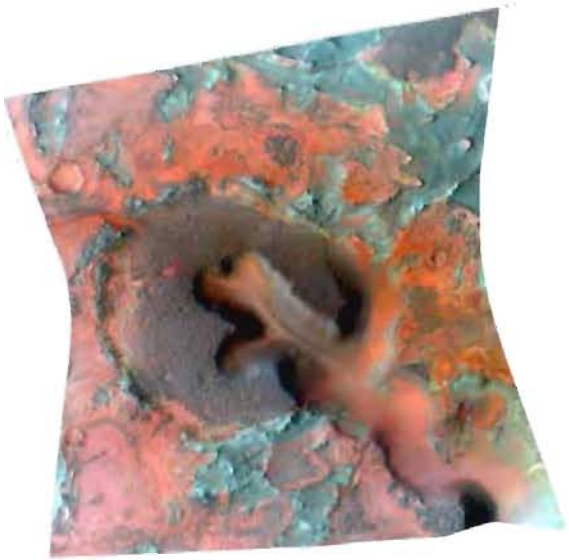
National Aeronautics and Space Administration

Mars Reconnaissance Orbiter Mission

Systems Engineering Challenges on the Mars Reconnaissance Orbiter Mission

Glen G. Havens
Jet Propulsion Laboratory,
California Institute of Technology



10 km

Space 2007 Conference
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Introduction

Systems Engineering Challenges — *Mars Reconnaissance Orbiter*

MRO project is a system of systems requiring system engineering team to architect, design, integrate, test, and operate these systems at each level of the project.

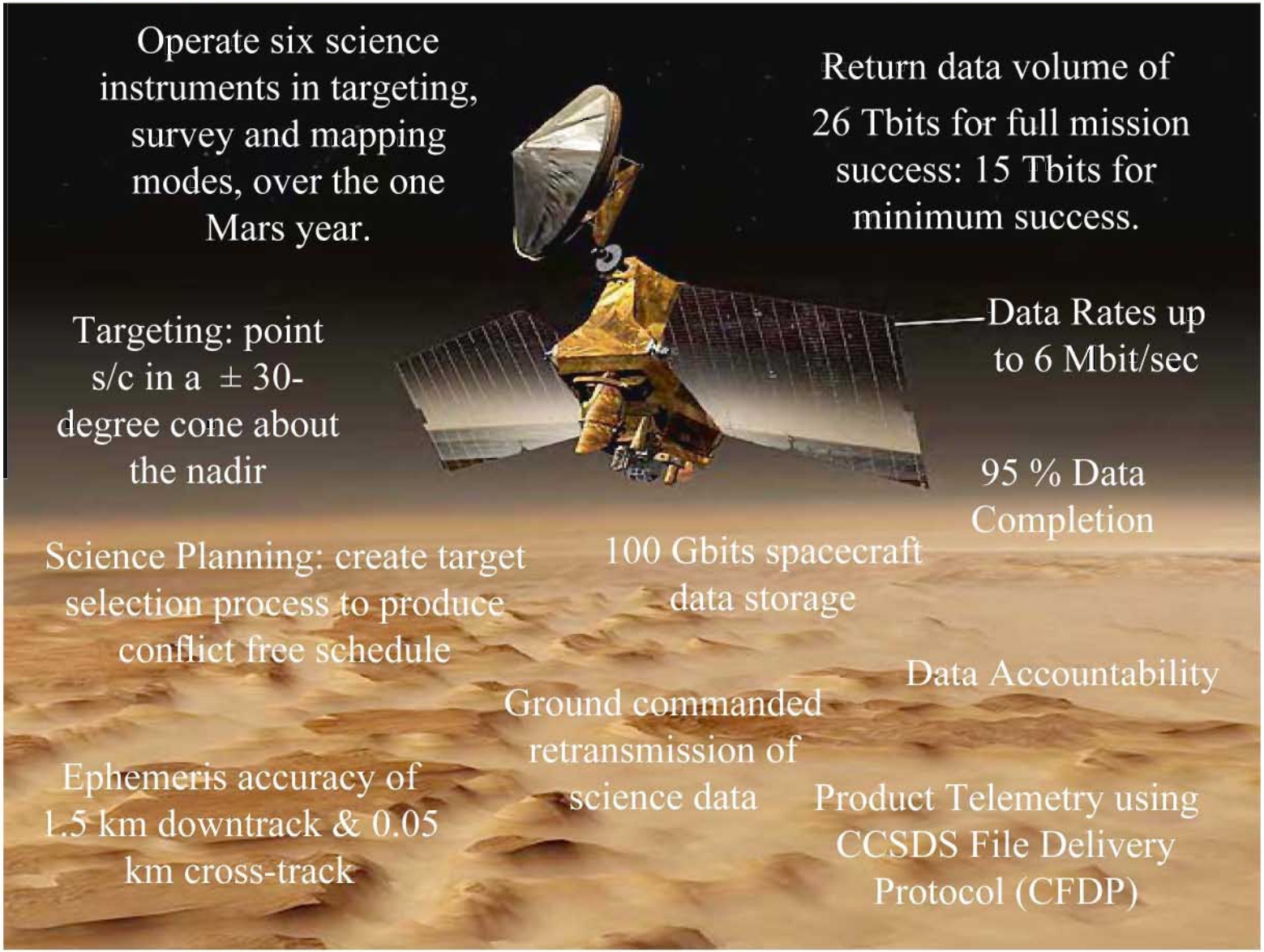
The challenge of system engineering mission objectives into a single mission architecture that can be integrated tested, launched, and operated.

Systems engineering must translate high-level requirements into integrated mission design .

MRO Project System		
Mission Design		
End-to-End Information System		
Ground System		
Mission Operations Teams	Mission Operations Processes	Ground Data System
Flight System		
Spacecraft	Payloads	ATLAS V Launch Vehicle

This presentation will discuss of some of the system engineering challenges that faced MRO, and their impact on the MRO system designs.

MRO Driving Requirements



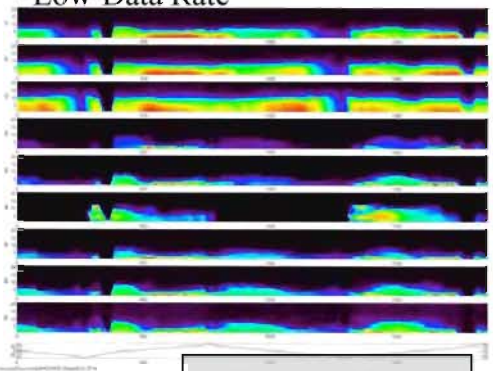
Diverse Mission Objectives of 6 Science Instruments

Systems Engineering Challenges — *Mars Reconnaissance Orbiter*

Climate Change

HiRISE: High-resolution Camera (0.5 m aperture)
- Very High Resolution
- Targeted Imaging
- Very High Data Rate

MCS: Atmospheric Sounder
- Daily Global Limb & Nadir Sounding
- Continuous Operations
- Low-Data Rate



Atmosphere

Surface Composition

CRISM: High-resolution Imaging Spectrometer
- Moderately-High Spectral & Spatial Resolution
- Targeted Observing & Global Survey
- Very High Data Rate

CTX: Mono-chromatic Context Camera
- High Resolution with Coverage
- Targeted Observing & Regional Survey
- High Data Rate

Surface Layering

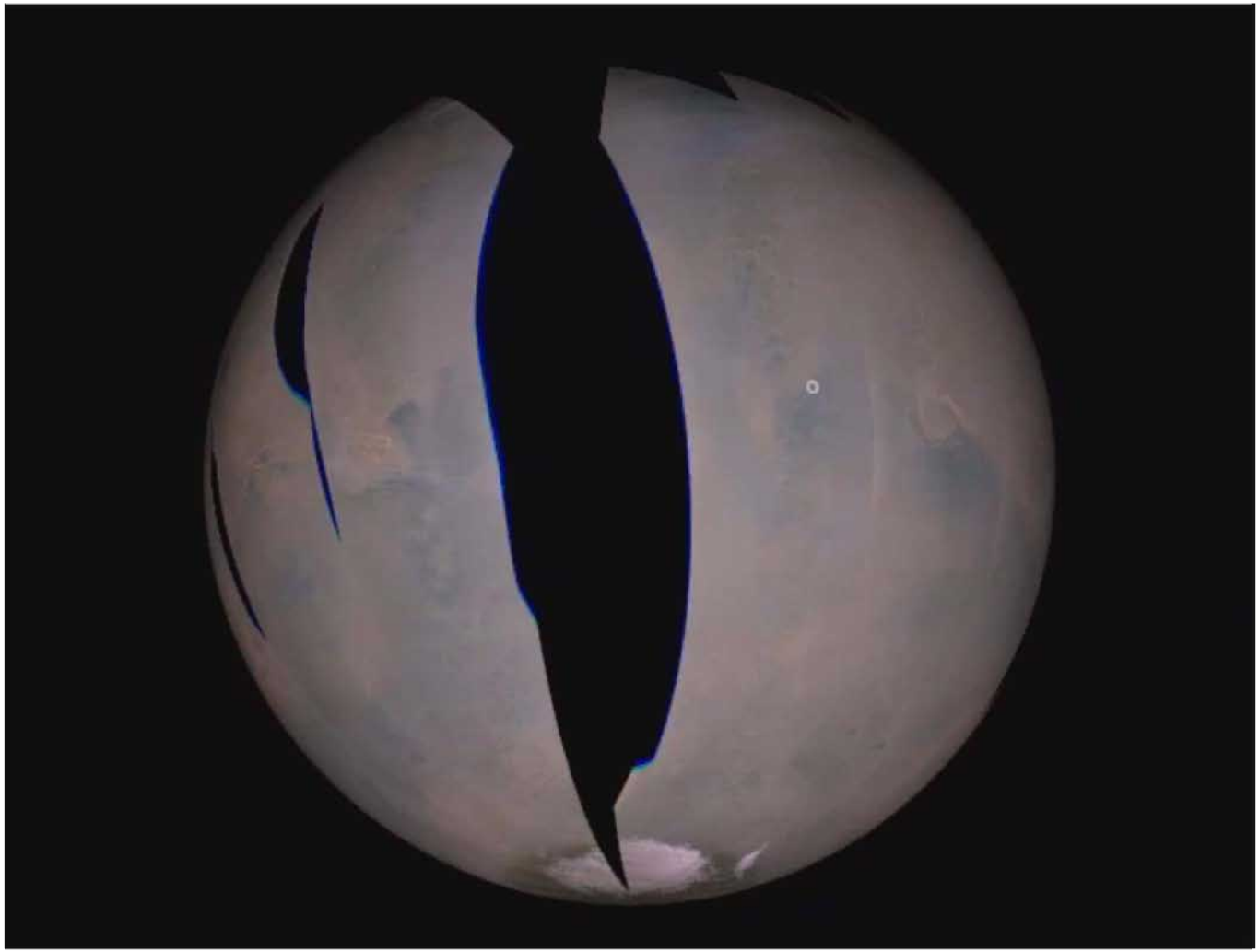
HiRISE

MARCI: Wide-angle Color Imager
- Daily Global Mapping,
- Continuous Dayside Operations
- Moderate Data Rate

Subsurface Ice & Structure

SHARAD: Shallow Subsurface Radar
- Shallow Sounding
- Regional Profiling
- High Data Rate

Conflicting Mission Objectives

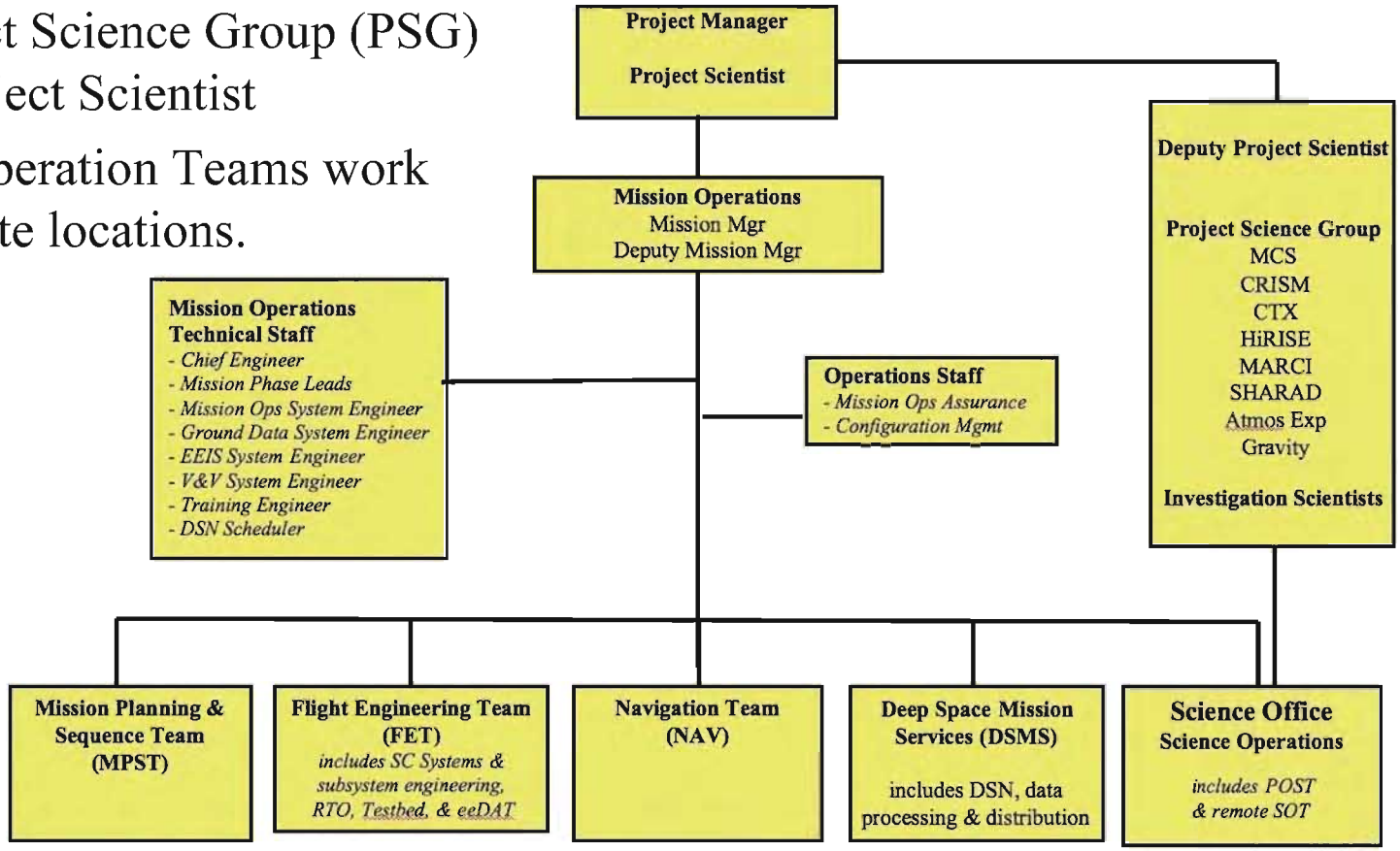


Target observations interrupting MARCI daily global maps

Mission Operations Overview

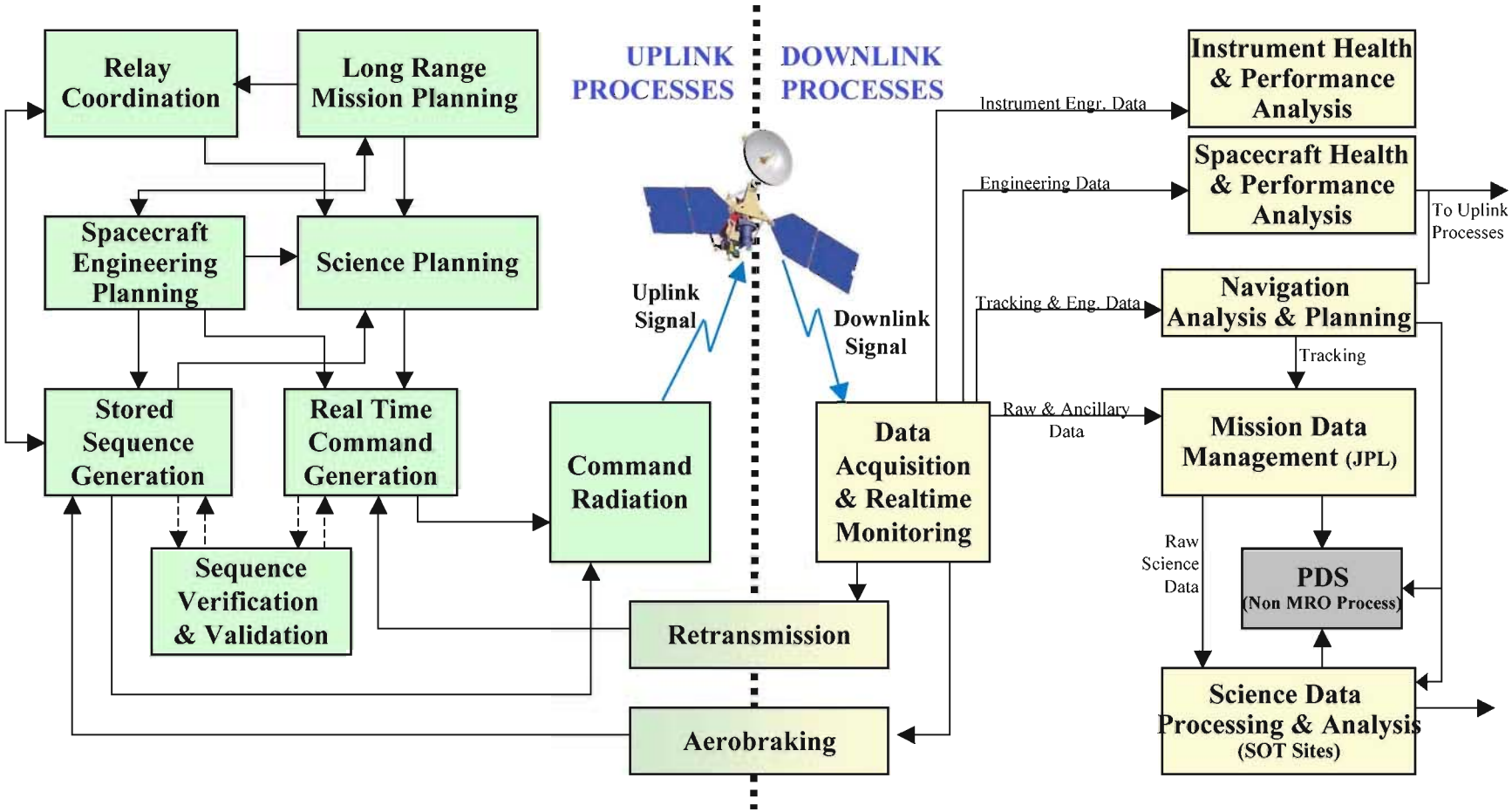
Systems Engineering Challenges — *Mars Reconnaissance Orbiter*

- Project is managed by JPL
- Lockheed Martin is main system contractor
- The Project Science Group (PSG) led by Project Scientist
- Science Operation Teams work from remote locations.



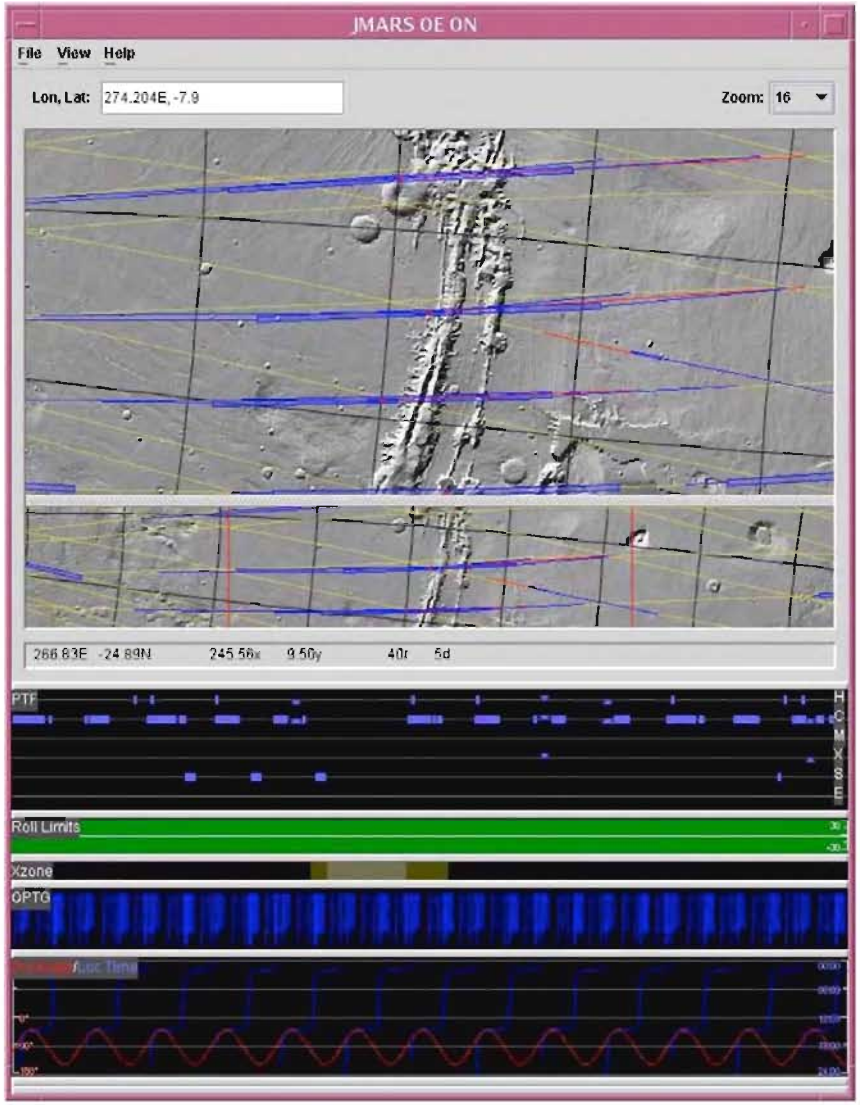
Mission Operations Overview

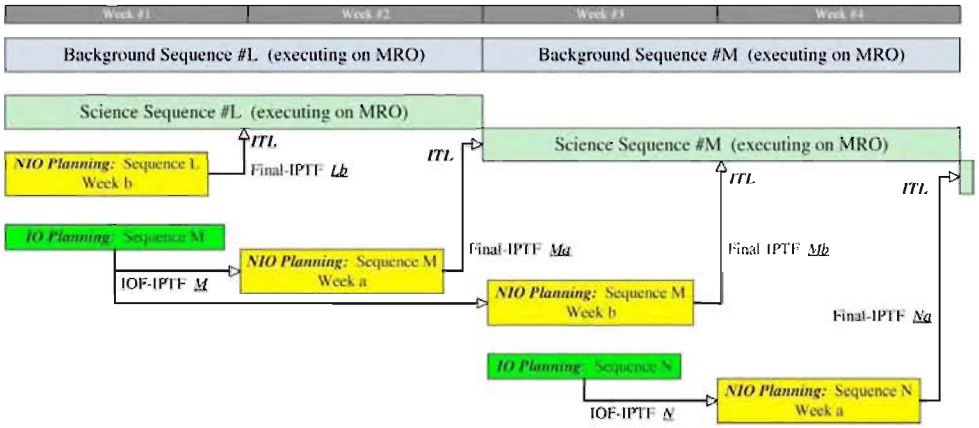
16 Operations Processes executed by MRO Operations teams



Systems Engineering Challenge 1: Development of an Integrated Science Planning Process

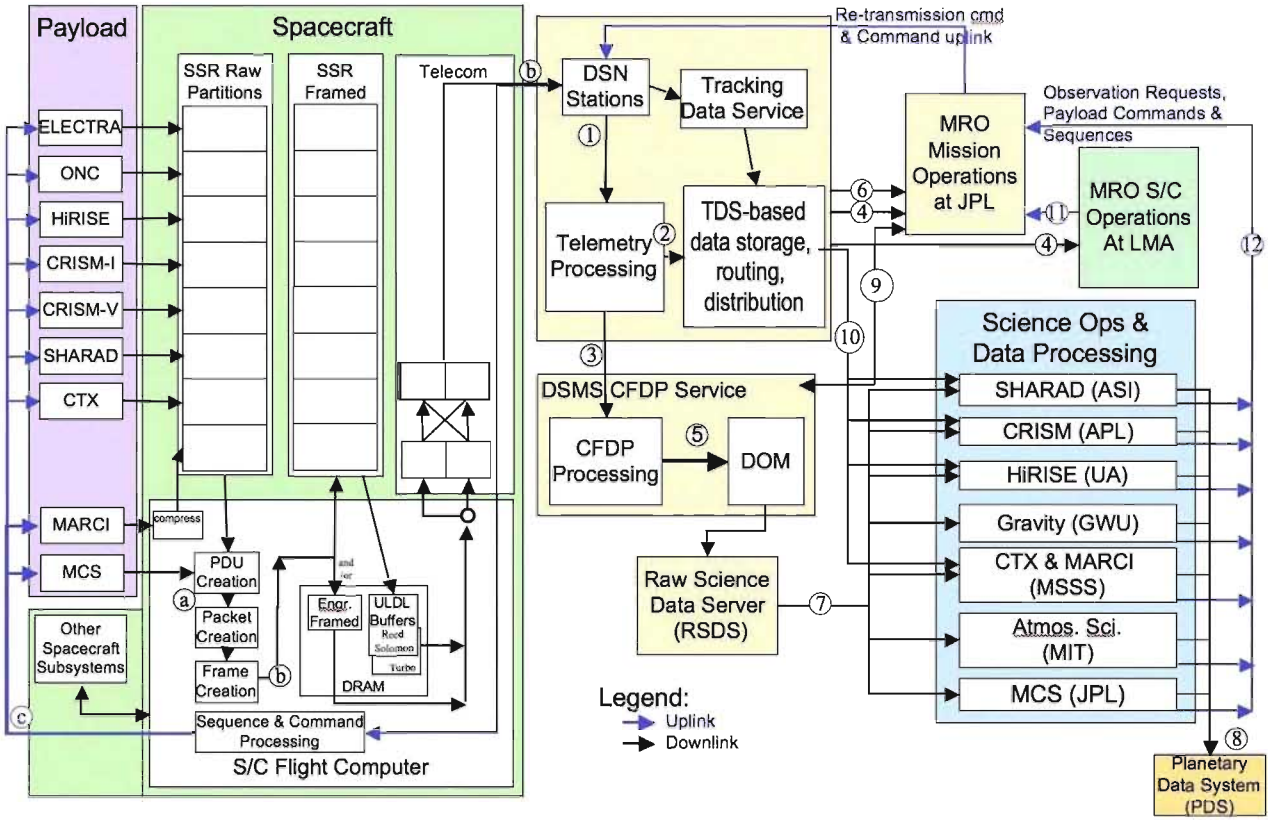
- Challenges of science planning:
  - Conflicting instrument observation modes
  - Maintain ephemeris accuracy
  - Meet science objectives
  - Resolve conflicts in an equitable manner.
- Solutions
  - Integrated Target List & onboard ephemeris
  - Creation of POST (Payload Operation Support Team)
  - Tools: MTT (Mars Target Tool), TOS (Target Opportunity Scheduler)
  - Waterfall scheduling process





Systems Engineering Challenge 2: Implementation of End-to-End Information System (EEIS)

- Challenges:
  - Over 34 Tbit in PSP
  - Rates up to 6 Mbps
  - 2000-3000 CFDP products/week
  - Limitations of DSN WAN
  - End-to-end visibility of science products
- Solutions:
  - Comprehensive EEIS testing
  - Established eeDAT team
  - New tool TRUST
  - Upgrades to DSN WAN and ground processing capability



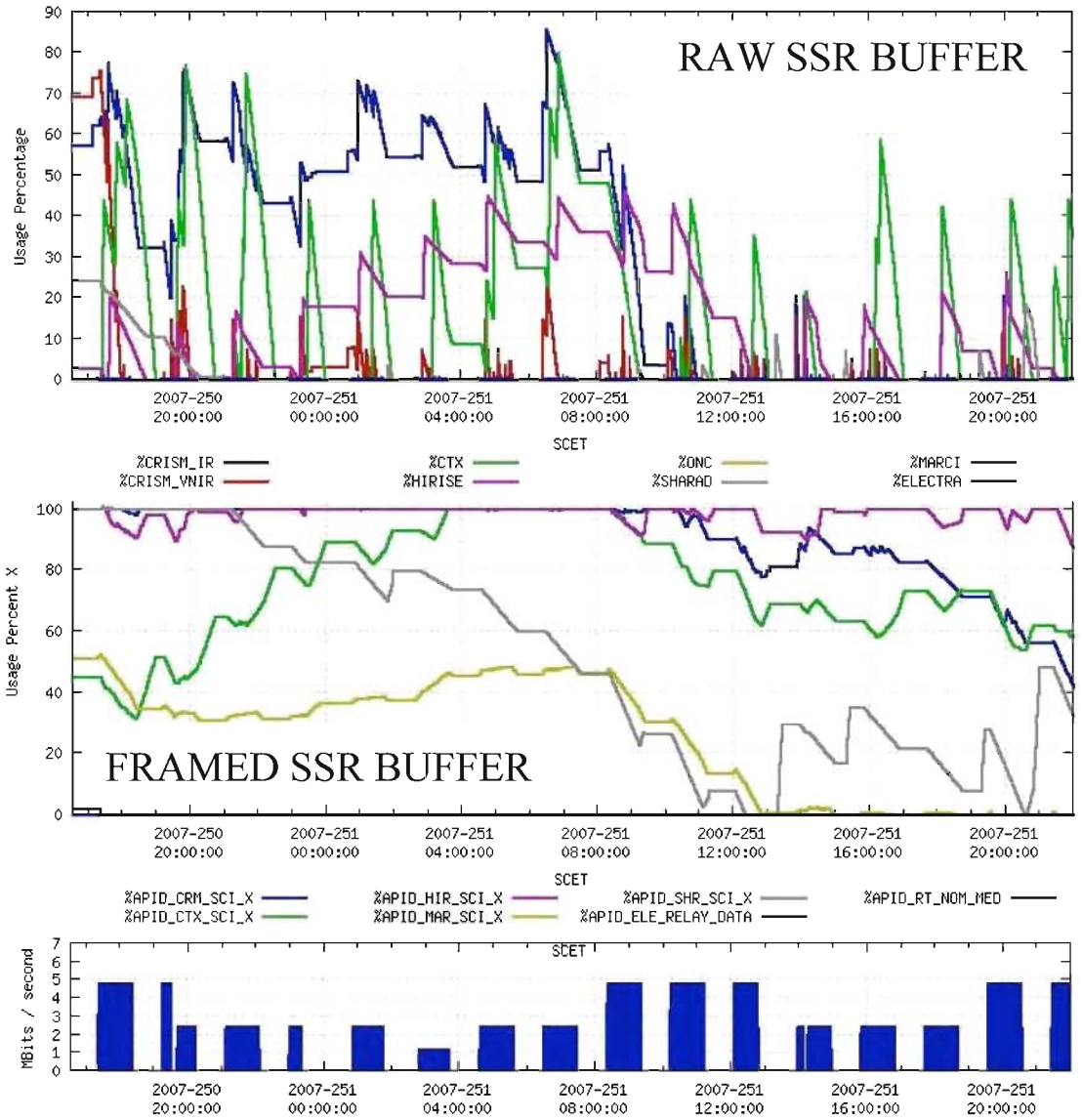
(a) CFDP PDUs
(b) AOS Frames
(c) Observation commanding

(1) SFDUs containing AOS Frames
(2) Non-CFDP Packets
(3) CFDP Packets
(4) S/C & Instr. Eng, & Tracking Data

(5) Science Data Products
(6) AOS Frame Accounting
(7) Science Products & Metadata Files
(8) PDS-labeled Science Products
(9) Science Product Accounting Data
(10) Instrument Engineering
(11) S/C Cmds & Seqs
(12) Instr. Cmds & Seqs

Systems Engineering Challenge 3: Management of Onboard Data Storage and Retransmission

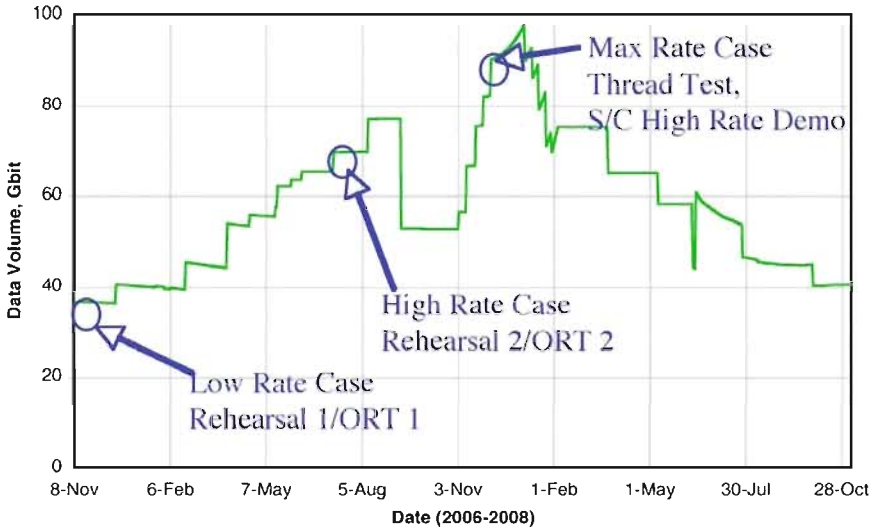
- Challenges:
  - 160 Gbit Solid State Recorder (SSR)
  - Utilize high downlink data volume without overflowing SSR
  - Provide science teams independence and fairness
  - Tight timeline to retransmit data before overwriting with new data
- Solutions:
  - Onboard data handling design provides operational independence for each instrument
  - PSG allocates downlink bandwidth % to science teams
  - Science Team & Data Tracker Tools
  - Automated retransmission commands based on frame gaps detected at DSN tracking stations.
  - Creation of retransmit framed buffer space to increase amount of time available to request



Systems Engineering Challenge 4: Design of Operational Readiness Tests

- Challenges of designing PSP ORT
  - Long duration: 4.5 weeks from beginning of PSP planning to end of 2-week execution cycle
  - Must demonstrate parallel/overlapping operations of planning multiple cycles, monitoring execution of current cycle, while downlinking and processing data at same time
  - Least heritage of PSP process from previous missions, compared to other mission phases, necessitated phased integration of components before testing higher rate scenarios

- Solutions
  - Thread test without timeline to validate team and software interfaces for science planning process
  - Low data rate and high data rate cases: "walk before you run"
  - Rehearsals provide experience working on timeline, output products executed on high fidelity test bed during ORTs
  - Finally, ORT's validate readiness for operations of parallel/simultaneous uplink & downlink processes.



Conclusion

- Systems engineering challenges were overcome utilizing a combination by creative designs built into MRO's flight and ground systems.
  - Design of sophisticated spacecraft targeting and data management capabilities
  - Establishment of a strong operations team organization
  - Implementation of robust operational processes
  - Development of strategic ground tools.

- The MRO system has met the challenge of its driving requirements.
  - MRO began its two-year primary science phase on November 7, 2006, and by July 2007, met it minimum requirement to collect 15 Tbits of data after only eight months of operations. Currently we have collected 22 Tbits.
  - Based on current performance, mission data return could return 70 Tbits of data by the end of the primary science phase in 2008.