GLAST Project Status

September 15, 2003

Al Vernacchio
GLAST Deputy Project Manager

Agenda

- ***Project Status***
- ***Organization***
- ***Systems Engineering***
- ***Mission Confirmation***
- ***Disposal Plan***
- ***Science Data Downlink on Ku Band***
- ***Top Issues and Risks***
- ***Upcoming Events***

Project Status (1 of 4)

- **LAT**
  - *Conducted extensive LAT CDR subsystem peer reviews (January through March 2003) and LAT CDR/CD-3 Review May 12-16.*
  - *Developed designs to resolve 2 of the 3 mechanical issues and an alternate plan to the 1 major programmatic issue (CNES withdrawal). Tracker EM environmental test is the remaining open CDR mechanical/thermal issue. LAT Re-baseline approved and in work.*
  - *Partially completed static testing of tracker bottom tray. Received 1x4 grid and awarded 4x4 grid contract.*
  - *Project and GSFC Mission Assurance and Engineering Directorate reviewed parts screening and qualification plans.*
- ***GBM***
  - *completed CDR for electronics and flight software.*
  - *CDR for German contributions planned for December 2003. System CDR planned for January 2004. EM detectors and DPU being tested.*
  - *DLR signed funding letter for GLAST Burst Monitor. DJO Contract awarded by MPE.*

Project Status (2 of 4)

- ***Spacecraft***
  - *Completed System Requirements Review (November 2002), PDR and Flight Software PDR May 5-8.*
  - *Several spacecraft component design reviews completed (Solid State Recorder, Reaction Wheel, Star Tracker, Battery)*
  - *Interface Simulators delivered to LAT and GBM.*
  - *Completed Flight Software designs and began design peer reviews.*
  - *Construction continuing ahead of schedule for Spectrum Astro's new integration and test facility: "Factory of the Future"*
- ***Continue to define spacecraft to instrument interfaces.***
  - *Spacecraft to instrument ICD signed.*

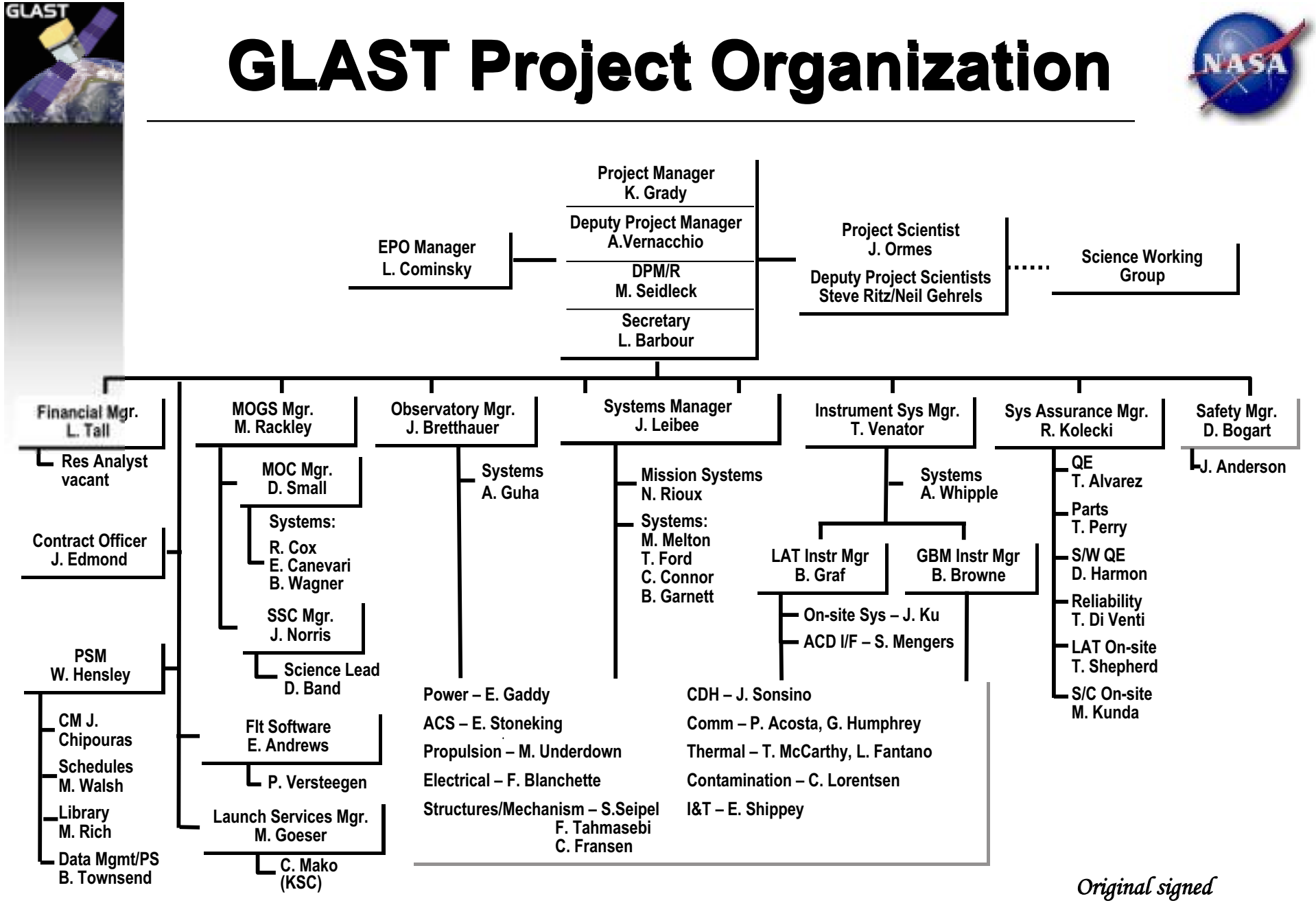
Project Status (3 of 4)

- ***Observatory Pointing Knowledge Analysis.***
  - *Completed unit thermal gradient analysis using existing delta-PDR models with updated thermal properties.Thermal/mechanical distortions being assessed. Four additional cycles with updated models planned to verify thermal/mechanical performance of the observatory.*
- ***Updated Coupled Loads Analysis in work at KSC. Results expected 11/03.***
- ***Conducted first Fault Management Technical Interchange Meeting.***
- ***Completed Ku-band science downlink trade study in response to the withdrawal of availability of the Malindi ground station***
  - *Performance and Life Cycle Cost benefits for utilizing TDRSS Space Network Ku-band service.*
  - *Ku-band is now the baseline.*

Project Status (4 of 4)

- ***Ground System SRR completed for all GLAST ground elements in July 2003***
- ***GLAST launch services: will utilize NASA Launch Services (NLS) contract to procure Delta 2920H launch vehicle***
- ***Completed GSFC and JSC orbital debris assessments***
  - *Results indicate that the GLAST debris casualty area is below the threshold for controlled re-entry with the implementation of 5 "design for demise" changes. Awaiting policy change to remove propulsion system from design.*
- ***Conducted GLAST Mission Preliminary Design Review and Non-Advocate Review on June 3-5***
- ***Completed GLAST mission schedule and budget assessment***

GLAST Project Organization



Original signed

Kevin Grady
GLAST Project Manager
September 9, 2003

GLAST Systems Engineering Roles and Responsibilities

- ***Lead and conduct systems engineering, systems integration, and systems management tasks across the project***
  - *Baselined all project level requirements documents*
  - *Allocated requirements to Elements (SC, LAT, GBM, Ground)*
    - *Project systems integrates the total effort – weekly coordination*
    - *Project SE resident at SLAC*
    - *GSFC representative resident at Spectrum*
    - *Spectrum contract will allow project representative at Gilbert*
    - *Spectrum fixed-price contract allows insight and all technical aspects*
  - *Project conducts detailed systems engineering analysis across interfaces*

GLAST Systems Engineering Roles and Responsibilities – (cont.)

- *Project systems resolves issues across interfaces*
  - *Weekly discipline working groups / Integrated SE team meetings*
  - *Trade studies / special studies*
  - *Drafts CCB action as needed*
- *Project systems drives risk management process*
  - *Proactively identifies risks and rolls up from lower levels*
  - *Develops mitigation plans and workarounds*
- *Project systems owns requirements verification matrix*
  - *Spectrum implements observatory I&V / On-orbit verification*
  - *Project systems reviews and approves all plans and documents*
  - *Project systems will review all non-conformances, approve closeouts*

Key System Margins

TPM	Requirement	Estimate	Margin
Observatory Mass (kg)	4627	4030	15%
Observatory Axial Center of Gravity (m)	1.37	1.35	0.02
Observatory (Pointed/Repointed Mode) Orbit Average Power (W)	1700	1288	32%
SC Attitude Determination Error for LAT (arcsec)	6.0	3.9	1.5 x
SC Attitude Determination Error for GBM (arcmin)	5.0	2.17	2.3 x
Data Storage Capacity (Gbits)	46	96 (BOL)	107%
Observatory Lateral Frequency (Hz)	>12	15.5	29%

NOTE: Performance Estimate values are expressed as CBE – Current Best Estimate

08-29-2003

Trade Studies - Completed

- ***Completed Trades***
  - *Delta II vs. Delta II heavy Launch Vehicle*
    - *Baselined heavy launch vehicle to provide greater lift capability*
  - *S-band downlink architecture*
    - *Selected interleaving real time and playback data on balanced 2.5Mbps I and Q channels*
  - *Orbit Altitude*
    - *Mission lifetime prediction less than 5 years at worst case launch dispersion and worst case solar cycle*
    - *CCR approved to change nominal orbit altitude to 565 km*
  - *Utilize Ku band SN link (TDRSS) for science data return*
  - *Design for demise vs. additional redundancy*

Process Leading to Mission Confirmation

- *GLAST Mission PDR/NAR: June 3-5*
- *GSFC Management Briefing: July 14*
- *NASA Astronomy and Physics Division Confirmation Briefing: August 14*
- *NASA Astronomy and Physics Division Confirmation Status: Sept 11*
- *NASA Confirmation Readiness Review: Oct 9*
- *NASA OSS Confirmation Review Briefing: tbd*
- *NASA Confirmation Review: November 17 (tbd)*

Mission Confirmation

- **Project continues to progress toward mission confirmation.**
- **Conducted Mission Preliminary Design Review and Non-Advocate Review**
  - Mission reviewed by NASA Headquarters Independent Review Team and NASA GSFC Systems Review Office Review Team.
  - Issues identified by review teams being worked. No significant impediments to confirmation.
- **A new GLAST Launch Readiness Date will be baselined as part of the confirmation process. LRD changed due to LAT Re-baseline.**
  - Driven by reallocation of LAT Calorimeter CDE effort and other LAT subsystem liens, and change in the science data downlink approach.
- **Completed NASA Project Management Guideline audit by GSFC Systems Review Office.**

GLAST Orbital Debris Assessment Status

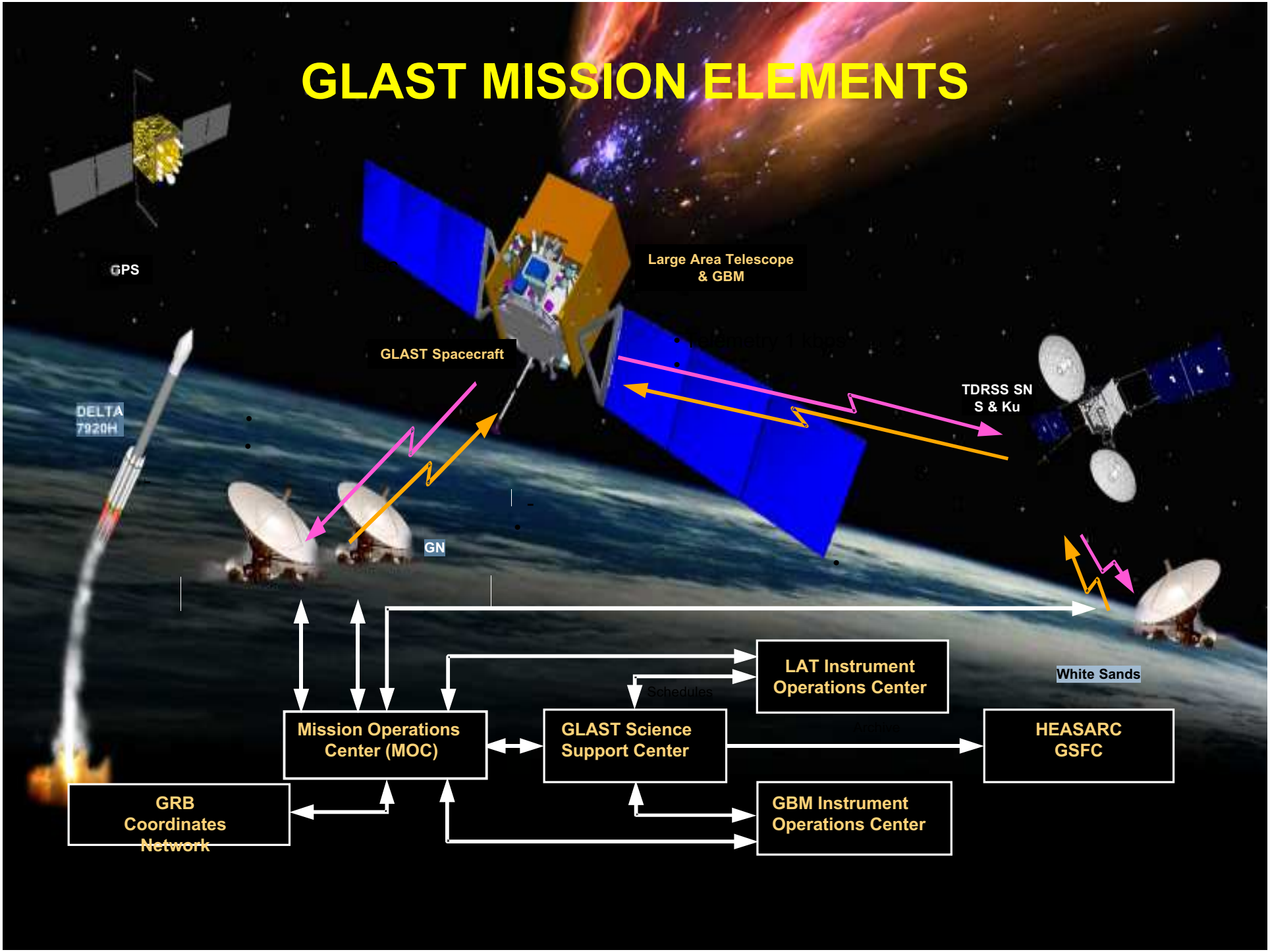
- ***GLAST Project has completed the activities necessary to make a recommendation as to how to comply with NASA Safety Standard 1740.14 (Orbital Debris)***
  - *Assumes new kinetic energy guideline & human casualty probability*
    - *"The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 Joules."*
- ***JSC completed ORSAT analyses to determine the surviving components on the GLAST observatory***
  - *JSC also verified the effectiveness of potential design changes to reduce the amount of surviving debris*
- ***GLAST Project recommends five low-risk modifications to the baseline design to reduce surviving debris***
  1. *Cut thick LAT tracker foils in half*
     - *Note: JSC has verbally indicated that there is no significant increased risk of human casualty from debris with impact energy between 15 J and 24 J*
  2. *Change spacecraft optical bench strut material from Titanium to graphite epoxy*
  3. *Change LAT mounting flexure cross section to make them demise on reentry*
  4. *Take advantage of change of science downlink from X-band to Ku-band*
  5. *Segment the ACD micrometeriod shield*

GLAST Re-Entry Status

- ***The results indicate that the GLAST mission is in family with other missions that had no controlled-reentry capability***
  - *DCA = 12.8 m^2 with propulsion system, DCA = 5.0 m^2 without propulsion system*
    - *Prop system removal makes GLAST compliant for un-controlled re-entry*
    - *Increases mass margin, simplifies spacecraft, reduces surviving debris*
  - *Additional redundancy not required*
- ***Recommendations result in a mission that meets new NASA Safety Standard 1740.14 guidelines without relying on controlled reentry***
  - *Greater safety, simplicity, reliability, cost savings: Improves Overall Mission*
- ***Project proceeding with the "Design for Demise" approach***
  - *Will retain propulsion module in the GLAST design until the safety standard guidelines are approved.*
- ***Will revisit removal of the propulsion system and potential change from the Delta 7920H to a Delta 7920 launch vehicle when change to NSS 1740.14 safety standard is approved.***

Science Data Downlink History

- ***Malindi originally proposed as the baseline ground station to support GLAST for normal operations at no cost to NASA***
  - *Command, Telemetry, Tracking*
  - *Science data down link (150 Mbps) at X-band*
- ***Down link rate limited to 20 Mbps due to bandwidth restrictions for X-band***
  - *Imposed by ITU*
- ***Italian funding shortfall resulted in inability to upgrade Malindi to support GLAST***
- ***USN identified as commercial vendor to replace Malindi***
  - *X-band remained as baseline for spacecraft*
  - *Increased cost to operations phase of the mission*
- ***Project conducted trade study to determine if alternative solutions to USN were viable***
  - *Ku-band identified as viable alternative*


GLAST MISSION ELEMENTS
GPS
Large Area Telescope
& GBM
GLAST Spacecraft
TDRSS SN
S & Ku
DELTA
7920H
GN
White Sands
LAT Instrument
Operations Center
Mission Operations
Center (MOC)
GLAST Science
Support Center
HEASARC
GSFC
GRB
Coordinates
Network
GBM Instrument
Operations Center

Ku-Band Concept of Operations

- ***2-4 Contacts a Day (Approximately 8-16 minutes total duration) to down link recorded engineering and science data***
- ***Gimbaled Ku-band antenna to maintain pointing accuracy and allow up to ~200 minutes of contact per day for down linking recorded science data***
- ***No change in concept for L&EO activities***
  - *TDRSS S-band service for commissioning phase*
- ***Burst alert capability unchanged***

Pros and Cons:
Science Data Downlink Options

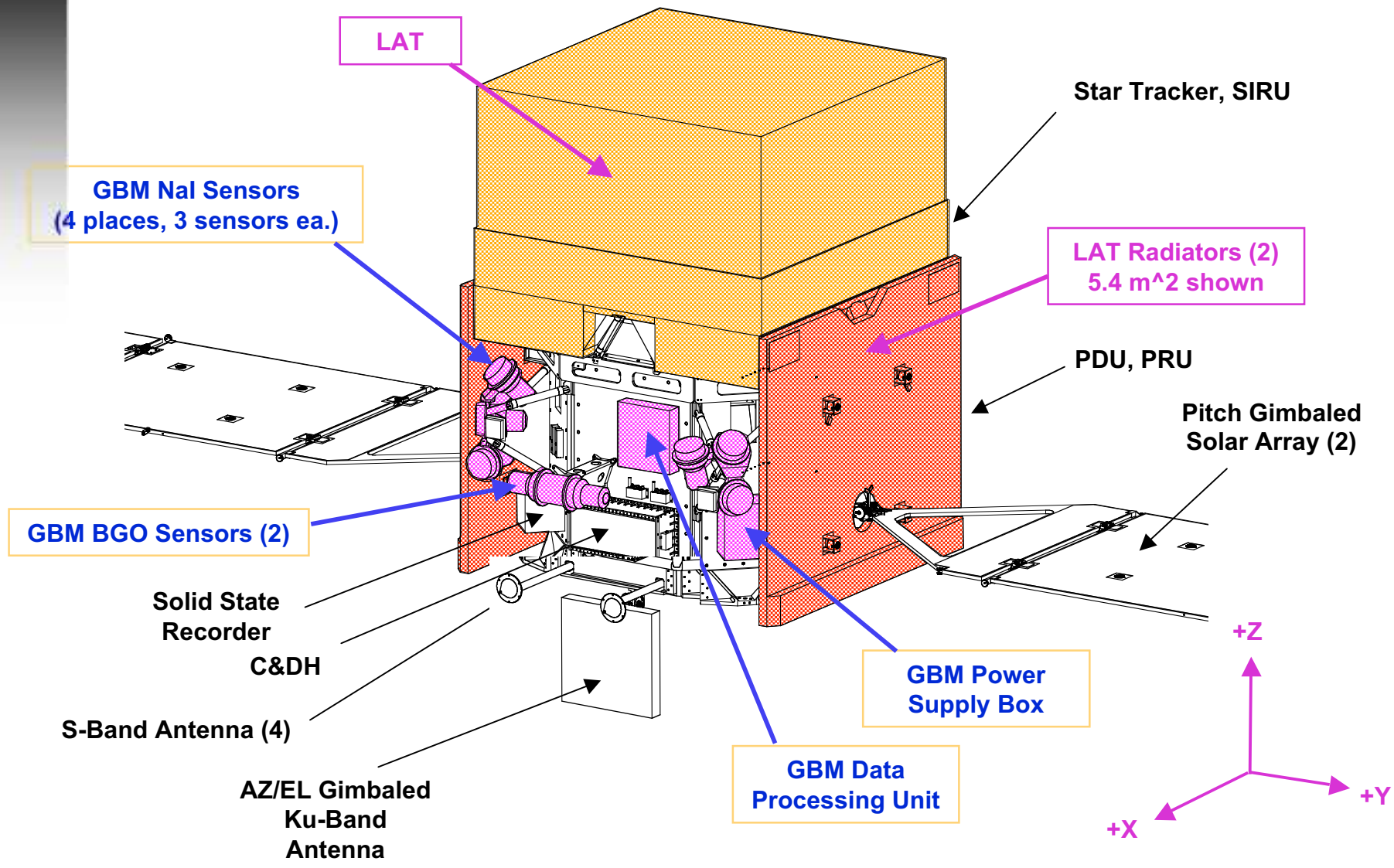
Option	Pros	Cons
USN only **(X and S-bands)**	▸ **No impact to current SC design** ▸ **Increased flexibility with multiple stations** ▸ **Existing, operational network**	▸ **Substantial Phase E cost increase, with limited options to reduce costs for mission extensions (17 M)** ▸ **Dependency on commercial vendor** ▸ **No control over vendor price** ▸ **Only two sites under USN direct control/ownership** ▸ **Relies on 20 MHz approval** –Extra filing/approval for Australia ▸**Difficult to support significant increases in LAT data rate in terms of contact opportunities and cost**

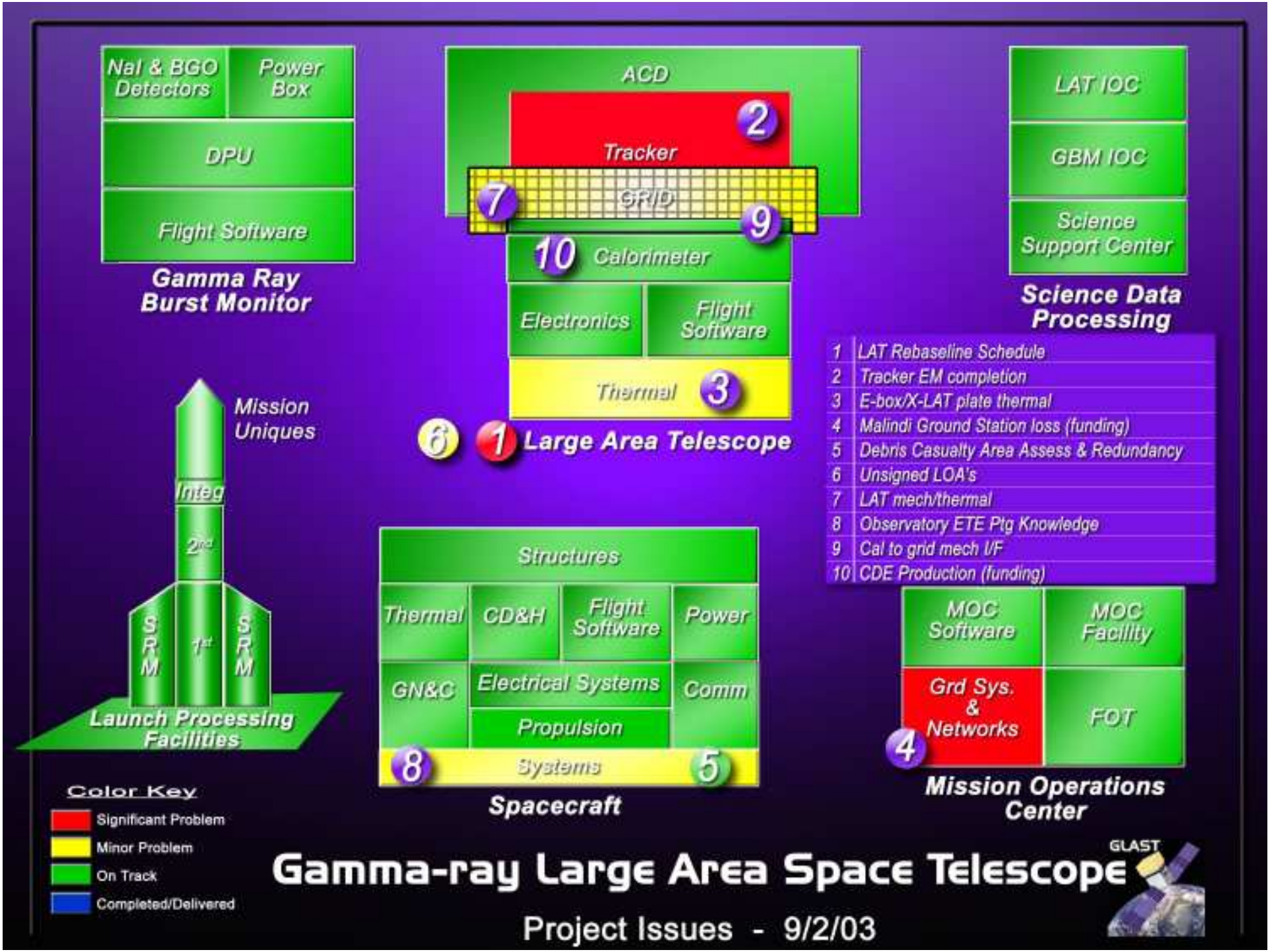
Option	Pros	Cons
TDRSS only **(Ku and S-bands)**	▸ **Code M funded – no Phase E costs except for the WSC front-end and WSC/MOC data link** ▸**Excellent for low cost mission extensions** ▸ **Best ops flexibility for L&EO, normal ops, safe modes, and reentry** ▸ **Much higher bandwidth (40 Mbps Ku)** ▸ **NASA controlled resources** ▸ **Existing high rate path to MOC** ▸ **Lowest data latency** ▸ **Facilitates end-to-end science data flows pre-launch** ▸**Greatly improves the ability to accommodate significant increases in the LAT data rate (up to 1 Mbps possible at times), with no corresponding increases in space-to-ground communications costs.**	▸ **Requires spending Phase C/D now – payoff comes during ops** ▸ **Impact to S/C design** ▸ **Must implement and maintain a WSC EDOS-like front end to handle Ku-band data** ▸ **No going back to use X-band to ground** ▸**Policy of Code M funding the SN costs could change**

TDRSS Assumptions

- ***GLAST Project funds GLAST-unique equipment at WSC for storing and forwarding of data and GLAST-unique WSC/MOC communications services***
  - *Consistent with other GSFC projects (e.g. Terra)*
- ***No cost to GLAST for other TDRSS services (e.g. Ku-band, S-band)***
  - *Based upon MOA for "Management of NASA's Space Communications Network" dated 09 May 2002 (No expiration date)*
    - *Signed by AAs for Code M, S, and Y*
- ***Discussions with GSFC TDRSS Program Office completed***
  - *No technical or programmatic impacts identified resulting in additional costs*
  - *Documented in signed letter from the TDRSS Program Office indicating no operations costs.*

GLAST Observatory

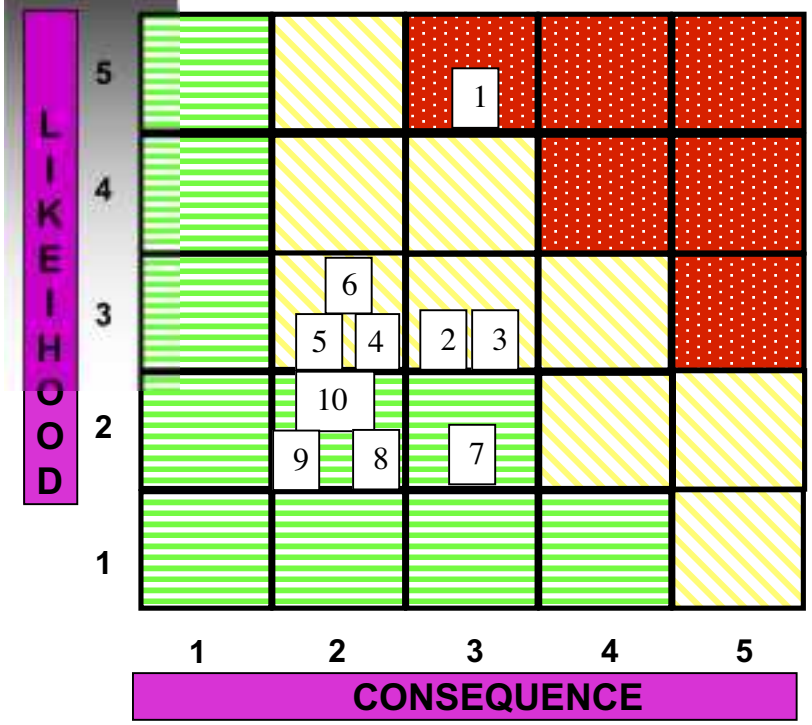



NaI & BGO Detectors
Power Box
DPU
Flight Software
Gamma Ray Burst Monitor
ACD
2
Tracker
7
GRID
9
10
Calorimeter
Electronics
Flight Software
Thermal
3
6
1
Large Area Telescope
LAT IOC
GBM IOC
Science Support Center
Science Data Processing
1 LAT Rebaseline Schedule
2 Tracker EM completion
3 E-box/X-LAT plate thermal
4 Malindi Ground Station loss (funding)
5 Debris Casualty Area Assess & Redundancy
6 Unsigned LOA's
7 LAT mech/thermal
8 Observatory ETE Ptg Knowledge
9 Cal to grid mech I/F
10 CDE Production (funding)
Mission Uniques
Integ
2nd
SRM
1st
SRM
Launch Processing Facilities
Structures
Thermal
CD&H
Flight Software
Power
GN&C
Electrical Systems
Comm
Propulsion
8
Systems
5
Spacecraft
MOC Software
MOC Facility
Grd Sys. & Networks
FOT
4
Mission Operations Center
Color Key
Significant Problem
Minor Problem
On Track
Completed/Delivered
Gamma-ray Large Area Space Telescope
GLAST
Project Issues - 9/2/03

Top Project Issues

	Issue	Impact	Status
1	LAT baseline schedule has 27 months between CDR and delivery. Insufficient float.	Schedule delays to hardware deliveries and/or I&T problems will result in delivery slips of LAT which will impact GLAST LRD.	Meeting with HQ A&P division planned for 9/11/03 to resolve budget changes.
2	Tracker EM Completion - analysis and test completed after CDR	Tracker EM testing may require design change after CDR is complete.	Sidewall drawing update nearing completion. Test panel in fab in Italy to check revised process. Test plans for tower vibration and T/V tests in Italy under review. Overall activity schedule still pending from SLAC.
3	Ebox/XLAT Heat Pipe Thermal Interface	Lack of a final design will cause erosion of schedule margin.	Rigid mount e-boxes were downselected. Analyses, test planning and design details in progress. Peer Review targeted for 9/29/03
4	Italian Funding for Malindi ground station support.	Loss of Malindi requires finding alternative site/method to download science and housekeeping data.	Preparing presentation to HQ wrt pros/cons of using KU-band. SAI Ku-band UDL task Study 10 has been turned on.
5	Debris Casualty Area and Spacecraft Redundancy	S/C degradation to zero fault tolerance for reentry could lead to decision to reenter GLAST before science mission is complete.	Project adopted approach of design for demise for LAT flexures, optical bench struts, slotting LAT foils and for segmenting ACD mm shield and maintain prop system for controlled reentry. Removal of prop system will be considered once new 1740.10 guidleines are implemented (e.g. 15 J KE).
6	Unsigned LOAs	International contributions to the LAT will be delayed.	Germany: LOA signed France: 2 MOAs with labs signed. 2 LOAs drafted in Code I review (CNRS & CEA) Italian LOA in Italy for signature. Japan still in Code I Sweden: LOA has been marked up to reflect changes due to CNES withdrawal. In Code I review.
7	LAT Mechanical/Thermal subsystem progress to schedule.	Continued erosion of the Mech/Thermal schedule will result in instrument delivery delay. Proceeding with h/w development in parallel with design risks cost growth if design mods needed. Release drawings not at CDR level.	1. Additional mechanical engineer hired by SLAC. John Ku made Mechanical Analysis lead. 2. Dan Klein/Swales added to support LAT thermal subsystem. Support from Ben Rodini secured to assist SLAC, esp. with Tracker. 3. New systems engineer hired to audit the SLAC drawing tree 4. Cal-grid closure review scheduled for 9/17 & X-LAT targeted for 9/29.
8	Verification of Observatory Pointing Knowledge	Presently no allocation for the contribution of the thermal-mechanical distortion at the spacecraft-LAT interface to the observatory pointing knowledge. Consequently, the SC and LAT designs cannot be fully validated or verified.	Spectrum re-reported Cycle 1 results using the updated LAT tracker boresight definitions. Results similar to initial findings (< 6 arc-sec for a 1 C gradient up the grid).
9	Calorimeter to grid mechanical interface design.	Lack of a final design will cause erosion of schedule margin.	Formal peer review scheduled for 9/17/03. Held a successful informal peer review with Jim Ryan 8/9/03.
10	CDE Production Rate and Schedule in France. (CNES funding withdrawal)	Potential delay in delivery of flight calorimeters to SLAC for instrument I&T.	CDE MRR was delayed and will be rescheduled to occur prior to flight production start which begins on 9/21..

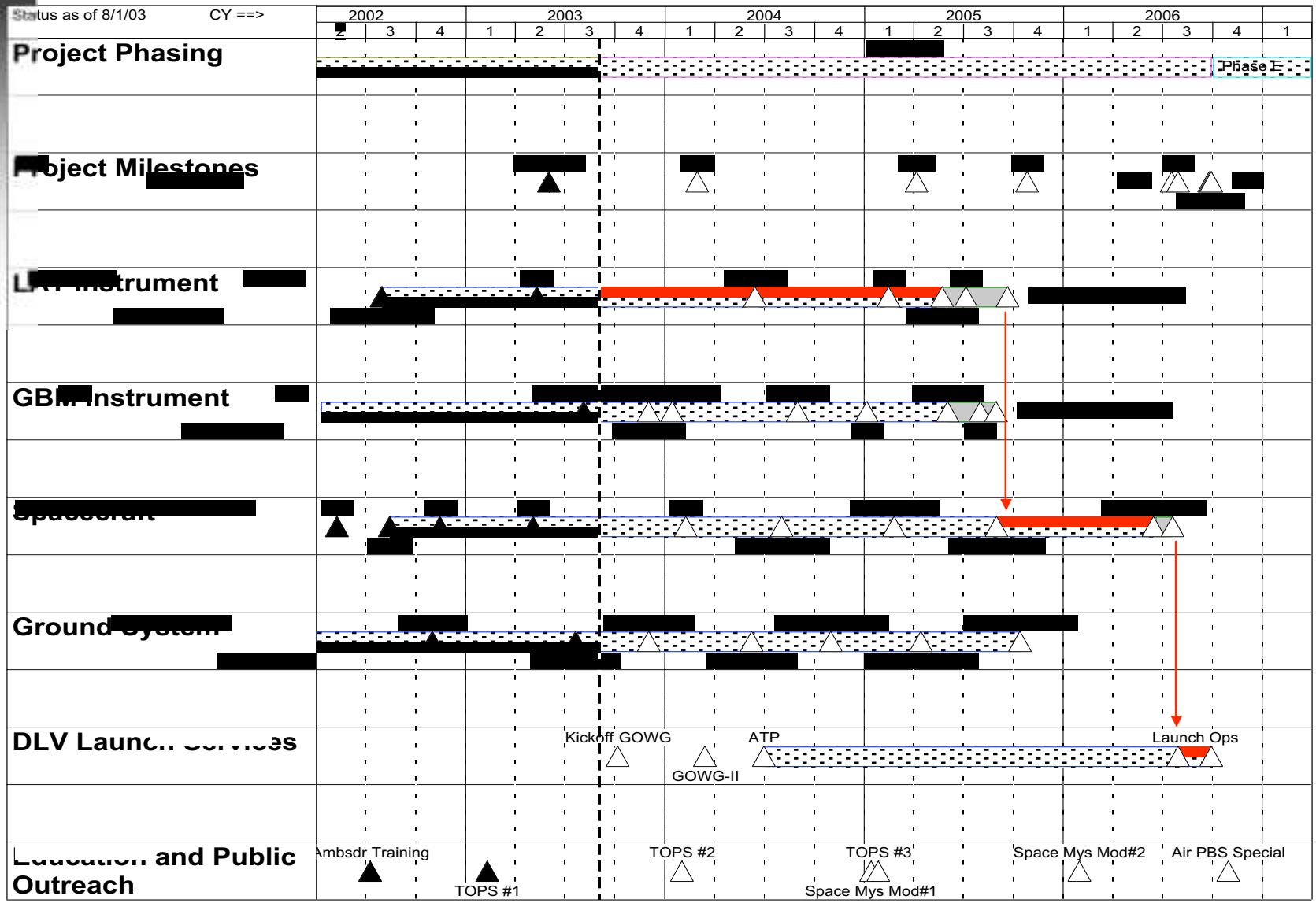
GLAST Top Risks



Criticality	L x C Trend	Approach
High	Decreasing	M - Mitigate
Med	(Improving)	W - Watch
Low	Increasing (Worsening)	A - Accept
	Unchanged New Since Last Period	R - Research

Rank & Trend	Risk ID	Approach	Risk Title
1	**000180**	M	*If the Tracker structure does not pass the qualification test; then a major impact to the LAT delivery schedule will occur.*
2	**000205**	M	*If LAT parts and vendor orders are completed late, then flight production schedules will be extended, and delivery of LAT subsystems delayed.*
3	**000130**	M	*If LAT FSW Requirements; processes; and Schedule are not well defined; an impact to the LAT Inst. delivery is likely.*
4	**000215**	M	*If ASICs fail to meet requirements then LAT delivery could be delayed*
5	**000060**	M	*If LV mechanical resonance @ MECO is not well defined, then this may result in added design work and testing.*
6	**000200**	M	*If a critical component failure occured post LAT integration requiring de-integration, then the cost & schedule impact would be significant*
7	**000160**	M	*If there is an anomaly with Solar Array deployment; then mission failure would result.*
8	**000190**	M	*If error occurs during manufact. of grid, may have to re-machine causing LAT I&T to be delayed, resulting in delivery delay to SA.*
9	**000135**	M	*If the Mission Mass Margin is insufficient; then budget and schedule resources may need to be expended to correct CG.*
10	**000185**	M	*If Atomic Oxygen Erosion of Solar Array Kapton occurs, then full mission life may not be achievable*

GLAST MASTER SCHEDULE



Upcoming Events

- ***Complete sequence of confirmation readiness reviews and confirmation reviews.***
- ***LAT: Close-out mechanical/thermal CDR issues, complete responses to CDR RFAs and proceed with flight hardware fabrication.***
- ***GBM: Complete subsystem and system CDRs.***
- ***Spacecraft: Complete open trades, complete PDR RFA responses and hold subsystem CDR peer reviews.***
- ***Award mission operations control center development contract.***
- ***Conduct Ground System Design Peer Reviews***
- ***Conduct first launch vehicle interface working group meeting in October.***

Back-up Material

Mission Architecture – Operations Overview

Routine Operations

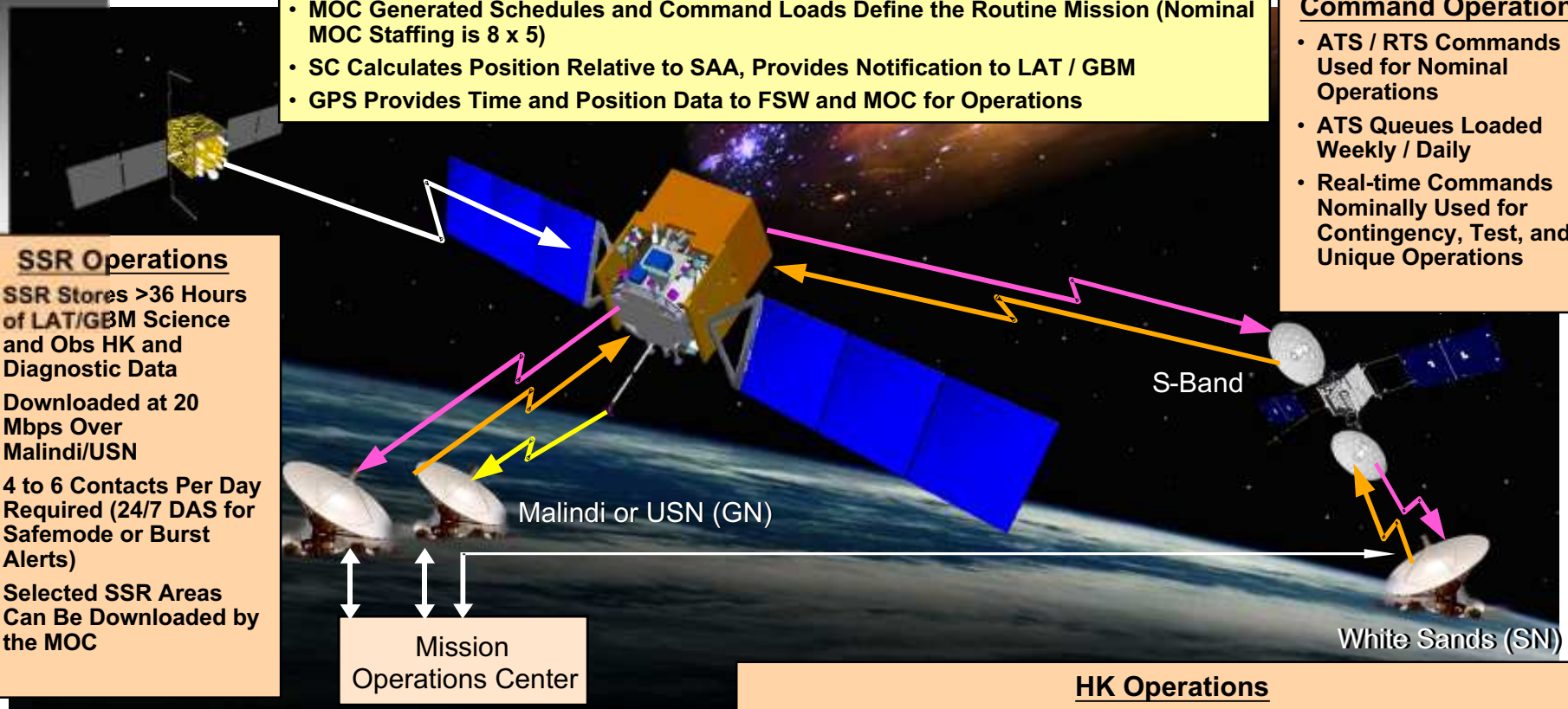
- MOC Generated Schedules and Command Loads Define the Routine Mission (Nominal MOC Staffing is 8 x 5)
- SC Calculates Position Relative to SAA, Provides Notification to LAT / GBM
- GPS Provides Time and Position Data to FSW and MOC for Operations

Command Operations

- ATS / RTS Commands Used for Nominal Operations
- ATS Queues Loaded Weekly / Daily
- Real-time Commands Nominally Used for Contingency, Test, and Unique Operations

SSR Operations

- SSR Stores >36 Hours of LAT/GBM Science and Obs HK and Diagnostic Data
- Downloaded at 20 Mbps Over Malindi/USN
- 4 to 6 Contacts Per Day Required (24/7 DAS for Safemode or Burst Alerts)
- Selected SSR Areas Can Be Downloaded by the MOC



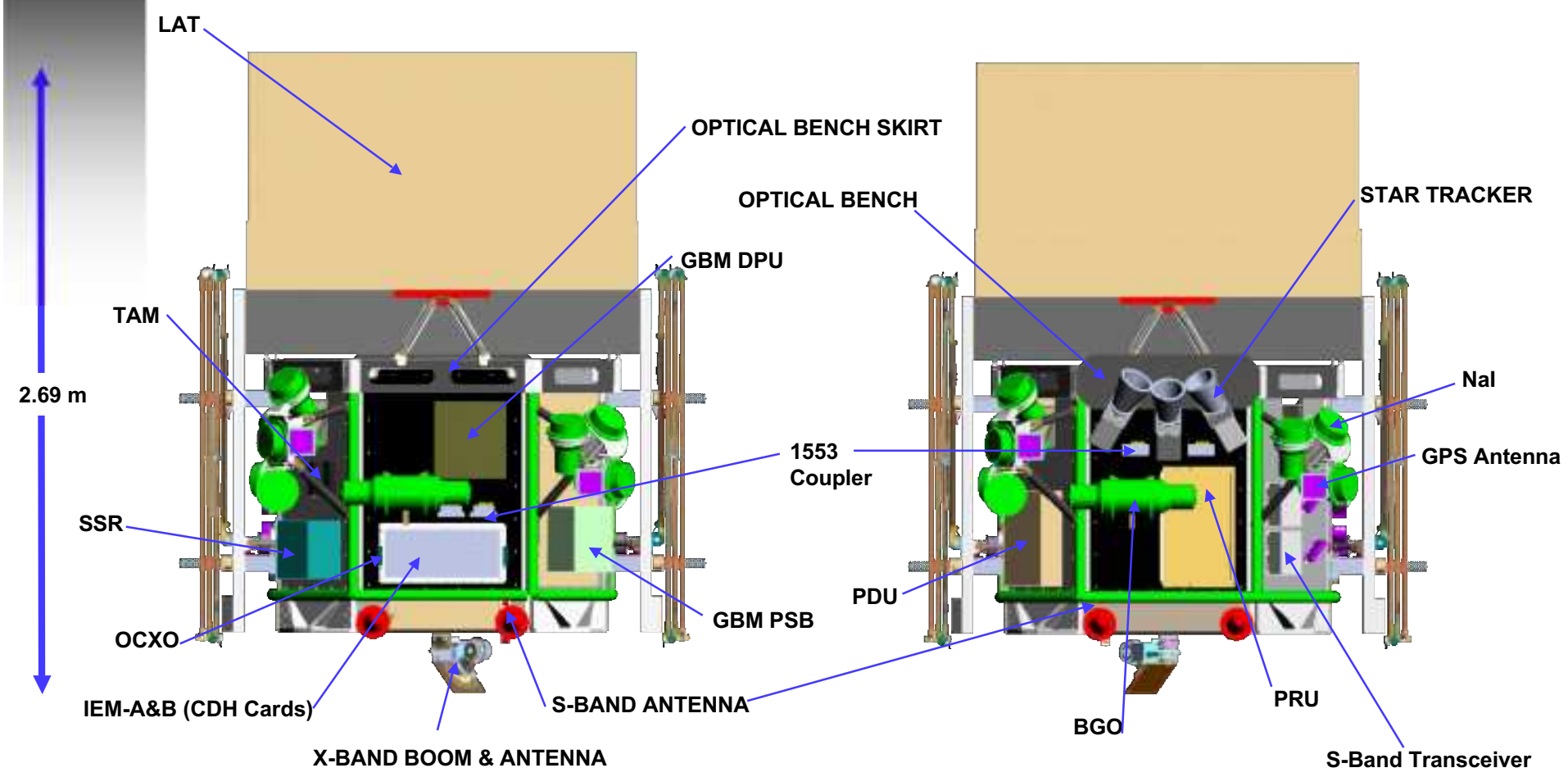
Science Modes

- MOC Commands the Instruments to the Proper Science Mode, Survey or Inertial Point (Planned Events) and Commands TOOs
- Observatory Notifies the MOC for Burst and LAT-Commanded Autonomous Re-pointing
- Observatory Resumes Planned Operations After Autonomous Re-point Completes (5 hr, Selectable Dwell)

HK Operations

- 32 kbps RT Stream Contains Both SC and Instrument Housekeeping Data
- Data Stored on the SSR in Separate Partition From Science
- 32 kbps Is Part of the 2.5 Mbps Data Stream
- Stored HK Data Downlinked on Every Contact
- Data Used to Determine Observatory Health and Status
- Stored HK Data Provides Long Term Data for Trending and Analysis
- Diagnostic/Calibration Data Upon MOC Command

Spacecraft Views



* Provided by Spaectrum Astro

Mass Budget

	Mass (kg)			
	Allocation	Estimate	Margin	%
Dry SC	1169	906	263	29
Propellant	361	360	1	0
LAT	3000	2680	320	12
GBM	97	84	13	15
Observatory mass	4627	4030	597	**15**

- *Delta II Heavy throw weight to 575 km with cg at 1.37 m = 4627 kg*
- *49.3% of LAT mass estimate is measured*
- *LAT has entered the CDR level of maturity, and is showing 12% margin.*
- *AIAA recommendations for the mass of flight systems recommend holding 7.2% margin at the PDR stage of the LAT program (193kg), and the LAT is holding 4.8% reserve on top of that (127kg).*
- *LAT is carrying 9.5% reserve beyond the AIAA PDR growth allocation for their unmeasured mass*

Power Budget

Orbit Average Power (Watts)

	Allocation	*Estimate*	*Margin*	*%*
Spacecraft	*985*	*660*	*325*	*49*
LAT	*650*	*573*	*77*	*13*
GBM	*65*	*55*	*10*	*18*
Observatory total	*1700*	*1288*	*412*	***32***

08-29-2003

Results of the July 2003 JSC/Lockheed ORSAT Analysis

- ***ORSAT modeling shows that the following items survive re-entry with impact energy < 15 J***
- ***No action is required is required to mitigate the risk of this material during an uncontrolled reentry***

Object Description	Qty.	Debris Casualty Area (m^2)	Impact Energy (J)
Tracker Tray Converter Foil 1	3840	1815.2	0.5
Nextel Side Sheet	16	60.8	1.9
Tracker Corner Flexures	64	27.6	2.7
Nextel Top Sheet	4	23.0	3.2
Tracker Tray Closeout	1216	597.4	8.3

Results of the July 2003 JSC/Lockheed ORSAT Analysis

- ***ORSAT modeling shows that the following items survive re-entry with impact energy > 15 J***
- ***All can be redesigned to demise or reduce impact energy to < 15 J***

Object Description	Qty.	Debris Casualty Area (m^2)	Impact Energy (J)	Modifcation	Change Effect	Impacts
Optical Bench Strut	8	3.7	20.8	Change material from Titanium to graphite epoxy	Struts demise on re-entry	No impact on start of SC I&T, strength testing of GrEp required
Tracker Tray Converter Foil 2	1024	484.0	24.2	Add a cut-out feature to the foils to effectively cut them in half	Impact energy reduced from 24 J to 12 J	No impact on start of LAT I&T, existing tooling can be used, minimal effect on LAT effective area
X-Band Ant. Boom Base Hinge	1	0.4	24.4	Hinge deleted with change from X-band to Ku-band science link		Change unrelated to reentry considerations
LAT Mounting Flexure	4	2.6	2611.5	Change flexure cross section from rectangular to square	Flexures demise on re-entry	No change in start of SC I&T, increases strength margins
Propulsion System (Frame, Tank, Valves)	7	7.8	5 to 10448	Delete propulsion system		Modular design of prop system facilitates removal

Results of the July 2003 JSC/Lockheed ORSAT Analysis

ORSAT modeling shows that the following items survive re-entry with impact energy > 15 J

Object Description	Qty.	Debris Casualty Area (m^2)	Impact Energy (J)	Modifcation
Solar Array Root Hinge	2	1.1	203.7	None practical
X-Band Antenna Gimbal	1	0.9	468.1	Replaced by Ku-band antenna gimbal
LAT Grid	1	3.0	21119.0	None practical

Total GLAST DCA is 5 m^2 after five changes to the baseline