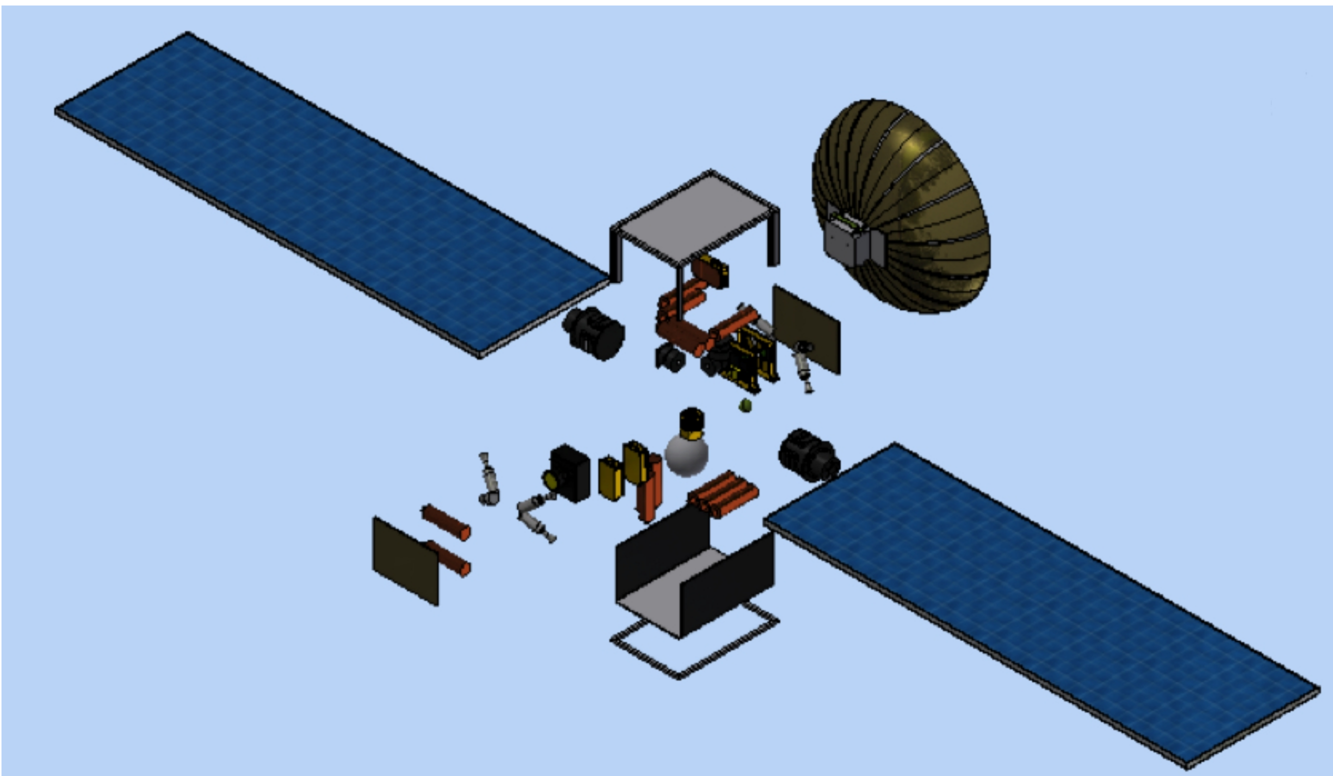
Precision Attitude Control System

Newly developed under the support of an Army SBIR, Princeton Satellite Systems presents the Precision Attitude Control System. It provides higher pointer accuracy along with the spacecraft control software and the verification simulations to get you flying in less time and to provide room for your own innovations and future expansion.



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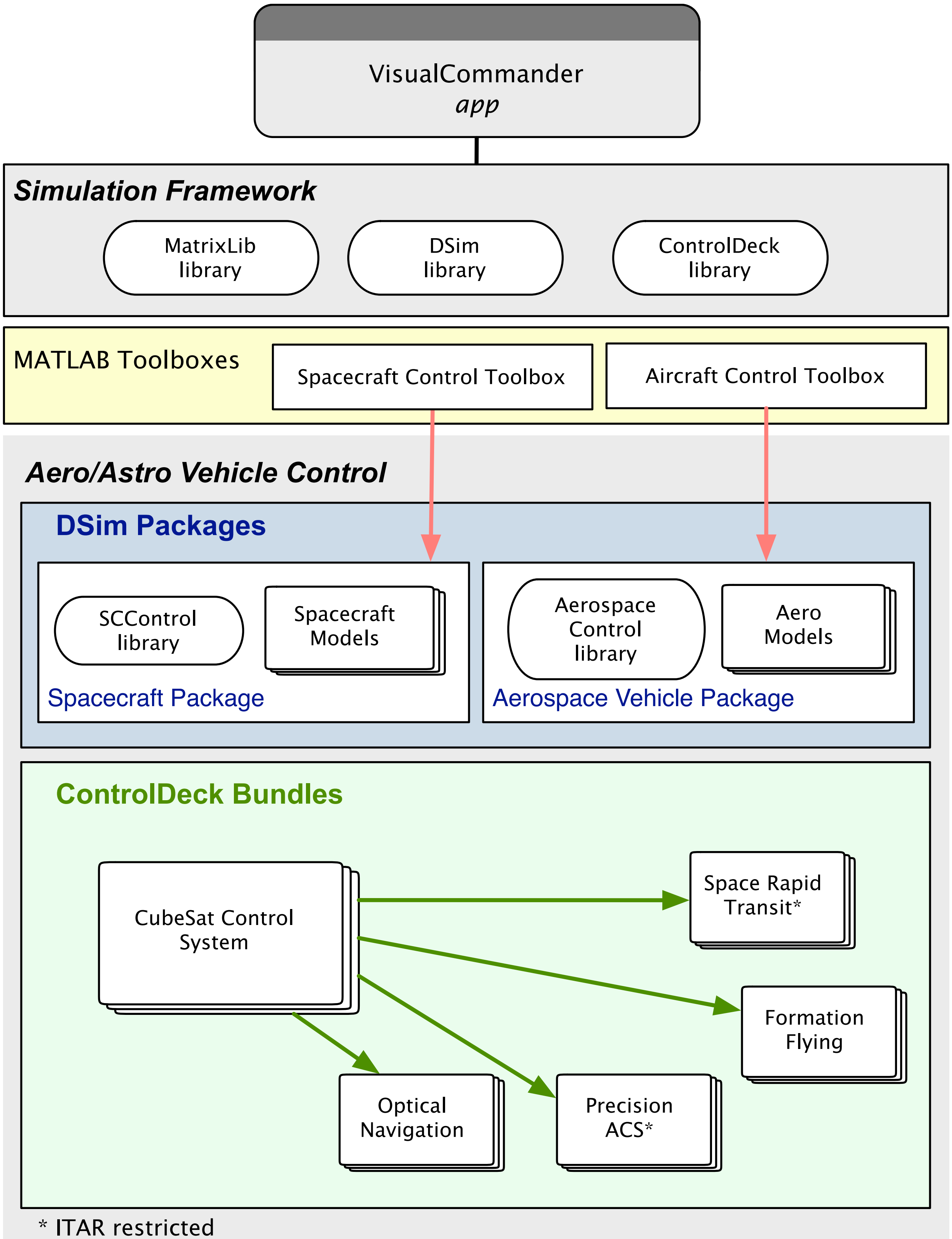
VisualCommander
app
Simulation Framework
MatrixLib
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DSim
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ControlDeck
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MATLAB Toolboxes
Spacecraft Control Toolbox
Aircraft Control Toolbox
Aero/Astro Vehicle Control
DSim Packages
SCControl
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Spacecraft
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Spacecraft Package
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Aero
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System
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Formation
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Precision
ACS*
* ITAR restricted

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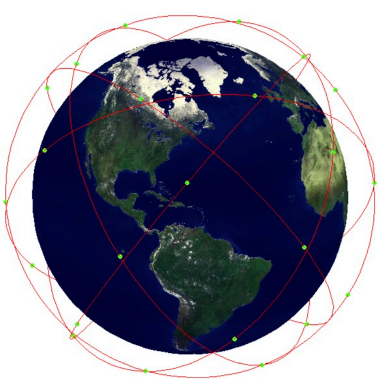
Precision ACS (PACS) is cutting-edge spacecraft software environment for any control application. It provides attitude control, orbit control, attitude estimation and orbit estimation in a flexible package. Its advanced star camera processing system provides greater accuracy than systems that are used in any size spacecraft. Each function is implemented in an asynchronous module, an instantiation of a lightweight C++ class, making it easy to construct reliable flight software that does exactly what you want. Precision ACS frees the engineer to focus on the unique aspects of their spacecraft's mission. Princeton Satellites Systems has used Precision ACS to design Pluto flyby spacecraft, asteroid orbiting spacecraft and precision Earth pointing satellites.

Precision Attitude Control System

… Precision ACS provides a complete control system for any space mission ….



Princeton Satellite Systems has been a pioneer in developing innovative technologies for satellite control and autonomy. Flight software is one of the most costly parts of a satellite design and often the cause of schedule slips and cost overruns.

By combining powerful attitude control software libraries system with high precision pointing algorithms and sophisticated simulations, Precision ACS provides a complete control solution for any mission. You can customize existing control modules that are provided or write your own from scratch.

The simulation libraries provide nearly all of the models that you will need for any spacecraft mission, whether in low Earth, geosynchronous orbit or heading into interstellar space. The sophisticated simulation engine can handle any level of fidelity. Spacecraft simulations are assembled just like you assemble your spacecraft.

With Precision ACS, we have implemented control systems ranging from 1U CubeSats to NASA New Horizons class deep space probes with optical navigation systems. Precision ACS facilitates rapid prototyping and spiral development. Its modular nature encourages code reuse and helps cut development costs for families of spacecraft.

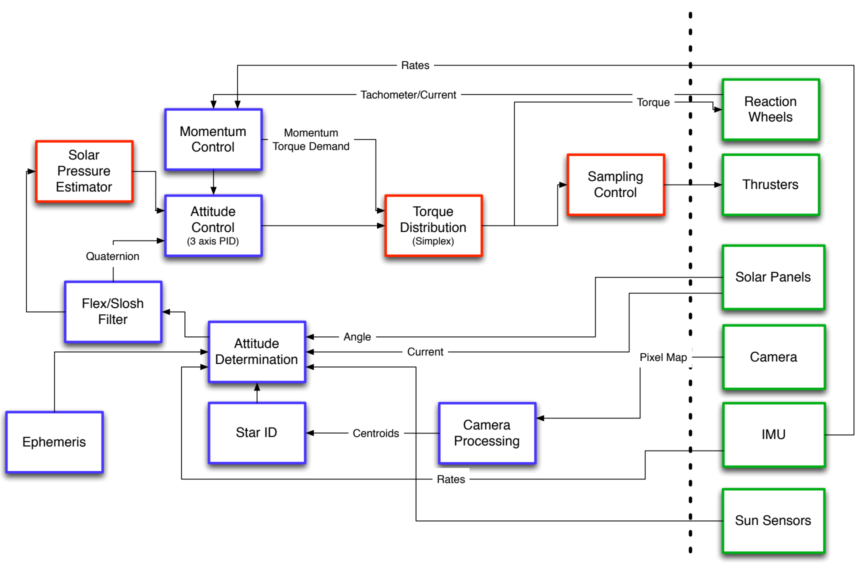
Whether you are new to spacecraft control or an experienced spacecraft control system engineer you will find Precision ACS to be the answer to your control system development needs.

A New Paradigm in Spacecraft Control

... PACS will get you going quickly and leave you room for expansion and customization ....

Precision ACS has its origins in the Indostar-1 attitude control system. Indostar-1 demonstrated that an attitude control system could be developed for 1/10th the cost of systems that were being flown at that time. It also demonstrated that an outside company could deliver a key part of a spacecraft software for the customer without support from the developer.

Precision ACS provides you with an advanced spacecraft control system that you can use to begin your software development. Sensor processing, attitude control and actuation distribution are provided in separate modules.



Attitude determination is performed using Unscented Kalman Filters. Sensing sources can include star cameras, Earth sensors, sun sensors and magnetometers. High precision star centroiding is available that reduces centroiding errors by orders of magnitude over other systems. Attitude determination can include an inertial measurement unit as the attitude dynamical base.

Attitude control is based on a controller with built in maneuver logic and a wide variety of pointing modes. Torque and force commands are distributed to the actuators using linear programming. This process eliminates complex actuation code and accommodates actuator failures without software. Momentum control is done with magnetic torquers in Earth orbit or thrusters anywhere.

The modular nature makes it easy to incorporate your existing software into your control system. Each module is an instantiation of the ControlDeck base class. Modules communicate via message passing. Each module can be timed independently and triggered off a variety of timers. Modules can also be scheduled to run in background. Messaging passing makes each module robust. Each new module will automatic connect to sources for its data. Each module can have its own telemetry and commands further simplifying implementation.

Army Kestrel Eye Satellite Program

PSS is working on an Army SBIR to support the Kestrel Eye program. Kestrel Eye is an electro-optical nano-satellite-class imagery satellite that will be tasked by the tactical ground component Warfighter. Capable of producing 1.5-meter resolution imagery, Kestrel Eye's data will be downlinked directly to the same Warfighter via a data relay network that is also accessible by other Warfighters in theater without any continental United States relay or data filtering. The intent is to demonstrate a tactical space-based imagery nanosat that could be built in large numbers to provide a persistent image delivery capability to ground forces.

Figure 1 SMDC Image from a proposed Kestrel Hand Device

The operator clicks on any point of the ground trace displayed on the world map and calls up the enlarged local map and selects targets. When satisfied, the operator clicks on “Send to Spacecraft” and the requested trajectory is transmitted. Kestrel Eye executes the planned track and snaps pictures at the designated times. Kestrel Eye immediately downlinks the requested images to a data relay network accessible by the Warfighter who tasked the satellite as well as any other Warfighter on the network who needs it.

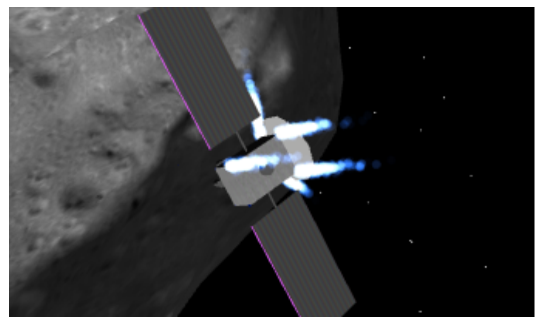
Kestrel Eye requires fully autonomous operation and precision ground tracking. In effect, the interface seen by the soldier on the ground should be no more complex than the scope on a soldier’s rifle. This requires a new class of satellite and satellite software that is being implemented using Precision ACS.

Initially single satellites will provide this capability. In the future clusters and constellations of satellites will coordinate to provide imagery and other products to forces on the ground. Multiple satellites may coordinate their pointing and orbits to provide stereo imagery or multiple views of single targets. This will require advanced formation and constellation control that can be provided by Precision ACS.

Example Missions

Asteroid Rendezvous and Orbit

We designed Asteroid Prospector to fly from low Earth orbit using an ion engine and to rendezvous and orbit an asteroid using its reaction control system. Asteroid Prospector is a fully autonomous 6U satellite with a full propulsion system, star cameras for attitude control and navigation, reaction wheels for primary attitude control. Operations around the asteroid employ mixed thruster and reaction wheel control.

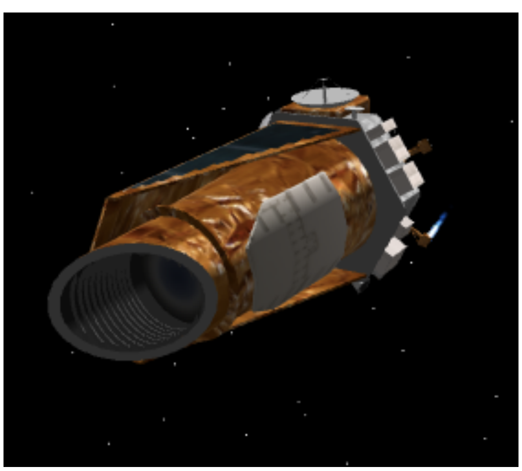


Attitude and orbit determination use star cameras with a common Unscented Kalman Filter. Fully nonlinear dynamical and measurement models are used for high reliability and accuracy.

The control system includes an optimal low thrust guidance system that works from low Earth orbit all the way to the asteroid. Navigation employs the PSS Optical Navigation System developed for NASA. See it orbiting an asteroid at Asteroid Prospector.

Kepler Telescope Mixed Control

Two of the reaction wheels failed on the Kepler observatory possibly ending its useful life as a scientific satellite. In response to a NASA RFI, Princeton Satellite Systems designed a control system using Precision ACS for Kepler that mixes reaction wheels and thrusters to give the spacecraft 3-axis attitude control in any orientation. The system could tolerate any number of reaction wheel failures and thruster failures and still operate without any changes in software.



We demonstrated the system to NASA during an invited RFI telecon. It would have required a major software change. Unlike Precision ACS, most other flight software is tightly coupled and difficult to update. Had Precision ACS been used originally for Kepler updating the software would have been relatively easy.

The new control system was implemented in a day. You can see a movie of a reorientation on our blog at Kepler Spacecraft Reorientation.

Precision ACS Software Suite

Precision ACS is written in C++. It includes a complete suite of software for implementing your control system. It comes with a baseline attitude control system that you can modify for your application. All of the real-time software is implemented using the Princeton Satellite Systems ControlDeck class library. With PACS you get the ControlDeck class library, DSim, the Spacecraft Model class library, VisualCommander and the SCControl Astrodynamics Function library. Two complete spacecraft control systems and simulations are provided. One is for a deep space mission and another for an Earth orbit mission. Full source code and doxygen-based APIs are provided.

Precision ACS comes with one year of technical support including a full week of onsite training. Our engineers will help you get going and can help you write any new code you will need. Launch support and additional consulting can be provided under a support contract.

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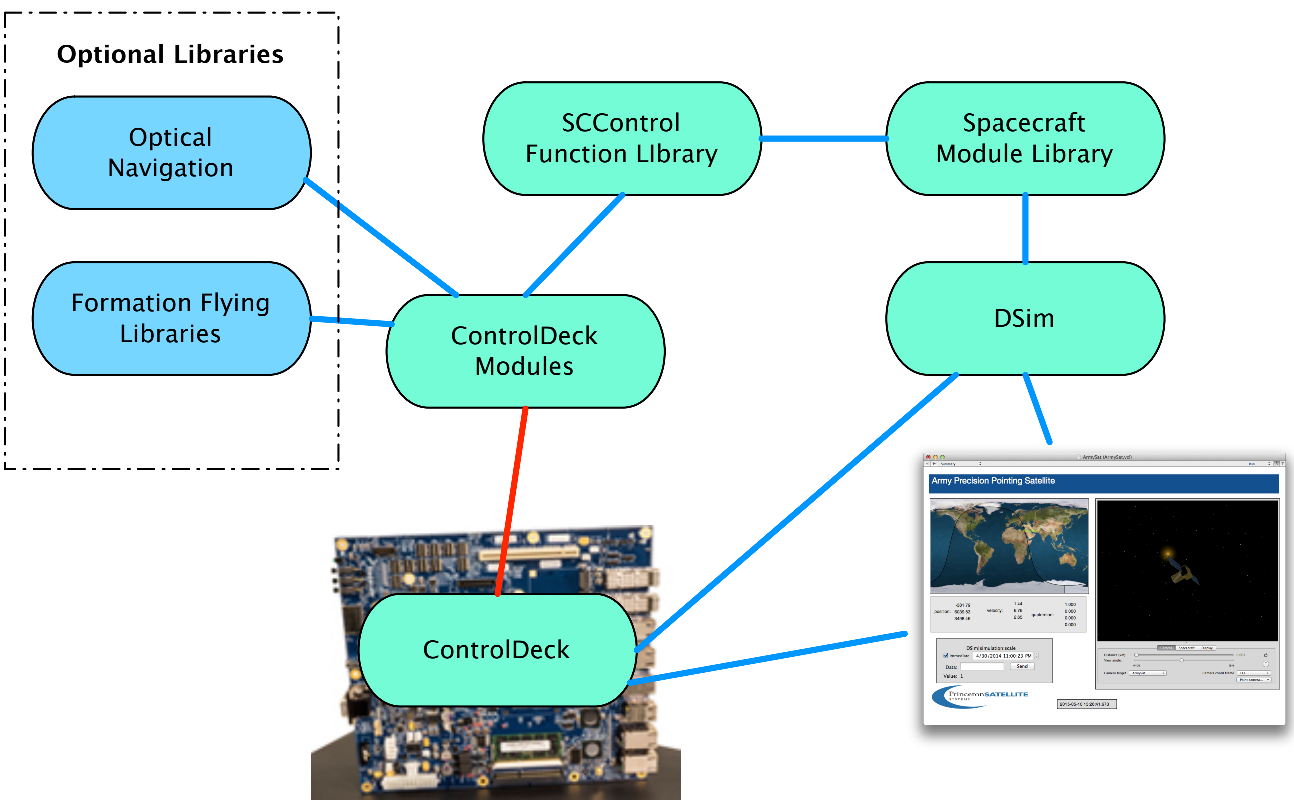
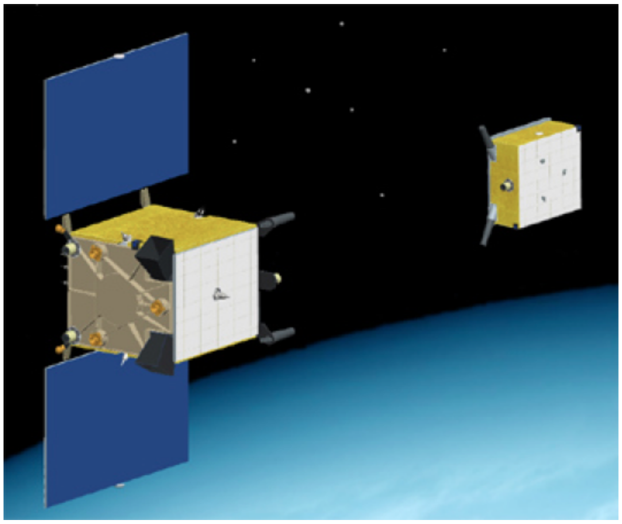


Formation Flying and Constellations

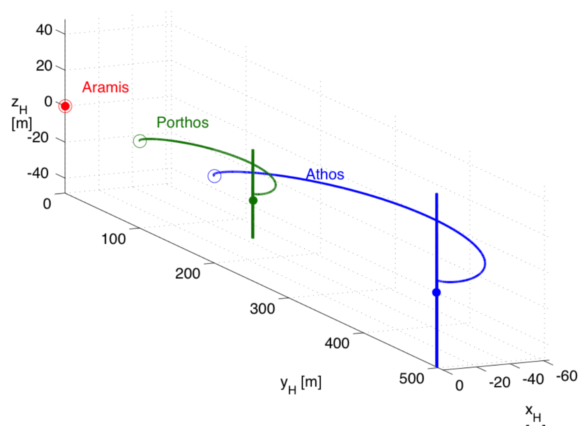
Formations of satellites and constellations can greatly expand the value of your spacecraft. Princeton Satellite Systems is on the forefront of satellite formation control since 1998. We worked on the Air Force Research Laboratory's TechSat-21 program to demonstrate a satellite synthetic aperture radar system using three or more satellites. We followed this with a NASA SBIR for Distributed Formation Flying that demonstrated practical methods for controlling large numbers of satellites.



We delivered the safe mode guidance system for the Swedish Space Corporation's Prisma Rendezvous Robots. This system is in operation whenever the experimental work is not underway. This system includes safe mode guidance and autonomous collision avoidance.

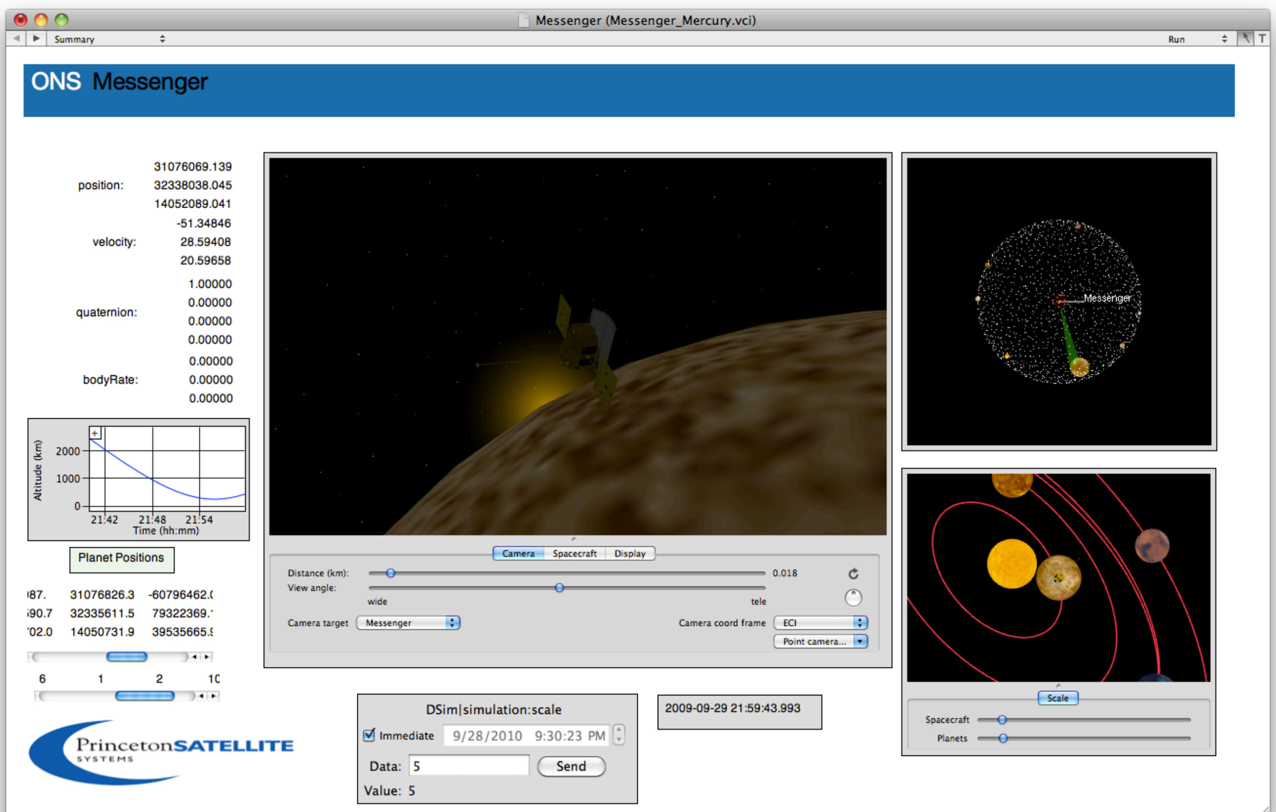
We provide a full suite of software and analysis tools for the design and operation of satellite formations and constellations.

The Precision ACS distributed formation flying (DFF) system is organized in a multiple-team framework. Complex functionality is distributed into independent tasks, which may be remotely added, removed or replaced post-launch to increase mission flexibility and robustness. The reconfigurable, decentralized control system enables the number of spacecraft in the cluster to change post-launch, and is capable of supporting clusters with large numbers of satellites, and allows significant software modifications to be made on-orbit in a robust manner. DFF is a system of 10 modules, consisting of a distributed guidance law, a decentralized control law, autonomous team formation and management capabilities, dynamic command and data-handling software, a robust inter-spacecraft message handler, constraint-driven thruster selection, and attitude coordination. The design includes formation self-organization; reconfigurable control laws; autonomous formation reconfiguration; and integrated, multi-spacecraft formation guidance and control.



Proven Track Record

PSS designed the control systems for the Indostar/Cakrawarta-1 commercial communications satellite. This spacecraft went operational at separation and successfully completed its seven-year mission. The same software was used on two other communications satellites. We developed the momentum management system for the NASA ATDRS spacecraft under contract to Hughes, an Optical Navigation System for spacecraft under a NASA contract, and software for satellite formation flying and relative orbit operations under several NASA and DoD contracts. We developed the safe-mode guidance system for the Swedish Space Corporation Prisma Rendezvous Robots satellite experiments. Our guidance system is used for all operations except specific experiments. We developed CubeSat control systems for several companies. Our flight operations experience includes Indostar-1, AsiaSat, Koreasat and Telstar IV.



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 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 sell the MATLAB Spacecraft, Aircraft and Wind Turbine Control Toolboxes. Our patents range from imaging sensors to spacecraft maneuvering algorithms, 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.

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 and finds this to be an effective way of growing our products and ensuring that they meets 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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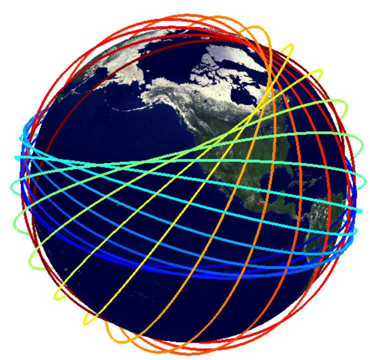

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