SIROM

D2.17: OG5-D2_User Manual

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1. INTRODUCTION AND SCOPE

The objective of the user manual (UM) is to provide information on design, operations and data of the product that is required by the user to handle, install, operate, maintain and dispose the product during its life time.

The UM shall address the whole product life cycle and all its modes: 1. Handling 2. Storage 3. Installation 4. Operations (nominal and contingency) 5. Maintenance 6. Disposal.

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2. REFERENCES

2.1 Applicable Documents

AD	Title	Reference
[AD01]	ANNEX 1 (part A) - Research and Innovation action	NUMBER — 730035 — SIROM
[AD02]	SRC_Guidelines_Space_Robotics_Technologies (COMPET-4-2016)_SYSTEM	--
[AD03]	PRSPR-ESA-T3.1-TN-D3.1-Compendium of SRC activities (for call 1)-v1.8_0	--

Table 2-1 Applicable Documents

2.2 Reference Documents

RD	Title	Reference
[RD01]	KO MoM	SIROM-MM-001
[RD02]	PM1 MoM	SIROM-MM-002
[RD03]	OG5-D0_Reviews Data Packages WP1	D1.1
[RD04]	OG5-D1_System Requirement Specification WP1	D1.2
[RD05]	OG5-D2_Design Justification File WP1	D1.3
[RD06]	OG5-D1_Multidisciplinary Simulation outcomes	D1.4
[RD07]	OG5-D0_Progress Report_M3	D7.3
[RD08]	PM2 MoM	SIROM_MM_03_PM2_MoM_rev1
[RD09]	OG5-D6_Consortium Website	D6.3
[RD10]	OG5-D2_Interface Control Document	D2.14
[RD11]	OG5-D0_Progress Report_M6	D7.4
[RD12]	OG5-D2_Design Definition File WP2	D2.9
[RD13]	OG5-D2_Design Justification File WP2	D2.10

Table 2-2 Reference Documents

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3. ACRONYMS LIST

Acronyms	Meaning
AIT	Assembly Integration and Test
APM	Active Payload Module
CAN	Controller Area Network
DDF	Design Definition File
EE	End Effector
EGSE	Electrical Ground Support Equipment
IF	Interface
KO	Kick-Off
MoM	Minutes of Meeting
NCR	Non Conformance Report
OBC	On Board Computer
OG	Operational Grant
PM	Progress Meeting
RfD	Request for Deviation
RfW	Request for Waiver
SIROM	Standard Interface for Robotic Manipulation
SpW	SpaceWIre
SRR	System Requirements Review
TBC	To Be Confirmed
TBD	To Be Defined
TC	Telecommand
TM	Telemetry

Table 3-1 Acronyms list

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4. SIROM DESIGN DESCRIPTION

4.1 General configuration

SIROM is a device provided by four IFs with capabilities to transfer loads, data, power and heat. The generic design is divided in blocks that envelope each IF achieving a compact design. Data, Power and Thermal IFs are located in a plate called Connectors Plate, while Mechanical IF is on its own. SIROM must match another SIROM in one flange (SIROM standard IF is androgynous and coupling is done between two functional units), whereas an APM will be fixed in the other. The idea is being capable of constructing a modular and scalable structure that will connect the APM to any spacecraft platform mechanically and provide data, power and thermal coupling.

Furthermore, the connection between SIROM and the robotic arm is made by an End Effector, which must ensure the functionality of SIROM IFs.

4.2 Physical description

The shape of SIROM is a cylinder of 120 mm diameter and 30 mm high. Those are the dimensions of the housing where IFs must be placed. For further information see [RD12]

4.3 Functional description

The functional description is divided in two main aspects:

- Mating stages
- Connection sequence and TM/TC timing

4.3.1 Mating stages

OG5 operations consist of two different aspects:

- Mating one SIROM against another to provide Mechanical, Power, Data and Thermal coupling between the robotic arm and the APM (or between two APMs).
- Once connection is made, receiving and complying commands from the OBC (or from another APM) and transmitting data from the APM to the OBC (or to another APM).

For the first aspect (mating), a two-staged connection is followed:

- First stage (latching):

  It includes guiding from the robotic arm misalignments to controlled and reduced misalignments using a capture mechanism to reduce the separation distance between SIROMs. Capture range is defined to allow capture before the contact of the guiding petals occurs to be able to use the position mode of the robotic arm. This stage starts when the Ready-to-capture status is detected by the robotic arm and ends when the Latched status is detected by the SIROM.

- Second stage (connecting Control, Data, PWR and thermal IFs):

  It is done by a second mechanism that provides the functional connection from a position driven by the design of the previous stage. This stage starts when the Latched

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status is detected by the SIROM and ends when the Connected status is detected by the SIROM.

4.3.2 Mating Connection sequence and related TM/TC timing

In this paragraph, mating sequence between SIROM A and SIROM B will be described. Every command is delivered via CAN Bus. First mechanical connection is defined, and then the Connectors Plate connection.

NOTE 1: Here below, it is assumed that SIROM B is isolated and has no power source to retract its latches or lift its Connector Plate. So, SIROM-SIROM coupling is designed to be redundant even in that case. When SIROM B has power and data sources, SIROM B latches will retract at the same time than SIROM A latches, and the Connectors Plate as well.

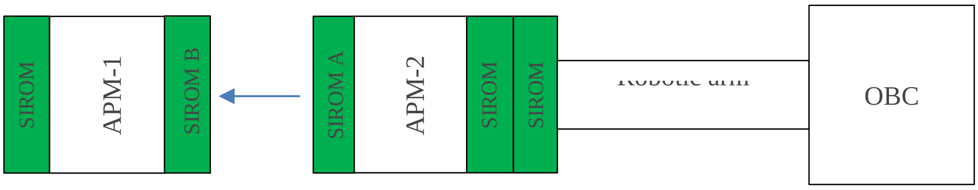

Figure 4-1. Example showing Connection between SIROM A and B.

- The OBC commands to connect SIROM A to SIROM B.
- The robotic arm places SIROM A in front of SIROM B (“ready to capture” position). This is done in position mode with the robotic arm accuracy.
- SIROM A Controller receives feedback from OBC that “ready to capture” position is reached.
- SIROM A Controller commands latches’ actuators to start moving and the latching process starts.
- “Captured” state is achieved by SIROM A sensors. SIROM A latches still have not made contact with SIROM B pockets.
- SIROM A Controller sends that information to OBC.
- OBC commands the robotic arm to be controlled in impedance mode.
- SIROM A Controller receives validation from OBC.
- SIROM A Controller commands latches to continue retracting. When a force or a torque superior to 2,5 N (TBC) or 0.15 Nm (TBC) is sensed by the robotic arm sensors, it starts moving (or rotating) toward SIROM B until the force and torque values are under the mentioned ones (2.5 N or 0.15 Nm). Meanwhile, latches continue retracting.
- While approximating SIROM A and SIROM B, the guiding petals correct possible misalignments by contacting the guide counterpart of the opposite SIROM.
- Both SIROM faces make contact and, after latches preloading, “latched” position is achieved.
- SIROM A Controller sends that information to OBC (for housekeeping).

At this point, SIROM A and SIROM B are mechanically connected, and the IF is compliant to loads arising to 200 N and 40 Nm. Now, connection of the other 3 IFs (Power, Data and Thermal) starts.

- SIROM A Controller sends command to SIROM Connector Plate’s motors to start moving
- The rotation of the 3 spindles produces the following movements:
    - SIROM A Connectors Plate approaches to SIROM B

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  - SIROM A dust cover is opened
  - SIROM B Connectors Plate approaches SIROM A
  - SIROM B dust cover is opened
- Connectors get connected and sensors provide to each SIROM Controller "connected" status.
- SIROM A Controller sends feedback to OBC.

At this point, SIROM A and SIROM B mechanical, power, data and thermal coupling is realized. However, still SIROM B latches have to move and latch onto SIROM A pockets.

- The OBC commands SIROM B Controller to retract SIROM B latches.
- "Captured" state is achieved by SIROM B sensors. SIROM B latches still have not made contact with SIROM A pockets.
- SIROM B Controller sends that information to OBC to ensure that the robotic arm is still in impedance mode.
- SIROM B Controller receives validation from OBC.
- SIROM B Controller commands latches to continue retracting.
- Latches continue retracting until they make contact on SIROM A pockets. After latches preload, SIROM B sensors detect "latched" position.
- SIROM B Controller sends feedback to OBC, and the connection process is finished.

The demating process is similar to the mating process described above with minor differences as, for example, the existence of SIROM A "disconnected" status communication to OBC (just for housekeeping) right before SIROM A Controller commands the capture mechanisms to unlatch.

4.4 Interfaces description

In the following paragraphs each IF will be described.

4.4.1 Mechanical IF

The Mechanical IF is responsible of providing SIROM berthing capability against another SIROM and proving compliant to loads arising during operations once attachment is made.

It is formed by hooks, sensors and actuators and a guiding system to correct misalignments. The robotic arm places the SIROM A close to SIROM B (the positioning error being the misalignment to be corrected by the guiding system) and SIROM A latches SIROM B continuing the sequence described above at a command performed by the OBC.

4.4.2 Power IF

Electrical IF (i.e. Power IF) is responsible of providing power to SIROM Controller and APM Controller and it is placed in the Connectors Plate. A power source shall be mounted in the Platform (satellite or rover) or APM, and cables will reach SIROM IF. As the APM may need up to 150 W, SIROM Electrical IF connectors must be compliant with those values. In addition, the Electrical IF will be protected against short circuits. The connectors selected are Dsubminiature ESA/ESCC 3401/002 DEMA with 9 contacts, Shell size E (Standard density).

The Connectors Plate is populated with one male and one female connector achieving an androgynous Electrical IF and redundancy at the same time.

4.4.3 Data IF

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Data IF is responsible of providing communication between SIROMs and OBC. This is understood in two communication types. One the one hand it holds commands for monitoring and controlling the SIROM and the APM, and on the other hand it ensures transmission of the data obtained (e.g. images taken) by the APM. It is located on the Connectors Plate and, as for the Electrical IF, a pair of connectors is provided for each communication type achieving androgyny and redundancy. The connectors selected are Micro-miniature D-type ESA/ESCC 3401/029 MDM with 9 contacts.

The Connectors Plate is populated with:

- For CAN bus: one male and one female connector achieving an androgynous Electrical IF and redundancy at the same time
- For SpW: one male and one female connector achieving an androgynous Electrical IF and redundancy at the same time

4.4.4 Thermal IF

Thermal IF is responsible of transferring heat flux from APM to APM and vice versa. The system consists on a fluid loop between SIROM A and SIROM B (connectors placed in the Connectors Plate) and 2 heating/cooling elements (one in each APM).

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5. ORBITAL APM

Two Orbital APMs are designed and built to support the test and demonstration of the functionalities and performance of the SIROM IF.

The two Orbital APMs developed for testing the SIROM IF in OG6 facilities in OG6 will be different:

- APM-1 will have two SIROMs and a Payload (camera)
- APM-2 will have one SIROM and one SIROM dummy (only mechanical IF without Data, Power or Thermal IFs) and no payload.

5.1 APM-1

The Orbital APM-1 Payload is a camera, which will take pictures of the OG6 environment. Commanded by the OBC-1 (OG6) it will ensure SIROM functionality. This camera's operation will demonstrate:

- SIROM capability to transfer Power loads (SIROM Power IF is in charge of switching on the camera)
- SIROM capability to transfer Data loads:
    - The camera will receive commands through data connectors
    - The camera will send to the OBC the pictures taken.

In the [RD13] further information is included.

5.2 APM-2

As agreed during SRR splinter meetings with OG6 and PSA, the Orbital APM-2 will have no payload. It will be just a dummy but with a full SIROM IF that will be permanently connected to the EGSE in order to allow for APM-1 data retrieval with the EGSE (even when the robotic arm is not connected to the APM-1 through the EE).

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6. PLANETARY APM

6.1 Design Description

6.1.1 General configuration

6.1.1.1 Primary APM

The concept of the Primary Automated Payload Module [P-APM] is to have a payload autonomous in term of power and control.

The main mission of the P-APM is charging batteries (Auxiliary APM) by harnessing solar power. P-APM is also equipped with optical sensor. The data from the optical sensor can be streamed to the EGSE or stored onboard for later retrieval.

P-APM can also dissipate heat into environment, providing limited cooling capability to itself and the Auxiliary APMs connected on it.

6.1.1.2 Auxiliary APM

The Aux-APM is basically a battery pack, which is capable of supplying to SIROM devices power (i.e. power discharge) or to be able to charge itself from SIROM equally autonomously. The mode of operation is controllable by the platform master (Rover, ground station or a primary APM) through SIROM command control port.

The Aux-APM will have two SIROM ports which the mechanical interfaces on each of them are controlled via a dedicated SIROM I/F controller.

The thermal operating conditions are controllable via SIROM thermal controller (TBC).

The Aux-APM should be able to seamlessly switch between IDLE, CHARGE, DISCHARGE modes of operation via a command from the SIROM master. Also, Aux-APM should be able to measure, compute and construct necessary telemetries (such as state of charge, number of charge/discharge cycles, total energy stored, total energy discharged, state-of-health, etc.) (TBD).

6.1.2 Physical description

6.1.2.1 Primary APM

Mechanically speaking there are two main functions of the P-APM:

- To deploy the solar panel, and
- To position solar panel to optimal position for harvesting sun energy (i.e. to track the sun).

To perform these function Primary APM consists of four main subassemblies:

- Main platform
- Central structure
- Hardware casing
- Rotative platform (including mast, solar panels and optical sensor)

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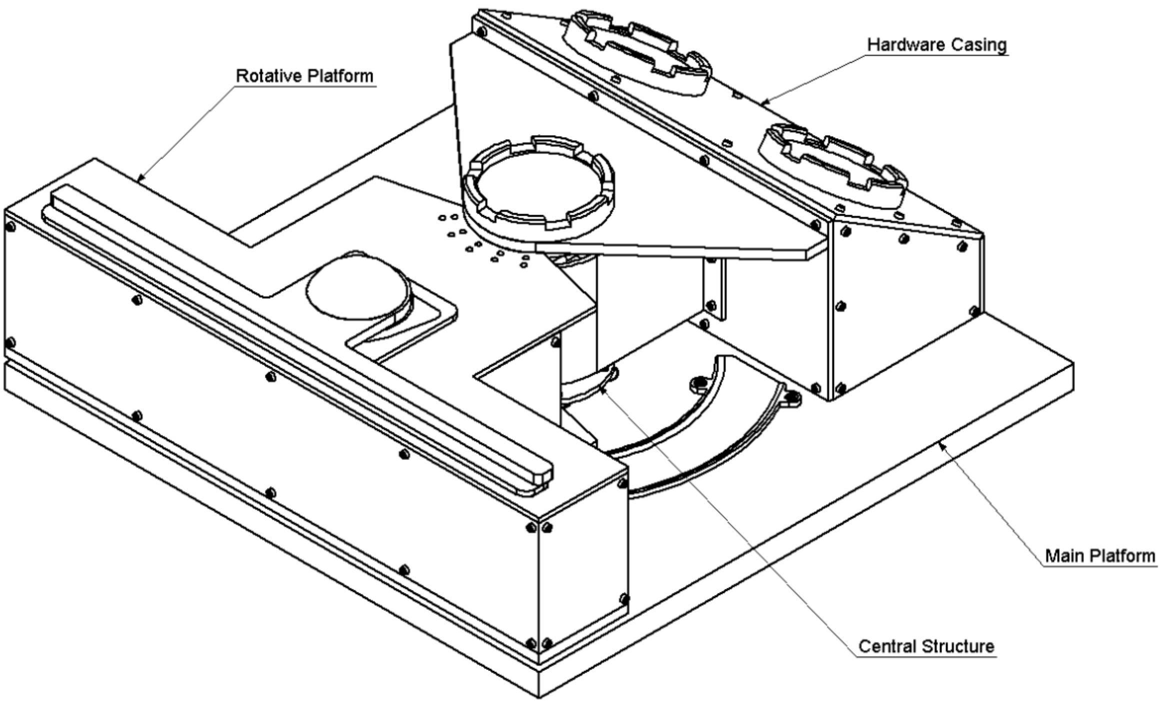
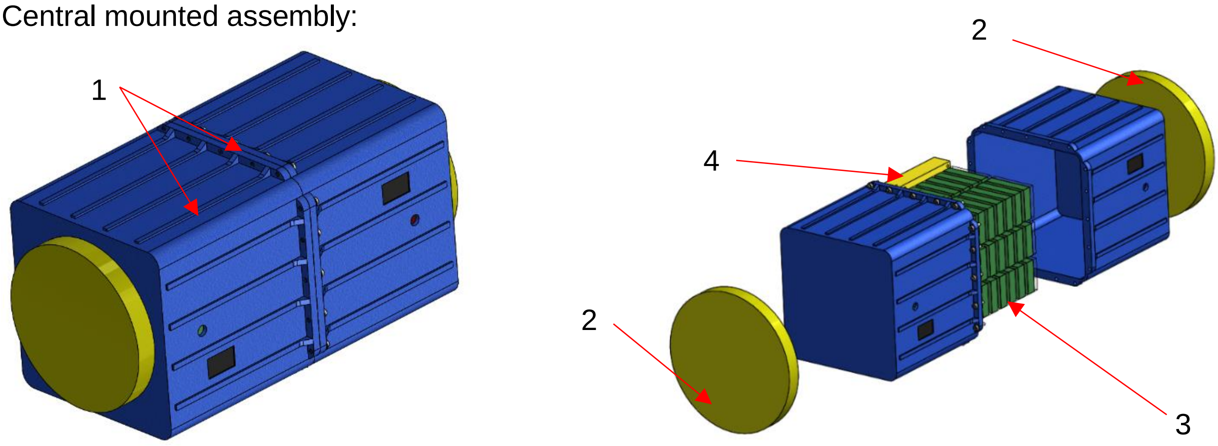


Figure 2 Primary APM – main subassemblies

6.1.2.2 Auxiliary APM – TBC

Central mounted assembly:



The Auxiliary APM will be comprised of:

- 2 chassis cages [1]
- 2 SIROM interfaces [2]
- 1 battery stack [3]
- electronic circuit boards [4]
- fasteners

The APM external body will be made from 2 identical chassis cages [1] joined together by a threaded connection (bolts) with a seal in between. The interfaces [2] will be assembled at both ends and seals will be placed to protect the internal electronics from the environment

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contamination. The battery stack [3] will incorporate thermal conductive elements (Copper wire) which will be connected to the interface's thermal ports [2]. Electronic circuit boards [4] are to be mounted on the chassis.

The Auxiliary APM will incorporate at least 1 additional connections for control (USB) and at least 1 LED. The external surface of the chassis cages [1] will have small ribs or grooves to provide better gripping surface for human operator of custom clamping system.

The main structural components, the chassis cages [1], should provide sufficient protection to the electronic equipment and should be able to transmit sufficient mechanical power as stated in the top-level documents.

6.2 Functional description

6.2.1 Primary APM

The three main activities of the P-APM are the following:

- Deploy a motorized solar panel in order to capture - and track - photovoltaic energy for charging the internal battery or the battery within the Aux-APM, through and
- Record on local storage and stream data from the optical sensor mounted on top of the solar equipment mast.
- Provide a limited cooling infrastructure that allows to dissipate its own heat but will also support cooling of the interfaced

This implies an autonomous system able to control its own equipment (solar, sensors, storage, …) but also be able to communicate with external systems and payloads.

The P-APM demonstrator architecture design contains different parts in order to achieve the mission described above, as shown in ***Figure 3***:

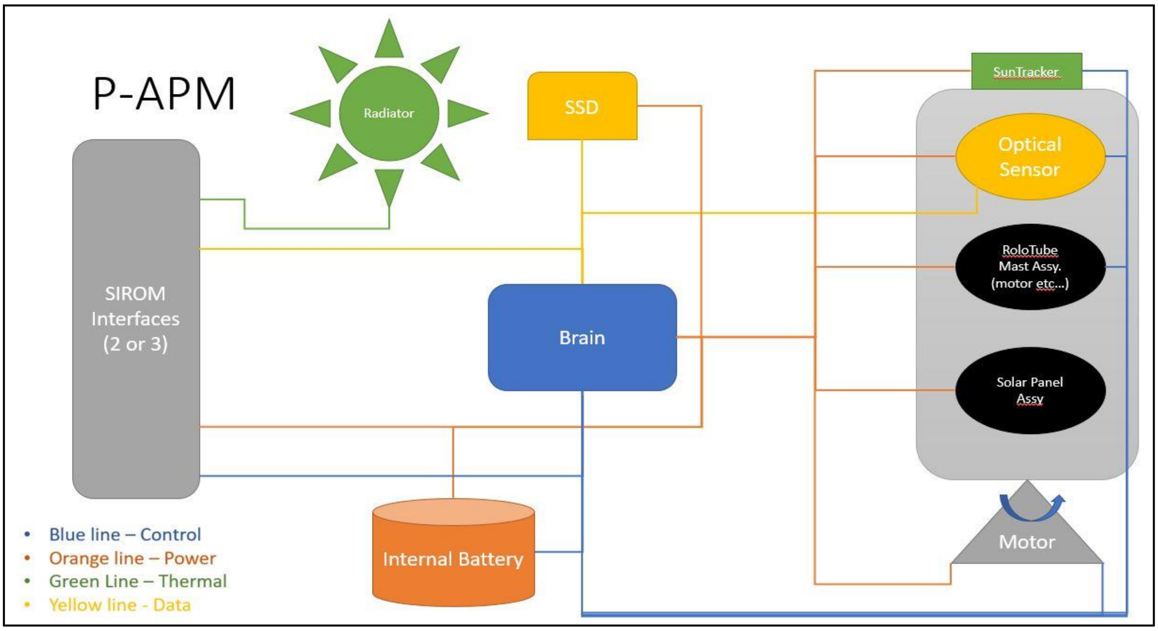

Figure 3 - P-APM Demonstrator Prototype Principle

This block diagram depicts the P-APM system principle with the different elements:

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- SIROM interfaces (with multiples instances)
- Cooling system with the radiator elements.
- The so-called 'Brain' box represents the P-APM controller and all the elements involved in the control, monitoring and communications activities.
- Sun-Tracker with the different elements for capturing and following solar energy, but also the Optical Sensor that will generate the data.
- Internal Battery will ensure the P-APM autonomy in terms of power

6.2.2 Auxiliary APM

The main functionalities of the Aux-APM controller can be organized in three main management functions:

- SIROM I/F Controller: The necessary block for the mechanical SIROM functions.
- SIROM Thermal Controller: The necessary heating and cooling functionality for the temperature conditions during battery charge, discharge and storage operational modes.
- Battery Pack: The battery cells grouped in series and parallel configurations to store the required electrical energy until the platform needs.
- Battery Balancing Circuitry: The circuitry which eliminates the charge/discharge characteristic differences between the cells which are inherent due to process. This functionality is needed for missions which imposes deep depth-of-discharge levels and/or large number of charge/discharge cycles.
- AUX-APM Controller: The circuitry which measures or computes the state of operation (i.e. current flow, battery voltage, battery impedance, bus voltage, battery pack temperature, depth of discharge (or state of charge), operation mode command from SIROM bus, charge counting etc. to produce the necessary outputs for the power circuity. This subsystem should also have its own power supply to self-power which could be equally supplied from bus or battery.
- Power Circuitry: circuitry based on solid state switches which are clocked from the AUX-APM controller to control the direction of flow of power.
- Battery Protection Circuitry: The overcurrent limitation circuity which hard limits the current drawn out from the batteries. The soft limits could be programmed to AUX-APM controller. This protection circuitry also includes a thermal protection circuit which monitors the temperature of the battery pack at some points and controls a switch on the current return path.
- Bus protection Circuitry: The overcurrent limitation circuitry which hard limits the current drawn out from the SIROM power bus. The soft limits could be programmed to AUX-APM controller.

6.3 Operations

6.3.1 Operational modes

6.3.1.1 Primary APM

- Active, stowed under the rover for the transport
- Active, folded on the surface
- Active, deployed on the surface

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6.3.1.2 Auxiliary APM

- Standby, stowed in the rover for the transport
- Active, being charged or supplying power

6.3.2 Functional modes

6.3.2.1 Primary APM

- Charging Auxiliary APM or itself
- Recording video from optical sensor
- Streaming video from optical sensor to EGSE
- Recording video from optical sensor and Charging Auxiliary APM or itself
- Streaming video from optical sensor to EGSE and Charging Auxiliary APM or itself
- No function – e.g. during night, with no Aux-APMs attached for charging
- Self-check

6.3.2.2 Auxiliary APM

- Charging
- Discharging
- Self-check

6.3.3 Telecommand and telemetry

6.3.3.1 Primary APM

Primary APM shall be controllable through wireless connection (TBD). Part of what would otherwise be APM's operational autonomy shall be taken over by APM team on test site; controlling functions like deployment and folding, and monitoring unit's health wirelessly.

More details on this are available in DDF.

6.3.3.2 Auxiliary APM

None.

6.3.4 Alarms management

TBD

6.3.5 Load definition

TBD

6.3.6 Contingencies

TBD

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7. UNPACKING AND INTEGRATION

7.1 ORBITAL APM

TBD

7.2 PLANETARY APM

TBD

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8. CONTROLLERS SW

8.1 SIROM CONTROLLER

No SW included in SIROM IF, there is a controller with an external IF which will include firmware. Further information will be included in a later stage.

8.2 APM CONTROLLER

With respect to APM the SW to control the payload is still to be confirmed once selection of payload is agreed. In any case this APM SW will be a commercial off the shelf SW linked to the payload element.

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9. LIST OF WARNINGS

TBD

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