Aero/Astro Vehicle Control

Aero/Astro Vehicle Control is a software suite for the control of aerospace vehicles, from aircraft to spacecraft. The suite includes control software and verification simulations to get you flying faster and to give you room to explore and innovate.

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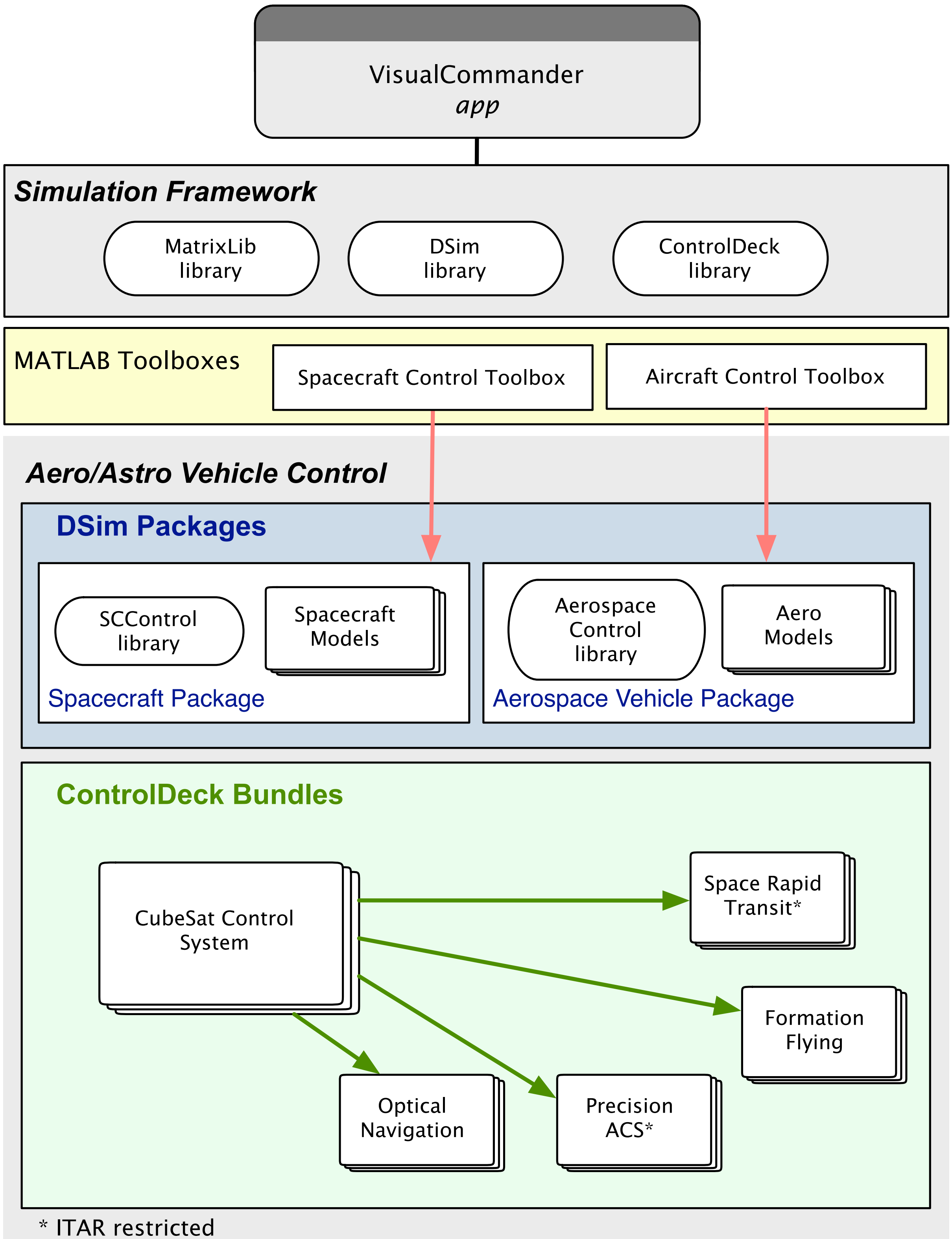
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Aero/Astro Vehicle Control (AAVC) is a cutting-edge flight vehicle software environment for any aerospace control application. It provides flight control, attitude control, and state estimation in a flexible package. Each function is implemented in an asynchronous module, as an instantiation of a lightweight C++ class, making it easy to customize reliable flight software. AAVC, thus, frees the engineer to focus on the unique aspects of their vehicles. Princeton Satellites Systems has used AAVC to design CubeSats, Pluto flyby spacecraft, asteroid orbiting spacecraft and two-stage-to-orbit launch vehicles.

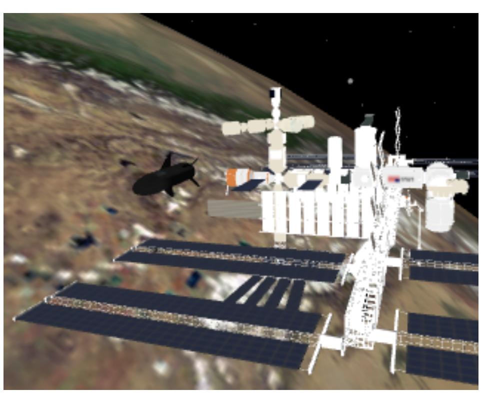
Aero/Astro Vehicle Control

… AAVC provides a foundation for a complete control system for any flight system ….

Princeton Satellite Systems is a pioneer in developing innovative and affordable technologies for satellite control and autonomous operation. Flight software can be one of the most costly parts of flight vehicle design and often the cause of such projects being over budget and behind schedule. AAVC, however, facilitates rapid prototyping and spiral development. Full source code is provided for all control and simulation software and its modular nature encourages code reuse; this helps to cut development costs when designing whole families of vehicles.

By combining powerful control software libraries with sophisticated simulations, AAVC provides a complete control solution for any mission. The simulation libraries provide many mission-relevant models, ranging from the Earth's surface, to orbit, and heading up into interstellar space. Specify the simulation fidelity, customize the modules, or even write your own - the sophisticated simulation engine allows you to assemble the model that best suits you.

Whether you are new to flight vehicle control or you are an experienced control system engineer, you will find AAVC to be the answer to your control system development needs.

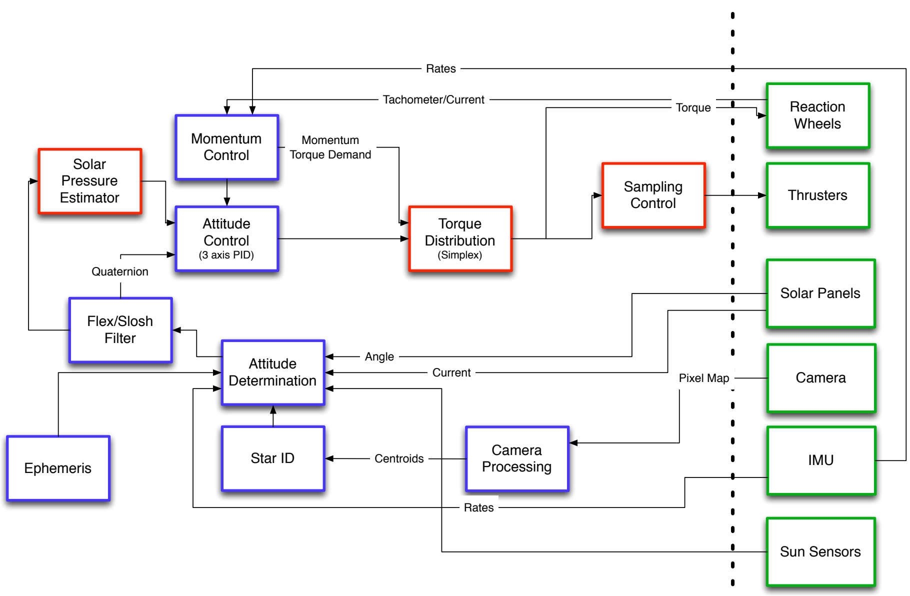


A New Paradigm in Flight Vehicle Control

AAVC 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 the systems that were being flown at that time. It also demonstrated that an outside company could deliver a key component of spacecraft software for a customer without continuing support from the developer.

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

AAVC provides you with an advanced flight vehicle control system that you can use to begin your software development. Sensor processing, attitude control and actuation distribution are provided in separate modules, as illustrated in the example of an attitude control system implemented in AAVC (left).



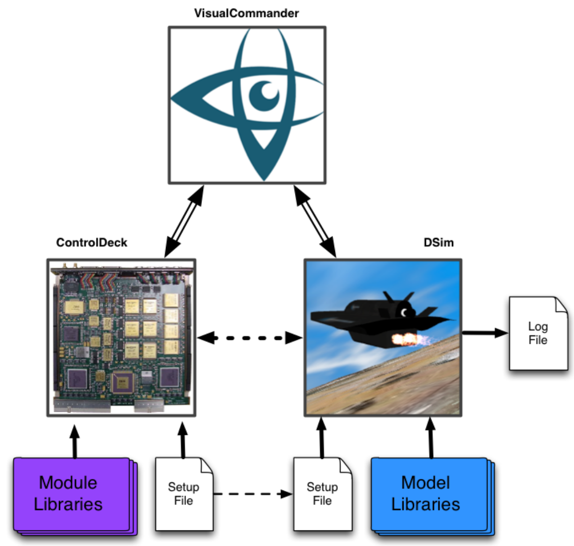
State estimation is performed using Kalman Filters while the sensor library includes star cameras, IMUs, Earth sensors, sun sensors, magnetometers and air data systems.

Attitude control is based on a controller with built-in maneuver logic and a wide variety of pointing modes. Then torque and force commands are distributed to the actuators using linear programming. This process eliminates complex actuation code and accommodates actuator failures without software. It also allows you to mix thrusters, aerodynamic actuators, momentum exchange devices and rocket engine gimbals for robust orientation control.

AAVC's modular nature makes it easy to incorporate existing software into your new control system. Each module is an instantiation of the ControlDeck base class, which communicate via message passing for robustness. Further capabilities include: independent timing and triggering, option to run in background, automatic connection with data sources, compartmentalized telemetry and a library of commands to further simplify implementation.

AAVC Software Suite

AAVC is written in C++ and all of the real-time software is implemented using Princeton Satellite Systems' ControlDeck class library. The CubeSat Control System is a baseline attitude control system that can be modified for your application. Two complete spacecraft control systems and simulations are provided. One is for a deep space mission and another for a low Earth orbital mission. Full source code for all of the libraries and doxygen-based APIs are provided. This provides you with an extensive set of examples to get you started. It also makes it easy to incorporate your own software into your simulations and control systems.



DSim Model Packages	
Spacecraft Package	Simulation models for spacecraft in orbit with the SCControl library
Aerospace Vehicle Package	Simulation models and displays for aerospace vehicles from launch to orbit, with the Aerospace Control library
ControlDeck Software Module Bundles	
CubeSat Control System	Baseline attitude control system software with momentum management and payload processing. Supports wheels, thrusters, and magnetic torquers.
Precision ACS *Add-on*	High fidelity ACS with precision star centroiding
Optical Navigation *Add-on*	Optical navigation algorithms developed for NASA
Formation Flying *Add-on*	Formation flying constellation control algorithms developed for NASA
Space Rapid Transit *Add-on*	Launch guidance, atmospheric flight control, formation flying and rendezvous software for a TSTO vehicle

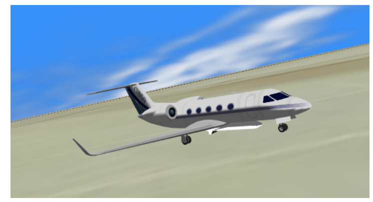
The VisualCommander graphical interface is currently only available for Mac OS 10.9+. All other software has been tested on Linux, Windows NT and Windows Vista. Movies for a wide variety of systems can be found at http://www.psatellite.com/vc/.

More information about the simulation framework can be found at http://www.psatellite.com/sim/. This includes online documentation found at http://www.psatellite.com/vc/help/.

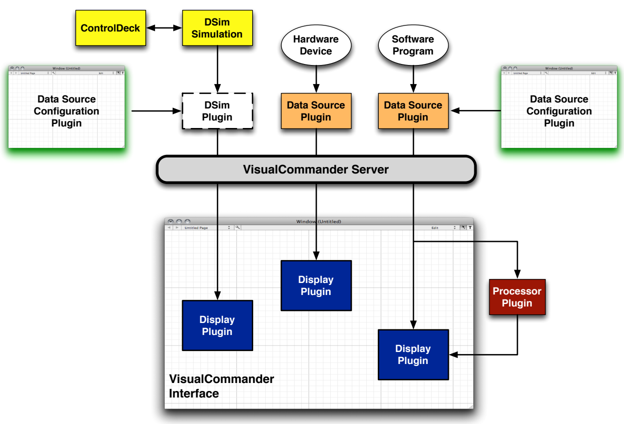
AAVC comes with one year of technical support including a full week of onsite training. Our engineers will help you get going and can help you write any new code you will need. Test support and additional consulting can be provided under a support contract.

AAVC Software Libraries

AAVC is written in C++ and includes three major class libraries: **MatrixLib**, **ControlDeck** and **DSim**. All three libraries are lightweight, efficient and cross-platform and have been tested on a wide variety of hardware.



MatrixLib is a sophisticated matrix library that allows you to use matrices just like you would use doubles in C++. MatrixLib provides access to LAPACK with many LAPACK functions accessible directly. MatrixLib is used in both ControlDeck and DSim models and can be used in any C++ software you write.



ControlDeck is used to write flight software and **DSim** to write simulation models. The ControlDeck libraries implement complete control systems for atmospheric vehicles and spacecraft. Whereas, the DSim modules are for a wide variety of spacecraft and aircraft hardware, dynamical models and environmental models.

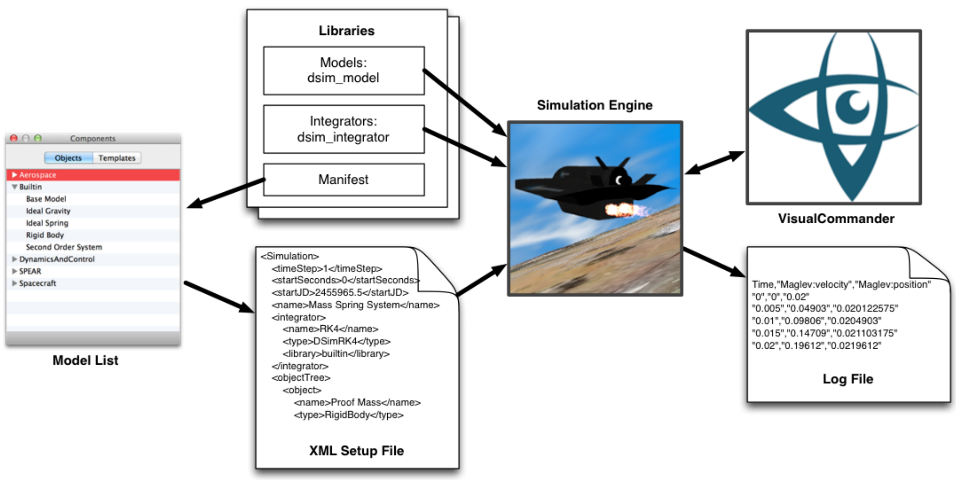
Both packages are message based and pass messages asynchronously which simplifies model interfacing (diagrammed, above) and makes the resulting software much more reliable than conventional software. Connecting hardware is straightforward and items can be connected to DSim models, ControlDeck modules or directly into VisualCommander using a Data Source plugin.

An example set-up (below) shows three DC motors with Phidgets® USB interface hardware connected to a ControlDeck controller. The laptop shows the VisualCommander drag and drop graphical interface displaying data from the motors, which are part of a 3-axis gimbal mechanism for CubeSat testing.

The SCControl library, which is part of the DSim Spacecraft Package (see system diagram on p.2) also includes hundreds of classes and functions ported from our Spacecraft Control Toolbox for MATLAB®. With the extensive software libraries provided, AAVC provides a complete design environment for the life cycle of your vehicle!

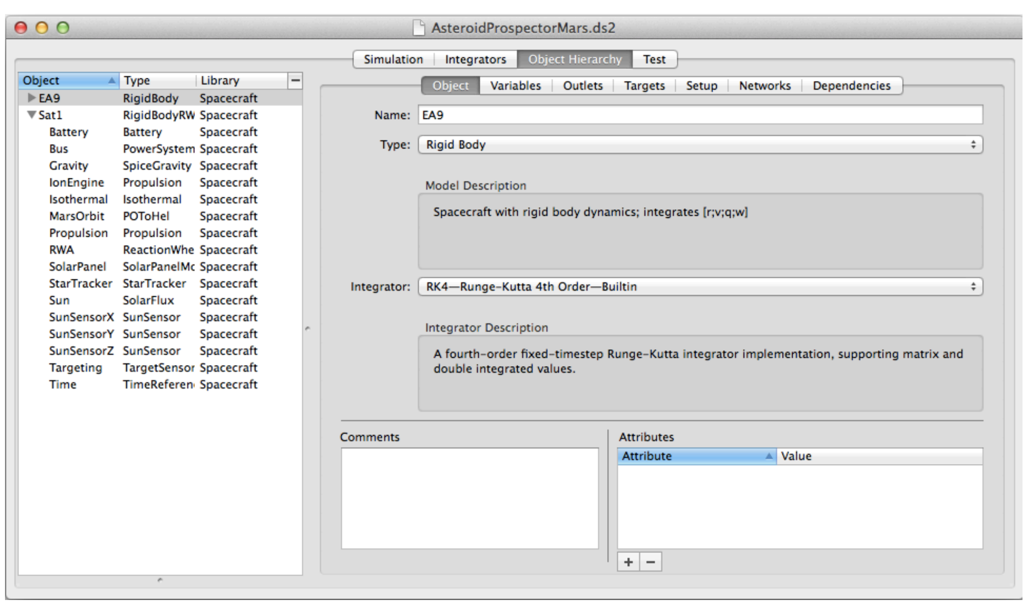
AAVC Simulation Environment

Simulation is critical for the design of aerospace vehicles. You can't afford endless test flights of aircraft to debug the software. With spacecraft, you don't get the opportunity for test flights at all. On Indostar-1 we went operational at separation – everything had to work right the first time.



The AAVC simulation environment allows you to rapidly test your software in a challenging environment. You can start early in the development cycle with simple models and then substitute higher fidelity models as the work progresses.

You can assemble vehicles just like you assemble the real ones. The example model window (below) shows a 6U CubeSat designed for a Mars mission. The components are incorporated in a tree configuration so that components can easily be assigned sub-components and you can quickly switch models without changing any code.

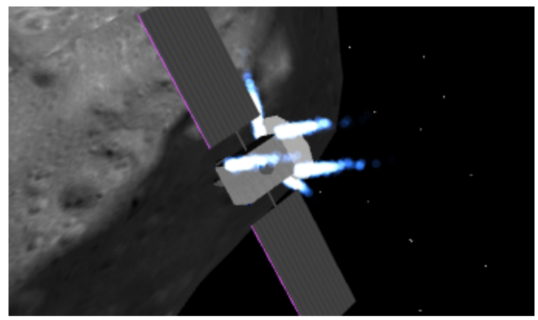


AAVC Examples

Asteroid Rendezvous and Orbit

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

Operations around the asteroid employ mixed thruster and reaction wheel control. The asteroid's gravity is so low that the spacecraft is really formation flying with the asteroid.



The torque and force distribution algorithm can tolerate multiple failures without re-programming or user intervention. This system was demonstrated to NASA as part of a response to an RFI for the Kepler space telescope.

A laser rangefinder provides range to the asteroid while the camera provides information about the shape of the asteroid.

The attitude and orbit determination systems use star cameras with an Unscented Kalman Filter, in a system known as sigma-point filtering. An Inertial Measurement Unit (IMU) is used as the dynamics base for attitude determination. This provides smoother attitude measurements and provides measurements if the camera cannot see any stars.

The accelerometers in the IMU provide measurements of thruster accelerations for navigation. Fully nonlinear dynamic and measurement models are used for high reliability and accuracy.

Low thruster autonomous guidance algorithms track a pre-computed trajectory, which can be updated onboard. Both optical and range data from ground tracking are integrated to produce a navigation solution.

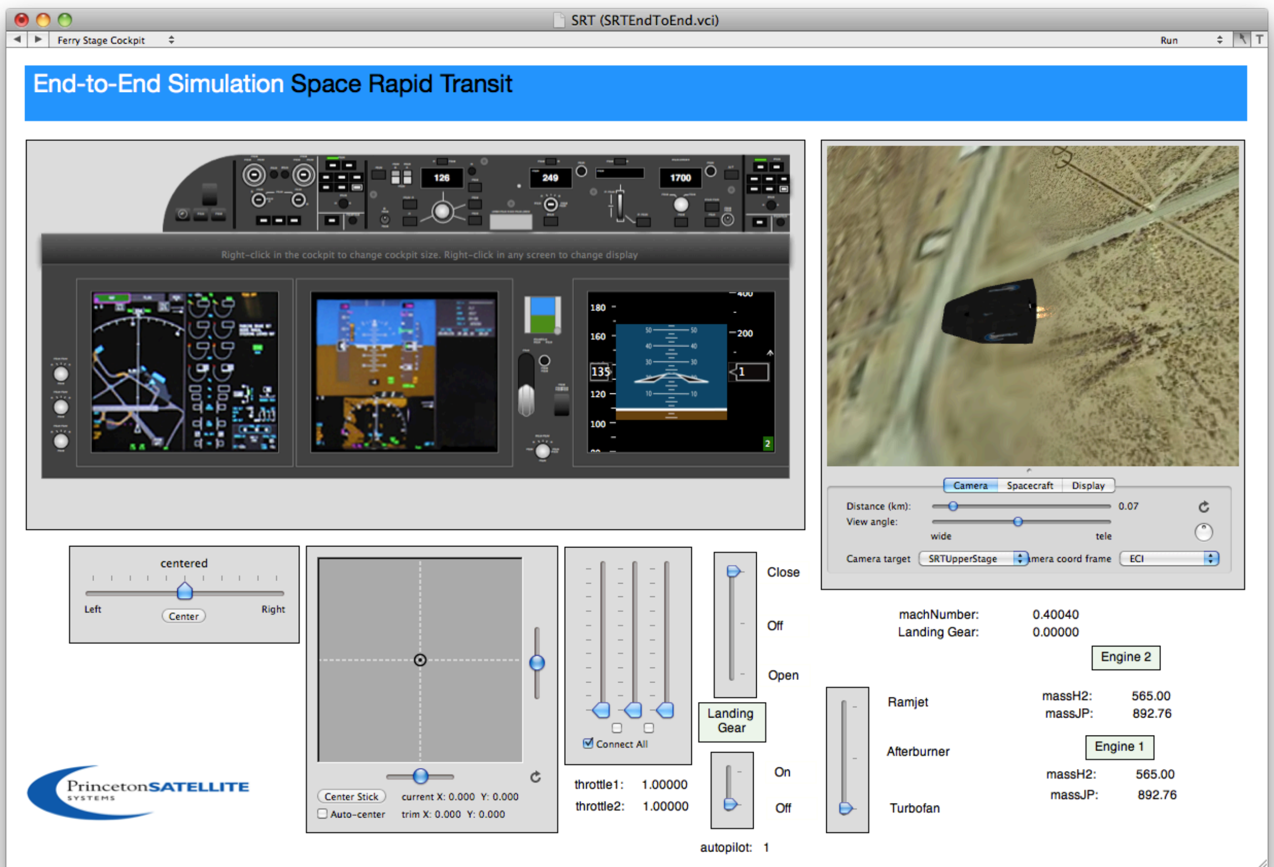
The control system includes an optimal low thrust guidance system that works from low Earth orbit all the way to the asteroid. Navigation employs the PSS Optical Navigation System developed for NASA.

For more information and to see the satellite orbiting the Apophis asteroid, check out our blog post "Asteroid Prospector".

Space Rapid Transit Launch Vehicle

Space Rapid Transit (SRT), is a horizontal-takeoff launch vehicle that has the power to revolutionize both the space launch and flight transportation industries. To break the cycle of escalating space launch systems cost, it is necessary to consider concepts that are drastically different from current launch systems. Thus, the SRT is a fully reusable two-stage-to-orbit vehicle, with the Ferry stage powered by a dual fuel, coaxial turboramjet.

When in turbofan mode the turbo ramjet in the Ferry stage uses jet fuel, while in ramjet mode it burns hydrogen.

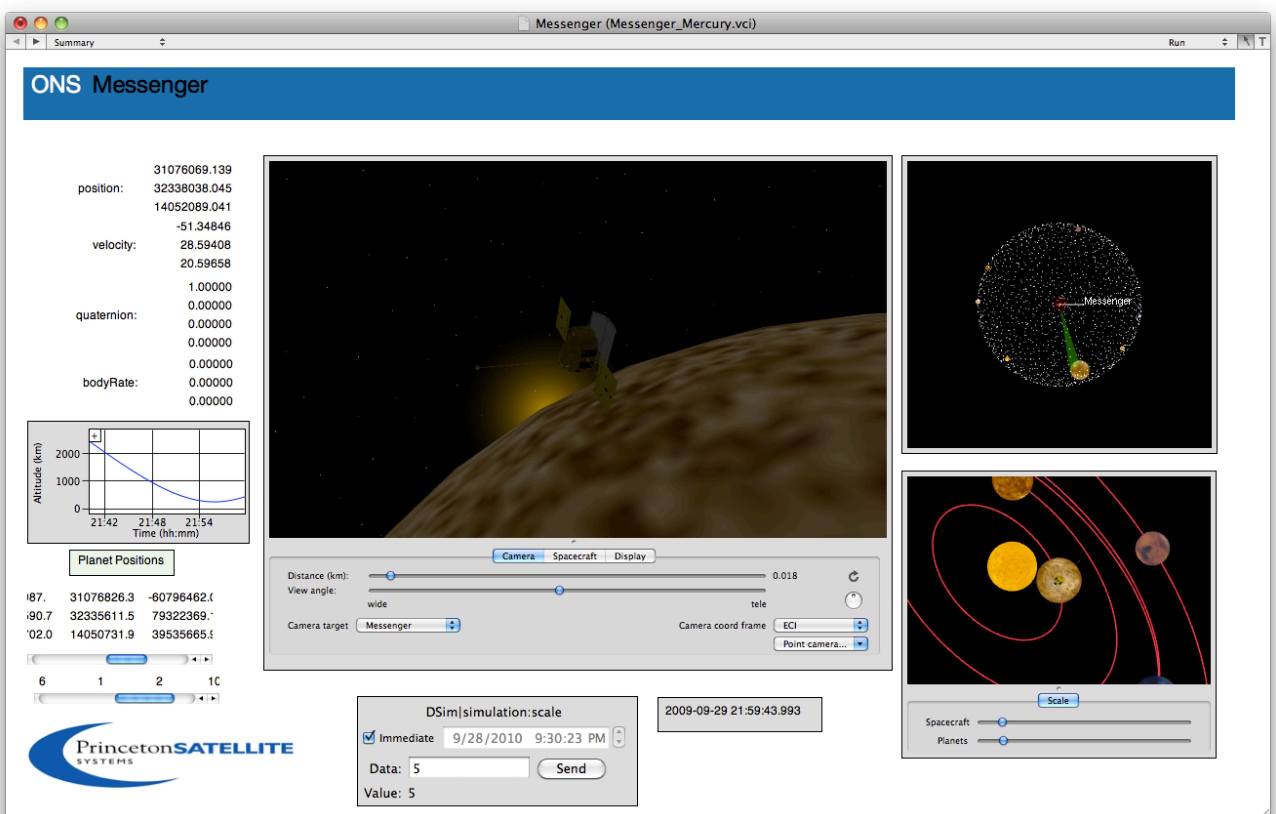


The Orbiter stage uses liquid hydrogen/liquid oxygen engines and the two stages separate at Mach 6.5 at 50 km. The full system, comprising the Ferry with Orbiter stages, is expected to deliver payloads to low Earth orbit for less than 300 USD/kg. The control systems include trajectory and orientation control of both stages.

For more information and to see the SRT in action, check out our blog post "SRT Reorientation".

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: GPS IIR and Telstar IV. We developed the momentum management system for the NASA ATDRS spacecraft under contract to Hughes, the 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 also designed the safe-mode guidance system for the Swedish Space Corporation Prisma Rendezvous Robots satellite experiments, where our guidance system is used for all operations except specific experiments. We have also developed CubeSat control systems for several companies. Our flight operations experience beyond Indostar-1 includes 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 Core 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.

AAVC is available now. For more information or a quote please contact our engineers directly:

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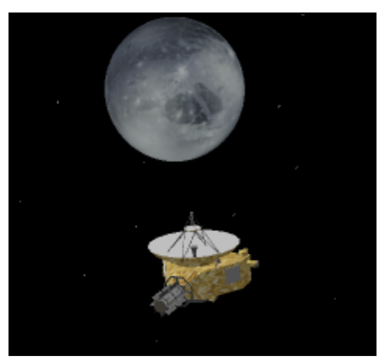

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