Rascal Request For Proposal

Saint Louis University

Rascal



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Copper Operational

Test Plan

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# Introduction

The Rascal mission consists of a 6U CubeSat-Class satellite that is to operate at any altitude above 300 km and inclination above 40⁰. Before describing the mission in further detail, it is important to establish the meanings of various terms that are associated with any given CubeSat mission, since most of such terms are not used outside of the small-satellite industry. Firstly, 1U, or one standard unit, is defined as a cube of a uniform edge length of 10 cm. A CubeSat-Class satellite (aka a “nanosatellite”) is a satellite whose dimensions derive from 1 or more of these standard units, a designation that was created by California Polytechnic University in the early 2000’s for describing the satellites being developed by various universities that met this definition. The reason for creating such satellites is twofold: it greatly reduces the time and monetary investment associated with developing custom satellite shapes and structures, while allowing the development of standard satellite deployers (such as the P-POD) for integration into any rocket configuration, thus allowing greater access to launch opportunities for university missions, such as Rascal. The largest deployer volume currently available is for 6U satellites, thus putting a design constraint on the Rascal structure as a whole.

The actual Rascal mission consists of two separate 3U spacecraft that will be mounted to a common base plate for flight-integration and early on-orbit operations. Both 3U spacecraft will have identical hardware and external structures, as to simplify development time and cost. Thus, each satellite will have its own infrared and visual-based navigation tools, six-degree-of-freedom propulsive control from 6 or more thrusters, image processing capabilities for navigation, Commercial of the Shelf (COTS) power, command and data handling, radio, and solar cell systems, and satellite-to-satellite GPS communication.

**The ultimate goal of the Rascal mission is to demonstrate proximity operations technologies on a CubeSat class spacecraft: infrared/visible navigation, six-degree-of-freedom propulsive control, and navigation algorithms to use these capabilities**. This will be accomplished by having one of the two 3U satellites eject from Rascal’s common baseplate, achieve stability, move out some distance from the remaining satellite, and return within a short distance of the remaining satellite, at which point the remaining satellite will go through the same process. If enough propellant is left in each satellite after this process, a docking maneuver between the two may then take place.

The parameters imposed upon this mission are listed in Table 1-1 below:

Table 1-1. Rascal Mission Parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Mass** | **Cube Size** | **Desired Orbit** | | **Acceptable Orbit Range** | **Desired Mission Life** |
| 8 kg | 6U | Altitude | 400 km | 300-900 km  40⁰-100⁰ | 6 Months |
| Inclination | 40⁰ |

Based on these parameters, and the time that has been allotted for work to be done on this mission, the focus of this senior design project will rest in two key areas: fully defining the Rascal Mission and the requirements that indicate its success and preliminary design and fabrication of the subsystems associated with the meeting of these requirements. The actual payload design and navigation protocols are beyond the scope of this particular project and are more suited for an electrical engineering or computer science design project.

# Mission Overview

## Mission Statement and Mission Success Requirements

The Rascal mission shall demonstrate two main objectives over the course of its mission life:

1. **The use of image-based navigation in the execution of orbital maneuvers associated with three key types of proximity operations:**
   * Low-Delta-V Stationkeeping,
   * Collision Avoidance,
   * And Long-Distance Satellite-to-Satellite Rendezvous.
2. **The execution of each of these types of proximity operations through the use of a cheap, small-scale, cold-gas propulsion unit that is able to fit within the volume and size specifications of a CubeSat-Class satellite and that could be used for future on-orbit service/inspection missions.**

The success of the Rascal spacecraft in meeting this mission statement will be determined by several mission objectives, four of which are listed below.

**Each spacecraft within the Rascal mission shall be able to:**

1. Capture an image of the other and calculate the relative displacement between each.
2. Demonstrate stationkeeping at a distance between 5 and 20 meters of the other using image-based navigation.
3. Demonstrate collision avoidance by performing an orbital maneuver that intentionally increases the relative displacement between each.
4. Demonstrate rendezvous by performing an orbital maneuver that decreases the relative displacement between each.

## Concept of Operations

The Rascal mission can be broken down into four discrete stages, as discussed in the following paragraphs.

**Phase 1: Launch Vehicle Ejection/Checkout**

This phase will commence upon ejection of Rascal from its rocket. After forty-five minutes has passed, any deployables that rocket has on board (such as antennas, solar panels, etc.) will be deployed, and radio beacons down to the ground will commence. Once radio communication has been made with Rascal, a ground crew will perform a full checkout of each subsystem of the spacecraft, as to ensure that Rascal survived launch and ejection. This process will likely take 2 to 4 weeks, depending on how long it takes to initially make contact with the spacecraft. Once this full functional checkout has been completed, Phase 2 can commence.

**Phase 2: Controlled Separation/Minimum Mission Success**

This phase is initiated by the release of one of the two separate 3U spacecraft from their common baseplate. Upon release, said spacecraft will drift away from the secured spacecraft at a controlled rate (a few centimeters a second). During this process, each spacecraft will orient itself such that their image navigation tools are pointed in the other’s general direction. Each spacecraft will continue to point at the other until a stable separation gap has been attained. This process will likely take 3-4 orbits and will occur autonomously. Also during this process, zero-net thrust bursts will be issued by each spacecraft for observation by the other.

**Phase 3: Rendezvous/Complete Mission Success**

Once this stable distance has been reached, a command will be sent to the released satellite to begin the process of returning within a short distance of the secured spacecraft. The same processes that took place during separation will also occur during this phase. Once a less than 10 meter separation has been attained for at least one orbit, the process will be repeated with the secured spacecraft. As a note, in order to mitigate the risk of one satellite losing the other in orbit, GPS receivers and communications crosslinks could be included on each spacecraft, as to keep track of each satellite if too large a separation was attained or in the event of a failure of the propulsion or navigation systems of either spacecraft. This entire process will likely take 2-4 weeks.

**Phase 4: Extended Operations**

After the completion of Phase 3, the secured spacecraft will be released from the common baseplate. After achieving stability, it will begin to drift away from the other spacecraft and the baseplate itself. After achieving a distance of 10-50 meters, each spacecraft will attempt to rendezvous with each other, as well as the baseplate. If possible, each satellite will dock with the other, by means of Velcro, electromagnets, or some other means, as determined by analyses that will be conducted in the upcoming semesters. This phase of the mission is not the ultimate focus of this project, but merely an objective to be attempted after the successful completion of the mission parameters, as laid out in the previous 3 phases.

## Mission Configuration Rationale

# Team Organization

Work on the mission will be separated between two specific teams: one focusing on the development of the propulsion system for each spacecraft, and one focusing on the development of the external structures associated with each satellite. This strict dividing line will help prevent the overspreading of human resources and speed along the development of each separate system.

Of the five members of this particular team, one will be designated as project manager, whose job it will be to oversee and participate in the development of both such systems, as well as determine the placement of all components within each satellite. The project manager will also be responsible for the adherence to schedules, the setting of weekly action items/deadlines, the maintenance of version control on all documentation, and the upkeep of the team’s project website, which will be running shortly. Any other specific task associated with the project (such as minutes taking, document archival, quality assurance, etc.) will be filled by each member as needed.

Table 2-2 on the following page lists out the names of each person on the project and the teams that he or she is associated with.

**Table 2-2. Team Members and Positions**

|  |  |  |  |
| --- | --- | --- | --- |
| **Team Member** | **Position** | **Email** | **Phone** |
| Tom Moline | Program Manager | [tmoline@slu.edu](mailto:tmoline@slu.edu) | 630-401-0791 |
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# Schedule

The major tasks expected to be completed over the coming semesters are listed in Table 4-1 below.

**Table 4-1. Rascal Schedule**

|  |  |  |
| --- | --- | --- |
| **Preliminary Design Phase** | * Refine Mission Objectives * Create Requirements Verification Matrix * Website Development * Preliminary Subsystem Drawings * Navigation Feasibility Study * Mass, Link, Power, Volume, Computing Budgets * Propulsion/Structures Trade Studies * Structural/Thermal Analyses | Completed in December 2013 |
| **Critical Design Phase** | * System Drawing * Subsystem Breadboard Tests and Results * Materials List * Structures Fabrication and Testing * Propulsion Unit Fabrication and Testing * Payload Integration and Testing (EE Senior Design) | Completed in May 2013 |

The prevailing focus of the first semester will be on initial trade studies associated with additive manufacturing processes (as related to propulsion units), as well as the affordability/usefulness of commercially available propulsion options. Other trade studies will also be conducted, with the vast majority focusing on the pros and cons of custom CubeSat skeleton design and manufacturing. Analyses will also be conducted into the risks associated with Phases 2-4 of Rascal’s mission life, as to determine the feasibility of the current goals listed in this document, as well as to refine the processes associated with the successful completion of each phase. Other goals include completing preliminary link, mass, and power budgets, determining the exact physical layout of the Rascal structure, researching the manner in which each 3U satellite can be secured to and released from their common baseplate, etc.

The second semester will predominately focus on the refining of the designs of the propulsion unit and satellite structures, with the ultimate goal at the end of the semester being the successful fabrication of the preliminary designs associated with each system.