ExoMars ROCC

Rover Operations Control Center

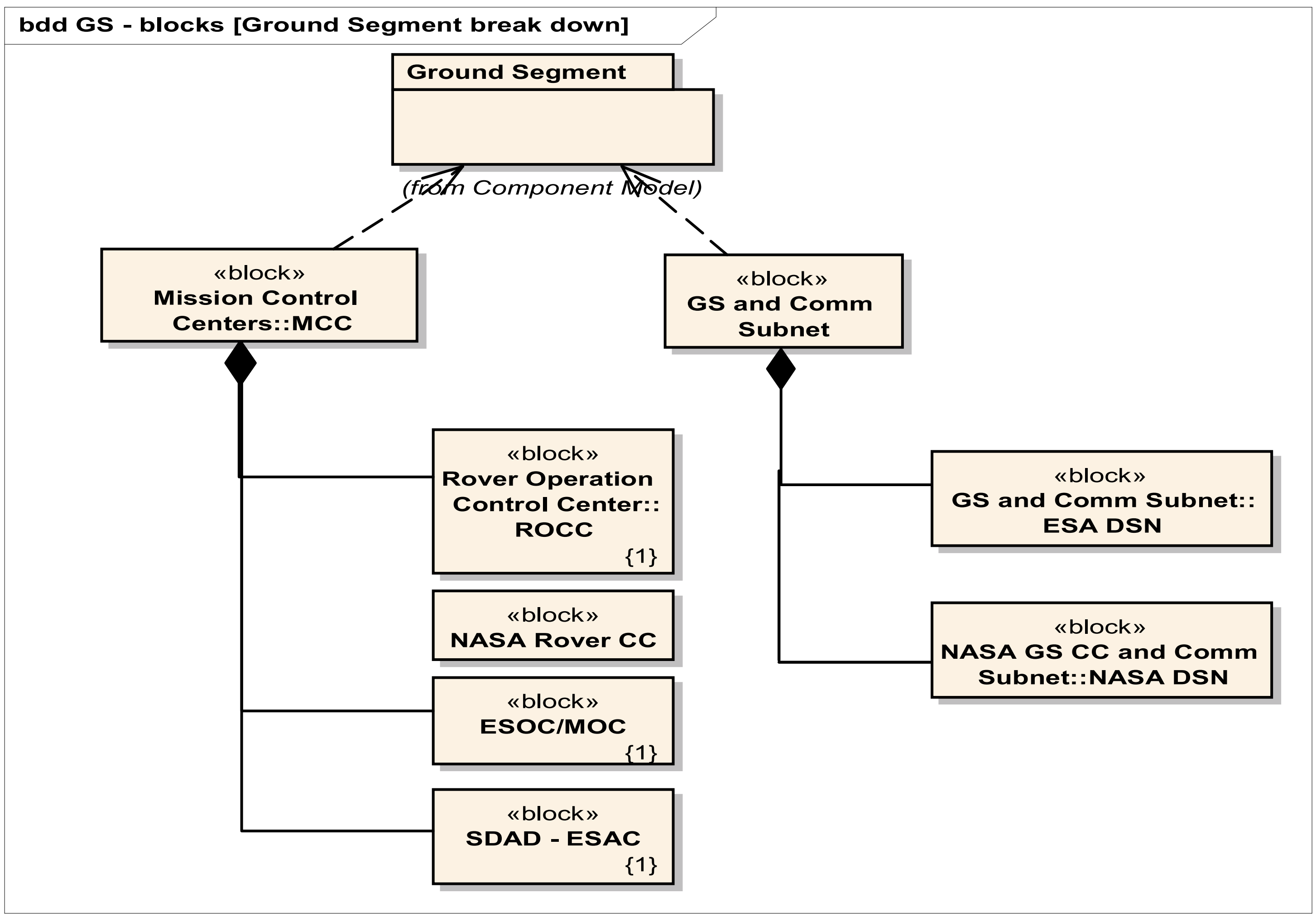
ROCC Overview & Complementary Activities

Industry Day

Agenda of presentation

- ExoMars Ground Segment Architecture
- Mission Operations Center (MOC) – ESOC
- Science data archiving and dissemination (ESAC) and NASA Rover Control Center – JPL
- ROCC responsibilities,capabilities and connections
- ROCC Mars Terrain Simulator
- ROCC functional breakdown
- ROCC ground communication infrastructure (RGCI), communication scenario and architecture
- ROCC operations control system
- ROCC System Context
- ROCC operation support system and global IT infrastructure service
- ROCC operations concept
- ROCC industrial consortium
- ROCC programmatic aspects

ExoMars Ground Segment Architecture



ExoMars Ground Segment Architecture

The ExoMars Ground Segment is constituted by the following elements:

- **The Mission Operations System, further subdivided into:**
  - **Mission Operations Centre (MOC), located at ESOC (Darmstadt - Germany)**
  - **Rover Operations Control Centre (ROCC), located at ALTEC (Turin - Italy)**
  - **Science Data Archiving and Dissemination, located at ESAC (Spain)**

- **The ESA Ground Stations and the associated Communication Subnet, comprising:**
  - **The ESA LEOP Network and the ESA DSN Ground Stations in New Norcia (Australia) and Cebreros (Spain) (35 m only antenna)**

- **The NASA Ground Stations/Centres and the associated Communication Subnet, comprising:**
  - **The NASA DSN Ground Stations (Goldstone-CA, Madrid-Spain, Camberra-Australia) (35 m and 70 m antennas)**
  - **The NASA Rover Operations Center (located at JPL)**

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Mission Operations Centre (MOC) – ESOC

The Mission Operations Centre (MOC) located at ESOC will be responsible for:

- **Managing and performing Mission Operations of the ESA Orbiter DRS**
- **Managing Rover command uplink and telemetry reception to/from the ESA Orbiter Satellite, including the management of communication between the Rover and the Orbiter over the proximity-1 link.**
- **Providing all the necessary communication infrastructure toward NASA Rover-CC for Rover TM/TC send/receive during the cruise phase when the Rover is inside the NASA composite module.**
- **Take care of any NASA resource negotiation, needed for the ExoMars mission.**
- **Providing the auxiliary planning information (namely available communication windows and deadlines for successful TC file deliveries) necessary for proper ROCC strategic and tactical planning.**

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Science Data Archiving and Dissemination (ESAC) and NASA Rover Control Center – JPL

The Science Data Archiving and Distribution (SDAD) located at ESAC (Spain) will be responsible for the long term archiving of Science data (raw and processed) and auxiliary files (containing also Housekeeping Rover data) of ExoMars.

The data sets are provided by the ROCC after a completeness check and post processing.Considering that the data distribution to the scientific team for mission operation support is part of the ROCC functions, the data transfer to ESAC is not required to be performed in line with the mission progress, but can follow a different time schedule that does not impact mission operation execution.

The NASA Rover Operation centre located at JPL, USA will be responsible for:

- **Spacecraft operations (NASA Carrier and DM composite) during all phases of the mission through to touchdown/egress on surface**
- **NASA Rover module operations through commands transmitted either by their own satellite or by commands transmitted by the Exomars 2016 Mission Orbiter. ESOC will act as Rover <> NASA Communication Hub and will be responsible to transfer commands and telemetries data from/to NASA.**

ROCC responsibilities

The Rover Operations Control Centre (ROCC) located at ALTEC (Italy) will be responsible for:

- Support the NASA Rover-CC during the launch, LEOP, interplanetary cruise, for the periodic checkout of the Rover (including PPL). The ROCC is requested to assess the transmitted data provided by NASA Rover-CC. Possible corrective actions will be managed by the NASA Rover-CC based on the input provided by ROCC.

- Performing full Rover Mission Operations (including science operations) for the entire Surface operations phase (nominal and extension (TBD)).

It is assumed that Rover Module activity planning, command sequencing and commands validation will take place every sol between telemetry (TM) downlink to Earth and the next up-link opportunity of telecommand (TCs) to the Rover.

Therefore, ROCC operation process shall be designed and sized to allow a day-to-day commanding of the Rover Vehicle and PPL, to increase the scientific return

ROCC capabilities

The ROCC will be able to :

- Collect data from Rover (including PPL)
- Transmit/receive data to/from Rover Vehicle, PSE and the boarded PPL
- Analyze Housekeeping/Engineering data to assess the hardware behavior
- Distribute the Science data to the involved Scientific teams for conduction of the Rover Mission operation
- Plan and re-plan the follow-on Rover Vehicle / PSE / PPL operations for the next 2 sols or longer time frame
- Archive the Rover Vehicle, PSE and PPL HK collected raw and processed data.
- Archive the science raw telemetry and L1 data, as well as the higher level set of science data products that are under ROCC processing responsibility.
- Allow data processing, calibration and formatting
- Archive the Science data (raw and processed)
- Transfer the Science data (raw and processed) and auxiliary files (containing Rover HK data) to ESAC facility for long term archiving

ROCC connections

The ROCC will be linked (directly or indirectly) with all the other elements pertaining to the ExoMars Ground Segment to fulfill its tasks:

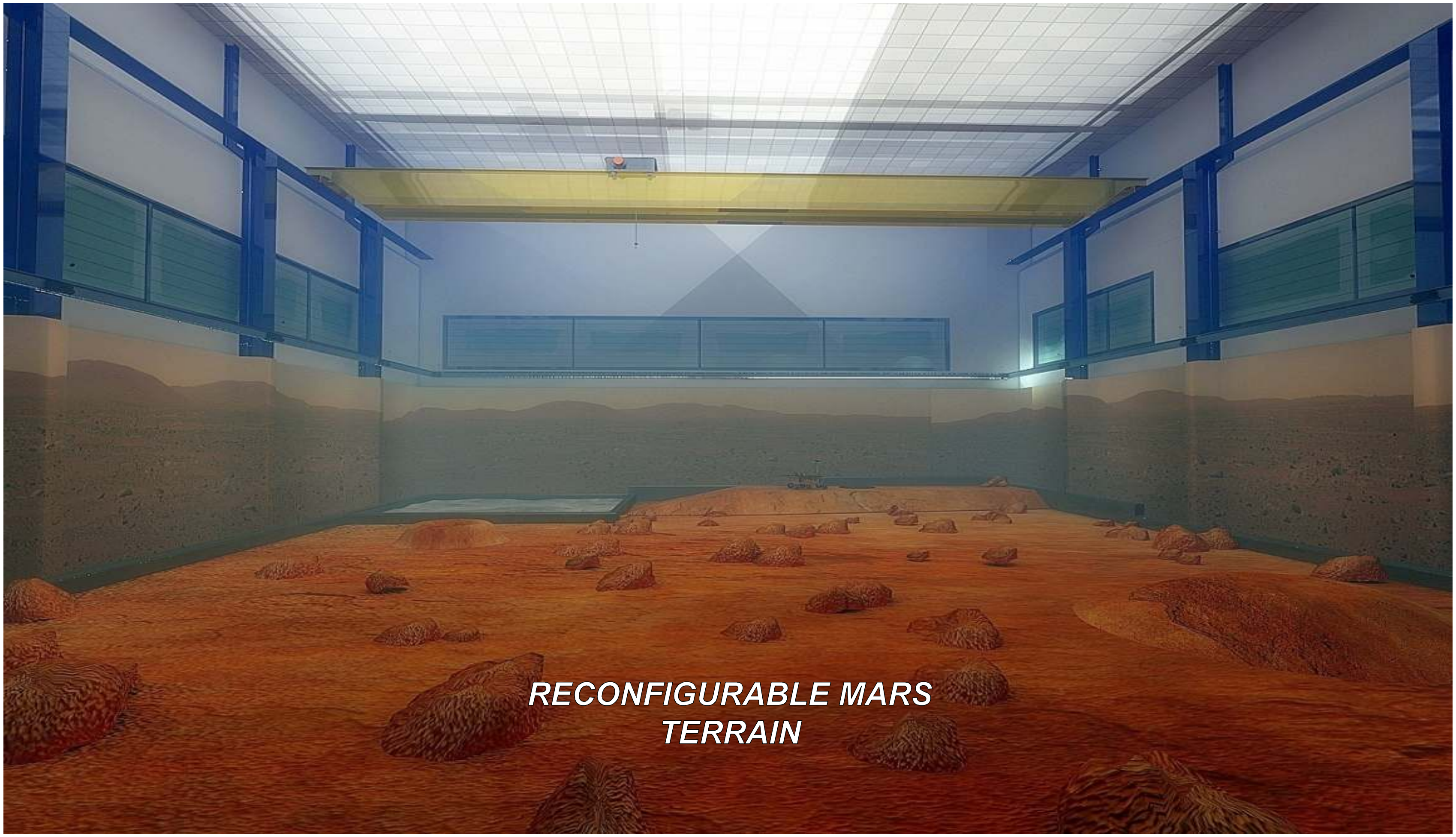
- **ESOC/MOC, via ESOC MOC Data System, during the surface operations to get and transmit data to the Rover via the ESA Orbiter Data relay.**
- **NASA Rover-CC, vis ESOC/MOC DDS, during the Cruise Operations Phase periodic Health Checks of Rover Vehicle and PPL**
- **ESAC, to transfer the Scientific data for long-term archiving**
- **Scientific Community remote sites for science data distribution during the mission and distributed Surface Operations Support**

ROCC Mars Terrain Simulator

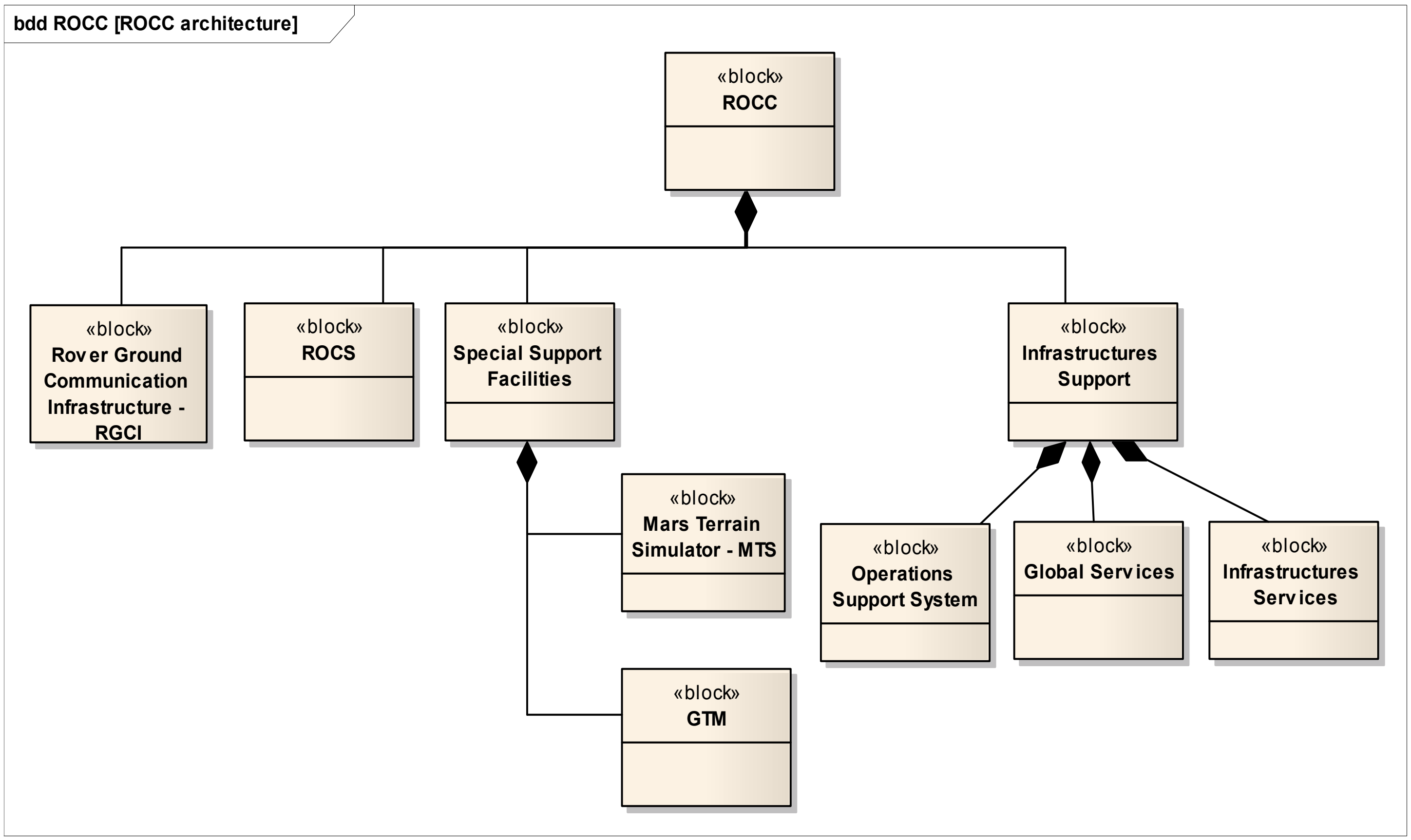
The ROCC will be equipped with the Mars Terrain Simulators facility addressed to support engineering and AIV/AIT activities in performing the following tests and verifications :

- **Rover Module deployment**
- **Rover Module egress from landing Platforms**
- **Mobility confidence End to end test**
- **Drilling verification**
- **Sample collection and distribution to PPL instruments**
- **PPL Analytical Instrument Operations**
- **Simulation of off-line nominal and non-nominal Rover surface operations (using Rover GTM), in particular for rehearsing, simulating, and validating “critical” Rover maneuvers, providing an easily reconfigurable Mars-like environment**

ROCC Mars Terrain Simulator



ROCC functional breakdown



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ROCC Ground Communication Infrastructure (RGCI)

The ROCC Ground Communication Infrastructure (RGCI) provides the ROCC with all the operational communications necessary to conduct Rover Operations, in particular in support of TM/TC, as required for the implementation of the selected communication scenarios.

The current communication scenario with the Rover can be split in two major phases:

- Attached Phase, covering Launch, Cruise, Entry, Descent and Landing, in which the Rover relies on the hardwire interfaces with the NASA spacecraft for its planned activities.
- Autonomous Phase, covering the entire Surface operations, in which the Rover relies on its own resources.

ESOC/MOC, depending on the mission phase attached or autonomous, provides all the necessary communication services for TM/TC forwarding from and to the space segment, reusing the existing communication infrastructure between ESOC and NASA JPL during the attached phase.

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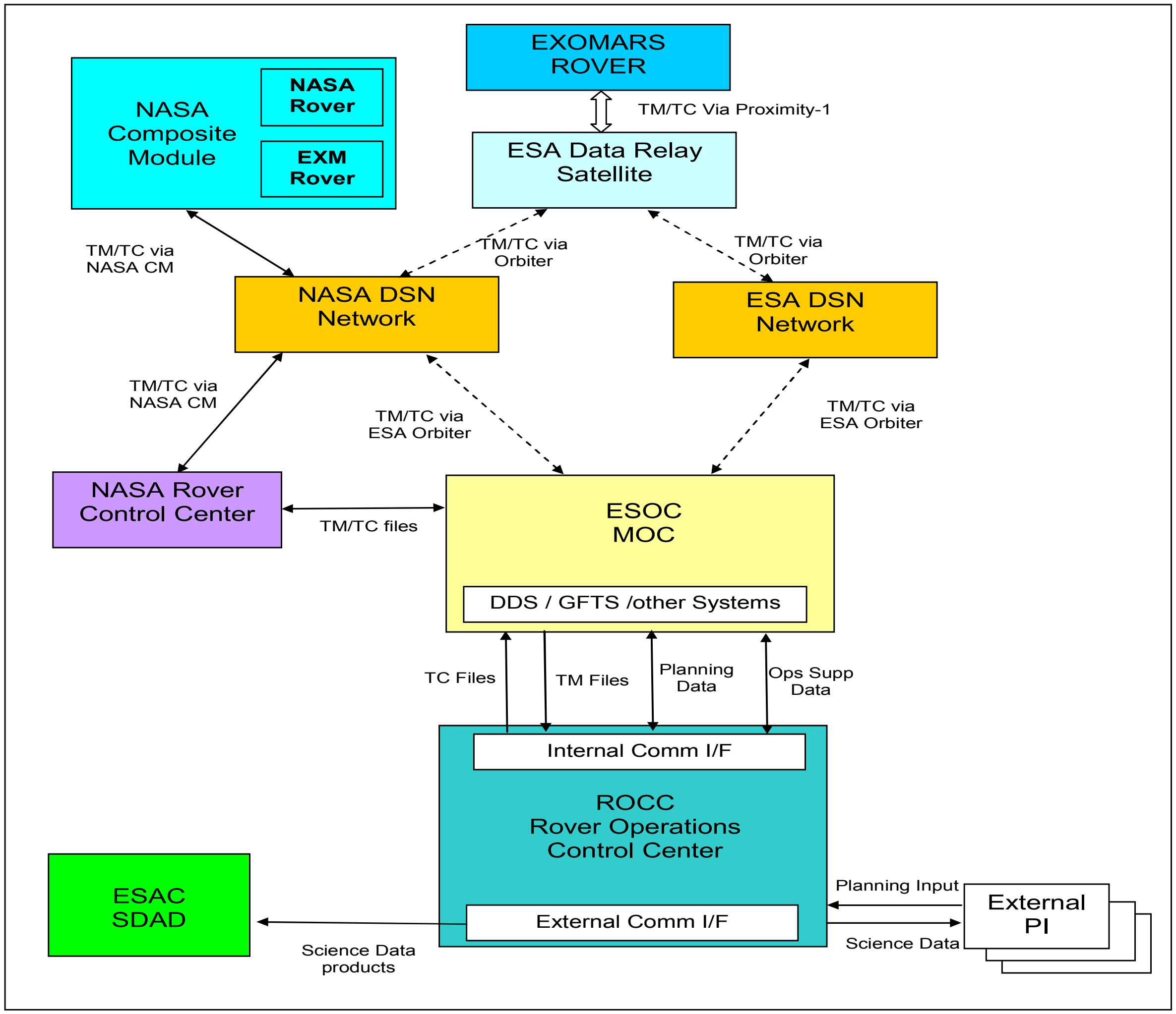
ROCC Ground Communication Scenario



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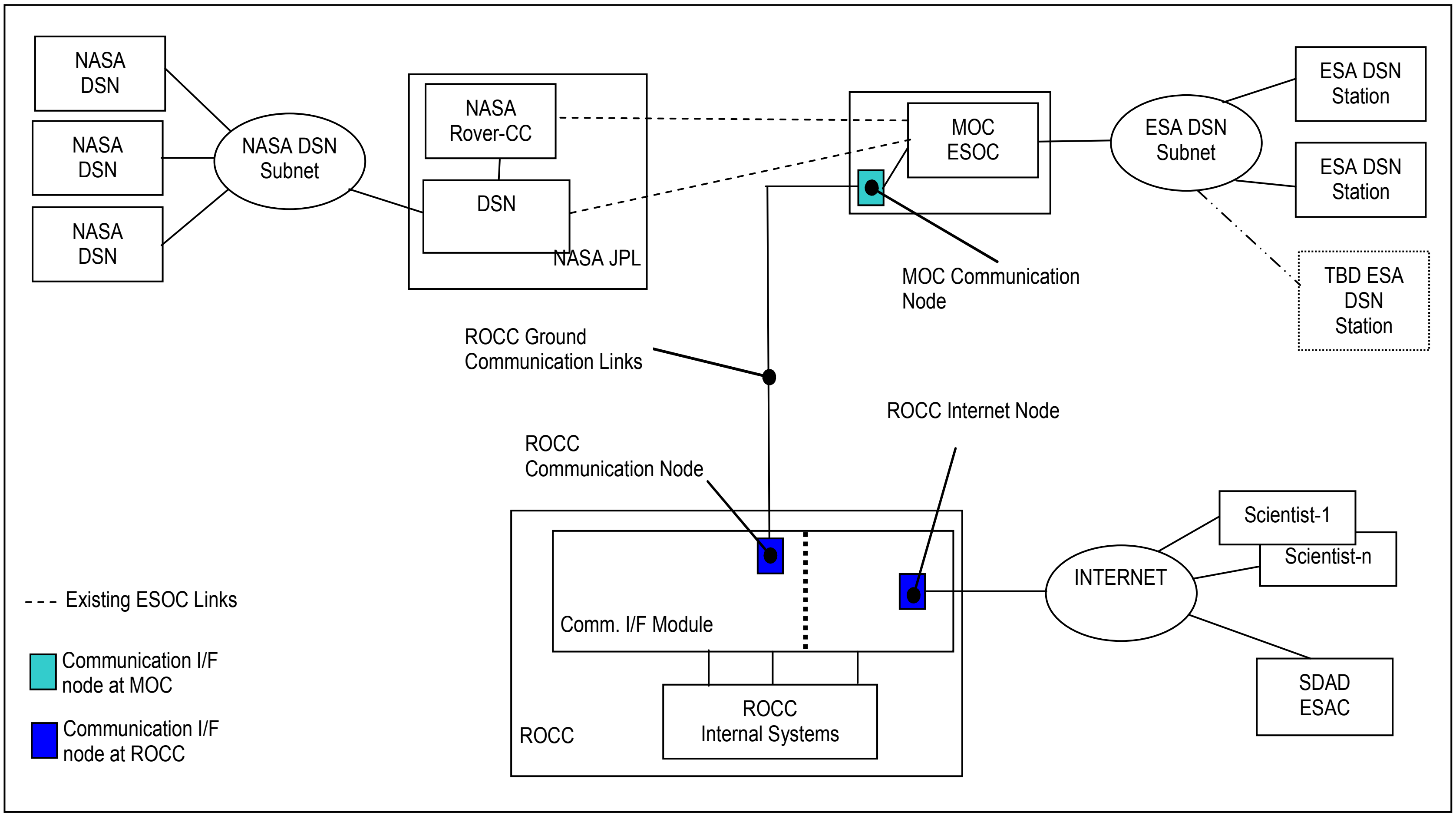
ROCC Communication Architecture



ROCC Operations Control System

The ROCC Operations Control System (ROCS) provides the core capabilities in direct support of Rover mission operations :

- telemetry receiving and analysis
- science and vehicle planning
- activity plan simulation and command sequence generation and validation
- on-board software management
- command sequence uplink.

The major key drivers for the concept design of this system are the following:

- Provides the Rover Operations team and the Science Team with a “complete set of down-linked products”
- Provides the Rover Operations team and the Science Team proper tools for the assessment of the Rover vehicle, the PSE and the payload status and their performances (with particular care to the navigation aspects), as well as for the assessment of the executed on board plan.

ROCC Operations Control System

The major key drivers for the concept design of this system are the following:

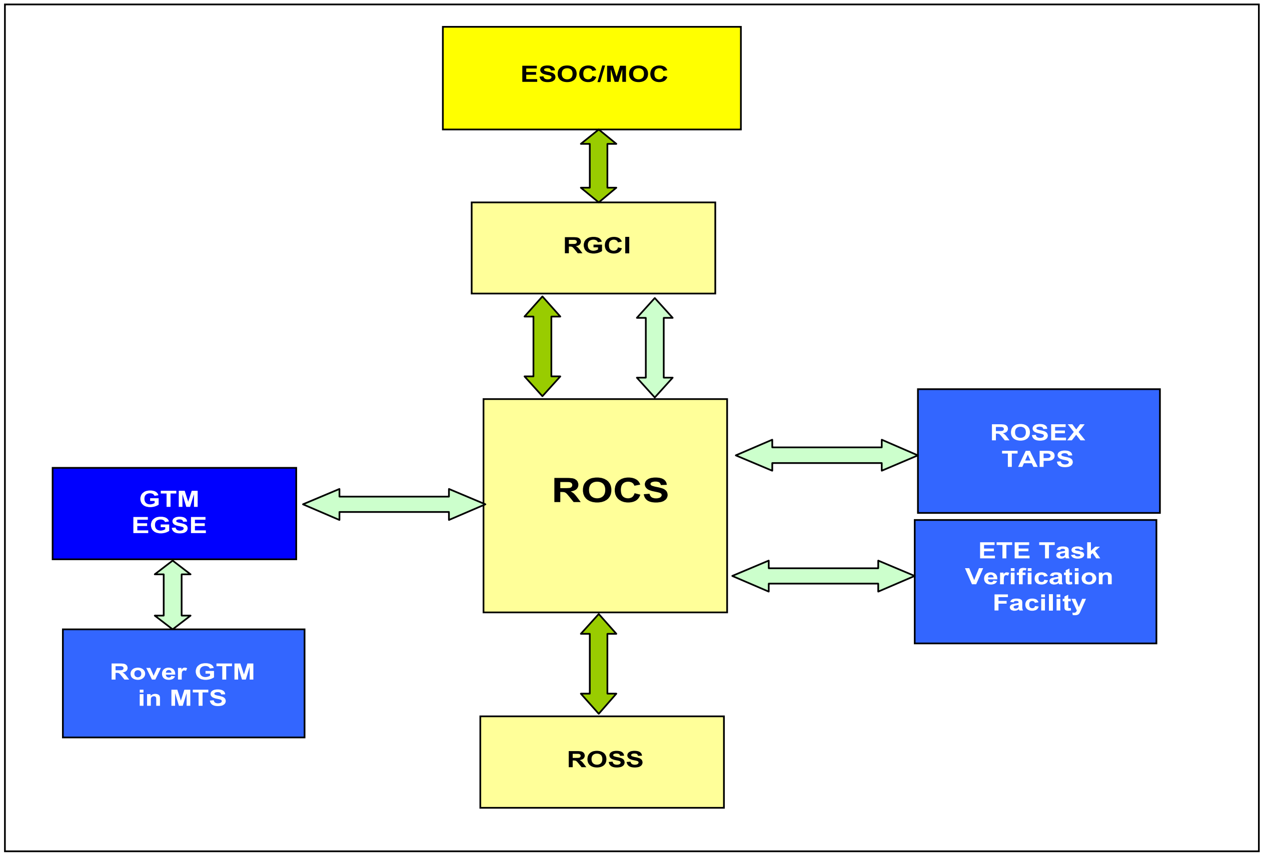
- **Provides the Science Team with a tool able to support local and distributed operation supporting the science objectives identification and a collaborative science activity plan building**

- **Provides the Rover Operations Team with proper tools for the preparation of the required Rover Activity Plan (including rover navigation and mechanism movement) based on the science requirements and engineering needs and constraints, its simulation, verification and final uplink to the Rover. It is necessary to react in due time within the next uplink opportunity and adapt plan and activities to the actual encountered conditions, always assuring the vehicle safety at the maximum level in order to not risk a mission loss.**

- **Provides support both the Tactical Planning (short term) as well as the Strategic Planning (long term) activities.**

The identified tools shall be also used for managing end-to-end simulation activities with the Rover HW in the loop (i.e. the Rover GTM in the Mars Terrain Simulator).

ROCS System Context



ROCC Operations Support Systems

The Operations Support Systems provide supporting operations capabilities to the ROCC necessary for mission operations, namely:

- **Voice Loops (internal / external)**
- **Time Management Systems**
- **Multimedia and Videoconferencing system**
- **Anomaly Reporting and Tracking System (both for Flight and Ground issues)**
- **Console Log**
- **Flight/Ground Procedures, Mission Database Rover Mission and System Documentation Archive (User Manuals, Reports, Drawings, CD phase documentation)**
- **ROCC operations portal**

Global IT and Infrastructure Service

The Global IT Services includes general purpose and standard capabilities that are provided in support of the ROCC, namely:

- Network Infrastructure
- Office Tools
- Internet Connectivity Services
- Logistic Support Tools

The Infrastructure Services provides the essential elements of a typical hosting facility, in particular:

- Operations/Support Rooms
- Special Facilities Area
- Technical Rooms
- Offices and Meeting Rooms
- Public Events Support Areas (e.g. Auditorium, Show Rooms, etc)

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ROCC operations concept (guidelines and constraints)

- The mission has clear scientific objectives to be achieved thanks to a complex ensemble of payloads (the Pasteur Payload – PPL),
- The instruments of the PPL needs to be operated according to precise sequences and, despite implementation of some on-board autonomy capabilities, some “decision points” are defined at which the scientists will choose the following steps to be executed,
- Some of the instrument (notably the PAN-CAM) outputs represent key element in defining the operations of the Rover
- The Rover will move and operate in a “un-deterministic” environment with basic physical parameters changing quasi continuously according to motion of the rover itself, daily and seasonal variations,
- The contact with the Rover will happen during limited slots occurring once a day with characteristics (duration and data exchange) varying depending on the mission conditions (visibility of rover and relay satellites)

ROCC operations concept (guidelines and constraints)

- **As Rover data reach the Control Centre they must be quickly analyzed starting the process that will end with the sending of the Command (Activity Plan) to the rover for the execution of the next activities.**

- **The Command (Activity Plan) generation process is made-up by substantial quantities of activities (specification, planning, scheduling and verification) has to be performed in a very short time**

- **The above statement remains true despite the implementation of Rover on-board autonomy. The Rover autonomy, in fact, will permit only limited variation on the commanded activity plan as reaction to specific environmental conditions, availability of resources, and opportunities.**

- **The baseline mission (lasting about 6 months, 180 sols) could be followed by a mission extension phase.**

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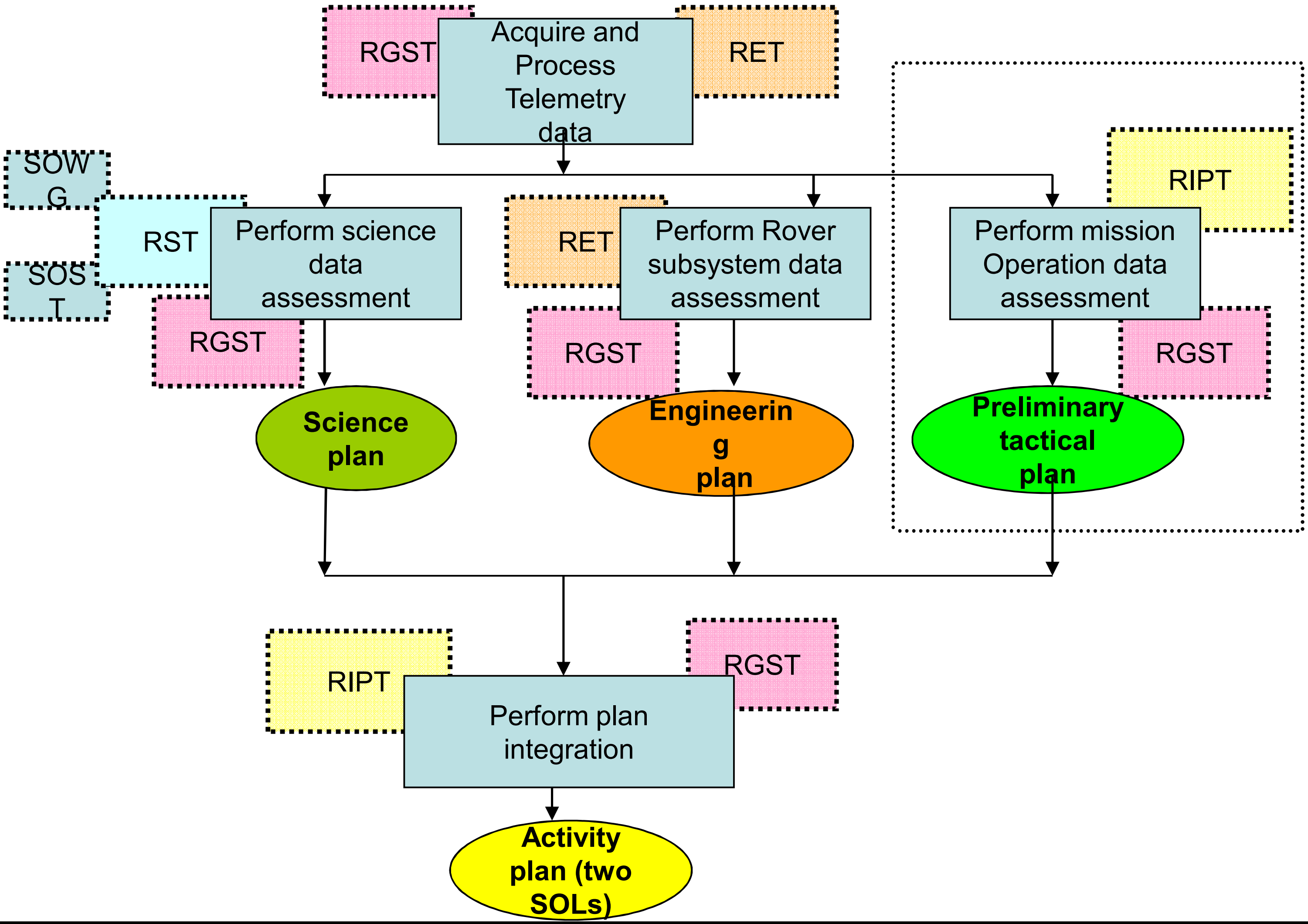
ROCC operations concept

- **Allow, avoiding role confusions, a strict interrelationships among the various teams utilizing h/w and s/w tools enabling an optimum transfer of data (*team definitions and tools*);**
- **Enable implementation of different solutions coherent with the different phases of the rover life (*different solutions*);**
- **Be fixed to a reasonable extent to be effective assuming a short time between data reception and sending of the telecommand (*fixed schedule of events*);**
- **Be flexible in order to adapt at changing conditions such as availability of data, different Rover operations phases (*flexibility*);**
- **Maximise the scientific exploitation of the mission starting from a limited amount of resources (*optimisation of the science planning*);**

ROCC operations (Activity plan preparation)



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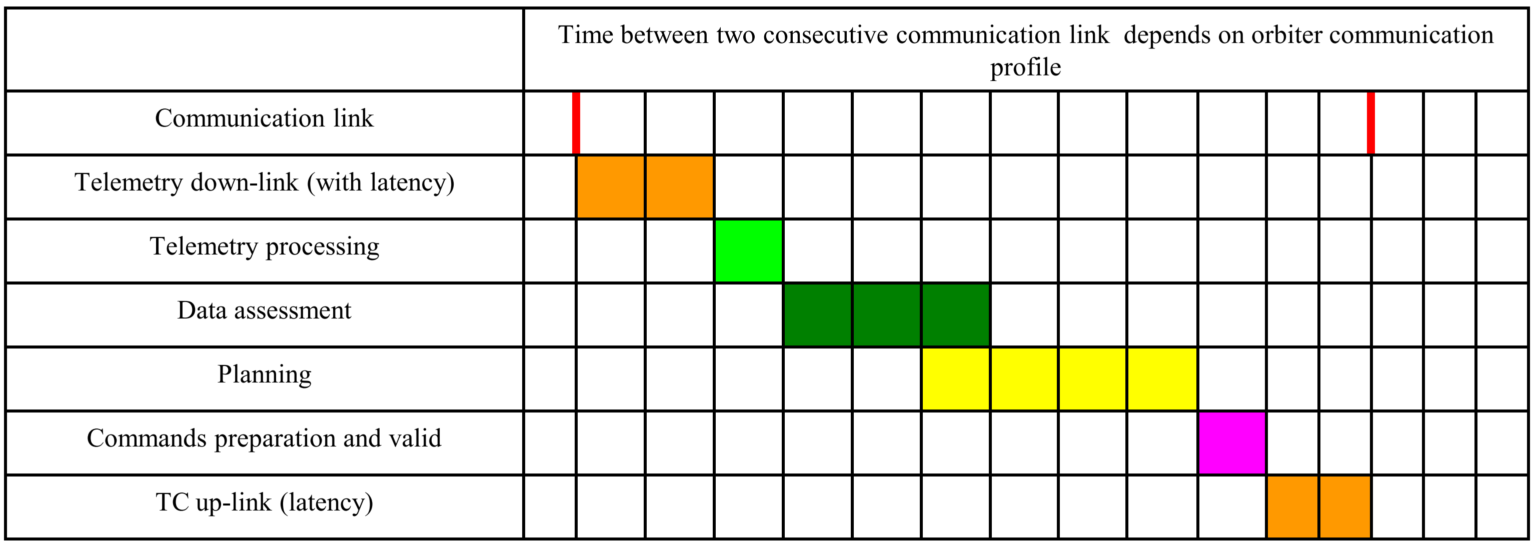
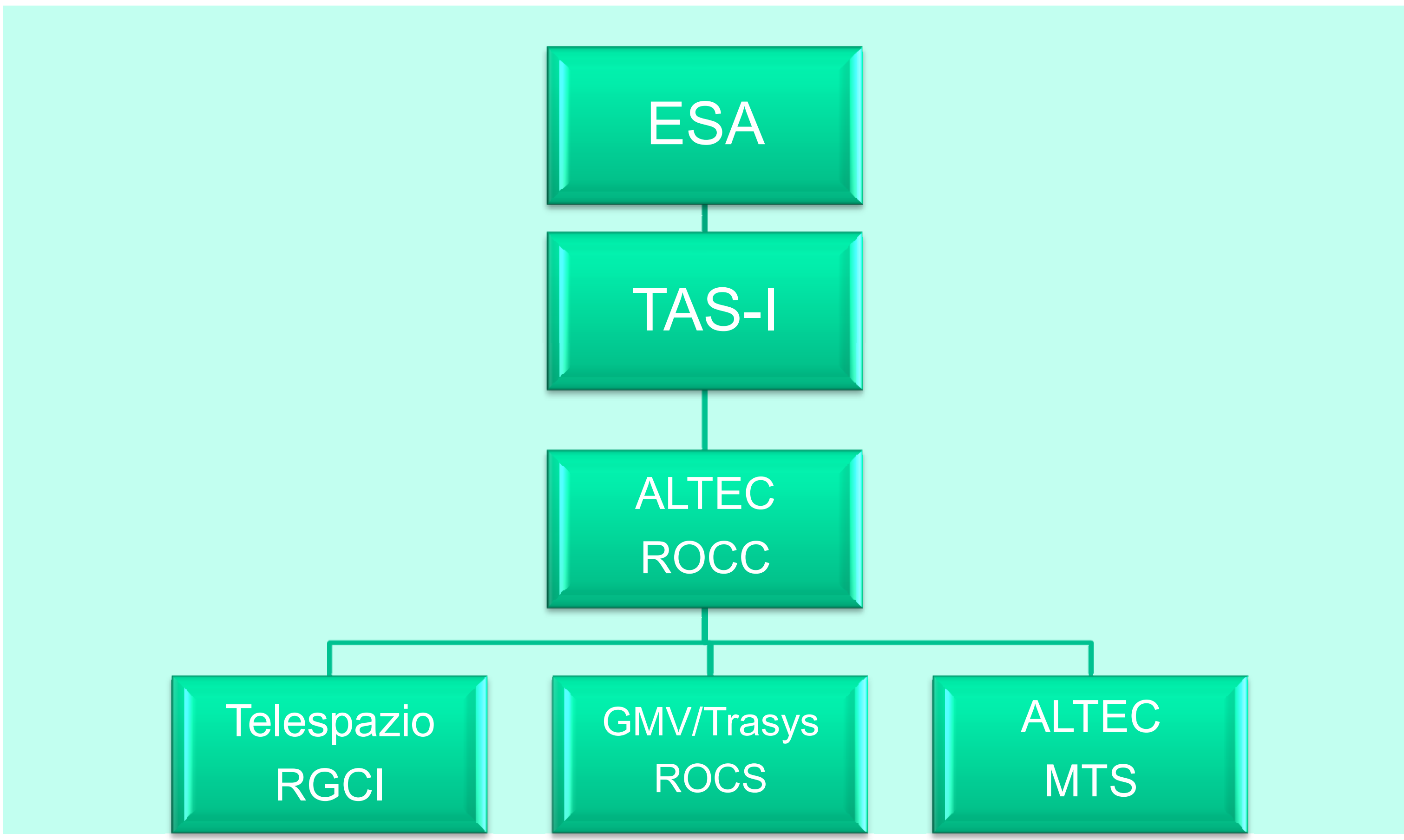
ROCC Operations (Ground operation timeline analysis)

The ROCC operations timeline will be maintained on a daily basis, thus accommodating any required immediate re-planning activity. The tactical plan process will then include at least the following basic activities :



In nominal and theoretical condition (assuming one communication link at sol) the available time to perform the telemetry processing, the data assessment , the planning activity and the commands preparation and validation is about 20 mars hours, assuming 2 hours (TBC) of data latency for the down-link process and 2 hours (TBC) for the up-link process.

ROCC Industrial Consortium



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ROCC Programmatic Aspects

- Phase B2X concluded in March 2010
- Phase B2X2 and Advance CD2 kicked-off in April 2010: activities addressed at system level, ALTEC and GMV/Trasys involved
- Data package delivery for System PDR in September 2010
- Phase C/D and E1 “Committing proposal” proposal foreseen for November 2010
- Closure of phase B2X2 at the end of March 2011

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ROCC Major Milestones

- Delivery to TAS-I of the committing phase C/D/E1 proposal : November 2010
- ROCC Design Review : June 2012
- ROCC Implementation Review : February 2015
- ROCC Readiness Review : July 2016

ExoMars ROCC

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