Development of a Comprehensive Mission Operations System Designed to Operate Multiple Small Satellites

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

Hawaii Space Flight Laboratory, University of Hawaii at Manoa, Honolulu, HI

Bruce D. Yost
Nanosat Mission Office, NASA Ames Research Center, Moffett Field, CA
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).
COSMOS Goals

- **Target Audience**
  - Developers and users of (multiple) small satellites
  - Small teams
  - Small budgets

- **Provide Hardware and Software Framework**
  - Hardware and software test bed and simulators
  - Hardware and software building blocks
  - Software elements
  - Industry standards

- **Support complete satellite lifecycle**
  - Design
  - Development
  - Fabrication and Integration
  - Testing
  - Operations
Mission Operations
Functional Flow Block Diagram

PLANNING PROCESS

Mission Planning & Scheduling

OTB/ Simulators

Anomaly Resolution

ANOMALY RESOLUTION PROCESS

ANALYSIS PROCESS

S/C Analysis

Orbit/ Trajectory Analysis

Mission Analysis

Data Processing

DATA MANAGEMENT PROCESS

Payload Customers

(Mission Customers)

Schedules, Contact Plans, Command & Flat Files

Precontact Setup

Initiate Contact

Postcontact Shutdown

Monitor & Control

Ground Network

R/T FLIGHT OPERATIONS PROCESS

Commands, Tasks, Constraints

Support Schedule

Command Loads/Scripts

Product & S/C Constraints

Reports/Logs

Anomalies & Eng. Data

Spacecraft

Relay Satellite

Payload Data

OTB/ Simulators

Anomaly Resolution

Payload Customers

Anomalies & Eng. Data

Information

S/C SOH Data

GN or S/C Track Data

Payload SOH Data

All Level 0 & SOH Data

Data Archive

Payload Data

Ground Network

R/T Commands (GN & S/C)

R/T Commands (GN & S/C)

Mission Analysis

Payload Customers

(Mission Customers)
COSMOS Functional Architecture

Ground Station Network

COSMOS GS Interface

COSMOS

Mission Planning & Scheduling
Contact Operations
Data Management
Mission Analysis
Anomaly Resolution
Simulators & Operations Testbed
Ground Network Control
Payload Operations
Flight Dynamics
System Management & Quality Assurance

Mission Status

Mission Data

Operator Commands

Reports

COSMOS GUI

Mission Operations Team

Tasking Requests

Payload Status

Reports

SC Engineers

Anomaly Resolution Report Tasking Requests

Payload Customers

Payload Status

Reports

Schedule
Pass Plan
Orbit
Ephemeris
SC Uploads
GS CMD
SC RTI CMD
GS Status
SC SOH TLM
P/L Data
Post-Pass Reports

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Features of COSMOS

- Set of software and hardware framework to support spacecraft mission operations
- Set of tools:
  - Mission Planning & Scheduling Tool (MPST)
  - Mission Operations Support Tool (MOST)
  - Ground Segment Control Tool (GSCT)
  - Data Management Tool (DMT)
  - 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
- Connections for COTS/GOTS and external tools
The Automated Collection Planning Tool is both a modeling and simulation environment and an automated planning tool for space based remote sensing. The system allows the user to evaluate the capability of a system to collect against a customer’s target and recommend a course of action if the revisit, GSD, or any other part of the requirement is insufficient.

ACPT Key Features:
- Configurable 4D Visualization
- GIS Data (terrain, imagery, and maps)
- Satellite Propagation and Modeling
- Collection Sensor Modeling
- Power and Memory Modeling
- Target/Tasking Management
- Historic Global Cloudfreeness Data
- Communications Planning
- Exclusion Calculators
- Collection Strategy Design
- Strategic and Tactical Planning
- Custom Report/Chart Tools

With 3D visualization and customize workflows, the collection planner can better understand the situation and provide executable plans.
Operations Test Bed (OTB)

Functional Architecture

Satellite

- ADCS
- TCS
- EPS
- PAYLOADS
- TELECOM
- OBCS/C&DH

Test Bed Controller Engine

- SD Data
- SE Data
- SD Data
- SE Data

Space Dynamics
- Orbital data
- Attitude
- ...

Space Environment
- Magnetic Field (B)
- Solar Radiation
- System Time
- ...

Portal Agent
- Tests Initialization
- Commands setup
- Data Flow

Portal Agent
- Tests Initialization
- Commands setup
- Data Flow

GSS

- Ground Station Simulator

Operations Test Bed

Monitoring & Control

- MOST
- GSCT
- DMT
- MPST

Test Bed Controller Tool

- TBCT

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OTB Usage

- Pre-launch
  - Concept/design
  - Development
  - Integration & Testing
  - Training and Rehearsals

- Post-launch
  - Cmd. load verification
  - New Software validation
  - Anomaly Resolution
  - Training and Rehearsals
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
  - Additional initial missions are UH’s Kumu A’o CubeSat and NASA ARC’s nano-satellites (e.g., PhoneSat)
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
  - LUNOPS program used to monitor science mission operations during the Clementine lunar mission
Mission Operations Support Tool (MOST)
COSMOS Executive Operator

Status of All Satellites

Enlarged Status Displays

COSMOS System Performance

Ground Tracks (selectable)

Resources

GROUND NETWORK MONITOR (TBD)
COSMOS Software Applications

Tools & Support Software

- **MPST**
  Mission Planning & Scheduling Tool
  Lead: TBD

- **MOST**
  Mission Operations Support Tool
  Lead: TBD

- **MOSE**
  Mission Operations Support Engine
  Lead: Mark Wood

- **GSCT**
  Ground Segment Control Tool

- **DMT**
  Data Management Tool
  Lead: TBD

- **GSCE**
  Ground Segment Control Engine
  Lead: TBD

- **DME**
  Data Management Engine

- **Analysis Tools**
  - **SC SOH**
  - **Mission**
  - **Orbit**
  - **Ground Segment**
  Lead: TBD

- **Support Programs**
  - **Orbit Ephemerator**
    Lead: Eric Pilger
  - Quality Assurance
  - Report Generation
  - COSMOS Editor

- **SCHEDULER**
  Generate Plan and Schedules

- **TIMELINER**
  Generates Single Orbit Timeline

- **ACPT**
  Automated Collection Planning Tool

- **CSG**
  Command Script Generator

- **TBCT**
  Testbed Control Tool
  Lead: Miguel Nunes

- **TBCE**
  Testbed Control Engine

- **COSMOS EXEC**
  Lead: Trevor Sorensen

Other Agents/Engines

- **Ground Station Simulator**
  Lead: Eric Pilger

- **Satellite Simulator**
  Lead: Miguel Nunes

- **Space Dynamics Simulator**
  Lead: Eric Pilger

Other Software

- **Libraries**
- **Devices**
- **Misc. Programs**
- **...**
- **...**

In development
COTS/GOTS
Not Started/TBD
Required for HS-1
COSMOS Code Architecture

- Agents
  - Provide “services”
  - Persistent, command able

- Programs
  - Perform “one-off” jobs

- Data
  - Files and Messages
  - Passed amongst Programs and Agents

- Tools
  - Graphical User front ends for higher level functionality

- Engines
  - Special Agents designed specifically to support Tools

- Developer Toolkit

- External Software
COSMOS Support Infrastructure

- Mission Operations
  - GUI: MOST
  - Interacts with COSMOS Exec, MOSE
- Mission Planning and Scheduling
  - GUI: MPST
  - Interact with DME, TBCE, GSCE
- Data Management
  - GUI: DMT
  - Interacts with DME, MOSE, GS Data Agents
- Ground Segment
  - GUI: Ground Segment Control Engine (GSCT)
  - Interacts with GS Data Agents, GSCE
- Operations Test Bed
  - GUI: TBCT
  - Interacts with Simulators, TBCE
COSMOS External Software Support

- **Ongoing collaborations**
  - MCT(ARC): will soon receive code and start exploring interactions with COSMOS
  - ACPT(RRI): currently integrating with COSMOS
  - MC3(NRL): in discussions to collaborate

- **Possible Collaborations**
  - GENSO(ESA): Ground Network
  - GMSEC(GSFC): Communication Backbone
  - AMMOS(JPL): Tools

- **Other Software of Interest**
  - Cubesat Space Protocol
  - Satellite Trajectory Analysis

Looking for other collaborators, especially universities!
Mahalo!

http://www.COSMOS-project.org
Backup Slides
OTB Features

- Calibration and testing of hardware components
- Integrate Software tools for hardware simulation
- Subsystem validation & monitoring
- Subsystems interaction & dynamics monitoring
- Pseudo-environment input (available up to a certain degree)
- Anomaly resolution support
- Measurable performance: like pointing, timing, speed, fast, power, etc.
- Remote control of the OTB using scripts
- Near real time testing and simulations
- Mission Training and rehearsals
- Trending and analysis
- System operation rehearsals and simulations with statistical analysis (e.g. Monte Carlo)
- Operability with different standard software development tools and languages: MATLAB, LabView, Phyton, C/C++, and/or other engineering COTS software utility tools.
- Support the development and operational test for different satellites
Mission Operations Support Tool (MOST)

- Stored Data
- Space Dynamics Engine
- R/T Data
- MOST
- Simulated Data
- FSW
- HW
- Operational Testbed
- Flight Controller
- Modes
  - R/T
  - Extrapolated
  - Simulated
  - Archival
- OBCS/C&DH
- EPS
- Telecom
- Orbit
- + others
- ADCS
- TCS
- FSW
- Payloads
- Mission Operations Support Tool (MOST)

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**Ground Station**

- Level 0 Processing
  - Frame header removal
  - Duplicates removal
  - Time ordering
  - Report generation

- Level 1a,b,c Processing

- Level 2 Processing

- Level 3 Processing

**MOC**

- Front-end Processing
  - Frame header removal
  - Conversion to Eng. Units
  - Telemetry page filter

- Real-Time Operations

- Data Analysis
  - S/C SOH Analysis
  - FD (Orbit) Analysis
  - Payload Analysis
  - Mission (objectives) analysis
  - Anomaly Identification
  - Reports Generation
  - Request/report mission changes

- Mission Planning & Scheduling

- MPS Products & Command Uploads

**SOC**

- GS Archive

- MPS Products

- Raw Science Data

- Stored SOH Data

- R/T SOH Data

- Stored SOH Data

- R/T SOH Data, Cmds, Logs

- Analyzed Engineering Data

- SOH Data

- Analysis Reports

- Tasking Requests

- Science Data & Reports

- Engineering Data Subset

- MPS Products & Command Uploads

- Level 0 Science Data

- Level 1 Science Data

- Level 2 Science Data

- Level 3 Science Data

- MPS Products & Command Uploads

- MPS Products & Command Uploads

- SOC Data Archive

- Science Data Archive

- MPS Products & Command Uploads
# COSMOS Project Schedule

<table>
<thead>
<tr>
<th>Milestones:</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
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<tr>
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- **Most Development**
- **OTB/Simulators Development**
- **MPST Development**
- **GSCT Development**
- **DMT Development**
- **Analysis Tools Development**
- **COSMOS HSFL Integration & Test**
- **HawaiiSat Definition**
- **Kumu a’o Definition**
- **ARC Nanosat Definition**
- **COSMOS ARC Integration & Test**
- **HawaiiSat & Kumu a’o Operations**

## Milestones:
-  **Sept. 1, 2010**  Project start
-  **Nov. 10, 2010**  Kick-off meeting with ARC
-  **June, 2011**  System Design Review (SDR)
-  **Oct. 2011**  Basic COSMOS ready to support HS-1
-  **January, 2012**  Test Readiness Review (TRR)
-  **Sept. 2012**  COSMOS-HSFL Mission Readiness Review
-  **May 2013**  COSMOS-ARC Acceptance Review
-  **August 2013**  Project Completion and Final Report