PrincetonSATELLITE
SYSTEMS

www.psatellite.com

Leadership Statement

Princeton Satellite Systems, Inc. is a small company specializing in aerospace control and simulation technology. Our agility and focus on software development enables us to rapidly develop innovative solutions to a wide range of aerospace and control problems. Our commercial software lines enable our customers to pursue the same types of demanding, state-of-the-art applications.

Our core values include a dedication to learning and an emphasis on innovation. We believe that each employee can grow intellectually, learn new disciplines, and contribute original ideas to our business areas.

We are working towards a sustainable future with our initiatives in renewable energy and STEM education. Our CubeSat Club at John Witherspoon Middle School in Princeton brings excitement about STEM fields to students at a young age. We encourage students to pursue engineering careers by offering paid internships and externships that expose them to the small company culture of flexibility and responsiveness.

Core Competencies

PSS is developing innovative technologies in three important areas:

Aerospace
- Expertise in design and evaluation of guidance, navigation and control solutions for space and air-borne systems.
- Automated decision support tools to support launch planning, vulnerability assessment, and optimal reconfiguration of satellites.
- A CubeSat product line, including: a 3U chassis, precision reaction wheel, attitude control system, and the CubeSat Control Toolbox.

Software
- MATLAB™ toolboxes to support design and analysis of aircraft, spacecraft and wind turbines.
- VisualCommander – an innovative new solution for a broad range of data acquisition, data fusion and visualization problems.
- MatrixLib – a C++ implementation of one and two dimensional matrices ideal for science and engineering applications.

Energy
- SunStation™ – the first 100% green charging station for electric vehicles, and a built-in battery to charge EVs 24 hours per day.
- Small-scale vertical axis wind turbines employing advanced integrated sensing, estimation and controls technology, including active blade pitch and camber control, efficient generator and power converter subsystems.
- Fusion propulsion research – the conceptual design of a modular fusion engine, and a 315 year Alpha-Centauri flyby mission.

Products/Services/
Other Application Areas of Technology

SPEAR – Satellite Planner for Execution and Reconfiguration

The Satellite Planner for Execution and Reconfiguration (SPEAR) is decision support software that allows satellite operators and operational commanders to respond to threats or component failures quickly, effectively and in consideration complex physical and operational constraints. With SPEAR, user-built automated workflows that leverage open optimization libraries are used to produce alternative courses of action (COA) allowing users to determine how available space assets can best be utilized.

The technology has demonstrated avoidance maneuver and payload reconfiguration planning for MUOS and is ready for operations center integration and trials. Focused on developing innovative solutions in autonomous guidance, navigation and control for a broad range of aerospace and defense applications, this company seeks resources for targeted development in operational environments such as NAVSOC, GSSC and JSpOC.
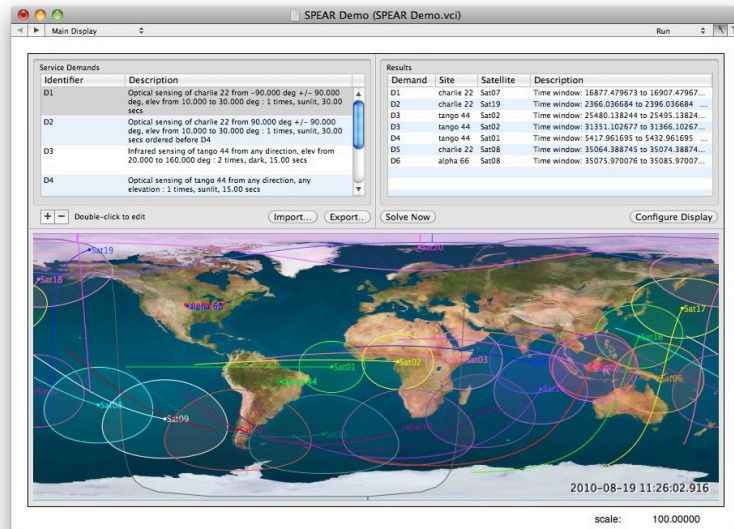

Web Services for Comprehensive Launch Analysis

We are developing model-based data mining tools that incorporate orbital dynamics with available data to assess the vulnerability of tactical satellites. Our JMS-compatible web services take available data on the orbital catalog and missile models and propagate into the future to determine vulnerability windows of satellites to either a direct ascent launch or a satellite from another orbit. The estimated delta-V capability of a selected satellite is used to compute windows of opportunity from a map of delta-V over time. An Unscented Kalman Filter is used to estimate satellite mass and maneuvers from ground observations, leading to better estimates of delta-V capability. A running forecast of possible threats is developed considering a database of missile models and sites and additional real-time dynamic analysis for discrimination between a benign launch and an attack. All current and future DoD space missions could benefit from this technology. Using all available data to predict the vulnerability of our assets is a critical part of situation assessment. In this case we are providing both static predictions based on the satellite catalog and potential launches, and dynamic prediction for actual direct ascent launches. This technology is applicable to commercial missions to assist with launch planning and collision risk assessment, although it is limited to US markets due to ITAR restrictions.

Autonomous Spacecraft Navigation

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.
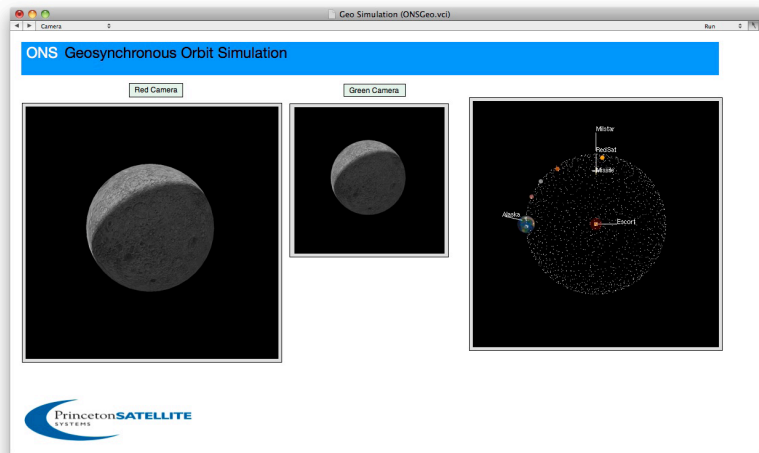
Missile Defense

PSS recently developed a simulation tool for the Missile Defense Agency to analyze defensive missile scenarios involving multiple cooperative missile interceptors pursuing targets that perform random, evasive maneuvers. This tool provides a versatile, user-friendly platform for testing and demonstration of flight path data integration, and interceptor guidance implementation in the presence of operational constraints. These constraints include interceptor performance limitations and communication imperfections. The simulation tool supports a wide array of guidance algorithms, target detection methods, and incorporates systematic procedures for implementing multi-interceptor cooperative control.

Wind Energy Conversion Systems

Princeton Satellite Systems is designing a small vertical axis wind turbine (VAWT) that employs novel control methods for individual blade pitch. The vertical orientation is ideal for small turbines, making them impervious to wind direction. Regulating each blade's angle of attack allows for a wider range of operational wind speeds, therefore improving the turbine's ability to extract energy. Simulations have shown individual blade pitch control to enable the generation of energy in cases where a lack of control would result in energy dissipation. PSS is also developing a high efficiency power conversion system and an aerodynamically-optimized blade design to maximize turbine power output. A VAWT prototype has been constructed to verify performance improvements resulting from control. It consists of a three-blade rotor assembly and a generator housing assembly joined by a main shaft.

Spacecraft Formation Flying

PSS has worked for several years on the problem of designing autonomous guidance and control systems for formation flying satellites. For the Air Force TechSat21 project, we developed the Cluster Manager software, which was an agent-based distributed software system responsible for orbit guidance and fault management. This led to innovative work on the design of formation flying escort vehicles for on-orbit protection of space assets. We were later awarded Phase 1 and Phase 2 SBIRs by NASA Goddard to develop a decentralized formation flying GN&C system, capable of supporting any type of periodic formation geometries in any central body orbit, for arbitrarily large formations. Throughout these efforts, we have developed efficient and robust algorithms to perform optimal maneuver planning and general multi-vehicle coordination tasks in a distributed software architecture.

Launched in June 2010, PRISMA is the first space mission to exhibit sustained autonomous formation flying. The two PRISMA satellites were designed and built by OHB Sweden (formerly Space Systems Division of SSC), with several subsystem contributions from ESA partners. PSS developed the collision avoidance algorithms and safe guidance mode under a Cooperative Research and Development Agreement. Proximity detection algorithms identify when the two spacecraft are too close and switches to the safe guidance mode. This mode is also used routinely during nominal operations to transition between formation flying experiments and when experiments are not being performed.
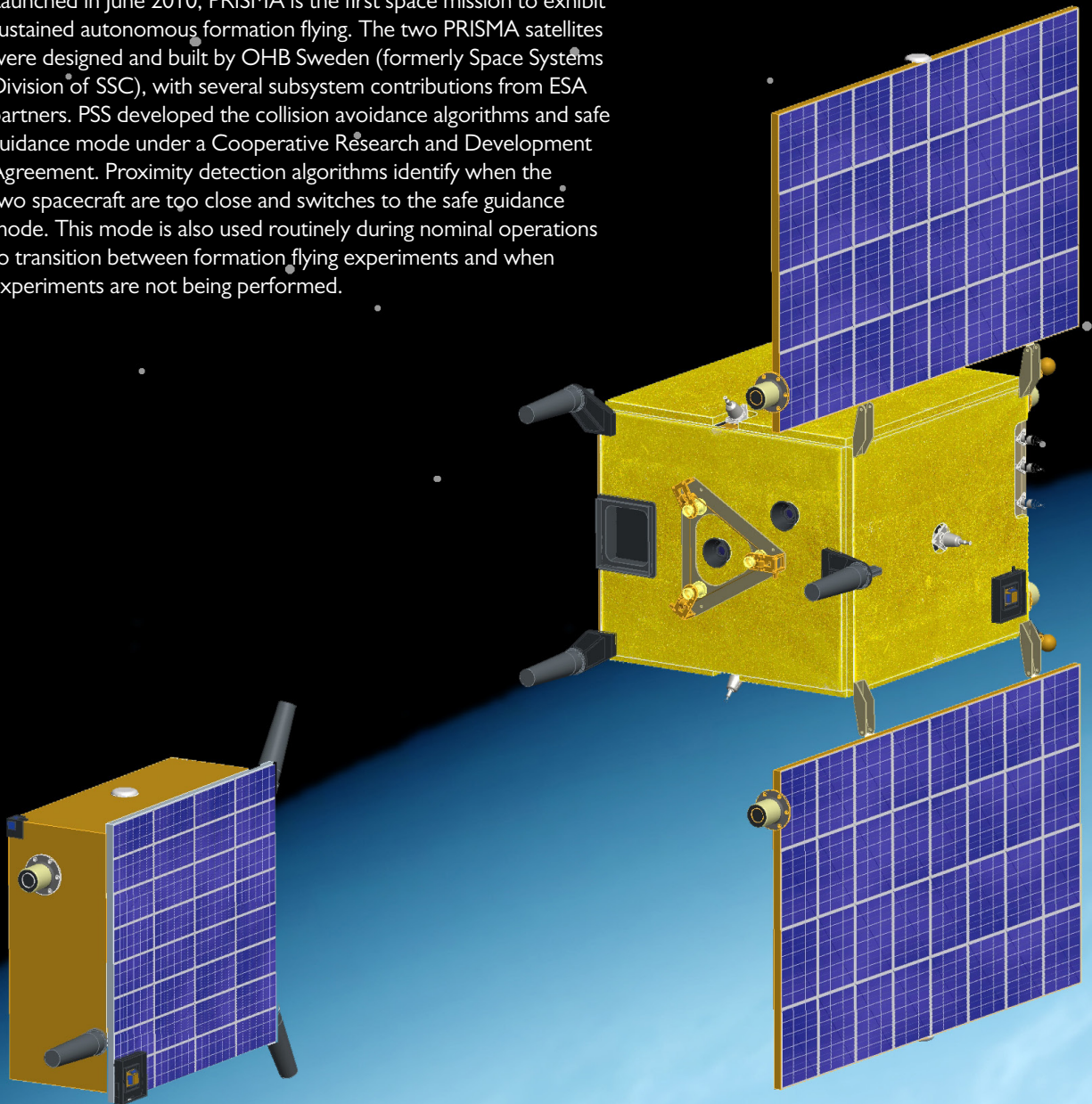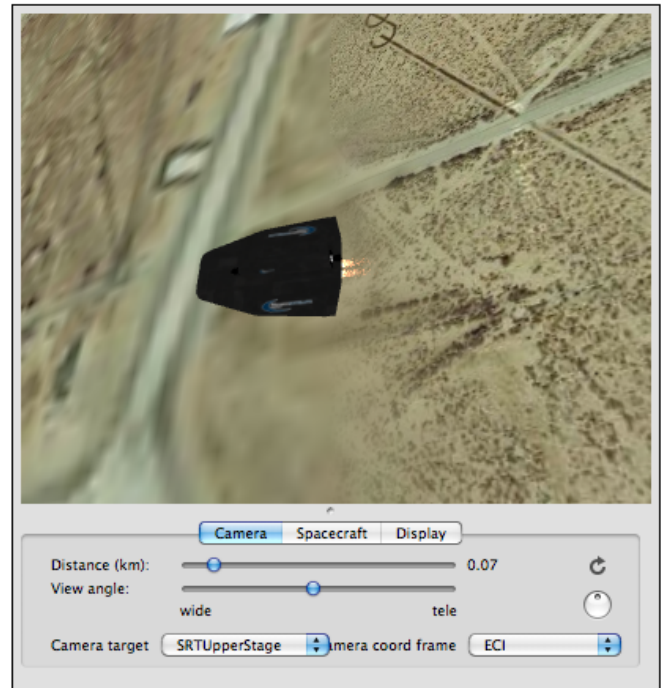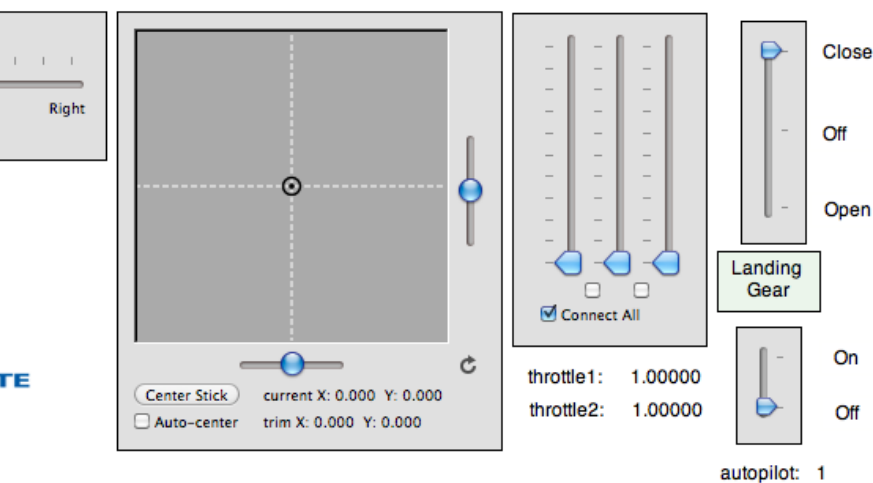
SunStation™ – Solar Powered Recharging System

Electric car owners will prefer to visit locations that provide recharging capability. The easiest way to add that capability is with the new SunStationTM from Princeton Satellite Systems. SunStation is the first 100% green charging station for electric vehicles. All power for recharging comes from the sun! With its built-in battery it can charge EVs 24 hours a day. The SunStation provides 240 V AC power and can fully recharge a Nissan Leaf in 8 hours, a Chevy Volt in 4 and a Toyota Prius Plugin Hybrid in 1.5. High-efficiency solar panels produce the maximum power with the minimum footprint. The station can charge up to two EVs simultaneously.

A SunStation™ can also provide backup power to homeowners in case of extended power outages, or emergency power without the fuel consumption or carbon monoxide risks of conventional generators. An off-grid SunStation can go anywhere! Retail owners may choose to charge for power with a credit card reader or display advertising on the built-in LCD. The optional grid-tie, if available, can allow extra power to be returned to the grid and can provide local energy storage for utility companies.

Run

ation Space Rapid Transit

126 249 1700

ght–click in the cockpit to change cockpit size. Right–click in any screen to change display

400
180
160   50   50   200
135   40   40
120   30   30
100   20   20
        10   10

1
2

Camera Spacecraft Display

Distance (km): ———————————○———— 0.07
View angle: ——————————————○————
                    wide   tele
Camera target SRTUpperStage ⬍ mera coord frame ECI ⬍

Right

Close

Off

Open

Landing
Gear

☑ Connect All

Center Stick   current X: 0.000 Y: 0.000
☐ Auto–center   trim X: 0.000 Y: 0.000

throttle1:   1.00000
throttle2:   1.00000

TE

On

Off

Ramjet

Afterburner

Turbofan

autopilot: 1

machNumber: 0.40040
Landing Gear: 0.00000

Engine 2

massH2:   565.00
massJP: 892.76

Engine 1

massH2:   565.00
massJP: 892.76

VisualCommander

VisualCommander (VC) is an extensible application system for integrated operation of multiple discrete experiments, processes or missions, providing storage, distribution, access control, command processing, and analysis with open interfaces for third party displays and data mining tools. VisualCommander comprises a cross-platform distributed server with an open client interface and an extensible, customizable client implementation supporting third-party plug-ins for data mining and display. The server is designed to seamlessly integrate multiple, heterogeneous telemetry and control streams, providing rich data feeds to any number of clients, thanks to state of the art load balancing and distribution technologies. The client provides customizable interfaces assembled from a library of innovative data display tools, featuring interactive two and three-dimensional graphical environments.

Key features are

▶ Cross-platform, distributed server
▶ Extensible, customizable architecture and support for third-party plug-ins
▶ Integrated support for multiple discrete missions/data sources
▶ Dozens of built-in advanced data mining views for telemetry analysis
▶ Easy to use API's for handling telemetry protocols
▶ Built-in recording capability to generate movies and DVR-like controls to perform playback animations

Design and Analysis Software Tools in MATLAB

Princeton Satellite Systems' design and analysis software tools include a full line of MATLAB toolboxes summarized below. The toolboxes also include extensive documentation, including tutorials.

Spacecraft Control Toolbox

The Spacecraft Control Toolbox (SCT) provides a core toolbox and comprehensive suite of add-on modules capable of:

▶ Spacecraft control system design and analysis
▶ Attitude dynamics modeling including flexible and multi-body spacecraft
▶ Ephemeris calculation
▶ Environmental modeling including atmospheric, gravitational, and magnetic field
▶ Pointing and propellant budgeting
▶ Spacecraft visualization in 3D
▶ Generating, calculating and managing mass properties
▶ Orbit dynamics analysis and simulation
▶ Formation flying and rendezvous maneuver planning
▶ Attitude and orbit estimation, including stellar attitude determination
▶ Thermal analysis
▶ Propulsion system analysis
▶ Link and radar analysis

These packages have been used for many different kinds of spacecraft. Recently PSS studied solar sails for NASA and ESA using SCT, resulting in a dedicated Solar Sail Module. Our ability to model actual spacecraft configurations and shapes when computing disturbances enabled us to easily extend our tools to this unique type of spacecraft.

Aircraft Control Toolbox

The Aircraft Control Toolbox provides a comprehensive set of functions for the design, simulation, and analysis of aircraft models and their control systems. Specific features include:

▶ Aircraft dynamics modeling including flexibility, actuator, sensor and engine dynamics, and the effects of added mass and inertia for buoyant vehicles.
▶ Suite of design, modeling, simulation and analysis tools for airships.
▶ Non-linear models for military and commercial aircraft, including subsonic and supersonic aircraft with all data contained in a convenient database format.
▶ Aircraft control system design and analysis including classical
▶ Eigenstructure assignment, output feedback and many other design methodologies.
▶ Environmental modeling, including the standard atmosphere, a steady-state horizontal wind model, real-time NOAA wind data, and a transient wind-gust model.
▶ Dynamic models and performance analysis tools for gas turbine engines
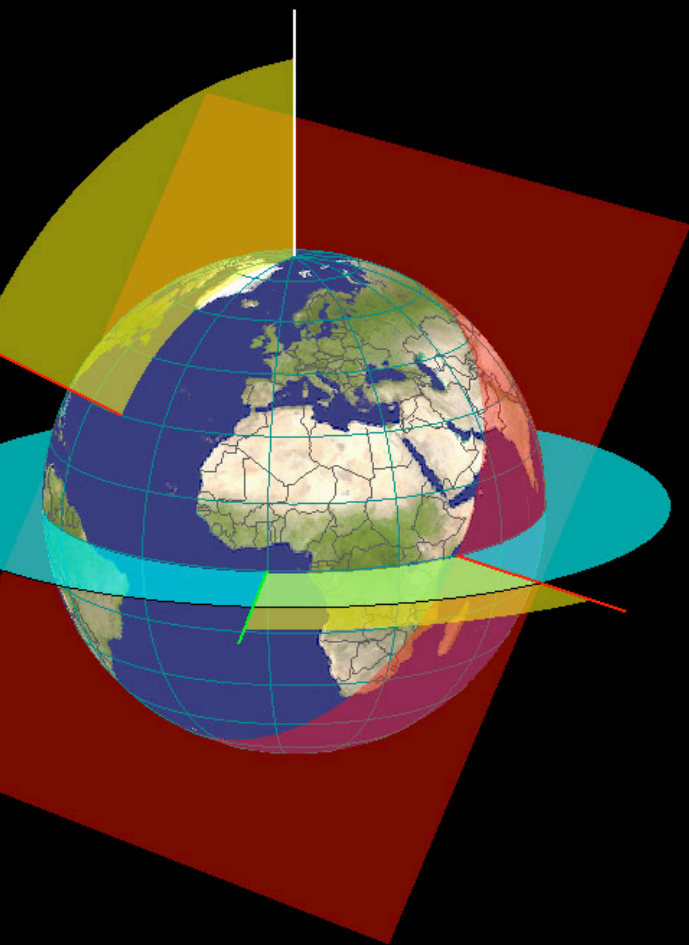
CubeSat Toolbox

The CubeSat Toolbox provides you with all of the engineering tools needed to design CubeSats, plan missions, and perform trade studies - all in the MATLAB environment. Features include:

▸ CAD Models and Simulations of Multiple CubeSats
▸ Control system design
▸ Communications link analysis
▸ Power and thermal analysis
▸ Orbit modeling and simulation
▸ Generate orbits from Two-Line Element sets
▸ Generate attitude profiles with sequences of primary and secondary alignments
▸ Relative orbit simulations and coordinate transformations
▸ Compute observation time windows of ground targets
▸ Compute line of sight to GPS satellites
▸ Compute the ground coverage of sensors pointing in arbitrary directions
▸ Animate the orbits of multiple satellites with sensor cones
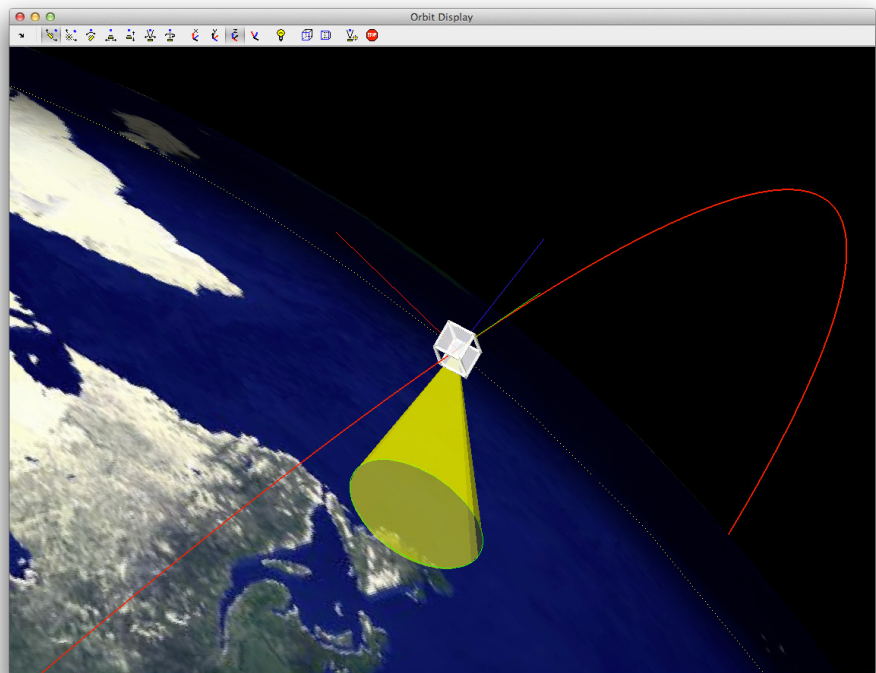
Markets/Customers

Our customers include NASA, the Department of Defense and commercial customers around the world including universities, aerospace companies large and small, and space agencies. Our toolboxes have a substantial international market and we have eight distributors spanning Asia and Europe. Selected previous federal and non-federal contracts are:

▶ Satellite Planner for Execution and Reconfiguration (SPEAR) – Navy SPAWAR
▶ Autonomous optical navigation system for deep space and GPS-denied missions - NASA.
▶ Automated detection and response tools for co-orbiting satellite threats – Air Force Research Laboratory
▶ Simulation tool to intercept multiple missiles employing random evasive maneuvers – Missile Defense Agency
▶ Development of a rapid prototyping system for agent-based real time software in C++ - Air Force Research Laboratory
▶ A reconfigurable, decentralized framework for formation flying control - NASA
▶ Enhancement of space operations training through an open-architecture, plug-in based application for simulation and visualization – Air Force Research Laboratory
▶ Simulations and data visualization for mission planning and assessment – Air Force Research Laboratory
▶ Comprehensive Solar Sail Simulation – NASA
▶ Autonomous Control System for High-Altitude Data Relay Stations – Edwards AFB

Profile

Princeton Satellite Systems, Inc. is a small company specializing in aerospace control and simulation technology. Founded in 1992 by Michael A. Paluszek, our work has included the GPS IIR attitude determination system, the Cakrawarta-1 attitude control system, the ATDRS flight software, and the PRISMA safe orbit guidance system. In 1995 we began selling the Spacecraft Control Toolbox for MATLAB™, which is now used by NASA, ESA, the DoD, and several aerospace companies and universities, both in the U.S. and in countries all around the world. We have been awarded over 20 different SBIR contracts, developing innovative solutions for a wide range of aerospace problems, including: stratospheric airships, missile defense, formation flying, optical navigation, space situational awareness, and on-orbit reconfiguration.

Core Advantage

PSS' software product lines and extensive experience on operational systems make us ideally suited to support advanced technology development for operational systems. Our focus on product development enables us to complete contracts on time and under budget, while exceeding specifications.

PSS has customers worldwide, including:
▶ Boeing
▶ Honeywell
▶ Orbital Sciences Corporation
▶ Surrey Satellite Technology
▶ Los Alamos National Laboratory
▶ Sandia Laboratory
▶ Air Force Research Laboratory
▶ NEC
▶ Canadian Space Agency
▶ ESTEC
▶ Energia (Russia)
▶ Lockheed Martin
▶ TRW
▶ Raytheon

Princeton Satellite Systems is a MathWorks Connections partner and an Analytical Graphics partner.

All of our products can be found on the GSA schedule.

GSA Schedule 70 (IT)
Contract #: GS-35F-0432X
www.psatellite.com/gsa_schedule.php

The employees at Princeton Satellite Systems have a diverse set of backgrounds and experiences, and we maintain involvement in several professional societies:
▶ AIAA – American Institute of Aeronautics and Astronautics
▶ AIAA Intelligent Systems Technical Committee
▶ American Astronautical Society
▶ IEEE – Institue of Electrical and Electronics Engineers
▶ ASME – Amereican Society of Mechanical Engineers
▶ Sigma Xi – The Scientific Research Society
▶ NCMS – The Society of Industrial Security Professionals
▶ APS – American Physical Society

Contact information

Our website contains more information on our products and projects. You can find white papers, references to our technical papers and publications, screenshots, videos and demos of our software products, and online APIs. Please visit!

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