ExoMars Cameras:

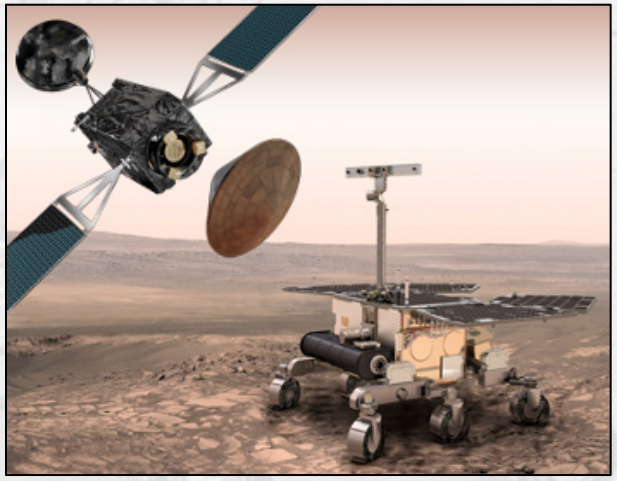
An Input To The Rover Autonomous Mobility System

Nick Cristello – May 13, 2015 PTMSS 2015

ESA ExoMars Program

- ExoMars Mission led by the European Space Agency
- Deliver a European rover and Russian surface platform to Mars in 2018: *on-surface mission duration 218 sols*

- Objectives:
  - Search for signs of past life
  - Investigate how environment varies
  - Investigate atmospheric gasses
  - Technology enabler for ISRU



http://exploration.esa.int/mars/47101-european-led-elements-of-the-exomars-programme/

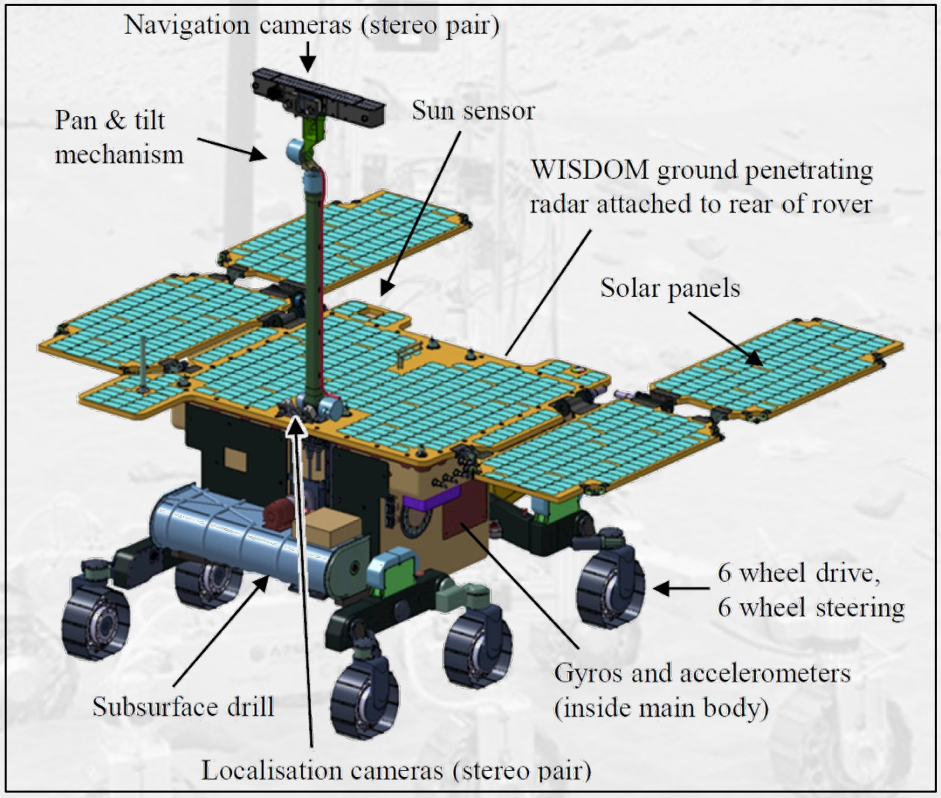
ESA ExoMars Program

- ExoMars Program Contractors:
  - European Space Agency (ESA)
  - Thales Alena Space – Italy (TAS-I)
  - Airbus Defense and Space – UK (ASU)

- Neptec has enlisted support of key subcontractors
  - Institut National d'Optique (INO)
  - e2v

ExoMars Rover Module

- 300 kg rover, to transport scientific payloads on Mars
- Employs sophisticated Guidance, Navigation and Control to enable rapid progress
- Limited power available for heating during Martian night
- External components subject to temperatures between -120°C and +40°C on Mars
- Pre-launch sterilisation done at +125°C



Autonomous Mobility System

- Mobility system enables traverse over large distances with minimal ground intervention
- Operation of Rover Vehicle for up to 2 Martian sols
- Expected traverses of 70 m each Martian sol
- System performance as follows:

Parameter	Value	
Average Driving Speed	14 m/h	(full autonomy)
Range accuracy (from target)	7m	(after 70m traverse)
Heading accuracy	15°	(after 70m traverse)
Heading knowledge	5°	(after 70m traverse)

Autonomous Mobility System

- Composed of several key hardware subsystems:
  - Deployable Mast Assembly
  - Cameras
    - Navigation Cameras
    - Localisation Cameras
  - Inertial Measurement Unit
  - Locomotion Subsystem
    - Actuator Drive Electronics
    - Bogie Electro Mechanical Assembly

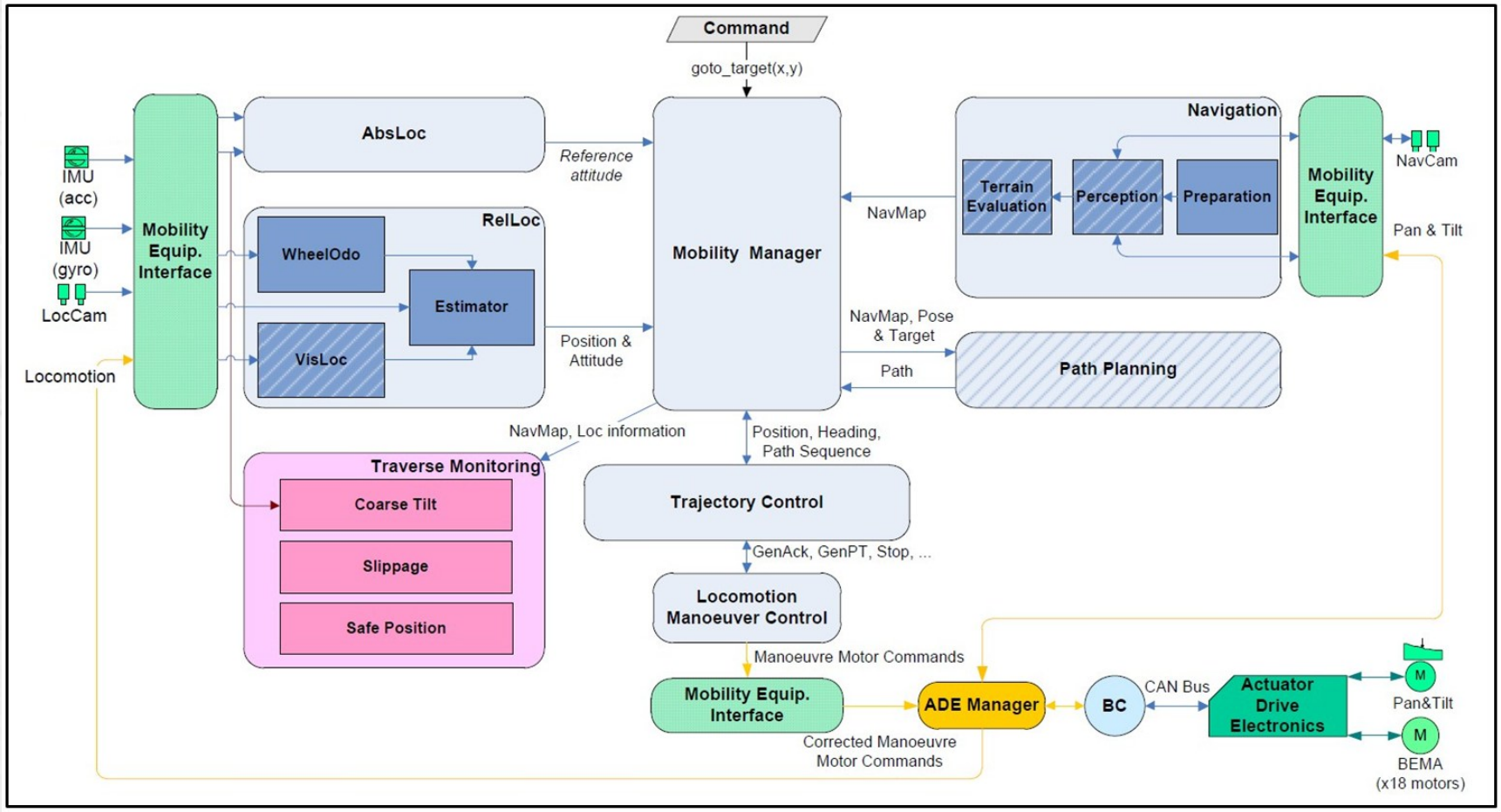
http://exploration.esa.int/science-e-media/img/dc/Exomars2010.jpg

Autonomous Mobility System

- Mobility System Architecture:
  - Absolute Localisation (Navigation Camera)
  - Navigation (Navigation Camera)
    - Perception (Navigation Camera)
    - Path Planning
  - Relative Localisation (Localisation Camera)
    - Visual Localisation (Localisation Camera)
  - Trajectory Control
  - Locomotion Manoeuvre Control
  - Traverse Monitoring

Autonomous Mobility System

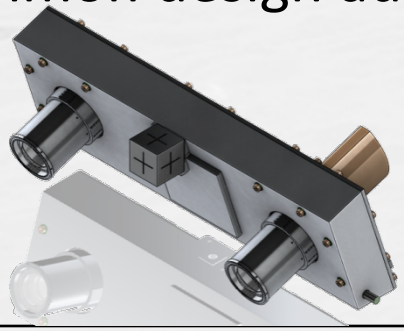
- Mobility System Architecture:

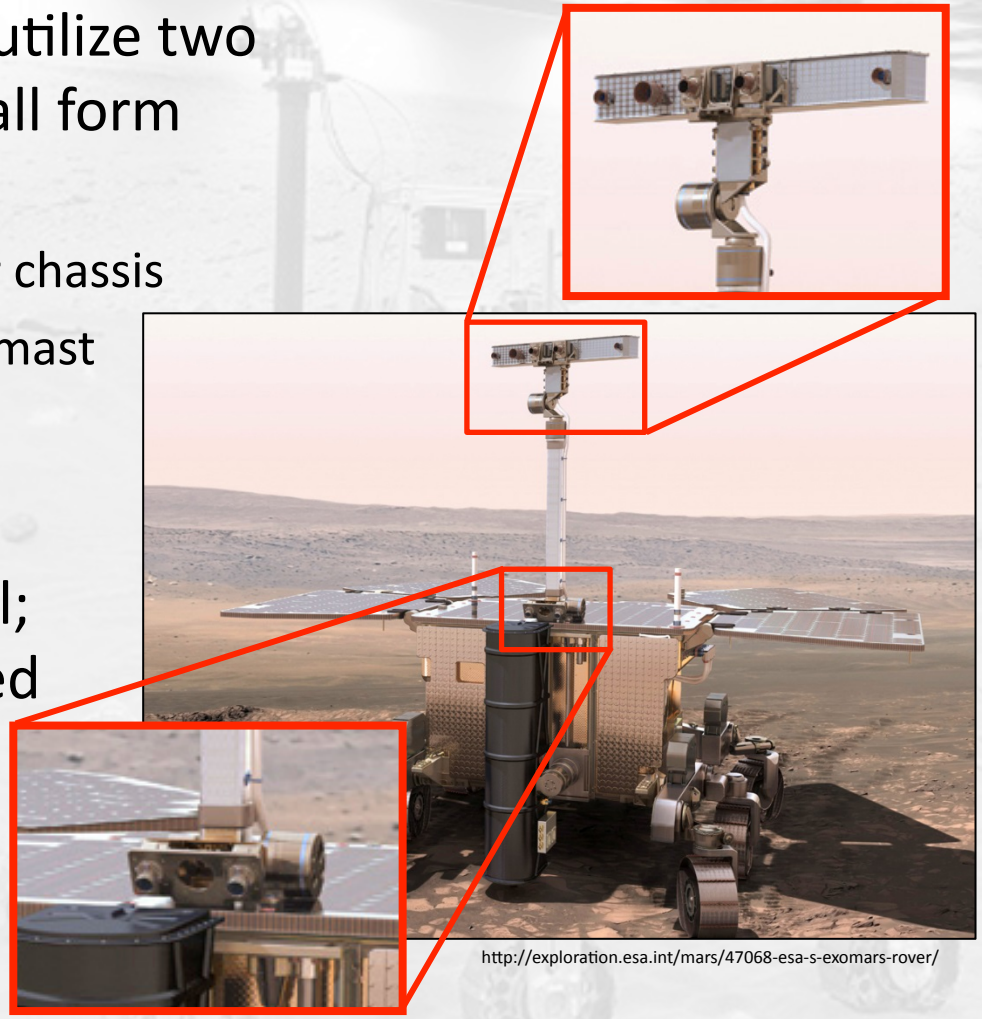


ExoMars Cameras

- ExoMars Rover Vehicle will utilize two lightweight, low-power, small form factor, stereo cameras:
  - Localisation camera; on rover chassis
  - Navigation camera; on rover mast

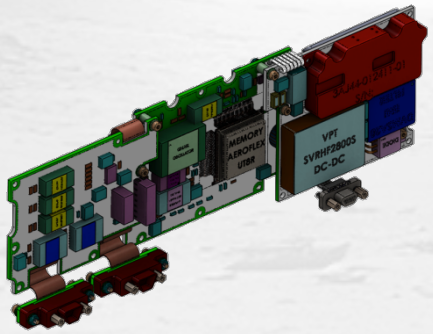
- Form, fit, function of both cameras is virtually identical; one common design adopted





http://exploration.esa.int/mars/47068-esa-s-exomars-rover/

ExoMars Cameras



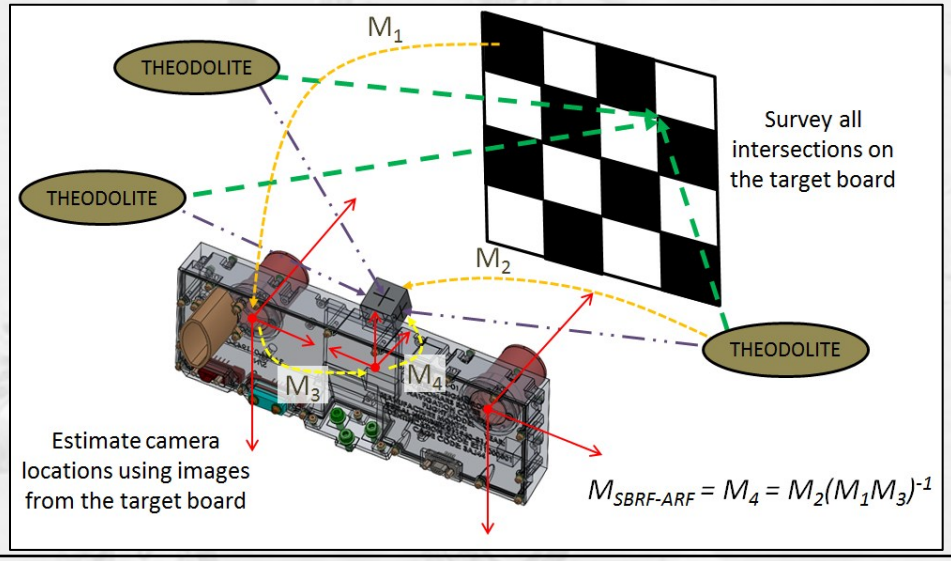
ExoMars Cameras

- Key features of navigation and localisation cameras:

Parameter	Value	
Overall Dimensions	290 mm x 82 mm x 79 mm	
Mass	< 800 g	
Power Consumption	< 2.0 W < 2.5 W	(standby) (operation)
Temperature Range	-120°C to +125°C - 50 °C to + 40°C	(storage) (operation)
Stereo Baseline	150 mm	
Image Resolution	1024 x 1024	
Exposure Type	Global Shutter	
Exposure Time	1 ms … 1000 ms	
F-Number	f/8	
Focal Length	4.0 mm	
Data Interface	Spacewire	

EXMC Calibration

- Ensures left & right images are aligned to within ¼ pixel
- Provides the transformation matrix between the Stereo Bench Reference Frame and the Alignment Reference Frame
- Accuracy demonstrated:
  - 60 arcsec in rotation
  - 0.1 mm in translation



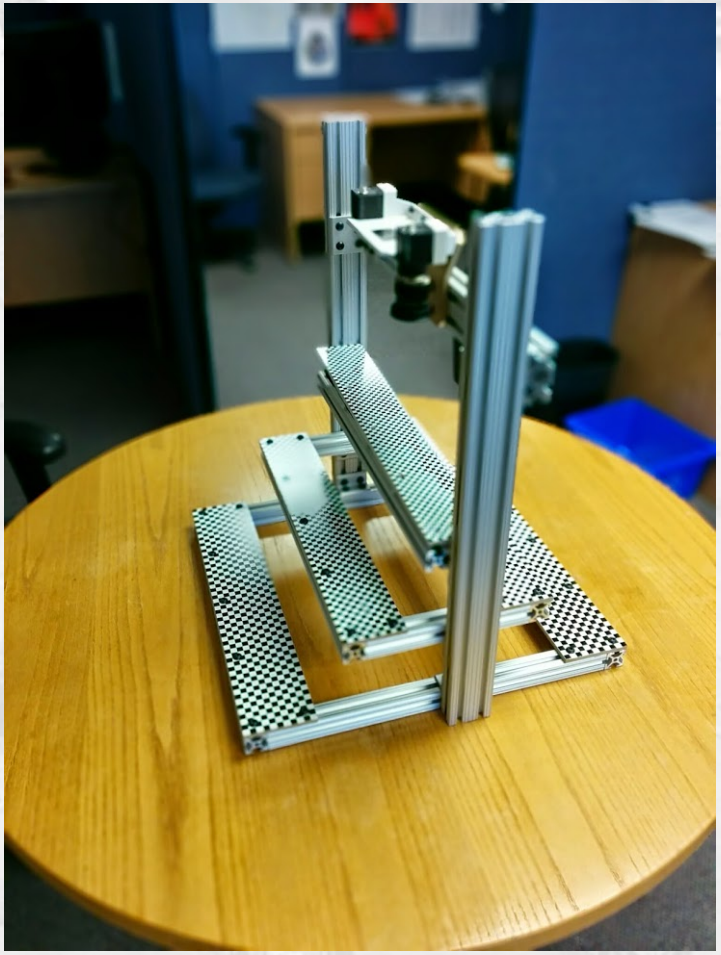
EXMC Calibration

- Calibration performed on-board using Field Programmable Gate Array
- Calibration relies on look-up tables for reduced processing overhead and computational time
- Distortion removal drives operating frequency of EXMC

	Processing Time (s)	
Acquisition Type	**1024 x 1024**	**512 x 512**
Acquisition Cmd Latency	0.005	0.005
Exposure Time (max)	1.000	1.000
Readout from Sensor	0.062	0.031
Spacewire Readout	0.185	0.046
Distortion Removal	1.729	0.432
Total per Image	2.981	1.515
Total per Stereo Pair	4.894	1.993

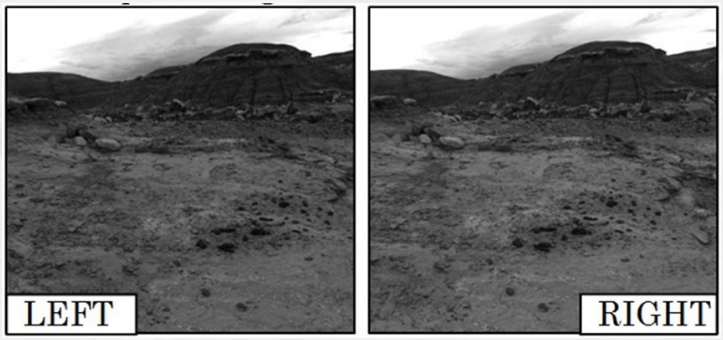
EXMC Calibration

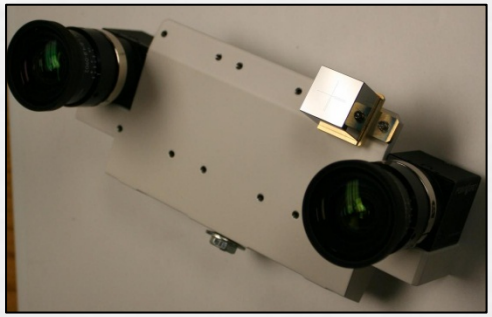
- Perfect mechanical stability of all parts is not realizable
- Calibration algorithm adjusted at multiple temperatures
- Thermal stability over full operational temperature range (-60°C to +50°C)
- Additional testing and characterization done at NDG

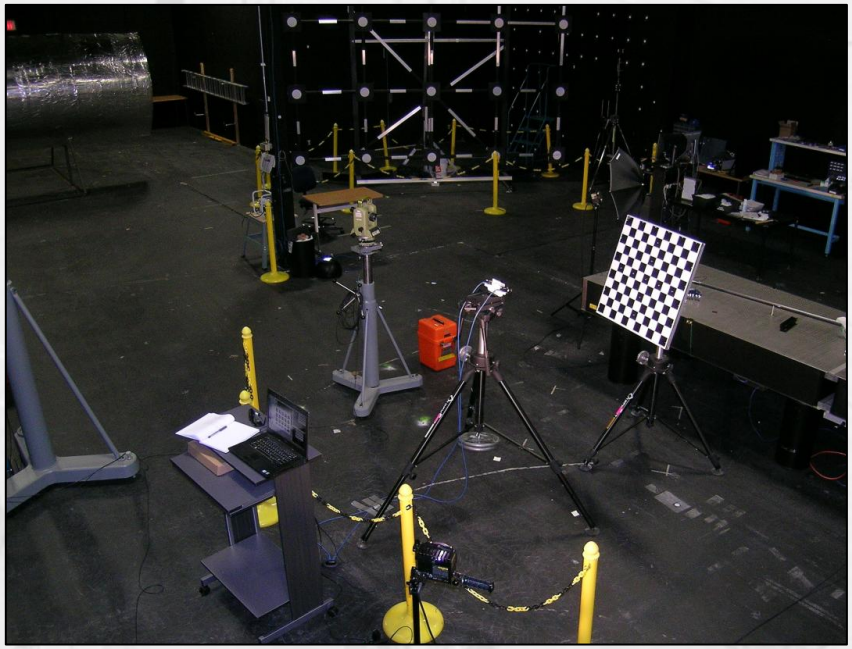


Verification

- Design and Manufacture of Breadboard Model
- Verification of Calibration Algorithm
- Demonstration at Mars Desert Research Station

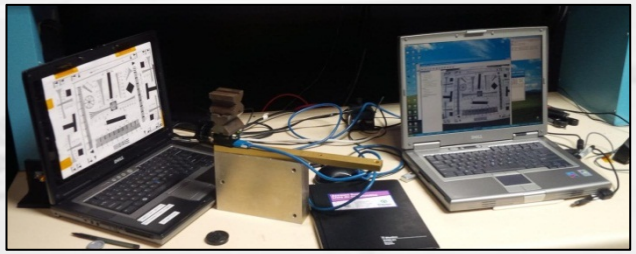


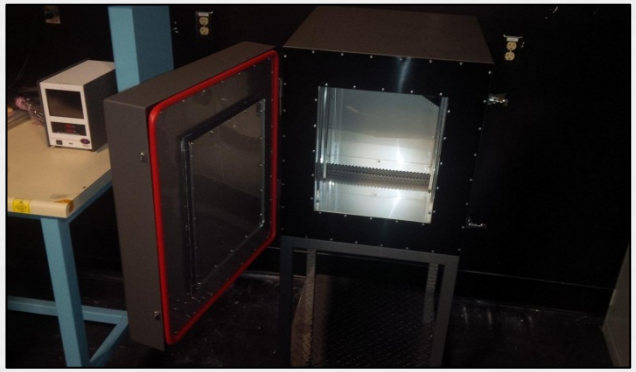


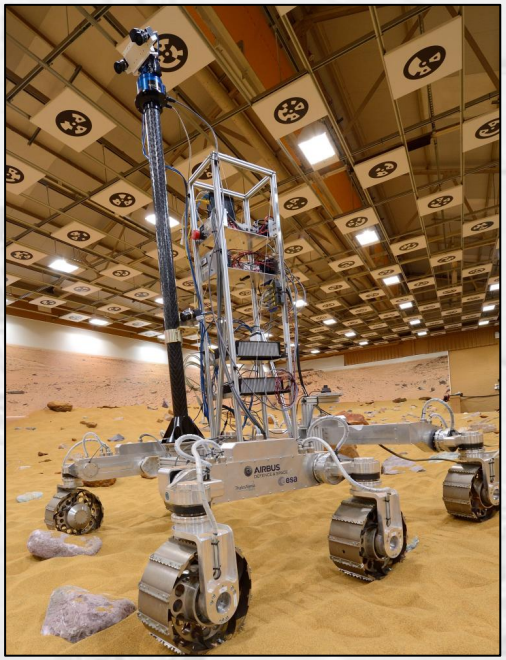


Verification

- Integrated testing of EXMC BM on Rover Vehicle
- Low-temperature cryogenic testing (-130°C to +50°C)
- Performance temperature testing (-50°C to + 40°C)

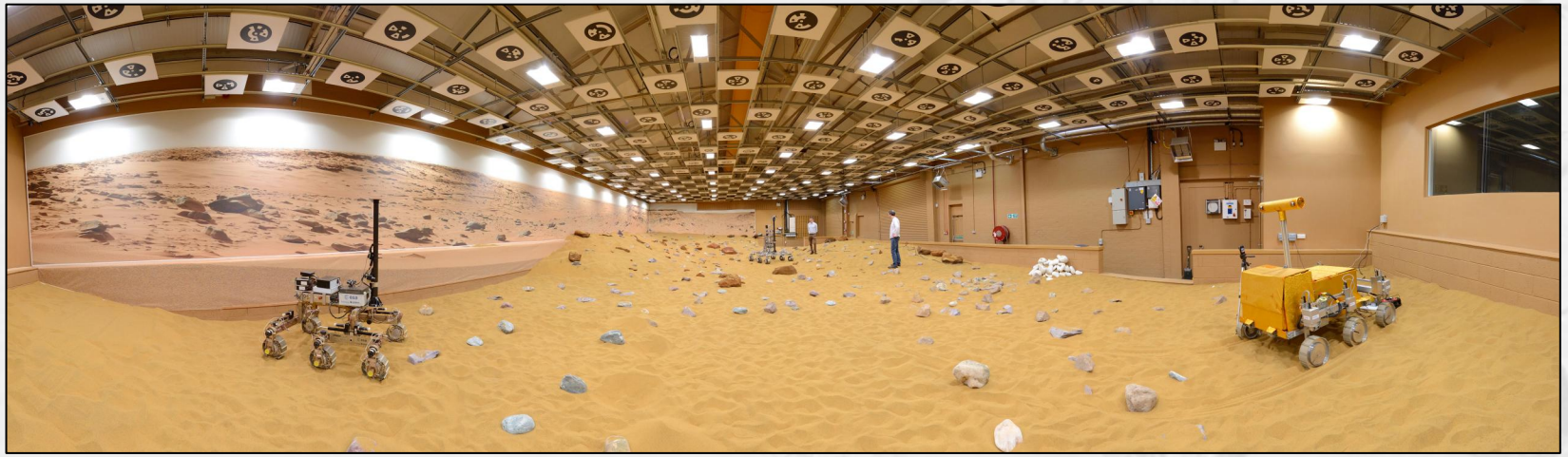






Beyond Mars

- Global Exploration Roadmap placed emphasis on In Situ Resource Utilization
- Well suited for harsh temperature environments
- Applications in commercial space mining, UAVs and dangerously remote areas of terrestrial exploration



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