EDHPC 2025

EUROPEAN DATA HANDLING & DATA PROCESSING CONFERENCE FOR SPACE

EDHPC2025 paper presentation:

Modular and Scalable Electrical Architectures for Satellite On-Board Data Handling and Processing – using ADHA (Advanced Data Handling Architecture)

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Presentation Scope and Overview

ADHA has already provided standardisation of some DHS functions (OBC, MM, etc).

An expansion of DHS functions to be standardised under ADHA is currently planned.

This paper presentation aims to provide possible examples of end-to-end data-handling / avionics architectures for representative mission profiles based on ADHA units, and module functions currently considered for standardisation under the ADHA-3 system study activity.

More details are included in the provided technical paper.

Presentation sections:

1. Standardised ADHA data-handling functions
2. Example unit architecture configurations
3. End-to-end data-handling system / avionics architectures based on ADHA units

1. ADHA standardised DHS functions

ADHA standardised DHS functions – current

ADHA standardises DHS functions as Module Functional Requirements Specifications.

Module Type	Module Sub-Type	Slot Profile
Power Module	-	Power Module Slot
OBC Module	OBC Processor Module	System Controller Slot
	OBC Extension Module	System Controller Extension Slot
Mass-Memory Module	Mass-Memory Master Module (MMM)	Extended Peripheral Slot
	Mass-Memory Extension Module (MEM)	Peripheral Module Slot
Data-Processing Module	-	Peripheral Module Slot

The currently standardised module functions include:

- **Power Module** – provides backplane power buses
- **OBC Module** – complete SAVOIR-compliant OBC
    - Possible to split over several modules – up to supplier!

- **Mass-memory** – complete (payload) mass-memory
    - Reference architecture split between MM master module and MM extension (storage) module)
- **DPM (Data Processing Module)** – for high-end (payload) data processing
    - Can also be provided as for co-processor, off-loading a payload ICU or platform OBC for processing tasks

ADHA standard DHS functions under consideration – platform

Module type	Profile Type	Short description	HW roadmap
RTU Controller Module	System Controller Slot	Provides control function for free-standing RTU unit, or for offloading OBC	Under dev.
RTU Generic I/O Module	Peripheral Slot	Generic I/O for thermistors, heaters, HPCs, etc. (similar to ICU Generic I/O module)	Under dev.
RTU AOCS I/O Module	Peripheral Slot	For interfacing AOCS sub-system (MAG, MTQ, RW, sun-sensor, etc.)	Under dev.
RTU Propulsion I/O Module	Peripheral Slot	For interfacing the propulsion sub-system	Under dev.
GNSS Receiver Module (GNSSRxM)	Peripheral Slot	GNSS (Galileo, GPS, etc) receiver	TDE ITT
TTC Transponder Module	Peripheral Slot	TTC transponder / radio (SDR)	GSTP Compen.
Payload Transmitter Module	Peripheral Slot	Payload transmitter / radio (SDR)	GSTP Compen.
Security Module	Peripheral Slot	Additional security functions (authentication, encryption, etc)	TBA

ADHA standard DHS functions under consideration – payload

Module type	Profile Type	Short description	HW roadmap
ICU Controller Module	System Controller Slot	Provides control of instrument/payload, instrument applications SW (IASW), interface to platform,	GSTP Compen.
ICU Generic I/O Module	Peripheral Slot	Generic I/O for thermistors, heaters, HPCs, etc. (similar to RTU Generic I/O module)	GSTP Compen.
Payload Power Module	Power Slot	High-end power module for highly dissipative units (500-1000W)	GSTP Compen.
Payload Power Distribution Module	Peripheral Slot	For distributing power to external payload units (e.g. sensor front-end, etc)	Future
Optical FEE I/O module	Peripheral Slot	For interfacing with optical sensors / FEEs, both analogue and digital output sensors	Future
RF Digital Backend module	Peripheral Slot	Provides digital backend for RF payloads, including ADCs/DACs, buffering, processing and synchronisation	Future

Flexibility in ADHA module design – mezzanines

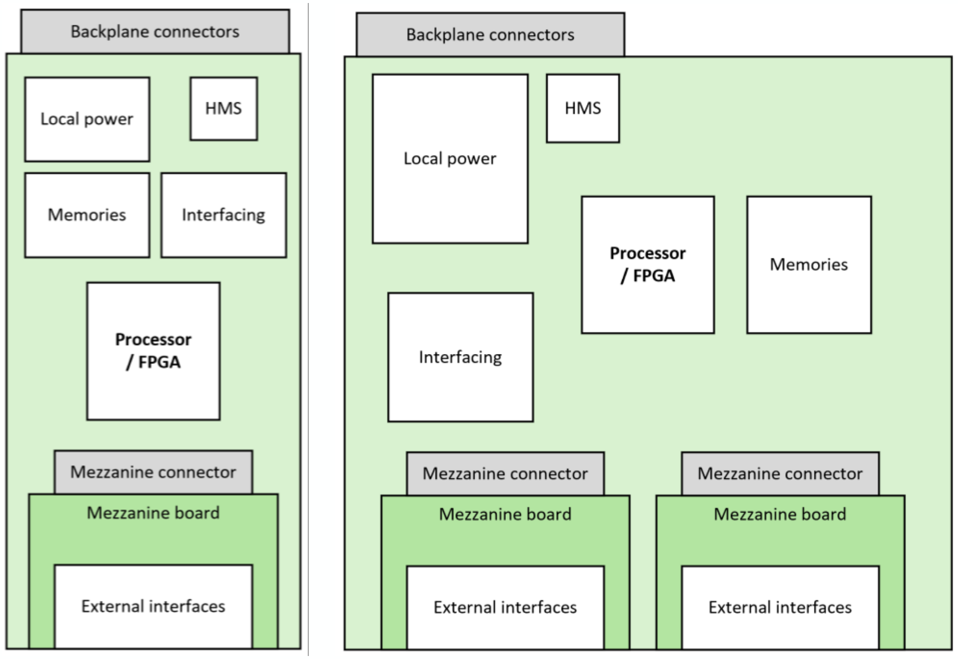
Note that it is possible to support multiple different ADHA DHS functions with a single hardware design!

Due to the standardised backplane interfaces, the same core hardware configuration can be kept – while adapting for specific DHS functions by:

- Changing the SW and FPGA design
- Adopting the front-panel interfaces

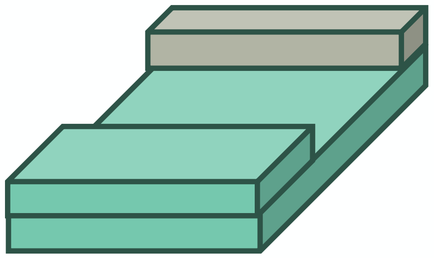
To make updating the front-panel interfaces more affordable – ESA plans to develop and qualify very-high performance (10-25Gbit/s/lane) mezzanine connectors, with high-pin count (>100 pins), for board-to-board configurations

- This allows to change the front-panel interfaces, without impacting the TRL of the core module design (including processor/FPGA, power, backplane interfaces)



3U 6U

Example ADHA modules with mezzanine boards



2. Example ADHA unit configurations

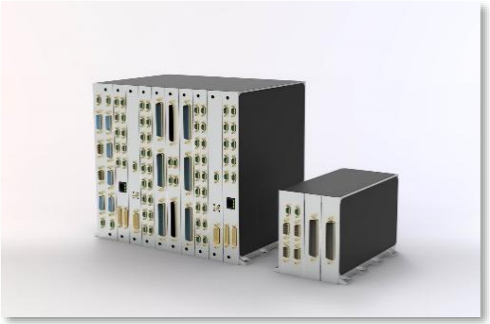
Example ADHA Unit Configurations

In the following slides, we will go through some possible example configurations of ADHA units – based on the standardised module functions described in the previous section.

…including the ones that are considered for future standardisation.

Examples:

1) Central Data Handling Unit (CDHU) – for institutional EO mission
2) Fully integrated platform DHS – for integrated platforms
3) Payload Data Handling Unit (PDHU)
4) Instrument Controller Unit (ICU)
5) Data Processing Unit (DHU)
6) Integrated instrument electronics



ADHA unit configuration example 1)

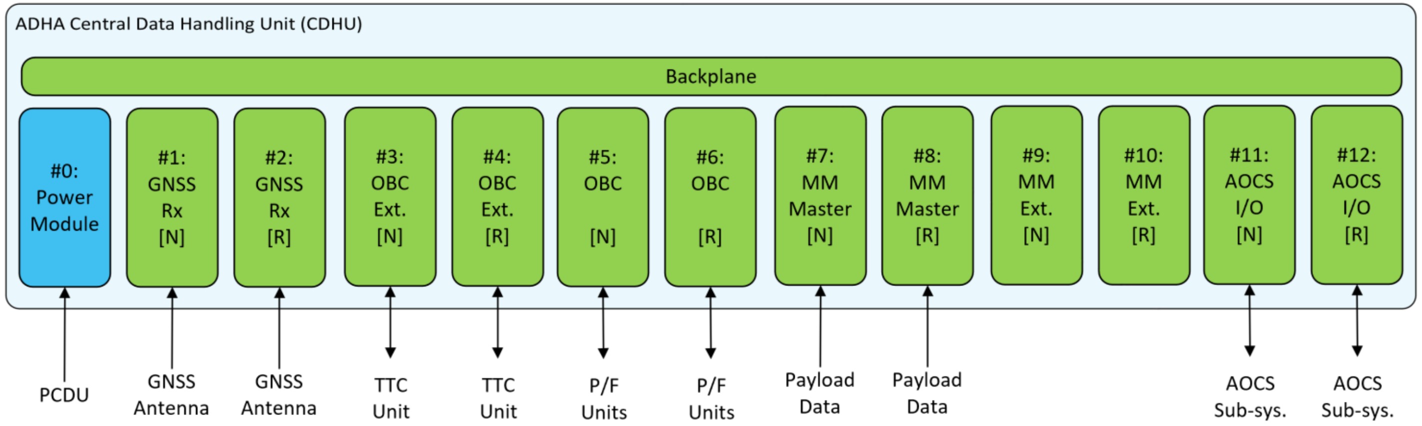
12-slot 6U-ADHA Central Data Handling Unit (CDHU)

The following CDHU (Central Data Handling Unit) integrates both platform and payload data handling in a single unit:

- Full platform OBC
- GNSS Receiver
- I/O Modules for AOCS
- Full payload Mass-Memory

Slot #	Module type	Redundancy
0	Power Module	Internally redundant
1-2	GNSS Receiver Module (GNSSRxM)	N+R
3-6	On-Board Computer (OBC)	N+R
7-8	Mass-Memory Master Module (MMM)	N+R
9-10	Mass-Memory Extension Module (MEM)	N+R
11-12	RTU AOCS I/O Module	N+R

Note: excepts additional external (u)RTU for propulsion sub-system, and thermistor acquisition – if necessary.



Options:

- AOCS I/O can be replaced with e.g. additional MM
- …or removed for a smaller 10-slot unit.

Possible optimisation:

- N+R GNSSRxM in a single slot (#1) with 2x FCGs
- …would allow a possibility to add a transponder (also 2xFCGs) in the open slot (#2)

ADHA unit configuration example 2)
Complete platform DHS

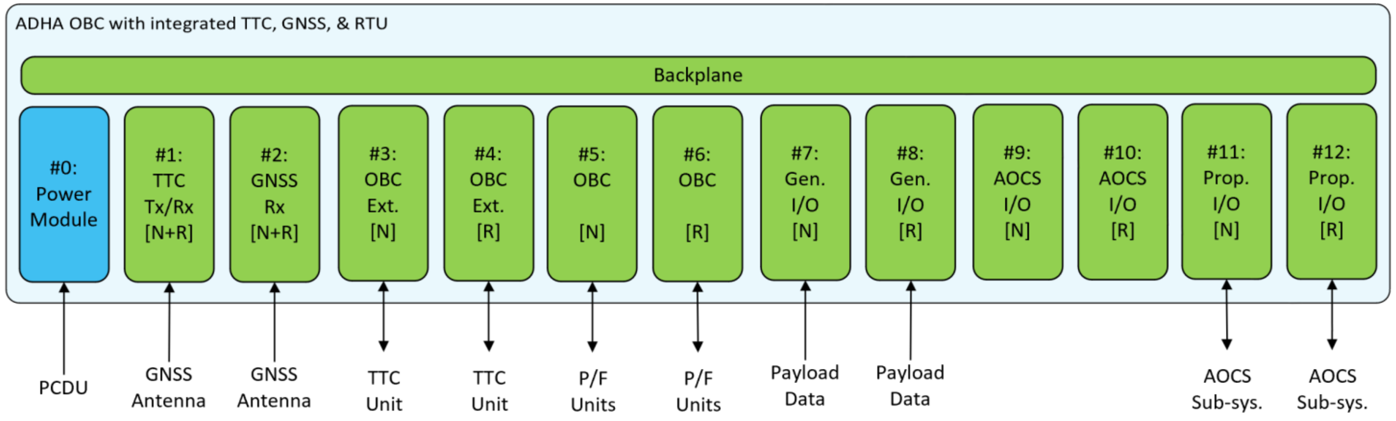
Targets a fully integrated platform functions is a single unit – suited for more integrated spacecraft configurations, that do not need to place RTU functions close to AOCS and propulsion sub-systems for harness management.

Note: expects payload data to be handled by external unit (e.g. PDHU)

Integrates:

- OBC
- TT&C Transponder
- GNSS Receiver
- RTU functionality – generic I/O, AOCS I/O and propulsion sub-system I/O

Slot #	Module type	Redundancy
0	Power Module	Internally redundant
1	TT&C Module	N+R (2FCGs)
2	GNSS Receiver Module	N+R (2FCGs)
3-6	On-Board Computer (OBC)	N+R
7-8	RTU Generic I/O Module	N+R
9-10	RTU AOCS I/O Module	N+R
11-12	RTU Propulsion I/O Module	N+R



Utilises 2xFCGs in slots #1-#2 for TT&C transponder and GNSS Receiver.

ADHA unit configuration example 3)

Stand-alone Payload Data Handling Unit (PDHU)

This example PDHU (Payload Data Handling Unit) targets the complete management of payload data

Integrates:

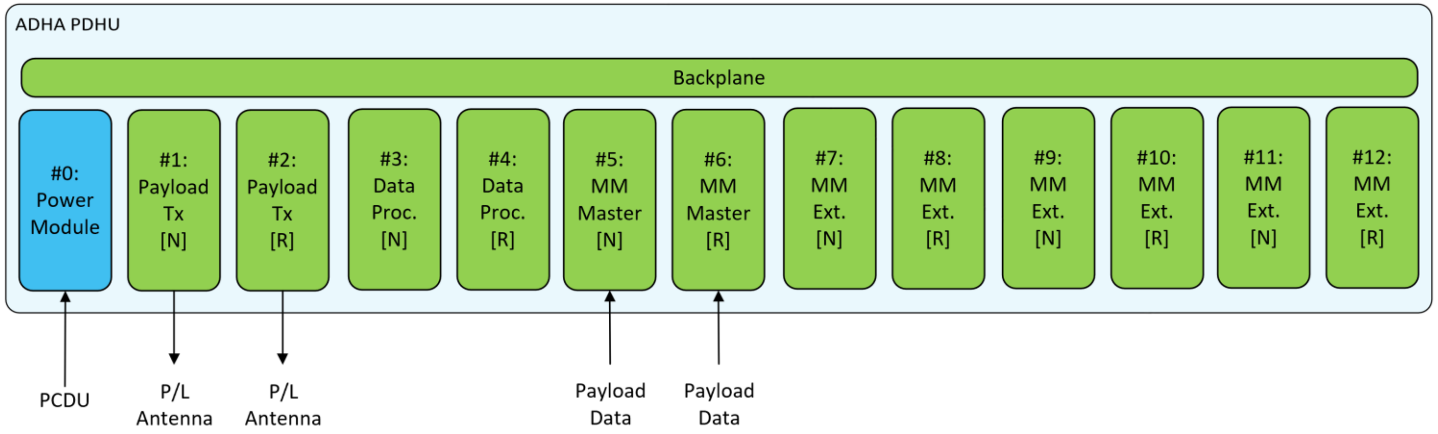
- MM master controller and memory slices
- Data processing module
- Payload transmitter radio

The number of MEM slices and/or DPMs can be adapted for the specific mission need.

Redundancy concept can also be adapted for the reliability: both N and R master-modules, have access to all (six) MEM slices – in principle all can be activated at the same time.

Possible optimisation: data processing can be provided by the MM master module.

Slot #	Module type	Redundancy
0	Power Module	Internally redundant
1-2	Payload Transmitter Module	N+R
3-4	Data Processing Module (DPM)	N+R
5-6	Mass-Memory Master Module (MMM)	N+R
7-12	Mass-Memory Extension Module (MEM)	3*(N+R)

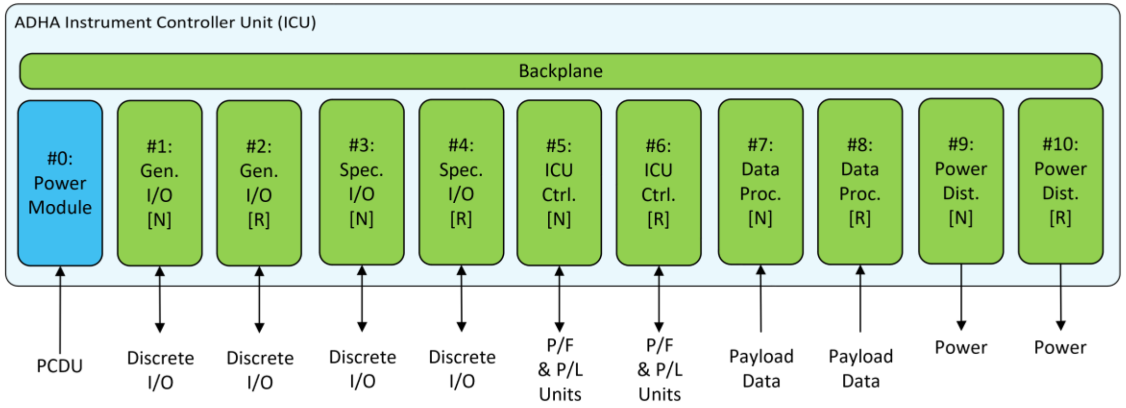


ADHA unit configuration examples 4) and 5)
Instrument Controller Unit (ICU) – and dedicated high-performance DPU

Instrument Controller Unit (ICU) includes:

- ICU control, generic and specific I/O functions (motor control, heaters, thermistors etc), power distribution for external payload units, and payload data processing.

Slot #	Module type	Redundancy
0	Power Module	Internally redundant
1-2	ICU Generic I/O Module	N+R
3-4	Custom payload-specific I/O module	N+R
5-6	ICU Controller Module	N+R
7-8	Data Processing Module (DPM)	N+R
9-10	Payload Power Distribution Module	N+R

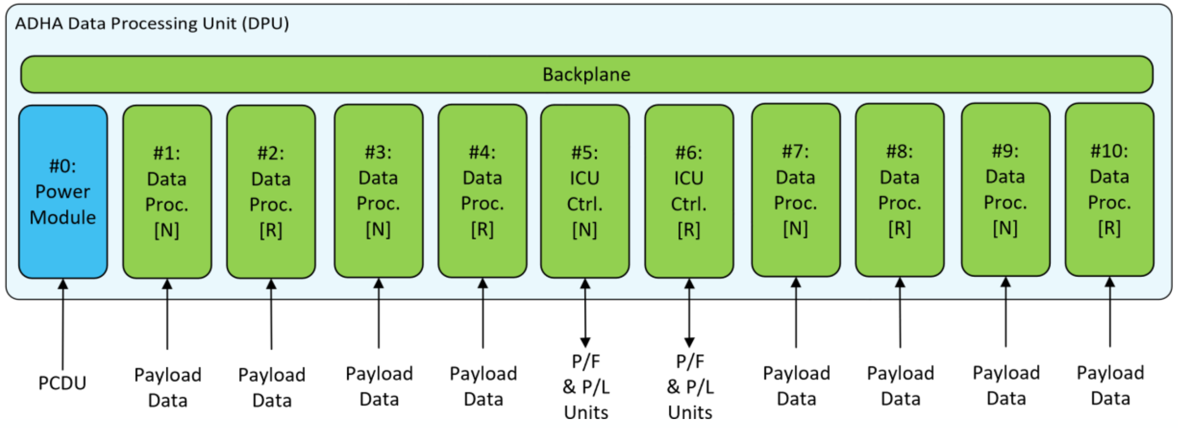


Data Processing Unit (DPU)

- For a very high-throughput payload (e.g. multi-sensor or SAR radar)

Integrates multiple DPMs (data processing modules) – scalable between 1-10 per unit (here shown with 8x).

Slot #	Module type	Redundancy
0	Payload Power Module	Internally redundant
1-4	Data Processing Module (DPM)	2*(N+R)
5-6	ICU Controller Module	N+R
7-10	Data Processing Module (DPM)	2*(N+R)



3U-ADHA integrated instrument electronics

A unit targeting a full instrument electronics for a less complex instrument.

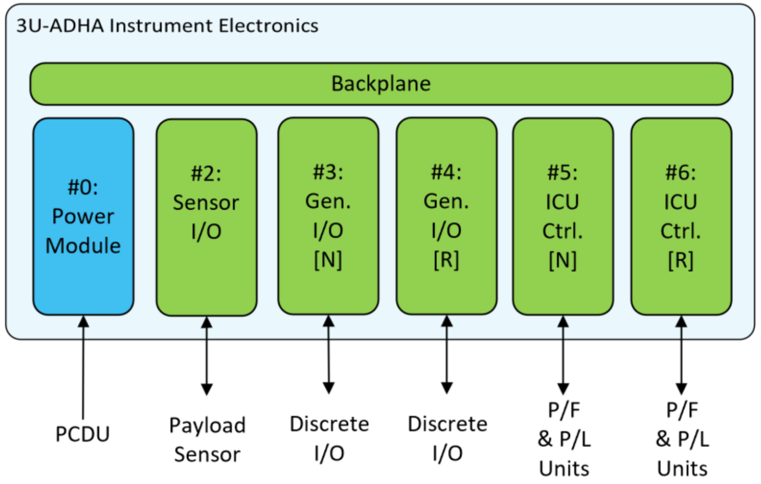
Integrates:

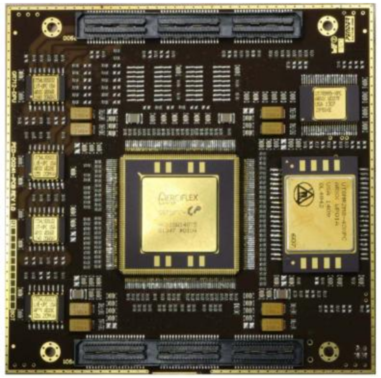
- ICU/DPU module for IASW, control and simpler processing
- Generic I/O for instrument discrete functions (e.g. payload mechanism)
- Specific (non-redundant) sensor I/O

Targets primarily science instruments developed by research institutes for ESA Science missions, as CFIs.

- Note: similar concept for a reference payload DPU reference design was e.g. used on the ESA JUICE mission.

Slot #	Module type	Redundancy
0	Power Module	Internally redundant
2	Mission-specific sensor I/O module	Non-redundant
3-4	ICU Generic I/O Module	N+R
5-6	ICU Controller Module	N+R



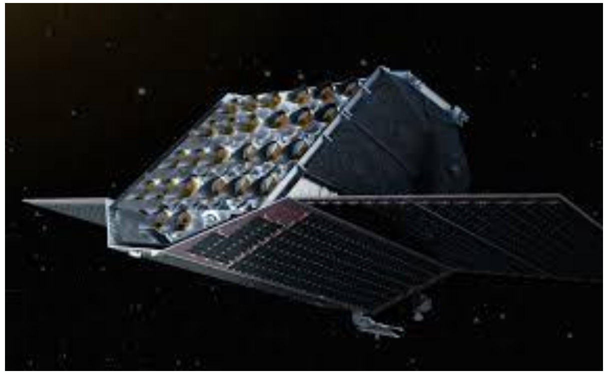


JUICE payload DPU reference design
Image source: Frontgrade Gaisler AB

3. End-to-end data-handling / avionics architectures based on ADHA units and modules

End-to-end data-handling / avionics architectures based on ADHA units and modules

In the following slides, we now present some example end-to-end data handling / avionics architectures based on the ADHA units and modules presented in the previous sections.



Examples:

1) Institutional EO mission
2) Mission with very high-rate remote-sensing payload
3) Multi-instrument science mission
4) Large-scale space telescope

ADHA-based avionics / data-handling architectures 1)
Institutional EO mission

Use-case description:

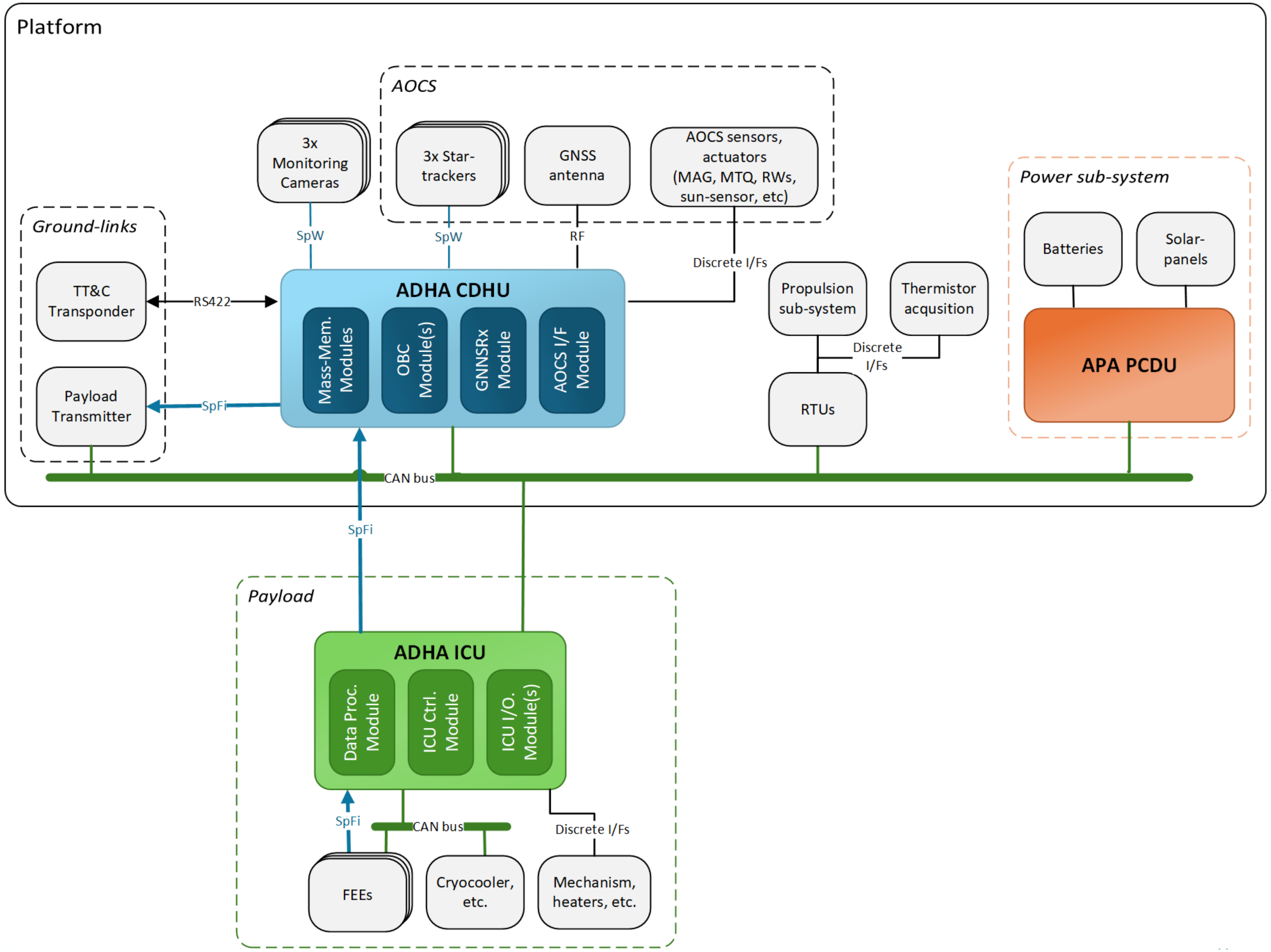
- Institutional EO mission with complex instrument, with medium data throughput

Platform:

- ADHA CDHU – for platform and payload data handling
- APA PCDU – for power conditioning and distribution
- Additional RTU(s) for propulsion etc
- External TTC transponder and payload transmitter

Payload:

- ADHA ICU – for instrument control, I/O and data processing
- Additional FEEs, cryocooler, mechanism etc



ADHA-based avionics / data-handling architectures 2)

Mission with very high-rate remote-sensing payload

Use-case description:

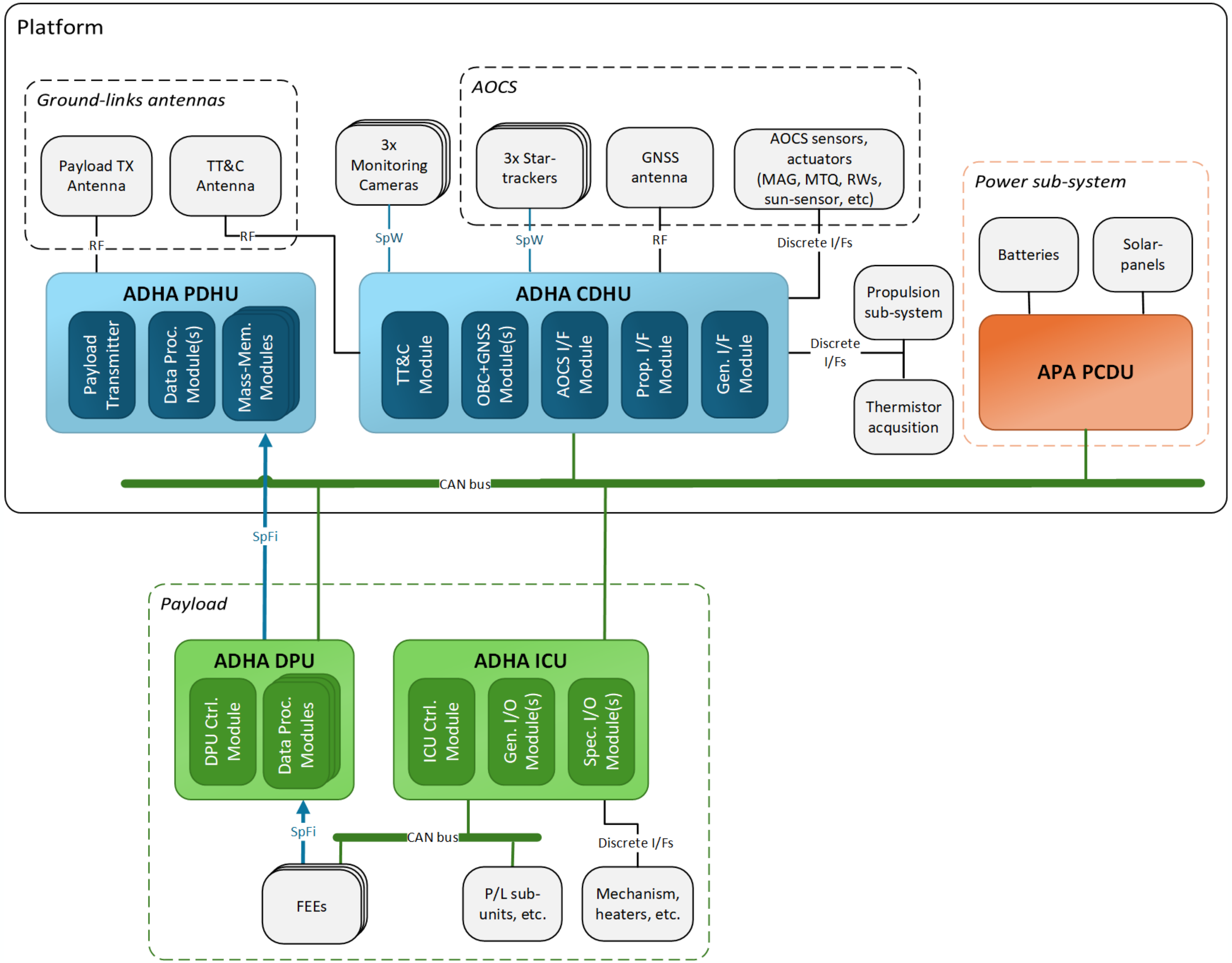
- A very high-rate remote-sensing payload (multi-sensor hyperspectral instrument, or SAR radar)

Platform:

- ADHA CDHU – for complete platform data handling (incl. GNSS, TTC, RTU)
- ADHA PDHU – for complete payload data handling (incl. payload transmitter)
- APA PCDU

Payload:

- ADHA ICU – for instrument control
- ADHA DPU – for payload data processing and synchronisation
- Additional front-end/sensor units, and mechanisms



ADHA-based avionics / data-handling architectures 2)
Multi-instrument science mission

Use-case description:

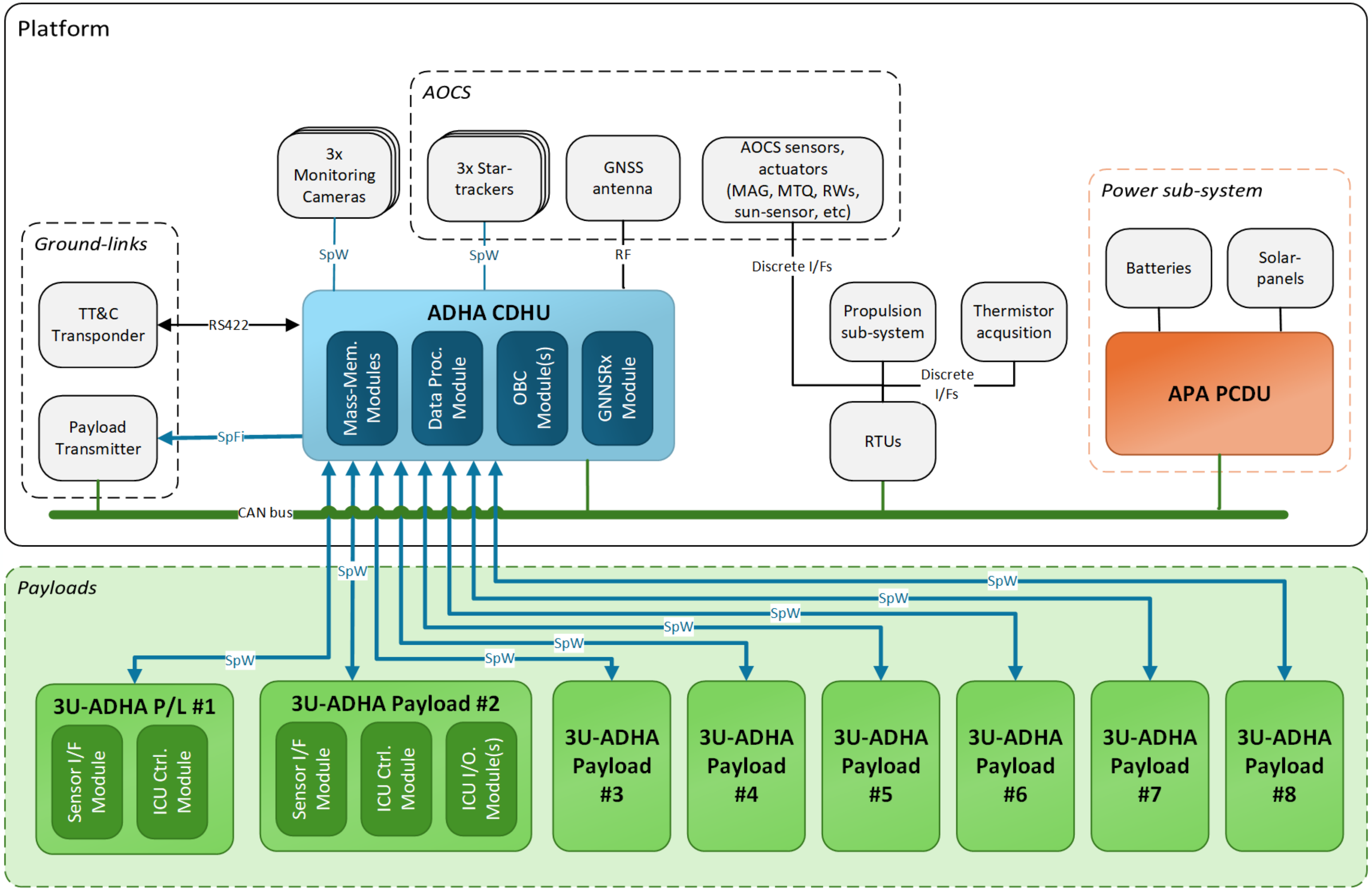
- Large-scale ESA deep-space science mission, with multiple CFI instruments from research institutes (e.g. JUICE, SolarOrbiter, BepiColombo, etc.)

Platform:

- ADHA CDHU for platform + payload data handling
- APA PCDU
- Additional RTUs, TTC transponder, payload transmitter

Payload:

- 8x 3U-ADHA based payloads
- All based on reference design



ADHA-based avionics / data-handling architectures 4)
Large-scale deep-space telescope

Use-case description:

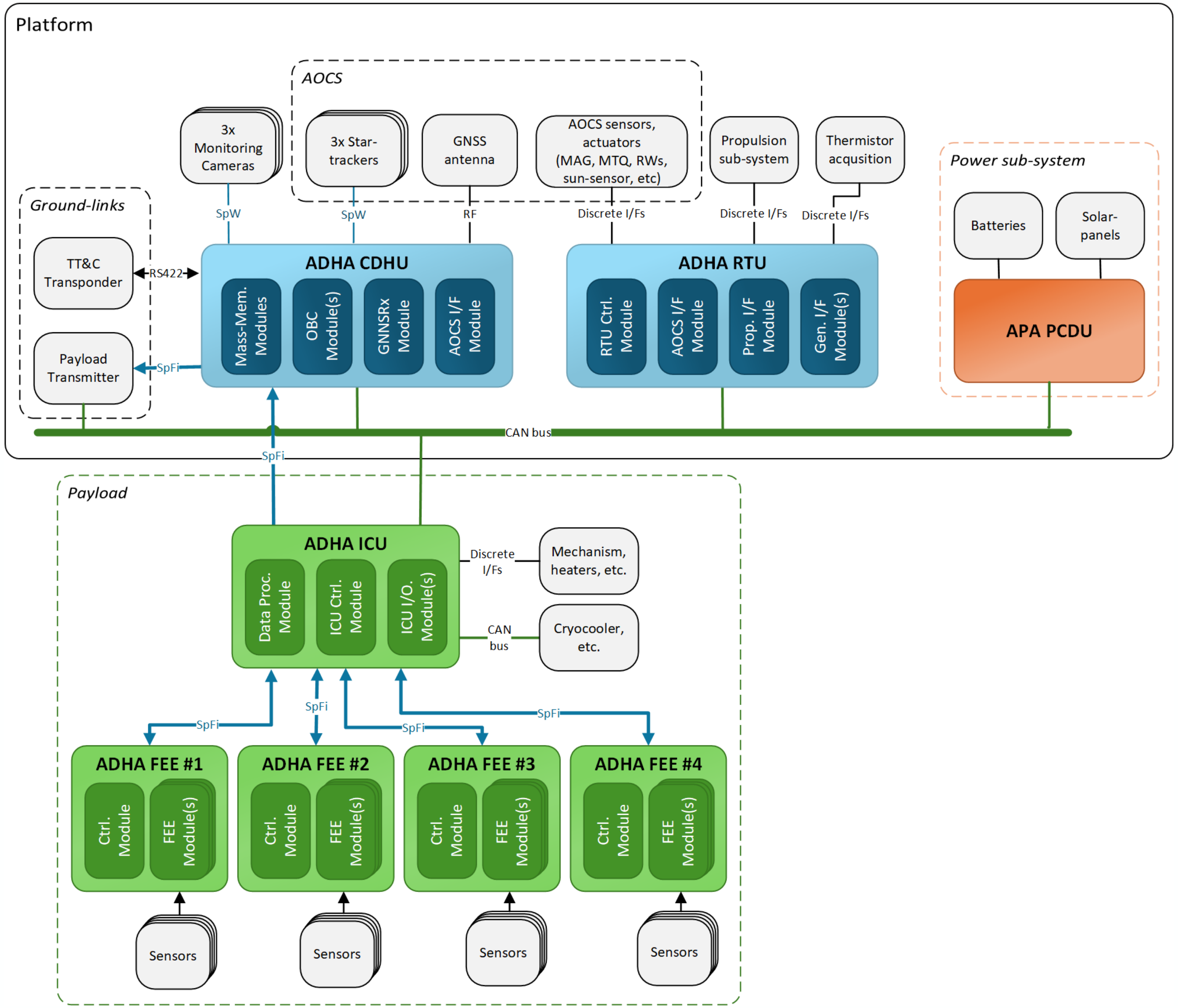
- Large scale ESA deep-space telescope (e.g. Plato, Euclid, etc.)

Platform:

- ADHA CDHU – for platform and payload data handling
- ADHA RTU – for AOCS, propulsion, discrete I/O
- APA PCDU

Payload:

- ADHA ICU – for instrument control and data processing
- 4x ADHA FEEs – for readout of multiple sensors per FEE, and data pre-processing



Summary and conclusions

Advanced Data Handling Architecture

We've shown the new planned DHS functions that are planned to be standardised as ADHA Functional Module Specifications.

- Many already under development as hardware – see next presentations within this session!

The new planned DHS specifications allows to derive different ADHA unit configurations.

- We've shown examples of different CDHU, RTU, PDHU, ICU, DPU, FEE configurations across both platform and payload DHS functions.

We've shown different DHS / avionics architectures based on the ADHA units and modules.

- Across different mission complexities and types (EO, Science, etc)

This shows that ADHA is flexible to enable different DHS / avionics configurations – pending on the preferences and designs of different satellite primes, and for different

- <u>Units can be configured with different functions - or split over multiple units – to meet needs of different mission profiles, across domains (EO, Science, Exploration, etc.)</u>

Advanced Data Handling Architecture

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