Technical Design for the Nose Cone of a Sounding Rocket

An Exploration of Necessary Practices for Long Term Space Habitation

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

While humans have been trying to uncover the meaning of the stars since ancient times, it was not until the 20th century that human space exploration became a goal (Genta & Rycroft, 2006). Several rocket research organizations were first formed around the world in the 1920s and 1930s. After the second world war, space exploration began to rise in prominence. Germany had one of the most advanced rocketry programs of the time and once it was defeated, the Allies raced to split up their resources. Two of the foremost among these were the United States (US) and the Union of Soviet Socialist Republics (USSR). Each nation sought to improve and expand their programs which caused competition to ensue, fueling the beginnings of the space race. New capabilities needed to be tested to further space exploration by both nations. Sounding rockets, which are rockets used in sub-orbital flight, became essential for the continued research and development of space exploration (McDonell and Ahuja, 2023). Since the formation of the National Aeronautics and Space Association (NASA) in 1959, over 3,000 sounding rocket missions have flown. Each of these has a combined science mission success rate of over ninety percent and a launch vehicle success rate of over ninety-seven percent (NASA Wallops Flight Facility, 2023).

Due to the costly and risky nature of space exploration, it is difficult to test new technologies. A solution to this is found in sounding rockets, which cost a maximum of only a few million dollars compared to the average forty-five million dollars of normal space missions (McDonell & Ahuja, 2023). Sounding rockets offer a cost-effective model for new technologies, techniques, and instrumentation that can be tested quicker (NASA Science, 2023). They allow students and researchers to gain valuable hands-on experience in a field where there are fewer opportunities for practice. An important program in bringing the sounding rocket experience to students has been the Intercollegiate Rocket Engineering Competition (IREC). Since 2006, IREC has been an annual competition that focuses on student teams from colleges and universities across the world building sounding rockets (Spaceport America Cup, 2023a). This competition allows people attending colleges and universities to get involved in rocketry, helping to encourage students to pursue careers in related fields and training the next generation of industry professionals. The technical project will focus on building a nose cone for a sounding rocket under the guidelines of the IREC competition.

Technical Design for the Nose Cone of a Sounding Rocket

The goal of this technical project is to build a sounding rocket, which can carry a payload of at least 4 kilograms and reach a maximum height, or apogee, of at least 10,000 feet (Spaceport America Cup, 2023b). This project is broken up into aerospace-structures, propulsion, and mechatronics and controls teams. My contributions will focus on the nose cone of the aerospace-structures section. A nose cone is the outer, forwardmost section of the sounding rocket. To effectively reach the desired apogee, the design of the nose cone must account for a reduction in drag. Nose cone shapes have been extensively studied and equations have been gathered as seen in Crowell Sr's 1996 publication. Using Crowell's equations, and other research, the elliptical, parabolic, and ogive (segment of a circle) shapes will be modeled with different length to diameter ratios using computer aided design (CAD) software and computational fluid dynamics (CFD) analysis to determine which design yields the least drag given flight conditions (Shah et. al., 2020).

Additionally, intersystem compatibility must be considered. We must ensure that the nose cone will fit into the body section of the sounding rocket and will not interfere with any other system. The nose cone will be primarily made with carbon fiber with an aluminum tip which will be used to combat extra heat and forces felt at the top of the nose cone. This will help the nose cone survive the flight conditions. To manufacture the nose cone, a wet layup method will be used. This will involve making a mold from a computer numerical control (CNC) machine. The wet layup process involves using epoxy resin to position layers of carbon fiber on the mold of the nose cone until the desired thickness is reached. There is an abundance of possibilities when designing the nose cone, each with different results. Finding a shape that is possible to manufacture, has the least drag, and works with the other systems will be key to completing the goals of the technical project.

Competitions such as IREC and the development of sounding rockets by student teams are good learning experiences and allow students to get involved in the space industry. Gaining hands-on experience at the undergraduate level is limited due to the nature and complex scope of space exploration including habitation missions. However, sounding rockets carry scientific technologies and tools that may prove useful in future habitation missions and give students experience on launch vehicles albeit on a much smaller scale than would be used for the launching of space habitation modules and resources.

An Exploration of Necessary Practices for Long Term Space Habitation

When designing sounding rockets, numerous people, policies, and organizations related to space habitation become visible. The main people involved are both private and public organizations such as NASA, the European Space Agency (ESA), and SpaceX. These organizations are at the forefront of designing and building space habitats whether that be for scientific research, space exploration, or commercial use. Scientific researchers are also involved in space habitation as they often implement science goals for a mission (Marconi, 2004). Both in the scope of space habitation and competitions such as IREC, different codes need to be followed for safety. For space habitation this means certain requirements, such as those defined by the Federal Aviation Administration (FAA) including necessary training and safety measures (Human Spaceflight Requirements, 2006). The Tripoli Rocketry Association (TRA) Safety Code and local airspace codes must be abided by for many competitions involving student projects (Spaceport America Cup, 2023a). These types of regulations implement standard operating procedures for launches of all types of missions, adding another dimension that influences overall design and implementation.

To understand the connections between technology and humans regarding space habitation, Star's (1999) concept of infrastructure can be used. In this framework the built environment becomes more developed in relation to organized practices and actions. One of the nine aspects of infrastructure is *reach or scope*. This aspect highlights a technology that is beyond a one-time occurrence but is instead something that has been implemented multiple times. For example, the International Space Station (ISS) brings together multiple flight vehicles and people from around the world. Before the ISS, the United States operated Skylab which was its only exclusive space station that was occupied from May 1973 to February 1974 (Kay, 1994). Around the world, many agencies are making plans for long-term space habitation including habitats for the ISS end of mission, lunar modules, and Mars habitats (Billings, 2006). Improvements can be made in the case of mistakes or failures, leading to additional contributions to long-term survival in space and spaceflight research (Chen et. al., 2021).

Another facet of infrastructure is *links with conventions of practice*, which means that infrastructure has the potential to both impact and be impacted by norms of behavior in a community. In the case of space habitation, politics are often largely considered. The earliest example is the Space Station Freedom. This was a proposed permanent space station orbiting the Earth whose frameworks evolved into the International Space Station (ISS). Freedom was initially approved but the complexity and size of the proposed design ultimately led it to have financial and political problems. It was ultimately shut down due to differing opinions (Kay, 1994).

A third aspect is *learned as part of membership*, which details how people become familiar with tasks, routines, and behavior as they become members. Before leaving Earth, astronauts must undergo a rigorous training regime over a two-year period that complies with regulations set by the relevant human spaceflight laws such as those set by the FAA (Human Spaceflight Requirements, 2006). Once an astronaut enters a space habitat, they must undergo an acclimation process. Since humans are used to the force of gravity being a constant presence, going to a place with less or no gravity takes a period of adjustment despite rigorous pre-departure training (Uri, 2020). Additionally, tests are conducted on the long-term effects of zero gravity on human physiology (Huntress, 2003). Knowing what these effects are and how to best counteract negatives is essential for long-term space habitation (Chen et. al., 2021).

Research Question and Methods

With the growing interest in long-term space exploration, there are lessons that can be learned through past experiences to influence future missions. A logical question follows: How do lessons learned from past experiences influence the practices that are needed for successful long-term space habitation?

To answer this question, I plan on conducting case studies of the ISS and on-Earth endeavors. I plan to examine how the ISS evolved from the Space Station Freedom (Lambright, 2019) and lessons learned from previous missions such as scheduling conflicts of the Skylab 4 crew (Uri, 2020). I also plan to examine the incremental growth of the ISS (Catchpole, 2008) and the influence of international cooperation and commercial space industry efforts on life in space.

The on-Earth endeavors I will examine are the Crew Health and Performance Exploration Analog (CHAPEA), Mars500, and Biosphere 2. CHAPEA is a series of one-year missions that simulate life on Mars (NASA, 2023). Mars500 was a psychological and physiological experiment that simulated living on Mars (ESA, 2023). Biosphere 2 is an Earth science research facility that was originally built as a closed ecological system. Initial experiments were geared towards examining the necessity of a similar system in human space habitats (Nelson, 2021). Lessons learned from these experiments will be useful in determining necessary practices for expanding human space exploration as well as the physical and emotional well-being of astronauts.

While analyzing these instances I will collect the practices needed for successful long-term space habitation by identifying practices highlighted by the aspects of infrastructure discussed previously. This data will then be compared with plans for future human spaceflight and regulations as stated in the most recent Planetary Science and Astrobiology Decadal Survey, a survey outlining recommendations for the next decade (National Academies of Sciences, Engineering, and Medicine, 2023), and the FAA Human Spaceflight Requirements (Human Spaceflight Requirements, 2006).

Conclusion

Sounding rockets are important tools for testing technologies for space exploration research. Competitions such as IREC allow students to gain hands on experience and interest in the space exploration field. The technical deliverable will focus on the nose cone of a sounding rocket in accordance with IREC. It is essential the design limits drag and integrates with other components.

As the space industry grows, there is more focus on space habitation for long missions. For the safety of the crew members sent to live in these habitation modules for extended periods of time, it is essential that thorough research on what is needed is done. For the research portion of the prospectus, deliverables will include lessons learned from past missions. These lessons will give insight into what practices must be implemented for safe and successful long-term space habitation in the future.

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