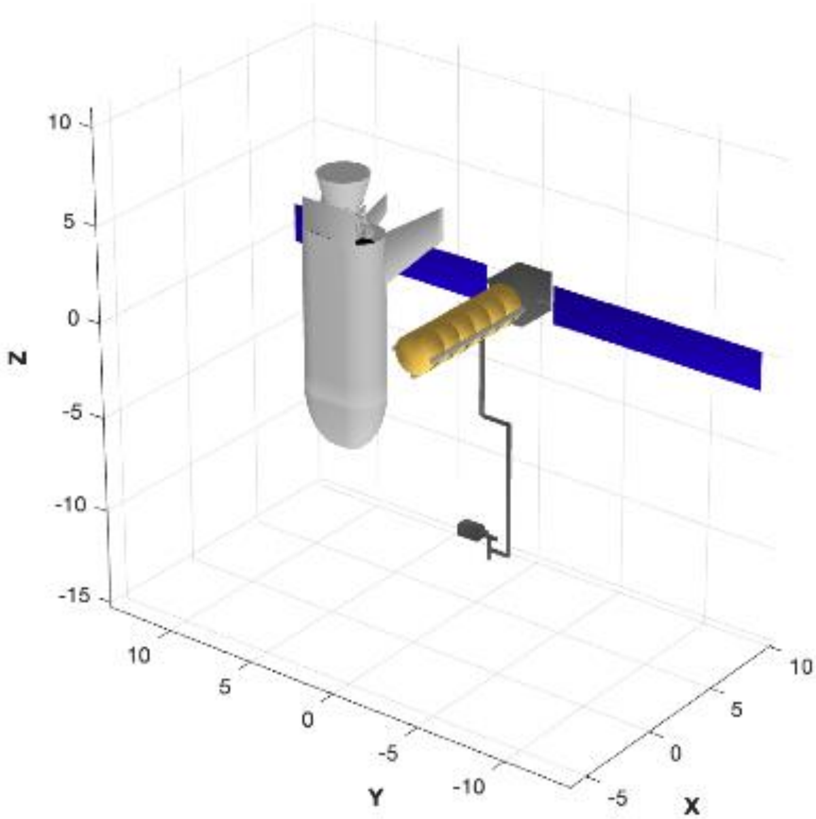
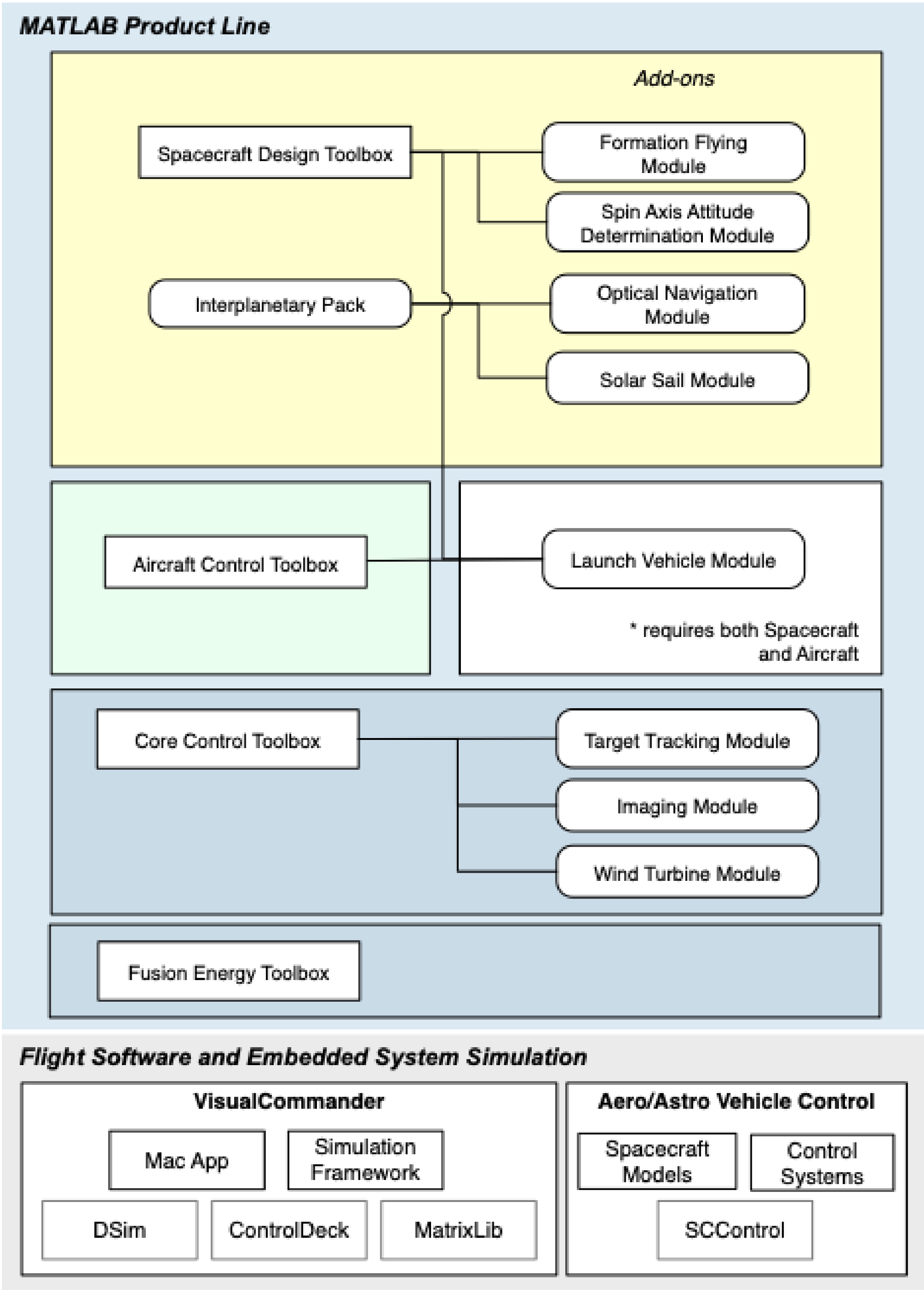
Toolboxes for MATLAB®

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.



> *"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."*
>
> *-- satisfied customer*

6 Market Street, Suite 926, Plainsboro, New Jersey 08536-2096
Phone: 609-275-9606 | Fax: 609-275-9609
E-Mail: info@psatellite.com Web: www.psatellite.com

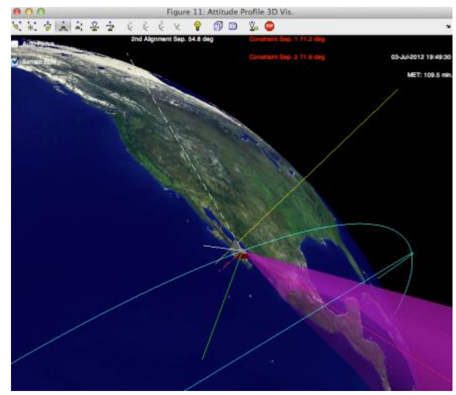

MATLAB Product Line
Add-ons
Spacecraft Design Toolbox
Formation Flying Module
Spin Axis Attitude Determination Module
Interplanetary Pack
Optical Navigation Module
Solar Sail Module
Aircraft Control Toolbox
Launch Vehicle Module
* requires both Spacecraft and Aircraft
Core Control Toolbox
Target Tracking Module
Imaging Module
Wind Turbine Module
Fusion Energy Toolbox
Flight Software and Embedded System Simulation
VisualCommander
Mac App
Simulation Framework
DSim
ControlDeck
MatrixLib
Aero/Astro Vehicle Control
Spacecraft Models
Control Systems
SCControl

Contents

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 Spin Axis Attitude Determination Module for satellite launch operations, and the Solar Sail Module for solar sail design, analysis, and simulation.

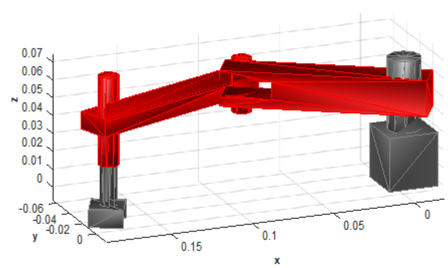
The toolboxes allow engineers to design vehicles, analyze them and simulate them, all within the MATLAB environment. The toolboxes include extensive control and estimation design functions and complete source code -- a necessity for advanced systems development. Extensive documentation and help systems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



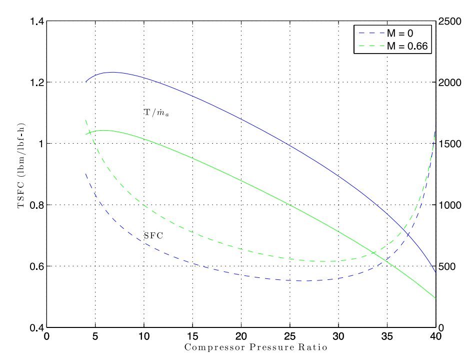
CubeSat Mission Planning

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, ESA, universities around the world, 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 Design 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.



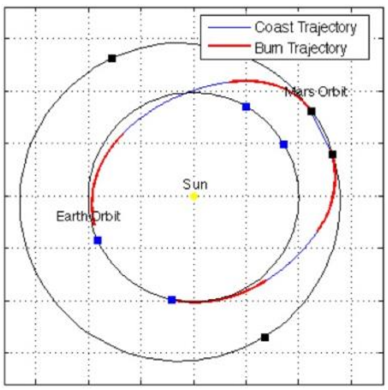
Jet engine modeling

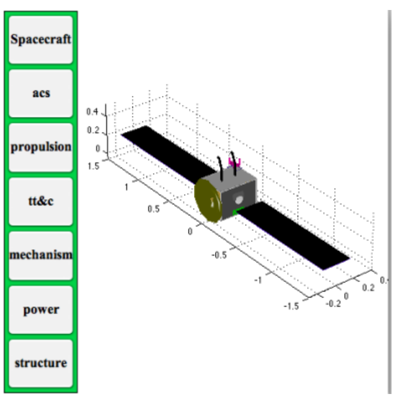
Our toolboxes are used worldwide by over a hundred organizations including the Canadian Space Agency, NASA, ESA/ESTEC, Energia in Russia, NEC, Lockheed Martin, Raytheon, General Dynamics, Orbital Sciences Corporation, and many others. The toolboxes are fully compatible with all versions of MATLAB after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

Spacecraft Design Toolbox

The Spacecraft Design Toolbox (SDT) product family includes the Spacecraft Design Toolbox, theory textbook, and add-on modules. 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 toolbox provides comprehensive software and extensive examples for designing any spacecraft control system, anywhere in the solar system. Add-on modules are available for formation flying, launch vehicles, optical navigation, solar sails, and spin-axis attitude determination in a transfer orbit.





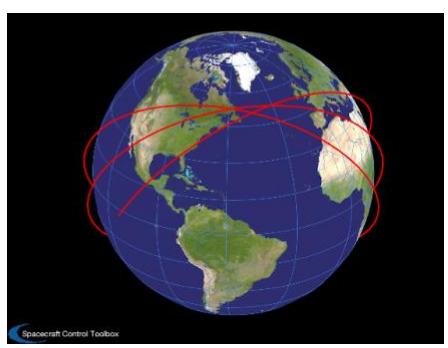
The toolbox includes hundreds of design examples and sample missions, from low earth constellations to geosynchronous satellites and deep space missions. Whether your satellite has a passive control system, basic sensors or a highly accurate IMU, reaction wheels and thrusters, or articulated appendages, you can model it.

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

Our CAD modeling package allows you to describe your spacecraft using geometric primitives and perform disturbance analysis that operates on the resulting mesh.

Most functions have built-in demos. Many analyses can be done with a couple of lines of code. Four lines give you an ISS orbit from the latest elements and one plots it.

```
[el, jD0] = ISSOrbit('latest');
p        = Period(el(1));
t        = linspace(0,3*p,1000);
```



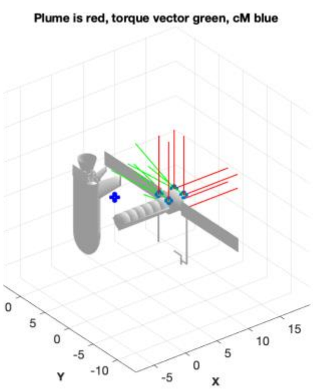
```
rECI      = RVOrbGen(el,t);
PlotOrbit( rECI, t, jD0 )
```

Case Study: LEO Space Station Control

We used the Spacecraft Design Toolbox to design a LEO space station control system. The space station is shown on the cover.

1. Computer-Aided Design in the Spacecraft Design Toolbox

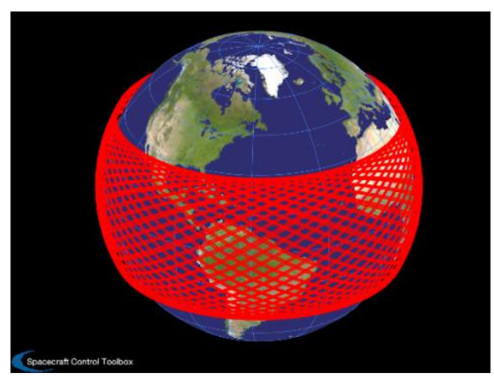
The model was created with the CAD tools. These tools generate the surface model for disturbance analysis and the inertia and center of mass. Models are created using a script which allows you to algorithmically build your model. Other features include automatically checking thruster arrangements to verify that you can get 3-axis torques. The image shows the Space Rapid Transit Orbiter, Canadarm3 and the plume and torque vectors for all the thrusters.



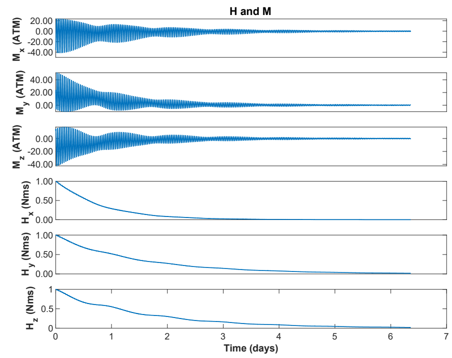
2. Momentum Unloading

The space station can use thrusters or magnetic torquers for momentum control. Exploring the momentum unloading system is easy by writing a simple script with just momentum control. The toolbox is designed to facilitate this kind of quick analysis.

```
%% Unloading script
jD0    = Date2JD([2029 6 1]);
n      = 10000; % Number of steps
sMA    = 6728; % km
% Momentum control gain
gain   = 0.001;
% Orbit
el     = [sMA 28.573469*pi/180 pi 0 0 0];
p      = Period(sMA);
t      = linspace(0,100*p,n);
[r,v,t] = RVOrbGen(el,t);
jD     = jD0 + t/86400;
b      = BDipole(r,jD); % Earth magnetic field, dipole model
%% Run the simulation
h      = [1;1;1]; % Initial momentum
xP     = zeros(15,n);
```



```
for k = 1:n
 bS      = Skew(b(:,k));
 tD      = -gain*h; % Proportional control
 m       = pinv(bS*bS)*bS*tD; % Dipole command
 tM      = bS*m; % Dipole torque
 xP(:,k) = [b(:,k);m;h;tD;tM];
 h       = h + dT*tM; % Euler integration
end
```



One line of code produces the orbit plot. The plots on the right show the dipole commands and the inertial angular momentum. The orbit plot is in the Earth-fixed frame. The same function can plot in the Earth-centered inertial frame.

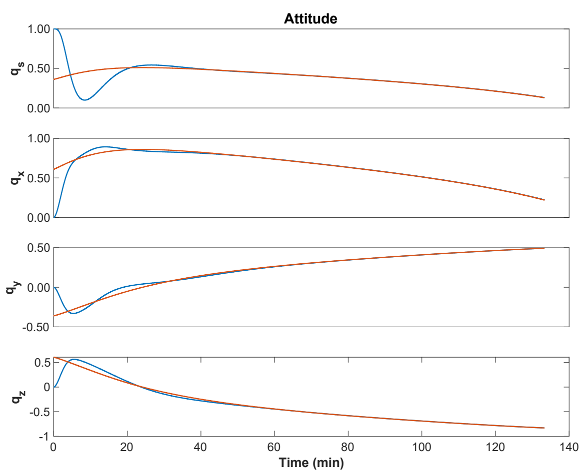
3. Space Station Control

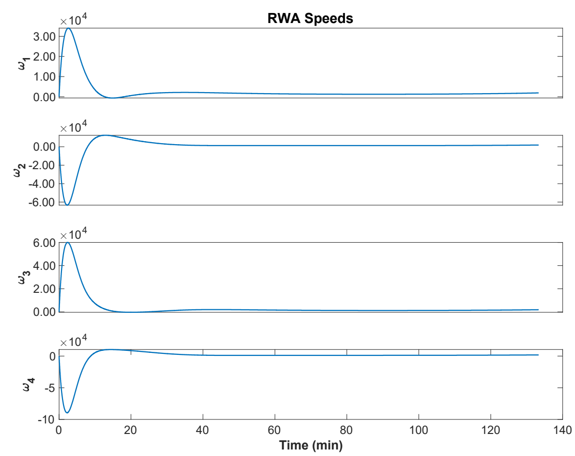
A slightly more complicated script implements and tests the space station control system. The controller uses a 3-axis proportional integral differential controller that works directly with quaternions. This is the code for the controller:

```
% The PID controller
d.dC.q_desired_state  = QLVLH(x(1:3),x(4:6));
[tRHS, d.dC]   = PID3Axis( q, d.dC );

% Reaction wheel torque is on the left hand side
d.torqueRWA = -d.pInvU*d.inr*tRHS;
```

The control torque is converted to reaction wheel control torques using a pseudo-inverse algorithm.





The simulation shows the acquisition of the Local Vertical Local Horizontal axis. Reaction wheels are used for the acquisition. The space station has four reaction wheels in a pyramid about the Y-axis. Drag forces and torque are applied to the space station in the simulation. The seven degrees of freedom dynamic model is propagated along with the orbit equations. It is important to include both in the simulation because disturbances are impacted by the orbital position, and the magnetic field, for momentum unloading, is also a function of the orbital position. The simulation only includes drag. Gravity gradient, solar pressure, albedo pressure, and Earth radiation pressure can be added. Simple step disturbance can be included to help debug the control system. The PID controller is running in quaternion tracking mode. It also has vector tracking, Earth target, and spinning modes.

The script does not include attitude determination. This can be added. The toolbox includes star camera attitude determination and algorithms for computing the attitude quaternion from the Earth sensor, sun sensor, and magnetometer measurements.

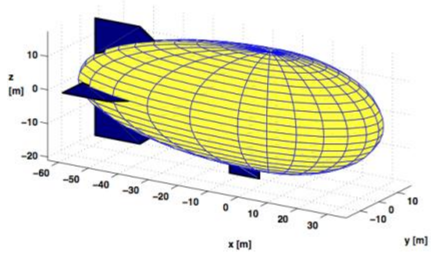
Functions for thermal, power, and link analysis can be added to the script. The control system includes momentum unloading. The nice thing about having a separate script with just unloading is that it makes debugging of your control system easier and faster.

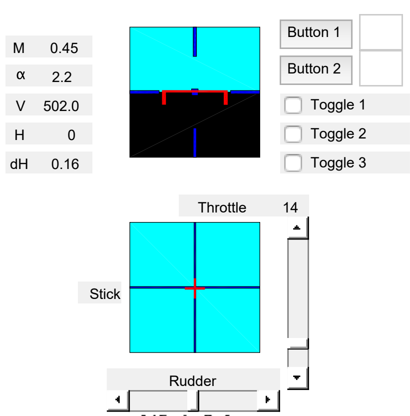
Core Control Toolbox

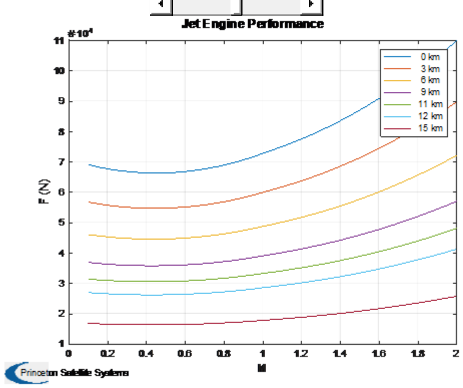
The Core Control Toolbox provides the control and estimation functions of our Spacecraft Design Toolbox with general industrial dynamics examples including robotics and chemical processing. The suite of Kalman Filter routines includes conventional filters, Extended Kalman Filters, and Unscented Kalman 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 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.







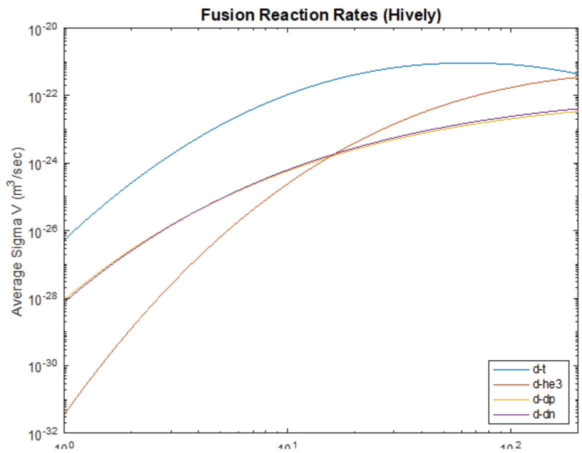
The toolbox provides extensive performance analysis tools. These allow you to quickly size your aircraft and perform trade studies. Our CAD tools allow you to layout your aircraft quickly without having to use solid modelers.

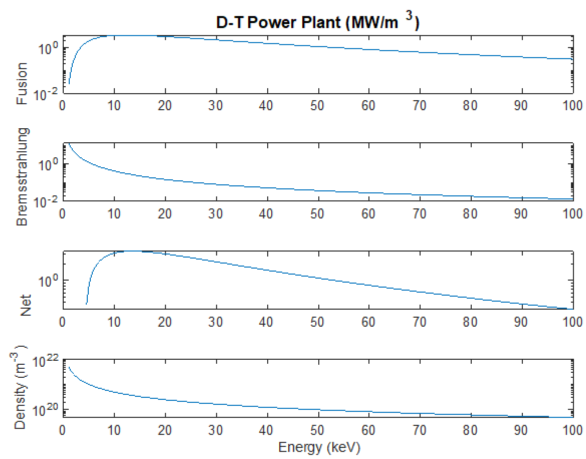
The extensive library of engine models provided encompasses turbojets, turbofans, and ramjets. Propeller models are also included. You can generate engine performance tables for use in simulations or use the functions directly.

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

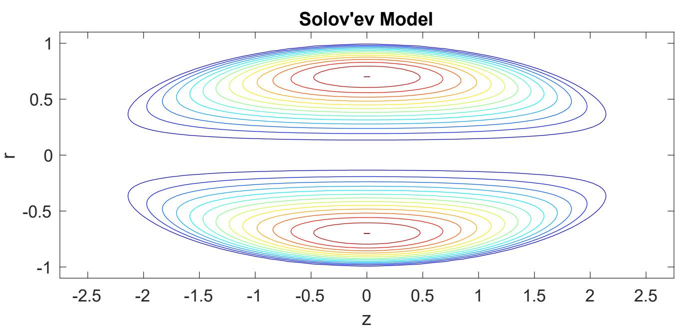
Fusion Energy Toolbox

This toolbox includes 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.



Princeton Satellite Systems

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 engine cycles
- `Cryo` – cryocooler sizing
- `Economics` – cost models
- `FRC`– field reversed configurations
- `HeatTransfer` – thermal analysis
- `Magnets` – magnet sizing
- `PlasmaPhysics` – basic models
- `Reactor` – fields, power, fuels
- `RFSystem` – amplifiers and RF drives
- `Shielding` – attenuation models
- `Tokamak` – tokamak models
- `Transport` – collisions and equilibration

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 reliable object tracking 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 both ACT *and* SCT)

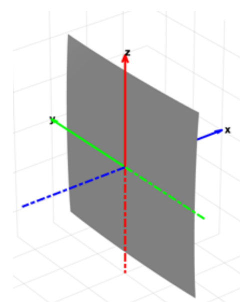
This module provides a versatile set of tools that support the design, modeling, simulation, and performance analysis of launch vehicles. LaunchVehicle provides design functions for sizing launch vehicles and finding launch windows to enter the desired orbit from a specified launch site. It provides simulation tools for simulating launch trajectories.

Formation Flying Module

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 Design 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

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



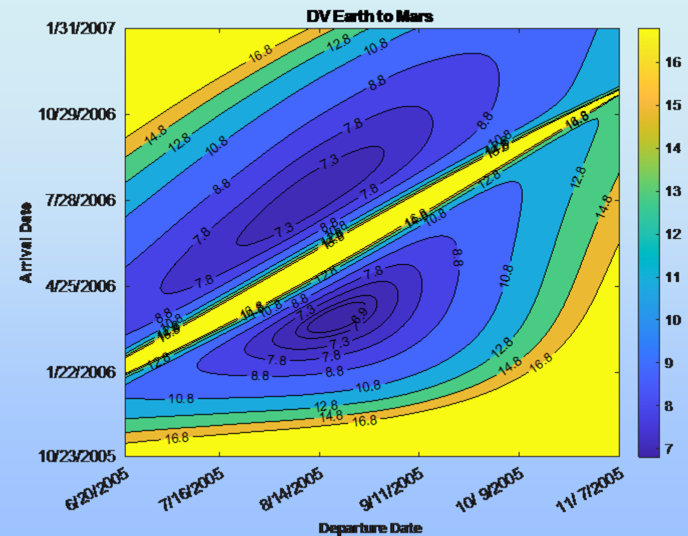
Spin Axis Attitude Determination Module

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.

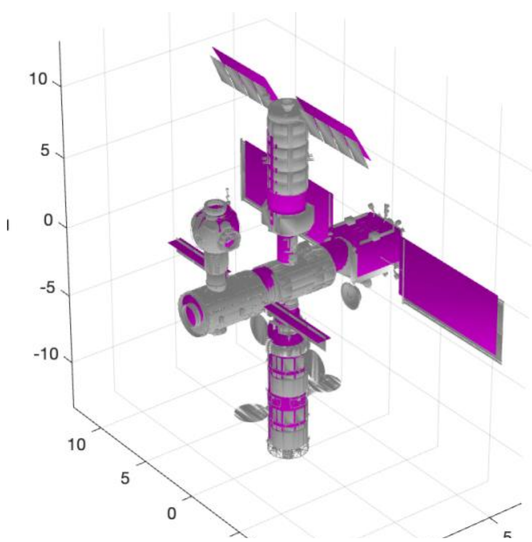
Latest Features

Over thirty new functions and scripts were added in Version 2025.1. 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.

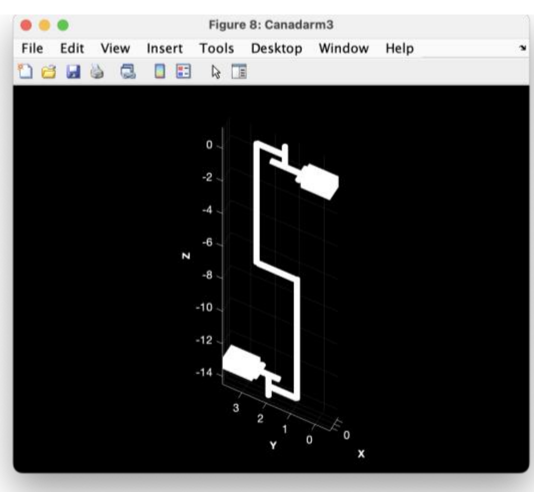
PorkChopTOF.m generates pork chop plots, right, that are used to plan interplanetary missions. Any planet pair can be selected. Examples for Earth to Mars and Earth to Jupiter are included. They can also be used with the existing database of asteroids.



A CAD model of the planned NASA Lunar Gateway was added, left. This lets you use the Gateway as a model for attitude control design. The image shows a simplified model, suitable for disturbance analysis superimposed on the full model. The simplified model has 460 vertices versus 85315 for the original model. A script with a disturbance analysis is included.



A new multi-body model was added. It allows you to easily write dynamics simulations with any number of bodies. It can be used for robot arms, CMGs, slosh, and many other purposes. A function to generate a Canadarm3 model is included. The arm is shown on the left.



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.

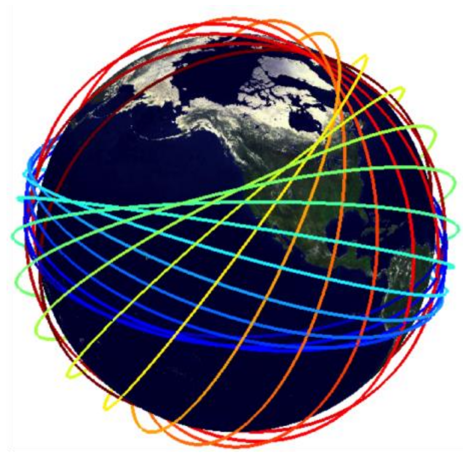
A variety of high-tech organizations use Princeton Satellite Systems software products for their work. These include Energia (Russia), ESA/ESTEC, NASA, the Canadian Space Agency, the Swedish Space Corporation, Raytheon, General Dynamics, Lockheed Martin, Orbital Sciences Corporation, MIT Lincoln Laboratories,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

For more information, please contact us directly:

Ms. Stephanie Thomas
sjthomas@psatellite.com

Mr. Michael Paluszek
map@psatellite.com



https://psatellite.com/

https://psatellite.freshdesk.com/