# CCSDS Mission Planning & Scheduling WG
# Fall Meeting 2022

## Attendants:

Peter van der Plas (ESA), chair
Marc Duhaze (CNES), deputy-chair
Christoph Lenzen (DLR)
Clement Hubin-Andrieu (CNES)
David Frew (ESA)
Dominik Marszk (ESA)
Evridiki Ntagiou (ESA)
Geoffrey Lochmaier (NASA)
Guillermo Buenadicha (ESA)
Lea Dubreil (ESA)
Maria Wörle (DLR)
Olly Page (UKSA)
Rachel Jenkins (ESA)
Roger Thompson (ESA)
Veniamin Zlobin (ESA)

## Agenda

| **Date** | **Time** | **WG** | **Topics** |
|---|---|---|---|
| Mon 17 Oct | 08:45 – 09:45 CET | CCSDS | CCSDS Opening Plenary |
| Mon 17 Oct | 09:45 – 10:45 CET | MOIMS | MOIMS Area Plenary |
| Mon 17 Oct | 10:45 – 12:30 CET | MP&S | WG day #1 morning session<br>- Welcome and agenda<br>- Blue Book technical discussion: overview and latest updates |
| Mon 17 Oct | 13:30 – 17:30 CET | MP&S | WG day #1 afternoon session<br>- Blue Book technical discussion: comments, open issues, AOB |
| Tue 18 Oct | 08:45 – 12:30 CET | MP&S | WG day #2 morning session<br>- Blue Book validation: hands-on session on the applicability of the MP&S standard to the DLR EnMAP mission |
| Tue 18 Oct | 13:30 – 17:30 CET | MP&S | WG day #2 afternoon session<br>- Blue Book validation: hands-on session on the applicability of the MP&S standard to the ESA ExoMars TGO mission |
| Wed 19 Oct | 08:45 – 12:30 CET | MP&S | WG day #3 morning session<br>- Prototyping: Yellow Book discussion including hands-on session |

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|---|---|---|---|
| Wed 19 Oct | 13:30 – 17:30 CET | MP&S | <u>WG day #3 afternoon session</u><br>- Prototyping: status and technical discussions<br>- Prototyping: hands-on session on XML file formats (planning request file, planning response file, plan file), both ESA and DLR |
| Thu 20 Oct | 08:45 – 12:30 CET | MP&S | <u>WG day #4 morning session</u><br>- MO Services and MAL status, feedback from SM&C, implementation and impact on Blue Book and prototyping<br>- MP&S Service Specification: status and updates for MAL evolution<br>- SANA Registry: Schemas for XML file formats and XML service specifications, next steps and actions |
| Thu 20 Oct | 13:30 – 17:30 CET | MP&S | <u>WG day #4 afternoon session</u><br>- OpsSat evolution, usage of MP Services and MAL implementation (ESA)<br>- Other BB evaluation efforts |
| Fri 21 Oct | 08:45 – 12:30 CET | MP&S | <u>WG day #5 morning session</u><br>- Look-ahead: adoption of the MP&S standard, potential activities<br>- Next steps, planning, actions<br>- Next WG meeting<br>- Reporting to MOIMS |
| Fri 21 Oct | 16:00 – 17:30 CET | MOIMS | MOIMS Area Plenary |

# MoM

## Session #1: Monday 17th October 2022, 10:45 to 17:30

Agenda: Welcome and agenda
Blue Book technical discussion: overview and latest updates
Blue Book technical discussion: comments, open issues, AOB

Minutes

The latest Blue Book draft G7 is available in the GDrive. In case there are any comments, please send to Roger and Peter.

Roger presented the latest Blue Book status and indicated some small changes to the MAL updates, with the inheritance from the MO Object compared to including an MO Object ID as first attribute in a data structure. However, this will have limited impact on the Blue Book.

The latest feedback on the Blue Book was discussed, see attachment [1].

## Session #2: Tuesday 18th October 2022, 08:45 to 17:30

Agenda: Blue Book validation: hands-on session on the applicability of the MP&S standard to the DLR EnMAP mission
Blue Book validation: hands-on session on the applicability of the MP&S standard to the ESA ExoMars TGO mission

Minutes

Christophe presented the DLR EnMAP mission (see attachment [2]), where the mission planning is based on services for the interaction between the ground segment elements.

A number of services could be mapped onto the MP&S services. It was noted that for the Planning Request status update, it is currently not possible to provide more complex and/or structured planning information back to the requester. This is used in EnMAP, for example in an acquisition request where the user is informed about the data takes of this request, including their status and details (latitude, longitude, view angle to target, target region as a coordinate list, etc.). It was agreed by the WG that this would be useful and it was proposed by Roger to provide the possibility for a return argument (parameter) list defined as simple name/value pairs (limited to MAL values).

Then the different planning request states (and transitions) were discussed; these EnMAP states apply a few different concepts. As a result, there was a lengthy discussion on the planning request state diagram, where the states inside the “Plan

Execution" box were simplified and in general additional state transitions are now allowed. It is now also possible to provide feedback to the user on any state transitions (instead of termination information only).

In EnMAP there are a number of services defined that do not map on MP&S services but rather on Flight Dynamics (NAV) services, such as orbit and event services. In CCSDS the CSS has recently published a Blue Book that covers Ground Station planning events, however this is a limited use case. The WG has identified the need for a more complete definition of the services in the MOIMS area and in particular with the NAV Blue Books (which are currently file-based).

Dave presented the ESA ExoMars TGO mission (see attachment [3]). The mission planning is completely file based here. Detailed planning requests definitions (observations), planning requests (timelines) and plans (resolved timelines) were presented. It looks like the mapping of these file onto the MP&S Information Model is feasible, but no in-depth review or a hands-on modelling exercise was done (yet). Peter suggested that part of the MP&S Information Model validation, the ExoMars TGO information could be used to perform an XML modelling of the data structures. ESA (Peter, Dave) will investigate if this activity could be performed, depending on the needed resources/manpower being available.

There will be a paper in SpaceOps2023 (paper accepted for presentation) to describe the potential use of the new PM&S standard in the two existing missions above, as such providing the potential benefits (and drawbacks) of the standard. There was a discussion on the contents and size of the paper. Guillermo and Peter will take an **action** to write the outline, such that Christophe/Maria and Dave can fill in their parts in a uniform manner.

## Session #3: Wednesday 19th October 2022, 08:45 to 17:30

Agenda: Prototyping: Yellow Book discussion including hands-on session
Prototyping: status and technical discussions
Prototyping: hands-on session on XML file formats (planning request file, planning response file, plan file), both ESA and DLR

Minutes

The latest Yellow Book v2.4 and Test Specifications v0.8 (XL spreadsheet) are available in the GDrive.

There was a discussion on the testing approach. The CCSDS requires inter-operability testing, which implies the connection of the two prototypes. The current approach is that the service providers are implemented by both ESA and DLR. However, the implementation of the test cases (service consumers) is done on a 50/50 basis between ESA and DLR, to reduce the effort. The output of the testbed with the ESA

and DLR implementations can then be compared (although it is deemed sufficient that both tests pass, as the results of the service invocations are checked by the testbed).

The WG considers this approach sufficient. Each of the test case implementations (split 50/50) will be connected to the service provider of the other Agency. In addition, for the interpretation of the Blue Book, the implementation of one side of the interface (service provider in this case) would validate the Blue Book. In addition, this approach has also been applied during the SM&C services prototyping. As such, the WG agreed that the prototyping will be completed with this approach.

The current Yellow Book has a description of the above approach that may be misleading and may give the impression that the both prototypes are not being connected. **Action** on Guillermo and Peter to reformulate the current section 3 of the Yellow Book.

Then there was a discussion on the coverage of the test cases in terms of structure attributes passed to the services. It was agreed that each attribute should be covered in a test case at least once (this could possibly show up mistakes in the XML Services Specification with wrong data types, invalid nullable attributes, etc.).

A systematic review of the Test Specification was done. This resulted in a number of issues/comments on the Blue Book. As Roger was not attending this session, the comments were discussed later on Thursday afternoon and Friday morning. There is an **action** on Guillermo to update the Test Specification and at a later stage the Yellow Book (to include the information from the spreadsheet into the Word document in the tables).

The actual prototyping work should then be continued as far as possible (also including the updates from Guillermo), given the workarounds for the missing MAL implementation (see Thursday discussion for the MAL implementation status and planning). Currently, ESA (GMV) has completed most of the work, DLR still has some remaining work to be done with manpower available again now.

The WG was reminded that the File Formats will also be subject to prototyping, as this is an inherit part of the MP&S standard. Currently, ESA (Peter) has done some work on the XML modelling (Planning Request completed). It was agreed by the WG that both ESA and DLR should perform an independent XML modelling of the File Formats, after which the results can be compared. This modelling will be based on a single Planning Request and a single Plan, selected from the Test Specification. The results of the XML prototyping shall be described in a dedicated section of the Yellow Book.

## Session #4: Thursday 20th October 2022, 08:45 to 17:30

Agenda: MO Services and MAL status, feedback from SM&C, implementation and impact on Blue Book and prototyping
MP&S Service Specification: status and updates for MAL evolution

SANA Registry: Schemas for XML file formats and XML service specifications, next steps and actions
OpsSat evolution, usage of MP Services and MAL implementation (ESA)
Other BB evaluation efforts

Minutes

The session was attended by SM&C experts (Cesar Coelho and Dominik). The current status of the MAL and its implementation and validation planning were provided, but only as an indication.

It was proposed that MP&S tests the MAL implementation (in particular the features requested by MP&S), before the MAL implementation is finalized. This will allow the testing of the specific MP&S use cases, whilst the MAL development is not yet completed. The WG agreed with the approach, however with the caveat that any testing on intermediate deliveries shall be based on a properly tested baseline, with a clear indication of the scope (which features are supported and which not). This to prevent ESA and DLR to waste effort on beta-testing the MAL implementation.

The XML Service Specification will require the updated MAL Schema. Cesar mentioned this is being worked on and should be available in the near term. The actual update of the definition of the XML Service Specification for MP&S may be cumbersome and error prone (4000 lines of XML). Cesar showed a new tool allowing to visualize the Service Specification using an HTML based viewer. It is available in GitHub. Roger asked to provide an executable version of the tool. By now, Cesar provided a link where the tool can be downloaded.

Cesar showed the capability of the tool to generate Blue Book tables from the Services Specification. Roger argued that for MP&S, the “truth” is in the Word document, as it contains a lot of additional information beyond the tables. Roger proposed to investigate extracting the information from the Blue Book using macros. **Action** on Roger to investigate if this would be easily possible and report back to the WG. The WG agreed that this tool provides a good addition to the services documentation, with the user friendly (hyper-linked) presentation of the services and data structures. Some investigation shall be done on how to automatically transfer some additional information into the XML Service Specification (service descriptive text, optional data structures).

In the afternoon session, Lea presented the ESA OpsSat mission (attachment [4]). Although the mission planning is largely performed file-based, there is a perspective for similar future missions (OpsSat2) to adapt the MP&S concepts and could be fully based on services.

After the regular WG session, Peter had a meeting with the SANA team, who maintains the SANA Registry. The process of how to request new SANA Registry elements was explained.

In principle, new SANA Registry elements referenced from non-published Blue Books shall be in the so-called SANA "Beta" Registry. Then once the Blue Book is published, these elements are moved to the "production" Registry. However, as we only have new elements, we could also go directly to the production Registry, as each SANA element also has a status flag, which is used to indicate if the element is under review or validated.

The SANA Registry does not provide versioning on their elements. This could be solved by adding elements with a version in the file name. However, there shall then be a "latest" file that matches the name is the Blue Book (and any software that relies on that name). This approach has already been applied in the draft MP&S Blue Book.

The MP&S Blue Book refers to two SANA elements for MP&S, the XML Services Specification that can be stored in an already existing MO directory with MO service specifications, and the XML File Formats schemas. For the latter, it was suggested to provide these files in a single ZIP archive, with the archive version in the file name. In this way, the schema file names would not need to be versioned (which would require a duplication, as the actual names are fixed due to references inside the schemas).

This discussion has clarified all issues related to the SANA Registry. For the Red Book (Blue Book version for Agencies Review) and final Blue Book (as published), it shall be ensured that the location and file names are matching the SANA Registry. For the Read Book it is expected that the XML Services Specification is still the "older" version with workarounds for the missing MAL updates. This is not considered an issue, as this file is not human-readable (4000 lines XML) and is only provided to the review for completeness. The actual validation of the final version of this file will be done by means of the prototyping, where all the details on the services and their data structure will be done.

## Session #5: Friday 21st October 2022, 08:45 to 12:30

Agenda: Look-ahead: adoption of the MP&S standard, potential activities
Next steps, planning, actions
Next WG meeting
Reporting to MOIMS

Minutes

Some remaining issues (resulting from the Yellow Book discussion) on the Blue Book were discussed and agreed. **Action** on Roger to update the Blue Book (and Information Model, XML Schemas) before the end of November (i.e. before the next WG telecon).

It is the plan to have the Blue Book and SANA Registry ready for Agencies Review by mid-December. As such, the next WG meeting will allow for the last review of the MP&S standard before the Agencies Review.

The next WG meeting date was agreed: 30 November 2022. The prototyping splinter will be in advance of this meeting, on 28 November 2022. **Action** on Peter to send the WebEx invite.

A presentation of the WG achievements was then created (attachment [5]), in preparation of the MOIMS plenary in the afternoon. The WG agreed to pursue the Agencies Review once the Blue Book is finalized by mid-December, acknowledging the risk arising from the updated MAL Blue Book not yet being published. However, the WG sees the benefit of having the Agencies Review in the short term, to get any feedback on the majority of the book as soon as possible in the process.

## Summary of actions:

- Guillermo/Peter: to write an outline of the SpaceOps2023 conference paper.
- Guillermo/Peter: to update section 3 of the Yellow Book to clarify the prototyping approach.
- Guillermo: to provide the update Test Specification.
- Roger: to investigate the feasibility of extracting the XML Service Specification data from the Blue Book using Word macros.
- Roger: to provide the update Blue Book, Information Model and XML Schemas in advance of the next WG meeting.
- Peter: to send the WebEx for the next regular WG telecon.

## Next meeting:

Next WG meeting will be on Wednesday **30 November 2022**, 16:00 – 18:00.

Next Prototyping splinter will be on Monday **28 November 2022**, 16:00 – 17:00.

## Attachments:

[1] MPS BB Open Issues Fall 2022
[2] CCSDS - EnMAP Interfaces
[3] TGOMPS case study
[4] OPS-SAT_Mo_services_case_study
[5] MPS-WG-Report-to-MOIMS-Area-Fall2022


# Mission Planning and Scheduling Services

## Open Issues

15/10/2019

# Open Issues

- **Latest draft of MPS BB is Draft G7 from July ‘22**
- **Open Issues Listed in §1.10 of MPS BB**
- **A few New Comments have arisen since then**

# MOv2 Related Issues

1. MO v2 MAL agreed position with SM&C WG that resolves open issues for MPS:
   - representation of MO Objects
   - representation of Object Identity and References
   - Filter Criteria on PUB/SUB Subscription
   - Support for Polymorphism
   - MAL defined enum for MAL::Attribute Types
   - SFPs and Object Keys harmonised and updated to reflect removal of scoping by Service from MAL (now only Area is used)
2. Above is subject to Agency Review of MAL v2 BB
3. The XML Specification has not been updated to reflect:
   - MAL v2: requires formal XML Specification of MAL which is not yet available
   - The existing XML Specification does not reflect the many detailed changes to the MPS BB made over the last 2 years
4. References to the MAL BB need to be updated to the new version when available.

# NAV Related Issues

- MPS assumes existence of SANA registries for Time Systems and Coordinate Systems
  - » maintained by NAV WG
  - » require consolidation as some NAV standards contain explicit lists of time and coordinate systems, some reference SANA registries and there is inconsistency between standards
- NAV Event Message currently under development – Reference in MPS BB will need to be updated when available.

# MPS File Format Issues

- File Formats have been defined for Planning Request, Planning Response and Plan Files
- Modelled within EA – XSDs can be autogenerated and then put through a post processor to generate the formal XSD schema
- These XSD schema will need to be formally placed in the SANA registry

# New Comments (1)

- **CL 09/08/22: Question relating to use of Tags when suspending activities using the Plan Execution Service**

  What exactly should the argument `tags` be used for? Is it a filter and if so, are the tags combined as `and` or `or`?

- **Response**

  Tags can be associated with any activity in order to allow a degree of coordinated control over them. It is up to the operating agency to define the tags and their meaning.

  If the Plan Execution Service is used to suspend activities specifying one or more tags, then only those activities associated with that tag are suspended – so yes, it is a form of filter.

  I would agree that the text of the standard does not clearly state how this should be applied – we should update it to clarify.

  I would assume we follow a similar pattern to PubSub subscription filters:

  - That multiple items within a filter are ORed – so tags would be ORed rather than ANDed.
  - That if multiple filters are specified (e.g. PlanID and tags), then these are ANDed together.

  It occurs to me that it should be possible to suspend all activities belonging to a Domain, but this is not available in the current definition of the operation (I don't think you can use wildcards for activityID fields in this context) – you can only list specific activities, or tags, within the context of specific Plans.

  We could add Domain as an additional filter option.

# New Comments (2)

- **Marvin Wittschen 22/09/22: Activation of Patch Plans**

1) In the blue book in section 4.4.8.1 Overview it is stated that “If the precursor plan is already active, then the changes can be merged into the active plan, but if it is not active then the reconstitution of the target Plan must take place prior to activation.“. Does that implicate that the patch plan should be merged into the precursor plan (same version) or should the target- and precursor plan be merged into a new target plan regardless of the activation status?

- **Response**

Summary: Patch Plan is a delta to its Predecessor, to activate it, it must be applied to its predecessor to generate the target plan. There is no operation to generate the Target from Predecessor and Patch. Previous WG discussion on this topic (brief) concluded the standard should not constrain how the reconstitution is done by Plan Execution – there are multiple options.

Propose clarify in BB that it is only possible to Activate a Patch Plan if its predecessor is already Activated.

Option for new operation to generate Target Plan from Patch Plan and its predecessor prior to Activation.

# New Comments (3)

- **Marvin Wittschen 22/09/22: PubSub doesn’t support Requirement**

2) In the functional requirement Req_4.3.4.F.11it is stated that the service provider shall assume that the latest plan version is required for the monitorPlanStatus operation. Does the MAL broker take care of this requirement, or should the service publish the latest plan twice, once with and once without a version specified to satisfy this requirement?

- **Response**

Good question.  I don’t think we want to publish twice, but you are correct that for PubSub operations such as monitorPlanStatus, this pr.obably doesn’t work unless there is functionality in the broker.

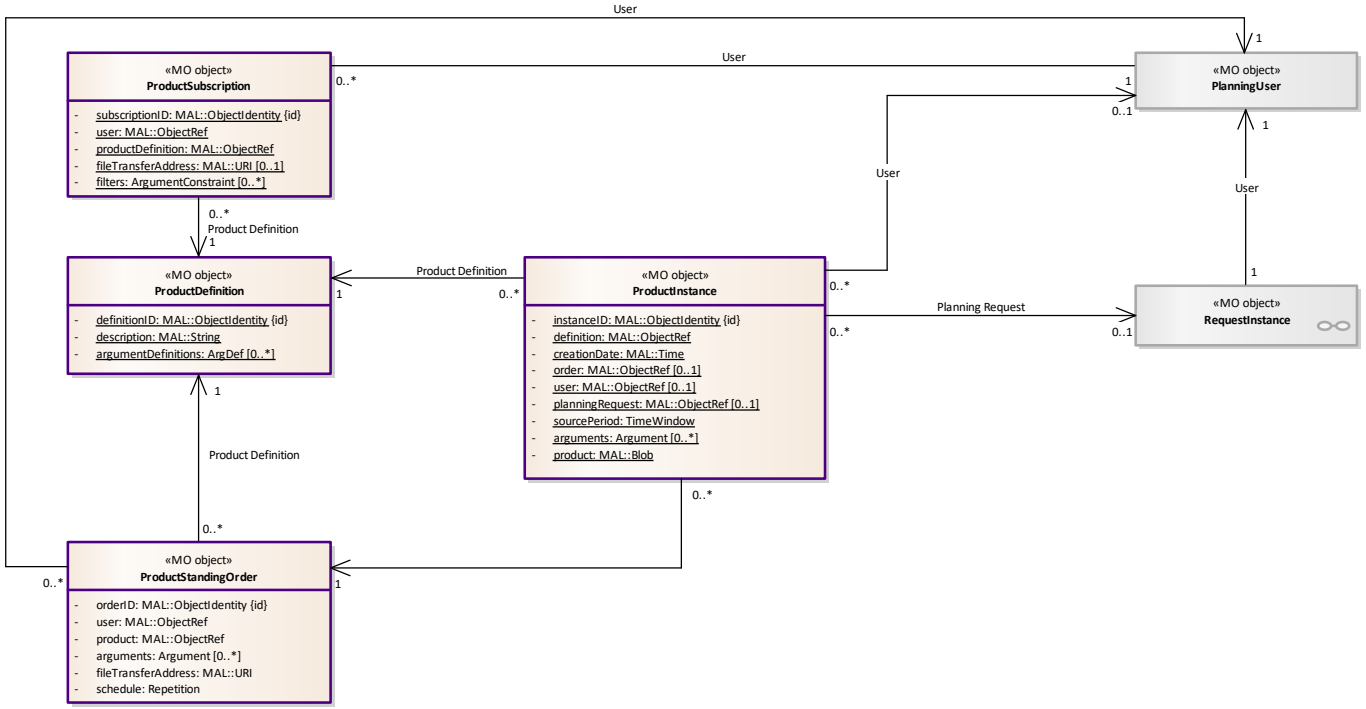
# New Comments (4)

- **RT 12/10/22: Concept of User should be Common to MO Services**

While drafting the Mission Data Product Distribution information model for the SM&C WG, it became apparent that there was potential for linkage between a Planning Request and the subsequent distribution of Data Products generated as a result of that Planning Request. To facilitate this, the Product has a relationship to both the Planning Request and the User requesting it; the Planning Request also has a relationship to the User.

But as currently formulated this is not the same MO Object, as the Planning User and the Data Product User are defined within their respective standards and will be identified as MO Objects within their respective Areas.

It occurs to me, that the concept of User might be better located within an MO Common area, to allow for implementations that integrate the User Object. Clearly this is not within the gift of the MPS WG, but at least to allow for potential harmonization, I propose that we rename Planning User simply as User.

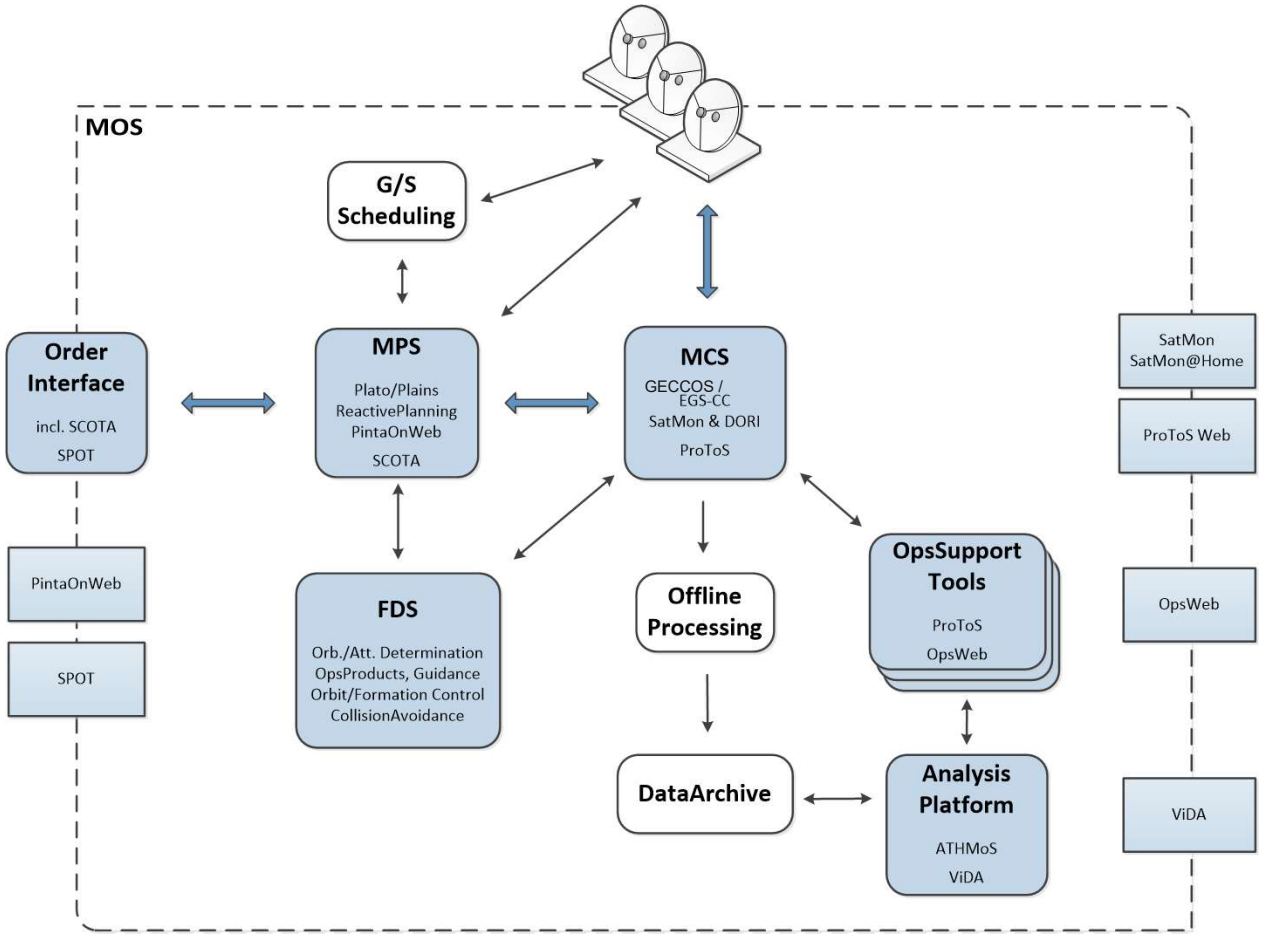


# EnMAP Mission Planning Interfaces and Workflows

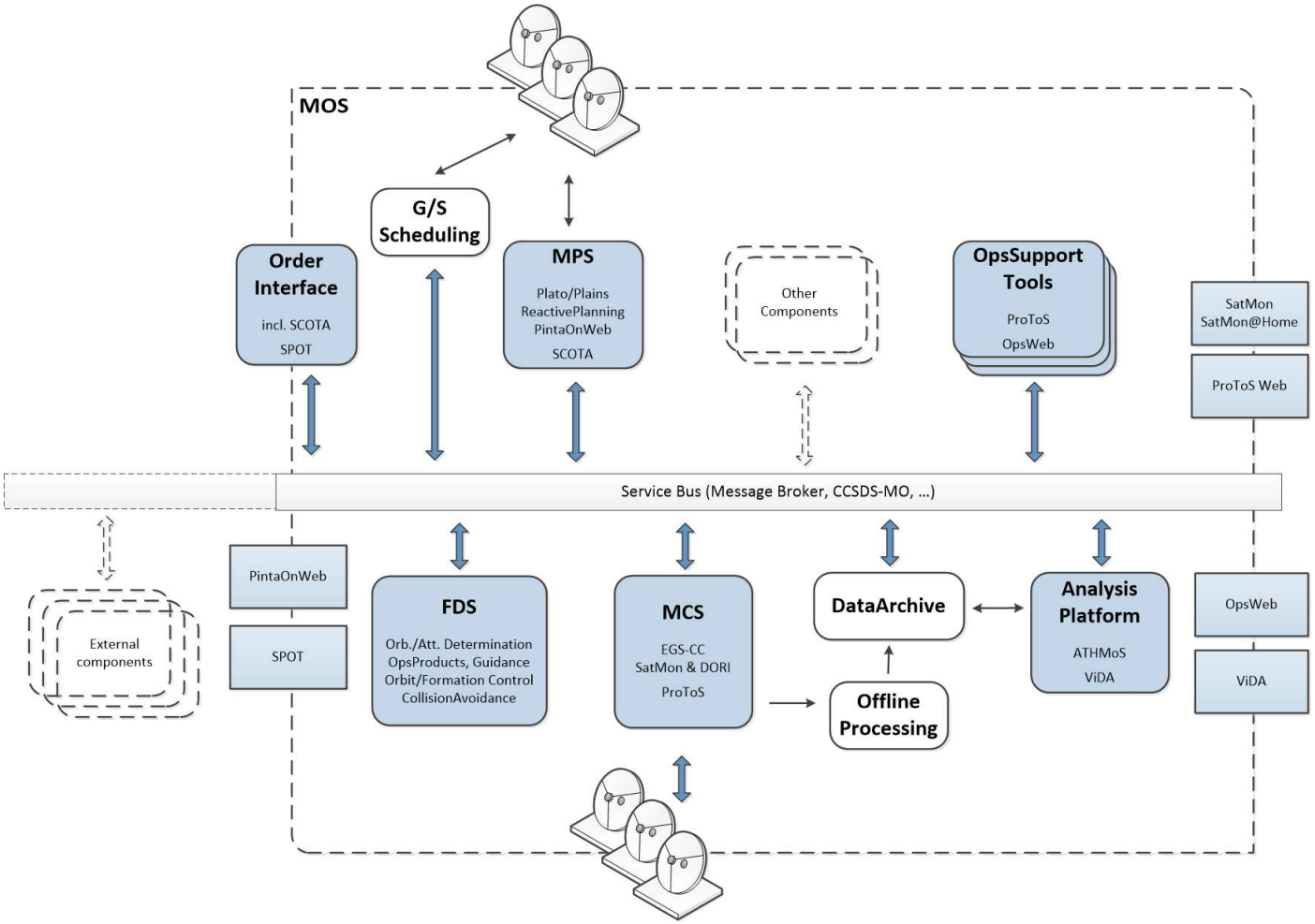
EnMAP
Hyperspectral Imager


DLR

# Current generic interfaces of a Mission Operations Segment (MOS) at GSOC

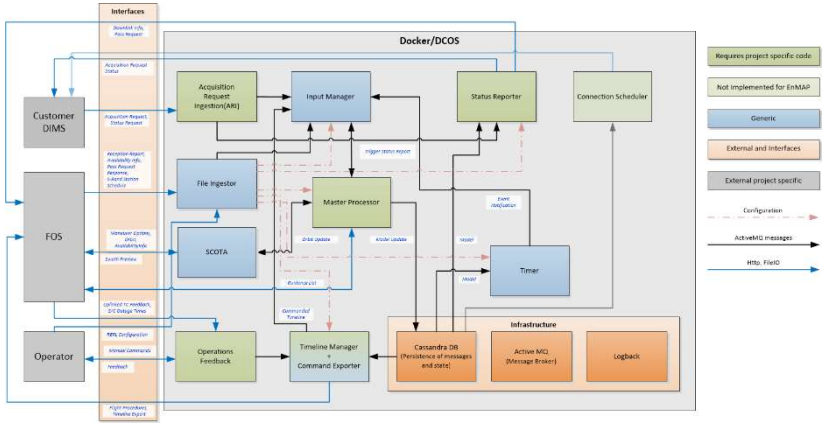



# Plan for future generic setup at GSOC



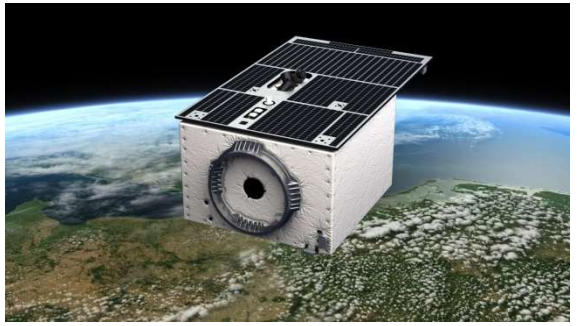

# EnMAP Mission Planning Interfaces and Workflows - Content

- The EnMAP mission
- Interfaces and their Workflows
  - Interface 1 – Acquisition Request
  - Interface 2 – Status Update
  - Interface 3 – Redo
  - Interface 4 – Cancel Request
  - Interface 5 – Close Request
  - Interface 6 – Pass Request, Availability Info
  - Interface 7 – Downlink Info, Reception Report
  - Interface 8 – Outages
  - Interface 9 – Orbit Information
  - Interface 10 – HK Downlink Station Schedule
  - Interface 11 – Orbit Maintenance
  - Interface 12 – Cloud Information
  - Interface 13 – Guidance List
  - Interface 14 – Commanding
  - Interface 15 – Swath Preview
  - Interface 16 – Preplanning
- Constraints
- CCSDS mission planning services applied to EnMAP mission planning




# The EnMAP mission

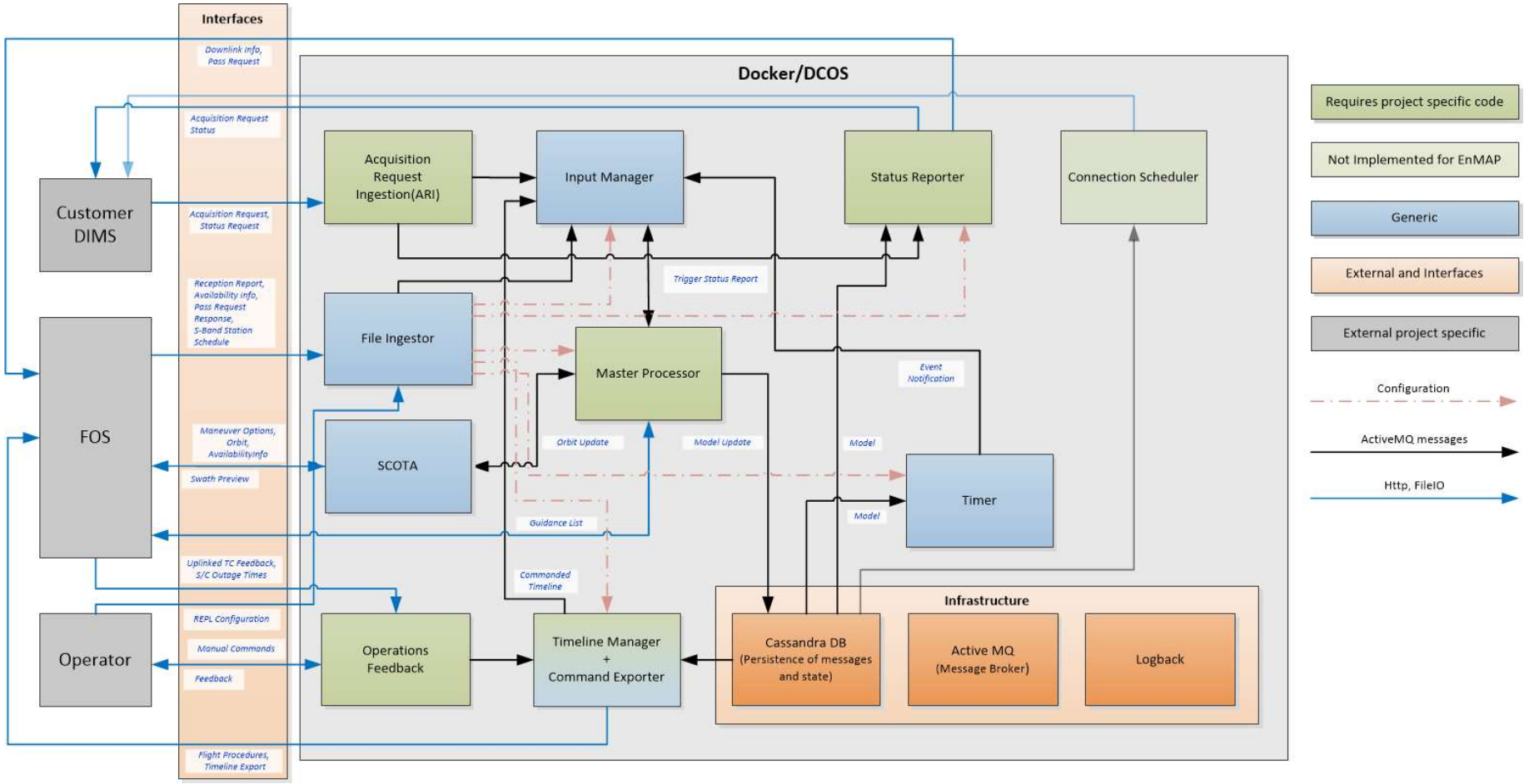
**En**vironmental **M**apping and **A**nalysis **P**rogram



- hyperspectral satellite mission
  - spectral range
    - VNIR: 420 nm .. 1000 nm
    - SWIR: 900 nm .. 2450 nm
  - high radiometric resolution and stability in both spectral ranges
  - swath width ~ 30km
  - resolution: 30 m x 30 m
  - off-nadir range: 30°
  - maximum revisit time: ~4 days
  - 1,000 km swath length per orbit, 5,000 km per day
- Launched 2022-04-01
- monitoring and characterizing the Earth's environment on a global scale
  - extracting geochemical, biochemical and biophysical parameters
- See http://www.enmap.org/

DLR

# EnMAP Mission Planning Interfaces




# EnMAP Planning Interfaces and their Workflows

- Interface 1 – Acquisition Request
- Interface 2 – Status Update
- Interface 3 – Redo
- Interface 4 – Cancel Request
- Interface 5 – Close Request
- Interface 6 – Pass Request, Availability Info
- Interface 7 – Downlink Info, Reception Report
- Interface 8 – Outages
- Interface 9 – Orbit Information
- Interface 10 – HK Downlink Station Schedule
- Interface 11 – Orbit Maintenance
- Interface 12 – Cloud Information
- Interface 13 – Guidance List
- Interface 14 – Commanding (Timeline Export & Command Feedback)
- Interface 15 – Swath Preview
- Interface 16 – Preplanning (Test-Ordering)

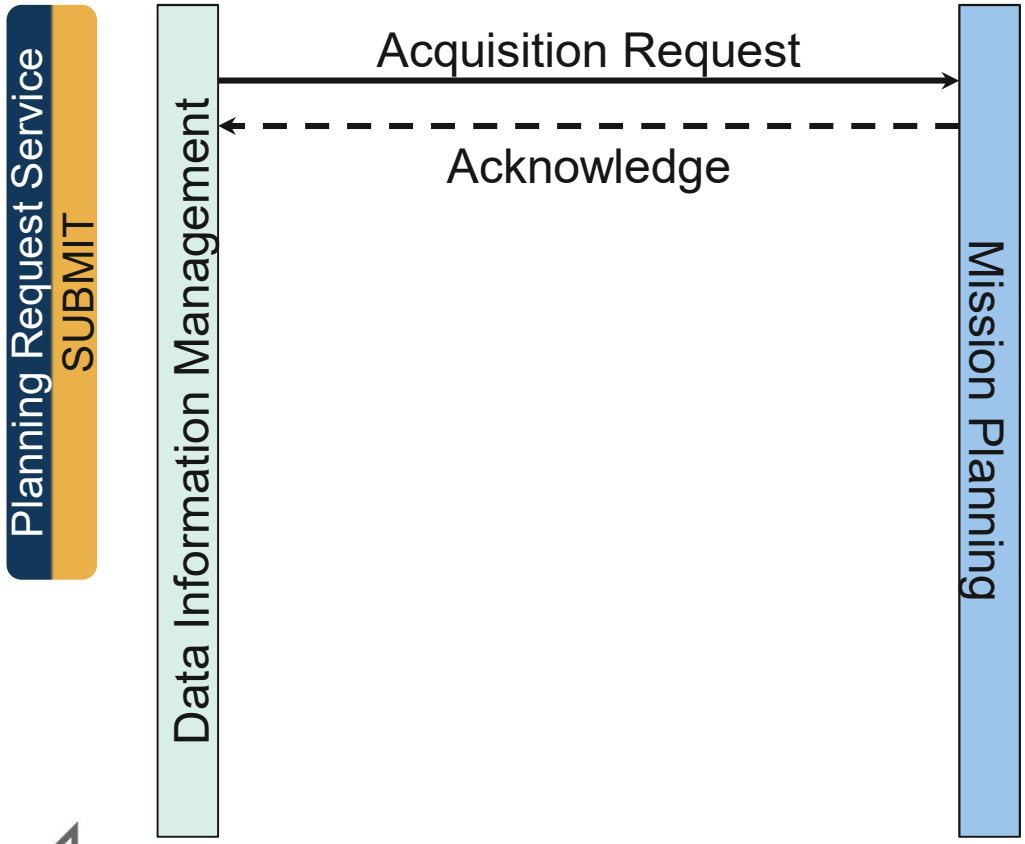
# EnMAP Planning Interfaces and their Workflows

→ following slides drafted for discussion:

how to map these best to the CCSDS MO MP&S and other CCSDS services…

(specific operations also not yet selected)

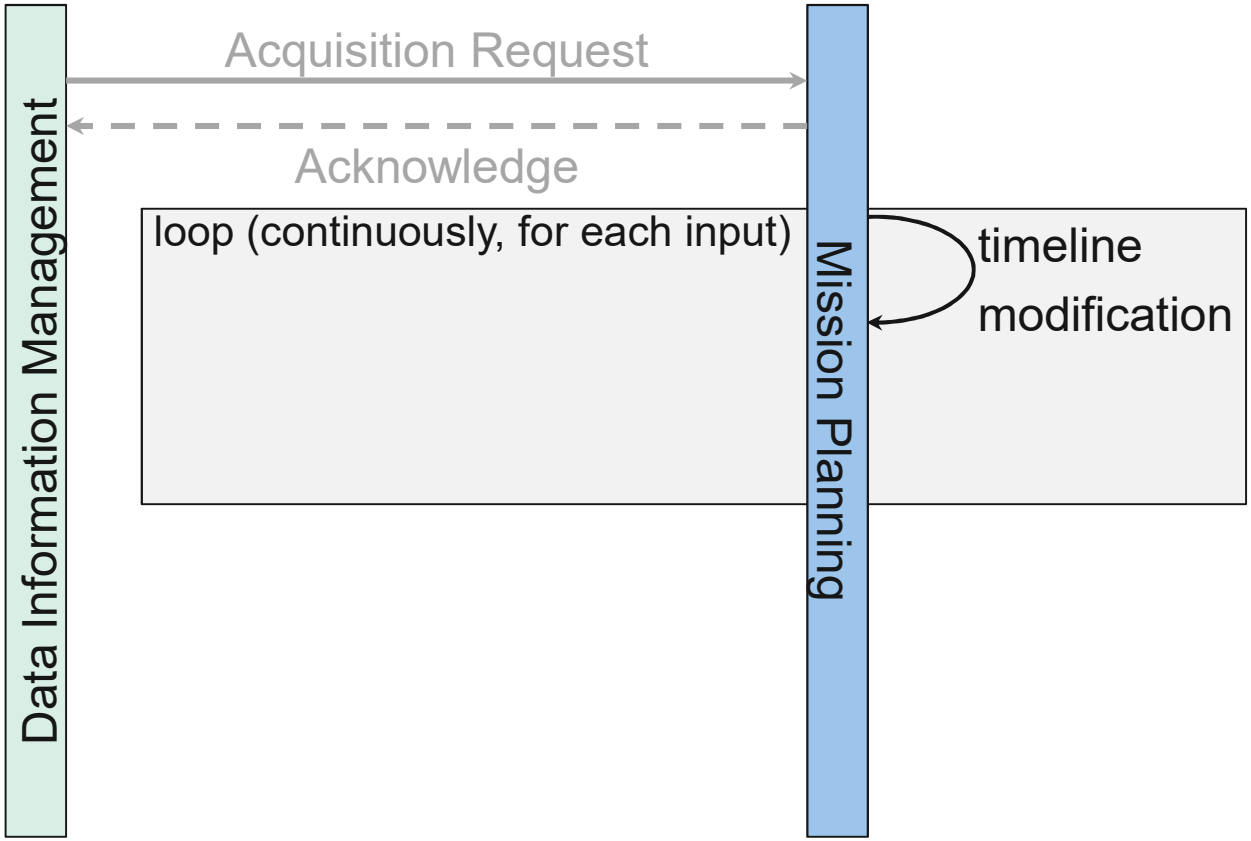
# EnMAP Planning Interface 1 – Acquisition Request



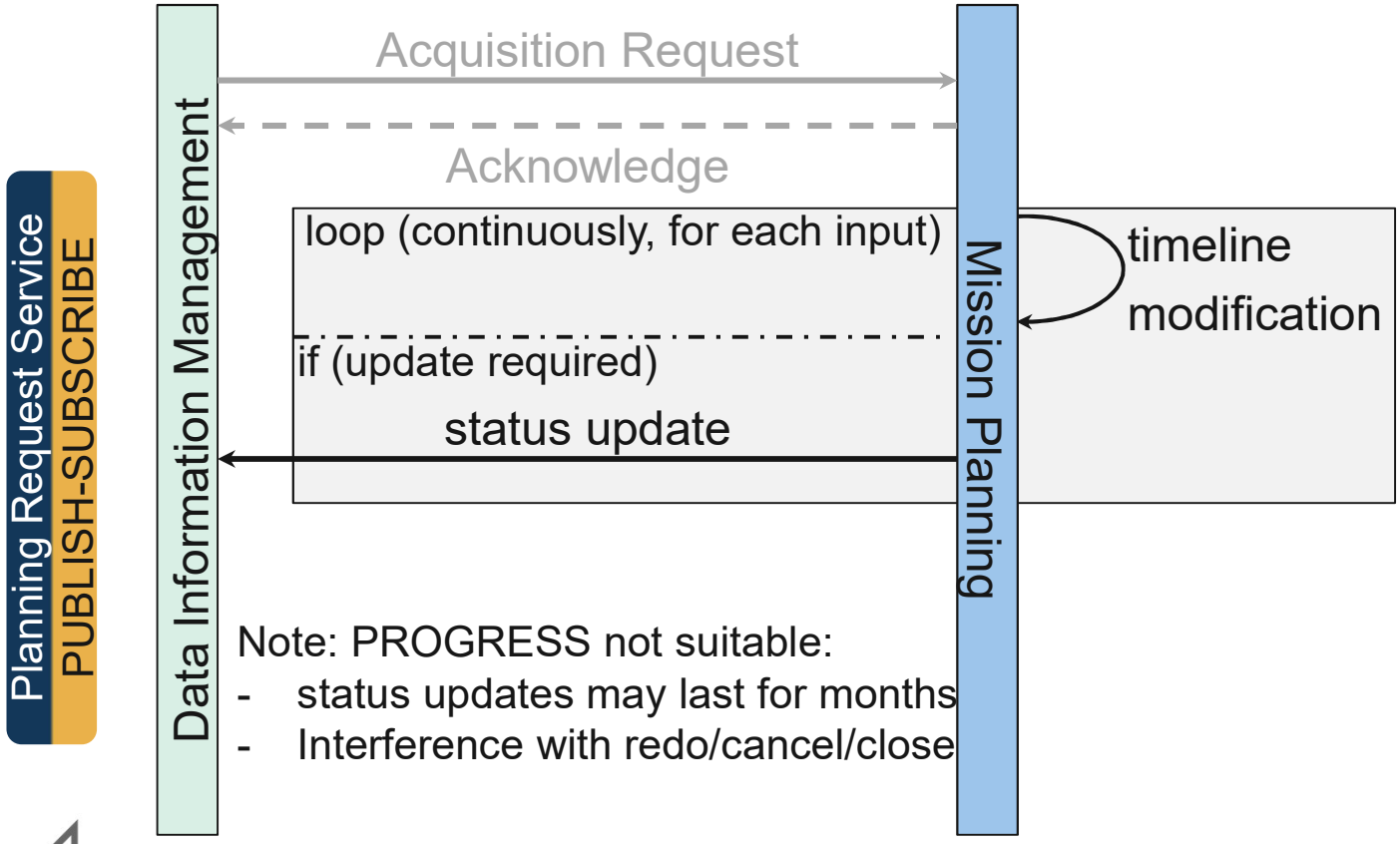

# EnMAP Planning Interface 1 – Acquisition Request

- Acquisition Request
  - Acquisition ID / Customer ID / Customer Group / User Data (strings)
  - Satellite ID / Order Date / Acquisition Priority
  - Downlink Priority / Receiving Stations (combined via ‘and’ or ‘xor’)
  - Acquisition Time Window
  - **Target Specification, one of:**
    - **Center Coordinate / Offsets**
    - **Target Area: polygon**
    - **Calibration: command parameters**
  - Maximum Cloud Coverage, Off-Nadir Angle Range
  - When preplanning is used: scheduling details (see interface 16)
- Acknowledge: Acquisition Request Response
  - Acquisition ID
  - Success Code
  - [optional] Error Description

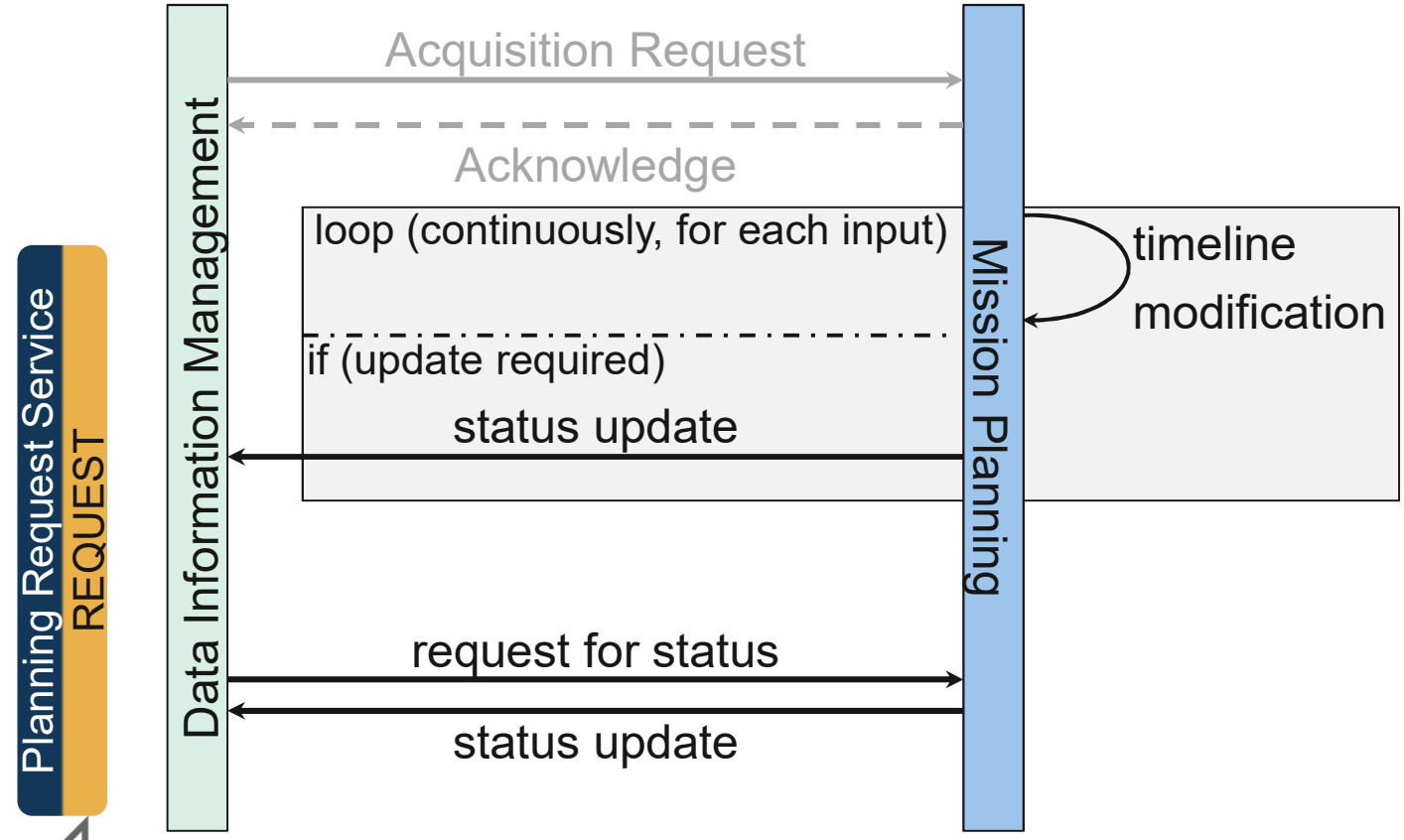
# EnMAP Planning Interface 2 – Status Update




# EnMAP Planning Interface 2 – Status Update



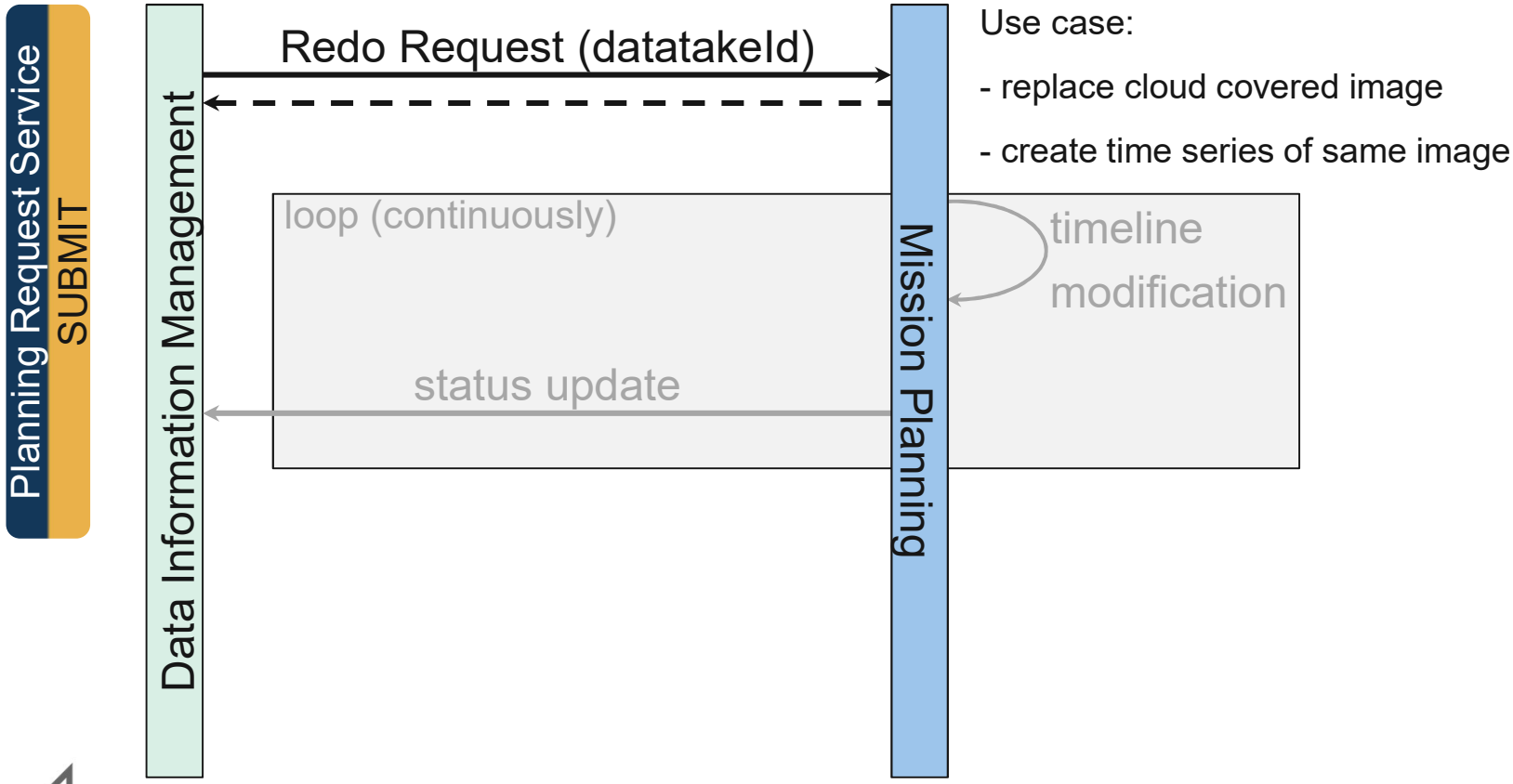

# EnMAP Planning Interface 2 – Status Update



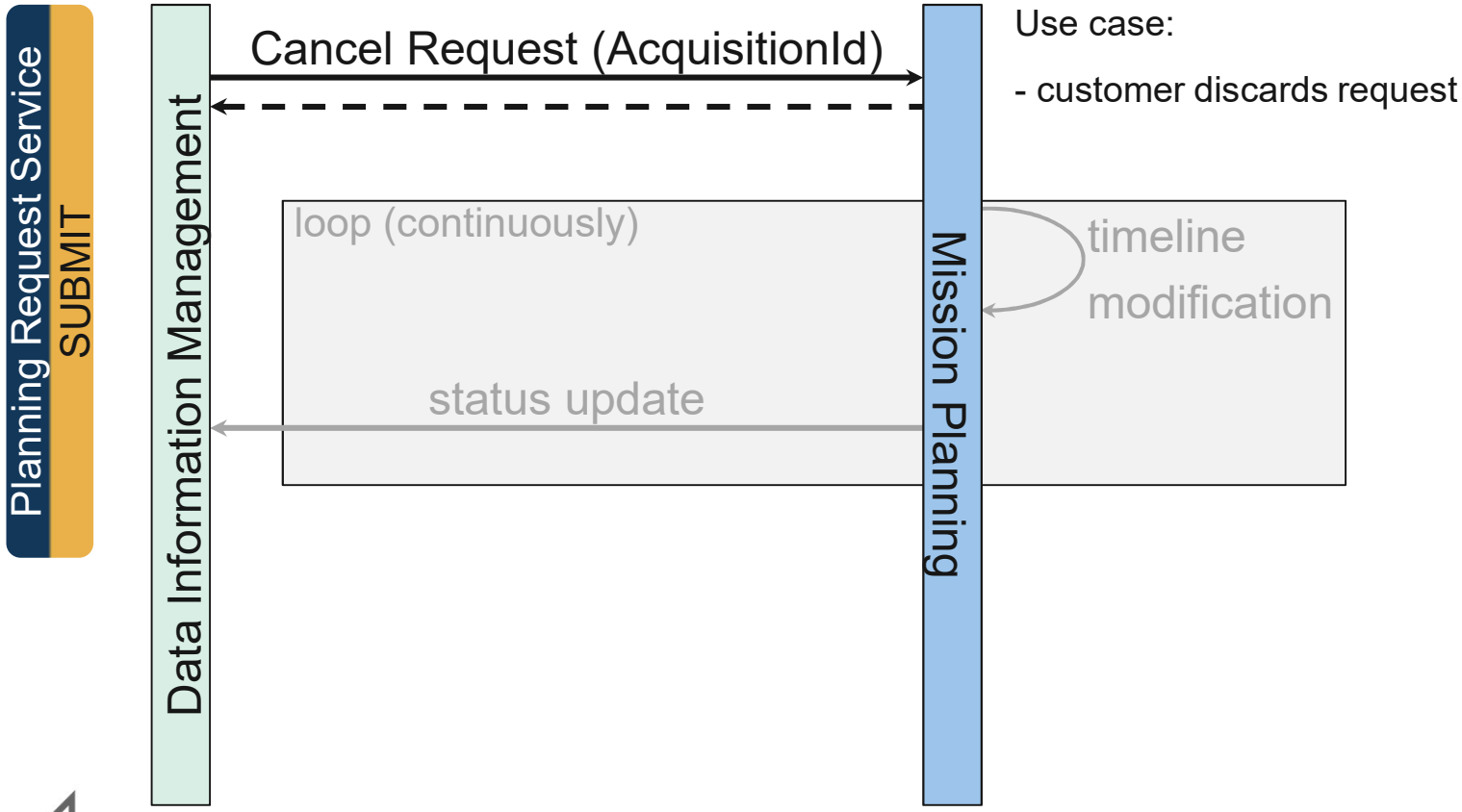

# EnMAP Planning Interface 2 – Status Update

- Acquisition Request Status
  - Acquisition ID
  - Status (initial, rejected, expired, inprocess, complete, incomplete, cancelled)
  - Status Time
  - **For each datatake of this acquisition request:**
    - datatakeId
    - satelliteId
    - datatake status (initial, unplanned, preplanned, planned, commanded, failed, complete, expired, cancelled)
    - **datatake info (e.g. lat, long, offsets, execution time, angle)**
    - **customer info (e.g. why the datatake is not yet scheduled)**
    - **downlink info (where and when the downlink takes place)**
    - childOf (the id of the datatake of which this is a copy)
    - numberOfRedo (number of redos which have been peroformed)
    - calibration datatakes: command parameter ID / serial number

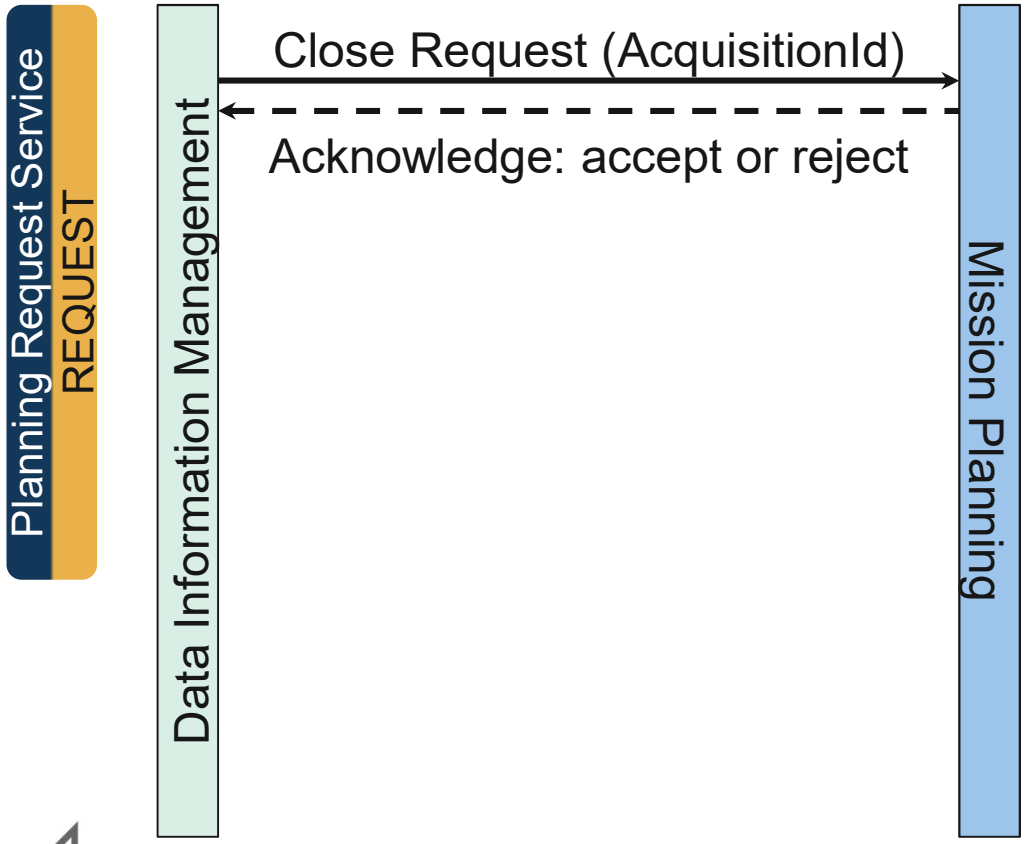
# EnMAP Planning Interface 3 – Redo




# EnMAP Planning Interface 4 – Cancel Request



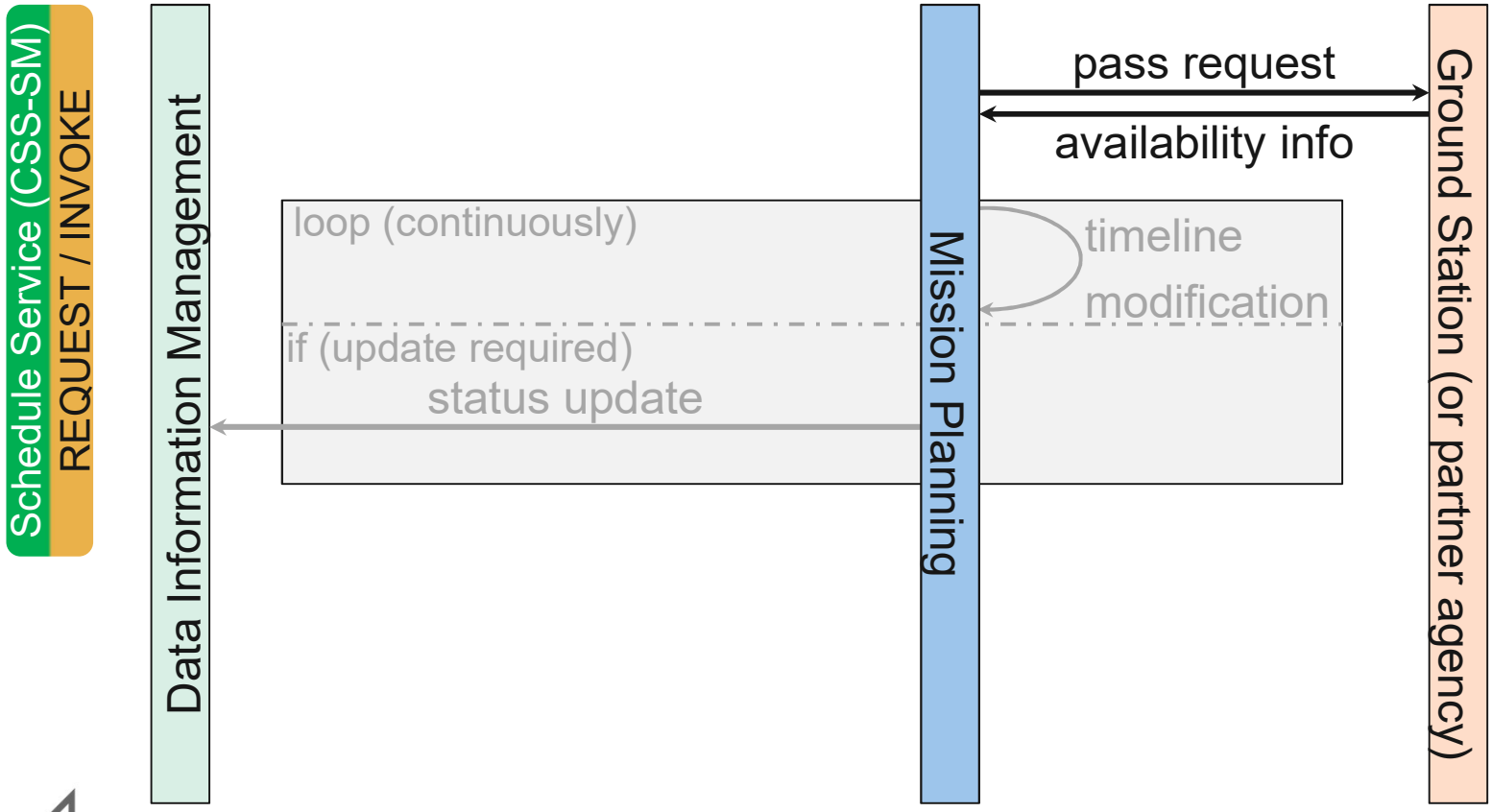

# EnMAP Planning Interface 5 – Close Request




Use case:

- customer claims final state of request, so it may be removed from the planning system

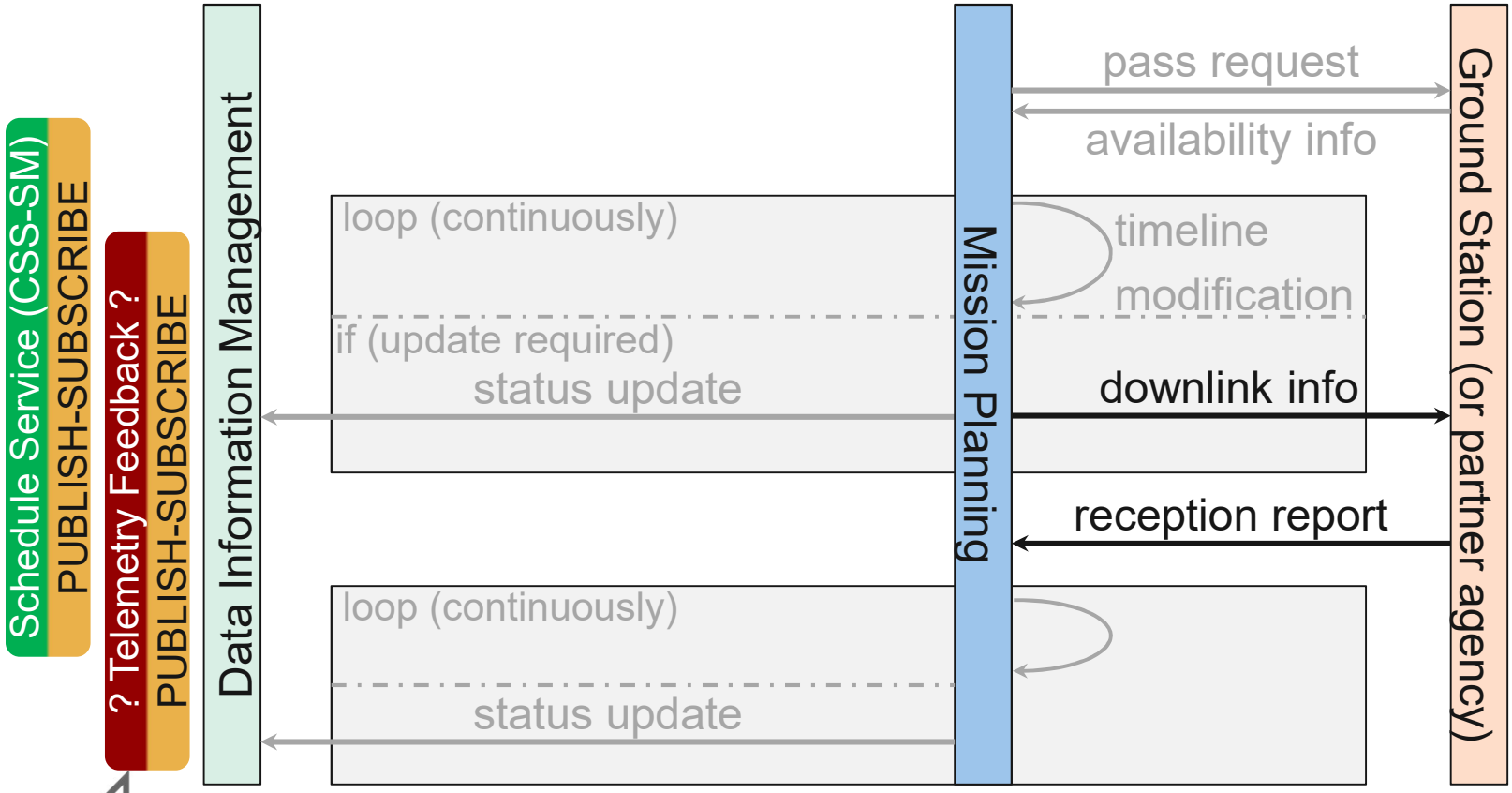
# EnMAP Planning Interface 6 – Pass Request, Availability Info




# EnMAP Planning Interface 6 – Pass Request, Availability Info

- Pass Request
  - satellite ID, ground station ID
  - time window
  - desired contact duration
  - contact parameters (frequency / isUplink / isDownlink / ..)
  - schedule parameter (e.g. choose contacts asap or distribute them evenly)
- Availability Info
  - satellite ID, ground station ID
  - time window
  - underlying orbit (e.g. two line element)
  - For each pass where the station is availabile:
    - earliest AOS, last LOS (w.r.t. readiness of downlink station)
    - contact parameters (frequency / isUplink / isDownlink / MinOnElevation / MinOffElevation / NumAntenna / ..)

# EnMAP Planning Interface 7 – Downlink Info, Reception Report

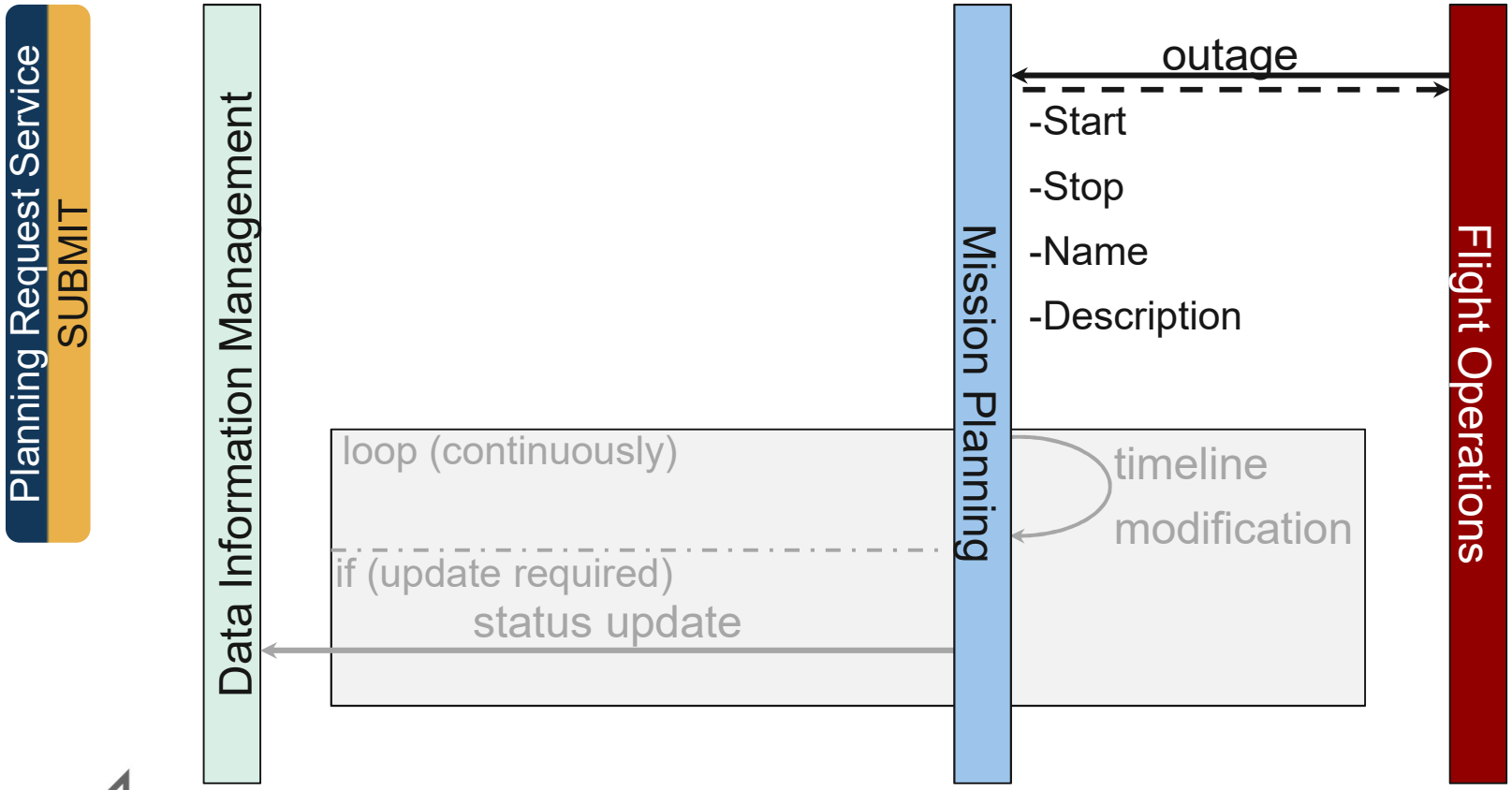



DLR

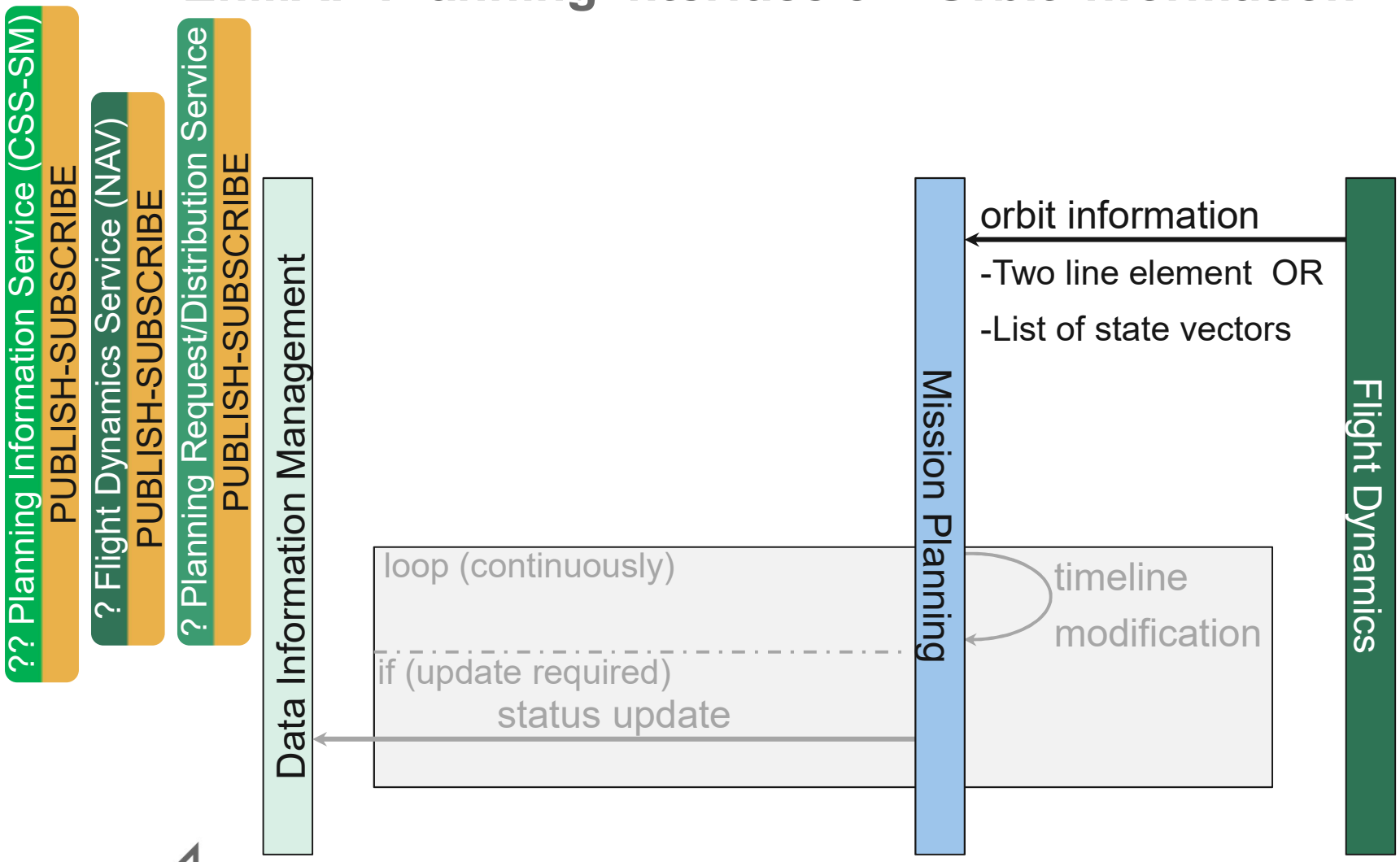
# EnMAP Planning Interface 7 – Downlink Info, Reception Report

- Downlink Information
    - satellite ID, ground station ID
    - time window
    - for each pass
        - start / end of transmission
        - data to be transmitted (not precise, since amount of data per datatake unknown)
- Reception Report
    - satellite ID, ground station ID
    - start / end of transmission
    - success state: one of
        - data received (datatakeID, segmentStart/End, endReached)
        - Reason for failure

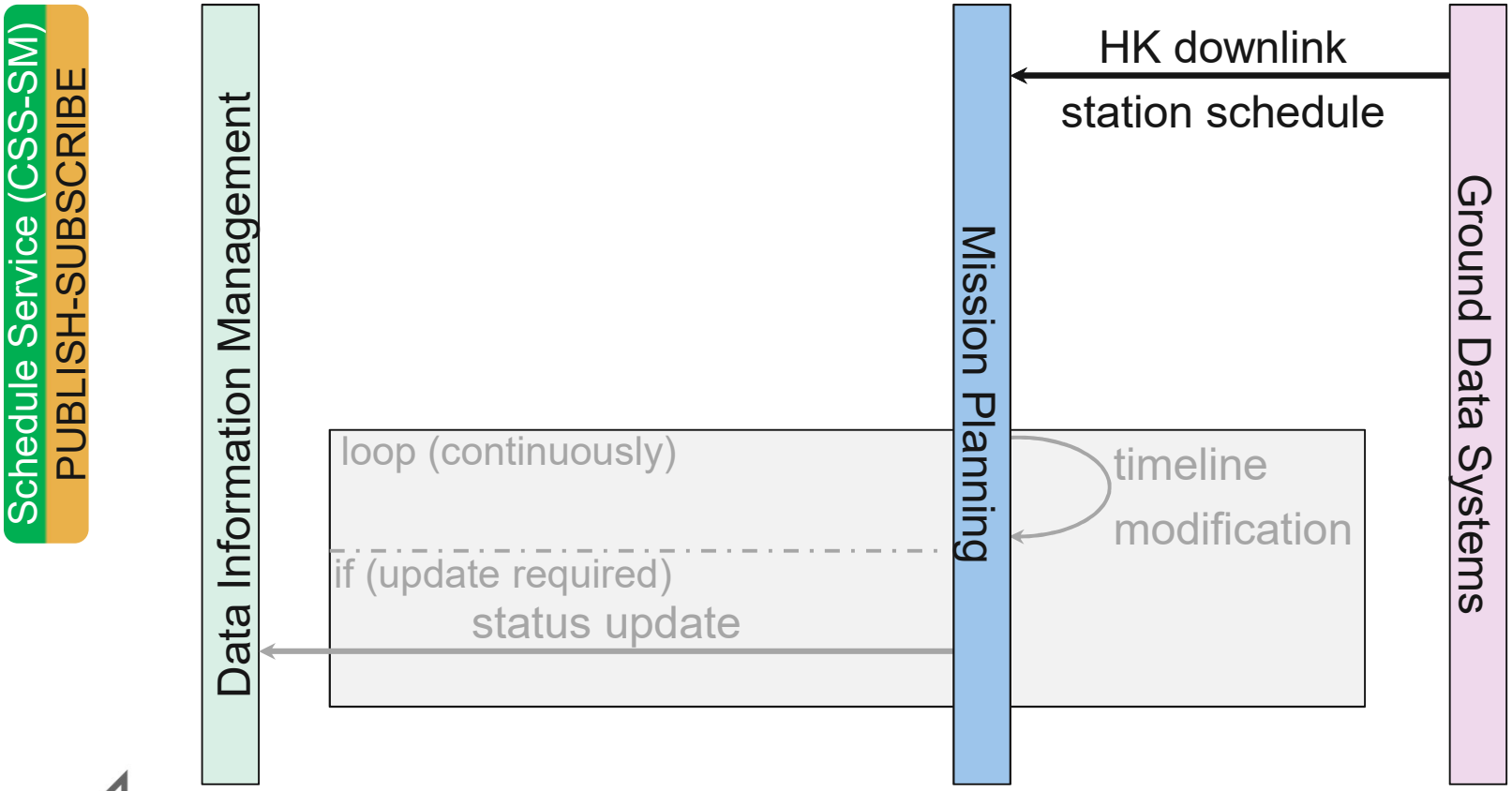
# EnMAP Planning Interface 8 – Outages




# EnMAP Planning Interface 9 – Orbit Information



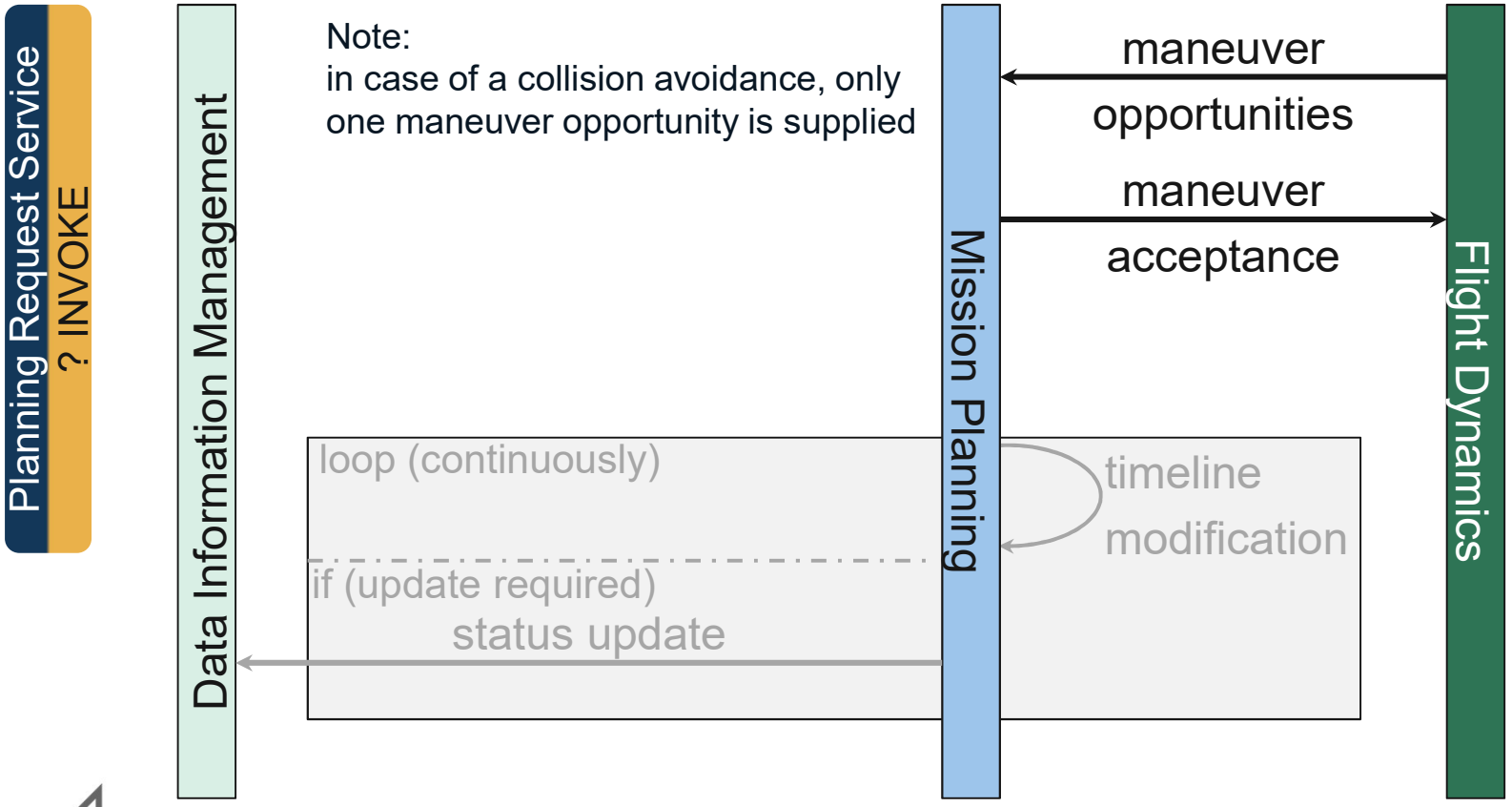

# EnMAP Planning Interface 10 – HK Downlink Station Schedule




# EnMAP Planning Interface 10 – HK Downlink Station Schedule

- generation date
- considered time frame
- For each scheduled ground station activity
    - activity identifier
    - type (pass / no pass)
    - start / stop
    - station / priority / data rate / maximum elevation
    - constraint (lateAOS / earlyAOS / both / none)

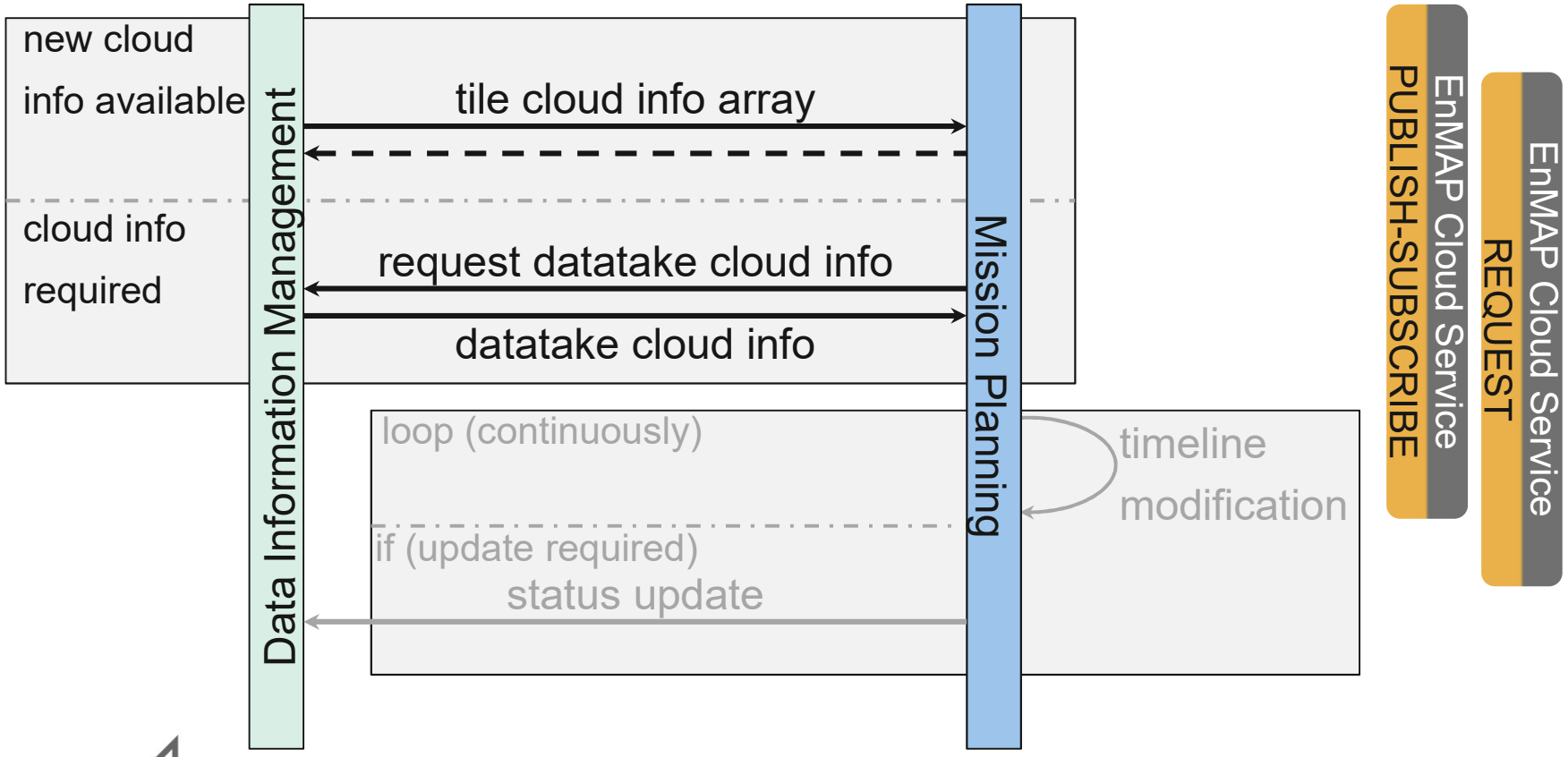
# EnMAP Planning Interface 11 – Orbit Maintenance




# EnMAP Planning Interface 11 – Orbit Maintenance

- Maneuver Opportunities (list of alternative possibilities for a maneuver)
  List of
    - EarliestStart
    - LastEnd
    - Duration
    - Parameter (e.g. FD internal Identifier)
- Maneuver Acceptance
    - planned maneuver
        - start
        - end
        - Parameter
    - OR reason for maneuver to be rejected

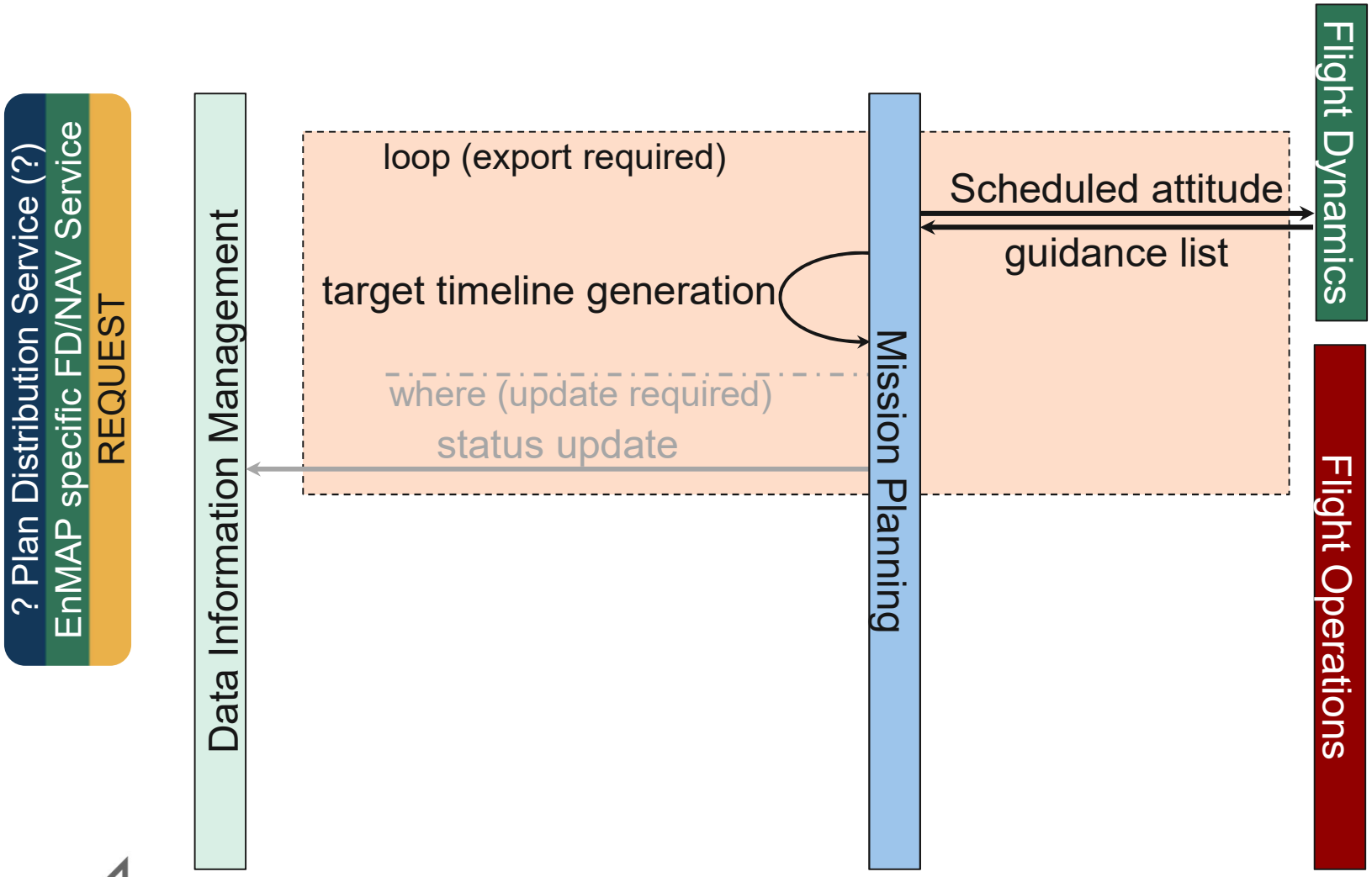
# EnMAP Planning Interface 12 – Cloud Information




# EnMAP Planning Interface 12 – Cloud Information

- TileCloudInfoArray
  array of TileCloudInfos:
    - tileId
    - CloudCoverage (0 ..100)
    - CloudDistribution (0 .. 100)
    - GeographicCoverage (polygon specifying the tile's area)
- DatatakeCloudInfo
    - datatakeId
    - TileCloudInfoArray
      consists of TileCloudInfos, whose GeographicCoverage overlaps with the datatake

# EnMAP Planning Interface 13 – Guidance List

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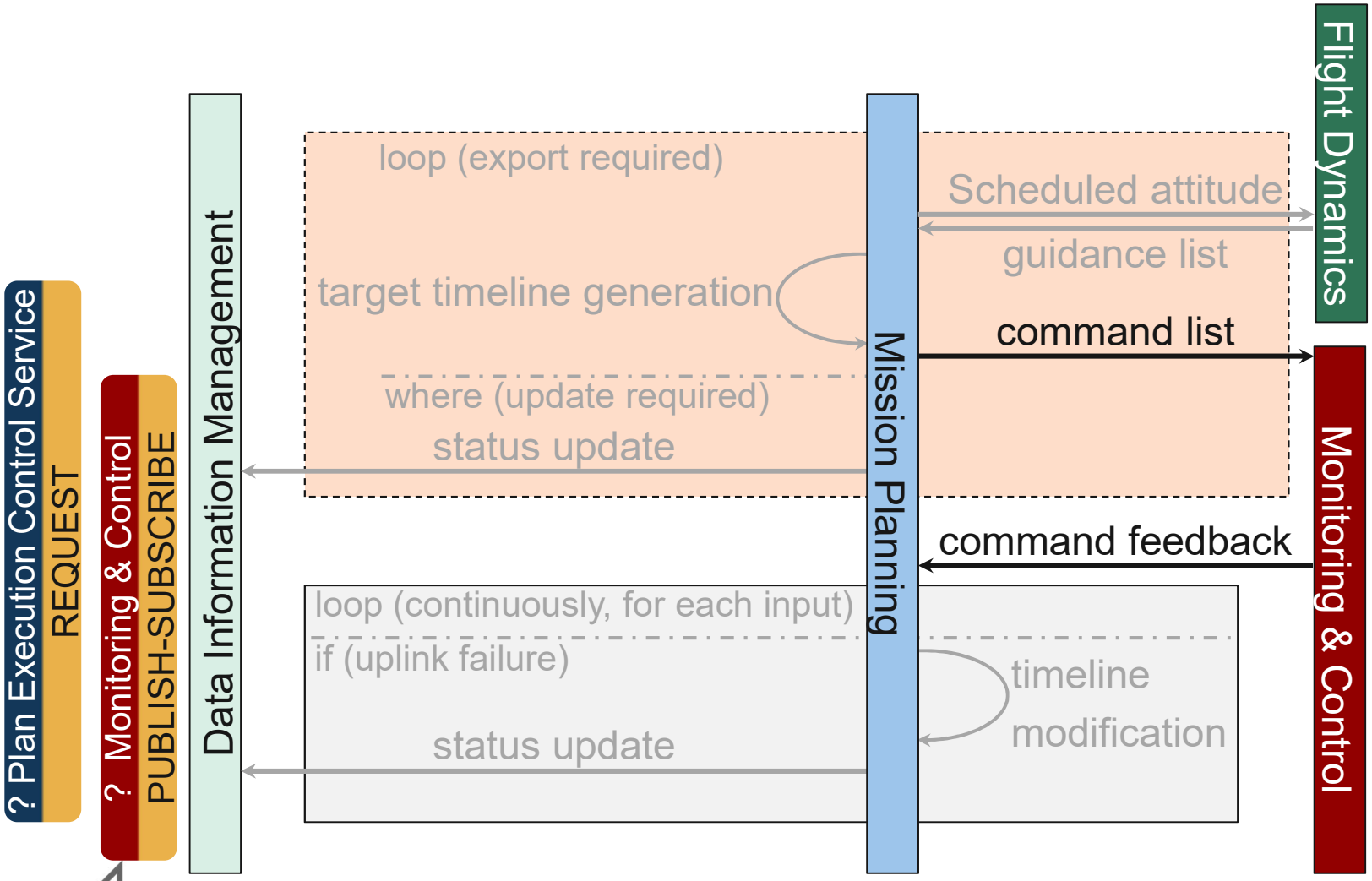
# EnMAP Planning Interface 13 – Guidance List

- Scheduled attitude
  List of attitude information:
    - Target pointing mode (linear interpolation in-between the points):
        - start (center coordinate / time)
        - waypoint (center coordinate / time)
        - end (center coordinate / time)
    - Sun pointing mode
        - start-time / end-time
    - Earth pointing mode
        - Start-time / end-time
- Guidance list
    - Satellite specific guidance list - to be forwarded to the satellite

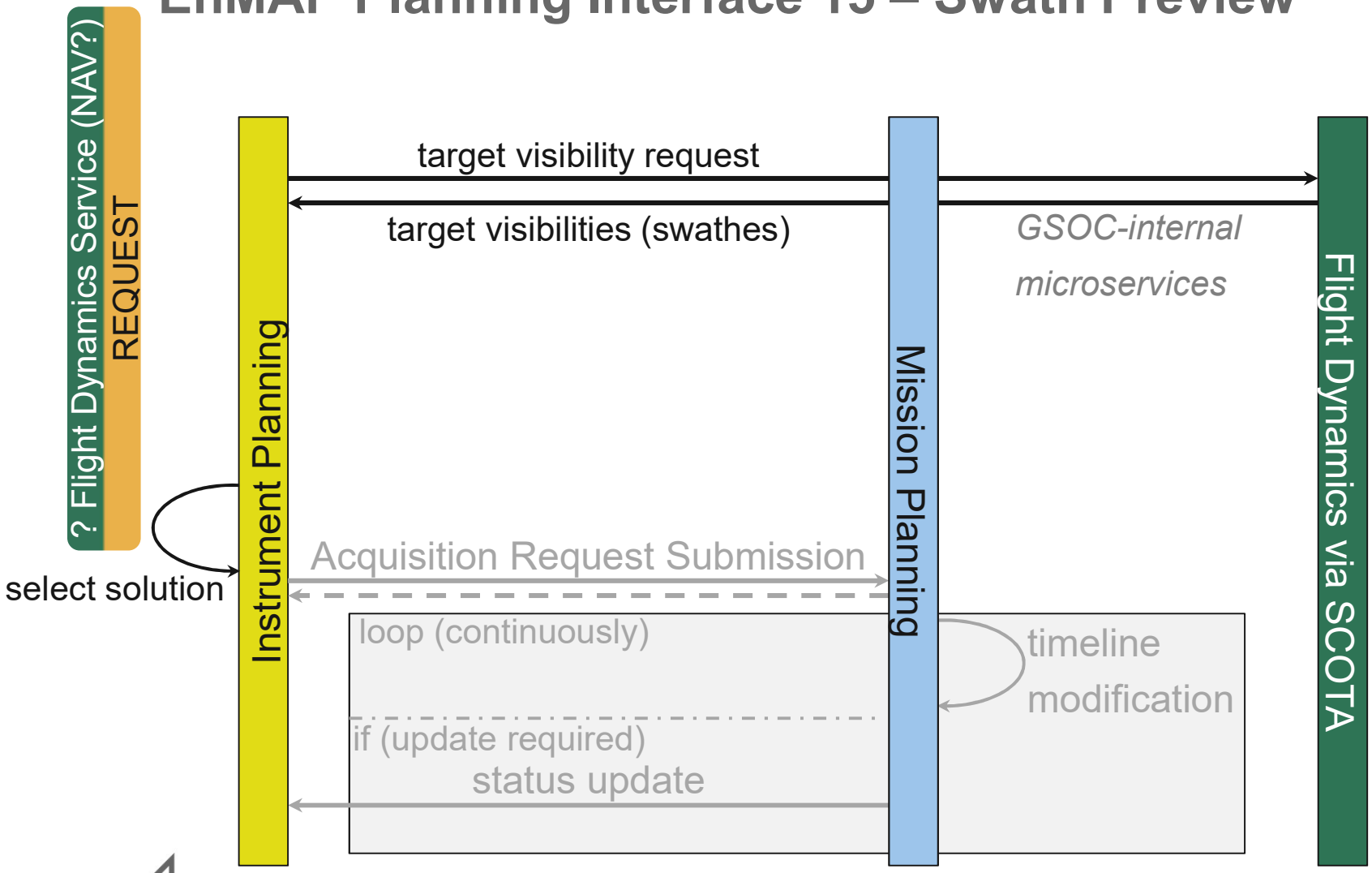
# EnMAP Planning Interface 14 – Commanding




# EnMAP Planning Interface 14 – Commanding

- Command List for Timeline Export
  - Satellite / Associated target timeline version
  - List of procedures to be executed by the satellite
    - procedureName / procedureVersion / procedureDescription
    - startTime / referenceTime
    - List of command blocks
      - commandName / commandCounter
      - procedureStepReference / procedureStepDescription
      - parameters (name / value / descript. / interpret. / alias / type)
    - includeFile (separate file, which needs to be included in the to-be-created commands)
- Command Feedback
  - Satellite / Associated target timeline version
  - Uplink state (success / failed / unknown)

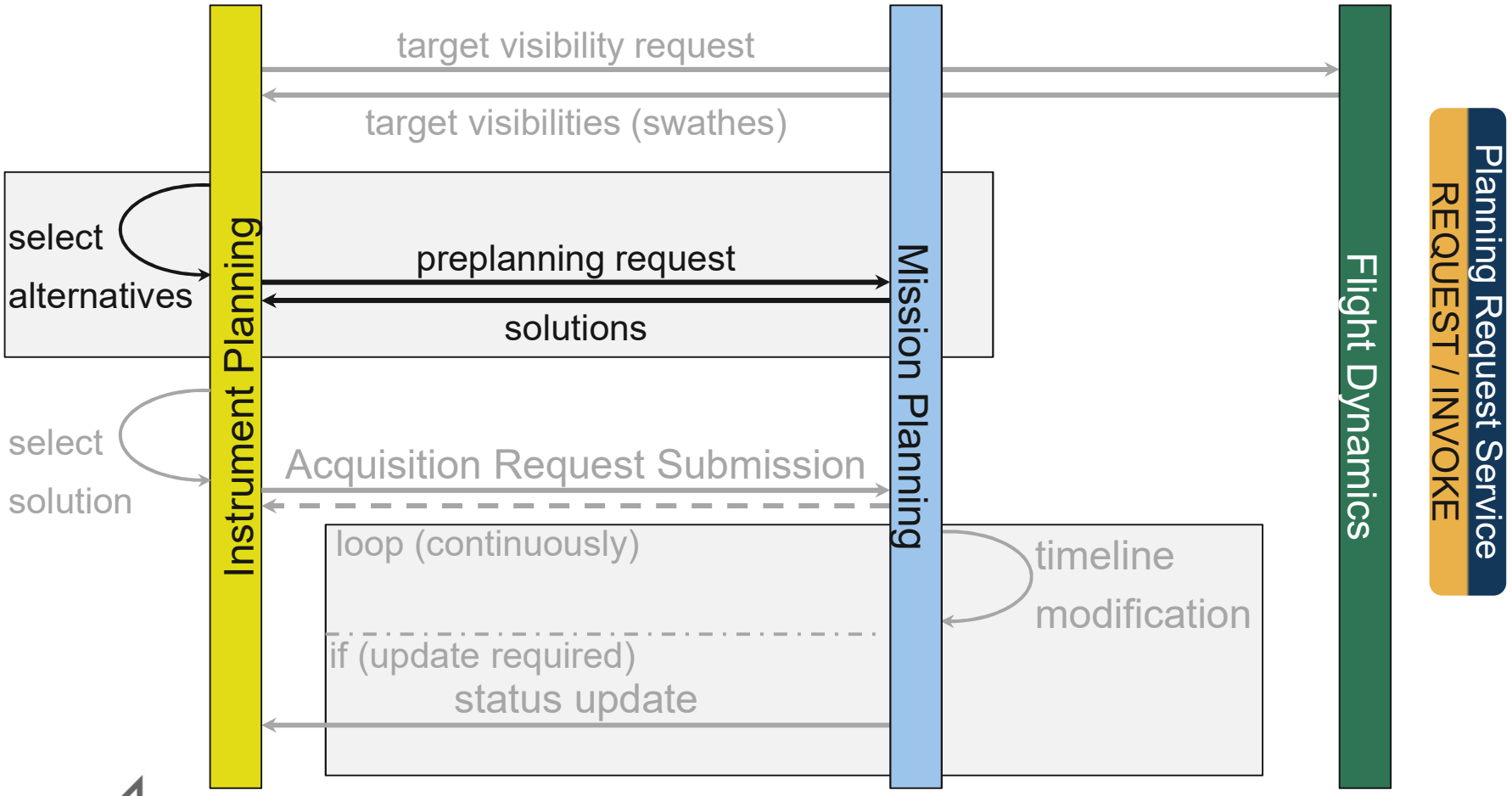
# EnMAP Planning Interface 15 – Swath Preview




# EnMAP Planning Interface 15 – Swath Preview

- target visibility request
  - acquisition time window
  - target
    - center coordinate / offsets OR
    - search polygon
  - further parameters, e.g.
    - looking angle range
    - ascending / descending
    - instrument mode → swath width
- target visibilities
  - for each visibility within specified parameters:
    - polygon specifying the swath
    - start/end time
    - further parameters (looking angle, asc/desc, instrument mode, ...)

# EnMAP Planning Interface 16 – Preplanning (optional extension)



# EnMAP Planning Interface 16 – Preplanning (optional extension)

- preplanning request
    - list of alternative Acquisition Requests (see Interface 1, slide 7)
- solutions
  Informs about which acquisition requests from the preplanning request may be scheduled and what the consequences would be. The result may be sorted and filtered, e.g. to assure that only the best solution is returned.
    - List of solutions:
        - acquisition request to be scheduled
        - ids of datatakes that would be removed from the timeline
        - scheduling details (e.g. start / end time of new timeline entry)

# EnMAP Planning Constraints

- Target visibilities
- Satellite attitude, slew rates (camera and antennas fix mounted)
- Onboard Memory, downlink rates
- Power: linear approximation
- Power & Temperatures: gliding windows
- Ground station antenna visibilities and availabilities
- Planning request specific downlink destinations
- Availabilities of ground segment, satellite bus and instrument

# CCSDS mission planning services appliable to EnMAP mission planning

| | no | Description | Comment |
|---|---|---|---|
| ✓ | 1 | Acquisition Request | Planning Request Service |
| ✓ | 2 | Status Update | Planning Request Service |
| ✓ | 3 | Redo | Planning Request Service |
| ✓ | 4 | Cancel Request | Planning Request Service |
| ✓ | 5 | Close Request | Planning Request Service |
| ✓ | 6 | Pass Request, Availability Info | Ground Station Scheduling Service (-> CSS) |
| ? | 7 | Downlink Info, Reception Report | Telemetry Service? |
| ✓ | 8 | Outages | Planning Request Service |
| ? | 9 | Orbit Information | NAV Service ?/ CSS-SM Service? / Planning Request /Plan Distr. Service? |
| ✓ | 10 | HK Downlink Station Schedule | Ground Station Scheduling Service (-> CSS) |
| ✓ | 11 | Orbit Maintenance | Planning Request Service |
| ? | 12 | Cloud Information | Cloud Service (EnMAP specific) |
| ? | 13 | Guidance List | Specific Flight Dynamics Service (-> NAV?) |
| ✓ | 14 | Timeline Export & Command Feedback | Plan Execution Control Service |
| ? | 15 | Swath Preview | Specific Flight Dynamics Service (-> NAV?) |
| ✓ | 16 | Preplanning (Test-Ordering) | Planning Request Service |

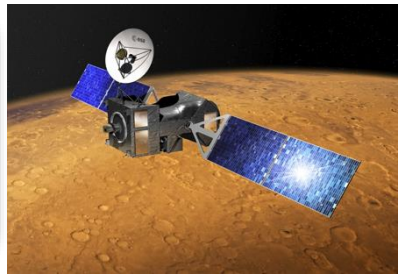
DLR

# Thanks for your attention…
# …and the further discussions…

# ExoMars 2016: Science Operations

Science Objectives

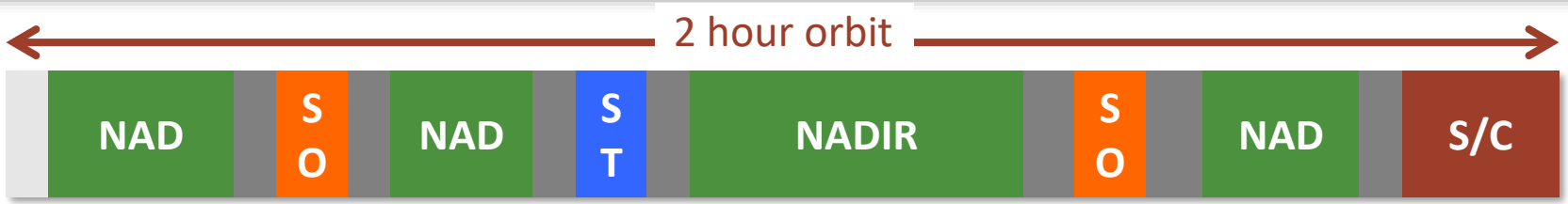
- Study Martian atmospheric trace gases & their sources



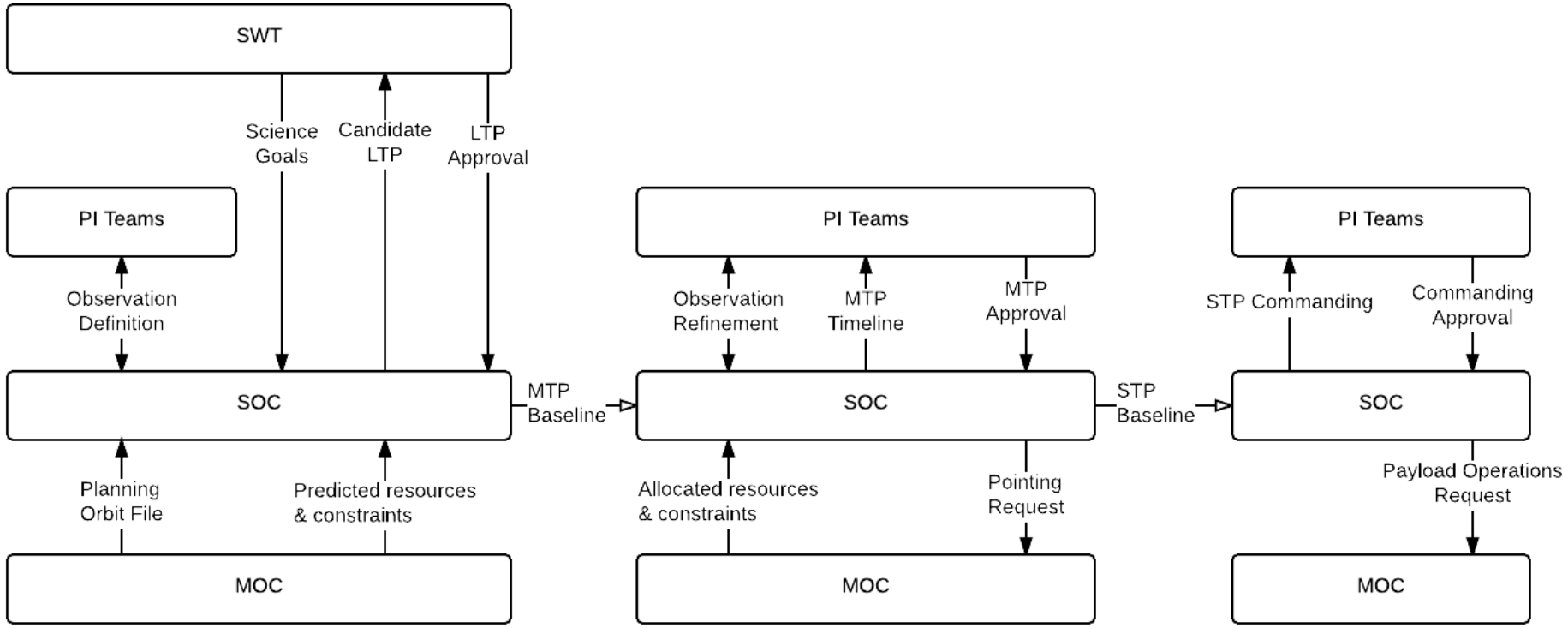
- Near Circular Orbit. Altitude: 400km, Period: 2 hours, Inclination: 74˚
- Pointing Modes: Nadir, Stereo, Solar Occultation, Inertial (+ slew/raster)

Typical Science Orbit (Based on all 4 Experiment Operations Plans)

- 7 observations + spacecraft maintenance ~ 2500 observations/month
- Targeted pointing for camera observations, including stereo pairs



# ExoMars 2016 Planning Cycles




**Long-Term Plan: 6 months**

**SWT:** Iterate on Science Goals:

- ❑ Coverage (e.g. latitude ranges), priority

**PI-teams:** Capture definitions:

- ❑ Observations, Models

**MOC:** Planning predictions

**Medium-Term Plan: 1 month**

**PI team:** Refine Planning Inputs

Observation level

**PI team:** Finalise Timeline

**SOC:** Fix Pointing & Resources

**MOC:** Final allocations

**Short-Term Plan: 1 week**

**PI team:**

Refine Commanding

Note: on EM16, this may be merged with the MTP

# TGO SOC External Interfaces

All TGO SOC Interfaces are file-based via SOC git repository:

- branching per planning period (4 week MTP)
- Git pull-request functionality to distribute files to teams and to merge updates
- Requests are for full planning periods, applying selected observation definitions to agreed repetition patterns (patterns not frequently updated = LTP interaction)
- Targeted Camera Observations are interleaved with SOC imposed plan & relay
  - exclusion windows, time margins are provided by SOC (files) to retrict the target selection
    - ~ Camera team subscribes to the SOC planing windows
  - selected targets (csv file) are used to generate pointing requests at SOC
    - checked vs scheduling and attitude constraints at SOC & constraints using FD web-service
    - Planning Requests are Accepted (=PLANNED) or REJECTED by SOC

Interactions: very primitive, no request/response, progress or pubsub

- Full set of planning products distributed by SOC to all PI teams
- Manual SOC evaluation of files submitted by PI teams

# List of Interfaces

- Interfaces to MOC
  - Inputs from FCT: Events = Communications Passes, Relay Slots
  - Inputs from FD: Events = LTP Orbit, STP Orbit
  - Outputs to FD: PTR = Pointing request coming form the resolved Activity Instances
  - Outputs to FCT: POR = Output timeline relative to LTP orbit (MTP POR) or STP orbit (STP POR)
- SOC/PI team Definition
  - Science Management level = Scheduling Rules
  - Activity Definition = Observation Definition = Commanding, Pointing
  - Event Definition= Combined Geometric Events, specific scheduling rules
- Interfaces to PI teams
  - Planning Events, generated by scheduler applying observation conditions & repeat patterns
  - Extracted STP Orbit information (ascending node events to fine-tune camera image times)
  - Target Observations (CaSSIS Camera), csv containing target info, timing information
  - Input Timelines (for entire planning periods), links Activity Definitions to Events
  - Output timelines, Commanding coming form the resolved Activity Instances

# Inputs from MOC

Provided at LTP (-6 months) = Orbit Events, Comms Events

- SOC “subscribes” to MOC inputs over FTS, Large event files via SFTP to SOC server, automatically checked and ingested at SOC
- Used for internal SOC planning, not distributed to PI teams

Provided at MTP (-3 months) = Comms Events, Relay Events

- Comms Events semi-automatically merged into GLOBAL event file
- Relay Events ingested at SOC (used to constrain science planning)
- MTP inputs used to generate SOC planning events distributed to PI teams

Provided at STP (-2 weeks) = STP Orbit file via FTS

- Used by SOC to refine commanding timelines
- **Information forwarded to CaSSIS camera team for timing updates**

# Interfaces to MOC

- Commanding (POR), Pointing (PTR) file deliveries to MOC covering entire planning period submitted to FTS (SFTP), forwarded to MOC systems
  - SOC receives request response with validity status (MIB consistency) = PLAN ACCEPTED
  - **No feedback on the plan execution status, only the TC history**
  - **No Mapping from TC history back to Observations Instances execution success on TGO**
- PTR validated vs FD web services. SOC uses the following services
  - Check the validity of the complete PTR
  - Error reports (text file in absolute time, e.g. slew-rates, angular momentum, Star-tracker blinding, illumination errors)
  - Attitude file (MOC format), SOC convert to SPICE CK and provide to PI teams
  - HGA repositioning slots (FD events), used by SOC to reduce COMMS pass data-volume
- POR validated using MOC systems
  - Manual interaction to update POR, i.e. email from MOC requesting update
  - MOC systems give pass/fail for entire (1-week/payload), hard to trace error location

# SOC / PI team definitions

Scheduling rules: **-> goes to SCIENCE PLANNING EVENTS**

- How the observations (activities) should be repeated and constrainted.
- JSON configuration file captures the SWT agreements
- Updated infrequently (at LTP, every 6 months – years)

Observation Definitions: **Plan Configuration Data**

- Library of generic activity types (files) for each payload
- Parameterised to adapt to computed geometry
- Commanding and Pointing relative to START/END events

Observation Opportunity Events:

- Required Geometry from PI teams, implemented by SOC
- Input to generation of **Science Planning Event File** for all possible opportunities

# Interfaces to PI teams

SOC provides all planning info to all teams (no filtering):

- **Planning Event file**: observation type specific events used to schedule the observations (activities). **Plan provided to teams that only contains events**
- Planned attitude: SPICE CK used by PI teams to compute e.g. parameter values
- Draft input timeline files: relating the planning events to the observation definitions. **(Activity type x for Event type y)**
- Draft output timeline files: default activities resolved to planning events
- Draft Pointing: default spacecraft pointing for entire period
- Exclusion windows: periods where PI teams cannot update
  - Provided as events to CaSSIS, **repsond with plan edit**
- Final Pointing: as info to teams, final request provided to FD
- Final Commanding: as info to teams, final commanding delivered to MOC

# PI – SOC iterations

All interfaces via GIT:

- Notifications sent from GIT to SOC engineer and to PI team
- Manual processes at SOC triggered by reception of file inputs

Observation Definition updates:

- Update the Observation Definition
- Triggers a regeneration of Observation instances by SOC

Pointing Update

- Camera team only, inserted in SOC designated slots (PLAN EDIT? now restricted to plan execution)
- Triggers validation at SOC, REJECTED slots provided to camera team for replanning

Timeline Update

- Refinement of SOC generated timeline (e.g. parameter values only)
- Complete over-write of SOC draft timelines

# Typical Plan Updates

- Changes to MOC inputs (e.g. moved relay slots)
  - SOC regenerates the entire plan, applying the scheduling rules and distributes full plan request to all teams
  - SOC distributes the detailed pointing and commanding to all of the teams for further refinement

- Resource Changes (e.g. reduced groundstation coverage)
  - SOC evaluates available data-volume
  - agrees with PI team which observation definitions to be changed
  - SOC regenerates the entire plan and distributes full plan request to all teams

- Orbit Event updates
  - SOC resolves instrument team commanding to new absolute time
  - SOC distributes new commanding updates to ALL instrument teams

# Areas where standard could be applied (by 2030)

- Insertion of targeted observations in plan
  - Provision of available time-periods
  - Submit target image requests
  - Validation of target image request: accepted/rejected (by SOC and by FD)
- Request/response interaction patterns for requests from PI teams
  - Most manual steps, SOC evaluations can be automated
- Relay Planning
  - SOC subscription to relay plan
  - SOC provision of attitude to lander relay community: big improvements to link-budget

# OPS-SAT – case study of the application of the CCSDS Mission Operations Services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**20 October 2022**

# Summary of content

# What is the OPS-SAT Space Lab?

## Mission

- **In Orbit Demonstration and Validation**
- Space Labs
  - 1st generation: OPS-SAT-1
    - OPS-SAT-1 launched in 18th Dec. 2019
    - SSO
    - Supported by ESOC
    - Operations on UHF (TU Graz) and S-band
  - Coming generations: OPS-SAT-2, OPS-SAT VOLT

## Purposes and motivations

- Break the cycle of “has never flown, will never fly”
  - For OPS but also scientific purposes
- Payload of opportunity:
  - Versatile & reconfigurable
  - Robust & powerful
- 2 in 1: a satellite within a satellite, control can be swapped

# What is the OPS-SAT Space Lab?

## User Profile

Allow 3rd party experimenters to load SW/FW to S/C, executing in during live passes or outside of visibility. Nature is usually not known in advance, tested on ground but not extensively like “normal” procedures.

→ Challenge 1 for MP&S: creation of new activities for each experiment: aggregation of activities + template.

From here the experiments can reconfigure and control all the spacecraft subsystems and payloads.

→ Challenge 2 for MP&S: create a set of constraints which the team has to be play with and around during Planning.

## Operations scale

- In nominal state: running up to 8 experiments occurrences a day.
- Database of 226 experiments activities
  + operations events.

# OPS-SAT operational concept

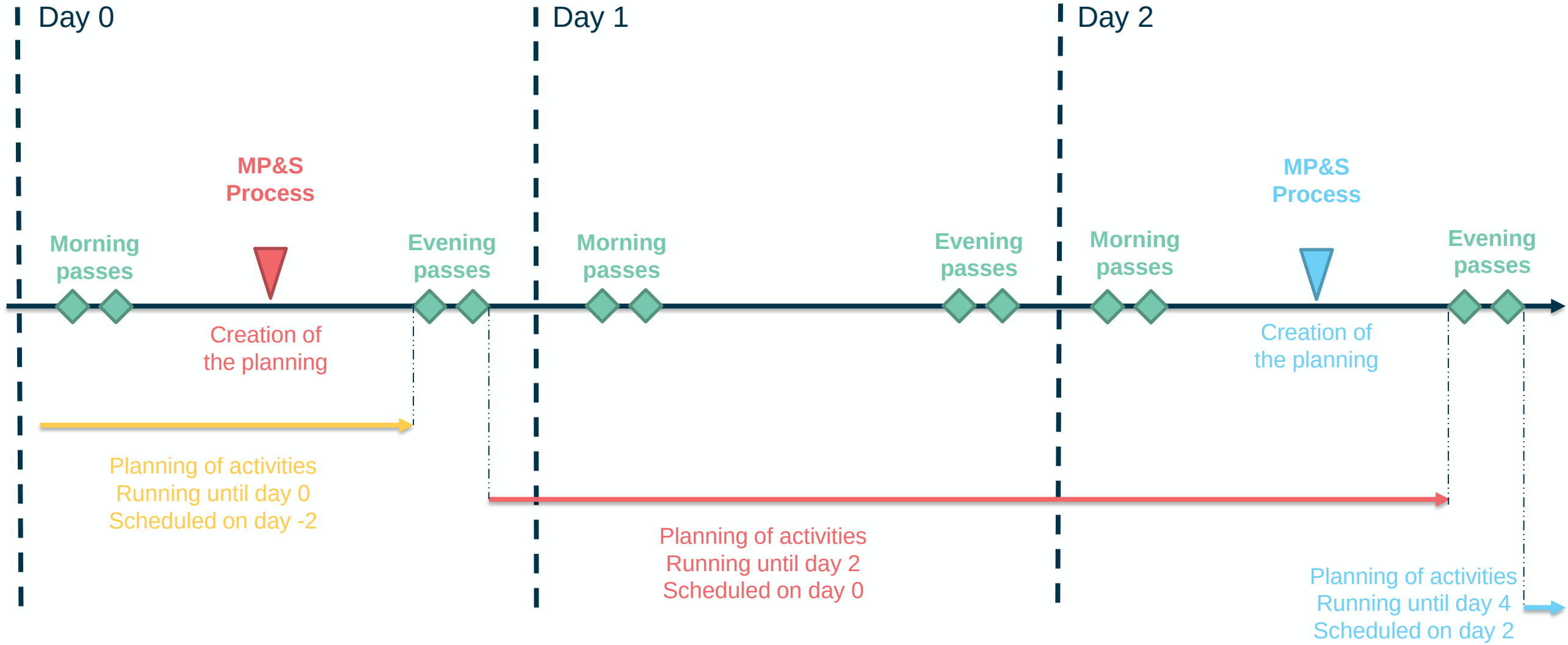
## Operations concept

- No complex constraints model…
- … but complex operations model.
- Depends on rudimentary FDIR, robustness of the ops, therefore planning of activities, is critical.
- Based on a mix of execution of schedule and live manual operations (procedures).

## MP&S concept

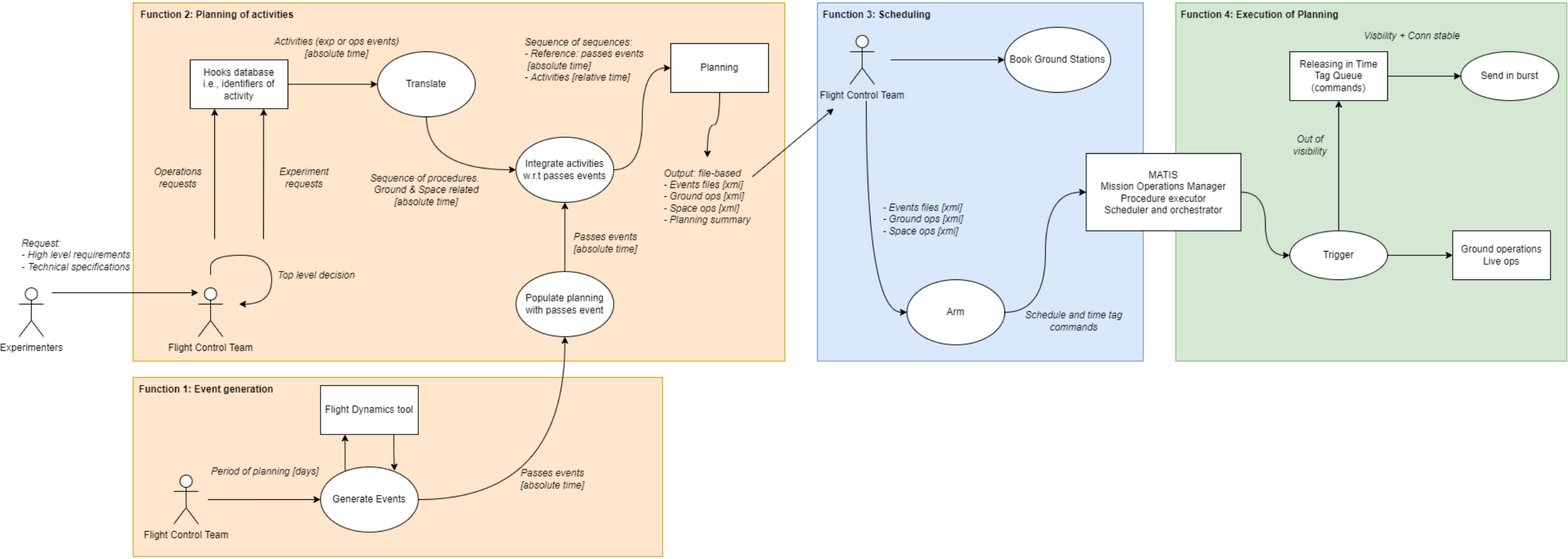
- Planning process complex due to multiplicity of experiments.
- Planning modification re-triggers the full process of MP&S.
- File-based planning.
- MP&S prompted every 2 days to 3 days, short cycle!

# OPS-SAT planning cycle



# OPS-SAT MP&S services

## Overall approach



# OPS-SAT MP&S services

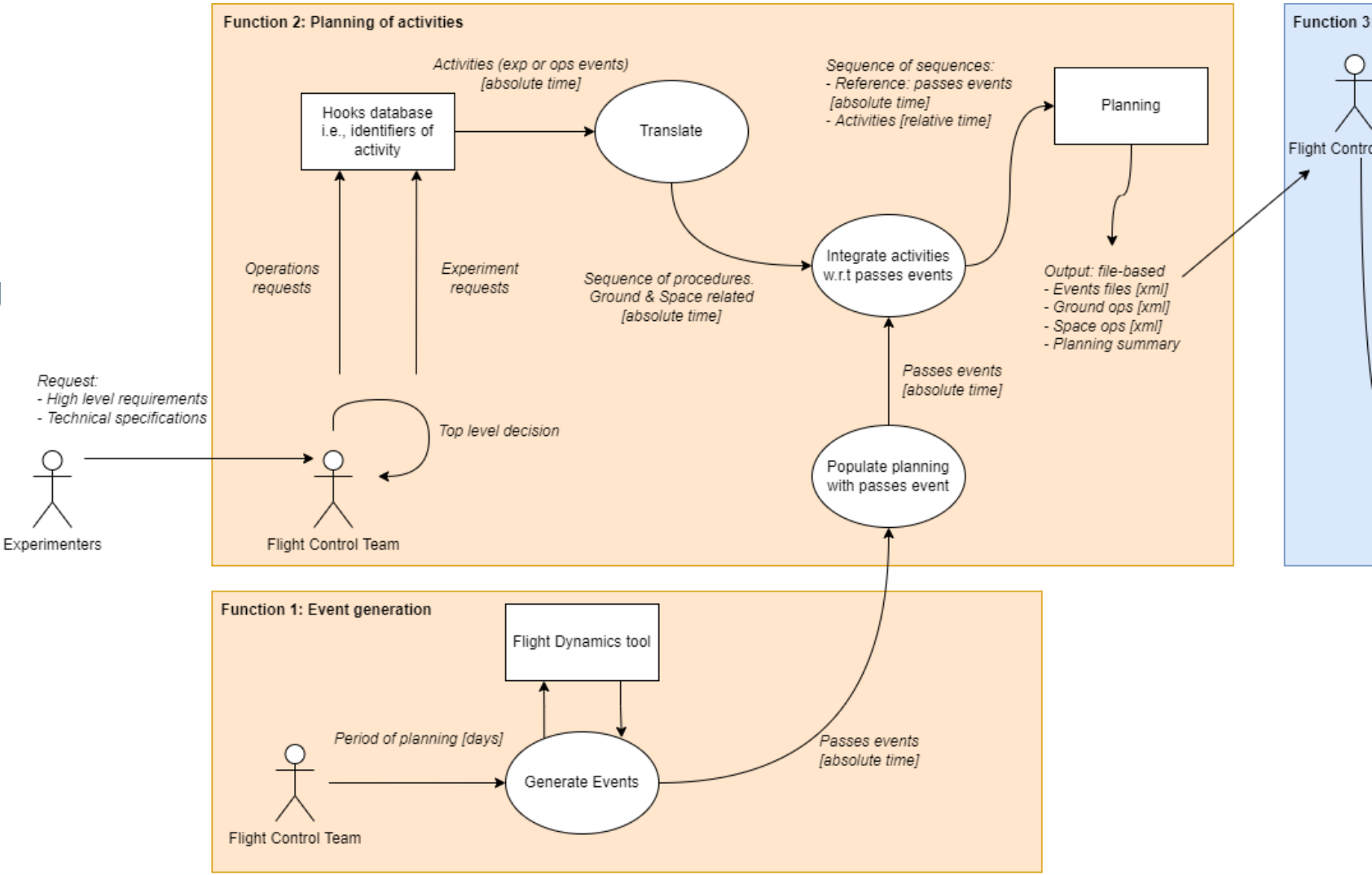
## Planning

Critical entry points:

- From experimenters.
- Operational requirements: changing at a very fast pace (every two day or so).

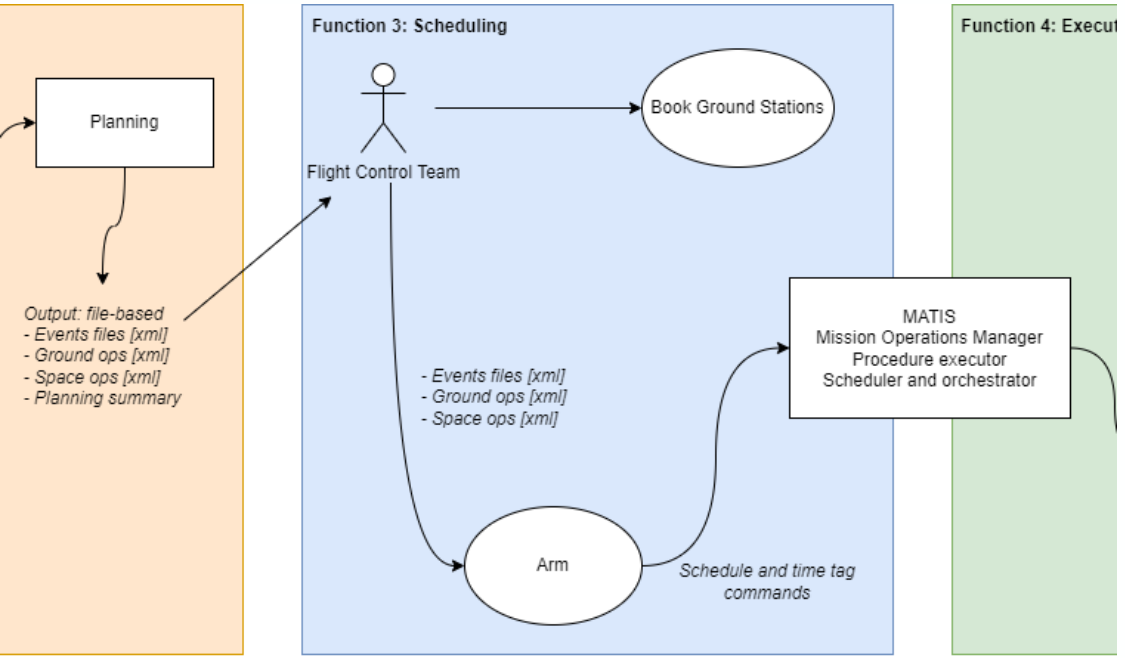
→ Makes planning request a complex task to process.

→ Planning possible only for a few days forward due to rapidly changing mission status.



# OPS-SAT MP&S services

## Scheduling




Based on planning, the particularities are…

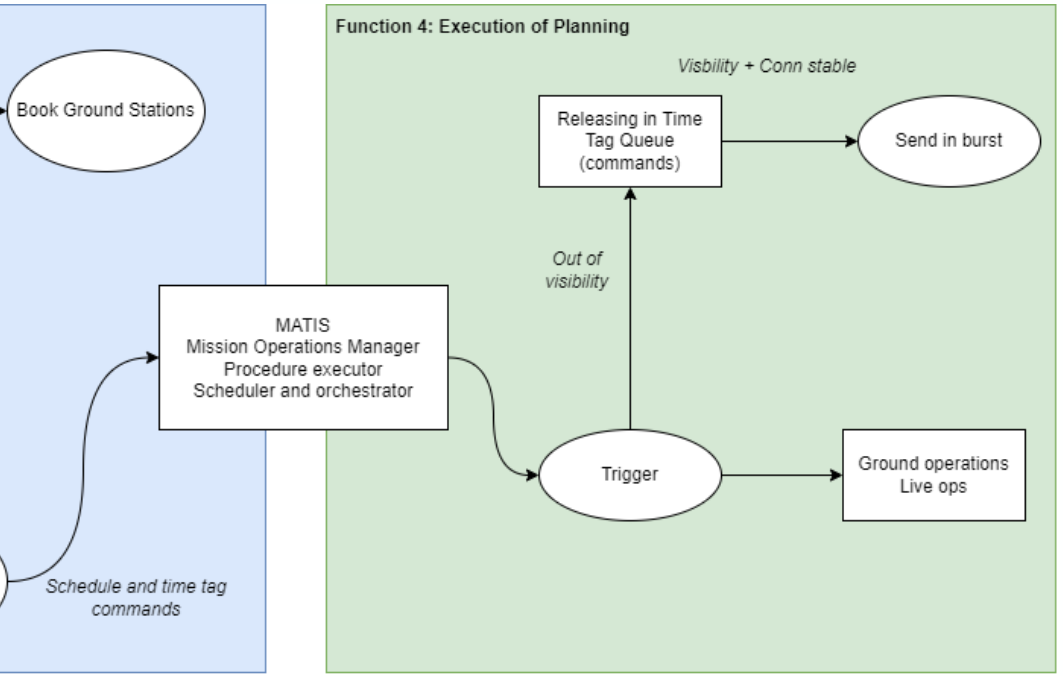
- The passes events timeline is expressed in absolute times whereas the activities, planned w.r.t these events, are expressed in relative times.
- The absolute time is the effective time in the end.

Inputs (files):

- Events file: orchestration on absolute time.
- Ground ops: configuration file.
- Space ops: time tag commands.
- Planning summary: for human operator.

# OPS-SAT MP&S services

## Executing




- Schedule released in burst, after loading out of visibility
- Live ops, via MATIS and its procedures.
- Procedures follow the same template as the one implemented in the planning function

# Mapping of the MP&S Services for OPS-SAT

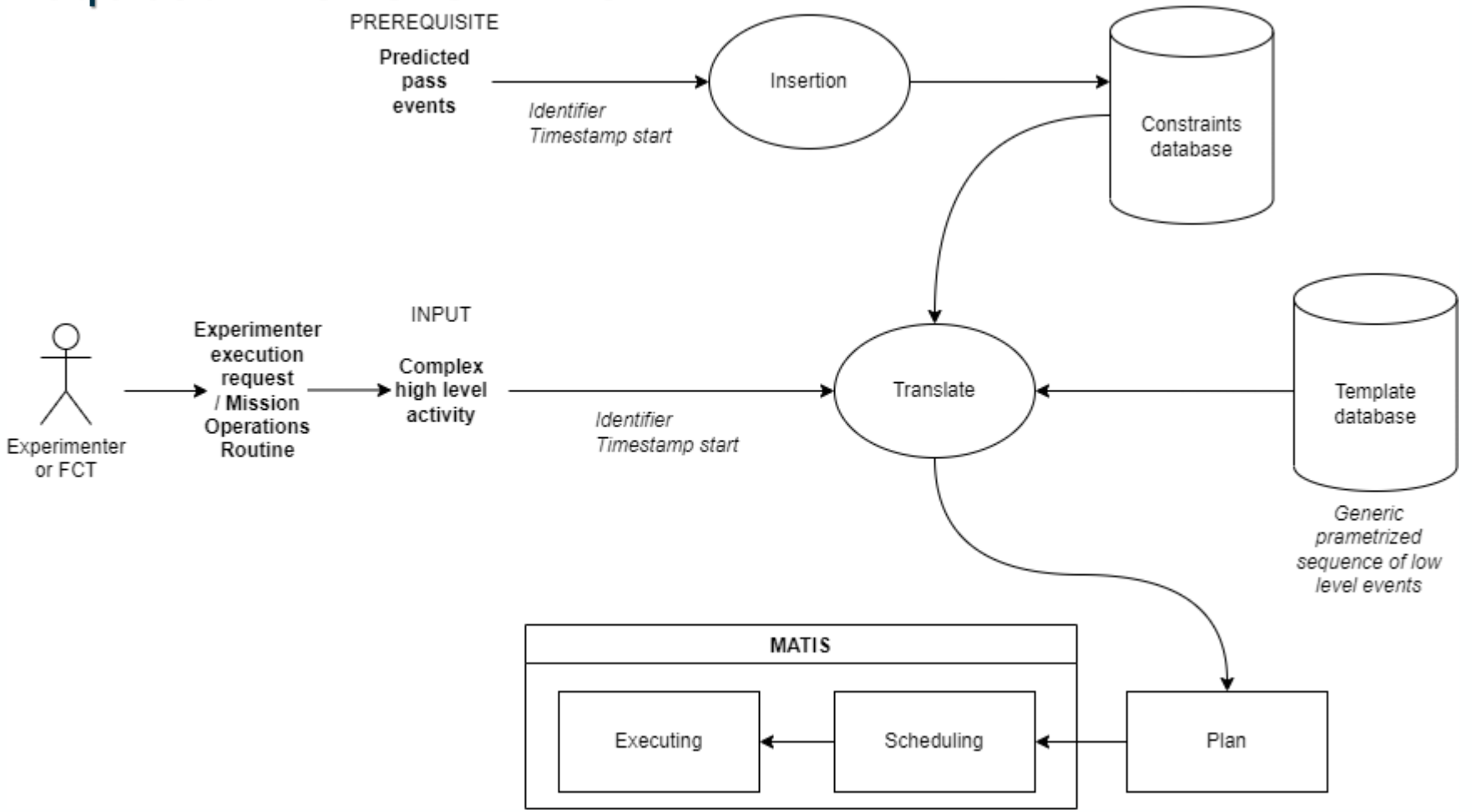
- How well would it map?
  - Planning system is almost there in terms of data and functionality.
  - Many interfaces would not be implemented – we only need a subset of capabilities.
- Main challenges:
  - Even though we need a subset of MPS, the mapping is not obvious to design and implement.
  - MPS has no service-oriented interfaces – wrapping certain actions and file based planning inputs/outputs to a service-oriented API is not straight forward
    - Possible to use the File-based backwards compatible interfaces instead.
  - The current system is very centered around manual actions by operator, and difficult to automate.
  - Complete automation of (re)planning is difficult. Removing the operator from the decision making is not feasible (too many edge cases to take into considerations, as the system state changes rapidly). But there are compromises which can be made:
    - Address the most common anomalies.
    - Keep the planning cycle shorter, to minimize discrepancies between assumed and actual state.

# Possible application of the MP&S services

## Example - Planning Request in OPS-SAT now

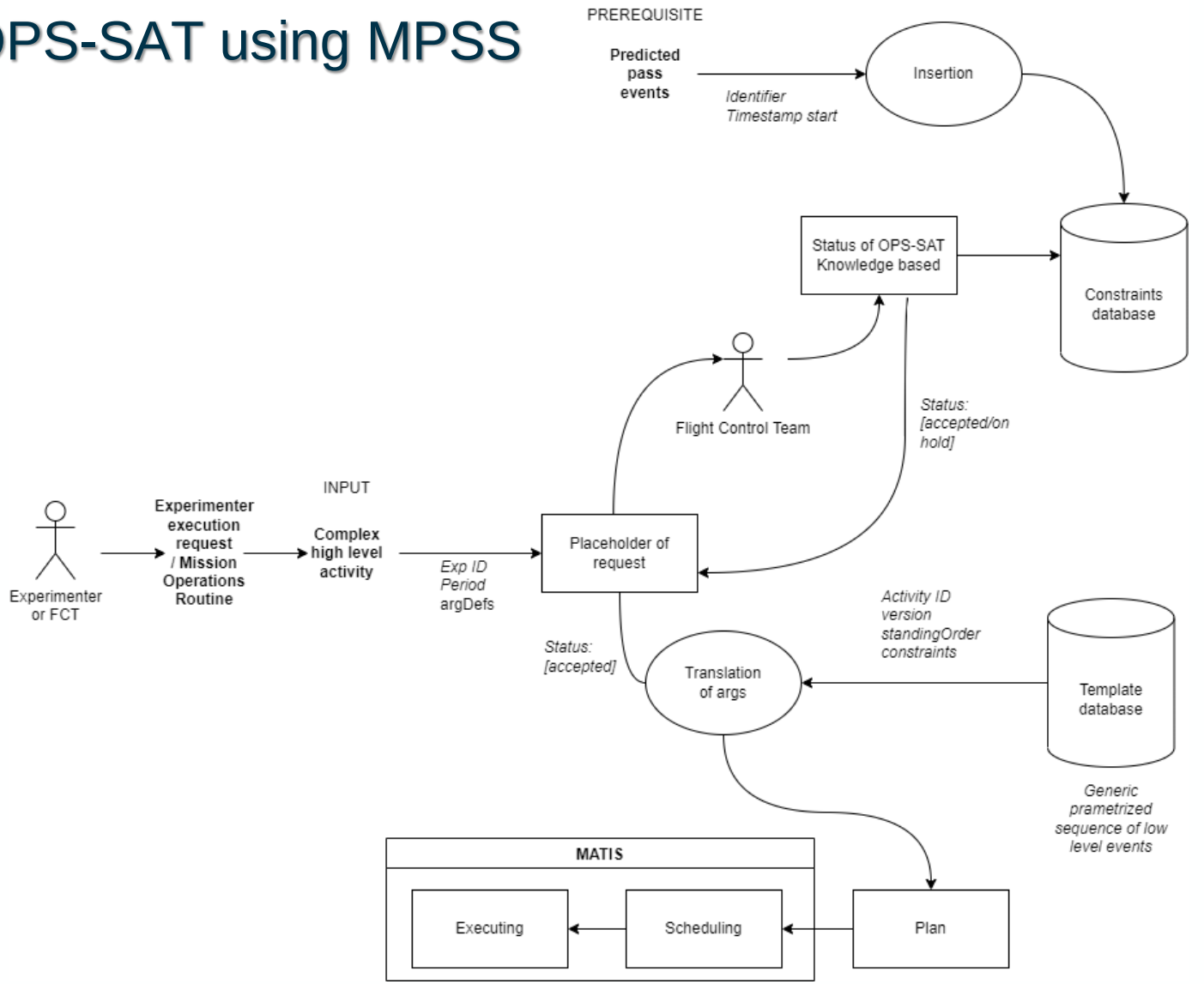
And then possible improvements:

- Better defined interface for Experiment Execution Request and its feedback (currently via email)
- Automation of more Mission Routine Operations inputs (via a feedback loop from the current S/C state)



# Possible application of the MP&S services

## Example - Planning Request in OPS-SAT using MPSS



# Further considerations

- The example is a very high level first step of how we could work towards MP&S data model and interface adoption.
- MP&S can provide us very rich, formalised interfaces for interactions across the system, both manual and automated.
- NMF-based onboard applications already allow to expose MO MPSS interface.
  - If the entire planning cycle becomes MP&S-compatible, it could easily integrate not only the core operations planning, but also payload application planning.
- The system design requires very in-depth study of the book to derive a sensible application.
- OPS-SAT-2 and its derivatives could be a very good validation environment for a “maximal” adoption

# Thank you!

# Mission Planning and Scheduling Working Group Report

## Fall Technical Meetings 2022

Peter van der Plas (WG Chair)
Marc Duhaze (WG Deputy Chair)

# MP&S WG Executive Summary

Achievements for this meeting cycle:

- Additional feedback on the Blue Book has been discussed and agreed
- Minor adaptations to the Blue Book including the Information Model are still pending
- The Blue Book is now in line with the current MAL Blue Book for Agencies Review
- The Yellow Book draft is available with agreements made on the scope of the prototyping
- The prototyping is progressing with workarounds due to the pending MAL implementation updates
- The applicability of the Blue Book in the context of actual space missions has been addressed
- The MP&S Blue Book is expected to be ready for Agencies Review by December

Working Group Status:

- 5 days of hybrid sessions during the CCSDS Fall 2022 Meeting
- ”High Momentum”: Very active and participating
- 2 CNES, 2 DLR, 6 ESA, 1 NASA, 1 UKSA

Interaction with other WGs

- Participation of SM&C experts in the discussion of the MP&S prototyping implementation and the related tooling, for MO Services and the Information Model inspection and adaptation

Problems and Issues:

- For the completion of the prototyping the updated MAL implementation, including the XML service specification and stub generation, will be essential. As soon as the MAL implementation will be available, the prototyping can be completed. However, this will then also require the availability of personnel from the prototyping organizations.

# MP&S WG Additional Viewgraph

- The WG recommends to pursue the Agencies Review of the MP&S Blue Book in parallel with the Agencies Review of the MAL Blue Book, with the expectation that potential changes to the MAL will have limited impact only

- Questions were raised regarding the availability of services beyond the scope of MP&S, to support a complete service-based solution for the ground segment (e.g. an orbital event service, an automation service, etc.)

- During the Spring 2023 Meeting the WG intends to discuss a new project on the Automation Service

- The return of the in-person meetings has proven to be very efficient and effective with longer sessions, however the capabilities for the hybrid meeting setup were considered a bit limited (microphones)

- The organization of the event in particular with the venue and food were considered very good, although a meeting room with windows would be appreciated next time

# MP&S WG Executive Summary

Resolutions agreed upon this meeting

- None

Further Resolutions anticipated in the next 6 months:

- The MP&S Blue Book is expected to be ready for Agencies Review by December 2022

Planning (only approved Projects):

| Area and WG name | CCSDS Ref Nr | Document Title | Status / Comments | Start and / or Target Publication Date |
|---|---|---|---|---|
| MOIMS MP&S | XXX | Mission Planning And Scheduling | • Agencies Review of the Blue Book is expected starting from January 2023<br>• Publication of the Blue Book will require prior publication of the MAL BB | Start date 10/05/2017<br>End date end 2023 |