



MOF: The ground support to Metis operations

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On behalf of MOF team

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MOF Introduction (1/2)



- The Metis Operations Facility (MOF) represents the **ground segment** system that allows the **Metis Instrument Science Team** to **prepare and execute the Metis operations** in the **Nominal Mission, Extended Mission and Post Mission Phases**.
- The project is funded by Italian Space Agency in the frame of the industrial contract n. 2020-10-I.0 “Solar Orbiter - Metis: supporto industriale in fase E”, between ASI and the ATI (Associazione Temporanea di Impresa) set up by OHB and TAS Italia for the design and the realization of Metis Coronagraph. **ALTEC has the task of defining, implementing and operating the MOF, in close cooperation with INAF.**
- MOF v2 has been released for the beginning of the Nominal Mission while **MOF v4 is the one currently deployed in the OPS environment**. A new major version of the MOF is foreseen every year and it is released only after a completion of a full System Test Campaign.



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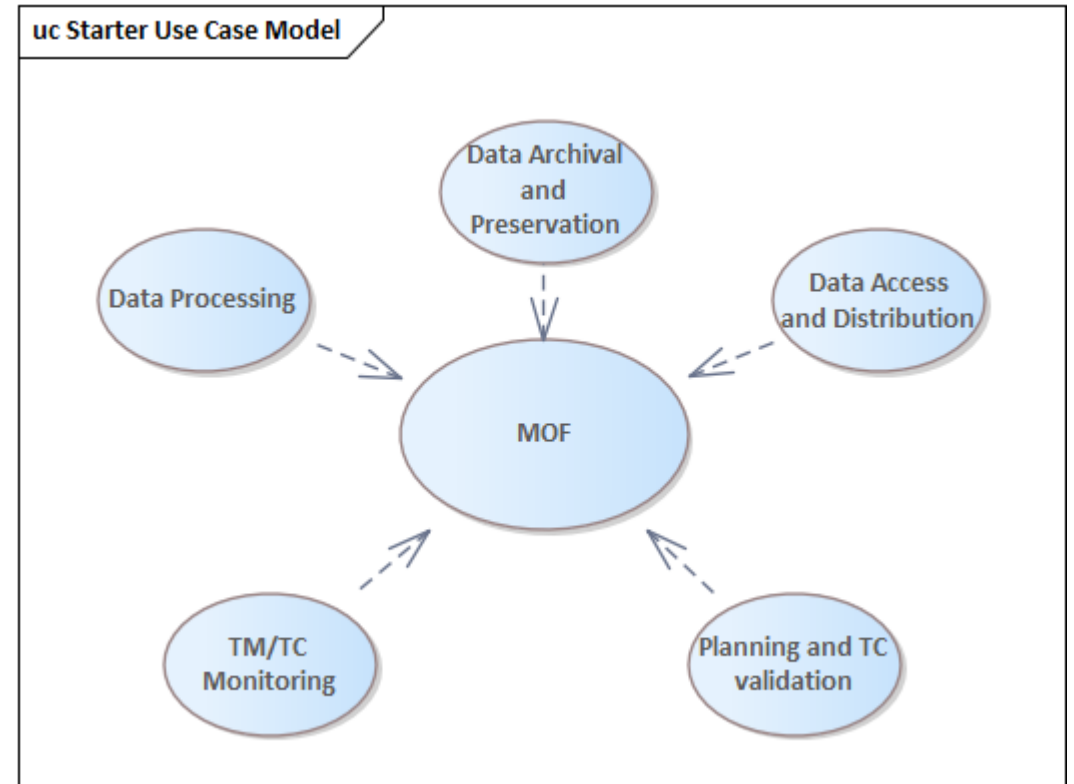
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MOF Introduction (2/2)

- The Metis Operation Facility implements **five main functions**

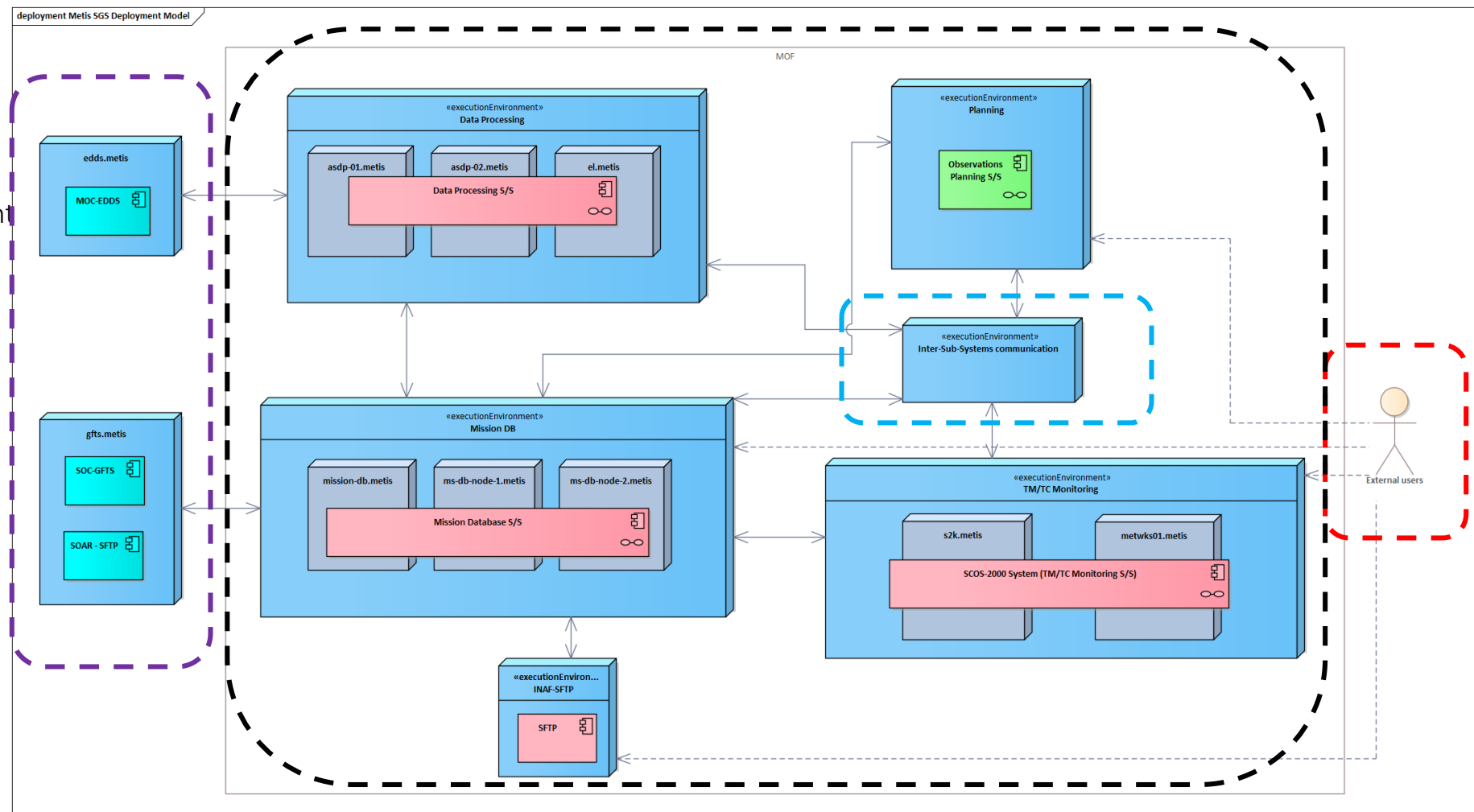
1. Data Processing
2. Data Archival and Preservation
3. Data Access and Distribution
4. TM/TC Monitoring
5. Observations planning and TC validation



MOF Architecture



- External entities
- End-user
- MOF main subsystems
- ALTEC infrastructure
 - 15 virtual nodes hosted @ALTEC
 - Network and storage management (VLAN, SAN)
 - SFTP for data transfer
 - SMTP for mail
 - VPN based access



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MOF Architecture – External Interfaces



MOC

- Raw Telemetry Data distribution with EGOS Data Dissemination System (EDDS).
- HTTPS web-based interface for requesting Spacecraft Telemetry packet and parameter data, Telecommand history, event data.
- Scheduled EDDS Request for DAILY automatic processing. Ad hoc request for reprocessing or contingency situation.

SOC

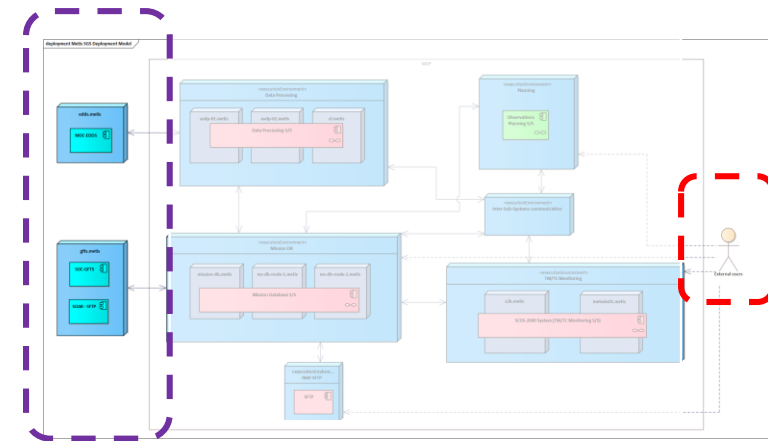
- Data exchange with SOC via Generic File Transfer System (GFTS).
- Retrieval from SOC planning input data, low latency processing output, spice kernel and auxiliary files.

Solar Orbiter Archive (SOAR)

- Data exchange with SOAR via SFTP
- **New interface**, direct data transfer to SOAR (no more via SOC)

Metis Science Team

- Access to Planning, TM/TC Monitoring, Mission DB S/S GUI
- Accessing/Extraction of science data for consistency checks, validation activities, perform extra-analysis.



Solar Orbiter Archive

SOAR 1.12.1

RESULTS #1 X

science (28817)

<input type="checkbox"/>	Item Id			Level	Descriptor
<input type="checkbox"/>	solo_L2_metis-uv-image_20211203T193500	Q	📄	N/A	L2 metis-uv-image
<input type="checkbox"/>	solo_L2_metis-vi-image_20211203T193501	Q	📄	N/A	L2 metis-vi-image
<input type="checkbox"/>	solo_L2_metis-vi-stokes_20211203T193501	Q	📄	N/A	L2 metis-vi-stokes



Generation of the Instrument Operation Request.

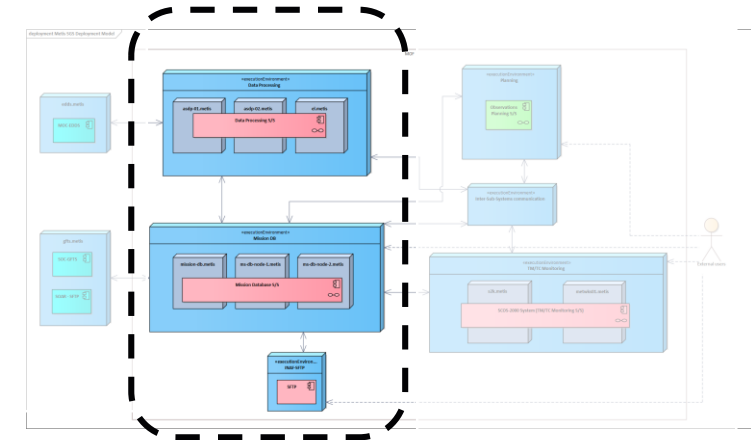
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MOF Architecture – Data Processing & Mission DB



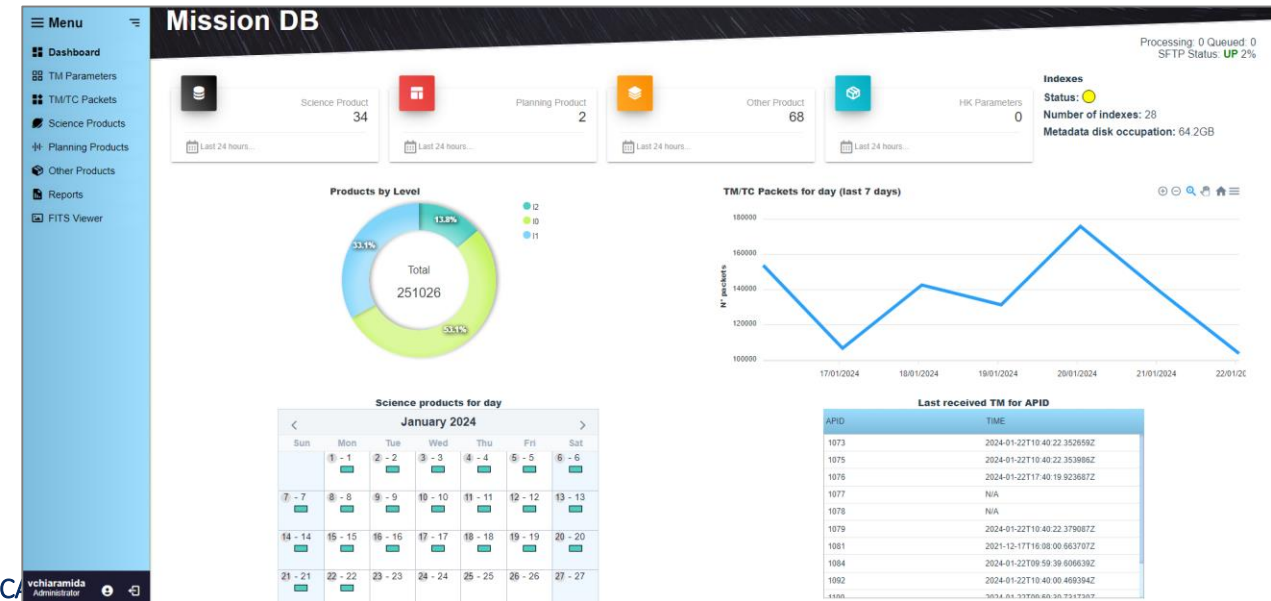
Data Processing S/S

- Runs the **scientific and processing pipelines** for data generation up to L2 data products
- Interacts with external components to retrieve raw data (MOC).
- Generates reports for validation and data quality assessment
- GUI for processing management, MDB data ingestion and retraction, OPS report generation and push data to SOAR.



Mission Database S/S

- Archives data retrieved from both external sources and produced by the MOF
- Preprocessing capabilities for augmenting data products metadata during ingestion
- Data products versioning and lineage
- Interacts with Data Processing, TM/TC Monitoring, Planning S/S
- Web-based GUI for data exploration, inspection and extraction with custom or pre-defined search filters
- API based access for authorized clients



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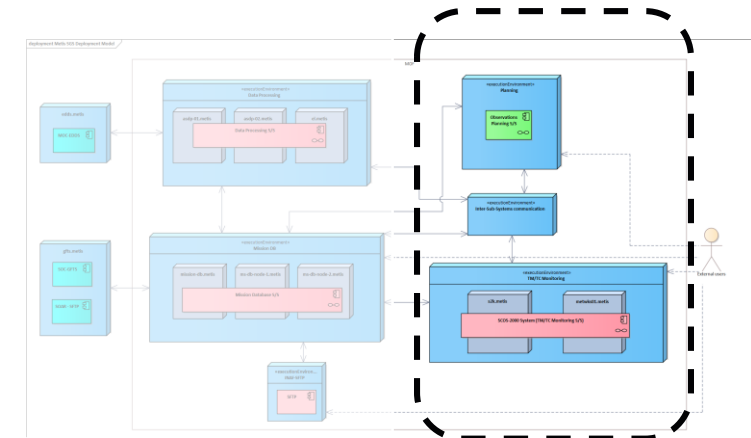
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MOF Architecture – TM/TC Monitoring & Planning



TM/TC Monitoring S/S

- Based on ESA SCOS 2000
- Components implemented for automatic ingestion and extraction of TM/TC packets (which are made available to all MOF S/S for data generation and validation).
- Monitoring Services for TM/TC assessment. Examples during the nominal mission:
 - UV channel anomaly (beginning of 2022)
 - Solar Orbiter SSMM anomaly (November 2022).



Observations Planning S/S

- Based on the MISO (Multi Instrument Schedule Organizer) software developed to generate CRFs for Solar Orbiter instruments
- Software deployed and integrated in a dedicated VM of the MOF infrastructure. Input and output data flows have been automated.
- Outputs of MISO tool are the following Command Request Files:
 - Instrument Operation Request (IOR)
 - Payload Direct Operation Request (PDOR)
 - Mission Direct Operation Request (MDOR).

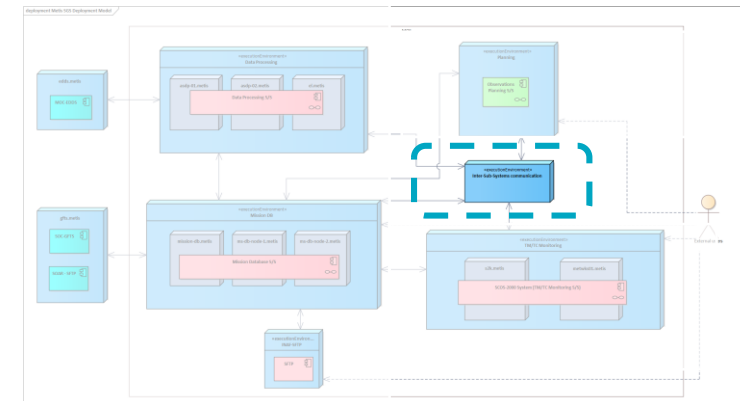


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MOF Architecture – Infrastructure

- MOF infrastructure is currently being involved in a migration process that will allow to exploit the new hardware resources (computing & storage) received, validated and installed @ALTEC in November 2023

- 2 x storage server nodes for generation, archiving and access to Metis data products:
 - 2 x Intel Xeon-Gold 6354 type CPU @ 3.0GHz with 18-core
 - 256GB of RAM
 - 1 Gbps redundant LAN cards; 16 Gbps redundant SAN cards
 - 1 x VMware vSphere Enterprise licenses (2 CPUs)
- 2 x HPE Nimble HF40 storage expansion units for a total of 84 TB per element each having the following characteristics:
- 20 x LTO-8 Ultrium type tapes with a capacity of 12 TB per unit



- Migration schedule organized in 4 phases

- Setup phase
- Early Operations phase
- Operations phase
- Optimizations phase

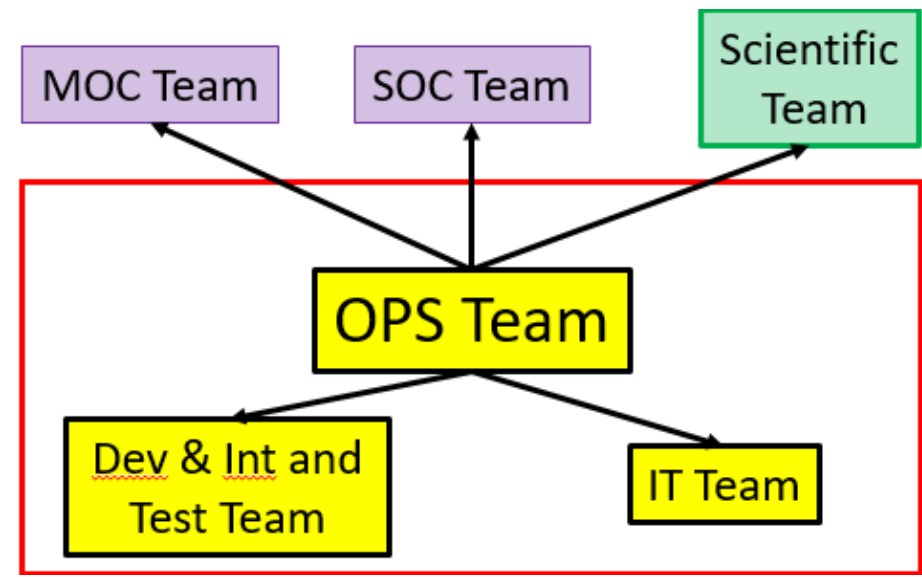
- **MOF System Test campaign** foreseen at the end of the Setup Phase in order to validate all the MOF data flows and functions on the new infrastructure
- Migration process designed **not to interrupt daily and reprocessing activities** to the best possible extent
- Completion foreseen by March 2024



MOF Operations (1/2)



- **Focus:** follow the Mission Plan, check MOF S/S status, monitor Infrastructure SW performance and release new SW version, monitor and execute the scientific processing and reprocessing, support the Metis scientific team.
- **OPS Organization:** two operators that alternate in order to execute all the foreseen activities. Interaction with internal team (ALTEC people) and external team.
- OPS Tools



Mission Log		Occurrence Date	Mission Phase, Type and Category	Content	Creator, Topics and Thread	Atta
558	UTC 2023/01/26 09:24:22	2023/01/26 09:13:00	Nominal Mission, Daily Check, Workflow	Data Processing 2023/01/26 [...]	fpinna as Metis OF	

TM/TC Monitoring

Telemetry Playback

Commands

Others

Time Correlation

File Archive

Automation

SOOPKitchen

Plan: LTP10_Dec2022-Mar2023 Baseline: 8 Version: 780 E-fecs Version:

	December 2022	January 2023			
SOOPs	26	1	6	11	16
Metis	METIS_SYNOPTIC				

Data Processing Interface

85	COMPLETED_SUCCESS		
c4670a07-4c23-4e84-ac74-b...	EDDSRawIngestion	84	COMPLETED_SUCCESS
d1a3204f-67d1-4981-9fae-d...	L1	83	COMPLETED_SUCCESS
d08e8934-d78e-4308-8744-...	L0	82	COMPLETED_SUCCESS

MOF Operations (2/2)



- **OPS Daily activities**
 - MOF operator checks each morning the status of the all data processing infrastructure and the result of the processing executed automatically during the night.
 - Consistency checks are performed between the different level of the pipelines, from the raw data generation to the production of L1 data.
 - Shall any exception be detected, it is properly analyzed and reported inside the issue tracking tool.
 - A Mission Log entry containing the status of the MOF is created each morning at the end the OPS procedure execution.
- **OPS Reprocessing activities** are executed for:
 - L2 data production as consequence of the availability of calibration data needed for the processing.
 - Producing updated data following of the release of newer versions of the scientific pipelines.
 - Recover missing data products.
- **MDB data retraction** procedure are executed to remove unwanted data from the MDB or to remove data for which a reprocessing activity has been completed.
- **Push L2 data to SOAR** at the end of the validation process.



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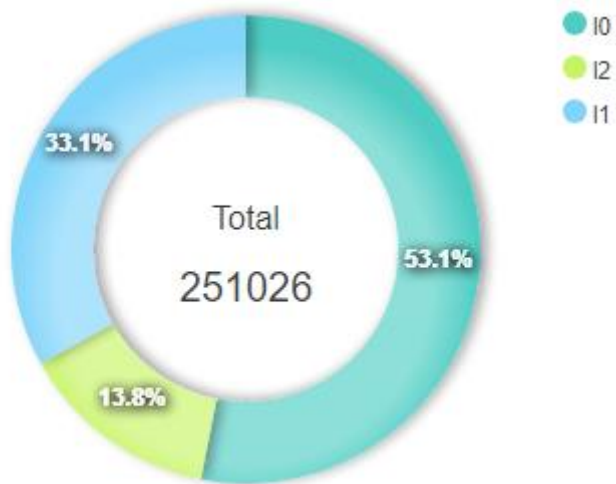
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MOF Data Archival



- MOF implements the archival and preservation functions for Metis data of different types:
 - Processing data products (BSQ, RAW, Calibration package)
 - Science data products (L0, L1, L2)
 - Planning data products (Timelines, EFECs, TMC/M, CRF, CRR)
 - Telemetry packets and housekeeping parameters
 - Reports
- It is MOF responsibility and duty to make such data **easily accessible** to authorized end-users before final archival in SOAR
 - Data access enabled by Mission DB GUI high availability. Average **uptime** between consecutive software reboot is **around 6 weeks**
 - SOAR hosts **28.817 L2 Metis data products** (23/01/24)



Science data products availability in MOF (23/01/24)

November 2023						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
			1 - 305	2 - 306	3 - 307	4 - 308
5 - 309	6 - 310	7 - 311	8 - 312	9 - 313	10 - 314	11 - 315
12 - 316	13 - 317	14 - 318	15 - 319	16 - 320	17 - 321	18 - 322
19 - 323	20 - 324	21 - 325	22 - 326	23 - 327	24 - 328	25 - 329
26 - 330	27 - 331	28 - 332	29 - 333	30 - 334		

January 2024						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1 - 1	2 - 2	3 - 3	4 - 4	5 - 5	6 - 6
7 - 7	8 - 8	9 - 9	10 - 10	11 - 11	12 - 12	13 - 13
14 - 14	15 - 15	16 - 16	17 - 17	18 - 18	19 - 19	20 - 20
21 - 21	22 - 22	23 - 23	24 - 24	25 - 25	26 - 26	27 - 27
28 - 28	29 - 29	30 - 30	31 - 31			

Science data products availability in MOF over time



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MOF Future and Acknowledgment (1/2)



- MOF is operating reliably and without interruption. The completion of the infrastructure migration will bring further improvements on several aspects including:
 - Reliability
 - Security
 - Maintenance
 - Performance
- Moreover, MOF roadmap includes evolutions and new features that will be implemented and released in the next months:
 - Evolution of the data validation and data quality pipelines
 - Evolution of the data archiving and distribution functions to support new tasks (i.e. big data/ML/AI activities)
 - Improvements in end-user experience for better and better access to data
 - Increase the automation level to ease operator duties
- All done in synergy with the scientific team, following activities identification according to MOF requirements and continuously received feedback



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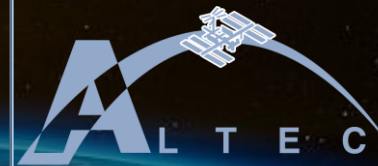
MOF Future and Acknowledgment (2/2)

- The MOF has been supporting METIS mission since the launch of Solar Orbiter, adapting to the mission evolution and needs.
- ALTEC is interested to consolidate its capabilities to define, implement and operate scientific ground segment in the **solar physics** domain and improve services provided to the scientific community. As a matter of fact ALTEC is being involved, in collaboration with INAF, UNIGE and other entities, in the following other projects:
 - **Heliospheric Data Center**: research project to prototype nowcasting and forecasting space weather services.
 - **SWESNET**: realization of the Space Weather Expert Service Centre for the CME propagation and forecast Tool (H.103e) and the Magnetic Effectiveness Tool (H.103d)
 - **Alxtreme**: support to the validation of space weather tools based on machine learning
- We look forward to **including Metis data** in this context and to support related activities. **AI-based tools and approaches** represent exciting opportunities to further exploit Metis data in cooperation with the scientific teams
- We gratefully acknowledge ASI and INAF, for the constructive cooperation and the support in setting up the project.





Grazie



MOF Team:

Lorenzo Bramante, Davide Calabrese, Vincenzo Chiaramida, Stefano Lanza, Rosario Messineo, Federico Pinna, Filomena Solitro, Eugenio Topa, Alfredo Villa

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