DHS ARCHITECTURE FOR HERA DEEP SPACE MISSION

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EUROPEAN DATA HANDLING & DATA PROCESSING CONFERENCE FOR SPACE EDHPC 2-6 OCTOBER, JUAN LES PINS, FRANCE

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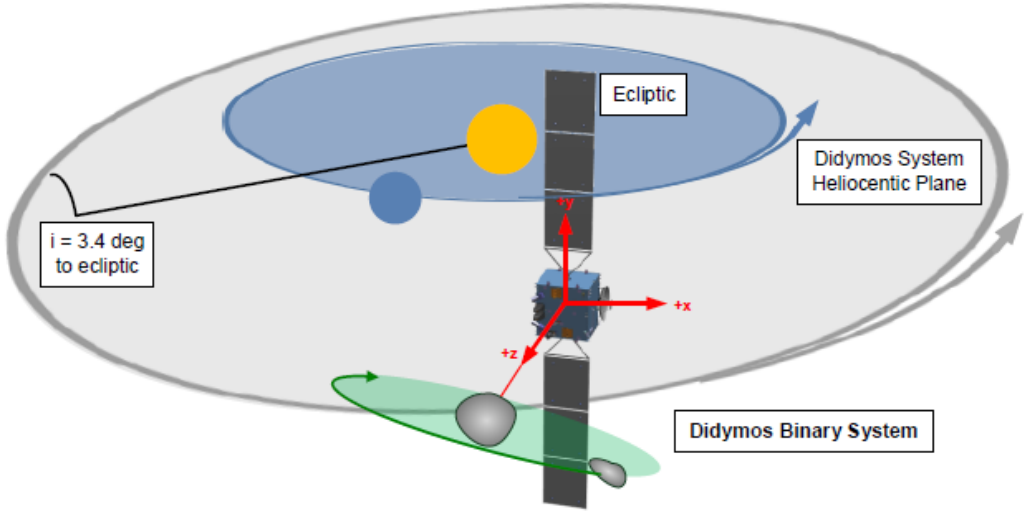
MISSION OVERVIEW & CHALLENGES (1/2)

- Hera is a deep space mission to advance our knowledge and capabilities in terms of planetary defence
- Hera is flying at a maximum distance of 2.36 AU from Sun and 3.34 AU from Earth.
- Autonomy and reliability are key drivers for the SC design.
- Due to the orbit of Didymos, next favourable launch opportunity is in 2024, which makes Hera a schedule critical mission
- No S/C ever closely observed a binary asteroid from vicinity
- Dimorphos will be the smallest body ever that a S/C has observed in close proximity



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MISSION OVERVIEW & CHALLENGES (2/2)

- **Data volume & return**:
  - Data return strategy strongly depends on the low data rates achievable with the X-band RF system.
  - Downlink windows of at least 8h per day (net duration) must be foreseen, putting a load on the ESTRACK Deep Space Antennae.
  - Rather large amounts of science data that might have to be stored on the SC mass memory before transmitting to Earth.
- **Operational autonomy:**
  - The SC must provide a degree of autonomy beyond typical levels required for Earth-bound satellites.
  - one-way light-time goes up to 28 minutes during the mission.
- **GNC autonomy:**
  - To acquire high-resolution images of Dimorphos with the given instrumentation, the SC must approach the surface of the asteroid to below 1 km for a resolution of 10 cm.
  - GNC autonomy is required with sophisticated on-board feature-tracking techniques and the capability of performing collision avoidance manoeuvres autonomously.

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DOWNLINK OPERATIONS (1/4)

- The downlink capability largely depends on the distance to Earth during the different mission phases. The RF capability has been analysed assuming the following constraint:
  - Earth distance and its resulting link capability
  - High Gain Antenna (HGA) antenna with 0.5 deg offset angle
  - Cumulative Distribution (due to weather condition)= 95%
  - Lowest elevation of 10 deg at the ground station
  - Frame error rate for Downlink of 1e-5
  - Worst-case ESTRACK DSA assumed (New Norcia)

Scenario	Distance [AU]	Travel time of the signal [Minute]	Signal Rate [sps]	Generation Packet time [Minute]	Total [Minute]
Maximum Distance	3.35	27.8	32.2	18.55022	46.4
Maximum OPS	2.10	17.5	60241.2	0.00991	17.5
Minimum OPS	1.17	9.7	400000.2	0.00149	9.7

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DOWNLINK OPERATIONS (2/4)

Traffic Analysis:

- 3 main categories of data defined: HK, Navigation and Science, and a subsequent subset for the cubesat data, present on this mission.
- HK and Navigation data was defined as the minimum traffic that needs to be granted all time.
- Based on these categories, traffic was analysed to obtain the on-board generated data volume, the required symbol rate for downloading and the necessary mass-memory size for buffering the excess data

Category	Description	Time OPS [hours]	User rate [bps]	User Volume [bits]	Symbol Volume [symbols]	Symbol Rate [sps]
HK	House Keeping Telemetry	24	2.000E+3	172.800E+6	803.575E+6	27.902E+3
NAV	Navigation images	16 images @ 8 bit 4 images @ 12bit		183.110E+6	851.522E+6	29.567E+3
CUB_NAV	Cubesat: HK + NAV	24	1.157E+3	100.000E+6	465.032E+6	16.147E+3
Sub TOT	Total operational data volume		6.439E+3	455.910E+6	2.120E+9	73.616E+3
SCI	Science data	15.5	4.768E+3	266.082E+6	1.237E+9	42.964E+3
CUB_SCI	Cubesat: SCI	24	1.157E+3	100.000E+6	465.032E+6	16.147E+3
Sub TOT	Total data volume		12.365E+3	821.992E+6	3.823E+9	132.727E+3

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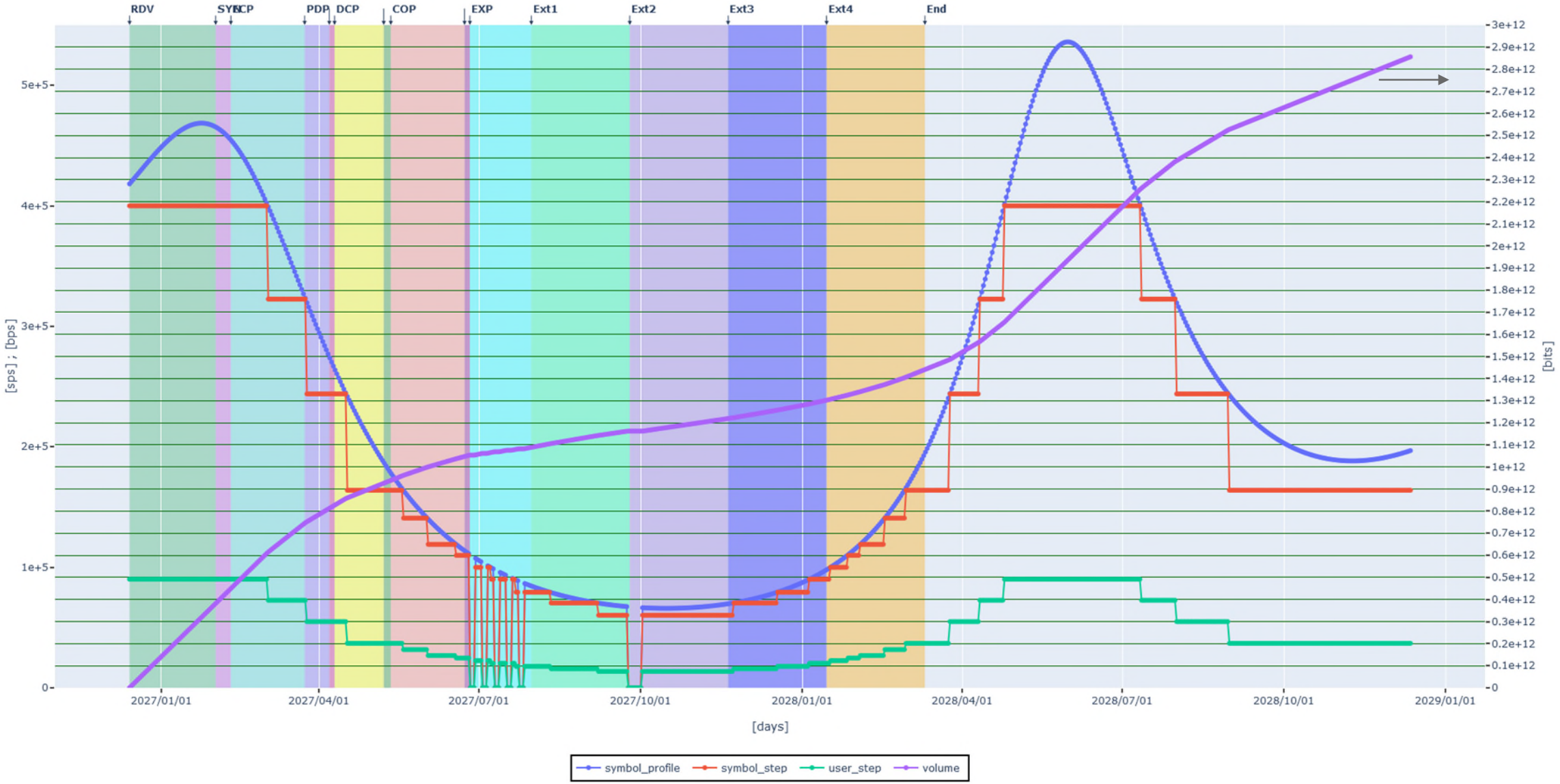
DOWNLINK OPERATIONS (3/4)



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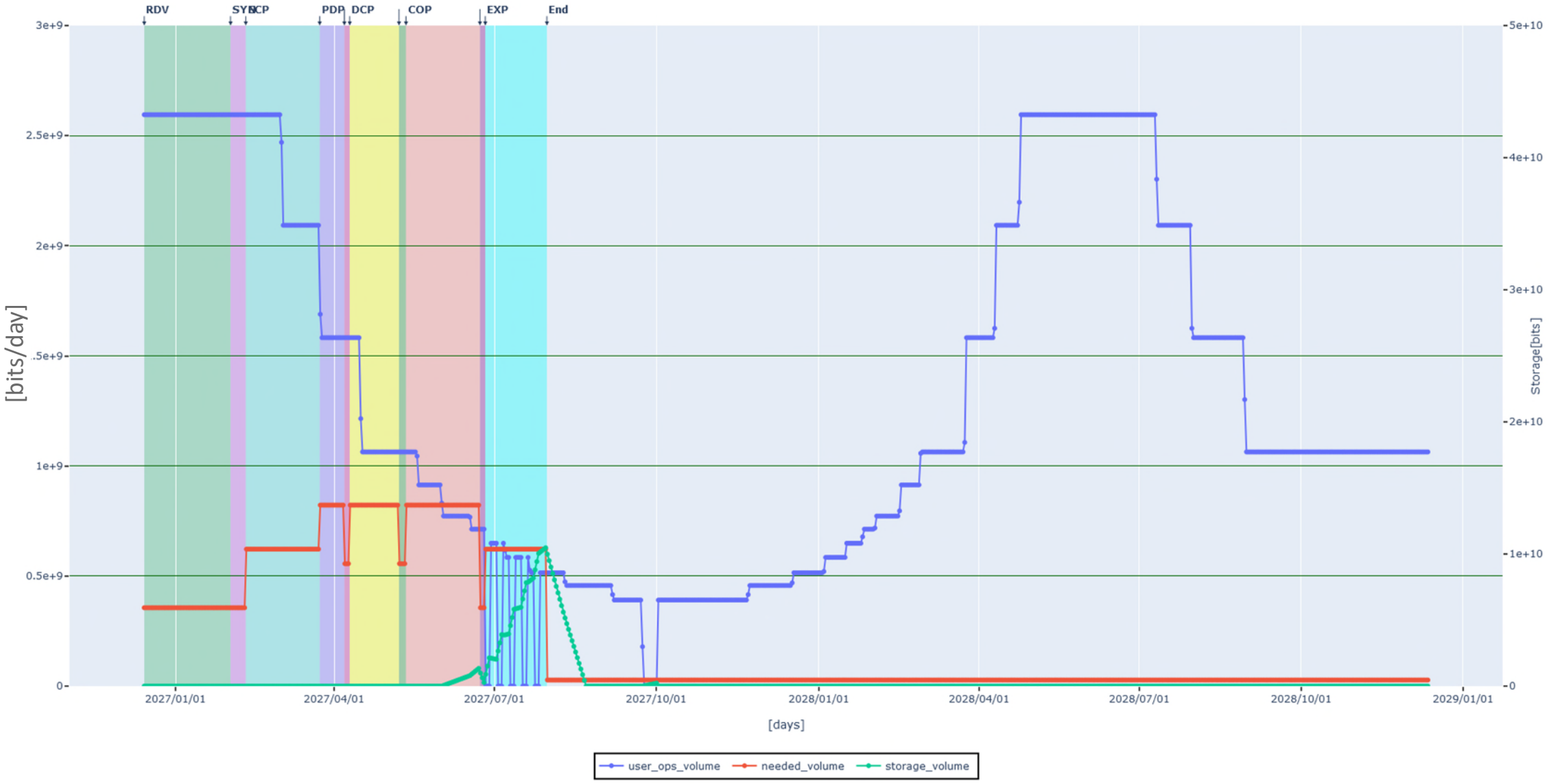
DOWNLINK OPERATIONS (4/4)



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GNC AUTONOMY (1/2)

- **Asteroid Framing Camera (AFC)**
  - Hera mission navigation and guidance will be based mainly in autonomous system.
  - During asteroid (Dimorphos) fly-by, **high-resolution (<10cm)** images of 100m x 100m will be taken to perform on-board feature-tracking techniques and approximation centroiding techniques.
  - Asteroid Framing Camera (AFC) is selected since it is capable to operate in visible and near infrared wavelength range spectrum.
  - AFC is considered as critical mission element because it provides key data for science and navigation purposes.
  - AFC can provide images with a bit depth of maximum 12 and minimum 8.
  - AFC has a non-standard SpW interface (without FCT) for image transmission and TM/TC communication and connects directly to the MMU

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GNC AUTONOMY (2/2)

- GNC requires for the feature tracking algorithm at least one image every 48 s
- Operational constraints:
  - In the close vicinity of Didymos the AFC shall provide non-saturated images from the resolved asteroid surface under the specified illumination conditions, brightest case (closest to the object as well as closest to the Sun) >> drives the minimum required exposure time as low as 224µs.
  - AFC is not able to buffer SpW packets, but instead spills them out at maximum SpW speed

As a consequence, there is a specific relation between exposure time and transmission duration of the packet via SpW.

Speed	Bit depth [bits]	Packet size [bits]	Tx time [us]
40Mbps	8 bits	8232	274.4
40Mbps	12 bits	12328	410.9
80Mbps	8 bits	8232	137.2
80Mbps	12 bits	12328	205.5

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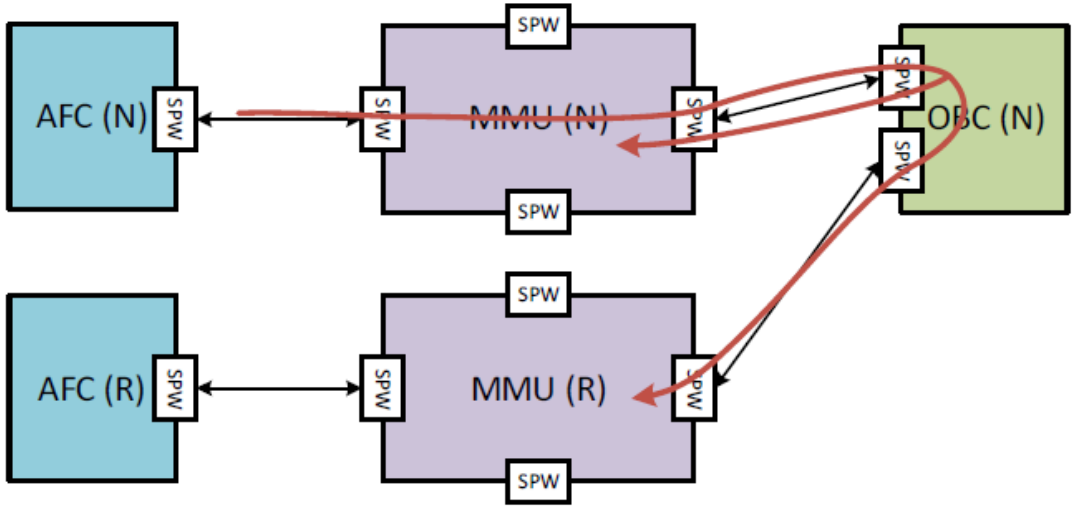
DHS ARCHITECTURE & SPW NETWORK (1/3)

- **Architecture drivers:**
  - AFC unit only provides one single SpW interface. Therefore, architecture shall support cross-strapping & redundancy of MMU
  - in order to be SPF, the MMU is designed to operate in hot redundancy
- The selected architecture allows reformatting of PL packets and duplication of data.
- **Drawback**: the OBC is in charge of pre-processing, memory scrubbing and data distribution >> **higher CPU Load**



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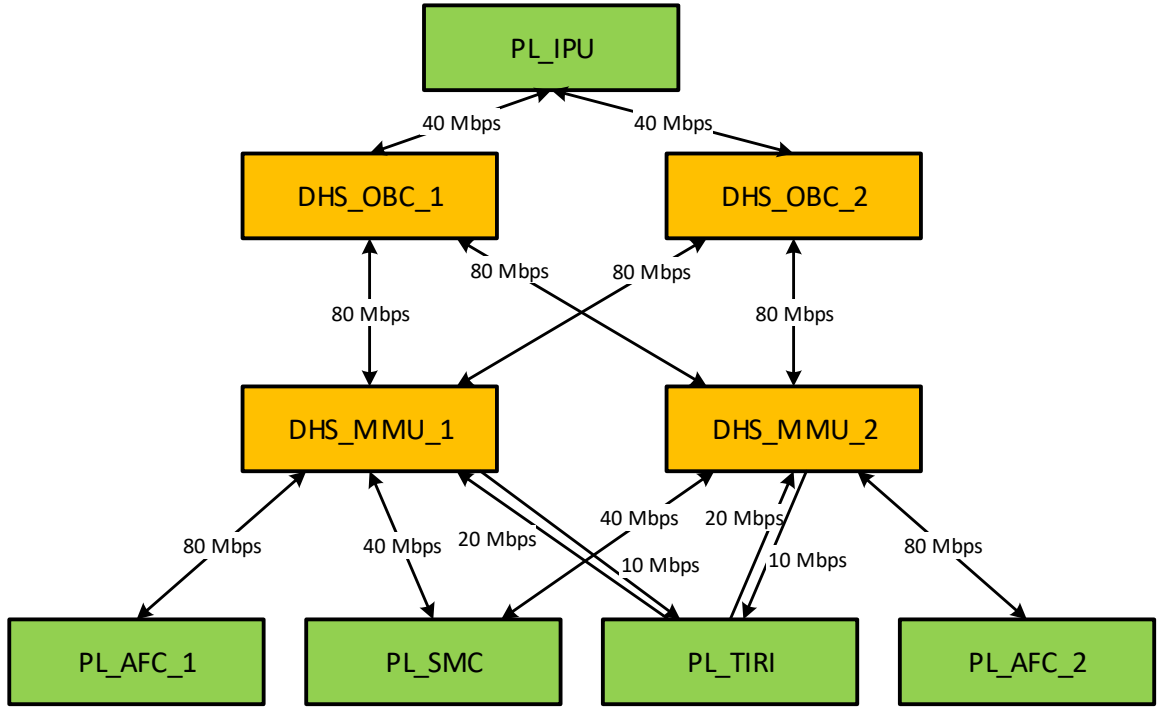
DHS ARCHITECTURE & SPW NETWORK (2/3)

- SpW Network Overview:
  - The whole HERA SpW network comprises several nodes, routers and paths, where data is transferred with different links speeds
  - Both logical as well as path addressing are used. Link speeds have been selected to fulfil the main mission goals



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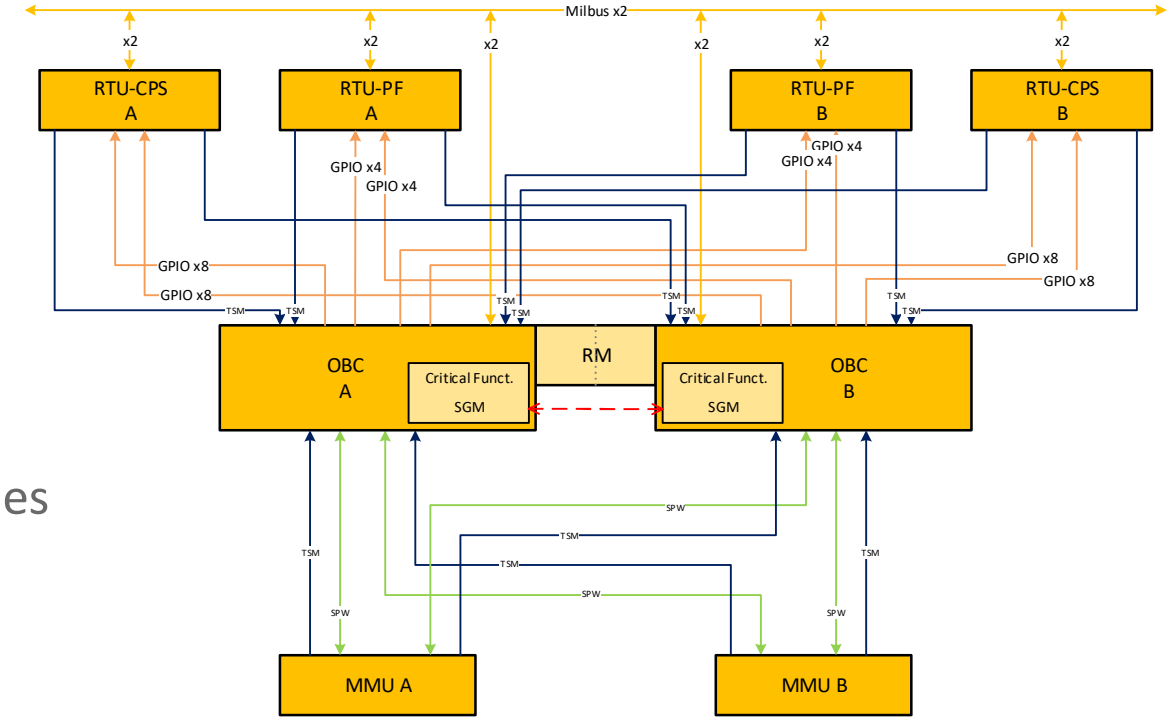
DHS ARCHITECTURE & SPW NETWORK (2/3)

- DHS Architecture Overview:
  - The DHS subsystem proposed for this mission consists of redundant architecture composes by an **OBC**, **mass-memory unit**, and **two RTUs**
  - Following communications standards implemented: **MIL-BUS 1553B, SpW and UART.**

- **OBC**
  - GR712RC which includes a dual-core LEON3FT (Fault-Tolerant) Large-scale companion FPGA RTG4 for peripheral control
- **MMU**
  - 2 independent halves in hot redundancy.
  - GR718B Spacewire Router (5 ports)
  - Nand-Flash Memory for non-volatile data storage of 512 Gb
- **RTU:** configurable assembly of core and IF modules
  - CMH module (core module for power supply, Mil-Bus & HPCs)
  - TAM module (interface modules for all analogue acquisitions)
  - ACM module (interface module for reaction wheel C&C)
  - OCMR modules (interface modules for propulsion IF)



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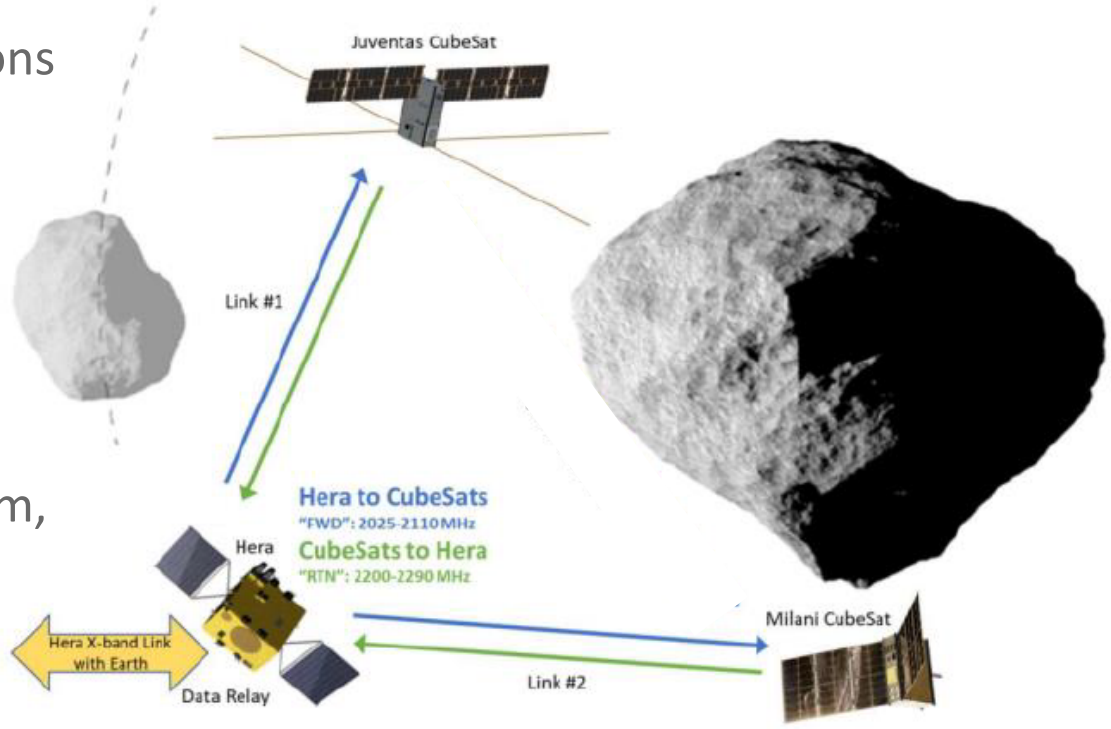
ISL

- The Inter-Satellite Link (ISL) system provides communications between Hera main spacecraft and all the deployable elements creating a local network in Deep Space.
- The network is composed by Hera main spacecraft as key node being the only element able to perform communication to/from Earth, and two CubeSats
- To reduce SW complexity for Hera main S/C to the minimum, it acts as a space-to-ground relay for the CubeSats, being transparent for the CubeSats



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CONCLUSIONS

- Main constraint on deep space mission is the distance, which drastically limits the communication to earth and impacts the time windows >> definition of minimum transmission scenarios
- Storage capability shall be designed accordingly to prevent data loss.
- Mission requires highly autonomous systems to reduce the need for frequent ground contacts.
  - >> powerful OBC needed to process science and navigation data
  - >> sophisticated SpW network required to allow for autonomous transmission of all data to the various targets

THANK YOU!

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