Implementing the Comprehensive Open-architecture Space Mission Operations System (COSMOS) to Operate Multiple CubeSats

Trevor C. Sorensen, Eric J. Pilger, Mark S. Wood, Miguel A. Nunes

Hawaii Space Flight Laboratory

University of Hawaii at Manoa

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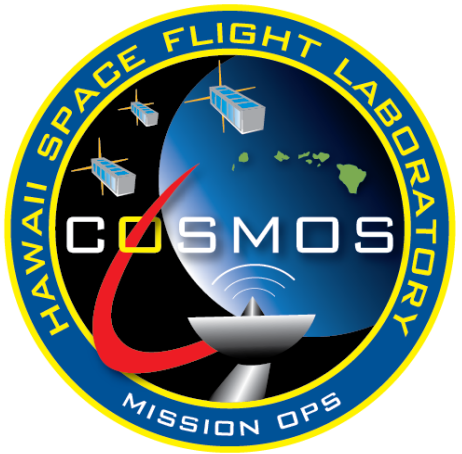


HAWAII SPACE FLIGHT LABORATORY

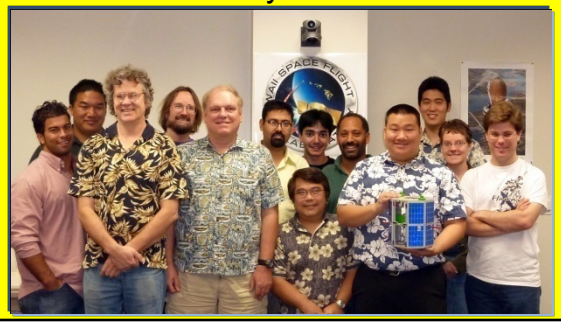
The mission of HSFL is to:

- promote innovative engineering and science research for terrestrial and planetary space missions
- develop, launch, and operate small spacecraft from the Hawaiian Islands to accelerate the validation of new space technologies
- provide workforce training in all aspects of unmanned space missions
- promote synergistic collaborations between educational, governmental, and corporate institutions interested in space exploration

Major Project Elements

Spacecraft

• Partner with NASA Centers and others to advance small spacecraft design.
•Design, build, launch, and operate 60-80-kg small satellite for science and education tasks.
•Support technology validation missions as well as other University missions.



Integration and Test

• Clean rooms in UH/POST will be used to assemble satellites.
–Systems integration
–Thermo-vac testing
–Vibration/shock testing
–Payload spin balancing

Instruments

•The HSFL can call on a diverse group of instrument-developing faculty from HIGP and SOEST.

•A number of businesses in Hawaii also develop a wide array of instrumentation. The HSFL will partner with these organizations to provide technology demonstration opportunities.

•NASA Centers (Ames and JPL) are interested in joint technology missions.

Launch Vehicle and Launch Support

• **Pacific Missile Range Facility (PMRF)**
•Local launch facility and mission support
•Modify existing PMRF launch pad for rail-fitted and modified VAFB Scout launcher.

• **Kauai Test Facility (KTF)/ Sandia National Lab**
•Experience with solid rockets and missile design. Use Super-Strypi launch vehicle.
•Can lift ~270 kg (594 pounds) to low-Earth orbit (400 km).
•Heritage working with PMRF as on-site vehicle integrator and launch agent.

Ground Station & Mission Operations

•UH/HSFL maintains UHF/VHF receiving stations with Kauai CC and Honolulu CC staff.
•Ground station provides command and control broadcast as well as data downlink capabilities.
•Mission Ops Center on POST 5th floor under development with UH support.

COSMOS Purpose

Comprehensive Open-architecture Space Mission Operations System (COSMOS)*

- Purpose:

  To develop a comprehensive open system of software and hardware tools that supports the design, testing, and operations of one or more spacecraft and is easily adaptable for adding spacecraft and porting to Mission Operations Centers (MOCs) at HSFL, NASA Ames Research Center, and other MOCs.

  – *COSMOS is being developed as a collaboration between HSFL and NASA Ames Research Center under a 3-year NASA EPSCoR grant (2010-2013).*

* Note: COSMOS is being renamed to:
Comprehensive Open-architecture Software for Mission Operations Systems

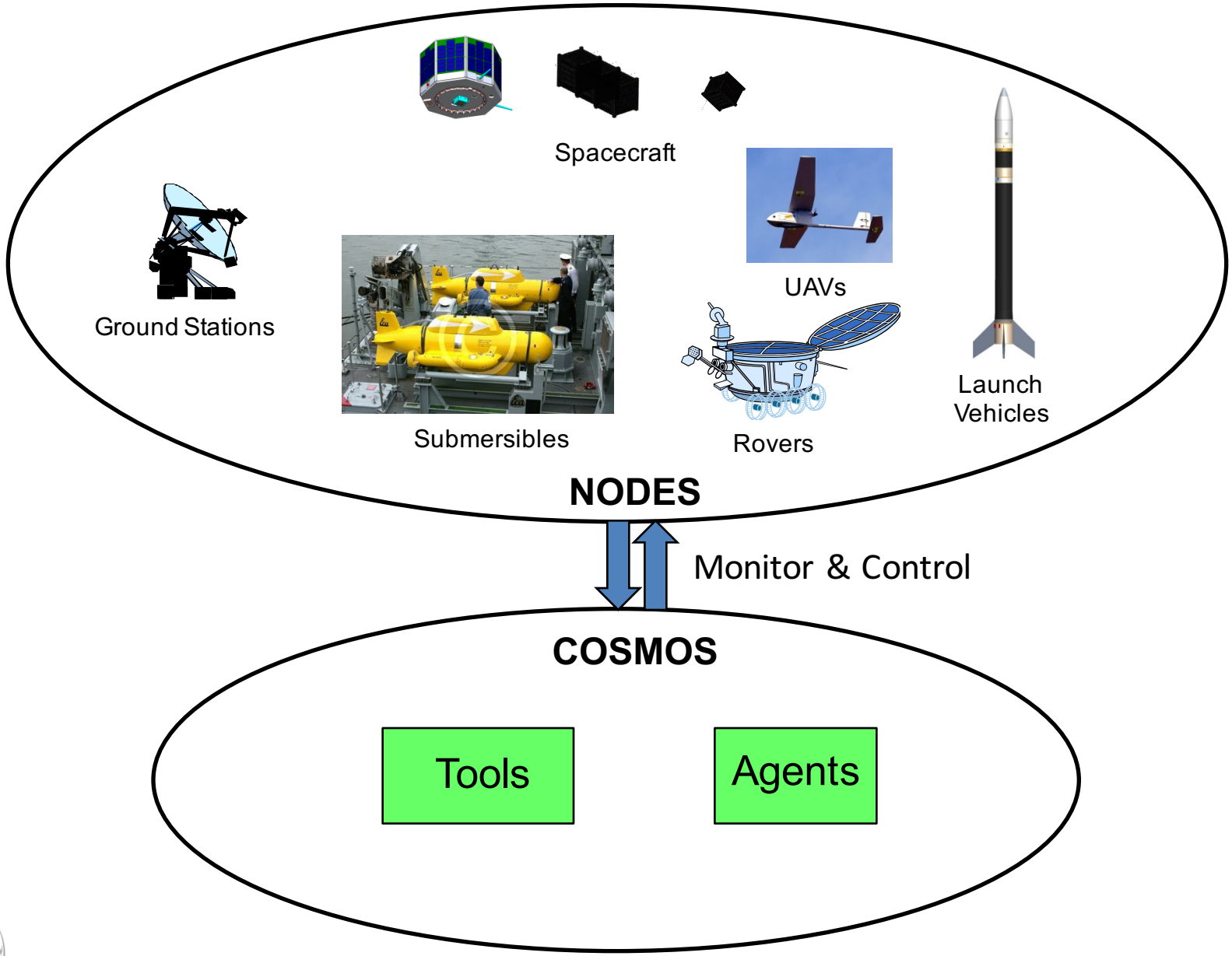
COSMOS Architecture - Background

- Explosive growth in “micro” and “nano” satellites.
- Industry need for comprehensive operations software toolkit
- Developing hardware concept of “Plug-n-Play”
- COSMOS combines “Plug-n-Play”, standard interfaces and protocols, and common coding practices
- COSMOS can be used across the spectrum, from conceptual design to mission operations

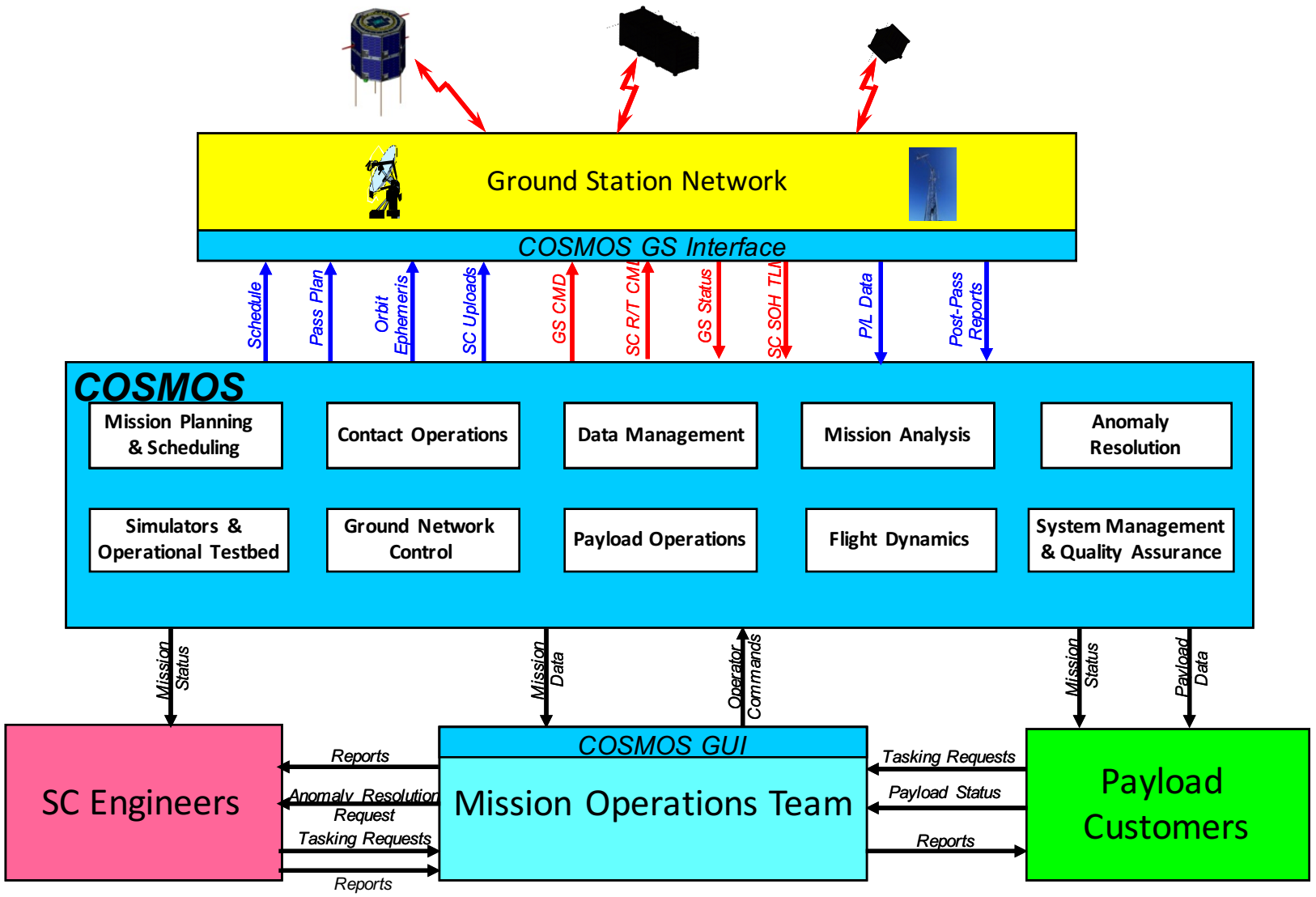
Features of COSMOS

- Set of software and hardware framework to support spacecraft and other vehicle mission operations
- Set of tools:
  - Mission Planning & Scheduling Tool (MPST)
  - Mission Operations Support Tool (MOST)
  - Ground Segment Control Tool (GSCT)
  - Data Management Tool (DMT)
  - Flight Dynamics Tool (FDT)
  - Analysis Tools
  - Test Bed Control Tool (TBCT)
- Open architecture to enable modifications and adaptation to new missions and MOCs
- User-friendly interfaces and short learning curves for users and software integrators
- COSMOS editor
- Uses Qt under LGPL licensing – helps ITAR issues
- Connections for COTS/GOTS and external tools

COSMOS Generalized Architecture



COSMOS Functional Architecture



COSMOS Architecture - Elements

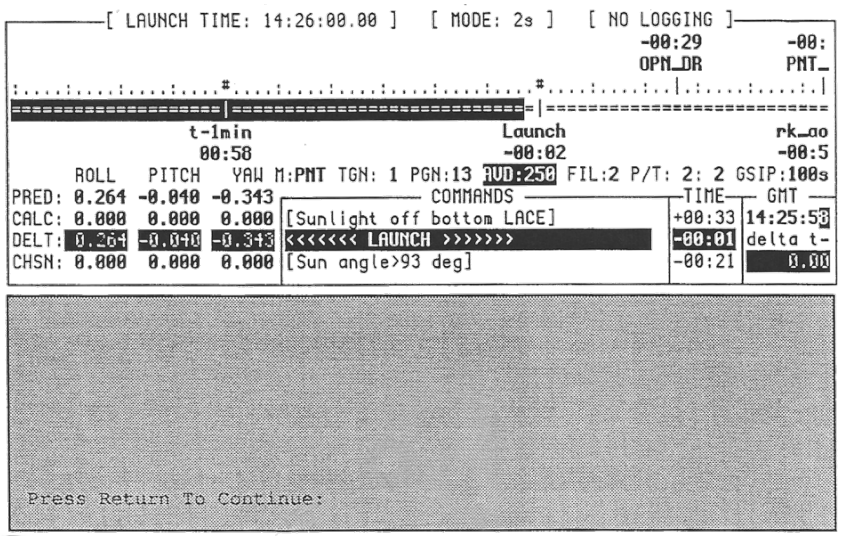
- Standards:
  - Language:
    - Posix compliant C++11
  - O/S:
    - Linux
    - MacOS
    - Windows 7
  - Protocols and Environments:
    - Qt
    - JavaScript Object Notation (JSON)

Mission Operations Support Tool (MOST)

- Primary visualization and commanding tool of COSMOS designed specifically for supporting near-realtime operations.
- MOST functions:
  - Spacecraft/payload monitor and control
  - Mission Planning
  - Simulations and testing
  - Training and rehearsals
  - Trending and analysis
  - Anomaly resolution
- Designed initially to support HSFL's HawaiiSat-1 mission
- Adapted to support missions with multiple elements

MOST Background

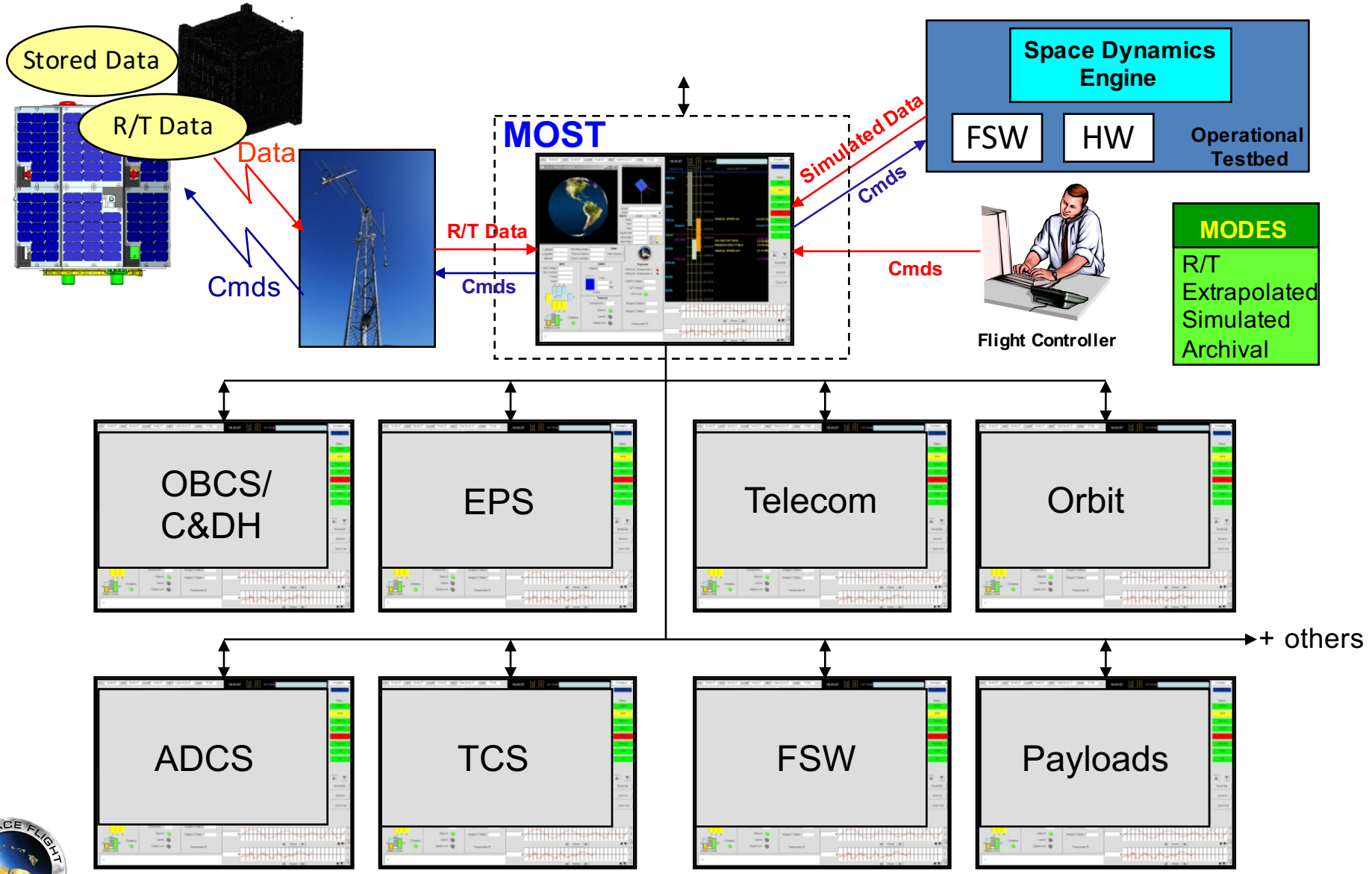
- Based on legacy programs designed by Dr. Sorensen for the Naval Research Laboratory:
  - UltraViolet Plume Instrument (UVPI) Encounter Manager for SDIO/LACE satellite encounter execution (1991)
  - LUNOPS program used to monitor science mission operations during the Clementine lunar mission (1994)



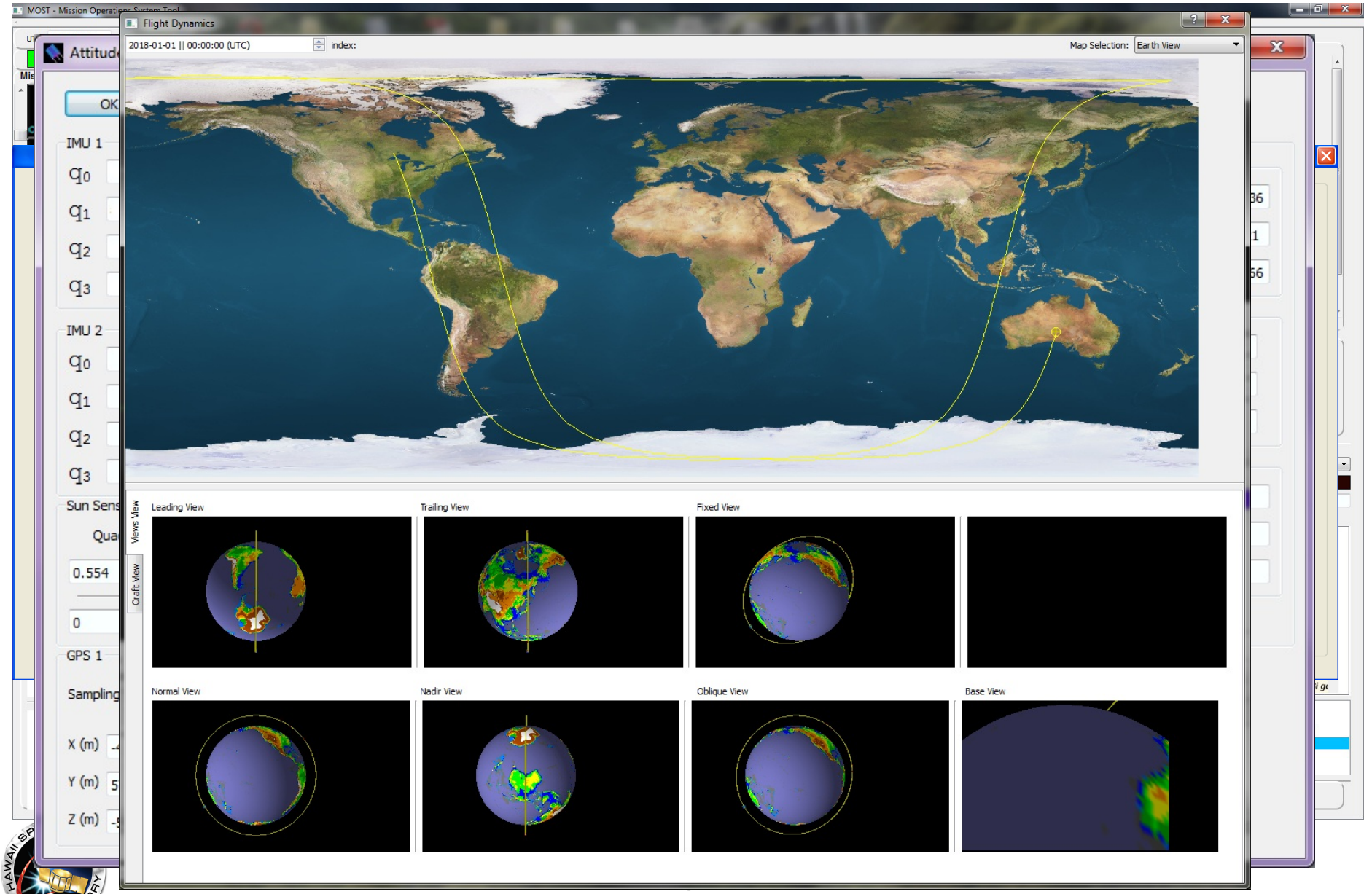
UVPI Encounter Manager Sample Screen

LUNOPS on Left Screen in Clementine MOC

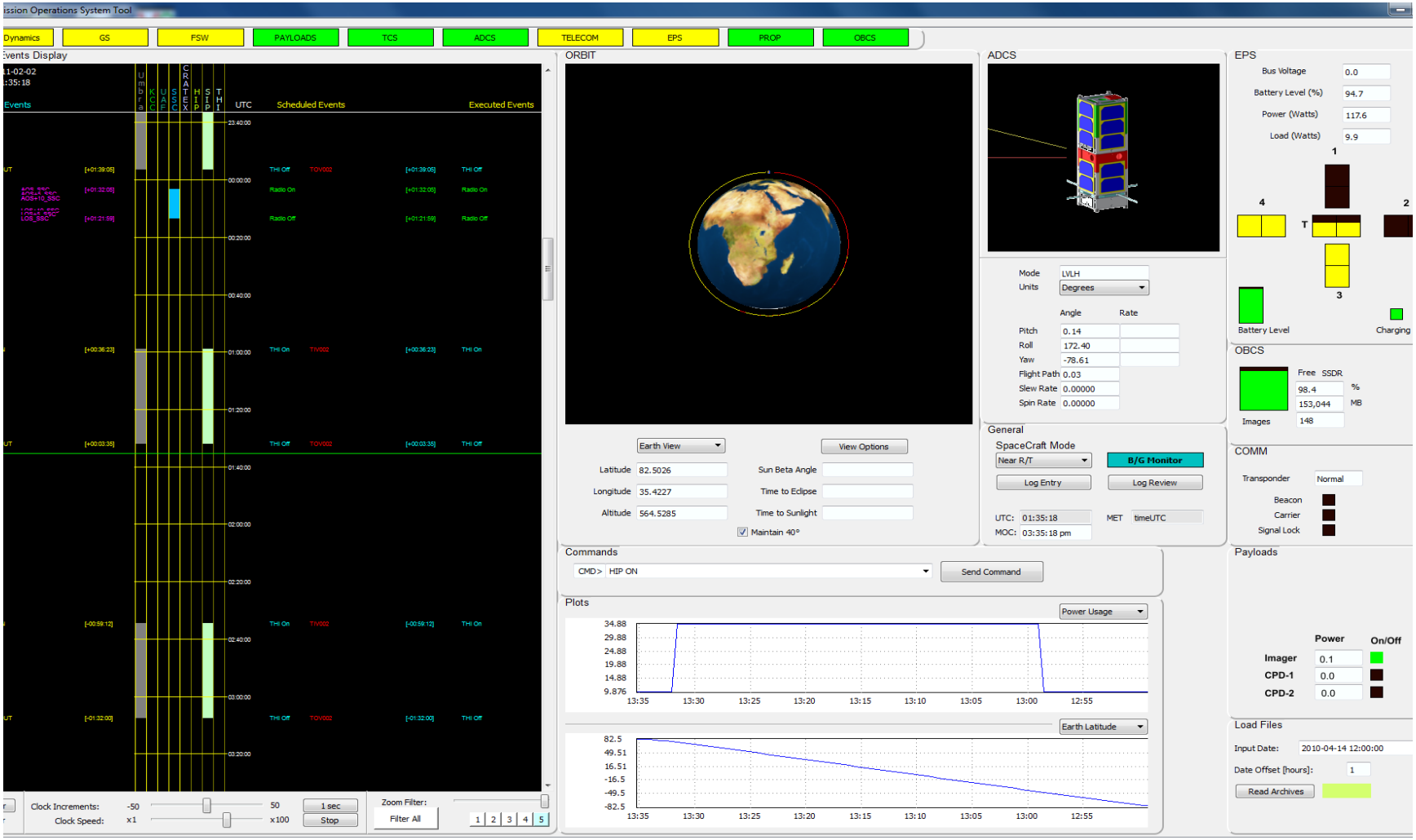
Mission Operations Support Tool (MOST)



Mission Operations Support Tool (MOST)



MOST Configured for 3U CubeSat



COSMOS Executive Operator (CEO)

- Provides Situational Awareness (Monitoring) of all Spacecraft Simultaneously
  - Initial design supports up to 100 spacecraft
  - Three different selectable levels of monitoring
    - Low – S/C ID, status of S/C, status of P/L, GS contact status
    - Medium – shows orbit position and data, day/umbra status (C/D T), GS contact status (C/D T), status of SS, S/C or ACS modes, etc.
    - High – Similar to main display of MOST giving detailed information
  - MOST can be launched to provide detailed SS information or commanding capability for any spacecraft
  - Displays orbit tracks of all spacecraft (filter to select specific s/c)
  - Can handle actual and simulated spacecraft simultaneously
  - Flight Dynamics Display shows relative positions of spacecraft
  - Communications Display shows satellite communication crosslinks (ideal for constellation monitoring)

CEO Features (cont.)

- Provides Monitoring of Ground Stations
  - Top-level status of all ground stations in network
  - Can launch GSCT for more detailed monitoring and control
- Provides Management of MOC Operations
  - Monitors allocation of COSMOS tools to spacecraft
  - Monitors personnel resource utilization
  - Access console logs (current or archived)
  - Communicate with one or MOC positions
- Monitors COSMOS System Performance
  - Monitors console computer performance and utilization
  - Monitors status of COSMOS tools and data flow between the COSMOS elements
- Launch any COSMOS Tools
  - MPST, MOST, GSCT, DMT, TBCT, Analysis Tools

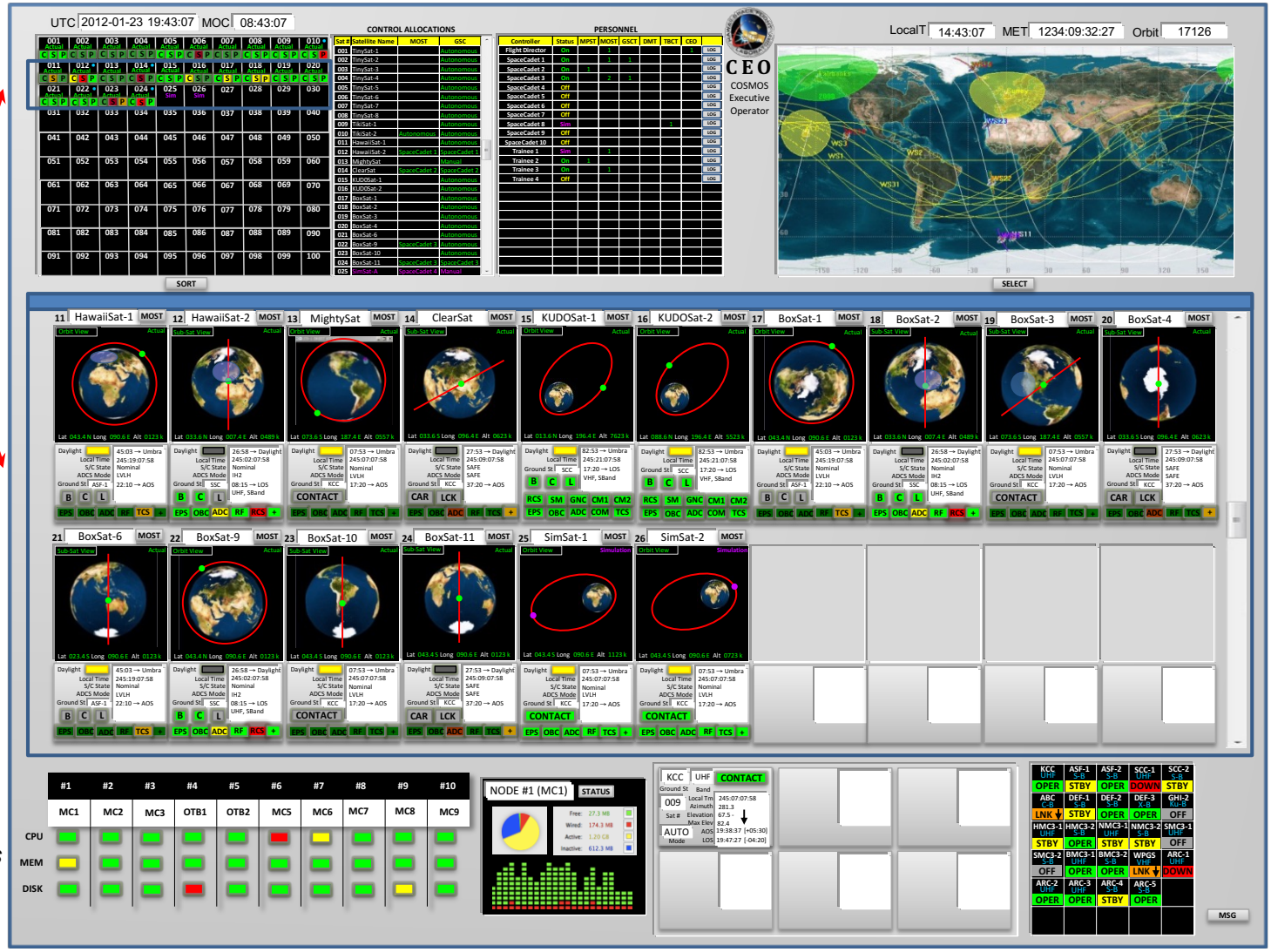
CEO - Main Display (Design)

Resources

Status of All Satellites

Enlarged Status Displays

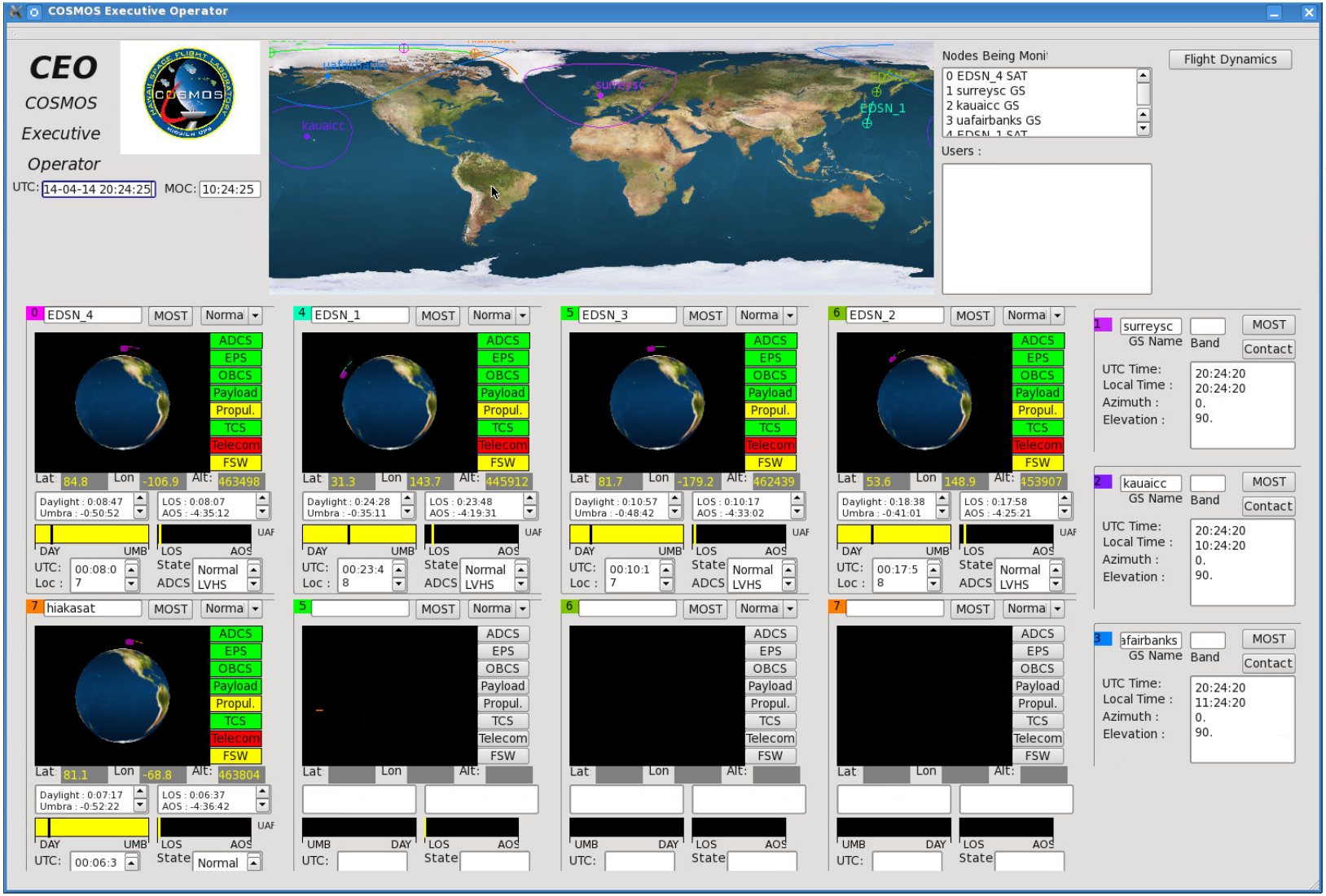
Ground Tracks (selectable)



MOC Computers Status

Ground Segment Monitor

CEO - Main Display (Current)

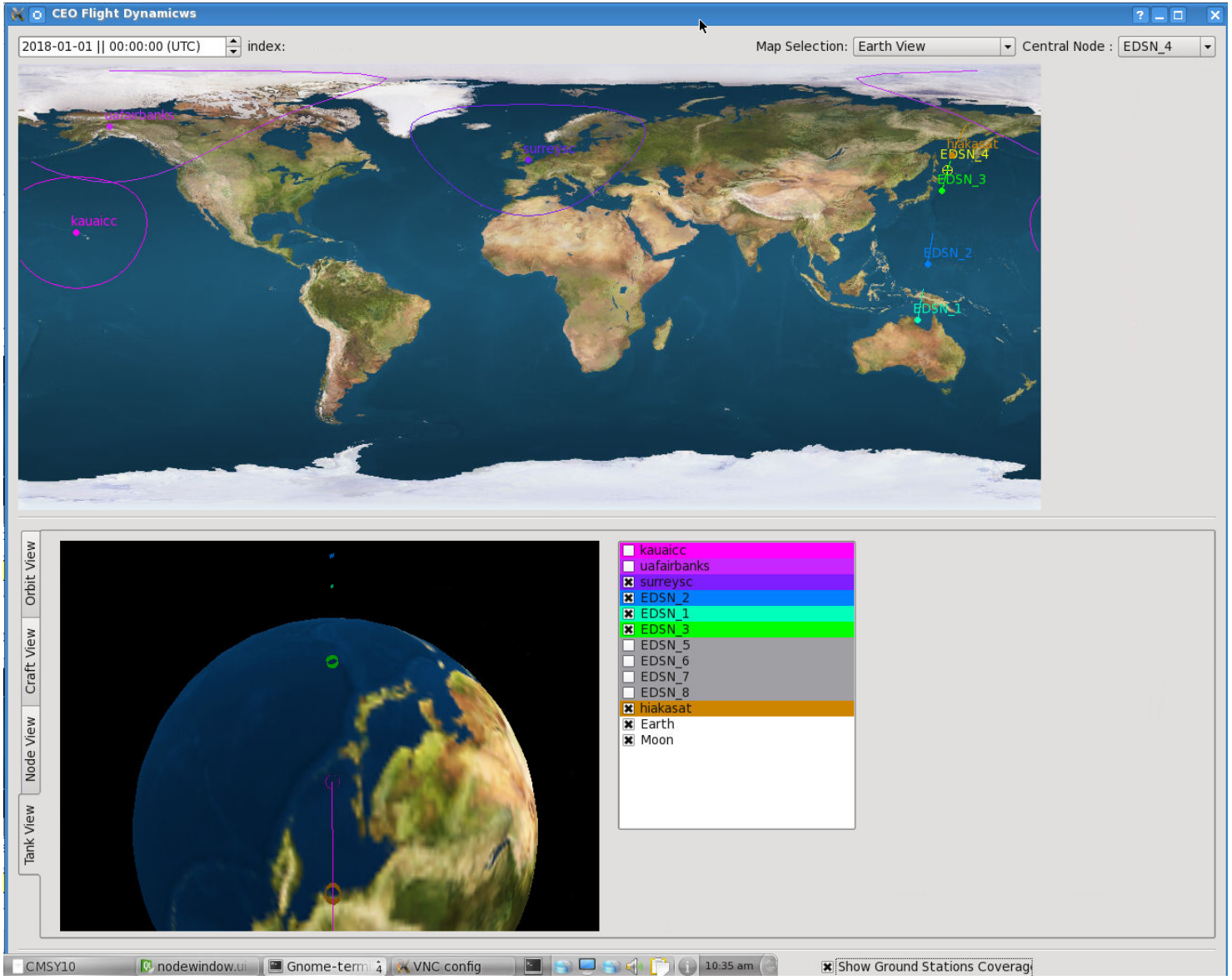


Ground Tracks (selectable)

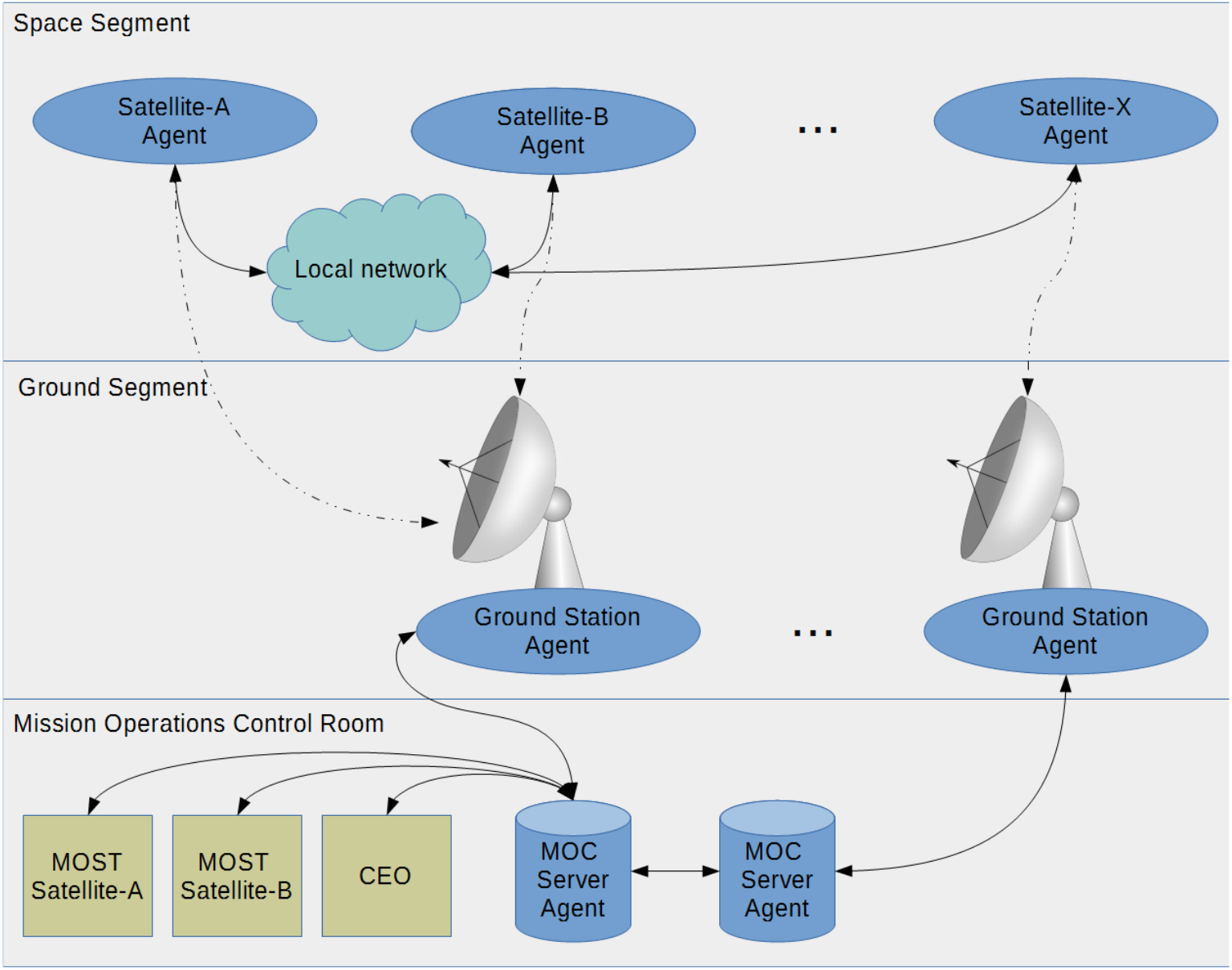
Status Displays (8)

Ground Segment Monitor

CEO – FD Display (Current)



COSMOS Multi-satellite Architecture



COSMOS Multi-satellite Architecture

- Data can be collected from multiple nodes that live in the same network
- In the case of multiple satellites, each satellite is a node
- Nodes are "COSMOS-aware"
  - Nodes execute COSMOS agents
  - Each agent complies with the COSMOS namespace
- Multiple ground stations can collect the data and forward the data using COSMOS agents
- The Mission Operations Center Servers
  - Synchronize the data
  - Parse the data into usable formats
- COSMOS Tools
  - Visualize the data in archival mode or real time
  - Command and Control scripts

Mahalo!

sorensen@hsfl.hawaii.edu