On-Board Data Handling for the HYONOSAT CubeSat project

Master’s Degree in Space and Astronautical Engineering
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Outline

Introduction (1/2)

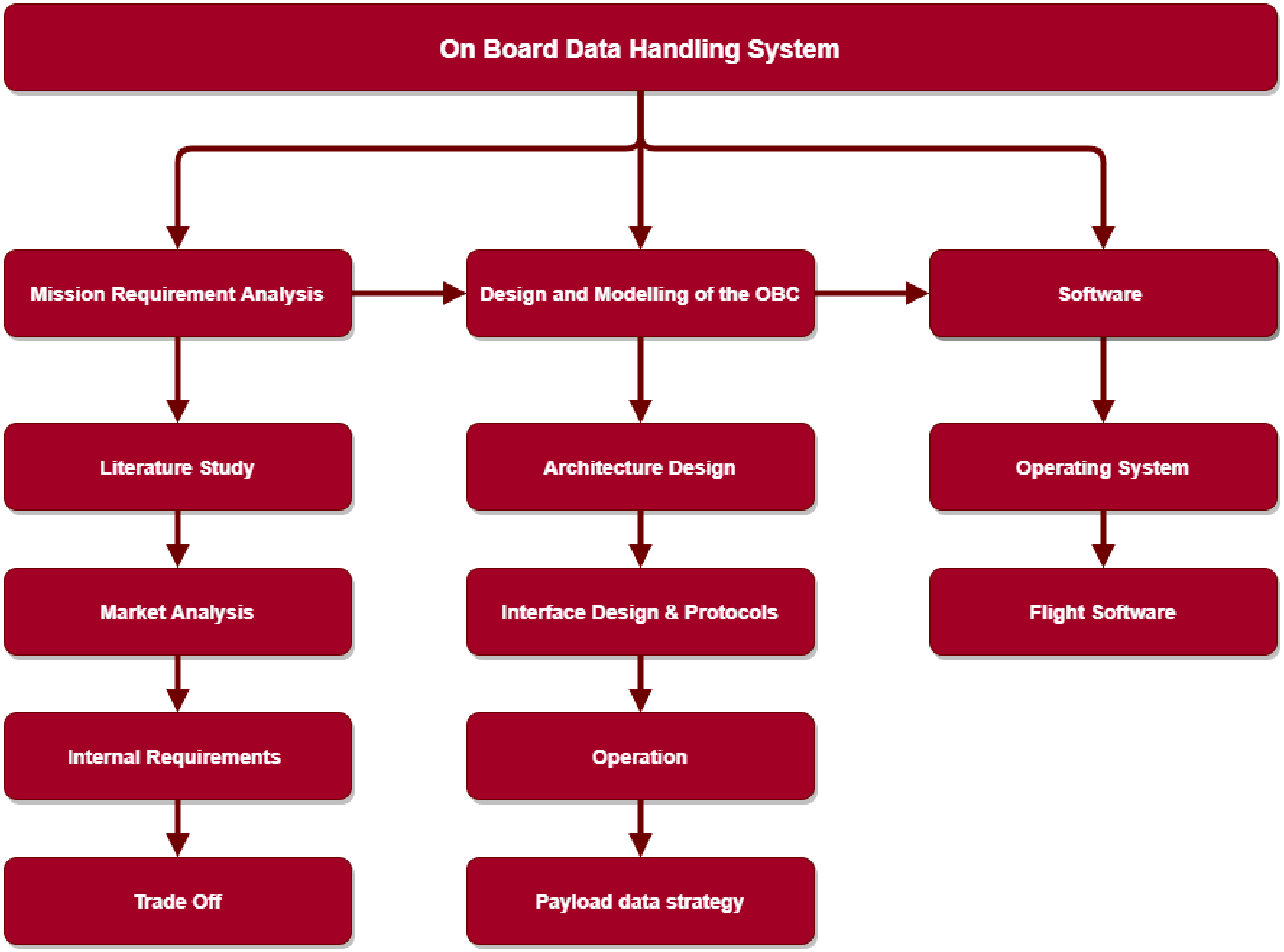
The On-Board Data Handling (OBDH) system is the brain of the CubeSat, and it plays a vital role in the HYONOSAT mission.

The On-Board Computer (OBC) of the satellite acts as the primary source of all the commands and monitors the status of the various subsystems.

Functions performed by the OBDH are:

- Receives, validates and processes ground commands; and execute or distribute these commands.
- Gathers, processes and formats housekeeping and mission data, and control downlink to ground.
- Supports attitude determination and control maneuvers of the spacecraft
- Supports safe-hold operations

Introduction (2/2)

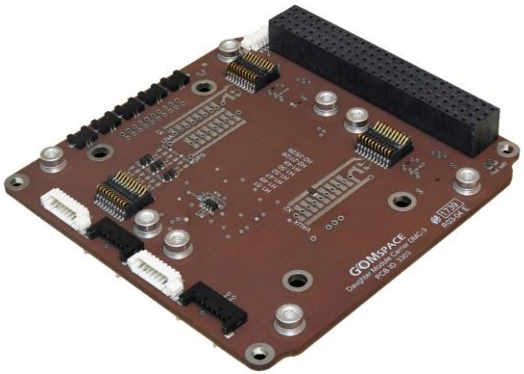


Hardware (1/3)

Component	Model	Number
OBC	NanoMind A3200 Hyperscout-2 OBC	2 1
Motherboard	NanoDock DMC-3 NanoDock P60	1 1
Interface board	COM-1274	1
Memories	Hyperscout-2 S-band transmitter FLASH memory Internal memories	1 1 1 2

Hardware (2/3)

- There are 3 OBC: a central unit, a payload dedicated one and an AODCS dedicated computer.
- A3200 CPU clock rate averages about 32 MHz
- High reliability having flight heritage experiences.



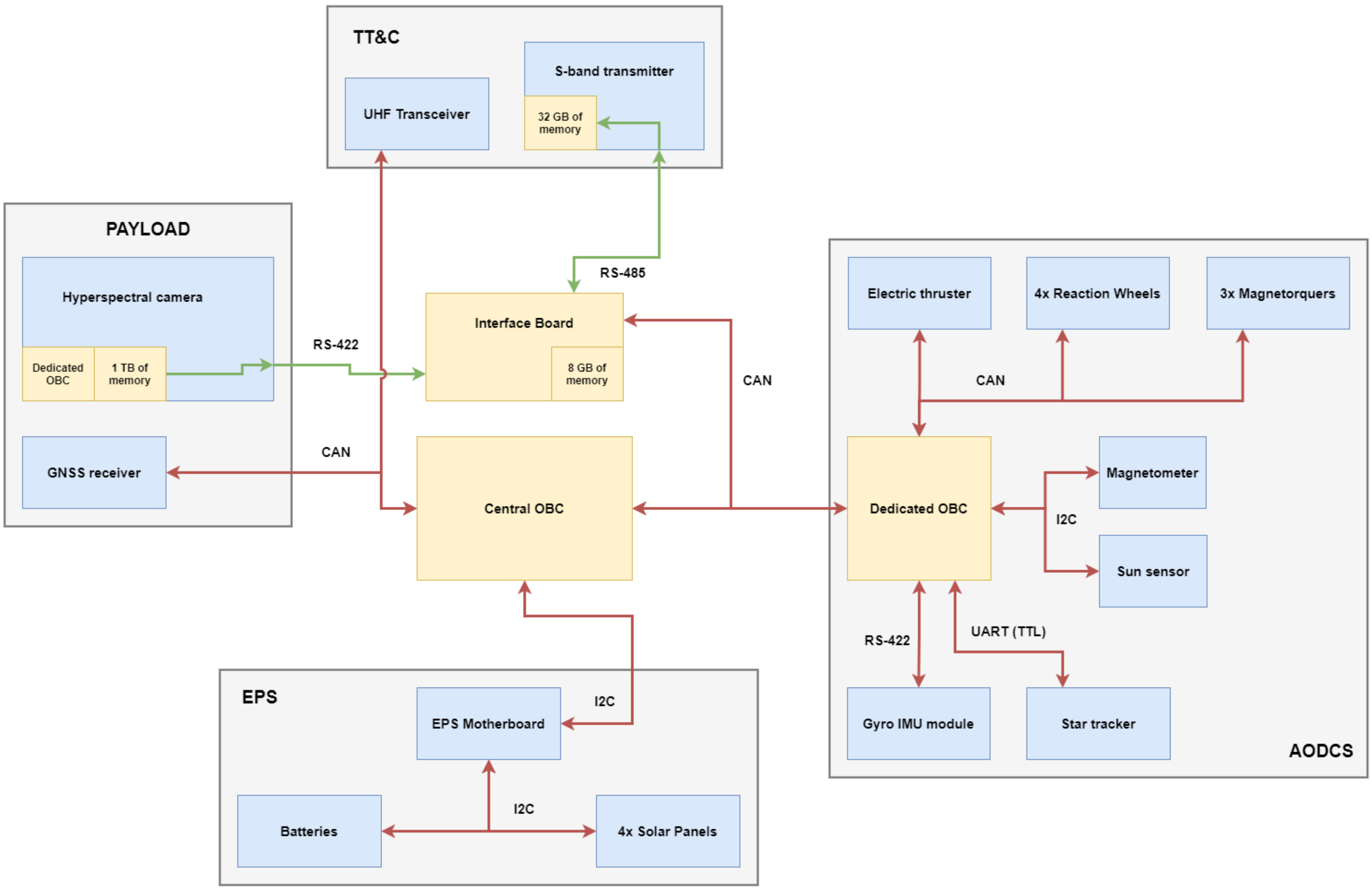
- Supports up to 4 daughterboards, including the A3200 and the UHF transceiver
- Follows the standard PC/104 and can be stacked
- DMC-3 supports high flexibility in interfacing.

Hardware (3/3)

- COM-1274 follows the standard PC/104.
- Offers a plethora of interfaces to interconnect devices, such as RS-422/485 and CAN.

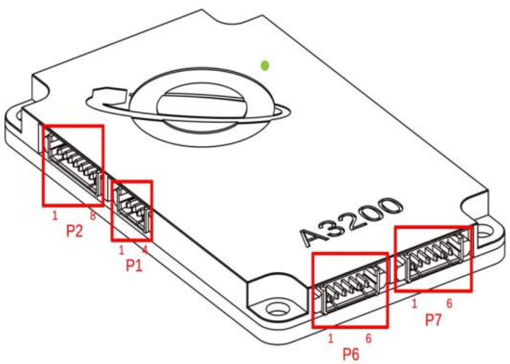
- 69F64G16 is a NAND flash memory and stores up to 64Gb (or 8GB).
- It is a non-volatile memory.
- It has the advantage of presenting fast access time and has a high tolerance to radiation effects.

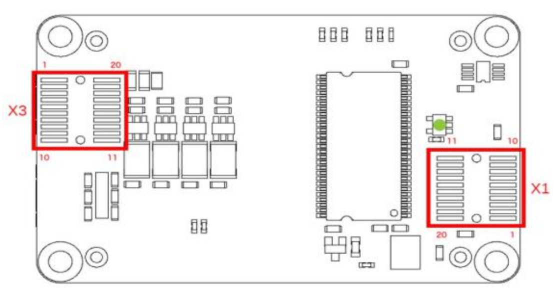
Architecture



Interfacing (1/4)

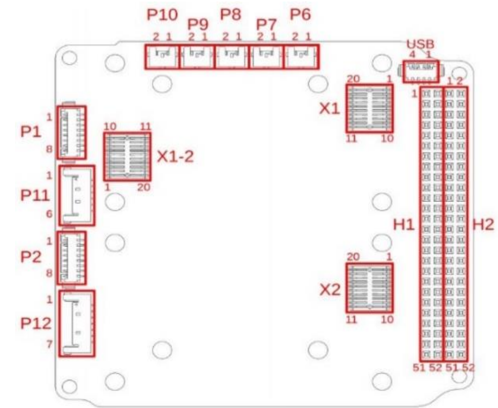
CAN | I2C | UART | RS-422 | RS-485 | GPIO

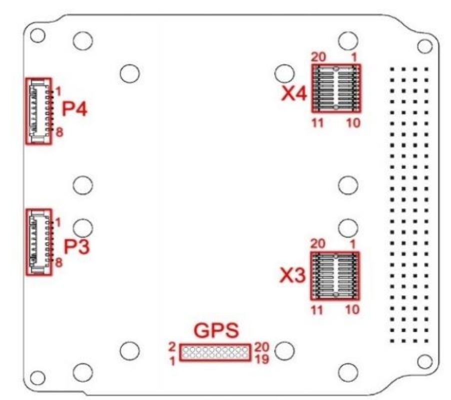




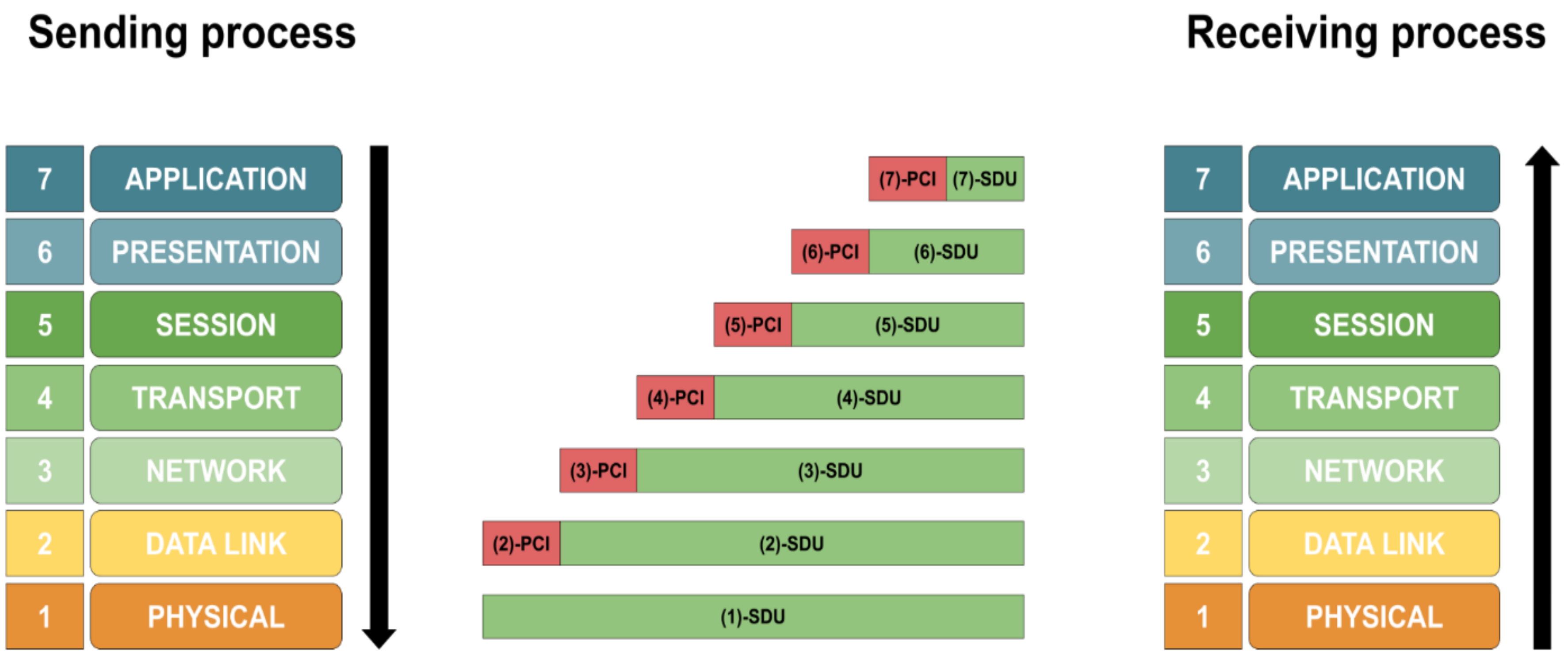
Nanomind A3200

NanoDock DMC-3



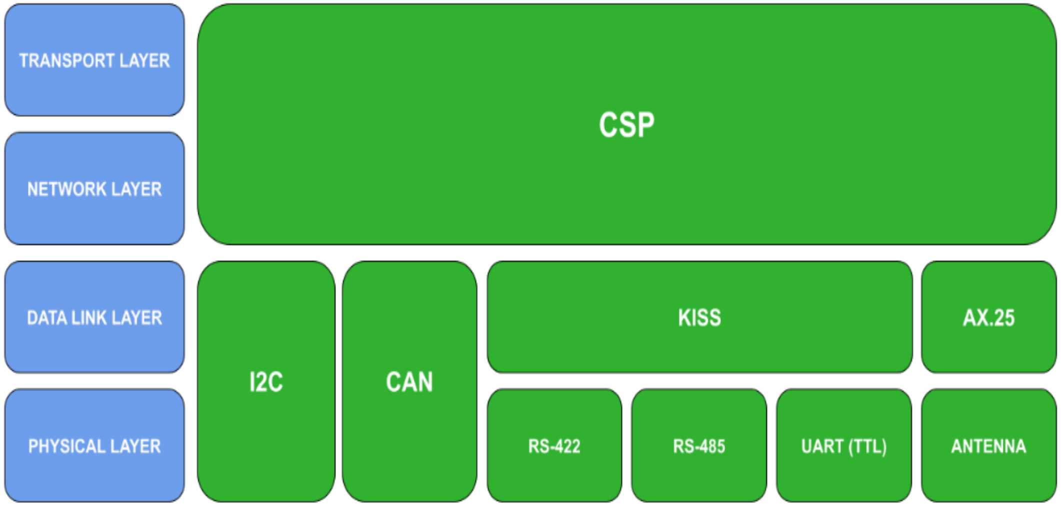


Interfacing (2/4)



Interfacing (3/4)

- CSP is proprietary of GomSpace.
- CSP is the upper-layer which grants QoS.
- It interfaces with different protocols such as I2C, CAN, KISS and AX.25.



Interfacing (4/4)

- CSP frame

Priority	Source	Destination	Destination Port	Source Port	Reserved	HMAC	XTEA	RDP	CRC
DATA									

- CAN frame

SOF	11-bit identifier	RTR	IDE	r0	DLC	DATA	CRC	ACK	EOF	IFS

- I2C frame

Start	Address	Read/ Write bit	ACK/ NACK bit	DATA 1	ACK/ NACK bit	DATA 2	ACK/ NACK bit	Stop

- KISS frame

FEND	Command code	DATA	FEND

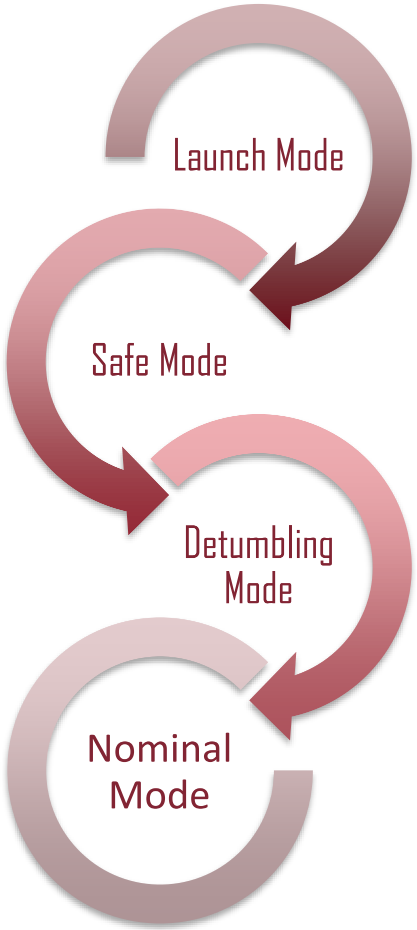
Operation (1/3)

The Launch Mode is only useful in the launch phase until the orbital deployment of the CubeSat and the kill switches are pressed down while the CubeSat is placed in its orbital deployer

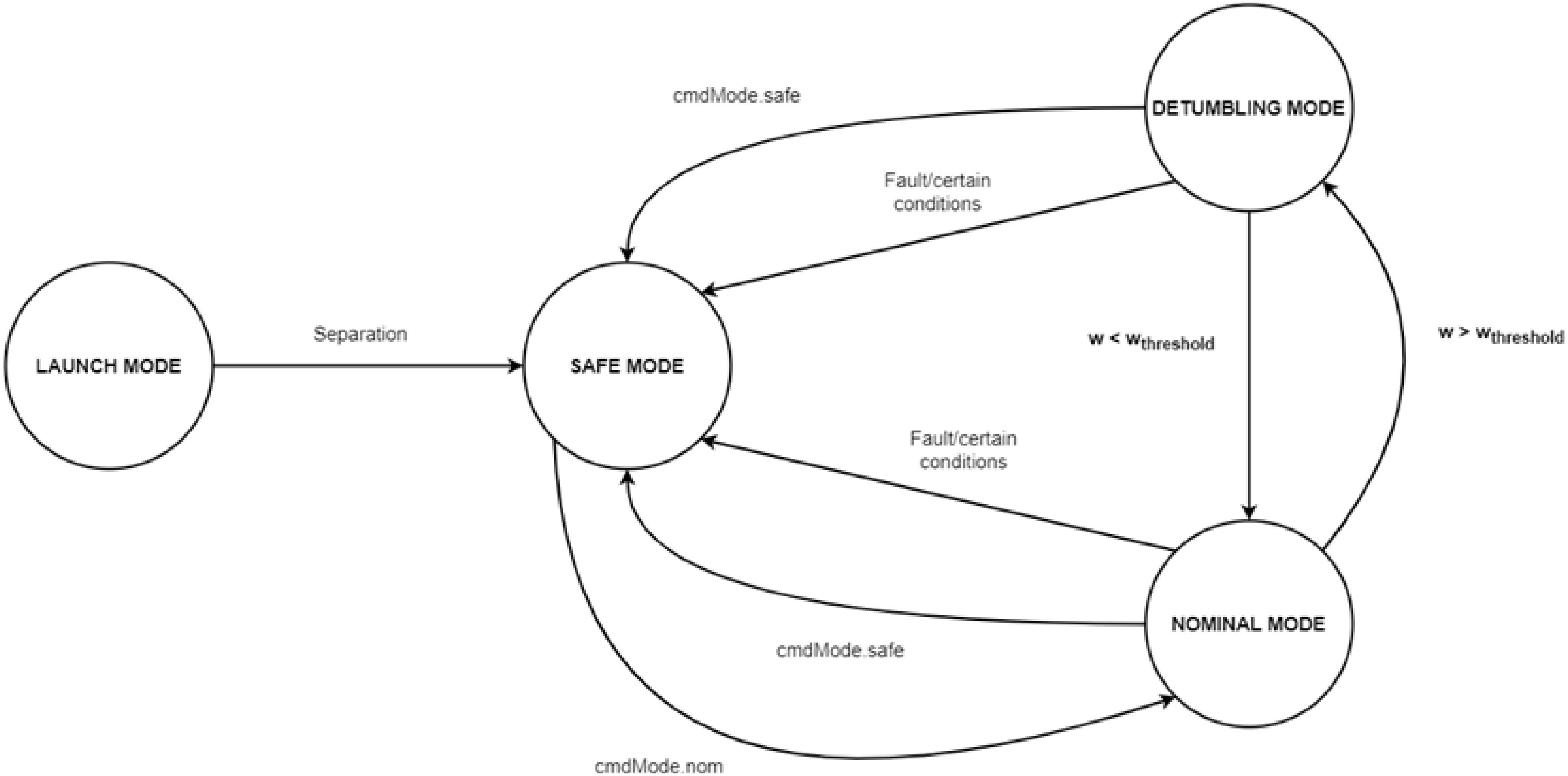
Safe mode is the operating mode of the CubeSat during which all nonessential systems are shut down and only essential functions such as radio reception and attitude control are active.

The Detumbling mode is the mode in which the main task is to detumble the satellite.

Nominal mode
- power is switched on for the requiring components
- radio link is active (telemetry and telecommand)
- payload and S-band transmitter are operating in certain time intervals
- Attitude control, housekeeping is active



Operation (2/3)



Operation (3/3)

Telemetry Data

- Taken once every 10 seconds (0.1 Hz).
- Collected from all relevant sensors and actuators and transferred to the central OBC.
- Either forwards it to the transceiver, if the CubeSat is in a window of visibility, or to store it in the internal memory otherwise.

Attitude Data

- Taken once every 0.2 seconds (5 Hz), according to the needs of the AODC algorithm for stabilization of the CubeSat.
- Data is collected from sensors and relayed to the dedicated OBC that runs the algorithm and forwards the proper telecommands to the actuators.

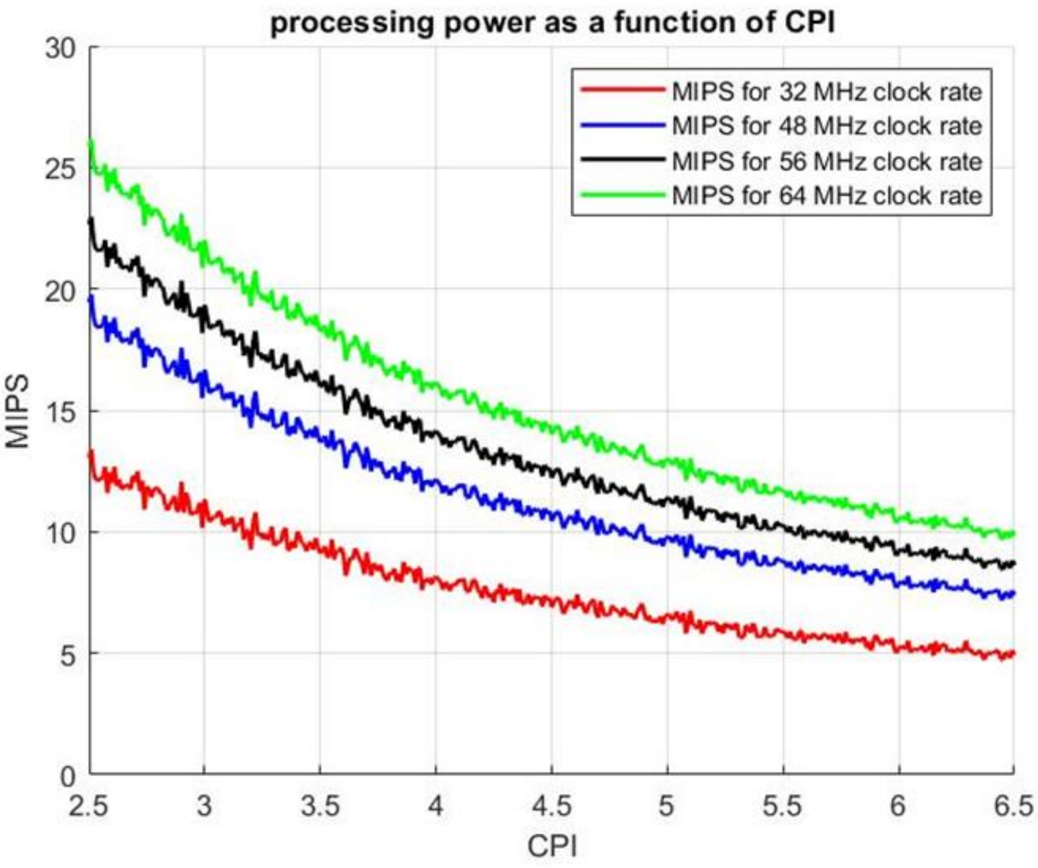
Processing power estimation (1/3)

- $$\boldsymbol{MIPS = \frac{clock\ rate}{CPI}}$$

MIPS stands for Million Instructions Per Seconds and is a measure of the processing power

- $$\boldsymbol{CPI = \frac{\sum_i IC_i \times CC_i}{IC}}$$

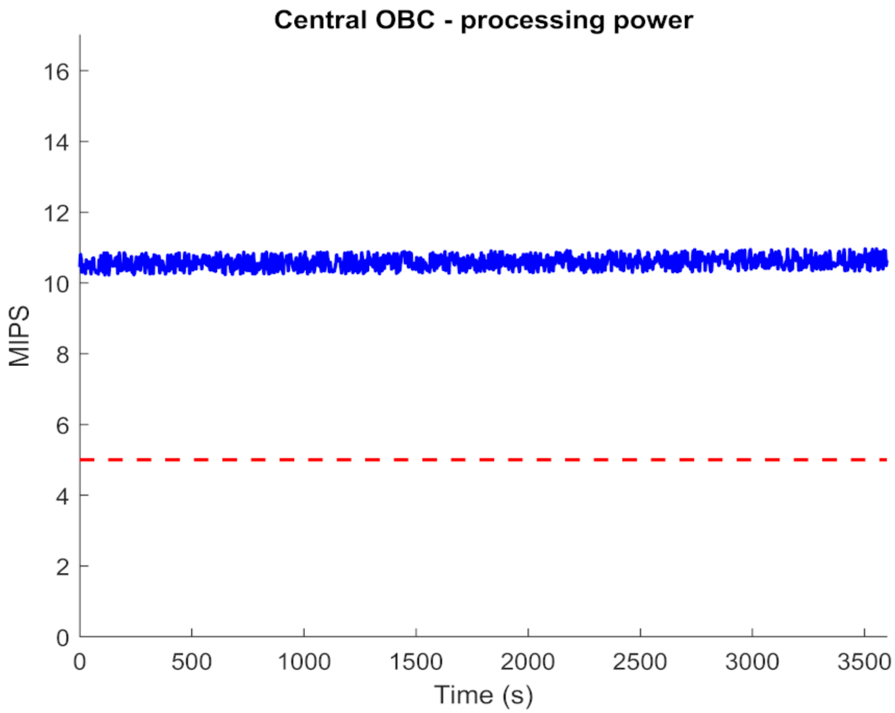
CPI is the Clock cycles Per Instruction



Processing power estimation (2/3)

Instruction type	Instruction frequency	Clock cycle count
Load/store data	0.4	6
Arithmetic instruct.	0.5	4
All others	0.1	3

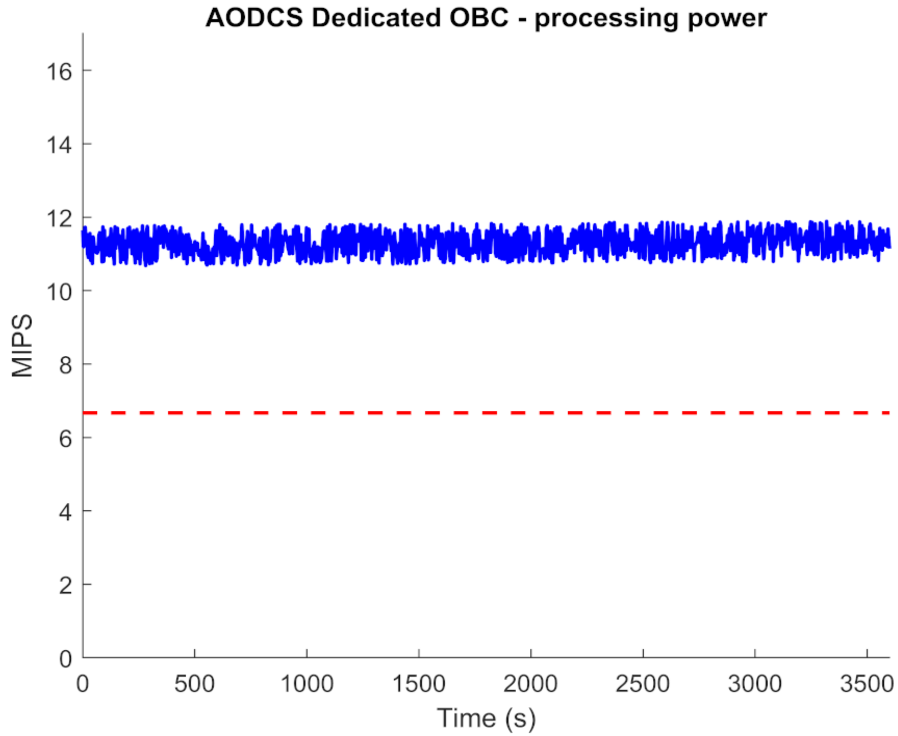
- OBC CPU runs at 48 MHz
- CPU grants 10.2 MIPS, which are enough to run the program in time.
- The request from the system is characterized by 5 MIPS, meaning each instruction set must be completed within 0.2 seconds.



Processing power estimation (3/3)

Instruction type	Instruction frequency	Clock cycle count
Load/store data	0.3	6
Arithmetic instruct.	0.6	4
All others	0.1	3

- OBC CPU runs at 48 MHz
- CPU grants 10.67 MIPS, which are enough to run the program in time.
- The request from the system is characterized by 6.67 MIPS, meaning each instruction set must be completed within 0.015 seconds.



Software (1/3)

The CubeSat is a *"time critical system"* thus a Real time OS will be in operational over a normal OS.

An RTOS is necessary when there are several processes and devices, and the processes' timing is more important than average performance.

Unlike a general-purpose OS, an RTOS is expected to meet computational deadlines, regardless of how bad the scenario can get for the RTOS.

The major benefits of choosing an FreeRTOS are Multitasking, Efficiency, Service, structure of the OS, Portability, and security.

OPERATING SYSTEM

FreeRTOS

FLIGHT SOFTWARE

Core Flight System

FreeRTOS Initialization

Task Implementation

Choosing Memory Scheme

Configuring FreeRTOS

Software (2/3)

The cFS is a platform and project independent reusable software framework and set of reusable software applications.

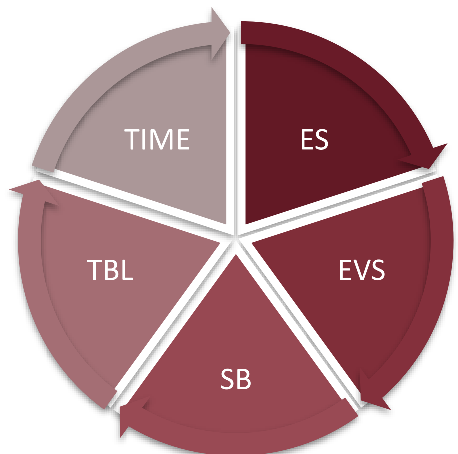
There are three key aspects to the cFS architecture: a dynamic run-time environment, layered software, and a component-based design.

Reduce	Reduce time to deploy high quality flight software.
Reduce	Reduce project schedule and cost uncertainty.
Facilitate	Facilitate formalized software reuse.
Enable	Enable collaboration across organizations.
Simplify	Simplify flight software sustaining engineering.
Provide	Provide a platform for advanced concepts and prototyping.

Software (3/3)

Executive Services (ES) provides ability to start, restart and delete cFS applications.

Event Services (EVS) provide an interface for registering an application's event filter masks, types, and type enable status.



Software Bus (SB) provides a portable inter-application message service which routes message.

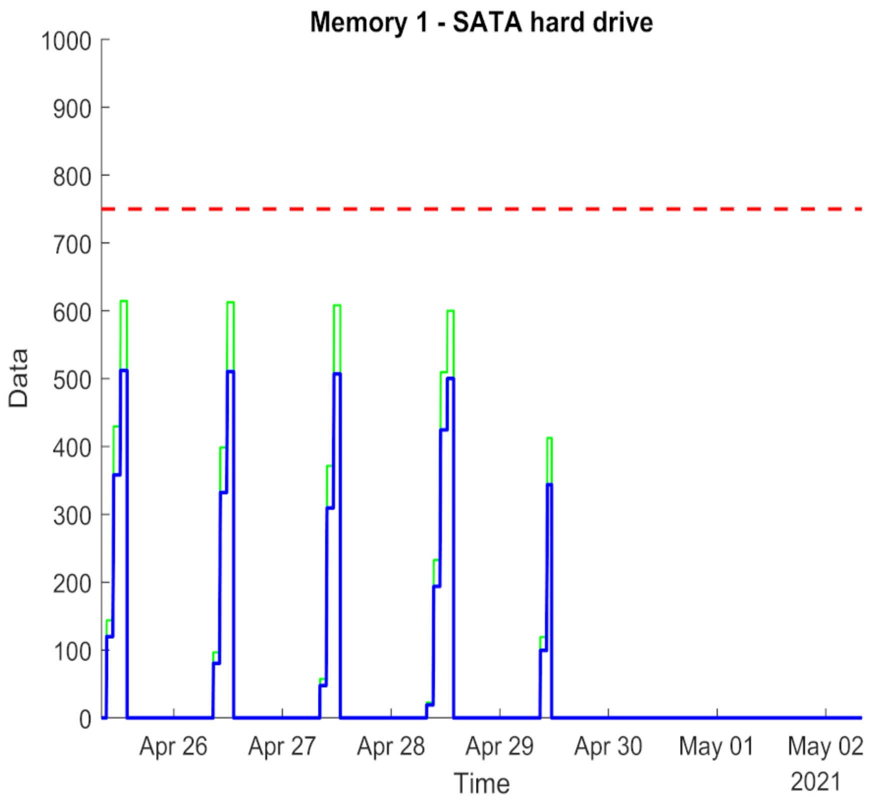
Table Services (TBL) manages all cFS table images.

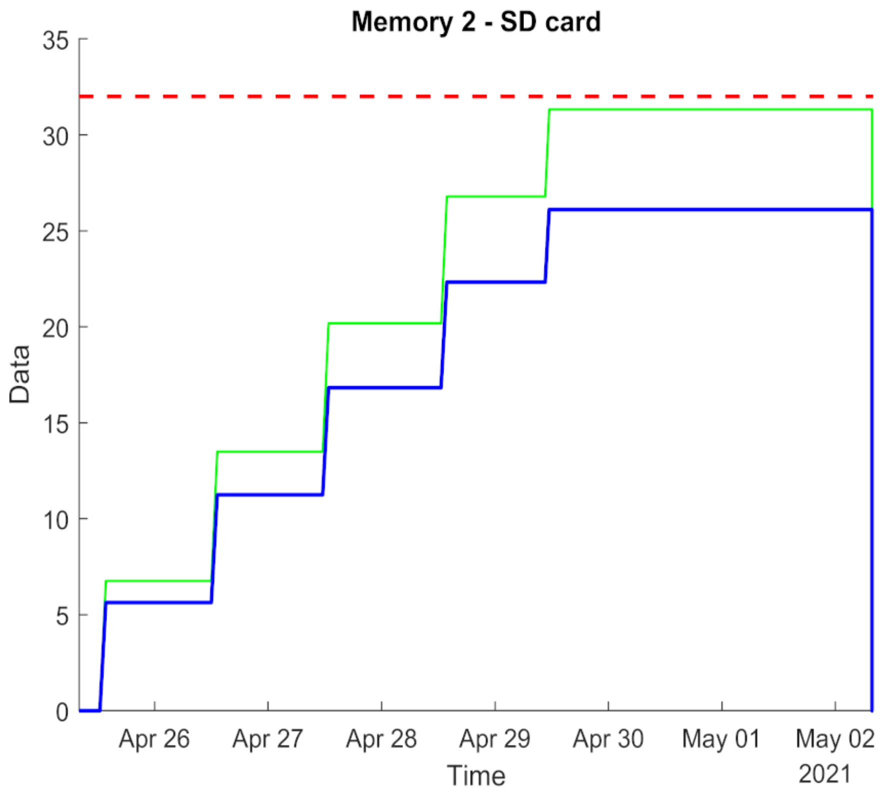
Time Services (TIME) provides a user interface for correlation of spacecraft time to the ground reference time.

Memory budget (1/3)

Memory	Size	Physical location	stores
SATA drive	1 TB	Hyperspectral camera	Acquisition data + Payload data (backup)
SD card	32 GB	S-band transmitter	Payload data
FLASH	8 GB	Accessible from the interface board	Telemetry data (backup) + software updates
Internal	128 MB	Central OBC	Telemetry and telecommand data
Internal	128 MB	AODC dedicated OBC	Telemetry and telecommand data
Total memory	1040.3 GB	Distributed	

Memory budget (2/3)





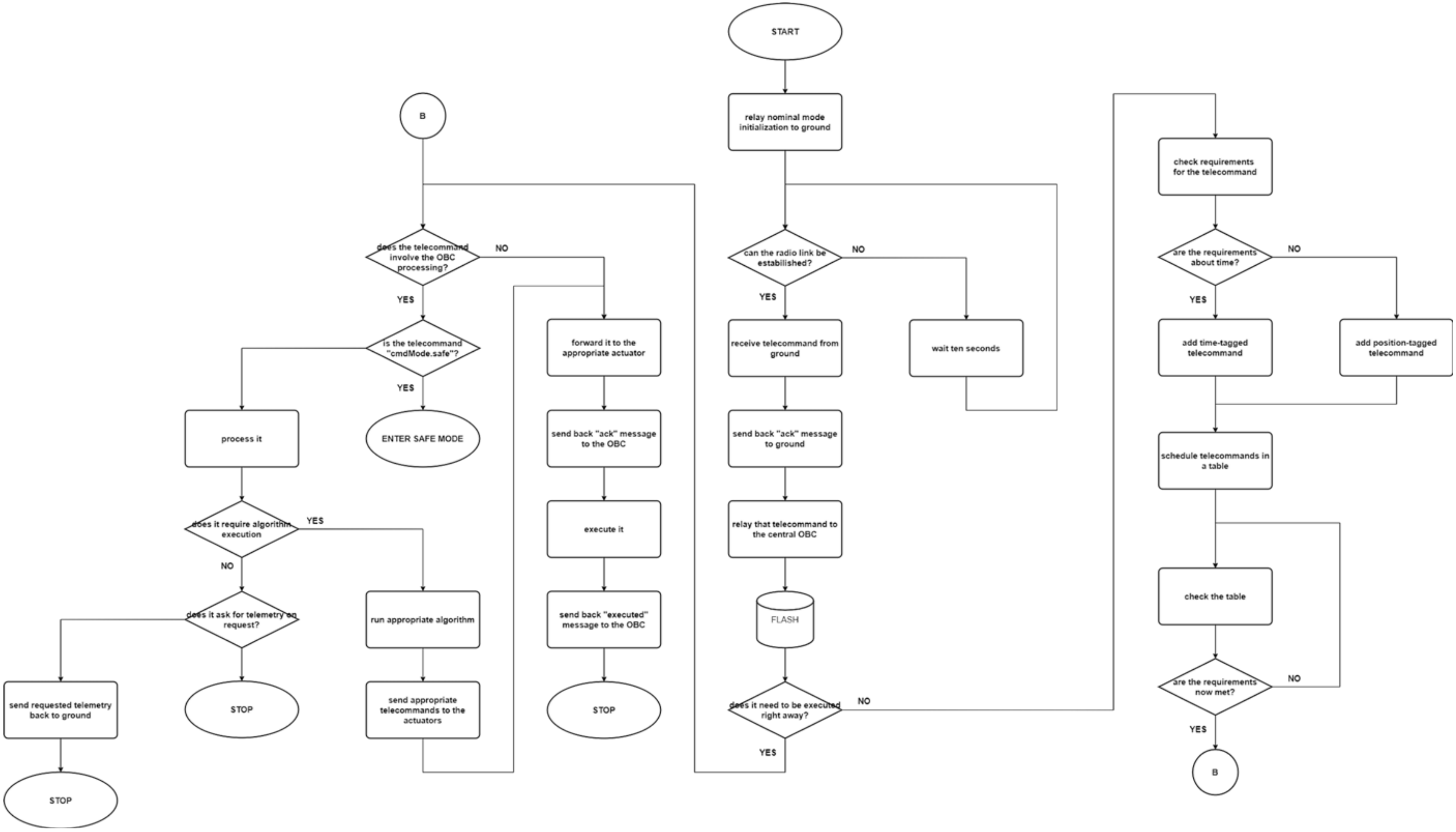
Memory budget (3/3)

SYSTEM	SENSOR	NUMBER	FREQUENCY (Hz)	BITS	DATA RATE (bps)
PAYLOAD	GSS receiver	1	5	64	320
AODCS	Magnetometer	1	5	72	360
	Star tracker	1	5	256	1280
	Sun sensor	1	5	64	320
	Gyro IMU module	1	5	128	640
	Magnetorquer	3	5	8	120
	Reaction wheel	1	5	8	40
	Electric Thruster	2	5	8	8
THERMAL	Temperature measurements	30	0,1	16	48
EPS	Voltage measurements	10	0,	16	16
	Current measurements	10	0,1	16	16
	Battery state	15	0,1	16	24
OTHER	Status bits	30	0,1	1	
OBDH	Central OBC	1		194	
	AODC dedicated OBC	1		80	
TOTAL				1976	3267

Thank you for attending

OBDH subsystem for the HYONOSAT project

Operation (4/4)



Market Analysis

Model Name	NanoMind A3200	ABACUS 2017
Supplier	GomSpace (Denmark)	GAUSS (Italy)
CPU rate	8MHz – 64 MHz	up to 25 MHz (MSP430) and 25/100 MHz (FPGA)
RAM	32kB FRAM +32 MB SDRAM	2 MB SRAM (FPGA)
Storage	512Kb (CPU) + 128 MB	2x 16 MB
Interfaces	2x I2C, UART, CAN, 7x GPIO, USB	34x GPIO, 8x GPI, 4x COM, 2x I2C, SPI
Size	65 x 40 x 7.1 mm (NanoMind)	90.1 x 95.9 x 23.2 mm
Mass	24 g (NanoMind)	62 g

Product Name	Memory (97D2H8G64)	Memory (69F64G16)	Memory (28LV010)
Supplier	DCC (USA)	DCC (USA)	DCC (USA)
Type	DDR2 SDRAM	FLASH	EEPROM
Non-Volatile	NO	YES	YES
Op. Voltage	1.8 V	1.8 V	3.3 V
Density	8 Gb	64 Gb	1 Mb
Configuration	128M x 64	x16 NAND	128k x 8

Requirements (1/1)

A set of requirements is used as inputs into the design stages of OBDH development. Requirements are also an important input into the verification process since tests should trace back to specific requirements. Requirements show what elements and functions are necessary for the OBDH project.

To support the platform and Mission operations, the OBDH system shall provide the following requirements. The requirements are classified into 6 classes.