

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

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CubeSat Developers' Workshop 2014
California Polytechnic Institute
San Luis Obispo, CA

April 24, 2014



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On the Leading Edge of Space Exploration and Research

Designed as a multidisciplinary research and education activity bringing together individuals from diverse areas to explore, study and advance the understanding of the space environment, the Hawai'i Space Flight Laboratory positions UH Mānoa to become the first university in the world with the capability to design, fabricate, launch and control its own satellites. For information about HSFL, its programs or the many educational opportunities provided for students interested in the areas of research, development and engineering, visit

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Microsatellite Design, Fabrication and Launch • Payload Design and Integration
Ground Systems and Operations Support • Workforce Development



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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

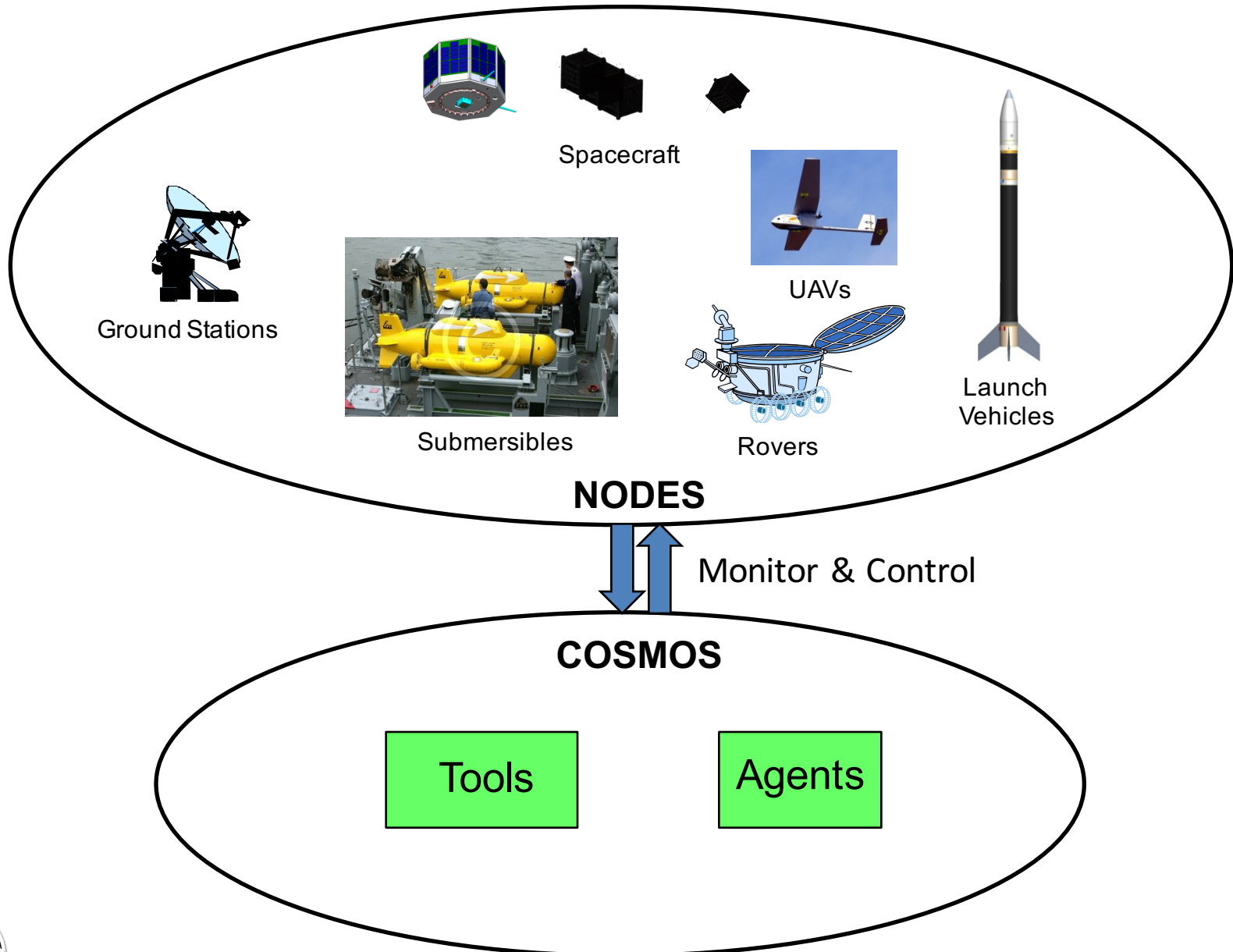


Features of COSMOS

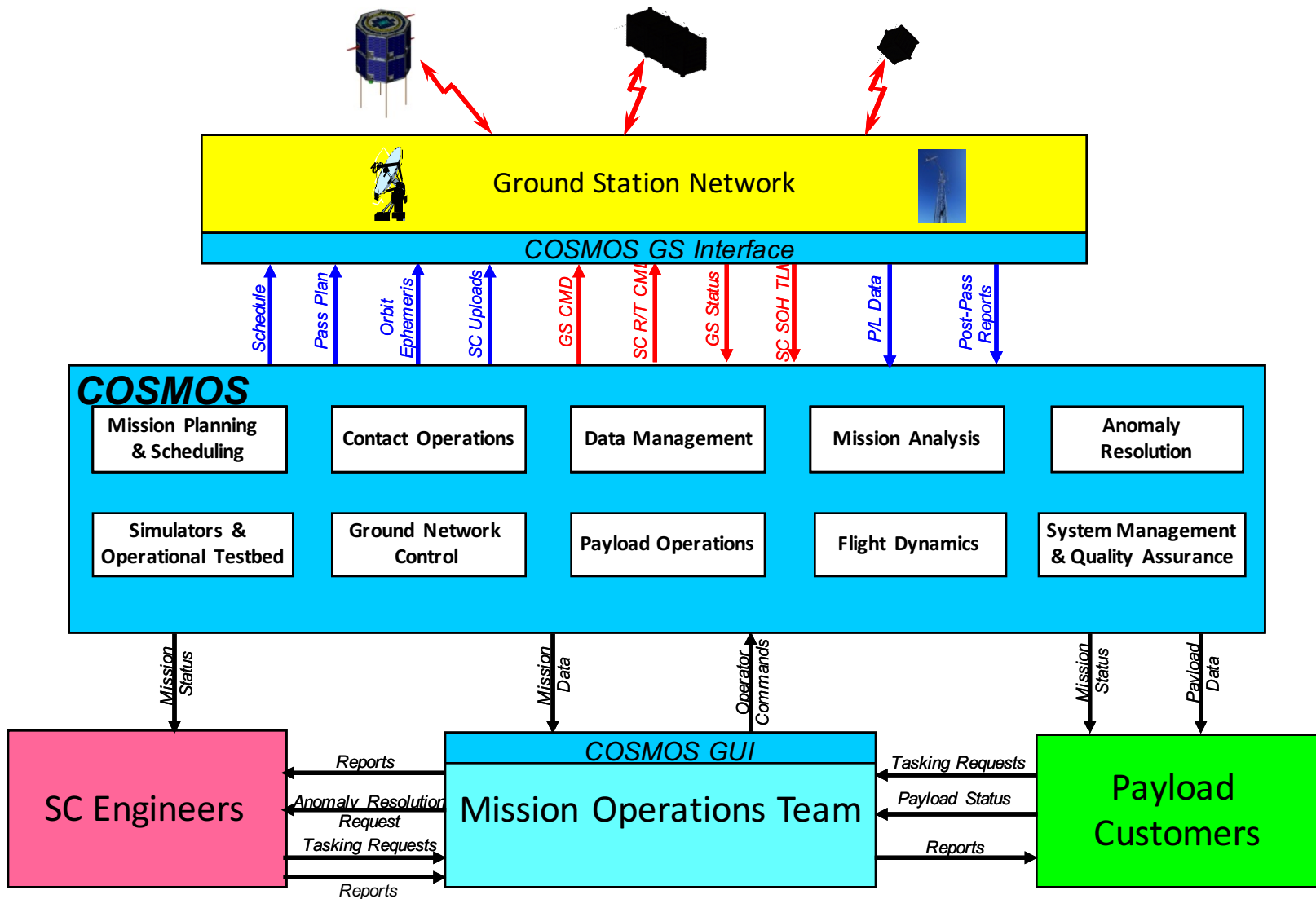
- Set of software and hardware framework to support spacecraft and other vehicle mission operations
- Set of tools:
 - Mission Planning & Scheduling Tool (MPST)
 - Mission Operations Support Tool (MOST)
 - Ground Segment Control Tool (GSCT)
 - Data Management Tool (DMT)
 - Flight Dynamics Tool (FDT)
 - 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)

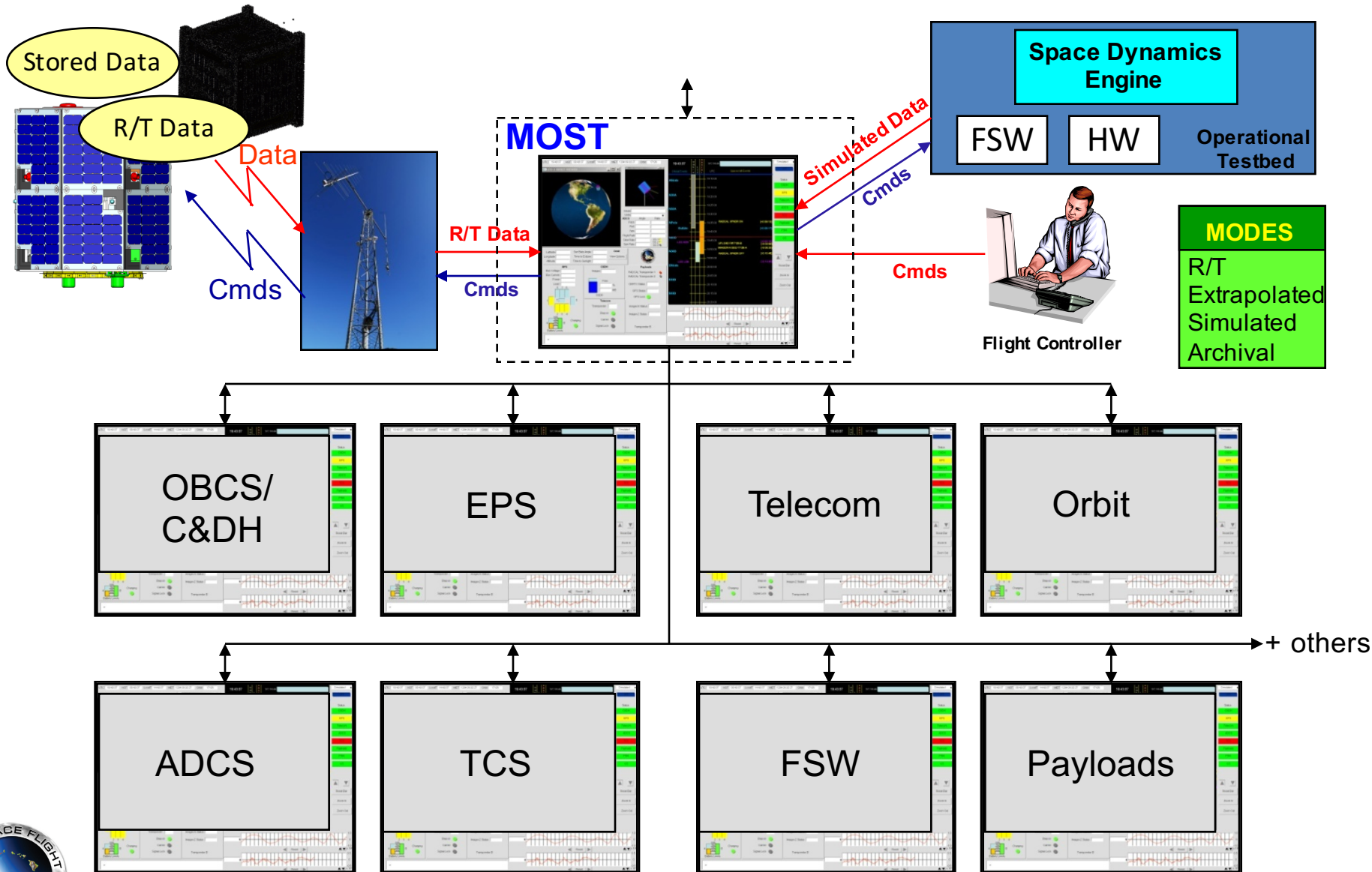


Mission Operations Support Tool (MOST)

- 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



Mission Operations Support Tool (MOST)



Mission Operations Support Tool (MOST)

The screenshot displays the MOST software interface. The main window, titled "Flight Dynamics", shows a 3D Earth map with a yellow orbital path. The top status bar indicates the date and time: "2018-01-01 || 00:00:00 (UTC)". The "Map Selection" dropdown is set to "Earth View".

On the left side, there are several control panels:

- Attitude Control:** Includes an "OK" button and a list of attitude parameters for two IMUs (IMU 1 and IMU 2), each with sub-parameters Q_0 , Q_1 , Q_2 , and Q_3 .
- Sun Sensor:** Includes a "Qual" parameter with a value of 0.554 and a "0" input field.
- GPS 1:** Includes a "Sampling" parameter.
- Position:** Includes input fields for X (m), Y (m), and Z (m).

At the bottom of the main window, there are eight small preview windows showing different views of the Earth and the satellite's position:

- Leading View
- Trailing View
- Fixed View
- Normal View
- Nadir View
- Oblique View
- Base View

On the far right, there are additional control panels with numerical input fields (36, 1, 66) and a vertical slider.



MOST Configured for 3U CubeSat

Events Display

UTC	Scheduled Events	Executed Events
[+01:38:58]	THI Off TOV002	[+01:39:05] THI Off
[+01:32:05]	Radio On	[+01:32:05] Radio On
[+01:21:59]	Radio Off	[+01:21:59] Radio Off
[+00:36:23]	THI On THV002	[+00:36:23] THI On
[+00:03:35]	THI Off TOV002	[+00:03:35] THI Off
[+00:59:12]	THI On THV002	[+00:59:12] THI On
[+01:32:00]	THI Off TOV002	[+01:32:00] THI Off

ORBIT

Earth View

Latitude: 82.5026
Longitude: 35.4227
Altitude: 964.5285

Sun Beta Angle: _____
Time to Eclipse: _____
Time to Sunlight: _____
 Maintain 40°

ADCS

Mode: LVLH
Units: Degrees

Angle	Rate
Pitch: 0.14	
Roll: 172.40	
Yaw: -78.61	

Flight Path: 0.03
Slew Rate: 0.00000
Spin Rate: 0.00000

EPS

Bus Voltage: 0.0
Battery Level (%): 94.7
Power (Watts): 117.6
Load (Watts): 9.9

OBSC

Free SDDR: 98.4 %
153,044 MB
Images: 148

General

SpaceCraft Mode: Near R/T
Log Entry
Log Review

UTC: 01:35:18
MET: timeUTC
MOC: 03:35:18 pm

Commands

CMD> HIP ON

Plots

Power Usage

Earth Latitude

COMMIT

Transponder: Normal
Beacon: _____
Carrier: _____
Signal Lock: _____

Payloads

Power	On/Off
Imager: 0.1	On
CPD-1: 0.0	Off
CPD-2: 0.0	Off

Read Files

Input Date: 2010-04-14 12:00:00
Date Offset [hours]: 1
Read Archives



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

UTC | 2012-01-23 19:43:07 MOC | 08:43:07

CONTROL ALLOCATIONS

Contractor	Name	MOST	ACC
001	EnviroSat-1	ON	ON
002	EnviroSat-2	ON	ON
003	EnviroSat-3	ON	ON
004	EnviroSat-4	ON	ON
005	EnviroSat-5	ON	ON
006	EnviroSat-6	ON	ON
007	EnviroSat-7	ON	ON
008	EnviroSat-8	ON	ON
009	EnviroSat-9	ON	ON
010	EnviroSat-10	ON	ON
011	EnviroSat-11	ON	ON
012	EnviroSat-12	ON	ON
013	EnviroSat-13	ON	ON
014	EnviroSat-14	ON	ON
015	EnviroSat-15	ON	ON
016	EnviroSat-16	ON	ON
017	EnviroSat-17	ON	ON
018	EnviroSat-18	ON	ON
019	EnviroSat-19	ON	ON
020	EnviroSat-20	ON	ON
021	EnviroSat-21	ON	ON
022	EnviroSat-22	ON	ON
023	EnviroSat-23	ON	ON
024	EnviroSat-24	ON	ON
025	EnviroSat-25	ON	ON
026	EnviroSat-26	ON	ON
027	EnviroSat-27	ON	ON
028	EnviroSat-28	ON	ON
029	EnviroSat-29	ON	ON
030	EnviroSat-30	ON	ON

PERSONNEL

Contractor	Name	MOST	ACC	DMT	TRC	CEO
001	Flight Director	ON	ON	ON	ON	ON
002	SpaceCadet 1	ON	ON	ON	ON	ON
003	SpaceCadet 2	ON	ON	ON	ON	ON
004	SpaceCadet 3	ON	ON	ON	ON	ON
005	SpaceCadet 4	ON	ON	ON	ON	ON
006	SpaceCadet 5	ON	ON	ON	ON	ON
007	SpaceCadet 6	ON	ON	ON	ON	ON
008	SpaceCadet 7	ON	ON	ON	ON	ON
009	SpaceCadet 8	ON	ON	ON	ON	ON
010	SpaceCadet 9	ON	ON	ON	ON	ON
011	SpaceCadet 10	ON	ON	ON	ON	ON
012	Traine 1	ON	ON	ON	ON	ON
013	Traine 2	ON	ON	ON	ON	ON
014	Traine 3	ON	ON	ON	ON	ON
015	Traine 4	ON	ON	ON	ON	ON
016	Traine 5	ON	ON	ON	ON	ON
017	Traine 6	ON	ON	ON	ON	ON

CEO COSMOS Executive Operator

LocalT | 14:43:07 MET | 1234:09:32:27 Orbit | 17126

Status of All Satellites

Enlarged Status Displays

Ground Tracks (selectable)

MOC Computers Status

Ground Segment Monitor

Status of All Satellites

Enlarged Status Displays

Ground Tracks (selectable)

MOC Computers Status

Ground Segment Monitor



CEO - Main Display (Current)

CEO
COSMOS
Executive
Operator

UTC: 14-04-14 20:24:25 MOC: 10:24:25

Nodes Being Moni:
0 EDSN_4 SAT
1 surreysc GS
2 kauaicc GS
3 uafairbanks GS
4 EDSN_1 SAT

Users:

Flight Dynamics

0 EDSN_4 MOST Norma
4 EDSN_1 MOST Norma
5 EDSN_3 MOST Norma
6 EDSN_2 MOST Norma
1 surreysc MOST
2 kauaicc MOST
3 uafairbanks MOST

Status Displays (8)

Ground Tracks (selectable)

Ground Segment Monitor

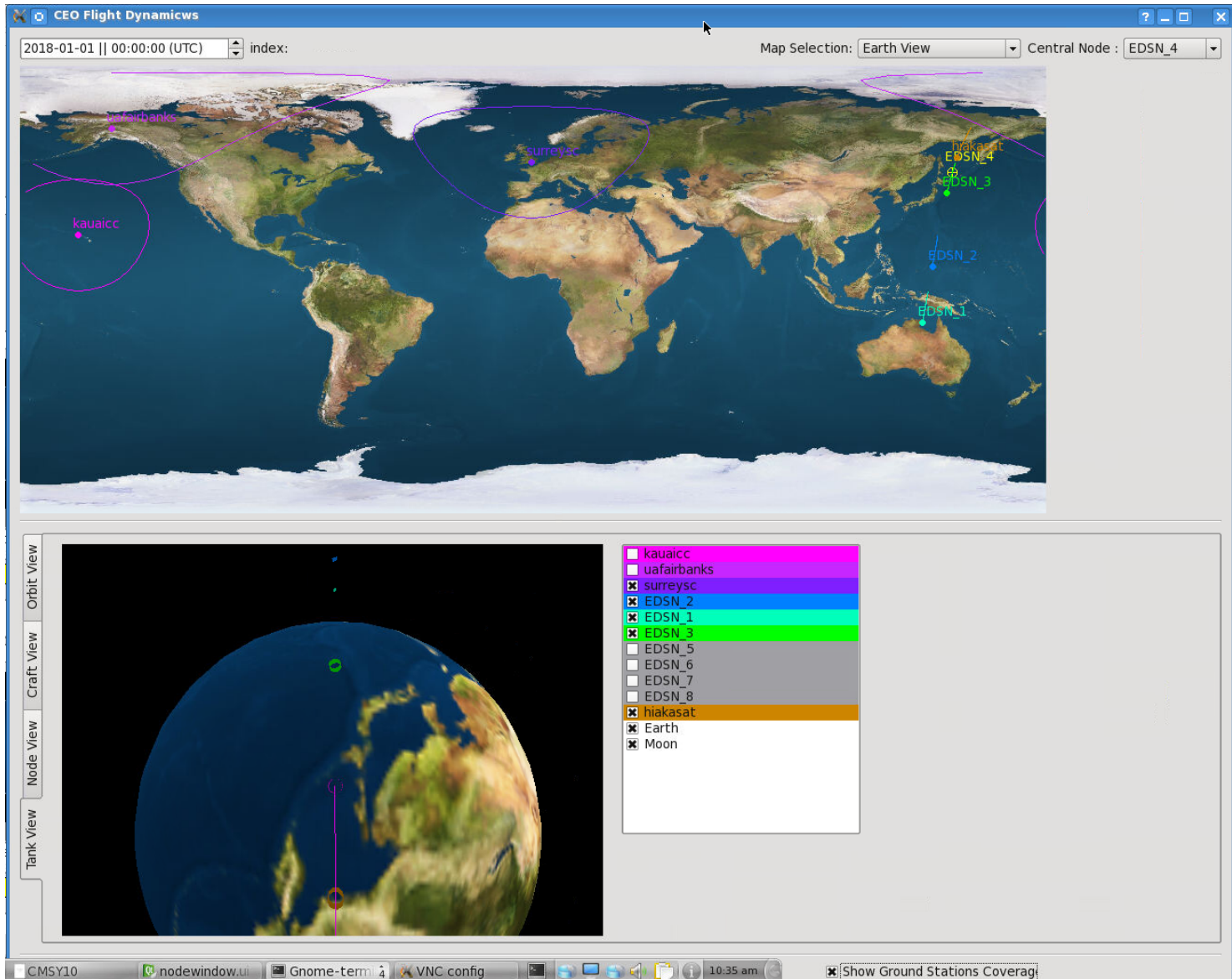
Status Displays (8)

Ground Tracks (selectable)

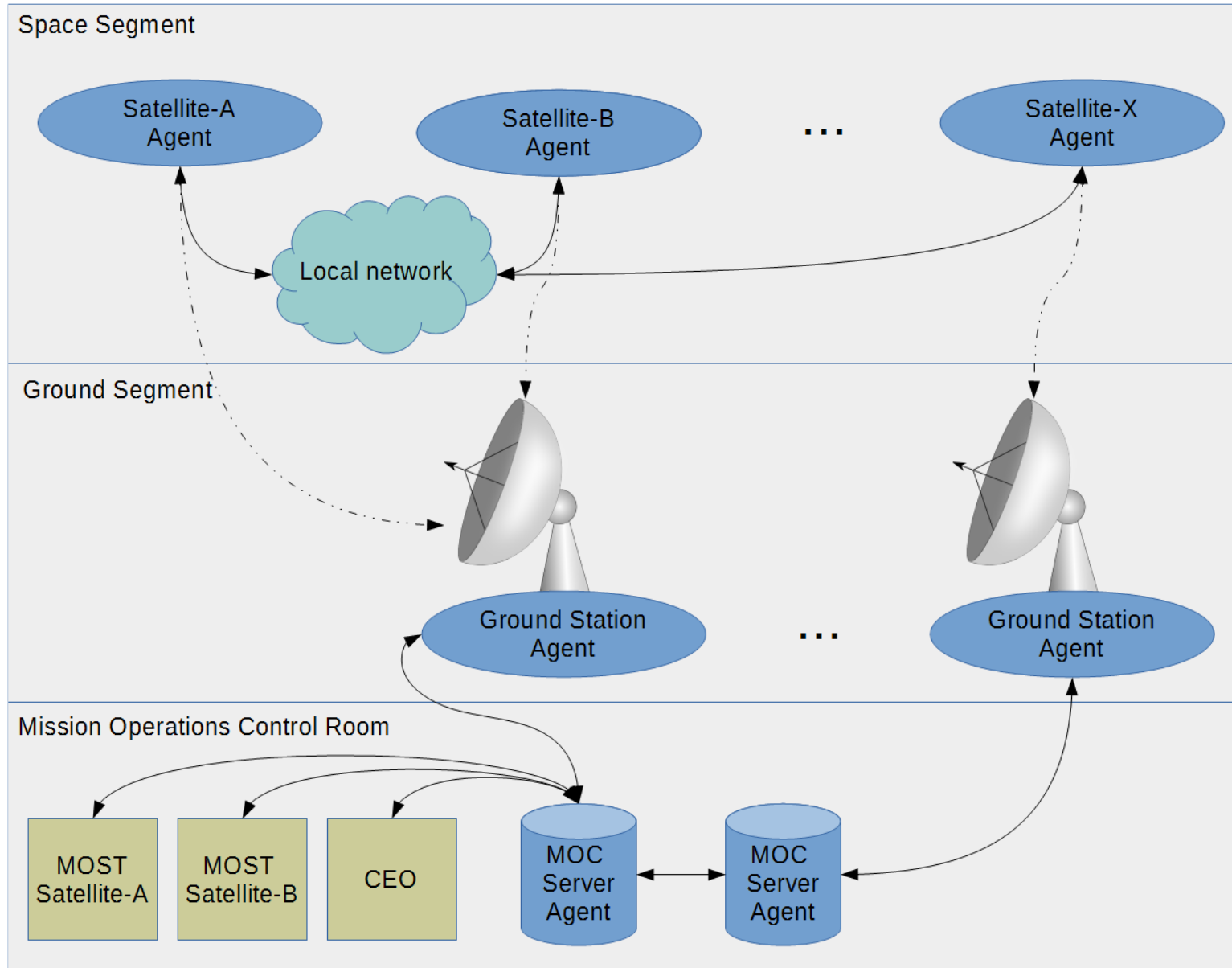
Ground Segment Monitor



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!

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