AAVC: AERO/ASTRO VEHICLE CONTROL

Princeton Satellite Systems Inc., 6 Market Street, Suite 926, Plainsboro, New Jersey 08536-2096, USA
Phone: 01 609 275 9606, Fax: 01 609 275 9609
Web: www.psatellite.com, Email: info@psatellite.com

AAVC

Princeton Satellite Systems announces the release of AAVC: Aero/Astro Vehicle Control. Save months of work and hundreds of thousands of dollars when developing your next aerospace control system or simulation using AAVC control systems packages for space applications. AAVC has been used by Princeton Satellite Systems to design control and guidance systems for missiles, air launch systems and spacecraft in orbits ranging from low earth to the edges of the solar system. Our typical simulation includes a half dozen vehicles, each with its own control and navigation system. Whether you are new to aerospace control or an experienced design organization you will find AAVC to be indispensible.

***MATLAB is a registered trademark of The MathWorks**

Price List (£)

NOTE THAT THESE PRODUCTS REQUIRE AN **EXPORT LICENSE**, PLEASE CONTACT FOR A PRICE QUOTATION AND MORE DETAIL:

- VisualCommander (application) (Site License).
- CubeSat Control System (CCS) Bundle (Site License).
- Aerospace Vehicle Bundle (Site License).
- Space Rapid Transit Bundle (Site License).
- Core GN&C Bundle (Site License).

VisualCommander is required for all bundles. It is highly recommended that customers of the Core GN&C and Space Rapid Transit Bundles also purchase the Aerospace Vehicle Bundle as they would then be provided with a working simulation. The CCS bundle includes a CubeSat simulation that does not require the Aerospace Vehicle Bundle. The Aerospace Vehicle Bundle and all modules in the Core GN&C bundle can also be used by CCS.

1. FEATURES

The control systems are organized into three packages:

UNITED KINGDOM
MeadoTech Ltd.
Provincial House, Solly Street, Sheffield S1 4BA, UK.
Phone: 08000224087, +44 (0) 114 201 49 16
Fax: +44 (0) 114 272 66 70
Email: info@meadotech.co.uk
web: www.meadotech.co.uk

- **Core GN&C:** Provides core functionality for general spacecraft guidance, navigation and control.
- **Space Rapid Transit:** Adds launch guidance, atmospheric flight control, formation flying and rendezvous for a TSTO vehicle.
- **CubeSat:** Adds momentum management, magnetic control and payload processing for CubeSat missions.

These systems are implemented in PSS's ControlDeck architecture and include a complete simulation and graphical user interface. ControlDeck is based on a set of asynchronous modules that communicate through a robust messaging architecture. This provides tremendous flexibility when implementing complex multi-rate control systems.

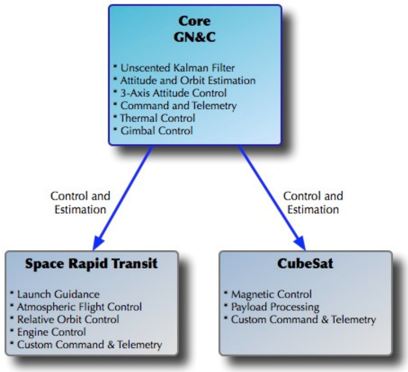
The control systems give you a starting point for your own designs saving you countless months and hundreds of thousands of dollars in development costs. Each package comes complete with simulation and control system code. All source code is provided for the control code and simulation. The software runs in the open-architecture VisualCommander making it easy to connect your own software tools, simulation and hardware. The same software can take you from conceptual design through flight.

Each package includes:

- C++ code implementing the control system using the ControlDeck architecture
- Complete simulation written in C++ using Princeton Satellite Systems DSim
- Graphical user interface in VisualCommander
- SCControl library with hundreds of C and C++ functions to support spacecraft modeling and control
- The spacecraft library of DSim C++ classes modeling dozens of spacecraft and aircraft components MATLAB functions and scripts that support the design of these control and navigation systems

DSim and ControlDeck will run on the Mac, UNIX, or Windows OS. The VisualCommander graphical user interface runs on MacOS 10.6+.

The figure below shows the connections between the packages. The Core GN&C package can be used to support many types of satellite operations. It also provides a common code base that supports the other two packages. Click on each box to view a block diagram of the package.



The technology in these products is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services.

2. PACKAGES

Sigma point estimation software including nonlinear measurement models for each type of measurement listed above

- Re-configurable graphical user interface pre-loaded with spacecraft trajectory and navigation views
- Control software for the sensor
- Batch estimation software
- Full simulation in VisualCommander of a spacecraft mission using the ONS as the navigation solution
- Matlab scripts to support control system design

ONS v1.0 is available under SBIR Data Rights at no cost to U.S. Government agencies.

2.1 Core GN&C

The Core GN&C package provides an extensive suite of guidance, navigation and control software that can be tailored to fit many different types of typical spacecraft missions. This package incorporates a new navigation solution developed for the NASA Phase II SBIR, entitled “Optical Navigation System”.

The Optical Navigation System (ONS) is a flexible navigation system for deep space operations that does not require GPS measurements. The navigation solution is computed using an Unscented Kalman Filter (UKF) that can accept any combination of range, range-rate, planet chordwidth, landmark and angle measurements using any celestial object. The UKF employs a full nonlinear dynamical model of the orbit including gravity models and disturbance models. The ONS package also includes attitude determination algorithms using the UKF algorithm with the Inertial Measurement Unit (IMU). This makes the sensor a more capable plug-in replacement for a star tracker, thus reducing the integration and test cost of adding this sensor to a spacecraft. The IMU is used as the dynamical base for the attitude determination algorithms. That is, the gyro model is propagated, not the spacecraft model. The linear accelerometers are used to measure forces on the spacecraft. This permits accurate measurement of the accelerations applied by thrusters during maneuvers.

The integrated sensor has two independently gimbaled telescopes each with a zoom lens. The zoom allows planetary targets to be imaged accurately from larger distances. The focal plane of each telescope uses a single Active Pixel Sensor (APS) such as the Cypress Star 1000 Complementary Metal Oxide Semiconductor (CMOS) sensor. These are used to measure the chordwidth of planets, moons or the sun; angles between landmarks; angles between planets; and angles to stars. Angles between centroids are used for planetary targets. The centroid can be measured using only part of the planetary disk.

The focal length is adjusted and telescope angles are changed using ultrasonic motors. Ultrasonic motors provide very high accuracies and are capable of adjusting the focal length to nanometer precision. In addition, they have large holding torques and forces so they do not require any caging mechanisms for launch. The sensor has a built-in BAE RAD750 processor which does all navigation processing. The processor is on a 3U board which includes built in SpaceWire which is used for internal and external data transfer. SpaceWire is being used on GOES-R, the James Webb Space Telescope and the Lunar Reconnaissance Orbiter.

The following optical measurements can be used for navigation in the Optical Navigation System:

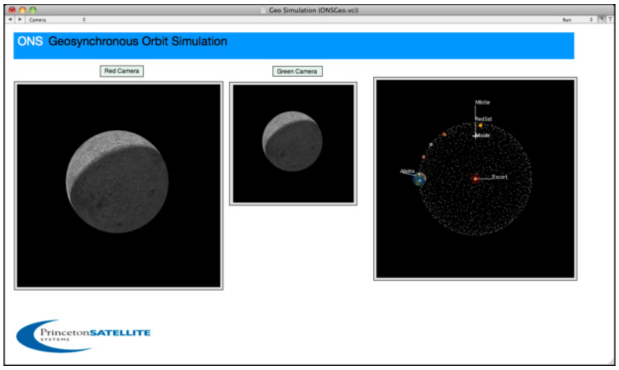
- planet, moon or asteroid size
- landmark size
- angle between a landmark and a star
- angle between two landmarks
- angle between a landmark and centroid
- angles between stars (for attitude determination)

Attitude determination is done with both cameras. Consequently the quaternion between the telescopes is known to high precision. The measurements from the gimbals are used as a measurement input to the Kalman Filter and as a check for fault detection.

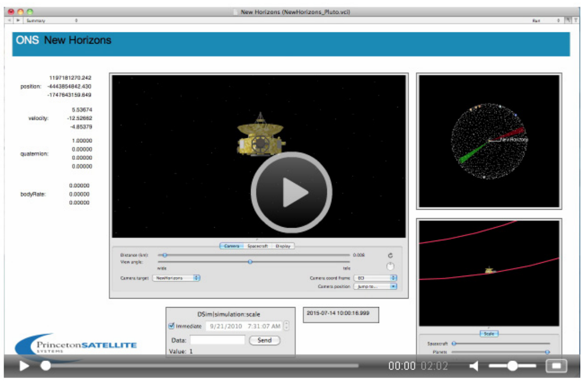
A feature of the sensor is that it can be pointed at targets mounted on the spacecraft for calibration. Camera intrinsic and extrinsic parameters are measured using a calibration cube with a checkerboard pattern. The imaging chip is calibrated with a light source. This allows the sensor to be re-calibrated after launch. Aberrations can be measured and corrected. The response of the pixels across the frame can also be measured allowing for the use of intensity. Calibration, batch orbit determination and targeting run in background. The targeting algorithms decide on the next camera targets based on a combination of geometric and measurement error. The targeting algorithm will attempt to find a target, and target type, that improves the solution the most. Improvement is defined as producing a solution that is most likely to improve the accuracy of the next orbit adjustment.

The Optical Navigation System is particularly well suited to advanced missions that require continuous navigation updates. Such missions include solar sail missions and spacecraft propelled by low thrust engines. Other applications would include satellites that cannot rely on GPS or other external sources of navigation information.

The following picture shows the camera views.



Spacecraft approaching Pluto.



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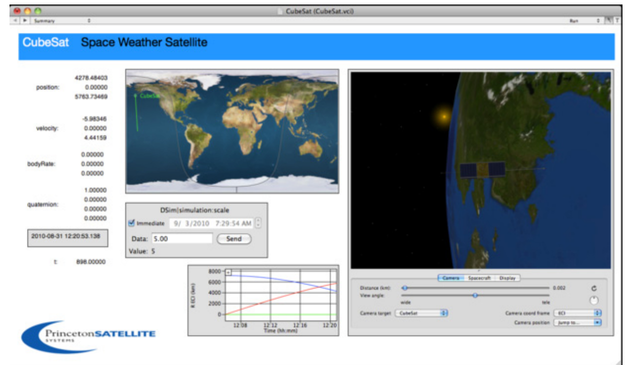
2.2 CubeSat

The CubeSat Attitude Control System is a 3-axis control system using reaction wheels for attitude control and magnetic torquers for momentum unloading. A star camera and MEMS Inertial Measurement Unit (IMU) is used for attitude determination. The control system can maneuver the CubeSat to any orientation. The magnetic torquers can also be used as a backup attitude control system if the reaction wheels are not operational.

The Attitude Control System uses an Unscented Kalman Filter (sometimes known as a sigma-point filter) for attitude determination. It can incorporate star camera measurements, magnetometer measurements and sun magnitude measurements from the solar panels. This makes it very robust.

The following figure shows both ground track and orbit views of a 3U CubeSat space weather satellite in orbit. With VisualCommander you can choose from a wide variety of graphics tools such as these to drag and drop onto the interface pages.



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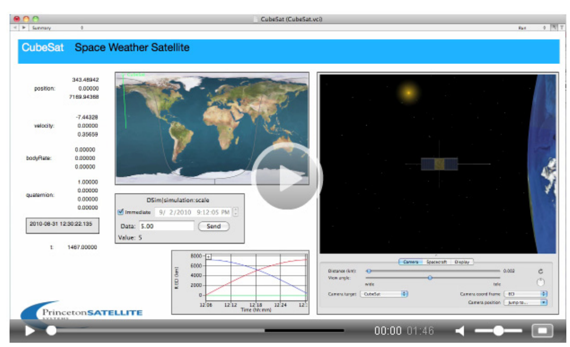
The following movie shows a reorientation maneuver using reaction wheels. The CubeSat is in a polar orbit. Several of the pages in the CubeSat display are shown during the movie. This CubeSat has 8 body mounted high-efficiency solar panels and the power output is shown on hte power page. It has 3 orthogonal reaction wheels and single skew wheel. All four are used during the maneuver.

A CubeSat reorientation maneuver.

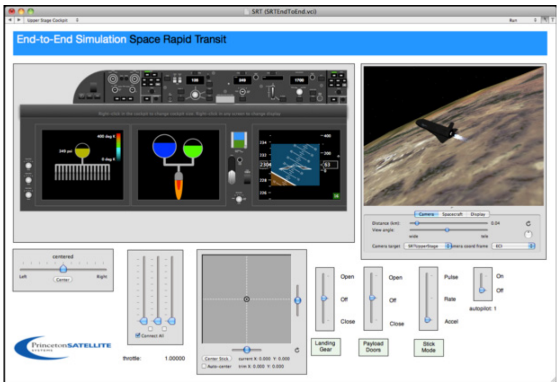


2.3 Space Rapid Transit

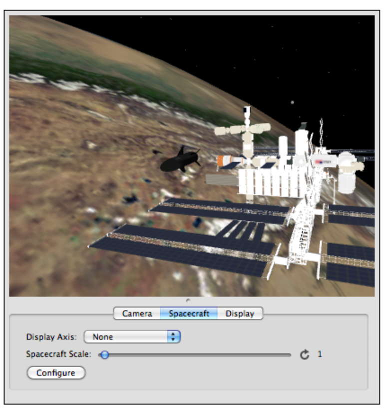
The Space Rapid Transit Package includes an end-to-end simulation in VisualCommander and a set of design tools in MATLAB. The design tools use the MATLAB Optimization Toolbox to generate optimal trajectories for the two stage vehicle. The optimization framework is set up to include a dynamic pressure constraint. Turbofan, ramjet, cryogenic upper stage engine and reaction control system models are included.

The control systems include orientation and tracking control during all phases of flight. On-orbit guidance, rendezvous and formation flying software is also included.

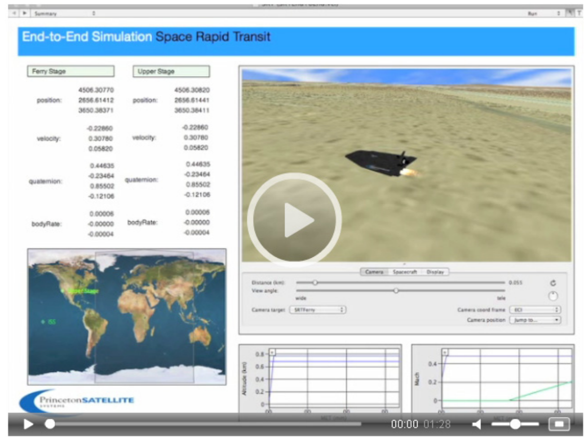
The following picture shows the Upper Stage cockpit. The picture shows the cockpit during the first main engine burn that puts the Upper Stage into an elliptical transfer orbit. The three displays show the reaction control system, the main engine and the vehicle attitude and altitude. When operating the reaction control system the pilot can choose pulse, rate or constant acceleration modes. All controls are operated using the mouse. Saitek flight controls can also be used with the SRT simulations.



The following picture shows the Upper Stage near the ISS.



The following movie shows SRT launch through ISS rendezvous.



Package Contents

- Sigma point estimation software including nonlinear measurement models
- Re-configurable graphical user interface pre-loaded with spacecraft trajectory and navigation views
- Attitude Control System
- Engine Control System
- Full simulation in VisualCommander of a mission from end to end
- Matlab scripts to support system design and optimization