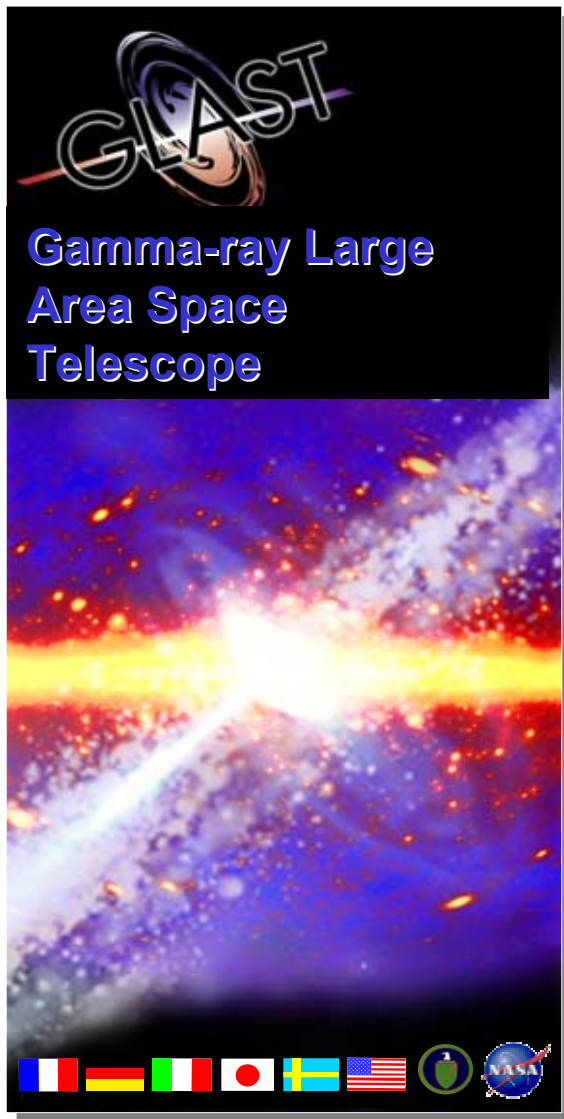


DRAFT REV 3

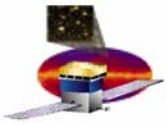


GLAST Large Area Telescope:

Instrument Operations Center Overview WBS: 4.1.B

Scott Williams
W.W. Hansen Experimental Physics Laboratory
Subsystem Manager

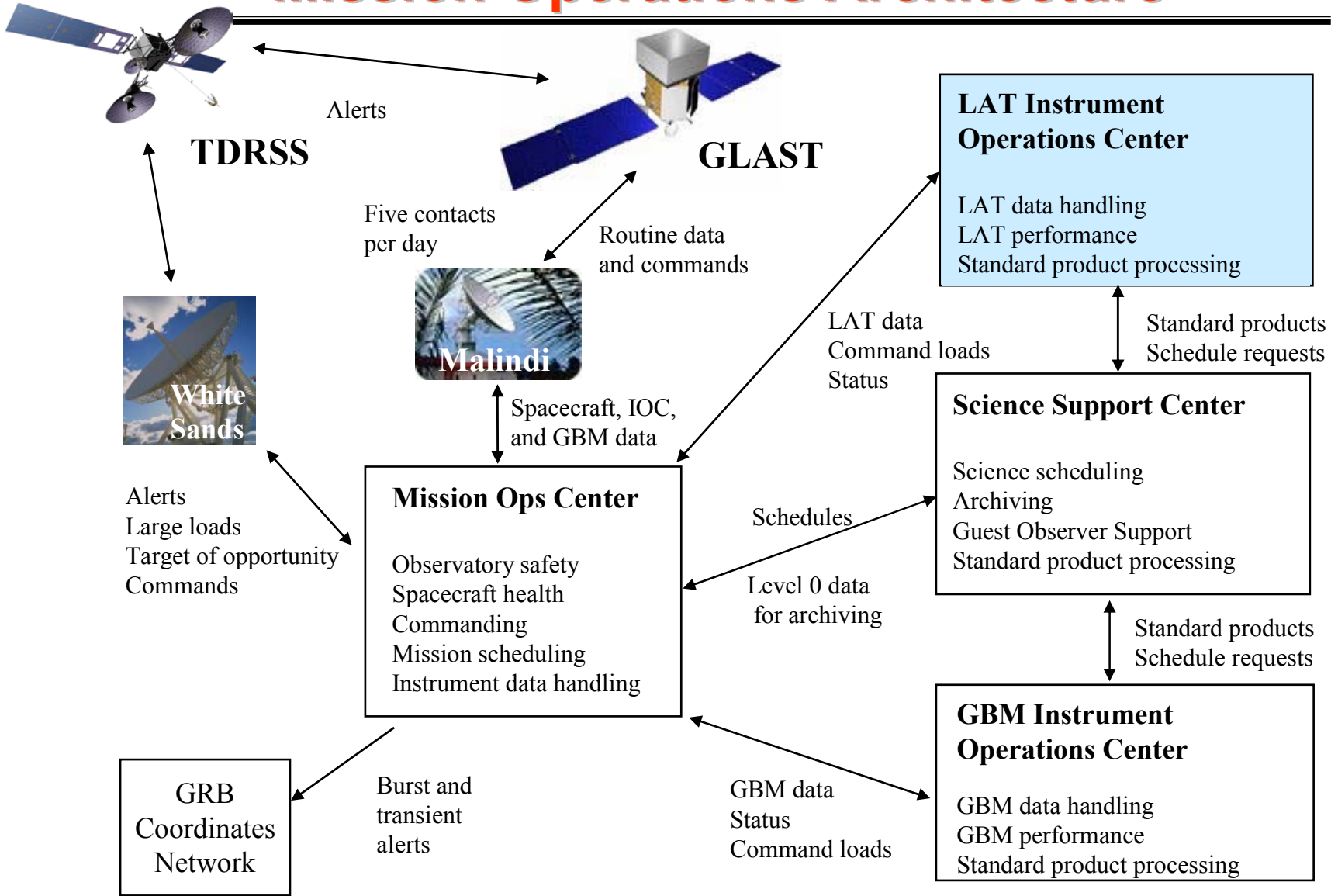
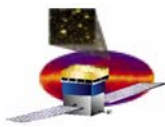
scott.williams@stanford.edu

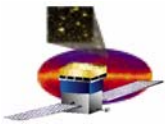


Outline

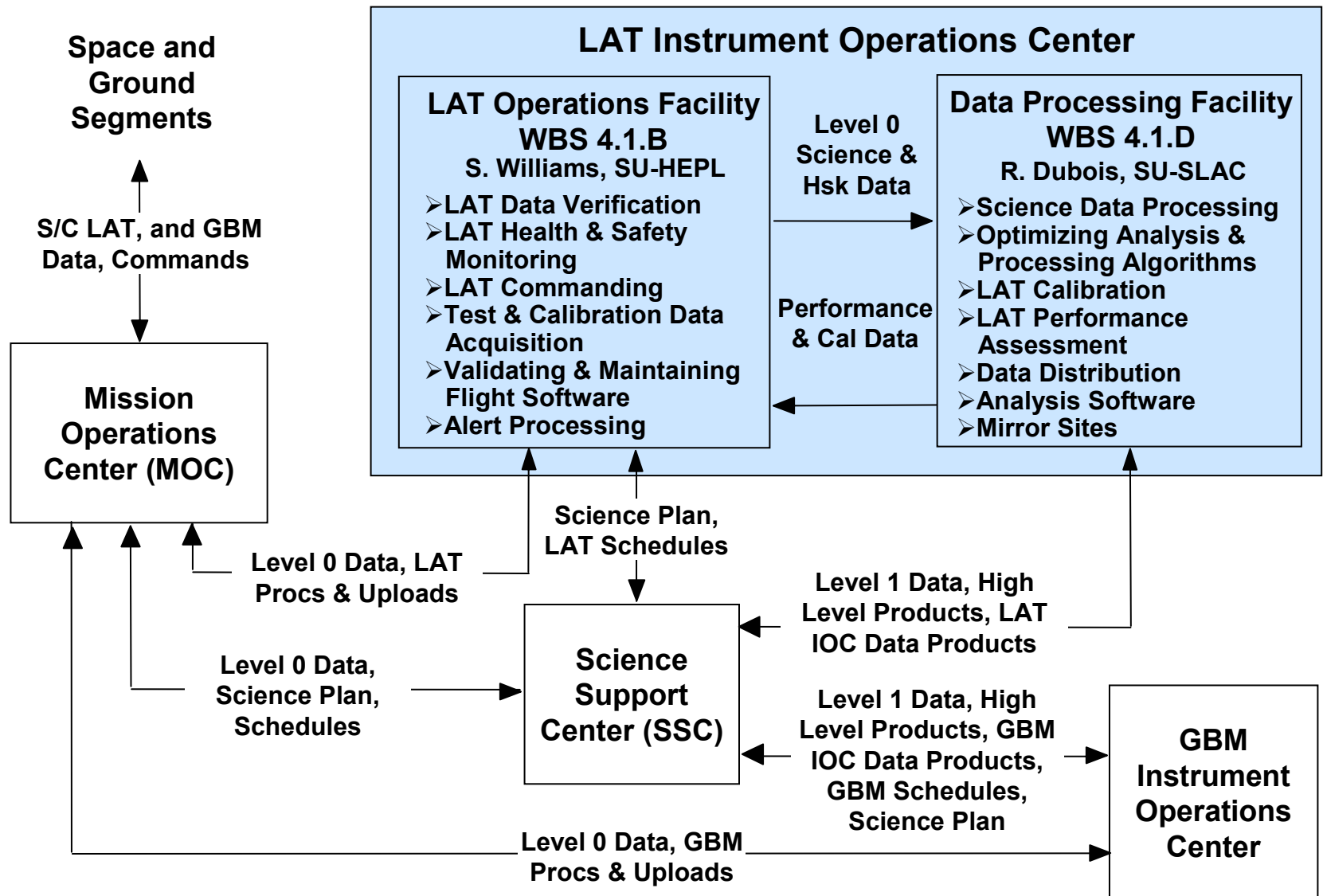
- **Overview**
- **Requirements**
- **Status**
- **Organization & Interfaces**
- **Schedule & Cost Plan**
- **Risk Assessment & Mitigations**
- **Conclusions**

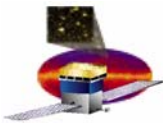
Mission Operations Architecture





LAT Operations Facility Functions





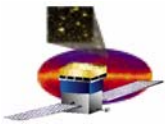
FUSE Comparison



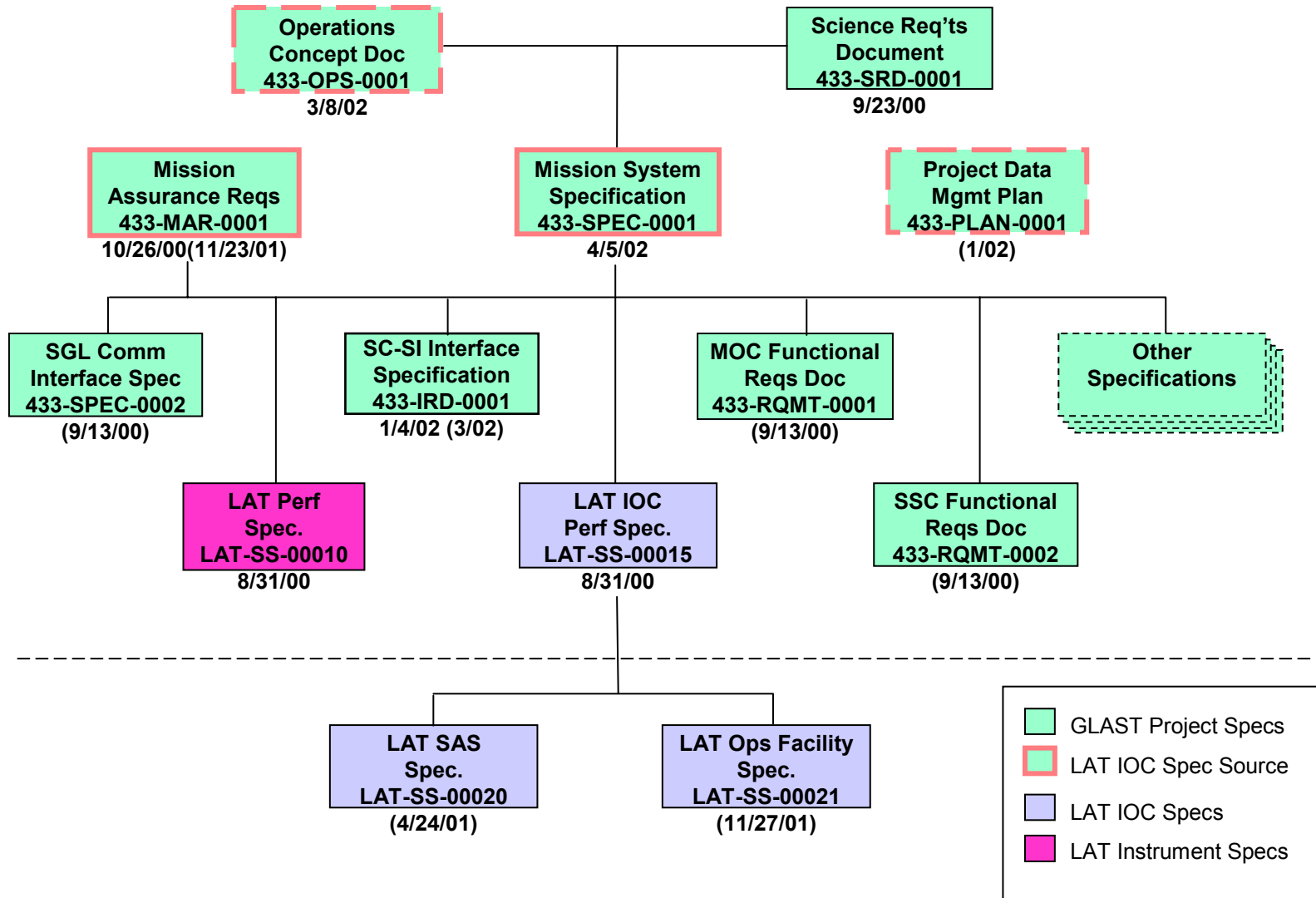
INTEGRATED TOOLSET

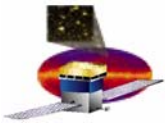
- **SCL**
- **SAMMI**
- O2
- **STK**
- *Orbix*
- *NDDS*
- **IDL**

The LOF will consist of about 1/2 the resource (as shown here inside blue border) of the Far Ultraviolet Spectroscopic Explorer (FUSE) Control Center at Johns Hopkins University Applied Physics Laboratory. Probable common COTS S/W tools are shown in red.



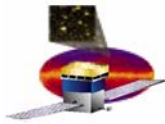
Requirements Status



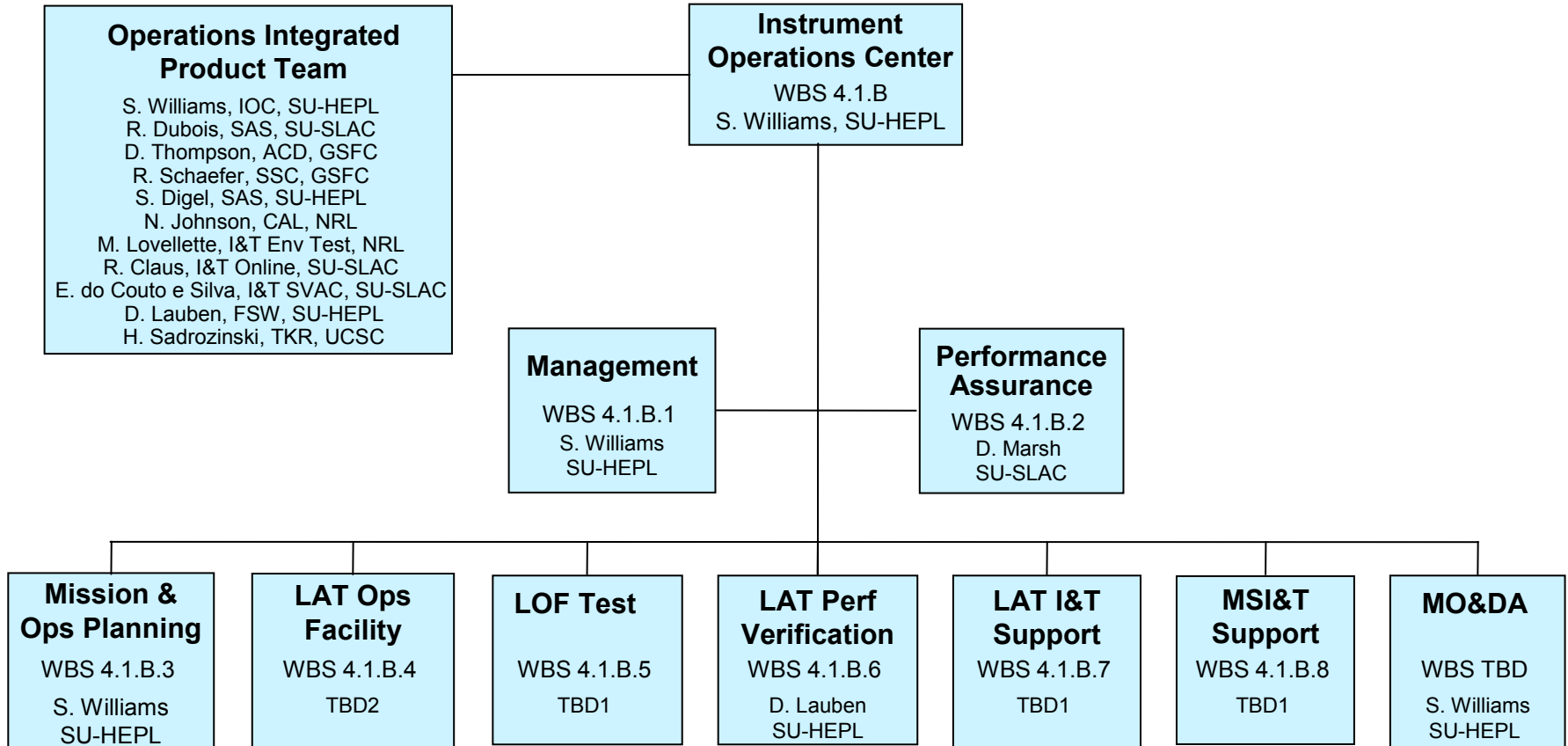


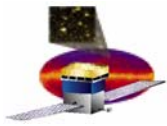
IOC Status

- **IOC effort is on schedule and budget**
- **Tasks completed since Pre-Baseline Review (2/13/01)**
 - Conducted IOC Requirements Review on 5/4/01, and IOC Peer Design Reviews on 8/17/01, 10/11/01.
 - Participated in GLAST Operations Working Group (GLOWG) for revision of GLAST Operations Concept Document and development of data product ICDs.
 - Supported development of Online System (EGSE) requirements.
 - Supported balloon flight EGSE and operations procedures development and 8/4/01 flight.
 - Revised WBS, schedule, and cost estimate to support 6 month launch slip and mandatory descope. Completed inputs to PMCS.
 - Supported I&T PDR preparations and developed PMCS inputs for I&T Instrument Operations Coordination (4.1.9.3).
- **LAT Baseline/PDR (1/12/02) Findings**
 - Baseline/PDR report recommended IOC be baselined.
 - Two other findings recommended focus on developing interfaces.

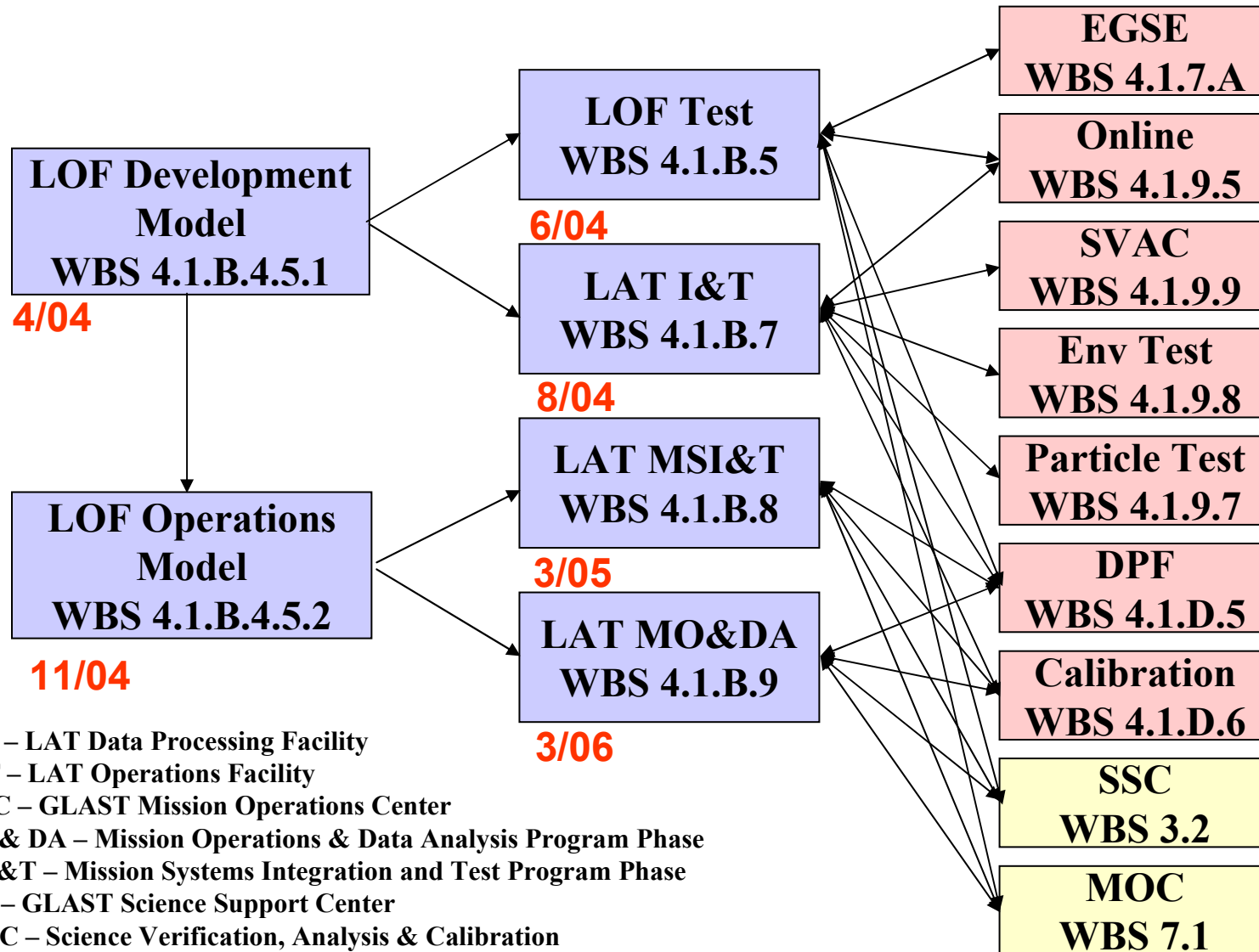


IOC WBS Organization

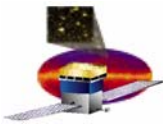




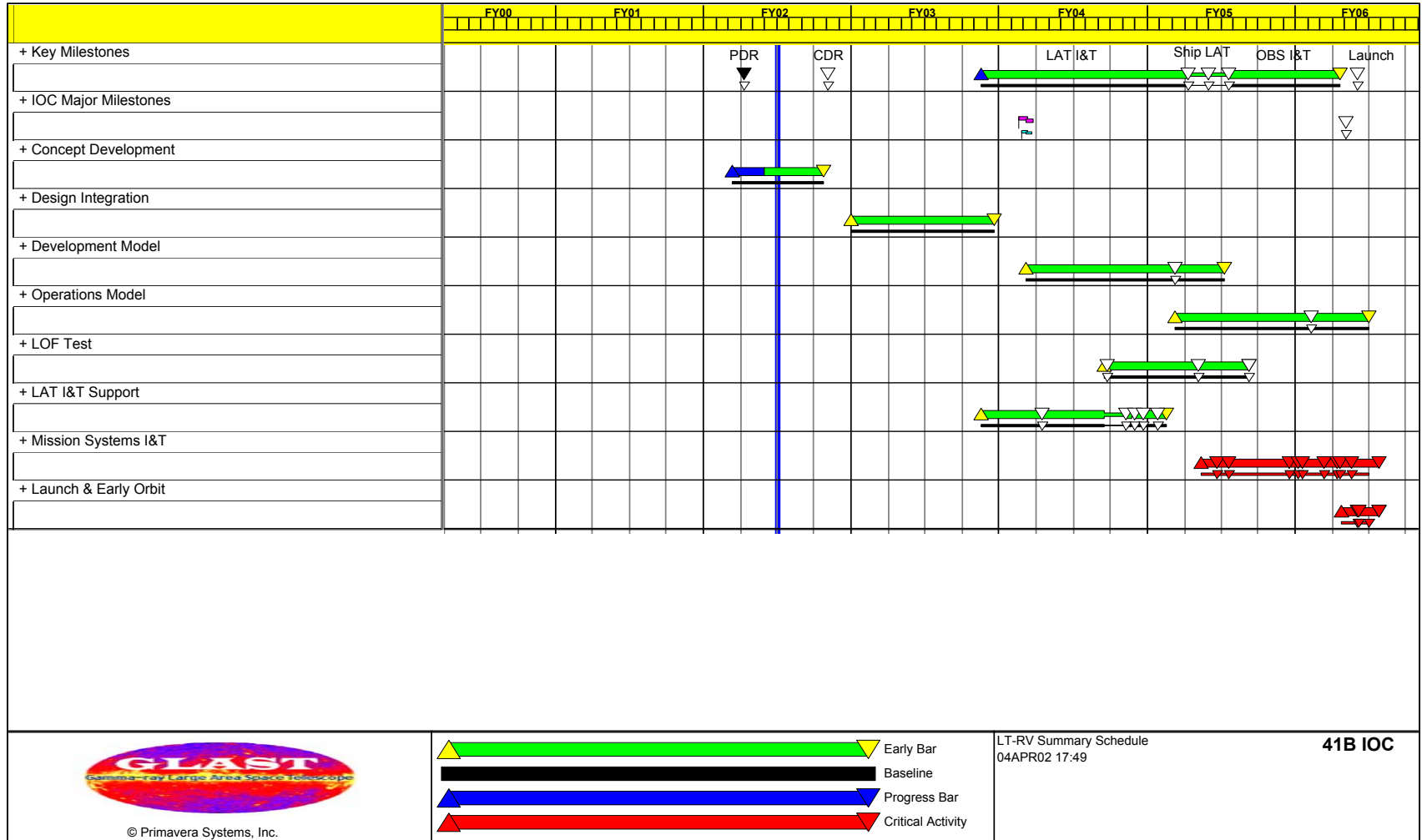
WBS Interfaces

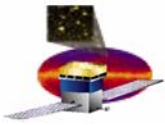


DPF – LAT Data Processing Facility
 LOF – LAT Operations Facility
 MOC – GLAST Mission Operations Center
 MO & DA – Mission Operations & Data Analysis Program Phase
 MSI&T – Mission Systems Integration and Test Program Phase
 SSC – GLAST Science Support Center
 SVAC – Science Verification, Analysis & Calibration



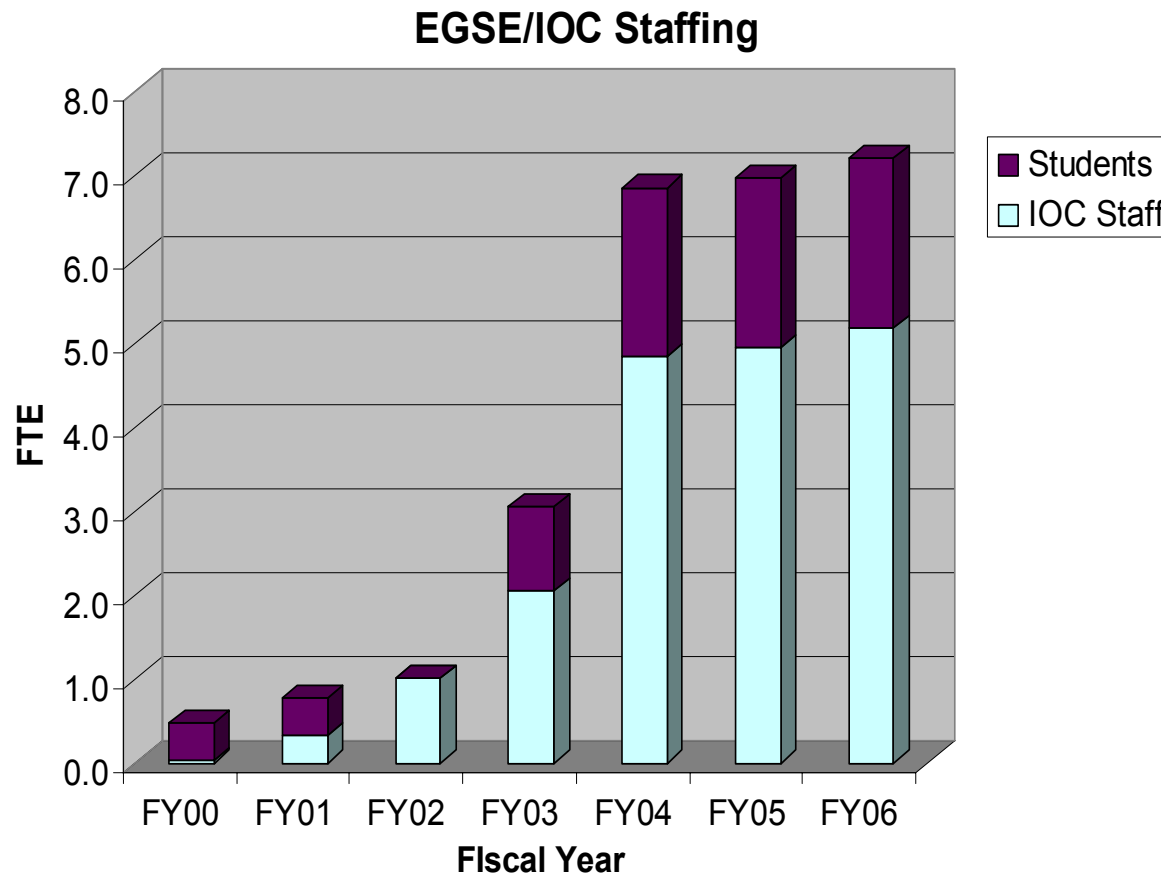
Schedule

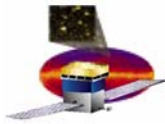




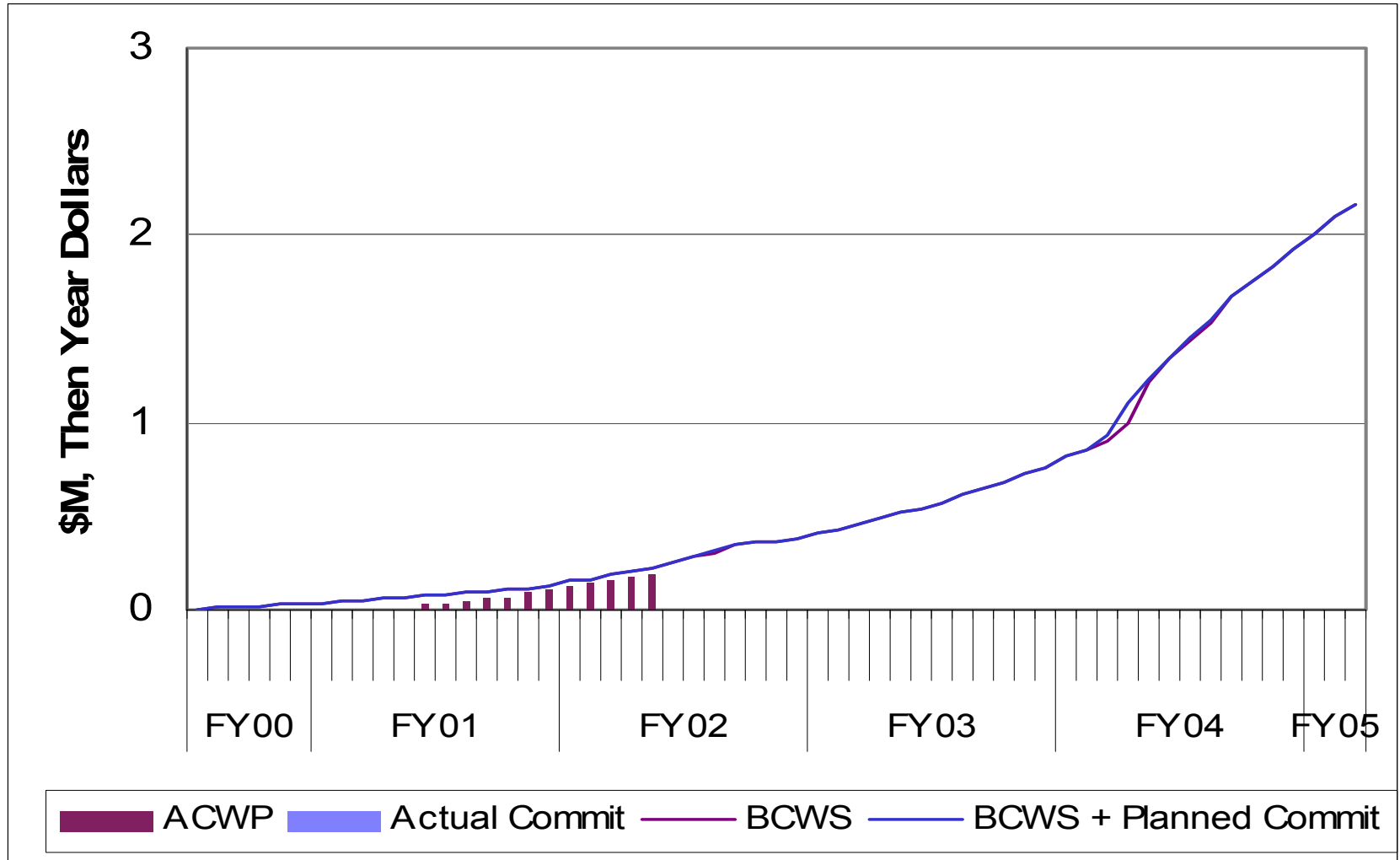
Labor Plan

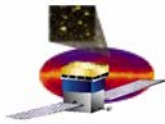
Staffing for IOC includes hiring profile of 1 FTE staff in FY03 (TBD2) and 2 FTE in FY04 (TBD1, TBD3) to stabilize at 5 FTEs plus students.



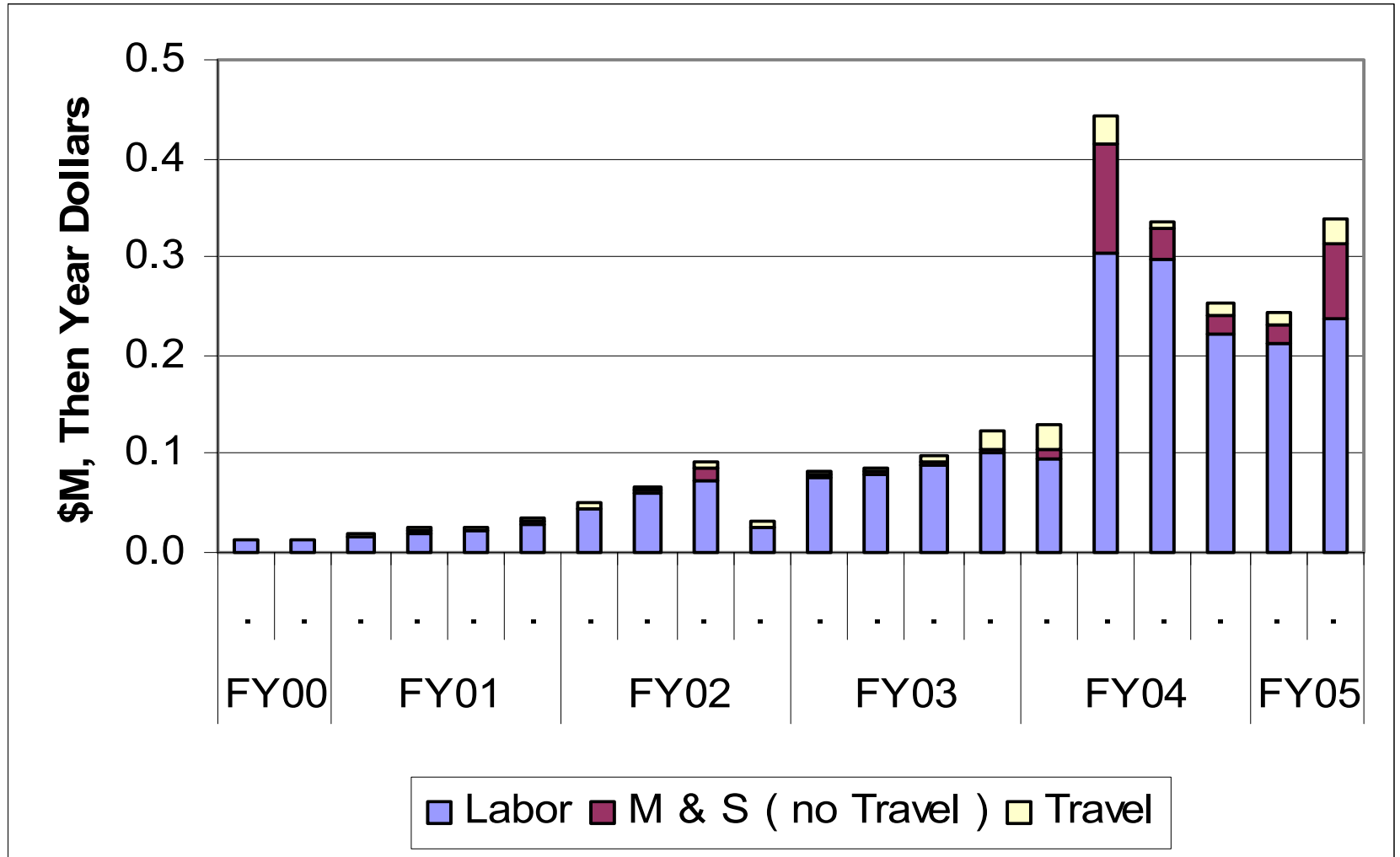


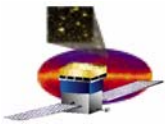
IOC Cost & Commitments





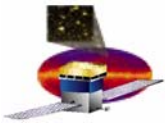
IOC Cost Profile





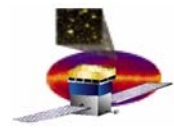
Risks & Mitigation

Risk	Recovery	Probability	Impact	Mitigation
Product/Technical Risk				
Uncertainty in data downlink plan complicates IOC planning and may result in additional support requirements	Additional resource, schedule slip	0.2	Moderate	Participate in GLOWG. Build in flexibility in LAT operations concept via globally distributed monitoring.
Inability to retain critical skills for maintenance of custom S/W over ten year mission life objective results in deteriorating IOC performance	Additional resource	0.2	Moderate	Pursue COTS S/W solutions from vendors with established track record. Build in-house expertise in LAT science stakeholders. Implement process improvement plan and active crew resource management.
Hardware platform or operating system maintenance terminated by vendor	Additional resource	0.2	Moderate	Plan for hardware and operating system upgrades and continued maintenance of IOC S/W. Pursue platform independence and/or multiplatform support for IOC S/W.
Provider of IOC COTS S/W terminates maintenance support resulting in deteriorating IOC performance	Additional resource	0.2	Moderate	Build in-house expertise in LAT science stakeholders. Implement process improvement plan and active crew resource management.
Implementation/Programmatic Risk				
Limited resources in FY02/03 delay IOC development.	Schedule slip	0.2	Moderate	Leverage off of I&T activities, use systems engineering resources, and exploit balloon flight experience
Schedule for MOC, spacecraft, and ground communications segment lags LAT schedule delaying definition of IOC interfaces and plans and resulting in erroneous resource planning.	Schedule slip, additional resource	0.3	Moderate	Supported detailed ground systems functional allocation study, participate in GLOWG to develop preliminary ICDs and plans, hold IOC PDR with LAT, but delay IOC CDR to match schedule with remainder of ground segment.
Requirements flowdown from Operations Concept Document through Mission Systems Specification is incomplete possibly resulting in erroneous planning for IOC	Schedule slip, additional resources	0.3	Moderate	Participate in GLOWG, actively support Ops Concept Document development, MSS update, and IOC level II specification revision. Work with Systems Engineering to implement in DOORS for traceability.
Difficulty in acquisition of critical skills for IOC positions to be filled in late FY03 and early FY04 impacts IOC software development	Schedule slip, additional resource	0.2	Significant	Leverage off of I&T activities, pursue migration of experienced I&T personnel into IOC. Pursue commonality of S/W tools with SAS and FSW.

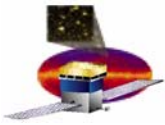


Conclusions

- **IOC plan is captured in PMCS and ready for baselining**
 - **Established cost plan fits available funding**
 - **Schedule meets program requirements**
 - **Contingency (24% overall, but 31% on LOF) is adequate**
 - **Delay in IOC CDR preserves flexibility to accommodate program level changes**
- **Requirements flowdown from GLAST Operations Concept must be completed**
 - **Updates needed for Mission System Specification, Project Data Management Plan, LAT IOC Level II Specification**
- **S/C selection in summer 2002 and MOC selection (TBD) is eagerly anticipated to allow development of**
 - **LOF interface requirements**
 - **LOF integration and test plan**
 - **MSI&T plan**
 - **Launch and early orbit plan**

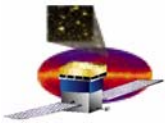


Background Material



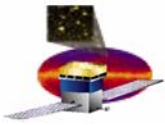
References

- **GSFC 433-SRD-0001, GLAST Science Requirements Document, P. Michelson and N. Gehrels, eds., September 23, 2000.**
- **GSFC 433-OPS-0001, GLAST Operations Concept Document, March 8, 2002.**
- **GSFC 433-PLAN-0009, GLAST Project Data Management Plan, DRAFT, January 2001.**
- **GSFC 433-SPEC-0001, GLAST Mission System Specification, April 5, 2002.**
- **GSFC 433-IRD-0001, GLAST Science Instrument - Spacecraft Interface Requirements Document, January 4, 2002.**
- **LAT-SP-00015, LAT Instrument Operations Center - Level II Specification, Sept. 1, 2000.**
- **LAT-SS-00021-07, LAT Operations Facility Subsystem Specification-Level III Specification, January 7, 2002.**
- **LAT-TD-00428-03, LAT Instrument Operations Center Preliminary Design Report, January 31, 2002.**
- **LAT-TD-00447, GLAST LAT Calibration Plan, December 5, 2001.**
- **LAT-TD-00446, GLAST LAT Calibration Requirements, December 5, 2001.**
- **LAT-TD-00499, LAT Operating Modes, 30 May 2001.**
- **LAT-TD-00501, LAT Mission Phases, 12 December 2001.**



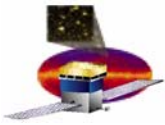
Acronyms

- **CDR** Critical Design Review (LAT 8/02, LAT IOC, 12/04)
- **CU** LAT Calibration Unit
- **DPF** LAT Data Processing Facility
- **EGSE** Electrical Ground Support Equipment
- **EM2** LAT Engineering Model 2, multiple towers
- **FU** LAT Flight Unit
- **GBM** GLAST Burst Monitor
- **GLAST** Gamma-ray Large Area Space Telescope
- **GRB** Gamma-ray Burst
- **IOC** Instrument Operations Center
- **LAT** GLAST Large Area Telescope
- **LOF** LAT Operations Facility
- **MOC** GLAST Mission Operations Center
- **MO&DA** Mission Operations & Data Analysis program phase
- **MSI&T** Mission Systems Integration & Test program phase
- **PSR** Pre-Ship Review (LAT, 1/05)
- **SSC** GLAST Science Support Center
- **TDRSS** Tracking and Data Relay Satellite System
- **WBS** Work Breakdown Structure



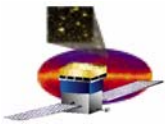
Definitions

- **Alert**
 - Packetized data transmitted by the spacecraft in response to a transient event. Alerts can be generated by instrument or spacecraft subsystems in response to the detection of anomalies or by the science instruments in response to transient scientific phenomena.
- **Phase**
 - Time period in mission characterized by unique operating modes or constraints.
- **Mode**
 - A specific configuration and set of operations or behavior that accomplish a specific purpose and impact the LAT to S/C interface.
- **Observing Efficiency**
 - Fraction of time available that is spent acquiring data. On the GLAST mission the time available is the time on orbit less time spent in the South Atlantic Anomaly (SAA).



Definitions

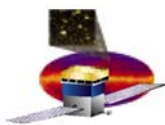
- **Level 0 Processing - Space-to-ground artifact removal**
 - Processing of raw instrument data. Level 0 data processing consists of time-ordering packets, removing corrupted, incomplete, or duplicate packets, annotating quality, and can include separating housekeeping, calibration, science, and engineering data streams.
- **Level 1 Processing**
 - Processing level 0 data into level 1 data consists of creating a database of reconstructed gamma-ray photons and cosmic rays which includes energy, direction of arrival, arrival time, quality parameters, and associated pointing and livetime history.
- **Higher Level Science Processing**
 - Processing of level 1 data into science products. Consists of calculating exposures, detecting sources, measuring their spectra, determining their time histories, and locating potential counterparts in other astronomical catalogs .



LOF Level III Requirements

Ref: LAT-SS-00021

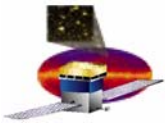
Requirement	Function	Requirement Summary	Verification Method
5.2	Level Zero Data	The LAT IOC receives the Level 0 GLAST data from the MOC, verifies data quality, and distributes the data to the DPF for processing.	Demonstration
5.3	Instrument Health and Safety Monitoring	The IOC monitors, assesses, and records the health and safety of the instrument and supports the resolution of anomalies.	Demonstration
5.4	Instrument Commanding	The IOC develops command uploads and procedures for the instrument to adjust the instrument configuration, on-board calibration, or flight software.	Demonstration
5.5	Anomaly Detection and Resolution	The IOC monitors the LAT instrument for anomalies and provides analyses to support their safe resolution.	Demonstration
5.6	Operational Databases	The IOC develops and maintains databases for LAT operations.	Demonstration
5.7	Test and Calibration Data Processing	The IOC acquires test and calibration data to aid in assessing the performance of the instrument and adjust the instrument tables, engineering calibration, or software as required.	Demonstration
5.8	Instrument Performance Assessment	The IOC monitors and assesses the performance of the instrument.	Demonstration
5.9	Instrument Configuration	The IOC monitors and adjusts the instrument configuration, calibration, or software as required.	Demonstration
5.10	Validating and Maintaining LAT Flight Software	The IOC maintains the onboard LAT flight software.	Demonstration
5.11	LAT Testbed	The IOC maintains and operates a LAT testbed for use in developing, validating, and verifying changes to LAT flight software, command procedures, and instrument parameters.	Demonstration
5.12	Alerts	The IOC supports transient event alerts from GLAST.	Demonstration
5.13	Data Standards	The IOC adheres to mission specified data standards.	Demonstration
5.14	Data Formats	The IOC adheres to mission specified data formats.	Demonstration
5.15	Maintainability and Availability	The IOC meets mission specified maintainability and availability requirements	Demonstration
5.16	Security	The IOC shall be connected to the other operations and support centers by an intranet of wide area networks that is closed to, or protected from, public users of the external internet per NASA NPD 2810.1.	Demonstration
5.17	Quality Assurance	The IOC shall maintain the integrity of LAT uploads and science data during transmission and processing of the data.	Demonstration
5.18	Integration and Test Support	The IOC supports LAT and GLAST mission systems integration and test.	Demonstration
5.19	Mission Support	The IOC supports the GLAST mission launch and orbital operations.	Demonstration



Work Breakdown Structure

WBS	Task	Responsibility
4.1.B	Instrument Operations Center	Williams
4.1.B.1	Project Management	Williams
4.1.B.1.1	Project Administration	
4.1.B.1.2	Meetings & Reviews	
4.1.B.1.3	Logistics Management	
4.1.B.1.4	Travel	
4.1.B.1.5	Project Support	
4.1.B.2	Performance Assurance	Marsh
4.1.B.2.1	IOC Performance Assurance	
4.1.B.2.2	IOC Verification	
4.1.B.3	Mission & Operations Planning	Williams
4.1.B.3.1	Operations Concept Development	
4.1.B.3.2	Integration & Test Planning	
4.1.B.3.3	Mission Operations Planning	
4.1.B.4	LAT Operations Facility	TBD2
4.1.B.4.1	System Conceptual Design	
4.1.B.4.2	Data Acquisition S/W Development	
4.1.B.4.3	Operations Software Development	
4.1.B.4.4	Command & Telemetry Development	
4.1.B.4.5	LOF System Development	
4.1.B.5	LOF Test	TBD1
4.1.B.5.1	Test Planning	
4.1.B.5.2	Test Development	
4.1.B.5.3	Verification Testing	
4.1.B.5.4	LOF Interfact Tests	
4.1.B.5.5	LOF I&T Travel	

WBS	Task	Responsibility
4.1.B.6	LAT Performance Verification	Lauben
4.1.B.6.1	Performance Verification Test Planning	
4.1.B.6.2	Analysis Software	
4.1.B.6.3	Display Software	
4.1.B.6.4	LAT Calibration Support	
4.1.B.6.5	LAT Testbed	
4.1.B.7	LAT Integration & Test	TBD1
4.1.B.7.1	Qualification Unit Test Support	
4.1.B.7.2	Flight Unit Test Support	
4.1.B.7.3	LAT I&T Travel	
4.1.B.8	Mission Systems Integration & Test	TBD1
4.1.B.8.1	Observatory Testing	
4.1.B.8.2	Ground Systems Testing	
4.1.B.8.3	Training Simulations	
4.1.B.8.4	Launch & Early Operations Support	
4.1.B.8.5	MSI&T Travel	
4.1.B.9	Mission Operations & Data Analysis	Williams
4.1.B.9.1	MO&DA Management	
4.1.B.9.2	Science Operations	
4.1.B.9.3	LAT Operations	
4.1.B.9.4	LOF Systems Support	
4.1.B.9.5	LAT Testbed	
4.1.B.9.6	LAT Engineering Support	



IOC Development Staffing

Manager - S. Williams

Technical management, reporting, mission planning, concept and requirements development, command & telemetry database, operations procedures and documentation, I&T support planning, crew resource management.

Scientist - D. Lauben

LAT performance verification, calibration support, analysis and display prototyping, science planning and ops tools, LAT Testbed support, **SSC interface (inst. scheduling)**, **DPF interface (level 0 data & performance metrics)**.

Scientist – S. Digel

LAT performance verification, calibration support, analysis and display prototyping, science analysis tools, **SSC and DPF interface (analysis tools)**.

Engineer - TBD2, mid-FY03

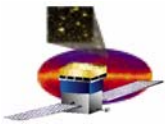
LOF development, operations S/W development, distributed monitoring, procedure and upload verification & validation, **MOC interface (data flow)**.

Engineer - TBD1, FY04

Verification and QA support, test planning, command & telemetry database, operations procedures and documentation, **I&T interface**, **MOC interface (commanding & databases)**.

Programmer - TBD3, FY04

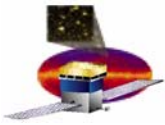
Computer systems management, data processing S/W, operations S/W, LAT Testbed support, LAT Testbed, **FSW interface**.



Key IOC Milestones

• IOC Requirements Review		05/01
• IOC Peer Design Review		08/01
• IOC Pre PDR		10/01
• LAT Instrument PDR		01/02
• Online System Specification from I&T		05/02
• LAT Instrument CDR		08/02
• MOC Selection (TBR)		Winter '03
• IOC CDR (TBR)		12/03
• LOF S/W Release 1		06/04
• Environmental Test Database Release		06/04
• LOF-DPF Interface Test		06/04
• LAT Operations Review		06/04
• Mission Operations Review		07/04
• LOF Development Model Complete		12/04
• Observatory I&T Database Release		12/04
• LOF S/W Release 2		02/05
• LOF-DPF-MOC-SSC Interface Test 1		02/05
• LOF-DPF-MOC-SSC Interface Test 2		06/05
• LOF Validation & Verification Complete		07/05
• Flight Operations Review		07/05

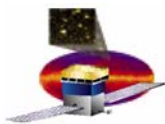
GLAST
Project
milestones
in blue



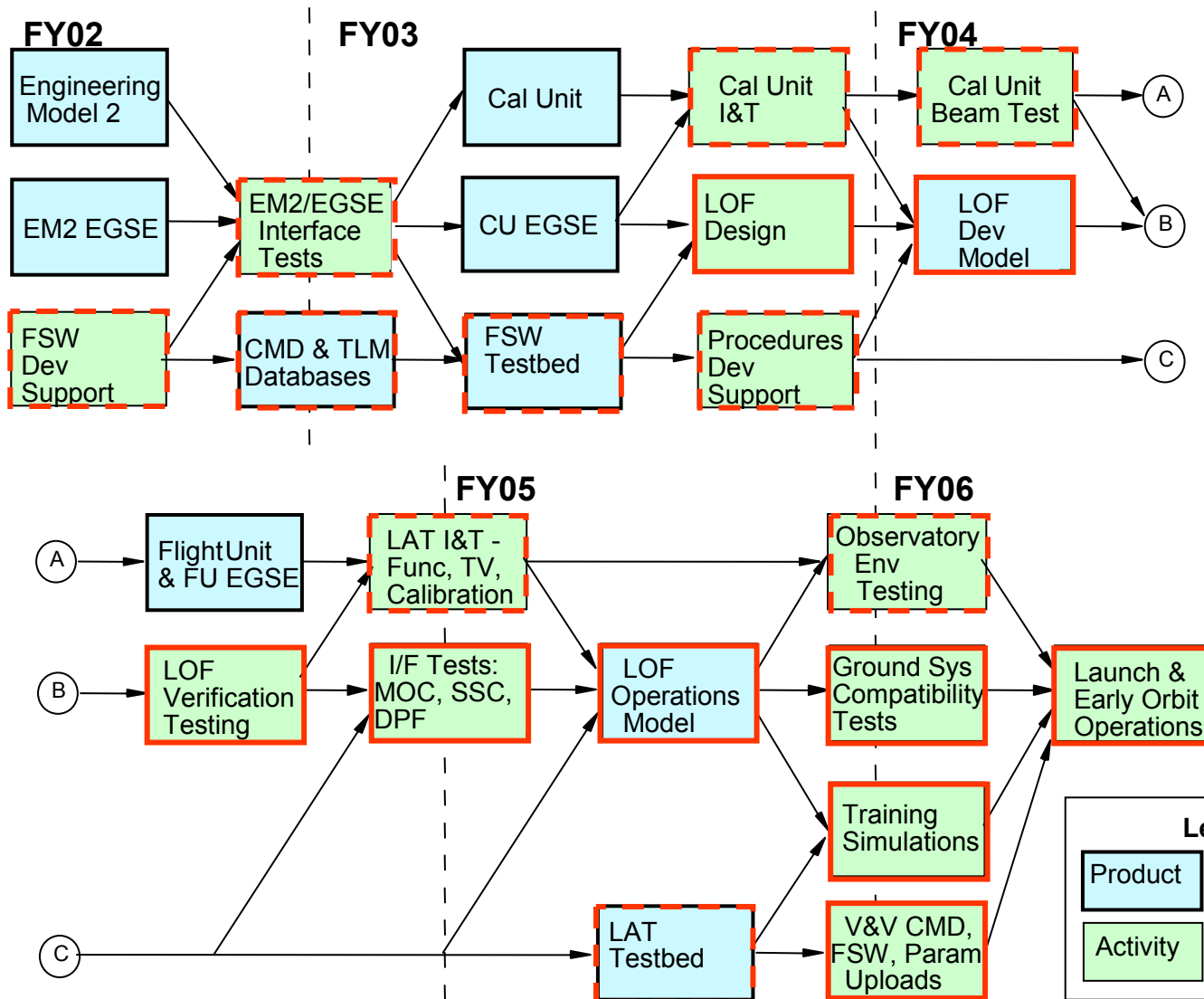
Key IOC Milestones

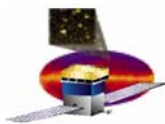
- **LOF S/W Release 3** **09/05**
- **Ground Systems Compatibility Test (TBR)** **09/05**
- **Operations Simulation 1 (TBR)** **10/05**
- **Mission Sequence Test (TBR)** **10/05**
- **LOF Operations Model Complete, Flight Database Release** **11/05**
- **Operations Simulation 2 (TBR)** **12/05**
- **IOC Readiness Review** **01/06**
- **LOF S/W Release 4** **01/06**
- **End-to-end Test (TBR)** **01/06**
- **LAT Flight Readiness Review (FRR)** **02/06**
- **Operations Simulation 3 (TBR)** **02/06**

- **Launch** **03/06**
- **LAT Operations Readiness Review** **L+3d**
- **LAT Activation and Checkout Complete** **L+30d**
- **LAT Instrument Commissioning Complete (Phase 0)** **L+60d**
- **LAT Verification Phase Complete (Phase 1)** **L+14m**
- **GLAST Science Phase (Phase 2)** **L+5y**



IOC Development Flow





Documentation Plan

Level II

LAT IOC
Specification
LAT-SS-00015

9/00

Ground System
I/F Reqs Doc

TBD

Level III

LOF Functional
Specification
LAT-SS-00021

11/01

LOF-DPF
ICD
LAT-TD-00nnn

LAT CDR

LAT Operations
Plan
LAT-TD-00nnn

LAT CDR

LAT Instrument
Ops Manual
LAT-TD-00nnn

LAT PSR

LAT CMD &
TLM Database
LAT-TD-00nnn

LAT PSR

LAT LEO
Ops Plan
LAT-TD-00nnn

LAT PSR

Level IV

LAT IOC PDR
Report
LAT-SS-00428

12/01

LOF Operations
Concept
LAT-SS-00nnn

LAT CDR

LOF Performance
Specification
LAT-SS-00nnn

LAT CDR

LOF Verification
Plan
LAT-TD-00nnn

LAT CDR

LOF Software
Mgmt Plan
LAT-TD-00nnn

LAT CDR

LOF Crew Res
Mgmt Plan
LAT-TD-00nnn

LOF CDR

LOF Facility
Specification
LAT-DS-00nnn

LOF CDR

LOF Computer
Procurement Spec
LAT-DS-00nnn

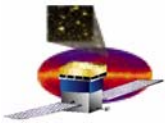
LOF CDR

LOF S/W
Procurement Spec
LAT-DS-00nnn

LOF CDR

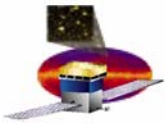
LOF Operations
Manual
LAT-TD-00nnn

LOF PSR



Mission Operations Overview

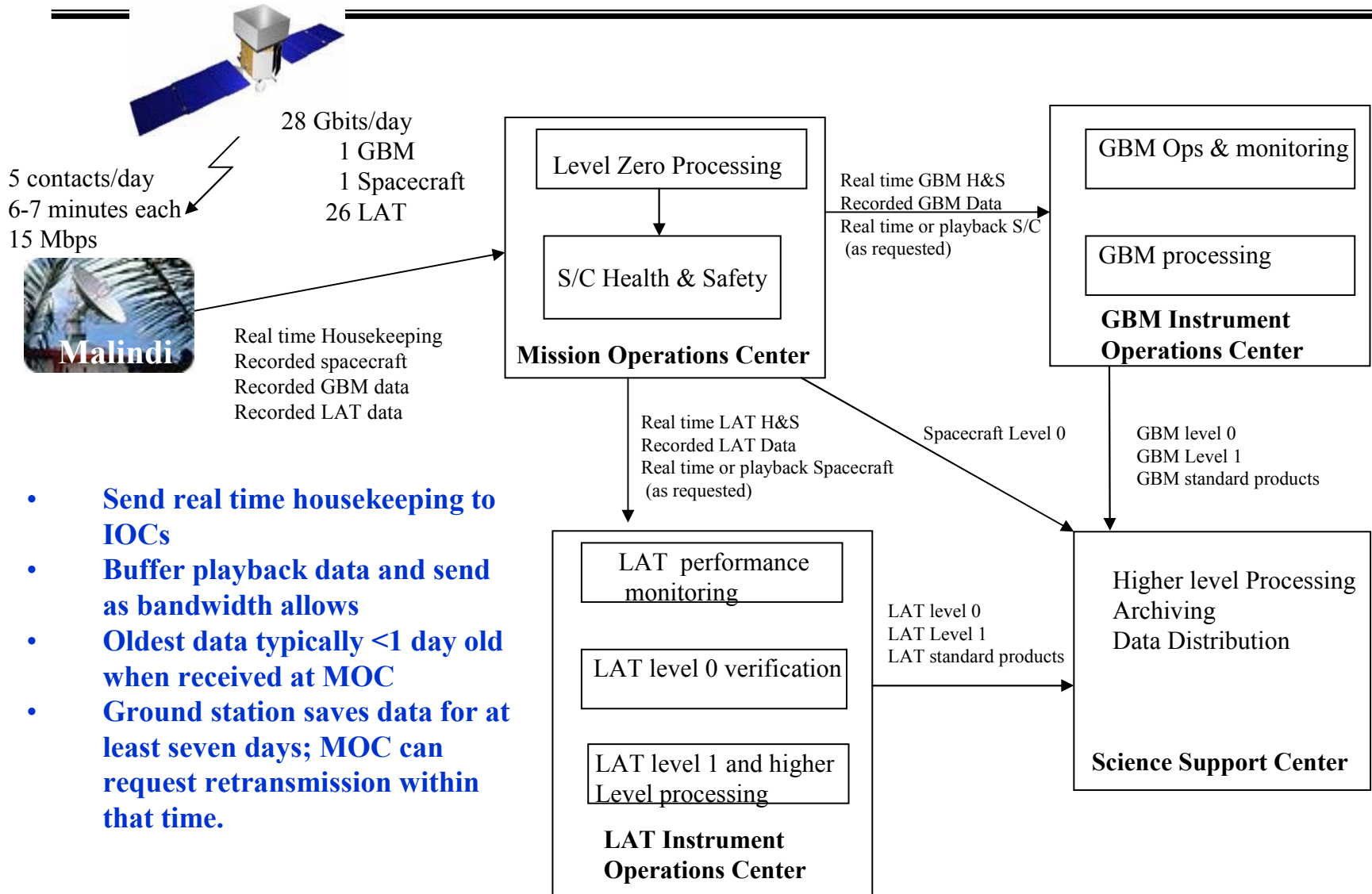
- **Launch Date:** March 2006
- **Mission Life:** 5 year required with 10 year goal
- **Orbit:** 470 to 550 km circular orbit, 28.5° inclination.
- **Spacecraft:** RSDO spacecraft, to be selected ~spring 2002.
- **Mission Operations Center:** TBD, to be selected ~spring 2002.
- **Ground Link:** Ground Station (Malindi) – Five contacts per day (TBR) to dump the bulk science data. Data volume is 28 Gbits per day. Downlink rate is 15 Mbps (TBR) over an X-band link. S-band used for real time housekeeping telemetry (32 kbps) and commanding (2 kbps).
- **Space Link:** Space Network – Demand Access System (DAS) used for gamma-ray burst alerts, health and safety alerts, and other science and housekeeping functions. Single Access Service (SAS) used for large command uploads and early orbital operations. Multiple Access Service (MAS) used for TOO commanding.
- **Operations Constraints:** Earth limb avoidance, radiator, and solar panel pointing constraints. Spacecraft may autonomously adjust its operation (including its pointing) in response to a gamma-ray burst.



GLAST Mission Phases

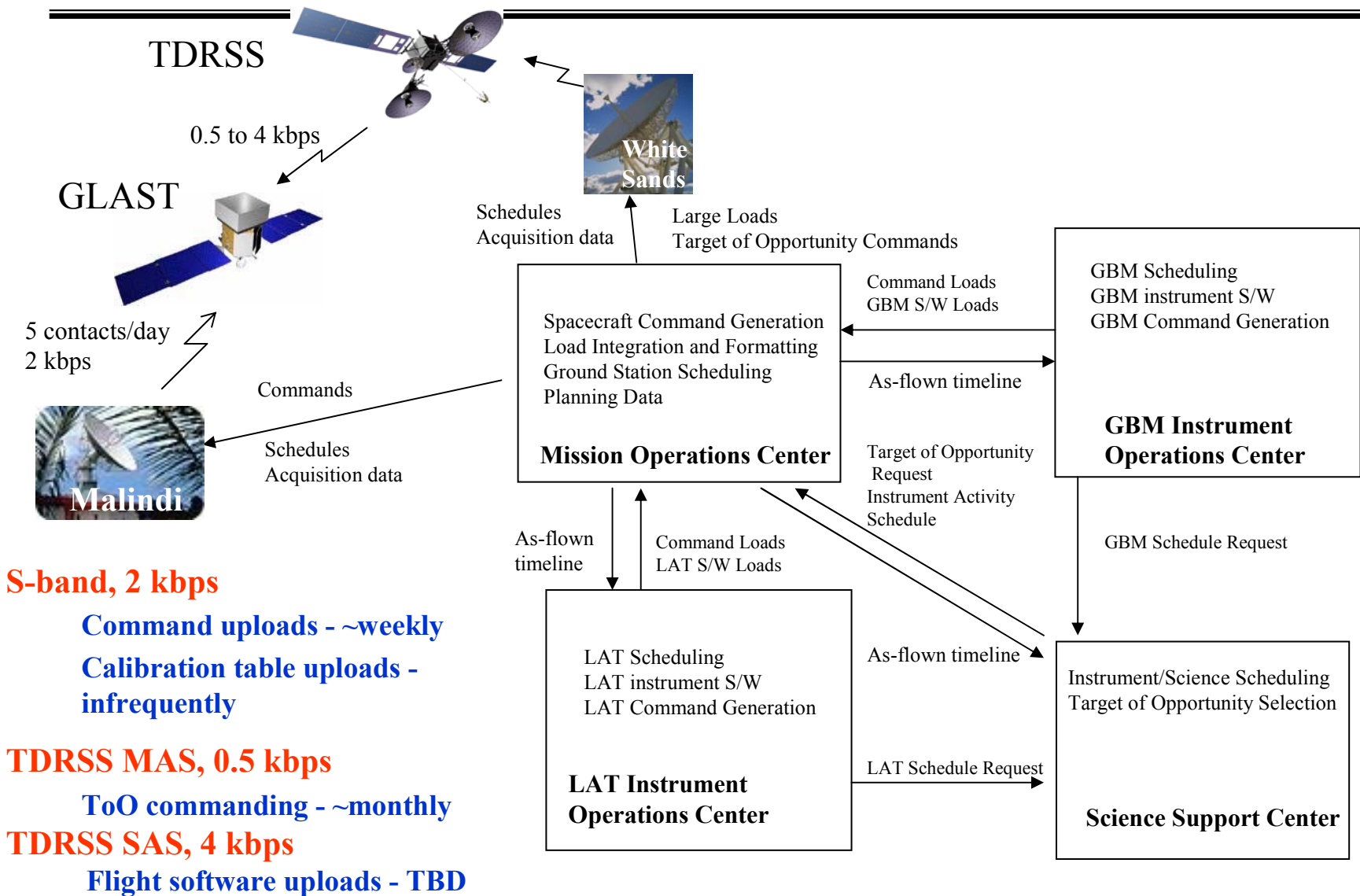
- **Launch Data – March 2006**
- **Phase 0 - Launch & early orbit: up to 60 days**
 - S/C configuration and checkout: 10 days
 - LAT responsible for thermal control using survival power bus
 - LAT turn-on, configuration, and checkout: 20 days
 - Subsystem checkout
 - Initial on-orbit calibration and alignment
 - LAT commissioning – 30 days
 - Science observation modes exercised and instrument response functions established
- **Phase 1 – Verification and Sky Survey: 12 months**
 - LAT science verification
 - up to 20% of observing time for LAT calibration and test
- **Phase 2 – Science Observations: minimum 4 years**
 - Peer review driven investigations
 - 5% observing time for LAT calibrations and maintenance

GLAST Science Data Flow



- Send real time housekeeping to IOCs
- Buffer playback data and send as bandwidth allows
- Oldest data typically <1 day old when received at MOC
- Ground station saves data for at least seven days; MOC can request retransmission within that time.

Schedule and Command Data Flows



S-band, 2 kbps

Command uploads - ~weekly

Calibration table uploads - infrequently

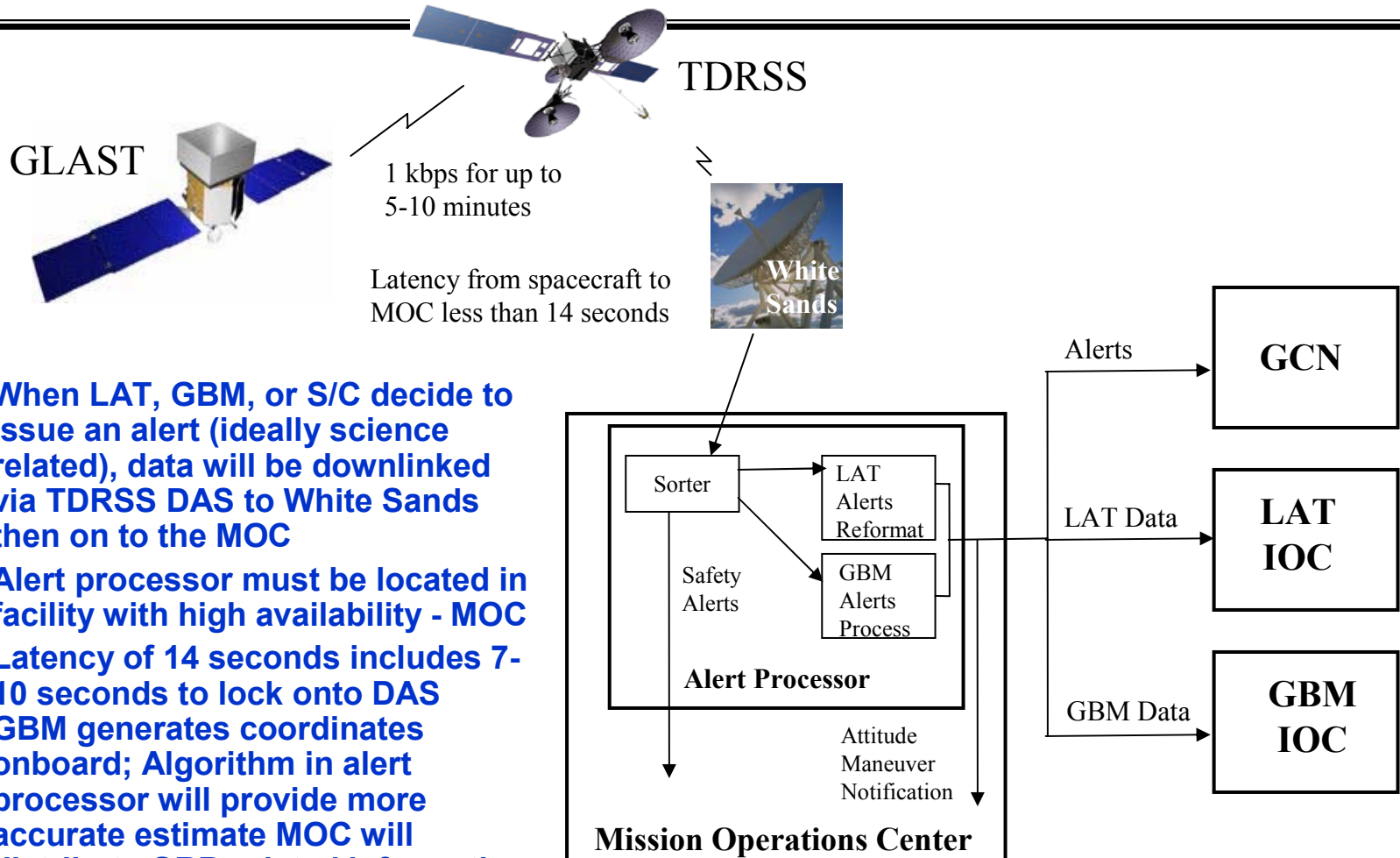
TDRSS MAS, 0.5 kbps

ToO commanding - ~monthly

TDRSS SAS, 4 kbps

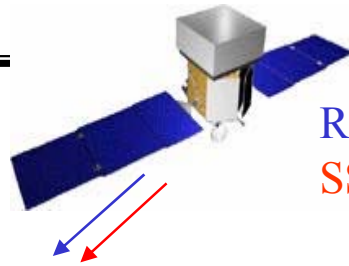
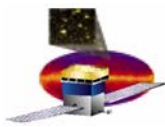
Flight software uploads - TBD

GLAST Alert Data Flows



- When LAT, GBM, or S/C decide to issue an alert (ideally science related), data will be downlinked via TDRSS DAS to White Sands then on to the MOC
- Alert processor must be located in facility with high availability - MOC
- Latency of 14 seconds includes 7-10 seconds to lock onto DAS
- GBM generates coordinates onboard; Algorithm in alert processor will provide more accurate estimate MOC will distribute GRB-related information to GCN
- MOC will also pass LAT-related data to the IOC

LAT Data Path



Realtime data: 32 kbps S-band
 SSR dump: 15 Mbps X-band

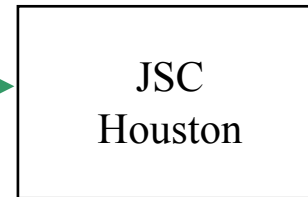


Malindi

Prime -
 2 Mbps
 Intelsat
 Backup -
 500 kbps

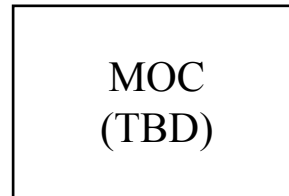


32 Mbps



Realtime S-Band
 Data and
 SSR Data

NISN or
 ASINet



NISN or
 Internet 2 via
 JPL



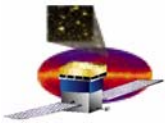
NISN or
 Internet 2 via
 ARC

Malindi gets ~35 Gbits per day from GLAST and 26 Gbits From Swift, and AGILE

Equivalent to ~400 kbps continuous

NISN should support whatever rates we deem necessary for the desired latency Another option is Internet 2

Realtime S/C and LAT HSK Data
 Followed by processed Level 0 Data



Risks & Mitigation

Uncertainty in GLAST operations concept for downlink rate, downlinks per day, and downlink margin complicates IOC planning.

Participate in GLAST Operations Working Group.

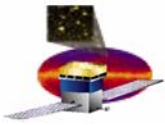
Provide flexibility in LOF support for downlinks via global monitoring concept.

The development schedule for the Mission Operations Center (MOC), Spacecraft, and ground communications segment lags the LAT schedule which introduces schedule and cost risk for the IOC.

Participated in detailed ground systems functional allocation study and developed level II requirements document.

Participate in GLAST Operations Working Group to develop preliminary ICDs and mission systems integration, test, and operations simulation and training plans.

Held IOC PDR with LAT but allow IOC CDR to match schedule with remainder of ground segment.



Risks & Mitigation

Limited resources in FY02/03 may impede and delay IOC development.

Leverage I&T online system development (WBS 4.1.9.5) by participating in development and planning for evolution to meet IOC requirements.

Leverage I&T development of operations procedures and functional tests by incorporating IOC requirements through role as I&T department head for Instrument Operations Coordination (4.1.9.3)

Use Systems Engineering resources to support systems level planning and design integration for operations.

Exploit balloon flight experience in display prototyping and data visualization.