2017 Small Satellite Conference

Operating Small Sat Swarms as a Single Entity: Introducing SODA

August 8, 2017

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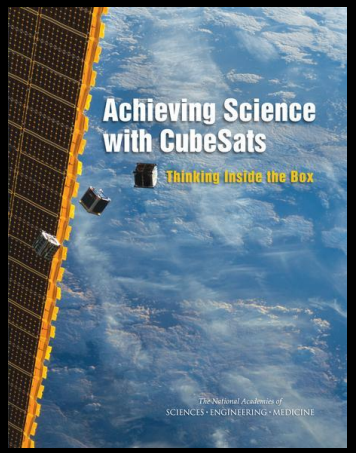
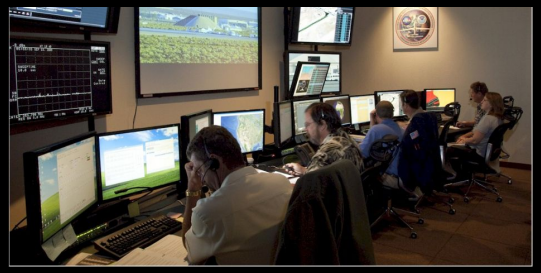
Motivation

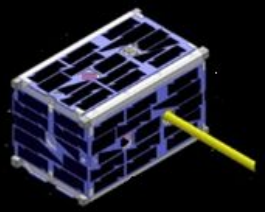
- Future space physics and Earth science investigations demand simultaneous measurements from a 3D volume of space.
- There is significant opportunity for distributed, autonomous small satellite mission concepts to provide new capabilities in observing space weather.
- However, current mission operations for planning and commanding individual satellites do not scale to systems of many cooperating satellites functioning as a swarm.



Committee on Achieving Science Goals with CubeSats; Space Studies Board; Division on Engineering and Physical Sciences; National Academies of Sciences, Engineering, and Medicine, 2016, Committee Chair: Thomas Zurbuchen

Current Ground Ops Do Not Scale





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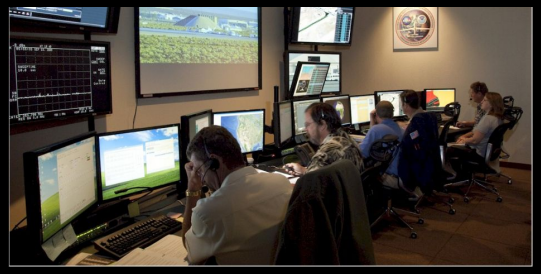

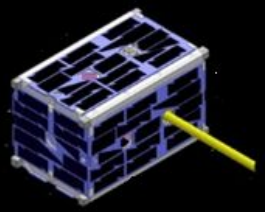

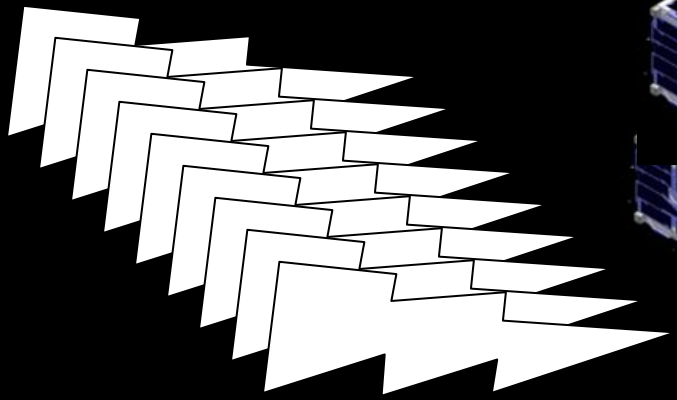

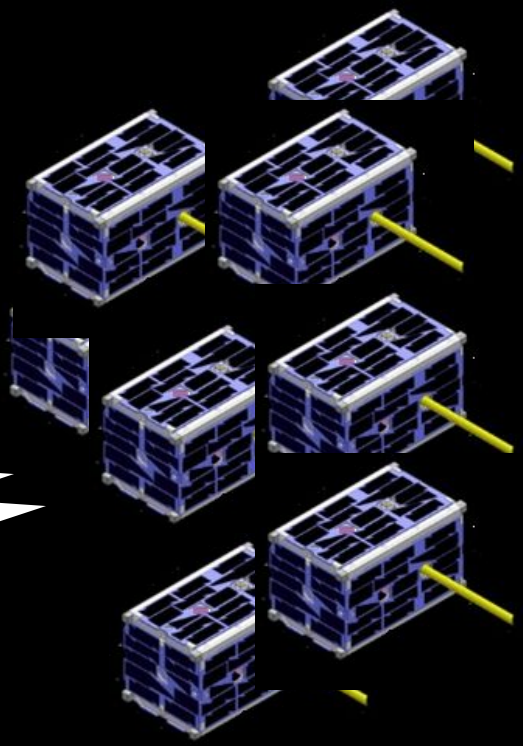

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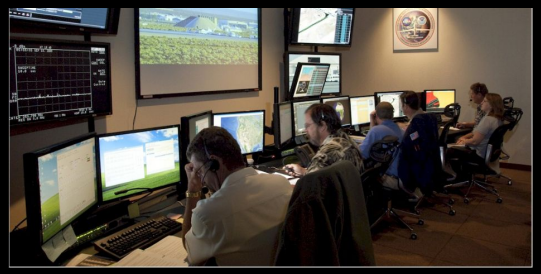
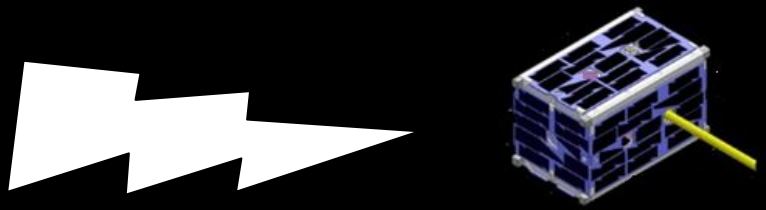
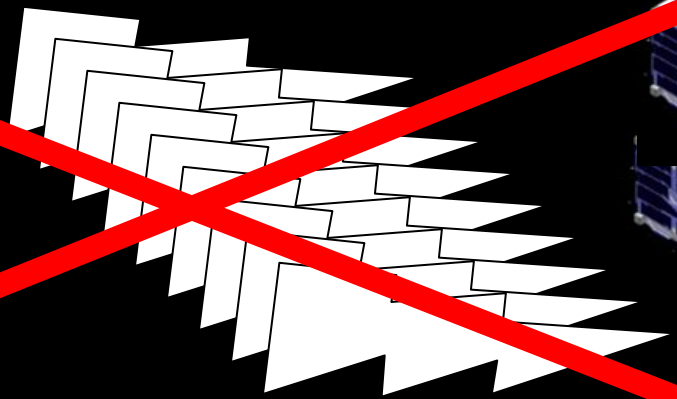
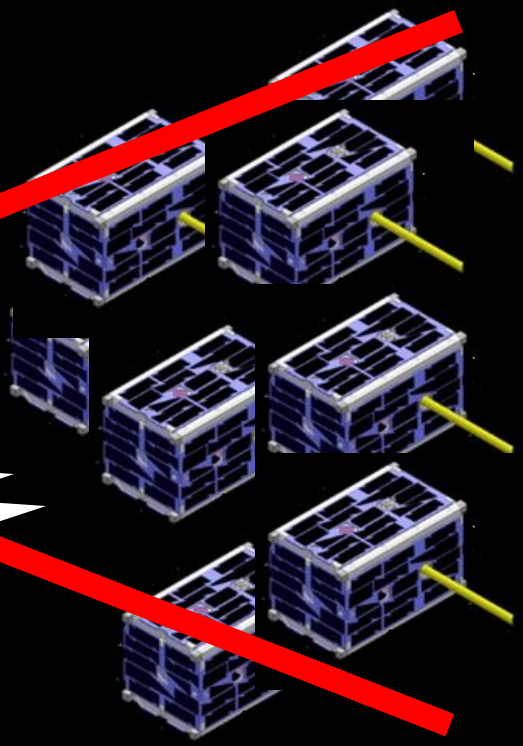






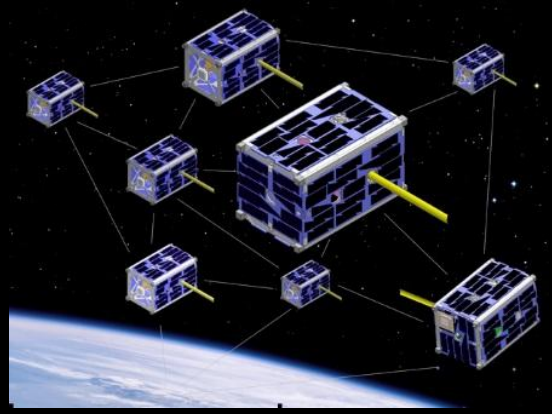


SODA: Swarm Orbital Dynamics Advisor

- To address the challenge of scalable control of a distributed spacecraft swarm mission, we introduce SODA.
- SODA will prescribe maneuvers, enabling swarm autonomy:
  - Input: high-level operator commands
  - Output: Δv for each individual satellite
- Currently, SODA is a design and simulation tool for swarm missions.
  - SODA shines a light on many aspects of swarm design that differ from traditional missions: con ops, spacecraft capabilities, inter-sat communication and cooperation, deployment strategies, etc.
- Ultimately, SODA will be expanded into flight operations.

High Level Operations Concept

SODA

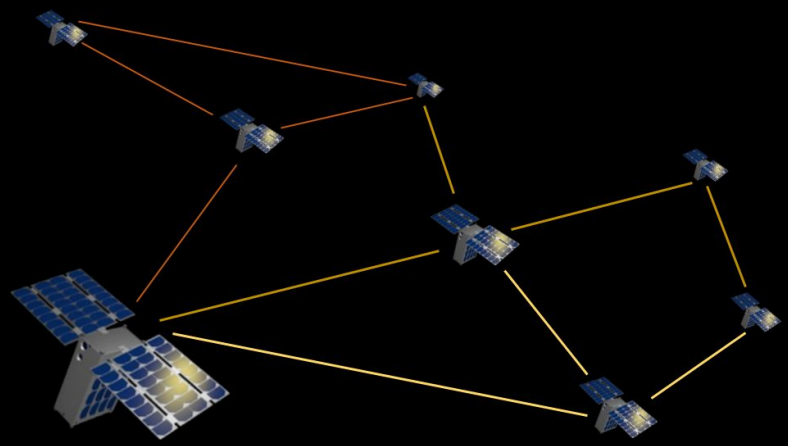


Operator issues high level commands to the swarm as a collective

SODA prescribes maneuvers for each satellite

Spacecraft execute maneuvers and swarm type is achieved

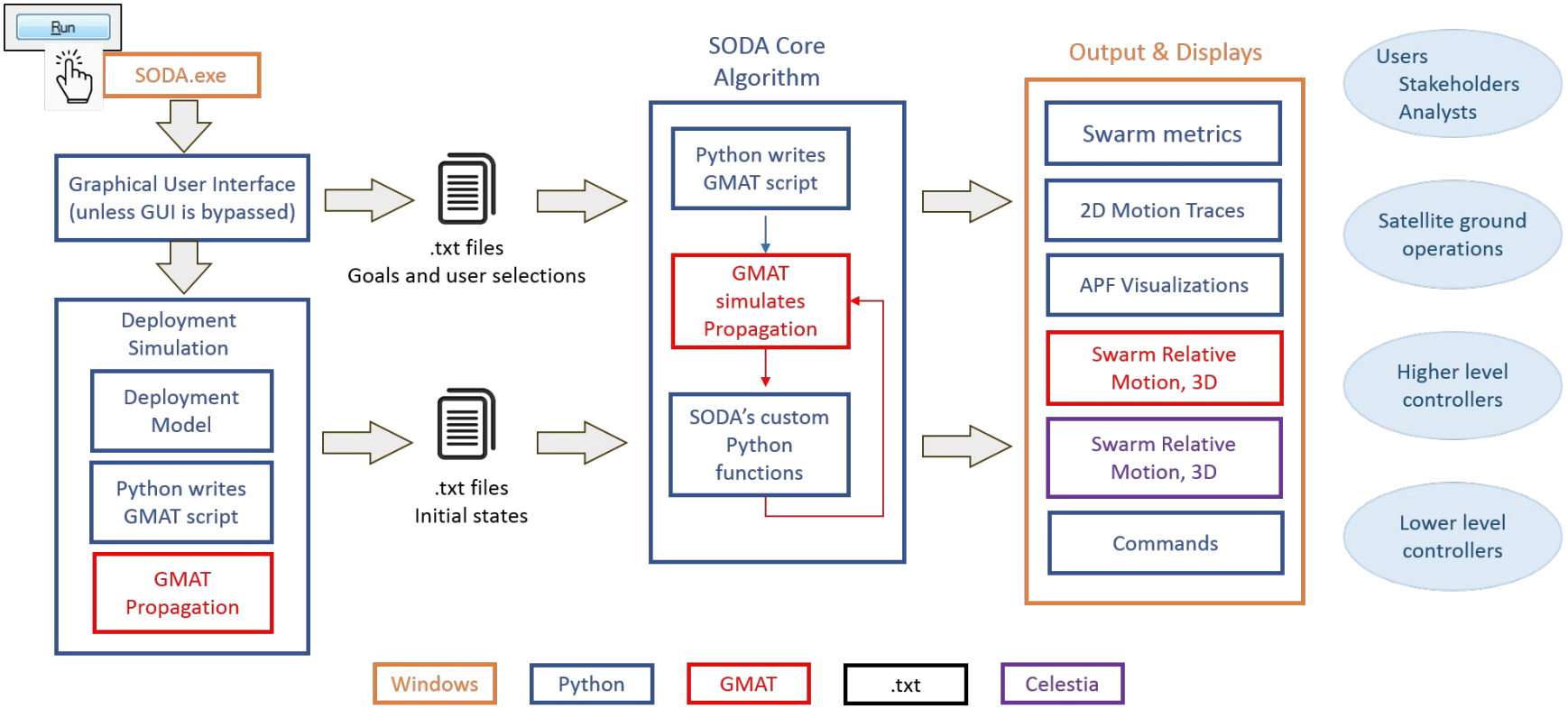
Constellation vs. Swarm



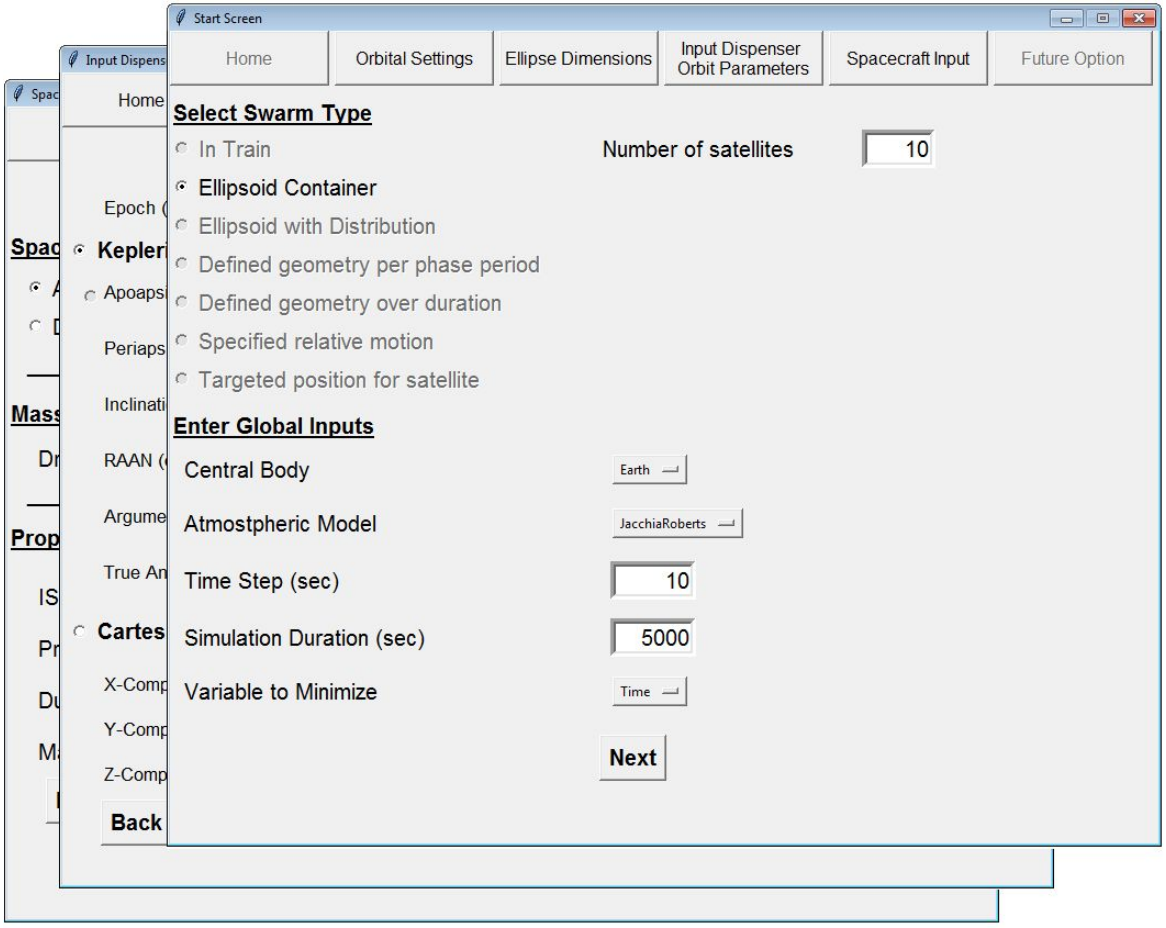
- Objective is typically ground coverage
- Satellites distributed across orbit(s)
- Examples: GPS, Galileo, GLONASS, Planet Lab's Doves, Iridium

- Multiple sats in about the same orbit
- Autonomously maintain a particular geometry, alignment, or separation
- Cross-link capability
- Cooperative system

SODA Architecture



SODA GUI


Start Screen
Home
Orbital Settings
Ellipse Dimensions
Input Dispenser Orbit Parameters
Spacecraft Input
Future Option
Select Swarm Type
In Train
Ellipsoid Container
Ellipsoid with Distribution
Defined geometry per phase period
Defined geometry over duration
Specified relative motion
Targeted position for satellite
Number of satellites
10
Enter Global Inputs
Central Body
Earth
Atmostpheric Model
JacchiaRoberts
Time Step (sec)
10
Simulation Duration (sec)
5000
Variable to Minimize
Time
Next
Input Dispens
Home
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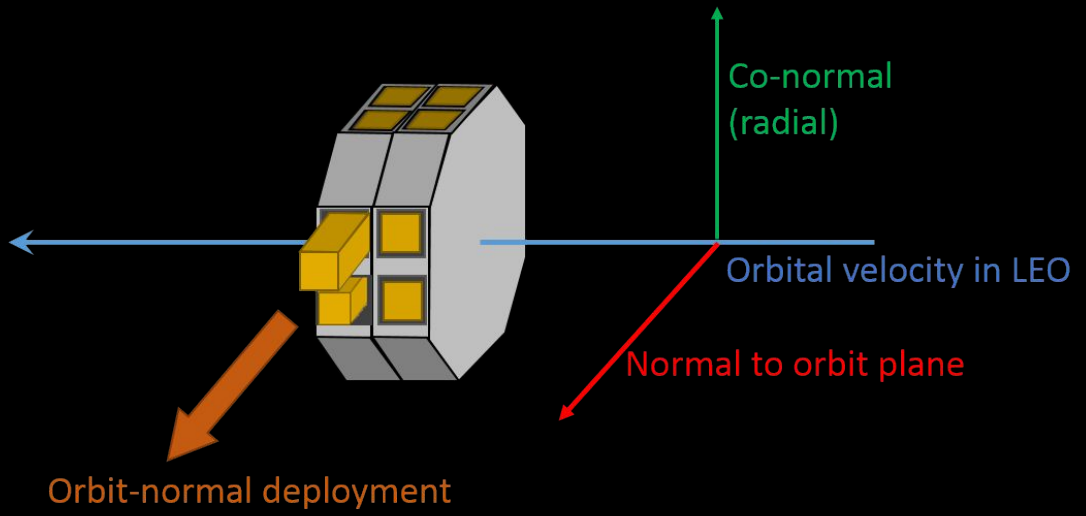
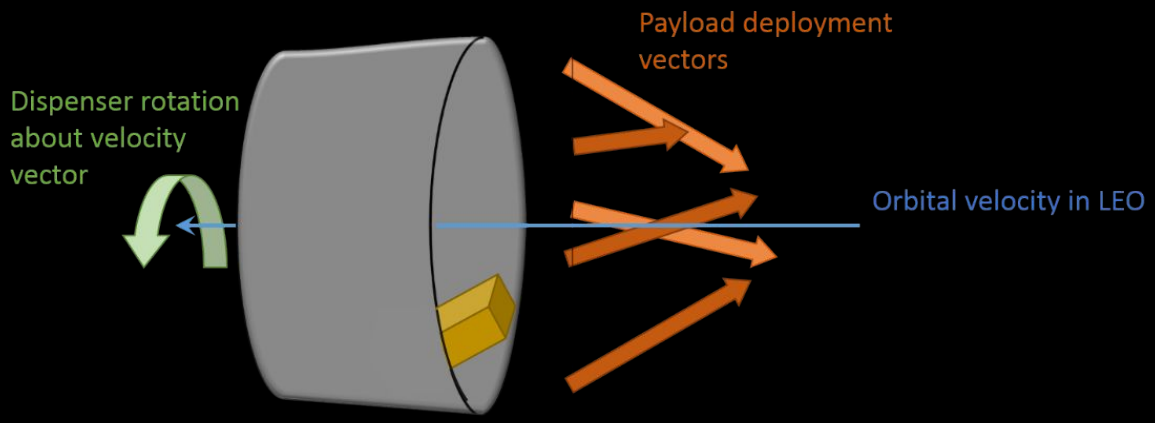
Cartes
X-Comp
Y-Comp
Z-Comp
Back

Simulated Dispenser Methods



VNC Directional

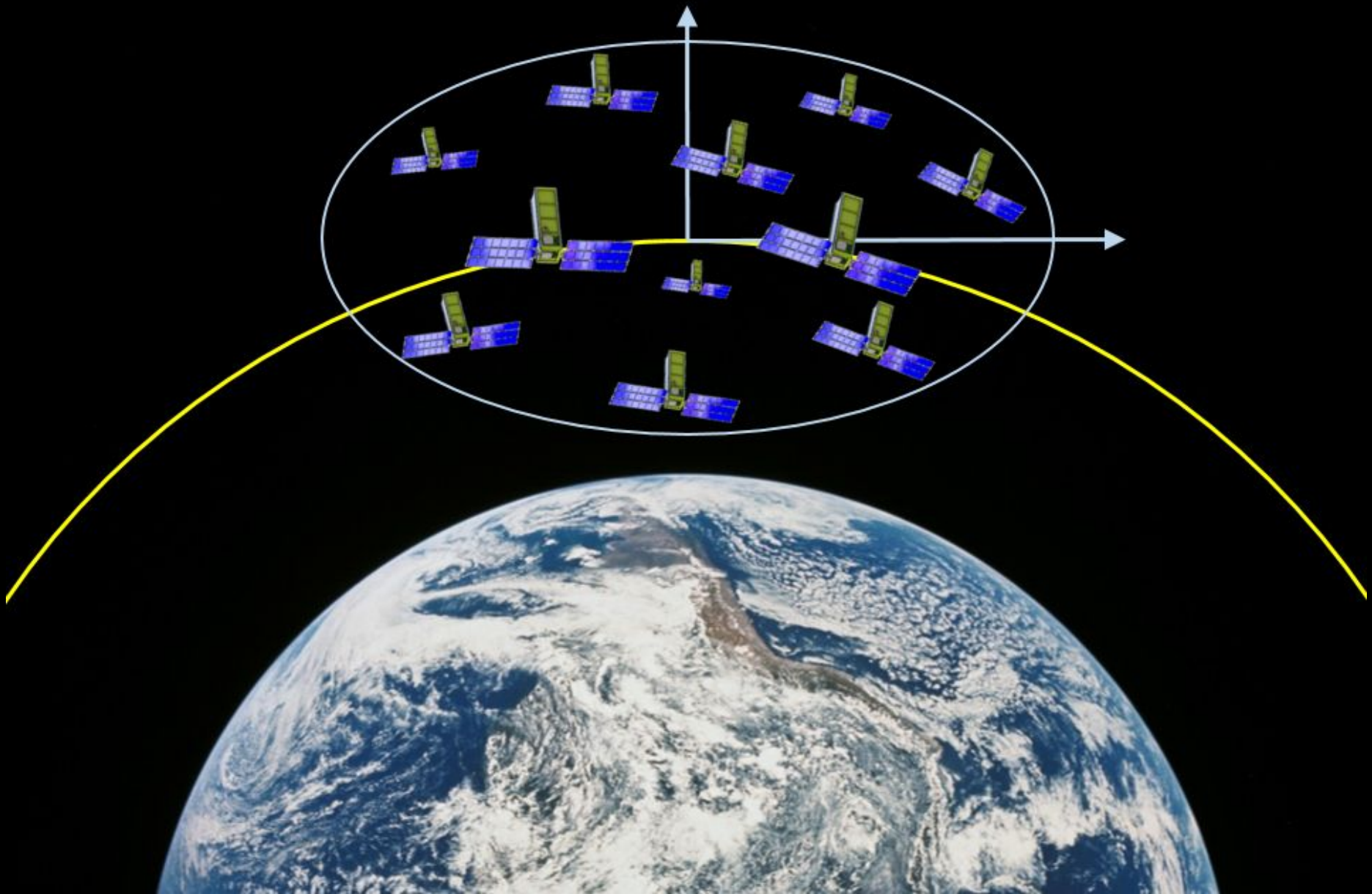


Rotating Dispenser

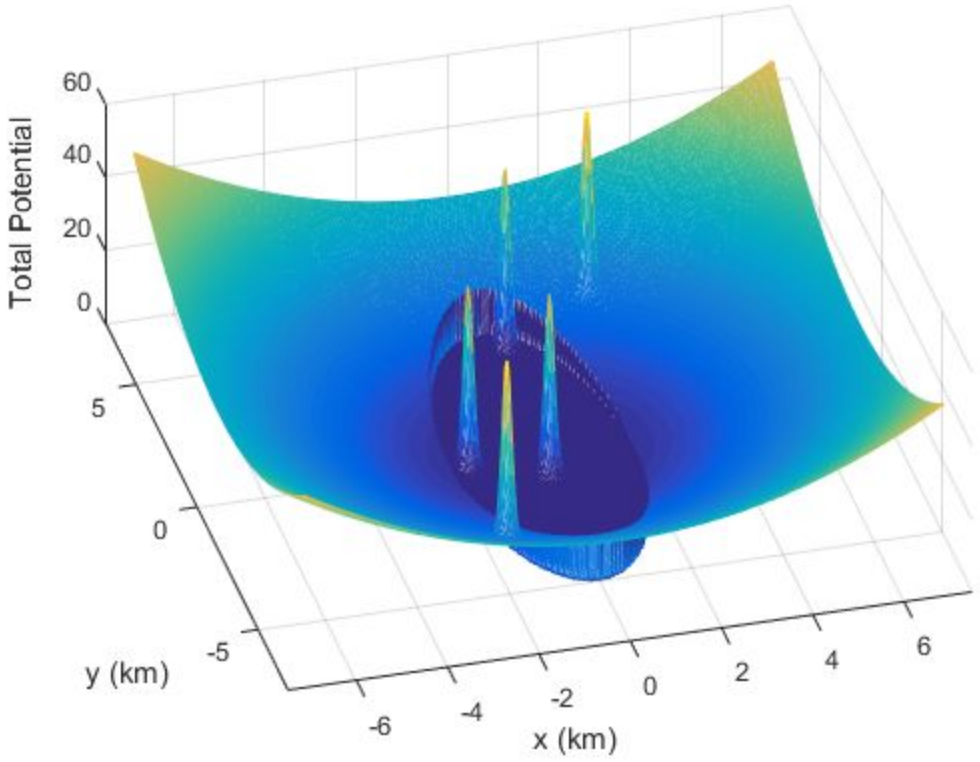
In-Train Swarm Type

placeholder for embedded video:
https://images.nasa.gov/#/details-in_train_swarm_example1.html

Ellipsoid Container Swarm Type



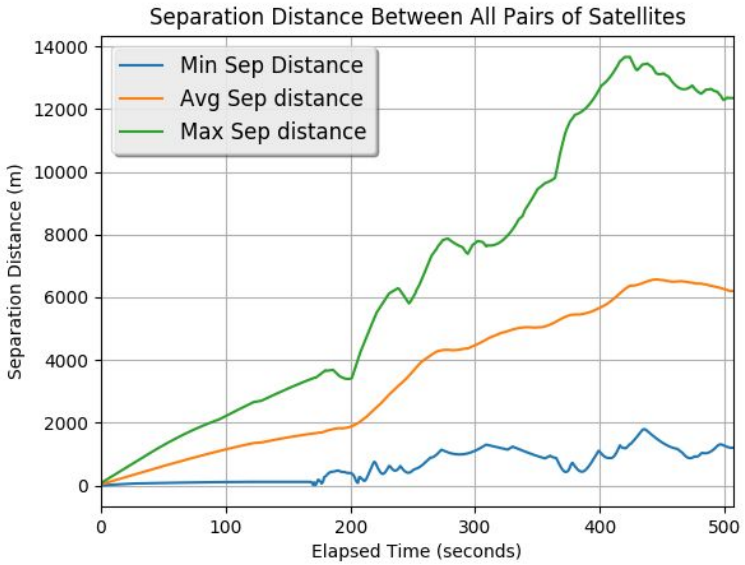
Artificial Potential Functions

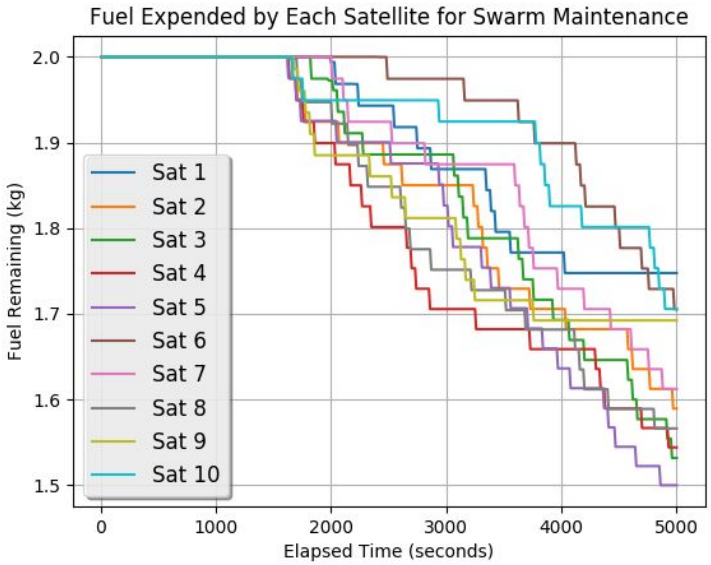


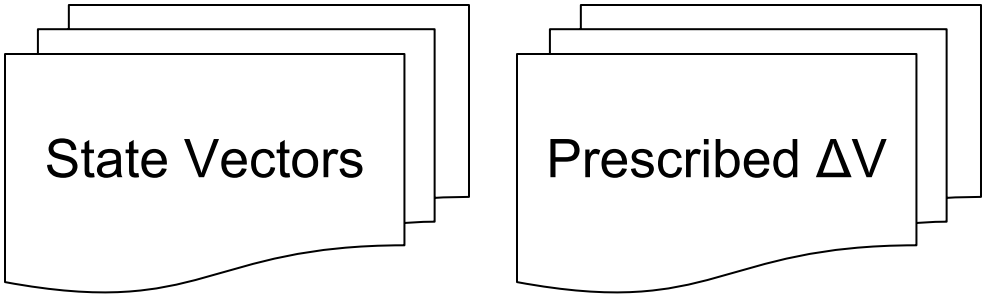
Swarm Example: 10 Satellites

placeholder for embedded video:
https://images.nasa.gov/#/details-ellipsoid_container_swarm_example2.html

SODA: Data Products







Future Goals for SODA

- Additional swarm formation types
  - Motivated by science goals
- Electric, low-thrust models
- Various measurement sources (GPS, angles-only navigation, etc.)
- Prognostics models → Autonomous response to subsystem failures
- Swarm design trade space studies
- Open source

Thanks for your attention!

Come see us at the NASA Ames booth!

For more info: arc-soda@mail.nasa.gov