KOM PRESENTATION (12th Feb, 2019)

AUTONOMOUS DECISION MAKING IN VERY LONG TRAVERSES (OG10)

European Commission

JOANNEUM RESEARCH DIGITAL

THALES

DFKI German Research Center for Artificial Intelligence

TRASYS INTERNATIONAL

magellium

KING'S College LONDON

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION HORIZON 2020

AIRBUS DEFENCE & SPACE

UNIVERSITY OF OXFORD

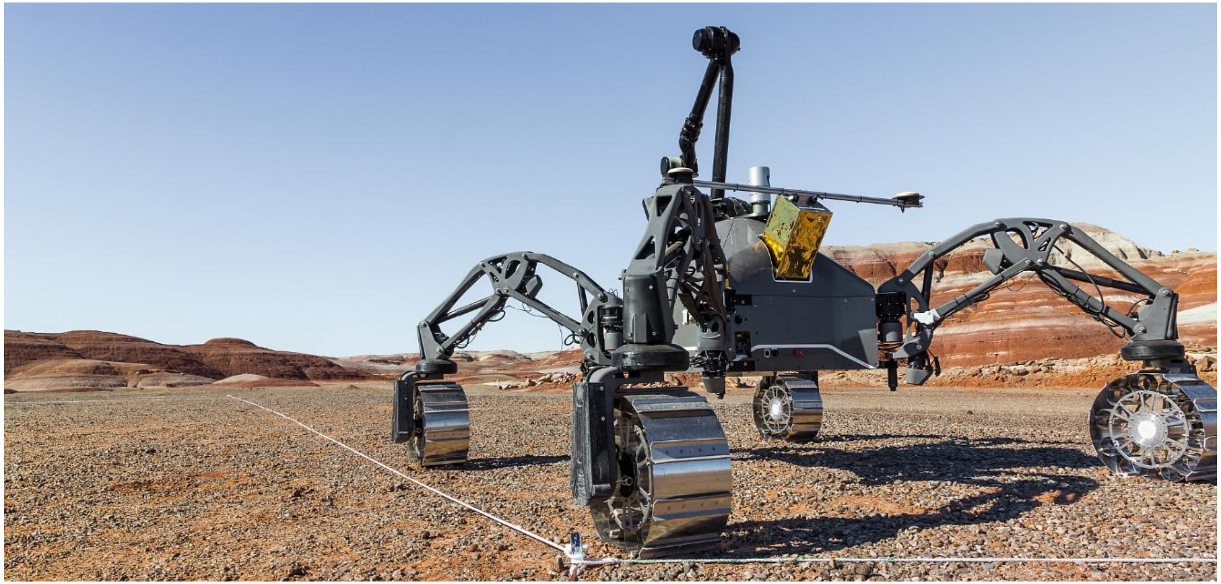
UNIVERSITÉ Grenoble Alpes

UNIVERSIDAD DE MÁLAGA

UNIVERSITÀ DEL SALENTO

gmv INNOVATING SOLUTIONS

ADE (OG10): Main goal (SRC):



The challenge of OG10 is to demonstrate the techniques needed to realize a planetary rover system with very long traverse capabilities (kilometres per sol) by independently taking the decisions required to progress, reduce risks and seize opportunities of data collection in a MSR scenario

The outcome sought in OG10 is the demonstration of such capabilities in a terrestrial analogue of a planetary environment

ADE OBJECTIVES

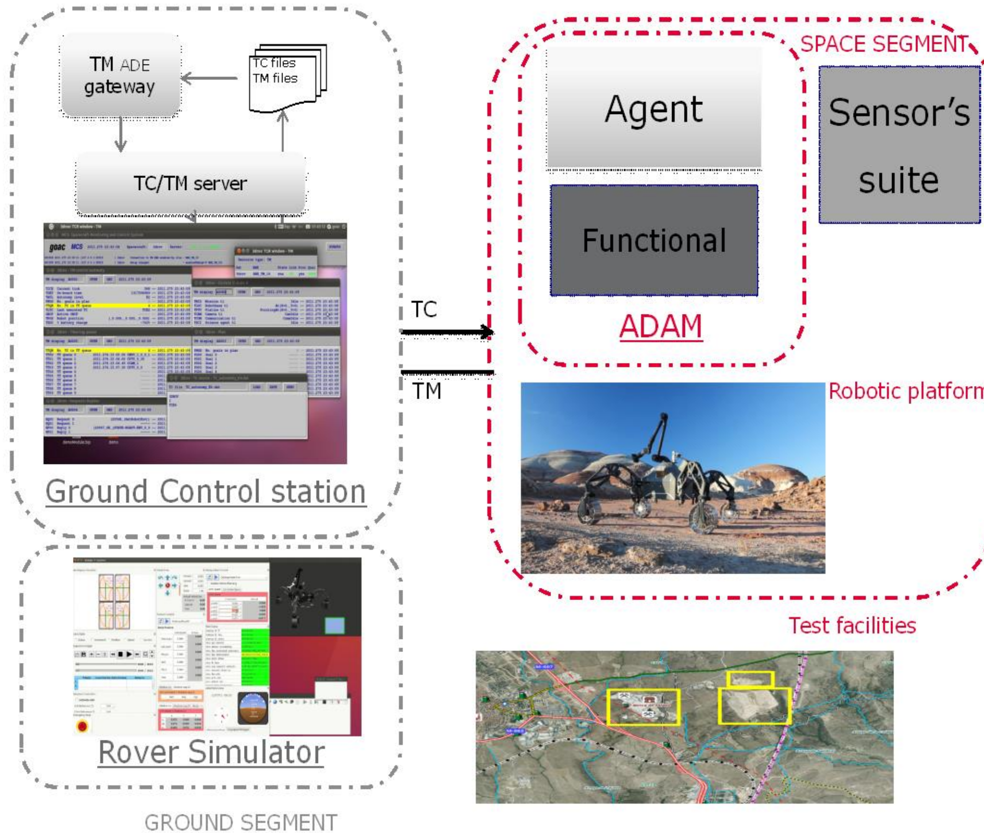
- *Obj 1.* Achieve autonomous long range navigation with high reliability
- *Obj 2.* Guarantee consistent data detection while avoiding un-detection of interesting data along mission path
- *Obj 3.* Autonomous decision making capabilities (E4) in presence of conflicts
- *Obj 4.* Mandatory re-use of Call 1 Building Blocks
- *Obj 5.* Reach a higher TRL level
- *Obj 6.* Safety
- *Obj 7.* Achieve a flexible-purpose surface robotic system design
- *Obj 8.* Spin-off / ground exploitation and commercialization
- *Obj 9.* Dissemination/Communication and Exploitation
- *Obj 10.* Collaboration/harmonization with other Call 2 OGs consortiums

WORKING AREAS

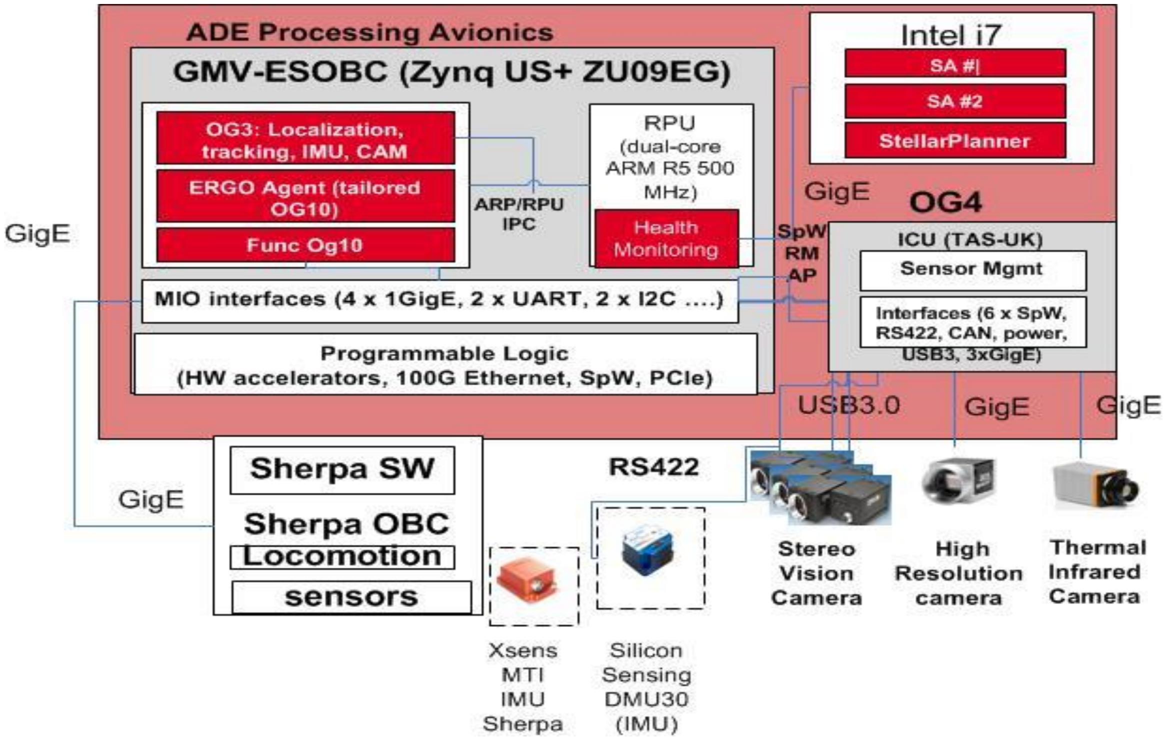
GMV	ADAM, Coordination, OG2+, OG1+
DFKI	Rover, Rover simulator
Airbus Defence & Space	Guidance
Université Grenoble Alpes	Formal Verification
Thales Alenia Space	Requirements
Joanneum Research Digital	Testing areas
King's College London	Planner
GMV	Mission Planner requirements & Extensions.
Trasys International	Ground Control Station
University of Oxford	Scientific Detectors
Universidad de Málaga	Coordinated Robotic Arm & Guidance Approach
Magellium	Localization / OG3*
Università del Salento	Soil Navigability

TECH SOL: COMPONENTS

- Rover System
  ADAM/S.Suite/SherpaTT
- Ground Control Station (GCS) Trasys's 3DROCS
- Rover Simulator DFKI´s SherpaTT Simulator
- Test Facilities
  mechanical/electrical/data interfaces



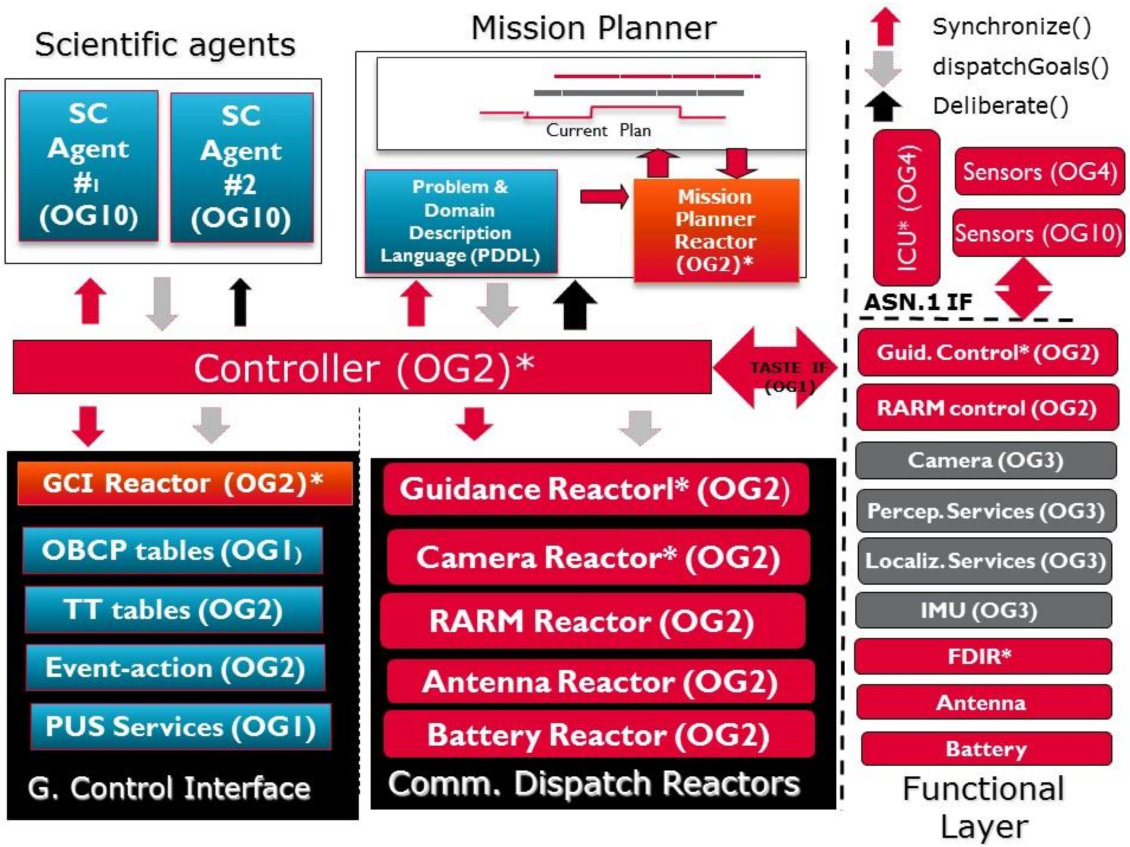
ADAM Avionics



The ADE Processing avionics consist of:

- GMV'S ADE On-board Computer is based on the Zynq UltraScale+ MultiProcessing System-on-chip (Quad-core ARM A53 1GHz Application CPU , Dual-core ARM R5 Real-time CPU and programmable logic). This board provides powerful HW in terms of performances and interfaces
- Dedicated Opportunistic planner computer (intel-i7) by means of Gigabit Ethernet
- The I3DS ICU from OG4 is developed by Thales UK and will integrate due selected sensors which can be connected by USB3.0 or Gigabit-Ethernet, high-resolution camera and thermal infrared camera connected with separated Gigabit Ethernet links

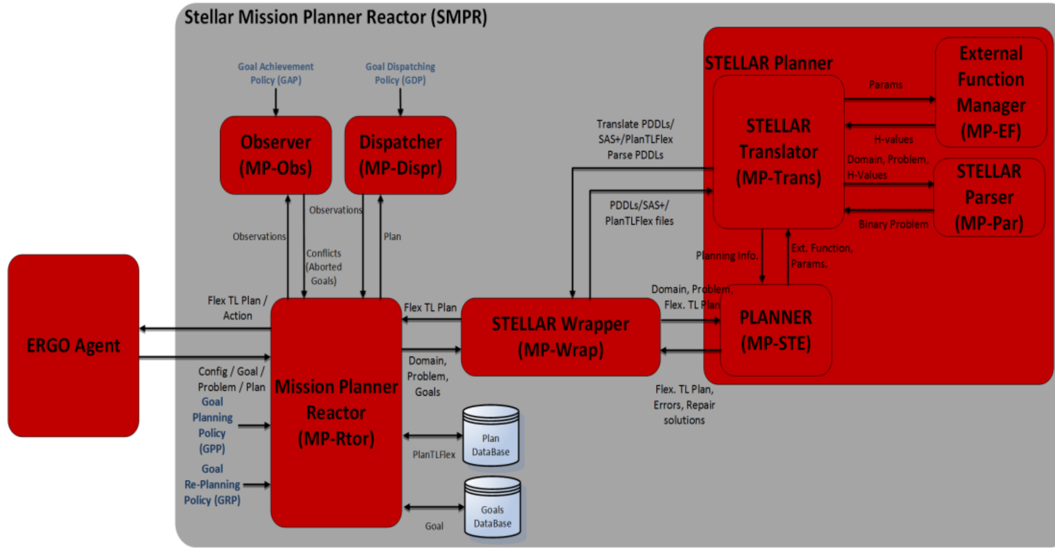
ADAM Components



- ERGO Controller (GMV)
- GCI Reactor (GMV)
- CD Reactors (GMV)
- Mission Planner & PDDL (KCL&GMVUK)
- Scientific agents (Oxford)
- OG4 Sensors
- OG3 ICU
- Guidance Control (Airbus)
- Robotic arm control (GMV)
- Perception Services (MAG)
- IMU (OG3)
- FDIR Component (UGA)
- Antenna and Battery (GMV)

Planning

- Updating anytime search algorithms, for use with over-subscription planning;
- Updating heuristics that estimate the effort to a new best plan;
- Development of a library of solution plans. As new goals are generated for opportunistic science, these may be most easily incorporated it to one plan than the other – keeping multiple plan options available will elegantly support this.

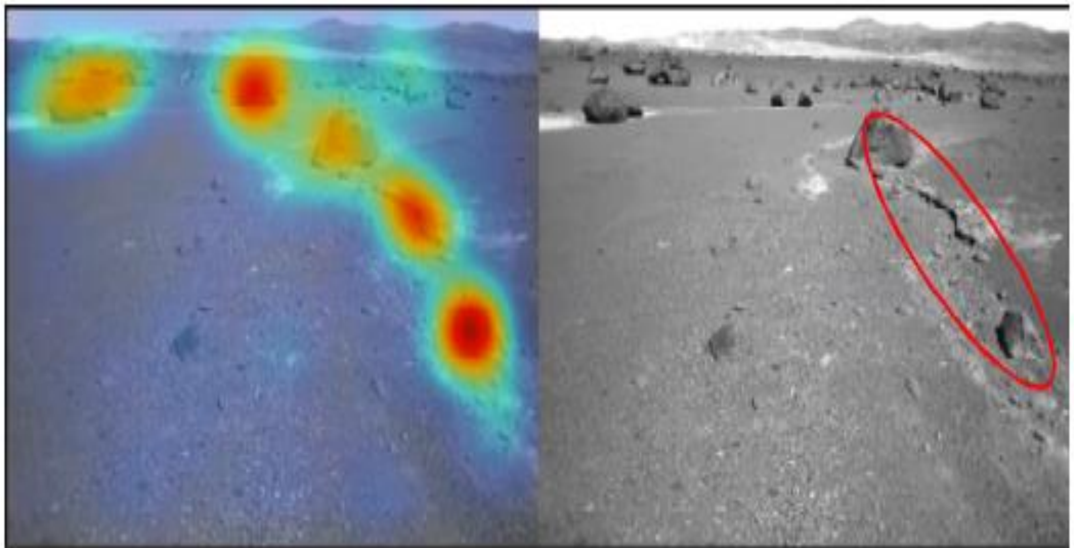


For the first two of these, we will adopt and extend a state-of-the-art heuristic for oversubscription planning. For the latter, we will take as our basis work on storing plan fragments within a policy, integrated with the search for a plan.

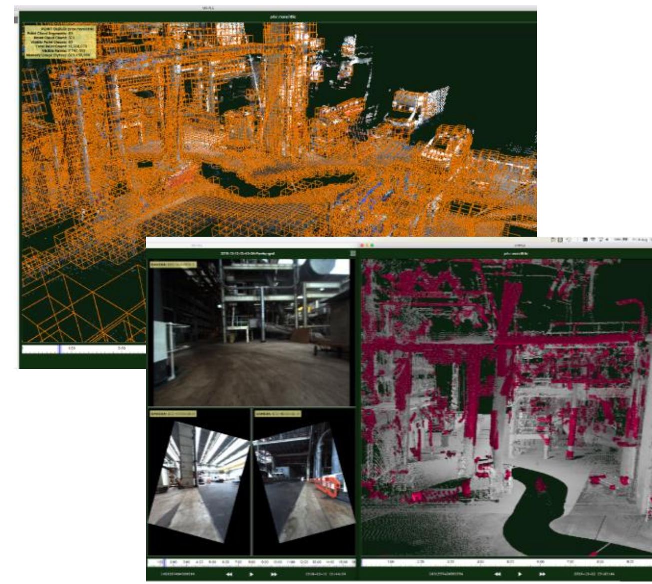
Scientific Detection

- **Opportunistic Science** using high resolution and thermal cameras

Space



Nuclear



InFuse Perception/Localization (OG3) Extension

OG3 InFuse localisation functions will be extended towards OG3+, to increase robustness, performance, and operational domain:

- Reuse, tune and adapt existing visual odometry and SLAM functions to OG10 long-range autonomy objectives and constraints
- Reuse, tune and adapt existing mapping functions to OG10 requirement
- Add absolute localisation functionality using orbital data and panoramic images
- Add a natural target relative localisation function based on current model-based approaches. This will be used to perform RV with a target of scientific interest.
- Integrate individual localisation functions in a complete on-board localisation system fusing data from various modalities: VO or SLAM, wheel odometry, sun sensor, inclinometers, orbital images, DEMs, panoramic images

Rover/Rover simulator Enhancements

SherpaTT electromechanical extension plan

- Evaluation of options for mechanical integration
- Issues known from OG6 are evaluated and solutions designed
- Suitable ways to integrate hardware extensions are identified and documented

Rover simulation

- Adaption of current rover model to OG10 needs
- Preliminary implementation of new sensors according to sensor suite
- Detailing sensor and environment simulation
- First design of integration plan with Trasys Ground Station
- Replaying mechanisms of sensor data

Validation Toolset

- Test data base design
- Initial design
- Supervision of execution

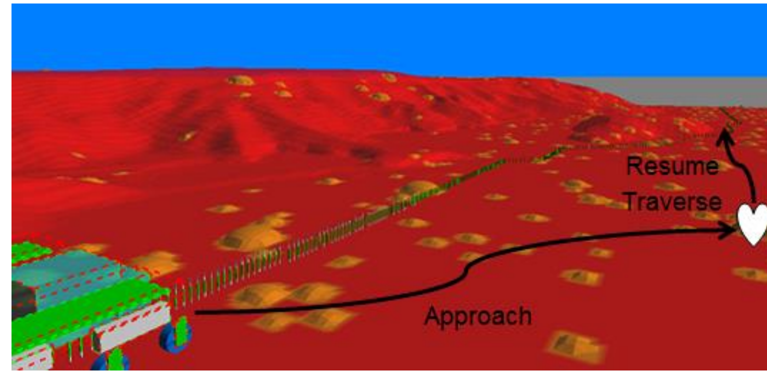
Long Range Rover Guidance Extension (OG2+) Detailed Design and Prototyping

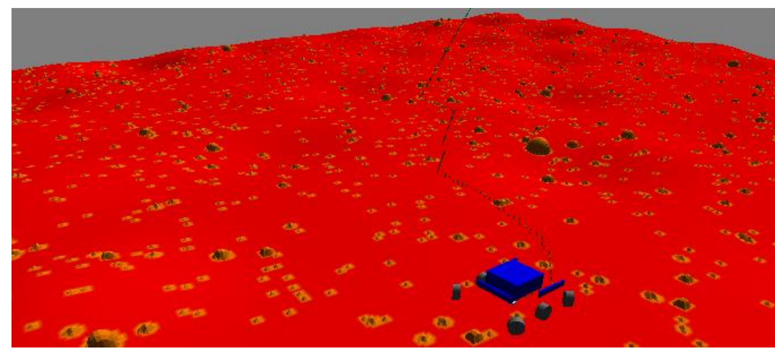
ADE will achieve the validation by ground demonstration of the rover guidance for very long rover traverse while also enabling the capability to seize **scientific opportunities** in the rover path's vicinity.

In order to improve distance traversed from a kilometre range (OG2) to a few kilometres (OG10).

We will improve OG2's existing framework with these enhancements:

- Detailed design of the updates of ERGO Rover Guidance & prototyping
- Implement and testing the RG updates.
- Prototyping of several additional RG levels.
- Support to integration of guidance function within ADAM prototype for preliminary validation within rover simulator





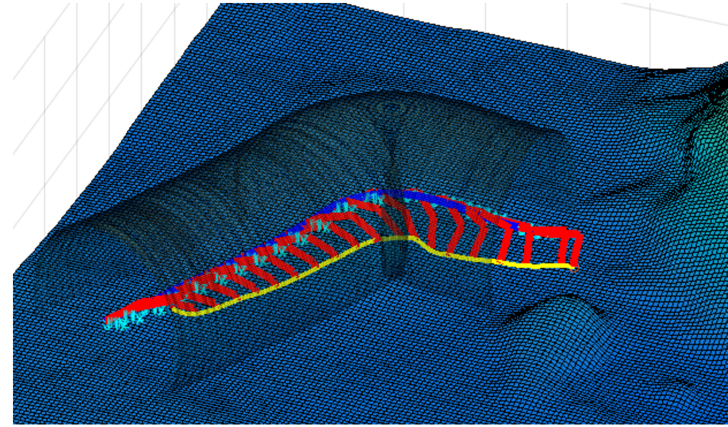
Rover Manipulation Motion Planning

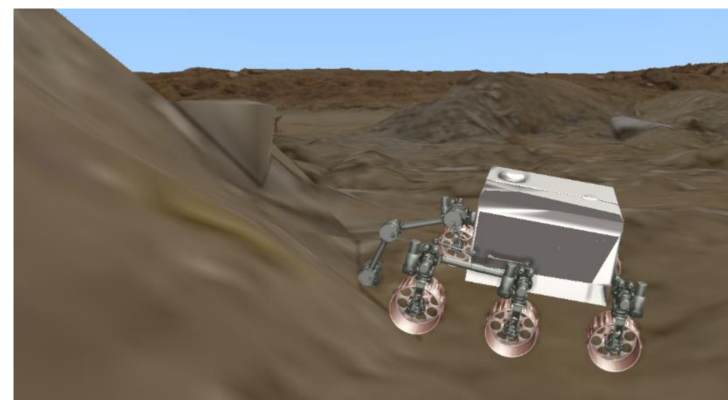
The main objective of this task is to perform approximation to scientific interesting site and/or sample catching using the robot arm. It requires a coupled **rover-manipulator control for reconfigurable wheel-legged rovers**. The use of this kind of rovers, in combination with a manipulator, would help to perform difficult sample fetching tasks:

- Taking samples from complex locations. The rover would approximate to and change its configuration to allow the manipulator reach a target that would imply a rover-manipulator combined motion.
- Reach the sample avoiding obstacles. In complex locations, complex rover-manipulator motion should be considered in order to avoid obstacles and place the rover without risks.

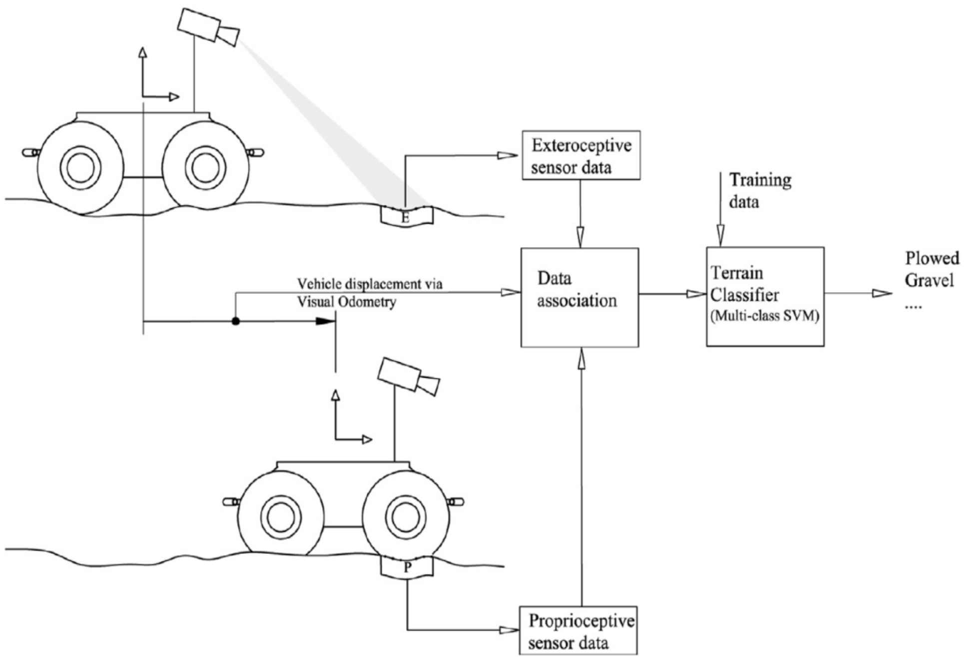
This objective suggests two stages to be solved:

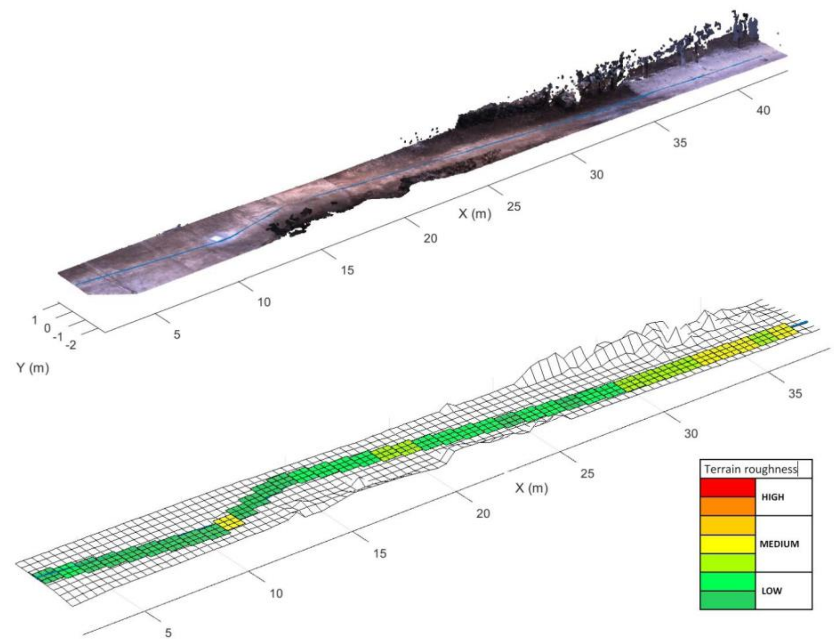
- **Approximation planning**. The rover should move towards the objective taking into consideration the rover kinematics, manipulator workspace and obstacles.
- **Rover-manipulator coupled control**. Useful to pick up samples in complex environments.





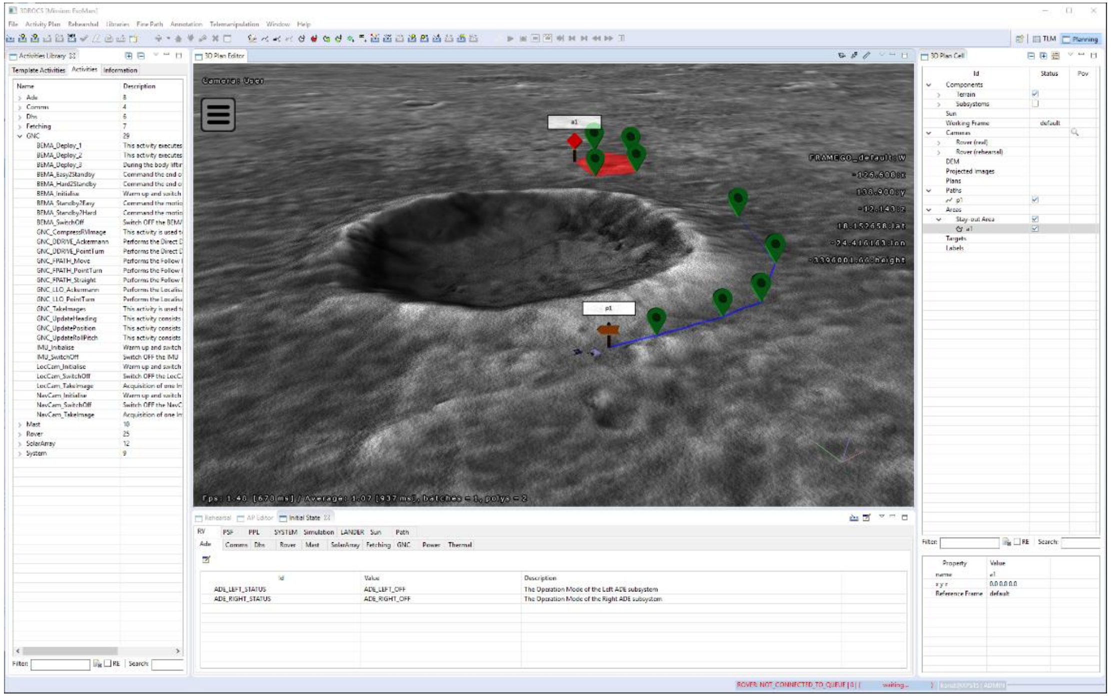
Soil Navigability Estimation (US)





Ground Station

- 3DROCS Ground Control Station



Operations

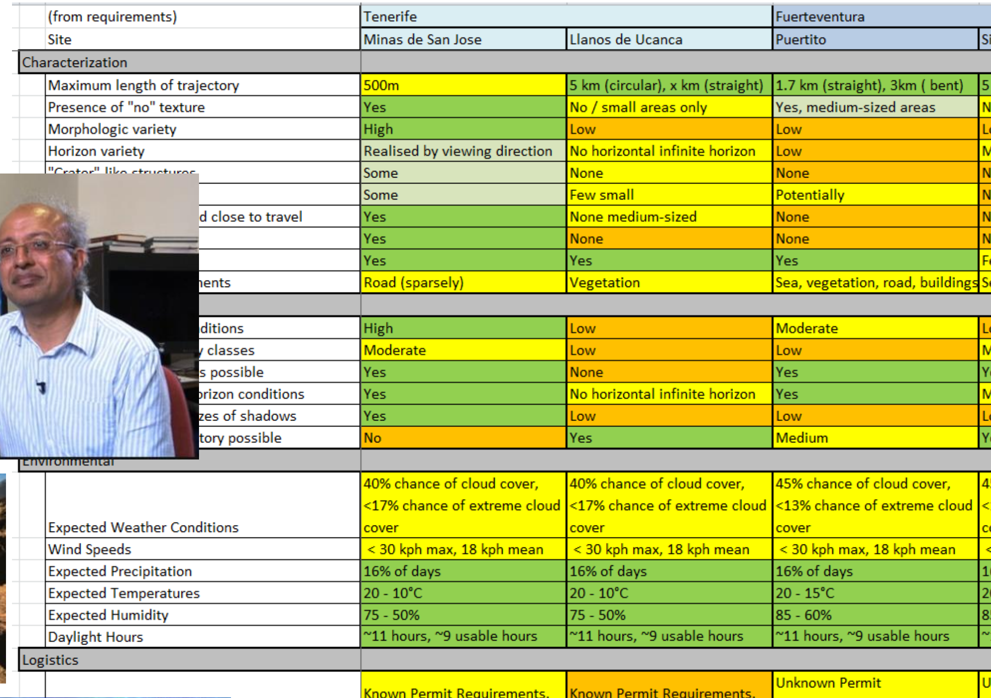
- Telemanipulation
- Interactive Autonomy (monitor & control)
- Autonomous Operations (AP Preparation & Validation)
- Data Assessment
- *ExoMars ROCS [GMV/TRA]*
- *Research Activities: LUCID, RACER, RAT, …*
- *Field Tests: ExoFit, ExoTer, …*
- *Future missions*

- Eclipse RCP dev. environment: mission independent & mission dependent plugins

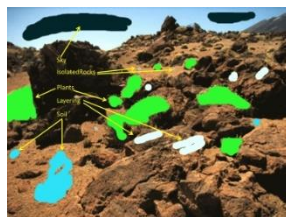
- Perspectives': function of the operating mode

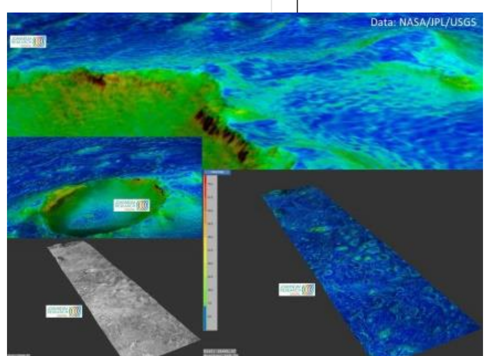
Testing site, ground truth and scientific target characterization

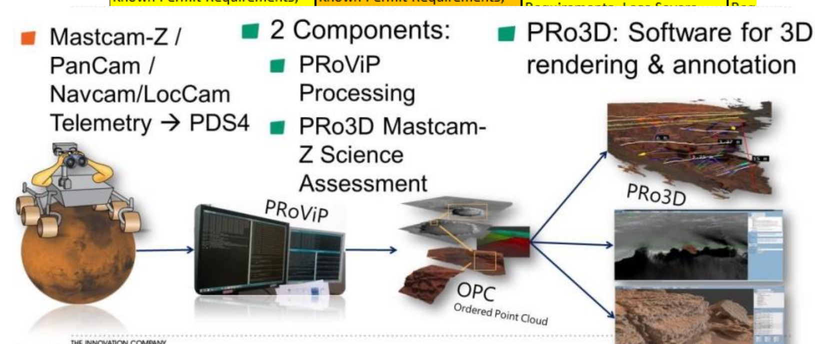
- Trading off among possible testing sites in relation to OG10 requirements
  - HRAF Pilot 2 Heritage on considerations
- Launch a small subcontract to Imperial College London (Prof. Gupta , MSL Scientist for scientific reference)
  - images annotation of science targets on images from real missions (MSL / MER) as well as 3D representations therefrom as processed by JR From pds releases – to be used as ground truth for the science autonomy component
- Render synthetic image sequences from HiRISE and/or existing large-scale MSL Mastcam 3D reconstructions to be used as ground truth for navigation



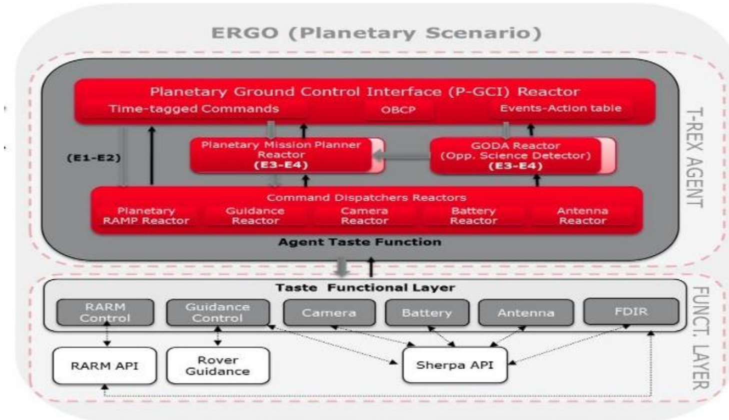
(from requirements)	Tenerife		Fuerteventura	
Site	Minas de San Jose	Llanos de Ucanca	Puertito	Site
Characterization				
Maximum length of trajectory	500m	5 km (circular), x km (straight)	1.7 km (straight), 3km (bent)	5 km
Presence of "no" texture	Yes	No / small areas only	Yes, medium-sized areas	No /
Morphologic variety	High	Low	Low	Low
Horizon variety	Realised by viewing direction	No horizontal infinite horizon	Low	Mec
"Crater" like structures	Some	None	None	Non
	Some	Few small	Potentially	Non
d close to travel	Yes	None medium-sized	None	Non
	Yes	None	None	Non
	Yes	Yes	Yes	Few
ents	Road (sparsely)	Vegetation	Sea, vegetation, road, buildings	Sea,
ditions	High	Low	Moderate	Low
classes	Moderate	Low	Low	Moc
s possible	Yes	None	Yes	Yes
rizon conditions	Yes	No horizontal infinite horizon	Yes	Moc
zes of shadows	Yes	Low	Low	Low
tory possible	No	Yes	Medium	Yes
Environmental				
Expected Weather Conditions	40% chance of cloud cover, <17% chance of extreme cloud cover	40% chance of cloud cover, <17% chance of extreme cloud cover	45% chance of cloud cover, <13% chance of extreme cloud cover	45% <13 cove
Wind Speeds	< 30 kph max, 18 kph mean	< 30 kph max, 18 kph mean	< 30 kph max, 18 kph mean	< 3
Expected Precipitation	16% of days	16% of days	16% of days	16%
Expected Temperatures	20 - 10°C	20 - 10°C	20 - 15°C	20 -
Expected Humidity	75 - 50%	75 - 50%	85 - 60%	85 -
Daylight Hours	~11 hours, ~9 usable hours	~11 hours, ~9 usable hours	~11 hours, ~9 usable hours	~11
Logistics				
	Known Permit Requirements,	Known Permit Requirements,	Unknown Permit	Unk



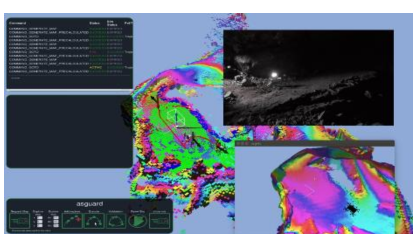


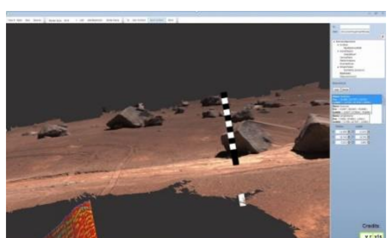


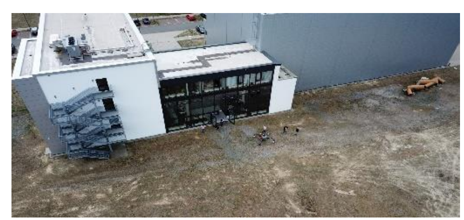
ADAM SW Detailed Design and Prototyping



UT → IT → Preliminary Tests → System tests







Nuclear spin-off Application

A terrestrial spin-off will be done via the development of a rover aimed to a set of nuclear demo test cases. These tests will be performed at GMV premises. In order to identify potential spin-off applications of the ADE development, we will:

- Collect and deliver **videos** and **datasets**.
- **Analyze/post-process** the nuclear demo **test results**.
- Report and **deliver the test results**.
- **Refine spin-off market analysis** as per obtained results.

SUMMARY OF AMBITION

- New Avionics: future space avionics able to be used in space
- ESROCOS-compliant: ESROCOS will be extended to support the Xilinx Ultrascale+ platform, is also the baseline for the ICU developed by OG4
- Building block integration (OG1-OG4)
- Separation of criticality
- Planning improvements for over-subscription
- Two different Scientific agents, using raw images from both THR and HRES cameras
- Long-range traverse capabilities, based on an improved guidance algorithm
- Improved resource to increase mission planner robustness to unexpected events and terrains
- Rover Manipulator Motion Planning component
- Training of the scientific agents via existing image databases
- Improved OG3 capabilities
- Soil navigability estimation
- Realistic Ground Control segment equipped with Mixed- initiative planning system
- Nuclear scenario

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THANK YOU

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