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Mission Statement

College of the Canyons’ Makerspace/Astronomy Physics club Payload Program, or MAPPP, aims to be our student’s guide to a bright future in the field of STEM. Our project with Rocksat X provides our members with the experience they need to be competitive in today’s job market while fueling their passions.

We expect that over the coming months, our members will grow from the challenges, failures, successes, and teamwork encountered. From a technical standpoint, we aim to discover just what it takes to build a true space-fairing vehicle and take our first steps into the real world of space exploration.

This project also has potential commercial and academic applications. If our project is successful, it opens up a new sector of low-cost, unmanned, autonomous reentry vehicles that could be utilized for interplanetary lander missions to worlds with heavy atmospheres, cargo return from Earth’s orbit, sub-orbital research, or rapid cargo delivery. If the concept can be scaled and proven reliable, it even has potential applications for manned reentry capsules.

Small scale private space organizations and academic institutions stand to gain the most out of the success of our project by utilizing these vehicles for their relatively low cost and the ability to safely return cargo or scientific research from LEO. Much in the way cubesats or weather balloons are utilized, our proposed system provides a new way of accessing space.
Why we are a prime candidate for selection

- We are bringing a bold and innovative concept that is specifically tailored to the vehicle and mission Rocksat X provides.
- The success of our project provides a potential new avenue for the exploration of space and interplanetary bodies.
- While similar experiments have been attempted, success would prove the feasibility of a new type of reentry vehicle.
- Our team is comprised of several veteran members to other NASA collaborative projects, such as the High Altitude Student Program, as well as recent and former NASA interns.
- College of the Canyons is one of the only community colleges that attempts to undertake such projects without the collaborative efforts of larger institutions while delivering equal or greater results.
- Strong mentor and support network including former NASA and household name software/technology company employees.
- Strong financial support from local and national aerospace and manufacturing companies.
- Strong support from the cities of Santa Clarita, Valencia, and Los Angeles.
Mission Objectives

Our mission will be comprised of a relatively short sub-orbital flight that deploys at or near apogee of the RSX rocket using the timed events available to participants. As the capsule enters the atmosphere, the trajectory and center of g will enable it to orient with the heatshield forward to provide protection from the intense heat of reentry. The capsule’s blades will remain undeployed until it enters the atmosphere, where it will utilize helical air channels to force the blades open as the pressure and speed builds and also providing spin.

A successful mission is defined as utilizing the properties of auto rotation to provide the necessary lift for the capsule to slow and successfully splashdown with the vehicle and test cargo intact. The minimum criteria for success includes deployment from the rocket, as well as confirmed reentry and auto rotation from downlink data.

We are hoping to collect a wide set of data, including: Temperature, orientation, rpm speed, pressure, gps location/altitude, humidity, current, and flight computer communication. At the minimum, we would require altitude, rpm speed, and flight computer communication.
Theory and Concepts

Much of our project’s conceptualization stemmed from both organic and scientific inspiration. The autorotation principles observed in falling maple or “helicopter” seeds combined with Apollo-era designs served as the catalyst for our payload’s design and operation. Deployable blades are used to provide the lift force necessary to slow the capsule’s descent velocity using the dynamic forces of the environment, in our case the air encountered upon reentry, to begin the autorotation process. The air density and the circular velocity of the blades, although not linear, should be in some sense directly proportional; we will rely on these principles in order to land successfully.
The reentry vehicle utilizes the principle of autorotation to decelerate. The aerodynamic forces at play produce a force tangential to the blade’s angle of attack. This, along with helical air channels designed into the capsule will drive the autorotation process. The negative velocity of the capsule is converted to rotational inertia, the trade off being that this additional energy can be used to decrease the velocity of the craft more efficiently than drag alone.
Theory and Concepts: Learning from the past

In previous years, several attempts at utilizing auto rotation has been performed by private and federal institutions including NASA and Lockheed. While these past projects did not yield results or were deemed unfeasible, our team has several reasons why we believe the idea is valid:

- Past attempts were focused on extremely heavy craft or modifying existing vehicles for testbeds. Our capsule is tailored for smaller payloads while specifically created for this task.
- Our capsule relies heavily on the principles of physics and mechanical processes for operation. Air pressure and speed deploy the blades and mechanically lock them in place, weight and the center of gravity orient the craft, and special machining on the capsule such as channels or weighted blades assists in spinning the vehicle and driving auto rotation.
Concepts of Operation

Our autorotation capsule is a self sustained system able to operate remotely and autonomously. It’ll remain attached to the rocket until apogee, transmitting housekeeping data throughout the time. At apogee, the capsule will jettison from the rocket and begin its descent to earth. Utilizing the services of the Iridium satellite network, we will have constant contact with the payload. Mathematical modeling is being used to calculate various parameters of the experiment like blade geometry, entry velocity, trajectory, terminal velocity, and angular velocity necessary to splashdown safely. Various sensors and instruments on board will be sending this data via Iridium to us in real time so we can assess the status of the payload. The principle of autorotation, generated by the payload’s body and blades, and airbreaking will slowly decrease the craft’s velocity until splashdown.
Expected Results

We expect to obtain valuable information about the journey from apogee to splashdown; this data will be critical in the payload’s potential future iterations. Through the predictions made from the mathematical modeling, we hope to come within 30% of those values. We do expect the payload to begin the autorotational process and would hope that despite the nonlinear conditions of actual flight, the rotation achieved during descent to be sufficient enough to slow the capsule enough to minimize damage on splashdown. Given the mission’s proof of concept status, data acquisition is of great importance to the possibility of future missions.
Dataset Return Expectations

Typical scientific data should return via our proposed iridium communications transceiver through binary based data strings and translated project home side into graphs and text statuses.

If successful, we should expect to see:

- Successful confirmation of deployment from rocket
- Accelerometer and GPS information until reentry for tracking and orientation purposes.
- Reestablished communication link after reentry.
- Pressure, altitude, and GPS data on descent to track the descent path.
- Successful confirmation of blade deployment and locking.
- RPM, pressure, altitude, and GPS data until splashdown to monitor the rotational energy and descent path of the capsule.
- Accelerometer data nominal within tolerances on ocean impact to determine survivability.
Science Design

The survivability of the capsule is of great scientific importance on its own, providing us with physical samples to examine such as the remnants of our heat shield and the internal components.

Otherwise, our capsule is aimed to be an autonomous vehicle to reduce complexity, and as such, relies heavily on passive sensor data to retrieve scientific data. We have included a vast sensor suite aboard our design, and intend to collect as much data as possible including:

- Temperature - Useful for examining the effectiveness of internal and external heat on reentry
- Pressure and altitude - Useful for examining the density of the air on descent and optimizing future capsule blade deployment
- G forces - Useful for determining the survivability of future capsule payloads or cargo and the potential for manned applications.
Full Assembly Concept
Utilizing information acquired from last year’s attempt, the team has begun to greatly simplify the design of this year’s capsule and engineered additive features that should help start the autorotation process. The craft now relies on more mechanical/environmental forces to assist and sustain many imperative operational systems such as blade deployment, rotation, airbreaking, and ejection. By reducing these systems to their simplest form, we can depend more on the physics of aerodynamic forces and capsule design rather than electrical or software driven components which have greater complexities and a higher chance of failure.
Mechanical Design: Capsule

The capsule utilizes an aerodynamic cylindrical shape to help it fall through the atmosphere with the correct orientation. Helical channels are cut into the capsule to aid in starting the process of autorotation; as an additional benefit, these channels will also reduce the capsule’s overall mass. Constructed from grade 5 titanium, the capsule will not only be structurally sound but also be able to withstand the temperatures of reentry. Within the capsule’s interior, the payload’s sensors and electrical hardware will be protected from the harsh environment. Holes will be drilled into the interior wall to add space for thermal insulation without significantly detracting from the wall’s structural integrity. There will be free space available that will serve as potential cargo storage for applicable missions in the future.

- The capsule will be a cylinder shape with a hollow center to hold our electrical components.
- The inside will be carved out in a hexagon shape for maximum space while keeping structural integrity.
- There will be a computer rack in the inside to keep our electrical components organized and stationary during flight.
- Both ends of the capsule will have slots to hold together the heat shield and blade hub.
Capsule CAD models

Newer
Mechanical Design: Blades

The complexity of blade geometry is being processed by the team’s mathematical modeling students. We can maximize the lift created by the blades in order to slow the craft down to its target splash down velocity. The blades will also be manufactured from grade 5 titanium as to withstand the forces of flight operation. There are current plans to try a two, three, and four blade design to see what maximizes aerodynamic forces. Blades will be held in place by a key inserted locking mechanism which will ultimately house the blades in their flight configuration after separation from the rocket.
Dolphin Blade Design

- The capsule will have a three blade design over four because of weight reduction while keeping optimum balance.
- Our team decided to have a wing deployment system that will be aided by our environment. Air will flow under the blades thus causing the wings to expand and deploy. The idea seems simple enough but future testing will determine if the idea is feasible.
- While the wind will cause the blades to deploy, the wings will reach a maximum point and a locking mechanism will ensure our blades will be remained with its fixed position.
Mechanical Design: Heat Shield

At the bottom of the capsule, a heat shield compromised of teflon and ceramic wool will be used to help initially slow the craft down and protect it during reentry. Additionally, we are researching different ablative materials to be paired in conjunction with our heat shield to minimize the effects of thermal expansion and protect the interior of the payload as much as possible. The heat shield will also fasten from the inside as to keep the exterior free from any imperfections that may pose a threat to the shield’s integrity. Finally, most of the capsule’s mass will exist in a recess in the heat shield, this will give the craft its desired center of gravity that, along with its shape, will help it to fall stably.

Outside Layout

- The capsule is going to be made out of titanium because of its strength. There will be holes drilled into the capsule from the inside to reduce the amount of heat that will be absorbed.
- The main heat shield will be made out of Aluminum Oxide Ceramic which will be able to withstand up to 3200 Degrees Fahrenheit. The heat shield will be located at the bottom of our payload to take the brunt of the heat.

Inner Layout

- Ceramic wool will be compressed into the capsule as an extra heat resistant precaution due to it being able to withstand around 2300 degrees Fahrenheit as well as being cost effective
- Myler will be used to wrap the electronic components for extra insulation
Main Heat Shield Design

- The Heat Shield will be designed in a saucer shape because we used Nasa as a role model.
- It has been proven that this shape is best to deflect the heat from the capsule and slow down descend onto the ground
Heat Shield CAD Model
Materials

- Titanium
- Aluminum Oxide Ceramic (for outer heat shield)
- Ceramic wool (inner layer)
- Mylar
Engineering Diagram: Mechanical FBD

Capsule Free-Body Diagram

- col: Center of Lift
- cog: Center of Gravity

- W: Capsule weight
- V: Capsule Velocity
- α: Angle of Entry
- ω: Angular Velocity
- Fl: Lift
- Fd: Drag

Blade Free-Body Diagram

- Lift
- Drag
- Angle of attack
- Relative flow direction
- Weight
Launcher Mechanism

While still in development, there are a few design aspects of our launcher that we wished to implement:

- Mechanical in design, utilizing the sounding rocket’s timed events to trigger an electric motor.
- The motor and system will most likely either be a screw driven device or a latching mechanism capable of keeping the capsule attached at all stages.
- Once the latch or attachment point is free, we will use a spring loaded plate to nudge our capsule from the rocket. This process will be mechanically linked to the latch or attachment point, requiring no computer aided process.
- A small gantry and rail system will be built around the capsule to help guide it from the rocket and on a correctly oriented path.
- All launcher materials will be constructed out of aircraft grade metals and hardware to ensure it survives the flight.
Launcher Mechanism Concepts
Electrical

The vehicle’s electrical supply consists of a set of lithium ion batteries rated by the FAA for aerospace purposes. When the payload is installed onto the rocket, a detachable umbilical will provide power and charge for the batteries. An inline main fuse placed between the batteries and the rocket will protect it from sudden or unexpected current spikes on both ends.

A fuse box/converter system will be utilized after the batteries to provide conditioned and protected power to our flight hardware and sensors. This will also allow us to reduce the noise on our transceiver to help maintain a connection with Iridium during the flight.

All wiring, fuses, and electrical hardware will consist of industrial grade or surplus military supplies to ensure that we do not encounter unexpected issues during flight. Connections will be soldered and covered in heat resistant paint and insulation to resist reentry heat.

Our payload’s electrical budget and power draw is still being developed, but references the RSX user guide as a base.
Electrical Budget Creation in action!

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Functional Block Diagrams: Electrical
Software architecture development!
Software

By removing uplink commands, we have reduced the complexity of the capsule by focusing on data retrieval and onboard autonomous functions. Additionally, we have removed advanced flight computer hardware and instead replaced them with consumer grade electronics which are easier to program and install. Our team does not believe the change will pose a threat to the hardiness of our system as we intended to completely shield and isolate our flight hardware inside an installable rack. We have flown similar hardware on the HASP project which operates at a level of near space.

Software architecture has been simplified, with the plan to use an arduino to process sensor and raw data. A teensy will be employed for communications, with both raw and downlink data recorded internally on an SD card and an RS232 data logger. Arduino utilizes a simplified computer language better suited for many of our entry level programmers and allows us more options for troubleshooting and developing the code we need for a successful mission.
Iridium Communications Example
Rocksat X User Guide Compliance

To ensure that we uphold the rules and regulations listed in the user guide, our team has developed an internal matrix that quickly highlights areas such as the following:

- Weight limits
- Electrical use limits
- Prohibited items
- Restricted actions during flight
- Allowable experiments
- Maximum ejection velocity

Additionally, our weekly team meetings references back to the user guide which has been distributed to each team member and is accessible at all stages of design.
Section 3: Management
Team Organization

Our program and RSX team is organized in a standard tiered system.

- Advisors/Mentors - Assist our team in skills development and support, as well as monitoring the team interaction.
- Joint Project Managers - MAPPP consists of several programs, and as such, two project manager positions ease the workload and provide support for scheduling or event purposes.
- Team Leads/Point of Contacts - To ensure that information is easily distributed, progress is updated, and schedules are adhered to, each area of our project has been assigned a lead or point of contact. They assist the project managers.
- Assistant Team Leads - RSX and MAPPP is a busy place, and to ensure that we give the leads the support they need, they work in tandem with an assistant lead, who can also act as a team lead in cases of absence or divided work.
- Team members - Our talented group of individuals support their respective areas and the team as a whole. They assist the team leads in accomplishing our important goals and deadlines.
Project Phases

To facilitate the successful development of our project, we have divided it into 4 distinct phases that allow us to separate the work out into a manageable timeline.

- Phase 1 - Restructuring, redevelopment, and conceptual planning (Sept - Oct 2018)
- Phase 2 - Prototyping, testing, and software development. (Oct - Dec 2018)
- Phase 3 - Design freeze, fabrication, RSX integration testing, assembly (Jan - Jun 2019)
- Phase 4 - Integration and launch!
Budget And Financing

To ensure that our program receives the necessary funding required for RSX, we have implemented the following actions:

● Partnered with the school’s financial contacts that are able to present our proposal to private and academic donors.
● Appealed to local aerospace companies for donations or materials or funding.
● Applied for several grants relating to our field.
● Are currently appealing to major companies such as NASA, Lockheed Martin, etc.
● Presented our project as a potential commercial avenue in the future, with this year being preliminary academic research and prototyping.
● Have planned a full schedule of outreach and funding events that connect with the community and the school district.
Budget Overview

MAPPP 2018/2019 Budget Request
Total Estimated Requested: $48,900

**HASP** - The High Altitude Student Platform, or HASP, is quickly becoming a yearly tradition for College of the Canyons. It offers an easier entry into collaborations with major Universities and agencies such as NASA, while still being challenging. HASP’s financial commitment is the lighter of our two planned projects, but unlike RSX, does not have the prior year’s ordered parts and resources to rely on. COC is applying for a larger payload slot this year, which requires more materials and components. Additionally, it was justified that due to the limitations placed on visiting teams to Wallops through the RSX program, that the budget should be increased to allow more students to travel to integration and flight for HASP. COC’s team has often been small in comparison to other participants, and we are attempting to give as many of our team the chance to experience the entirety of HASP from beginning to end, with the hope that the journey will mark the first steps on a very long and fulfilling career in the aerospace industry.

Total estimated cost: $17,500 - $19,000

**RockSatX** - RockSat X represents a major step forward in College of the Canyon’s emergence as a key player in providing students a foothold in gaining real and tested experience in the aerospace industry. The project however does require a significantly increased financial commitment in comparison to HASP. Although the project did not fly last year, $8,000 of the initial earnest deposit is still available to COC, with a remaining $16,000 needed if selected. Aerospace grade titanium and advanced ceramics account for majority of the materials budget and have proven difficult to obtain, but bulk manufacturer sources do exist. We at MAPPP however truly believe that the costs, while hefty, are justified to the students who pour their hearts and dedication into this intense, but rewarding project. Just like the rocket that will carry us to the edge of the Earth, we hope that RSX will carry our members to possibilities and careers that wouldn’t be possible without this experience.

Total estimated cost: $32,000-$35,000
Budget Breakdown

MAPPP 2018/2019 Budget

- RSX Payment ($16,000) - 32.7%
- RSX Travel ($7,500) - 15.3%
- HASP Travel ($15,000) - 30.7%
- Raw Materials ($6,500) - 13.3%
- HASP Chemicals ($200) - 0.4%
- Electronics ($2,500) - 2.5%
- Electrical Supplies ($1,200) - 2.5%
Risk Assessment

At this stage of the design, without having tested concepts, it is very difficult to compile all of the potential areas of risk or complications that our project could encounter. Some main concerns however are:

- Development of a heat shield capable of surviving the heat of reentry. We currently have a proposed list of materials and tentative design in place to begin fabrication, and the solution to this issue is extensive testing.
- Establishing reliable and efficient downlink data through the untested iridium system. We will need to work closely with iridium support to allow us understanding of their system and to implement a text based data downlink.
- Initiating auto rotation. Several past experiments have had trouble with this area and the only way to solve any issues is extensive real world testing.
Mentors and Advisors

Teresa Ciardi - Amazing advisor and woman of action

Gregory Poteat - Machinist extraordinaire

Peregrine Mcgehee - Coding and Software wizard

Remi Drai - Premier Mathematician
# Team Roster

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# Contact and Availability Matrix

Please note all times are in PST

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<td>Joint Project Mgr</td>
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Section 4: Conclusions and Questions
Conclusion

While we still have a long road ahead of us to an actual flight ready payload, we have enough of the conceptual design behind our team to move to Phase 2, which will greatly advance the reality of our project.

Materials have already been ordered, prototyping and CAD models are underway, and we have no doubt that the leap from Phase 1 to Phase 2 will be impressive.