Central Software (CSW)  
Technical Data Sheet  

CI Code: 14000

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Document type | Nb WBS | Keywords |
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TN             |        | CSW      |

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SUMMARY

This document provides a brief technical description of the Gaia Central Software (CSW).
<table>
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<th>Issue/Revision</th>
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### PAGE ISSUE RECORD

Issue of this document comprises the following pages at the issue shown:

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1 INTRODUCTION

This document provides a brief technical description of the Gaia Central software (CSW).

The purpose of this document is to give basic knowledge of the Central Software architecture, and in particular of its applications:

- System and operability manager.
- Attitude & Orbit Control Software (AOCS).
- Platform manager (TT&C, power, TCS).
- Payload manager.
2 GLOSSARY

AOCS  Attitude and Orbit Control System
BAM  Basic Angle Monitoring
BC  Bus Controller (MIL-STD-1553B bus)
B IOS  Basic Input/Output Software
BM  Bus Monitor (MIL-STD-1553B bus)
BOL  Beginning Of Life
CDMU  Control & Data Management Unit
CDU  Clock Distribution Unit (CDU in PLM)
CPDU  Command Pulse Distribution Unit (CPDU)
CPS  Combined Propulsion System
CSW  Central Software
DHS Core  Data Handling System Core (used in the context of "DHS Core" product reuse)
DMS  Data Management System = all data management services for Gaia
DSA  Deployable Sunshield Assembly
EEPROM  Electrically Erasable Programmable Read-Only Memory
EIU  Electrical Interface Unit
E-SVM  Electrical Service Module
FDIR  Failure Detection, Isolation and Recovery
FOM  Flight Operations Mode (spacecraft mode)
FSS  Fine Sun Sensor
Gbit  $10^9$ bits
Gibit  $2^{30}$ bits
GOM  Ground Operations Mode (spacecraft mode)
HK  HouseKeeping (telemetry data)
ICB  Internal Control Bus (within CDMU)
IGM  Inertial Guidance Mode (AOCS mode)
INIT  Spacecraft INITitialisation mode (spacecraft mode)
LAM  Launch & initial Acquisition Mode (spacecraft mode)
LGA  Low Gain Antenna
MDE  Mirror Drive Electronics
MMU  Mass Memory Unit (within CDMU)
MPS  Micro-Propulsion System
M-SVM  Mechanical Service Module
NCO  Numerically Controlled Oscillator
NM  Normal Mode (AOCS mode)
OBT  On Board Time (in PLM CDU)
OCM  Orbit Control Mode (AOCS mode)
OSE  Optical Source Electronics
PAA  Phase Array Antenna
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDEC</td>
<td>Packet Telecommand Decoder</td>
</tr>
<tr>
<td>PDHU</td>
<td>Payload Data Handling Unit</td>
</tr>
<tr>
<td>PLM</td>
<td>Payload Module</td>
</tr>
<tr>
<td>PM</td>
<td>Processor Module</td>
</tr>
<tr>
<td>PPS</td>
<td>Pulse Per Second</td>
</tr>
<tr>
<td>PROM</td>
<td>Programmable Read-Only Memory</td>
</tr>
<tr>
<td>PSK</td>
<td>Phase Shift Keying</td>
</tr>
<tr>
<td>PUS</td>
<td>Packet Utilization Standard</td>
</tr>
<tr>
<td>Red</td>
<td>Redundant</td>
</tr>
<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
<tr>
<td>RM</td>
<td>Reconfiguration Module</td>
</tr>
<tr>
<td>RT</td>
<td>Remote Terminal (MIL-STD-1553 bus)</td>
</tr>
<tr>
<td>SAM</td>
<td>Sun Acquisition Mode (AOCS mode)</td>
</tr>
<tr>
<td>SBM</td>
<td>Stand-By Mode (AOCS mode)</td>
</tr>
<tr>
<td>SCET</td>
<td>SpaceCraft Elapsed Time (time reference within SVM CDMU)</td>
</tr>
<tr>
<td>SGM</td>
<td>SafeGuard Memory</td>
</tr>
<tr>
<td>SHP</td>
<td>Standard High Power Command</td>
</tr>
<tr>
<td>SKEL</td>
<td>Spacecraft Key Event Log</td>
</tr>
<tr>
<td>SOM</td>
<td>Science Operations Mode (spacecraft mode)</td>
</tr>
<tr>
<td>SpW</td>
<td>SpaceWire link (ECSS-E-50-12A)</td>
</tr>
<tr>
<td>SRAM</td>
<td>Static RAM</td>
</tr>
<tr>
<td>SREM</td>
<td>Standard Radiation Environment Monitor</td>
</tr>
<tr>
<td>SSC</td>
<td>Separation Sequence Counter</td>
</tr>
<tr>
<td>SSM</td>
<td>Spacecraft Safe Mode (spacecraft mode)</td>
</tr>
<tr>
<td>STR</td>
<td>Star Tracker</td>
</tr>
<tr>
<td>SUSW</td>
<td>(CDMU) Start-Up Software</td>
</tr>
<tr>
<td>TC</td>
<td>Telecommand</td>
</tr>
<tr>
<td>TFG</td>
<td>Transfer Frame Generator</td>
</tr>
<tr>
<td>TM</td>
<td>Telemetry</td>
</tr>
<tr>
<td>TSM</td>
<td>Transition Mode</td>
</tr>
<tr>
<td>TTC</td>
<td>Telemetry, Tracking and Command</td>
</tr>
<tr>
<td>TTR</td>
<td>Telecommand, Telecommand &amp; Reconfiguration</td>
</tr>
<tr>
<td>UART</td>
<td>Universal Asynchronous Receiver Transmitter</td>
</tr>
<tr>
<td>VC</td>
<td>Virtual Channel</td>
</tr>
<tr>
<td>VPU</td>
<td>Video Processing Unit</td>
</tr>
</tbody>
</table>
3 SYSTEM CONTEXT

Figure 1: Showing Central Software within Gaia Electrical Architecture
### 3.1 GAIA ON-BOARD SW ARCHITECTURE PRINCIPLES

The Gaia on-board software architecture relies on the following design principles:

- **Implement a central computer (CDMU) and software (CSW)** covering the overall spacecraft, Service Module (SVM), and Payload Module (PLM) command/control (C&C).
- **Reuse SW and lessons learnt from experienced missions**: this takes into account as major feature the capacity of reusing existing software and standards (e.g., Real-Time Operating System, Core Data Handling System with set of PUS Services), as well as taking benefits of positive feedback (autonomy functions, operability) from relevant missions (e.g., Rosetta / Mars Express / Aeolus / Herschel-Planck).

### 3.2 TARGET MACHINE

Refer to Figure 2: Gaia CDMU & EIU Block Diagram hereafter.

| CPU          | RISC processor items of the ESA’s SPARC family:  
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ERC32 TSC695F implementing the SPARC V7, 20 MHz</td>
</tr>
<tr>
<td>MEM</td>
<td>6 Mbyte SRAM for CSW execution on each CDMU Processor Module (PM).</td>
</tr>
<tr>
<td>Time</td>
<td>Time: free-running (when CDU is not in the loop) + capacity of being synchronised by an external pulse received from PLM CDU. Smooth synchronisation algorithm within CSW. The time reference of the CDMU/CSW is the Spacecraft Elapsed Time (SCET) derived from the master oscillator of the CDMU.</td>
</tr>
<tr>
<td>MMU</td>
<td>2 x 8 Gbit BOL Mass Memory Unit (MMU) with BER ≤ 10^{-14} within CDMU. Provides hardware-implemented mechanism for down-linking packet stores through VC2.</td>
</tr>
<tr>
<td>TC</td>
<td>TC @ 4 kbps, LVDS/NRZ-L signals</td>
</tr>
<tr>
<td>TM</td>
<td>TM @ 10 Mbps, LVDS/NRZ-L signals</td>
</tr>
</tbody>
</table>
| VC           | 5 TM Virtual Channels: VC0, VC1 (science), VC2, VC3 (science) and VC4.  
|              | - 3 x 2 internal VC (VC0, VC2, VC4) @ 256 kbps; two real-time (VC0, VC4); one playback from CDMU MMU (VC2).  
|              | - 2 x 2 external* VC (VC1, VC3) @ 10 Mbps; one Real-Time + one Play-Back; * PacketWire links. |
| Bus          | 2 x dual-redundant MIL-STD-1553 buses:  
|              | - 1 dual-redundant MIL-STD-1553B bus for SVM  
|              | - 1 dual-redundant MIL-STD-1553B bus for PLM |
| SpW          | 2 x 2 SpaceWire links @ 10 Mbps  
|              | - In flight: all links are connected from CDMU to EIU.  
|              | - On ground: possibility to connect one of these SpW links to the SIF (CSW diagnostic tool). |
| Test         | 2 x 1 RS422/UART serial links (used on ground only). |
4 CENTRAL SOFTWARE (CSW) DESCRIPTION

4.1 OVERVIEW OF CSW LAYERED ARCHITECTURE

The Central Software (CSW) is broken down into five (5) main components in a bottom-up approach as shown on

- RTEMS: the real-time operating system.
- BIOS: a library of low-level services, without any task, for access to the hardware interfaces of the CDMU. It is provided by the CDMU supplier in order to simplify the HW/SW integration on the CDMU.
- I/O System: this element implements all the Input/Output operations that are necessary at application level. It is dedicated to the operations that take place in the CDMU and on the buses and links that are connected to it. The detailed operations of equipment that is connected to these buses and links are implemented by the relevant application.
- DMS: implements the Packet Utilisation Services (PUS) and supports the applications.
**Product**

<table>
<thead>
<tr>
<th>Gaia Central Software (CSW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applications: these components implement the functional processing associated to the management of the spacecraft: Attitude and Orbit Control Software (AOCS), platform control, payload management and system management. They rely on the DMS for the PUS services and on the I/O System for Input/Output operations. The coupling between the different applications is kept as low as possible to ease parallel development.</td>
</tr>
</tbody>
</table>

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**Figure 3: Central Software (CSW) Architecture**

### 4.2 CENTRAL SOFTWARE COMPONENTS NOT SUBMITTED TO ITT

**OS**

- **Real-Time Operating System: RTEMS** V4.6.1 version or later qualified version. The Real Time Executive for Multiprocessor Systems (RTEMS) is an Open Source COTS real-time operating system. It has been released into the public domain and ported on ERC32 with ESA support in 1995.
- The adaptation of the RTEMS software on ERC32 processor is available, but whenever the computer HW would require adaptation, corresponding information will be provided as part of the Basic SW from the computer H/W supplier.

**BIOS**

- The BIOS (inherited from CDMU Basic Software) is a low-level software that allows encapsulating the access to the core computer hardware functions for the applications.
- The BIOS does not have any active process in order to give entire control of the dynamic aspects to the applications. The same principle is applied for FDIR where the BIOS only performs detection of failures but does not perform any isolation or recovery action which are taken at application level.

**DMS**

- The DMS software based on the DHS Core is an ANSI-C library of data handling services for the support of PUS applications, independent from the specific HW aspects. It is organized as a catalogue of SW components starting from the documentation up to the
• The DHS Core has been designed for reuse and to provide a solution for implementing the PUS concepts, which can be quite memory and CPU consuming. It has been based on experience and lessons learned from PUS projects like Rosetta, Mars Express, Venus Express and was developed for TerraSAR-X and Pléiades on top of RTEMs in 2003 and according to the latest ECSS-E70-41A PUS version (PUS 2003).

• The DMS provides some architectural services, e.g. for communications between applications based on TC, TM and event software buses, and the PUS services as listed in the table below. In addition, the CDHS allows implementing and connecting, on top of its general packet handling services, all the other PUS services that are linked to the HW or private services specific to an application.

<table>
<thead>
<tr>
<th>PUS service</th>
<th>Comments</th>
<th>Reuse</th>
<th>CSW</th>
</tr>
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<tr>
<td>#1 – TC verification</td>
<td>TC acknowledgement: acceptance &amp; execution</td>
<td>Full</td>
<td>X</td>
</tr>
<tr>
<td>#2 – Device command distribution</td>
<td>Direct access to on-board devices</td>
<td>New</td>
<td>X</td>
</tr>
<tr>
<td>#3 – Housekeeping and diagnostic data reporting</td>
<td>Periodic HK &amp; diagnostic TM</td>
<td>Full</td>
<td>X</td>
</tr>
<tr>
<td>#5 – Event reporting</td>
<td>Events, Spacecraft Key Event Log (SKEL)</td>
<td>Adapted</td>
<td>X</td>
</tr>
<tr>
<td>#6 – Memory management</td>
<td>Memory load, dump, check</td>
<td>New</td>
<td>X</td>
</tr>
<tr>
<td>#8 – Function management</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>#9 – Time management</td>
<td>Spacecraft Elapsed Time (SCET) update, Time Report</td>
<td>New</td>
<td>X</td>
</tr>
<tr>
<td>#11 – On-board operations scheduling</td>
<td>Mission Time-Line</td>
<td>Adapted</td>
<td>X</td>
</tr>
<tr>
<td>#12 – On-board Monitoring</td>
<td></td>
<td>Full</td>
<td>X</td>
</tr>
<tr>
<td>#13 – Large Data Transfer</td>
<td>Ground to space uplink</td>
<td>New</td>
<td>X</td>
</tr>
<tr>
<td>#14 – Packet forwarding control</td>
<td>X-band TM transmission control</td>
<td>Full</td>
<td>X</td>
</tr>
<tr>
<td>#15 – On-board TM storage &amp; retrieval</td>
<td>Control of spacecraft TM storage and playback into/from CDMU MMU</td>
<td>Adapt</td>
<td>X</td>
</tr>
<tr>
<td>#17 – Test</td>
<td>Ping</td>
<td>Full</td>
<td>X</td>
</tr>
<tr>
<td>#18 – On-board operations procedure</td>
<td>On Board Control Procedures</td>
<td>Full</td>
<td>X</td>
</tr>
<tr>
<td>#19 – Event-Action</td>
<td>SW FDIR: reactions to events</td>
<td>Full</td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 4: PUS Implementation in Gaia DMS Software
The Gaia DMS is designed for minimizing the coupling between applications. That is the reason why the data and their related processing have been separated: the DMS library provides the code/algorithms for the PUS services and this processing is made and configured by tables provided by each application process independently through a register mechanism. In addition to this dynamic initialisation, the DMS is also configured at compilation time by several parameters like:

- The PUS mission parameters defined in annex B of the ECSS document such as the TC/TM packets checksum type, the maximum number of monitoring, the minimum diagnostic interval.
- The sizing parameters for the TC/TM data flows such as the size of the routing queues, or the sizes and numbers of packets of each type that can be processed by the ASW.

### 4.3 CENTRAL SW COMPONENTS SUBMITTED TO ITT

#### 4.3.1 General Description of CSW Applications

The Figure 5: Central Software Component Architecture shows a more detailed architectural breakdown of the Central Software (CSW).

The applications that are submitted to the CSW Components ITT are:

1. system & operability manager
2. AOCS
3. platform control
4. payload manager
Gaia Central Software (CSW)

CSW Components submitted to ITT

RTEMS Operating System

Figure 5: Central Software Component Architecture

CSW Application
System Manager & Operability

Contents
Spacecraft mode manager (see Modes Diagram below)
Spacecraft initialization
Launcher separation sequence
Deployable Sunshield Assembly deployment sequence
Spacecraft safe mode
Flight operations mode (cruise and trajectory control, commissioning)
Science operations mode (coupled operations with Payload Module, science at L2)
Context manager (Safeguard Memory)
Time and synchronization manager
Spacecraft Key Event Log
Death Report
System FDIR: hierarchical, 5 levels of FDIR up to Last Chance configuration
TM manager and TC manager
File manager (CDMU MMU)
## Product

### Gaia Central Software (CSW)

<table>
<thead>
<tr>
<th>CSW Application</th>
<th>Contents</th>
</tr>
</thead>
</table>
| **AOCS**        | AOCS mode manager (see Modes Diagram below)  
|                 | Stand-By Mode  
|                 | Sun Acquisition Mode  
|                 | Inertial Guidance Mode  
|                 | Orbit Control Mode  
|                 | Transition Mode  
|                 | Normal Mode  
|                 | Guidance laws; Earth ephemeris (for PAA)  
|                 | Gyro-stellar estimator  
|                 | Astro-stellar estimator  
|                 | Controllers  
|                 | AOCS-Payload Module (PLM) interface control  
|                 | AOCS-Phased Array Assembly (PAA) interface control  
|                 | AOCS Monitoring/FDIR  
|                 | For each AOCS/CPS/MPS unit:  
|                 | - AOCS Equipment Function (FCT)  
|                 | - AOCS Equipment Software Resource (SWR)  
|                 | - AOCS Hardware Abstraction Libraries (HAL) |

<table>
<thead>
<tr>
<th>CSW Application</th>
<th>Contents</th>
</tr>
</thead>
</table>
| **Platform Manager** | Thermal control & monitoring software application (TCS)  
|                 | Power management software application & pyrotechnics/NEA device management  
|                 | TT&C subsystem management application  
|                 | For each TT&C and power unit:  
|                 | - Equipment Function (FCT)  
|                 | - Equipment Software Resource (SWR)  
|                 | - Hardware Abstraction Libraries (HAL) |

<table>
<thead>
<tr>
<th>CSW Application</th>
<th>Contents</th>
</tr>
</thead>
</table>
| **Payload Manager** | Interface management with PLM:  
|                 | - Management of PLM units: Payload Data Handling Unit (PDHU), Video Processing Unit (VPU), Mirror Drive Electronics (MDE), Optical Source Electronics (OSE), Clock Distribution Unit (CDU)  
|                 | - Mirror, laser source controls  
|                 | - ESA Space Radiation Environment Monitor (SREM) data acquisition |

### 4.3.2 Application Breakdown Template

Each application is typically structured in the same way with five layers:

- **The mode manager layer**: contains the mode manager objects, in charge of modes and sub-modes transitions management, processing scheduling and FDIR management. For complex applications, such as System and AOCS, there is one mode manager object for each mode (in charge of managing the sub-modes of that mode) and a top-level mode manager (in charge of managing the application mode).

- **The processing layer** gathers all control laws processing used for the application completion. The “Set of processing” object is in charge of these processing scheduling and monitoring the functional behaviour.
### product | Gaia Central Software (CSW)

![Diagram](image)

**Figure 6: Application Breakdown Template through AOCS Sample**

- **The equipment function** (FCT) layer is in charge, for each kind of unit, of defining interfaces to be used by the “set of processing”, the mode manager objects. These are functional interfaces hiding the details of the Gaia SVM and PLM equipment units management from the “set of processing” objects. The FCT layer is also in charge of the selection of the equipment units that are effectively used. It also provides interfaces for ground or mode manager layer, to configure the equipment (switch them on/off) or reconfigure in case of failure detection. For that, the FCT implements a part of FDIR that is the recovery actions to be performed for a kind of equipment.

- **The equipment software resource** (SWR) layer is in charge of the commanding and monitoring of individual equipment units. It is also in charge of converting raw data into physical data according to the equipment unit characteristics. These physical data are made available to equipment FCT objects through dedicated interfaces.

- **The equipment Hardware Abstraction** layer is in charge of HW interface with the equipment through the HW interface layer of the DMS. It enables/disables the acquisitions / commands and determines the validity of acquired data. It defines the equipment
configuration procedures (on/off switching). Raw data is made available to the equipment SW resource objects through dedicated interfaces.

The good health of the equipment is performed at unit SWR level and the monitoring of functional behaviour is performed at equipment ORB level and set of processing level. But the decision of the recovery action to be performed is centralised on mode management level in order to manage the priority between the different requests and priority between requests of the same type in cases of simultaneous failures.

### 4.3.3 Application Dynamic Template

A dynamic template is defined for each application of the Central Software (CSW). It is defined by the following rules and illustrated in the Figure 7: Application Dynamic Template below:

- One cyclic task performs TC reading, dispatching and execution, control processing, cyclic TM generation inside the application.
- One or several asynchronous tasks that perform long activities “subcontracted” by the cyclic task, either in terms of CPU usage or in terms of overall duration for blocking activities such as unit configuration sequences (sequences of commands separated by delays).
- The asynchronous tasks are only activated by the cyclic task. When necessary, the asynchronous tasks are monitored by the cyclic task. When the cyclic task detects that an asynchronous task has not succeeded to complete its processing, it triggers an FDIR event.

![Figure 7: Application Dynamic Template](image-url)
4.3.4 Focus on “System” Software Component

The Gaia Central Software (CSW) “System” component provides a spacecraft mode manager that implements and controls the modes shown on Figure 8: Spacecraft Modes & Transitions Diagram below:

- Spacecraft Initialisation Mode (INIT)
- Ground Operations Mode (GOM)
- Launch & initial Acquisition Mode (LAM)
- Spacecraft Safe Mode (SSM)
- Flight Operations Mode (FOM)
- Science Operations Mode (SOM)

Figure 8: Spacecraft Modes & Transitions Diagram
The Failure Detection, Isolation and Recovery (FDIR) function is not considered as a unique separate object. Specified, SW-implemented, FDIR mechanisms are periodically executed (e.g., AOCS, power, TT&C, PLM surveillances) or asynchronously triggered (e.g., via Event or Parameter monitoring) within each post-launch modes and can lead either (i) to continue in the same mode or (ii) to enter the Safe Mode (FDIR levels 2 to 4, and Last Chance level). In other words, the FDIR takes the form of mechanisms distributed to every operational modes and centralised backup mode (Safe Mode).

These mechanisms can be enabled or disabled depending upon the mode in which the spacecraft operates. When enabled, their triggering upon fault occurrence can lead either to FDIR Level 1 reconfiguration (same spacecraft mode continues to execute) or the FDIR Level 2 to 5 triggering (Safe Mode).

**Figure 9: System FDIR Levels**

The CSW “System” component also provides autonomous operational functions for:

- The sequence following the separation from the launcher: from Launch Pad until Earth Acquisition with automatic restart in case of failure leading to computer reset of processor switchover.
- The sequence performing the Combined Propulsion System (CPS) priming: firing pyro valves for initial pressurisation of the propulsion with automatic restart in case of failure leading to computer reset of processor switchover.
- The sequence performing the deployment of the Deployable Sunshield Assembly (DSA) deployment and the heating of the deployment mechanism.
- The TC reception time-out monitoring and the TC link recovery, including reconfiguration of transponder and RF switches.
- The TM maintenance, including reconfiguration of transponder and RF switches.
The “AOCS” component implements the following modes:

- **Stand-By Mode**

- **Sun Acquisition Mode**

- **Inertial Guidance Mode**

- **Orbit Control Mode**

- **TranSition Mode**

- **Normal Mode**
  - Zoom
  - Gate ASTRO Phase
  - Normal ASTRO

- CPS controlled
- MPS controlled
4.3.6 Focus on “Platform” Software Component

The “platform manager” component provides the following functions:

- **Thermal Control Software:**
  - Table-driven temperature control.
  - Table-driven temperature monitoring.

- **TT&C equipment manager – Transponder, Phased Array Antenna, RF switches:**
  - Initialisation.
  - On-line supervision.
  - Reconfiguration procedures.

- **Power equipment manager – PCDU:**
  - PCDU TM reset
  - Selection of “PCDU controller in use”
  - Low battery voltage surveillance

4.3.7 Focus on “Payload” Software Component

The “payload manager” component of the CSW interfaces with other components as shown on Figure 11: PLM Manager Interfaces below.
Figure 11: PLM Manager Interfaces

The “payload manager” implements and controls the PLM modes and transitions as shown on Figure 12: PLM Manager Modes & Transitions Diagram

Figure 12: PLM Manager Modes & Transitions Diagram

The “payload manager” provides equipment management for the PLM and some open loop controls:

- PLM units supervision and reconfiguration procedures.
- Mirror drive control (open loop).
- Laser source control (open loop).

Finally, the “payload manager” component SREM:
- Data acquisition.
- CCSDS packetisation.
- Storage into CDMU MMU.