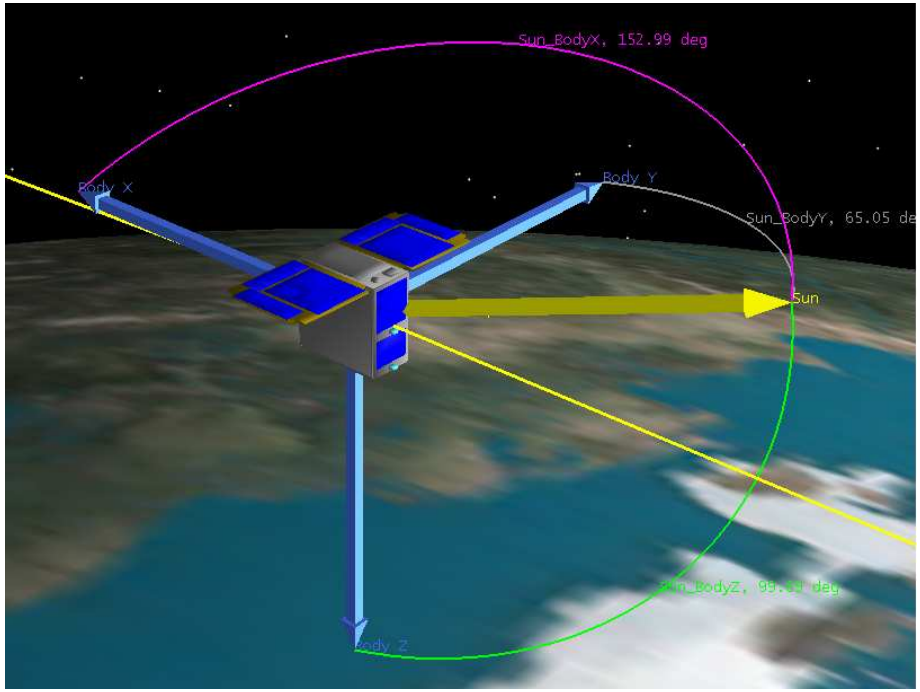
Japan Canada Joint Collaboration Satellite – Formation Flying (JC2Sat–FF) Mission Design



Presenter: Balaji Kumar

Authors: Balaji Kumar and Alfred Ng

Canadian Space Agency

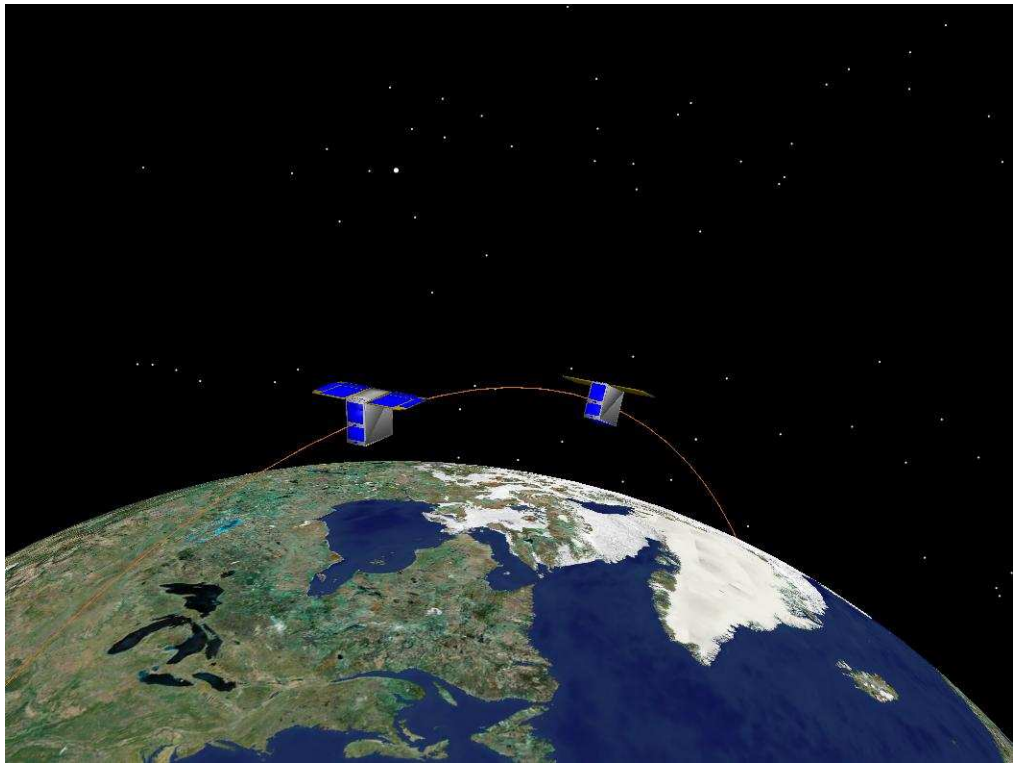
Presentation Outline

- JC2SAT-FF Mission Background
  - Mission Information
  - Mission Concept
- Use of STK for Mission Design
  - Feasibility Study
  - Mission Planning

JC2SAT-FF Mission Background

JC2SAT-FF Mission

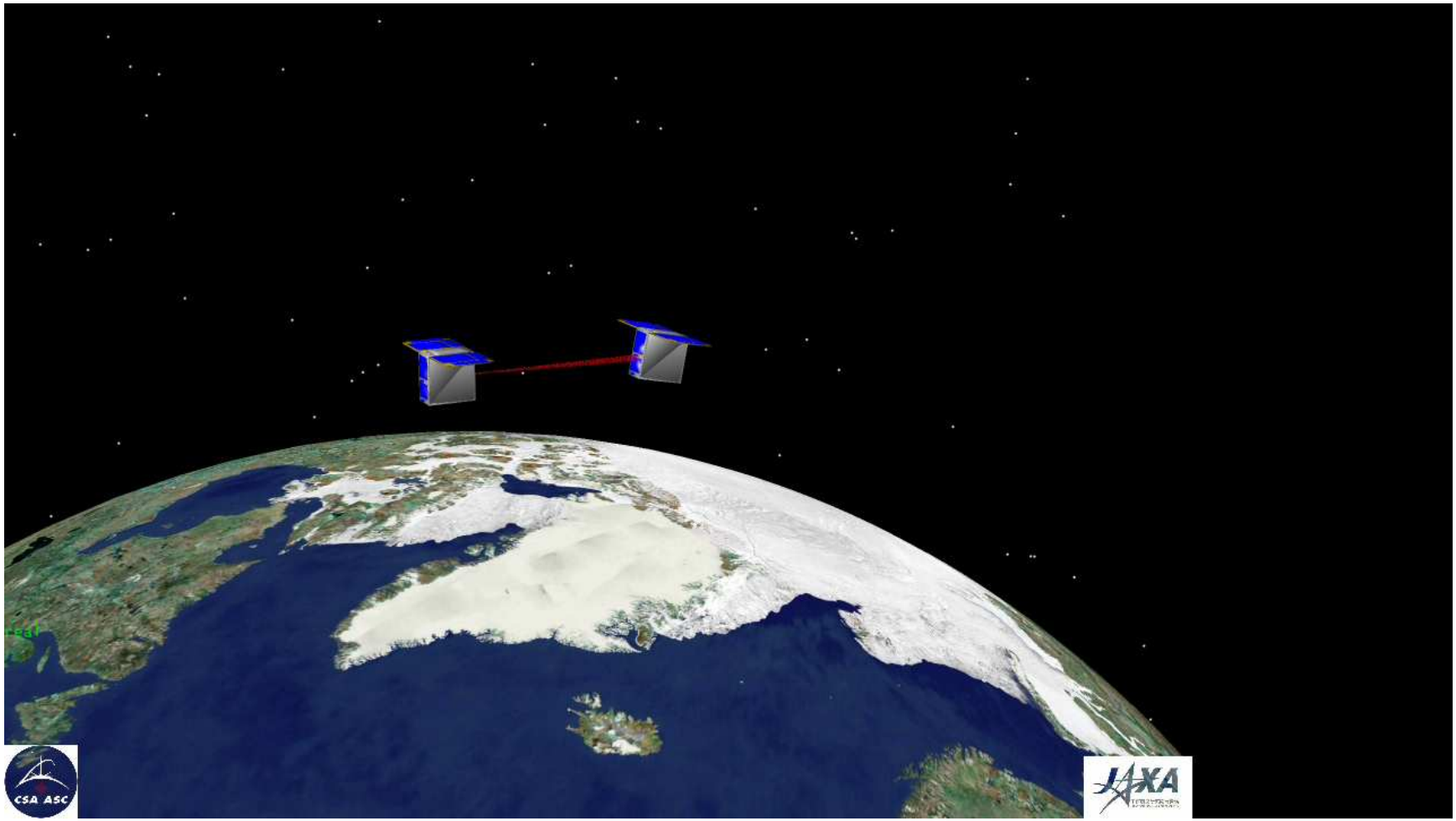
- Two almost identical satellites weighing about 17 kg each
- Orbital parameters
  - Altitude 650 km (Sun Synchronous)
  - LTAN 1030 – 1330
- Separation Distance will vary from 100 meters to 5 km
- Proposed launch date: 2010 or 2011



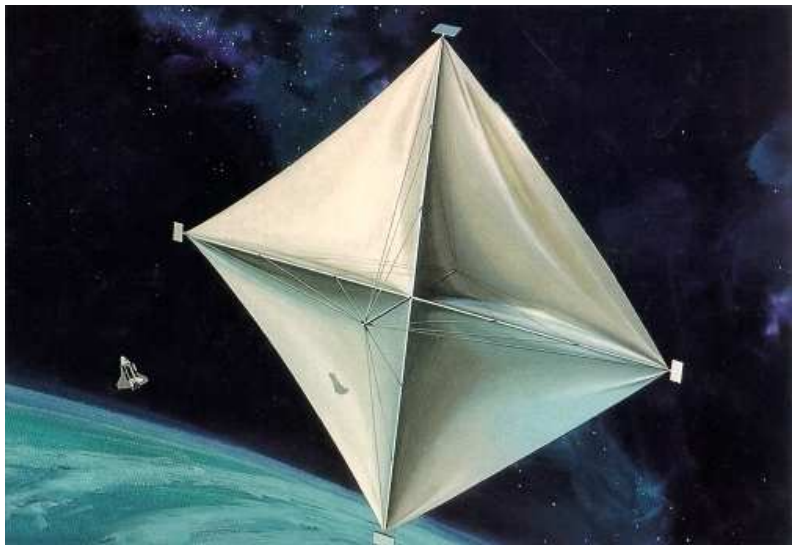
Mission Objectives

- To validate and demonstrate new technologies
  - Demonstration of Autonomous Formation Flight only with differential drag
  - Demonstration of Precise Relative Navigation
  - Demonstration of the Miniature far Infrared radiometer (Mirad)
- To build in-house expertise and strengthen relationship with JAXA

Mission Concept



Will this work ?



JC2Sat Mission Design with STK

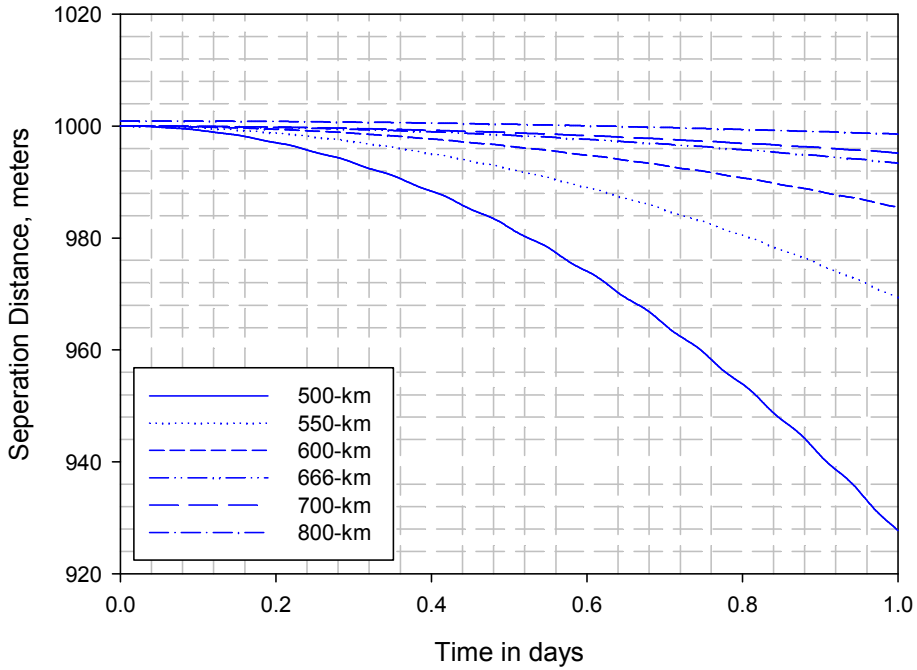
Feasibility Study

- Is the altitude too high for the differential drag concept? (Desired altitude: 650 km)
- Do we have sufficient drag area for control ? (Max available: 0.135 m^2)
- Do we have a limit on the inter-satellite separation distance? (Max desired distance: 20 km)

Tools for the Study

- STK HPOP and Astrogator

  (Manual study was also performed using analytical methods)
- STK Connect with Matlab script for Monte-Carlo analysis (instead of STK Analyzer)
- Matlab and Excel for plotting

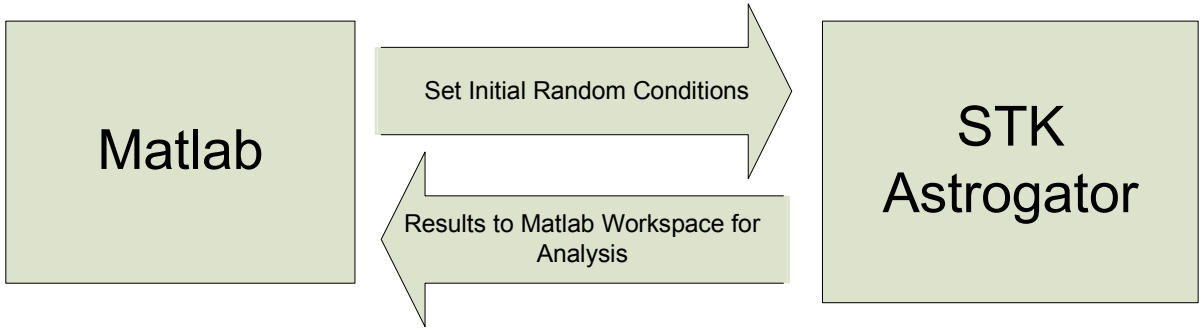


Purpose of the Monte Carlo Analysis

- Monte Carlo analysis was suggested by external reviewers at Mission PDR.
- To find a realistic estimate of the value of the differential drag acceleration for the available drag panel area.
- To identify worst-case (highest) values of differential perturbations in order to verify control authority at large separation distances.

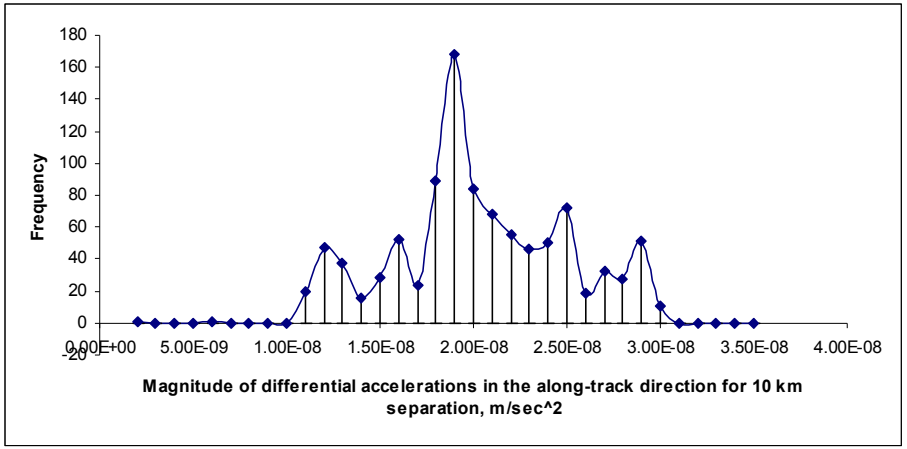
Method (Simplest Explanation)

- Since we did not have STK/Analyzer, we had to create an almost equivalent tool for this analysis
- Matlab script is used to randomly choose parameters from a range of values (example, altitude 600 – 650 km).
- Set of initial conditions are send to STK Astrogator for Propagation.
- Value of the required parameter (averaged over an orbit) is sent back to Matlab.

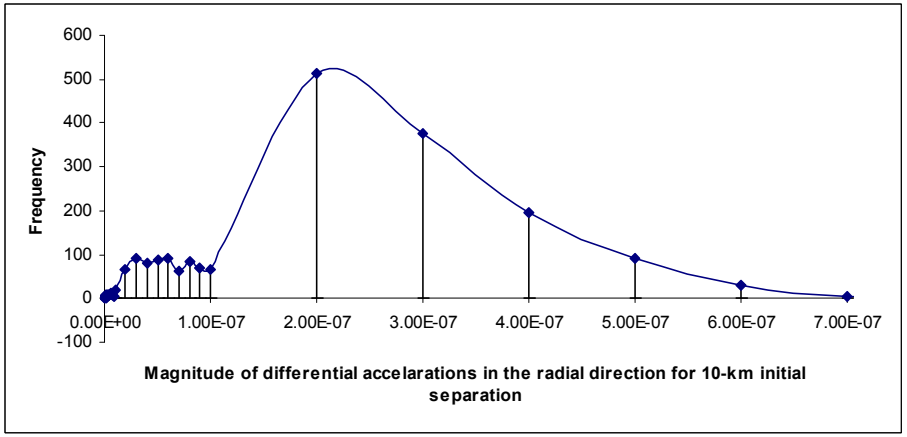


Results and Surprises

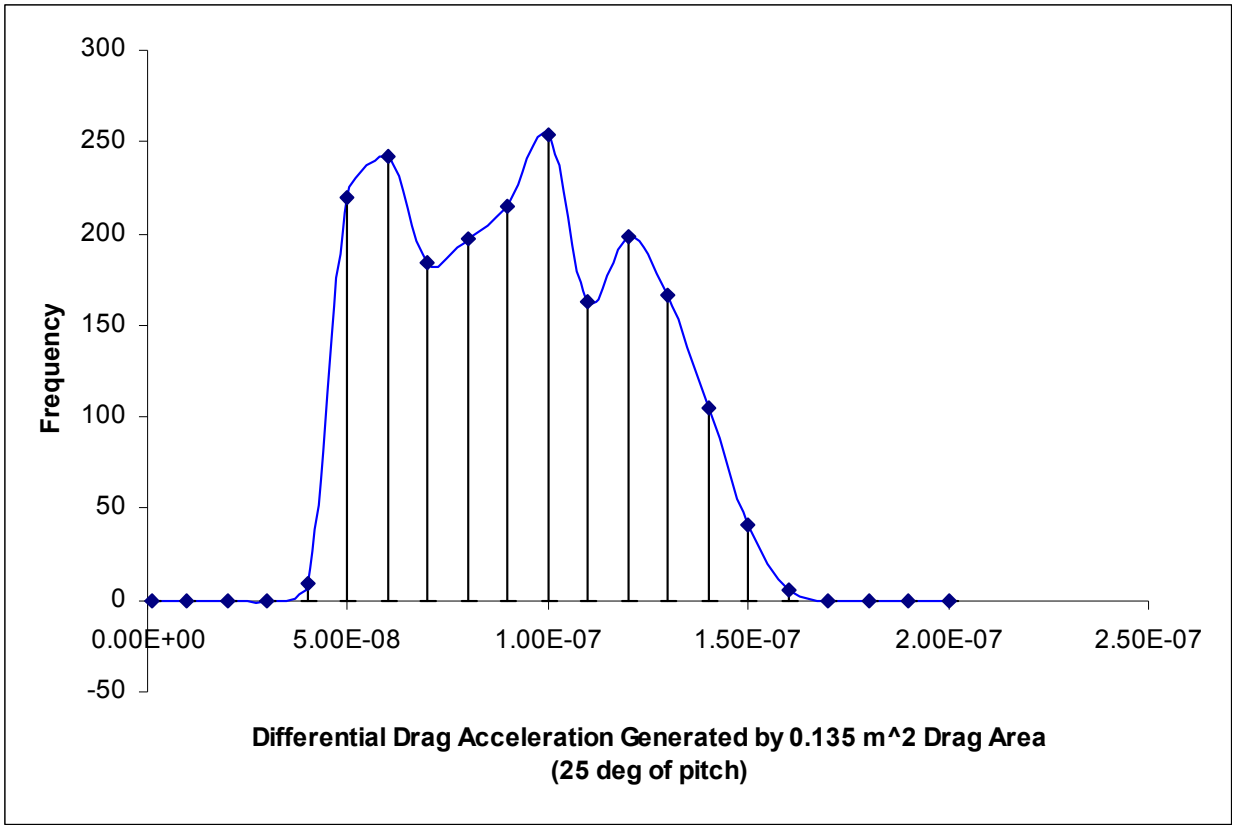
- Magnitude of differential perturbative acceleration was found to be 30 times more than the hand computed values



- The perturbative acceleration in the radial direction was found to be 20 times more than in the along-track direction



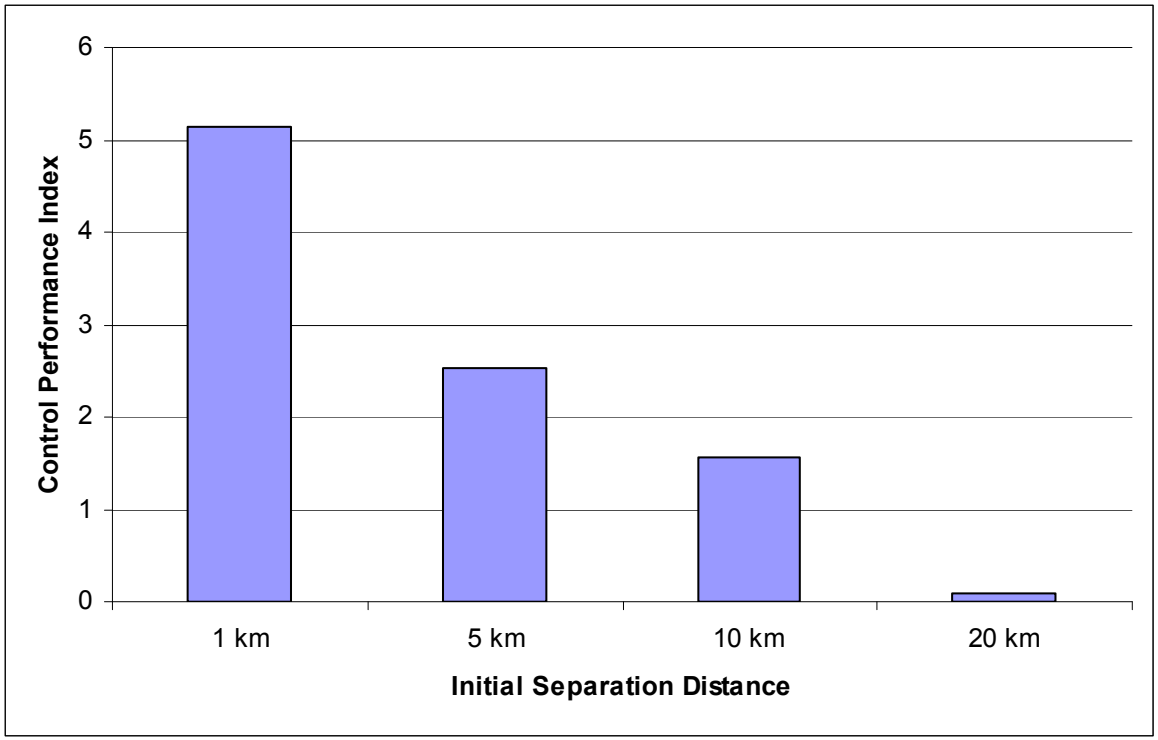
Differential Drag Acceleration Estimation



Least value = 5×10^{-8} m/sec^2

Control Performance Index for Various Separation Distances

$$CPI = \frac{y_{drag}}{y_{perturbations}}$$



Summary of the Feasibility Study

- Control with differential drag is possible even at 650 km if separation distance does not exceed 5 km
- Part of this study was published as an IEEE conference paper

  Balaji Shankar Kumar, Alfred Ng, '**Differential Drag as a Means of Control For Spacecraft Formation Flight**' IEEE Aerospace Conference proceedings, March 2007 (paper also accepted for publication in *IEEE Aerospace Transactions Journal*).

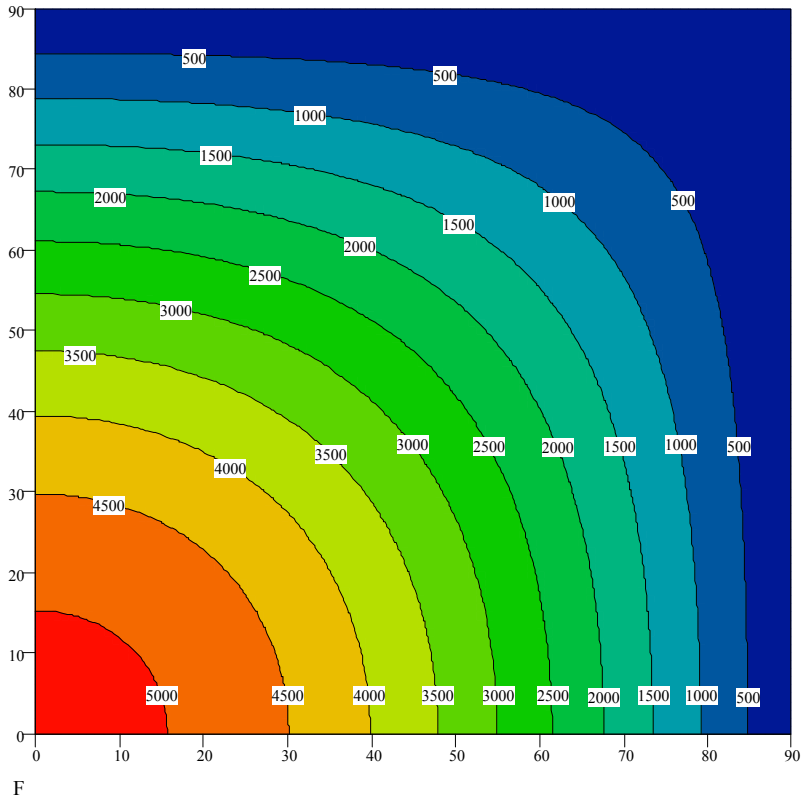
STK for Mission Planning

Mission Planning Tool

- Inter-satellite Separation Analysis
  - Identification of the best velocity and angles of separation
  - Cross-track drift analysis
- Solar Panel Power Analysis
  - Best and Worst power scenarios for stowed and deployed cases
  - FF Control Analysis
  - Maneuver analysis

Inter-Satellite Separation Analysis

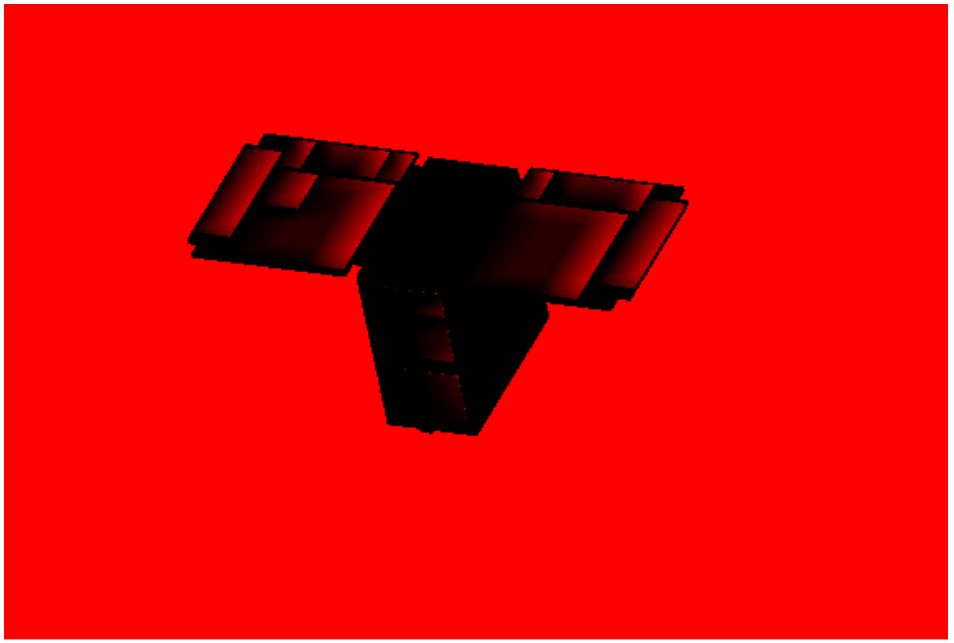
- Goal is to identify the best scenario that would reduce the along-track, radial and cross-track drifts
- Analysis shows that an almost cross-track separation (Azimuth = 80 deg) with a separation velocity of 0.01 m/sec would satisfy the requirements



Inter-satellite separation

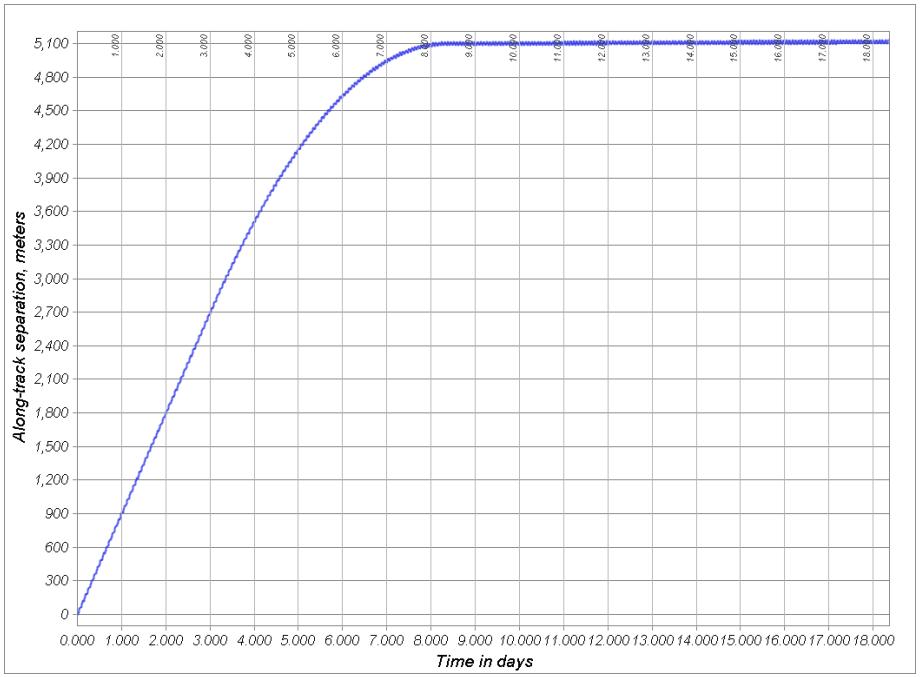
Power Analysis

- Worst case power analysis for the stowed and the deployed cases using the real model
- Identification of the best attitude for power generation after deployment from the launch vehicle



FF Control Analysis

- Simple closed loop control possible with STK with the help of online functions in Astrogator
- Difficult to simulate closed loop control for formation flight with Astrogator due to the lack of a channel for exchanging control input during propagation



Conclusions

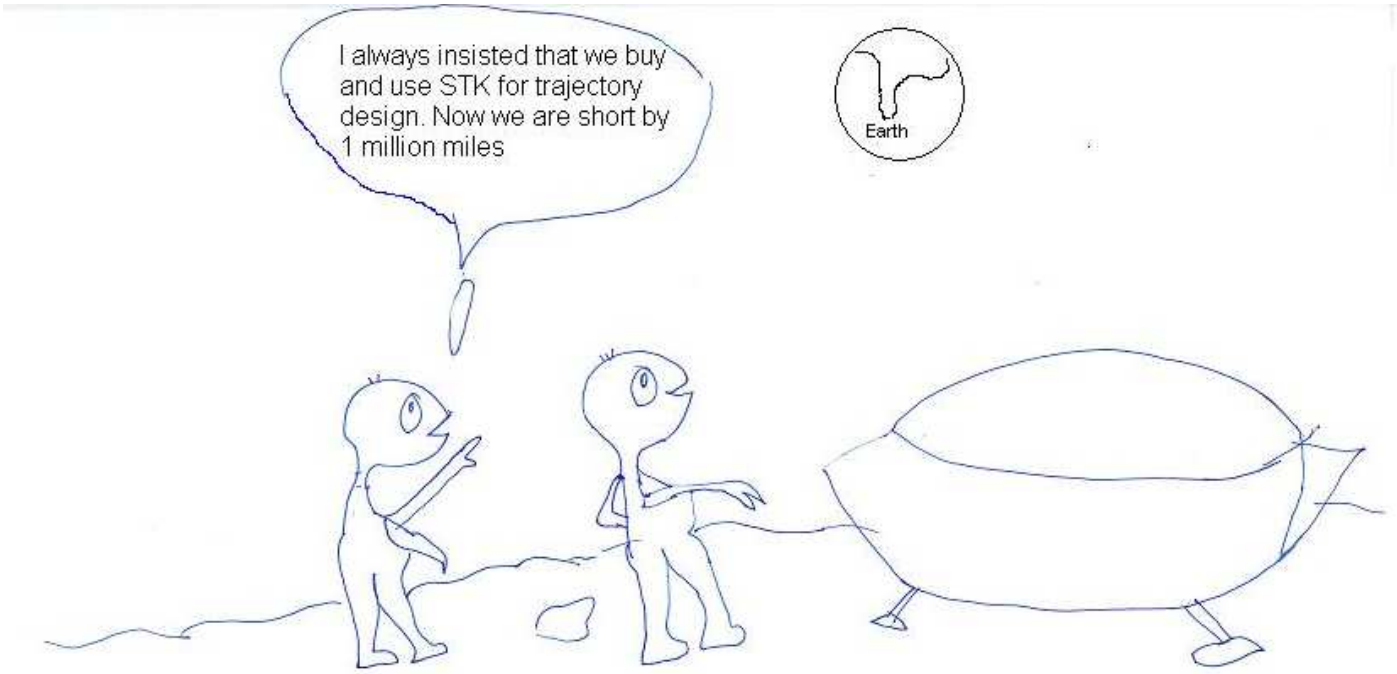
- STK plays a critical role in every phase of the JC2Sat-FF mission.
- The ability to interface with Matlab expands the capability of STK.

Why Choose STK?

Quick results in the form of graphs and reports

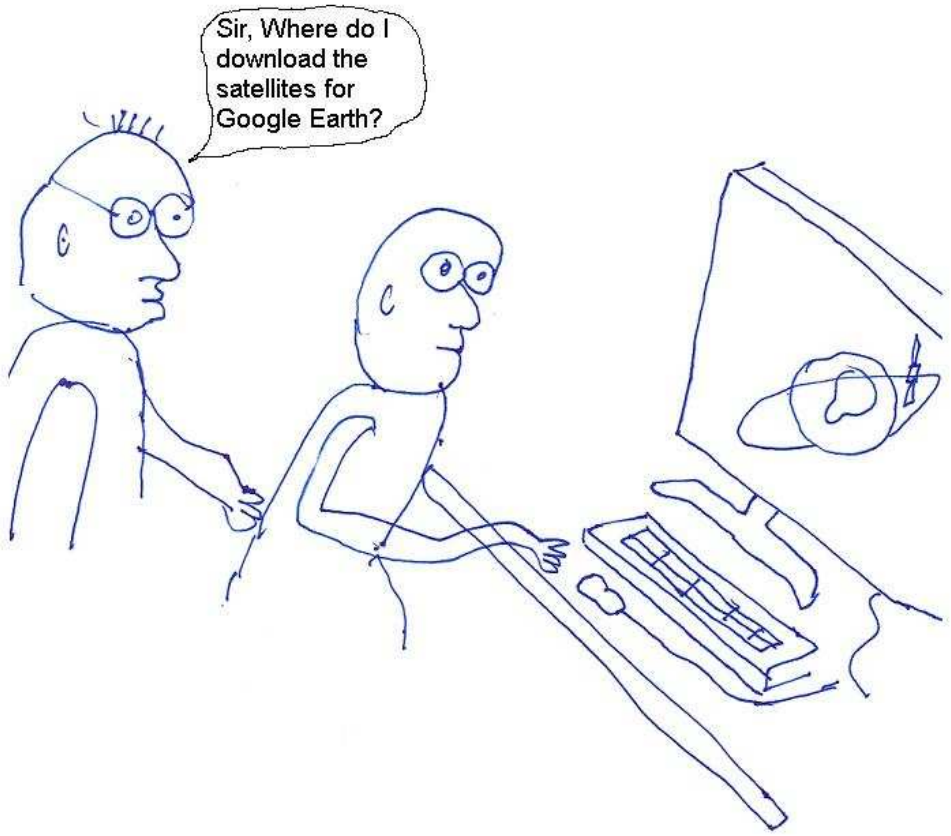
Why Choose STK?

Ability to easily control accuracy of numerical propagation and get precise results



Why Choose STK?

Best of all, It is fun to use….



Acknowledgement

- We rely a lot on the technical support at AGI
- Their expertise and helpfulness are superb

Questions & Comments