A General-Purpose Multi-body, Multi-spacecraft Simulation Tool

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Code 591

Summary

- 42 is a comprehensive general-purpose simulation of spacecraft attitude and orbit dynamics.
- Its primary purpose is to support design and validation of attitude control systems, from concept studies through integration and test.
- 42 accurately models multi-body spacecraft attitude dynamics (with rigid and/or flexible bodies), and both two-body and three-body orbital flight regimes, modelling environments from low Earth orbit throughout the solar system.
- 42 simulates multiple spacecraft concurrently, facilitating studies of rendezvous, proximity operations, and precision formation flying.
- 42 features visualization of spacecraft attitude.

Features

- Multi-body dynamics (tree topology, rotational and/or translational joints)
- Rigid and/or flexible bodies
- Multiple spacecraft (prox ops, formation flying, or independent)
- Inter-spacecraft and spacecraft-surface contact forces support landers, rovers, and spacecraft servicing scenarios
- Two-body or three-body orbits, anywhere in the solar system
- Optional visualization
- Socket-based interprocess comm (IPC) interface to other apps
- Fast setup for concept studies
- Rigorous and full-featured to support full spacecraft life cycle

42 Supports Distributed Systems

- Multiple spacecraft modeled concurrently
  - Example: 31-spacecraft formation simulated for Stellar Imager Study (2005)
- Inter-spacecraft contact forces support docking, servicing scenarios
- Common reference orbit preserves numerical accuracy
  - Example: Sub-nanometer accuracy over 10-km formation for Stellar Imager Study

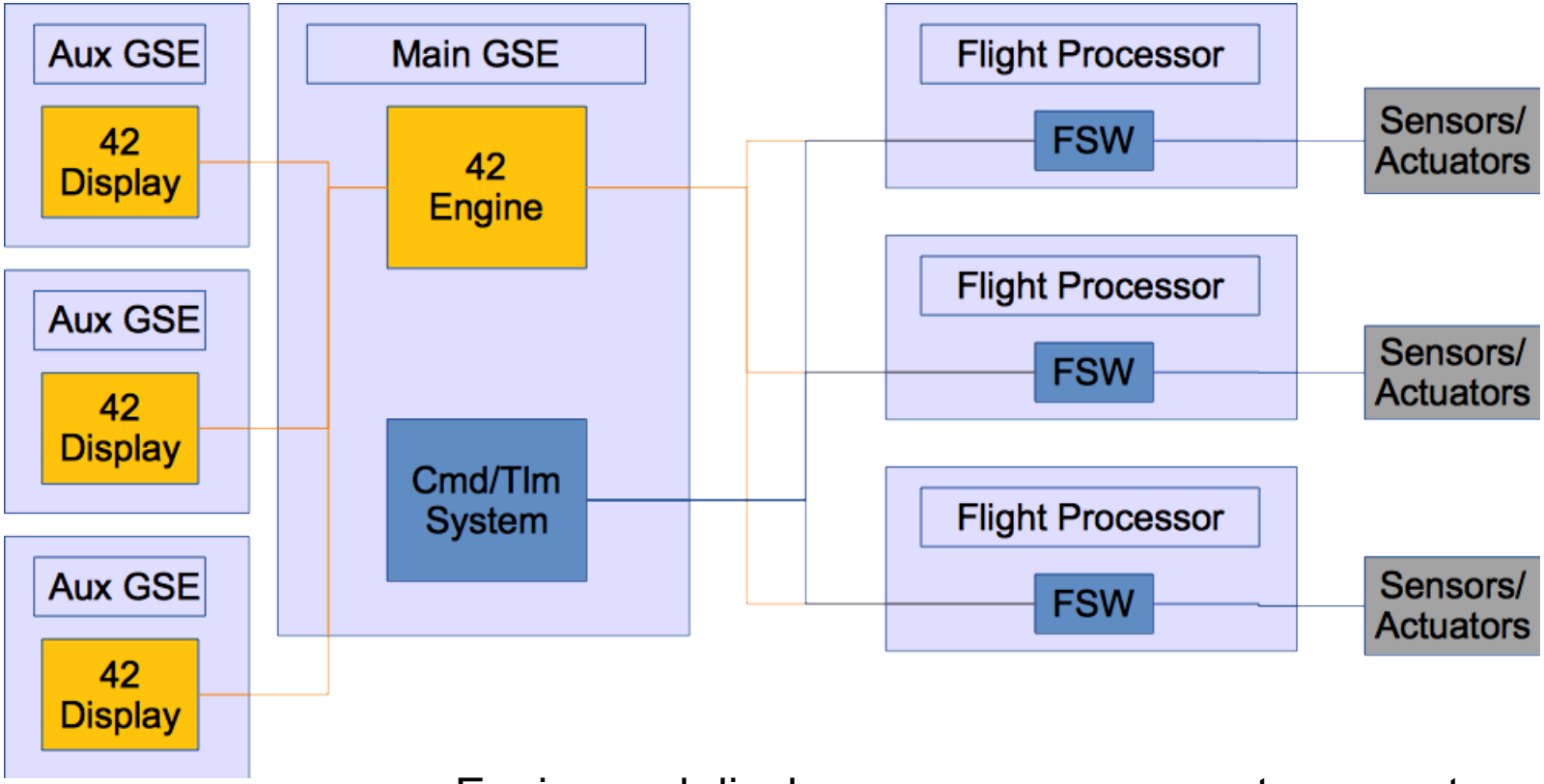
42 Supports ACS Design in All Phases

- Intended for use from concept studies through ops
  - Rapid prototyping makes it useful for MDL studies
  - Environment models support actuator sizing, performance studies
  - High-fidelity dynamics handle multi-body, flexible-body spacecraft
  - Portability (Mac, linux, Windows) minimizes infrastructure requirements
  - Clean interface aids progression from flight software "model" to dropping in actual flight software
    - Interfaces to cFS are under discussion
  - Visualization aids situational awareness from concept to operations
- Designed to be powerful, but easy to get started

42 is Open Source, Portable, Integrable

- Released under NOSA in March 2015
  - sourceforge.net/projects/fortytwospacecraftsimulation
  - Github/ericstoneking/42
- Runs on Mac, linux, Windows
- 42 is a command-line program
  - Can be called from other processes (incl. Matlab, python, perl)
- Sockets enable Inter-Process Comm
  - One application runs concurrently with commercial CFD software
  - Dynamics engine and visualization front end can run as separate processes on separate computers

42 as a Multi-spacecraft HWIL Sim



- Engine and displays can run on separate computers
  - Communication by sockets
- Engine interfaces with flight processors via cFS over serial port
  - (ref Cubesat IRAD, Dellingr)

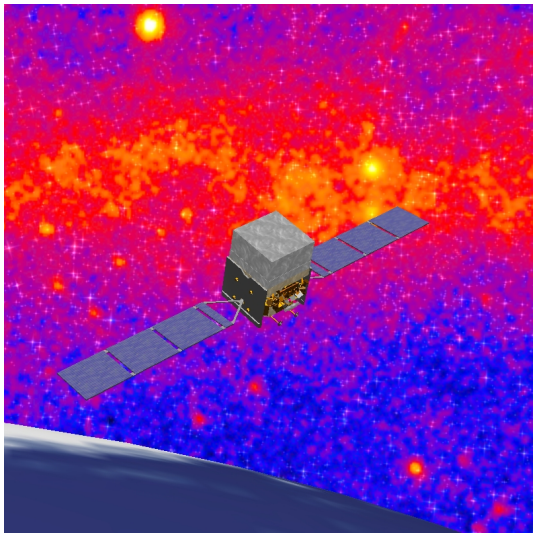
42 Features a Fleshed-out Solar System

- Multiple spacecraft, anywhere in the solar system
- Flight regimes include two-body, three-body orbit dynamics, planetary surfaces, comet/asteroid prox ops
- One sun, nine planets, 45 major moons
  - Minor bodies (comets and asteroids) added as needed

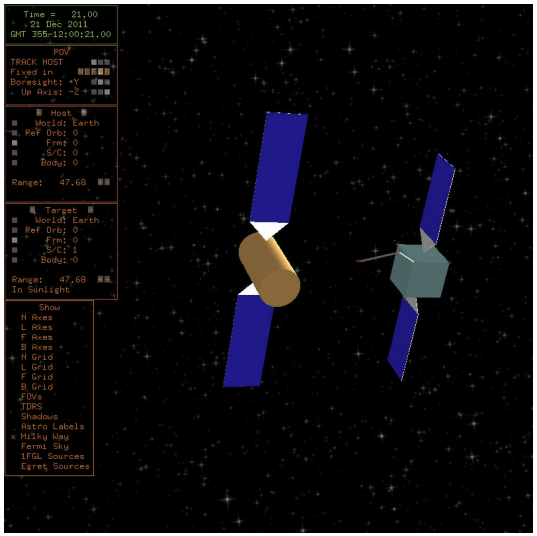
42 Dynamics Formulation Preserves Accuracy

- Multiple spacecraft may share a reference orbit for formation flying, prox ops
  - Enables nanometer accuracy with km-scale formations
- Kane's dynamics are efficient, avoid numerical issues that drive performance of Differential-Algebraic-Equation (DAE) formulations
- Multiple bodies, each rigid or flexible
- Joints support rotation, translation degrees of freedom

Screenshots

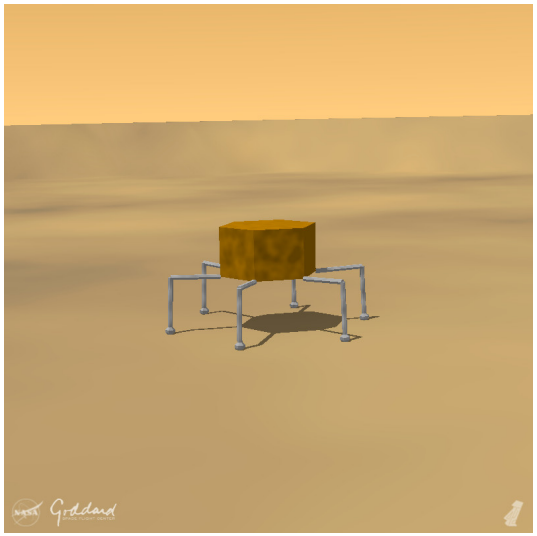


Fermi Gamma-ray Space Telescope. Gamma-ray sky derived from FGST survey data.



Conceptual rendezvous and capture scenario

Conceptual spacecraft in orbit about Comet 67P-CG



Conceptual hexapod rover on the surface of Mars