



Gamma-ray Large Area Space Telescope (GLAST) Mission Operations Concept

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GLAST Mission Operations Manager

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Prepared By:

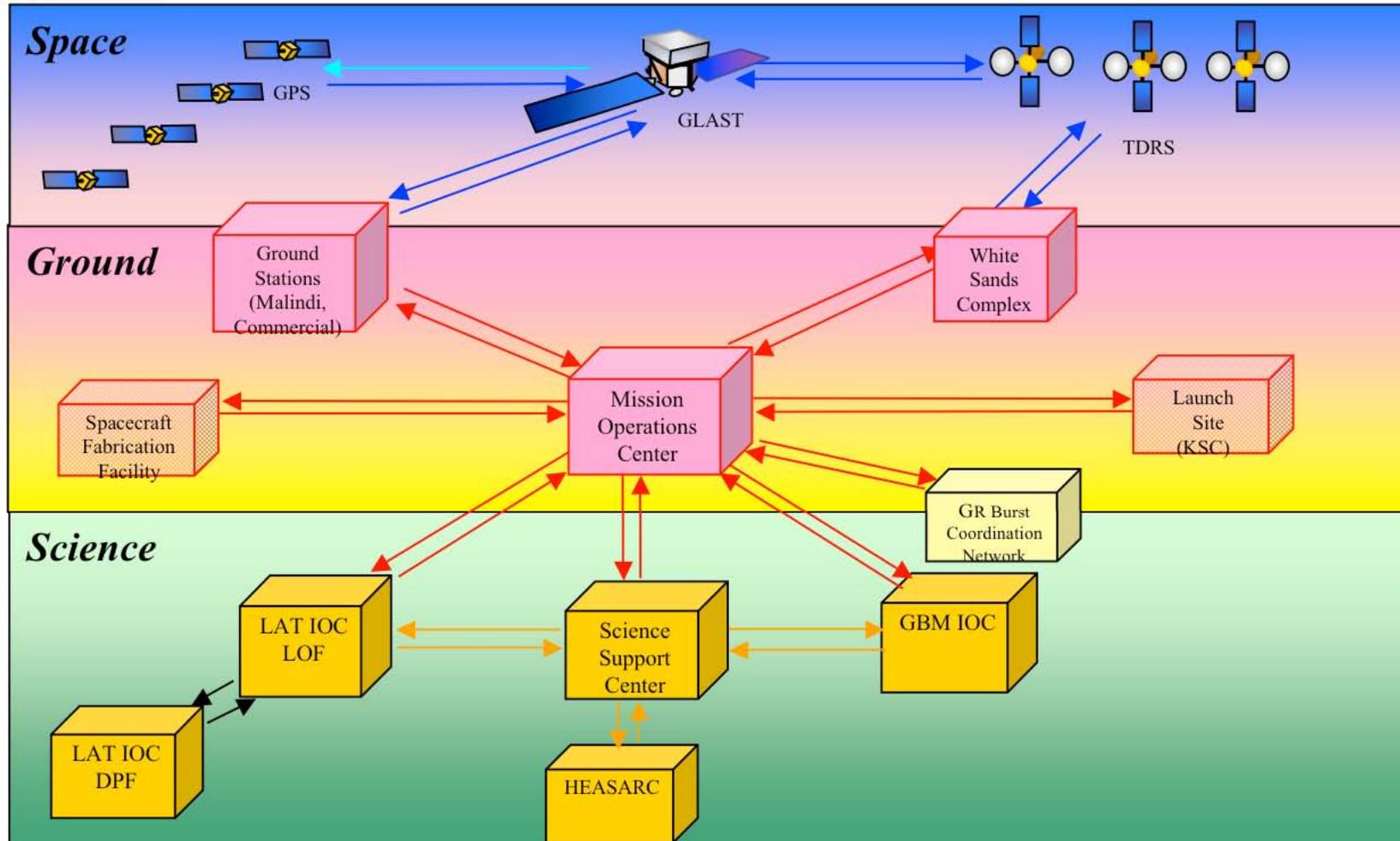
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ASRC Aerospace Corporation





GLAST Operations Concept Ground System Interfaces





GLAST Operations Concept AGENDA



- Introduction
 - Purpose
 - Ground Rules
 - Issue Handling
 - Definitions
 - Operations Goals
 - Presentation Content
 - Operations Element Functions by Location
- Interface Descriptions
 - Commands
 - Memory Loads
 - Telemetry
 - Memory Dumps
 - Alerts
 - Science Data
 - Scheduling
 - Databases
 - Orbit Determination
 - Trending
- Mission Phases
 - Testing
 - Launch
 - Check-out
 - Mission
 - De-orbit





GLAST Operations Concept Introduction



- Purpose - The Request For Offer (RFO) process has clarified and provided details that changed the Operations Concept(s), therefore it is desirable to:
 - Establish baseline of understanding among all GLAST entities
 - Uncover cross-understandings
- Ground Rules/Guidelines
 - Follow the Data Products and Configurable Items through their data paths
 - Show product usage and paths
 - Describe processing and roles
 - Known Issues/Unknown Details
- Issue Handling
 - We Won't Solve It Here
 - Questions are welcome but time is limited
 - Send Email with Slide Number and Questions to Dennis and CC:Ross
 - DSmall@pop500.gsfc.nasa.gov
 - Ross.M.Cox@AkSpace.com





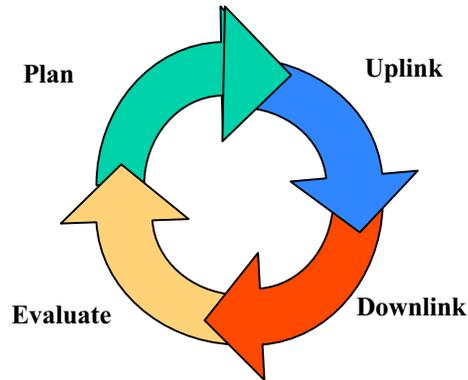
GLAST Operations Concept Introduction



- Definitions -
 - Observatory - Integrated GLAST
 - Spacecraft - GLAST without instruments
 - Instruments - the instruments -- the Large Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM)
 - Satellite - the Moon is a satellite -- we don't fly it (yet!)
 - Frequency - count of occurrences of piece of data or data item
 - Timing - Duration of the generation of data items within a ground system element usually with respect to some other product or event
 - Latency - Allowable lag between end of transmission and end of receipt of data item between ground system elements



GLAST Operations Concept Introduction

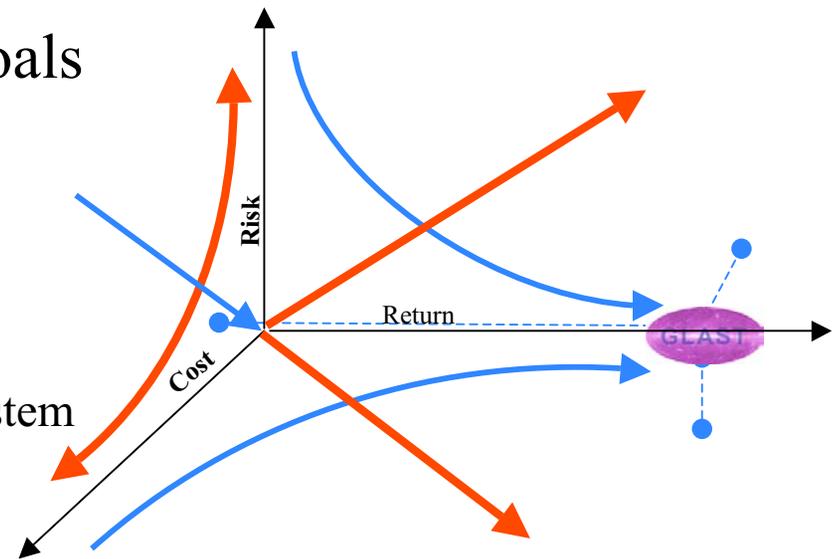


•What is Mission Operations?

- Planning Activities
- Uplink Activities
- Downlink Activities
- Evaluation Activities

• General Mission Operations Goals

- Maximize Science Return
 - Efficient Data Capture and Return
- Minimize Mission Risk
 - Smart Observatory/Smart Ground System
- Control Lifetime Costs
 - Automate As Much As Possible





GLAST Operations Concept Introduction



- GLAST Specific Mission Operations Goals
 - Support the scientific community in using the observatory to make significant discoveries in the following areas
 - Active Galactic Nuclei
 - Isotropic Background Radiation
 - Gamma-Ray Bursts
 - Molecular Clouds, Supernovae Remnants, and Normal Galaxies
 - Endpoints of Stellar Evolution (Neutron Stars and Black Holes)
 - Unidentified Gamma-ray Sources
 - Dark Matter
 - Solar Flares



GLAST Operations Concept Introduction



- Two distinct methods of data collection have been identified
 - Sky Survey
 - Cover “entire sky” every two orbits
 - Pointed Observation
 - Remain “inertially fixed” on a certain target
- Operations will support the mission through
 - Providing an efficient scheduling system for normal and special operations
 - Assuring data quality throughout the ground system elements
 - Performing real time commanding and monitoring as required
 - Analyzing engineering data to assess observatory health and status



GLAST Operations Concept Content



- The operations concept covers the following items
 - Commanding
 - Telemetry
 - Ground operations support and coordination
 - Scheduling
 - Databases
 - Trending
 - Special Operations
 - Burst Alerts
 - Orbit Determination
 - Anomaly Resolution
 - Safehold Alerts



GLAST Operations Concept Content



- The operations concept covers the following Mission Phases
 - Pre-Launch
 - Launch
 - Check-Out
 - Mission Phase
 - De-Orbit



GLAST Operations Concept Functions by Location



- Mission Operations Center (MOC)
 - Real time (R/T) operations
 - Contact scheduling
 - Low level data processing
 - Engineering analysis
- Science Support Center (SSC)
 - Science planning and scheduling
 - Product distribution
- High Energy Astrophysics Science Archive Research Center (HEASARC)
 - Archive GLAST data and comparison to other missions



GLAST Operations Concept Functions by Location



- LAT Instrument Operations Center(IOC) LAT Operations Facility(LOF)
 - LAT operations interface
 - Data quality reporting
- LAT IOC Data Processing Facility(DPF) {a.k.a., Science Analysis Software (SAS)}
 - High-level data processing
- GBM IOC
 - GBM operations interface
 - Data quality reporting
 - High level data processing



GLAST Operations Concept Functions by Location



- GCN (Gamma-ray Coordinates Network)
 - Alert distribution to the world of Gamma-Ray astronomers
- Spacecraft Fabrication Facility (SFF)
 - Integrate Instruments to Spacecraft
 - Prelaunch Testing
- Launch Site - Kennedy Space Center (KSC)
 - Launch Support Data flows
 - Mission Rehearsals
 - Payload(Observatory) Processing at Pad
 - Launch Voice Control



GLAST Operations Concept Functions by Location



- White Sands Complex (WSC)
 - R/T Tracking and Data Relay Satellite* (TDRS) Operations
 - Burst transmission via TDRS Demand Access S-band (DAS) service
 - Tracking data
- Ground Network (GN)
 - R/T Ground-Based Operations
 - Data capture and playback
 - Tracking data
- Global Positioning System (GPS)
 - Orbit determination

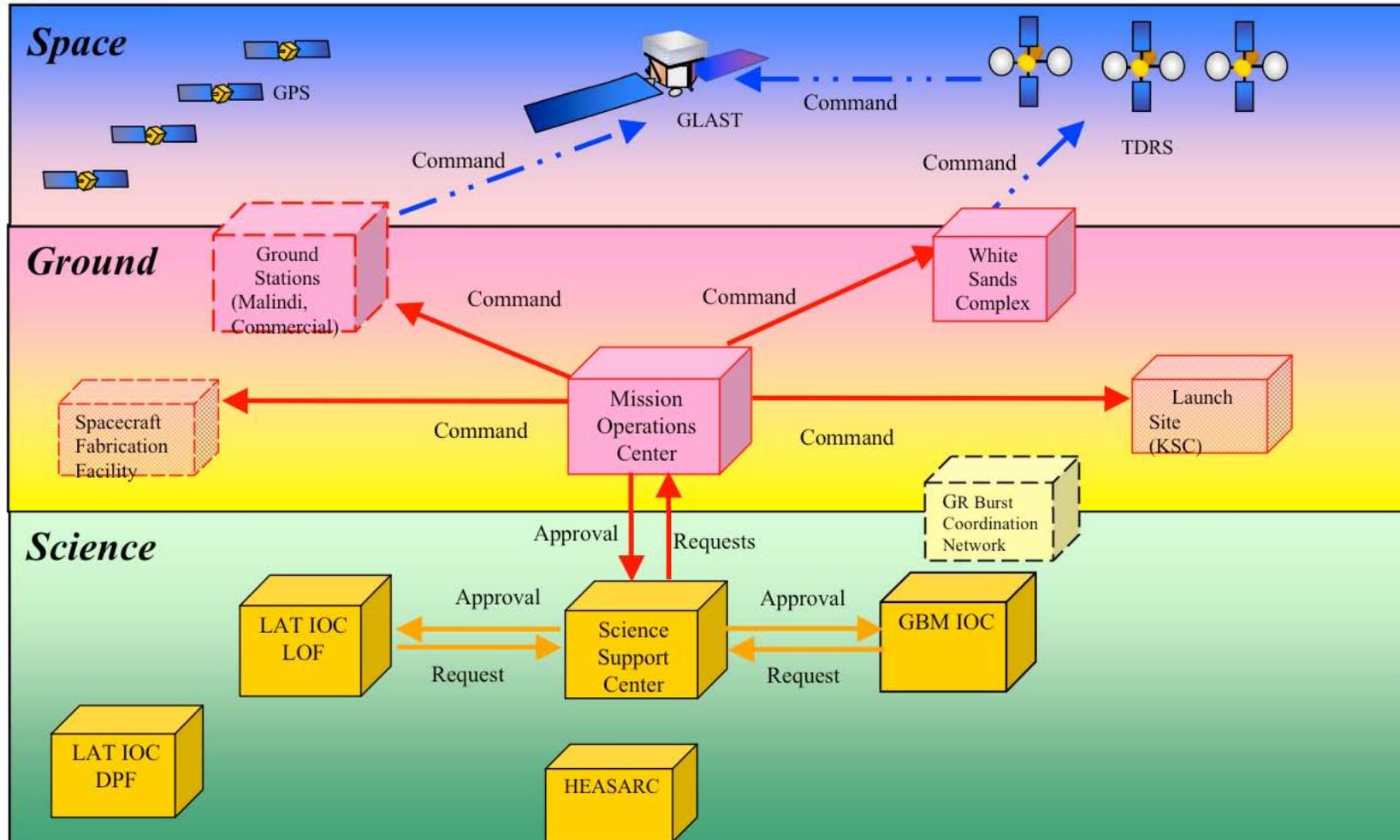


*Invented before people knew the Moon was a satellite



GLAST Operations Concept

Real Time Command





GLAST Operations Concept

Real Time Command

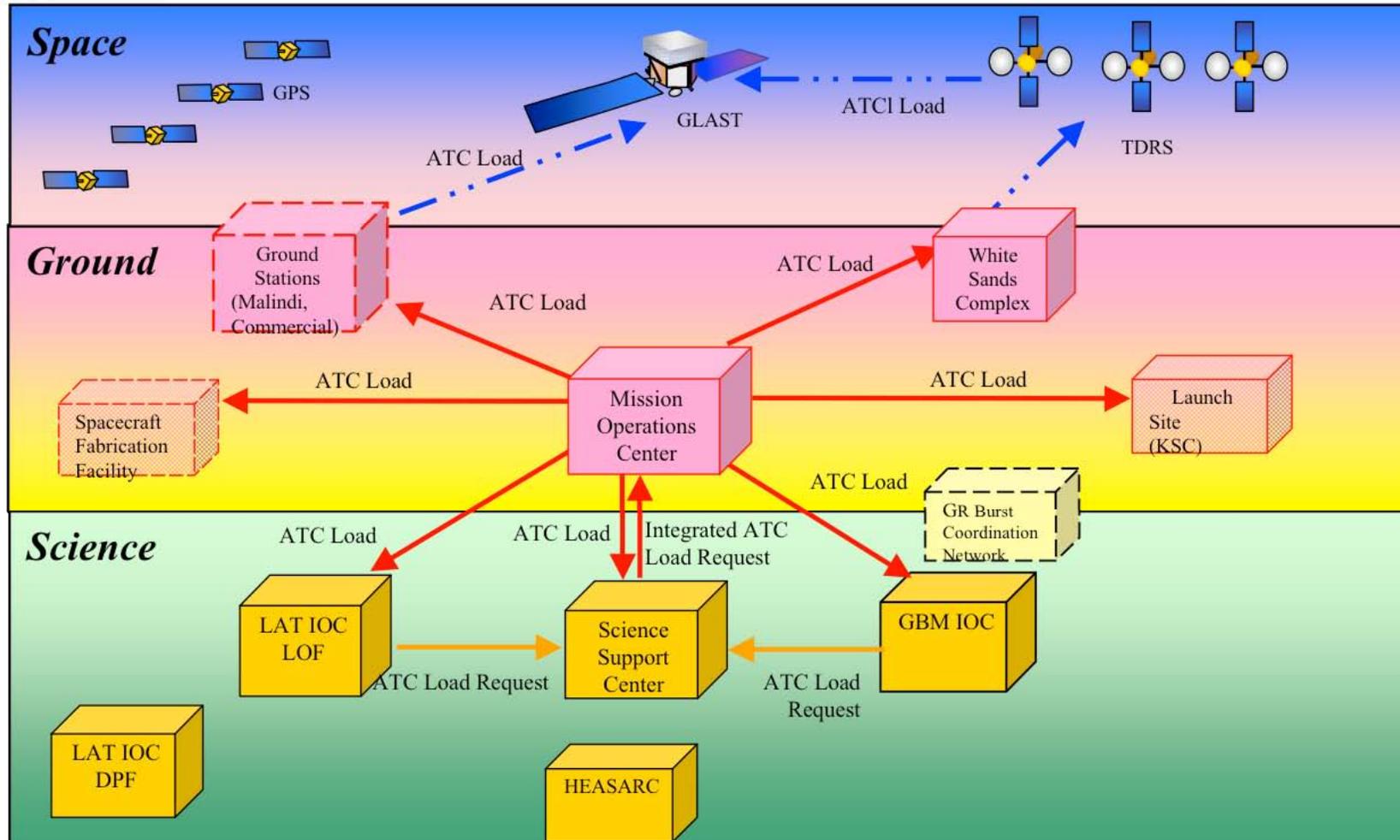


- Command that can be sent to the observatory by a human during a real time support
- Used to execute instructions to the observatory that must be sent during a ground contact.
 - Largely configuration oriented
 - SSR management
 - Table dump requests
 - Should Override all other commands in the event of a collision
- Normally all R/T commanding follows strict pass plan
 - Raw commanding is discouraged, most commanding will be done through command procedures for repeatability and reliability.
- Frequency, Timing , Latency
 - Real time command opportunities will occur as many as 4-5 times daily
 - Command to Observatory transit time ≤ 2 seconds



GLAST Operations Concept

Absolute Time Commands (ATC)





GLAST Operations Concept

Absolute Time Commands

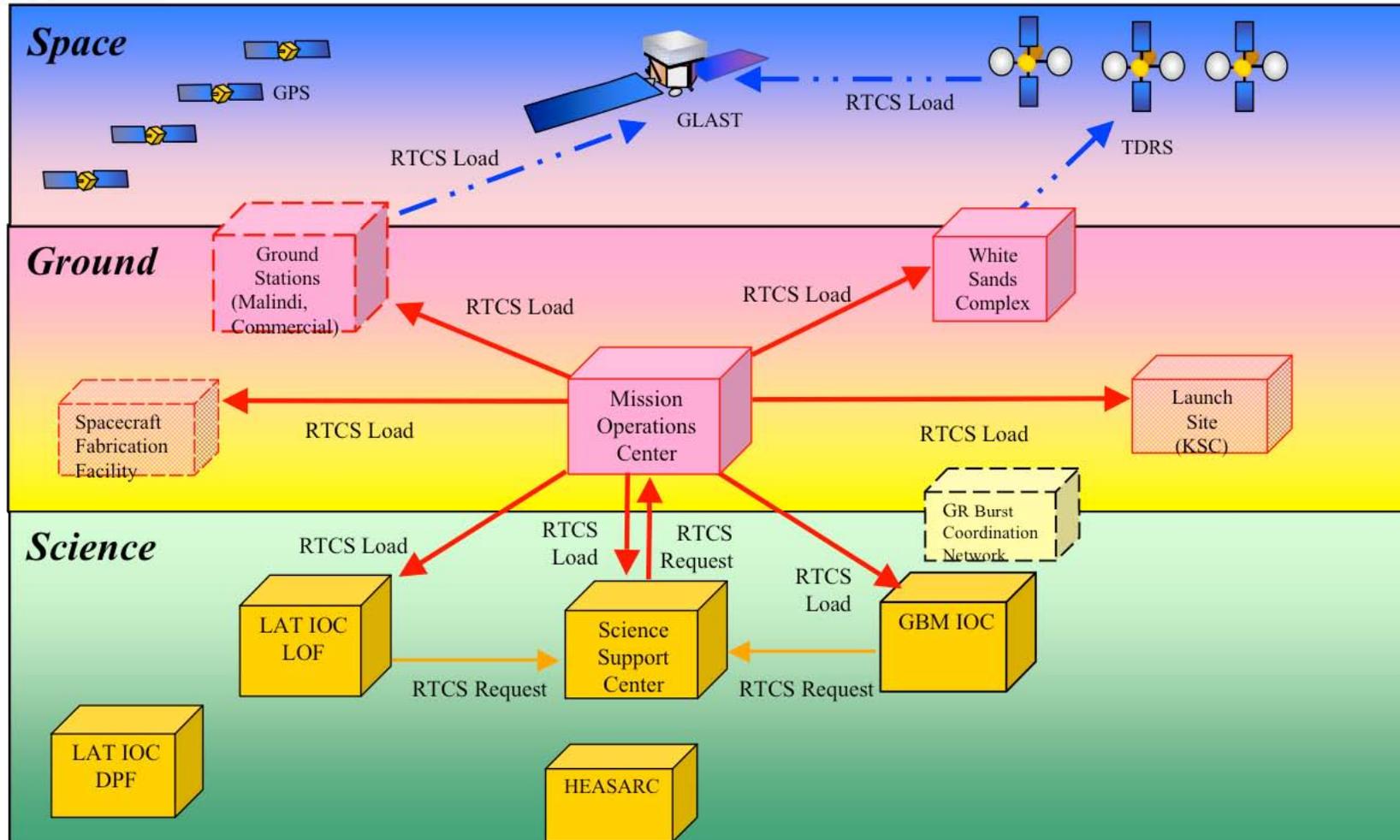


- Series of command/time-tag pairs stored onboard
 - Command executes at associated time
 - Ground system should track the execution on the ground
- Used to execute instructions to the observatory that must occur at a particular moment in time.
- Frequency, Timing , Latency
 - Loads will occur once per week.
 - Latency of command execution will be near the resolution of the onboard clock (very fast)
 - Temporal spacing of commands is vendor specific but should be rather coarse (of order seconds).
 - Precisely time spaced commanding should use RTCs.



GLAST Operations Concept

Relative Time Command Sequences (RTCS)





GLAST Operations Concept

Relative Time Command Sequences

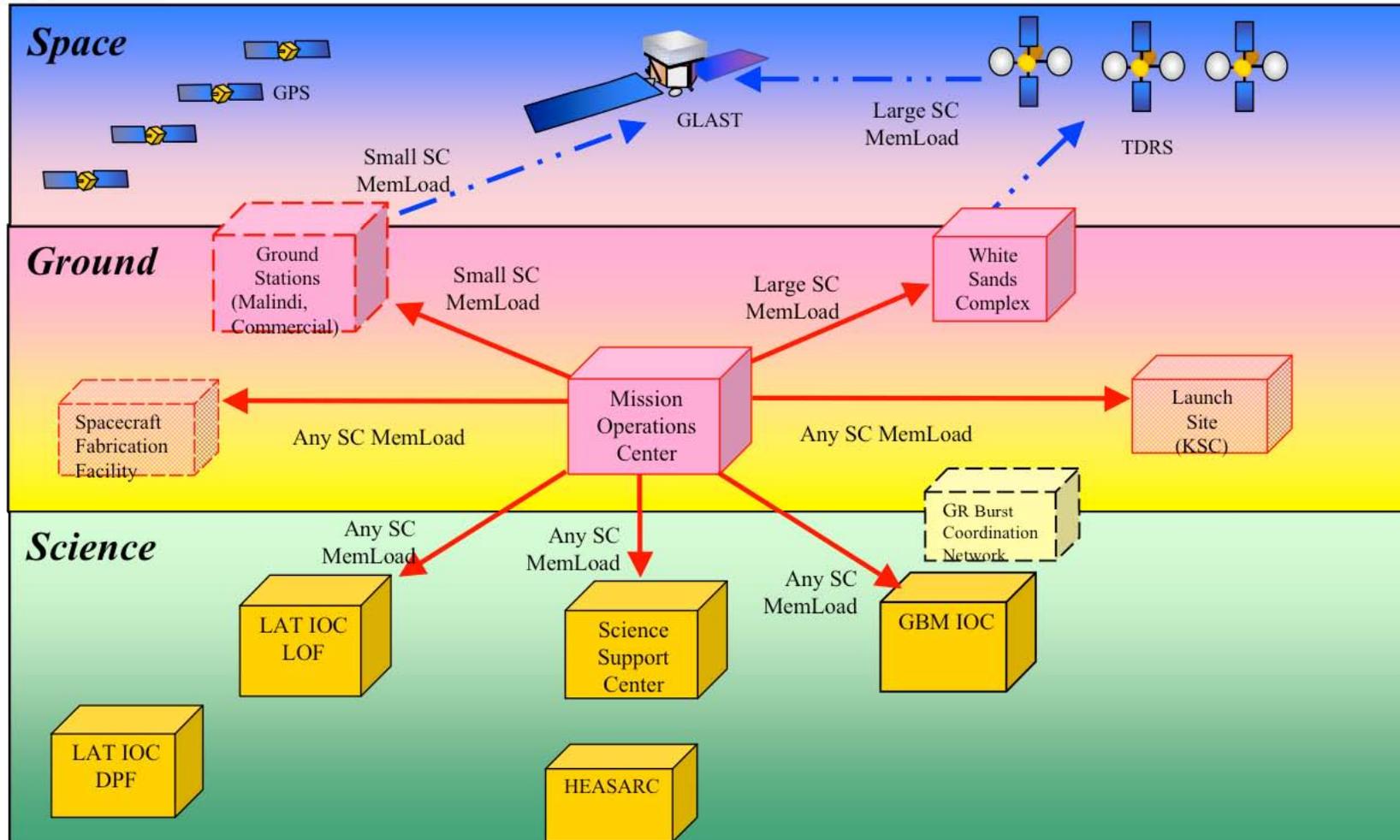


- Series of commands separated by exact time periods stored onboard
 - Initiated with a single (meta-)command
 - Time periods are measured relative to the time the (meta-)command is issued.
- Used to execute a series of commands that require specific time spacing between execution.
 - Useful for complex operations
 - Allow RTCSs to call other RTCSs
 - Telemetry status (active, enabled, disabled, etc)
- Frequency, Timing, Latency
 - Loads will be very infrequent after establishing the baseline set of RTCS (end of check out phase)
 - Latency will be at the resolution of the onboard clock (very fast)



GLAST Operations Concept

Spacecraft Memory Loads





GLAST Operations Concept

Spacecraft Memory Loads

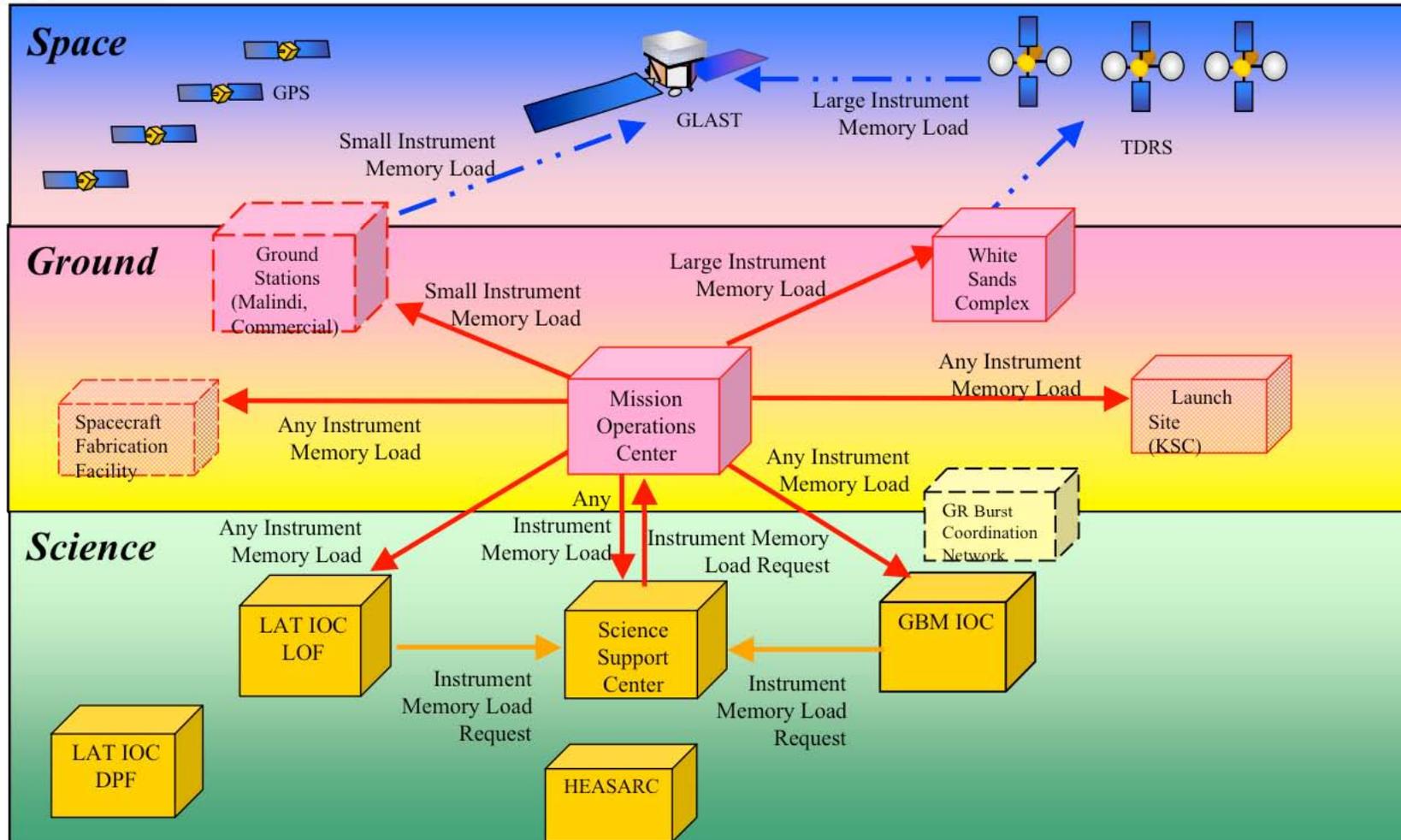


- Software objects that “only” effect the spacecraft operation
 - Tables?
 - Ephemerides
 - Patches
- Used to manage onboard software objects (executable and data)
 - Come in large and small varieties
 - Require ability update while executing
- Frequency, Timing , Latency
 - Large loads will use TDRS for higher rate at longer duration
 - Small loads will use ground stations (perhaps multiple)
 - Relatively infrequent after check-out
 - Frequency depends on what is being loaded



GLAST Operations Concept

Instrument Memory Loads





GLAST Operations Concept

Instrument Memory Loads

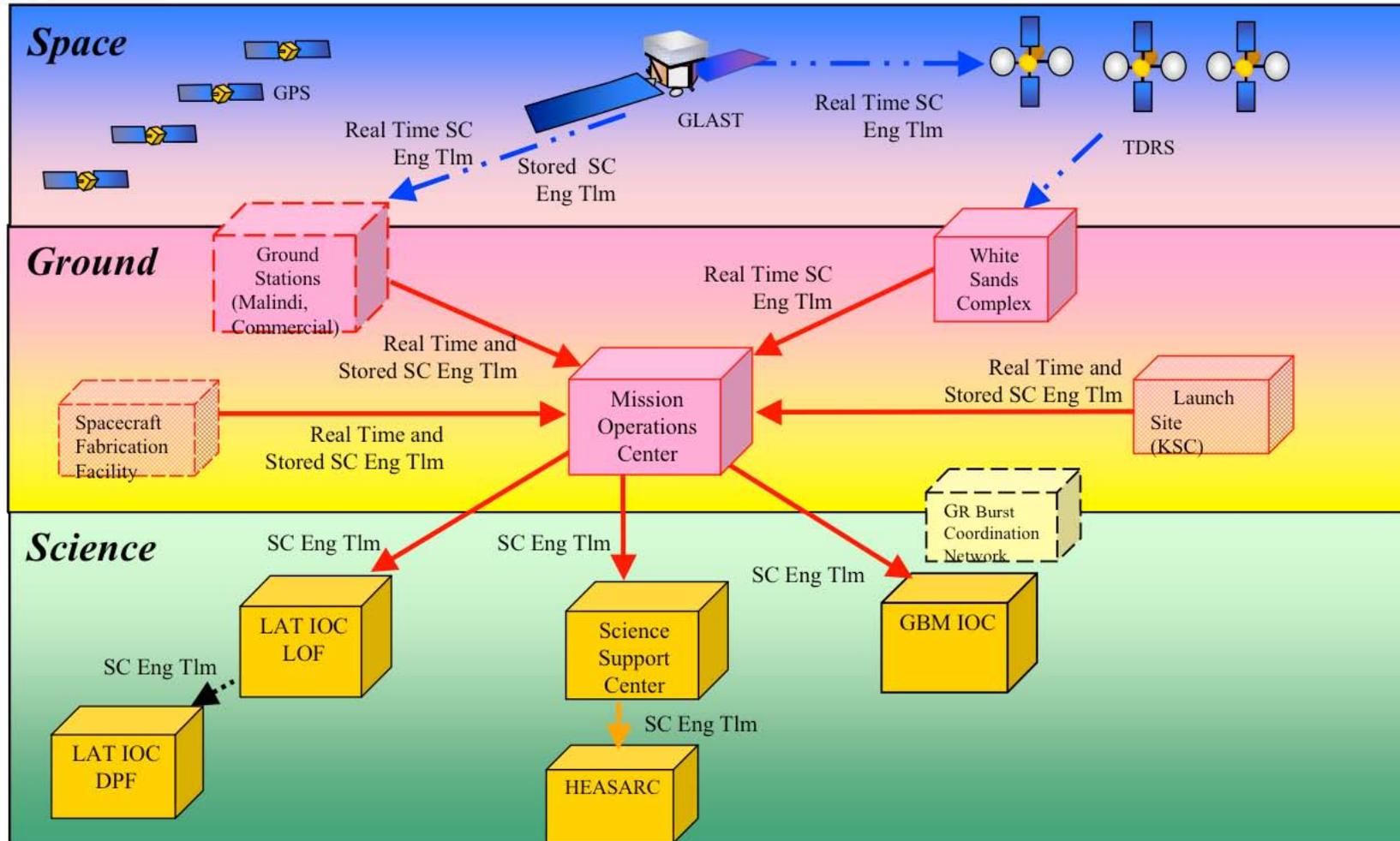


- Software objects that “only” effect the instrument operation
- Used by Instruments to assure their functionality
 - Come in large and small varieties
 - Large via TDRS, Small via GN
 - Passed through by spacecraft
- Frequency, Timing , Latency
 - Relatively infrequent after check-out
 - Perhaps weekly or daily under TBD conditions



GLAST Operations Concept

Spacecraft Engineering Telemetry





GLAST Operations Concept

Spacecraft Engineering Telemetry

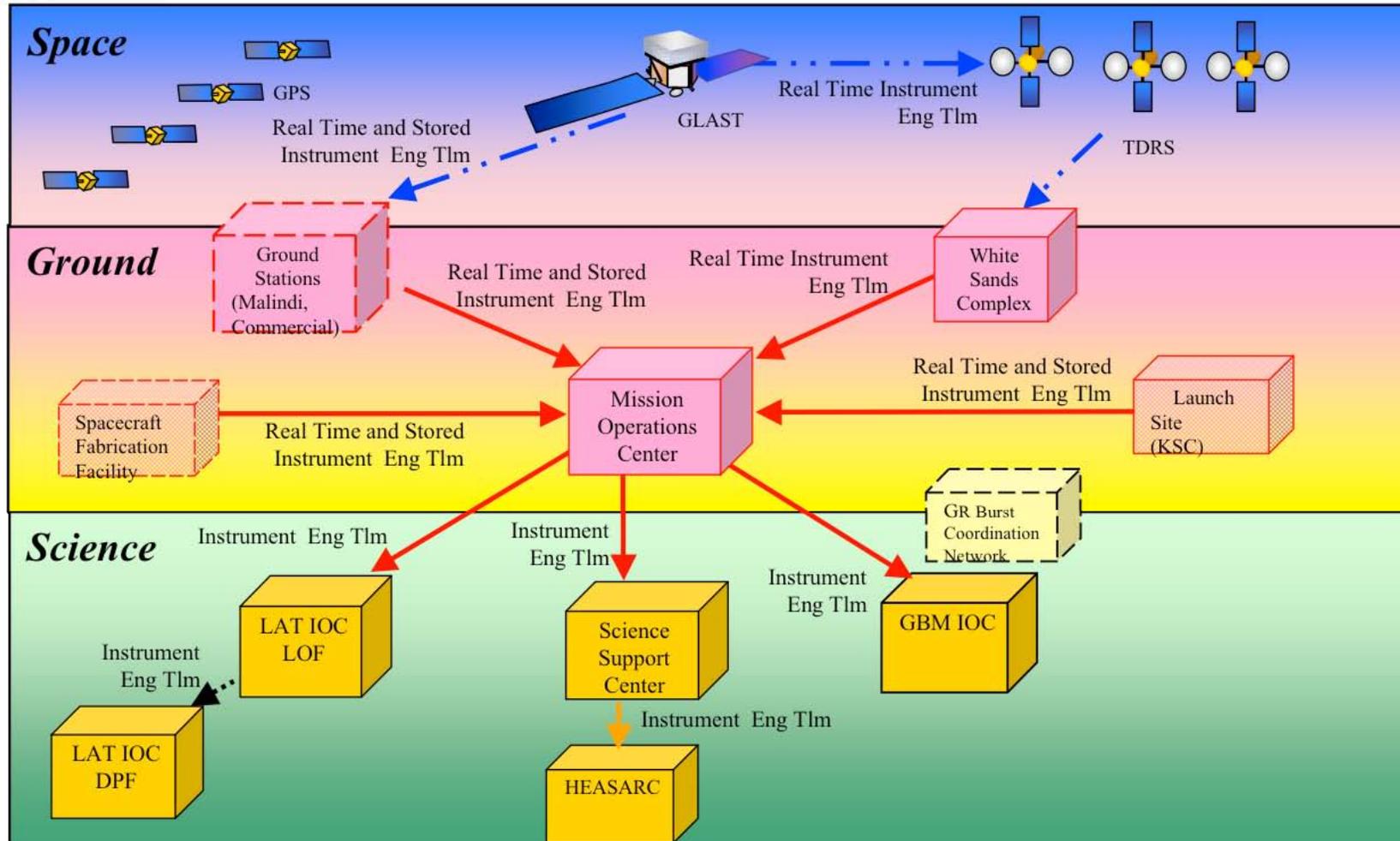


- Data from the spacecraft that describe how it is performing
 - Transducer output, status flags, selected memory location contents, and more!
- Used to monitor Spacecraft Subsystems
 - Real time, stored on board and stored in ground archives
 - Input to daily, weekly, monthly, and lifetime plots
 - Drives realtime display pages
 - Drives onboard Failure Detection and Correction(FDC) Logic
- Frequency, Timing , Latency
 - R/T Telemetry 4-5 times per day
 - Stored used to fill in 24 hour status



GLAST Operations Concept

Instrument Engineering Telemetry





GLAST Operations Concept

Instrument Engineering Telemetry

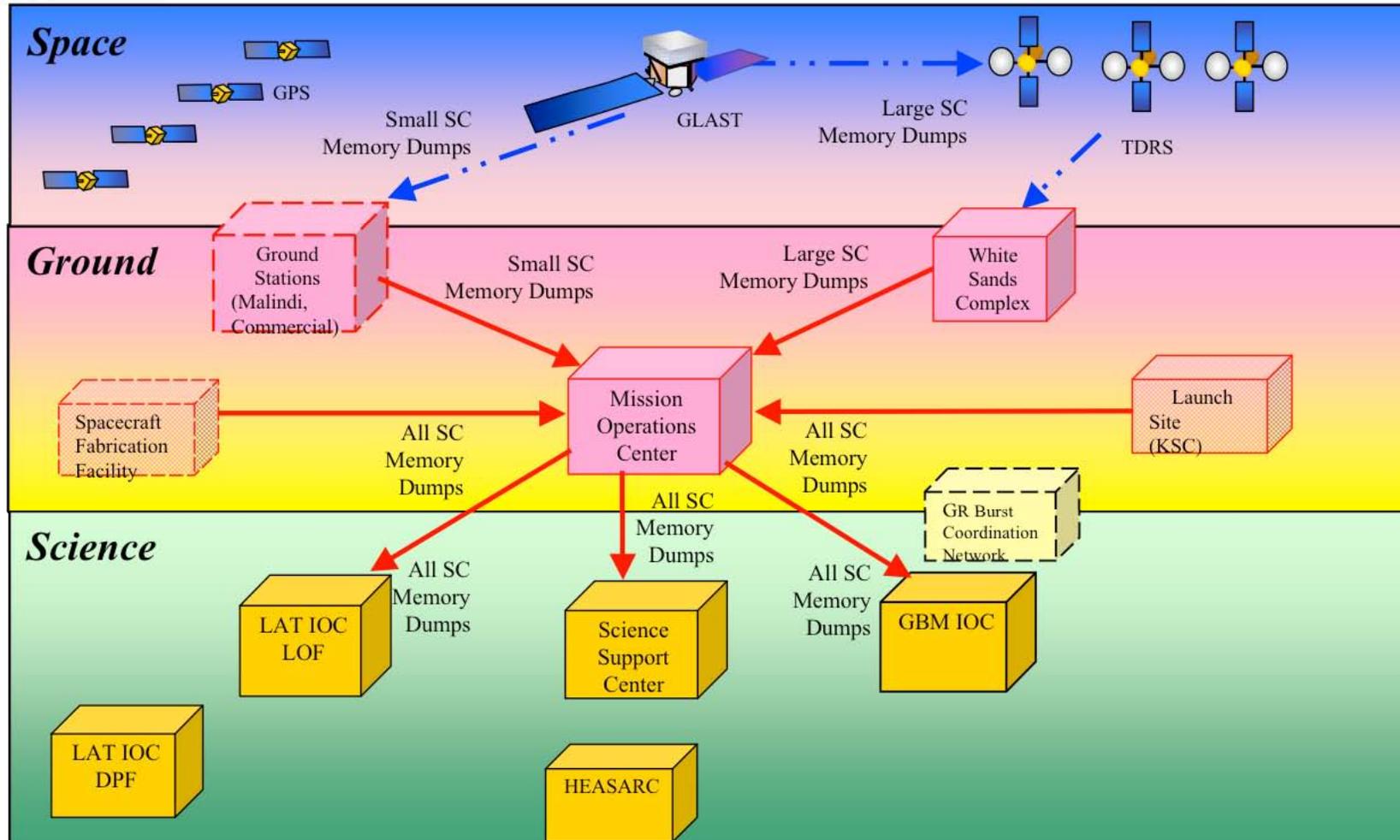


- Non-science readouts from the instruments that indicate how it is performing
 - Each instrument gets its own engineering telemetry
- Used to monitor Instrument Subsystems
 - Real time stored onboard and stored in ground archives
 - Input to Daily, Weekly, Monthly and Lifetime Plots
 - Drives realtime display pages
 - Drives onboard FDC logic
- Frequency, Timing, Latency
 - R/T Telemetry 4-5 times per day
 - Stored used to fill in 24 hour status



GLAST Operations Concept

Spacecraft Memory Dumps





GLAST Operations Concept

Spacecraft Memory Dumps

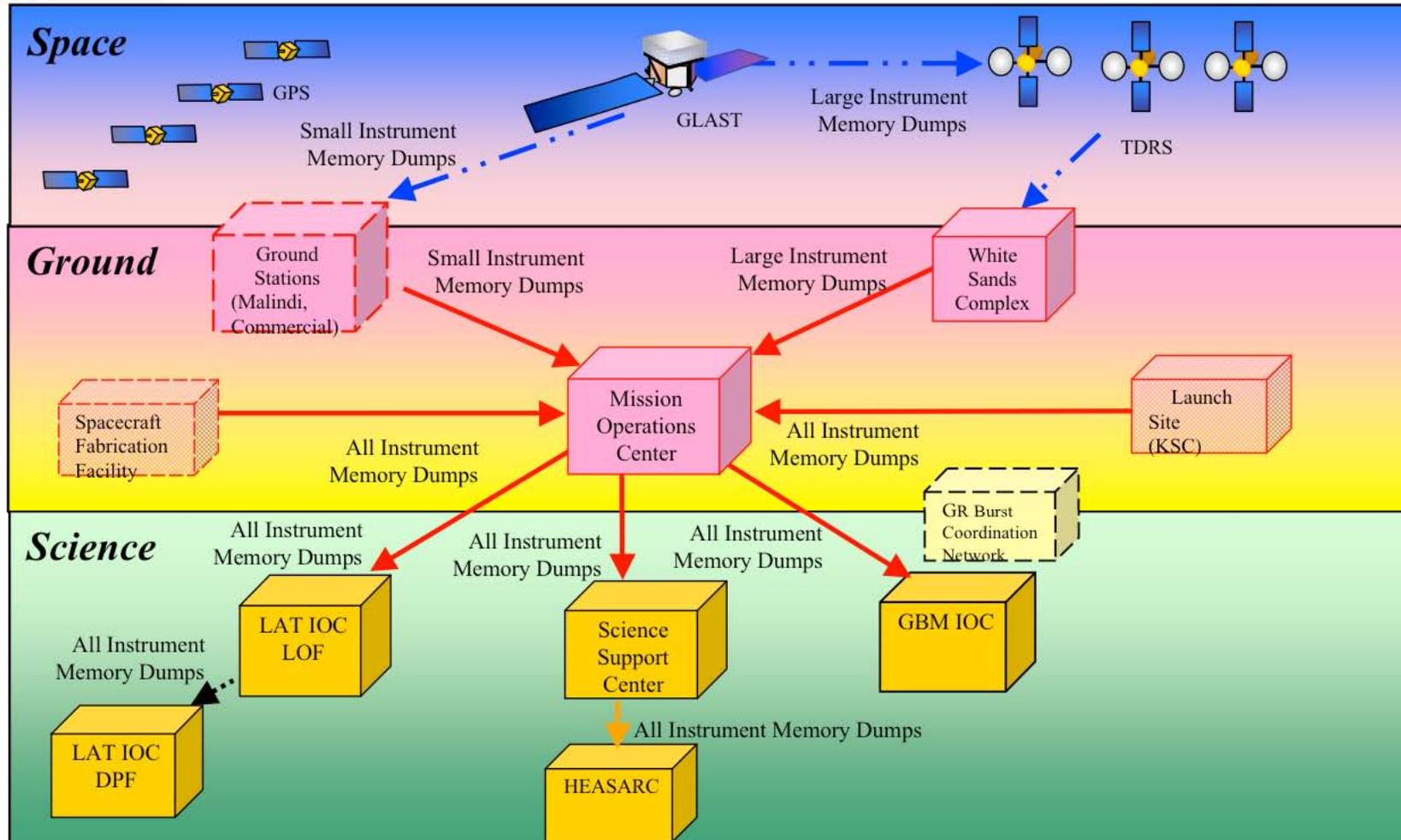


- Request from the ground to the observatory to transmit contents of one or more location in spacecraft memory
- Used for
 - Monitoring operations
 - Verifying loads
 - Retrieving onboard logs
- Frequency, Timing , Latency
 - Memory Dumps always follow Memory Loads



GLAST Operations Concept

Instrument Memory Dumps





GLAST Operations Concept

Instrument Memory Dumps

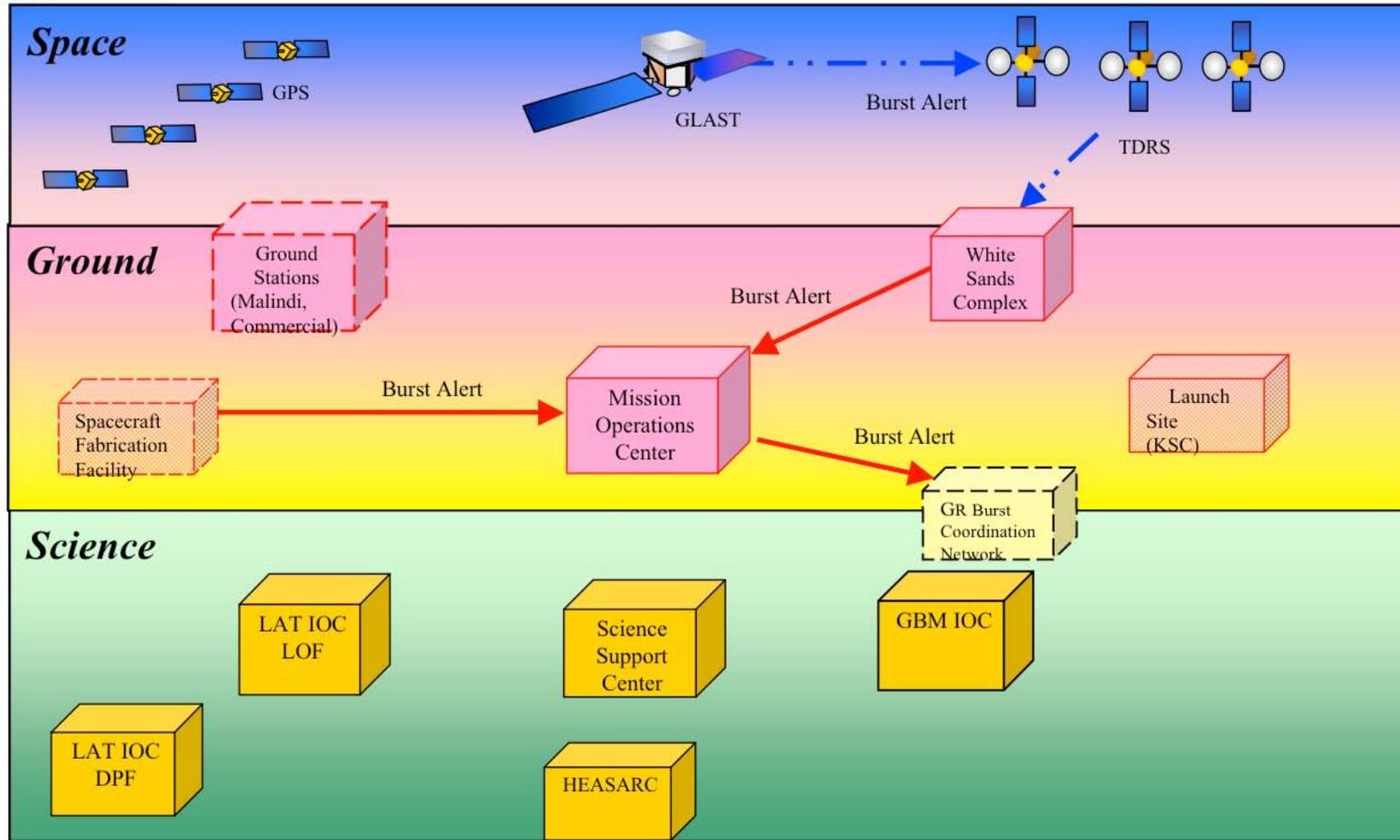


- Requests from the ground to the observatory to transmit the contents of one or more locations of the instrument memory.
- Used for
 - Monitoring operations
 - Verifying loads
 - Retrieving onboard logs
- Frequency, Timing , Latency
 - Memory Dumps always follow Memory Loads



GLAST Operations Concept

Burst Alerts





GLAST Operations Concept

Burst Alerts

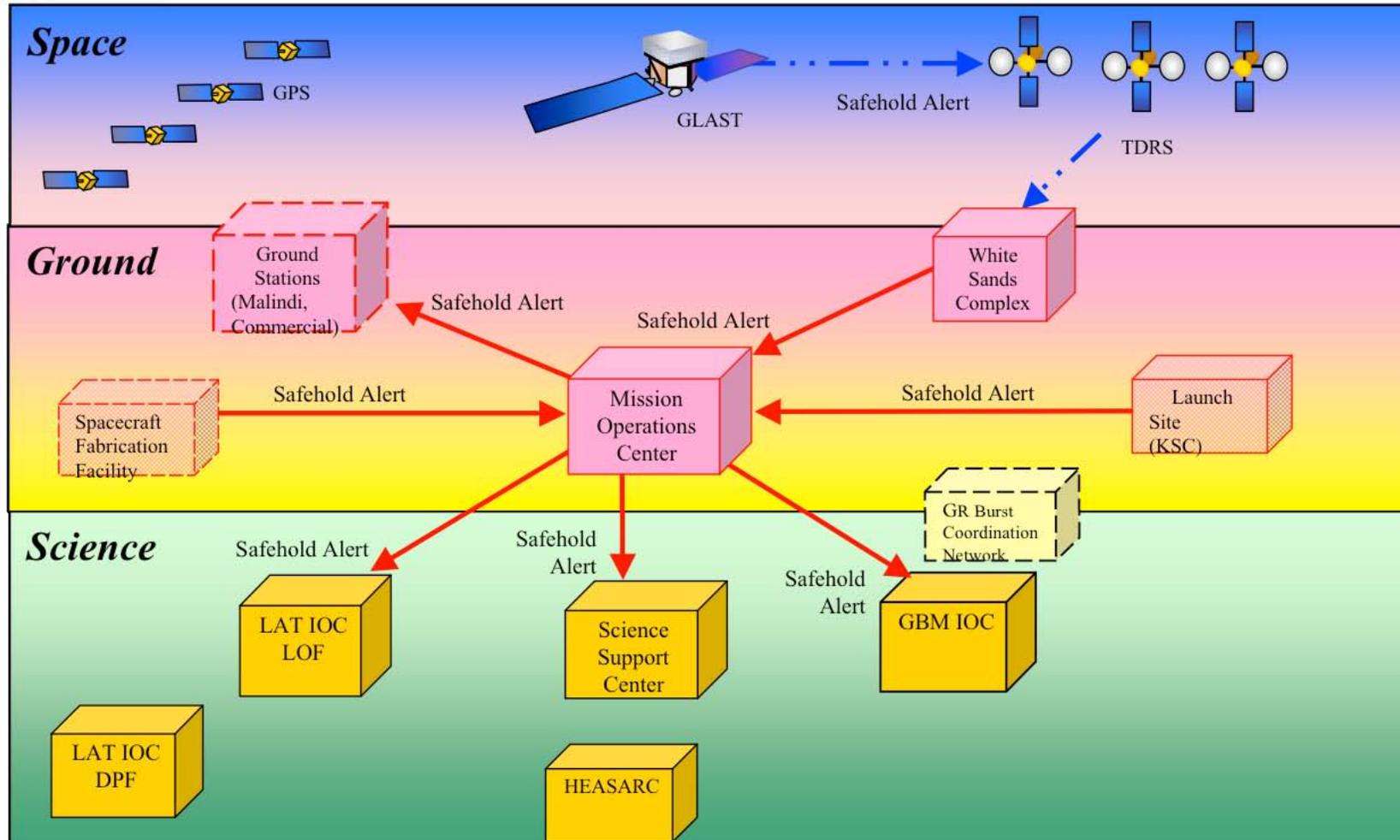


- Messages sent when a Gamma-Ray Burst (GRB) with characteristics which trigger the threshold algorithm are observed
 - Messages are operationally of two types
 - Initial alert messages are short with intense response requirements
 - Refinement data message are longer and are not time critical
- Used to notify other observatories world-wide of the occurrence of a possibly interesting burst event.
- Frequency, Timing , Latency
 - Filtered to occur 2 to 3 times per week
 - Initial alert within 7 seconds
 - Refinement data for next ten minutes with +/- 30 second resolution



GLAST Operations Concept

Safehold Alerts





GLAST Operations Concept

Safehold Alerts

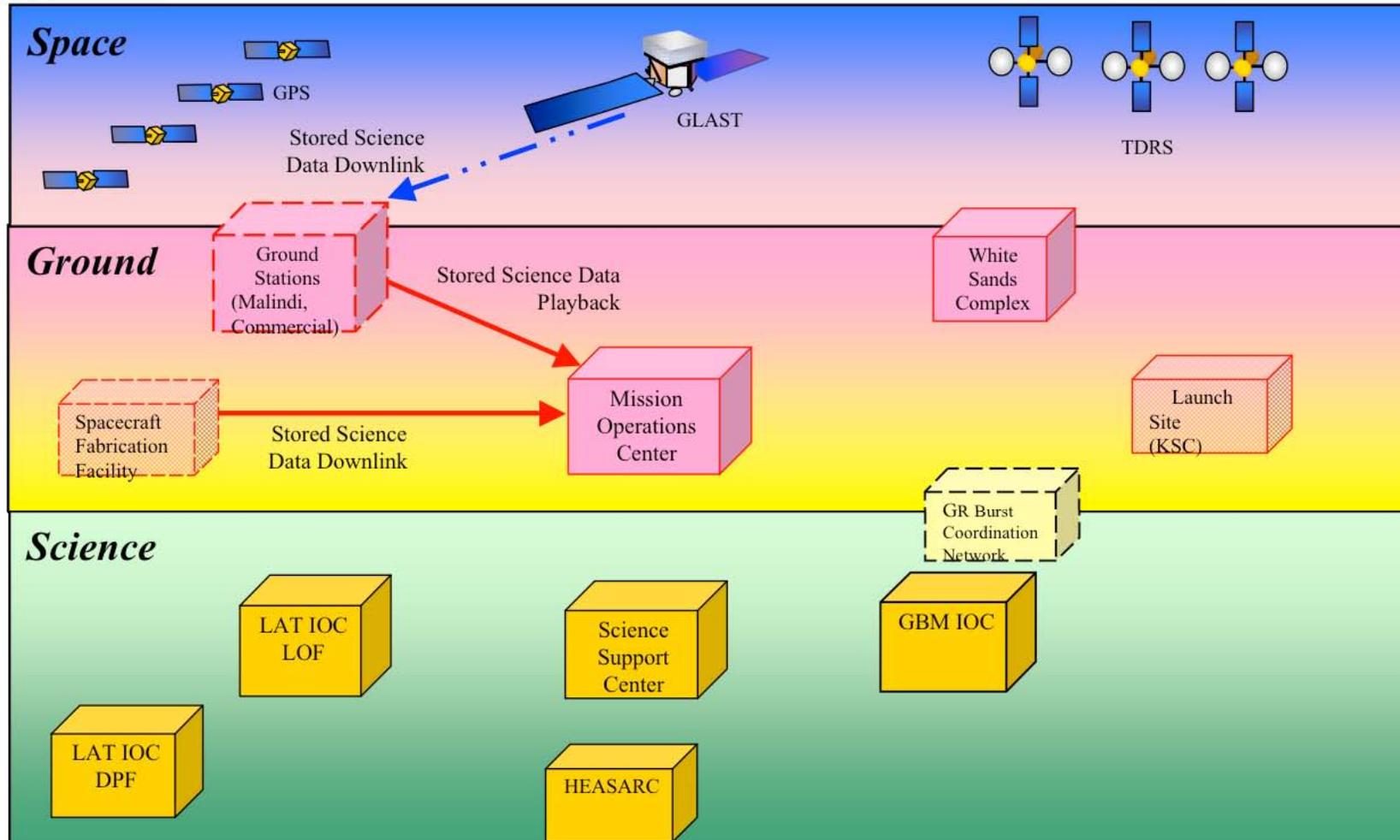


- Messages indicating the observatory has entered safehold
- Used to rapidly respond the cause of the safehold and begin recovery
 - Schedule more supports than normal
 - Begin data analysis sooner
- Frequency, Timing , Latency
 - Spacecraft never go into safehold
 - Rough average about 3 safeholds per 5 year mission- some more, some less.
 - Latency on Alert will be exactly the same as a burst alert after necessary data is collected for the safehold alert.
 - Issue of Latency could be precluded by 24x7 DAS 1 kb engineering telemetry.



GLAST Operations Concept

Raw(Unprocessed) Science Data





GLAST Operations Concept

Raw(Unprocessed) Science Data

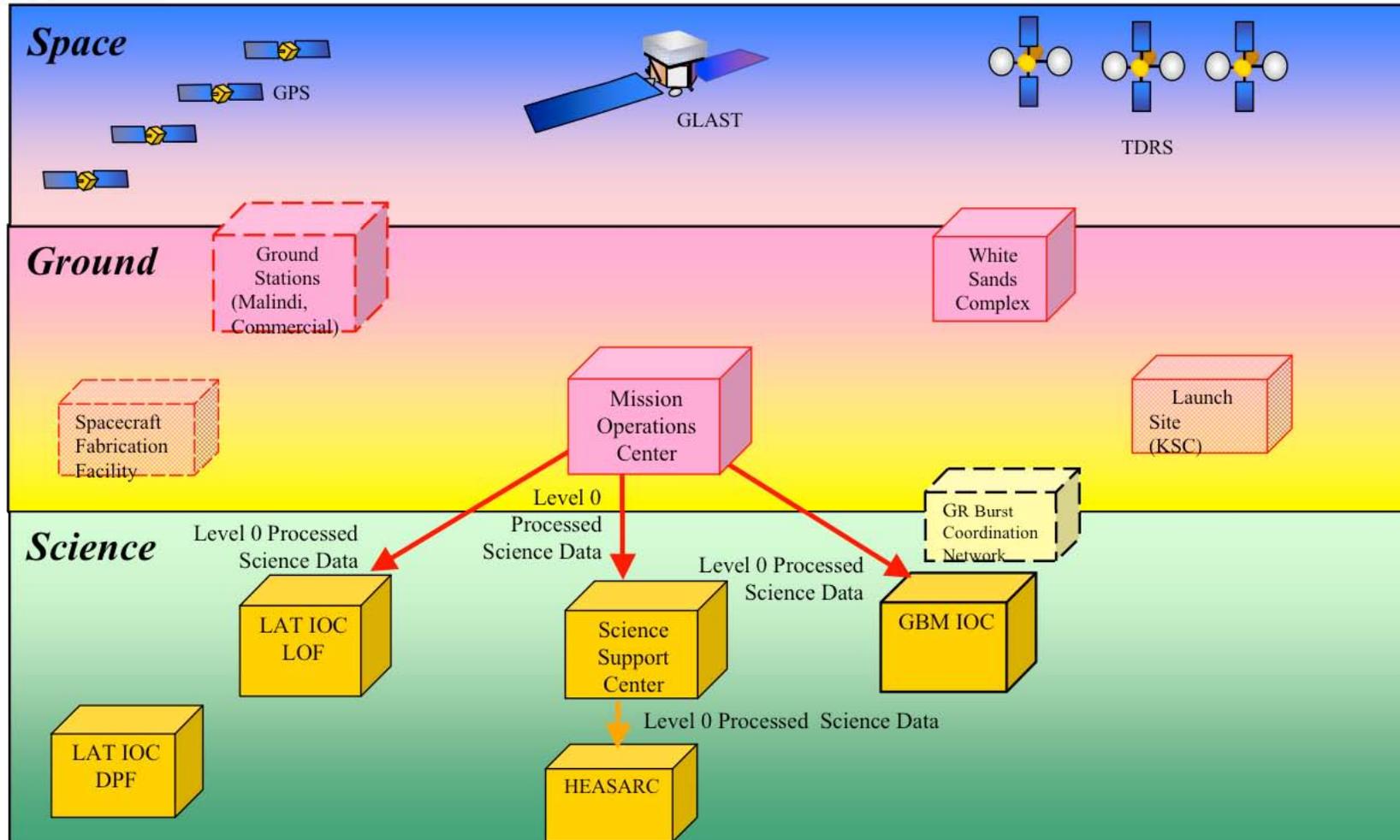


- Event data readouts from the instruments that have been stored on board.
- Used by Observatory to store events
 - Events = “good” photon detections
- Frequency, Timing , Latency
 - Downlink time and Playback time are not the same
 - P/B Dependent on Ground Link Characteristics and Throughput
 - Mission Requires 4 to 5 downlinks per day
 - Station view dependent
 - Downlink bandwidth dependent
 - Time from receipt of raw at GN to completion of transmit of Level 0 (next slide) from MOC is 12 hours.
 - GN to store 7 days of Raw Downlinked Telemetry



GLAST Operations Concept

Level 0 Processed Science Data





GLAST Operations Concept

Level 0 Processed Science Data

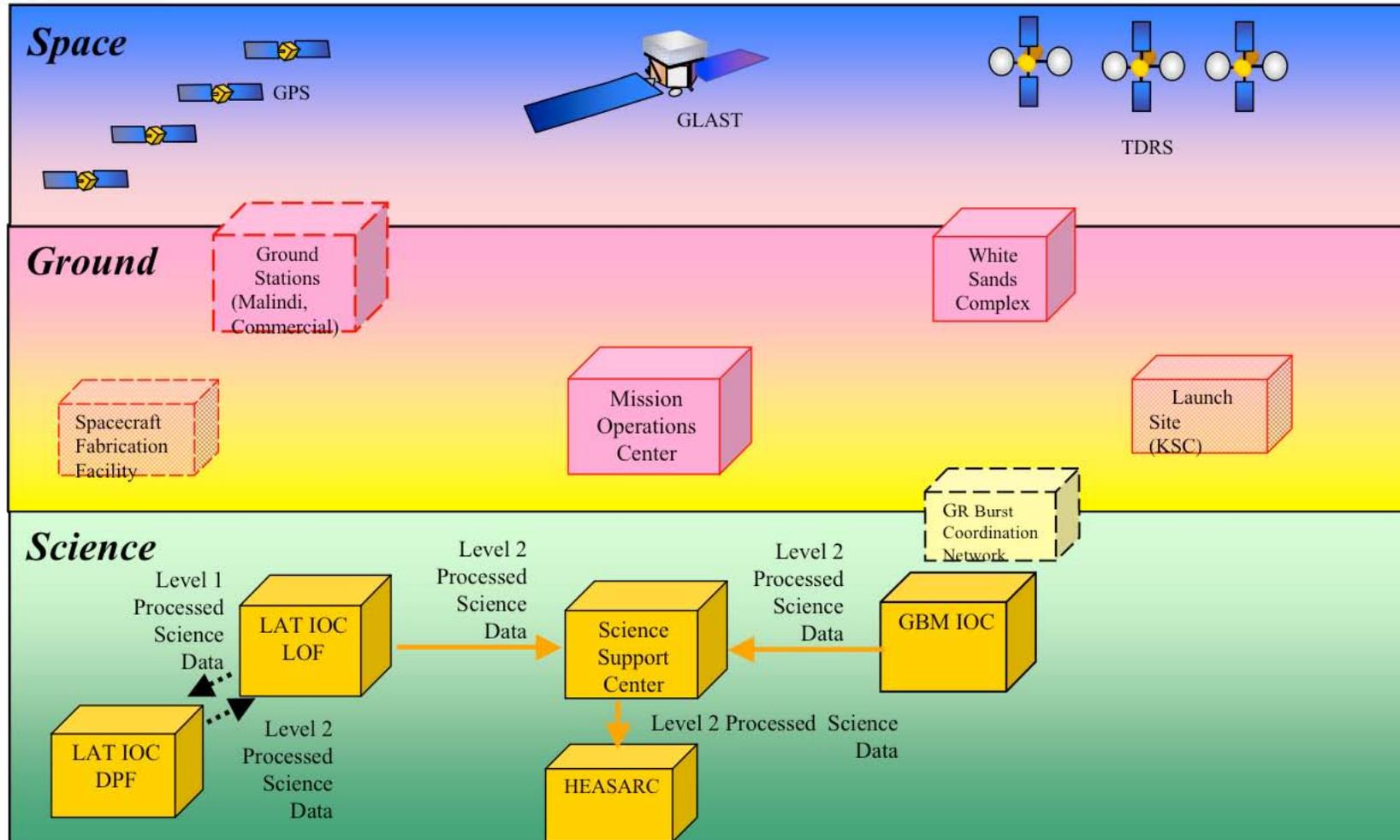


- Time ordered, non-duplicate, good-block only data sets
- Used by ground system to avoid transmitting useless data to the IOC
 - but MOC will transmit some cross- dump duplicates and will honor duplicate retransmit requests.
- Frequency, Timing , Latency
 - MOC will be transmitting this data a lot.
 - Amount of parallel processing will depend on MOC implementation.
 - Time from receipt of raw(previous slide) at GN to completion of transmit of Level 0 from MOC is 12 hours.
 - MOC to store 30 days of Level 0 Data for possible retransmit.



GLAST Operations Concept

Higher Level Processed Science Data





GLAST Operations Concept

Higher Level Processed Science Data



- Level 1 Data
 - Cleaned up Level Zero Data
 - Level Zero is minimally processed for speed and simplicity
 - MOC does not track what has already been delivered to IOC in detail
 - MOC keeps records of what playbacks have been sent to IOC but don't assure there is no overlap in the data content
 - Level 1 has overlaps removed and is the best data set available for Level 2 processing
- Level 2 data
 - Data useful to the science community
 - The Real Data or Data Ready to be Analyzed for Valuable Science Return



GLAST Operations Concept

Higher Level Processed Science Data



- Frequency, Timing , Latency
 - LAT IOC
 - Sends Level 1 data to SAS as is arrives
 - SAS sends Level 2 data back to LAT IOC.
 - LAT IOC sends Level 2 data to SSC with 24 hours of receipt of transmission of Level 0 from MOC.
 - GBM IOC
 - MOC/GBM Data Processing Level definitions are not in synch yet
 - GBM routine data processing is not expected to be overly complex
 - Bursts are their data driver
 - SSC
 - MOC/SSC Data Processing Level definitions are not yet in synch



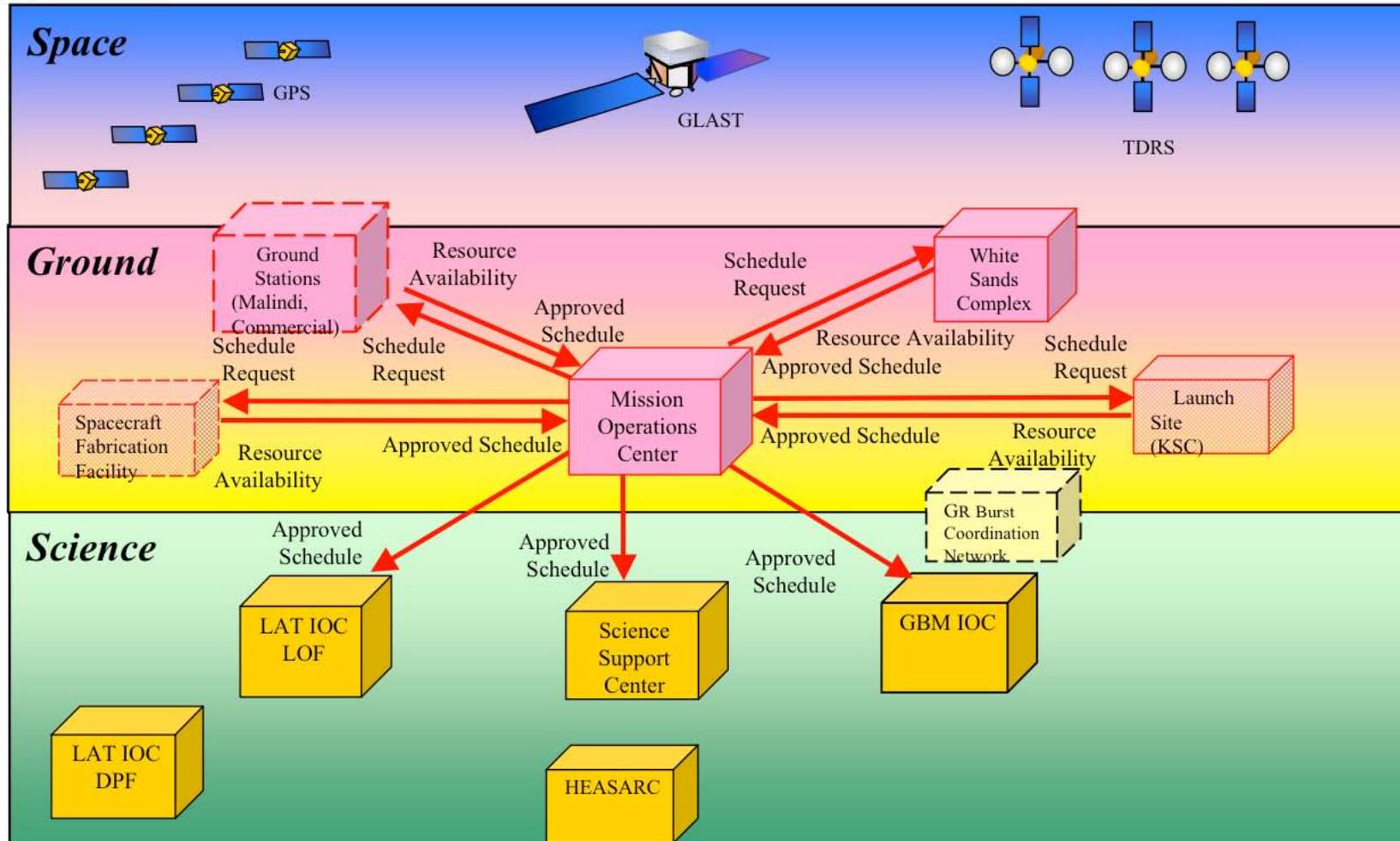
GLAST Operations Concept



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GLAST Operations Concept Scheduling





GLAST Operations Concept

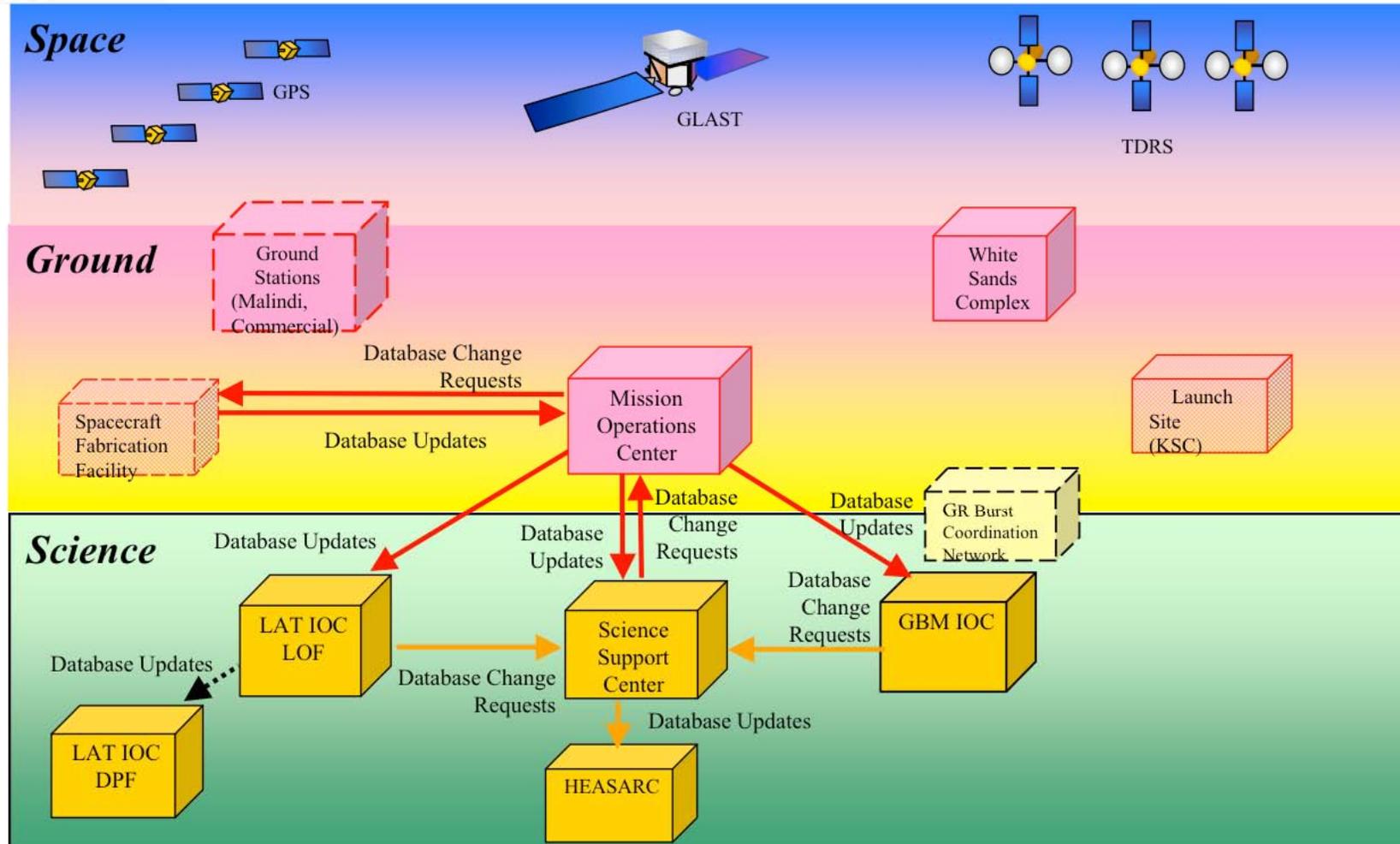
Scheduling



- Process of allocating useful ground and space network real time contacts
 - Determination
 - What we need and when we need it
 - What is available
 - Request
 - Arbitration
- Frequency, Timing , Latency
 - Weekly schedule requests
 - Sent from MOC one week in advance of 1st contact requested
 - 48 hour turn around by SN and GN
 - Emergency Requests
 - Turn around within two hours



GLAST Operations Concept Databases





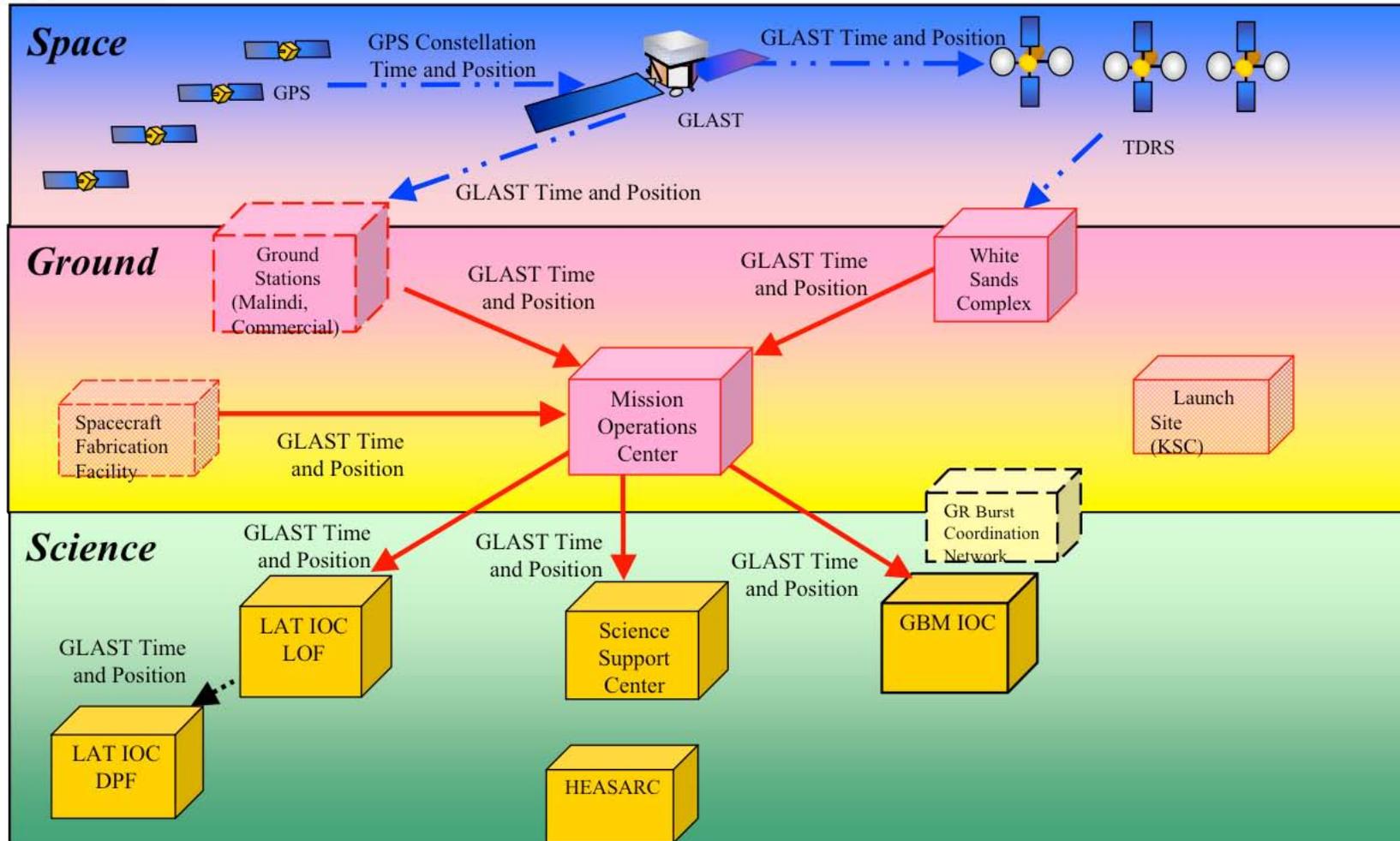
GLAST Operations Concept Databases



- Ground System components that describe formats of data products
 - Command (pre-requisites, associated telemetry, criticality, restrictions)
 - Telemetry (engineering and science)
 - Calibration Curves
 - Limits (Red, yellow, green)
- Used to allow the MOC to safely command the spacecraft and monitor its activity.
- Frequency, Timing , Latency
 - Implementation Will Synch up with Ground Software Deliveries
 - Frozen at L-60 Days
 - Infrequently updated once on-orbit



GLAST Operations Concept GPS





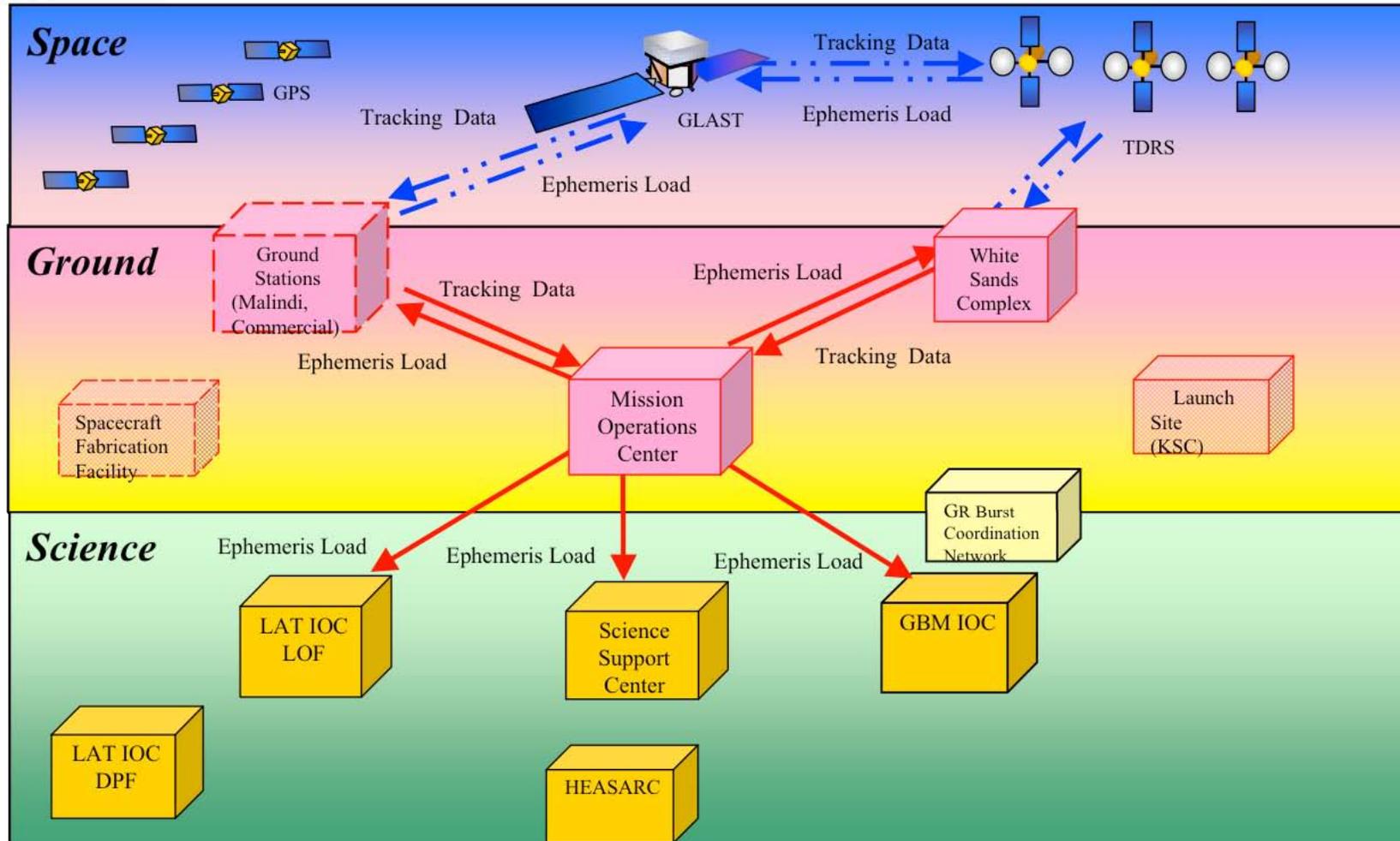
GLAST Operations Concept GPS



- On board Orbit Determination System in a box
- GPS spacecraft provide their time and position data for the observatory to process into its time and position data
- Frequency, Timing , Latency
 - Boxes take up to 24 minutes to determine a solution from the “Off” state.



GLAST Operations Concept Ground Based Orbit Determination





GLAST Operations Concept Ground Based Orbit Determination

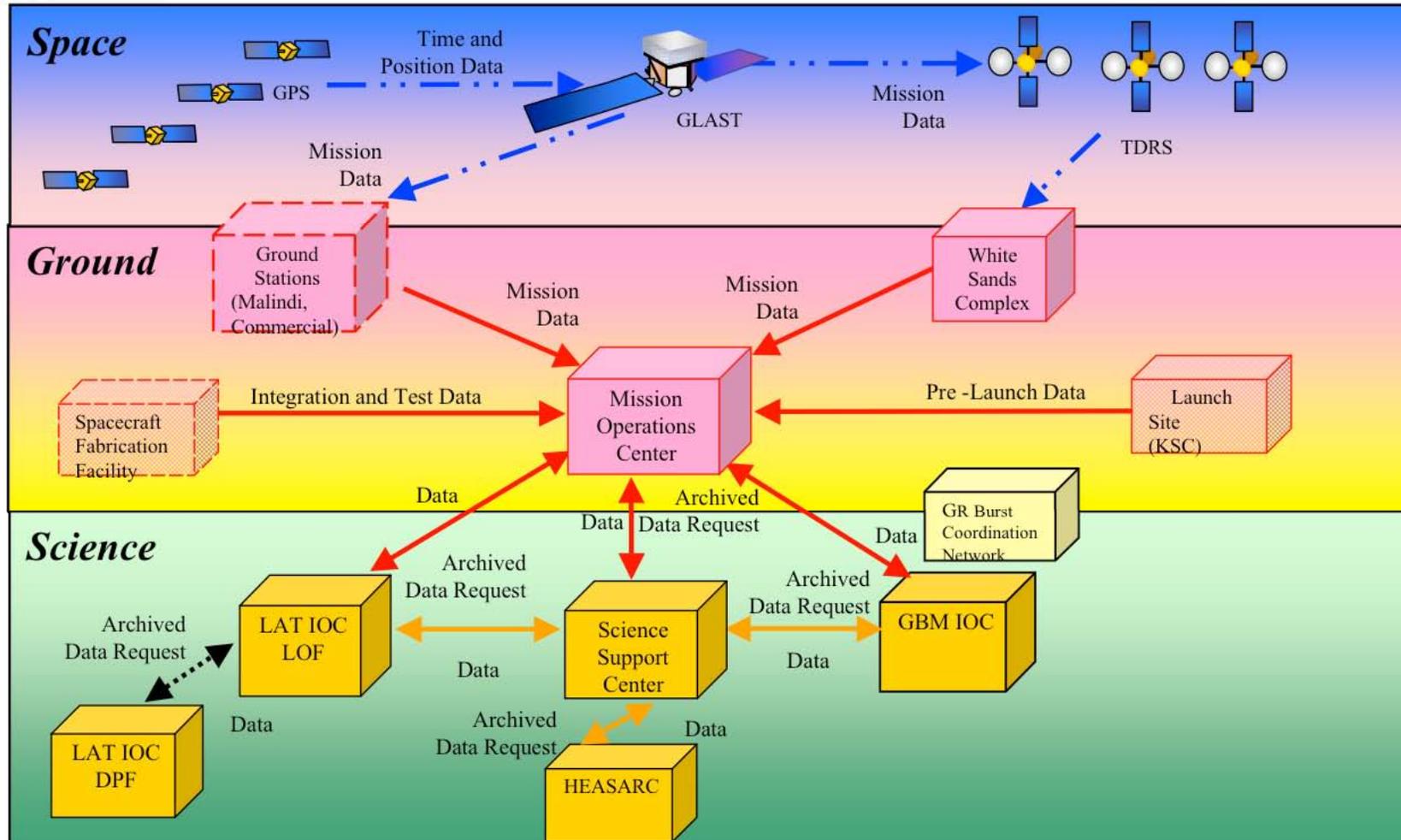


- Ground processing of tracking data to determine the orbit and create product for use onboard
- Tracking data can be delivered from TDRS or Ground Source
- FDF may or may not have a role -vendor specific
- Used as a backup and verification to GPS.
- Frequency, Timing , Latency
 - Requires specially scheduled tracking supports
 - Used extensively during checkout and early orbit
 - Will occur infrequently on-orbit (hopefully)



GLAST Operations Concept

Trending





GLAST Operations Concept

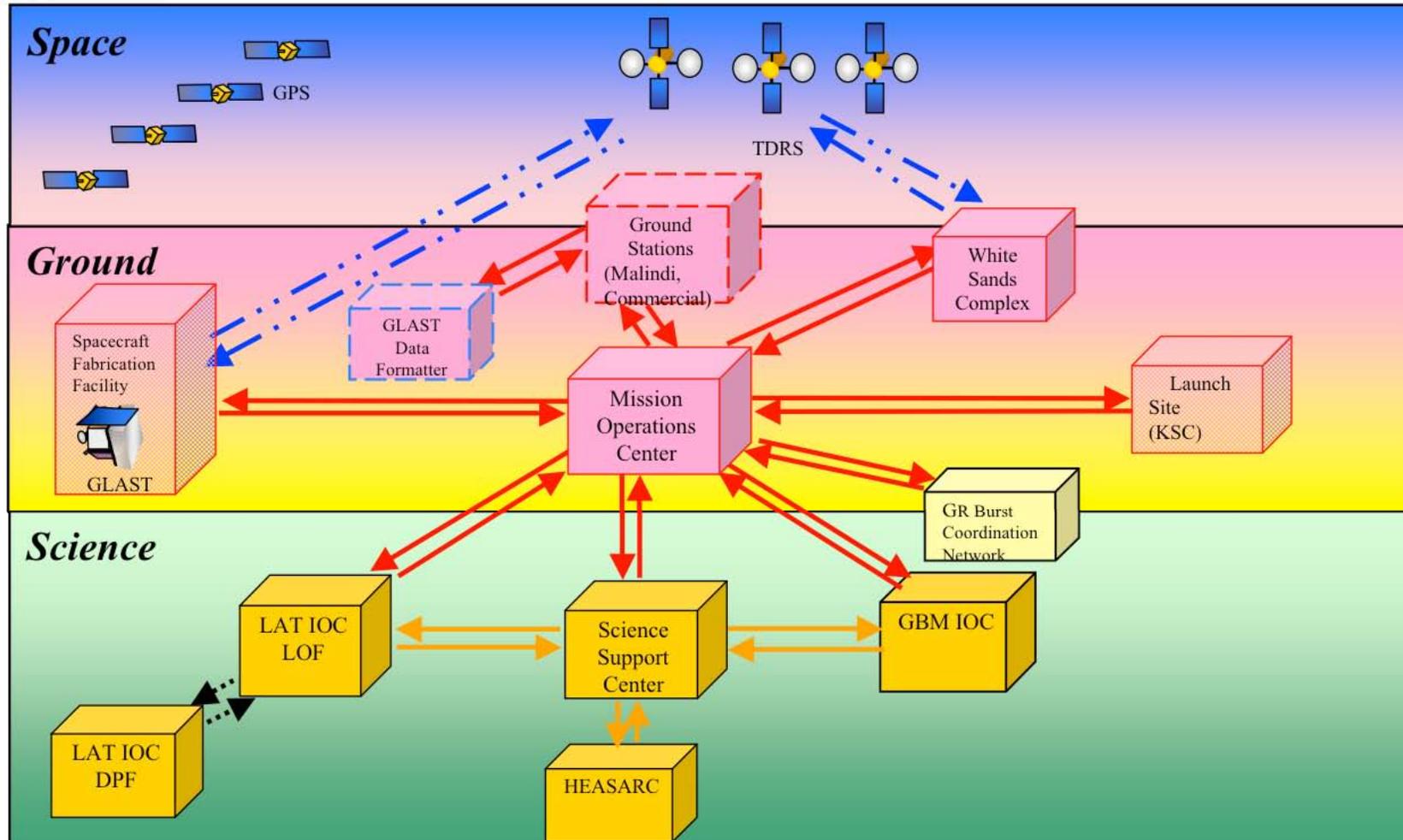
Trending



- Process of routinely gathering, processing and distributing the archived data.
 - Each Element will save the data it thinks it wants or needs
 - Elements will be able to request data from other's archives
 - Useful for studying things not thought of a priori that turn out to be interesting
 - Subject to data rights of course
- Used to assess the long term health of the observatory
- Frequency, Timing , Latency
 - Elements will set their own frequency
 - MOC should produce orbital, daily and weekly products at a minimum.



GLAST Operations Concept Test Configuration





GLAST Operations Concept Test Configuration

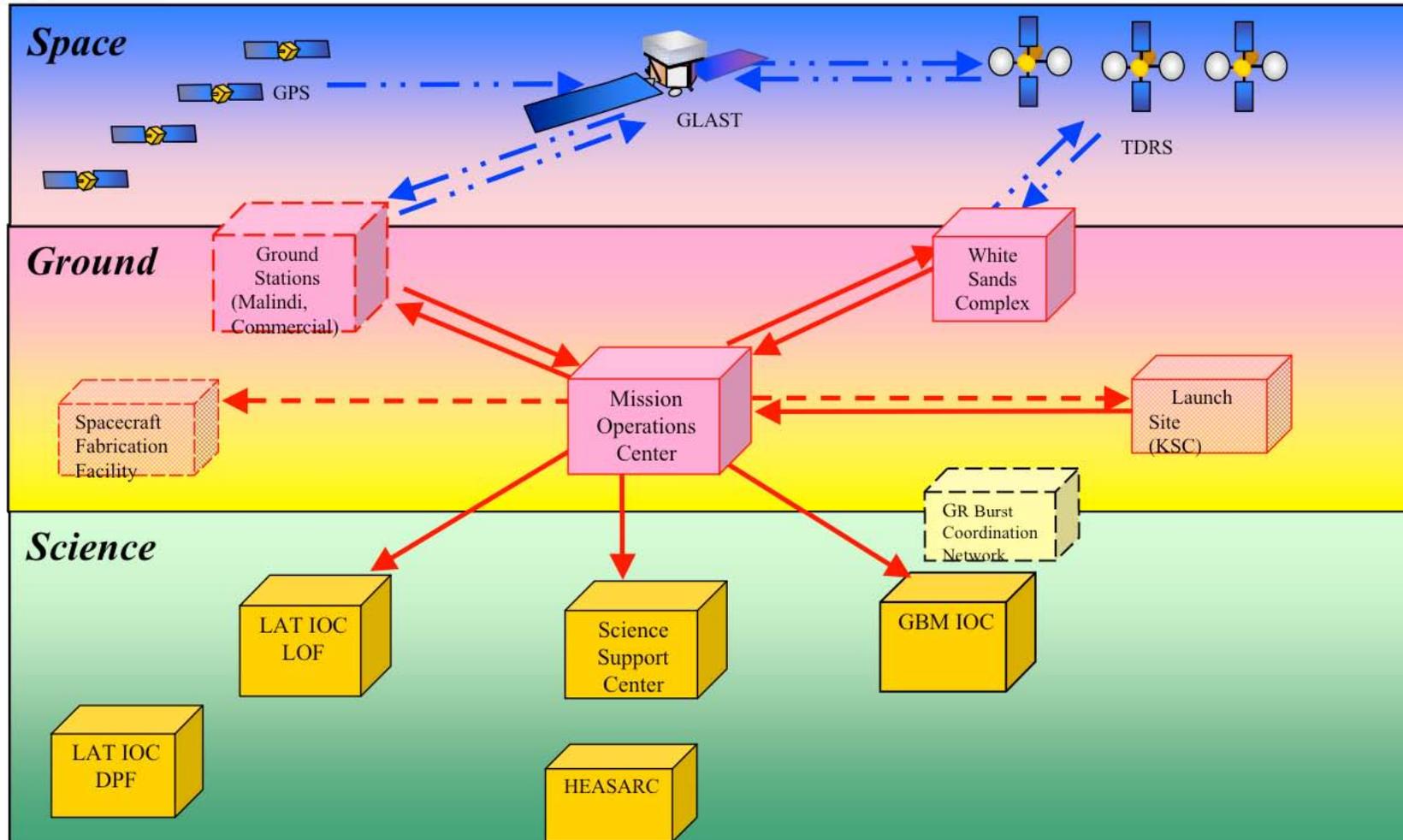


- Used in pre-launch preparations
- Ground Stations not tested with actual spacecraft
 - Use data formatter for T&C verification of site\
 - Details of how this happens are Vendor dependent
- GPS spacecraft not tested with GLAST
 - Not a risky interface



GLAST Operations Concept

Launch Configuration





GLAST Operations Concept Launch Configuration

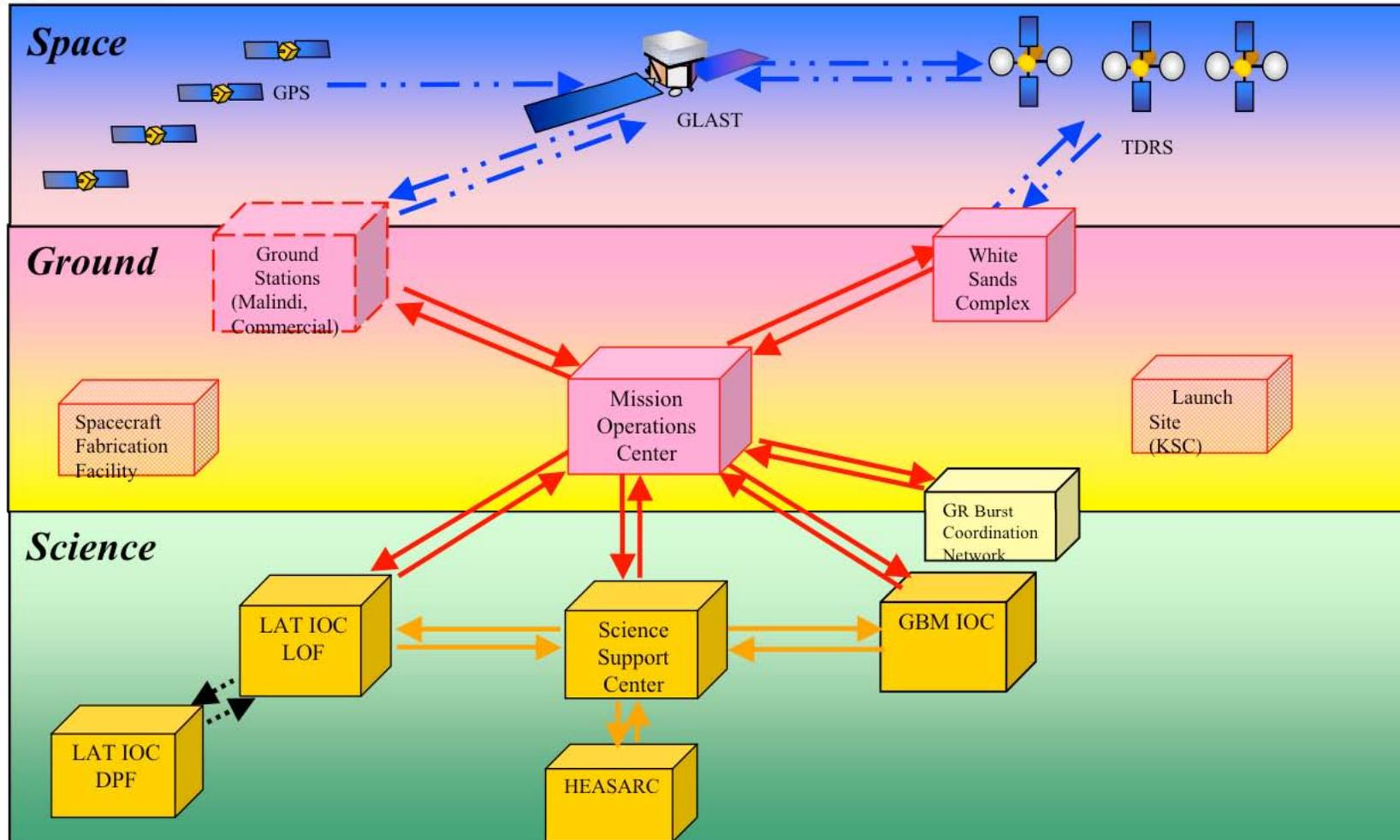


- Used from From L-24 hours to L+72 hrs
- Single Dashed lines may terminate well before L-0
- All interfaces are bare bones between elements
 - Engineering Telemetry and Command
 - Sufficient Expertise should be located in the MOC in the event of an unexpected situation - attitude, power, thermal, FSW, etc.



GLAST Operations Concept

Check-Out Configuration





GLAST Operations Concept

Check-Out Configuration

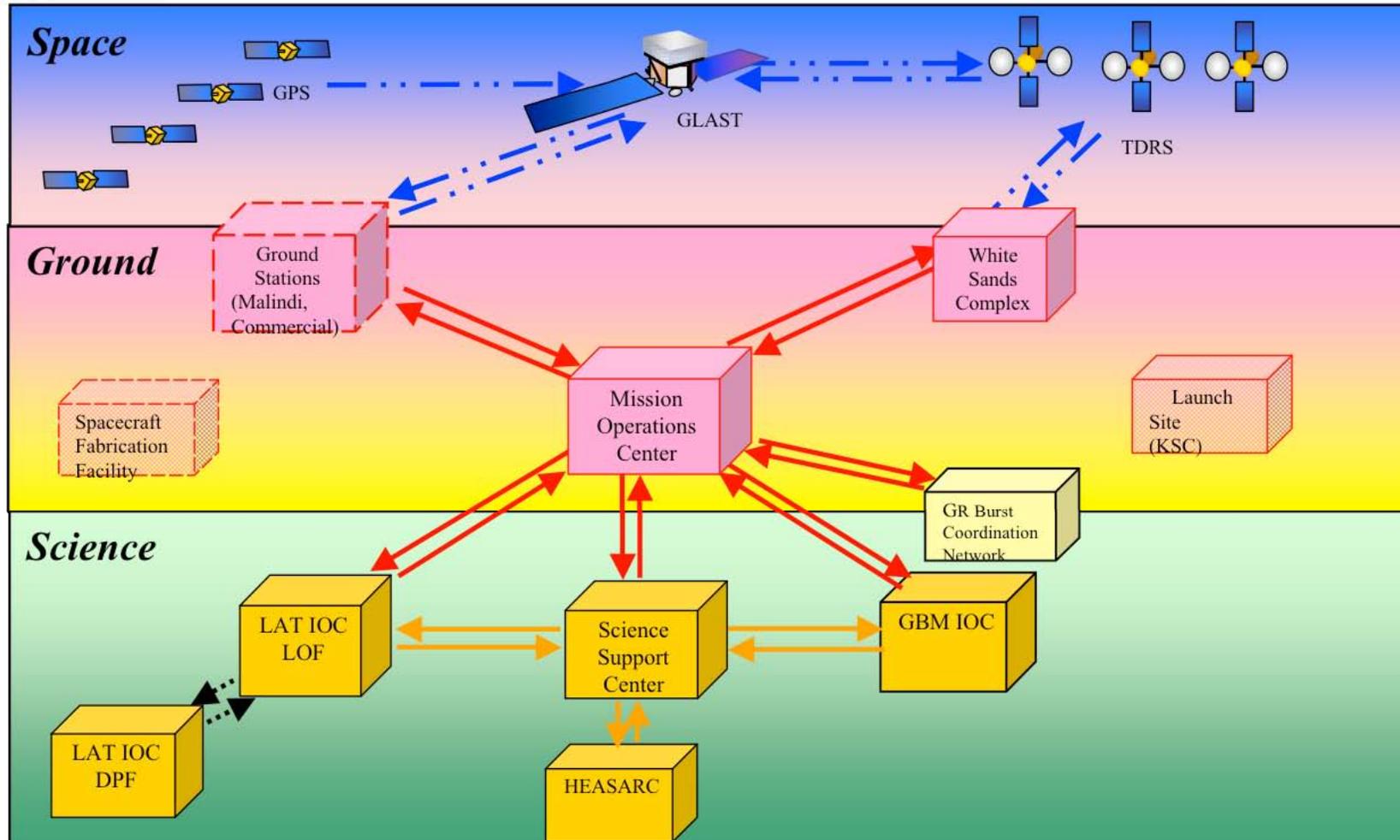


- Used from From L+72 hours to L+60 days
- Transition from Launch Configuration to Mission Configuration
 - From Engineering Telemetry and Real time Commanding
 - To Science Telemetry and Stored Commanding
- All interfaces are systematically and incrementally activated until all mission products are flowing their appointed routes.



GLAST Operations Concept

Mission Configuration





GLAST Operations Concept Mission Configuration



- L+60 days until De-orbit Decision is Made, Argued and Executed
- All products mentioned in this presentation flow along the paths described
 - Plus some that are yet to be discovered
- All interfaces operate at peak efficiency for a long, long, time!
- De-orbit configuration looks like the end of the checkout period
 - Selected expertise at the MOC to assist with planning the execution