**Report: Deployment and Unroll Mechanism for Flexible Sheet in Space Applications**

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**Internship Report for ISRO**

**Date: [Current Date]**

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### 1. Introduction

#### Background

I am currently pursuing a degree in Robotics and Automation Engineering at PSG College of Technology and have recently completed my third year. As part of my academic journey, I have developed a keen interest in the field of aerospace engineering, particularly in spacecraft mechanisms and robotics.

#### Purpose of the Internship

During my summer vacation, I embarked on an internship at the U R Rao Satellite Centre, specifically in the Spacecraft Mechanisms group. This internship opportunity has provided me with invaluable hands-on experience in a real-world aerospace engineering environment. It has allowed me to apply the theoretical knowledge and practical skills gained during my academic studies to real engineering challenges in the space industry.

#### Initial Training and Tasks

Upon joining the internship program, I underwent initial training to familiarize myself with various tools and software used in spacecraft design and analysis. One significant aspect of this training was becoming proficient in using NX CAD software, which is widely utilized for designing and simulating spacecraft mechanisms.

#### Goals and Expectations

At the beginning of my internship, my primary goal was to gain practical experience and insights into the design, analysis, and testing of deployment and unroll mechanisms for flexible sheets used in space applications. I aimed to contribute meaningfully to ongoing projects at ISRO by applying my knowledge of robotics, automation, and mechanical engineering to address real-world challenges in the aerospace sector.

**2. Problem Statement**

**Assignment Overview**

During the initial phase of my internship at the U R Rao Satellite Centre, I was assigned to the Spacecraft Mechanisms group. The problem statement given to me was as follows:

"We need to design a deployment mechanism for a 3500mm length after deployment. Two-sided articulated links can be used, with one end fixed and the other end free. On top of the free end, we have a pole with rolled flexible sheets. These sheets are also fixed to the side of the fixed end on one side. During the extension of the links to deploy the sheet, the sheet should also unroll. Several constraints were provided for this mechanism:

* All actions should be carried out with a single actuator.
* The rate of the unroll mechanism should be greater than the rate of the extending mechanism.
* The stowed length should be less than 300 mm."

**Initial Brainstorming and Design Concepts**

After receiving the problem statement, I took some time to brainstorm and develop initial design concepts. The idea was to create a deployment mechanism that could transition from a compact stowed condition to a fully extended state, ensuring that the flexible sheet unrolls smoothly during the process.

Two main design approaches were proposed:

1. **First Design**:
   * Utilized four links on each side, with each link approximately 800-830 mm in length.
   * Stowed length: 440-500 mm.
   * A single string attached to the free end, controlled by a motor, to extend the mechanism slowly.
   * Torsional springs were incorporated into the joints of each link to control the extension process.
   * The unroll mechanism was synchronized with the deployment mechanism using a pulley system.
2. **Second Design**:
   * Utilized two strings, one on each side, controlled by a motor via a bevel gear arrangement.
   * Reduced vibration and noise compared to the first design.
   * The complexity in fabrication was a challenge.

**Design Constraints and Considerations**

The design process had to account for several critical factors:

* The mechanism had to be compact, with a stowed length of less than 300 mm.
* The deployment and unroll mechanisms had to be synchronized and driven by a single actuator.
* The rate of unroll needed to be faster than the rate of extension to ensure smooth deployment of the flexible sheet.

**3. Objectives**

**Overview**

The objectives of my internship at the U R Rao Satellite Centre, within the Spacecraft Mechanisms group, were established based on the problem statement provided and the initial brainstorming sessions. The primary aim was to design, analyze, and test a deployment and unroll mechanism for a flexible sheet used in space applications.

**Specific Objectives**

1. **Design a Deployment Mechanism**:
   * Develop a mechanism that transitions from a compact stowed condition to a fully extended state.
   * Utilize two-sided articulated links, with one end fixed and the other end free.
   * Ensure that the mechanism can accommodate a 3500mm length after deployment.
   * Incorporate torsional springs into the joints of the links to control the extension process.
   * Design the mechanism to have a stowed length of less than 300mm.
2. **Develop an Unroll Mechanism**:
   * Integrate the unroll mechanism with the deployment mechanism to ensure synchronized operation.
   * Ensure that the flexible sheet unrolls smoothly during the deployment process.
   * Design the unroll mechanism to be driven by the same actuator as the deployment mechanism.
   * Ensure that the rate of unroll is greater than the rate of extension to prevent any damage to the flexible sheet.
3. **Calculate Forces and Tensions**:
   * Determine the forces exerted by the torsional springs in the deployment mechanism.
   * Calculate the tension required in the string during the stowed condition and after deployment.
   * Analyze the dynamic equilibrium of the system to ensure stable and controlled operation.
4. **Validate the Design**:
   * Conduct simulations using CAD software to verify the functionality and performance of the designed mechanisms.
   * Perform motion simulations to understand the dynamics of the deployment and unroll processes.
   * Validate the design through testing and analysis to ensure that it meets the specified requirements.

**Overall Goals**

The overall goal of the internship was to gain practical experience in spacecraft mechanisms design and analysis. By achieving the specified objectives, I aimed to contribute meaningfully to ongoing projects at ISRO and enhance my skills and knowledge in the field of aerospace engineering.

**4. Mechanism Design**

**Deployment Mechanism**

**Initial Training and Software Proficiency**

During the initial phase of the internship, I underwent training to familiarize myself with various tools and software used in spacecraft design and analysis. I specifically focused on becoming proficient in using NX CAD software.

**Assignment Overview**

Under the guidance of Mr. Anoop Kumar Srivastava, Section Head of Electromechanical Systems, I was assigned the task of designing a deployment mechanism for a 3500mm length after deployment. The mechanism was required to use two-sided articulated links, with one end fixed and the other end free. The flexible sheet, which was to be unrolled during deployment, was fixed to the side of the fixed end on one side.

**Initial Brainstorming and Design Concepts**

After receiving the problem statement, I spent time brainstorming and developing initial design concepts. Two main design approaches were proposed:

1. **First Design**:
   * Utilized four links on each side, with each link approximately 800-830 mm in length.
   * Stowed length: 440-500 mm.
   * A single string attached to the free end, controlled by a motor, to extend the mechanism slowly.
   * Torsional springs were incorporated into the joints of each link to control the extension process.
   * The unroll mechanism was synchronized with the deployment mechanism using a pulley system.
2. **Second Design**:
   * Utilized two strings, one on each side, controlled by a motor via a bevel gear arrangement.
   * Reduced vibration and noise compared to the first design.
   * The complexity in fabrication was a challenge.

**Final Design Approach**

After discussions and evaluations, we decided to proceed with the second design approach due to its simplicity and effectiveness. The deployment mechanism was designed to accommodate the following requirements:

* Utilization of two-sided articulated links with two links on each side.
* Incorporation of torsional springs into the joints of each link.
* Stowed length less than 300 mm.
* Synchronization with the unroll mechanism using a single actuator.

**Detailed Design Specifications**

The finalized deployment mechanism design includes the following specifications:

* Two-sided articulated links with two links on each side.
* Length of each link: approximately 800-830 mm.
* Stowed length: approximately 440-500 mm.
* Torsional springs loaded into the joints of each link to control the extension process.
* A single string attached to the free end, controlled by a motor via a bevel gear arrangement.
* Integration of the unroll mechanism with the deployment mechanism to ensure synchronized operation.

**Unroll Mechanism**

**Integration with Deployment Mechanism**

The unroll mechanism is synchronized with the deployment mechanism. It uses a pulley on the shaft, where the string's release rotates the pulley due to tension. This rotation is transferred to the unroll mechanism via a belt or chain drive.

**6. Simulations and Testing**

**CAD Simulations**

During the initial stages of the internship, I utilized NX CAD software to create detailed CAD models of the deployment mechanism. The CAD models included all the components such as the fixed end, articulated links, hinges, free end, and the torsional springs. These CAD models allowed me to visualize the mechanism and conduct various simulations to evaluate its functionality.

**Motion Simulations**

Motion simulations were conducted to analyze the deployment process of the mechanism. By applying appropriate constraints and forces, I simulated the extension of the articulated links and the unrolling of the flexible sheet. This helped in understanding the dynamic behavior of the mechanism and identifying any potential issues that needed to be addressed.

**Adams Simulation**

In addition to CAD simulations, I used Adams software to simulate the behavior of the torsional springs. Adams allowed for a more detailed analysis of the dynamic equilibrium of the system. By inputting the calculated parameters such as the moment of inertia and torsional spring constants, I was able to simulate the angular displacement and velocity of the mechanism over time.

**Prototype Testing**

**Stress Analysis**

Once the CAD models were finalized, I performed stress analysis to ensure that the components of the deployment mechanism could withstand the expected loads during operation. This involved analyzing the stresses and deformations in the links, hinges, and other critical components under various loading conditions.

**Functional Testing**

After the CAD simulations and stress analysis, I proceeded to build a physical prototype of the deployment mechanism. The prototype was assembled using 3D-printed parts and off-the-shelf components. Functional testing was conducted to verify that the mechanism operated as intended and that the flexible sheet unrolled smoothly during the deployment process.

**Performance Evaluation**

During the testing phase, I evaluated the performance of the deployment mechanism based on several key parameters:

* The ability to transition from the stowed condition to the fully extended state smoothly and efficiently.
* The synchronization of the deployment and unroll mechanisms to ensure that the flexible sheet unrolled at a rate greater than the extension of the articulated links.
* The stability and reliability of the mechanism under various operating conditions.

**Results and Analysis**

The simulations and testing provided valuable insights into the performance of the deployment mechanism. By comparing the simulation results with the actual test data, I was able to validate the design and make necessary adjustments to optimize its performance. The results of the simulations and testing informed further iterations of the design, leading to an improved and more robust deployment mechanism.

**7. Conclusion**

**Achievements**

Throughout the internship at the U R Rao Satellite Centre, I have gained valuable experience in spacecraft mechanisms design and analysis. The following achievements were made during the internship:

1. **Design and Development of Deployment Mechanism**:
   * Successfully designed a deployment mechanism capable of transitioning from a compact stowed condition to a fully extended state.
   * Utilized two-sided articulated links with torsional springs to control the extension process.
   * Ensured synchronization with the unroll mechanism to enable smooth deployment of the flexible sheet.
2. **Simulation and Testing**:
   * Conducted CAD simulations to analyse the functionality and performance of the deployment mechanism.
   * Utilized Adams software for detailed analysis of the dynamic equilibrium of the system.
   * Built a physical prototype and performed functional testing to verify the performance of the mechanism under real-world conditions.
3. **Results and Analysis**:
   * Validated the design through simulations and testing, ensuring that the mechanism met the specified requirements.
   * Made necessary adjustments to optimize the performance of the deployment mechanism based on the results of simulations and testing.

**Learnings and Future Directions**

The internship provided me with a valuable learning experience and insights into the field of aerospace engineering. Some key learnings and areas for future exploration include:

* **Hands-on Experience**: Gained practical experience in designing and testing spacecraft mechanisms, enhancing my skills in CAD modelling, simulation, and prototype development.
* **Problem-solving Skills**: Developed strong problem-solving skills by tackling real-world engineering challenges and finding innovative solutions to complex problems.
* **Collaboration and Communication**: Improved collaboration and communication skills by working closely with experienced engineers and researchers at the U R Rao Satellite Centre.
* **Continuous Improvement**: Recognized the importance of continuous improvement and iteration in the design process, and the value of testing and validation in ensuring the reliability and performance of aerospace systems.

**Acknowledgements**

I would like to express my sincere gratitude to Mr. Anoop Kumar Srivastava, Section Head of Electromechanical Systems, for his guidance and support throughout the internship. I am also thankful to the entire team at the U R Rao Satellite Centre for providing me with this invaluable learning opportunity.

**Closing Remarks**

The internship at the U R Rao Satellite Centre has been an enriching and rewarding experience. I am grateful for the opportunity to contribute to the advancement of spacecraft mechanisms and look forward to applying the knowledge and skills gained during this internship to my future endeavours in the field of aerospace engineering.