Assembly of Space Structures

Northrop Grumman

Prepared for:
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Project Outline

Introduction
  International Space Station
  Requirements
Preliminary Research
  Robotic Servicing of Geosynchronous Satellites (RSGS)
  NASA’s Restore-L
  James Webb Space Telescope (JWST)
  DARPA’s Orbital Express
Project Candidates
  Candidate Requirements
  Spider
  Canadarm2
Conclusion
  Designs
  Simulation
References
Project Objective

Our primary aim is to develop a candidate space robotics system optimized for assisting in the construction of the new International Space Station (ISS). Our approach involves comprehensive research into historical, ongoing, and prospective space missions as well as robotic technologies. Through this research, we will not only construct the proposed candidate system but also identify and select the most suitable robotic candidates for integration into the ISS construction planning phase.
Project Stakeholders

- Northrop Grumman
- U.S. Government Agencies
- Project Team and Engineers
- Space Agencies
- Opposing Companies
International Space Station 1998

The ISS is a collaborative project.

It has been continuously occupied since 2000.

The cost of assembling the ISS was $150 billion (USD).

More than 40 assembly flights were required to build the station.

Symbol of international cooperation and a testament to engineering and technology capabilities.
"Drawing of the International Space Station with all of the elements labeled."
Source: https://www.nasa.gov/international-space-station/space-station-facts-and-figures/
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"The Japanese Kibo laboratory module with its Exposed Facility, Pressurized Module, Logistics Module, and robotic arm is pictured as the International Space Station orbited over the southern Pacific Ocean."

Source: https://www.nasa.gov/international-space-station/japanese-experiment-module-kibo/
## Candidate Requirements

<table>
<thead>
<tr>
<th>Functional Requirements</th>
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<tbody>
<tr>
<td>1.1 Human Intervention</td>
<td>The candidates shall be controlled remotely with minimal human physical interaction</td>
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<tr>
<td>1.2 Compatibility</td>
<td>The candidates shall be compatible with modules from all Space Agencies</td>
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<td>1.3 Accessibility</td>
<td>The candidates shall be able to move easily and have access to every location on the new ISS</td>
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<td>1.4 Compatibility</td>
<td>The candidates shall collaborate to berth/stage new modules as well as dock these modules with ease</td>
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<td>1.5 Safety</td>
<td>Candidate shall insure safe interaction if humans are present</td>
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<td>1.6 Autonomy</td>
<td>The candidate shall be capable of precise and dexterous manipulation</td>
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<tr>
<td>1.7 Autonomy</td>
<td>The Candidate shall be able to handle sensor failure or communication disruptions</td>
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<tr>
<td>1.8 Communication</td>
<td>The candidate shall communicate with ground station or other spacecraft</td>
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<tr>
<th>Physical Requirements</th>
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<tbody>
<tr>
<td>2.1 Payload Handling</td>
<td>The robot should accommodate various payloads (e.g., cameras, sensors, tools)</td>
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<td>2.2 Mass Payload</td>
<td>The candidate shall have a minimum payload capacity of at least 36,000 lbs</td>
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<tr>
<td>2.3 Maximum Length</td>
<td>The candidate shall be able to manipulate a payload with the maximum length of at least 37 ft</td>
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<tr>
<td>2.4 Maximum Diameter</td>
<td>The candidate shall be able to manipulate a payload with the maximum diameter of at least 15 ft</td>
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<tr>
<td>2.5 Environmental adaptability</td>
<td>The candidates shall withstand temperatures ranging from -250°F to 250°F</td>
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Robotic Servicing of Geosynchronous Satellites (RSGS)

Dexterous Robotic Arms & Supporting Technology (DARPA)

Designed to:
- Repair
- Refuel

Its operation:
- Arms
- Tools

Artist's Concept
NASA Restore-L

- Autonomous navigation.
- Refueling Landsat 7 satellite.
- Robotic arms.
- Autonomous test capabilities

Launch to LEO
1 day

On-orbit Checkout
53 days (max)

Autonomous Rendezvous & Docking
7 days

Transit to Landsat 7
15 days

Landsat 7 Refueling Task
1. Cut blanket
2. Cut wires
3. Remove caps
4. Fuel
5. Blanket close-out

~1 week

Landsat 7 Servicing
~1 week

Program Option:
Service other clients

Departure to Disposal Orbit
17 days

Decommissioning
2 days

Total Mission Duration: ~95 days min., excluding Program Option

Source: https://www.nasa.gov/wp-content/uploads/2015/05/restore-l-info_nnh15heomd001_r7.pdf?emrc=e131ba
James Webb Space Telescope (JWST)

- Project by NASA, ESA, & CSA with NGC acting as the primary contractor.
- Launched December 25, 2021
- Launched on Ariane 5 rocket from Kourou in French Guiana.
- Specifications - 18 hexagonal polished mirrors, 6.5 meters in diameter.
- Total Polished Area - 26.3 meters squared, with .9 meters square obstructed by support struts
- Launched on Ariane 5, with payload of 4.57 meters in diameter and 16.19 meters in length
DARPA: Orbital Express

The Orbital Express mission, led by DARPA in 2007, featured the ASTRO service vehicle as a pioneering example of autonomous orbital capabilities.

Main Objectives

- Autonomous spacecraft
- Safe Maneuvers
- On-Orbit Servicing
- Modular Design
- In-Space testing

Source: https://images.app.goo.gl/TocnSgorSMygXSETA
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SPIDER

- **Components:**
  - Communications antenna
  - Lightweight composite beam

- **Investigation:**
  - Maxar Technologies
  - Additional Information:
    - Restore-L and OSAM 1

Spider (mounted on OSAM-1) refuels satellite. Source: [https://www.youtube.com/watch?v=gverl0Ypf0k](https://www.youtube.com/watch?v=gverl0Ypf0k)
Pros

- Infrastructure for human exploration
- Design complexity and system mass
- Reduce need for multiple launch vehicles

Cons

- Technology for space missions
- Space assembly

Source: NASA Funds Demonstration of Assembly and Manufacturing in Space - NASA
Canadarm

- April 1981-July 2011
- Capable of lifting 29,000lbs
- 50ft reach capability
- 5 Joints with 5 Degrees of Freedom
- Stationary, Fixed to Space Shuttle Columbia

Canadarm2

- Installed April 2001
- Capable of lifting 255,000lbs
- 57.7ft reach capability
- 7 Joints with 7 Degrees of Freedom
- Permanently fixed on ISS

"Canadarm2 catching SpaceX’s Dragon resupply ship as it arrives at the ISS in 2016"
Canadarm2

Pros:
• Increased Mobility
• Increased Strength
• Space Repairability

Cons:
• Slower Operational Speed
• Increased Vulnerability
• Increased Complexity in Maintenance

Source: https://www.nasa.gov/wp-content/uploads/2015/05/design_iss_systems_engineering_case_study.pdf
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Candidate Designs
Simulation
Conclusion

In summary, our project aims to identify the optimal compatibility among our candidate systems, specifically focusing on the collaborative capabilities of the **Canadarm 2 and the Spider**, to effectively achieve the assembly of new space structures.

Source: https://apod.nasa.gov/apod/ap060522.html

Source: NASA Funds Demonstration of Assembly and Manufacturing in Space - NASA
Conclusion Continued...

Furthermore, despite these two systems being excellent for the example we provided; they are particularly suitable for large structures. For medium-sized structures, the **RSGS satellite** (Robotic Servicing of Geosynchronous Satellites) may be more efficient. This system offers an innovative and effective alternative for maintenance and servicing tasks in geostationary orbit, showcasing the versatility and adaptability of space technologies.

Source: https://images.app.goo.gl/Juc8rM3k7fcCvArA9
References

- NASA. "Japanese Experiment Module 'Kibo'." Accessed at: https://www.nasa.gov/international-space-station/japanese-experiment-module-kibo/