Overview
This research presents a modeling tool for the rapid design of CubeSat rendezvous and proximity operation missions. The model is applied to a concept for a low Earth orbit CubeSat constellation designed to demonstrate the technological capability of docking with liquid apogee engines. The model analysis includes:

- An open-loop, fuel-optimal maneuver planner capable of generating controls over a complete orbital period
- A closed-loop, model predictive control (MPC) algorithm capable of locally-fuel optimal trajectories with collision-avoidance measures.
- Computer vision algorithms for relative range finding and translational positioning.

Trajectory Design
Both guidance methods solve discrete-time fuel minimization problems in the LVH frame of the chief satellite. An open-loop trajectory planner is capable of:

- **Fuel-optimal maneuver planning** for relative ellipse resizing
- Complex concept of operations design

Model predictive control is used for closed-loop control during close-proximity operations and docking with the apogee engine.

- **Multi-objective cost function** to allow for greater control over the behavior of the deputy spacecraft in proximity operations.
- Mixed-integer linear programming for binary constraints allows for binary-thrust control and collision avoidance

Attitude and Sensor Models
The model includes an attitude controller that reacts to automated trajectory design.

- Model-based attitude actuator sizing for pointing requirements

**Attitude controller**

Attitude concept of operations for chaser satellite maintaining sensor alignment with target spacecraft.

**Model predictive control.**

Control signals and cost function for the collision avoidance example below.

**End-to-end simulation**

Complete trajectory and attitude simulation of detumble, rendezvous, and proximity operations. Exports ephemeris files for post process visualization.

**Collision avoidance**

Automated collision avoidance while repositioning along the radial access of the Target satellite.

The concept chaser “Active” satellite is equipped with an optical sensor suite and computer vision processor.

- Chaser equipped with a wide and a narrow field of view lens.
- Uses knowledge of the LAE nozzle diameter to scale images to calculate range and relative translational position.
- OpenCV-based computer vision algorithm development.

Constellation Design Concept
- 3U “target” CubeSat with an onboard liquid apogee engine representation
- 6U “active” satellite which acts as the chaser with RPO capability and demonstration technologies.
- Using a cold-gas propellant tank and the presented guidance methods, the 6U is capable of a large rendezvous and several docking attempts.

Summary and Future Work
This work provides the user with the ability to:

- Rapidly design microsatellite RPO concept of operations.
- Evaluate different thruster performance on mission ability.
- Calculate Δv and fuel usage for constrained station keeping. Future improvements and additions to this work include:
  - Migration of the work to a system programming language is necessary to benchmark the performance.
  - Implementation of a method to convert discrete-time outputs in continuous-time control signals.
  - High-precision propagation with corrective measures using similar techniques.