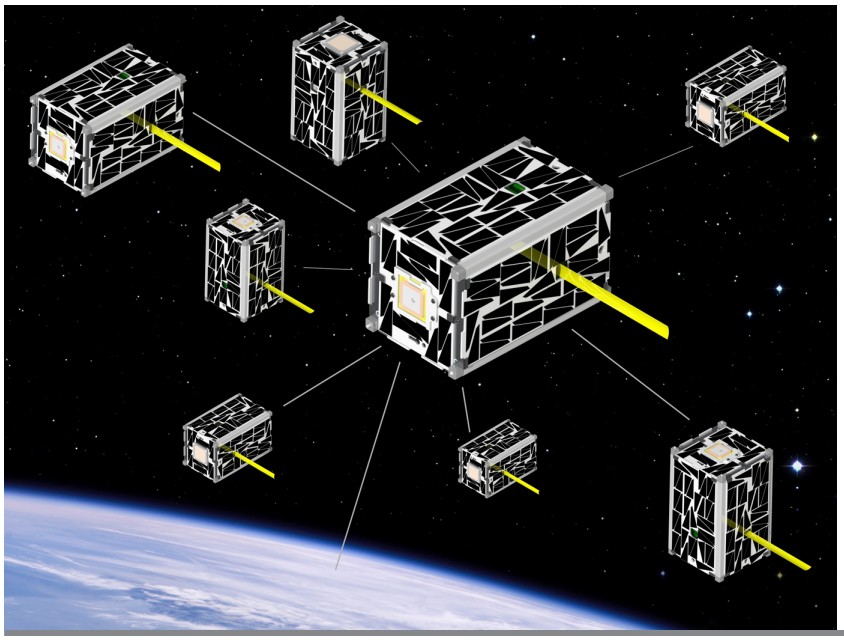


National Aeronautics and Space Administration

NASA

TECHNOLOGY SOLUTION

Aerospace

# Modelling and Analyzing Inter-Satellite Relative Motion

PATENT ONLY. NO SOFTWARE AVAILABLE.

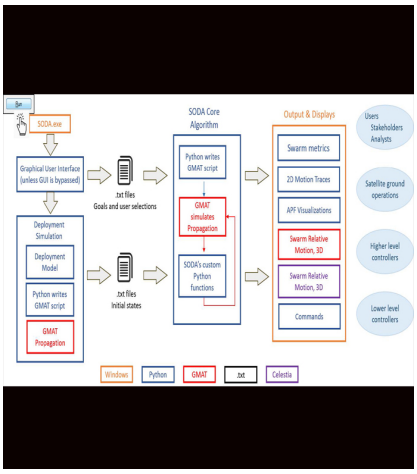
Swarm concepts—multiple satellites flying in formation near one another in similar orbits—are of growing interest in the small satellite community. The capabilities needed to support swarm missions go beyond operator-specified geometry, alignment, or separation, but also cross-link communication with maintaining position in the formation. Swarm station-keeping poses a planning challenge due to the limited scalability of ground resources. To address scalable control of orbital dynamics, NASA Ames has patented SODA – Swarm Orbital Dynamics Advisor – a solution that accepts high-level configuration commands and provides the orbital maneuvers needed to achieve the desired type of swarm relative motion. Rather than conventional path planning, SODA's innovation is the use of artificial potential functions to define boundaries and keep-out regions.

## BENEFITS

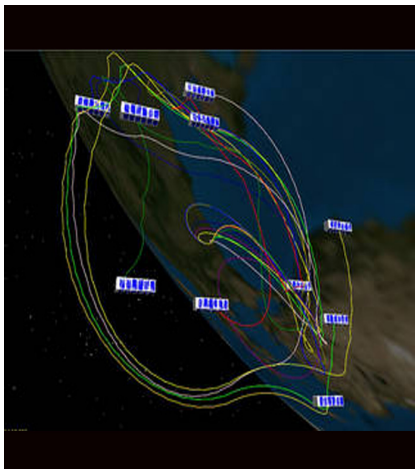
- Allows satellite swarms to be controlled by one high level command
- Compatibility with a wide variety of visualization tools
- Useful for multiple swarm types, including in-train distribution and an ellipsoid volume container
- Multiple interfaces for use: graphical user interface for small analyses or developing customer awareness, text files for "hands-off" applications such as Monte Carlo analyses, and a defined software interface for future integration with higher- and lower-level users/controllers
- Swarm deployment and controller design becomes an exercise in simultaneously containing the satellites, thereby decreasing the risk of collision

## THE TECHNOLOGY

Swarms of large numbers of cooperating satellites will introduce new space mission capabilities and complexities. From a mission operations perspective, swarms pose a planning challenge due to the limited scalability of ground operations. The approach of planning and commanding individual satellites simply does not scale for multi-sat swarms of tens or hundreds. If the current state-of-practice continues to be applied, operation of large swarms (e.g., 100 spacecraft or more) will become intractable and cost prohibitive. To avoid this operations bottleneck, a new approach
is required: the swarm must operate as a unit, responding to high level commands and constraints. Swarm Orbital Dynamics Advisor (SODA) enables high level user inputs in a single planning cycle. From one high level command, SODA determines all of the required individual satellite maneuvers over time, relieving ground personnel of the tasks of designing and commanding the placement of the swarm members. SODA provides the orbital maneuvers required to achieve a desired type of relative swarm motion. The purpose of SODA is two-fold. First, it encompasses the algorithms and orbital dynamics model to enable the desired relative motion of the swarm satellites. Second, SODA is compatible with a variety of visualization tools. The purpose of SODA's visualization element is to illustrate this concept clearly with a variety of graphics and animations. After computing the optimal orbital maneuvers to modify the swarm, these results are simulated to demonstrate successful swarm control.




The different functions of SODA are implementable via GUI scripts, custom Python functions, and the applications GMAT and Celestia



Snapshot of a 10-satellite swarm simulation using the SODA tool

## APPLICATIONS

The technology has several potential applications:

- Satellite industry
- Swarm missions
- Interferometric synthetic aperture radar (InSAR) monitoring
- Ground-based laser communications to a chief satellites that can be calibrated with the assistance of atmospheric probe lasers from deputy satellites to reduce power loss
- Rapid stereographic imaging and other sparse antenna array applications

## PUBLICATIONS

Patent No: 11,091,280

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https://www.nasa.gov/feature/swarmsoda/

https://images.nasa.gov/details-ellipsoid_container_swarm_example2.html

https://images.nasa.gov/details-in_train_swarm_example1.html

https://ntrs.nasa.gov/citations/20170011298

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