

SpaceOps-2025, ID # 141

Optimizing Payload Operations Management through an Automated Commanding Request Framework
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Abstract

The preparation and delivery of payload command requests are fundamental to ground segment mission planning. These requests, typically created by payload teams, mission managers, and satellite operators, are integrated into mission planning and control systems. At the European Space Operations Centre (ESOC), these payload requests are part of a broader concept known as Command Request Files (CRFs), which encapsulate various operational requests—including telecommands, sequences, automation procedures, and mission-critical events—collectively referred to as occurrences.

Starion has developed a web-based tool to support payload operations for generation and delivery of Payload Operations Requests (POR/PDOR), a specific subtype of CRF. These requests adhere to the CRF format and align with the applicable Mission Information Database (MIB) integrated into the ESOC Ground-based data systems. Initially created for the BepiColombo mission, this approach has demonstrated its adaptability in missions like JUICE.

Historically, prior missions employed a decentralized approach for CRF management, where users were devising their own methods for creating and delivering CRFs. This approach often led to extensive interactions with the Flight Control Team at ESOC due to incompatibilities with the Mission Information Database (MIB) and the Interface Control Documents (ICDs) of ESOC systems. The widespread adoption of this centralized framework by various ESA mission operations centers has proven to be a highly effective solution, streamlining interactions with diverse end-users and leading to significant cost savings within flight operations control teams.

This framework not only enhances operational efficiency but also fosters collaboration among various stakeholders by providing a unified platform for payload command request management. This results in streamlined workflows, reduced operational overhead, and improved mission planning accuracy. Moreover, its adaptability across different missions underscores its versatility and potential for broader applications. The key capabilities of the solution include:

- **CRF Editing:** Providing robust tools for creating and editing CRFs to ensure accuracy and completeness.
- **Management of MIB Updates:** Effectively managing updates to the MIB, addressing, and resolving conflicts to maintain data integrity.
- **MIB Compatibility Validation:** Ensuring that all CRFs are compatible with the MIB to prevent operational discrepancies.
- **ICD Compliance Verification:** Verifying that CRF file contents conform to the operations planning ICDs for seamless integration with mission systems.
- **CRF Generation and Delivery:** Streamlining the creation, submission, and monitoring of CRFs to ensure timely delivery and acknowledgment processes.

In conclusion, the solution developed by Starion represents a significant advancement in the management of payload command requests for ESA missions. Its successful implementation in missions like BepiColombo and JUICE, and its potential adoption in future missions, highlight its effectiveness and scalability. This sets a new standard for

payload command request management, ensuring efficient, reliable, and cost-effective mission planning and operations support.

Keywords: payload operations, planetary, commanding, cruise phase, automated framework

Acronyms/Abbreviations:

- CRF: Command Request File
- ESA: European Space Agency
- ESAC: European Space Astronomy Centre
- ESOC: European Space Operations Centre
- ICD: Interface Control Document
- JAXA: Japan Aerospace Exploration Agency
- JUICE: JUpter ICy moons Explorer
- LEGA: Lunar-Earth Gravity Assist
- MCS: Mission Control System
- MIB: Mission Information Database
- MPS: Mission Planning System
- NECP: Near Earth Commissioning Phase
- POR: Payload Operations Request
- PDOR: Payload Direct Operations Request

1. Introduction

BepiColombo is an interdisciplinary ESA mission launched in October 2018 to explore Mercury in cooperation with the Japan Aerospace Exploration Agency (JAXA). A long cruise phase of 7.2 years toward the inner part of the Solar System will bring BepiColombo to Mercury, after 9 planetary flybys, 1 to the Earth, 2 to Venus, and 6 to Mercury.

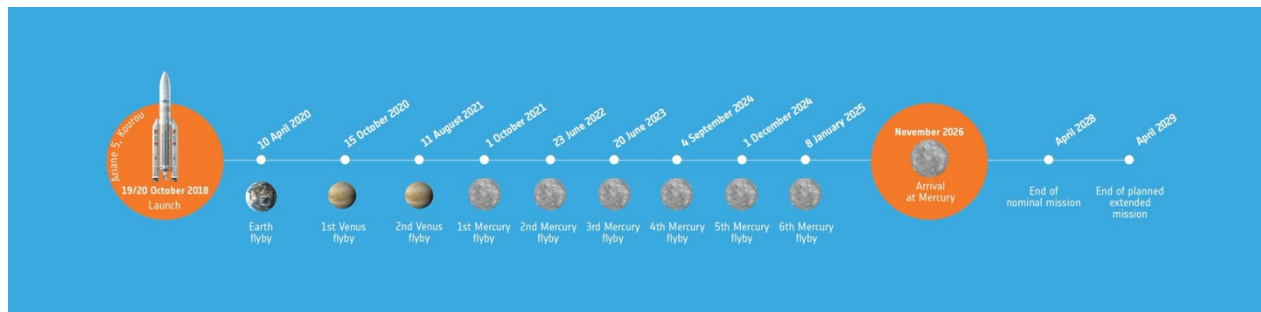


Figure 1: BepiColombo Cruise Phase and Milestones

JUICE - JUpter ICy moons Explorer - is a first large-class mission launched in April 2023 and with arrival at Jupiter in 2031, it will spend at least three years making detailed observations of the giant gaseous planet Jupiter and three of its largest moons, Ganymede, Callisto and Europa. A long cruise phase will bring JUICE to Jupiter and its moons, after 4 planetary flybys, 3 to the Earth and 1 to Venus.

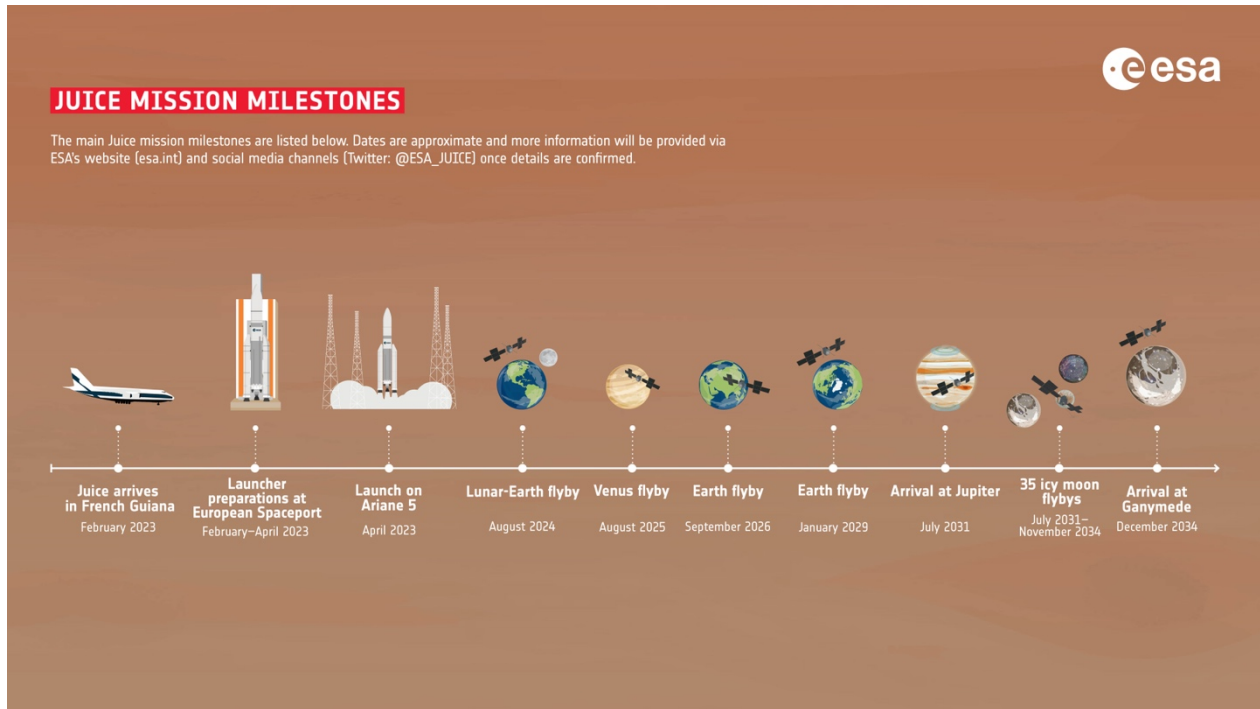


Figure 2: JUICE Mission Cruise Phase and Milestones

During the BepiColombo and JUICE long cruise phase, instrument check-outs and science operations commanding have to be generated as payload operations (direct) requests (POR/PDOR) by the scientific Instrument Teams using the Command Request File format (CRF).

Under the ESA EFC2 frame contract, the Starion Service Team at ESAC has developed a centralized web-based framework. This framework serves to facilitate ESA Science Operations Centers at ESAC and supports Payload teams in generating and submitting payload (direct) operations requests (POR/PDOR), a specific subtype of CRF. These requests adhere to the CRF XML format and align with the applicable Mission Information Database (MIB) integrated into the ESOC Ground-based data systems. Initially created for the BepiColombo mission, this framework has already demonstrated its adaptability in missions such as JUICE, while also garnering interest from missions like HERA and ARIEL.

2. BepiColombo CRF editor Case

During the Bepicolombo Cruise phase the payload commanding request are provided by the Instrument Teams to the MOC at ESOC using Command Request File format (CRF):

- Payload Direct Operations Request (PDOR)
- Payload Operations Request (POR)

The CRF editor framework, known as SPOT Cruise, has been supporting the Instrument Teams in the generation of the Command Request Files (CRFs) compatible with European Space Operations Centre (ESOC) tools: the Mission Planning System (MPS), the Mission Control System (MCS) and the applicable Mission Information Database (MIB).

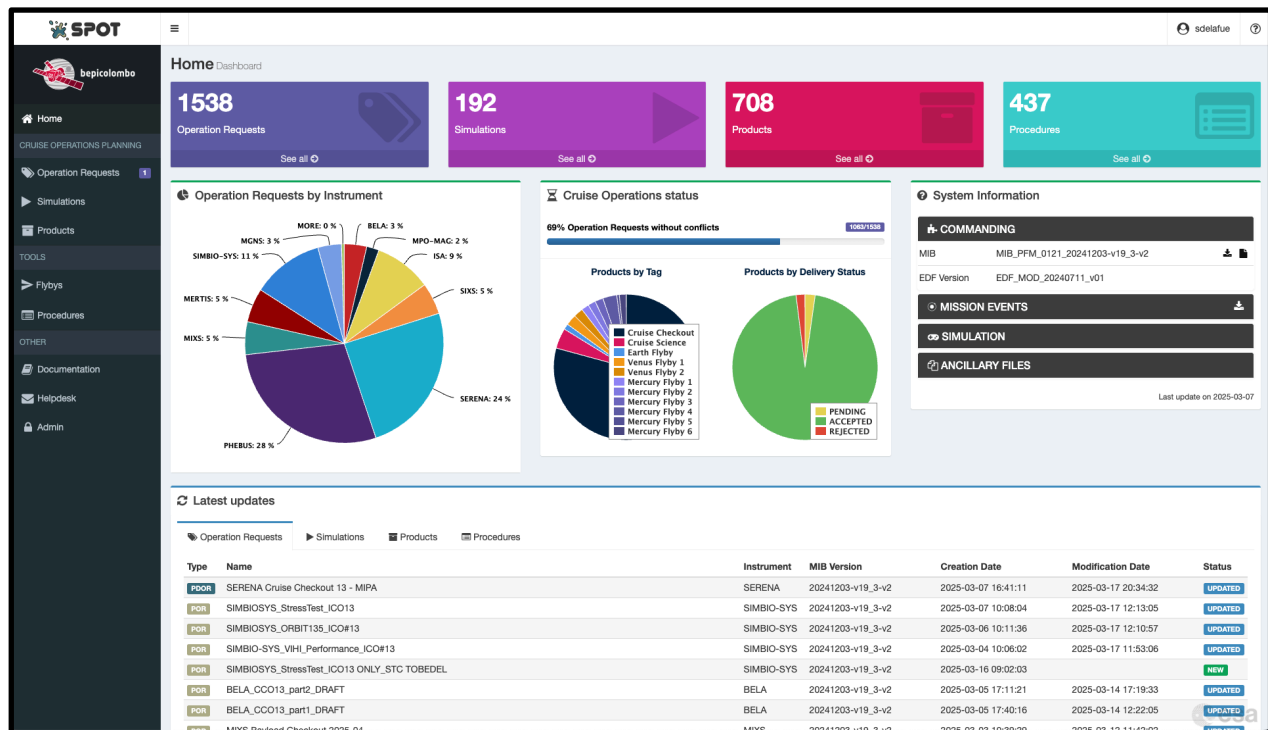


Figure 3: BepiColombo CRF Editor Dashboard

The “SPOT Cruise” has already supported the Instrument Teams in the preparation for the Near Earth Commissioning Phase (NECP) operations, the periodic instrument check-out operations (every 6 months) and the generation of science operations for the 9 planetary flybys (Earth flyby, Venus flybys and Mercury flybys) plus additional cruise science operations. More than ~ 1500 BepiColombo Payload Operational request have been already generated using SPOT Cruise since the mission Launch as shown in previous figure.

The main features of SPOT Cruise used during the long BepiColombo Cruise phase are listed below:

- User Access Control (COSMOS LDAP)
- POR/PDOR editor (create/clone/edit/delete)
- MIB compatibility checks
- Email Notifications on user actions (update/delete)
- Full Traceability of changes
- MIB update handling and conflicts resolution
- Availability of Flight Dynamics and Science events
- Product generation & direct Submission to MOC in compatible format (CRF), including delivery and acknowledgment monitoring
- 3D Flybys Visualisation
- POR/PDOR Simulation (Timeline and Resources)
- Advanced Search
- Procedure Builder (MOIS compatible)

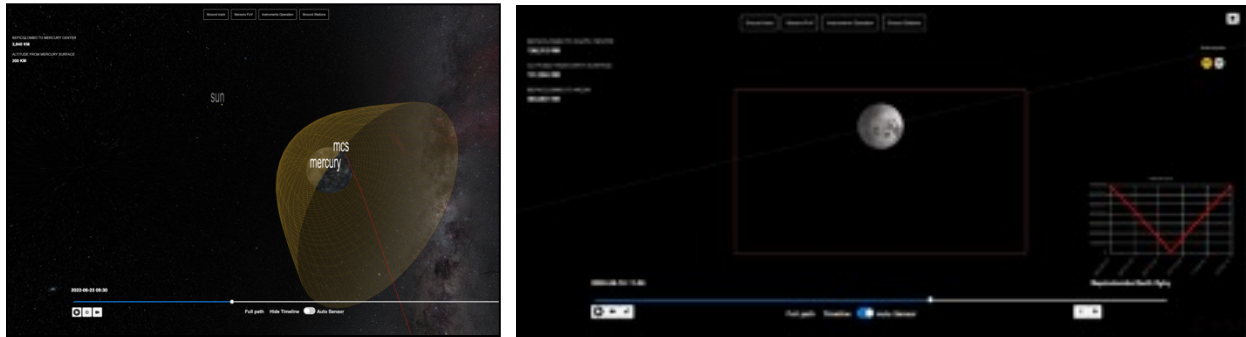


Figure 4: BepiColombo SPOT Cruise 3D visualisation

All the information in SPOT is centralised and version-controlled. Additionally, privacy and confidentiality of the data is ensured through user authorisation and authentication.

3. JUICE CRF editor Case

The CRF editor tool was adapted to JUICE in 2021 based on BepiColombo implementation, excluding the flybys 3D visualisation, the Procedure builder and the simulation functions but keeping the CRF editor and delivery capabilities. The JUICE CRF editor framework, known as SPOT JUICE, has been already supported the Payload Ground Testing activities before the Launch, the Near Earth Commissioning Phase (NECP) operations, the periodic instrument check-out operations (every 6 months) and the generation of science operations for the Lunar-Earth Gravity Assist (LEGA) in August 2024. More than ~ 700 JUICE Payload Operational request generated with SPOT.

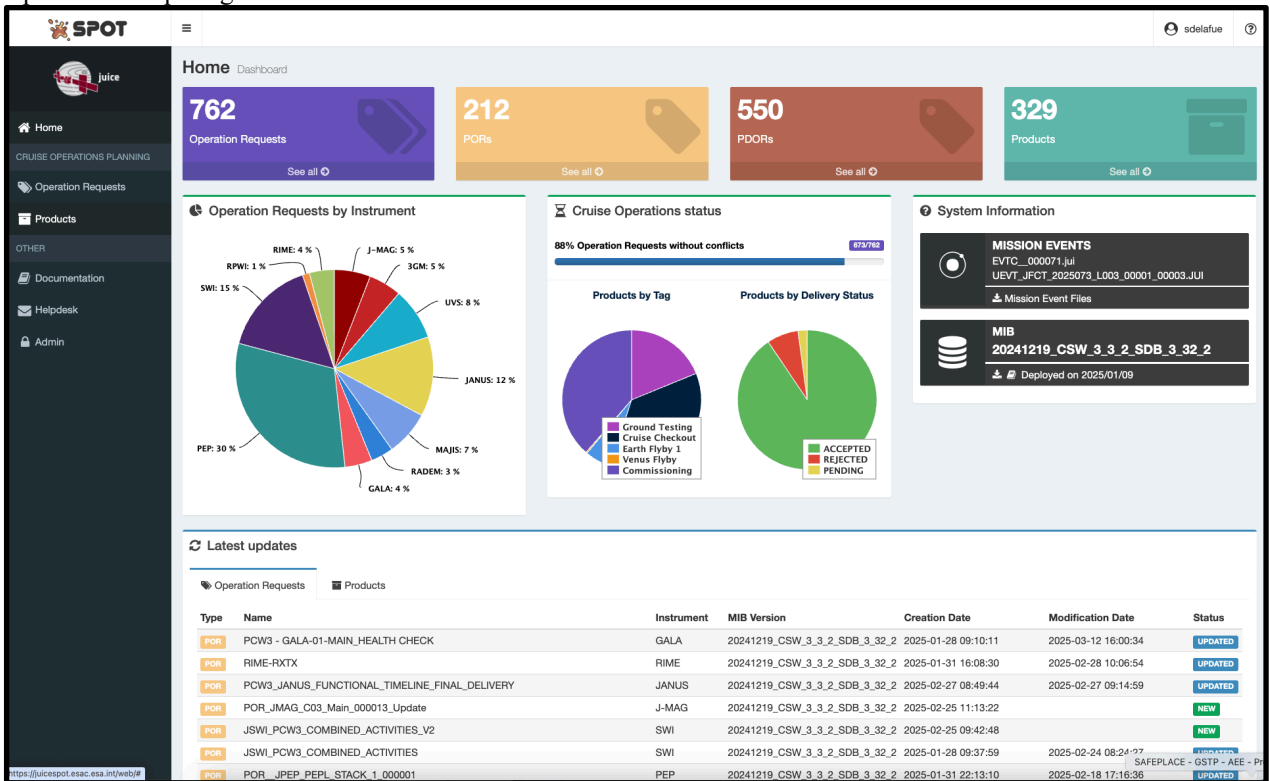


Figure 5: JUICE CRF Editor Dashboard

The main features of SPOT JUICE used during the long JUICE Cruise phase are listed below:

- User Access Control (COSMOS LDAP)
- POR/PDOR editor (create/clone/edit/delete)
- MIB compatibility checks
- Email Notifications on user actions (update/delete)
- Full Traceability of changes
- MIB update handling and conflicts resolution
- Availability of Flight Dynamics events
- POR/PDORs Direct Submission to MOC in compatible format (CRF)

4. Summary of the Commanding Request Framework Functions

The key capabilities of the Automated Commanding Request Framework solution include:

- **CRF Editing:** Providing robust tools for creating and editing CRFs to ensure accuracy and completeness.
- **Management of MIB Updates:** Effectively managing updates to the MIB, addressing, and resolving conflicts to maintain data integrity.
- **MIB Compatibility Validation:** Ensuring that all CRFs are compatible with the MIB to prevent operational discrepancies.
- **ICD Compliance Verification:** Verifying that CRF file contents conform to the operations planning ICDs for seamless integration with mission systems.
- **CRF Generation and Delivery:** Streamlining the creation, submission, and monitoring of CRFs to ensure timely delivery and acknowledgment processes.

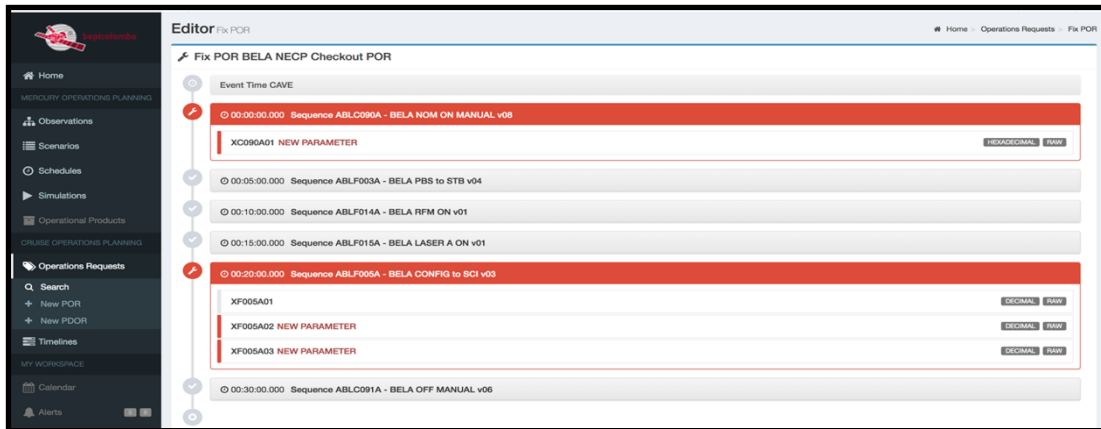


Figure 6: MIB Conflicts Fix editor

5. Commanding Request Framework advantages

The above-mentioned commanding request framework facilitates the interactions of the wide number of PI teams with ESOC, and also provides monitoring and visualisation of the generation process via web interface and minimises incompatibility with the agreed interfaces

The main advantages to stress of these tools are:

- Avoidance of manual edition of the data via files reducing errors, time and cost of production and minimising the number of iterations between ESOC and the instrument teams.
- Full compatibility with ESOC tools (Mission Planning System , Mission Control System)
- Provide a centralise repository of the data that guarantees its recovery at any time in more reliable and secure way.
- Facilitate the compatibility with and management of Operational Database in where the telecommands and telemetry elements are defined (so- called MIB) in the preparation of the products (CRFs)

ID	Name	Instrument	Operation Requests	Tag	Change Log	Status
CRFG00046	JANUS SOVT PORs	JANUS	JJAN00035 JJAN00032	Ground Testing	✓	ACCEPTED
CRFG00047	JANUS SOVT PDORs	JANUS	JJAN00036 JJAN00034	Ground Testing	✓	ACCEPTED
CRFG00044	GALA SOVT PDORs	GALA	JGAL00116 JGAL00109	Ground Testing	✓	ACCEPTED
CRFG00045	GALA SOVT PORs	GALA	JGAL00107 JGAL00108	Ground Testing	✓	ACCEPTED
CRFG00043	MAJIS Test	MAJIS	JJIS00080	Ground Testing	✓	ACCEPTED
CRFG00042	PEP-Lo SOVT PORs	PEP	JPEP00060 JPEP00063	Ground Testing	✓	ACCEPTED
CRFG00041	PEP-Lo SOVT PDORs	PEP	JPEP00068 JPEP00067	Ground Testing	✓	ACCEPTED
CRFG00039	JMAG SOVT PORs	J-MAG	JMAG00058 JMAG00054	Ground Testing	✓	ACCEPTED
CRFG00040	JMAG SOVT PDORs	J-MAG	JMAG00067 JMAG00063	Ground Testing	✓	ACCEPTED
CRFG00037	HAA PORs SOVT	SGM	JSGM00048 JSGM00065	Ground Testing	✓	ACCEPTED
CRFG00038	SGM PDORs	SGM	JSGM00068 JSGM00047 JSGM0006A JSGM0006B	Ground Testing	✓	ACCEPTED
CRFG00032	RPWI PDORs	RPWI	JRPW00063 JRPW00096	Ground Testing	✓	ACCEPTED
CRFG00028	UVS test products POR	UVS	JUVS00076 JUVS00071	Ground Testing	✓	ACCEPTED

Figure 7: Products Delivery monitoring

4. Conclusions

Historically, prior missions had employed a decentralized approach to CRF generation and delivery, with users devising their methods to create and transmit CRFs. This often led to extensive interactions with the Flight Control team at ESOC, stemming from incompatibilities with the Mission Information Database (MIB) and the ICDs of ESOC systems. Starion has developed a framework to support payload operations for generation and delivery of Payload Operations Requests (POR/PDOR), a specific subtype of CRF. Initially created for the BepiColombo mission, this approach has demonstrated its adaptability in missions like JUICE. The adoption of this framework has conclusively proven to be a highly effective solution. It streamlines interactions with diverse payload teams, leading to significant cost savings within flight control teams.

References

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