# METERON Operations Environment - Preparing Data Systems for Robotic Exploration

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# Outline

- The METERON Project
- METERON Operations Environment (MOE)
- MOE in Robotic Exploration Experiments

# Context: initial thoughts

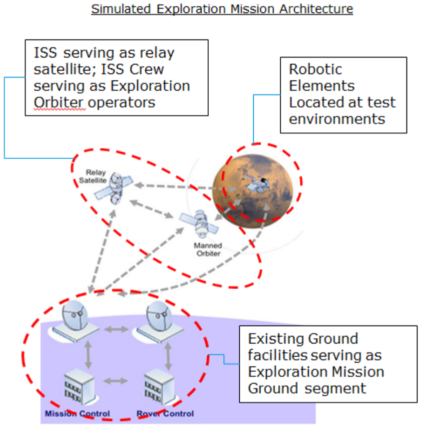
1. Future exploration architecture study teams have made assumptions about how crew can remotely perform work on a planetary surface, and more specifically operate surface robot from orbit when circumstances (contingency, etc.) preclude Earth control

2. Assumptions
   1. Maturity of crew-controlled tele-robotics
   2. Existing technology gaps (and how these can be bridged)
   3. Operational risks (proficiency, performance, failure modes)

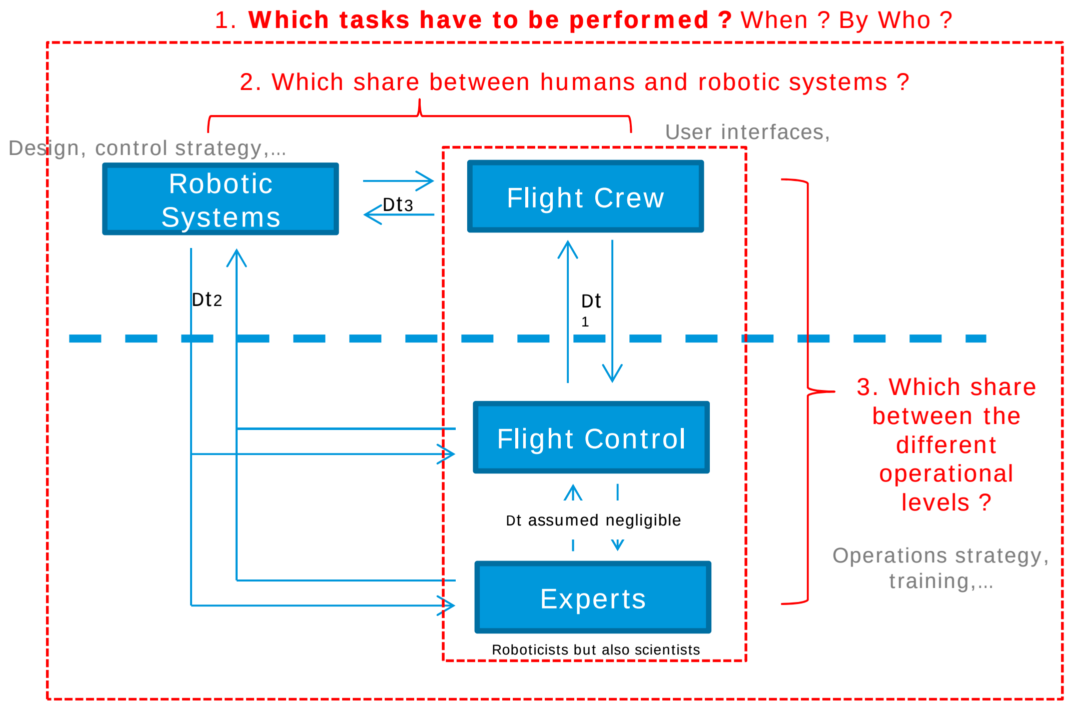
3. ESA-led study in 2009 showed that it is feasible to implement an infrastructure, encompassing the ISS, that could be used for Ground Simulations, In-Orbit Demos and their combination.

4. Multipurpose End-to-End Robotics Operations Network

(NASA GSFC)



# Some key questions




→ Helping getting answers to these questions is a the core of the METERON project

# METERON at a glance

- Objectives
    - Demo **communications** concepts and technologies
    - Test **operations** concepts and technologies
    - Evaluate **robotics** technologies and operations
- Key questions:
    - Control from Earth or from close-by?
    - Supervisory control or low latency tele-ops?
    - Comms and ground segment - how to run such ops?
- Approach
    - Ground Simulations / Utilise the ISS when needed
    - Build upon existing infrastructure(s)
- Implementation
    - Set-up of a simulation environment
        - Goal is “plug and play”
    - Operators and Astronaut(s) on Ground/ISS
    - Various robotic assets on Earth
    - Gradually increase complexity
    - Risk reduction through gradual steps

# The Multipurpose Operations Environment (MOE)

MOE is conceived as a **generic** and **flexible infrastructure** comprising several systems that can be deployed on different locations on ground and in space according to specific experiment needs.

Provides **standardised** and **consistent** system and interfaces, which are **independent** of the target robotic asset and experiment setup

Satisfies requirements for:

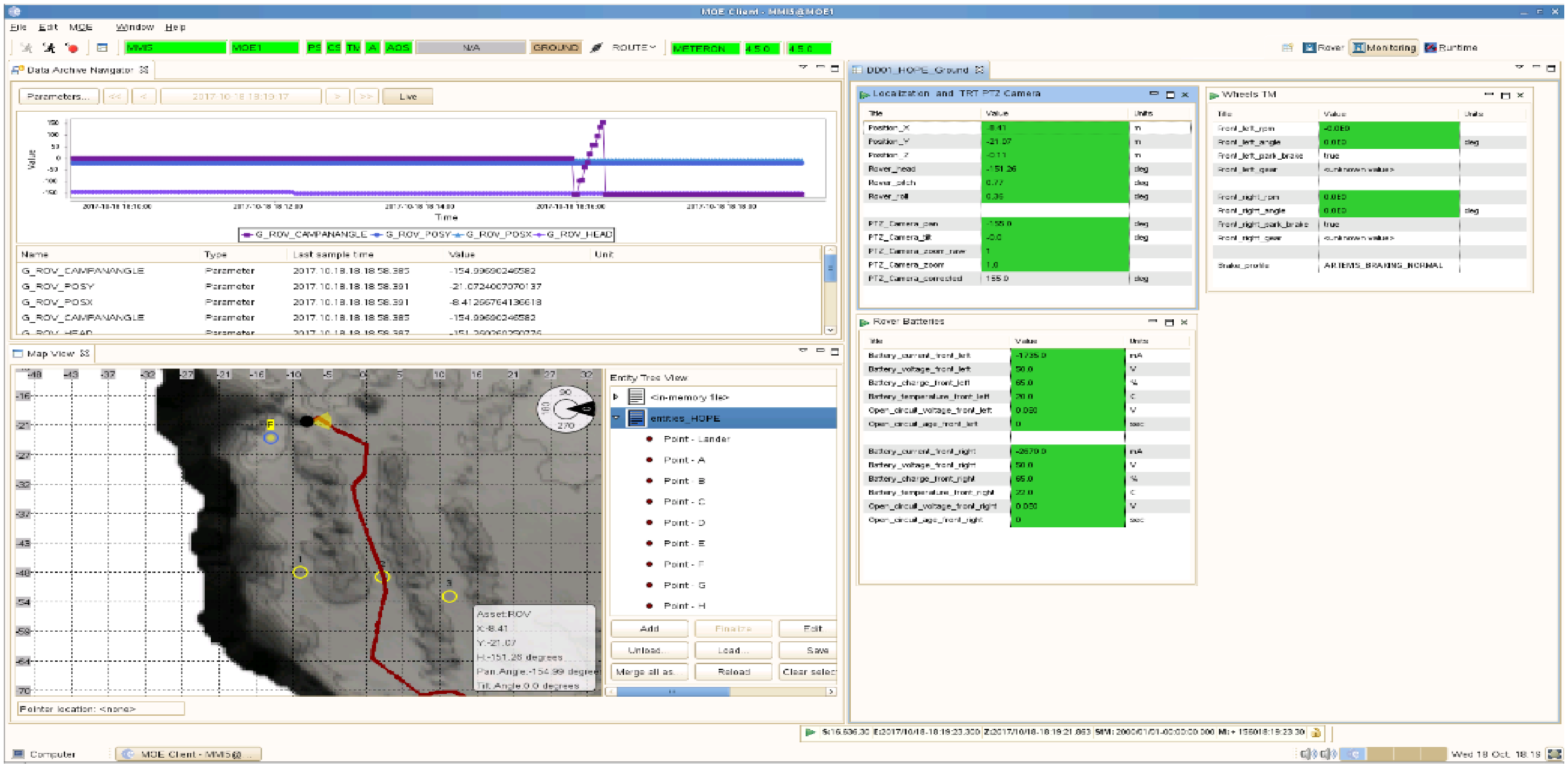
- Flexibility
- Adoption of new technologies
- Data distribution
- Monitoring and control of (multiple) robotic assets

# MOE Main Features

The MOE provides the following main features:

- Monitoring and control of a robot via direct link and via relay link
- Management, distribution, transfer, storage, and display of data produced by the robotic systems
- Monitoring and control of experiment execution
- Support for planning of experiments and generation of command schedules
- Archiving and retrieval of all experiments data
- Simulation of an orbiter (latency, AOS/LOS, data rates)

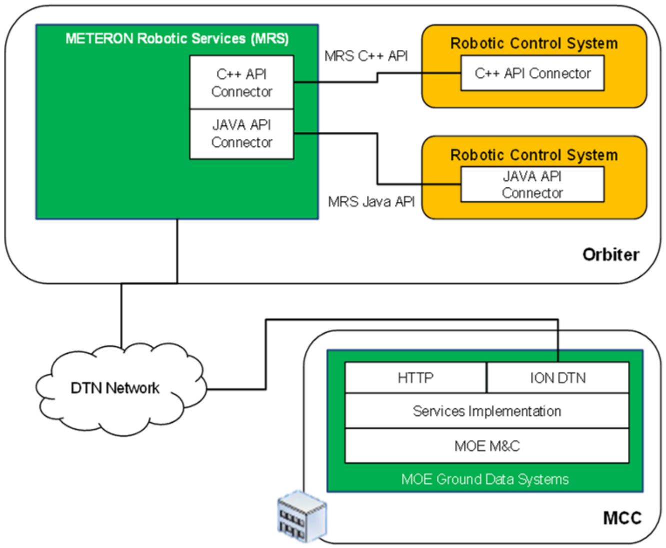
# MOE Main Features



# MOE Systems

### MOE M&C system

- main data system for ground operators
- monitoring and control for the various robotic systems
- deployable on various ground nodes
- interfaces to the METERON Robotic Services (MRS)

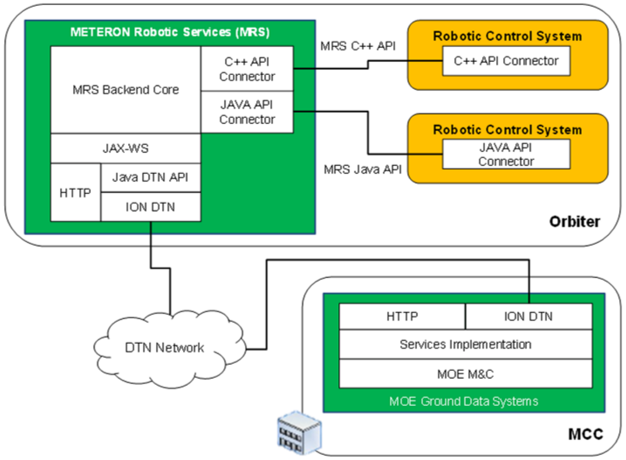



### METERON Robotic Services (MRS)

- flexible generic service based interface
- deployable on ground and in space
- designed and implemented following the principles of the CCSDS Mission Operation (MO) standard
- proof-of-concept for the CCSDS MO M&C Services and the CCSDS Telerobotic Operations Services (Green Book)

# METERON Robotic Services Implementation

- Compliant to the CCSDS Mission Operation (MO) Services
- Standard Java and C++ API to integrate systems with the MRS services
- Implemented as web-services
- Two communication technologies:
  - HTTP - only for ground comms (data distribution on ground)
  - DTN - for the space to ground comms
- Custom Java API (JDTN) to DTN Bundle Protocol

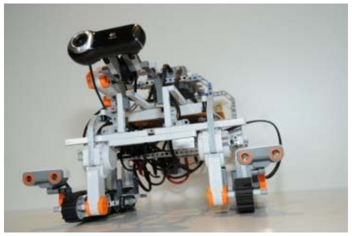



The MRS services are implemented as several independent components, which can be configured and deployed individually on both space and ground.

# METERON Experiments & MOE Evolution 1/3

*"METERON is a combination of Ground Simulation Testing (GST) and In-Orbit Demonstration (IOD) organised in a series of "steps" of increasing complexity"*

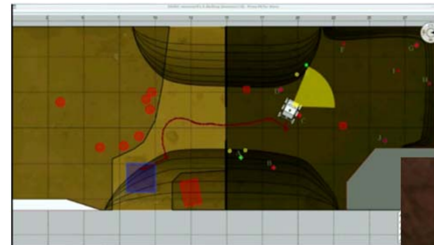
- **OPSCOM1**
  - October 2012
  - ISS Crew: Sunita Williams
  - to validate end-to-end M&C comms (first DTN demo)
  - simplified Rover: LEGO MOCUP



- **OPSCOM2**
  - August 2014
  - ISS Crew: Alexander Gerst
  - to validate end-to-end M&C comms using full duplex DTN
  - Realistic rover: ESA EUROBOT
  - **first use of MOE M&C and MRS**
    - implementation of MOE M&C
    - implementation of generic and robotic services (no video)
    - support for one robotic asset
    - implementation driven by the target robotic asset and RCS

# METERON Experiments & MOE Evolution 2/3

- **SUPVIS-M**
  - April 2016
  - ISS Crew: Timothy Peake
  - to investigate various robotics and operations strategies with human in the loop
  - collaboration with the United Kingdom Space Agency (UKSA) and Airbus UK
  - Robotic asset: Bridget test-bed



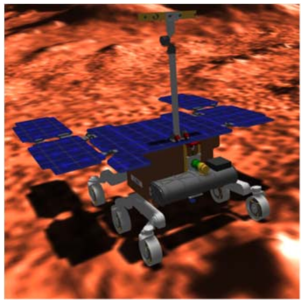
- **MOE was used to monitor and control the Rover and distribute video feeds on ground**
  - definition of Video Service to distribute video feeds to multiple clients on ground
  - support for the definition of synthetic TM parameters
  - Support for Ackermann driving (via GUI and direct commanding)

# MOE Integration with ESTEC (TEC-MMA) ExoTeR Rover

- Enabling the monitoring and control of
  - the ExoTeR rover via relay link through the proprietary Rover Control System both located at ESTEC
  - the ExoTeR 3Drov simulation via direct link deployed at ESOC

- **MOE was adapted to provide CCSDS Services to**
  - Demonstrate the applicability of CCSDS MO Services (COM and M&C) to the domain of Telerobotics
  - Translate of Robotic Web Services into CCSDS Robotic Services

- The same (Java/C++) MRS API used for the services deployed for METERON experiments was also implemented for the MOE CCSDS Services to facilitate the integration



- The CCSDS Services were implemented using the NanoSat MO Framework used for OPS-SAT

# METERON Experiments & MOE Evolution 3/3

- **HOPE** (**H**uman/robotic **O**perations **P**reparation **E**xperiment)
  - Ground based experiment
  - Collaboration with CSA
  - CSA Rover in “lunar scenario”
  - Distributed operations teams in Canada (CSA) and Germany (ESA/ESOC)
    - Surface Operations Teams (planning & coordinating)

      <->

    - Rover Operations teams (driving & navigating)

- **MOE was used to define in and out of scenario environments**
  - Distributing data with/without delays to in/out scenario teams
  - Generating synthetic parameters to provide a more realistic immersed experience to the in-scenario team

# MOE for different scenario teams

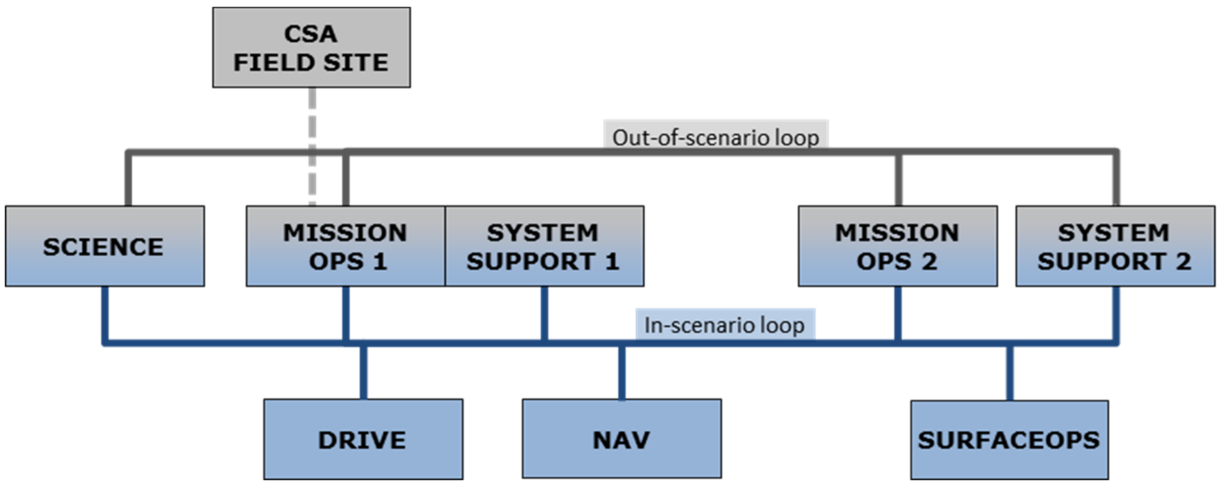
Clear separation of
**in-scenario operations**
and
**out-of-scenario** execution

In-Scenario MOE:

- Shared maps,
- collaboration for planning,
- “lunar setup” and **delays**

Out-of-Scenario MOE:

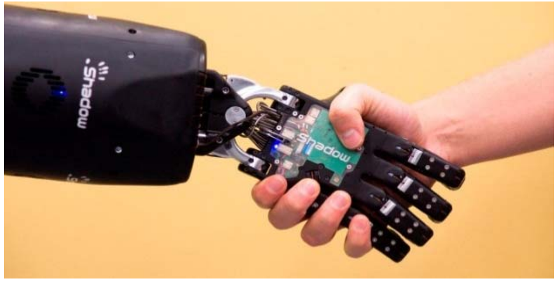
- Logistics of setup and communications
- different MMI’s and views,
- **no artificial delay**
- generation of synthetic parameters



# MOE as enabler for:

- Swift integration of robotic asset due to MRS – CCSDS MO Services
- Operators trained on interface even if using “foreign” rover
- Distributed nature of the in-scenario operations team highlighted need for suitable tools that make it easy to share and discuss the relevant data.
    - Opportunity to discuss plans with in-scenario operators
    - Collaborative route planning as important aspect of experiment
    - A distributed command history shared amongst all systems across sites was crucial in a distributed operations environment.
- Tight integration, synchronisation and sharing of information between systems (especially Rover Control System and Mission Control System) was essential.

# Thank you!

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