LAT Flight Software

LIM Package Design

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A description of the design of the LAT Instrument Manager (LIM) package and its control of the operating mode of the LAT Flight Software.

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0 Introduction

The LAT Instrument Manager (LIM) package contains functions and command handlers that run on the SIU CPU and manage the operating mode of the LAT flight software. The operating mode determines the types of operations the LAT flight software is allowed to perform, based on the current state of the LAT instrument. LIM is responsible for transitioning between the operating modes and ensuring that the flight software performs only the actions appropriate for the current mode.

Most transitions of the LAT operating mode are initiated by commands sent to LIM from the ground, the spacecraft, and other flight software tasks. When LIM receives one of these commands, it performs all actions necessary to transition to the new mode, such as applying power to various parts of the instrument or notifying other flight software components that a mode change has occurred.

LIM intercepts commands intended for certain other flight software tasks to ensure that only allowed actions are performed. If LIM determines that a command is valid for the current mode, it forwards the command to the intended target task. In some cases, LIM delays forwarding these commands until the LAT instrument enters an appropriate operating mode. By filtering commands in this manner, other flight software does not have to be aware of the current LAT operating mode.

1 Modes and States

The LIM software manages the operating mode of the LAT flight software. LIM uses a number of factors to determine the current instrument operating mode:

- Commands and messages received from the spacecraft, ground, and other flight software tasks,
- Internal events such as repoint observation timer expirations,
- State of various flight software tasks.

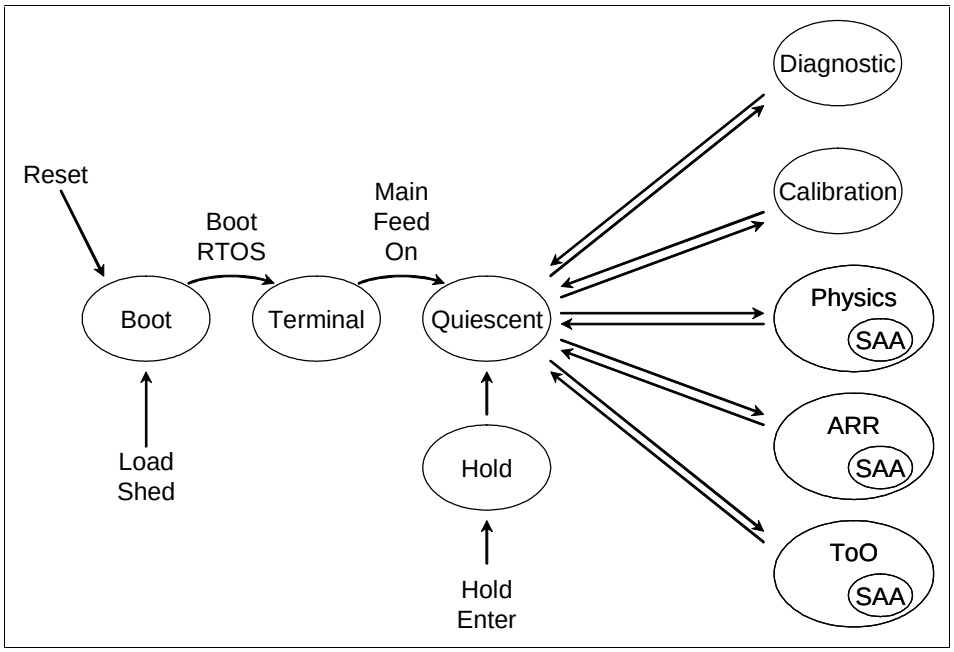
1.0 Operating Modes

At any given time, the LAT instrument can be in one of several operating modes, as described in Table 1. Transitions between these modes are initiated by commands, messages, and internal LIM events. Figure 1 is a diagram of these transitions and identifies some, but not all, of these initiating commands.

Table 1 – LIM Operating Modes

Name	Description
Boot	Primary Boot Code (PBC) running and LIM not running.
Terminal	Initial LIM mode.
Quiescent	Ready for physics observations, calibration, or diagnostics.
Hold	Stable mode for troubleshooting.
Diagnostic	Diagnostic functions are active.
Calibration	Charge injection calibration functions are active.
Physics	Normal sky survey or pointed observation activity is in progress.
ToO	Target of Opportunity observation activity is in progress.
ARR	Autonomous Repoint Request activity is in progress.

Figure 1 – LIM Mode Transition Diagram



The spacecraft, LAT instrument, and LAT flight software also operate within their own sets of states and modes – some of which are determined by the LIM operating modes. Table 2 shows the correlation between the LIM and some of these external states and modes.

Table 2 – Operating Mode Correlations

External Mode/State	LIM Mode
Primary Boot	Boot
Secondary Boot	LIM transitioning from Boot to Terminal
Load Shed	Boot
GASU/PDU Power	Quiescent
SAA Transit	Supported in all LIM modes
Engineering	Quiescent, Diagnostic, Calibration, Hold
Sky Survey	Physics
Pointed Observation	Physics
Repointed Observation: ToO	ToO
Repointed Observation: ARR	ARR

1.0.0 BOOT Mode

Immediately after reset, the SIU is in a mode in which only the Primary Boot Code (PBC) is running. No other flight software (including LIM) is running in this mode, and the SIU is the only LAT component that is powered. Even though LIM is not running, this mode of SIU operation is identified as LIM's BOOT mode because it is the mode into which LIM places the SIU when it receives a Load-Shed command.

From the BOOT mode, LIM transitions to the TERMINAL mode when the secondary boot process starts the LIM task. The secondary boot process is initiated by the PBC when it receives the Boot-RTOS command.

LIM returns to the BOOT mode when it receives the Load-Shed command, regardless of the current mode. LIM makes this transition by resetting the SIU as the final step of its Load-Shed command handling procedure.

1.0.1 TERMINAL Mode

When LIM is started by the secondary boot process, it begins operation in the TERMINAL mode. When LIM is in this mode, all other flight software tasks are running, as well, but some are idle. As is true during BOOT mode, the SIU is the only component of the LAT instrument that is powered during TERMINAL mode.

While in this mode, LIM accepts only those commands that affect the safety of the instrument (SAA-Enter, SAA-Exit, and Load-Shed) and the command that causes a transition to the QUIESCENT mode (Main-Feed-On). All other commands are rejected, including commands intercepted by LIM but intended for other tasks.

From the TERMINAL mode, LIM transitions to the QUIESCENT mode when it receives the Main-Feed-On command.

1.0.2 QUIESCENT Mode

The primary purpose of the QUIESCENT mode is to provide a mode in which the LAT can be made ready for physics observations, diagnostic procedures, and charge injection calibrations. When LIM is in this mode, the GASU and PDU have been powered and LIM accepts commands to enable and configure power to other LAT components.

From this mode, LIM transitions to a number of different modes, depending on the type of activity requested (physics observations, diagnostic procedures, or charge injection calibrations). Once one of these activities has started, LIM must return to the QUIESCENT mode before a new activity can begin.

1.0.3 HOLD Mode

The HOLD mode exists to provide a stable environment in which commands can be sent to the LAT instrument for error investigation and recovery. While in this mode, LIM rejects all commands except those that affect the safety of the instrument (SAA-Enter, SAA-Exit, and Load-Shed) and the command that causes a transition out of the HOLD mode (Hold-Exit). This keeps the LAT instrument in a stable state even if the spacecraft continues to send previously-scheduled commands.

LIM enters the HOLD mode only when it receives a Hold-Enter command. It remains in this mode until it receives a Hold-Exit command, at which time it transitions to the QUIESCENT mode. (As in most other modes, LIM will also leave the HOLD mode if it receives a Load-Shed command.)

1.0.4 DIAGNOSTIC Mode

The DIAGNOSTIC mode is used to perform testing and troubleshooting procedures that cannot be performed in TERMINAL mode. While in DIAGNOSTIC mode, LIM forwards all intercepted

LDF commands to the LDF task. (LIM rejects intercepted LDF commands when not in the DIAGNOSTIC mode.)

LIM transitions to this mode when it receives a Diagnostic-Start command while in the QUIESCENT mode.

LIM remains in the DIAGNOSTIC mode until it receives a message from the LDF task indicating that the diagnostic procedure has completed, at which time LIM returns to the QUIESCENT mode. The LDF task sends this completion message either as a result of a Diagnostic-Abort command or the completion of a pre-determined diagnostic procedure. If the LDF task fails to send this completion message, LIM remains in the DIAGNOSTIC mode until it receives a Load-Shed or Hold-Enter command.

1.0.5 CALIBRATION Mode

The CALIBRATION mode is a specialized form of the DIAGNOSTIC mode. When in this mode, LIM forwards all intercepted LCI commands to the LCI task. (LIM rejects intercepted LCI commands when not in the CALIBRATION mode.)

LIM transitions to this mode when it receives a Calibration-Start (LCI-CALIBRATE) command while in the QUIESCENT mode.

LIM remains in the CALIBRATION mode until it receives a message from the LCI task indicating that the calibration procedure has completed, at which time LIM returns to the QUIESCENT mode. The LCI task sends this completion message either as a result of a Calibration-Abort (LCI-ABORT) command or the completion of a pre-determined calibration procedure. If the LCI task fails to send this completion message, LIM remains in the CALIBRATION mode until it receives a Load-Shed or Hold-Enter command.

1.0.6 PHYSICS Mode

When LIM is in the PHYSICS mode, it allows the LPA task to perform normal Physics Observation operations. This mode encompasses the Sky Survey and Pointed Observation LAT observation modes, which are identical from the perspectives of LIM and LPA. During this mode, LIM forwards all intercepted LPA commands to the LPA task.

LIM transitions to this mode from the QUIESCENT mode when a Physics-Start command is available for execution. If LIM accepts a Physics-Start command while in the QUIESCENT mode, it transitions to the PHYSICS mode immediately. If LIM accepts this command while in some other mode, however, the command is saved and made available for execution when LIM next returns to the QUIESCENT mode.

LIM remains in the PHYSICS mode until it receives a message from the LPA task indicating that the physics observation has completed, at which time LIM returns to the QUIESCENT mode. The LPA task sends this completion message only as a result of a Physics-Stop command. Unlike diagnostic and calibration procedures, the LPA task ends a physics observation only when told to do so by command. If the LPA task fails to send this completion message, LIM remains in the PHYSICS mode until it receives a Load-Shed or Hold-Enter command.

A physics observation can be interrupted by a repointed observation initiated by a ToO-Start or ARR-Start command. When LIM receives one of these commands, it suspends the current physics observation and transitions to the ToO or ARR mode. At the completion of the repoint period, LIM resumes the suspended physics observation and returns to the PHYSICS mode. (Depending on the virtual mode, though, LIM may not resume the suspended physics operation – see section 1.2).

1.0.7 ToO Mode

The Target of Opportunity (ToO) mode is entered when the ground wants to interrupt a scheduled activity to observe an unanticipated target. When LIM receives the ToO-Start command, it ends the current diagnostic procedure, calibration procedure, or physics observation and starts a repointed observation. While in ToO mode, LIM rejects Diagnostic-Start and Calibration-Start commands, but keeps track of Physics-Start and Physics-Stop commands and maintains a virtual mode that it uses to determine which mode to enter when the repointed observation is completed.

LIM remains in the ToO mode until the end of the repoint period. The length of the repoint period is specified in the ToO-Start command.

At the conclusion of the repoint period, if the virtual mode indicates that an interrupted physics observation should still be active, LIM transitions back to the PHYSICS mode and resumes the interrupted observation. If the virtual mode indicates that a new physics observation should be started, LIM transitions to the PHYSICS mode and starts the new observation with the saved Physics-Start command. If neither of these conditions is true, LIM returns to the QUIESCENT mode. Note that LIM will not resume a diagnostic or calibration procedure that was in progress when the ToO-Start command arrived.

1.0.8 ARR Mode

The Autonomous Repoint Request (ARR) mode is entered when the LPA task wants to interrupt a scheduled normal physics run to observe an unanticipated target. When LIM receives an ARR-Start command from the LPA task, it suspends the current normal physics observation run and starts the ARR run. Since Autonomous Repoint Requests are initiated by the LPA task, ARR-Start commands are rejected when the LPA task is not running.

At the completion of the time period specified in the ARR response, LIM stops the ARR observation run, resumes the suspended normal physics run, and transitions back to the PHYSICS mode. (Depending on the virtual mode, though, LIM may not resume the suspended physics run.)

1.1 SAA

When LIM receives the SAA-Enter command, it does not change its operating mode. Instead, LIM alters the ACD configuration to place it in a state that is safe for SAA transit. It also updates its internal state to indicate that a transit is in progress. LIM holds the ACD in this safe state until it receives the SAA-exit command, at which point it restores the ACD to its nominal state.

If the current mode is PHYSICS, ToO, or ARR when the SAA-Enter command is received, LIM suspends the observation run by sending the Physics-Stop command to the LPA task. During the SAA transit, LIM continues to obey the mode transition rules, with the exception that it does not start or resume physics observations. When LIM receives the SAA-Exit command, it either restarts a suspended observation run by sending the Physics-Restart command to the LPA task, or transitions to the QUIESCENT mode to handle any saved commands (according to the virtual mode).

If the current mode is TERMINAL, HOLD, or QUIESCENT when LIM receives the SAA-Enter command, it operates normally, with the restriction that it must hold the ACD in a safe state.

1.2 Virtual Mode

There are several situations in which a normal physics run must be delayed or interrupted while the LAT instrument performs a higher priority activity. This would be the case, for example, when an SAA transit begins during a normal physics run, or a Physics-Start command arrives during a Target-of-Opportunity observation. To handle these situations, LIM maintains a 'virtual' mode that it uses to determine which operating mode to enter once the higher priority activity is completed.

In addition to handling pre-emption by higher priority activities, LIM also uses the virtual mode to delay the start of a normal physics run until the completion of a diagnostic or calibration procedure. This is useful for avoiding dead time before a normal physics run when the length of a preceding diagnostic or calibration procedure is not known.

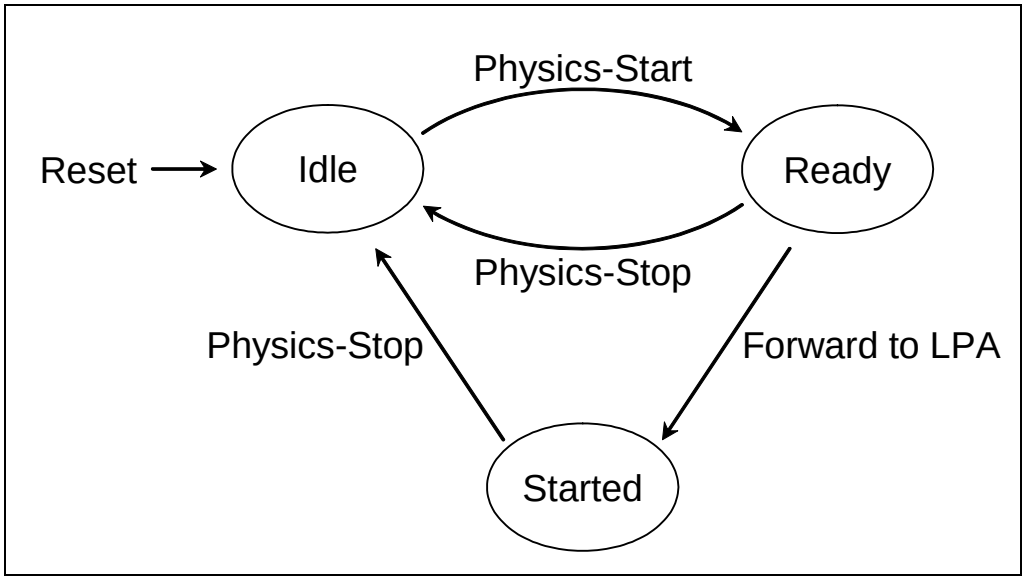
There are three virtual modes, as shown in Figure 2.

IDLE: LIM starts in the IDLE virtual mode, which indicates that no normal physics run is in progress or waiting to be started or resumed. Note that this mode does not necessarily indicate that the actual operating mode is QUIESCENT – it is only an indication that no normal physics run is being delayed by the current operation.

READY: This virtual mode indicates that LIM has received and saved a Physics-Start command. LIM remains in this virtual mode until it either forwards the saved command to the LPA task or receives a Physics-Stop command. In the former case, the virtual mode transitions to STARTED, and in the latter case it transitions to IDLE.

STARTED: This virtual mode indicates that a normal physics run has been started but not yet completed. LIM remains in this virtual mode until it receives a Physics-Stop command, at which point the virtual mode transitions to IDLE. While in this virtual mode, the normal physics run may be interrupted one or more times by higher priority activities. Unless LIM itself receives a Physics-Stop command during the interruption, the virtual mode remains as STARTED.

Figure 2 – LIM Virtual Modes



1.3 Target of Opportunity

One of the 'higher priority' activities that the LAT instrument can perform is a Target-of-Opportunity (ToO) repointed observation initiated by a ToO-Start command. When LIM receives this command, its response depends on the current operating mode:

- In the DIAGNOSTIC or CALIBRATION mode, LIM aborts the current procedure before starting a physics run for the ToO observation. In this case, LIM saves the ToO-Start command that initiated the ToO observation and forwards it to the LPA task when the Diagnostic-Complete or Calibration-Complete command is received. Note that the aborted diagnostic or calibration procedure is not restarted at the completion of the ToO observation.
- If LIM is in the PHYSICS or ARR mode when a ToO-Start command arrives, it immediately sends the Physics-Reconfigure command to the LPA task to reconfigure the task for the ToO observation.
- In the ToO mode, LIM rejects ToO-Start commands because the LAT instrument is already performing a ToO observation.
- In the TERMINAL or HOLD mode, LIM rejects ToO-Start commands because the LAT instrument is not ready to perform physics observations.

1.4 Autonomous Repoint Request

Another 'higher priority' activity that the LAT instrument can perform is an Autonomous Repoint observation. This type of observation is initiated by the LPA task when it sends the ARR-Start command to LIM.

When LIM receives this command, its response depends on the current operating mode:

- In the TERMINAL, HOLD, DIAGNOSTIC, or CALIBRATION mode, LIM rejects the ARR-Start command because the LPA task is not running.
- If LIM is in the PHYSICS mode when the ARR-Start command arrives, it reconfigures the current observation run by sending the Physics-Reconfigure command to the LPA task.
- In the ARR mode, LIM rejects ARR-Start commands because the LAT instrument is already performing an ARR observation.
- In the ToO mode, LIM remembers that an ARR observation was requested, but waits until the ToO observation has completed before reconfiguring the observation run.

1.5 LCI, LDF, and LPA State

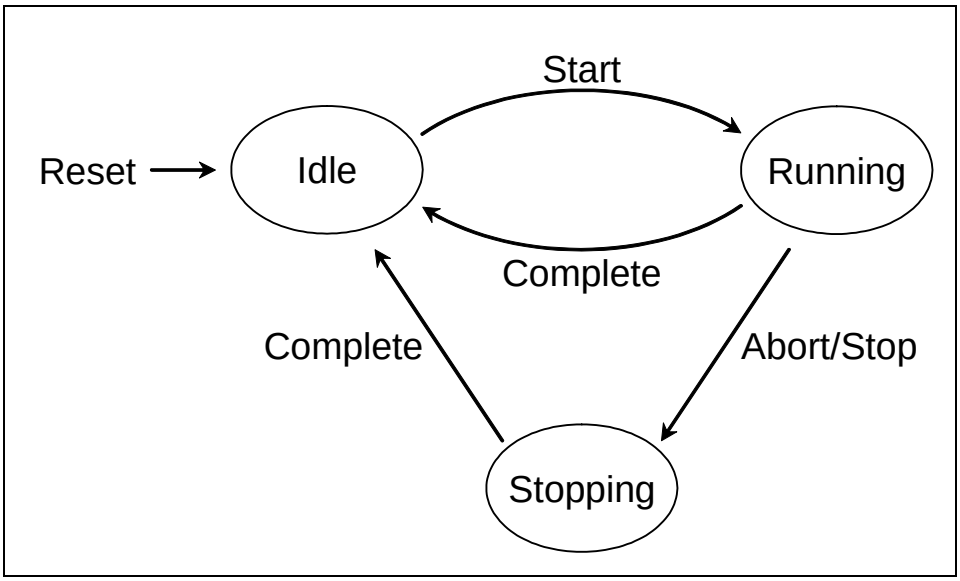
To help determine the current operating mode, LIM keeps track of the current 'state' of each of three other tasks – LAT Charge Injection (LCI), LAT Diagnostic Framework (LDF), and LAT Physics Acquisition (LPA). At any particular time, LIM considers each of these tasks to be either **Idle**, **Running**, or **Stopping**. The tasks themselves are not aware of these states, however, since they are only for the convenience of LIM.

Initially, LIM considers a task to be **Idle**, as shown in Figure 3. When LIM forwards a 'Start' command to a task, it changes the task's state to **Running**. LIM changes the state back to **Idle** when it receives a 'Completion' message from the task.

While in the Running state, if LIM forwards an 'Abort' or 'Stop' command to a task, it changes the task's state to **Stopping**. This state indicates that LIM is waiting for the task to acknowledge that

it has completed its operation. When the task sends it ‘Completion’ message, LIM changes its state back to **Idle**.

Figure 3 – LCI, LDF, and LPA States



2 Commands and Messages

LIM responds to certain commands by changing its operating mode, applying power to LAT components, and notifying other tasks of mode and state changes. LIM also intercepts commands intended for other tasks, determines if they are valid for the current operating mode, and forwards them to the intended target task if appropriate.

2.0 LCI Commands and Messages

The LAT Charge Injection task (LCI) handles instrument calibration procedures. LIM intercepts all commands sent to LCI and forwards those that are appropriate for the current operating mode and for the current LCI task state (as described in section 1.5). LIM also receives Calibration-Complete messages sent by the LCI task at the completion of a calibration procedure.

LIM uses the Calibration-Start (LCI-CALIBRATE) command and the Calibration-Complete message to determine operating mode transitions. When in the QUIESCENT mode, LIM transitions to the CALIBRATION mode whenever it forwards a Calibration-Start command to LCI. The operating mode changes back to QUIESCENT when LIM receives the Calibration-Complete message.

2.0.0 Calibration Start (LCI-CALIBRATE)

Description: This command is a request to start a calibration procedure.

Action: LIM intercepts this command and forwards it to the LCI task if it is appropriate for the current operating mode and LCI task state. If not appropriate, LIM rejects this command.

Parameters: LIM does not interpret any of the parameters that this command may contain.

Operating Mode: LIM accepts and forwards this command if either (1) the current operating mode is QUIESCENT or (2) the current mode is CALIBRATION and the LCI task is not in the **Stopping** state. In the first case, LIM transitions from the QUIESCENT mode to the CALIBRATION mode.

LCI State: If forwarded to the LCI task, this command causes LIM to change the LCI task state to **Running**.

Virtual Mode: This command does not affect the virtual mode.

2.0.1 Calibration Abort (LCI-ABORT)

Description: This command is a request to abort a calibration procedure.

Action: LIM intercepts this command and forwards it to the LCI task.

Parameters: LIM does not interpret any of the parameters that this command may contain.

Operating Mode: LIM accepts and forwards this command in all operating modes except TERMINAL and HOLD. The receipt of this command does not affect the operating mode directly. Instead, LIM determines whether a mode transition is necessary when it receives the Calibration-Complete message that the LCI task sends in response to this command.

LCI State: If the LCI task is in the **Running** state when LIM forwards this command to LCI, it changes the LCI state to **Stopping**. Otherwise, LIM does not change the LCI task state and reports a warning (the command is still forwarded to the LCI task, though).

Virtual Mode: This command does not affect the virtual mode.

2.0.2 Calibration Complete

Description: This message indicates that the LCI task has completed a calibration procedure.

Action: LIM uses this message to change the operating mode and LCI task state.

Parameters: LIM does not interpret any of the parameters that this message may contain.

Operating Mode: This message causes LIM to transition from the CALIBRATION mode to the QUIESCENT mode. If LIM is not in the CALIBRATION mode, though, LIM reports a warning and does not change the operating mode.

LCI State: This message causes LIM to change the LCI task state to **Idle**. LIM reports a warning if the LCI task is already in the **Idle** state.

Virtual Mode: This command does not affect the virtual mode.

2.0.3 Other LCI Commands

Description: These commands direct the operation of the LCI task during a calibration procedure.

Action: LIM intercepts these commands and forwards them to the LCI task if they are appropriate for the current operating mode and LCI task state. If not appropriate, LIM rejects these commands.

Parameters: LIM does not interpret any of the parameters that these commands may contain.

Operating Mode: LIM accepts and forwards these commands only in the CALIBRATION operating mode. They do not cause LIM to change the operating mode.

LCI State: LIM accepts and forwards these commands only if the current LCI task state is **Running**. They do not cause LIM to change the LCI state.

Virtual Mode: These commands do not affect the virtual mode.

2.1 LDF Commands and Messages

The LAT Diagnostic Framework task (LDF) handles instrument diagnostic procedures. As with the LCI task, LIM intercepts all commands sent to LDF and forwards those that are appropriate

for the current operating mode and for the current LDF task state. LIM also receives Diagnostic-Complete messages sent by the LDF task at the completion of a diagnostic procedure.

LIM uses the Diagnostic-Start command and the Diagnostic-Complete message to determine operating mode transitions. When in the QUIESCENT mode, LIM transitions to the DIAGNOSTIC mode whenever it forwards a Diagnostic-Start command to LDF. The operating mode changes back to QUIESCENT when LIM receives the Diagnostic-Complete message.

2.1.0 Diagnostic Start

Description: This command is a request to start a diagnostic procedure.

Action: LIM intercepts this command and forwards it to the LDF task if it is appropriate for the current operating mode and LDF task state. If not appropriate, LIM rejects this command.

Parameters: LIM does not interpret any of the parameters that this command may contain.

Operating Mode: LIM accepts and forwards this command if either (1) the current operating mode is QUIESCENT or (2) the current mode is DIAGNOSTIC and the LDF task is not in the **Stopping** state. In the first case, LIM transitions from the QUIESCENT mode to the DIAGNOSTIC mode.

LDF State: If forwarded to the LDF task, this command causes LIM to change the LDF task state to **Running**.

Virtual Mode: This command does not affect the virtual mode.

2.1.1 Diagnostic Abort

Description: This command is a request to abort a diagnostic procedure.

Action: LIM intercepts this command and forwards it to the LDF task.

Parameters: LIM does not interpret any of the parameters that this command may contain.

Operating Mode: LIM accepts and forwards this command in all operating modes, except TERMINAL and HOLD. The receipt of this command does not affect the operating mode directly. Instead, LIM determines whether a mode transition is necessary when it receives the Diagnostic-Complete message that the LDF task sends in response to this command.

LDF State: If the LDF task is in the **Running** state when LIM forwards this command to LDF, it changes the LDF state to **Stopping**. Otherwise, LIM does not change the LDF task state and reports a warning (the command is still forwarded to the LDF task, though).

Virtual Mode: This command does not affect the virtual mode.

2.1.2 Diagnostic Complete

Description: This message indicates that the LDF task has completed a diagnostic procedure.

Action: LIM uses this message to change the operating mode and LDF task state.

Parameters: LIM does not interpret any of the parameters that this message may contain.

Operating Mode: This message causes LIM to transition from the DIAGNOSTIC mode to the QUIESCENT mode. If LIM is not in the DIAGNOSTIC mode, though, LIM reports a warning and does not change the operating mode.

LDF State: This message causes LIM to change the LDF task state to **Idle**. LIM reports a warning if the LDF task is already in the **Idle** state.

Virtual Mode: This command does not affect the virtual mode.

2.1.3 Other LDF Commands

Description: These commands direct the operation of the LDF task during a diagnostic procedure.

Action: LIM intercepts these commands and forwards them to the LDF task if they are appropriate for the current operating mode and LDF task state. If not appropriate, LIM rejects these commands.

Parameters: LIM does not interpret any of the parameters that these commands may contain.

Operating Mode: LIM accepts and forwards these commands only in the DIAGNOSTIC operating mode. They do not cause LIM to change the operating mode.

LDF State: LIM accepts and forwards these commands only if the current LDF task state is **Running**. They do not cause LIM to change the LDF state.

Virtual Mode: These commands do not affect the virtual mode.

2.2 LPA Commands and Messages

The LAT Physics Acquisition task (LPA) handles physics observations in both pointed and repointed modes of operation. As with the LCI and LDF tasks, LIM intercepts all commands sent to LPA and forwards those that are appropriate for the current operating mode and for the current LPA task state. LIM also receives Physics-Complete messages sent by the LPA task at the completion of a physics observation.

LIM uses a number of different LPA commands, along with the Physics-Complete message, to determine operating mode transitions. This determination is complicated by two situations that LIM supports – (1) the interruption of a normal physics observation by a repointed observation (Target-of-Opportunity and Autonomous-Repoint-Request), and (2) the delay of a physics observation until the completion of a diagnostic or calibration procedure. The handling of these situations is described in chapter 1 and in the command descriptions below.

2.2.0 Physics Start

Description: This command is a request to start a physics observation run.

Action: LIM intercepts this command and uses it to determine the current virtual mode. If the command is appropriate for the current operating and virtual modes, LIM accepts it and saves a copy of it to be forwarded to the LPA task at a later time. If the command is not appropriate, however, LIM rejects this command.

Parameters: This command contains five parameters – the OBSERVATION-ID to associate with the run, the initial operating MODE for the run (TOO, ARR, or normal PHYSICS), and three CONFIGURATION-ID values. The three

CONFIGURATION-ID values specify the default configurations to use when in the TOO, ARR, and normal PHYSICS operating modes.

Operating Mode: LIM rejects this command if the operating mode is TERMINAL or HOLD. Otherwise, LIM accepts and saves a copy of this command (provided the virtual mode is IDLE).

LPA State: LIM changes the LPA state to **Running** when it forwards the saved copy of this command to the LPA task.

Virtual Mode: LIM accepts and saves a copy of this command only if the virtual mode is IDLE (provided the operating mode is not TERMINAL or HOLD). If the virtual mode is not IDLE, LIM rejects this command since that would imply two Physics-Start commands arrived without an intervening Physics-Stop command.

When LIM accepts and saves this command, it changes the virtual mode to READY. Later, if the saved command is forwarded to the LPA task, LIM changes the virtual mode to STARTED.

2.2.1 Physics Stop

Description: This command is a request to stop a physics observation run.

Action: LIM uses this command in two different ways. First, when an external source (spacecraft, ground, other task, etc.) sends this command, LIM intercepts it and uses it to determine the current virtual mode. Unlike the Physics-Start command, LIM does not save copies of incoming Physics-Stop commands. Second, LIM creates and sends this command to the LPA task when it wants to stop or suspend the current physics observation.

Parameters: This command contains no parameters.

Operating Mode: LIM rejects this command in the TERMINAL and HOLD operating modes. In all other operating modes, LIM accepts this command (provided the virtual mode is not IDLE).

LPA State: LIM sends this command to the LPA task only if the LPA task state is **Running**, at which point it changes the LPA task state to **Stopping**.

Virtual Mode: LIM changes the virtual mode to IDLE when it receives this command (provided the operating mode is not TERMINAL or HOLD). If the virtual mode is already IDLE, however, LIM rejects this command since that would imply two Physics-Stop commands arrived without an intervening Physics-Start command.

2.2.2 Physics Reconfig

Description: This command instructs the LPA task to change the operating mode and configuration of the current observation run.

Action: LIM sends this command to the LPA task when it wants to transition between ToO, ARR, and normal PHYSICS observation runs.

Parameters: This command contains two parameters – the identifier of the new operating MODE and the CONFIGURATION-ID of the new configuration. If the CONFIGURATION-ID value is the reserved ‘DEFAULT-FOR-MODE’ value, the

LPA task uses the default configuration for the new MODE (which was specified in the Physics-Start command).

Operating Mode: LIM sends this command only when the operating mode is ToO, ARR, or PHYSICS.

LPA State: This command does not affect the LPA task state.

Virtual Mode: This command does not affect the virtual mode.

2.2.3 Physics Restart

Description: This command instructs the LPA task to start an observation run using the OBSERVATION-ID and CONFIGURATION-ID values in effect when the previous Physics-Stop command was received.

Action: LIM sends this command to the LPA task when it wants to restart a physics observation that was previously interrupted.

Parameters: This command requires a single parameter that specifies the operating MODE (TOO, ARR, or normal PHYSICS) in which the previous run should be restarted.

Operating Mode: LIM sends this command only when the operating mode is ToO, ARR, or PHYSICS.

LPA State: LIM changes the LPA state to **Running** when it sends this command to the LPA task.

Virtual Mode: In the PHYSICS operating mode, LIM sends this command to the LPA task only if the virtual mode is STARTED, since the STARTED virtual mode indicates that a previously-suspended physics observation would still be in progress had it not been interrupted.

2.2.4 Physics Complete

Description: This message indicates that the LPA task has stopped a physics observation.

Action: LIM uses this message to change the LPA task state, which, in turn, may cause an operating mode change.

Parameters: This message contains a single parameter – the final STATUS of the observation run.

Operating Mode: This message may cause LIM to transition to the QUIESCENT mode from the ToO, ARR, or PHYSICS mode. LIM makes this transition if a higher-priority activity is pending (so that it can then transition from QUIESCENT to ToO or ARR) or if no activity is pending (in which case it remains in QUIESCENT). If the current operating mode is QUIESCENT, CALIBRATION, DIAGNOSTIC, or TERMINAL, LIM reports a warning since the LPA task should not be active in these modes.

LPA State: This message causes LIM to change the LPA task state to **Idle**. LIM reports a warning if the LPA task is not in the **Stopping** state when this message arrives.

Virtual Mode: This command does not affect the virtual mode.

2.2.5 Other LPA Commands

Description: These commands direct the operation of the LPA task during a physics observation.

Action: LIM intercepts these commands and forwards them to the LPA task if they are appropriate for the current operating mode and LPA task state. If not appropriate, LIM rejects these.

Parameters: LIM does not interpret any parameters that these commands may contain.

Operating Mode: LIM accepts and forwards these commands only in the PHYSICS operating mode. They do not cause LIM to change the operating mode.

LPA State: LIM accepts and forwards these commands only if the current LPA task state is **Running**. They do not cause LIM to change the LPA state.

Virtual Mode: These commands do not affect the virtual mode.

2.3 Repoint Commands and Responses

These commands inform LIM that a repointed observation should start or end.

2.3.0 ARR Start

Description: This command is a request to start an Autonomous-Repoint-Request (ARR) repointed observation.

Action: LIM intercepts this command and uses it to update the ARR State and

Parameters: This command contains four parameters – the time of the request, a transaction ID for the request, the length of time that the repointed observation will be active, and the location to which the spacecraft should be repointed (RA and DEC).

Operating Mode: LIM rejects this command in the TERMINAL, QUIESCENT, CALIBRATION, DIAGNOSTIC, and HOLD operating modes. In all other modes, LIM accepts this command and updates the ARR state.

ToO State: LIM updates the ARR state to **Ready** when it accepts this command. LIM reports a warning if the ARR state is already **Ready**.

Virtual Mode: This command does not affect the virtual mode.

2.3.1 ARR Response

Description: This message from the spacecraft indicates that an autonomous repoint request (ARR) was accepted or rejected.

Action: LIM acknowledges receipt of this message by sending alert telemetry.

Parameters: This message contains two parameters – a transaction ID that associates this response with its request, and one that indicates whether the ARR was accepted or rejected.

Operating Mode: This message does not affect the operating mode.

ARR State: This message does not affect the ARR state.

Virtual Mode: This command does not affect the virtual mode.

2.3.2 ARR Abort

Description: This command is a request to abort an autonomous repoint activity.

Action: LIM intercepts this command and uses it to update the ARR State.

Parameters: This command requires no parameters.

Operating Mode: LIM accepts this command in all operating modes. In the ARR mode, LIM sends a Physics-Reconfigure or Physics-Reconfigure command to the LPA task when it receives this command.

ARR State: LIM changes the ARR state to **Idle** when it receives this command. LIM reports a warning if the ARR state is already **Idle**.

Virtual Mode: This command does not affect the virtual mode.

2.3.3 ToO Start

Description: This command is a request to start a Target-of-Opportunity repointed observation.

Action: LIM intercepts this response and uses it to update the ToO State.

Parameters: This command contains five parameters – the OBSERVATION-ID to associate with the run, the duration of the run, and three CONFIGURATION-ID values. The three CONFIGURATION-ID values specify the default configurations to use when in the TOO, ARR, and normal PHYSICS operating modes.

Operating Mode: LIM rejects this command in the TERMINAL and HOLD operating modes. In all other modes, LIM accepts this command and updates the ToO state.

ToO State: LIM updates the ToO state to **Ready** when it accepts this command. LIM reports a warning if the ToO state is already **Ready**.

Virtual Mode: This command does not affect the virtual mode.

2.3.4 ToO Abort

Description: This command is a request to abort a Target-of-Opportunity repoint activity.

Action: LIM intercepts this command and uses it to update the ToO State.

Parameters: This command requires no parameters.

Operating Mode: LIM accepts this command in all operating modes. In the ToO mode, LIM sends a Physics-Reconfigure or Physics-Reconfigure command to the LPA task when it receives this command.

ToO State: LIM changes the ToO state to **Idle** when it receives this command. LIM reports a warning if the ToO state is already **Idle**.

Virtual Mode: This command does not affect the virtual mode.

2.4 Miscellaneous Commands

These commands are sent to the LIM task directly.

2.4.0 Bias ACD

Description: This command is a request to set bias voltages for one or more ARC components within the LAT instrument.

Action: When LIM receives this command, it sets ARC bias voltages using appropriate PIG functions.

Parameters: This command requires parameters to indicate which ARC bias voltages to set and the values to which they should be set.

Operating Mode: LIM accepts this command only in the QUIESCENT mode. This command does not change the operating mode.

SCP Support: This command can be sent within the SCP environment by the LIM_sendBiasAcdHv() and LIM_sendBiasAcdSaa() functions. These functions allow the HV or SAA bias voltage for a single ARC to be specified in the command payload (there are no SCP functions to specify multiple bias voltages within a single command). These functions require two parameters, which are the ID of the ARC for which the bias voltage should be set (0-11) and the bias voltage value to use (0-4095).

2.4.1 Bias CAL

Description: This command is a request to set bias voltages for one or more CAL components within the LAT instrument.

Action: When LIM receives this command, it sets CAL bias voltages using appropriate PIG functions.

Parameters: This command requires parameters to indicate which CAL bias voltages to set and the values to which they should be set.

Operating Mode: LIM accepts this command only in the QUIESCENT mode. This command does not change the operating mode.

SCP Support: This command can be sent within the SCP environment by the LIM_sendBiasCal() function. This function allows a single CAL bias voltage to be specified in the command payload (there is no SCP function to specify multiple CAL bias voltages within a single command). LIM_sendBiasCal() requires two parameters, which are the ID of the CAL for which the bias voltage should be set (0-15) and the bias voltage value to use (0-65535).

2.4.2 Bias TKR

Description: This command is a request to set bias voltages for one or more TKR components within the LAT instrument.

Action: When LIM receives this command, it sets TKR bias voltages using appropriate PIG functions.

Parameters: This command requires parameters to indicate which TKR bias voltages to set and the values to which they should be set.

Operating Mode: LIM accepts this command only in the QUIESCENT mode. This command does not change the operating mode.

SCP Support: This command can be sent within the SCP environment by the LIM_sendBiasTkr() function. This function allows a single TKR bias voltage to be specified in the command payload (there is no SCP function to specify multiple TKR bias voltages within a single command). LIM_sendBiasTkr() requires two parameters, which are the ID of the TKR for which the bias voltage should be set (0-15) and the bias voltage value to use (0-65535).

2.4.3 Configure GBM

Description: This command is a request to configure the handling of commands from the GBM.

Action: When LIM receives this command, it sets the value of the gbm_repoint_allow flag that indicates if the LIM task is allowed to send repoint requests to the spacecraft on behalf of the GBM.

Parameters: This command requires a single parameter which is the new value of the gbm_repoint_allow flag.

Operating Mode: LIM accepts this command in all operating modes. This command does not change the operating mode.

SCP Support: This command can be sent within the SCP environment by the LIM_sendConfigGbm() function. This function requires a single parameter, which is the new value of the gbm_repoint_allow flag (0=don't allow, 1=allow).

2.4.4 Configure HV

Description: This command is a request to configure the handling of the ACD high voltage.

Action: When LIM receives this command, it sets the value of the hv_allow flag that indicates if the LIM task is allowed to enable the ACD high voltage.

Parameters: This command requires a single parameter which is the new value of the gbm_repoint_allow flag.

Operating Mode: LIM accepts this command in all operating modes. In all but the TERMINAL operating mode, if this command indicates that LIM is allowed to enable the ACD high voltage, it does so if the spacecraft is not within the SAA. Likewise, if the command indicates that LIM is **not** allowed to enable the ACD high voltage, LIM disables the high voltage (if not in TERMINAL operating mode). This command does not change the operating mode.

SCP Support: This command can be sent within the SCP environment by the LIM_sendConfigHv() function. This function requires a single parameter, which is the new value of the hv_allow flag (0=don't allow, 1=allow).

2.4.5 Configure PID

Description: This command is a request to configure the discrete signals (PIDs) between the spacecraft and the LAT instrument.

Action: When LIM receives this command, it configures the PIDs using appropriate VxWorks functions.

Parameters: This command requires a parameter to indicate whether primary or redundant PID input signals should be selected.

Operating Mode: LIM accepts this command in all operating modes. This command does not change the operating mode.

SCP Support: This command can be sent within the SCP environment by the LIM_sendConfigPid() function. This function requires a single parameter, which is a flag to indicate if the primary PID input signals should be selected (0=redundant, 1=primary).

2.4.6 Hold Enter

Description: This command is a request to transition into the HOLD operating mode.

Action: When LIM receives this command, it immediately transitions to the HOLD operating mode.

Parameters: This command requires no parameters.

Operating Mode: LIM rejects this command in the TERMINAL and HOLD operating modes. In all other modes, LIM transitions immediately to the HOLD mode.

SCP Support: This command can be sent within the SCP environment by the LIM_sendHoldEnter() function, which requires no parameters.

2.4.7 Hold Exit

Description: This command is a request to transition out of the HOLD operating mode.

Action: When LIM receives this command, it immediately transitions from the HOLD to the QUIESCENT operating mode.

Parameters: This command requires no parameters.

Operating Mode: LIM accepts this command only in the HOLD operating mode. In all other modes, LIM rejects this command.

SCP Support: This command can be sent within the SCP environment by the LIM_sendHoldExit() function, which requires no parameters.

2.4.8 Load Shed

Description: This command is a request to remove power from the LAT instrument.

Action: When LIM receives this command, it aborts the current activity (diagnostic, calibration, or physics), sends an LTC-Stop command to the LTC task, waits five seconds, removes power from the LAT instrument using the PIG_shed() function, then resets the SIU using the pbs_reboot() function. At the conclusion

of this process, the SIU is the only component of the instrument that is powered.

Parameters: This command requires no parameters.

Operating Mode: This command causes LIM to transition from any mode to the BOOT mode.

Virtual Mode: This command causes LIM to transition from any virtual mode to the IDLE virtual mode.

SCP Support: This command can be sent within the SCP environment by the LIM_sendLoadShed() function, which requires no parameters.

2.4.9 Main Feed On

Description: This command is a request to apply power to the GASU and PDU, and to initialize the SIU.

Action: When LIM receives this command, it applies power to the GASU and PDU, and initializes the SIU, using appropriate PIG functions.

Parameters: This command requires parameters to indicate which primary and redundant components of the instrument should be powered and selected.

Operating Mode: This command causes LIM to transition from the TERMINAL mode to the QUIESCENT mode. LIM rejects this command if it is not in the TERMINAL mode.

SCP Support: This command can be sent within the SCP environment by the LIM_sendMainFeedOnPrimary() function. This function sends the command with primary main-feed, DAB, SSR path, and GBM path specified in the command payload (there is no SCP function to specify the redundant counterparts). LIM_sendMainFeedOnPrimary() requires three parameters, which are the ID of the SIU (0-2), the mask of PDUs to power (0-3), and the PPS source (0-3).

2.4.10 Power Off

Description: This command is a request to remove power from components of the LAT instrument.

Action: When LIM receives this command, it removes power from the LAT components using appropriate PIG functions.

Parameters: This command requires parameters to indicate which LAT components should be unpowered.

Operating Mode: LIM accepts this command only in the QUIESCENT mode. This command does not change the operating mode.

SCP Support: This command can be sent within the SCP environment by the LIM_sendEpuOff() function. This function allows a single EPU to be specified in the command payload (there is no SCP function to specify other LAT components). LIM_sendEpuOff() requires a single parameter, which is the ID of the EPU from which power should be removed (0-2).

2.4.11 Power On

Description: This command is a request to apply power to components of the LAT instrument.

Action: When LIM receives this command, it applies power to the LAT components using appropriate PIG functions.

Parameters: This command requires parameters to indicate which LAT components should be powered.

Operating Mode: LIM accepts this command only in the QUIESCENT mode. This command does not change the operating mode.

SCP Support: This command can be sent within the SCP environment by the LIM_sendEpuOn() and LIM_sendTemOn() functions. These functions allow a single EPU or TEM to be specified in the command payload (there are no SCP functions to specify other LAT components). LIM_sendEpuOn() requires two parameters, which are the ID of the EPU to which power should be applied (0-2) and the PDU to use (0-1). LIM_sendTemOn() also requires two parameters, which are the ID of the TEM to which power should be applied (0-15) and the PDU to use (0-1).

2.4.12 SAA Enter

Description: This command is a notification that the LAT instrument has entered the South Atlantic Anomaly (SAA).

Action: When LIM receives this command, it uses the PIG_enter_SAA() function to remove the high-voltage from the ACD (unless the operating mode is TERMINAL). LIM also updates its internal state to indicate that an SAA transit is in progress.

Parameters: This command requires no parameters.

Operating Mode: LIM accepts this command in all operating modes, but does not change the operating mode.

LPA State: If the LPA task is in the **Running** state, LIM suspends the current observation by sending the Physics-Stop command to the LPA task. LIM waits five seconds after sending this command before it calls the PIG_enter_SAA() function.

SCP Support: This command can be sent within the SCP environment by the LIM_sendSaaEnter() function, which requires no parameters.

2.4.13 SAA Exit

Description: This command is a notification that the LAT instrument has exited the South Atlantic Anomaly (SAA).

Action: When LIM receives this command, it uses the PIG_exit_SAA() function to restore the high-voltage to the ACD (unless the operating mode is TERMINAL). LIM also updates its internal state to indicate that an SAA transit is no longer in progress.

Parameters: This command requires no parameters.

Operating Mode: LIM accepts this command in all operating modes. In the PHYSICS, ToO, and ARR operating modes, LIM resumes the interrupted observation by sending the Physics-Restart command to the LPA task.

SCP Support: This command can be sent within the SCP environment by the LIM_sendSaaExit() function, which requires no parameters.

3 Telemetry

LIM responds to certain events by sending a telemetry packet to the spacecraft. This telemetry packet contains the following information:

- Action that caused the telemetry packet to be sent.
- MSG status code for the action.
- Current operating mode.
- Current virtual mode.
- Indication of whether an SAA transit is in progress.
- Current states of the LCI, LDF, and LPA tasks,
- Indications of whether a TOO or ARR activity is ready to be started.
- Indications of whether a TOO or ARR activity is active.

LIM also sends alert telemetry when it sends repoint requests to the spacecraft and when it receives responses to these repoint requests. Per the LAT-GBM ICD, LIM sends LATAUTOREPREQTLM (APID 0x344) alert telemetry whenever it requests a repoint via the SACSLEWREQUEST (APID 0x600) command. When the spacecraft responds with a LSLEWREQREPLY (APID 0x661) message, LIM sends LATARRRESPONSETLM (APID 0x345) alert telemetry. These actions are summarized in the table below.

Table 3 – Alert Telemetry Conditions

LIM sends SACSLEWREQUEST (0x600)	=>	LIM sends LATAUTOREPREQTLM (0x344)
LIM receives LSLEWREQREPLY (0x661)	=>	LIM sends LATARRRESPONSETLM (0x345)

4 LPA Interaction

This chapter describes the interaction between the LIM and LPA tasks.

4.0 Observation Runs

The LPA task performs physics observation runs that are started, reconfigured, restarted, and stopped by commands received from the ground, the spacecraft, and the LIM task. Each observation run has an identifier that the LPA task echoes in all telemetry and data packets related to the run. This OBSERVATION-ID (aka GROUND-ID) value is provided to the LPA task within the Physics-Start command that initiates an observation run.

To perform an observation run, the LPA task must configure the event filter software. The amount of information needed to specify this configuration is rather large, so it is stored in a file instead of being provided within a command. To handle different types of observations, there are multiple configuration files available to the LPA task – each identified by a unique CONFIGURATION-ID value.

4.1 Telecommands and Messages

LIM expects the LPA task to accept the following commands:

- Physics-Start: This command instructs the LPA task to begin an observation run. It contains five parameters – the OBSERVATION-ID to associate with the run, the initial operating MODE for the run (TOO, ARR, or normal PHYSICS), and three CONFIGURATION-ID values. The three CONFIGURATION-ID values specify the default configurations to use when in the TOO, ARR, and normal PHYSICS operating modes.
- Physics-Reconfigure: This command instructs the LPA task to change the operating mode and configuration of the current observation run. The command contains two parameters – the new operating MODE for the run (TOO, ARR, or normal PHYSICS), and the CONFIGURATION-ID of the new configuration. If the CONFIGURATION-ID value is the reserved 'DEFAULT-FOR-MODE' value, the LPA task uses the default configuration for the new MODE (which was specified in the Physics-Start command.)
- Physics-Stop: This command instructs the LPA task to stop the current observation run. It contains no parameters.
- Physics-Restart: This command instructs the LPA task to start an observation run using the OBSERVATION-ID and CONFIGURATION-ID values in effect when the previous Physics-Stop command was received.

The command contains a single parameter, which is the MODE for the restarted run.

All other commands accepted by the LPA task must be classified into one of two categories – those that are valid only when the LPA task is active and those that are valid only when the LPA task is IDLE.

LIM expects the LPA task to send the following commands and messages:

- ARR-Start: This command instructs the LIM task to send a Repoint-Request command to the spacecraft. The ARR-Start command contains all the parameters required for the spacecraft Repoint-Request command, plus one parameter that is used by LIM – the DURATION of the ARR observation run. LIM expects the LPA task to send this message to the BULK queue of the task that sent the Physics-Start command (which under normal circumstances is the LIM task).
- Physics-Complete: This message notifies the LIM task that the LPA task has completed an observation run. LIM expects the LPA task to send this message to the BULK queue of the task that sent the Physics-Start command (which under normal circumstances is the LIM task). The Physics-Complete message contains a single parameter – the final STATUS of the observation run.

4.2 Normal Physics Observation

A normal Sky Survey or Pointed observation run begins when the LIM task intercepts a Physics-Start command from the ground or spacecraft. When LIM intercepts this command, it saves a copy of its parameters and indicates that a normal physics observation is ready to start. The LIM task then considers the normal observation run to be READY until it intercepts a Physics-Stop command. LIM rejects all Physics-Start commands that arrive while a normal observation run is already READY.

If the LPA task is IDLE when the Physics-Start command arrives, LIM starts a new observation run by sending a Physics-Start command to the LPA task. This Physics-Start command includes all the parameter values specified in the intercepted Physics-Start command.

In certain situations, LIM defers the start of a normal observation run:

- If LIM is in the CALIBRATION operating mode, LIM allows the calibration procedure to continue and defers the start of the normal observation until it receives a Calibration-Complete message.
- If a TOO or ARR repointed observation run is in progress when the Physics-Start command arrives, LIM defers the normal observation run until the repointed observation ends. When LIM eventually starts the normal observation run, it does so by stopping the LPA task (with Physics-Stop) and starting a new observation run (with Physics-Start).
- If the instrument is within the SAA, LIM defers the start of the normal observation until it receives an SAA-Exit command.

The normal observation run ends when LIM intercepts a Physics-Stop command. If the LPA task is actively running the normal observation when this command arrives (i.e. it's not being deferred), LIM forwards the command to the LPA task. If the LPA task is not actively running the normal observation, though, LIM simply indicates that the run is no longer READY.

4.3 Target-of-Opportunity Observation

A target-of-opportunity (TOO) observation run begins when LIM receives the TOO-Start command from the ground or spacecraft. When LIM receives this command, it saves a copy of its parameters and indicates that a TOO observation is ready to start. LIM also starts a countdown timer at this point, which keeps track of the amount of time remaining until the TOO observation ends. The duration of this timer is specified in the TOO-Start command. The LIM task considers the TOO observation run to be READY until the timer expires or until a TOO-Abort command arrives. LIM rejects all TOO-Start commands that arrive while a TOO observation is already READY.

If the LPA task is IDLE when the TOO-Start command arrives, LIM starts a new observation run by sending a Physics-Start command to the LPA task. LIM is able to do this because the TOO-Start command contains all the parameters required by the Physics-Start command – OBSERVATION-ID, NORMAL-CONFIGURATION-ID, ARR-CONFIGURATION-ID, and TOO-CONFIGURATION-ID. (The MODE parameter value for the Physics-Start command is set to 'TOO' in this situation.)

If, on the other hand, an observation run is already in progress when the TOO-Start command arrives, LIM immediately reconfigures the LPA task for a TOO observation by sending a Physics-Reconfigure command to the task. The MODE parameter value for this command is set to 'TOO' and the CONFIGURATION-ID value is set to the TOO-CONFIGURATION_ID value specified in the TOO-Start command. When the LPA task is reconfigured for TOO mode in this way, the OBSERVATION-ID, NORMAL-CONFIGURATION-ID, and ARR-CONFIGURATION-ID values within the TOO-Start command are ignored.

In certain situations, LIM defers the start of a TOO observation run. If the instrument is within the SAA, LIM defers the start of the TOO observation until it receives an SAA-Exit command. If LIM is in the CALIBRATION operating mode, LIM aborts the calibration and defers the start of the TOO observation until it receives a Calibration-Complete message.

The TOO observation run ends when the LIM task receives a TOO-Abort command or the timer for the observation run expires. At this point, LIM either stops the observation run altogether by sending a Physics-Stop command to the LPA task, or reconfigures the LPA task for a deferred ARR or normal observation run (using Physics-Reconfigure).

4.4 Autonomous-Repoint-Request Observation

An Autonomous-Repoint-Request (ARR) observation run begins when the LPA task sends an ARR-Start command to the LIM task. When LIM receives this command, it uses the information within the command to create and send a Repoint-Request command to the spacecraft. LIM also starts a countdown timer at this point, which keeps track of the amount of time remaining until the ARR observation ends. The duration of this timer is specified by the LPA task in the ARR-Start command. The LIM task considers the ARR observation run to be READY until the timer expires or until an ARR-Abort command arrives. LIM rejects all ARR-Start commands that arrive while an ARR observation is already READY.

In response to the Repoint-Request command, the spacecraft sends an ARR-Response message to the LIM task. This response message can be *positive*, indicating that the request was honored, or *negative*, indicating that the request was not honored. In either case, however, LIM essentially ignores the ARR-Response message and remains in the ARR mode until an ARR-Abort command arrives or the ARR countdown timer expires. (LIM doesn't completely ignore the ARR-Response message, though, since it sends alert telemetry indicating that it received the message.)

If the LPA task is active when the ARR-Start command arrives (as it should be, since the LPA task sent the command), LIM immediately reconfigures the LPA task for an ARR observation by sending a Physics-Reconfigure command to the task. The MODE parameter value for this command is set to 'ARR' and the CONFIGURATION-ID value is set to the 'DEFAULT-FOR-MODE' reserved value.

In certain situations, LIM defers the start of an ARR observation run:

- If a TOO observation run is in progress when the ARR-Start command arrives, LIM defers the ARR observation run until the TOO observation ends. When LIM eventually starts the ARR observation run, it does so by reconfiguring the LPA task with a Physics-Reconfigure command.
- If the spacecraft is within the SAA, LIM defers the start of the ARR observation until it receives an SAA-Exit command. When LIM eventually starts the ARR observation run, it does so by sending a Physics-Restart command to the LPA task.

The ARR observation run ends when the LIM task receives an ARR-Abort command or the timer for the observation run expires. At this point, LIM either stops the observation run altogether by sending a Physics-Stop command to the LPA task, or reconfigures the LPA task for a deferred normal observation run (using Physics-Reconfigure).

4.5 GBM Commands

The LIM task receives a number of commands from the GBM instrument. These are the Calculated-Information, Candidate-Repoint-Recommendation (CRR), and Closeout commands. If an observation run is in progress when LIM receives one of these commands, the LIM task forwards the command to the LPA task, regardless of the operating mode. If no observation run is in progress, though, LIM accepts *positive* CRR commands and rejects Calculated-Information, *negative* CRR, and Closeout commands. (A *positive* CRR command is one in which a repoint is recommended.)

Upon accepting a positive CRR command that it does not forward to the LPA task, the LIM task sends a Repoint-Request command to the spacecraft. All the parameters required by the Repoint-Request command are copied from the CRR command, except the DWELL TIME parameter, which LIM sets to a value of 0 to indicate that the spacecraft should use its default dwell time value.

When the LIM task receives an ARR-Response message from the spacecraft, it handles the message in the manner described in section 4.4.

5 Use Cases

This chapter describes the behavior of LIM in response to various scenarios and sequences of commands.

5.0 Normal Activity

These scenarios describe normal calibration, diagnostic, and physics observation activities.

Normal calibration procedure

Actions	Mode	LCI State
Initial condition	Quiescent	Idle
Receive Calibration-Start command - Forward to LCI	Calibration	Running
Receive other LCI commands - Forward to LCI	“	“
Receive Calibration-Complete message from LCI	Quiescent	Idle

Normal diagnostic procedure

Actions	Mode	LDF State
Initial condition	Quiescent	Idle
Receive Diagnostic-Start command - Forward to LDF	Diagnostic	Running
Receive other LDF commands - Forward to LDF	“	“
Receive Diagnostic-Complete message from LDF	Quiescent	Idle

Normal physics observation

Actions	Mode	Virtual Mode	LPA State
Initial condition	Quiescent	Idle	Idle
Receive Physics-Start command - Save command	"	Ready	"
- Forward saved command to LPA	Physics	Started	Running
Receive other LPA commands - Forward to LPA	"	"	"
Receive Physics-Stop command - Send Physics-Stop to LPA	"	Idle	Stopping
- Wait for end of physics observation	"	"	"
Receive Phys-Complete message from LPA	Quiescent	"	Idle

Physics observation before end of calibration procedure

Actions	Mode	Virtual Mode	LCI State	LPA State
Initial condition	Quiescent	Idle	Idle	Idle
Receive Calibration-Start command - Forward to LCI	Calibration	"	Running	"
Receive Physics-Start command - Save command	"	Ready	"	"
Receive Calibration-Complete from LCI	Quiescent	"	Idle	"
- Forward saved Physics-Start to LPA	Physics	Started	"	Running
Receive Physics-Stop command - Send Physics-Stop to LPA	"	Idle	"	Stopping
- Wait for end of physics observation	"	"	"	"
Receive Phys-Complete message from LPA	Quiescent	"	Idle	Idle

5.1 Aborted Activity

These scenarios describe aborted calibration and diagnostic activities.

Aborted calibration procedure

Actions	Mode	LCI State
Initial condition	Quiescent	Idle
Receive Calibration-Start command - Forward to LCI	Calibration	Running
Receive other LCI commands - Forward to LCI	“	“
Receive Calibration-Abort command - Forward to LCI	“	Stopping
- Wait for end of calibration procedure, **rejecting any LCI commands that may arrive**	“	“
Receive Calibration-Complete message from LCI	Quiescent	Idle

Aborted diagnostic procedure

Actions	Mode	LDF State
Initial condition	Quiescent	Idle
Receive Diagnostic-Start command - Forward to LDF	Calibration	Running
Receive other LDF commands - Forward to LDF	“	“
Receive Diagnostic-Abort command - Forward to LDF	“	Stopping
- Wait for end of diagnostic procedure, **rejecting any LDF commands that may arrive**	“	“
Receive Diagnostic-Complete message from LDF	Quiescent	Idle

5.2 Target-of-Opportunity Activity

These scenarios describe Target-of-Opportunity (ToO) repointed observation activities.

Normal Target-of-Opportunity observation

Actions	Mode	LPA State
Initial condition	Quiescent	Idle
Receive ToO-Start command - Start ToO timer - Forward command to LPA	ToO	Running
ToO timer expires - Send Physics-Stop to LPA	"	Stopping
- Wait for end of physics observation	"	"
Receive Phys-Complete message from LPA	Quiescent	Idle

Target-of-Opportunity interrupts a calibration procedure

Actions	Mode	LCI State	LPA State
Initial condition	Quiescent	Idle	Idle
Receive Calibration-Start command - Forward to LCI	Calibration	Running	"
Receive ToO-Start command - Start ToO timer - Save ToO-Start command - Send Calibration-Abort to LCI	"	Stopping	"
- Wait for end of calibration procedure, **rejecting any LCI commands that may arrive**	"	"	"
Receive Calibration-Complete message from LCI	Quiescent	Idle	"
- Send Physics-Start to LPA to start the ToO repointed observation	ToO	"	Running
ToO timer expires - Send Physics-Stop to LPA	"	"	Stopping
- Wait for end of physics observation	"	"	"
Receive Phys-Complete message from LPA (Note that the interrupted calibration procedure is not restarted at the completion of the ToO)	Quiescent	"	Idle

Target-of-Opportunity interrupts a physics observation, which continues after the ToO

Actions	Mode	Virtual Mode	LPA State
Initial condition	Quiescent	Idle	Idle
Receive Physics-Start command - Save command	"	Ready	"
- Forward saved command to LPA	Physics	Started	Running
Receive ToO-Start command - Start ToO timer - Send Physics-Reconfigure to LPA	ToO	"	"
ToO timer expires - Send Physics-Reconfigure to LPA to resume the interrupted physics observation, since no Physics-Stop command was received during the ToO observation	Physics	"	"
Receive Physics-Stop command - Send Physics-Stop to LPA	"	Idle	Stopping
- Wait for end of physics observation	"	"	"
Receive Phys-Complete message from LPA	Quiescent	"	Idle

Target-of-Opportunity interrupts a physics observation, which ends during the ToO

Actions	Mode	Virtual Mode	LPA State
Initial condition	Quiescent	Idle	Idle
Receive Physics-Start command - Save command	"	Ready	"
- Forward saved command to LPA	Physics	Started	Running
Receive ToO-Start command - Start ToO timer - Send Physics-Reconfigure to LPA	ToO	"	"
Receive Physics-Stop command - Accept command, but change only the virtual mode	"	Idle	"
Receive Diagnostic-Start command - **Reject command**	"	"	"
Receive Calibration-Start command - **Reject command**	"	"	"
Receive Physics-Start command - Save command	"	Ready	"
ToO timer expires - Send Physics-Stop to LPA	"	"	Stopping
- Wait for end of physics observation	"	"	"
Receive Phys-Complete message from LPA	"	"	Idle
- Forward the saved Physics-Start command to LPA since the interrupted physics observation ended during the ToO observation	Physics	Started	Running
Receive Physics-Stop command - Send Physics-Stop to LPA	"	Idle	Stopping
- Wait for end of physics observation	"	"	"
Receive Phys-Complete message from LPA	Quiescent	"	Idle

5.3 SAA Activity

These scenarios describe SAA transits during various other activities.

SAA during normal diagnostic procedure

Actions	Mode	LDF State
Initial condition	Quiescent	Idle
Receive Diagnostic-Start command - Forward to LDF	Diagnostic	Running
Receive other LDF commands - Forward to LDF	"	"
Receive SAA-Enter command - Call PIG_enter_SAA to configure ACD high voltage	"	"
Receive SAA-Exit command - Call PIG_exit_SAA to configure ACD high voltage	"	"
Receive Diagnostic-Complete message from LDF	Quiescent	Idle

SAA during normal physics observation

Actions	Mode	Virtual Mode	LPA State
Initial condition	Quiescent	Idle	Idle
Receive Physics-Start command - Save command	"	Ready	"
- Forward saved command to LPA	Physics	Started	Running
Receive SAA_enter command - Send Physics-Stop to LPA	"	"	Stopping
- Wait 5 seconds	"	"	"
- Call PIG_enter_SAA to configure ACD	"	"	"
Receive Phys-Complete message from LPA (this may arrive before the end of the 5 second waiting period)	"	"	Idle
Receive SAA_exit command - Call PIG_exit_SAA to configure ACD - Send Physics-Restart to LPA	"	"	Running
Receive Physics-Stop command - Send Physics-Stop to LPA	"	Idle	Stopping
- Wait for end of physics observation	"	"	"
Receive Phys-Complete message from LPA	Quiescent	"	Idle

SAA during interrupted physics observation

Actions	Mode	Virtual Mode	LPA State
Initial condition	Quiescent	Idle	Idle
Receive Physics-Start command - Save command	"	Ready	"
- Forward saved command to LPA	Physics	Started	Running
Receive ToO-Start command - Start ToO timer - Send Physics-Reconfigure to LPA	ToO	"	"
Receive SAA_enter command - Send Physics-Stop to LPA	"	"	Stopping
- Wait 5 seconds	"	"	"
- Call PIG_enter_SAA to configure ACD	"	"	"
Receive Phys-Complete message from LPA (this may arrive before the end of the 5 second waiting period)	"	"	Idle
Receive SAA_exit command - Call PIG_exit_SAA to configure ACD - Send Physics-Restart to LPA	"	"	Running
ToO timer expires - Send Physics-Reconfigure to LPA to resume the interrupted physics observation, since no Physics-Stop command was received during the ToO observation	Physics	"	"
Receive Physics-Stop command - Send Physics-Stop to LPA	"	Idle	Stopping
- Wait for end of physics observation	"	"	"
Receive Phys-Complete message from LPA	Quiescent	"	Idle

5.4 Invalid Command Sequences

These scenarios describe invalid command sequences for which LIM rejects one or more commands.

Nested physics observation

Actions	Mode	Virtual Mode	LPA State
Initial condition	Quiescent	Idle	Idle
Receive Physics-Start command - Save command	"	Ready	"
- Forward saved command to LPA	Physics	Started	Running
Receive a second Physics-Start command - **Reject the command**	"	"	"
Receive Physics-Stop command - Send Physics-Stop to LPA	"	Idle	Stopping
- Wait for end of physics observation	"	"	"
Receive a second Physics-Stop command - **Reject the command**	"	"	"
Receive Phys-Complete message from LPA	Quiescent	"	Idle

Calibration procedure before end of diagnostic procedure

Actions	Mode	LDF State
Initial condition	Quiescent	Idle
Receive Diagnostic-Start command - Forward to LDF	Diagnostic	Running
Receive Calibration-Start command - **Reject the command**	"	"
Receive Diagnostic-Complete message from LDF	Quiescent	Idle

6 Control and Status

The LIM package provides functions that control the operation of the LIM task and command handlers. It also contains a function that reports the status of the LIM task. These functions act as the interface to the LIM package.

All of the LIM functions described here return a MSG status code which indicates whether the function succeeded or failed.

6.0 LIM_initialize()

The LIM_initialize() function allocates resources used by the LIM package and sets configuration values to their default state. It accepts a single parameter:

- The ID of the LIM task.

6.1 LIM_init_with_db()

The LIM_init_with_db() function is a wrapper for the LIM_initialize() function that uses the LIM_DB configuration database to determine the LIM task ID. It requires no parameters.

6.2 LIM_start()

The LIM_start() function starts the LIM task. It accepts a single parameter:

- A pointer to an attribute structure for the LIM task. If this pointer value is NULL, LIM uses the CPU_DB configuration database to determine the task attributes.

6.3 LIM_start_with_db()

The LIM_start_with_db() function is a wrapper for the LIM_start() function that uses the CPU_DB configuration database to determine the LIM task attributes. It requires no parameters.

6.4 LIM_stop()

The LIM_stop() function stops the LIM task. It requires no parameters.

6.5 LIM_shutdown()

The LIM_shutdown() function frees resources allocated by the LIM package. It requires no parameters.

6.6 LIM_getInfo()

The LIM_getInfo() function returns information about the state of the LIM package. This state includes the same type of information as is found in the LIM telemetry packet (see chapter 3). This function requires a single parameter, which is a pointer to a buffer into which the LIM information should be stored.

6.7 LIM_capture_cal()

The LIM_capture_cal() function instructs LIM to capture all commands with the specified APID and handle them as if they were calibration commands intended for the LCI task. It accepts three parameters:

- The APID of the commands to capture.
- The function code of the Calibration-Start command. If this value is '-1' LIM assumes that the Calibration-Start command uses a different APID.
- The function code of the Calibration-Abort command. If this value is '-1' LIM assumes that the Calibration-Abort command uses a different APID.

This function may be called only after the LIM_initialize() and LCI_initialise() functions have been called and before the LIM_start() and LCI_startTask() functions have been called.

This command may be called multiple times – once for each APID used by the calibration commands. If it is called more than once, the Calibration-Start function code parameter can be non-negative in only one of these function calls. Likewise for the Calibration-Abort function code parameter.

6.8 LIM_capture_cal_with_db()

The LIM_capture_cal_with_db() function is a wrapper for the LIM_capture_cal() function that uses the CPU_DB configuration database to determine the APIDs and function codes of the LCI commands. It requires no parameters

6.9 LIM_capture_diag()

The LIM_capture_diag() function instructs LIM to capture all commands with the specified APID and handle them as if they were diagnostic commands intended for the LDF task. It accepts three parameters:

- The APID of the commands to capture.
- The function code of the Diagnostic-Start command. If this value is '-1' LIM assumes that the Diagnostic-Start command uses a different APID.
- The function code of the Diagnostic-Abort command. If this value is '-1' LIM assumes that the Diagnostic-Abort command uses a different APID.

This function may be called only after the LIM_initialize() and LDF_initialize() functions have been called and before the LIM_start() and LDF_start() functions have been called.

This command may be called multiple times – once for each APID used by the diagnostic commands. If it is called more than once, the Diagnostic-Start function code parameter can be

non-negative in only one of these function calls. Likewise for the Diagnostic-Abort function code parameter.

6.10 LIM_capture_diag_with_db()

The LIM_capture_diag_with_db() function is a wrapper for the LIM_capture_diag() function that uses the CPU_DB configuration database to determine the APIDs and function codes of the LDF commands. It requires no parameters

6.11 LIM_capture_physics()

The LIM_capture_diag() function instructs LIM to capture all commands with the specified APID and handle them as if they were physics commands intended for the LPA task. It accepts four parameters:

- The APID of the commands to capture.
- The function code of the Physics-Start command. If this value is '-1' LIM assumes that the Physics-Start command uses a different APID.
- The function code of the Physics-Resume command. If this value is '-1' LIM assumes that the Physics-Resume command uses a different APID.
- The function code of the Physics-Stop command. If this value is '-1' LIM assumes that the Physics-Stop command uses a different APID.

This function may be called only after the LIM_initialize() and LPA_initialize() functions have been called and before the LIM_start() and LPA_start() functions have been called.

This command may be called multiple times – once for each APID used by the physics commands. If it is called more than once, the Physics-Start function code parameter can be non-negative in only one of these function calls. Likewise for the Physics-Resume and Physics-Stop function code parameters.

6.12 LIM_capture_physics_with_db()

The LIM_capture_physics_with_db() function is a wrapper for the LIM_capture_physics() function that uses the CPU_DB configuration database to determine the APIDs and function codes of the LPA commands. It requires no parameters.

command.