 3D mapping capabilities: Capable of generating 3D models of environments, useful for navigation and exploration.
- Directional focus: A narrower beam allows for more precise measurements without interference from surrounding objects.
- Rapid pulses of light reflected off surfaces that can generate 3d mapping by generating a set of dots to reflect the object
- Will help determine the location on the satellite that requires the robot's service

Cons:

- Expensive: LiDAR systems are more costly than ultrasonic sensors.
- Environmental sensitivity: Performance can be affected by reflective surfaces, fog, or dust, although space's vacuum environment mitigates these issues.
- Complexity: More complex to operate and maintain compared to ultrasonic sensors.
- Power consumption: LiDAR typically consumes more power, which can be a critical factor in space applications.

LiDAR Specs

- Range:
  - Short-range models: 0.1 m to 10 m
  - Long-range models: Up to 300 m or more
- Accuracy: ±1 mm to ±2 cm (much higher precision compared to ultrasonic)
- Scanning Rate: 10 Hz to 1 MHz (very fast response)
- Field of View:
  - Horizontal: Up to 360° (rotating LiDAR)
  - Vertical: 30° to 90° (depending on design)
- Power Consumption: Typically 2–20 W
- Operating Wavelength: Near-infrared: ~850 nm to 1550 nm (eye-safe wavelengths)
- Weight:
  - Compact models: ~100 g
  - High-performance models: ~500 g to 2 kg
- Temperature Range: -40°C to 85°C (space-ready models available for extreme conditions)
- Environmental Sensitivity: Works in a vacuum but may be affected by highly reflective or non-reflective surfaces.

LIDAR vs Ultrasonic

LiDAR will be our method of visual analysis due to it working in a vacuum

Specs	LIDAR	Ultrasonic
Range	25 meters	20 meters
Imagery type	2D/3D	2D/3D
median	light	sound

References

- https://www.nasa.gov/centers-and-facilities/white-sands/micrometeoroids-and-orbital-debris-mmod/
- https://www.researchgate.net/figure/The-forecast-of-space-debris-increase-NASA-low-Earth-orbit-LEO-medium-Earth-orbit_fig1_337294533

Thank you so much for responding and have made the necessary changes given the feedback.
To Horrace,
We made slide 4 to talk about problems in space that exist and we chose the problem of damage on satellites to be our purpose.

Slide 5 is telling the audience the problem we are looking at and why it is important to have a robot to repair damage as there is a growing issue of space Junk in space.

Chart 5 shows the growing issue and is being quantified for the reader to see.

Slide 6, the goal is for the welder to be able to patch damage and if need be weld two sheets together to cover damage.

Slide 10, Pulse has been spelled correctly now. Specs for all welding technology is on the slides, you will find them on slides 9, 12, and 15.

Slide 13, The requirement will be to penetrate less than the thickness of the satellite's wall

General Comment: Added a slide dedicated to a lidar sensor for the robot to be able to detect the damage.

TO MIKE
Slide 4, we briefly considered a mission from astroscale, but we are unsure if we should mention it in potential objectives