Smart Nanosatellite Attitude Propagator

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Release Date: May 2011

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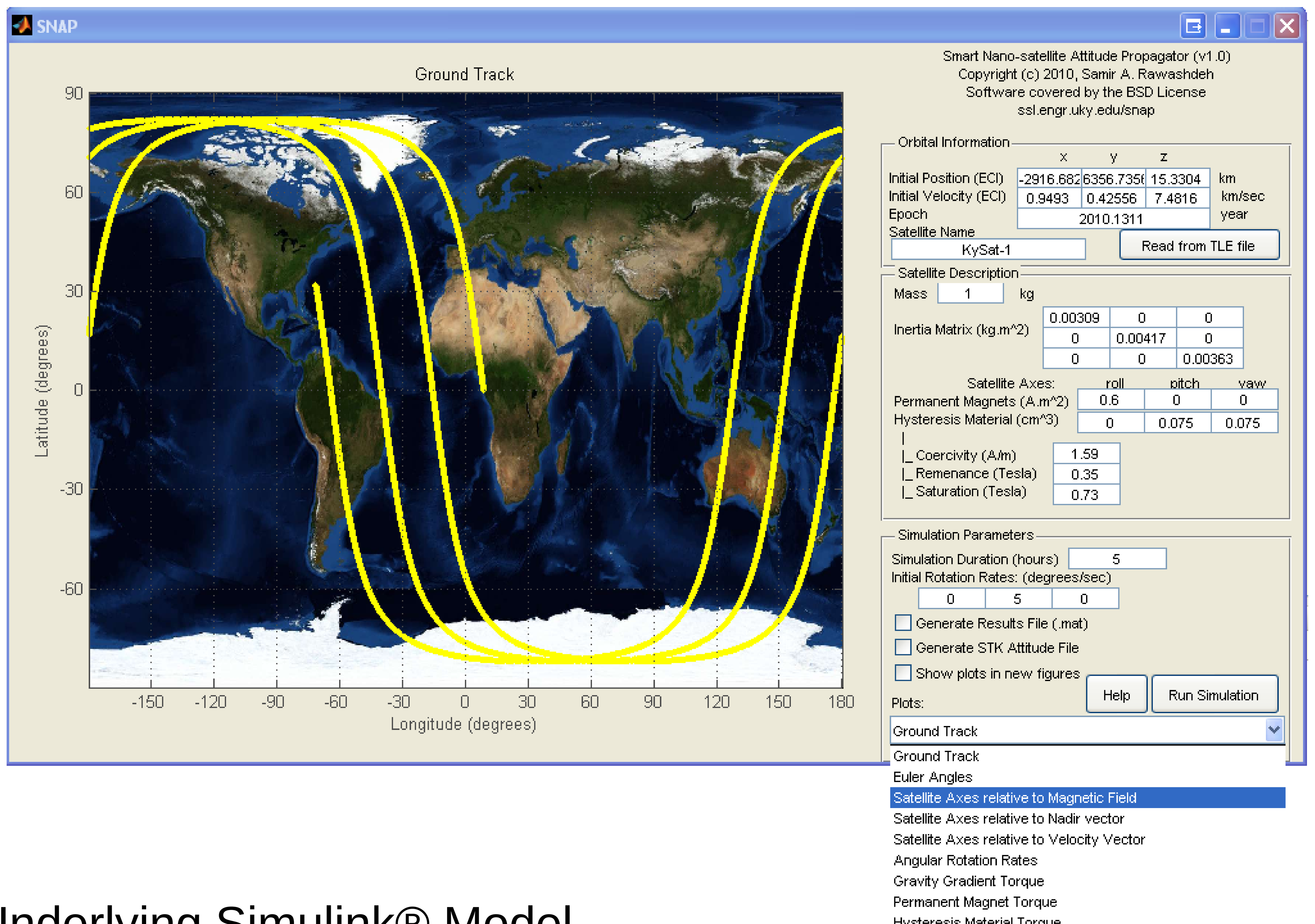
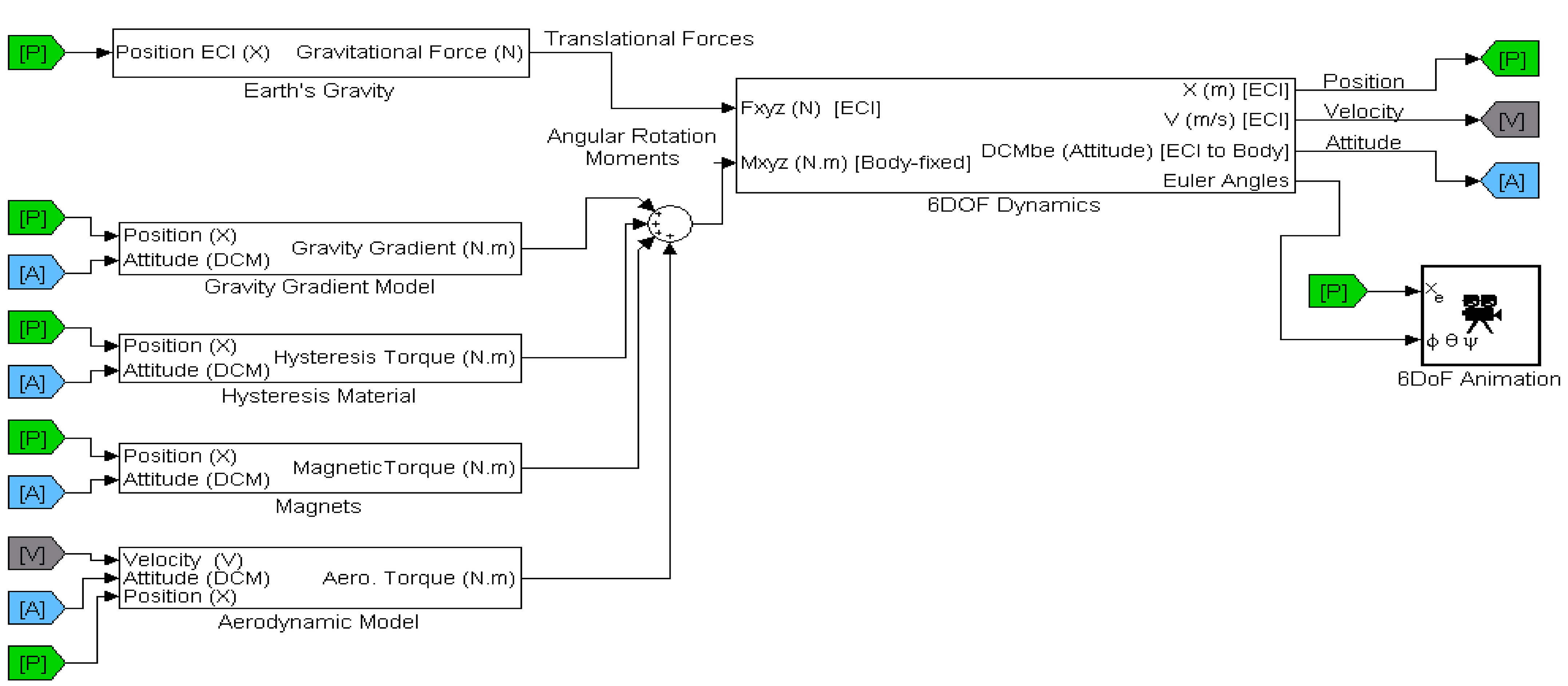
Overview

Nano-satellites such as CubeSats pose volume, mass, and power limitations on all components and modules within the satellite. Passive attitude stabilization techniques such as Passive Magnetic Stabilization and Gravity Gradient stabilization are effective and relatively simple methods to control the attitude of small satellites and provide basic pointing control. The Smart Nanosatellite Attitude Propagator (SNAP) was developed in MATLAB and Simuink to address the design questions of these stabilization systems. This is achieved by modeling all the major environmental effects of the desired orbit to study the on-orbit behavior and the effectiveness of the stability system in overcoming the disturbance torques. Orbit parameters, gravity gradient torque, the Earth's magnetic field, magnetic torque, and magnetic hysteresis material behavior are all modeled in SNAP.



Underlying Simulink® Model



Features

The Smart Nanosatellite Attitude Propagator incorporates the major environmental torques from a small-satellite perspective, as well as magnetic hysteresis material which is a passive solution to angular rate damping. The Simulink model essentially propagates the satellite's attitude given its mass properties and orbit parameters. At each time step, the various environmental torques are calculated given the magnetic field at that point, the velocity, position in orbit, and the satellite orientation. The satellite position and orientation are modeled by a 6-DOF body model. Simulink offers a variety of differential equation solvers to propagate the models and obtain attitude reports for analysis and animation.

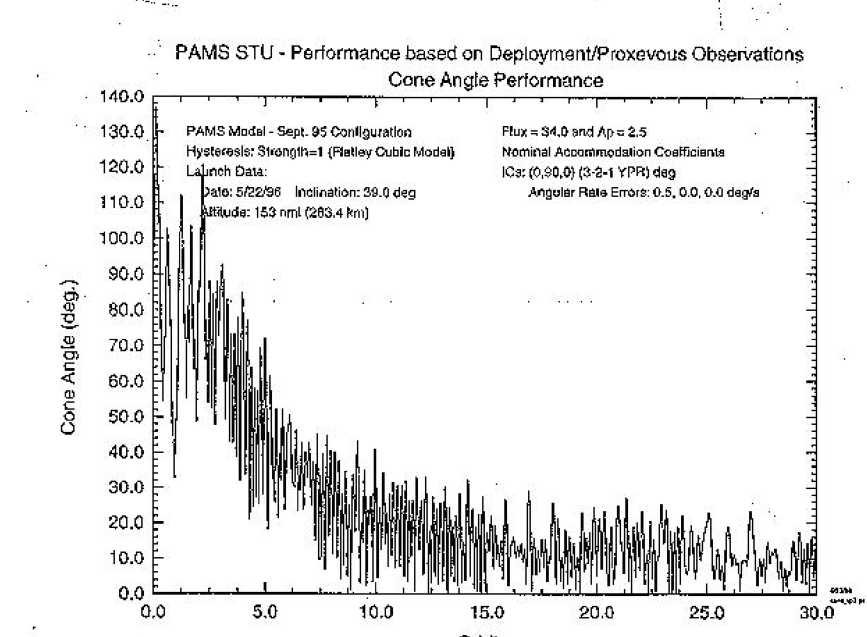
Capabilities

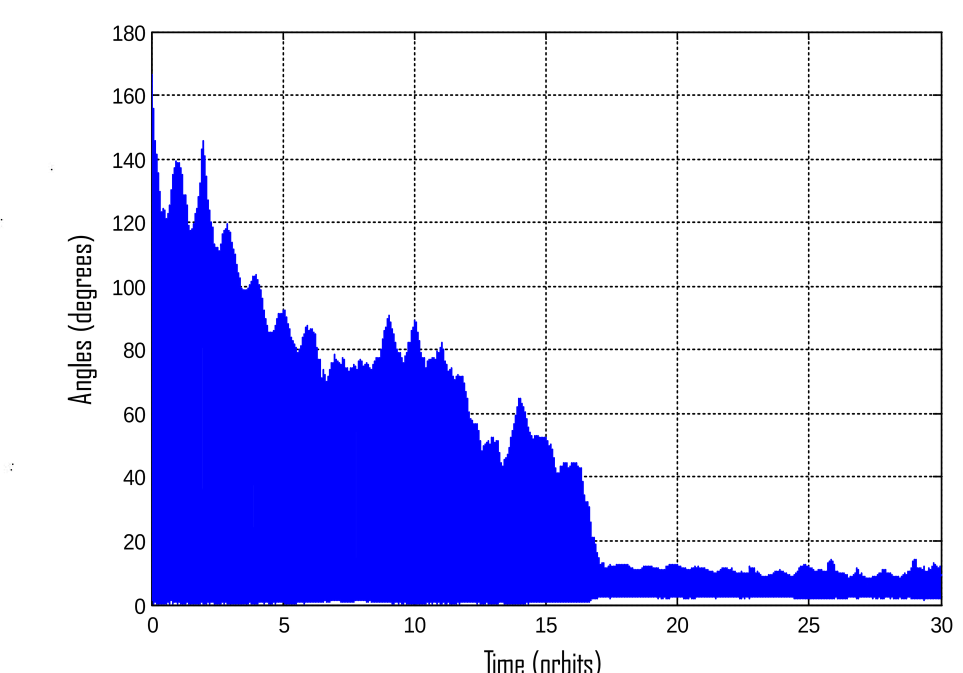
- Satellite Passive Magnetic Stabilization Design
- Satellite Gravity Gradient Stabilization Design
- Studying Magnetic Hysteresis Material Performance
- Attitude Propagation (Gravity Gradient, Magnetic, and Hysteresis)
- Generation of STK (Satellite Tool Kit) Attitude Files for Animation
- Future Extension to Active Attitude Control Systems

Verification

In order to verify the accuracy of the Orbital Environment Simulator, several launched satellites employing passive stabilization techniques were simulated. Given the satellite design parameters, the orbital conditions, and the initial tumble rate, the actual on-orbit observations were compared to the simulation results. The results of the simulator were within the scope of the actual observations.

The set of figures show PAMS: the Passive Aerodynamically Stabilized Magnetically Damped Satellite, which was an experiment on STS-77 in 1996. The attitude profile provided by NASA resembles to simulated profile to the same initial conditions. This scenario was simulated using an extended version of SNAP that incorporates an aerodynamic torque model.





S. Rawashdeh, J. Lumpp, *"Nano-Satellite Passive Attitude Stabilization Systems Design by Orbital Environment Modeling and Simulation"*, *AIAA* Infotech@Aerospace 2010, Atlanta, GA

Passive Magnetic Stabilization

The screenshot highlights the use of permanent magnets and magnetic hysteresis material to stabilize KySat-1, the first CubeSat developed by Kentucky Space. Unfortunately, KySat-1 was lost due to a contingency on the NASA Glory mission in March 2011. The simulation assumes a polar sun-synchronous orbit having an altitude of about 700 km and an inclination of 98˚ .

Design Summary

Parameter	Details	Description
Magnets	Magnet Material	Alnico-5
	Total Volume	0.59 cm^3
	Total Magnetic Dipole	0.5869 Am^2 (calculated)
	North Pole	CubeSat -Z face
Hysteresis Material	Type	HyMu80
	Total Volume	0.15 cm^3 (0.075 cm^3 per axis)
	Coercivity	1.59 A/m
	Saturation	0.73 Tesla
	Remenance	0.35 Tesla
Orbit Parameters	Orbit Altitude	700 km
	Inclination	98˚