BepiColombo MPO Science Operations Planning Drivers

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BepiColombo MPO Science Ground Segment

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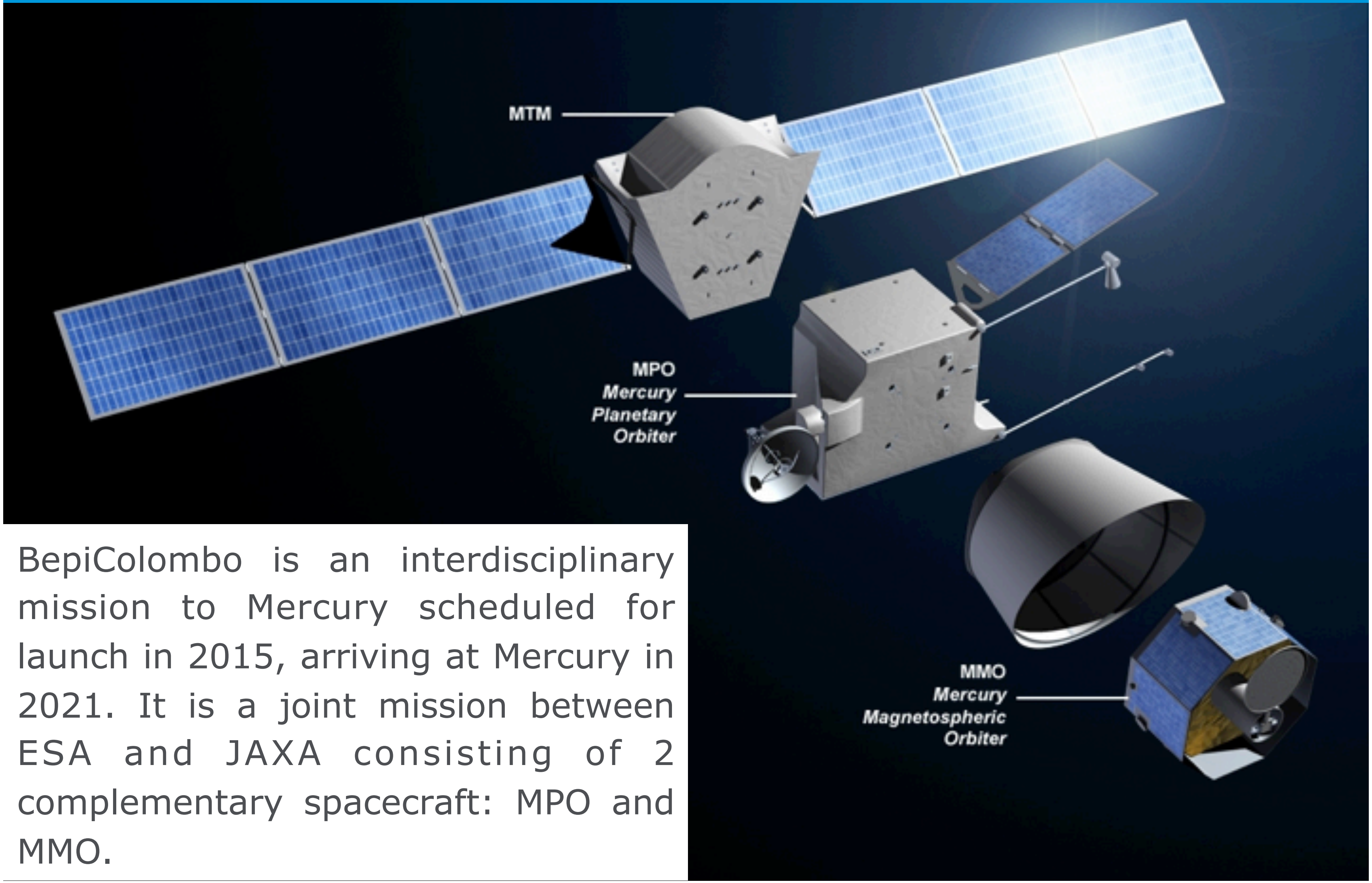
Summary

This presentation summarizes the main drivers for the BepiColombo MPO Science operations planning described in the paper. Those drivers are:

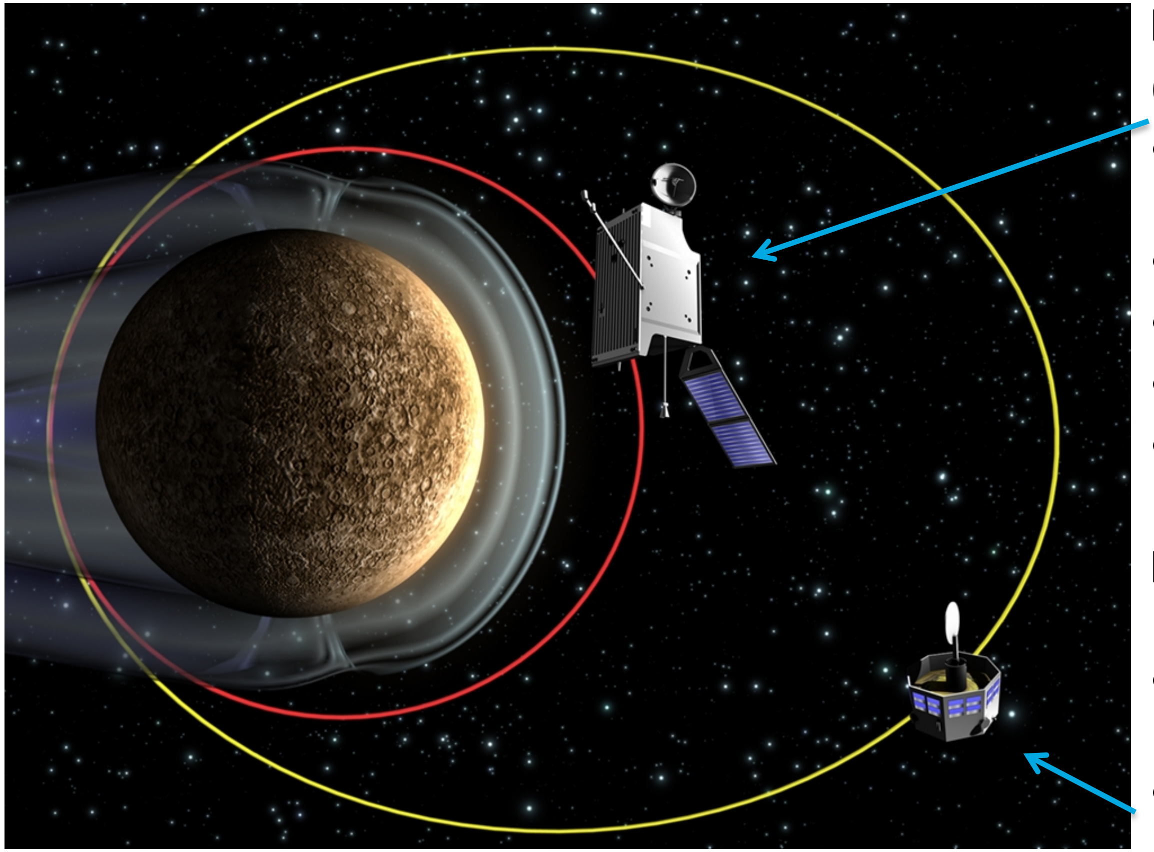
1. **Science observations** performed by the scientific instruments.
2. **Operational constraints**, like power constraints, data downlink constraints, and pointing constraints.
3. **Mission characteristics**, like mission duration, experiment characteristics and Orbit characteristics.

BepiColombo Mission overview



BepiColombo is an interdisciplinary mission to Mercury scheduled for launch in 2015, arriving at Mercury in 2021. It is a joint mission between ESA and JAXA consisting of 2 complementary spacecraft: MPO and MMO.

BepiColombo MPO overview



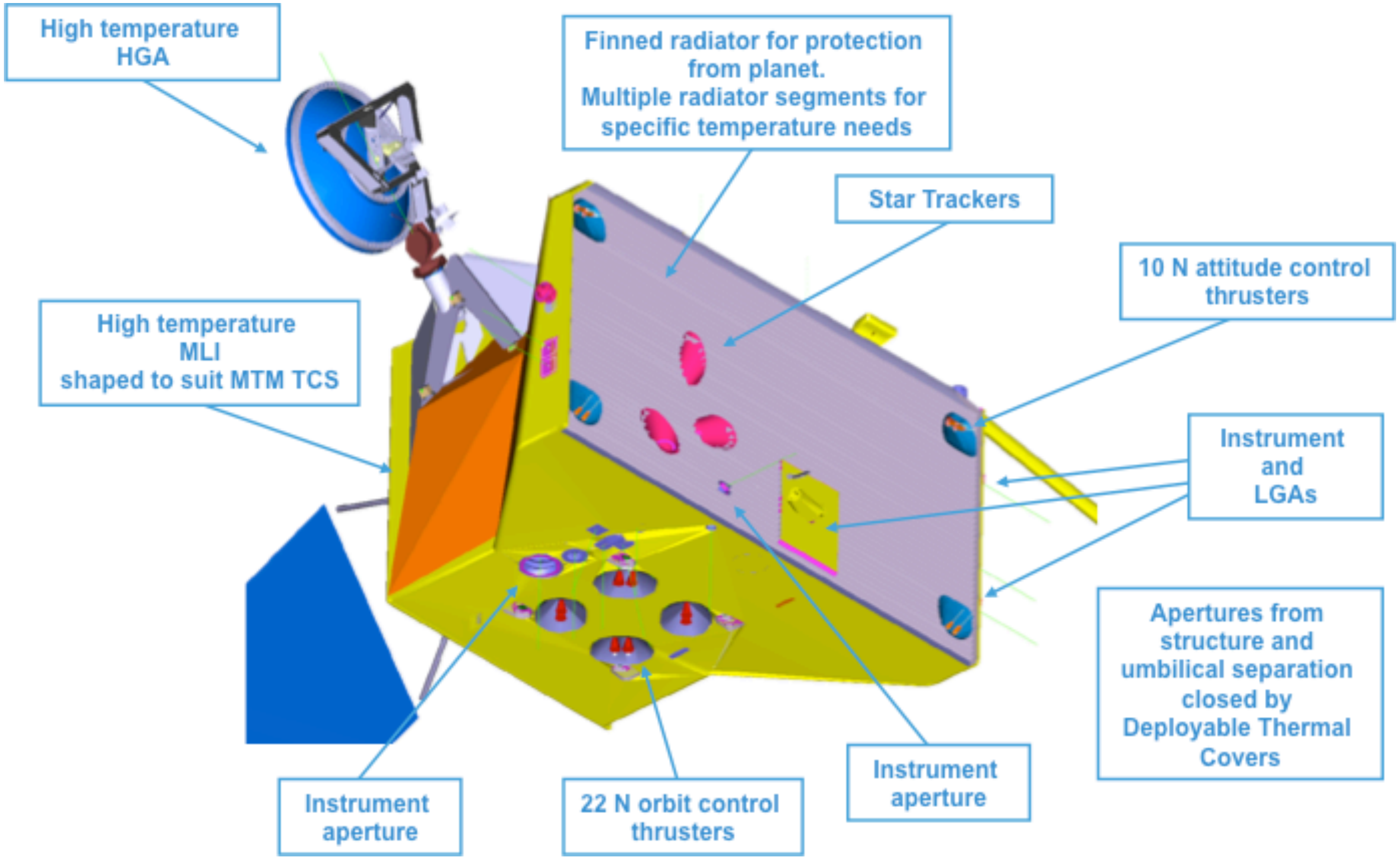
Mercury Planetary Orbiter (MPO)

- polar orbit optimized for study of the planet itself
- 400x1500 km
- 2.3 hours period
- Data volume ~1550Gbits/year
- Mainly nadir pointing

Mercury Magnetospheric Orbiter (MMO)

- polar orbit optimized for study of the magnetosphere
- 400x12000 km
- 9.2 hours period
- Data volume ~100Gbits/year

BepiColombo MPO Configuration



BepiColombo MPO Scientific Payload

Instrument	Long Name	Scientific Objective
BELA	BepiColombo Laser Altimeter	Mercury surface topographic mapping
ISA	Italian Spring Accelerometer	Non-gravitational acceleration measurements of the spacecraft
MERMAG	Mercury Magnetometer	Measurement of Mercury magnetic field, its source and interaction with solar wind
MERTIS	Mercury Thermal & Infra-red spectrometer	Global mineralogical mapping, surface temperature and thermal inertia
MGNS	Mercury Gamma-ray & Neutron Spectrometer	Elemental surface and sub-surface composition, volatile deposits on polar areas
MIXS	Mercury Imaging X-ray Spectrometer	Elemental surface composition, global mapping and composition of surface areas
MORE	Mercury Orbiter Radio-science Experiment	Core and mantle structure, Mercury orbit, fundamental science, gravity field
PHEBUS	Probing of Hermean Exosphere by Ultraviolet Spectroscopy	UV spectral mapping of the exosphere
SERENA	Search for Exospheric Refilling and Emitted Natural Abundances	In-Situ study of composition, vertical structure and source and sink process of the exosphere
SIMBIO-SYS	Spectrometers & Imagers for MPO BepiColombo - System	Optical high-resolution and stereo imaging. Near-IR imaging spectroscopy for global mineralogical mapping
SIXS	SIXS Solar Intensity X-ray and Particle Spectrometer	Monitor for solar X-ray intensity and solar particles in support of MIXS

Science Operations Planning Drivers: Science Observations

The science observations will be defined in a Science Traceability Matrix (TMX).

The TMX provides the link between the contribution of the different experiments observations to BepiColombo science goals.

GOAL 1	PERFORM A PHYSICAL CHARACTERIZATION OF MERCURY
Objective 1.1	Determine the origin and evolution of Mercury
Objective 1.2	Study the internal structure
Objective 1.3	Determine the rotational state
Objective 1.4	Characterize the magnetic field
Objective 1.5	General relativity
GOAL 2	CHARACTERIZE THE SURFACE AND COMPOSITION
Objective 2.1	Determine the origin of Mercury
Objective 2.2	Study the evolution of Mercury
GOAL 3	STUDY THE MERCURY ENVIRONMENT

Mission duration

Nominal science mission duration: **12 months with the possibility of 12 months extension.**

Many observations depend on particular geometrical conditions and seasonal peaks in resource demands are expected.

Aphelion is the most advantageous period for high resolution imaging when periherm is on the dayside.

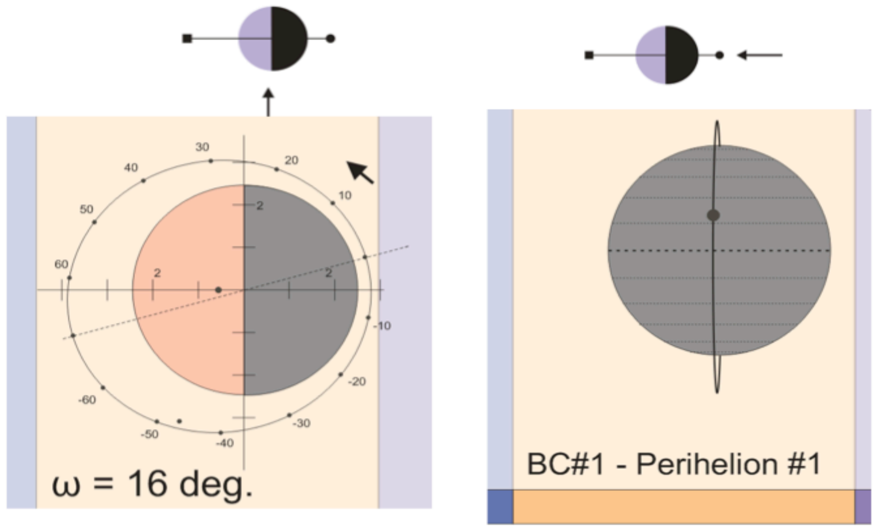
Availability of feasible opportunities needs to be considered when scheduling operations and resolving planning conflicts, in order to avoid missing opportunities.

MPO orbit Characteristics

The MPO orbit is in an inertially fixed low-eccentricity orbit (400 x 1500 km) of 2.3-hour period.

The MPO orbit is not maintained and several effects will have an impact on its evolution:

- Solar Radiation Pressure
- Albedo and Infrared radiation
- Wheel off loadings (2 every 24h)
- Safe-modes
- Mercury gravitational coef. J2&J3



The SGS planning process has to be able to address the issue of poor long-term orbit predictability and assume enough margins when scheduling science payload operations relative to events.

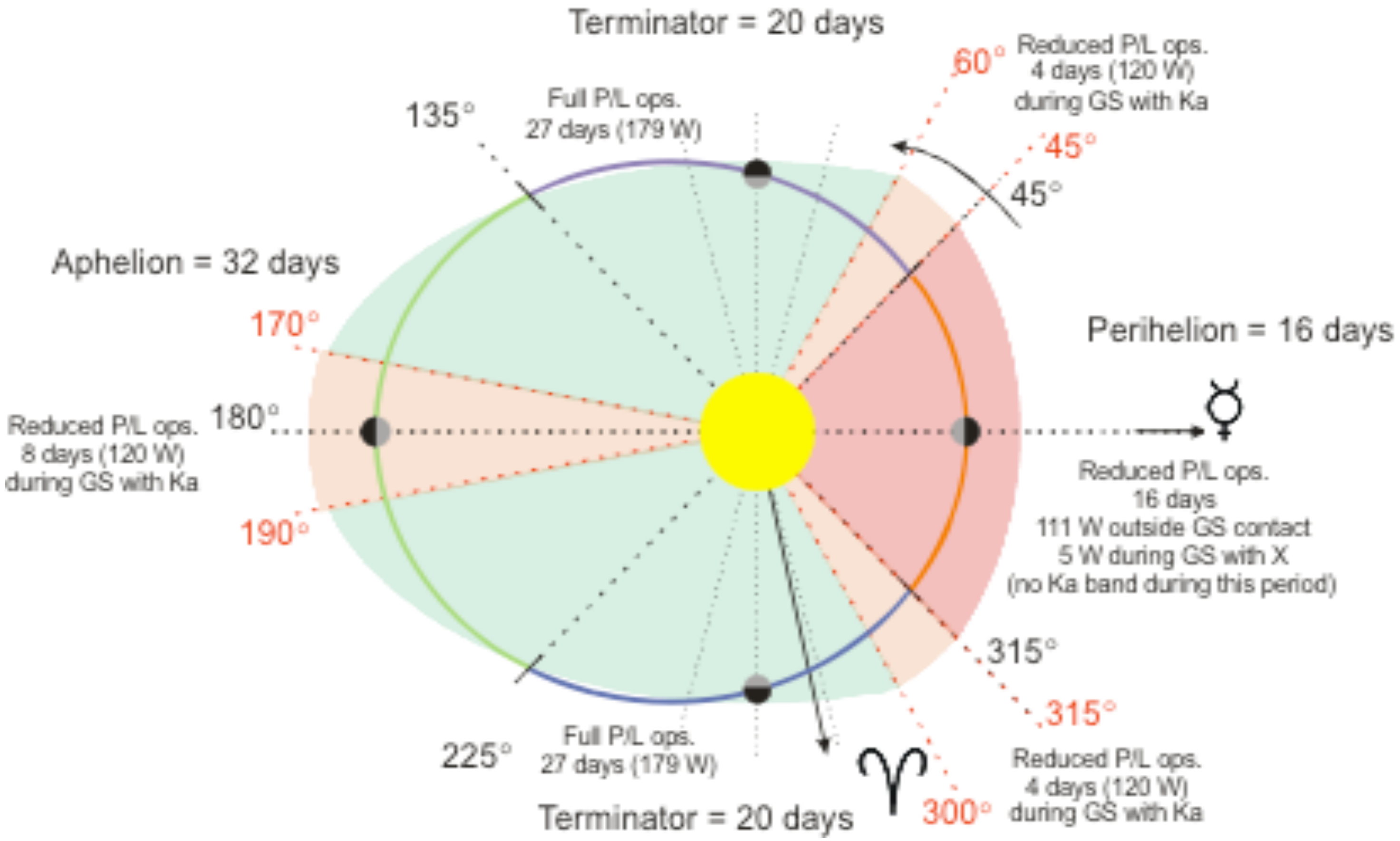
Science Operations Planning Drivers: Operational Constraints summary

The following mission characteristics will drive the BepiColombo MPO Science operations planning:

- **Power**
- **Data downlink**
- **Pointing**
    - **Wheel off-loading**
    - **Flip-over maneuvers**
- **Thermal**

Power Constraints

Due to high spacecraft temperatures at perihelion and aphelion, the thermal limitations of the solar arrays and eclipses, the power available for **payload operations and Ka-band transmitter** is expected to be **limited during periods around perihelion and aphelion**.

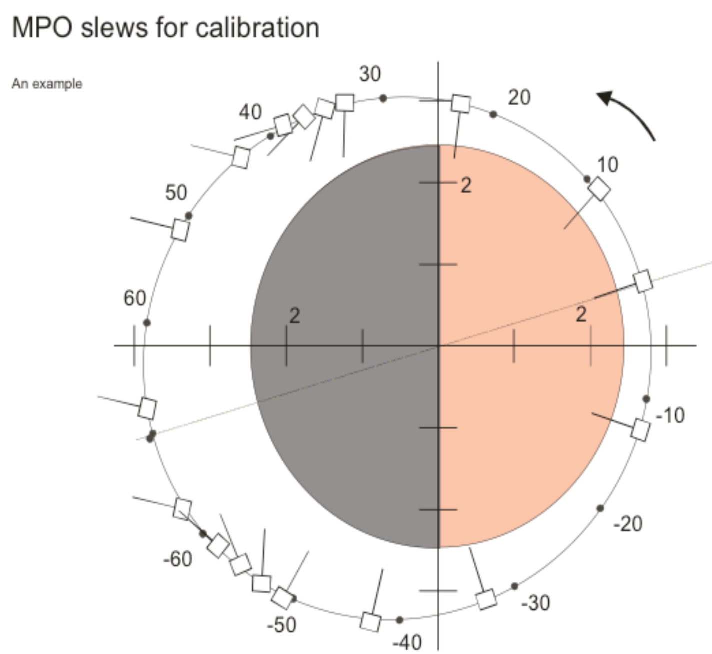


Pointing Constraints

BepiColombo MPO is a considered a **NADIR mission**: the spacecraft has the +Z axis (experiments bore-sight) aligned with the nadir direction for a continuous observation of the planet. As MPO is specifically designed as a NADIR pointing spacecraft in a harsh thermal environment off pointing capabilities are limited.

When an observation requires off-pointing attitude from nadir, it has to be checked:

- **Pointing attitude** compatibility with **geometrical** constraints (mainly coming from thermal constraints
- **Compatibility** with the rest of observations

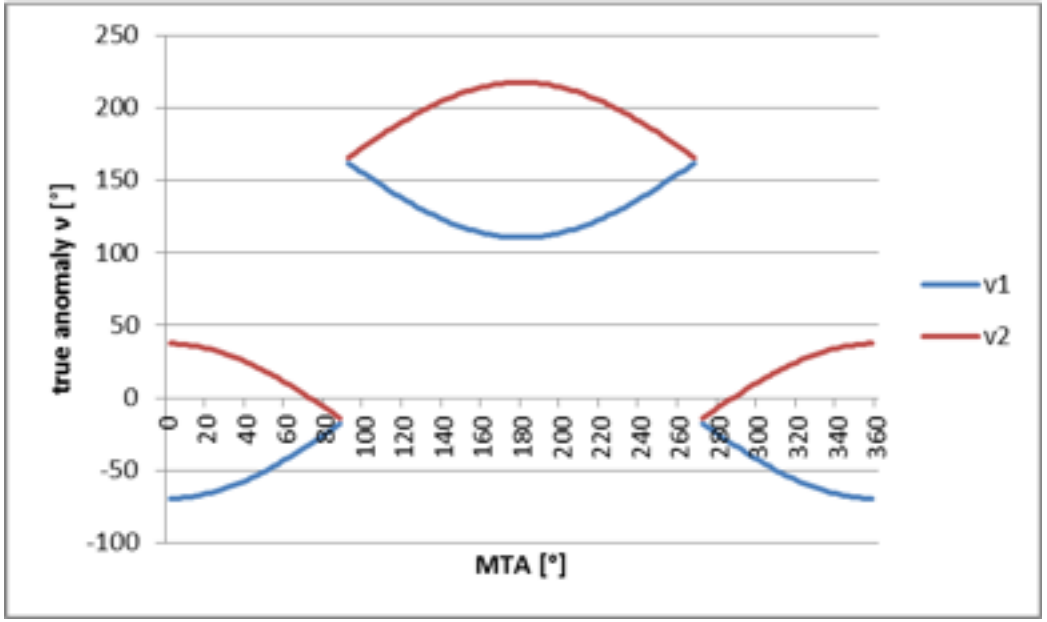


In case of incompatibility, it has to be evaluated:

- the **priority** of the observation
- if it is possible to **reschedule** it
- how many observations are **affected**

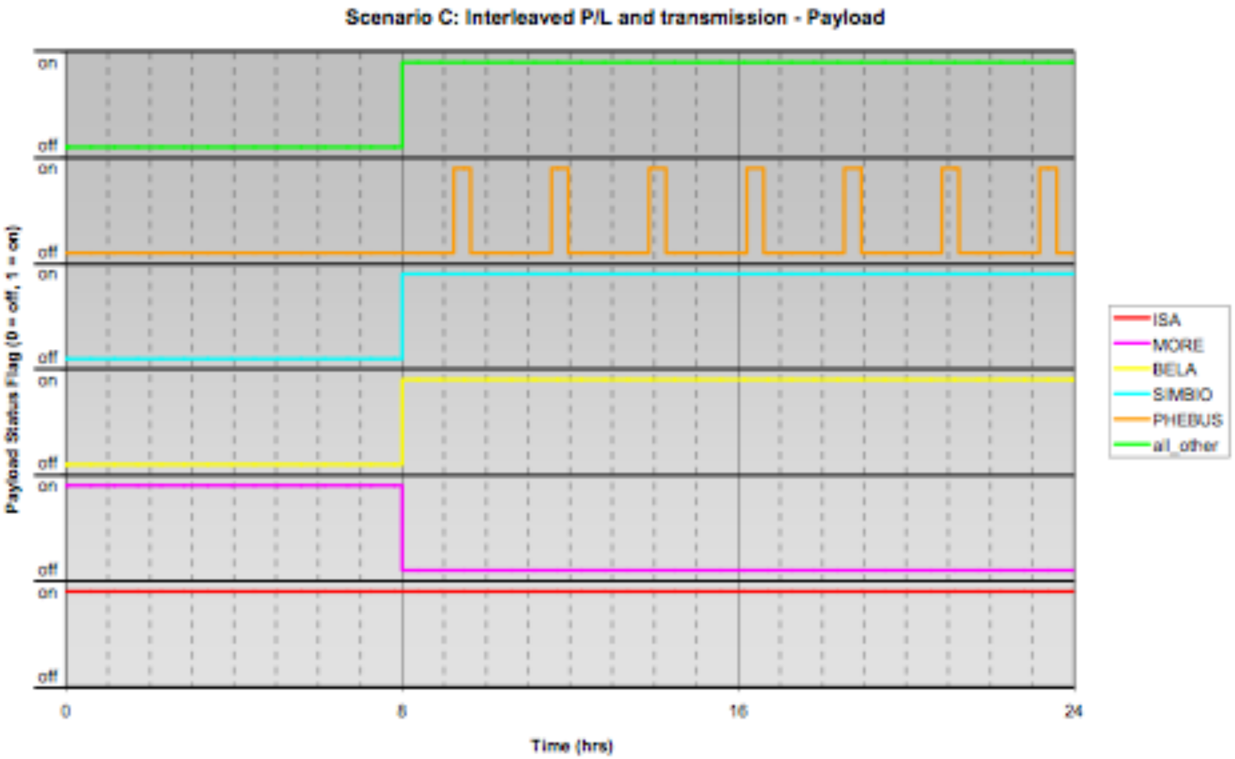
Wheel off-loading constraints

- Wheel off loadings frequency: **two** times **every 24 hours**
- Planned by the Science Ground segment
- MPO spacecraft orbit positions depending on Mercury true anomaly and the argument of periherm where wheel off loading shall not be schedule unless in eclipse (thruster failure during reaction wheels offloading can cause illumination of payload danger zone)



Thermal constraints

Around perihelion season, interdependency thermal constraints between instruments have to be also considered, to avoid that switching one instrument overheats another one. Inter-experiment thermal issues at perihelion are currently under analysis.



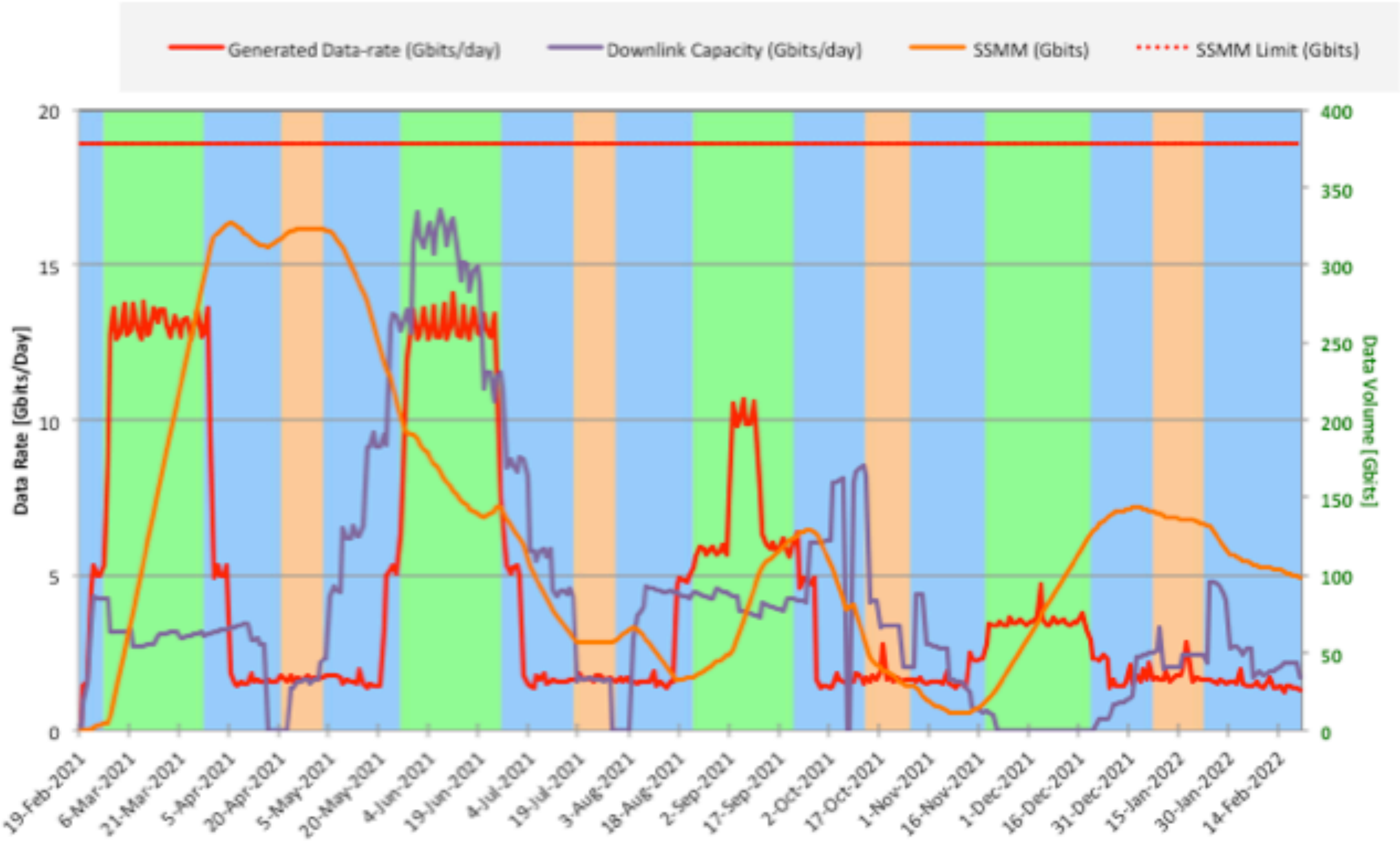
European Space Agency

Science Operations Planning Drivers: Mission Characteristics summary

The following mission characteristics will drive the BepiColombo MPO Science operations planning:

- **Mission duration**
- **Experiment characteristics**
- **Solid state mass memory characteristics**
- **Science data downlink mechanisms**
- **Two RF- bands for downlink**
- **MPO Orbit characteristics**

MPO Science Operational Timeline



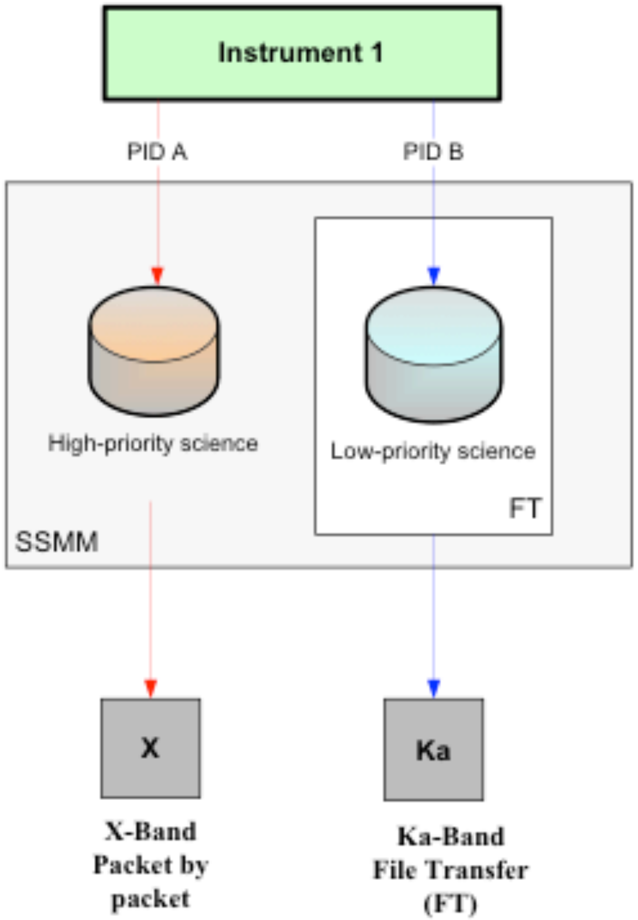
SSMM characteristics

SSMM total size: 384 Gbit (5 Gbit for Engineering stores, 16.8*2 Gbit for internal memory and 345 Gbit for Payload science stores)

The telemetry science data packets are stored in the SSMM packet stores based on **PIDs.**

One PID can only be associated to one SSMM packet store at a time, but several PIDs can be routed to the same SSMM packet store.

The instruments will generate low- and/or high-priority science data and store it in different packet stores based on the PIDs



Two RF- bands for downlink

X-band	Ka-band
• To return engineering data and **high-priority science data**. • Downlink is done **packet by packet** • it is possible to define a downlink priority of the packet stores. Engineering data is always given a higher priority than science data. • Data return latency of this band is **1-2 days**.	• To return only **low-priority science data** • It is affected by Earth weather conditions and therefore does not have the predictability of the X-band. • Downlink is done using a dedicated **file transfer downlink function/protocol**. • **No priorities** can be set for the File Transfer. • Data return **latency could be very high** (more than 40 days).

Downlink Mechanisms

Different mechanisms can be used to downlink science data in BepiColombo MPO:

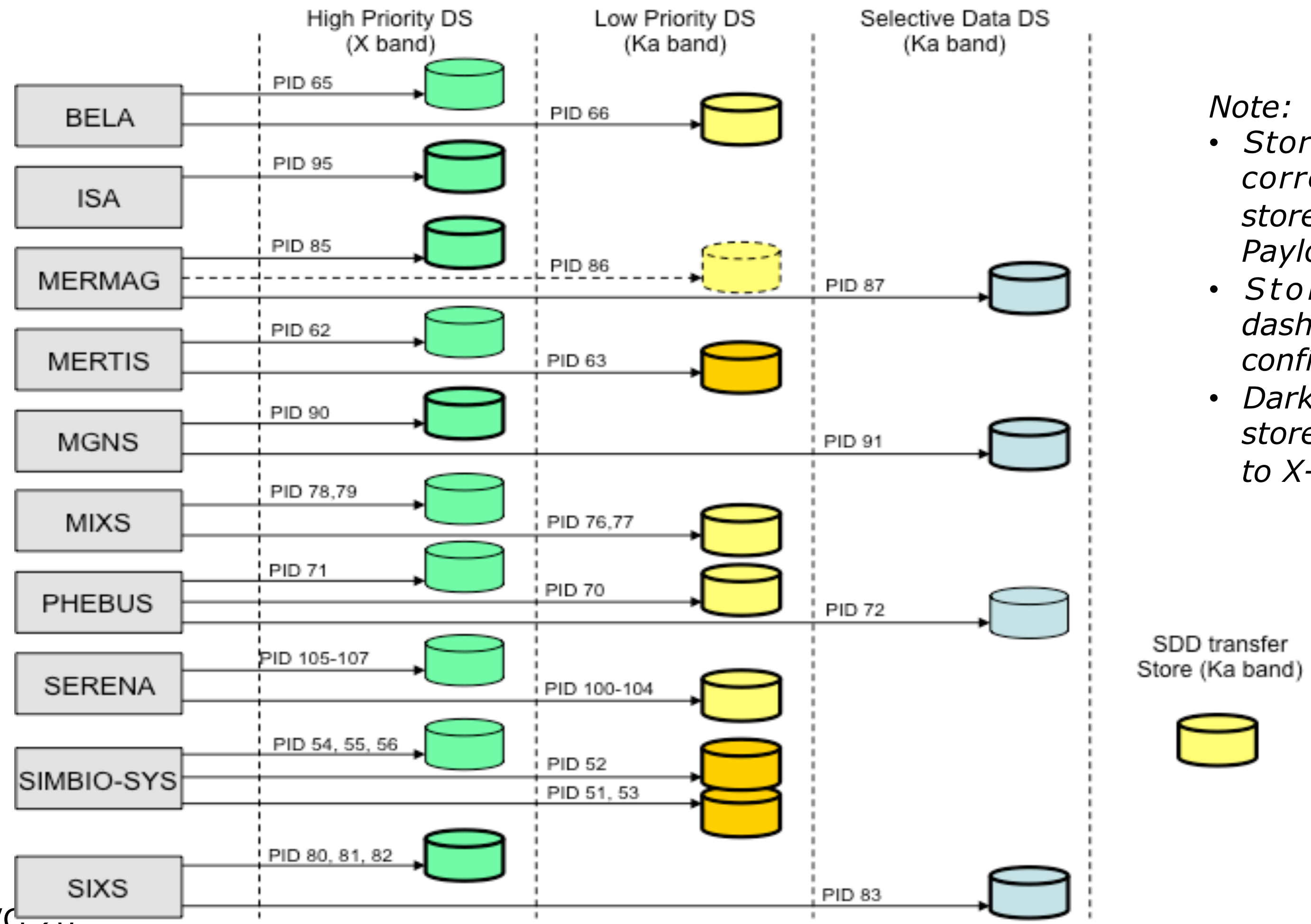
- Nominal Downlink
- Flexible data downlink
- Re-routing of Ka-band stores to X-band
- Selective data downlink

The Science Ground Segment will use these mechanisms to downlink the science data, taking into account:

- **Full utilisation** of X-band and Ka-band downlink capabilities
- SSMM does **not overflow**
- SSMM **data stores have enough capacity**
- **High priority** science data is downlinked to ground **first**.

Nominal Downlink

Nominal Downlink refers to the downlink process that will be used by default in the science phase of the mission.



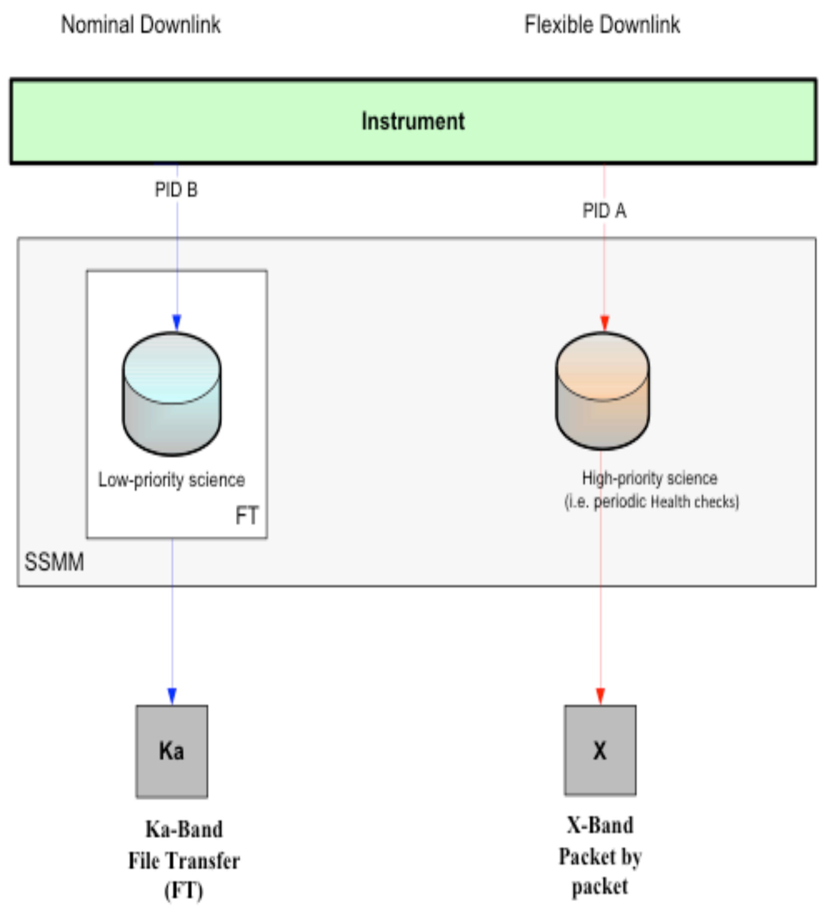
Note:

- *Stores highlighted in bold correspond to the default stores used nominally by the Payload*
- *Stores highlighted with dashes are stores that are not confirmed to be used*
- *Dark yellow stores are data stores suitable for re-routing to X-band*

Flexible Downlink

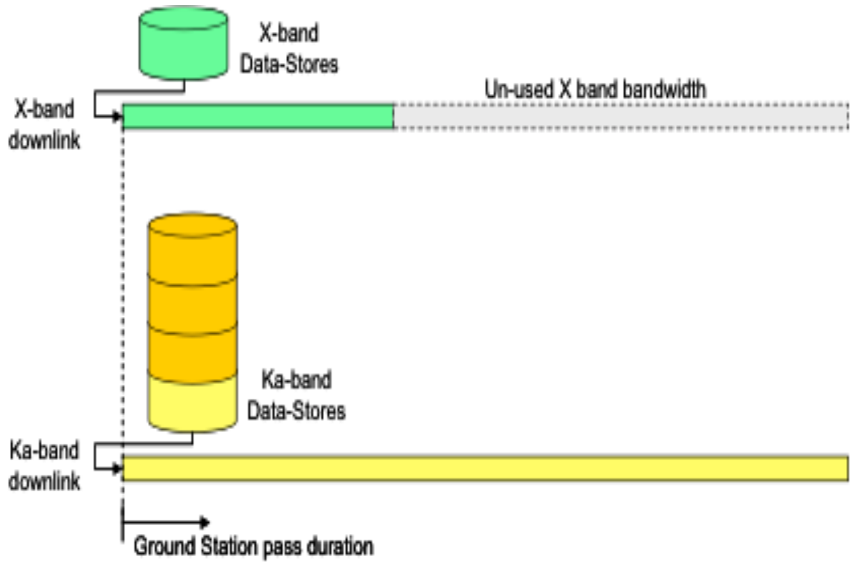
It will be ONLY used for **HIGH PRIORITY DATA**. An instrument that nominally sends its data to a low priority Ka-band store can temporarily send its high priority data to the X-band store (using a different PID).

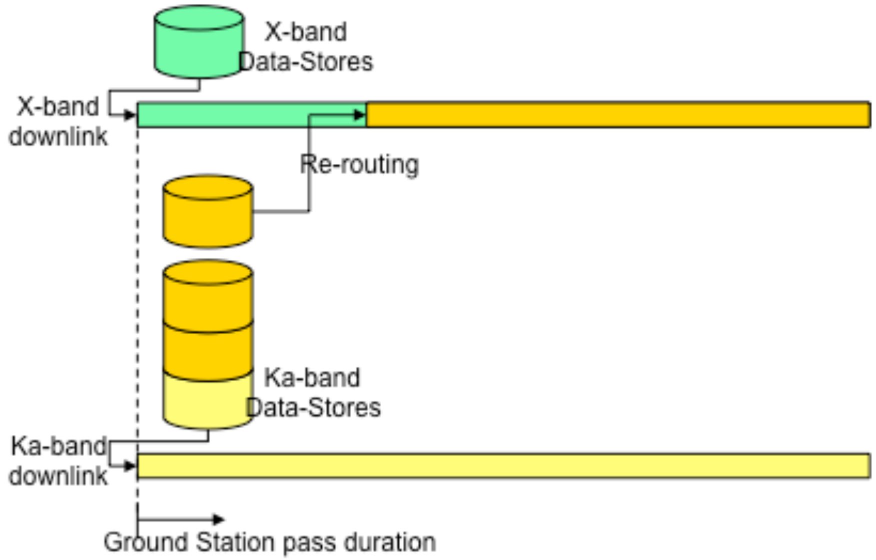
The science data received via X-band can be used to make a **quick scientific publication** (i.e. interesting picture of Mercury) or to perform **health checks** of the science operations. Those checks will be performed using **Quicklook** tools on ground.



Re-routing of Ka-band stores to X-band

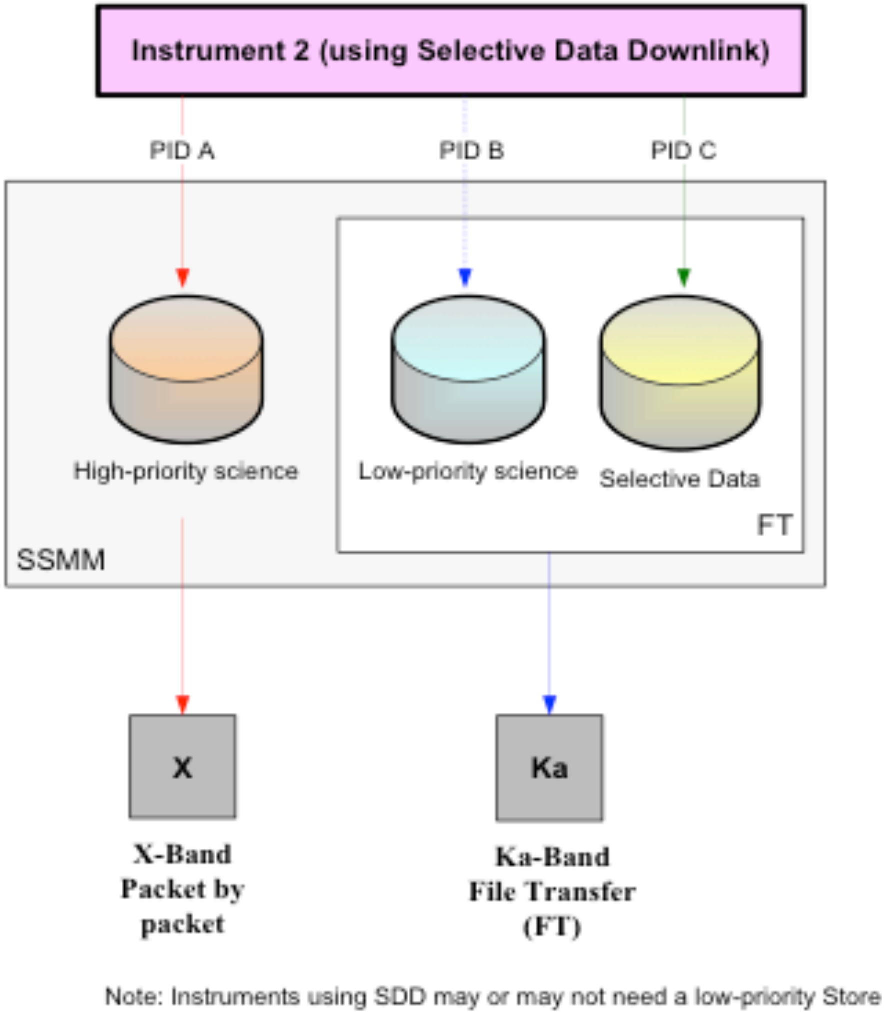
There are some points in the mission where there is not enough science data to be dumped via X-band to fully utilize the X band bandwidth. In order to ensure that the X band bandwidth is fully utilized, there is the option to **re-route a low-priority data store** (which contains a significant amount of data) using the X-band. The re-routed stores are set to low priority and remain to be considered **low priority science data**.





Selective Data Downlink

- Instruments using this feature will generate and store **low- and high-priority science data of the same observation**
- The **high-priority science** data will be downlinked via the **X-band**
- The **high-priority science data will be analysed** on ground, together with other MPO instruments data and MMO data
- If the analysis indicates an interesting feature, a **selection of the low-priority** science data will be done via **copy request to be downlinked via Ka-band**



Conclusions

BepiColombo MPO has the typical drivers of a planetary mission such as power, data volume, thermal and pointing constraints.

Additionally it has **some unique characteristics like a large SSMM which allows different downlink mechanisms and two different downlink channels.**

The science ground segment **planning system** will need to cope with those drivers and characteristics in order to efficiently plan the science payload operations.

A specifically adapted science planning approach will be needed to ensure that **all constraints and interdependencies** are considered while balancing the **available resources** and maximizing the scientific return of the mission.

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Thanks!

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