



Mission Operations Center

GS SDR Section 18

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Outline



- ▶ **Operations Overview**
 - *Mission Planning and Command Generation*
 - *Space Network Scheduling*
 - *Real-time Telemetry*
 - *Target of Opportunity Handling*
 - *Burst Alert Handling*
 - *Solid State Recorder Management*
- ▶ **Data Processing**
- ▶ **Off-Line Analysis**
- ▶ **Automation**
- ▶ **Contingency Operations**

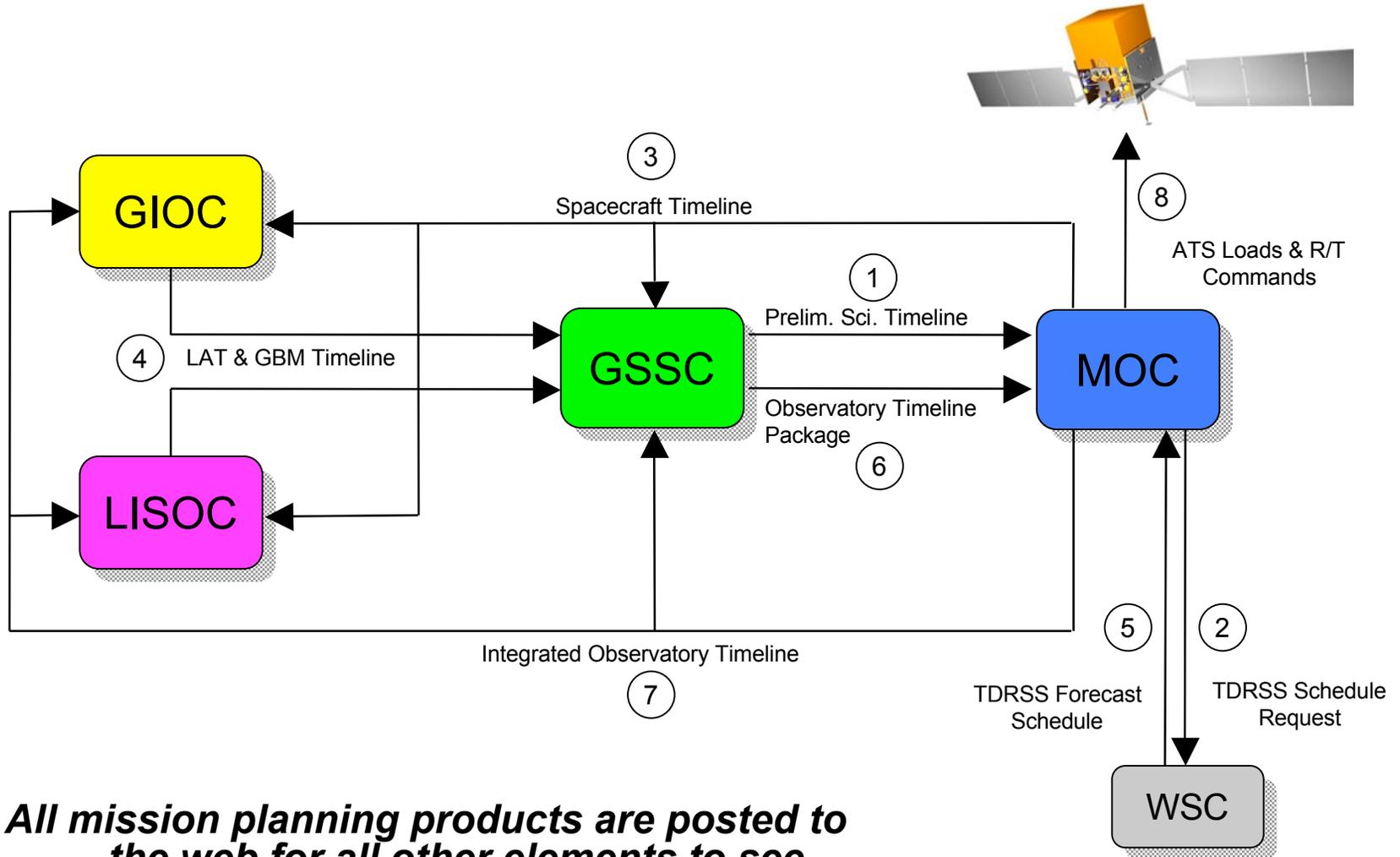


Mission Planning

- ▶ **Mission planning process is designed to produce weekly command and ATS loads for GLAST**
- ▶ **Process is driven by TDRSS scheduling requirements and the need to maximize flexibility**
 - **Timing**
 - TDRSS Schedule requests must be made 14 days prior to the Monday of the first contact
 - TDRSS scheduling week does not correspond with the observatory ATS week
 - **Flexibility**
 - Science planners need to be able to schedule observations as late as possible
 - Instrument operators need to be able to schedule calibrations and adjustments as late as possible
- ▶ **TDRSS contacts are scheduled prior to defining the final science and instrument activities (contacts scheduled around other activities)**
- ▶ **Observatory activities are scheduled around the requested TDRSS contact times**
- ▶ **Once final TDRSS contact times are received, the MOC will construct the weekly command and ATS load**



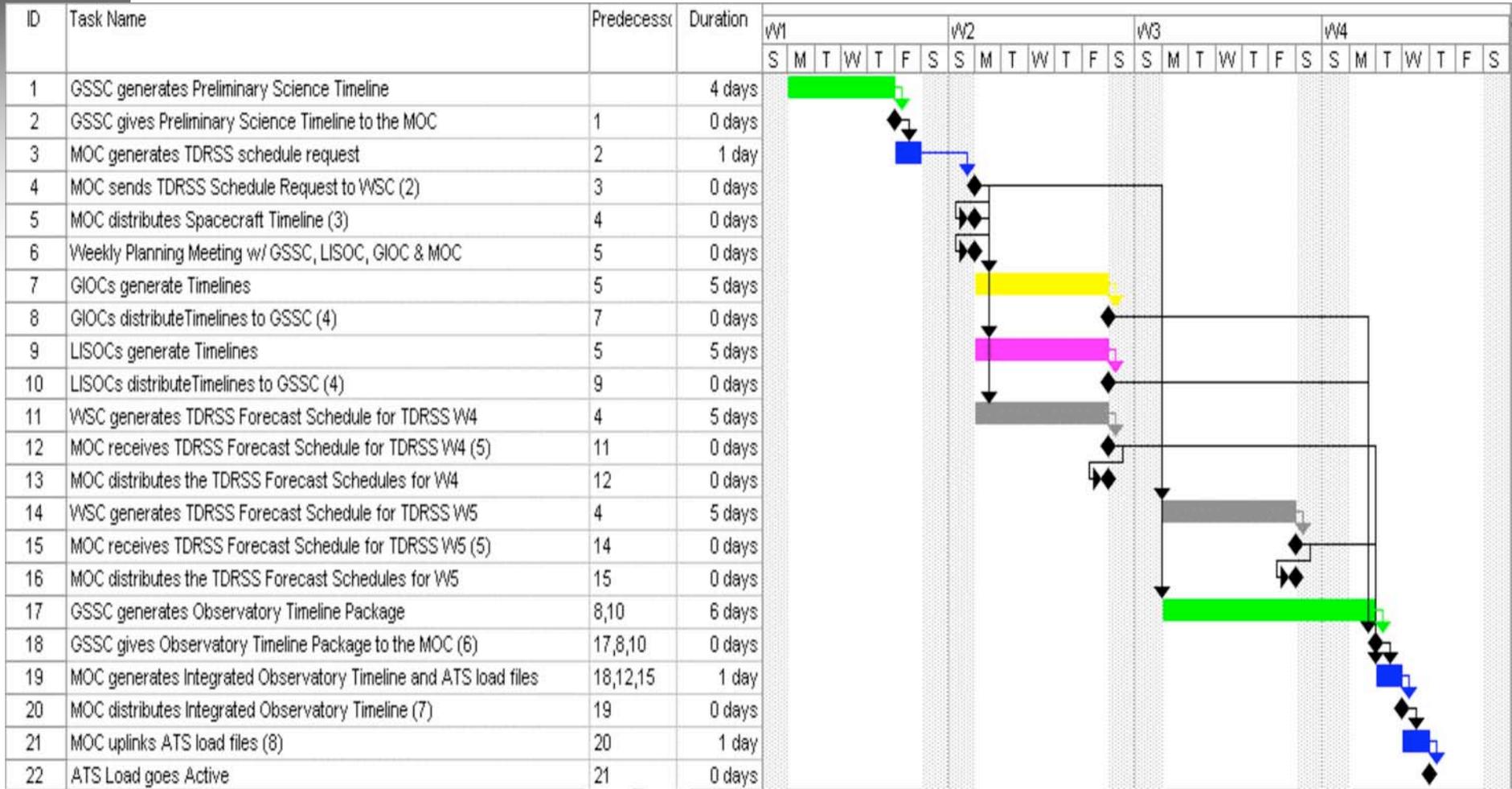
Mission Planning Flow



All mission planning products are posted to the web for all other elements to see



Mission Planning Timeline





Space Network Scheduling



▶ **Observatory commanding**

- ***MOC receives file uploads, r/t commanding activities, and integrated science timeline from GSSC***
 - *Science conflicts resolved by the GSSC prior to delivery*
 - *MOC checks for engineering constraint violations*
- ***File uploads and r/t commanding activities uploaded whenever necessary***
- ***ATS loads created and uploaded weekly from integrated science timeline***

▶ **Pass scheduling**

- ***Ku-band antenna configuration and spacecraft attitude limit TDRS contact to 6-10 minutes per contact***
 - *Minimum of 52 mins. per day to downlink 24 hrs. of science and housekeeping*
 - *Current best estimate is 75+ opportunities for passes each day with TDRSS*
- ***Ku-band antenna TDRSS contacts are dependent upon spacecraft attitude***
 - *MOC extracts attitude information from the integrated science timeline*
 - *Create a week long predicted attitude file modeling the s/c motion during the science plan*
 - *MOC tools read predicted attitude and predict all GLAST to TDRSS views using antenna mask, predicted orbit ephemeris, and TDRSS ephemerides*
 - *MOC scheduling tools filter the TDRSS view periods choosing the best passes based on pass length, length between passes, number of minutes per day of downlink*
 - *MOC analysts review the schedule for completeness and schedules the 7 to 8 passes per day with SWSI*
 - *IOCs and GSSC notified of the scheduled TDRSS supports*



Space Network Scheduling



▶ **TDRSS schedule impacts**

- *Last minute changes to the integrated science timeline received from GSSC*
- *Target of Opportunities (ToO) are high priority requests from the GSSC*
 - *Cause deviation from the scheduled plan*
 - *ToO frequency is expected 1 per month*
- *Autonomous Repoints (AR) are an automated spacecraft response to significant gamma ray bursts*
 - *Cause unscheduled observatory repointing*
 - *Expected to occur about 1/week and last 5 hrs (TBD)*
 - *Have a high probability of impacting a previously scheduled TDRSS pass*
 - *MOC will notify the SN if an AR caused a scheduled TDRSS support to be missed*

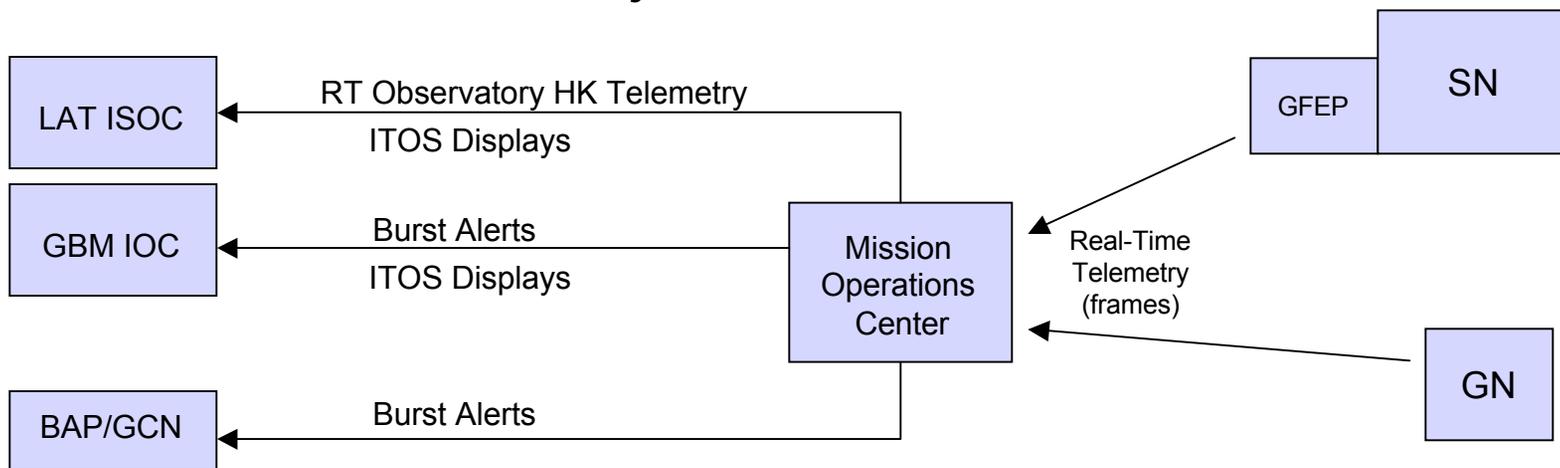
▶ **Scheduling options**

- *Several real-time command opportunities for uplinks during MOC staffed periods*
- *Extra “contingency” downlink minutes scheduled daily to compensate for missed passes, should they occur. Data will be recovered over a series of supports following the AR or ToO*
- *If necessary the MOC will use the TDRSS Unscheduled Time (TUT) for additional uplink and downlink opportunities*



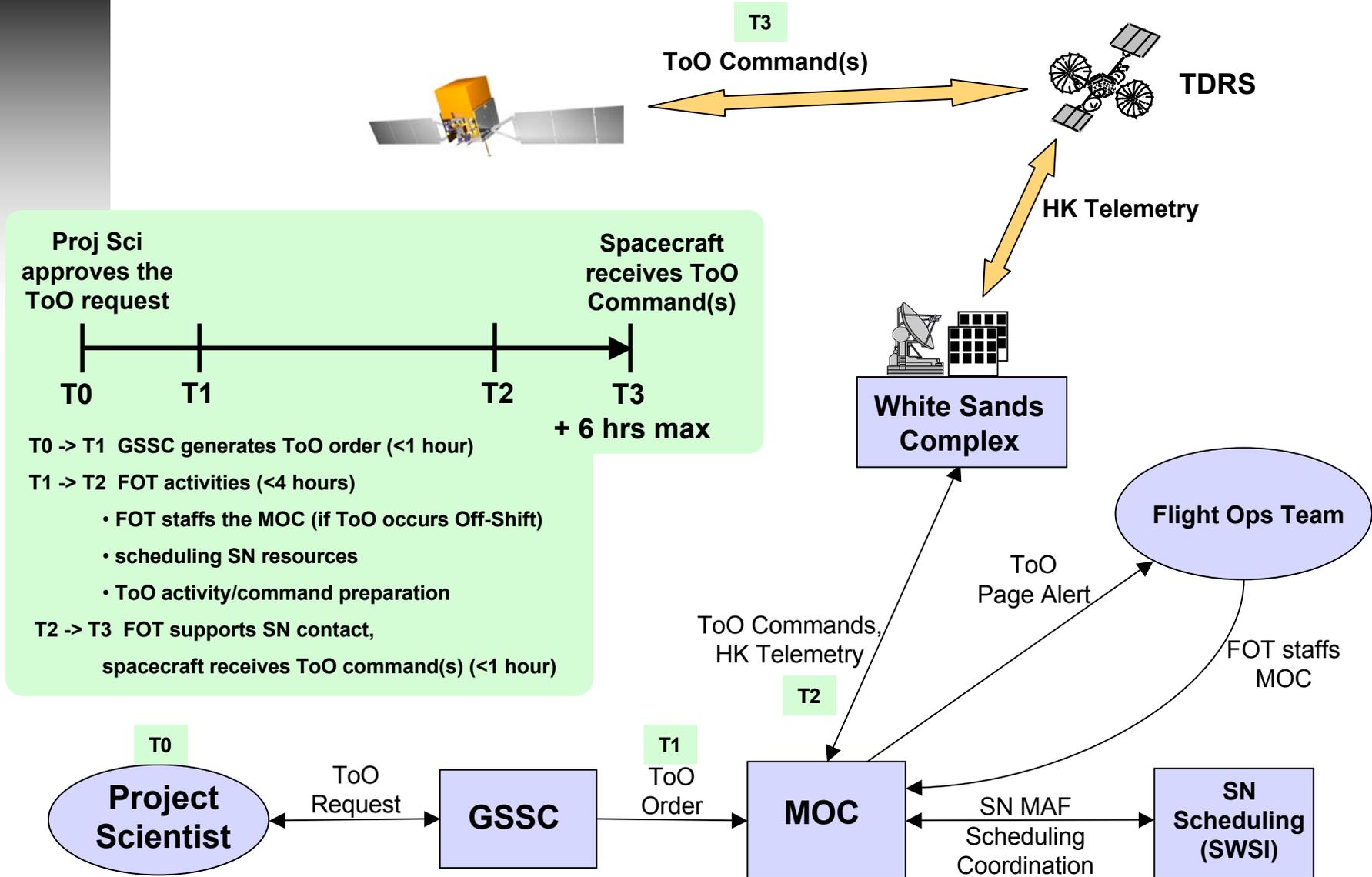
Real-Time Telemetry

- ▶ **GFEP at WSC forwards selected Virtual Channels (VC's) to MOC in real-time (frame data)**
 - Observatory HK telemetry, Burst Alerts, Safe-mode telemetry, and Memory Dumps
 - All VC's stored at station and forwarded to MOC post-contact
- ▶ **MOC performs traditional real-time processing on telemetry**
 - Extract packets, decommutate and display HK data, generate/display event messages and alarms, perform command verification
- ▶ **MOC will forward instrument packets in real-time to the LAT ISOC to assist in instrument monitoring**
 - IOC's can call up MOC ITOS displays via the MOC ITOS Web server
- ▶ **Autonomous downlink of burst alerts or safe-mode telemetry using Space Network Demand Access System**





Target of Opportunity Handling



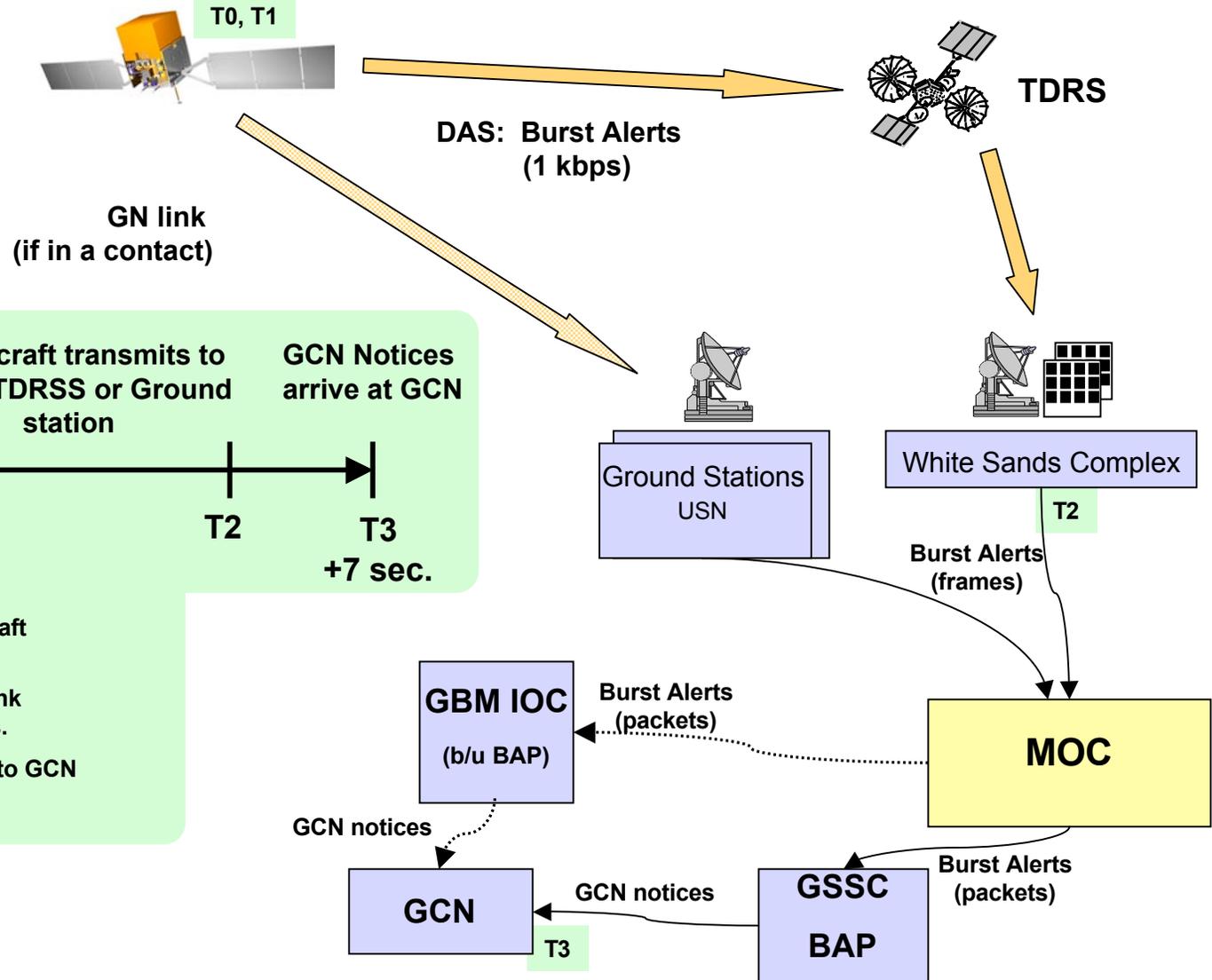


Target of Opportunity Handling

- ▶ ***Upon receiving authorization to proceed with the ToO, the GSSC constructs the ToO Order and forwards to the MOC***
 - *GSSC checks for constraint violations, occultation, availability, etc.*
 - *Approved ToO Order is sent to the MOC*
- ▶ ***MOC recognizes ToO Order and notifies appropriate FOT personnel for action***
 - *FOT processes ToO Order*
 - *Works with SN to schedule a forward link via TDRSS*
 - *MOC transmits the ToO commands to the spacecraft as soon as the SN forward link is available*
- ▶ ***Observatory autonomously returns to on-board observing schedule at completion of the ToO***



Burst Alert Handling



Inst. sends Burst Alert on 1553 Bus **Spacecraft transmits to either TDRSS or Ground station** **GCN Notices arrive at GCN**

T0 T1 T2 T3

0 sec. +7 sec.

T0 -> T1 Inst. To Spacecraft transmission <1 second.
T1 -> T2 Space-ground link transmission <5 seconds.
T2 -> T3 Ground system to GCN transmission <1 second.



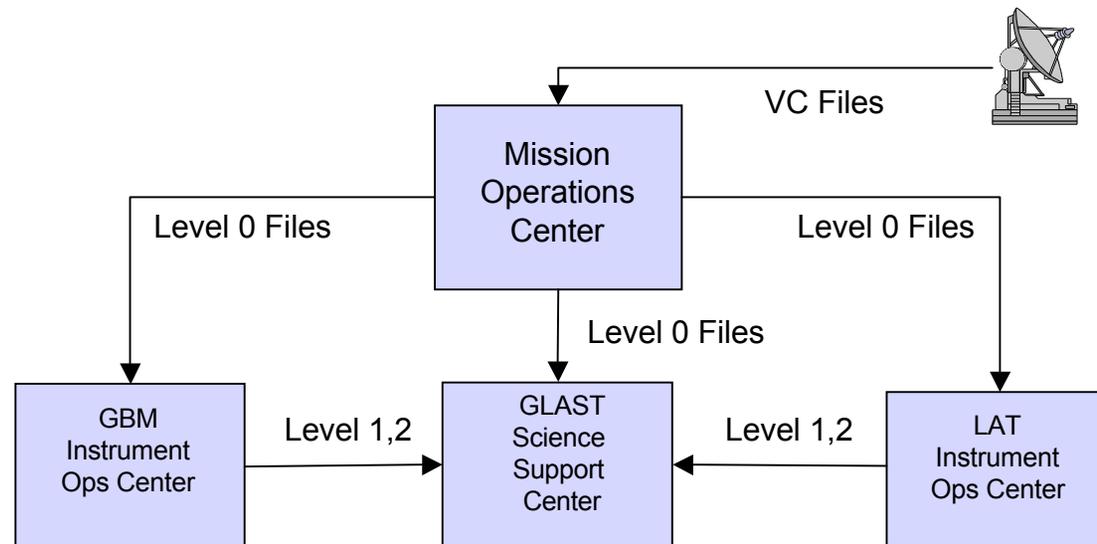
Burst Alert Handling (cont.)

- ▶ **Spacecraft initiates link with TDRSS/DAS, and sends Burst Alert packets as received from instruments**
 - *Burst Alerts go through the Ku-band link if GLAST is in a Ku-band contact*
 - *Burst Alerts go through S-band link if GLAST is in a ground station contact*
 - *If the GRB warrants, LAT requests spacecraft to slew to the target (referred to as an Autonomous Repoint)*
- ▶ **SN forwards messages to MOC, which pulls out Burst Alert packets and forwards to:**
 - *Burst Alert Processor (BAP) located at the GSSC and in the GIOC*
 - *BAP processes the messages from both instruments and creates Gamma-Ray Coordinates Network (GCN) Notices*
 - *BAP and GIOC forward the GCN notices to the science community via Gamma-Ray Coordinates Network*
- ▶ **Burst Alerts are sent to a single location i.e. the MOC**
 - *Burst Alerts received by multiple locations (SN and GN)*
 - *Prefer to centralize Burst Alert frame processing*



Data Processing

- ▶ **Level 0 processing performed on a dump file basis**
 - *Ku-band GFEP records frame-level data during each TDRSS contact, sorts by VCID, and automatically transfers to MOC post-contact*
 - *MOC automatically begins Level-0 processing on files as they are received from the SN or ground station*
 - *Extraction of packets from frames, Reed-Solomon (RS) decoding, time ordering of data, removal of duplicate packets, and quality and accounting information.*
 - *Upon completion of Level 0 processing the files are sent to the LISOC, GIOC, and GSSC*
 - *IOC's generate Level 1 and 2 data products and provide to GSSC*





Contingency Operations

- ▶ **Ground System Anomalies**
 - *Built in process monitoring and fail over procedures*
- ▶ **Observatory Anomalies**
 - *On-board telemetry monitoring senses known anomalous conditions and either alerts the ground through telemetry and/or initiates a RTS to safe the instruments and/or spacecraft*
- ▶ **Contingency procedures developed to recover from anomalous conditions**
 - *Identified by the Systems, Subsystem, Instrument, and Flight Ops teams*
 - *Consist of Flow Charts, Procedures, PROCs, and notification lists*
 - *Observatory recovery procedures written by Spectrum Astro and IOCs and captured in the **On-orbit Operations Descriptions Manual***
 - *Ground recovery procedures written by the FOT and captured in the **Flight Operations Manual***



Operations Product Development



▶ **Procedures**

- **Observatory Operations Description Manual (OODM) delivered by Spectrum Astro**
- **Flight Operations Manual written by the FOT**
- **Format documented in the Procedure and PROC Style Guide**

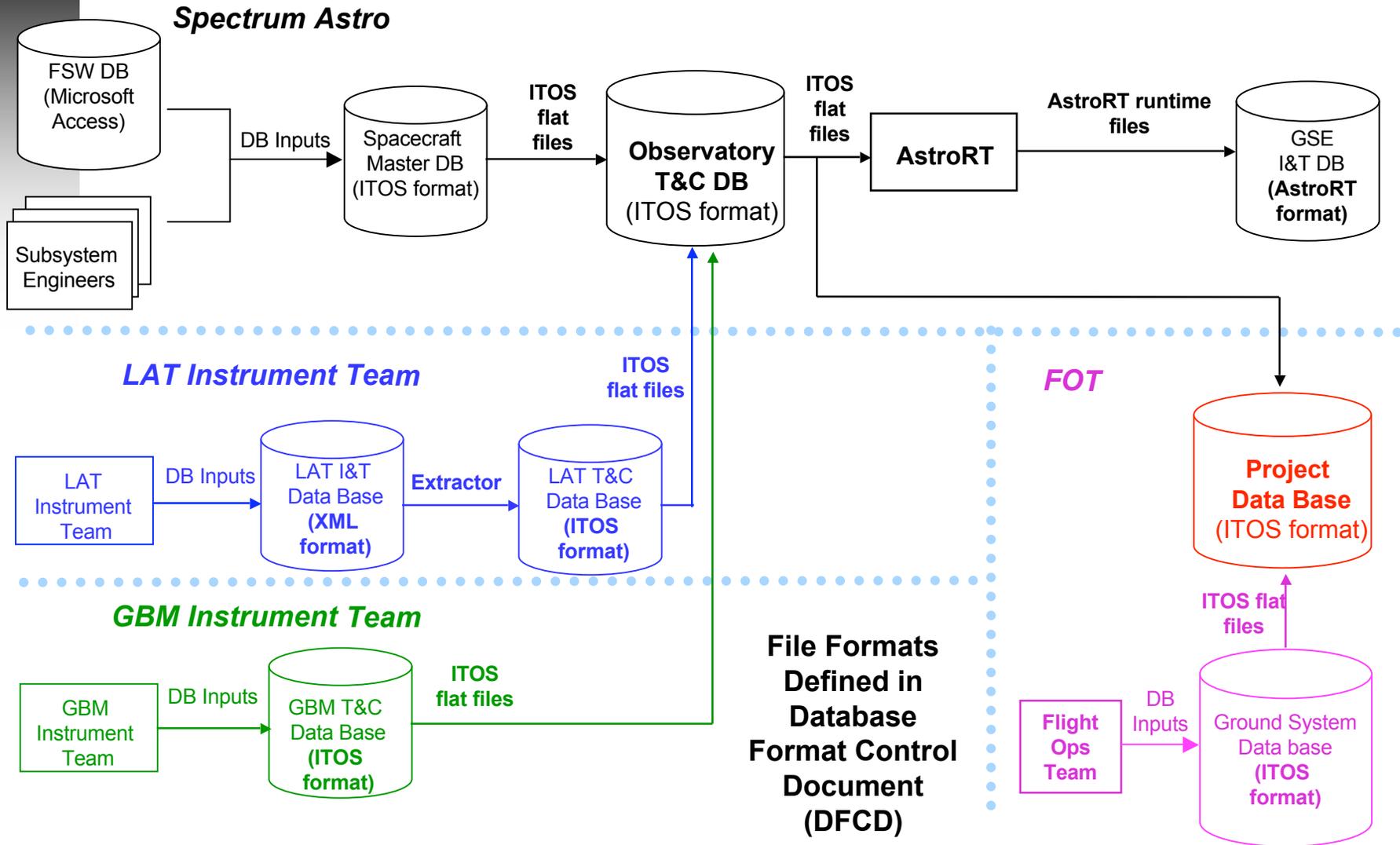
▶ **PROCs**

- **ITOS System Test Operations Language (STOL) executables**
- **Developed by the FOT from the procedures in OODM and Flight Operations Manual**
- **STOL PROCs approved by Spectrum Astro, IOCs, and FOT Lead**
- **Validated against appropriate simulator (MTS or hotbench) prior to use with the observatory**

▶ **L&EO timelines, Database, Contingency procedures, pages, configuration monitors, etc.**



T&C Database Flow





Project Database Validation

- ▶ **Observatory Database consists of Telemetry & Command database inputs from Spectrum Astro, LAT, and GBM**
 - *T&C Database consists of telemetry and command definitions, engineering unit conversions, discrete conversions, red and yellow limit definitions*
 - *Database format defined in the **GLAST Database Format Control Document***
 - *Delivered by Spectrum Astro until handover at L+60 days*
 - Validated telemetry and command databases
 - Delivered to the FOT in ITOS format by Spectrum Astro
- ▶ **Project Database consists of Observatory database and Ground System database**
 - *Ground Database developed by the FOT*
 - USN Ground Station and GFEP status telemetry and GFEP control directives
 - *Merged into a Project database by the FOT*
 - Changes validated by the FOT after L+ 60 days
 - *Maintained under CM control as part of the Operations CCB*
 - *Distributed to other ground system elements*
- ▶ **Process documented in the **GLAST Mission Operations Agreement****



Observatory Integration and Test Support



- ▶ ***FOT presence at the Spectrum Facility for both spacecraft and observatory integration and test activities***
- ▶ ***MOC workstations running ITOS in parallel to the Spectrum's AstroRT workstations***
 - *Not part of the critical path of Spectrum Astro I&T success*
 - *Allows early page and PROC development while at Spectrum facility*
- ▶ ***Early FOT participation provides valuable insight into the spacecraft, subsystems, and instruments well prior to launch***
- ▶ ***GSFC MOC and FOT will also participate in Observatory tests, thermal vacuum, etc.***



FOT Preparation for Launch



- ▶ **Ops product validation**
 - Ensures products properly tested prior to use
 - Make full use of simulators as appropriate
 - Validation process documented in **MOC Test and Validation Plan**
- ▶ **Simulators**
 - **Portable Spacecraft Simulator (PSS)**
 - GSFC simulator developed to use as a data source for early ground system testing
 - **MOC Training Simulator (MTS)**
 - Medium fidelity Spectrum Astro simulator for use primarily as a training tool
 - Delivered to the MOC in two builds, runs a modified version of the flight software
 - **Hotbench**
 - High fidelity spacecraft simulator at Spectrum Astro
- ▶ **Ground Readiness Tests (GRT)**
 - Seven ground-system oriented tests using the simulators or recorded test data
- ▶ **End to End Tests (ETE)**
 - series of 5 end-to-end tests (approximately 2 days in length each) to verify the compatibility between the MOC and the observatory



FOT Preparation for Launch (cont.)



► *Mission Simulations*

- *Scheduled between May 2006 and February 2007*
- *Normal Ops*
 - *Day in the Life*
 - *Week in the Life*
 - *Routine Operations*
- *Launch and Early Orbit Simulations*
 - *Two complete Launch Rehearsals*
 - *Selected portions of 60 day L&EO*
 - *Spacecraft Activation and Checkout*
 - *LAT Activation and Checkout*
 - *GBM Activation and Checkout*
- *Contingency Simulations (also mixed in with other simulations)*
 - *Launch Contingencies*
 - *Ground Contingencies*
 - *On orbit Observatory contingencies*
- *Special Operations*
 - *FSW Loading*
 - *Calibration activities*



FOT Training



- ▶ **Training covers 3 areas for FOT**
 - Classroom
 - I&T and S/C Simulation Console
 - Simulations
- ▶ **All training material derived directly from engineering and operational documentation**
- ▶ **Subsystem training includes S/C and instrument design, operations, configuration, and data flows**
- ▶ **Procedure walkthroughs**
 - walkthroughs of bus, instrument and ground ops procedures
 - Additional walkthroughs prior to each simulation
- ▶ **I&T Support**
 - Work with Spectrum Astro engineers and instrument teams
 - Participation in thermal vacuum other observatory level tests
- ▶ **Simulations**



FOT Certification Plan

- ▶ **Documented in Training and Certification Plan**
- ▶ **Two levels of FOT certification**
 - Level 1 - Command Controller
 - Level 2 - Spacecraft Analyst
- ▶ **Certification criteria**
 - Skills Checklist/Demonstration of Proficiency
 - Certification Test
 - All pre-launch personnel demonstrate skills during pre-launch testing, I&T, and Simulations
 - All FOT Certified prior to launch
- ▶ **New FOT Members**
 - Complete a mentored training program (GLAST specific) to reach Command Controller level
 - Required to pass certification test



FOT Staffing – Transition from L&EO to Normal Ops



		Launch & Early Orbit (L+60)							Normal Ops
		Week 1 24h x 7d	Week 2 24h x 7d	Week 3 24h x 7d	Week 4 16h x 7d	Week 5 16h x 7d	Week 6 16h x 7d	Week 7 12h x 7d	Week N 8h x 5d
Prime Shift		1 Ops Lead 4 Ops Engrs 1 S/W Devr	1 Ops Lead 4 Ops Engrs 1 S/W Devr	1 Ops Lead 3 Ops Engrs 1 S/W Devr	1 Ops Lead 4 Ops Engrs 2 S/W Devr	1 Ops Lead 5 Ops Engrs			
					3 Ops Engrs 1 S/W Devr	2 Ops Engrs 1 S/W Devr	2 Ops Engrs 1 S/W Devr		
Back Shift		3 Ops Engrs 1 S/W Devr	3 Ops Engrs 1 S/W Devr	3 Ops Engrs 1 S/W Devr	On Call	On Call	On Call	On Call	On Call

▶ L&EO

- Core FOT (Ops Lead, OEs) augmented by certified team members and support personnel (S/W Developers, System Engineers)
- FOT hours support Spectrum Astro, LAT, and GBM checkout activities
- Gradual ramp down of FOT support and shifts as successful turn on and checkout activities completed

▶ Following 24x7 Support, Ops Engineers On-Call

- Support for Critical Activities during off shift on As-Scheduled basis (adjust shift schedule as necessary)



Road to MOR...



- ▶ ***Ops product development & verification***
 - *Begin development of PROCs, procedures, pages, configmons, etc.*
 - *Begin verification on MTS and Hotbench*
- ▶ ***Support Ground System Testing***
 - *Prepare for and conduct GRTs, ETEs*
- ▶ ***Participate in Observatory I&T***
 - *Install MOC system at Spectrum Astro I&T Facility*
 - *FOT participate in observatory tests*
- ▶ ***Complete documentation***
 - *Ops Readiness Plan, Training Plan, User Guides, Flight Operations Manual*