34th TFAWS Interdisciplinary Paper Session

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MSR-ERO Thermal design and analysis using Systema

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Agenda

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Mars Sample Return (MSR)

A quick introduction to the mission

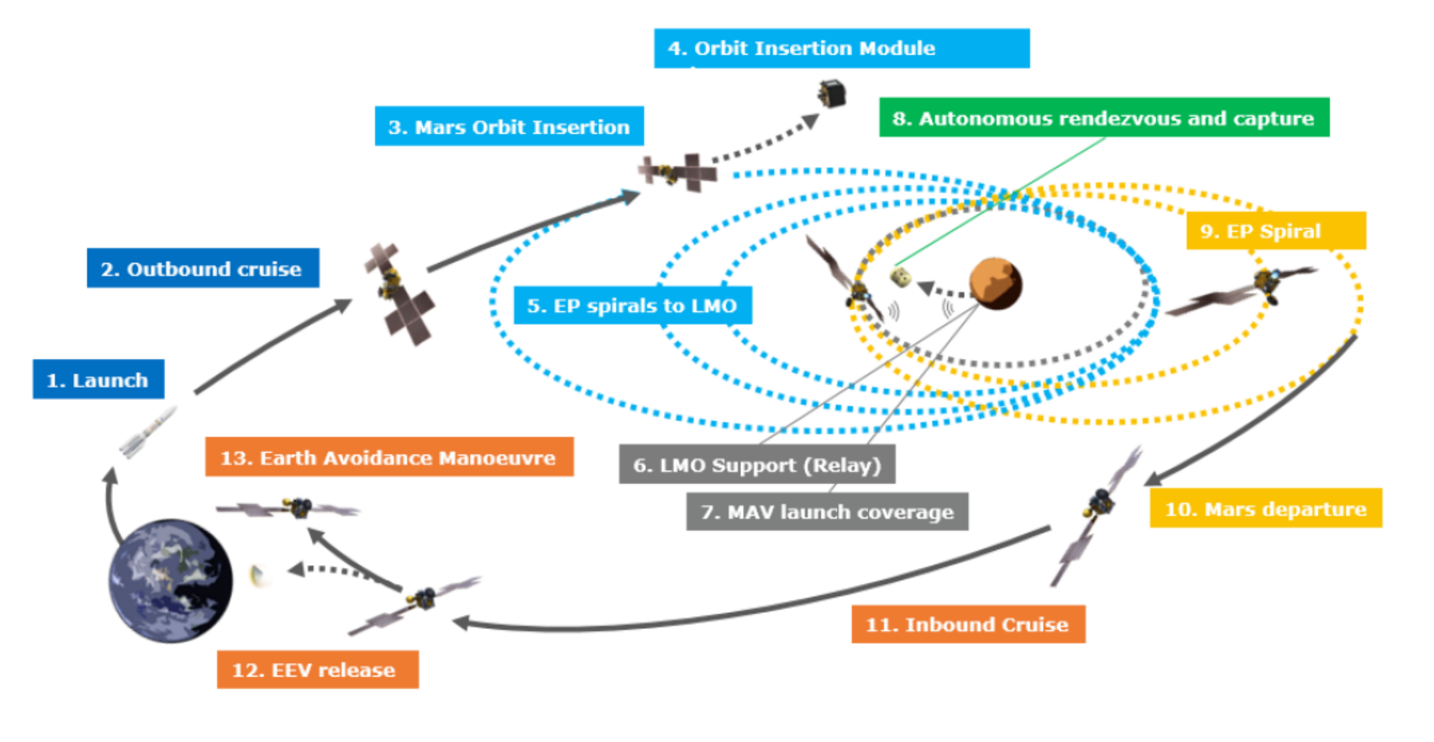
- **NASA-ESA** joint program
- Bringing Martian samples back to Earth by **2033**
- **Several spacecraft** involved (*Perseverance*, ERO, SRL)
- First sample return from another planet!

Credits: NASA/ESA/JPL-Caltech/GSFC/MSFC

Earth Return Orbiter (ERO)

From Earth to Mars and back

- Mission duration: **6 years**
  - **Outbound** transfer: **~3 years**
    - *(OIM Separation)*
  - At **Mars**: **~1 year**
    - *(CE separation)*
  - **Inbound** transfer: **~2 years**
- **Plasma propulsion** for OTP and ITP
- **Chemical propulsion** for MOI
- Evolving spacecraft **configuration**

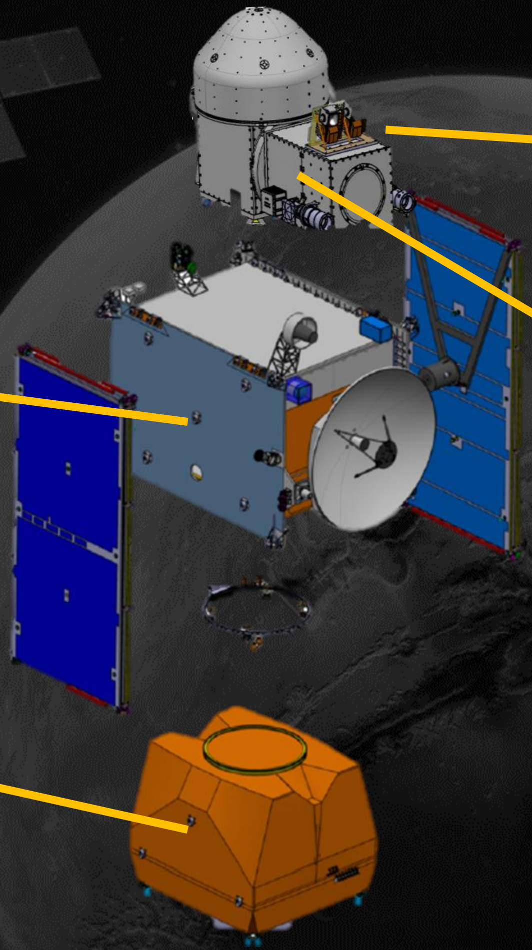


Credits: Airbus

Earth Return Orbiter (ERO)

Spacecraft description

→ A highly **modular** spacecraft



Rendezvous Sensor Suite *(ESA)*
(Mounted on the CCRS)
Cameras & LiDARs

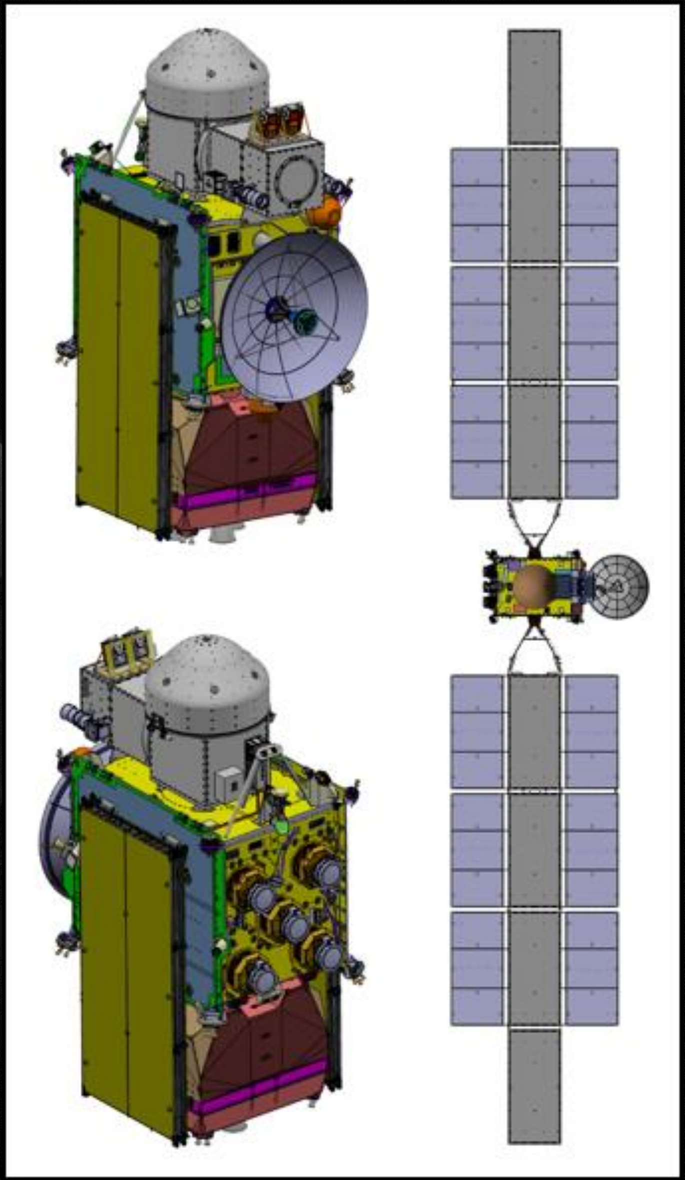
Capture, Containment and Return System *(NASA)*
(Partial separation after samples recovery)
Samples capture & biosealing
Earth jettison system

Return Module *(ESA)*
Avionics & communications
Plasmic and Chemical propulsion

Orbit Insertion Module *(ESA)*
(Separation at Mars arrival)
Chemical propulsion

Earth Return Orbiter (ERO)
Spacecraft description

- Dimensions: **6.6 m** x **4.1 m** x **2.7 m** (without solar arrays)
- Launch mass: **7.2 tons** (~4 tons of Xenon and chemical propellant)
- Chemical propulsion: **2** x **400 N** (**OIM** - for **Mars orbit insertion**)
- Plasma propulsion: **4** x **250 mN** (**RM** - for **outbound** and **inbound** cruise)
- Solar arrays area: **144 m²**
- Platform power: **42kW** @Earth, **20kW** @Mars



Credits: Airbus

Earth Return Orbiter (ERO)

Return Module thermal design

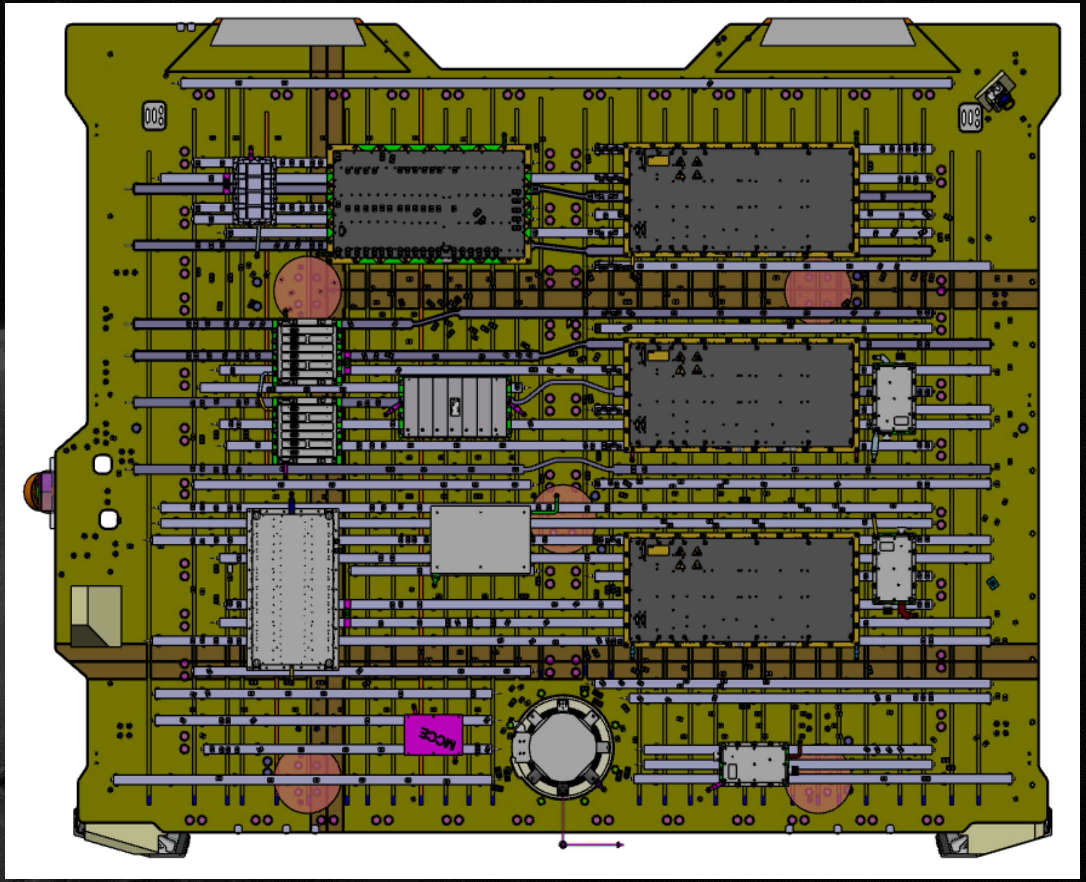
- Peak power dissipation: **5 kW**
- **1** single internal thermal zone

- Radiator surface: **12 m²** (OSR)
- MLI blanket surface: **22 m²** (black MLI)

- Heat pipes total length: **275 m** (embedded and surface)

- Installed heating power: **5 kW** (140 nom. + 140 red. + **13 tri.** heaters)

Some functions are triplicated to ensure planetary protection!



Credits: Airbus

Systema

What is Systema?

System level tool to model spacecraft **interactions** with its **environment**

Systema is an **Airbus** product, has been existing for more than **30 years**, quite well used in Europe and throughout the world.

Systema

The multidiscipline solution to support space system engineering.

Dedicated to Space, **mission oriented**, offers a **unified framework** for dealing with several physics domains linked to space, such as **Thermal, Power, Space Physics applications**

Currently, version Systema-4.9.2P1 is available for download on our website !
https://www.airbus.com/en/products-services/space/customer-services/systema

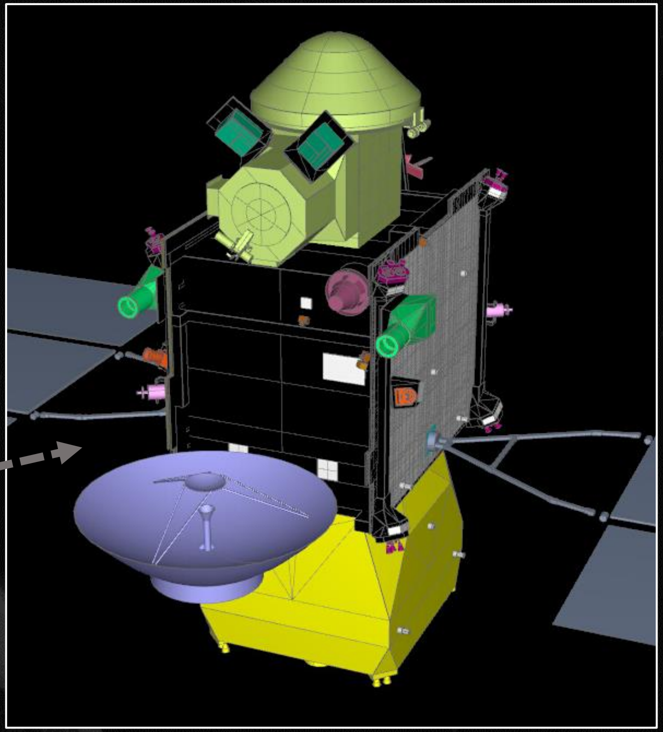
Systema

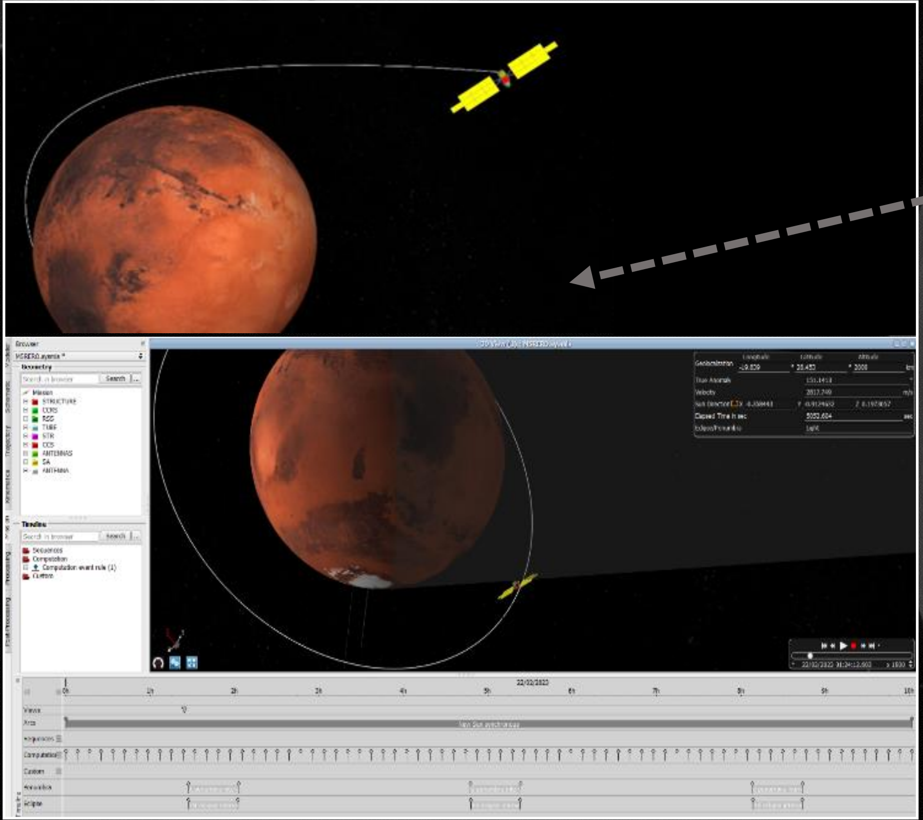
How does Systema work?

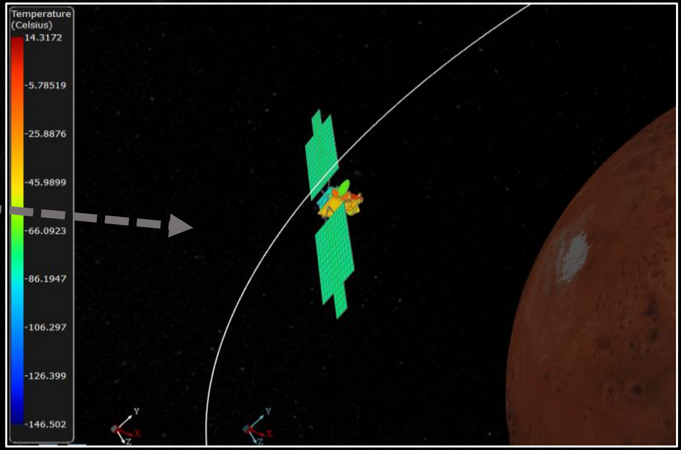
Geometry modeling, physical properties and meshing

Mission modeling: orbit and pointing

Physical simulation:
Scientific **computation** via the applications







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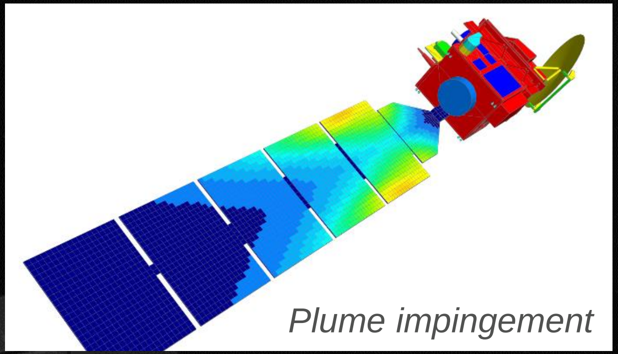
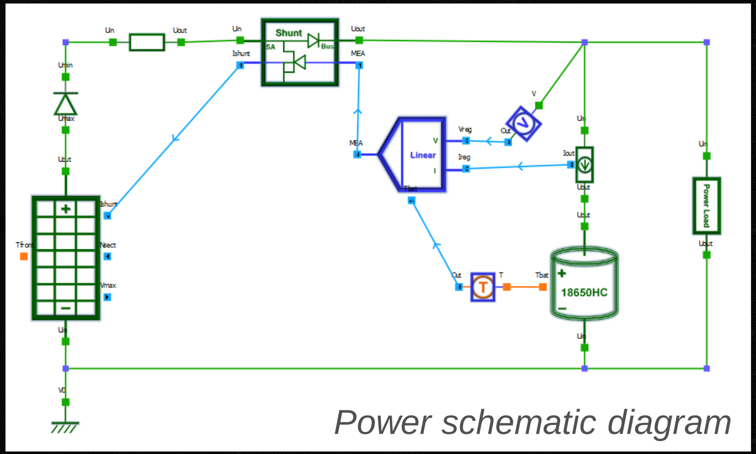
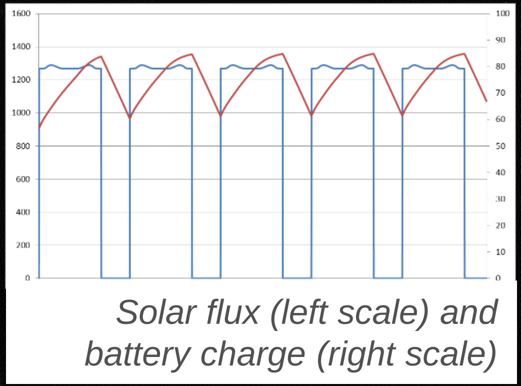
Systema

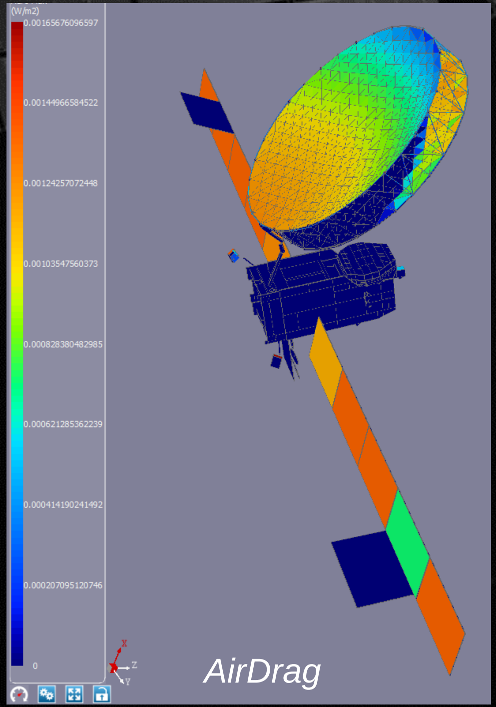
Software presentation

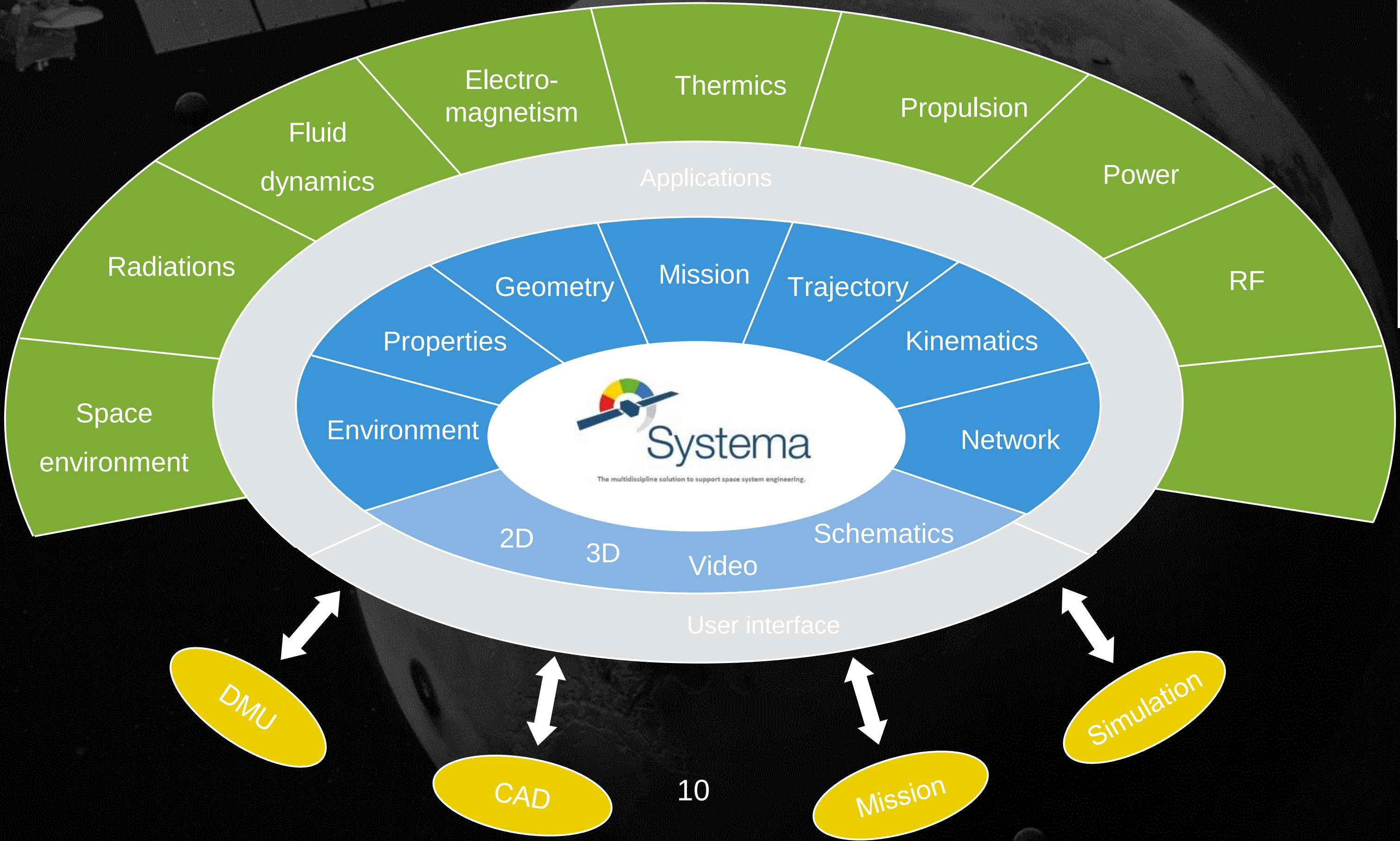

Plume impingement



Power schematic diagram


Solar flux (left scale) and battery charge (right scale)


AirDrag



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Systema

Why should you use Systema?

User friendly **thermal analysis tool**
(Radiation with Quasi-Monte-Carlo, Conduction with RCN method)

A well furnished **Python API**, allowing to **drive** or **customize** entirely the tool, allowing to put in a global process chain.

Systema

The multidiscipline solution to support space system engineering.

A **unique framework** allowing for the same geometrical & mission definition for **Thermal & other studies** *(Power, AirDrag, Atomox, Plume…)*

Mission definition & events (eclipses) with the trajectory based on **OREKIT** library.

Able to model classical as well as **unusual trajectories** with accurate contributions from planets, moons and the Sun.

OREKIT : https://www.orekit.org/

MSR-ERO thermal analyses
The objective of the campaign

- **Understand** and **predict** the thermal behavior of the spacecraft through a **realistic** geometrical and thermal modeling in order to **assess the global thermal design** and provide data for **thermoelastic** and **power budget** studies:
  - ✓ *Are the radiators big enough to evacuate the heat from the spacecraft?*
  - ✓ *Is the installed heating power sufficient to heat up the units while in cold conditions?*
  - ✓ *What is the max. power we can allocate to plasma propulsion while ensuring all internal units temperature remains below max. allowance?*

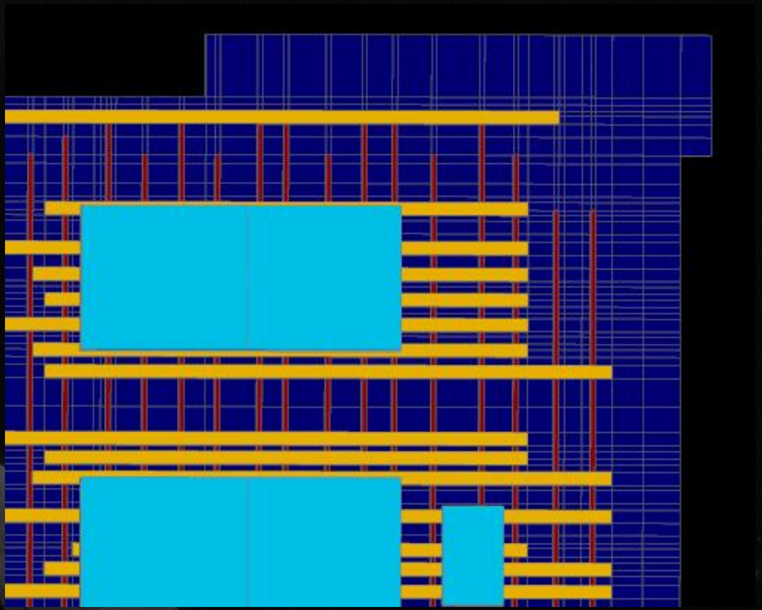
➢ **Internal** and **external** geometrical modeling of the satellite

➢ Integration of ~40 submodels delivered by ~20 different suppliers for **coupled analyses**

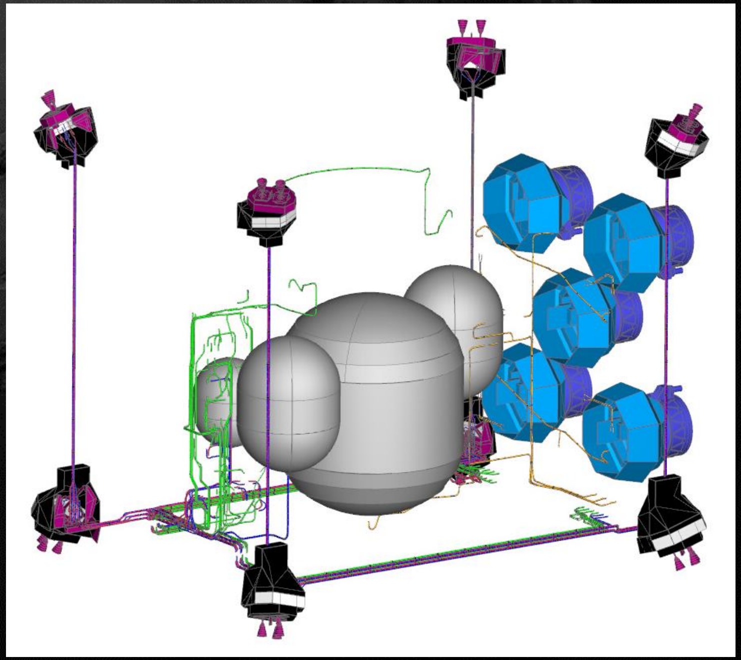
MSR-ERO thermal analyses
A precise internal geometrical model

- Detailed **structure modeling**: honeycomb panel, embedded and surface heatpipes
  - ➢ Precise computation of conductive exchanges between units and structure
  - ➢ Evaluation of the efficiency of radiator temperature homogenization by heatpipe networks

- Precise **propulsion piping meshing**: RM CPS and PPS
  - ➢ Realistic computation of heating power budget



Focus on +Z wall meshing



CPS and PPS piping and tanks

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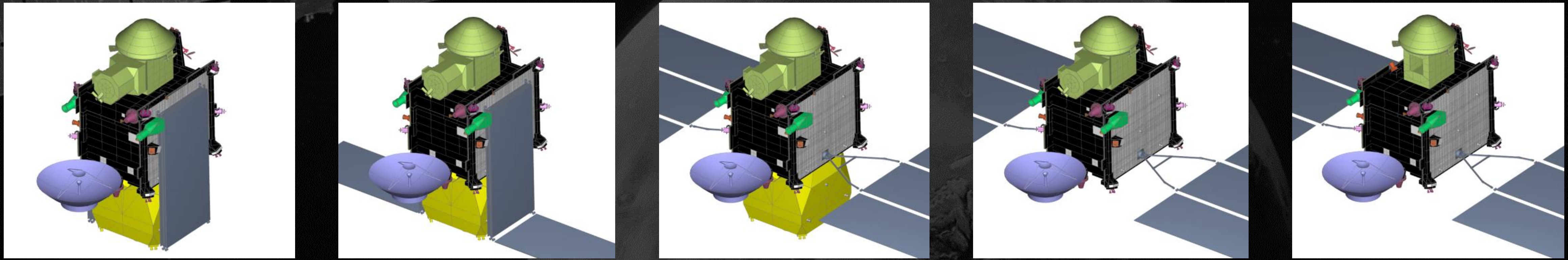
MSR-ERO thermal analyses

A modular external geometrical model

- Different **spacecraft configurations** for different mission phases:



Launch

Outbound transfer

Mars

Inbound transfer

Solar arrays full deployment

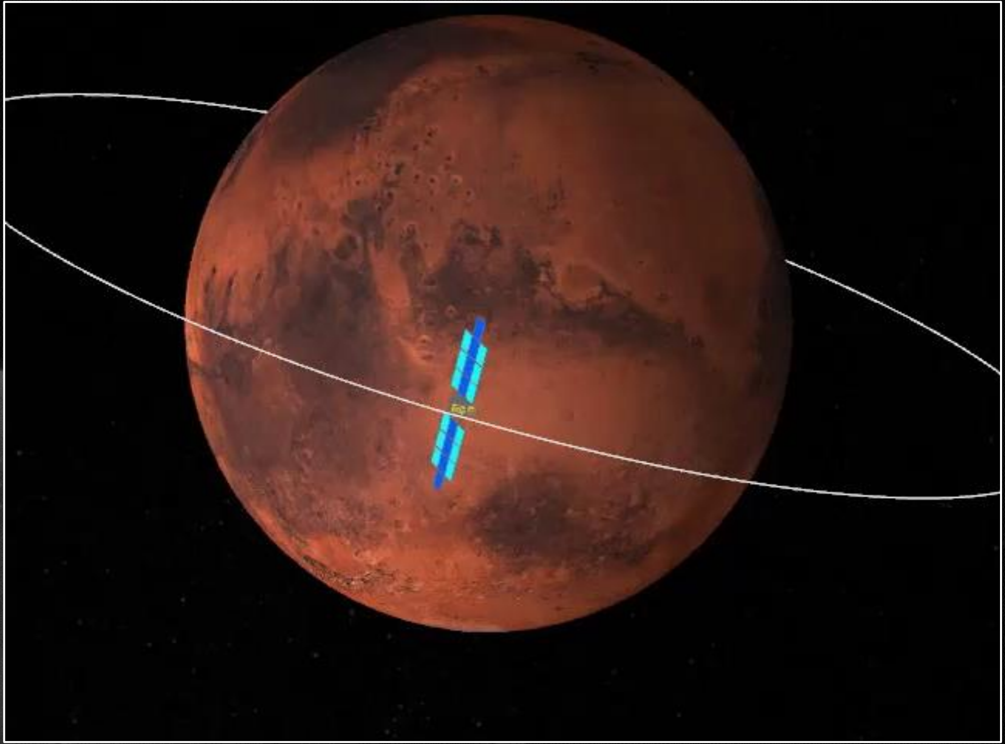
OIM separation

CE separation

MSR-ERO thermal analyses

A complete analyses campaign

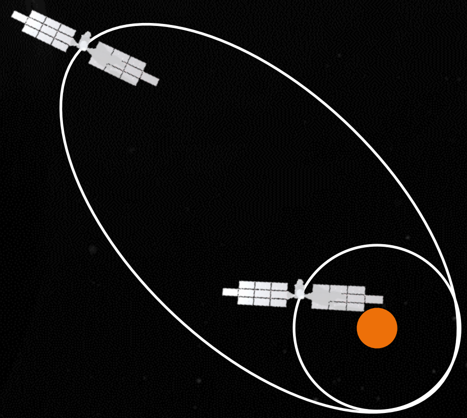
- Each mission phase is covered by several **sizing run cases**



- Example for **Spiraling down** phase

➢ Three different runs to assess several system topics:

Case	Orbit	Solar distance	PPS	Dissipation	Outputs
31a	Elliptic (400-21000 km)	1.4 AU	3 Motors	MAX	**Power budget**
31b	Circular (450 km)	1.67 AU	2 Motors	MAX	**Power budget**
32	Elliptic (400-21000 km)	1.4 AU	Standby	MIN	**Heater line sizing**



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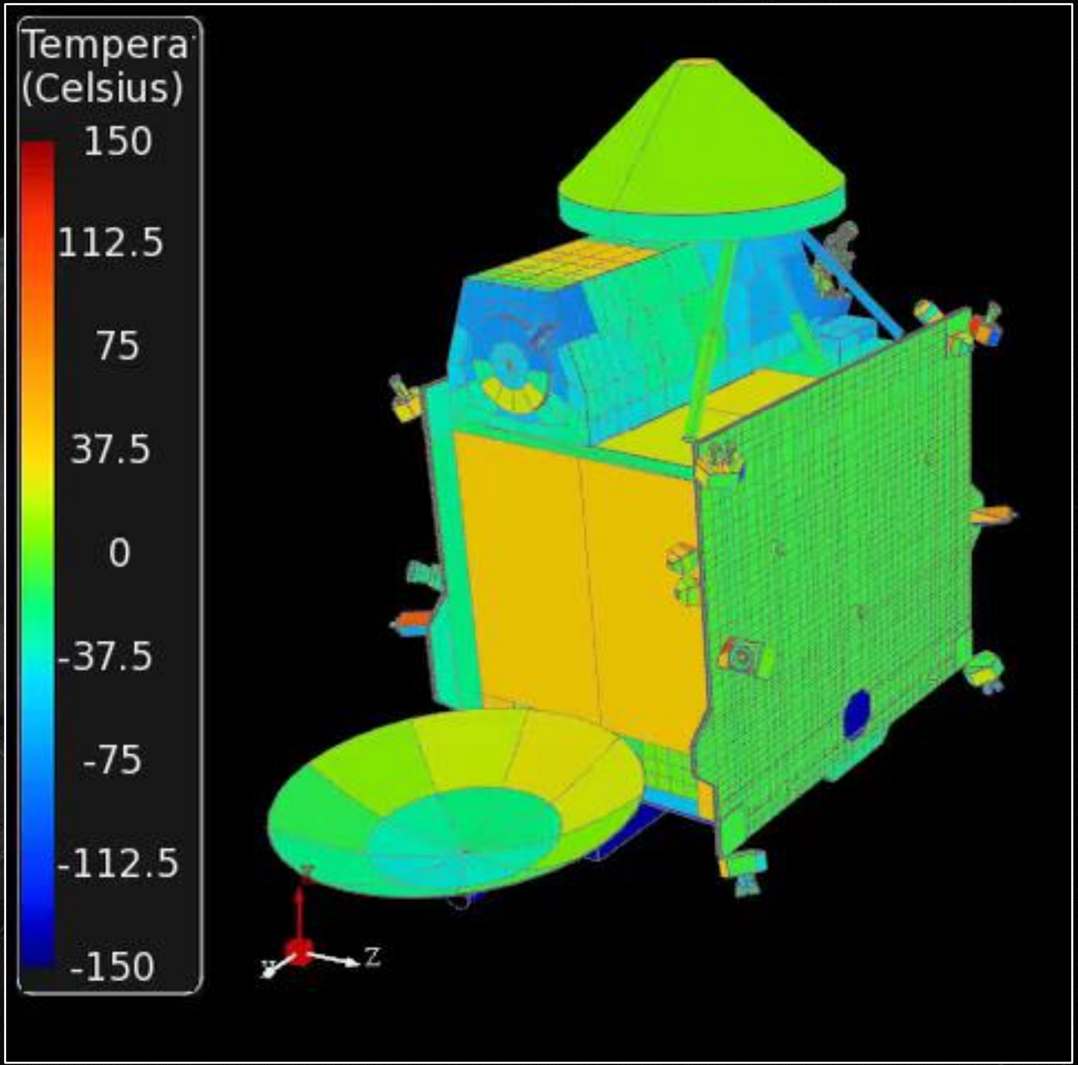
MSR-ERO thermal analyses

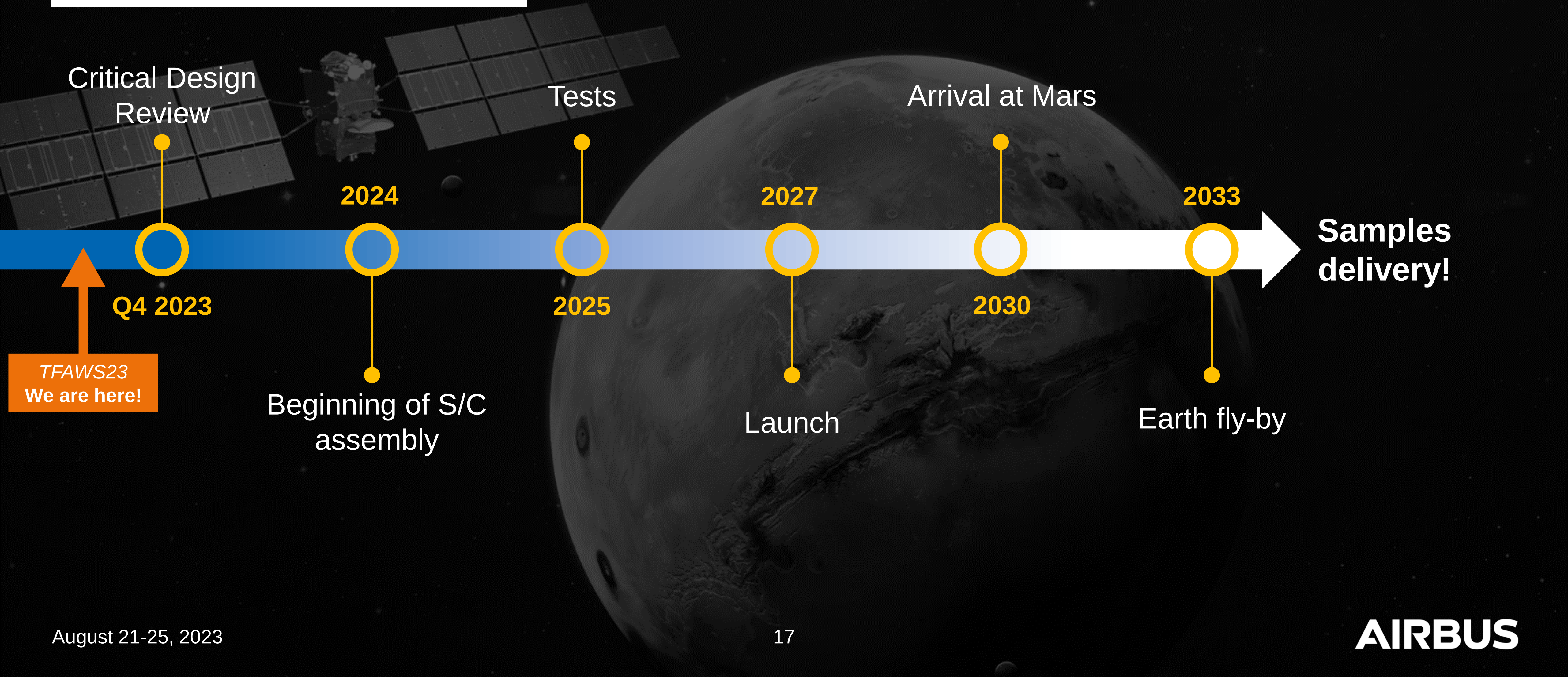
… in a nutshell

- **6** years of mission
- … covered through **8** different phases
- … and **35** run cases
- … with **5** different geometrical models
- … containing **40** submodels integrated
- … for a total of **70 000+** thermal nodes!



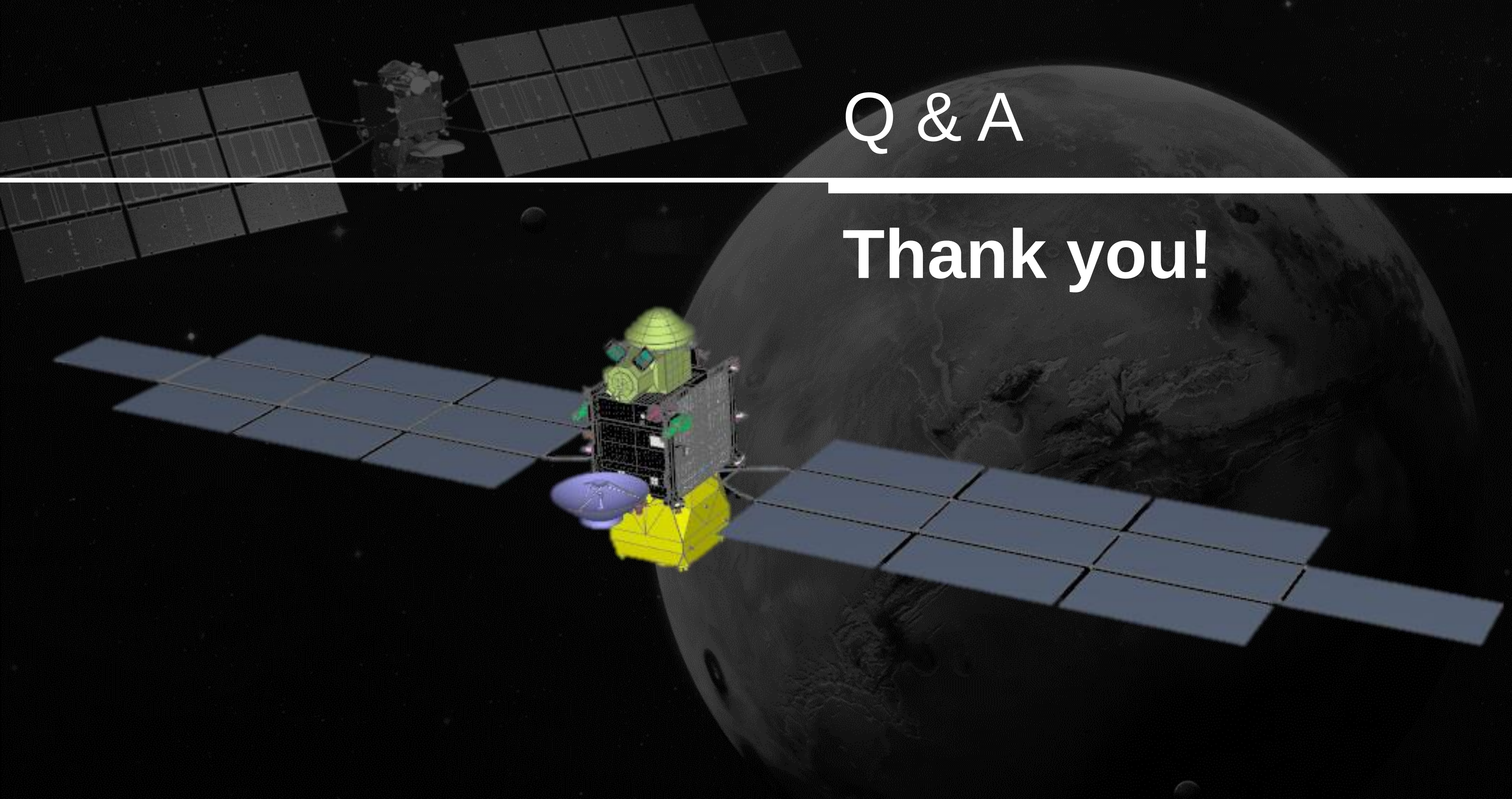
Future milestones & perspectives

What's next for MSR-ERO?



Q & A

Thank you!



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