Planetary defense from a software perspective

Dr. Ir. Joffrey Coheur

Switch to Space – Palais d'Egmont

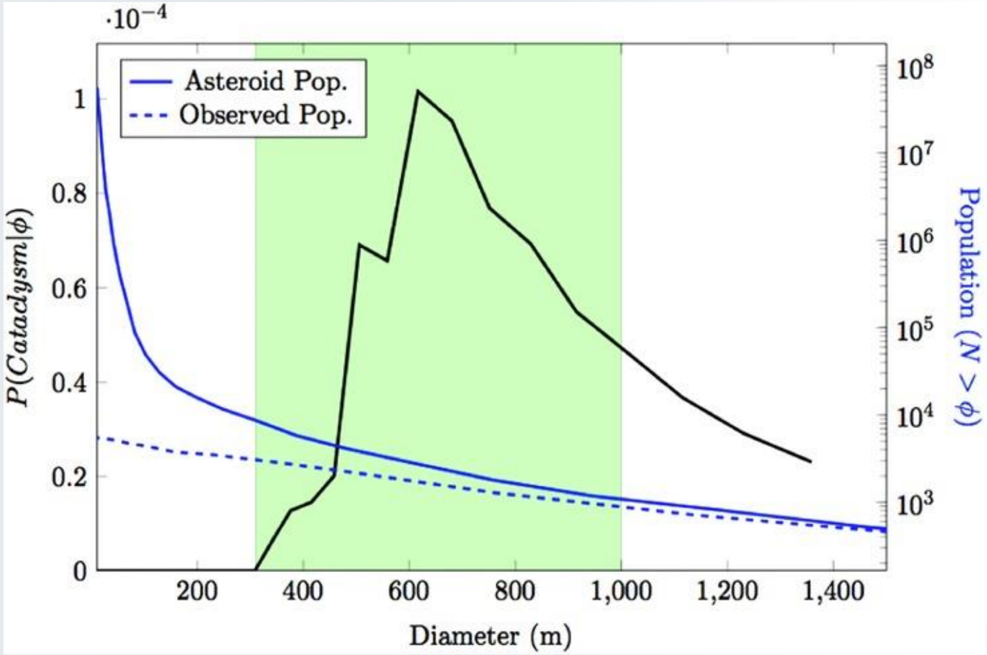
BRUSSELS – 19/10/22

COMMERCIAL IN CONFIDENCE

INTRODUCTION

Artist’s concept of asteroid impact.
Img. credit: Rada Mateescu.

Img. credit:Взрыв метеорита над Челябинском



Risk Analysis, Volume: 36, Issue: 2, Pages: 244-261, First published: 28 July 2015, DOI: (10.1111/risa.12453)

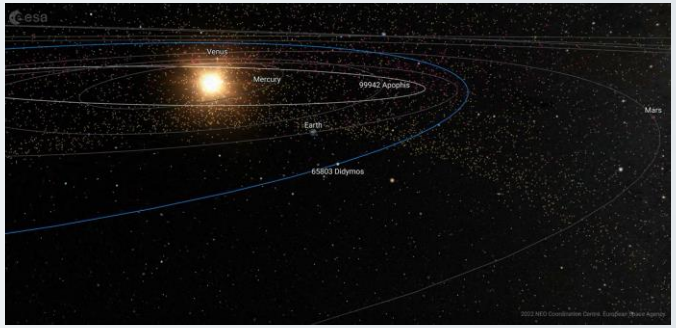
- Introduction
- Planetary defense programs
  - Objectives
  - Understanding near-Earth objects
- Spacebel contribution to satellite missions
  - The Hera program
  - On-board software
  - Simulation & modeling software
  - Mission operation center
- Conclusions & perspectives

PLANETARY DEFENSE

Example of ESA's Planetary Defense Office roadmap for Earth protection against risky near-Earth objects (NEOs)

Observation:

- Search for NEOs and map their orbits.



Orbit Visualisation Tool. Credit: ESA / PDO / NEOCC

Data provision:

- Impact monitoring,
- Risk analysis,
- Data dissemination (e.g. ESA Risk List).

Mitigation:

- Develop methods to deflect any risky asteroids

HST observations from DART impact. Img. credit: NASA

UNDERSTANDING NEAR-EARTH OBJECTS

Overview of past milestones


Artist's concept of Giotto's flyby (left); spacecraft (right)
Img. credit: ESA

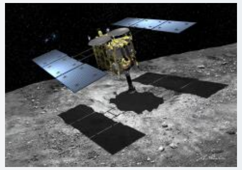
Vega 1 & 2 (1984)

Giotto (1985)

Near Shoemaker (1996)

Deep space 1 (1998)

Stardust (1999).

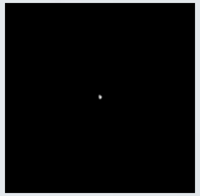

Artist's concept of Hayabusa on Itokawa
Img. credit: JAXA

Hayabusa (2003)
Sample return (land+takeoff)

Rosetta (2004)


Rosetta spacecraft.
Img credit: ESA

Deep impact (2005)


Encounter with comet 9P/Tempel.
Img. credit: NASA

Osiris-Rex (2016)


Artist's concept of Hera with Juventas and Milani cubesats.
Img. credit: ESA.

AIDA:
DART (2021)
HERA (2024)

M-Argo (>2023)

Comet-I (2027)

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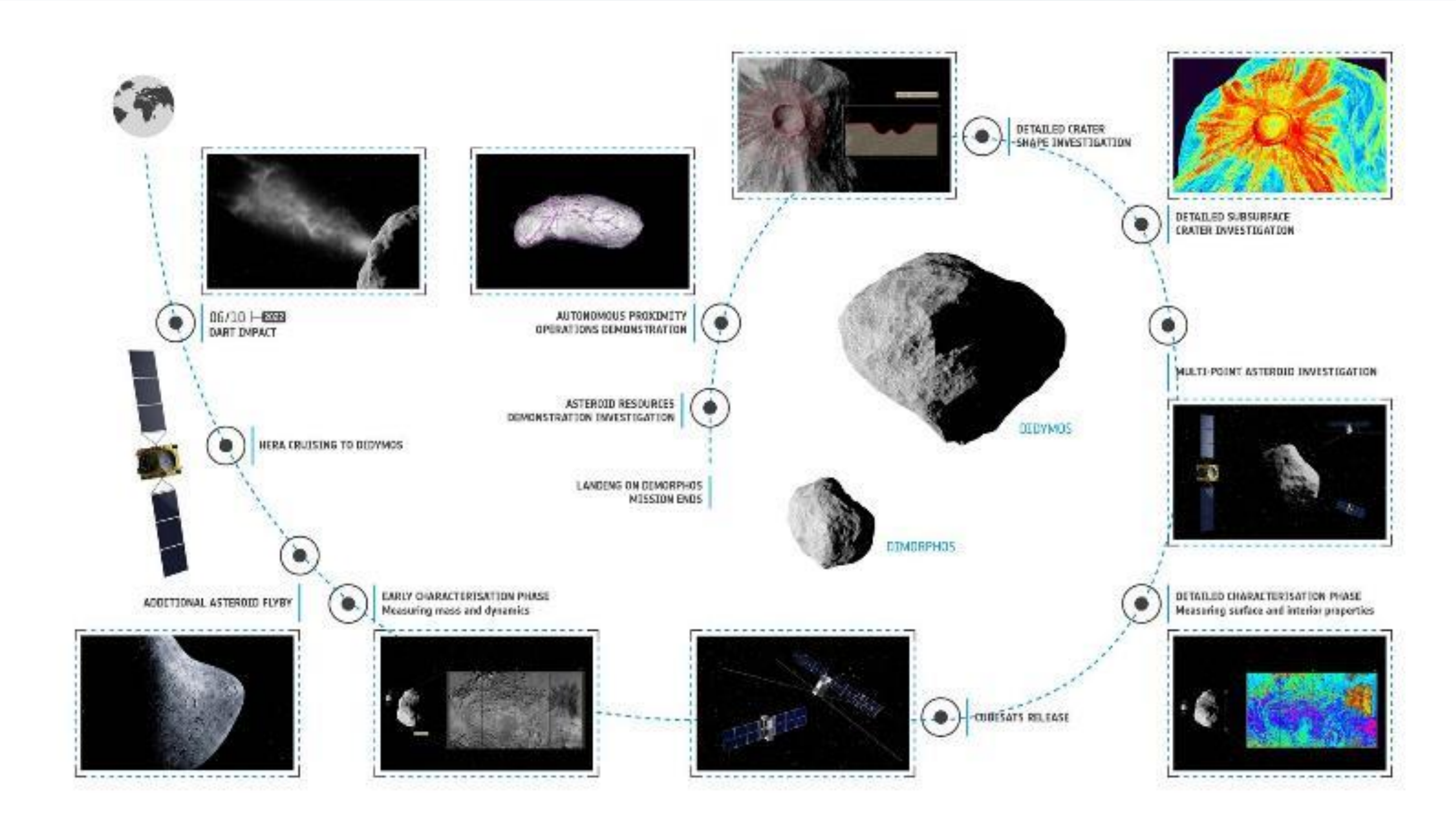
THE HERA PROGRAM

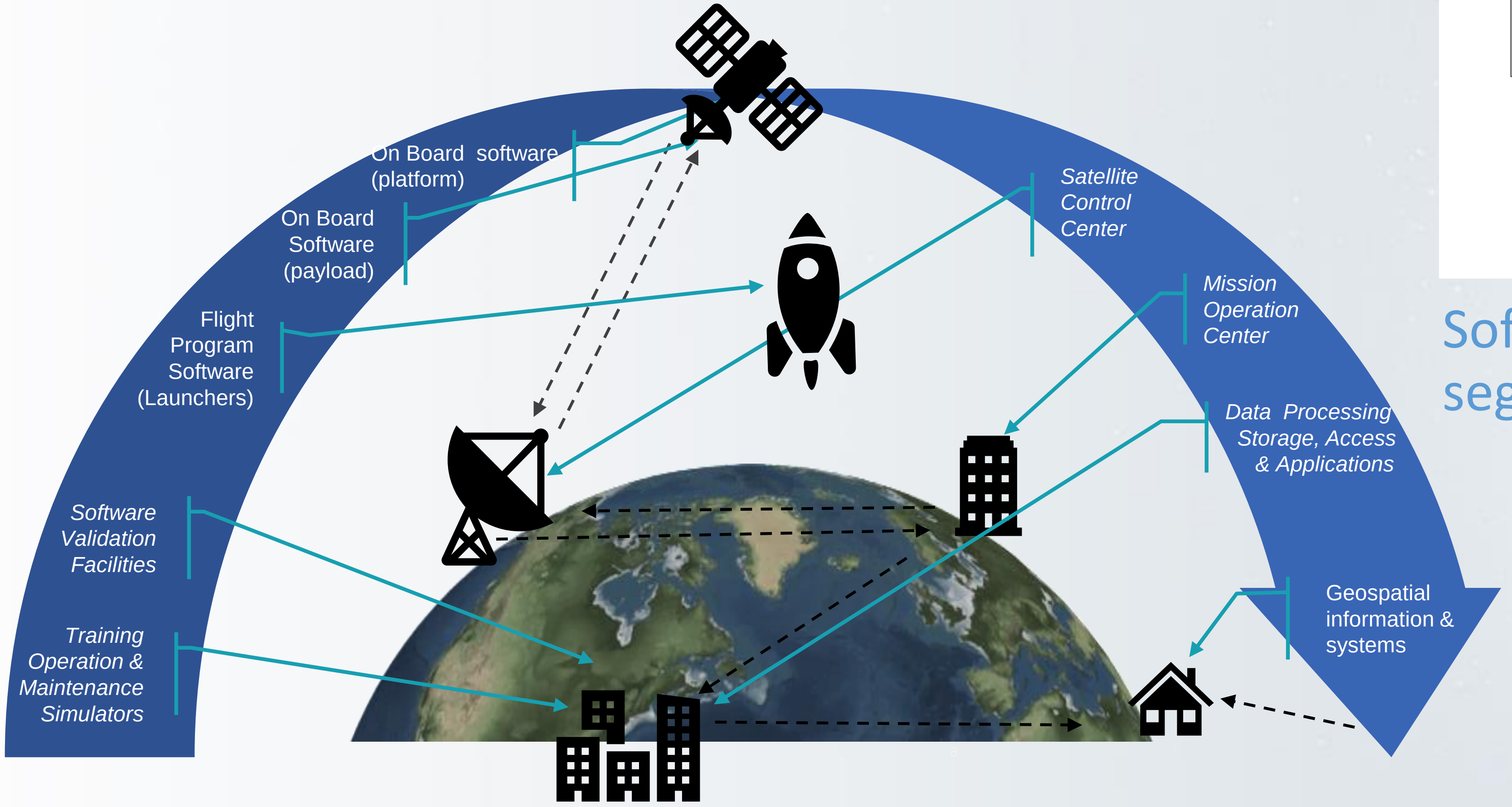
Spacebel contribution to a satellite mission



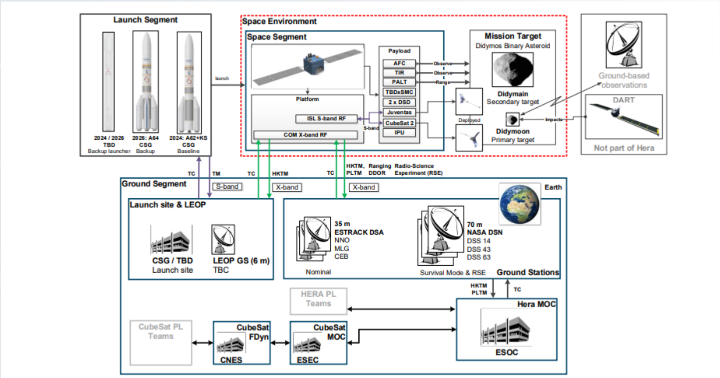
AIDA mission sequence and key objectives. Img. credit: ESA.

SPACE SYSTEM AND SOFTWARE ENGINEERING

Spacebel role in space programs



Hera mission architecture. Img. credit: OHB.

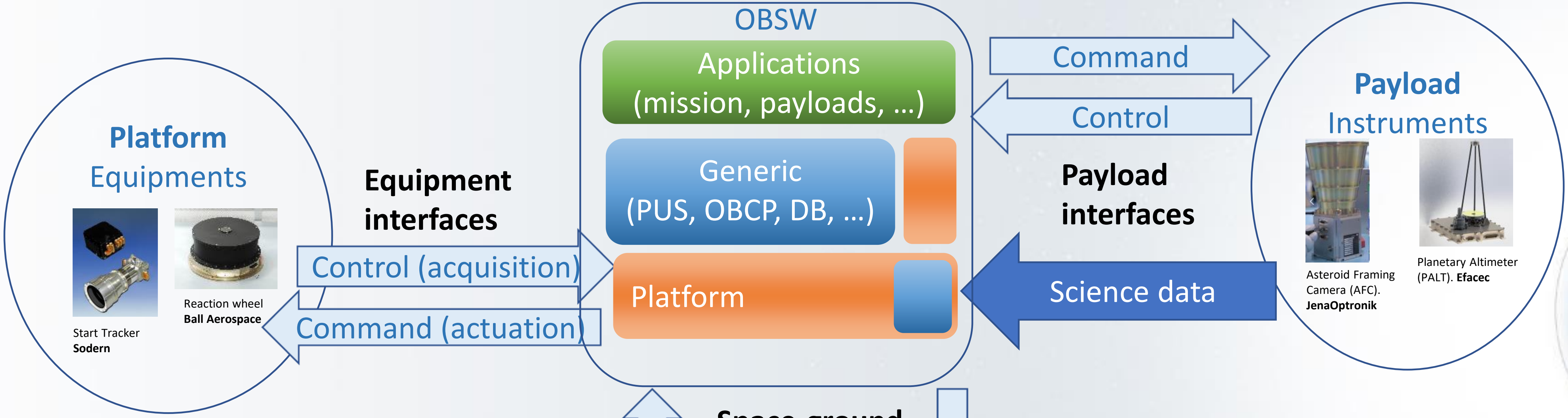


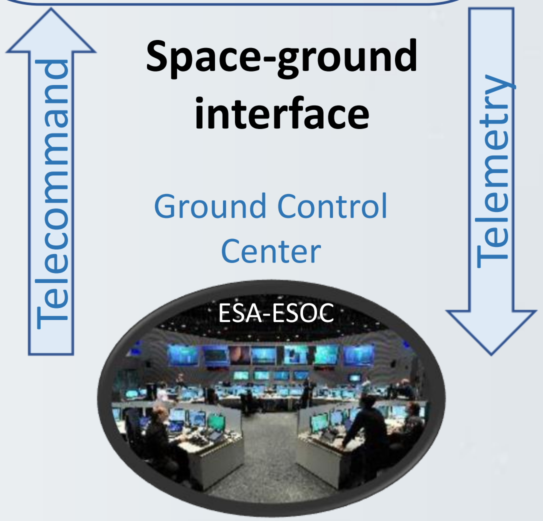
Software is present in every segment and at all levels

- Launch segment
- Space segment
  - On-board software
- Ground segment
  - Mission control centers
  - Simulation & modeling software
  - Training, operations & maintenance

ON-BOARD SOFTWARE (OBSW)

On-board software interfaces & data flows





Telecommand

- High priority command
  - Hardware
- Nominal command
  - Software
- Macro command
  - Expanding
- Time-tagged command
  - Scheduling

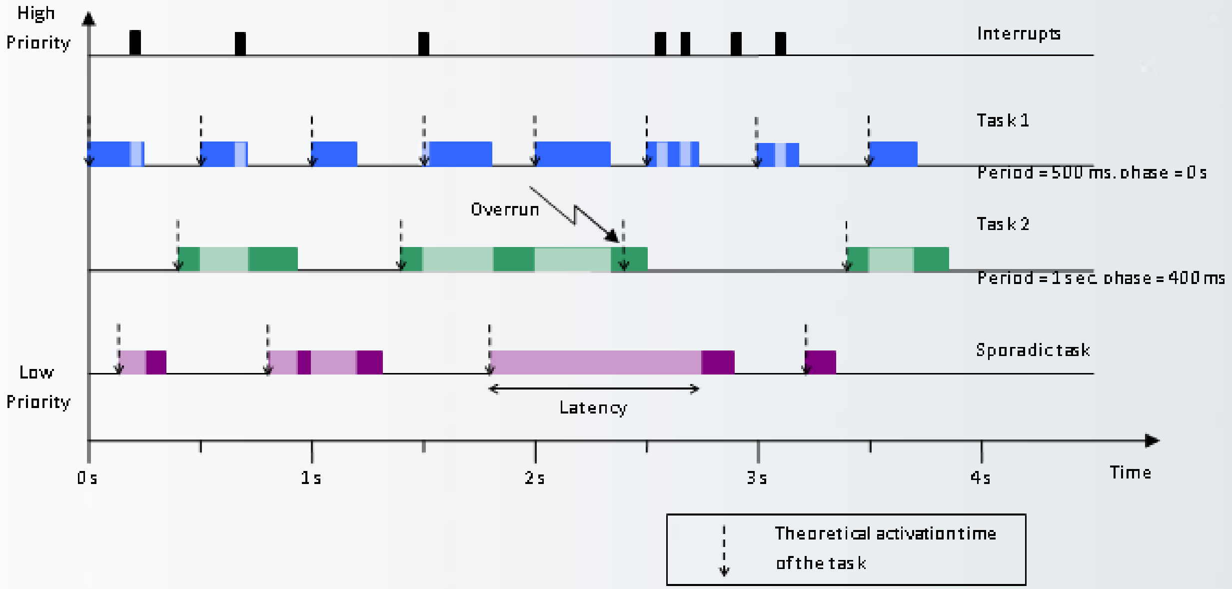
Telemetry

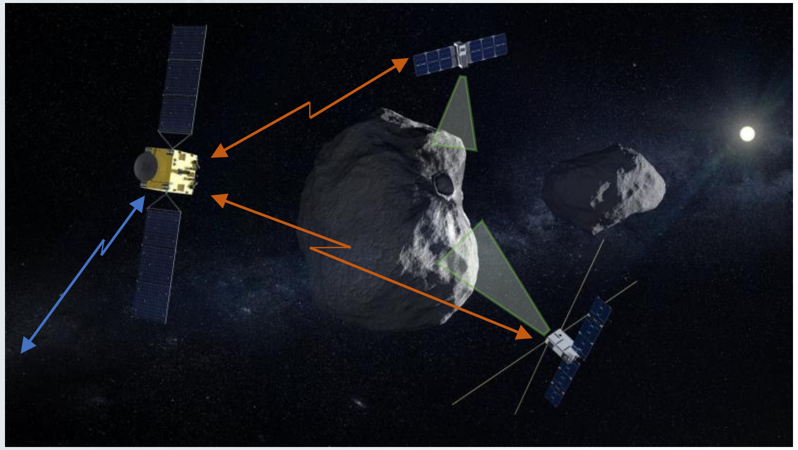
- Housekeeping (platform & payload)
  - Temperature, pressure, status, …
- Science data (payload)
  - E.g. raw or compressed images
- Anomaly reports

EXAMPLE: ASTEROID PHASE

Real-time operating systems: importance of the scheduling of the satellite activities.

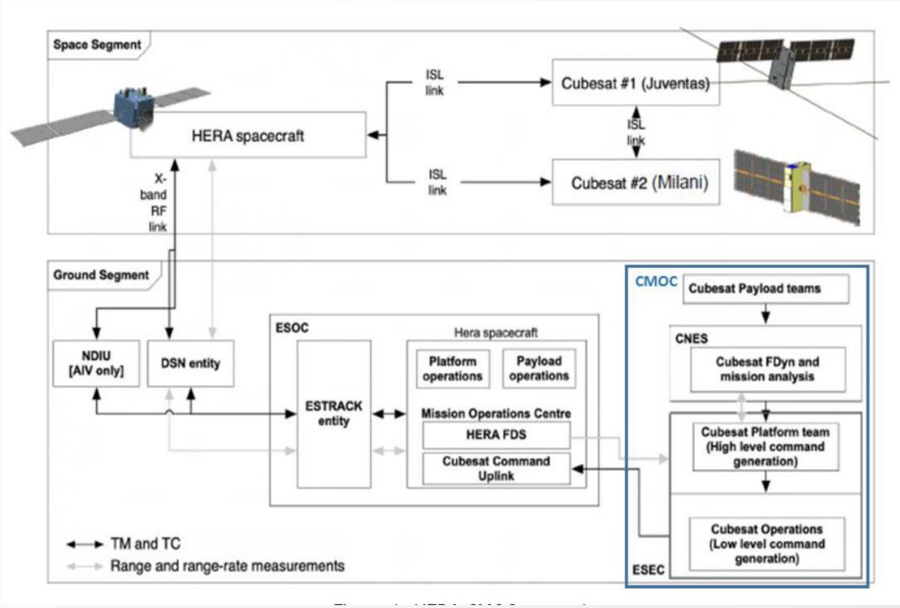
- AOCS
- Collision avoidance
- Inter-satellite communications





Artist's concept of Hera with Juventas and Milani cubesats.
Img. credit: ESA.

HERA CUBESAT MISSION OPERATION CENTER



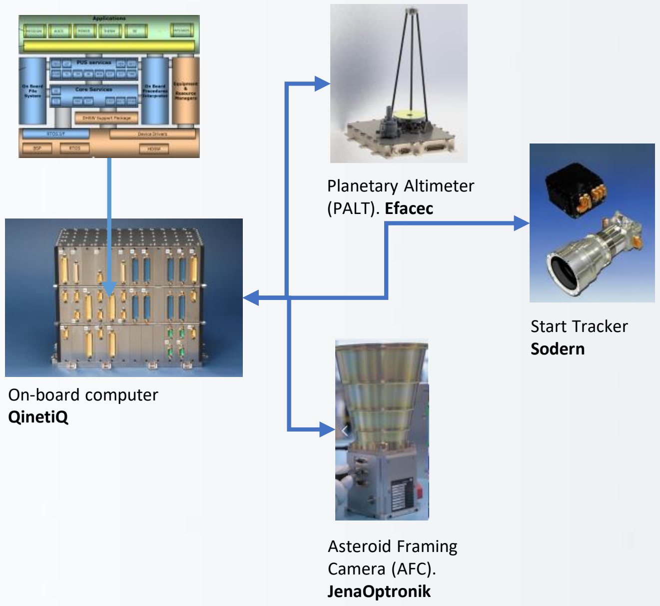
ESA-ESOC, Darmstadt, Germany.
Img. credit: ESA.

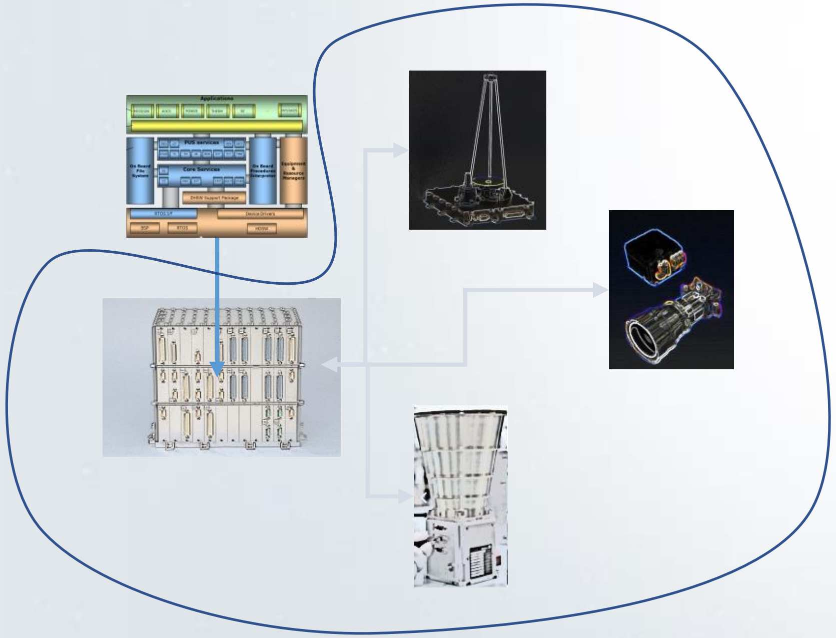
ESA-ESEC, Redu, Belgium.
Img. credit: ESA.

SIMULATION & MODELING SOFTWARE

- Software validation facility (SVF)
  - Digital copy of the satellite system and simulation of the celestial environment
  - OBSW validation & testing

- TOMS: Training, Operations and Maintenance Simulation
  - Training operations for remote commanding a satellite
  - Operational maneuvers preparation
  - Maintenance of systems
  - Simulation for preparation of missions
    - Hybrid simulation HW + SW





Numerical representation of the satellite components

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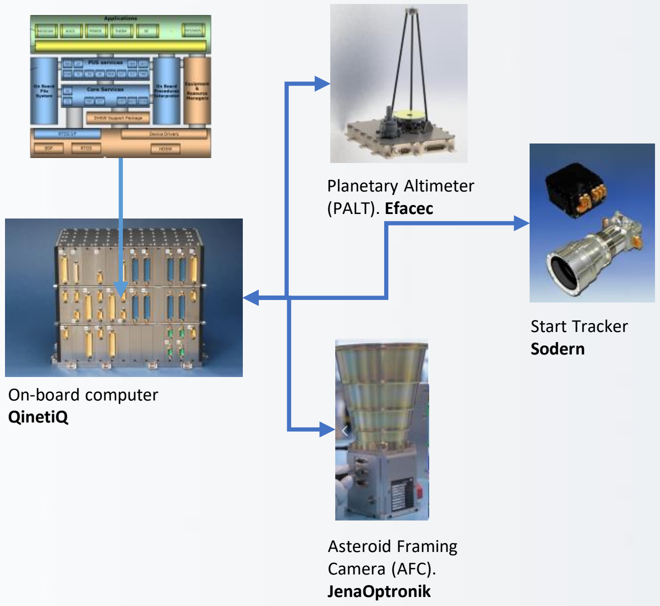

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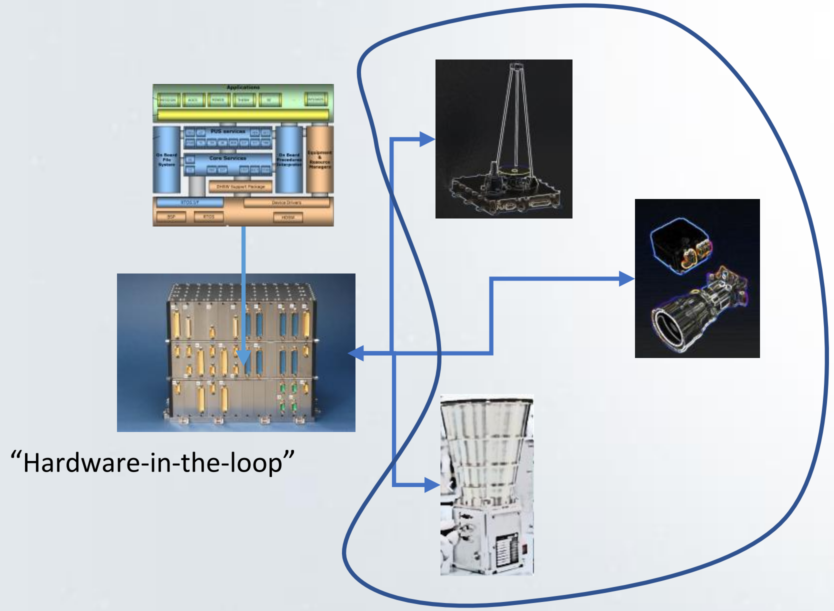

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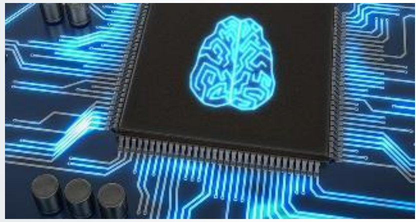
CONCLUSIONS & PERSPECTIVES

Summary

- Risk: non-zero impact probability with NEOs
- Need for planetary defense techniques to be developed (e.g. DART)

Challenges & future trends

- Short implementation time
    - In the past, “new” NEOs have only been discovered a few months to years before they pass through their closest approach to the Sun.
- Enhanced spacecraft autonomy
    - Increased complexity for control software.
    - Inclusion of artificial intelligence for on-board decision.
- Development of digital twins for satellites
- Inclusion of low-cost technology (e.g. cubesat/microsat)
    - Propulsion system, communication (low bandwidth and signal-to-noise ratio), power issues far from the Sun, …



Future satellite missions

- Incoming Hera launch in 2024; M-Argo (>2023); Comet-I (2027).
- NASA OSIRIS-Rex -> OSIRIS APEX. ESA contribution?

SPACEBEL
REACHING INTO SPACE TOGETHER

www.spacebel.com

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Career Opportunities @ Spacebel

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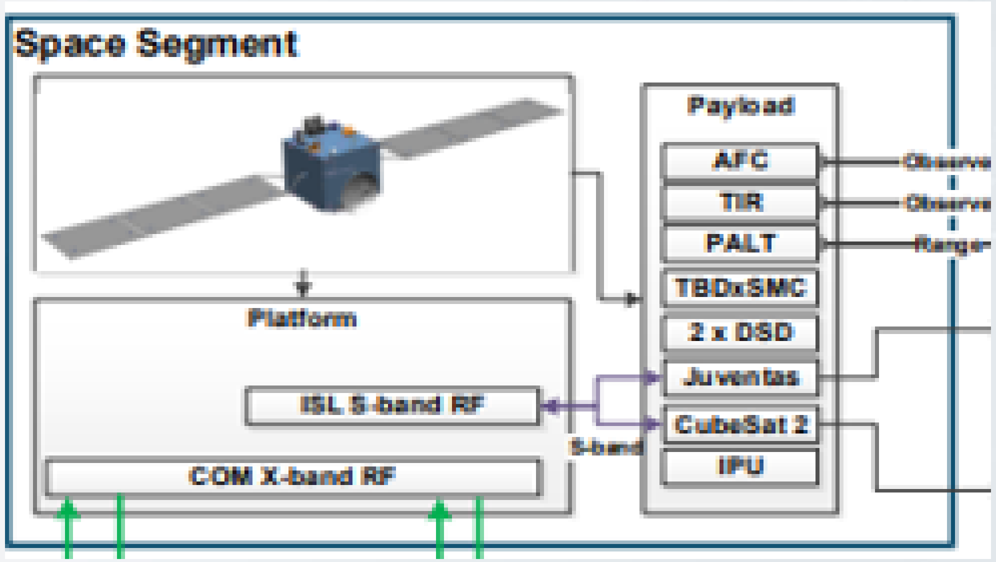
BACKUP SLIDES

ON-BOARD SOFTWARE (OBSW) OVERVIEW

Data management
- Acquisition
- Storage
- Download

Platform management
- Thermal
- Power
- Communication
- Attitude and orbit control



Equipment management
- Command and control
- Configuration
- Fault detection
- Redundancy

Mode management
- Mission phases
- Spacecraft operational modes
- Equipment states

Payload management
- Command and control
- Configuration

Operations
- Ground commands

Command, monitoring and control
- Observability
- Commandability
- Autonomy

Mission timeline
- Time-triggered actions
- Position-triggered actions

OBSW OVERALL ARCHITECTURE