COSMIC Capstone Challenge: Final Briefing

Space Bender Team, Cal State LA: Space Wire Bender

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Agenda

Team Overview

Space Wire Bender

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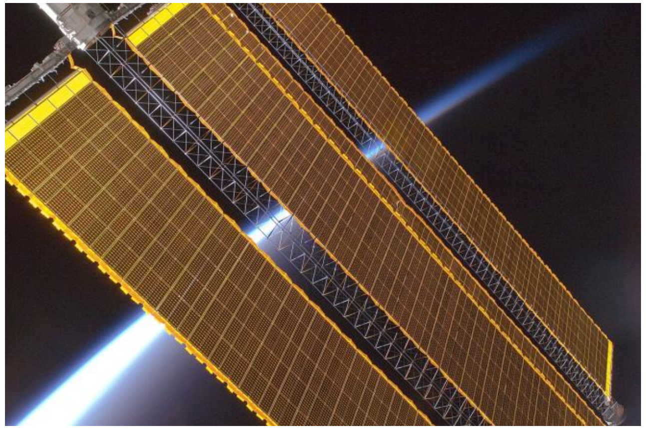
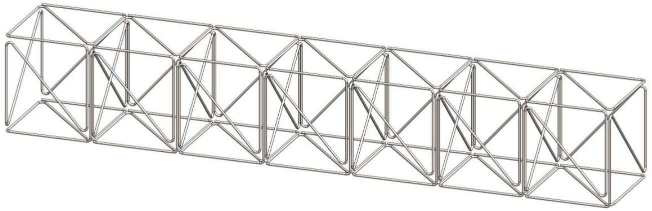
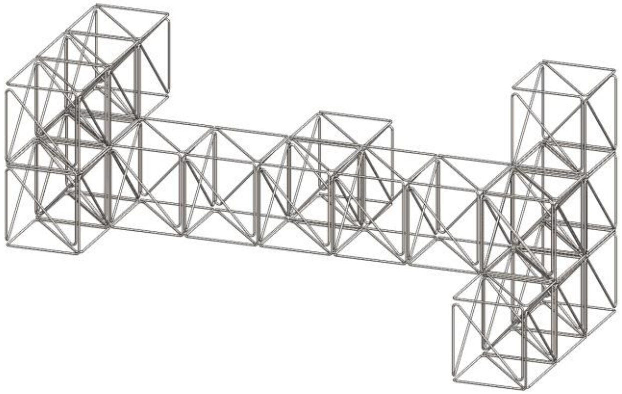
Executive Summary

Space Wire Bender

- The Problem
  - Expensive, time-consuming boom construction in-space
  - Restricted boom designs
- The Solution
  - Bend wire to form truss blocks in-space
- How it Solves the Problem
  - On-site fabrication → fewer launches, shorter timeline
  - Trusses: any size, shape & length
- Current State
  - Conceptual design complete

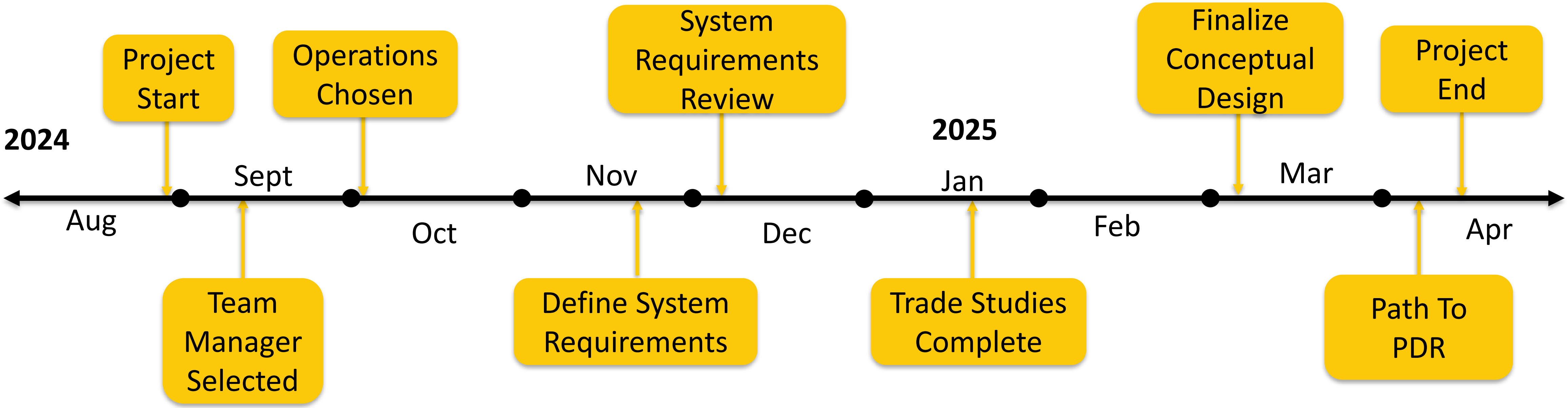






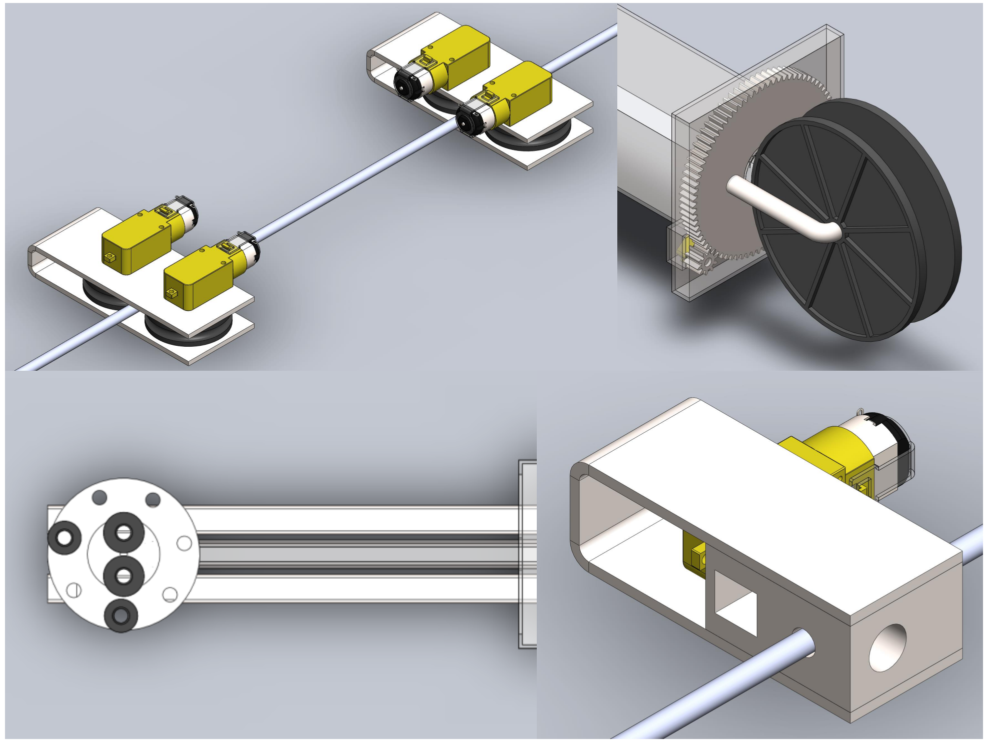
System Engineering Milestones Chart

2.5 System Engineering



ISAM Capability & Operations

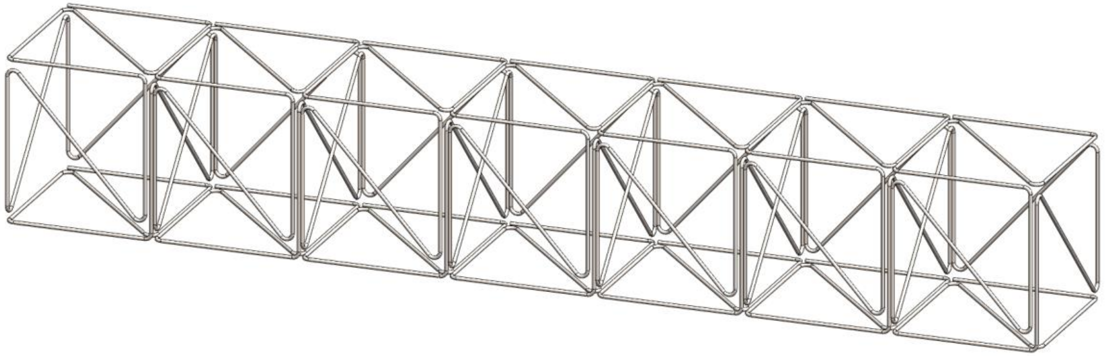
- Capability: bending wire to form truss blocks in orbit
- ISAM Operations
  - 1) Draw wire from spool
  - 2) Rotate wire with spool
  - 3) Bend wire
  - 4) Cut wire
- Subsystems
  - Feed
  - Rotator
  - Bender
  - Cutter

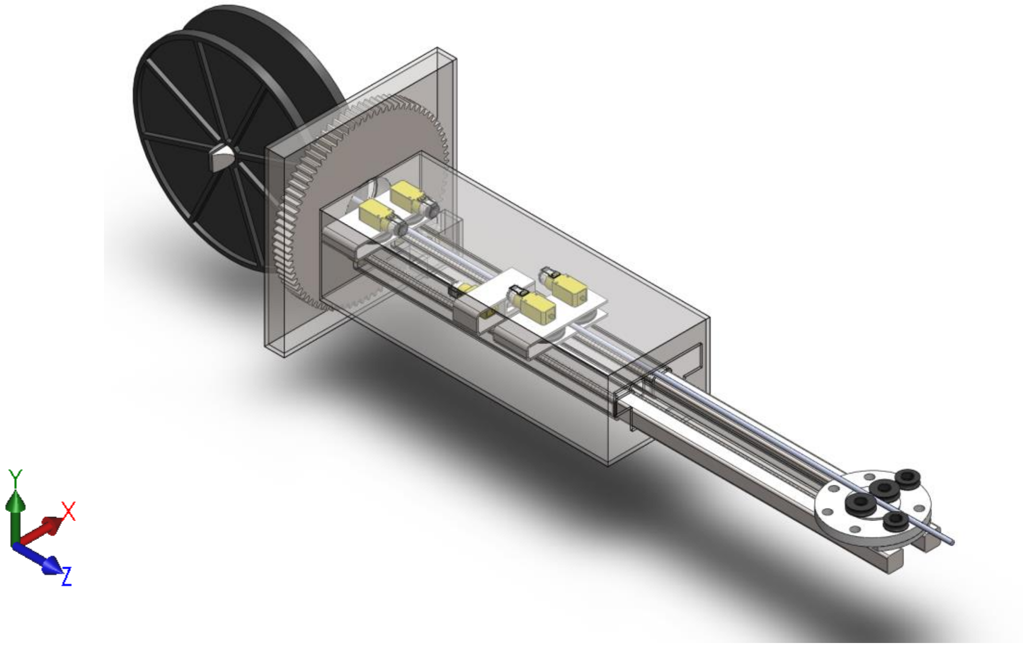


Impact

1.1 Impact

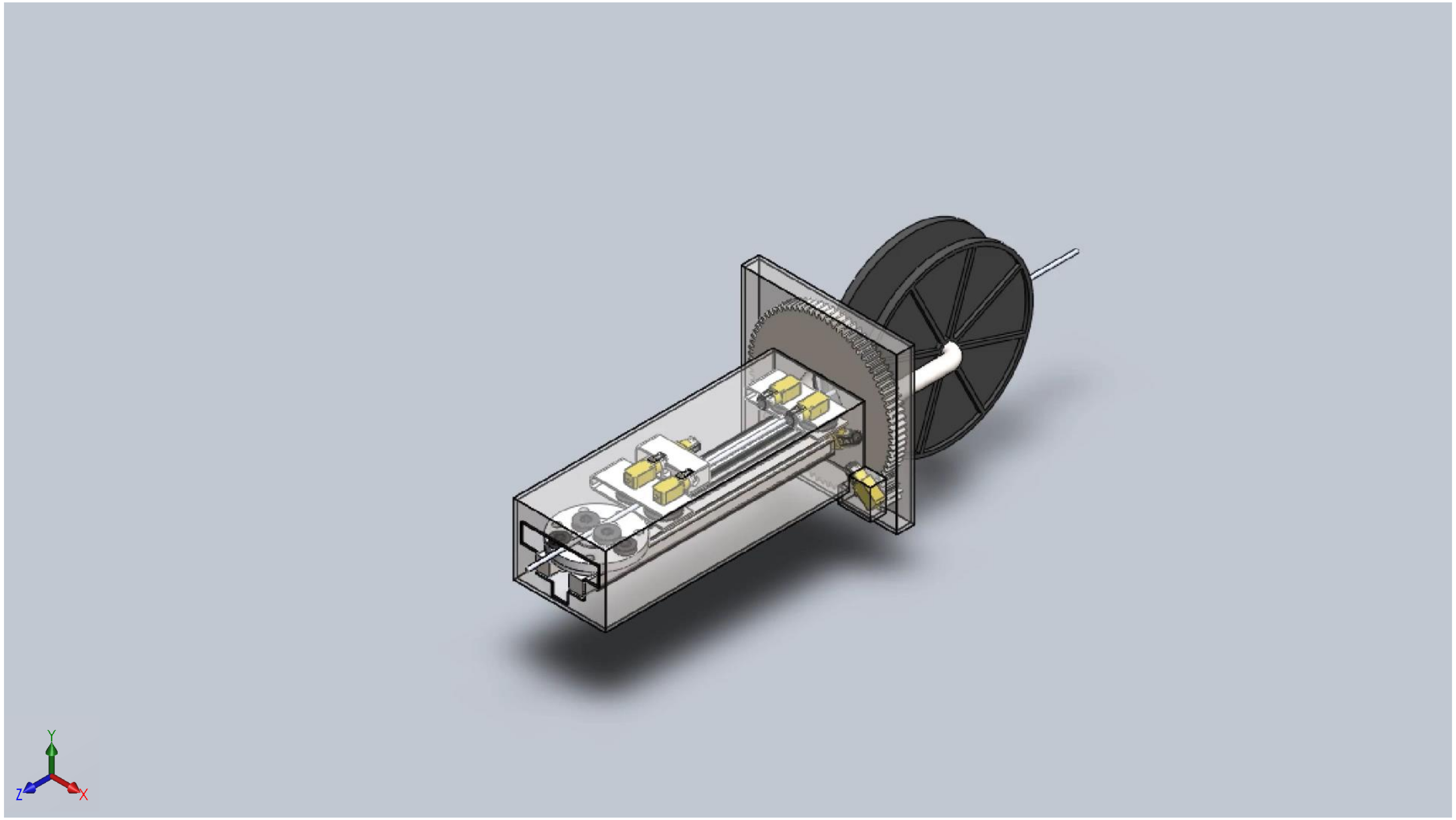
- Creates trusses in space without size or weight limitations
- augment or repair existing satellites by providing pieces of framing
- Technology is an application of what we do on Earth modified to work in space
- Technology needed to join nodes & assemble blocks





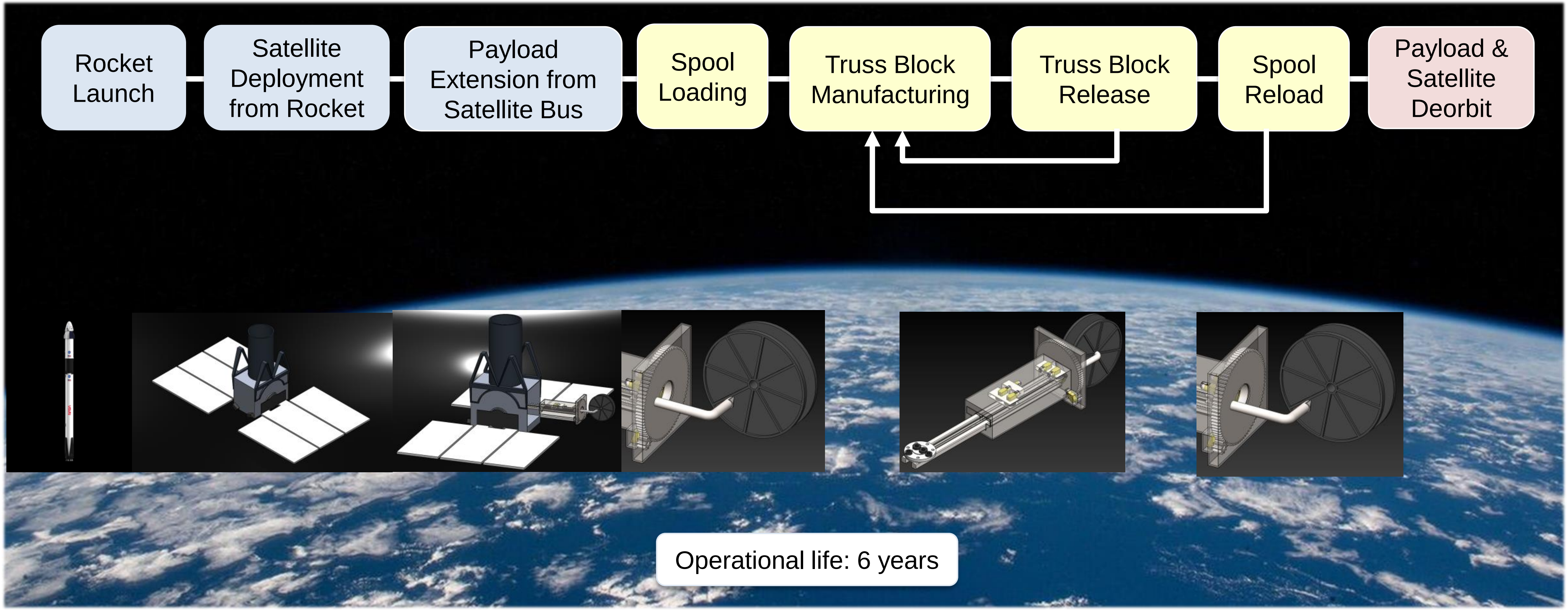
ISAM Operation/Subsystem Animation

2.1 Animation of Key Operating Sequence



Storyboard Chart

2.2 Storyboard of Operation



Feed Mechanism Chart

1.7 Trade Studies

Blue - great
yellow - okay
red - bad

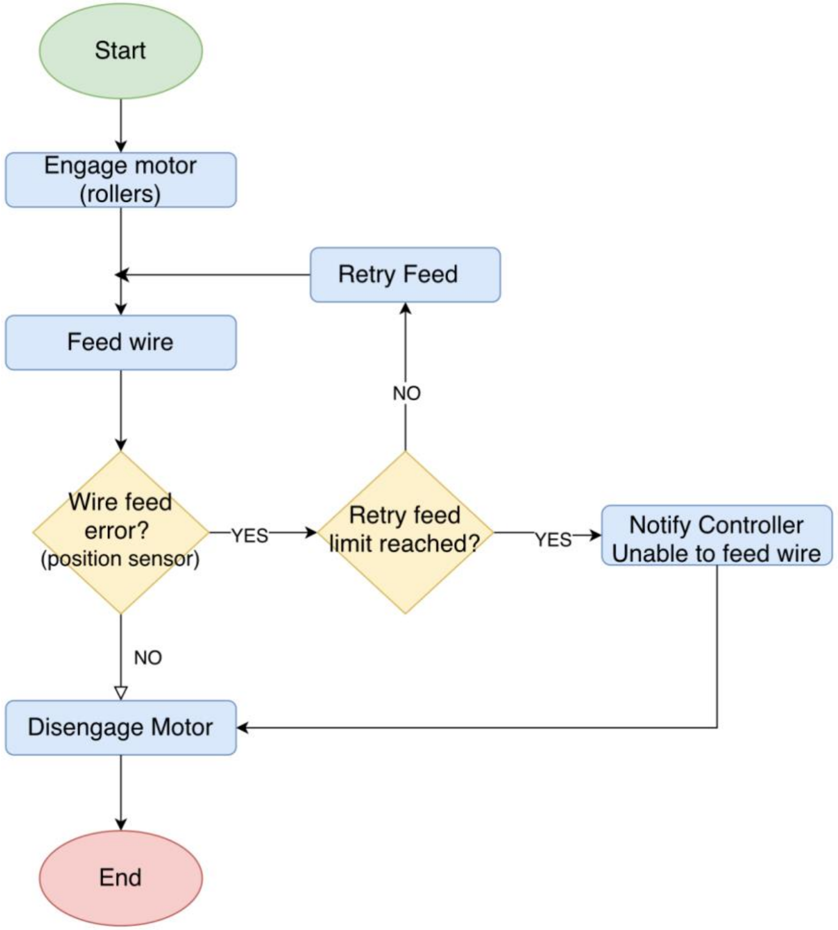
***Evaluating roller types for material feeding system.**
***Scoring matrix: 1–5 (5 = best overall choice).**

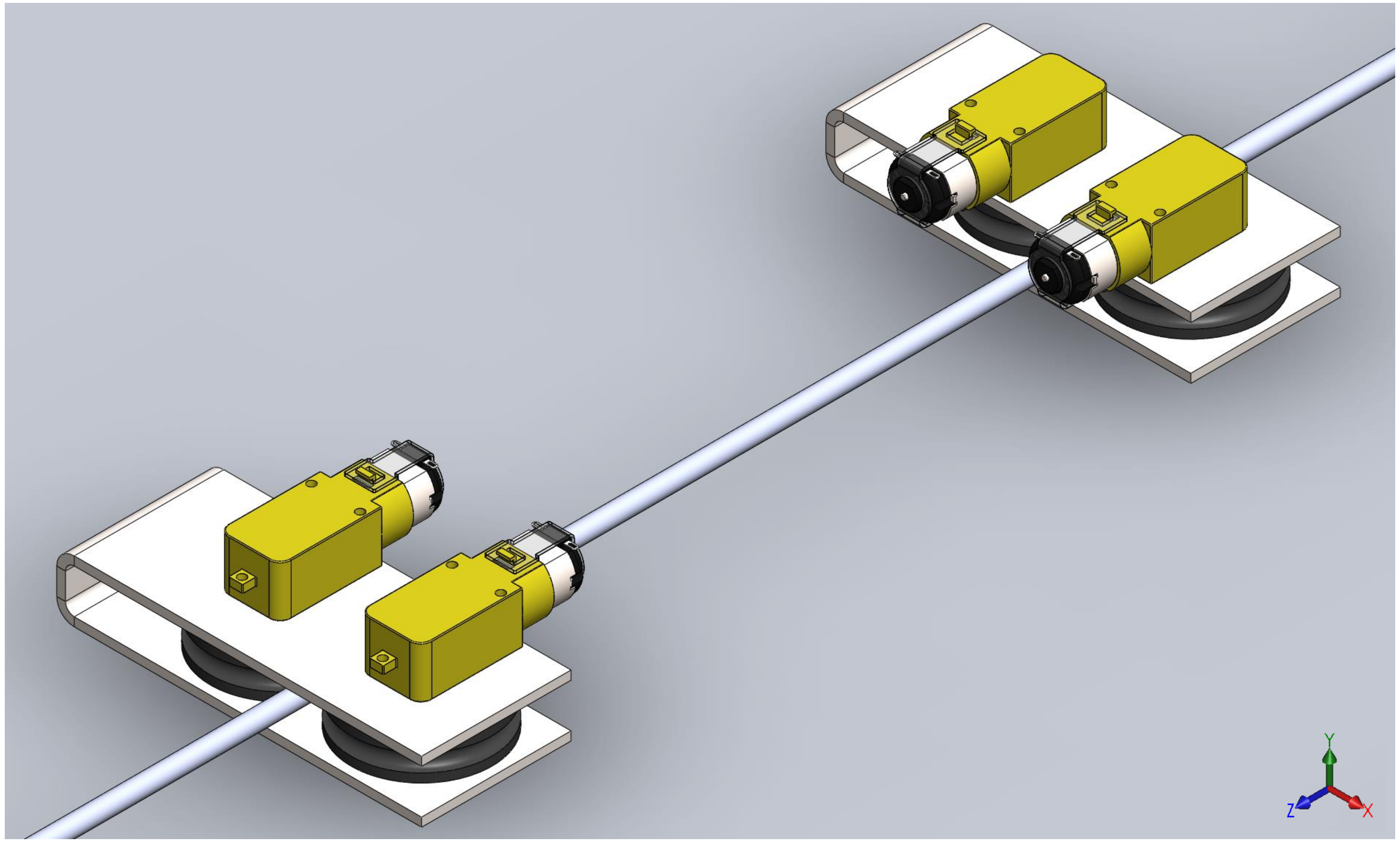
Type of Roller	Roller Weight	Durability	Power Requirement	Load Capacity	Maintenance Needs	Total Score
Belt Driven Roller	2	1	3	4	2	~~12~~
Chain Driven Roller	1	5	2	5	2	~~15~~
Motor Driven Roller	4	5	2	4	4	**19**

Motor driven Rollers are the best choice-Highest load capacity durability and low maintenance

System Architecture

Feed





Rotator Mechanism Chart

1.7 Trade Studies

Requirement	Spool Arm & Gear	Spool Arm & Internal Gear	Wire Clamp
Holds Spool	5	5	1
Precision	5	5	3
Mass	1	1	5
Volume/Footprint	2	1	5
Torque	5	5	2
Total	18	17	16

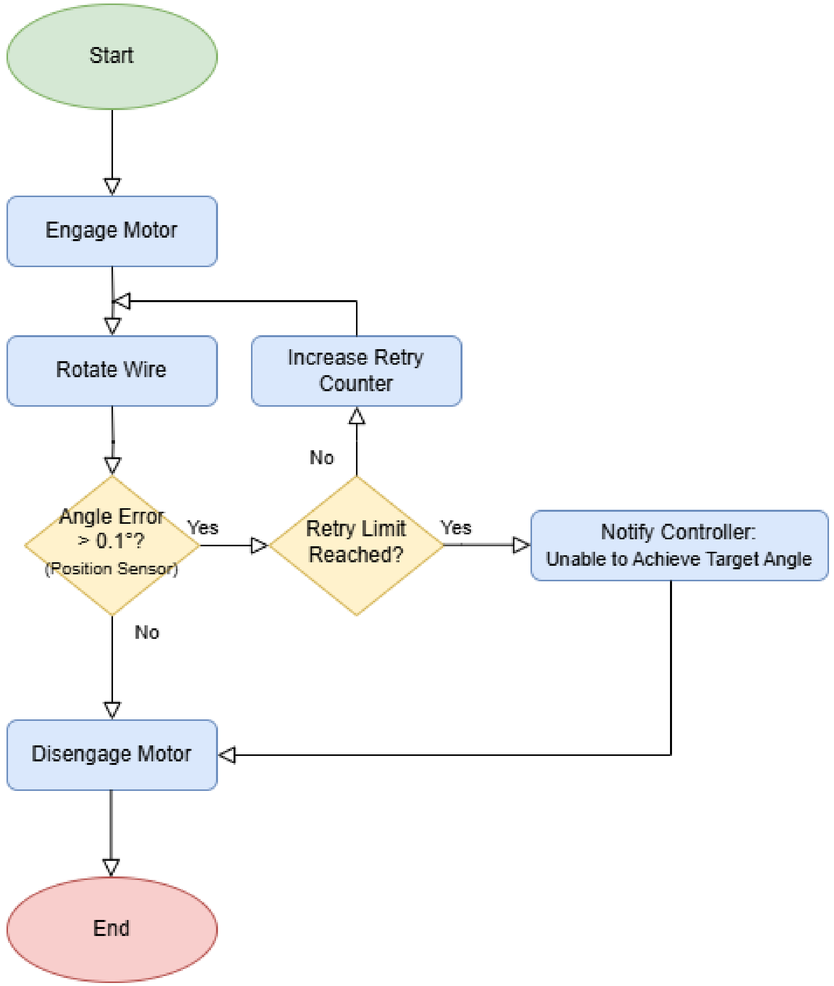
5-Point Scale

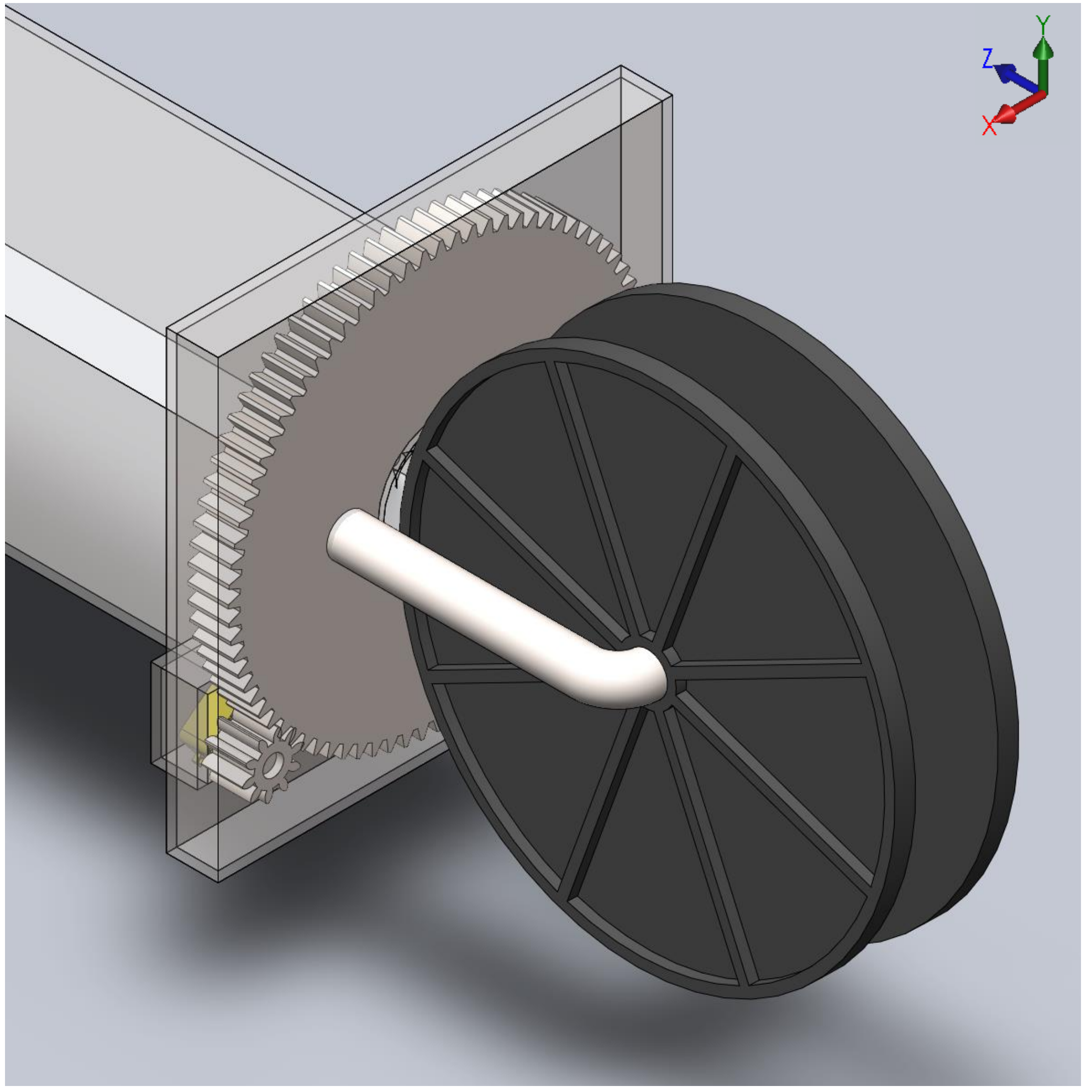
Blue - Great
yellow - Okay
red - Bad

Spool arm & gear- Best precision & torque while able to hold spool

System Architecture

Rotator





Bender Mechanism Chart

1.7 Trade Studies

Requirement	Air bending	3-point bending	Rotary Bending	Roll Bending
Speed(1)	Very Fast	Middling speed	Fast	Fast
Component complexity (2)	Very Simple	Moderately Complex	Moderately Complex	Simple
Part complexity (4)	Simple Fabrication	Middle Fabrication	Complex Fabrication	Simple Fabrication
angle Range (5)	Medium Range	High Range	Large Range	Medium Range
low die number(3)	Many Dies	Few Dies	1 Die	Many Dies
Size(3)	Smal footprint	Medium Footprint	Small Footprint	Medium Footprint
Total	~~43~~	~~53~~	75	~~50~~

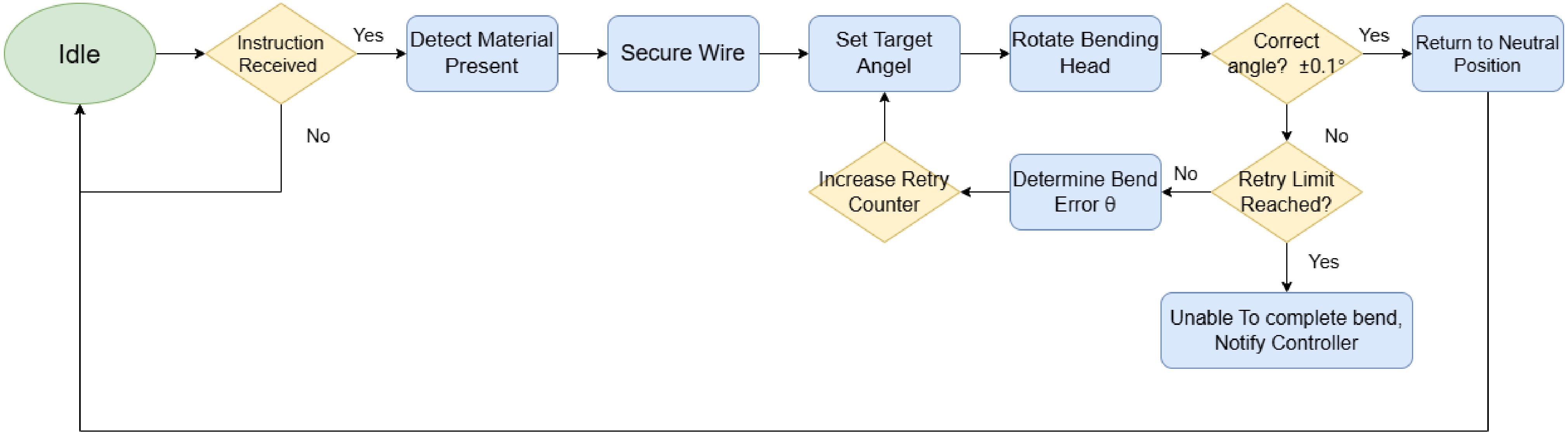
Each criteria graded on a 5-point scale then multiplied by criteria weight total scores are out of 80

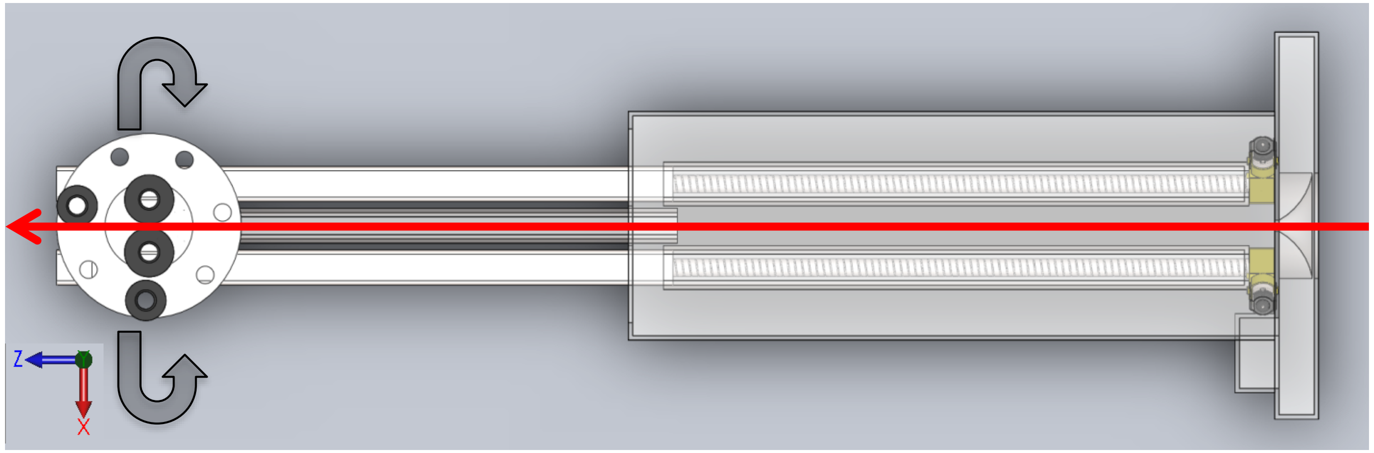
Blue - great
yellow - okay
red - bad

Rotary Bending is the best choice-Largest bending range, least dies, and smallest footprint

System Architecture

Bender





Cutter Mechanism Chart

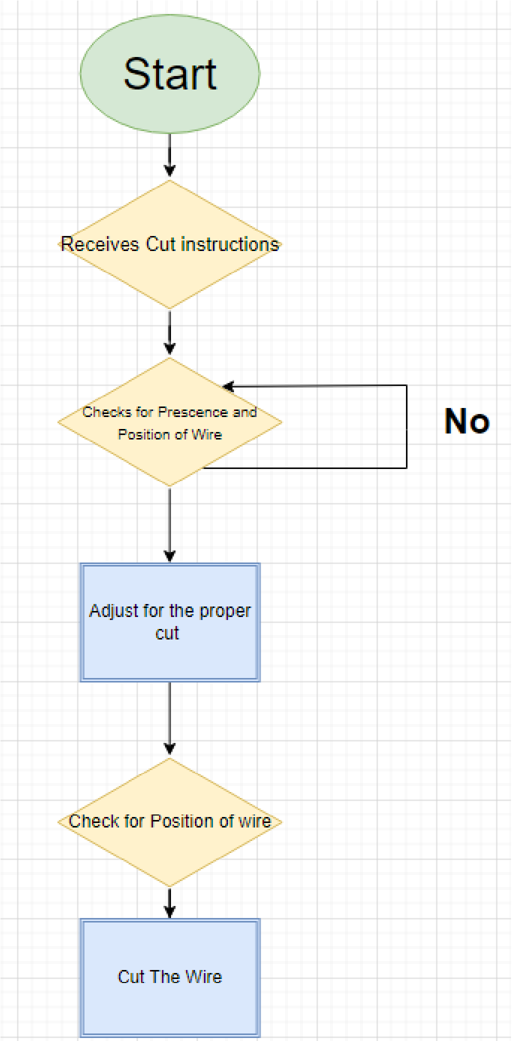
1.7 Trade Studies

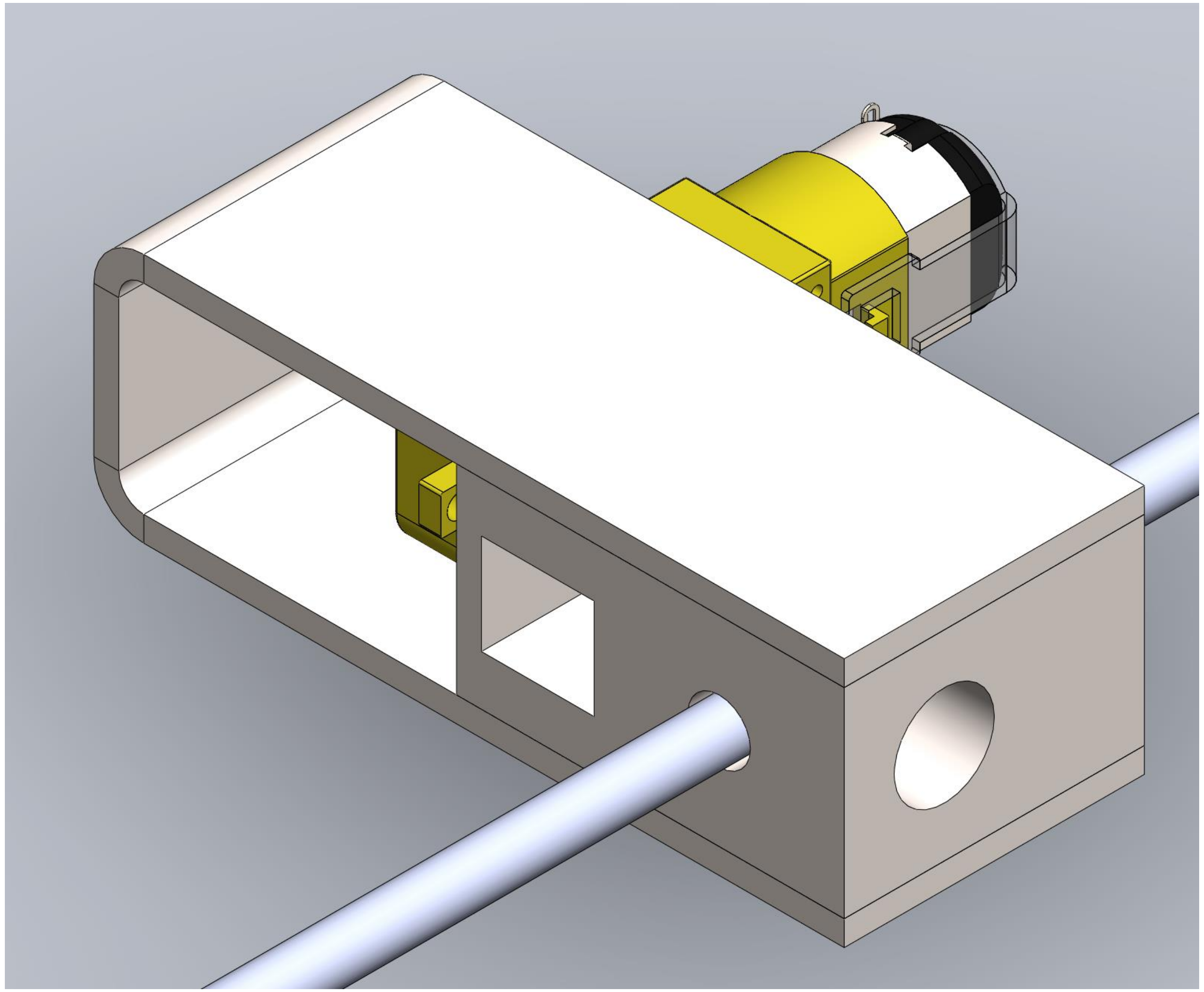
Criteria	Mechanical Cutter	ECM (Electrochemical Machining)	Grinder
Debris creation	Small debris, Debris Collector	None	Debris collector apparatus
Score (1-3)	2	3	1
Speed	Fast	Slow	Slow
Score (1-3)	3	1	1
Size	Compact, adjustable	Large	large and heavy
Score (1-3)	3	2	1
Power	Low power, Efficient	Medium power	Low power
Score (1-3)	3	1	3
Material Compatibility	works with some workable metals	Most materials	Most materials
Score (1-3)	2	3	3
Total	13	10	9

Mechanical Cutter is the best choice- High speed with low power use and small form factor

System Architecture

Cutter





Truss Material Chart

1.7 Trade Studies

Desirable Material properties	Material Considerations				
	304 Stainless	A286 Stainless	Hastelloy C	Copper	316 Stainless
Strength (2)	1	2	2	1	1
Bendability(3)	3	1.5	1.5	3	3
Stress-Corrosion Resistant(3)	2	3	3	3	3
No Prior Work Needed (1)	1	1	1	0	1
Total	**7**	**6.5**	**6.5**	**7**	**8**

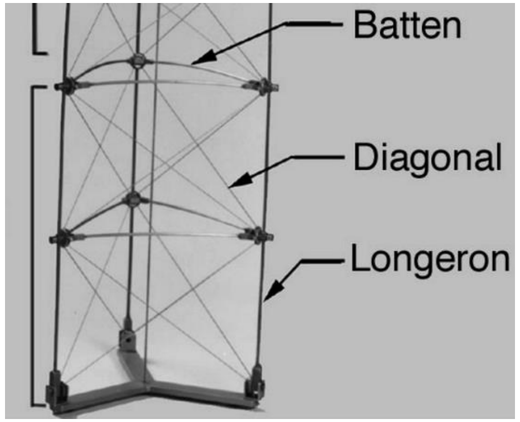
- Alloys evaluated on scale against desirable material properties
- Weight based on importance higher weight means more important, higher score represents how well it meets that need

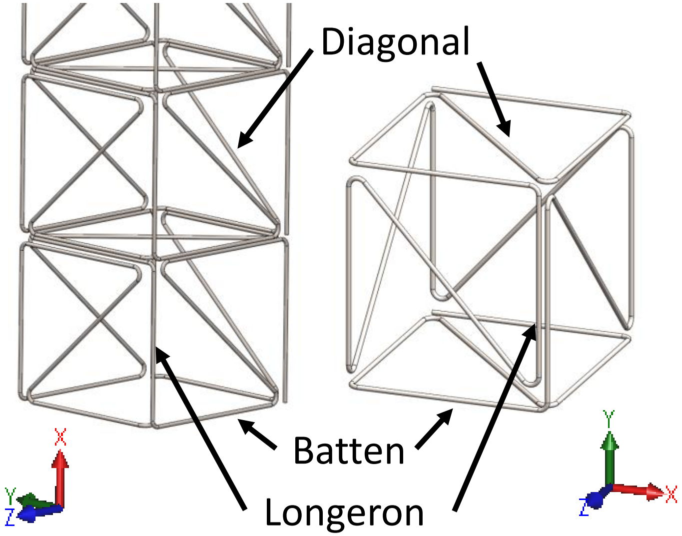
Blue - great
yellow - okay
red - bad

316 Stainless is the best choice- Highly bendable and resistant to corrosion without need for prior work

Truss Design

- Design
  - Primary & secondary members replaced by continuous wire
- Pitfall
  - Nodes need to be joined
  - Truss blocks need to be assembled
- Wire
  - 316 SS wire, AWG 4 (0.204”) diameter

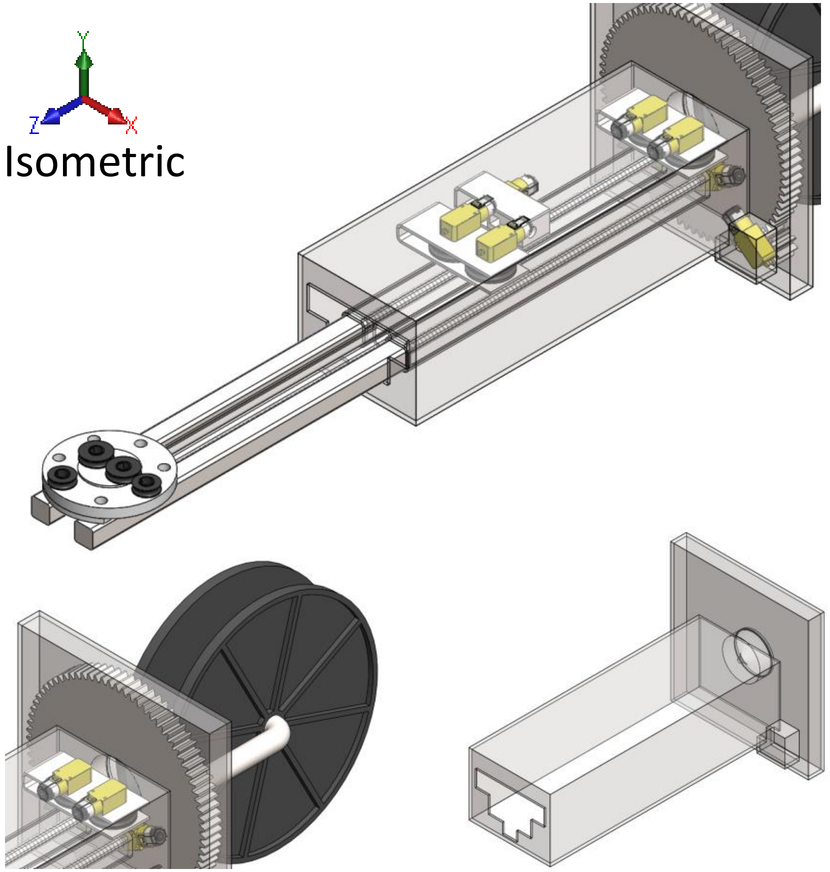




Design for LEO Environment

1.4 Required Elements

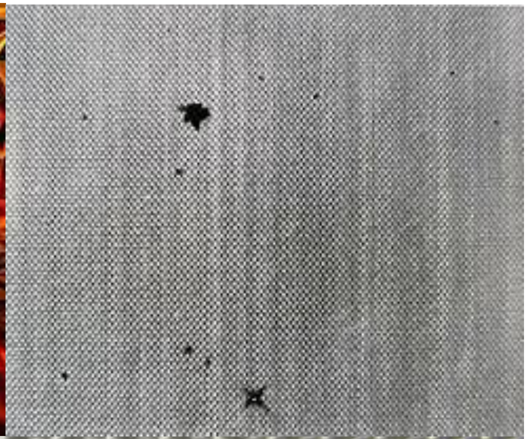
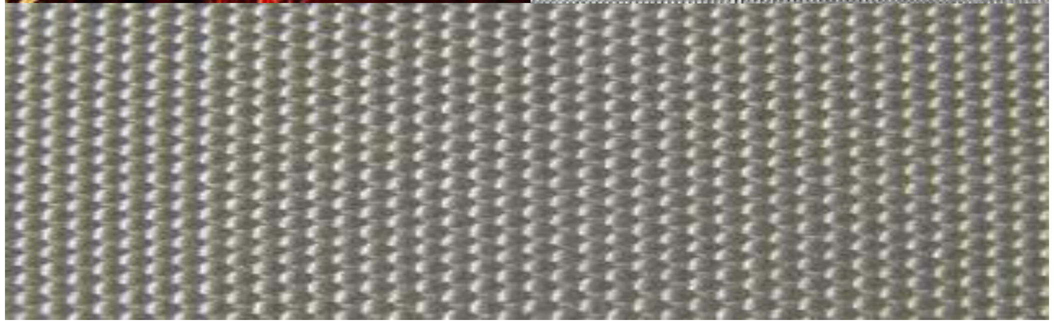
- Moving parts
  - Self-contained jackscrews, gears, rollers
  - Titanium
  - MoS_2 lubricant
  - 2 motors/mechanism
  - Outgassing avoided by design
- Housing & shielding
  - Titanium
  - Multilayer insulation
  - Spool shield mechanism
  - Thermal Pylons
  - Phase Change Material



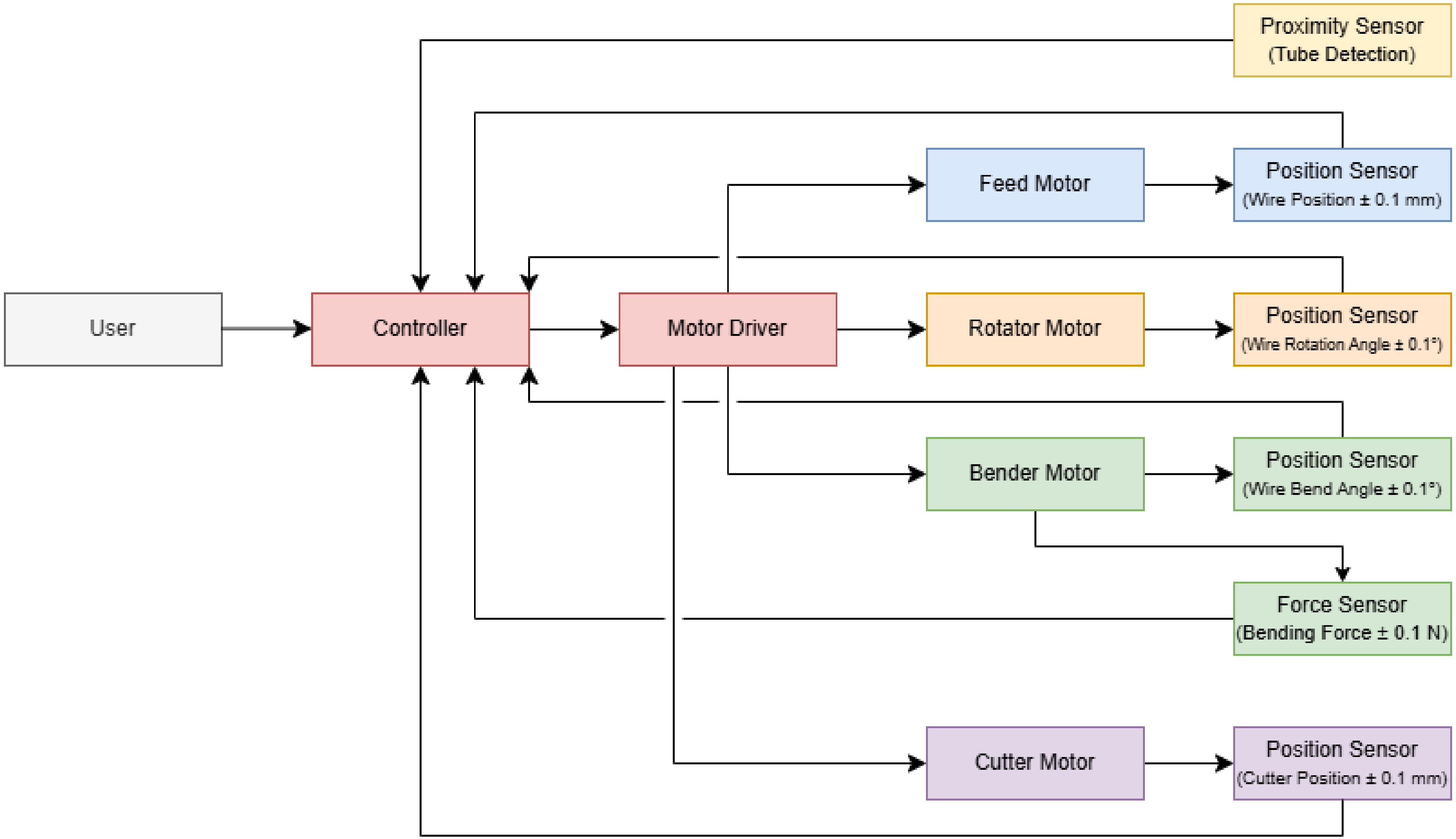
Design for LEO Environment (cont.)

1.4 Required Elements

- Aluminized Kapton
  - Temperature Range: -269°C to +400°C
  - Highly durable
- Dacron mesh
  - High strength and deformation resistance
  - UV resistance
- Beta-Cloth
  - Temperature range: up to 650 °C
  - Highly durable and resistant to tearing
- Polyimide based Adhesive
  - Heat resistant-flexible

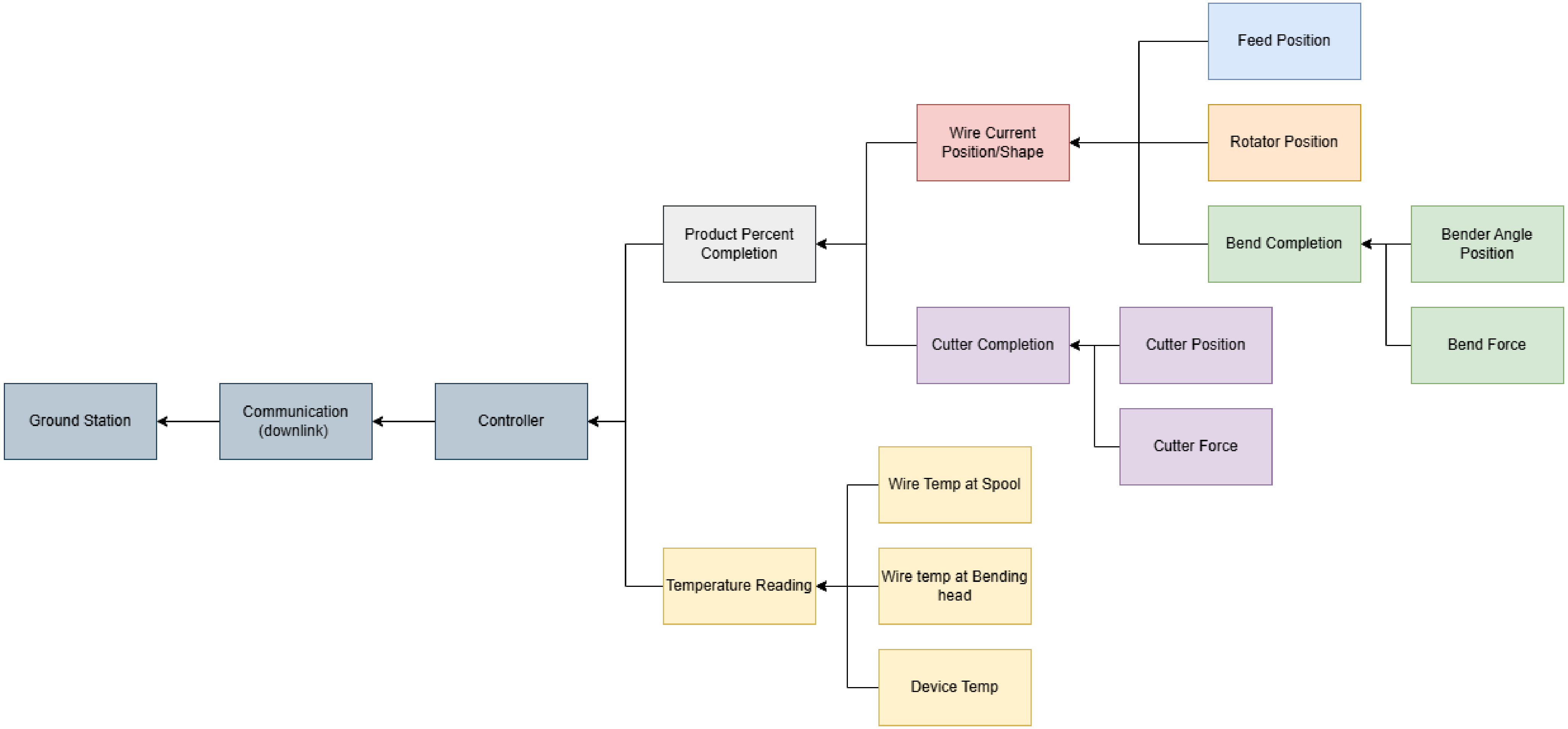




Control Block Chart



Data Block Chart

2.4 Data Handling & Comms



Design for Launch

1.4 Required Elements

- A series of tests technology is required to pass for launch

Mechanical Tests	Payload
Strength	1
Sinusoidal Sweep Vibration	2
Random Vibration	2
Acoustics	2
Mechanical function	2

Thermal Tests	Payload
Thermal Vacuum Thermal Cycle	2
Thermal Balance	2
Bakeout	2
Leak Test for Sealed Components	2

Functional Tests	Payload
Electrical Interface	2
Comprehensive Performance	2
Failure-Free Performance	2
End-to-End Compatibility Tests	2
Life Test Program	2

1 - May be accomplished by analysis
2 - Required Test

Tech Gap Assessment Chart

3.2 Most Important Technology Gaps

- Overall system Readiness
  - Space Bender [Level 2]
- Subsystem Readiness
  - Feeder [Level 6]
  - Rotator [Level 6]
  - Bender [Level 4]
  - Cutter [Level 4]
  - Motors [Level 6]
  - Attitude Control [Level 8]
  - Data Handling [Level 8]

9	Actual System Proven in Operational Environment
8	System Complete and Qualified
7	System Prototype Demonstrated in Operational environment
6	Tech. Demonstrated in Relevant Environment
5	Tech. Validated in Relevant Environment
4	Tech. Validated in Lab
3	Experimental Proof of Concept
2	Technology Concept
1	Basic Principles

Risk Assessment Chart (cont.)

1.5 Risks

Probability ↑ / Impact →	Low	Moderate	High
High		**Exceed Power Req**	
Moderate	**Positioning Error**	**Bend Error**	**Truss Impact**
Low	**Wear and Tear**	**Cut Error**	**Material Contamination**

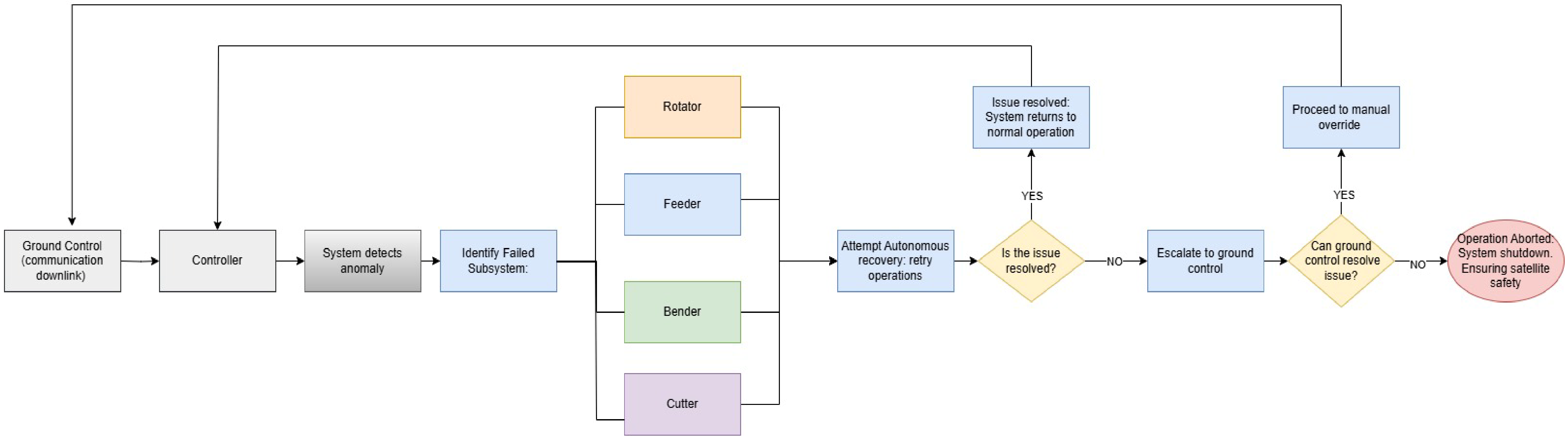
Risk Assessment Chart (cont.)

1.5 Risks

Criticality	Risk Title	Risk Description	Mitigation Approach
Low	Wear and Tear	Regular Maintenance caused by wear and tear over time	Design so not an issue during functional life
Low	Positioning Error	Material is under/over fed/rotated	System for reattempting feed process
Low	Cut Error	Material is not fully cut at end of process	System for reattempting Cut process
Moderate	Bend Error	Bend angle is less or greater than desired	System for reattempting bend or removal of structure
Moderate	Mat. Contamination	Material is non-homogenous or contains contaminants	Quality control testing of material prior to installation onto payload
High	Exceed Power requirement	Draws more power than storage or generation can provide	Keepign power requirements well under generation and storage
High	Truss Impact	Structure impacts satellite during construction	Structure design so at all bends contact with paylod wont be an issue

Fault Recovery Plan Chart

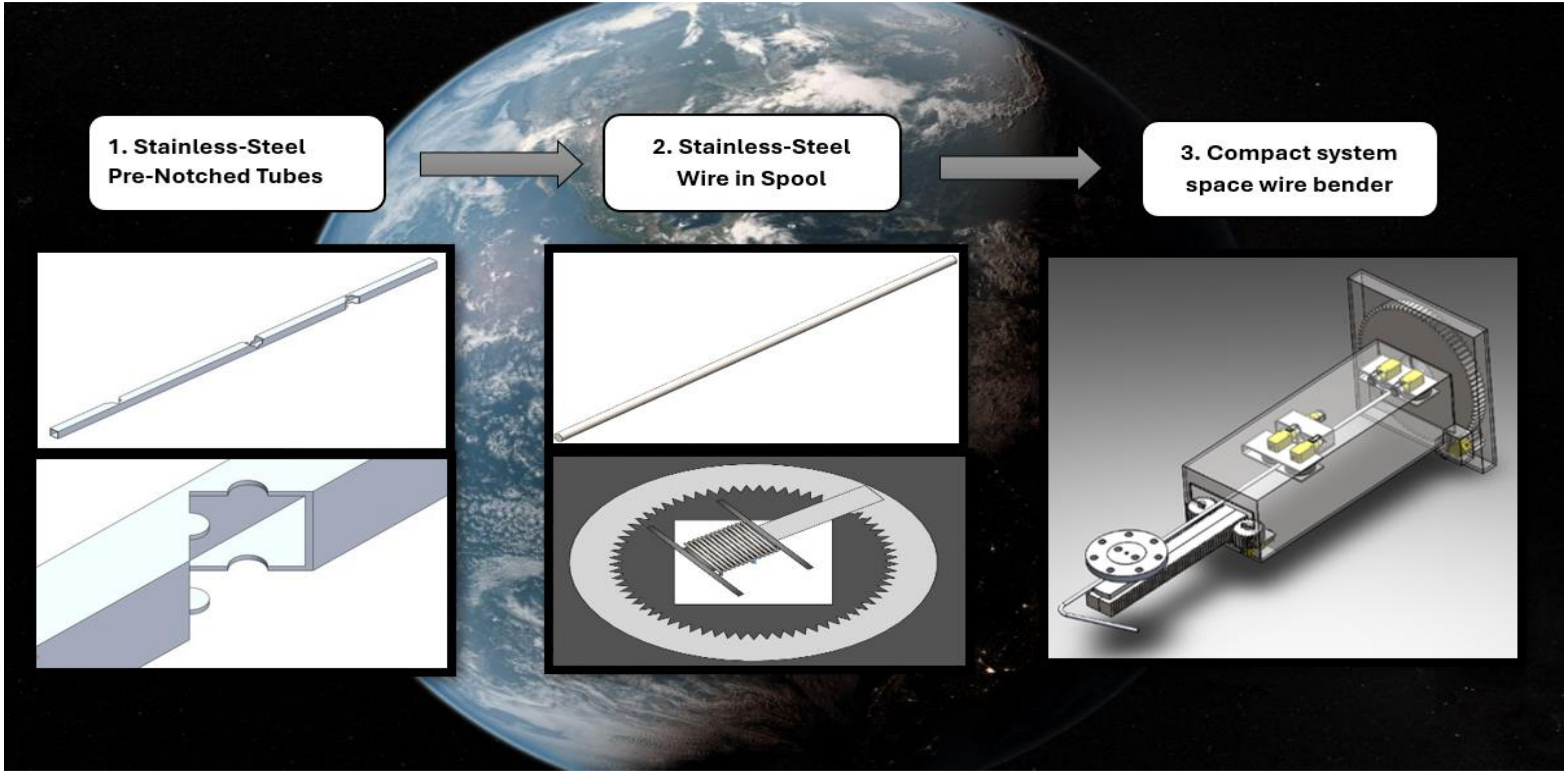
2.3 Fault Recovery Plan



Safety: The fault recovery process ensures satellite integrity

Innovative Concepts Chart

3.1 Most Innovative Concepts Considered



Biggest Challenges Chart

3.3 Biggest Challenges Encountered

- Team wanted to created robotic manipulators, this exceeded power requirements.
- Considered friction stir welding, could not dissipate heat
- Adjusting technology to fit into size and power requirements

Idea	Challenge	Mitigation
Robotic Manipulators	Volume/Power/Heating	Pivoted
Friction Stir welding	Power/Heating	Pivoted
Bender	Volume	Modified + Iterated

Path to PDR Chart

1.6 Path to Preliminary Design Review (PDR)

- Cost Analysis/Budget
- Life Cycle Sustainment Plan
- Development, Testing, and Evaluation Plan
- Peer Reviews
- Software Development
- Attitude Control System
- Joint Securement Method

Summary/Conclusion/Highlights

- Problem Addressed
  - High-cost, time-consuming construction of large structures
  - Restricted boom designs
- Solution
  - Bend wire into truss blocks
- Challenge
  - 2^{nd} ISAM capability to join nodes/assemble blocks
- Next steps
  - Prototyping, environmental testing, and payload system integration.

Questions?