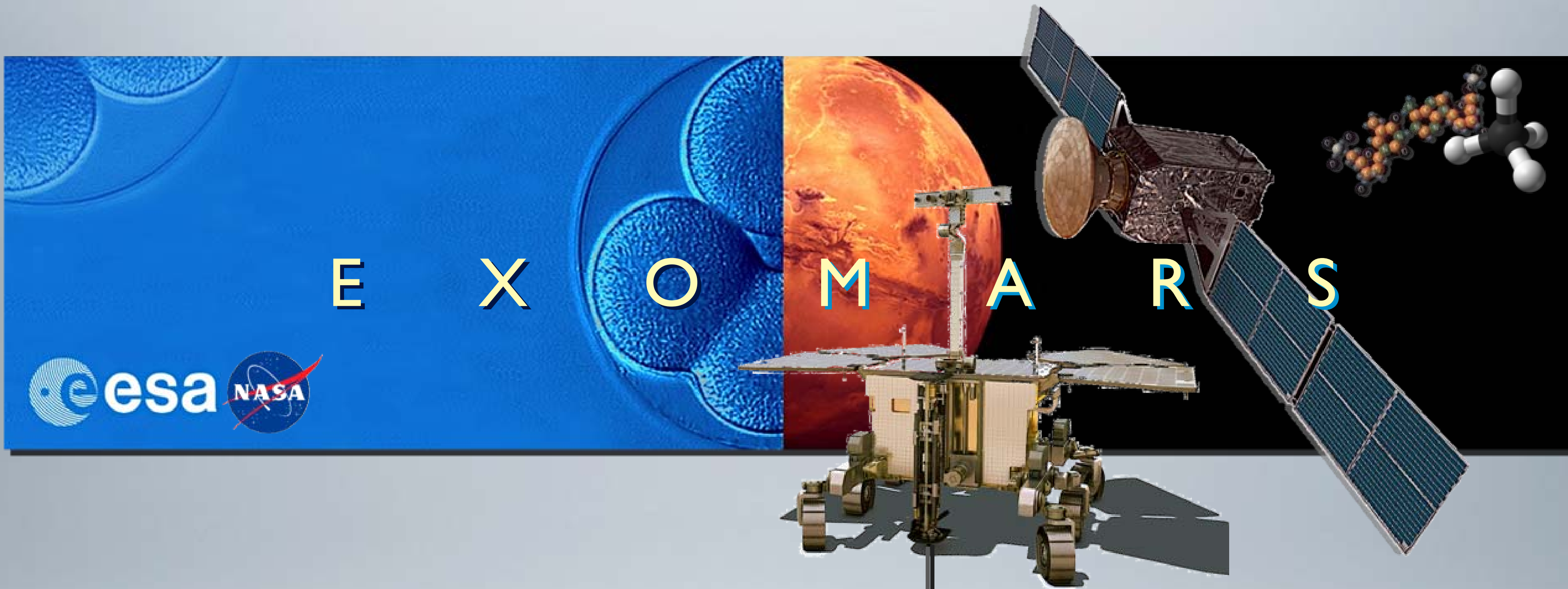



# ExoMars: Planetary Protection Requirements & Implementation

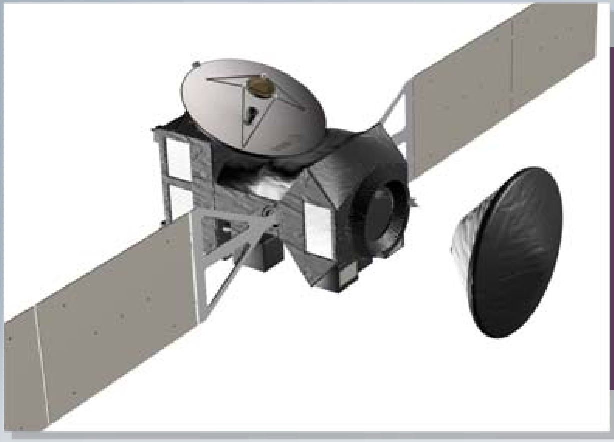
G. Kminek and the ExoMars Project Team

Presentation to the NASA PPS
20 January 2011, NASA-HQ

# Programme Building Blocks

EXOMARS

- ESA and NASA have agreed to embark on a joint Mars robotic exploration programme:
  - Initial missions have been defined for the 2016 (January) and 2018 launch opportunities;
  - Missions for 2020 and beyond are in a planning stage;
  - The joint programme's ultimate objective is an international Mars Sample Return mission.

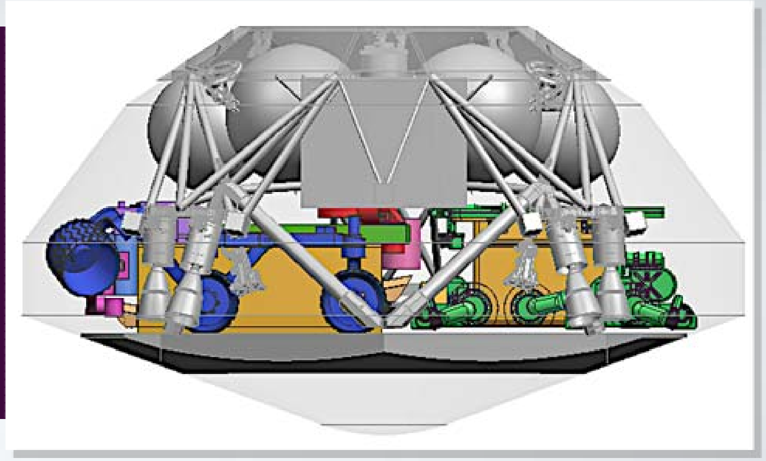


## 2016 ESA-led mission

| | |
|---|---|
| Launcher: | NASA – Atlas V-431 |
| Orbiter: | ESA |
| Payload: | NASA-ESA |
| EDL Demo: | ESA |

## 2018 NASA-led mission

| | |
|---|---|
| Launcher: | NASA – Atlas V-531 |
| Cruise & EDL: | NASA |
| Rover 1: | ESA |
| Payload: | ESA-NASA |
| Rover 2: | NASA |



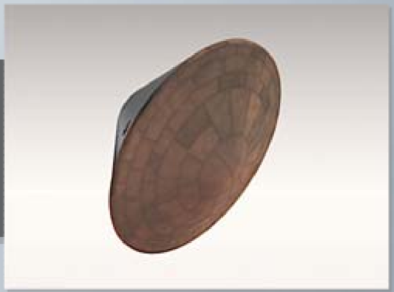
# 2016 Mission Objectives

E X O M A R S

## 2016

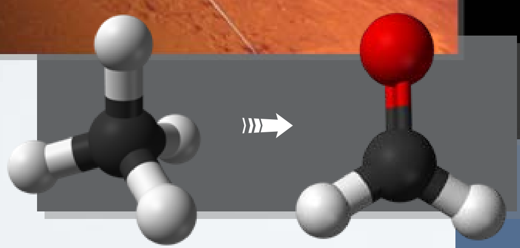
### TECHNOLOGY OBJECTIVE

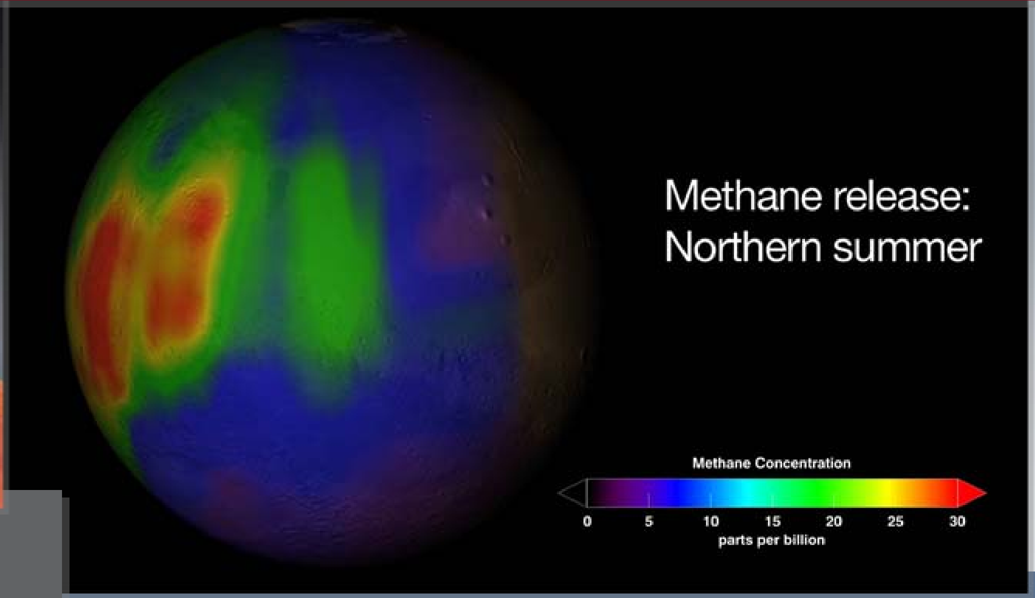
- Entry, Descent, and Landing (EDL) of a payload on the surface of Mars.



### SCIENTIFIC OBJECTIVE

- To study Martian atmospheric trace gases and their sources.






- Use of aerobraking to achieve science orbit.
- Provide data relay services for landed missions until 2022.

# 2016 Trace Gas Orbiter Payload

E X O M A R S

## PRIORITISED GOALS / INSTRUMENTS

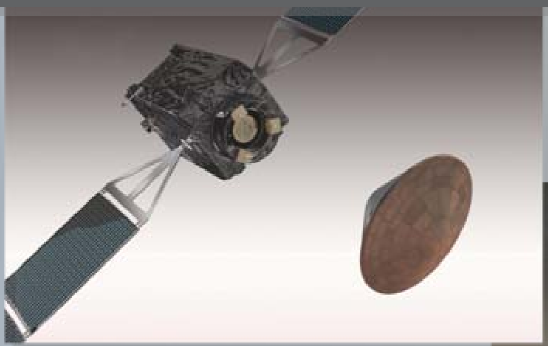
| | | H/W / Science |
|---|---|---|
| 1. **Detect a broad suite of atmospheric trace gases** and key isotopes with high sensitivity. | **MATMOS (ppt)** | **US**, CAN (H/W)<br>B, F, RUS (Science) |
| 2. **Map their spatial and temporal variability** with high sensitivity. | **NOMAD ($10^{-1}$ ppb)** | **B**, E, I, UK<br>USA, CAN |
| 3. **Determine basic atmospheric state** by characterising P, T, winds, dust and water aerosol circulation patterns. | **EMCS (P, T, dust, ices, $H_2O$)** | **USA**, UK<br>F |
| | **MAGIE (Full hemisphere WAC)** | **USA**<br>B, F, RUS |
| 4. **Image surface features** possibly related to trace gas sources and sinks. | **HiSCI (HRC 2 m/pixel)** | **USA**, CH<br>UK, I, D, F |

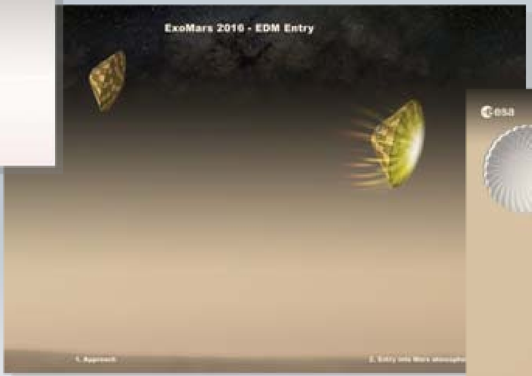
Excellent coverage of high-priority objectives.

# 2016 EDL Module (EDM)

## EDM

- A European technology demonstrator for landing medium-large payloads on Mars;
- Provides a limited, but useful means to conduct scientific measurements during the dust storm season.








## EDM PAYLOAD

- Integrated payload mass estimate: 3 kg;
- Lifetime:  4 sols;
- Data:  1 pass of 50 Mbits.

# 2018 ExoMars RM Objectives

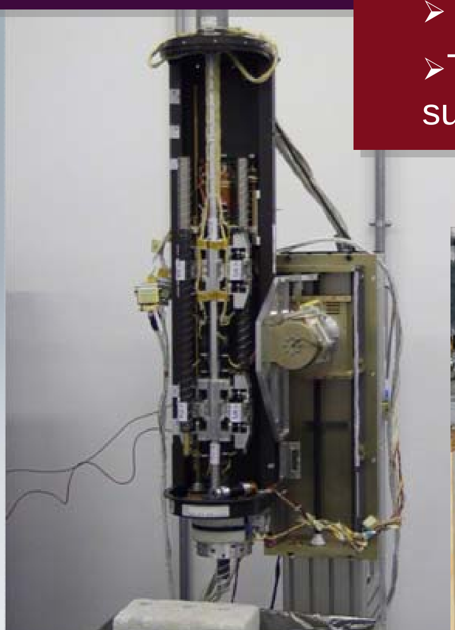
## 2018

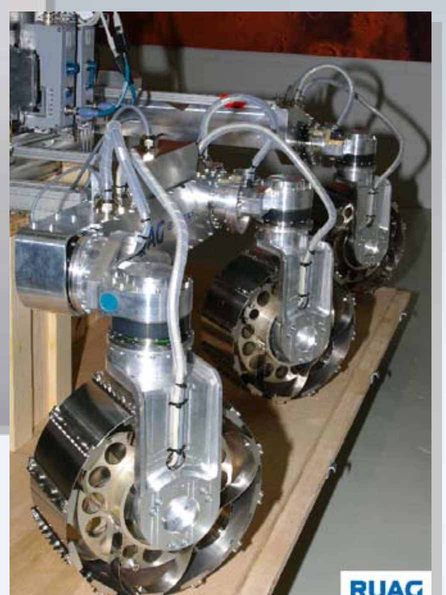
### TECHNOLOGY OBJECTIVES

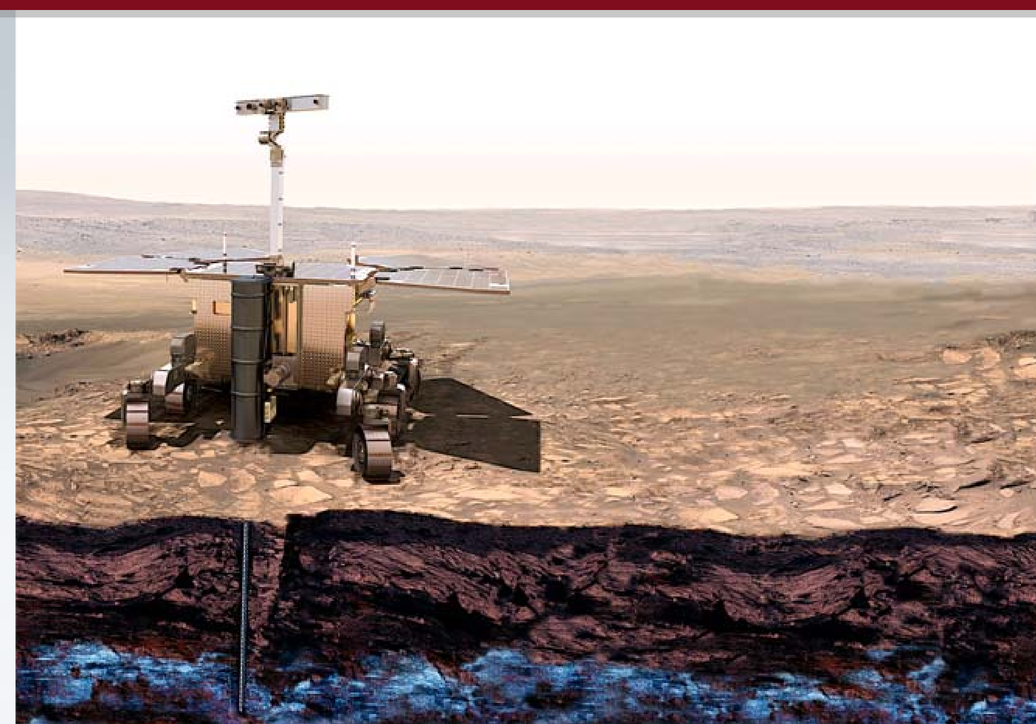
- ➢Surface mobility with a  rover (having several kilometres range);
- ➢Access to the subsurface to acquire samples (with a drill, down to 2-m depth);
- ➢Sample acquisition, preparation, distribution, and analysis.

### SCIENTIFIC OBJECTIVES

- ➢To search for signs of past and present life on Mars;
- ➢To characterise the water/subsurface environment as a function of depth in the shallow subsurface.

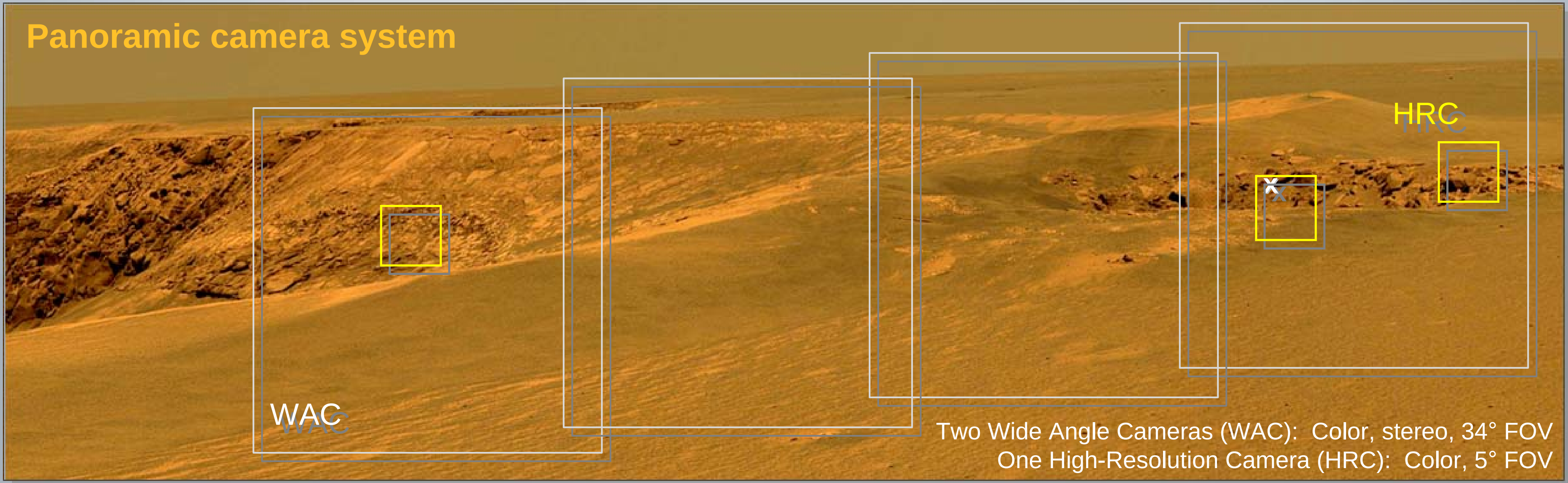


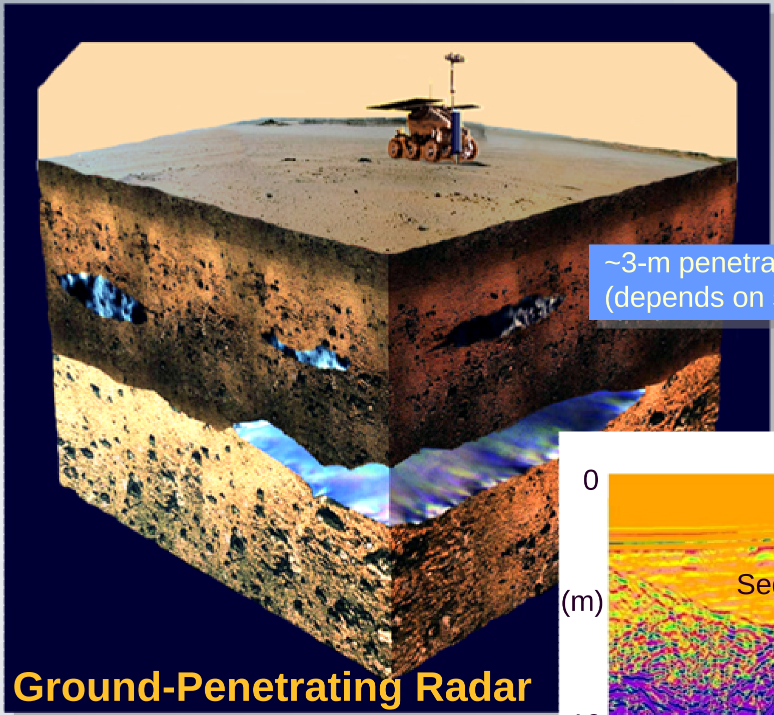


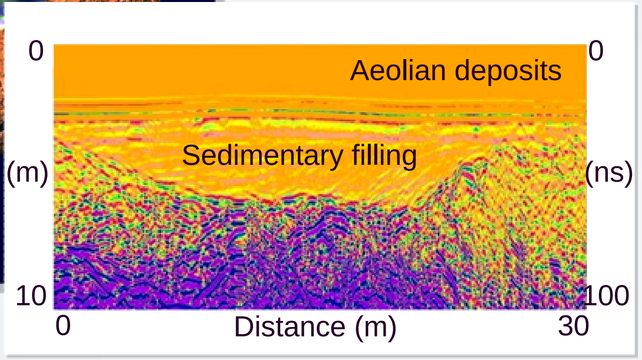
# 2018 Pasteur Payload

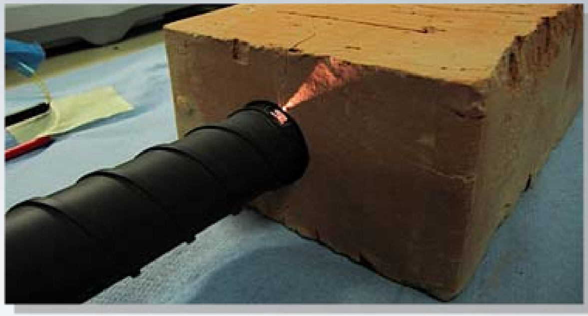





~3-m penetration, with ~2-cm resolution (depends on subsurface EM properties)



Spectral range: 0.4–2.4 µm,
Sampling resolution: 20 nm

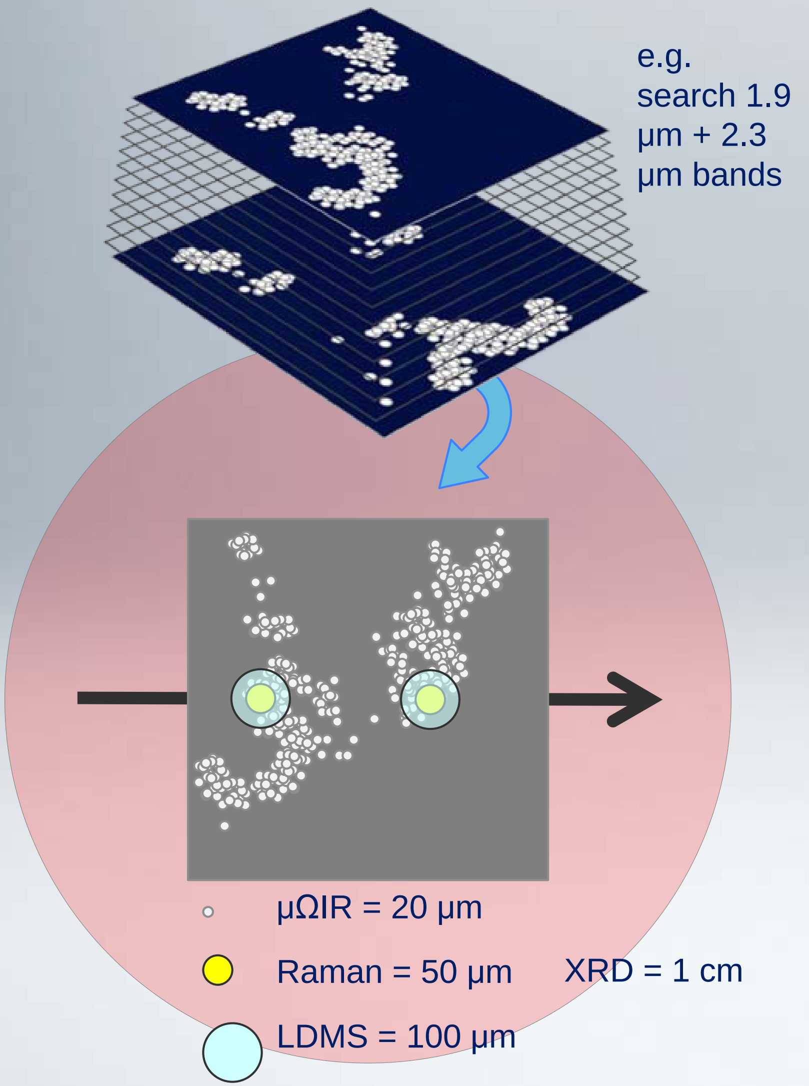
Analytical Lab

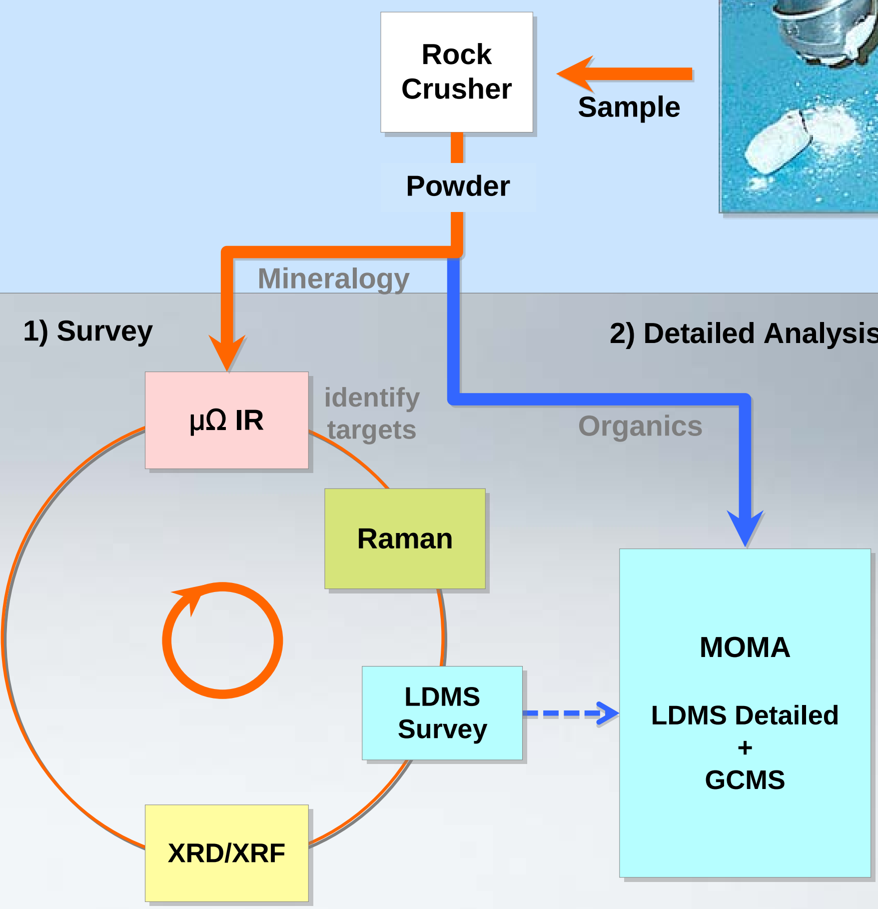
# 2018 Pasteur Payload

E X O M A R S

Use mineralogical + imaging information from µΩIR to identify targets for Raman and MOMA LDMS.

Imaging IR spectrometer,
256 x 256 pixels, 20-µm/pixel resolution,
0.85–2.6 µm spectral range, 500 steps




+ Life Marker Chip

Raman: spectral shift range 200–3800 $cm^{-1}$
Spectral resolution ~6 $cm^{-1}$

LDMS = Laser-Desorption Mass Spectrometry,
GCMS = Gas-Chromatograph Mass Spectrometry

# PP Category

EXOMARS

## Establishing Planetary Protection Category and Requirements

- ESA is mission lead for the 2016 mission and hence responsible for issuing the planetary protection category and the associated requirements and verifying their correct implementation, in accordance with the ESA and NASA Planetary Protection Policies.
- NASA is mission lead for the 2018 mission and hence responsible for issuing the planetary protection category and the associated requirements and verifying their correct implementation, in accordance with the ESA and NASA Planetary Protection Policies.
- Due to the launch of the mission from a NASA facility and the large contribution of US and NASA hardware (e.g., launcher, payload), the NASA PPO has been involved in the categorization and establishment of the associated requirements and is still involved in reviewing their correct implementation (e.g., PDR), in accordance with NASA NPR 8020.12.
- Categories, top level requirements and implementation approach have been presented to the COSPAR Planetary Protection Panel in 2010.


## Planetary Protection Categories

- ExoMars TGO is planetary protection category III
- ExoMars EDM is planetary protection category IVa (no access to Mars special regions and no life detection capability)
- No planetary protection category has been yet assigned by NASA to the 2018 mission but based on the caching of samples for a future return mission a planetary protection category V, restricted Earth return, with equivalent IVb requirements for the outbound leg is expected in compliance with the COSPAR planetary protection policy; this would also be compatible with the life detection objectives of the ExoMars rover

# 2016 PP Requirements

### Controlled environments
- Use of ISO standards for cleanroom spec (14644-1) and control (14644-2)
- Standard to be used for bioburden control in cleanrooms → ECSS-Q-ST-70-58
- Requirements and procedures similar to NASA Mars missions

### Compatibility with bioburden assays and alcohol wipes
- Standard to be used for bioburden assay → ECSS-Q-ST-70-55

### Bioburden assessment
- All bioburden constraints have to be verified pre-launch
- Total bioburden of the flight system has to be assessed

### Organic inventory and archive
- Delivery of archive with flight H/W to mission lead (ESA) for storage

### Impact probability constraint for launcher
- Impact probability: ≤ $1 \times 10^{-4}$ until 50 years after launch
- Task for launch service provider

### Bioburden control for the S/C stack (TGO and EDM)/TGO
- Total bioburden: ≤ $5 \times 10^{5}$ spores, OR
- Impact probability: ≤ $1 \times 10^{-2}$ until 20 years after launch, and ≤ $5 \times 10^{-2}$ for the time period 20-50 years after launch

### Bioburden control for the EDM
- Total bioburden: ≤ $5 \times 10^{5}$ spores, and
- Surface bioburden: ≤ $3 \times 10^{5}$ spores, and
- Average bioburden: ≤ 300 spores/$m^2$

# 2018 RM PP Requirements



## Controlled environments

- Use of ISO standards for cleanroom spec (14644-1) and control (14644-2)
- Standard to be used for bioburden control in cleanrooms → ECSS-Q-ST-70-58
- Additional standards used for molecular contamination control

## Compatibility with bioburden assays and alcohol wipes

- Standard to be used for bioburden assay → ECSS-Q-ST-70-55

## Bioburden assessment

- All bioburden constraints have to be verified pre-launch
- Total bioburden of the RM, including HEPA filter isolated volumes, has to be assessed

## Organic inventory and archive

- Delivery of archive with flight H/W to mission lead (NASA) for storage

## Bioburden control for the RM

- Surface bioburden: $\leq 2\times10^4$ spores[†], and
- Average bioburden: $\leq 300$ spores/$m^2$, and
- Sample pathway contamination level (biological and molecular): driven by the particular life-detection experiments (MOMA and LMC), i.e. sterile and < 50 ng TOC/g of sample delivered to the life detection experiments

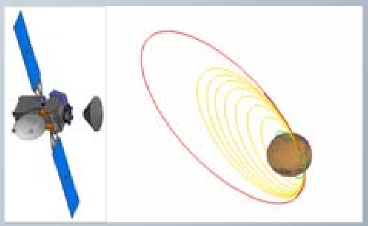
[†]Driving requirement, $1.6\times10^4$ spore allocation for delivery to ESA can be met with ~200 spores/$m^2$ average bioburden, like for MER and MSL

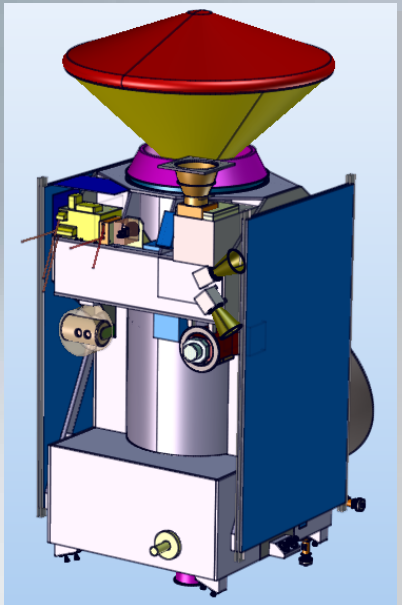
# 2016 PP Implementation

EXOMARS

## Important aspects to consider

➢Launch stack (TGO + EDM) is first large stack after Viking → affects probability of impact assessment and recontamination potential
➢TGO is using aerobraking to achieve final science orbit → affects probability of impact assessment





## Cleanroom assembly

➢ISO 8 for general OPs (e.g., TGO) and ISO 7 for bioburden controlled OPs (e.g., EDM)
➢Bioburden controlled OPs and need for microbiological lab at KSC

## Trade-off for S/C stack/TGO bioburden control approach

➢Probability of impact analysis for S/C stack and for the TGO post EDM separation
➢Depending on result, bioburden control might be necessary for TGO
➢Break-up/burn-up of TGO could be used as bioburden reduction process (e.g., like MRO)†

## Recontamination prevention of EDM backshield

➢EDM backshield temperatures during entry not sufficient to claim adequate bioburden reduction → bioburden on backshield has to be accounted for, including launch recontamination
➢External TGO & launcher fairing average bioburden ≤ 1000 spores/$m^2$

## Recontamination prevention of EDM interior

➢Contamination sources: external elements during testing, storage and transport (contingency), external TGO and launcher faring during launch
➢Use of HEPA filter at aeroshell level

## Use of pre- and post launch processes for bioburden reduction

➢Used for e.g., CFRPs (polymerization) and heat shield tiles (bake-out)
➢Used for pyro-and mortar cartridges with 30 spores/$cm^3$ allocation for unburned residue†
➢Not always possible, e.g., parachute vacuum stripping before folding

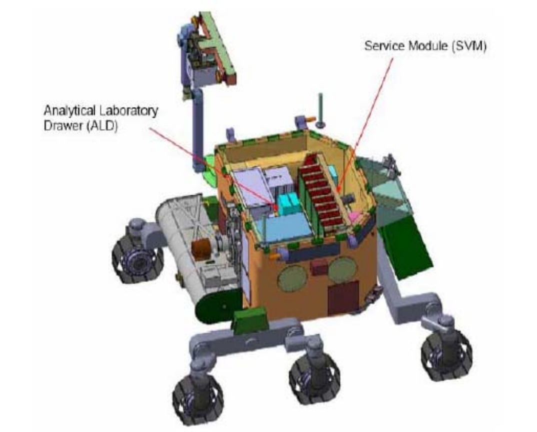
†Deviation of pre-launch requirement

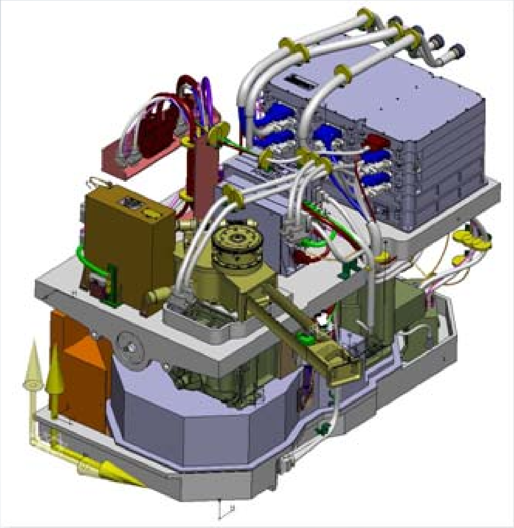
# 2018 RM PP Implementation

E X O M A R S

## Important aspect to consider

- Recontamination of ExoMars RM after delivery to NASA → commit on delivery and begin-of-operation bioburden and recontamination levels



## Cleanroom assembly

- ISO 8 for general Ops, ISO 7 for bioburden controlled OPs (e.g., after delivery to NASA), ISO 3, ISO AMC-9 for elements in the sample pathway (e.g., parts of MOMA P/L, drill and sample distribution system)
- Bioburden controlled OPs and need for microbiological lab at KSC

## Control of hardware used for the acquisition, transport and analysis of the samples

- Use of biological and molecular barriers, in particular a pressurized and sealed Ultra-Clean-Zone (UCZ)
- Use of VERY clean (e.g., similar to Viking) and sterile sample pathway
- Assessment of re-contamination potential during sample acquisition and transport
- Avoiding contamination sources in the sample pathway that could compromise life-detection experiments
- Assessment of molecular contamination sources in the sample pathway that cannot be avoided, including cleaning agents
- Use of blanks during operation on Mars

## Control of RM internal environment (i.e. service module and part of payload)

- Isolation with H14 HEPA filters†
- Condition for use of HEPA isolation: average bioburden of HEPA isolated volumes ≤ 1000 spores/$m^2$
- Used for H/W outside the UCZ and inside the bathtub and on electronic modules outside the RM (e.g., PanCam, Ma_Miss electronics)

†Deviation of pre-launch requirement

# PP Training

## Different levels of training apply depending on the individual tasks

➢Level 0: Ensuring a common understanding throughout the project of the reasons for planetary protection, and why it is important to everyone. To be attended by all involved personnel in the project.

➢Level 1: Intended for any of the workforce NOT required to work in bioburden control area but nevertheless whose actions may affect work inside the bioburden controlled area, e.g., some subcontractors, stock control, goods inward.

➢Level 2: Intended for any of the workforce working inside bioburden controlled areas, including cleanroom cleaners, maintenance workers, ATLO personnel.

➢Level 3: Intended for planetary protection supervisors – personnel monitoring the operation of the bioburden controlled facility and any activities inside.

## Progress

➢Training organized by ExoMars Prime Contractor (Thales Alenia Space-Italy, TAS-I) currently covers level 0 and 1; approx. 350 participants so far since 2008

➢ESA/NASA training courses are credited for level 0 and 1; 140 participants so far since 2003

➢Training has been attended by almost all ESA and TAS-I project discipline managers and engineers

# Status



## General ExoMars program status

- Successfully passed system-PDR in December 2010
- Price proposal for phases C/D/E1 expected in February 2011
- Kick-off for phase C/D expected in April 2011
- ESA-NASA Memorandum of Understanding concerning cooperation on the robotic exploration of Mars currently in final draft version

## Payload status

- TGO (2016) payload selected based on joint ESA-NASA AO
- EDM (2016) payload joint ESA-NASA AO issued November 2010, proposals due 1st March, selection expected in June 2011
- Rover (2018) Pasteur Payload selected

## Planetary protection status

- Category and requirements have been coordinated with COSPAR and NASA
- Planetary Protection Plan was reviewed during PDR and final version expected in March 2011
- Verification methods of requirements agreed
- Bioburden reserve for 2016 mission (TGO + EDM) at PDR: ~30% at TAS-I level; 10% of this reserve will be allocated to the flight system, keeping a 20% bioburden reserve at TAS-I level until CDR
- Bioburden reserve at ESA level will be kept until joint operation at launch site
- Bioburden reserve for 2018 ExoMars rover at PDR: 15% at TAS-I level; additional 20% at ESA level
- Expected deviations from requirements have been identified (use of HEPA isolation, use of bioburden reduction post-launch for explosive cartridges and heat shield) considered acceptable during PDR