



Integrated Design Center / Mission Design Laboratory

PACE 2012

Mission Operations

14 – 18 May, 2012

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N A S A G O D D A R D S P A C E F L I G H T C E N T E R





Topics

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- **Mission Overview/Ground System Functional Architecture**
- **Driving Requirements**
- **Design Requirements & Assumptions**
- **Mission Timelines**
- **Operations Plan**
- **Critical Events**
- **Technology Required**
- **Additional Trades**
- **Ground System Cost WAG**
- **Risk/Issues/Concerns**





Overview/Ground System Functional Architecture

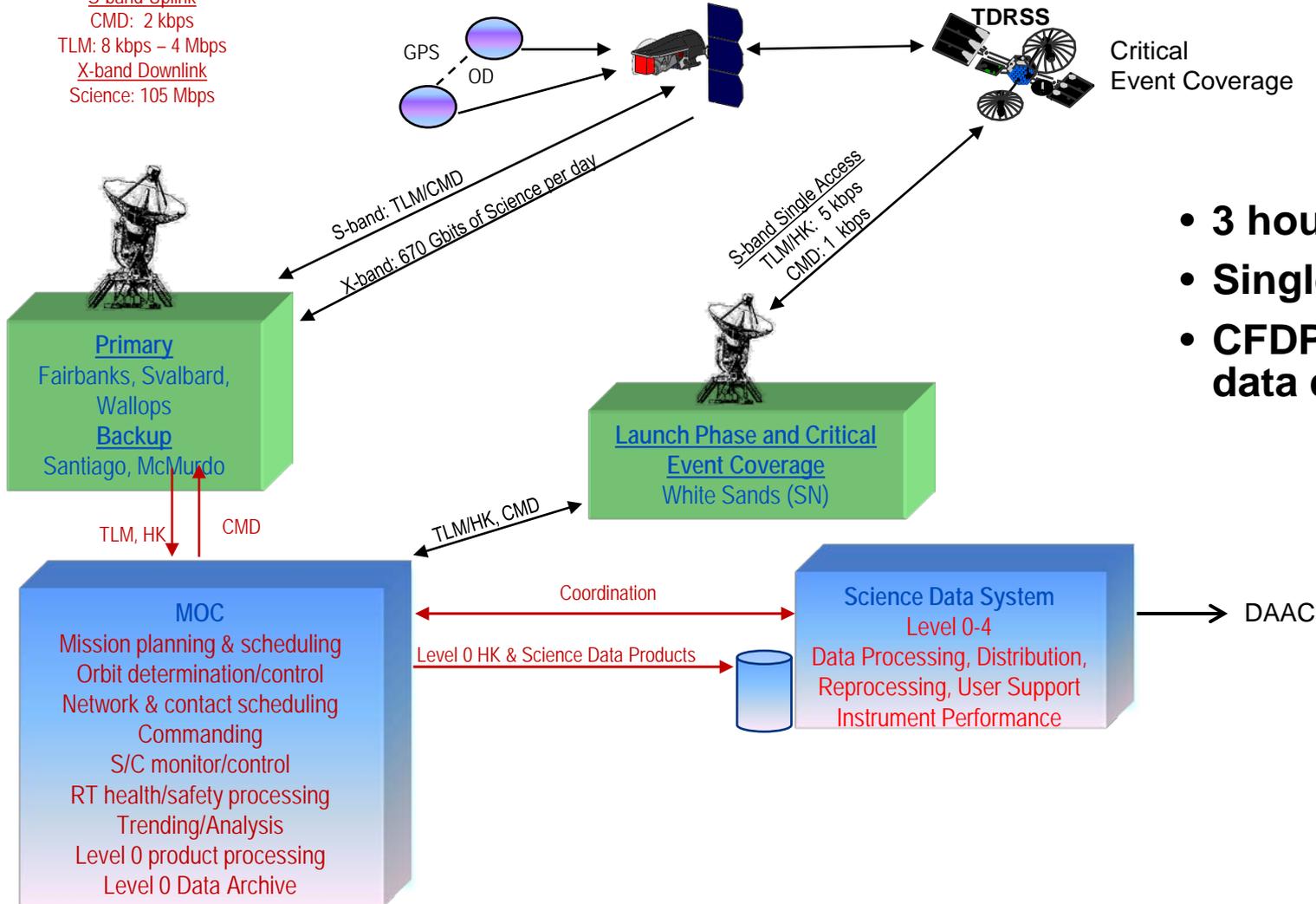
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S-band Uplink
 CMD: 2 kbps
 TLM: 8 kbps – 4 Mbps
X-band Downlink
 Science: 105 Mbps

Basis of cost study is in red

Legend:

CMD = Commanding
 HK = House-Keeping data
 OD = Orbit Determination
 TLM = Telemetry data



Critical
 Event Coverage

- 3 hour latency
- Single shift ops
- CFDP for complete data delivery





Driving Requirements

- **Launch date:** Mission Design Laboratory
 - October 1, 2019
- **Mission Life:**
 - 3 years (5 years goal)
- **Orbit:**
 - 700 km circular sun synchronous noon MLTAN
 - 98.2° inclination
- **Science Data:**
 - 670 Gbits per day (includes 30% contingency)
- **Data Latency**
 - 3 hours (95% of the time)
- **Data Completeness**
 - 99% (enabled by CFDP)
- **End of Mission:**
 - Controlled Re-entry
- **Mission Type:**
 - Class C mission





Design Requirements & Assumptions

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- **Mission Operations Control (MOC):**
 - Provides S/C commanding, mission planning/scheduling, and telemetry monitoring, housekeeping trending and analysis and Level Zero Processing (LZP)
- **Science Operations Control (SOC):**
 - Science data processing, instrument performance monitoring, instrument command generation, user community support, preparation for archiving
- **Ground Stations**
 - Fairbanks
 - Svalbard
 - Wallops
 - McMurdo, Santiago (Backup)
 - TDRSS (Launch & Critical Events)
- **Ground Contacts**
 - Contacts every orbit ~8.5 minutes long
- **Spacecraft data rates via NEN**
 - X-Band downlink data rate of 105 Mbps
 - S-Band uplink data rate of 2kbps for CMD and downlink data rate of 8 kbps – 4 Mbps for TLM/HK
 - Class 1 CFDP for TLM/HK and Science data
- **TDRSS link for critical event coverage**
- **Data Latency Requirements:**
 - 3 hours
- **Orbit Determination and Time Correlation:**
 - Onboard GPS





Orbit Timeline

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Minutes

10 20 30 40 50 60 70 80 90



POL

Observe

Night

OCE

Observe, -20° tilt

Switch at zenith

Observe, 20° tilt

Once per day

Switch to 0° tilt

Solar Calibration

Set to 0° tilt

Night

Eclipse

Spacecraft

Svalbard
Contact

Solar Cal location on timeline is approximate – actual time depends on instrument/sun geometry

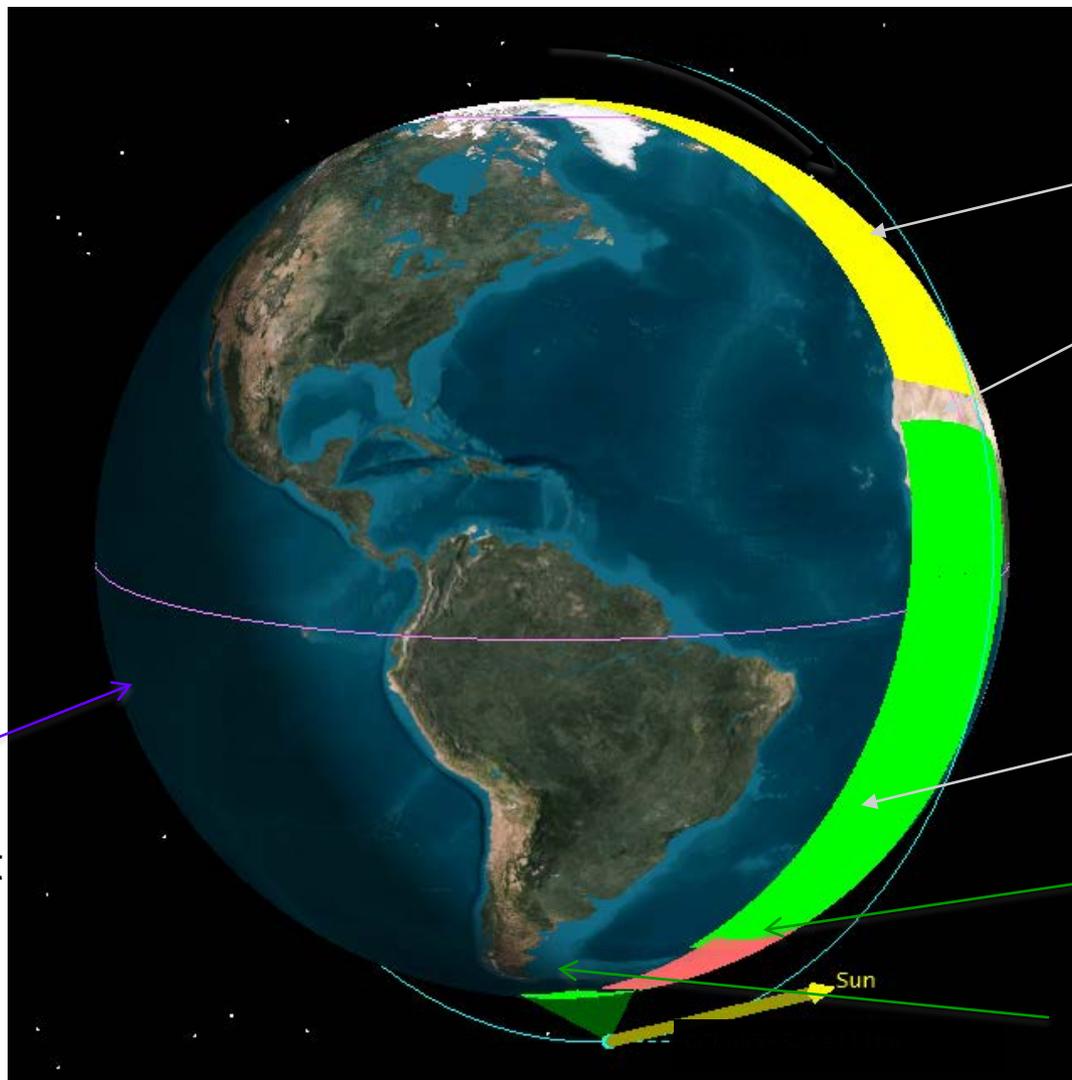
May interfere with end of observation





Forward and Aft Scans Switched at Sun Zenith

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-20° along track tilt

Switch at Sun Zenith

+20° along track tilt

Switch to 0 tilt nadir

Daily Solar cal, nadir

Reset to -20° along track tilt





2 Day Timeline

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Orbits

3 6 9 12 15 18 21 24 27



Solar Cal



Vicarious Calibration



Ground Station

Contacts

Svalbard



Wallops



Poker Flat

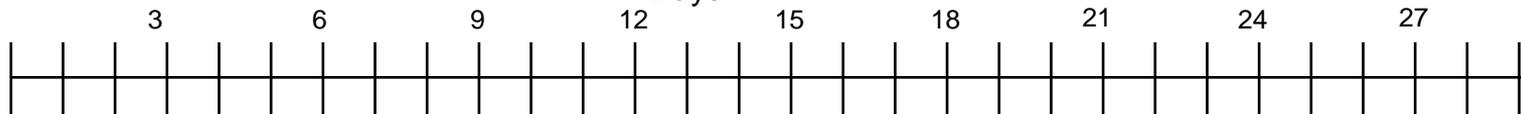




Monthly Timeline

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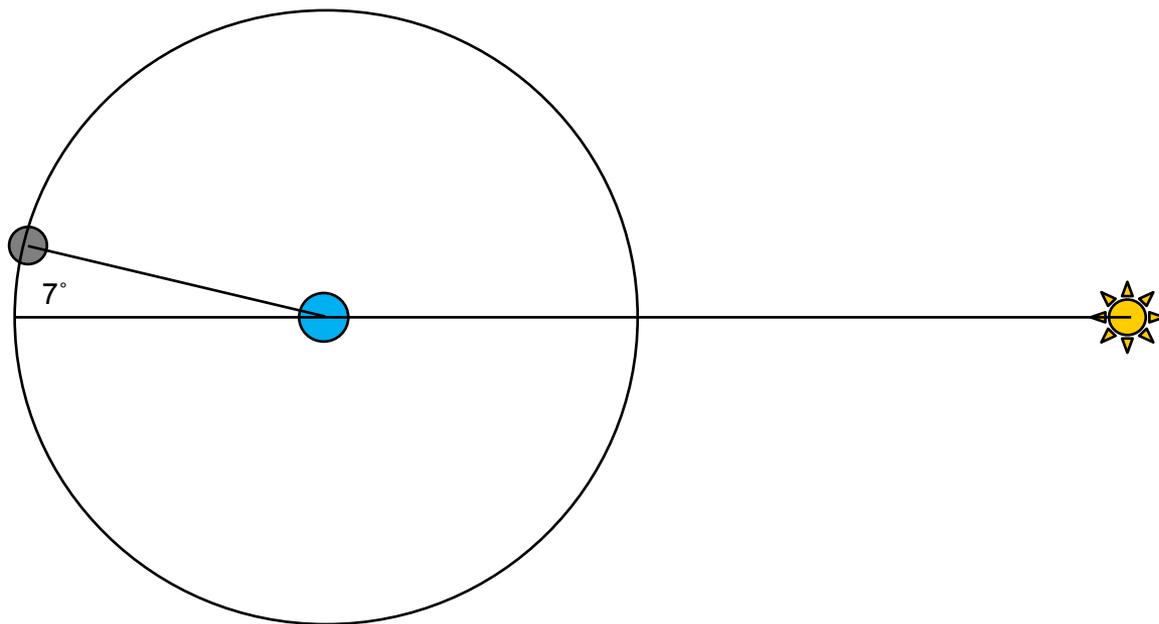
Days



Lunar Cal



- Once per lunar cycle
- 7° from full, within 0.5°
 - Only one orbit meets this requirement

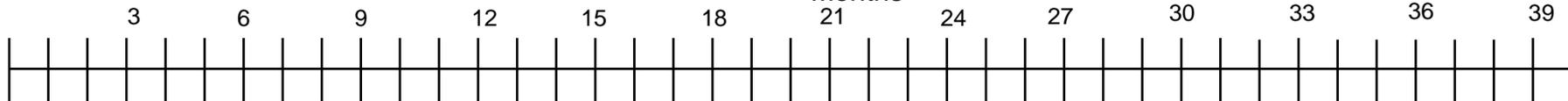




Mission Timeline

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Months



▼ Launch

Checkout and Commissioning

3 months

Normal Operations

36 months

End of mission deorbit —
1 month

▼ Orbit Correction

Deorbit ▼

- **No orbit maintenance required**





Post Launch Timeline

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Weeks

3

6

9

12

▼ Launch

▼ Separation

▼ Attitude acquisition

▼ Solar Array Deployment

▼ Propulsion system test

▼ Orbit Correction

Critical Events

Spacecraft Checkout

Outgassing

Instrument Checkout

Instrument Calibration and Commissioning

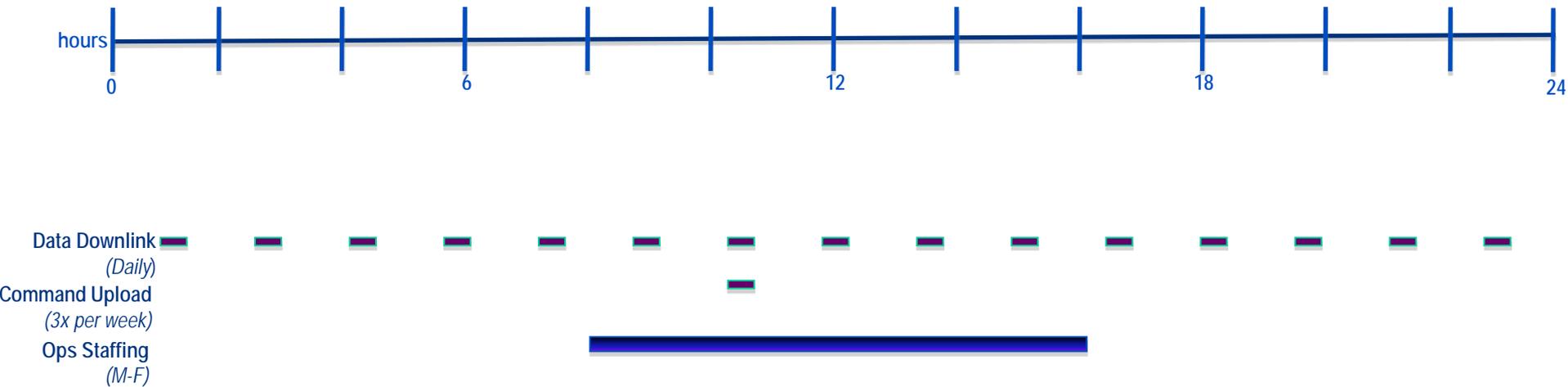




Daily Ground Operations

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Ground Operation





Operations Plan

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- **Operations Staffing**
 - 8x5 operations
 - Autonomous monitoring when unstaffed, and designated ops team members alerted in the event of a problem or opportunity
- **Operations Center Development**
 - Reuse existing facility and software
 - Due to simple and modest spacecraft operations, a multi-mission MOC will be the most cost-effective approach





Critical Events

M i s s i o n D e s i g n L a b o r a t o r y

- **Launch phase**
 - Fairing separation
 - Initial attitude acquisition
 - Solar array deployment
 - Propulsion system checkout
 - Orbit Maneuvers

- **Coverage via TDRSS**
 - No supplemental resources required

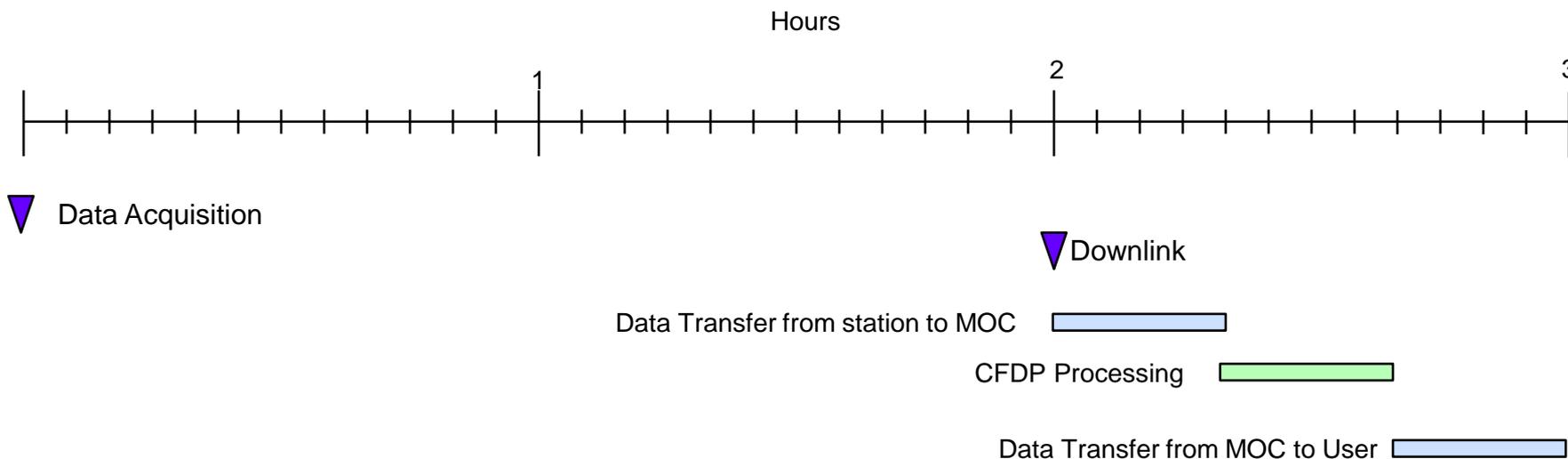




Latency

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- Requirement 3 hours 95% of the time
- Requires high priority for access to shared bandwidth between stations and MOC
- ≥ 50 Mbps ground transfer data rates





Technology Required

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- **MOC Implementation**

- No mission requirements that drive technology -- technology required is readily available and operational today for several spacecraft.
- Existing centers and equipment will provide sufficient capabilities to satisfy all mission requirements

- **LZP Requirements**

- Achieve through CCSDS File Delivery Protocol

- **Technology Readiness Level: 8-9**

- All required technologies have been at least demonstrated, most in current operational systems.

- **Technology Complexity: Minimal**

- Currently available/operational technology proposed in virtually all instances.





Ground System Cost WAG

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- Ground systems ~10% of overall mission cost
- MOC cost derived from costs for similar earth science missions
- Rest of cost allocated to Science data system
- Reprocessing all data several times a year
 - Not likely to be a significant challenge
 - For example, SeaWiFS started with a 10x real time reprocessing capability and ended up with a 5000 x reprocessing capability

\$M	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	Total
MOC	1	2.5	3.5	4	4	2.5	1.5	1.5	0.5	21
SOC/SDP	1	3	6	8	10	4	3	3	3	41
Comm					0.2	0.2	0.2	0.2	0.1	0.9
Total	2	5.5	9.5	12	14.2	6.7	4.7	4.7	3.6	62.9





Trades

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- **Data Latency – 3 hours vs. 48 hours**
 - Longer latency would allow for fewer contacts
 - Would require higher downlink rates
 - Use of CFDP and allowing for some data to not meet the 3 hour requirement minimize the cost impact of the short data latency
 - Requires high bandwidth networks from all ground stations
 - McMurdo has a 60 Mbps link to NOAA
 - Santiago might need to be upgraded





Risks / Issues / Concerns

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- **Risks**

- None

- **Issues**

- None

- **Concerns**

- CFDP Implementation – work with CFDP community to ensure CFDP will work with the data rates and number of stations used for PACE
 - For example uplink bandwidth for acknowledgements and handling of files that start at the end of one contact and complete on the next
 - Larger onboard recorder could protect from data loss due to a problem that affects multiple passes (e.g., ground station problem at Svalbard)





Acronyms

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CDR	Critical Design Review
CFDP	CCSDS File Delivery Protocol
CMD	Command
COTS	Commercial Off the Shelf
EOM	End of Mission
FT	Functional Test
GOTS	Government Off the Shelf
GPS	Global Positioning System
HGA	High Gain Antenna
HK	Housekeeping
ISF	Instrument Support Facility
Kbps	Kilo-bits per second
Km	Kilometers
LV	Launch Vehicle
LZP	Level Zero Processing
Mbps	Mega-bits per second
Msp/s	Mega-symbols per second
MOC	Mission Operations Center
NEN	Near Earth Network
OD	Orbit Determination
RT	Real Time
SA	Solar Array
S/C	Spacecraft
SDS	Science Data System
SOC	Science Operations Control
TDRSS	Tracking & Data Relay Satellite System
TLM	Telemetry

