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DEPARTMENT OF AEROSPACE ENGINEERING

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OSTM/Jason-2 Mission

Assignment 7: Configuration System and On-Board Data Handling

Group 25

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Acronyms

ADCS Attitude Dynamics and Control Subystem. 9

AMR Advanced Microwave Radiometer. 4, 5

DHU Data Handling Unit. 6, 7

DORIS Doppler Orbitography and Radiopositioning Integrated by Satellite. 5

EPS Electrical Power Subsystem. 9

FOV Field of View. 5

GPS Global Positioning System. 5

GPSP Global Positioning System Payload. 5

LRA Laser Retroreflector Array. 5

NASA The National Aeronautics and Space Administration. 11

OBDH On-Board Data Handling. 2, 7–9

PCE Power Conditioning Equipment. 9

POD Precise Orbit Determination. 4, 5

POSEIDON Positioning,Ocean,Solid Earth, Ice Dynamics, Orbital Navigator. 4, 5

PROTEUS Plateforme Reconfigurable pour l'Observation, les Télécommunications Et les Usages Scientifiques. 4, 6, 7, 11

PS Propulsion Subsystem. 9

RAM Random Access Memory. 10

ROM Read-Only Memory. 9, 10

SA Solar Array. 5

SADM Solar Array Drive Mechanism. 9

SHM Safe Hold Mode. 7

SSM Secondary Surface Mirrors. 5

STA Star Tracker Array. 5

TCS Thermal Control System. 9

TTMTC Tracking Telemetry & Telecommand. 9

1 Configuration System

In space missions, satellite configuration design plays a critical role in maximizing performance, volume, and cost-efficiency. This kind of optimization is necessary to ensure long-term missions and success.

In this section, the guiding principles behind the development of the Jason series are explored, utilizing documented sources and a reverse engineering approach. It is important to note that Jason-2 utilizes the robust Proteus platform, developed by the current Thales Alenia Space. This versatile platform is a multi-platform bus satellite designed to fulfill various missions, including COROT, SMOS, CALIPSO, and giove B, among others [5]. Furthermore, it simplifies the Jason team's design, testing, and assembly procedure to only configuring the payload with scientific instruments and verifying compatibility. This strategy saves both money and time.

In order to satisfy the technical and mission requirements, the configuration system process began with the PROTEUS documentation and continued from there [3]. To initiate the discussion, it is essential to highlight the particular requirements that guide the configuration choices:

R1: Nadir pointing for communication and scanning Earth

R2: High accuracy in Precise Orbit Determination (POD)

R3: High accuracy in pointing

R4: Constraints due to the launcher adapter of Delta II

R5: Symmetry and center-of-mass considerations for control

R6: Developing the payload based on Proteus dimensions and considerations

R7: Positioning of elements taking into account thermal control

For the analysis, initial considerations will focus on the launcher and the volume constraints it imposes. Following this, a straightforward design evaluation of the external distribution will be conducted, along with an analysis of the internal configuration.

1.1 Vehicle Shape and Interface with Launcher Fairing

The final dimensions of Jason-2 in its folded configuration are 1x1x3.7 meters [6]. According to the Proteus manual[3], a brief overview of the generic payload configuration is provided in Figure 1 .

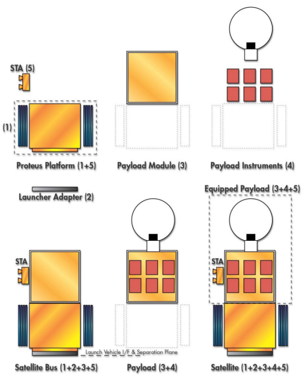

Fig. 1: General Satellite Architecture based on Proteus Bus

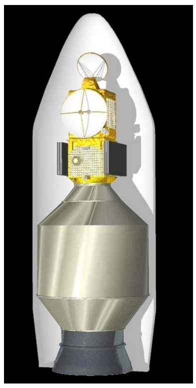

Fig. 2: Jason 2 Launcher Configuration

As it can be seen, the satellite must develop vertically in order to meet the launcher constraint. Proteus acts as the base, supporting the entire satellite with dimensions of 0.945x0.945x1 meters. Ideally, the payload should match the dimensions of Proteus. However, this is not possible due to two specific components. Firstly, POSEIDON-3 has an antenna with a diameter of 1.2 meters [1], which is contained vertically within the system. Consequently, the payload dimensions become 0.945x0.945x1.28 meters. Secondly, the Advanced Microwave Radiometer (AMR), must be oriented towards the Earth to map the planet. This instrument needs to be placed at the top of the satellite because it does not have any folding mechanical parts. After accounting for the AMR's 1.5 m total height (one meter for the antenna's diameter and around 0.5 m for the supports), the overall height of the entire satellite (payload module + proteus) is 3.7 m.

Moreover, it is necessary to verify the lateral dimensions. The worst case is not in the direction of the solar array but in the Z direction (see reference system in Figure 3). The communication antenna on the -Zs panel and the Doris antenna on the +Zs panel represent the longest points. The antennas are about 45 cm long [3], and from the various images analyzed, the Doris antenna appears to be slightly longer (50-60 cm). Therefore, in the Zs direction, the total length is about 2 meters versus the 2.743 meters fairing of the Delta 2 [7].

1.2 External Surface design

To accurately describe the positioning of each satellite component, it is essential to establish a reference system. The reference system outlined in the Proteus manual will be utilized for consistency.

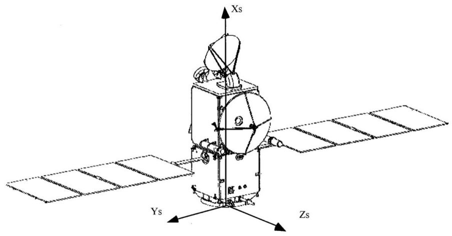

Fig. 3: Reference Frame of Jason 2 [3]

Requirement R1 is crucial, as it mandates the positioning of quite all instruments to face the Earth due to the satellite's nadir pointing orientation. As previously stated in section 1, due to spatial constraints, POSEIDON-3 occupies the entire +Zs panel. LRA and DORIS are symmetrically placed at the base of the +Ys and -Ys panels, respectively, always pointing towards the Earth. This opposite placement is due to weight distribution considerations. Moreover, both instruments are mounted on a structural extension to avoid obstructing the FOV of other scientific payloads (as shown in Figure 4 and Figure 6). The AMR is positioned on the +Xs panel, with its 1 meter diameter antenna facing the Earth. Due to the nadir pointing requirement (R1), the GPSP system is mounted across the -Zs and +Xs panels to maintain communication with GPS satellites in higher orbits, which are part of the mission's space segment. In some ways, this placement also satisfies Requirement R2, since the POD system requires an unhindered view. Similarly, the Star Tracker Array (STA) is placed on the back of the satellite on the -Zs panel to ensure a clear FOV free from other systems. This careful arrangement of instruments ensures optimal functionality and adherence to mission requirements like R3.

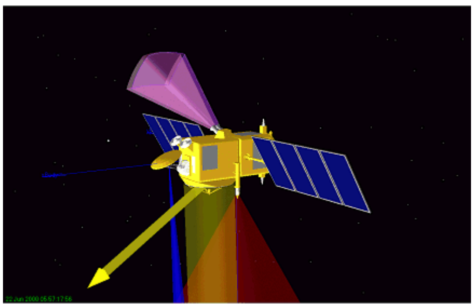
Fig. 4: Instrument FOV Analysis

It is now possible to inspect the Proteus platform's external components. First, consideration is given to the thruster position on the -Xs panel. By placing the thruster here, the design ensures that all thrust is applied along a single axis, simplifying the propulsion system and improving the efficiency of orbital adjustments and station-keeping maneuvers. Moreover, the +Ys and -Ys panels are where the SA are located. Additionally, Proteus is equipped with two antennas for Earth communication. One antenna points towards Earth, while the other, located on the opposite panel, serves as a redundant system. Final considerations can be made regarding the silvered SSM that covers most of the satellite's faces to dissipate excess heat. Notably, the SSM on the star tracker array is particularly useful for maintaining optimal operating temperatures, on sigle long SSM on the Star Tracker Array is particularly useful for maintaining optimal operating temperatures is particularly useful for maintaining optimal operating temperatures because it dissipates heat from the active star tracker to the inactive one [4].

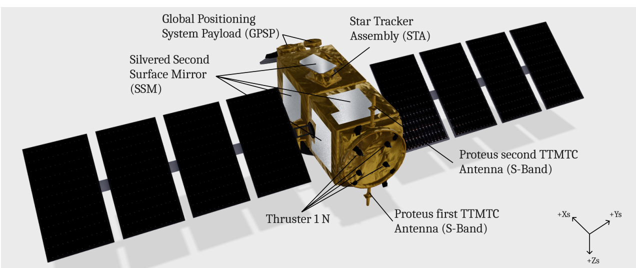

Fig. 5: Back View of Jason 2

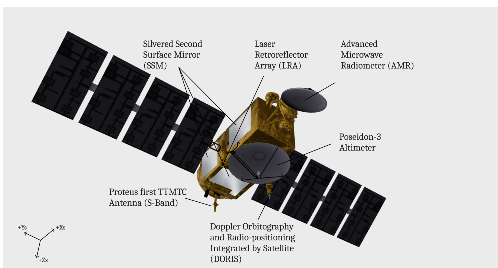

Fig. 6: Bottom View of Jason 2

1.3 Internal design

Disposition of subsystems, instruments and structures inside the satellite is critical for achieving the wanted AOCS and TCS requirements: R5,R7. Due to the versatility, launcher and payload interfaces requirements of PROTEUS a cube geometry has been selected with the internals placed on the various dedicated internal faces.

As easily seen in Figure 7 and Figure 8 the different parts of the internals of PROTEUS have been disposed with maximum symmetry to both achieve the most geometrically centered centre of mass.

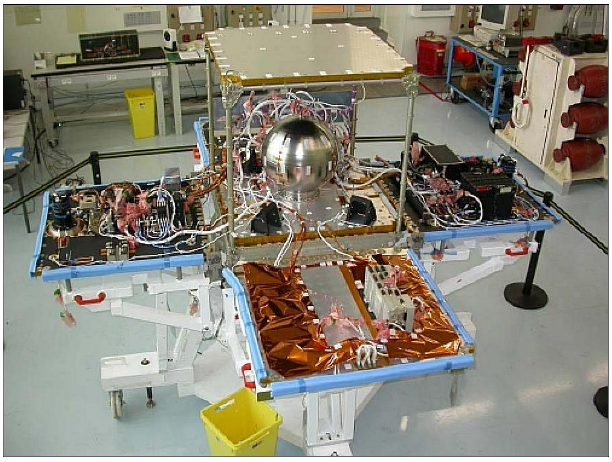

Fig. 7: PROTEUS's internals photo

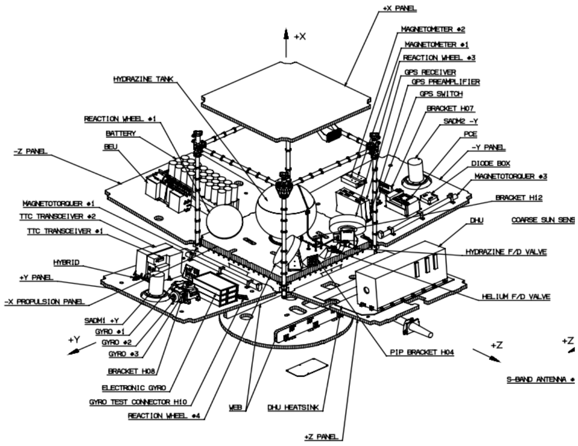

Fig. 8: PROTEUS internal elements

As examples: battery and DHU are big and heavy elements and so placed on opposite faces, reaction weels are in symmetrically placed, so are the s-band antennas, and many other elements, but most importantly the hydrazine tank due to the contained 28kg of propellant. The hydrazine tank is placed in the middle most position possible, for two main reasons: one, for packing, being a sphere placed in a cube; two, for reducing to the minimum the center of mass displacement due to the reducing mass of hydrazine.

Moreover this symmetry helps to distribute heat coming from different subsystems with dedicated thermal radiators across multiple faces. Primarily the two most heat generating elements, the battery and the DHU, are placed on opposite faces with dedicated radiators.

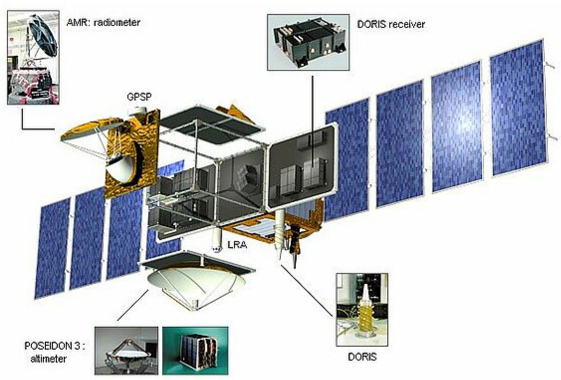

Fig. 9: Jason-2 payload internal elements

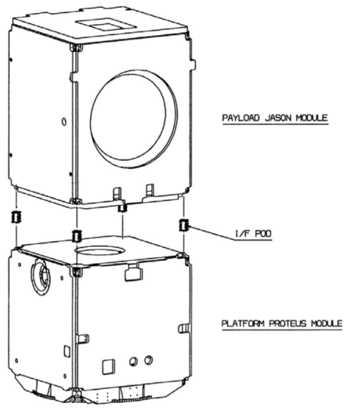

Fig. 10: PROTEUS interface with Jason payload

This philosophy is also present on the payload as clearly visible in Figure 9, in fact the geometry is a rectangular prism with the platform coupling face of the same dimensions of PROTEUS. This geometry allows for a easy coupling with PROTEUS through four bolts placed at the vertices of the coupling face, and a hollow circular passage for all the cables and environment continuity as shown in Figure 10.

2 On-Board Data Handling

Acting as the satellite's brain, the On-Board Data Handling (OBDH) ensures efficient communication between subsystems, coordinates command execution, and facilitates accurate data transmission to ground stations. Its effective design is vital for the satellite's overall performance and longevity, ensuring reliable operations in the challenging environment of space. Its main functions can be resumed in:

- Satellite mode management; automatic mode transitions and routines
- Failure detection and recovery; monitoring spacecraft health and switching to SHM if necessary
- Onboard visibility; generation, maintenance and downlink of housekeeping telemetry
- Satellite command and control, consisting of management of telecommands sent by ground either to hardware or software

2.1 Architecture

2.1.1 Flight computer architecture

All of the spacecraft's computing functions are managed by the Data Handling Unit, which is centered around a computer processor known as the MA 31750. This subsystem includes 128 Kwords of 16-bit non-volatile memory, 256 Kwords of random access memory, and three gigabits of dynamic RAM mass memory[3]. It runs the Jason 2 flight software and controls the spacecraft through interface electronics. Additionally, it handles all payload data transmitted to Earth whenever the satellite is within range of a ground station. Especially for this subsystem redundancy is fundamental to reduce the risk of failure of the electronic components, that is why all units within the DHU, including the main processor, are redundant.

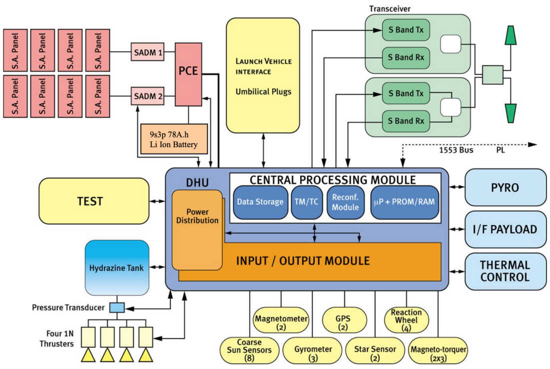

Fig. 11: On board computer system diagram

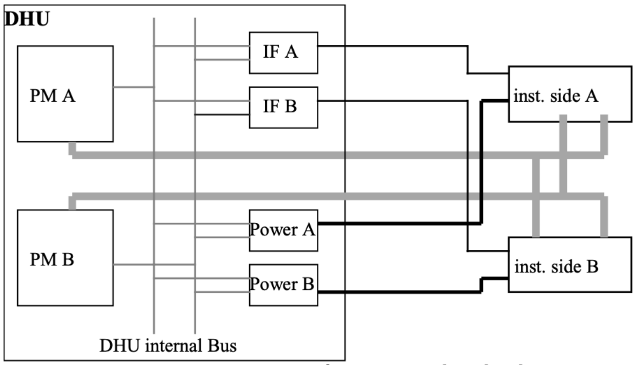

Fig. 12: PROTEUS interface with Jason payload

As shown in Figure 12 the DHU is divided into two halves, each with its own processor module, so that if one of the two halves suffers any damage, the other can continue to perform the required functions by continuously sending and managing the data received from the structure. This type of structure allows for an increase in the overall reliability of the system. The following table illustrates the concept of this redundancy, showing which elements are shared between the two halves.

	Unit	Nominal	Redundancy	Remarks
DHS	Data Handling Unit	PMA	PMB	**Half Satellite**
	Mass Memories	MM0, MM1, MM2, MM4	MM3 cold redundancy	Shared
TTCS	TT&C Transmitter	Tx1	Tx2	**Half Satellite**
	TT&C Receiver	Rx1, Rx2	1 Rx loss allowed	Hot redundancy
AOCS	GPS Receiver	GPS1 4 or more satellites 99% of the time	GPS2	**Half Satellite**
	Reaction Wheels	RW1 to RW4	1 RW loss allowed	Shared; no aging effects detected
	Magneto-Torques	MTB1 to MTB3 nominal coils	MTB1 to MTB3 redundant coils	**Half Satellite**
	SA Drive Mechanism	SADM1&2 nominal motor	SADM1&2 redundant motor	**Half Satellite**; accuracy > 1%
		Potentiometer & REED relays	Potentiometer loss allowed	Shared
	Thrusters	THR1 to THR4	1 THR loss allowed	Shared (not used in NOM)
	Gyrometers	GYR1, GYR2	GYR3 cold redundancy	Shared; GYR3 checked every 6 months
	Star Trackers	STR1 Accurate>99.45% per orbit	STR2 cold redundancy	Shared; STR2 checked periodically
	Magnetometers	MAG1 No anomaly	MAG2	**Half satellite** (not used in NOM; checked every 6 months)
	Coarse Sun Sensors	CSS1 to CSS8	1 CSS loss allowed	Shared (not used in NOM; checked every 6 months), aging effect < 2%
EPS	Power Conditioning Electronic	12 section available	1 section loss allowed	Shared
		Nominal TM/TC	Redundant TM/TC	**Half Satellite**
	Battery Electronic Unit	BEU Nominal	BEU Redundant	**Half Satellite**
	Solar Array	32 strings of 100 cells each	4 strings loss allowed	Shared (4 strings = 1 panel section) Aging measurement is 0.75% per year versus expected 1.1%
	Battery	9 packs of 3 Lithium-ion cells	1 pack loss allowed	Shared

Table 1: Redundancy of main processors[2]

2.1.2 Payload management

The DHU manages the payload throughout the commands, offers standard thermal control, and standardized electrical interfaces (23/36V power supply, 1553 bus, specific point to point lines). A payload specific software application can be implemented in the DHU to control complex payload. The Data Handling Unit has an internal mass memory organised in two main areas :a housekeeping area to record payload and platform housekeeping data out of visibility periods and a data payload area of 2 Gbits, split in two size programmable areas to store and transmit independently payload data to ground during visibility periods. The data is transmitted from payload to mass memory through a1553 link with a maximum rate of 100 kbits/s or through a specific high speed line with a data rate up to 10 Mbits/s.

2.2 Reverse Sizing

The first step in correctly sizing an On-Board Data Handling subsystem is to list all the functions allocated for each subsystem. Table 2 collects all of the general functions used by the spacecraft, with their typical throughputs and frequencies.

It is worth noticing that all of these functions are not used simultaneously during each mode of the satellite, but to account for a worst-case scenario, the sizing is done considering all of the functions above as simultaneous.

To compute the throughput of each function, the estimation-by-similarity method is implemented, where the desired throughput is computed by comparing proportionally typical values for similar functions to the required acquisition frequency of the Jason-2 satellite.

$$KIPS = \frac{KIPS_{typ} \cdot f_{acq}}{f_{typ}} \quad (1)$$

As an acquisition frequency, it was assumed the use of 2 distinct frequencies: 1 Hz for secondary and non-critical functions and 40 Hz for primary and critical functions. It was chosen 40 Hz as this is the maximum payload frequency allowed (8 Hz [3]) with a 400% margin, thus allowing control systems to act faster than the payload itself.

This process is repeated for the code and data sizes, in words per function, without having to proportionally adjust for changes in acquisition frequency.

Once these values are obtained for each allocated function, the total values for throughput, data sizes and code sizes are computed. To these values, a 400% margin is applied in order to assure an operational subsystem at all times, since typical sizes and throughput were assumed for most of the data and real values could vary significantly.

Component	**Number**	**Typical Throughput**	**Typical Frequencies**	**Acquisition Frequencies**	**Throughput** $[KIPS]$	**Code Size** $[Kwords]$	**Data Size** $[Kwords]$
Attitude Dynamics and Control Subystem							
StarTrackers	2	2.0	0.01	1.0	200.0	2.0	15.0
Gyrometers	3	9.0	10.0	40.0	36.0	0.8	0.5
Magnetometers	2	1.0	2.0	1.0	0.5	0.2	0.1
Coarse Sun Sensors	8	1.0	1.0	1.0	1.0	0.5	0.1
Reaction Wheels	4	5.0	2.0	40.0	100.0	1.0	0.3
Magnetorquers	3	1.0	2.0	40.0	20.0	1.0	0.2
Thrusters	4	1.2	2.0	40.0	24.0	0.6	0.4
Attitude Determination	1	150.0	10.0	1.0	15.0	15.0	3.5
Attitude Control	1	60.0	10.0	40.0	240.0	24.0	4.2
Orbit Propagation	1	20.0	1.0	1.0	20.0	13.0	4.0
Complex Ephemerides	1	4.0	0.5	1.0	8.0	3.5	2.5
Error Determination	1	12.0	10.0	1.0	1.2	1.0	0.1
Propulsion Subsystem							
Pressure Sensors	5	3.0	0.1	1.0	30.0	0.8	1.5
Engine Control	1	5.0	0.1	1.0	50.0	1.2	1.5
Electrical Power Subsystem							
Solar Array Drive Mechanism	2	1.0	2.0	40.0	20.0	1.0	0.3
Power Voltage Control	1	5.0	1.0	1.0	5.0	1.2	0.5
Power Current Control	1	5.0	1.0	1.0	5.0	1.2	0.5
Power Conditioning Equipment	1	5.0	1.0	1.0	5.0	1.2	0.5
Thermal Control System							
Heaters	22	3.0	0.1	1.0	30.0	0.8	1.5
Thermistors	66	1.0	2.0	1.0	0.5	0.5	0.1
Tracking Telemetry & Telecommand Subsystem							
Uplink	1	7.0	10.0	1.0	0.7	1.0	4.0
Downlink	1	3.0	10.0	1.0	0.3	1.0	2.5
Main System Functions							
Simple Autonomy	1	1.0	1.0	1.0	1.0	2.0	1.0
Complex Autonomy	1	20.0	10.0	40.0	80.0	15.0	10.0
Fault Detection	1	15.0	5.0	40.0	120.0	4.0	1.0
Fault Correction	1	5.0	5.0	40.0	40.0	2.0	10.0
Test and Diagnostic	1	0.5	0.1	1.0	5.0	0.7	0.4
			Total		1058.2	89.6	66.2
			Total with margin		5291	448	331

Table 2: Functions allocated to the OBDH Subsystem and typical throughputs

2.2.1 Read-Only Memory (ROM) Computation

The Read-Only Memory is the memory allocated to store permanent (non-volatile) data.
Knowing that a word is composed by 16 bits [3], it is possible to calculate the ROM in Kilobytes as:

$$ROM = \frac{Code \cdot 16}{8 \cdot 1000} \; [Kb] \quad (2)$$

The total required ROM is obtained by summing the ROM of each function.

2.2.2 Random Access Memory (RAM) Computation

The Random Access Memory is the memory allocated to store the volatile data of the spacecraft.
The RAM can be computed in Kilobytes as:

$$RAM = \frac{(Code + Data) \cdot 16}{8 \cdot 1000} \; [Kb] \tag{3}$$

The total required RAM is obtained by summing the RAM of each function.

2.3 Conclusions

Throughput $[MIPS]$	**ROM** $[Kb]$	**RAM** $[Kb]$
5.291	896	1558

Table 3: Final requirements for the processor

In Table 3 are reported the total values of ROM, RAM and Throughput required by the spacecraft. These values were obtained considering a worst case scenario in which every function is activated simultaneously.

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