Simulation Tool for Autonomous Multi-Spacecraft Mission Design around Small Bodies

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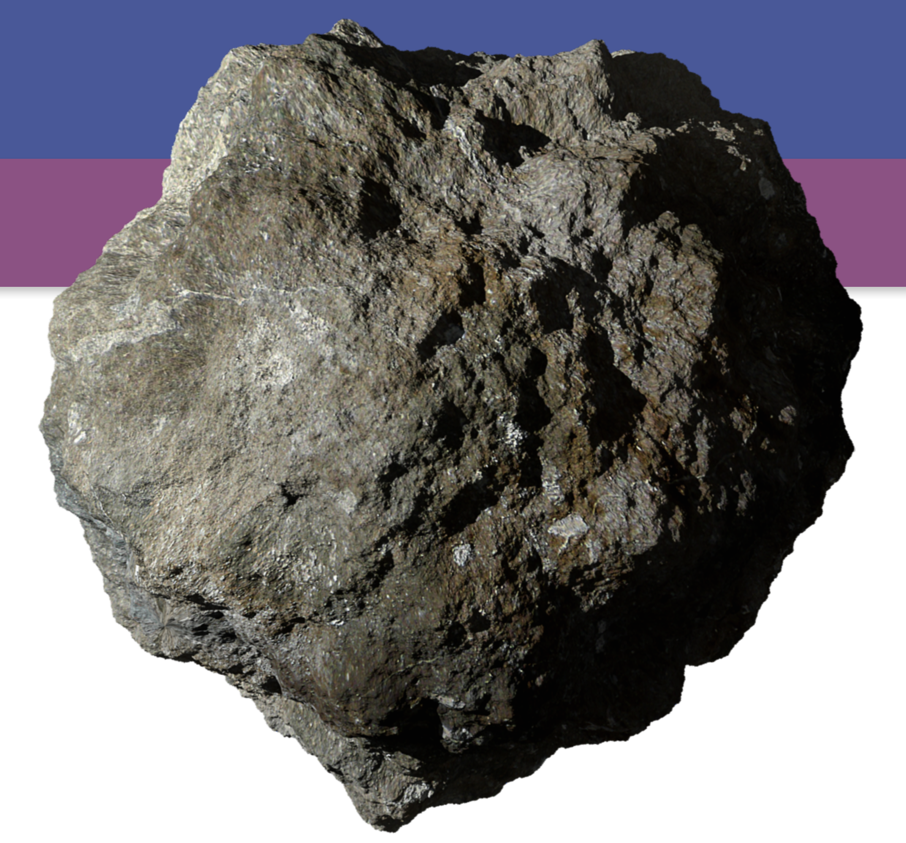


Architecting & Optimizing Future Missions

Over the past few years, the acceleration in technology development enables new capabilities and ambitions in terms of space mission design. In particular, the miniaturization of SmallSat and CubeSat avionics enhances the possibilities for multi-spacecraft mission architectures. However, new configurations introduce new challenges during the preliminary mission design phase since the current tools are mostly adapted for single-spacecraft architectures and the number of feasible configurations grows exponentially for multi-spacecraft architectures. A new tool is required that will allow designs to rapidly design interplanetary mission systems and verify their ability to achieve mission success.

Multi-Spacecraft Concept and Autonomy Tool (MuSCAT) aims to answer this need. It was first built for the Distributed Radar Observation of Interior Distributions (DROID) mission concept, which is a three-spacecraft architecture around the small-body Apophis. This case study illustrates the need for a such tool, having multiple spacecraft with different avionics and payloads, with different trajectories, and different roles to play during the mission. MuSCAT's objective is to iterate quickly from one design to another, allowing us to assess the key mission success parameters, such as science yield, and determining the impact to spacecraft resources, such as power, momentum, data storage, and others.

Simulating Science & Mission Performance In the Same Loop

General Approach

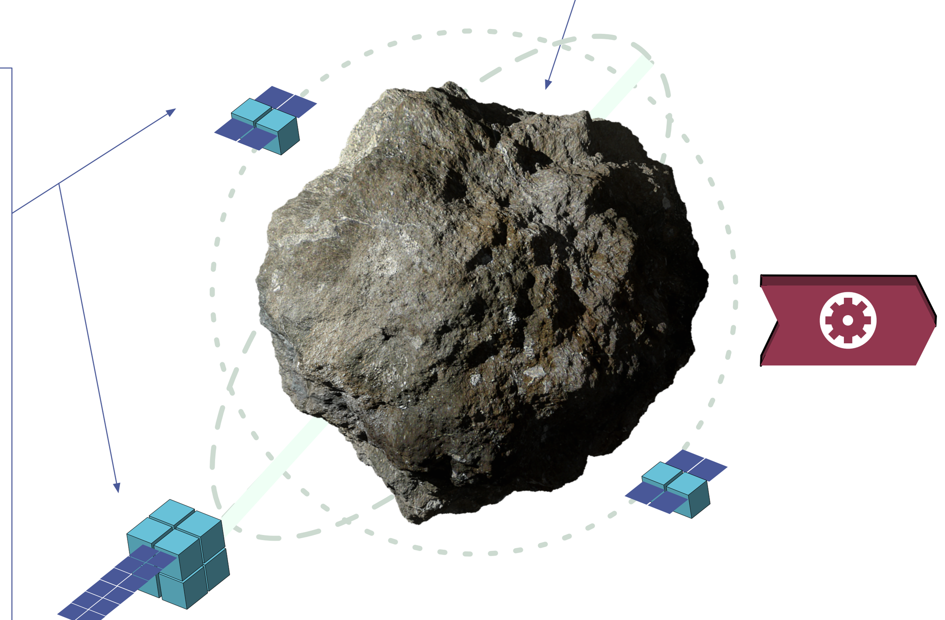
The simulation takes several classes of inputs:
- Spacecraft parameters that define performance and design
- Spacecraft behaviors that define rules for how spacecraft behavior within and change between modes
- Enivonmental parameters that define the target body and positions of Sun & Earth
- Mission parameters that define the context of the mission and value of science measurements

Environmental Parameters
- Body shape, gravity model
- Body spin rate, axis
- Sun, Earth, body locations
- Solar pressure

Mission Parameters
- Datetime
- Science coverage quality definitions

Spacecraft Parameters
- Masses, areas, moments of inertia, solar panel geometries
- Desired & true trajectories
- Sun, Earth, body angles
- Spacecraft performance (e.g. momentum storage)
- Payload specification (e.g. FOV)

Spacecraft Behaviors
- Payload use rules (e.g. imaging)
- Telecom (crosslink, DTE) rules
- Propulsion (TCM, desat) rules
- Spacecraft mode change rules



Simulation Outputs
- Science coverage & quality
- Data downlinked
- Spacecraft states & modes
- Resource use (e.g. propellant, power, momentum, data)

Progress Toward Improving Model Fidelity

DROID Integrated Model
- Specific Build
- Focused on Science
- No attitude control
- No orbit control
- No autonomy

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Single Agent - NEW
- One spacecraft
- Model ACS and environment physics
- Model telecom

→

MuSCAT Development - NEW

Develop generic simulation tool using elements from Single Agent software push

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MuSCAT Use - NEW

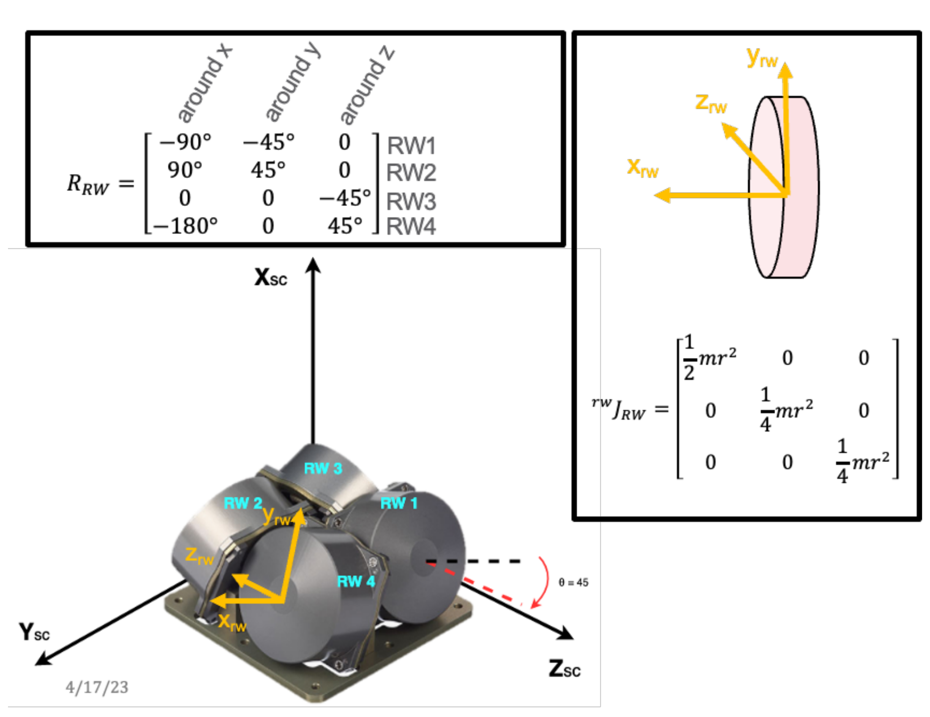
Model DART and DROID missions using MuSCAT

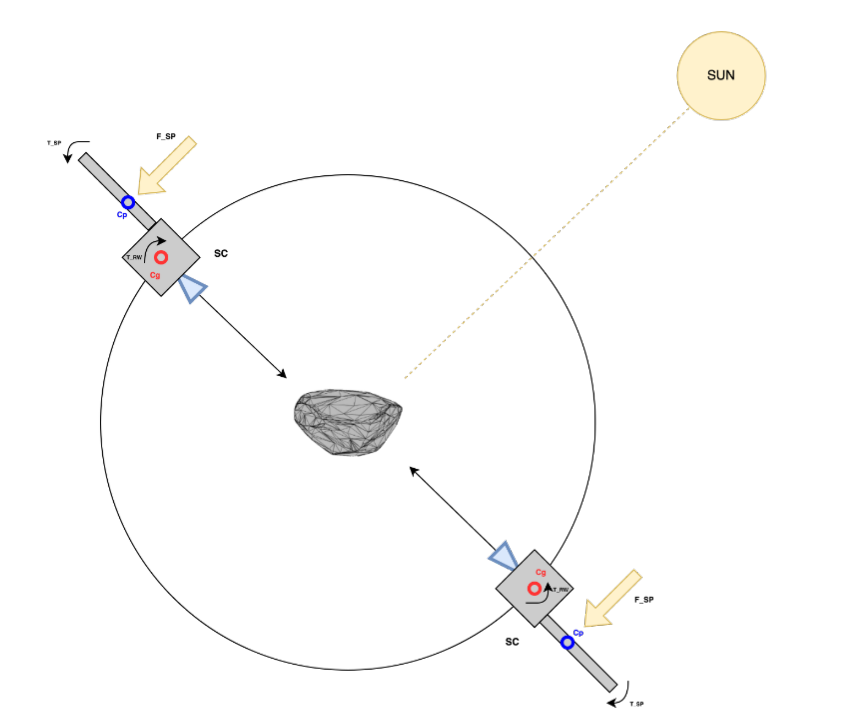
New Simulation Models

Modeling ACS, Propulsion Behaviors and Environmental Effects

RWA geometries and momentum management are fully modeled. Desats are performed when wheel momentum thresholds are met.

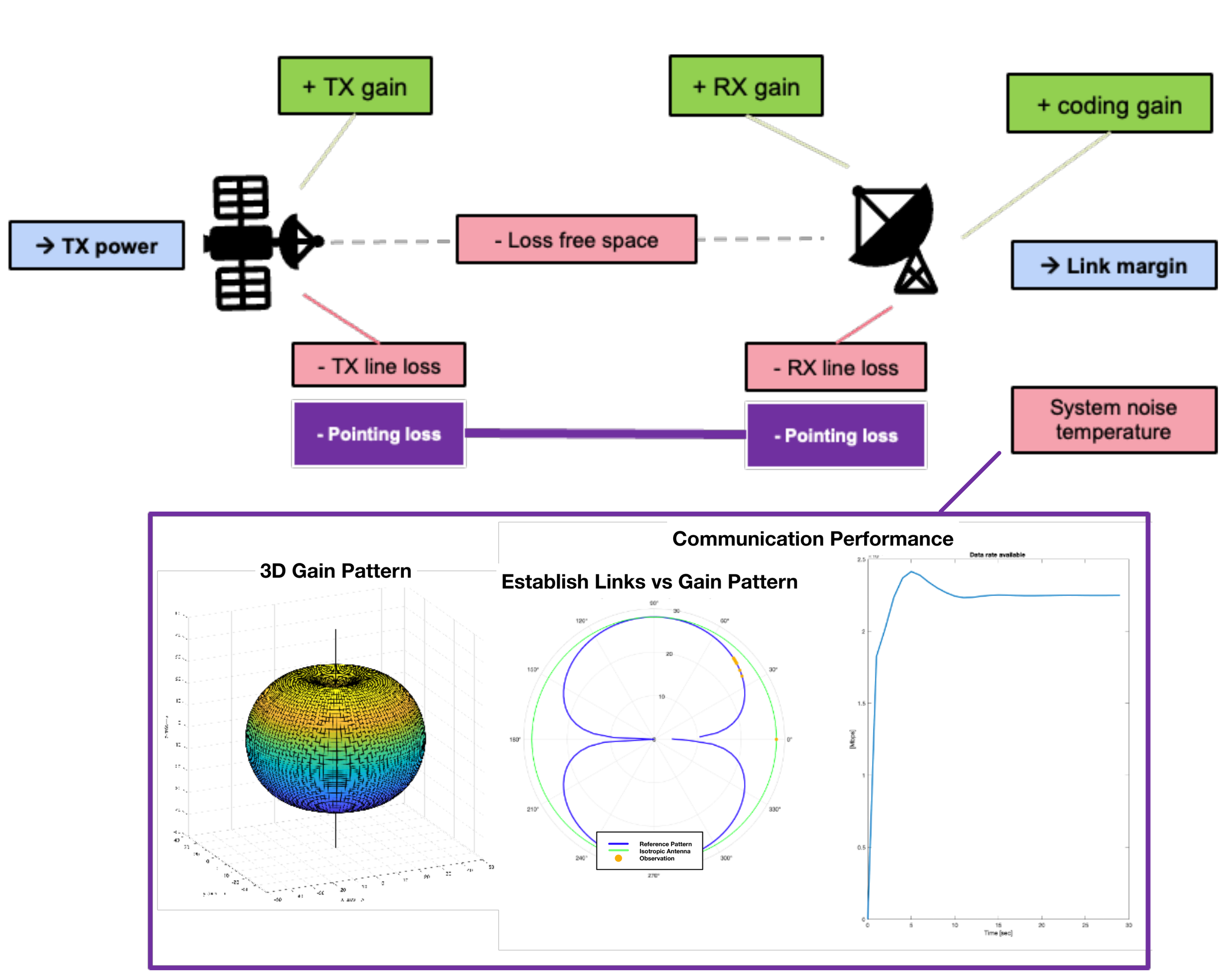
Body geometries and moments of inertia are modeled the generate realistic solar pressure and gravity gradient effects on mission and systems performance.





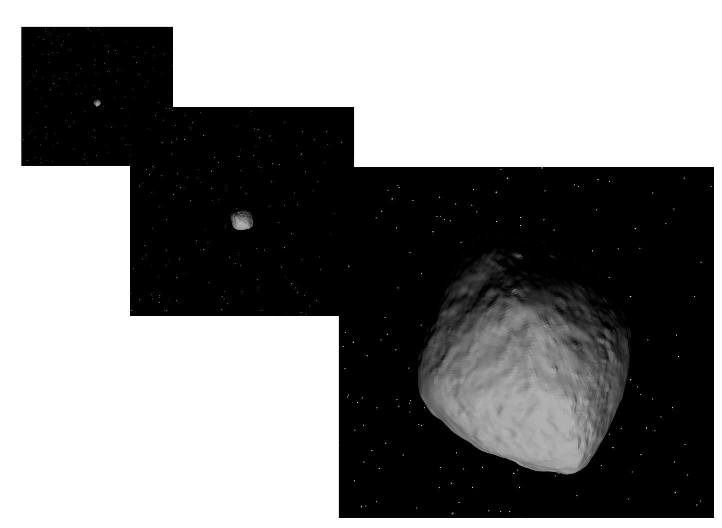
Modeling Telecom System Performance

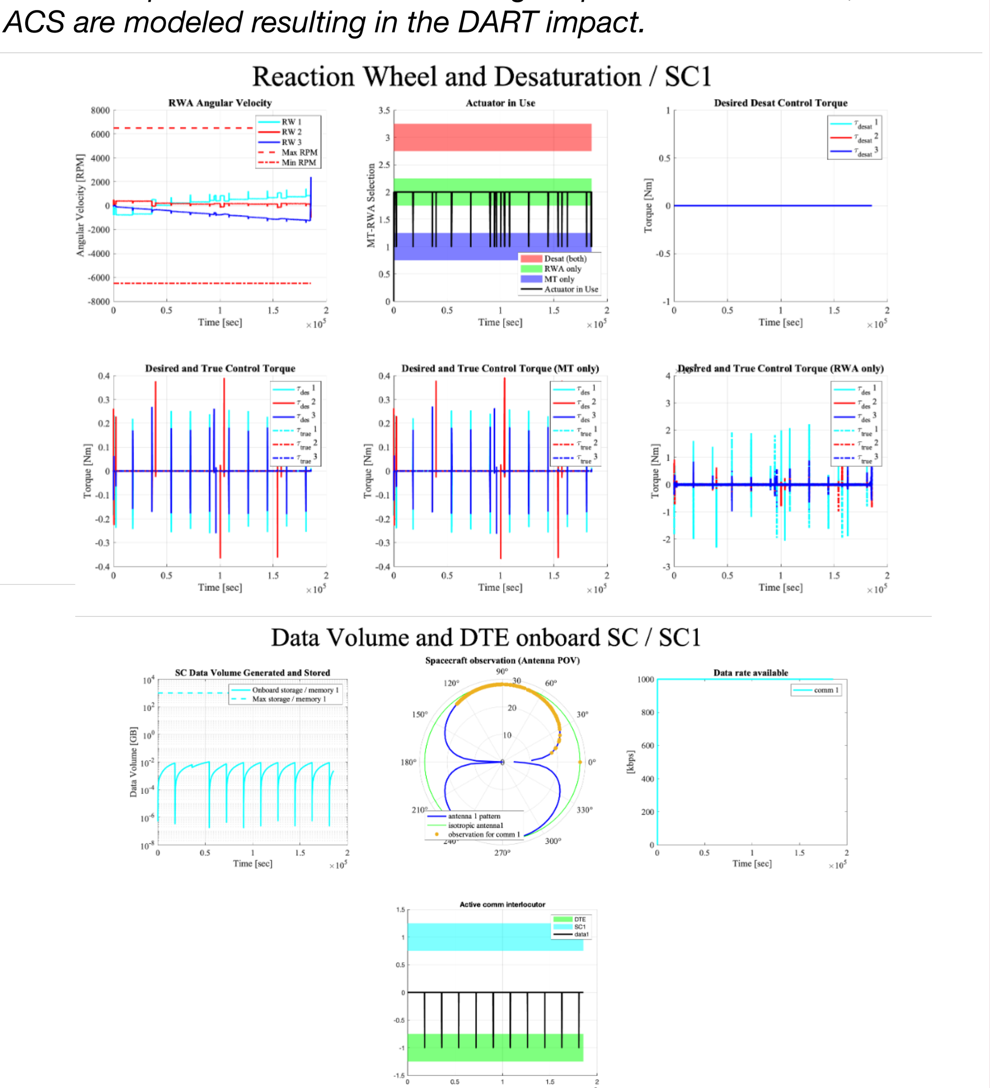
The entire link equation is modeled, including antenna gain patterns, to estimate link margin and expected data rate performance as a function of link and pointing parameters.

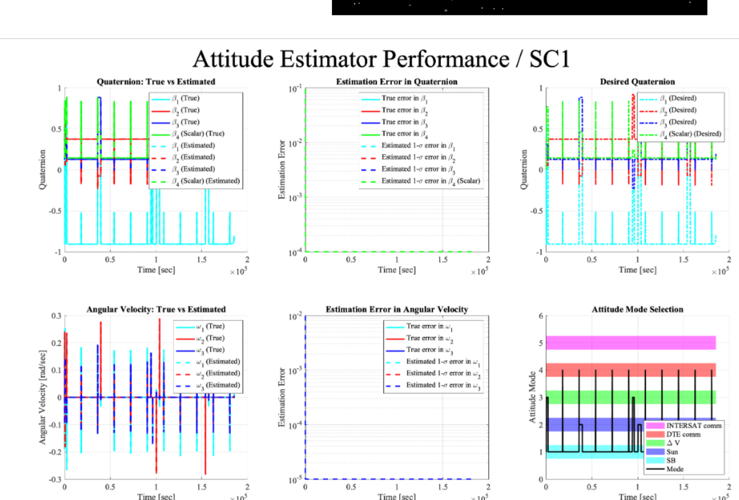


DART & DROID

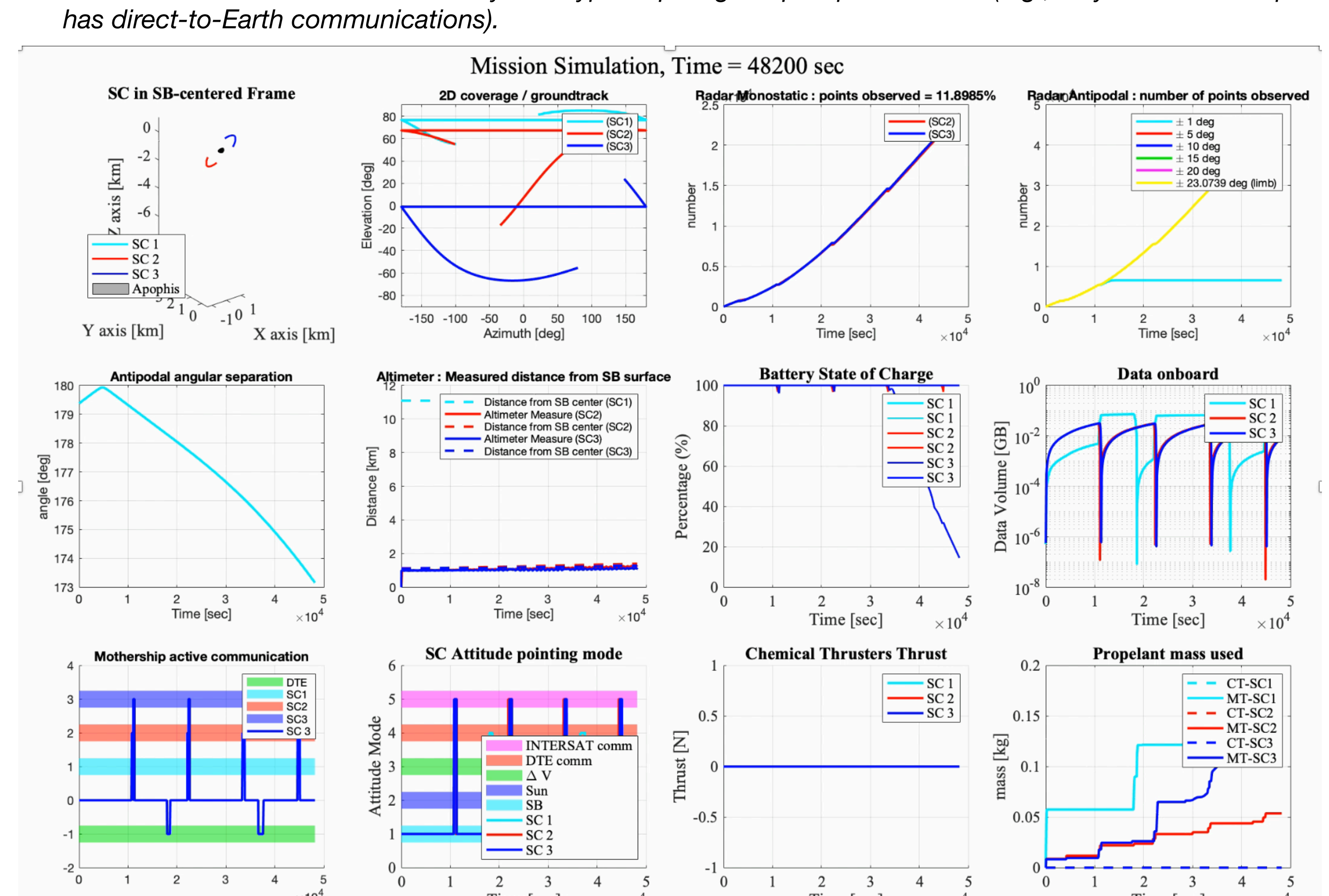
DART *To test MuSCAT, we inputted parameters of the DART spacecraft and mission design. Spacecraft behaviors, including payload, telecom, propulsion, and ACS are modeled resulting in the DART impact.*







DROID *For this case study, we model DRIOD's three-spacecraft constellation that has rendezvoused with Apophis in order to image and take monostatic and bistatic radar measurements. The constellation has a mothership and two identical CubeSats – each system type requiring unique specifications (e.g., only the mothership has direct-to-Earth communications).*



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