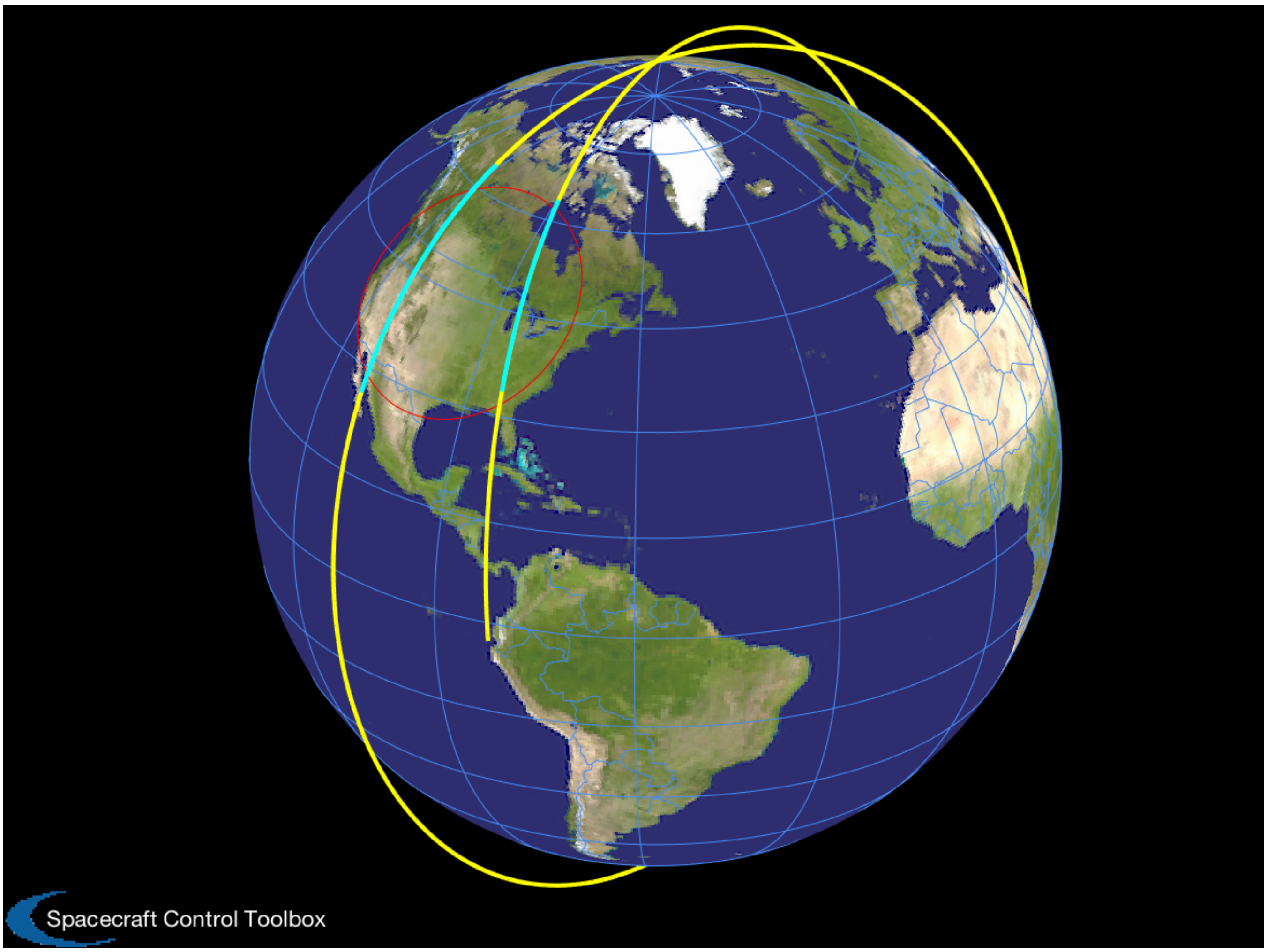
Toolboxes for MATLAB®

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.



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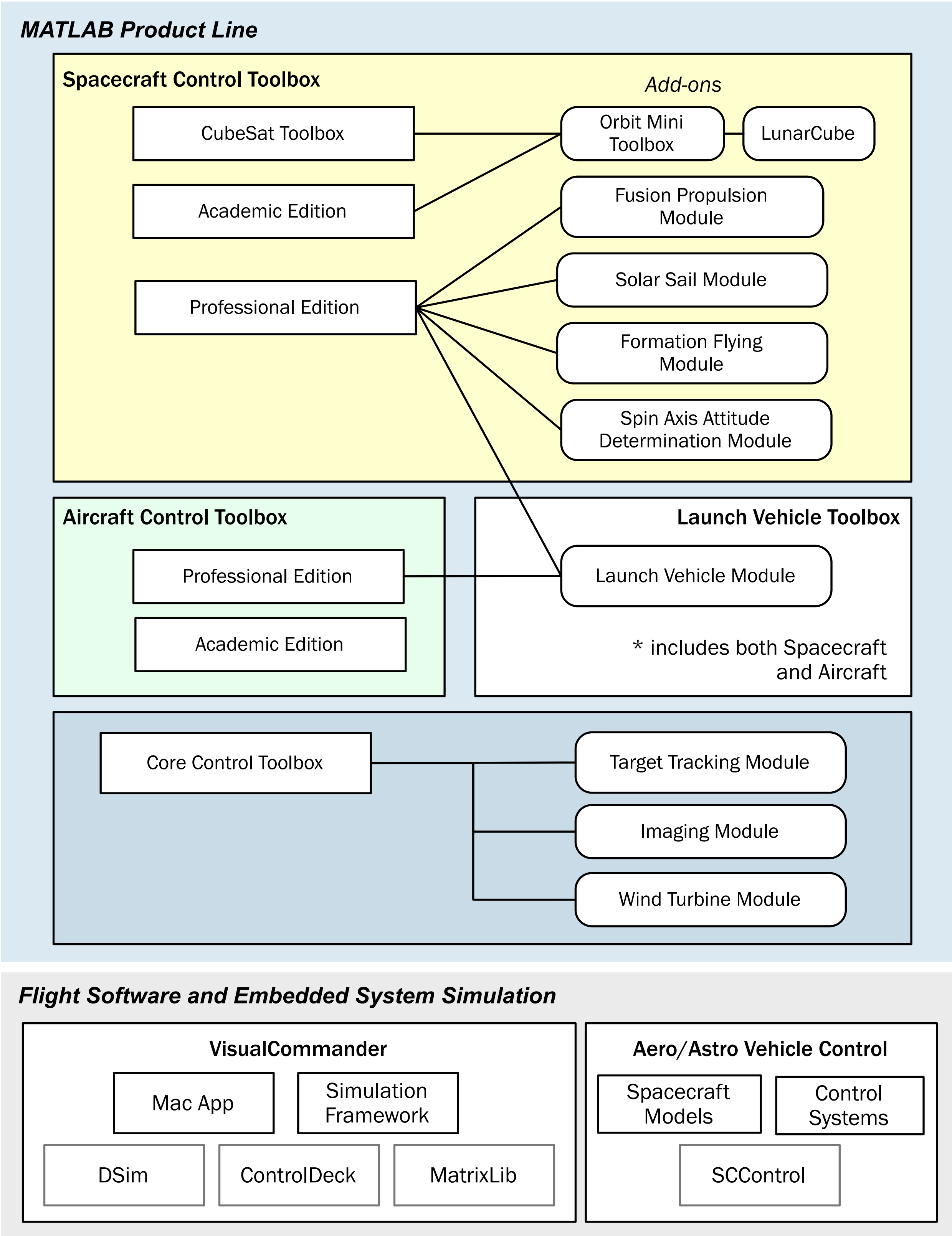
MATLAB Product Line
Spacecraft Control Toolbox
Add-ons
CubeSat Toolbox
Orbit Mini Toolbox
LunarCube
Academic Edition
Fusion Propulsion Module
Professional Edition
Solar Sail Module
Formation Flying Module
Spin Axis Attitude Determination Module
Aircraft Control Toolbox
Launch Vehicle Toolbox
Professional Edition
Launch Vehicle Module
Academic Edition
* includes both Spacecraft and Aircraft
Core Control Toolbox
Target Tracking Module
Imaging Module
Wind Turbine Module
Flight Software and Embedded System Simulation
VisualCommander
Mac App
Simulation Framework
DSim
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Aero/Astro Vehicle Control
Spacecraft Models
Control Systems
SCControl

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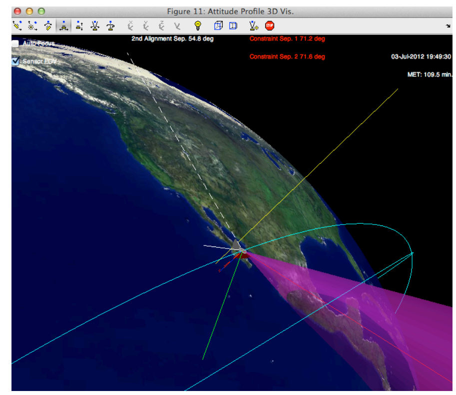
Princeton Satellite Systems MATLAB® Toolboxes

Princeton Satellite Systems sells MATLAB toolboxes for spacecraft, aircraft, wind turbine 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.

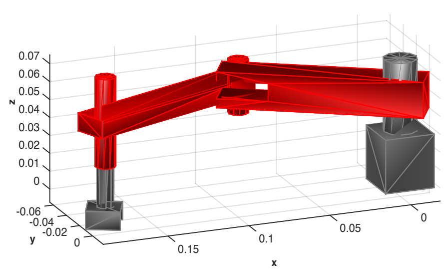
The toolboxes allow engineers to design vehicles, analyze them and simulate them, all within the MATLAB environment. The toolboxes include extensive control and estimation design functions, as well as complete source code -- a necessity for advanced systems development. Extensive documentation and help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



CubeSat Mission Planning

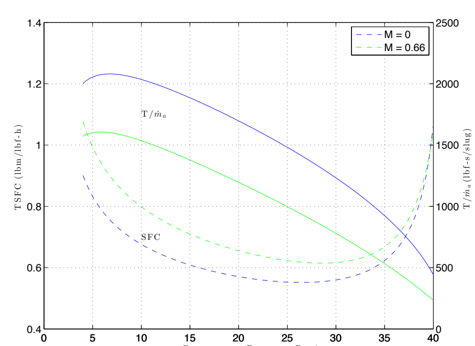
The toolboxes are used internally for all of our work and they are constantly refined and updated. We have had dozens of contracts with NASA, the Air Force, Navy, Army, ESTEC and many commercial organizations.

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 ATDRS momentum management system.



SCARA Robot Arm

We developed a novel Optical Navigation System for NASA with our Spacecraft Control Toolbox. Recently we designed a magnetic hysteresis control system for a CubeSat using our CubeSat toolbox. We are currently developing an ultra-precision pointing control system for small satellites for the U.S. Army.



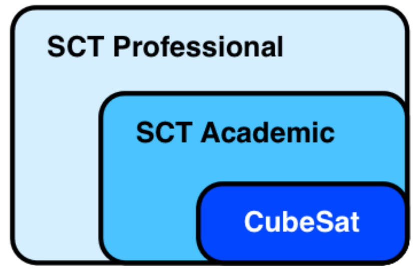
Jet engine modeling

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.

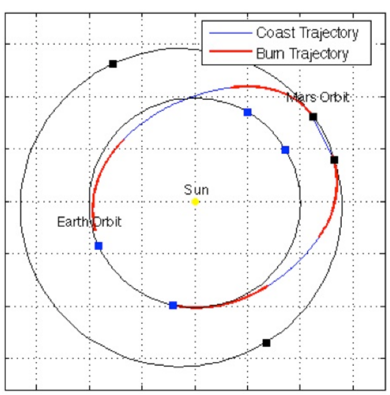
Our toolboxes are used worldwide by over a hundred organizations including the Canadian Space Agency, NASA, ESTEC, Energia in Russia, NEC, Lockheed Martin, Raytheon, General Dynamics, Orbital Sciences Corporation and many others.

Spacecraft Control Toolbox

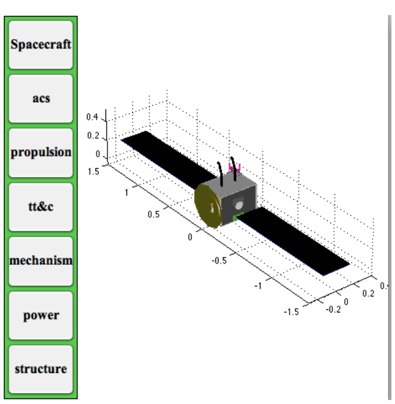
The Spacecraft Control Toolbox product family includes the Professional Edition, the Academic Edition, and the CubeSat Toolbox. You can model a satellite using the CAD layout tools; design and analyze estimation and control systems; perform disturbance analyses; and test your algorithms in a six degree-of-freedom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



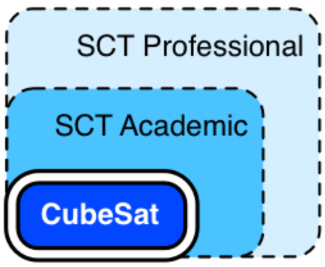
The toolbox is a library of space environment and satellite modeling functions, but it is also so much more – hundreds of design examples and sample missions, from low earth constellations, to geosynchronous satellites and deep space missions. Whether your satellite has a passive control system, basic sensors or a highly accurate IMU, reactions wheels and thrusters, or even flexible articulated appendages, you can model it. Our comprehensive textbook, <u>Spacecraft Attitude and Orbit Control</u>, 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. Include often overlooked disturbances such as RF torques and thermal emissions, and account for rotating solar arrays. Calculate a frequency analysis of the disturbances in your mission orbit for use in statistical simulations.

CubeSat Toolbox

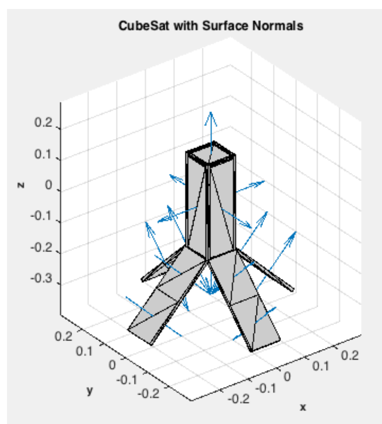


The CubeSat Toolbox is our entry-level toolbox for CubeSat university teams. Its unique simplified surface model lets users calculate full disturbances and model power subsystems without complicated CAD models. The toolbox also provides mission planning tools, link and thermal analysis, and full attitude 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 plot to the right shows a 3U solar wings. The arrows show the surfaces. Panels can be attached orientation; just specify the position

We have improved the disturbance toolbox. They match the Spacecraft models closely. The Spacecraft to model more complex spacecraft surfaces that are normally not found

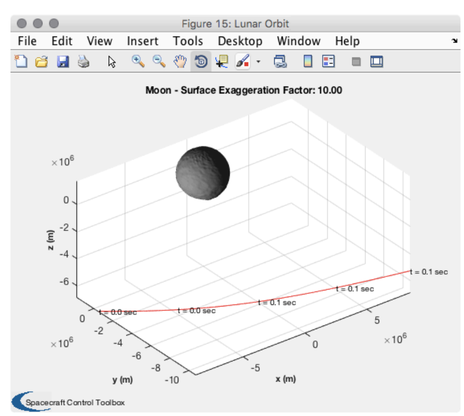


CubeSat with four canted surface normals for all of the anywhere and in any and normal.

models for the CubeSat Control Toolbox disturbance Control Toolbox allows you with multiple rotating on CubeSats.

LunarCube Module for CubeSat

The LunarCube module adds all the tools needed to send your CubeSat into lunar orbit. Mission planning tools for translunar flight and lunar orbit operations are included. The module also includes a new dynamical model that is applicable 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 also included.



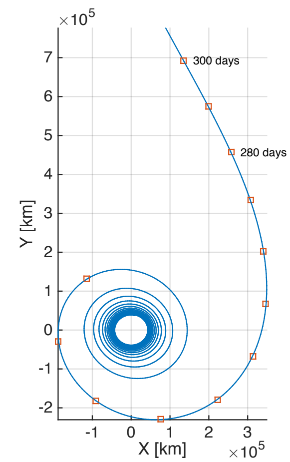
You can combine the LunarCube functions and scripts with the other tools in the CubeSat toolbox to go from conceptual design to space operations.

Case Study: Asteroid Prospector

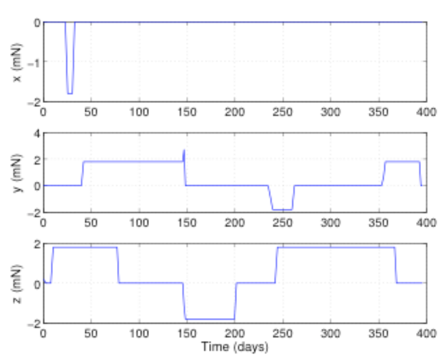
We used SCT to generate a complete design for Asteroid Prospector, a small reusable spacecraft capable of flying to an asteroid from Earth orbit, operating near the surface of the asteroid and returning samples. The first step is estimating the delta-V required and analyzing the trajectory. Then, we 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

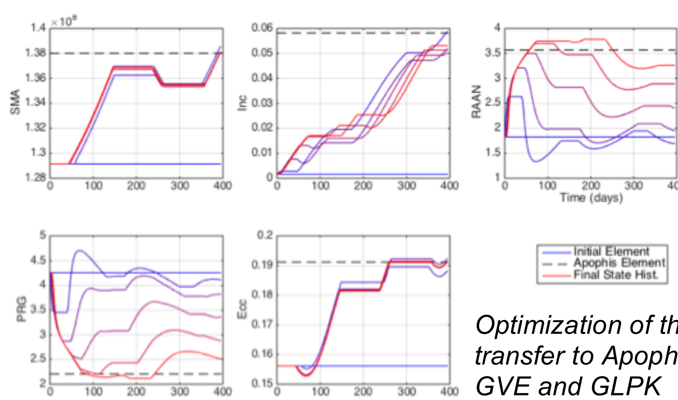
We first use approximate orbital elements for the Apophis asteroid to estimate the delta-V for two low-thrust transfers: an Earth escape spiral and a low-thrust transfer spiral. This can be done with analytical methods available in the toolbox. We then simulate the Earth escape phase, where thrust is 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%. The plots below show the final thruster control commands in the LVLH frame as well as the six iterations of the orbital elements.



Simulation of Earth escape spiral



Thrust control vector in LVLH frame



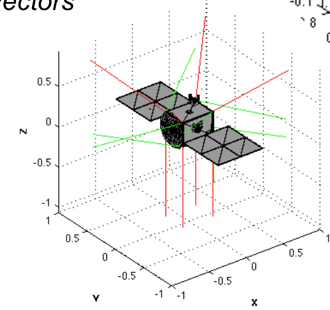
Optimization of the transfer to Apophis using GVE and GLPK

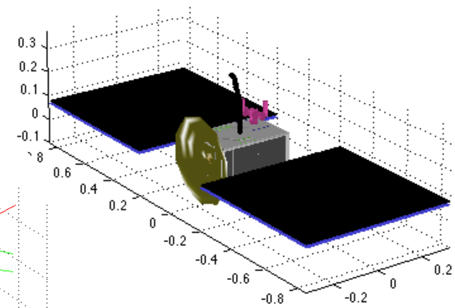
2. Model the spacecraft

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

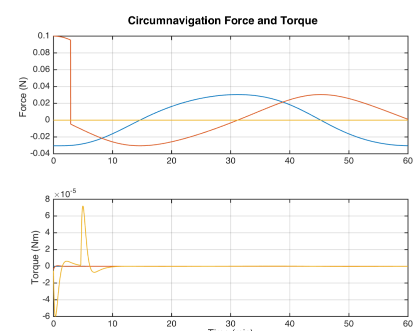


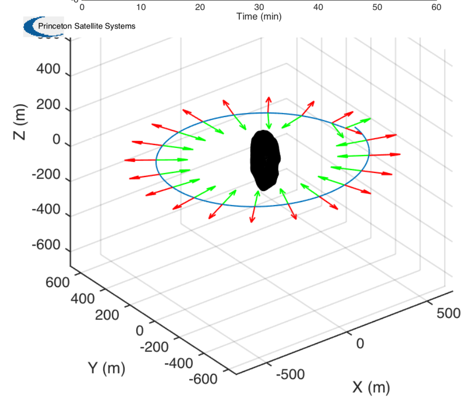


AsteroidProspector CAD Model

3. Near-Asteroid Operations

Apophis has a diameter of only 325 m and an mass of about $4{\times}10^{10}$ kg, so that at its surface, the gravitational acceleration is still 200× smaller than that from the sun at 1 AU. As a result, 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.



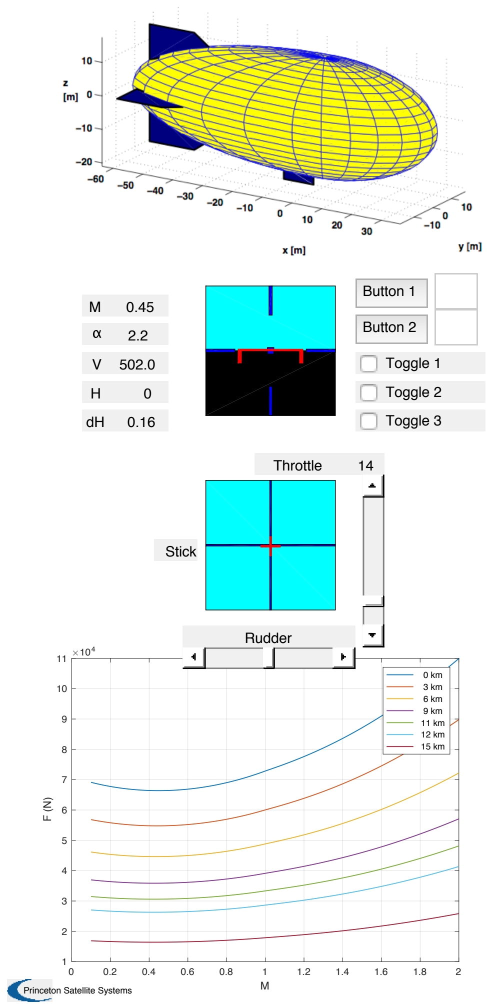


Core Control Toolbox

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 of 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 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 let you 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.

Add-On Modules

Wind Turbine Control Module

The Wind Turbine Control Module can leverage all of 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 of multiple objects. It is essential for 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.

Imaging Module (Core only)

This module includes lens models, image processing, ray tracing and image analysis tools. This module is included with SCT Professional.

Formation Flying Module (SCT Only)

Constellations of small satellites are proving to be 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.

Fusion Propulsion Module (SCT Only)

This module includes an extensive library of functions for modeling fusion propulsion systems. It includes fundamental plasma physics functions, fusion reactor functions and functions specifically for designing nuclear fusion engines.

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.

LunarCube (CubeSat/SCT Academic)

This new module provides lunar mission planning, lunar gravity models and complete simulations. Included in SCT Pro.

Orbit Mini Toolbox (CubeSat)

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

New in Version 2017.1

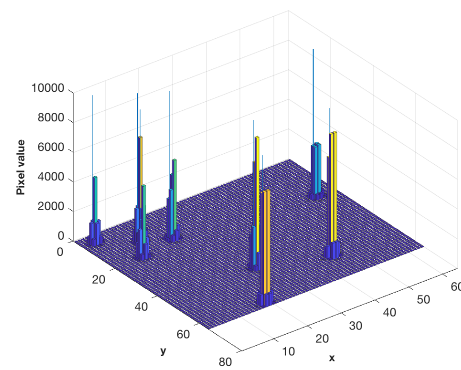
Over 60 new functions were added in Version 2017.1 and updates to dozens of existing functions were made to improve their performance and expand their applications.

In the Aircraft Control Toolbox we added an inlet loss function to compute losses due to shockwaves. Our Unscented Kalman Filter algorithm was updated.

We expanded our support for heliocentric missions. This includes functions to compute solar eclipses in heliocentric orbits, heliocentric sphere of influence, heliocentric trajectory plotting and thermal models for heliocentric spacecraft.

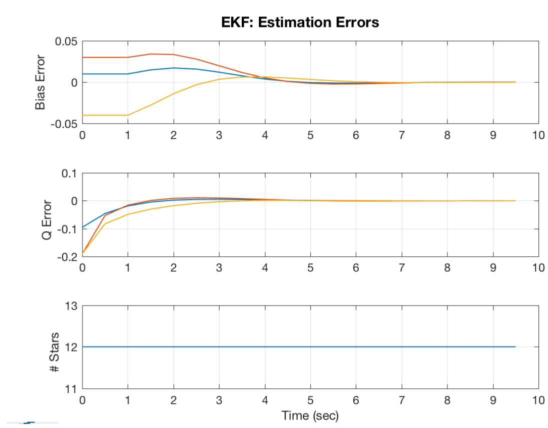
Several new component models were added for use with the CAD modeling functions. These included a Liquid Apogee Engine, curved tubes and triangular trusses.

We have added all new star identification functions. These are based on a pyramid star identification algorithm using four stars for a definitive match during lost-in-sky conditions. The algorithm provides reliable star identification with almost any star catalog and in any orientation. We have updated image processing algorithms for star centroid determination.

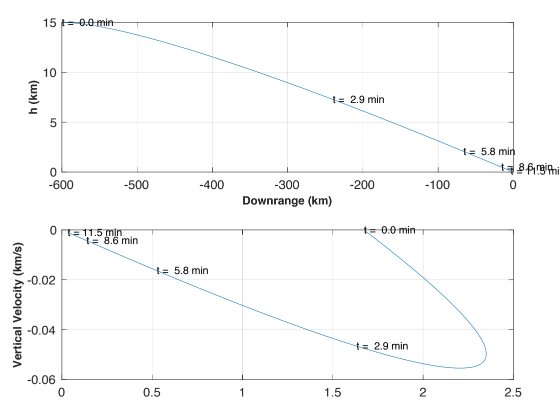


Updated center of mass star centroiding,

New attitude determination demos and algorithms were added for mixtures of different sensors, such as sun measurements, earth chords and magnetic field measurements. You can compare the performance of extended and Unscented Kalman Filters. A new second order guidance law was added for planetary and lunar landing that provides a simple and effective algorithm for landers.



Extended Kalman Filter demo.



Second order landing guidance.

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 of 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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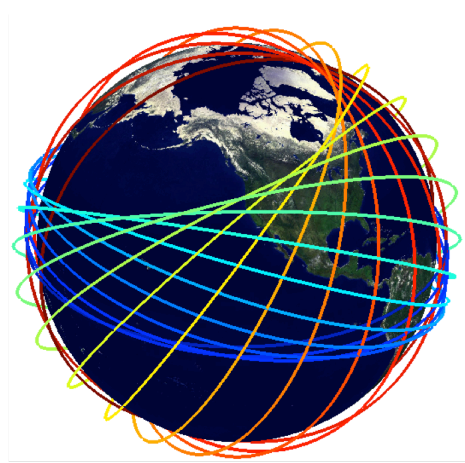

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