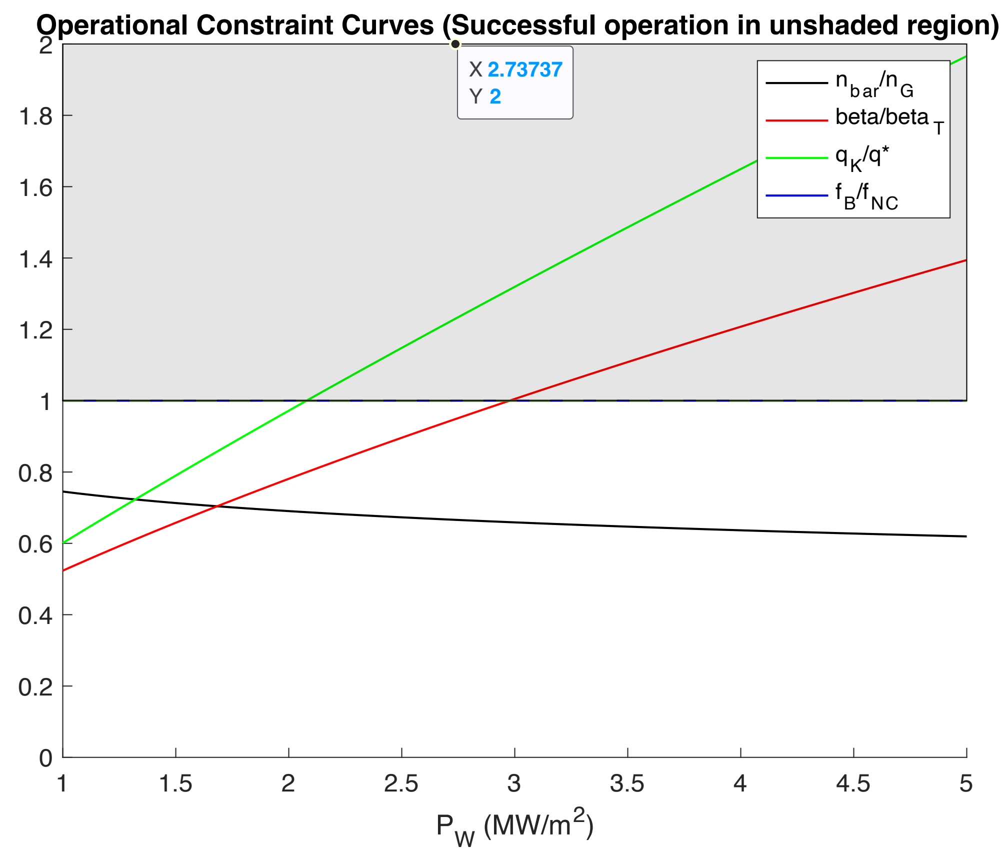
Toolboxes for MATLAB®

Princeton Satellite Systems, Inc. is a trusted provider of advanced control software. Our MATLAB® toolboxes provide you with the tools you need to create cutting edge products. Whether you are a new customer or an existing customer, you will find exciting new tools to accelerate your research and development.



From the new FusionReactorDesign function in the Fusion Toolbox.

> ***Customer quote: "A lot of our mission planning and capabilities evaluation software are built on a foundation of the PSS libraries, and it has been very helpful. It easily saved me over a year of development time."***

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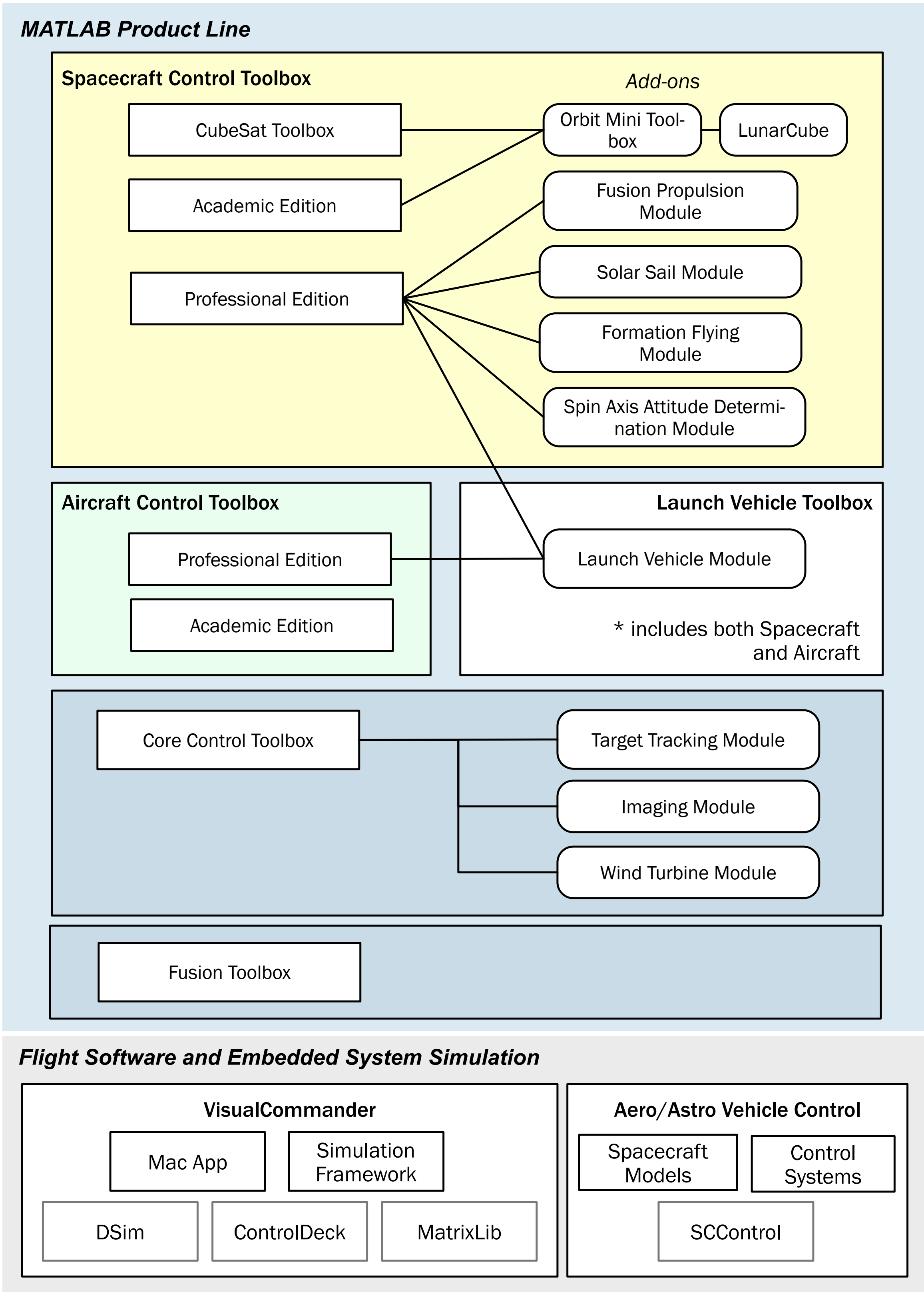
MATLAB Product Line
Spacecraft Control Toolbox
Add-ons
CubeSat Toolbox
Orbit Mini Tool-box
LunarCube
Academic Edition
Fusion Propulsion Module
Solar Sail Module
Professional Edition
Formation Flying Module
Spin Axis Attitude Determi-nation Module
Aircraft Control Toolbox
Launch Vehicle Toolbox
Professional Edition
Launch Vehicle Module
Academic Edition
* includes both Spacecraft and Aircraft
Core Control Toolbox
Target Tracking Module
Imaging Module
Wind Turbine Module
Fusion Toolbox
Flight Software and Embedded System Simulation
VisualCommander
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Simulation Framework
DSim
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Aero/Astro Vehicle Control
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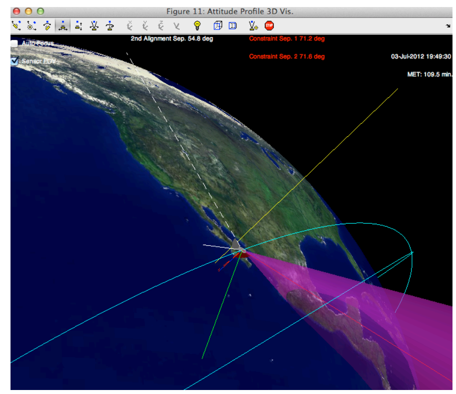
Princeton Satellite Systems MATLAB® Toolboxes

Princeton Satellite Systems sells MATLAB toolboxes for spacecraft, aircraft, fusion power, wind turbines, and industrial problems. Modules for these toolboxes include the Target Tracking Module for robust target tracking, the Fusion Propulsion Module, the Spin Axis Attitude Determination Module for satellite launch operations, and the Solar Sail Module for solar sail design, analysis, and simulation.

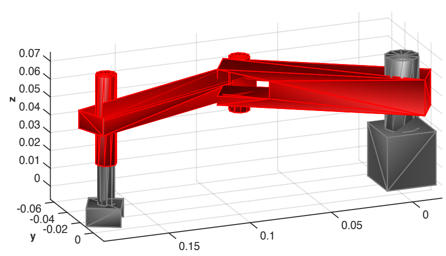
The toolboxes allow engineers to design vehicles, analyze them and simulate them, all within the MATLAB environment. The toolboxes include extensive control and estimation design functions and complete source code -- a necessity for advanced systems development. Extensive documentation and help systems make our toolboxes accessible to engineers at every level and students from high school to graduate school.



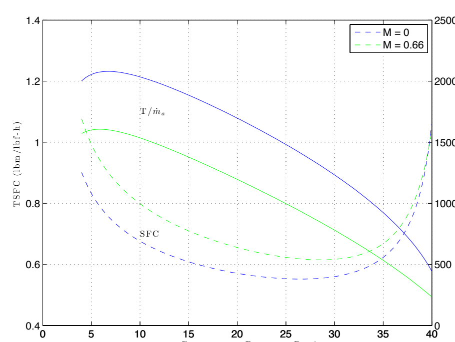
CubeSat Mission Planning

The toolboxes are used internally for all our work and they are constantly refined and updated. We have had dozens of contracts with NASA, the Air Force, Navy, Army, ESTEC, and many commercial organizations.

We used our toolboxes to develop the attitude control system for the geosynchronous Indostar-1, the safe mode guidance system for the Prisma formation flying satellites, the TechSat-21 formation flying system, and the TDRS H, I, J momentum management system. We developed a novel Optical Navigation System for NASA and a precision ACS with our Spacecraft Control Toolbox.



We leverage our toolboxes to provide custom solutions to customers. These solutions can include new scripts and new functions. We actively seek feedback from customers so that we can improve our products and provide features that our customers need.

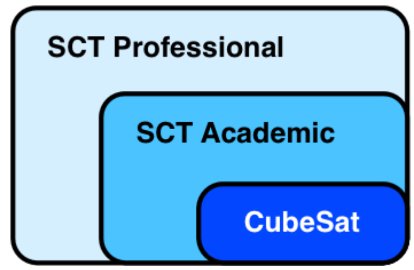


Jet engine modeling

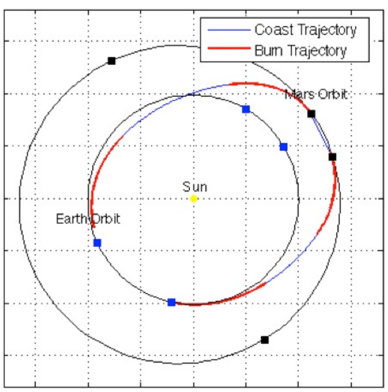
Our toolboxes are used worldwide by over a hundred organizations including the Canadian Space Agency, NASA, ESTEC, Energia in Russia, NEC, Lockheed Martin, Raytheon, General Dynamics, Orbital Sciences Corporation, and many others. The toolboxes are fully compatible with all versions of MATLAB after R2014b. A limited number of functions require the Optimization toolbox. The toolboxes will run on any platform that runs MATLAB.

Spacecraft Control Toolbox

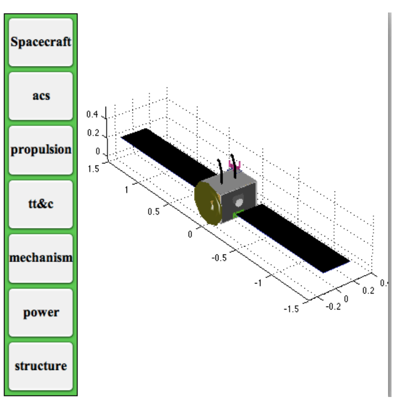
The Spacecraft Control Toolbox product family includes the Professional Edition, the Academic Edition, and the CubeSat Toolbox. You can model a satellite using the CAD layout tools; design and analyze estimation and control systems; perform disturbance analyses; and test your algorithms in a six-degree-of-freedom simulation - all in the MATLAB environment.



The Professional Edition provides comprehensive software and extensive examples for designing any spacecraft control system, anywhere in the solar system. Add-on modules are available to the Pro Edition for formation flying, fusion power generation, launch vehicles, solar sails, and spin-axis attitude determination in a transfer orbit. The Academic Edition is a subset of the Pro software intended for undergraduate and graduate level attitude control system design and analysis. The CubeSat Toolbox is our entry-level product that has been specifically designed for CubeSat teams.



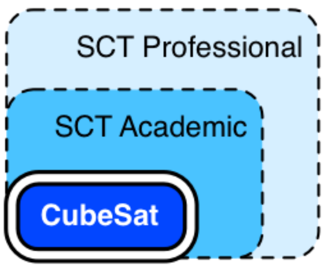
The toolbox is a library of space environment and satellite modeling functions, but it is also so much more – hundreds of design examples and sample missions, from low earth constellations to geosynchronous satellites and deep space missions. Whether your satellite has a passive control system, basic sensors or a highly accurate IMU, reactions wheels and thrusters, or even flexible articulated appendages, you can model it. Our comprehensive textbook, Spacecraft Attitude and Orbit Control, helps you relate the theory to the code.



Our orbit analysis functions enable you to model trajectories anywhere in the solar system. Design and perform Hohmann transfers, stationkeeping maneuvers, low-thrust spirals, and even perform advanced interplanetary targeting. A variety of classic and novel algorithms are available including Lambert targeting and optimal landing laws.

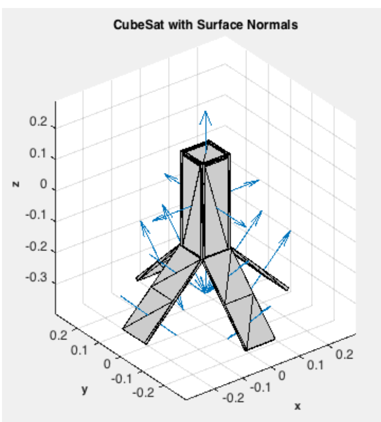
Our CAD modeling package allows you to describe your spacecraft using geometric primitives and perform disturbance analysis that operates on the resulting mesh. It Includes often overlooked disturbances such as RF torques and thermal emissions and accounts for rotating solar arrays.

CubeSat Toolbox



The CubeSat Toolbox is our entry-level toolbox for CubeSat university teams. Its unique simplified surface model lets users calculate full disturbances and model power subsystems without complicated CAD models. The toolbox also provides mission planning tools, link and thermal analysis, and full attitude and orbit simulation [limited to Earth orbits].

CubeSats are getting more sophisticated and everyone wants more power! One way to get that is with deployable solar panels. Our `CubeSatModel` design function now allows you to add deployable solar panels. You can pick the number, location, and location of the panels. The function automatically generates the surface, power, mass, and thermal models for the spacecraft. It outputs the data structure used by the right-hand-side functions, simplifying the design process for CubeSats.

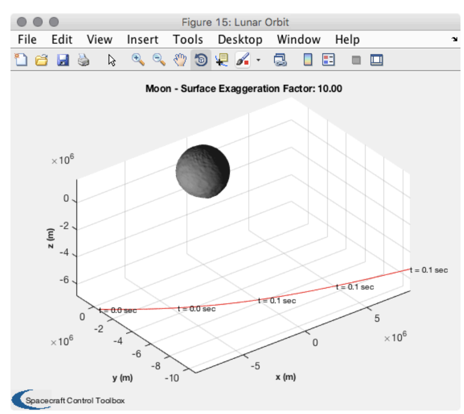


The figure on the left shows a 3U CubeSat with four canted solar wings. The arrows show the surface normals for all the surfaces. Panels can be attached anywhere and in any orientation; just specify the position and normal.

We have improved the disturbance models for the CubeSat toolbox. They match the Spacecraft Control Toolbox disturbance models closely. The Spacecraft Control Toolbox allows you to model more complex spacecraft with multiple rotating surfaces that are normally not found on CubeSats.

LunarCube Module for CubeSat

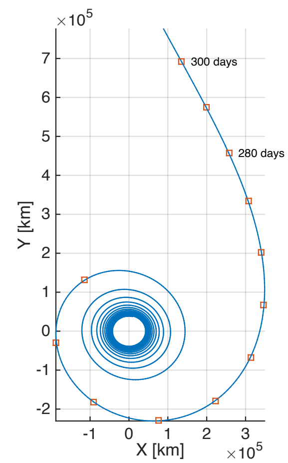
The LunarCube module adds the tools needed to send your CubeSat into lunar orbit. Mission planning tools for cis-lunar flight and lunar orbit operations are included. The module also includes a spacecraft dynamical model that applies to Earth orbit, lunar transfer, and lunar orbit. It includes reaction wheels, thrusters, a power system model, and a thermal model. High-fidelity lunar gravity and lunar surface topography models are included.



Case Study: Asteroid Prospector

We used SCT to generate a complete design for Asteroid Prospector, a small reusable spacecraft capable of flying to an asteroid from Earth orbit, operating near the surface of the asteroid, and returning samples. The first step is estimating the Delta-V required and analyzing the trajectory. Then, we built a model of the spacecraft, demonstrating that the components fit in the desired form factor. Finally, we specified the individual thruster locations and simulated operations near the asteroid, requiring relative orbit dynamics due to the very low asteroid gravity.

1. Model the trajectory



Simulation of Earth escape spiral

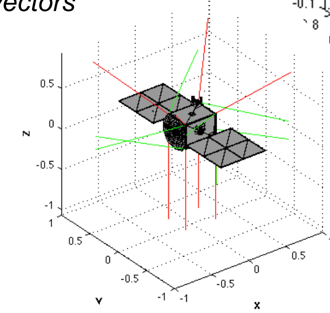
We first use approximate orbital elements for the Apophis asteroid to estimate the Delta-V for two low-thrust transfers: An Earth escape spiral and a low-thrust transfer spiral. This can be done with analytical methods available in the toolbox. We then simulate the Earth escape phase, where the thrust is applied along the velocity vector, raising the orbit. This simulation uses the Sun-Earth circular restricted three-body dynamics for a more accurate estimate of the spiral duration. Starting from 850 km altitude, it takes about two years and 6.8 km/s Delta-V to escape the Earth's gravity well using a 2 mN ion engine; with a change to one line, we can test departing from GEO altitude instead, resulting in a 2.4 km/s Delta-V in just 283 days, at right. To rendezvous with the asteroid from this Earth, departure trajectory is a complex three-dimensional problem; we developed a custom optimization for the rendezvous phase using the Gauss variational equations functions in the toolbox. GLPK is used to compute the control acceleration. An initial trajectory is planned with linearized dynamics, the control solution is found and applied in an open-loop nonlinear simulation, and this new trajectory is used as the reference orbit for the next iteration. The full transfer calculated after 6 iterations takes 395 additional days and matches the asteroid's semi-major axis and eccentricity to within 1%.

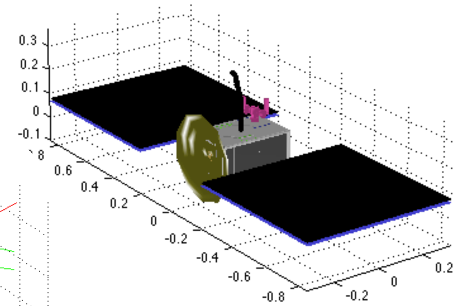
2. Model the spacecraft

The trajectory modeling work shows that we can reach Apophis with 13.5 km/s Delta-V using a 2 mN ion engine. We created a model of the satellite, with a 27-kg total mass, 10.5 kg Xenon, and 1.7 kg chemical propellant for the RCS system. The spacecraft has reaction wheels for attitude maintenance, dual articulated telescopes for optical navigation and star sensing, and a mini deployable high gain antenna (S-band). There is a robot arm for collecting a sample of the asteroid. We also modeled the power and communication subsystem, sizing and laying out all the components. The resulting CAD model and spacecraft properties are below.

Bus dimensions	30 x 40 x 30	cm
Total mass	27	kg
BOL Power	272.6	W
Ion Delta-V	13.5	km/s
RCS Delta-V	150	m/s
Xenon mass	10.5	kg
Xenon tank diameter	19	cm
RCS mass	1.7	kg
Ion engine power	80	W
Antenna diameter	>50	cm
Transmit power	7	W

RCS force and torque vectors

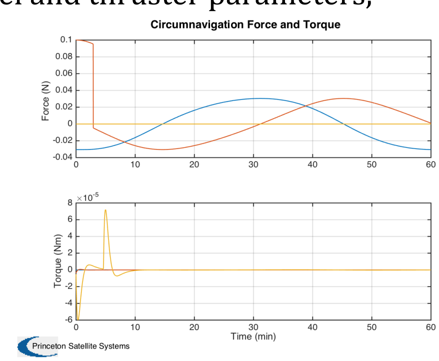


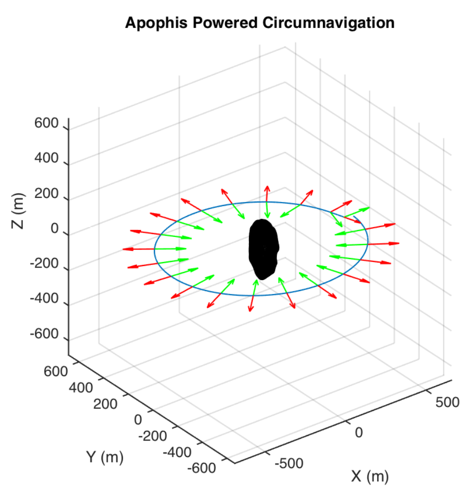


Asteroid Prospector CAD Model

3. Near-Asteroid Operations

Apophis has a diameter of only 325 m and a mass of about 4×10^{10} kg so that at its surface, the gravitational acceleration is still 200 smaller than that of the sun at 1 AU. Thus, this acceleration can be considered a negligible disturbance, and the motion of the spacecraft around the asteroid is achieved completely by the acceleration provided by the RCS system. We wrote a 6 DOF simulation of proximity operations around the asteroid using rigid body dynamics with a double integrator position model. A circumnavigation at a 500-m radius requires continuous thrust, with a tangential impulse of 17 Ns required to initial the trajectory and a continuous radial force of 0.03 N to maintain it. For the next level of fidelity, the forces and torques produced by this simulation could be further modeled using the actual reaction wheel and thruster parameters, such as wheel friction and tachometer loops, thruster minimum impulse bit, and pulse width modulation.



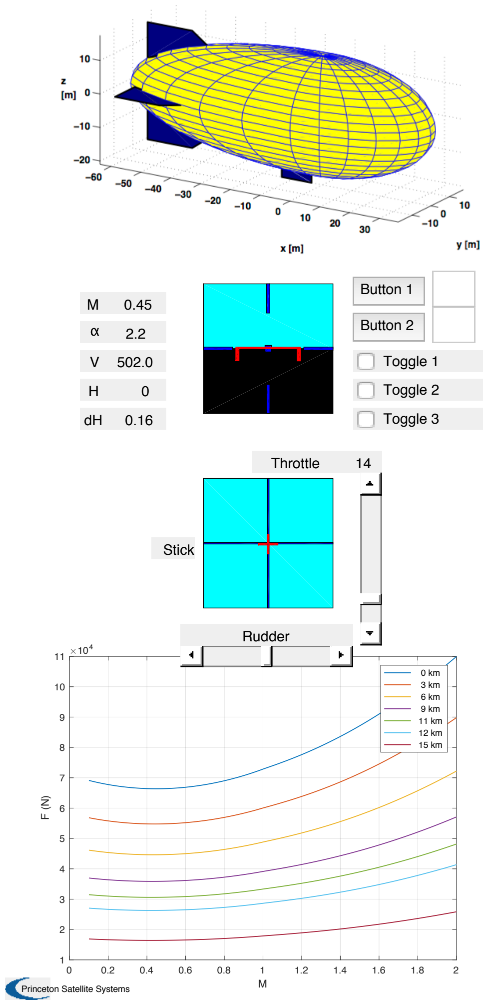


Core Control Toolbox

The Core Control Toolbox provides the control and estimation functions of our Spacecraft Control Toolbox with general industrial dynamics examples including robotics and chemical processing. The suite of Kalman Filter routines includes conventional filters, Extended Kalman Filters, and Unscented Kalman Filters. The Unscented Filters have a new faster sigma point calculation algorithm. All the filters can now handle multiple measurement sources that can be changed dynamically. Add-ons for the Core Control Toolbox include our Imaging, Wind Turbine, and Target Tracking modules.

Aircraft Control Toolbox

The Aircraft Control Toolbox is a complete package for the analysis, design, and simulation of air vehicles. It also has professional and academic editions and includes a module on airships; you can model any air vehicle. Available aircraft dynamics models include flexibility, actuators, and sensor and engine dynamics. There is an integrated nonlinear simulation with built-in linearization and trimming – you can add as many degrees of freedom as necessary. This simulation includes the attitude dynamics of the aircraft; there is also a trajectory-only simulation and even a set of graphical controls for controlling your aircraft in flight. You can fly entire missions from takeoff roll to landing. Subsonic, supersonic, and hypersonic vehicles can all be modeled seamlessly.



The toolbox provides extensive performance analysis tools. These allow you to quickly size your aircraft and perform trade studies. Our CAD tools allow you to layout your aircraft quickly without having to use solid modelers.

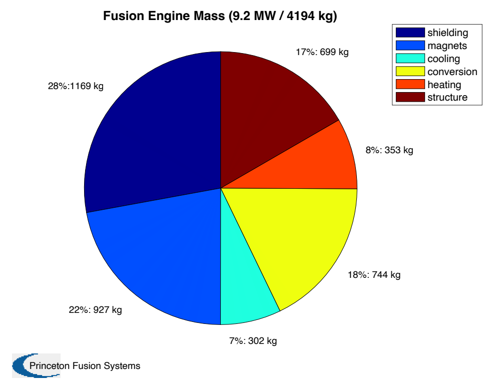
The extensive library of engine models provided encompasses turbojets, turbofans, and ramjets. Propeller models are also included. You can generate engine performance tables for use in simulations or use the functions directly.

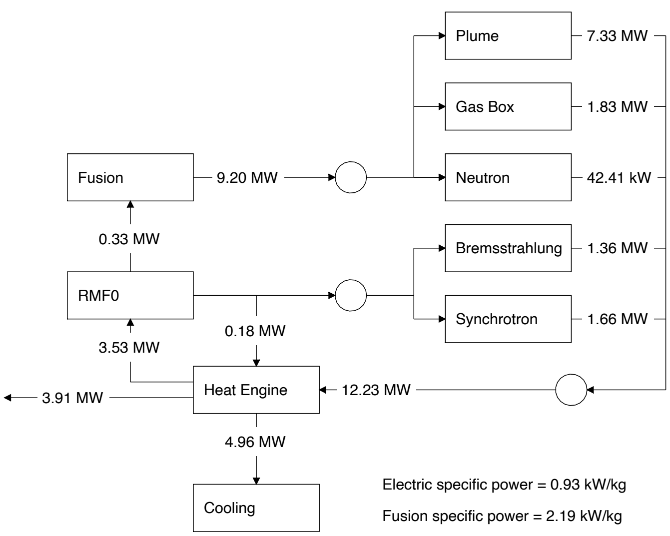
The toolbox has sophisticated atmosphere models. These include the standard atmosphere reaching to the edge of space and wind and gust models.

Fusion Energy Toolbox

This toolbox includes an extensive library of functions for modeling nuclear fusion energy systems. It includes fundamental plasma physics functions, fusion reactor functions, and system-level functions.

The plasma physics functions are geared toward steady-state magnetic fusion reactors but include functions of universal plasma physics relevance such as the emission of bremsstrahlung and synchrotron radiation, classical particle, and energy transport, and fundamental plasma time/length scales.





The fusion reactor functions help design the various subsystems of a fusion reactor, again geared toward steady-state magnetic fusion reactors. Functions help size superconducting coils, Brayton cycle heat engines, cryocoolers, radiofrequency heating systems, and more.

System-level functions help tie the lower-level functions together. A broad trade space of fusion reactors can be produced from simple engineering drivers like required total power and lifetime.

The modules included in the Fusion Energy Toolbox are:

`Brayton` – heat cycles
`Cryo` – cryocooler sizing
`EngineDesign` – mass models and sizing
`FRC`– field reversed configurations
`HeatTransfer`
`Magnets` – including energy methods
`PlasmaPhysics`
`Reactor` – fields, and power
`RFSystem` – amplifiers and RF drives
`RMF` – rotating electromagnetic fields
`Shielding` – attenuation models

Selected Add-On Modules

Wind Turbine Control Module

The Wind Turbine Control Module can leverage all the new control, estimation, and mathematical functions in the Core Control Toolbox to provide enhanced wind turbine control system design capabilities.

Target Tracking Module

This module implements Multiple Hypothesis Testing (MHT) for tracking multiple objects. It is essential for the reliable tracking of objects in a noisy environment. Applications of MHT include automobile adaptive cruise control, people tracking in crowds, and air traffic control. This module works with the Core Control Toolbox and contains a wide range of demos.

Launch Vehicle Module (Requires ACT and SCT)

The Launch Vehicle Toolbox (LVT) also requires the Aircraft Control Toolbox. The LVT provides a versatile set of tools that support the design, modeling, simulation, and performance analysis of launch vehicles.
LVT provides design functions for sizing launch vehicles and finding launch windows to enter the desired orbit from a specified launch site. It provides simulation tools for simulating launch trajectories

Formation Flying Module (SCT Only)

Small satellite constellations are a cost-effective way of solving many remote sensing problems. The Formation Flying Module is an add-on to the Spacecraft Control Toolbox that gives you cutting-edge algorithms, some of which were tested on the Prisma rendezvous robots mission! Formation control and planning tools are provided.

Solar Sail Module (SCT Only)

This module adds solar sail functions to the Spacecraft Control Toolbox. It includes a full set of design and trajectory analysis tools for sailcraft.

Spin Axis Attitude Determination Module (SCT Only)

Spin-axis attitude determination is a reliable way of attitude determination during transfer orbit. This module provides flight-tested software. A graphical user interface is provided to facilitate use in real-time. It is also very easy to customize for your own sensor set. The module includes batch and recursive estimators including our highly reliable nonlinear batch estimator.

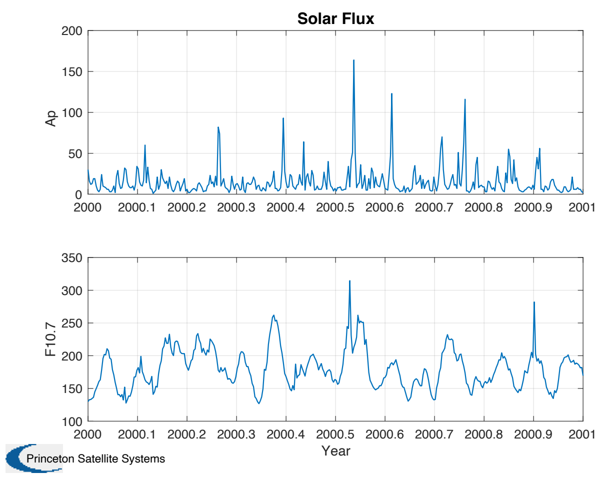
Orbit Mini Toolbox (CubeSat)

A high-fidelity orbit propagation module that can also stand alone.

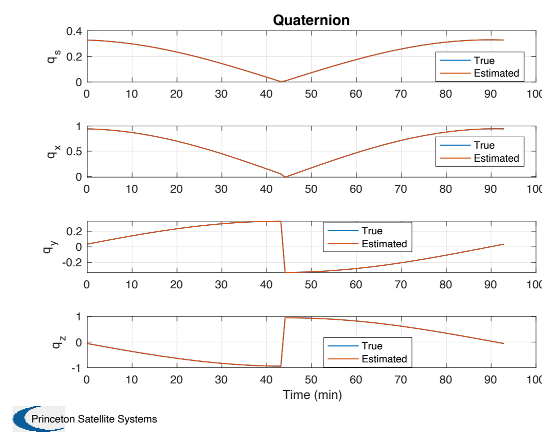
New in Version 2022.1

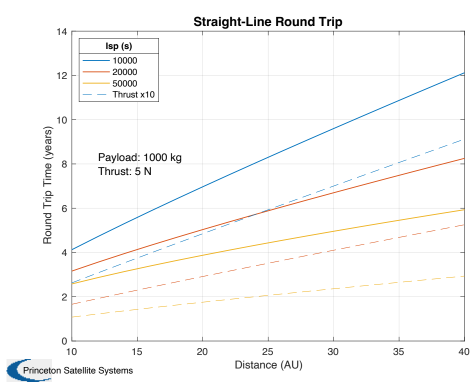
Over thirty new functions and scripts were added in Version 2022.1. Improvements were made to dozens of existing functions to improve their performance and expand their applications. Built-in demos and default data structures were added to more functions.

In the Spacecraft Control Toolbox, a new function `SolarFluxHistorical` plots the solar flux over time. This is important for atmosphere models. The solar flux is an important factor in atmosphere models. Atmospheric drag is a major orbital perturbation for low Earth orbit satellites.



Another function, `TwoUToQ`, computes a complete attitude quaternion from two vectors such as a nadir vector, sun vector, or a magnetic field vector. This is used when you don't have a star camera or tracker and want a complete attitude quaternion from the ECI frame to the body frame.





`RoundTripTime` plots the round trip time for straight line orbital trajectories. Straight line trajectories are a good first start for any deep space mission using electric propulsion. There are a wide variety of straight line tools, including optimization tools, in SCT.

Founded in 1992, Princeton Satellite Systems is an innovative engineering firm pushing the state-of-the-art in Aerospace, Energy, and Control. We help our customers implement control systems that are easy to use and understand. We have been an integral part of the control system development for the Cakrawarta-1 Communications Satellite, NASA ATDRS, the GPS IIR satellites, and the Prisma Space Rendezvous Robots. Our extensive satellite operations experience includes Asiasat, Telstar, and Koreasat. We have patented a wide range of innovative technologies, ranging from imaging sensors and spacecraft maneuvering algorithms to wind turbines and nuclear fusion propulsion. Our staff provides user-focused engineering talent in developing and applying new and innovative solutions to any set of complex problems. PSS sells the MATLAB Spacecraft, Aircraft, and Wind Turbine Control Toolboxes.

A variety of high-tech organizations use Princeton Satellite Systems software products for their work. These include Energia (Russia), ESTEC, NASA, the Canadian Space Agency, the Swedish Space Corporation, Raytheon, General Dynamics, Lockheed Martin, Orbital Sciences Corporation, MIT Lincoln Laboratories, NEC, Boeing, and many colleges and universities.

Princeton Satellite Systems regularly customizes and enhances our software to meet specific client requirements; we find this to be an effective way of enhancing our products and ensuring that they meet all our clients' needs. Princeton Satellite Systems combines custom development with commercial software components to provide powerful control software in minimal time and with maximum flexibility to adapt to the latest customer requirements.

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