



SSC11-IX-3

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

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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).*

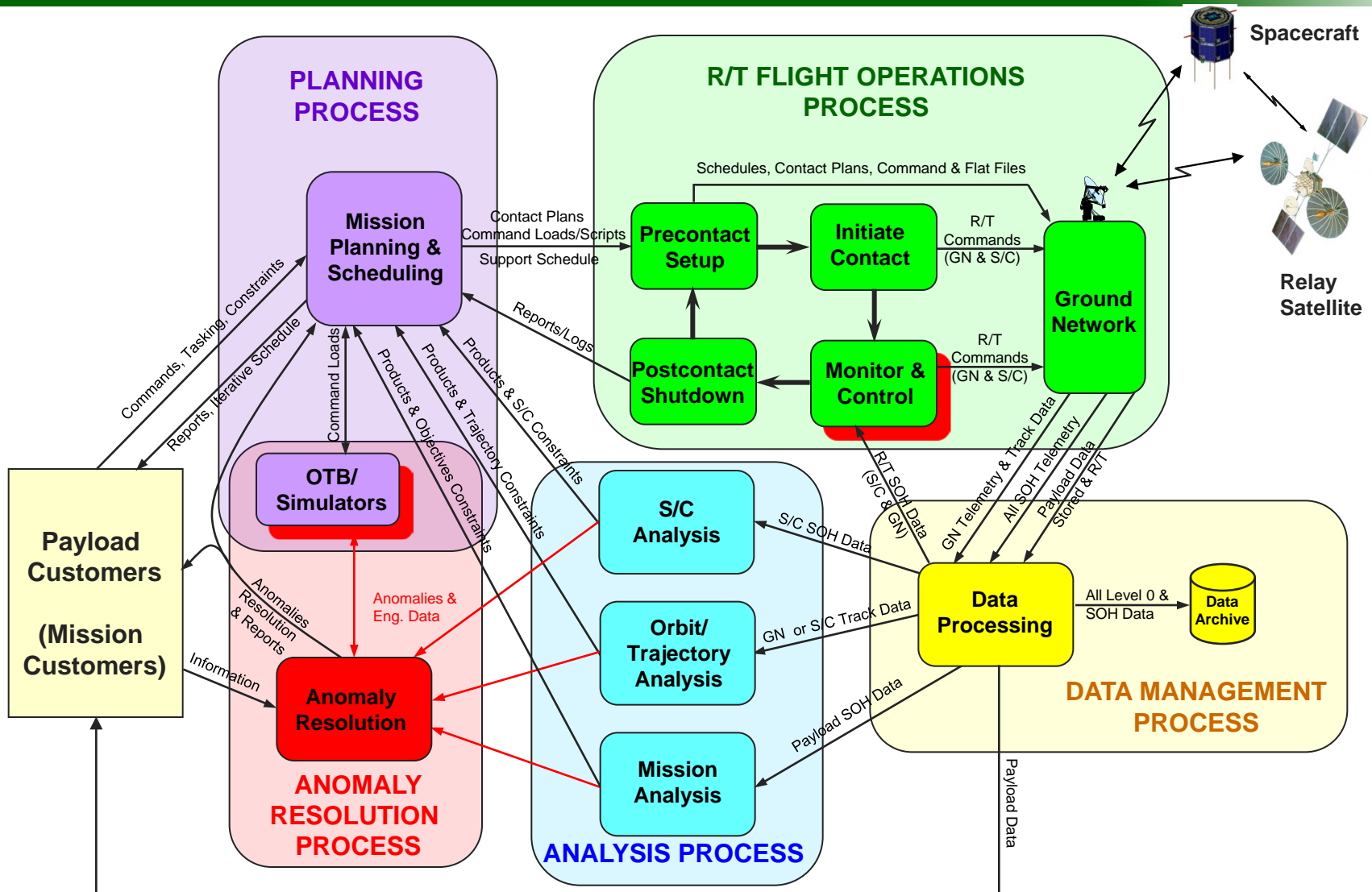


COSMOS Goals

- 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

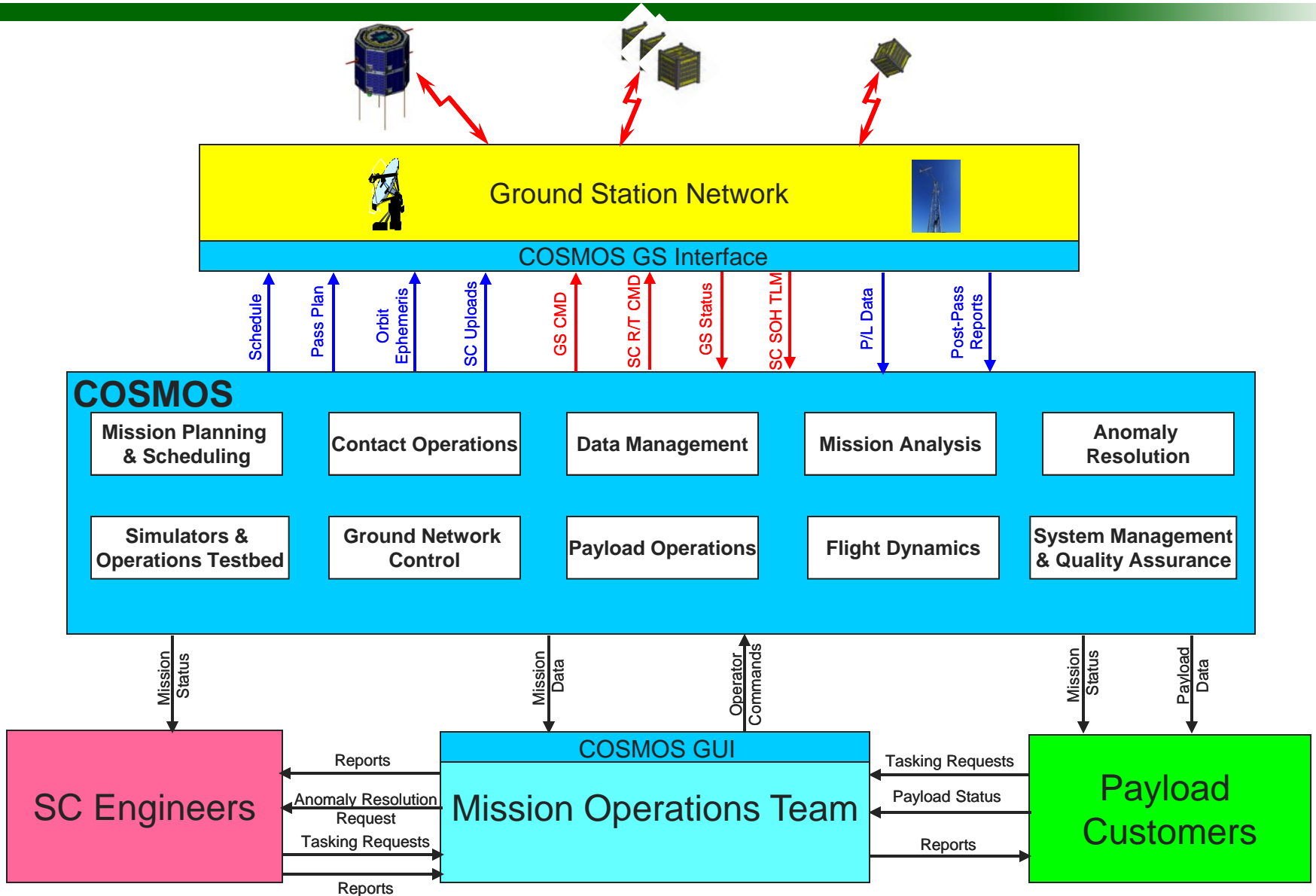


Mission Operations Functional Flow Block Diagram





COSMOS Functional Architecture

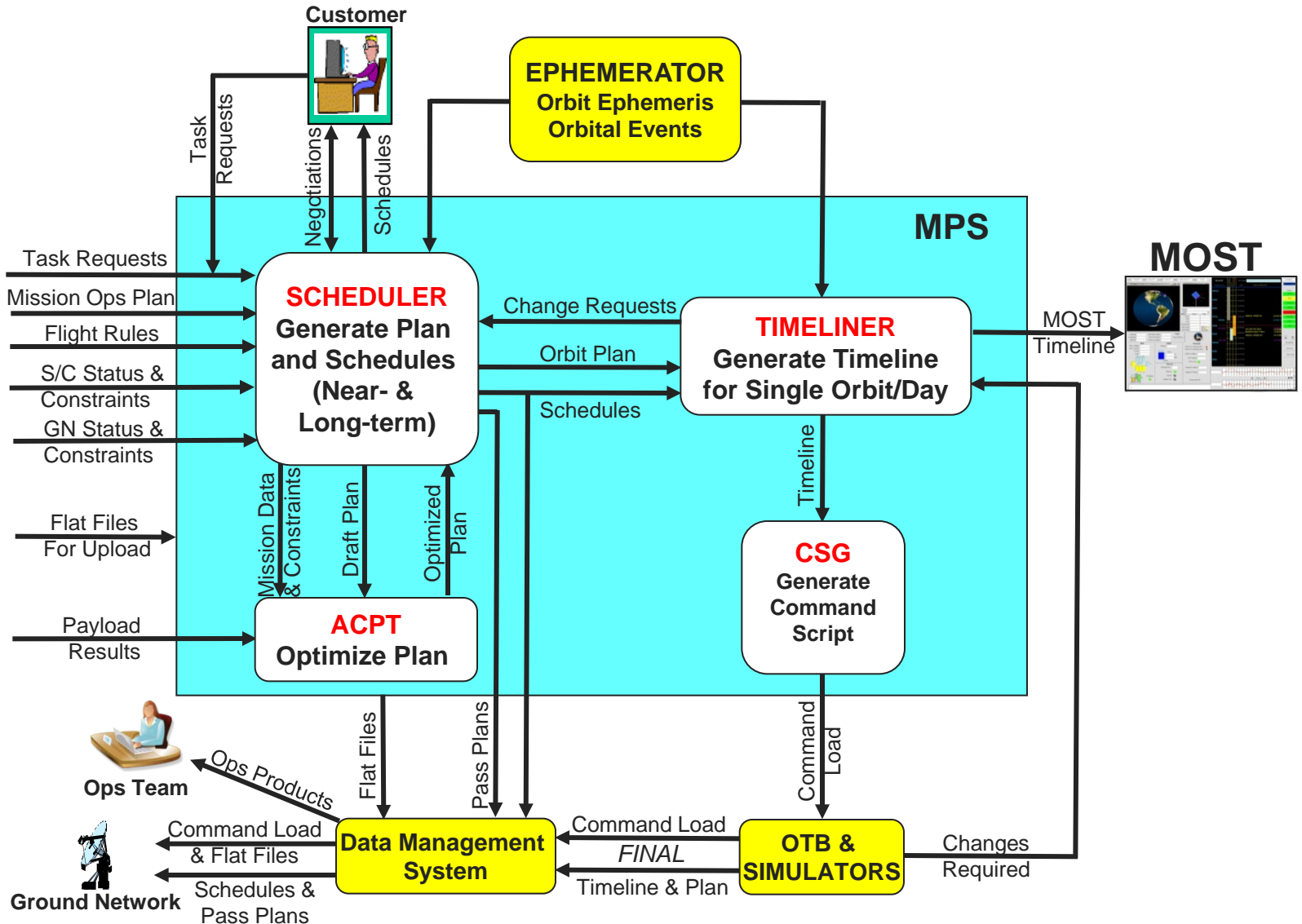




Features of COSMOS

- 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

Mission Planning & Scheduling Tool (MPST)





ACPT by Riverside Research Institute



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:

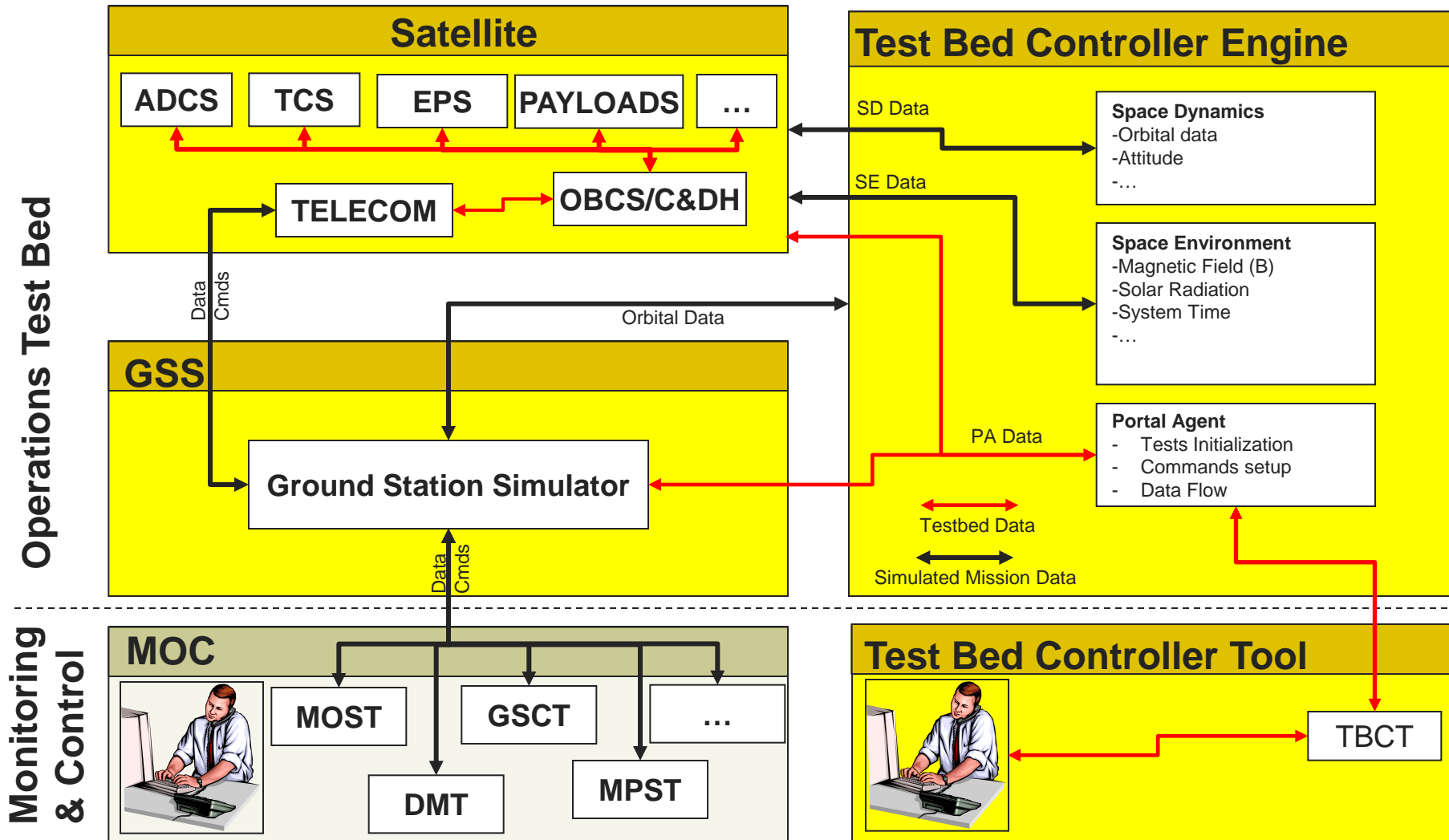
- Configurable 4D Visualization
- GIS Data (terrain, imagery, and maps)
- Satellite Propagation and Modeling
- Collection Sensor Modeling
- Power and Memory Modeling
- Target/Tasking Management
- Historic Global Cloudfreeness Data
- Communications Planning
- Exclusion Calculators
- Collection Strategy 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

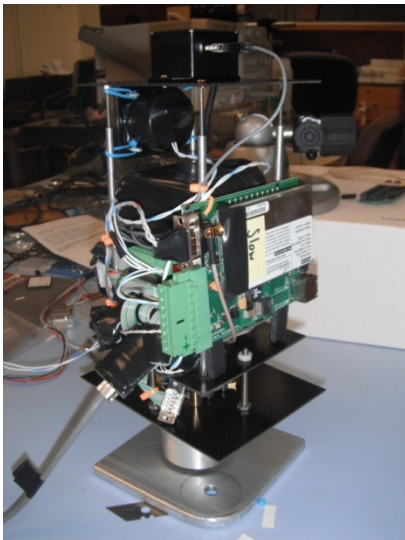




OTB Usage



HS-1 Mockup in Cradle



HS-1 ADCS Single Axis Test Bed

- 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

```

[ LAUNCH TIME: 14:26:00.00 ] [ MODE: 2s ] [ NO LOGGING ]
                                -00:29 -00:
                                OPN_DR  PNT_
-----*-----*-----
                                t-inin      Launch      rk_ao
                                00:58      -00:02      -00:5
ROLL  PITCH  YAW  M:PNT TGN: 1 PGN:13 AUD:250 FIL:2 P/T: 2 2 GSIP:100s
PRED: 0.264 -0.040 -0.343
CALC: 0.000 0.000 0.000 [Sunlight off bottom LACE] +00:33 14:25:53
DELT: 0.264 -0.040 -0.343 <<<<<< LAUNCH >>>>>> -00:01 delta t
CHSN: 0.000 0.000 0.000 [Sun angle>93 deg] -00:21 0.00
  
```

Press Return To Continue:

UVPI Encounter Manager Sample Screen



LUNOPS on Left Screen in Clementine MOC



Mission Operations Support Tool (MOST)

Attitude Determination and Control Subsystem [ADCS]

UTC 11.02.15 07:57:56 am HST 07:57:56 am

OK

IMU 1

Q0

Q1

Q2

Q3

Acceleration (m/s²)

X

Y

Z

Magnetic Field (nT)

Satellite Vector View

Reference Frame

Estimated States

Total Attitude Matrix

| | | |
|--------|--------|--------|
| 0.203 | -0.646 | -0.736 |
| -0.899 | -0.421 | 0.121 |
| -0.388 | 0.637 | -0.666 |

Total Angular Velocity

X (Deg/s)

Y (Deg/s)

Z (Deg/s)

Position

Lat. (Deg)

Long. (Deg)

Altitude (m)

Sun Sensor 1

| Quadrant Voltages | | Azimuth (Deg) |
|-------------------|---|-----------------|
| 0.554 | 0 | 82 |
| | | Elevation (Deg) |
| 0 | 0 | 33.6 |

Sun Sensor 2

| Quadrant Voltages | | Azimuth (Deg) |
|-------------------|---|-----------------|
| 0 | 0 | 352 |
| | | Elevation (Deg) |
| 0 | 0 | 33.6 |

Sun Sensor 3

| Quadrant Voltages | | Azimuth (Deg) |
|-------------------|-------|-----------------|
| 0 | 0 | 262 |
| | | Elevation (Deg) |
| 0 | 0.554 | 33.6 |

GPS 1

Sampling Rate (Hz)

X (m) Lat. (Deg)

Y (m) Long. (Deg)

Z (m) Altitude (m)

GPS 2

Sampling Rate (Hz)

X (m) Lat. (Deg)

Y (m) Long. (Deg)

Z (m) Altitude (m)

Controls

| | Torque (Nm) | Current (A) |
|----------------|---------------------------------------|------------------------------------|
| Torquerod 1 | <input type="text"/> | <input type="text"/> |
| Torquerod 2 | <input type="text"/> | <input type="text"/> |
| Torquerod 3 | <input type="text"/> | <input type="text"/> |
| | Torque (Nm) | Speed (rpm) |
| Reaction Wheel | <input type="text" value="1.88e-08"/> | <input type="text" value="0.355"/> |



COSMOS Executive Operator

Resources

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

CONTROL ALLOCATIONS

| ID | Lat | Lon | Name | MOCID | OSC |
|-----|-----|-----|------|-------|-----|
| 001 | 001 | 002 | 003 | 004 | 005 |
| 006 | 007 | 008 | 009 | 010 | 011 |
| 012 | 013 | 014 | 015 | 016 | 017 |
| 018 | 019 | 020 | 021 | 022 | 023 |
| 024 | 025 | 026 | 027 | 028 | 029 |
| 030 | 031 | 032 | 033 | 034 | 035 |
| 036 | 037 | 038 | 039 | 040 | 041 |
| 042 | 043 | 044 | 045 | 046 | 047 |
| 048 | 049 | 050 | 051 | 052 | 053 |
| 054 | 055 | 056 | 057 | 058 | 059 |
| 060 | 061 | 062 | 063 | 064 | 065 |
| 066 | 067 | 068 | 069 | 070 | 071 |
| 072 | 073 | 074 | 075 | 076 | 077 |
| 078 | 079 | 080 | 081 | 082 | 083 |
| 084 | 085 | 086 | 087 | 088 | 089 |
| 090 | 091 | 092 | 093 | 094 | 095 |
| 096 | 097 | 098 | 099 | 100 | |

PERSONNEL

| Control | Station | MOCID | OSC | DMIT | TRCT | AO |
|-----------------|---------|-------|-----|------|------|----|
| Flight Director | 001 | | | | | |
| SpaceCaret 1 | 019 | | | | | |
| SpaceCaret 2 | 019 | | | | | |
| SpaceCaret 3 | 019 | | | | | |
| SpaceCaret 4 | 019 | | | | | |
| SpaceCaret 5 | 019 | | | | | |
| SpaceCaret 6 | 019 | | | | | |
| SpaceCaret 7 | 019 | | | | | |
| SpaceCaret 8 | 019 | | | | | |
| SpaceCaret 9 | 019 | | | | | |
| SpaceCaret 10 | 019 | | | | | |
| Trn sec 1 | 019 | | | | | |
| Trn sec 2 | 019 | | | | | |
| Trn sec 3 | 019 | | | | | |
| Trn sec 4 | 019 | | | | | |

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

STATUS OF ALL SATELLITES

ENLARGED STATUS DISPLAYS

GROUND TRACKS (SELECTABLE)

COSMOS SYSTEM PERFORMANCE

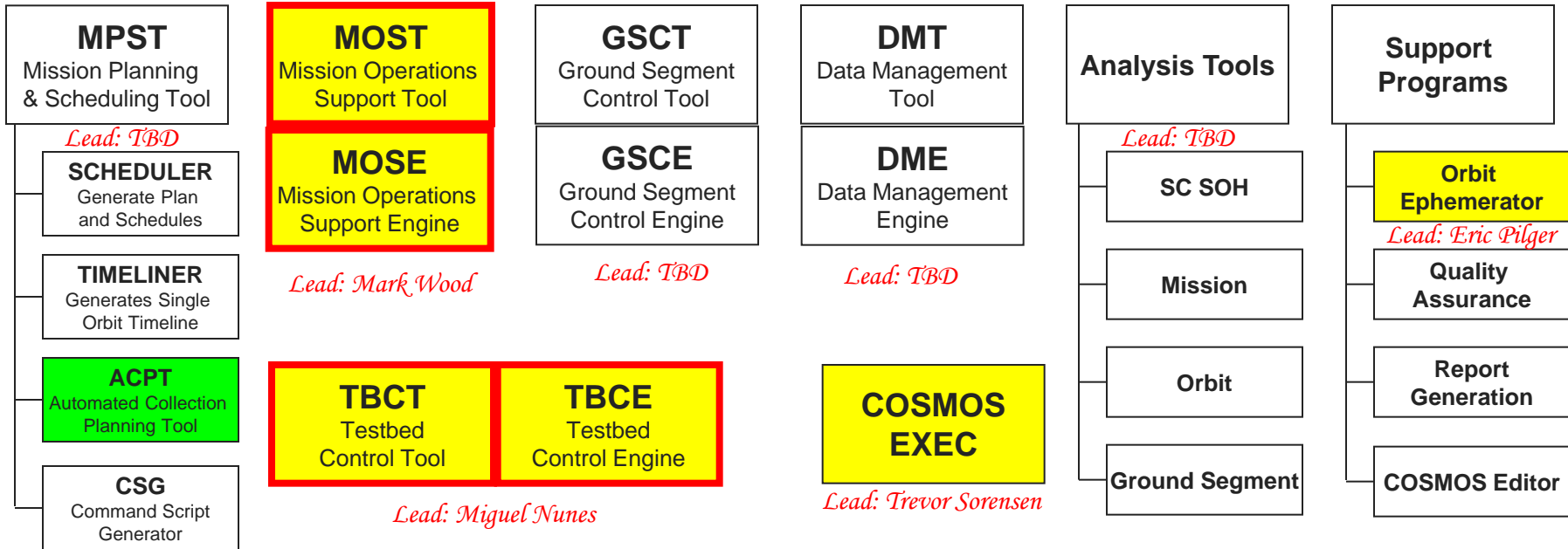
| | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 |
|------|-----|-----|-----|------|------|-----|-----|-----|-----|-----|
| CPU | MC1 | MC2 | MC3 | OTB1 | OTB2 | MC5 | MC6 | MC7 | MC8 | MC9 |
| MEM | | | | | | | | | | |
| DISK | | | | | | | | | | |

GROUND NETWORK MONITOR (TBD)



COSMOS Software Applications

Tools & Support Software



Other Agents/Engines



Other Software



| | | | |
|---|---|---|--|
| 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

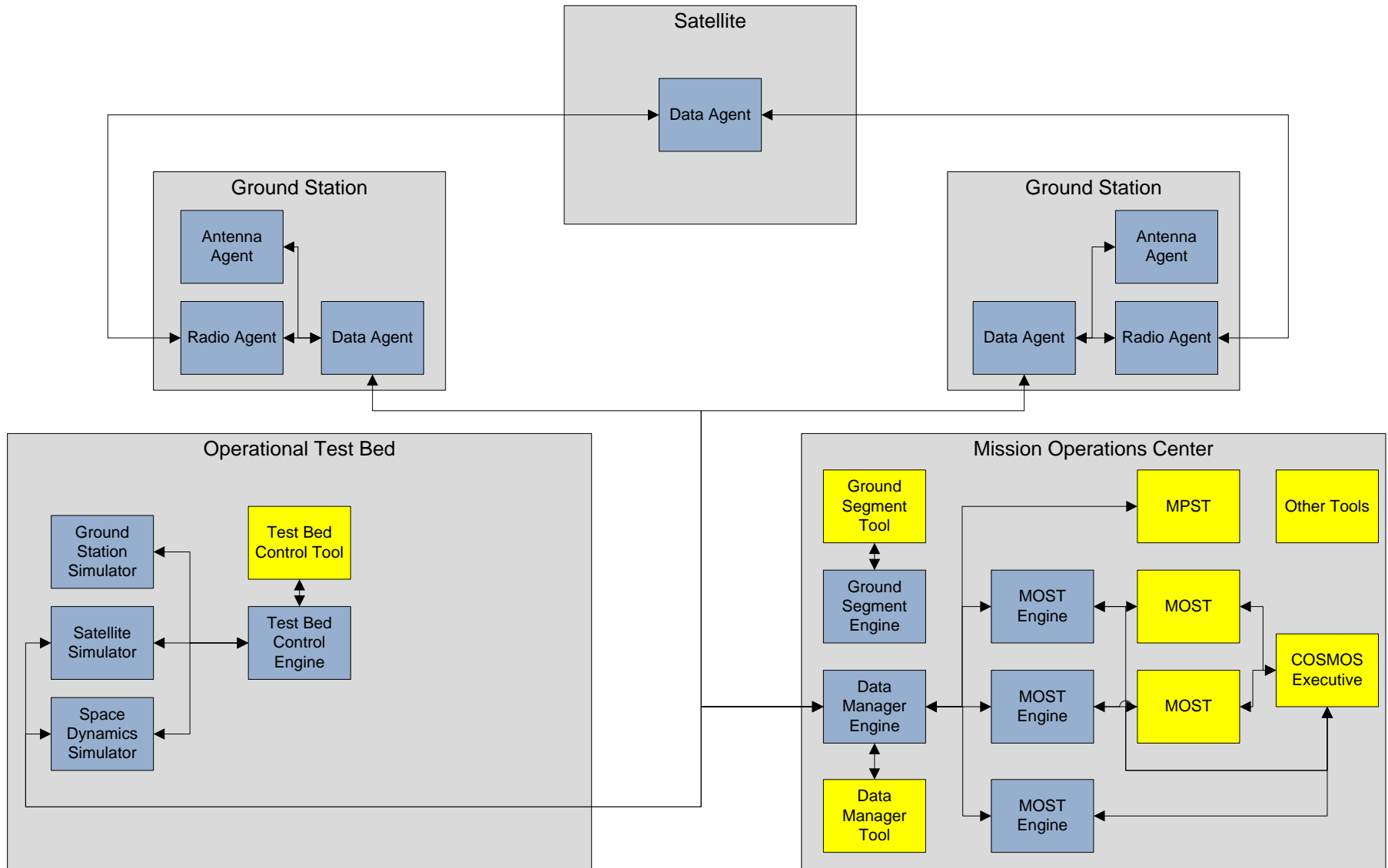


COSMOS Support Infrastructure

- 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 Process Interactions





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>

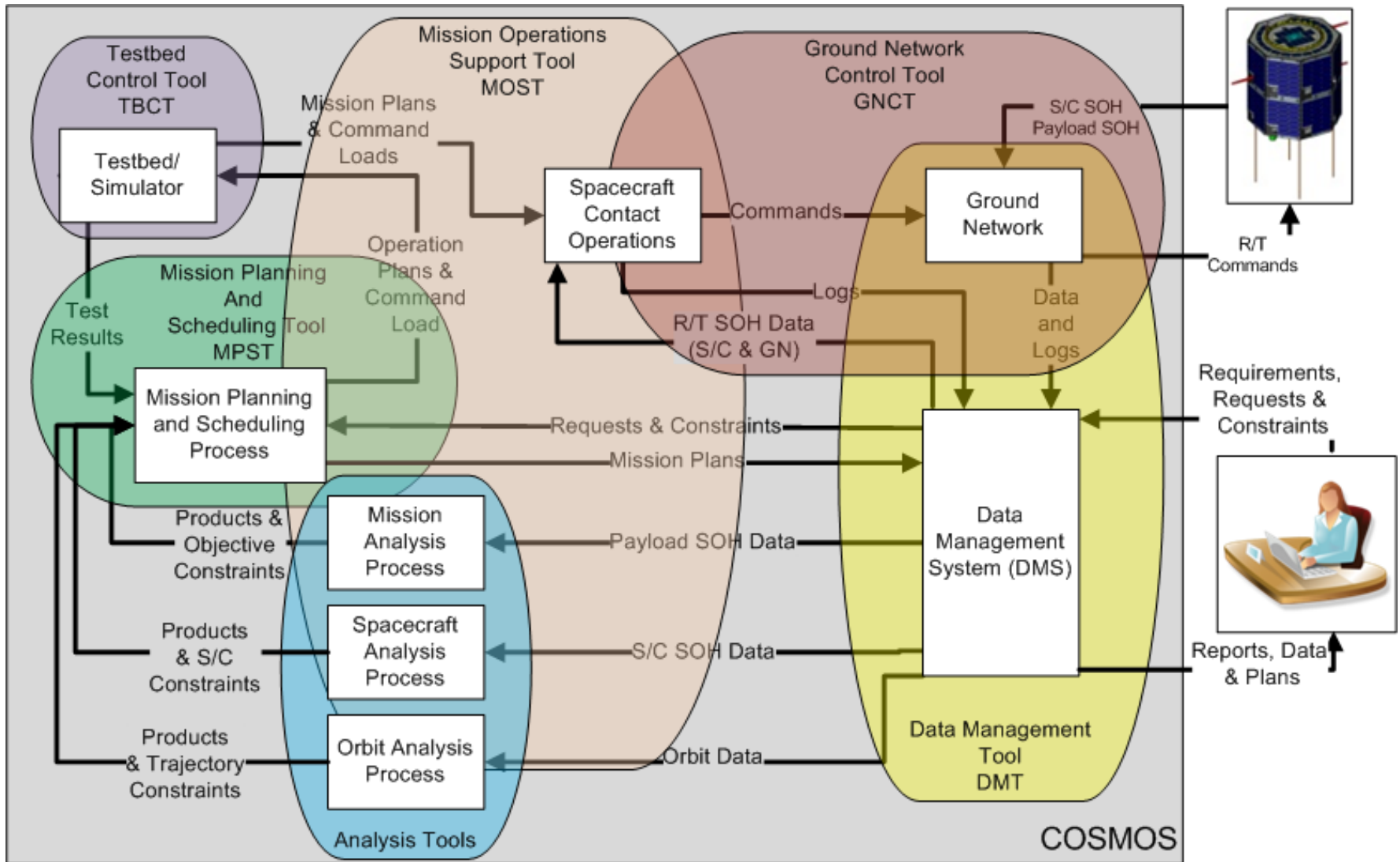




Backup Slides



COSMOS Block Diagram



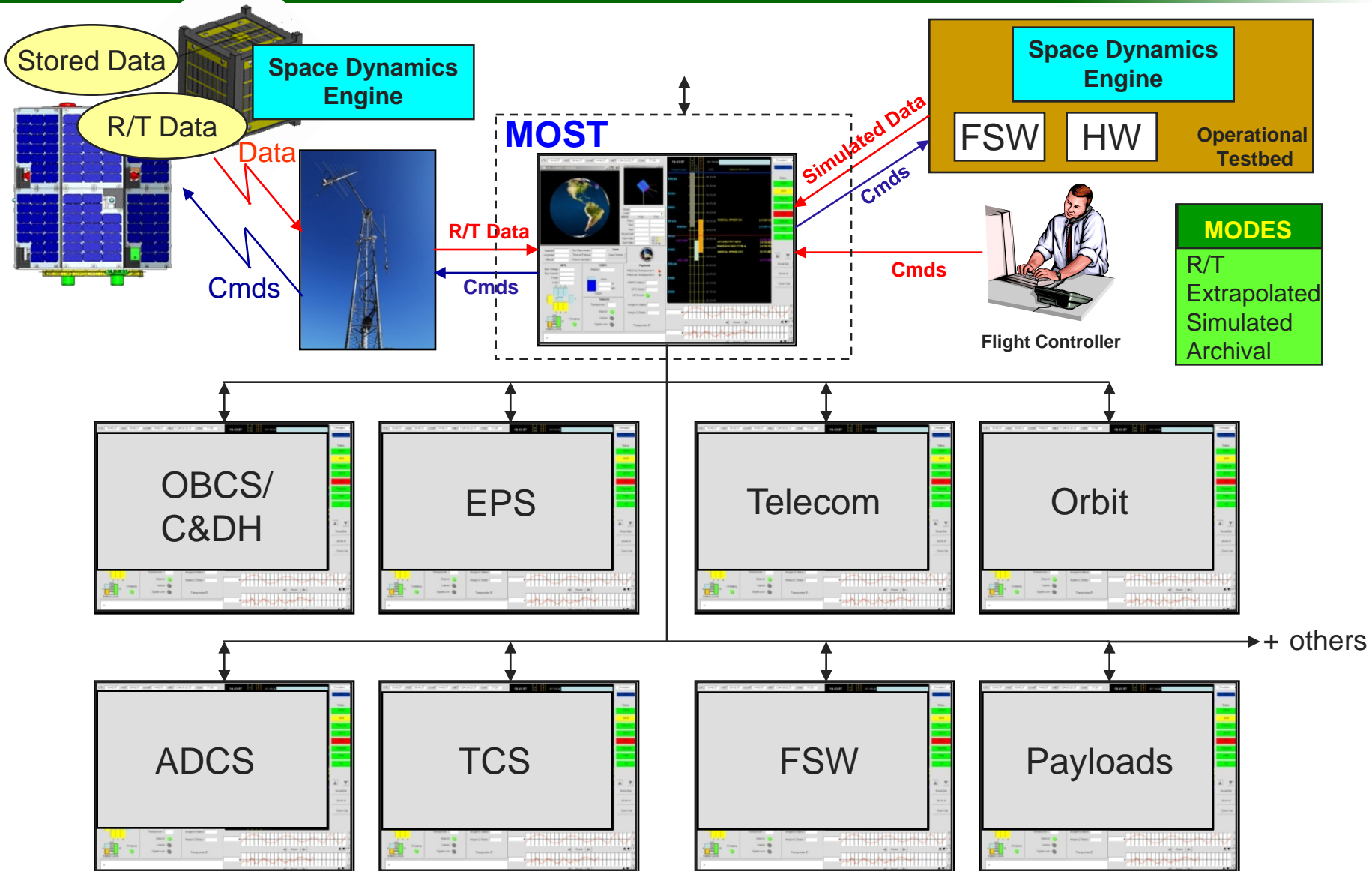


OTB Features

- 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, Python, C/C++, and/or other engineering COTS software utility tools.
- Support the development and operational test for different satellites

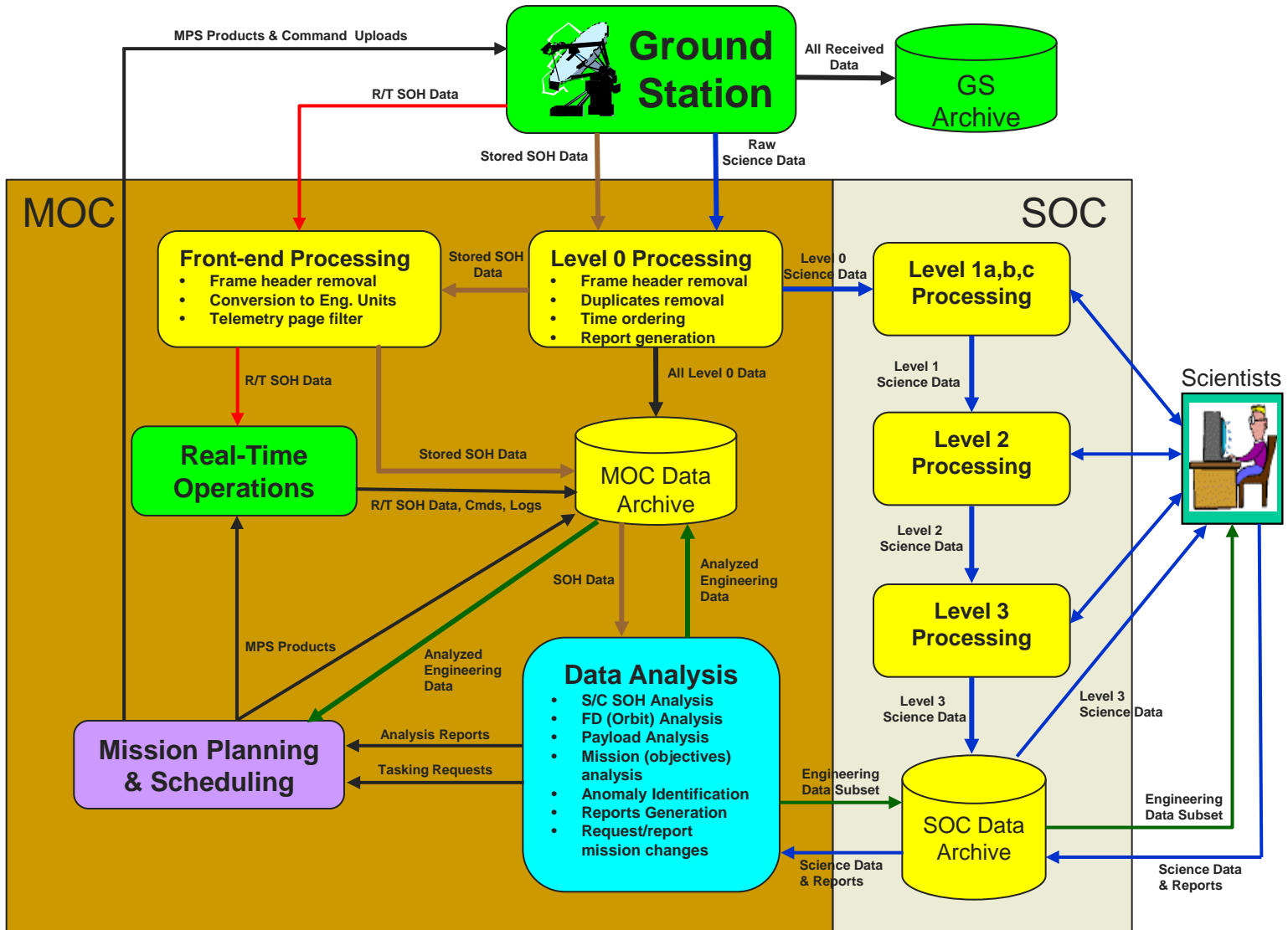


Mission Operations Support Tool (MOST)





DMS FF Block Diagram





COSMOS Project Schedule

| | 2010 | | | | 2011 | | | | | | | | 2012 | | | | | | | | 20 | | | | | | | | | | |
|----------------------------------|------|---|---|---|------|---|---|---|---|---|---|---|------|---|---|---|---|---|---|---|----|---|---|---|---|---|---|---|---|---|---|
| | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M |
| 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
- Nov. 10, 2010
- June, 2011
- **Oct, 2011**
- January, 2012
- Sept. 2012
- May 2013
- August 2013

Project start

Kick-off meeting with ARC

System Design Review (SDR)

Basic COSMOS ready to support HS-1

Test Readiness Review (TRR)

COSMOS-HSFL Mission Readiness Review

COSMOS-ARC Acceptance Review

Project Completion and Final Report