Spiral Thrusting for Momentum Control of Planetary Solar Electric Missions

[#8032]

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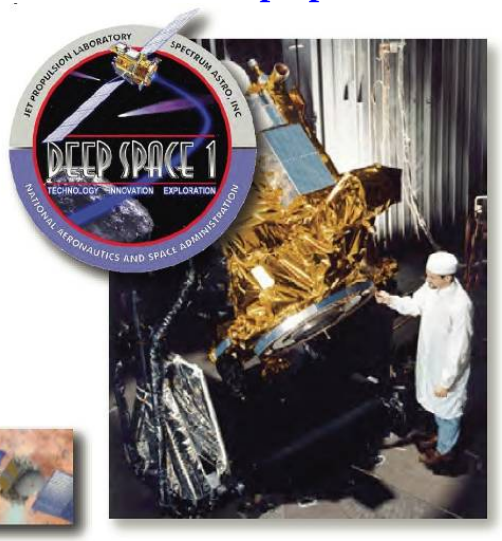
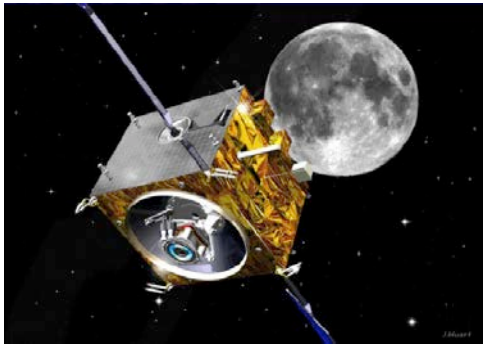
Background and Motivation

DAWN

Deep Space 1



SMART-1



Hayabusa

- Solar Electric Propulsion enables many future small body and planetary missions, however, electrostatic and Hall-effect SEP thrusters produce substantial “swirl” torques when in operation.

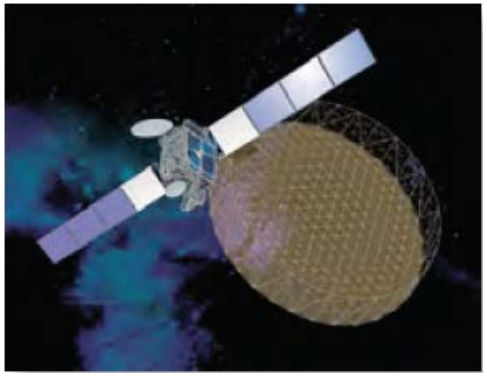
- Historically, planetary SEP missions have used hybrid chemical/electric systems with chemical thrusters providing direct thrust-line attitude control or periodic unloading of the swirl angular momentum.

Background and Motivation (cont.)

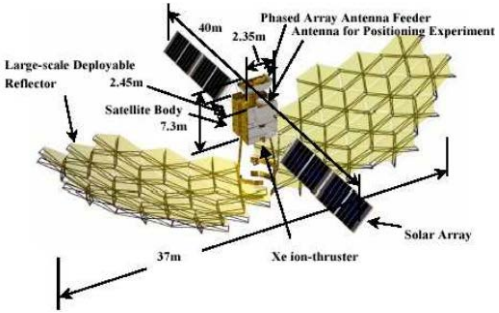
ESA Artemis

Boeing 702

Loral MBSAT



JAXA ETS-VIII



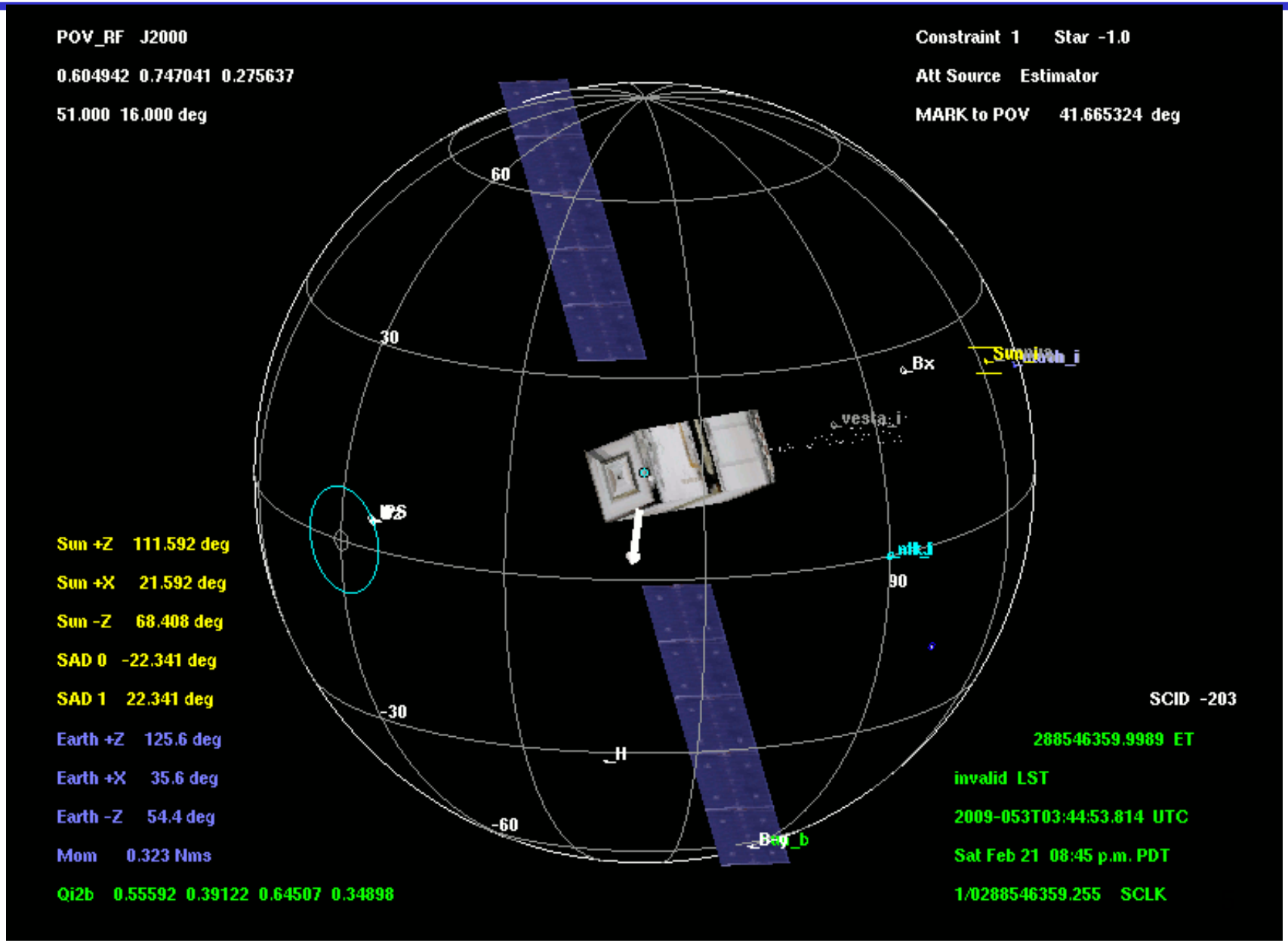
- Commercial comsat providers moving towards All-Electric architectures, using new momentum control algorithms, thruster gimbal configurations, and xenon cold gas/resistojet thrusters
- ***All-Electric buses now on offer from Boeing, Loral, OHB, and Thales***
- All-Electric spacecraft can offer significant cost, mass and complexity reductions over hybrid designs, but they present challenges in planetary applications.
- They commonly exploit 24 hr orbital motion (1/4 orbit coupling) to allow full 3-axis momentum unloading and are not optimized for the long, continuous thrusting typically required by planetary missions.

SEP Spiral Thrusting

- Spacecraft attitude commanded to make the instantaneous SEP thrust vector circle around the desired delta-V direction
- A conventional “Array Steering” algorithm controls the attitude about the free axis, keeping the arrays on-sun

- Motion provides “1/4 orbit coupling” even in interplanetary cruise
- Allows 2-axis SEP gimbal to “continuously” dump wheel momentum (e.g. from swirl torque) in all 3 inertial axes

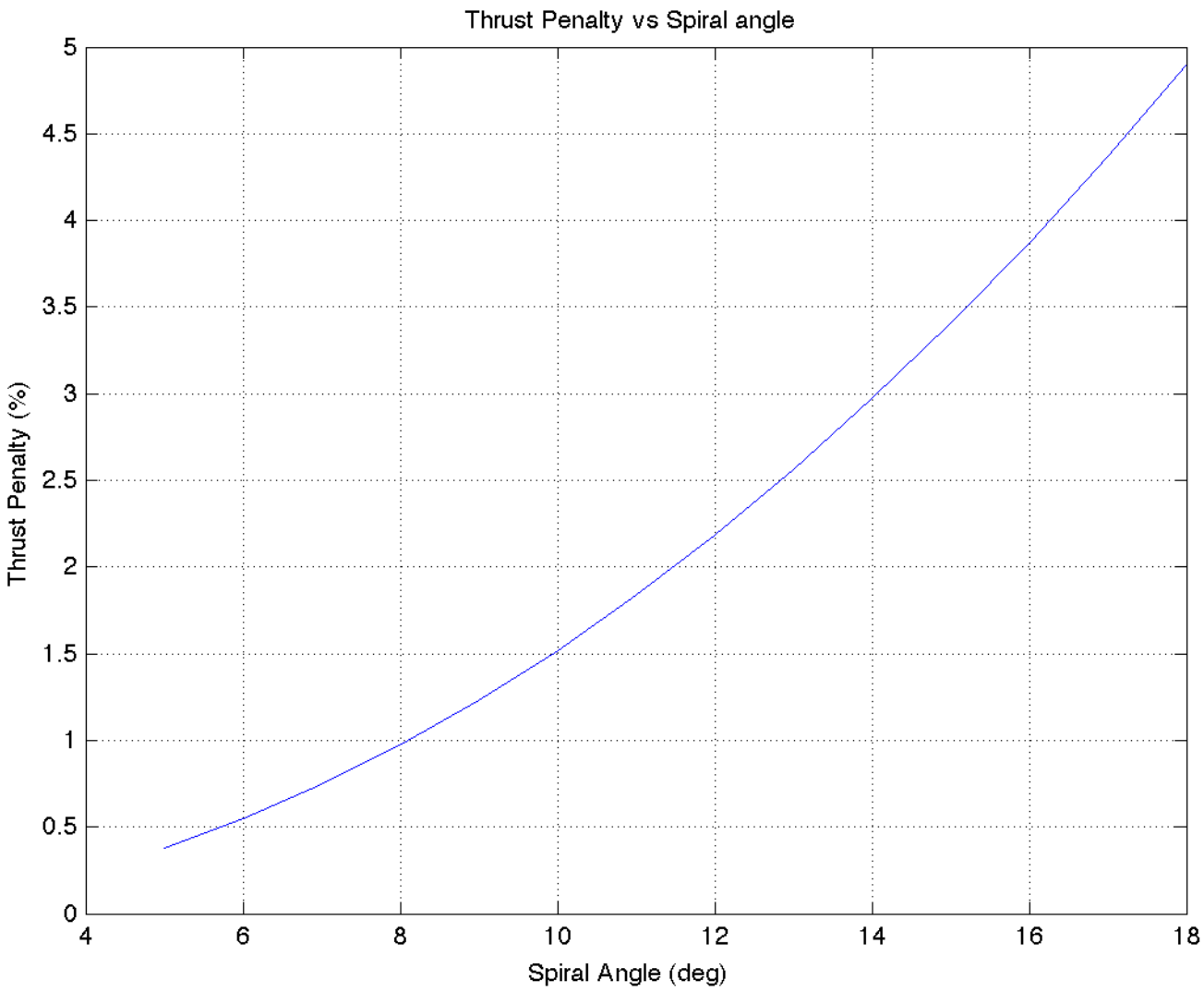
8 deg SEP Spiral



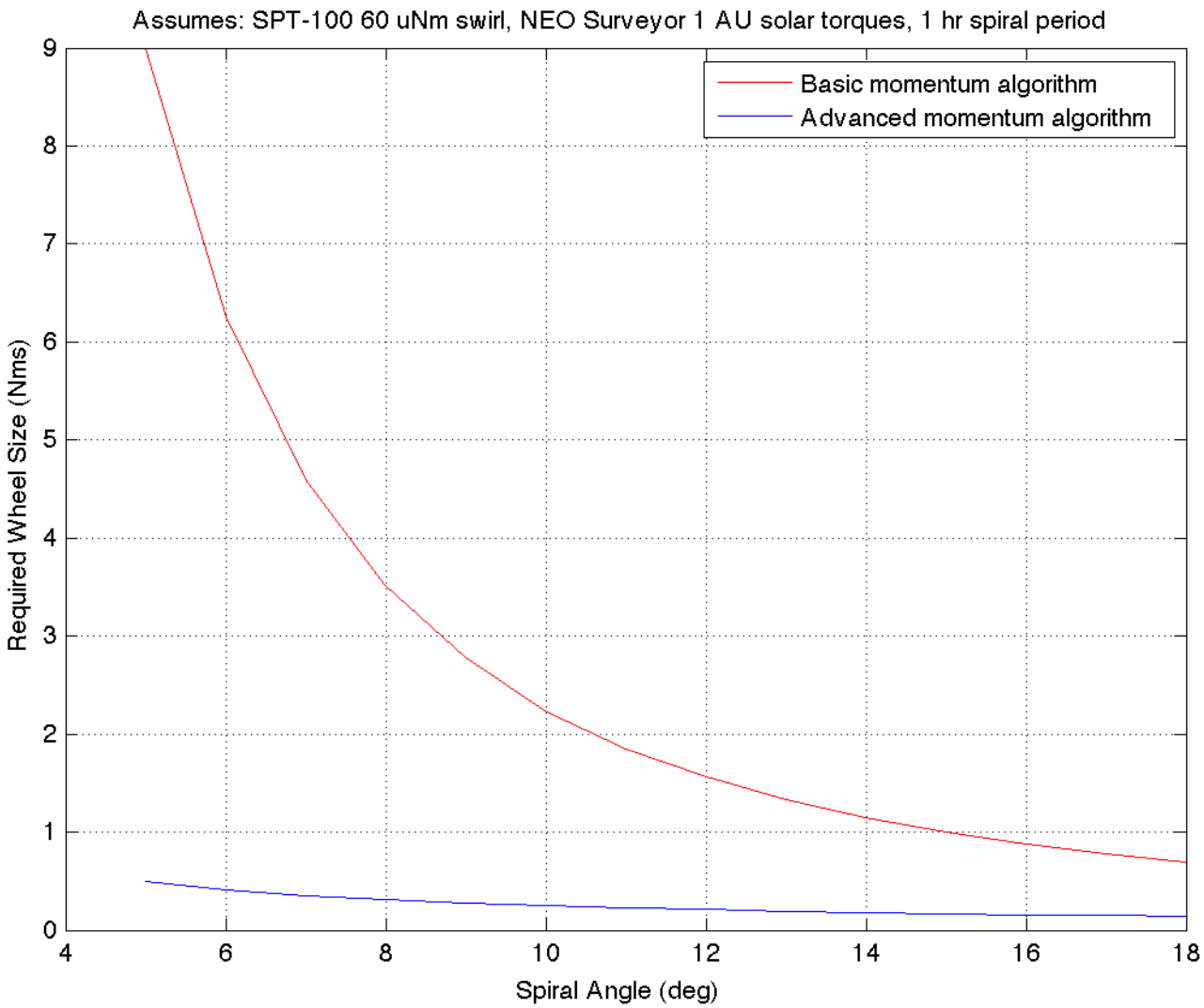
Study Overview

- Developed a simulation of spacecraft momentum balance
  - Small spacecraft (300 kg) reference design
  - 1 SEP thruster, 2 axis SEP gimbal, 1 axis array gimbal, 4 RWAs (similar to Dawn, DS1, etc)
  - SEP thruster “swirl” torque model (SPT-100, BPT-4000)
  - Solar torque model (validated against Deep Impact model)
  - Parameterized spiral thrust profile (angle, period)
  - Prototype momentum dump algorithm

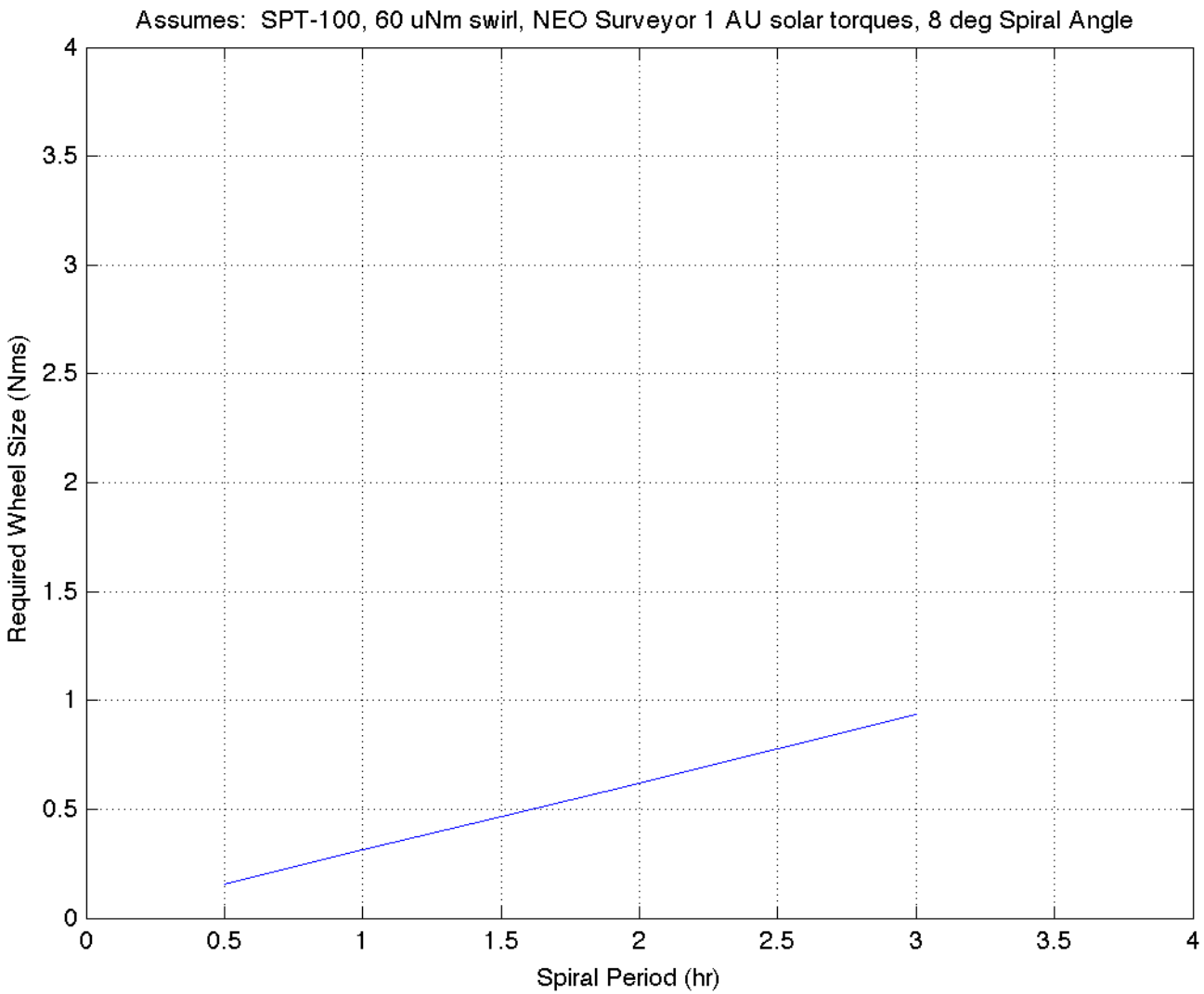
Thrust Penalty vs Spiral Angle



Wheel Size v Spiral Angle (SPT-100)



Wheel Size v Spiral Period (SPT-100)



Study Results

- Minor impacts to reference design
  - Thrust penalty ~1% for 8 deg spiral angle
  - Spiral period >= 1 hour shown to be effective
  - Momentum wheel capacity used < 1 Nms
  - Gimbal travel < +-1 deg , gimbal wear < 50 deg/day
  - Results believed to scale to both larger and smaller spacecraft designs

- Conclusion: **Spiral Thrusting seems feasible**