WE LOOK AFTER THE EARTH BEAT

ASTRA 2015

Andrea Biggio

DESIGN AND IMPLEMENTATION OF A ROBOT MANAGEMENT FRAMEWORK AND MODULAR GNC FOR ROBOTIC SPACE EXPLORATION

VALIDATION AND VERIFICATION OF MODULAR GNC BY MEANS OF TAS-I ROBOT MANAGEMENT FRAMEWORK IN OUTDOOR ROVERS EXPLORATION FACILITY

13/05/2015

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Contents

- Thales Alenia Space Italia Expertise in Robotics
- STEPS2 Project
- Robot Management Framework
- ROvers eXploration facilitY
- GNC and Manipulation

The activities subject of this presentation have been performed in the frame of STEPS program - Systems and Technologies for Space Exploration - a research project co-financed by Regione Piemonte (Piedmont Region) within the Phase 2 of P.O.R. - F.E.S.R. 2007-2013 EC program.

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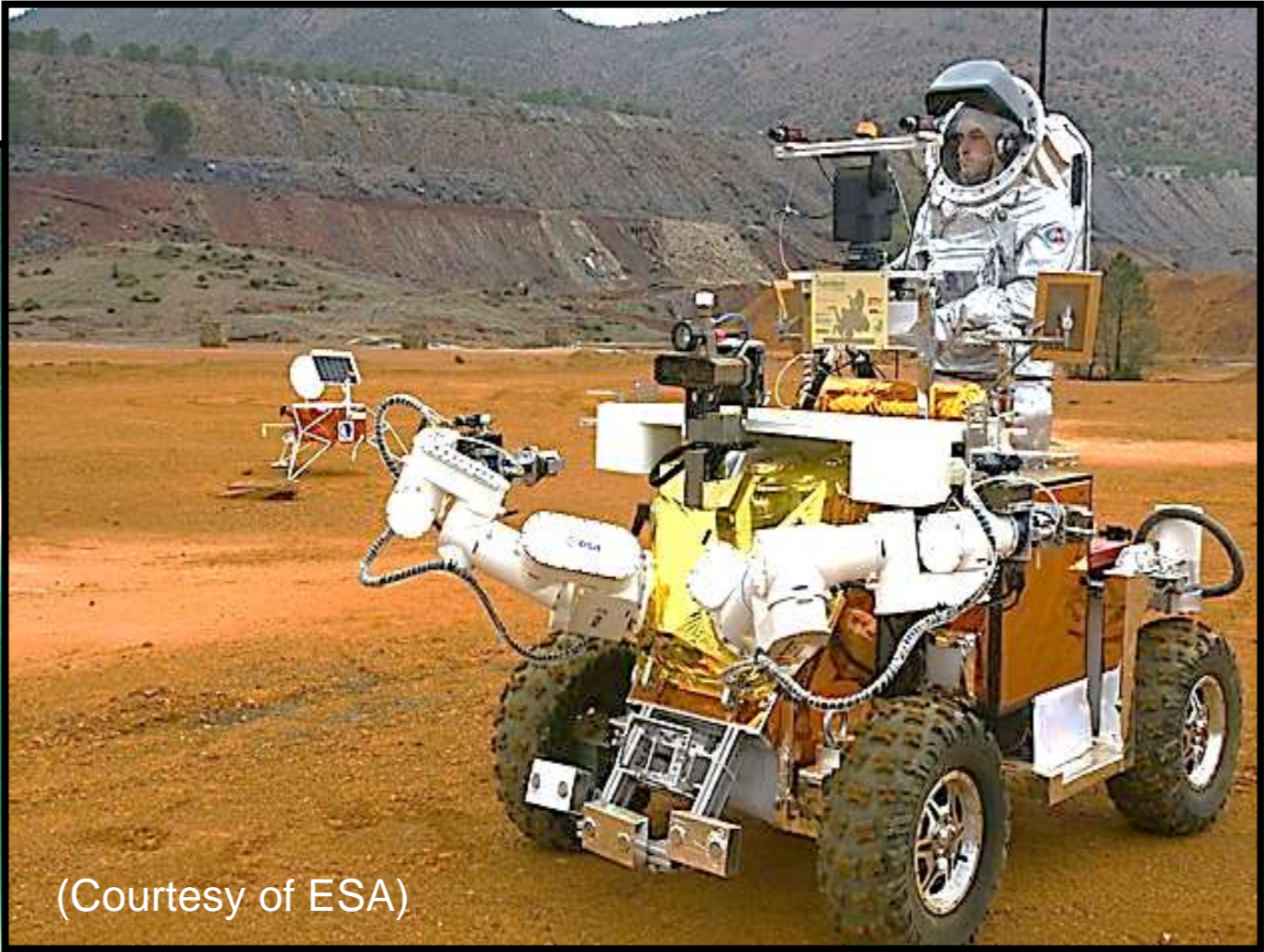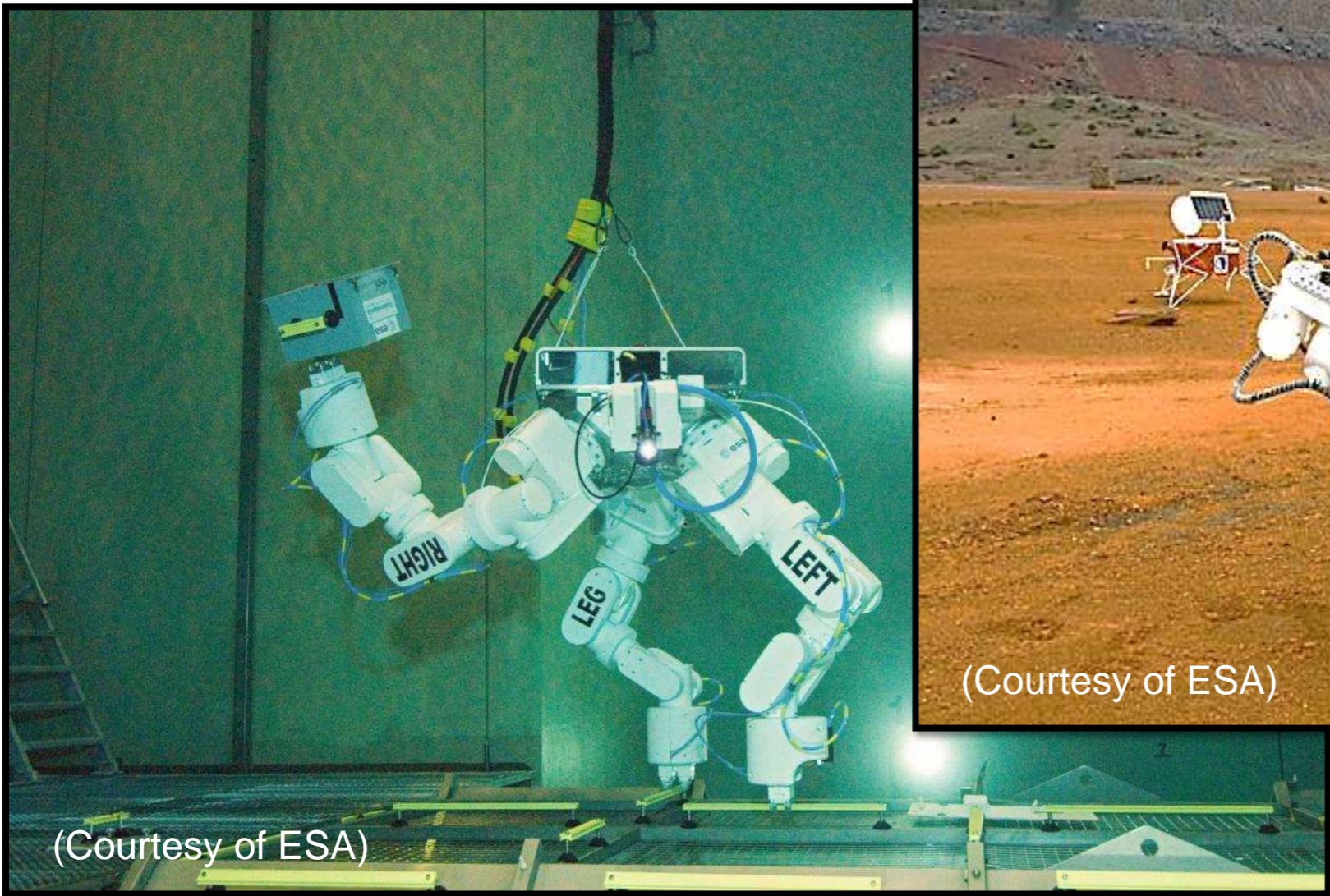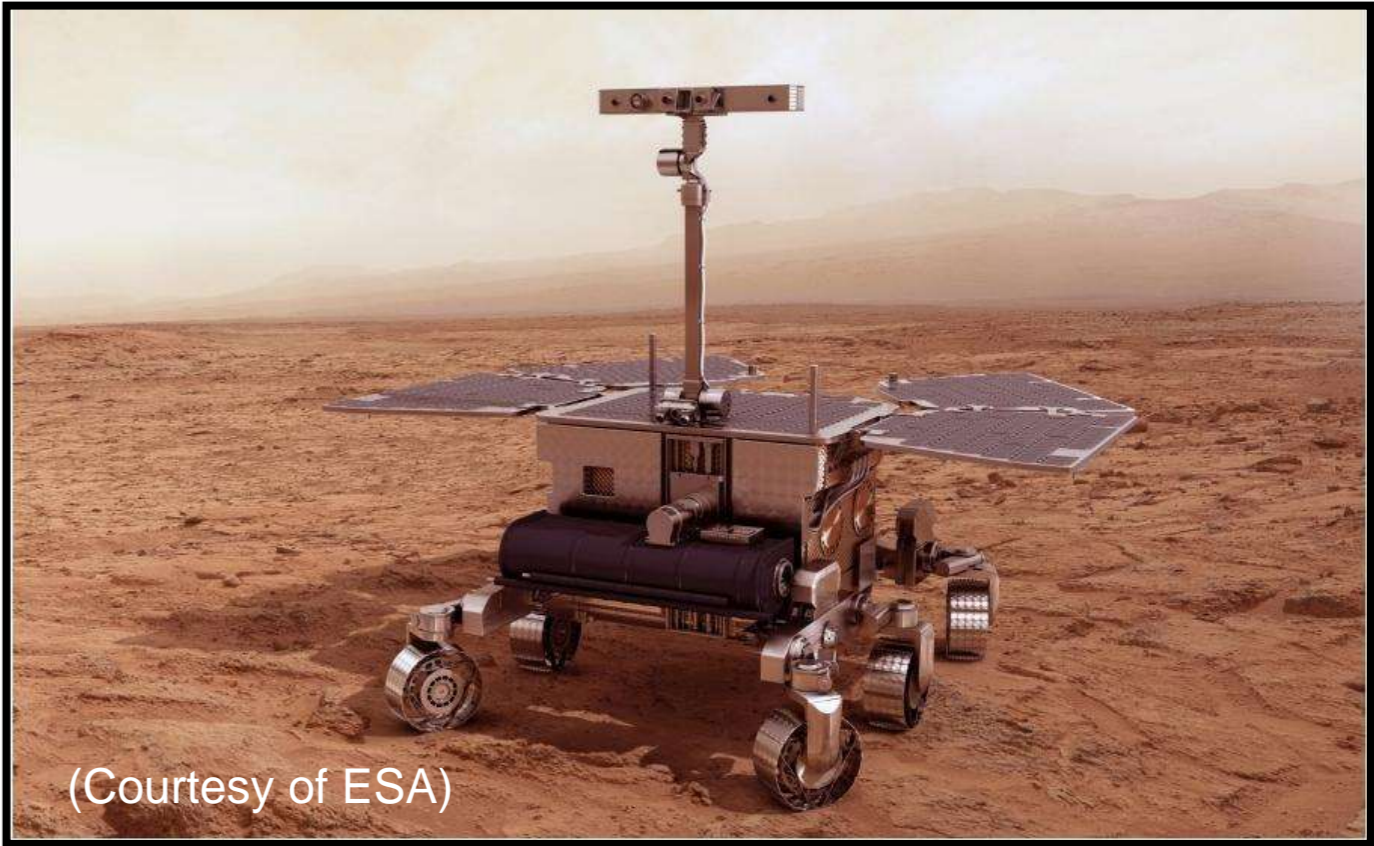# Thales Alenia Space Italia Expertise in Robotics

(Courtesy of ESA)

(Courtesy of ESA)

Eurobot WET and
Ground Prototype
METERON

(Courtesy of ESA)

Exomars
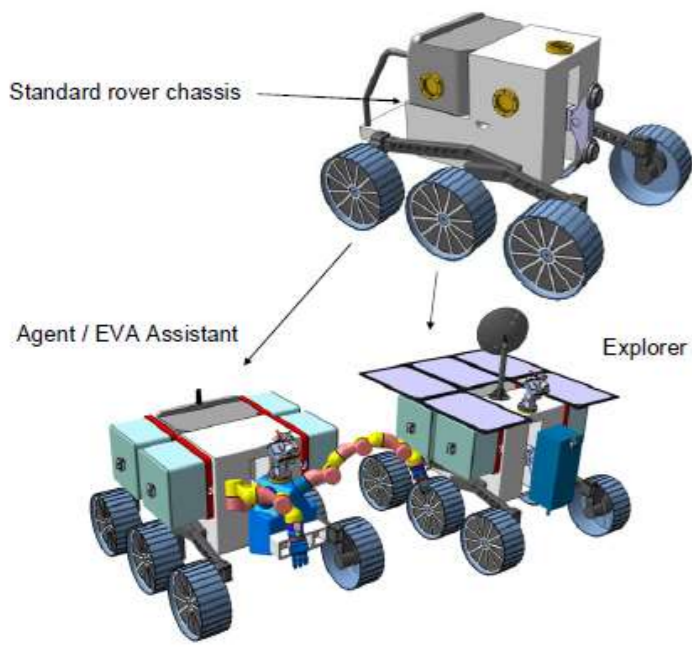
Advanced Robotic Concepts,
Technology studies
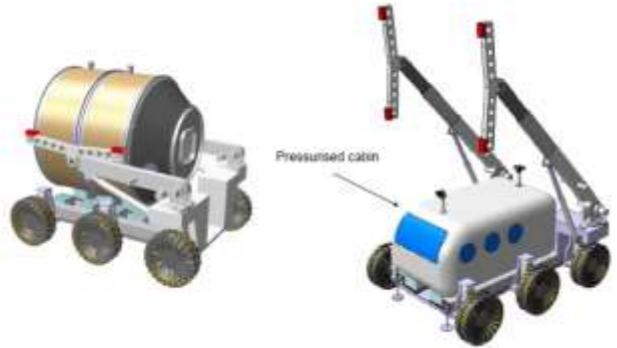
(Courtesy of ESA)

System Studies (Sample
Fetching Rover,
Phootprint, Inspire, …)

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STEPS2: Systems and Technologies for Space Exploration – Phase 2
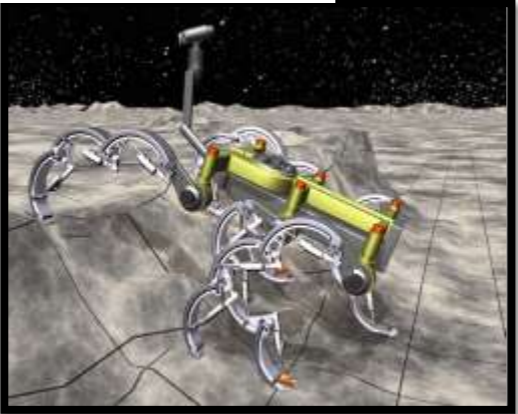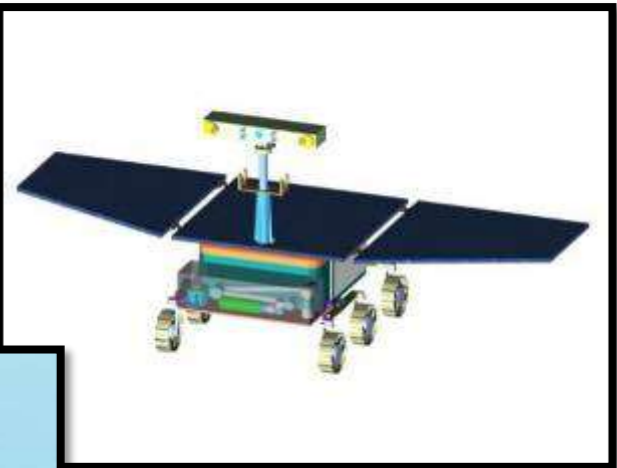
STEPS 2

R&D programme co-funded by EU and **Regione Piemonte** (POR FESR 2007/2013) to **design** target flight hardware, and to **develop** a ground prototype and functional testing

Consolidate Piedmont Aerospace District

To **accelerate** the innovation of aerospace technology within the Region and reassuring its worldwide **excellence**

Technological Development

Continue the technological development in strategic areas with the objective to pass from a TRL 3 to 5/6 in order to be ready for possible **in-orbit validations** in the short-medium term

Technology Transfer

To **ensure** that technological developments are **accessible** to a wider range of users who can then further develop and **exploit**

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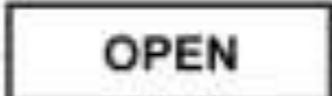
STEPS2 Technologies
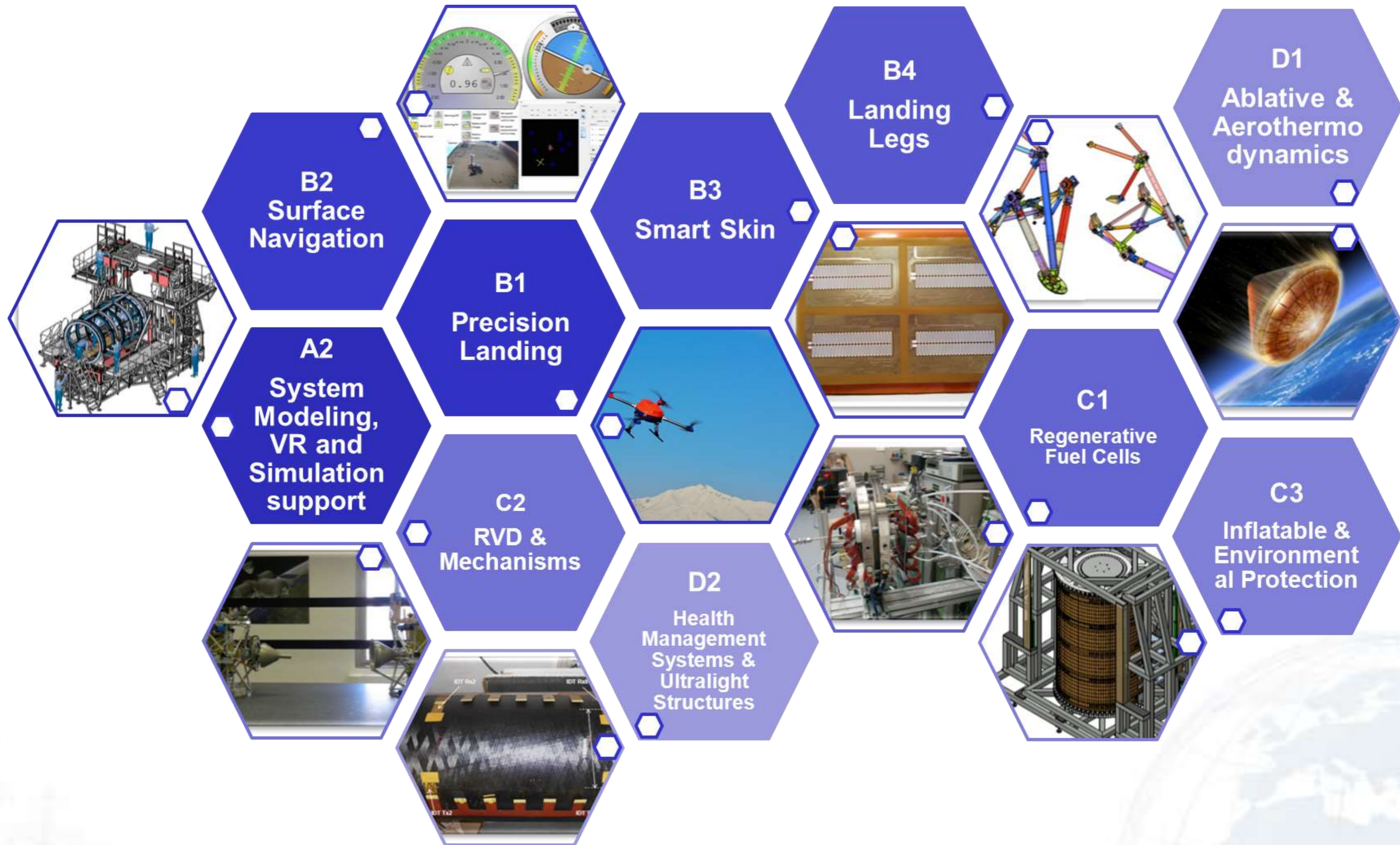
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STEPS2 "Rover Surface Navigation"

- **Reference Mission Scenario:**
    - Sample Canister Identification
    - Traverse/Exploration Phase
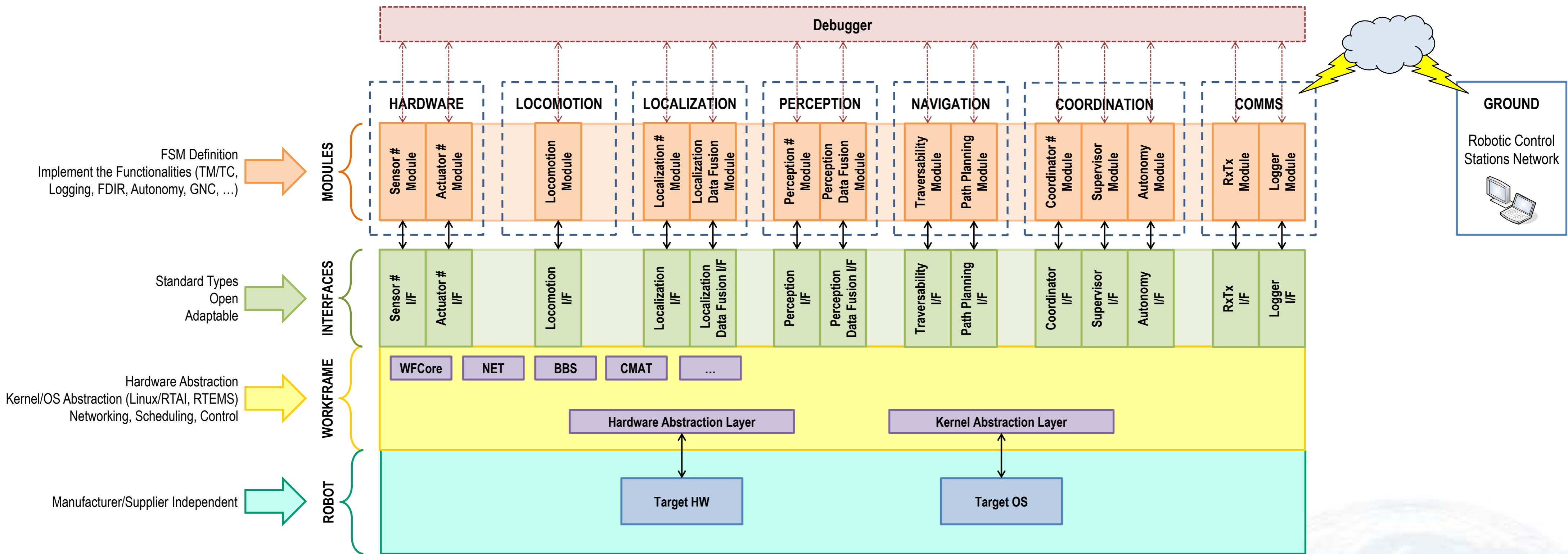   - Sample Canister Acquisition and Storage

- **Key Technologies:**
    - Robot Management Framework
    - ROvers eXploration facilitY
    - Research Robots
    - Modular Robot Control Software

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OpenRTMaist

Orocos

ROS

OPRoS

Orca

CLARAty

Miro

Marie

?

GenoM

OpenRDK

RCSA

Microsoft RDS

ERSP

RoCK

Webots

RoboFrame

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Robot Management Framework – Architecture

Integration, Validation and Verification of Robotic Technologies and Algorithms.

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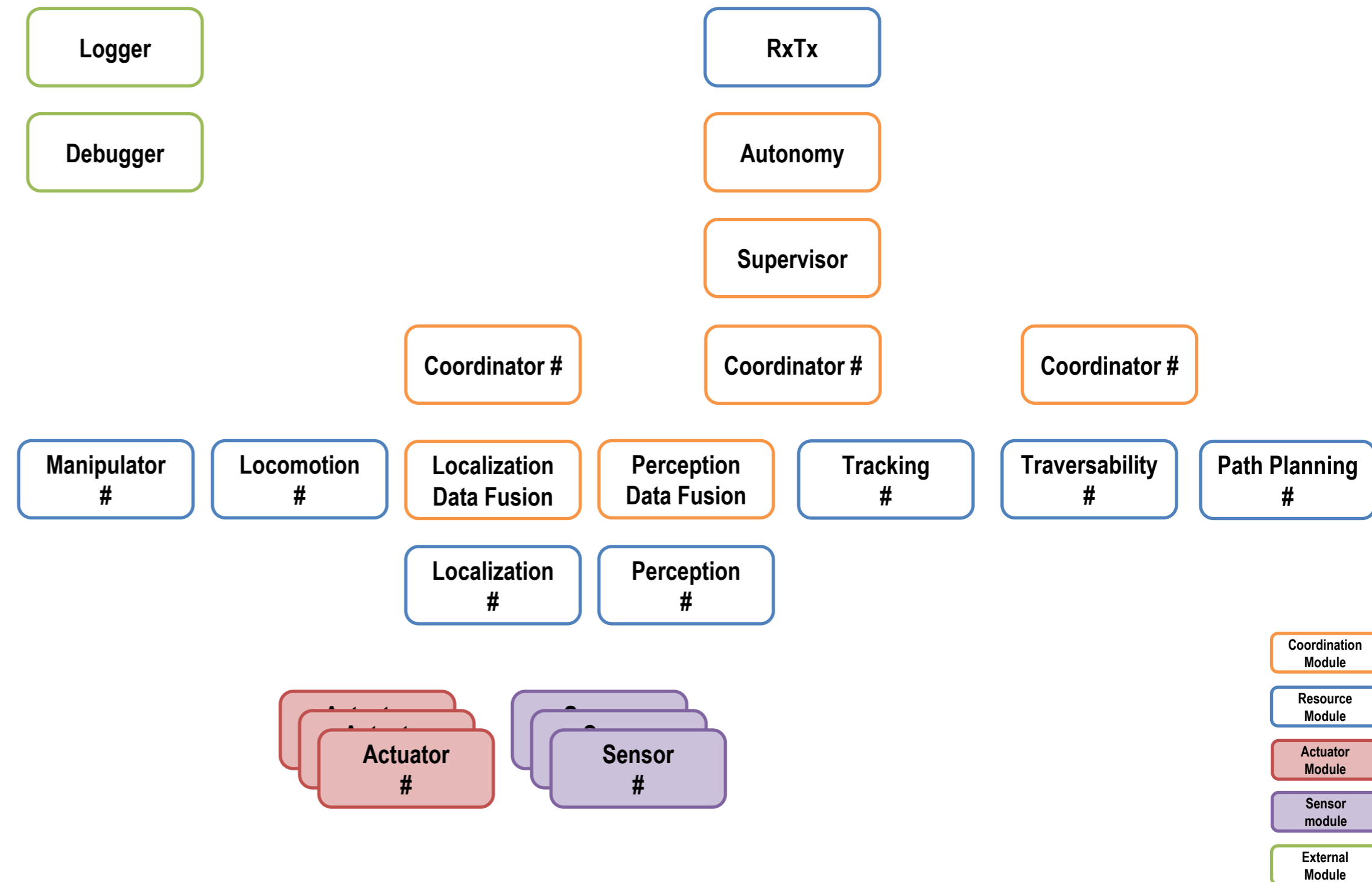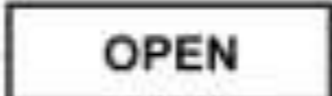OPEN

- 5 Modules Types:
  - Resource Modules
  - Coordination Modules
  - Actuator Modules
  - Sensor Modules
  - External

- Modules hierarchy is deployed according to the Robotic system complexity

- Modules can be deployed on local and remote machines

Modularity, Scalability

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Robot Management Framework – Modes FSM

- **Operational Context:**
  - DryRun, with simulated Hardware
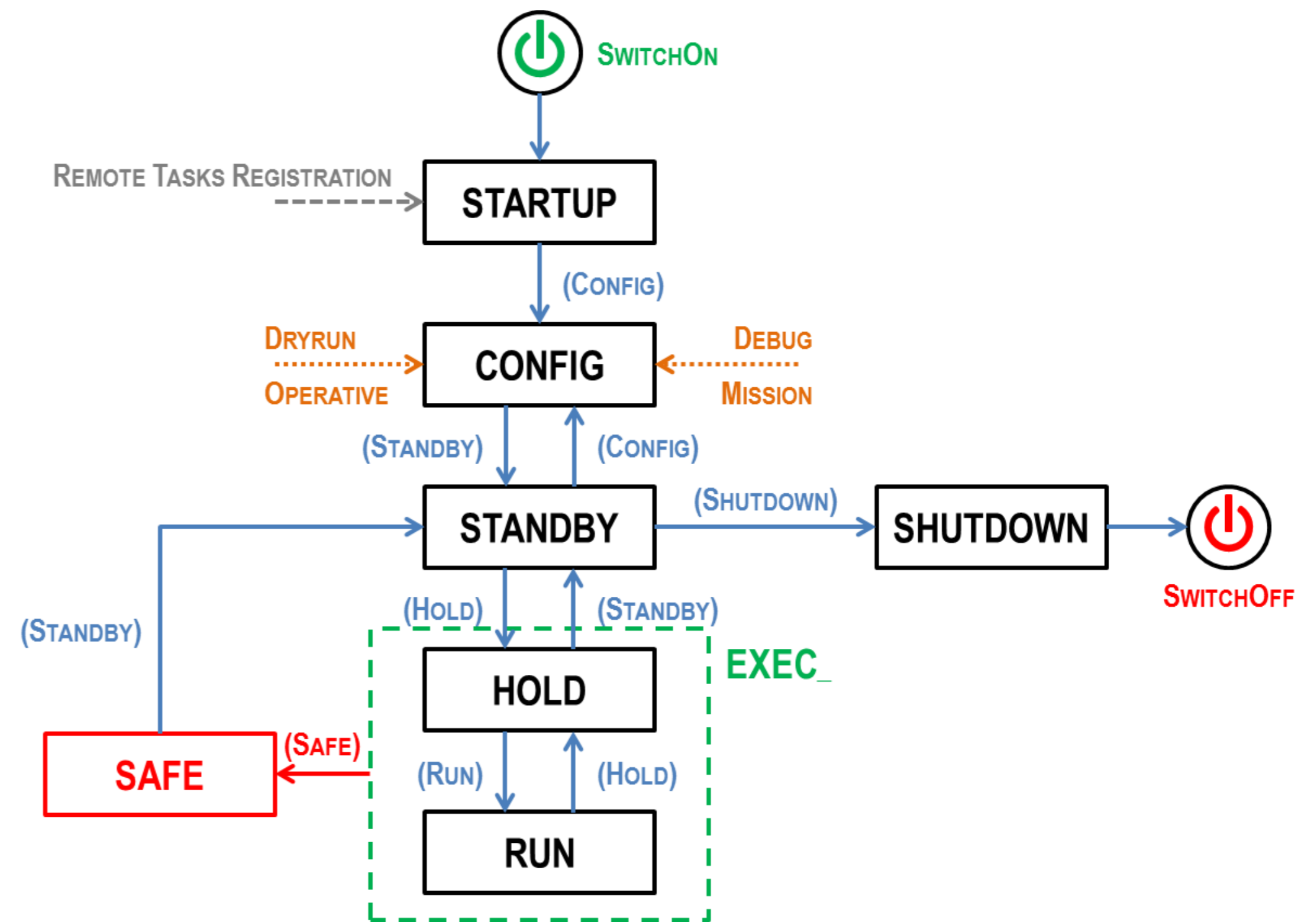 - Operative, with Hardware-in-the-loop
- **Execution Context:**
  - Debug
    - Debug Version of Modules states are used
    - Debugger module is active to inject failures into the system
  - Mission
    - Release version of the Modules states are used
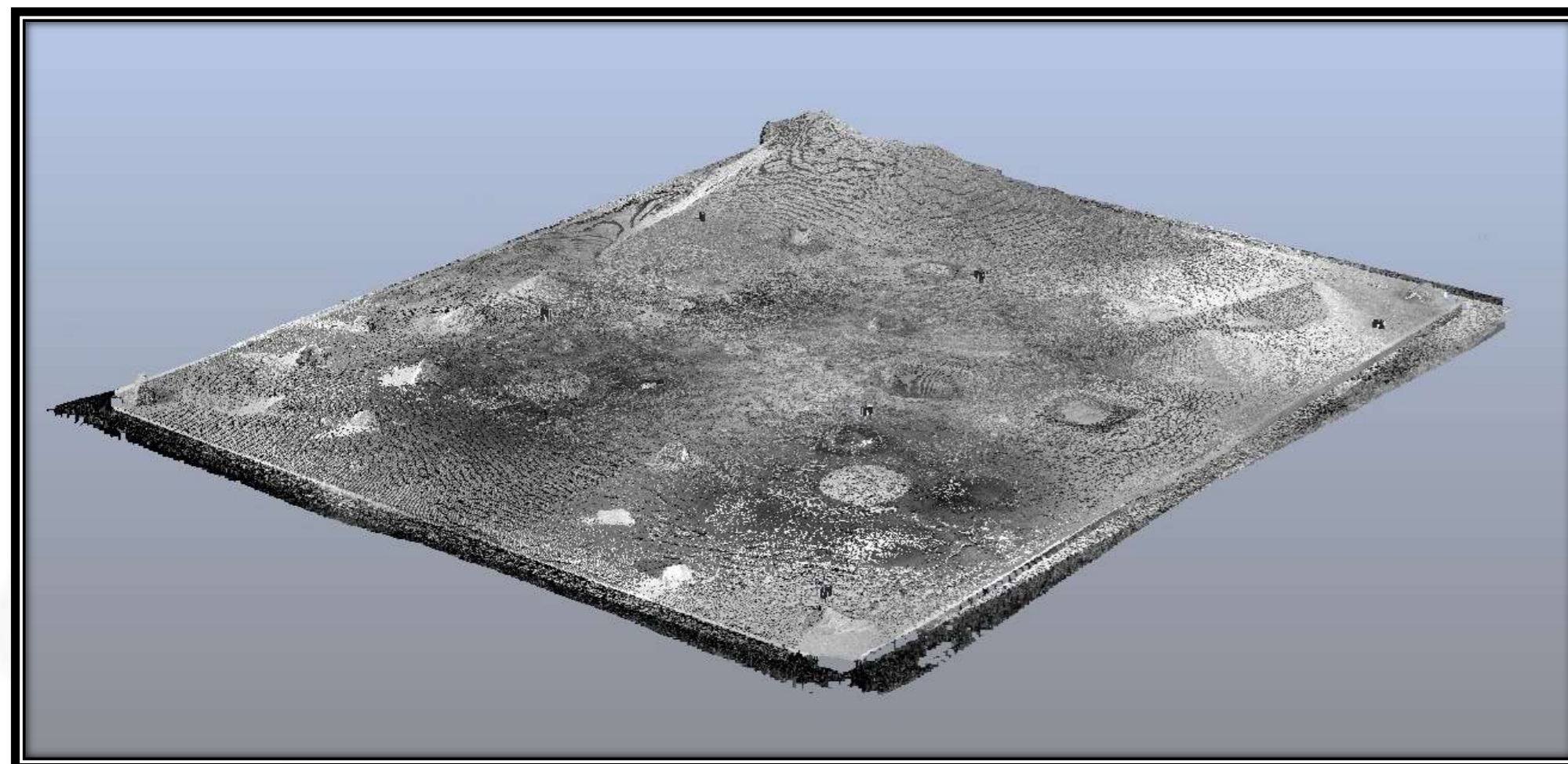   - Debugger module is inactive

RunTime Re-Configuration, FDIR, Mission Rehearsal and Validation

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ROvers eXploration facilitY (ROXY) – Area

- ~400 m^2 terrain playground reproducing visual and morphology characteristics of a Mars area (reconfigurable)

- Workshop and Control Room hosted in Deployable Office Boxes

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ROvers eXploration facilitY (ROXY) – Research Robots
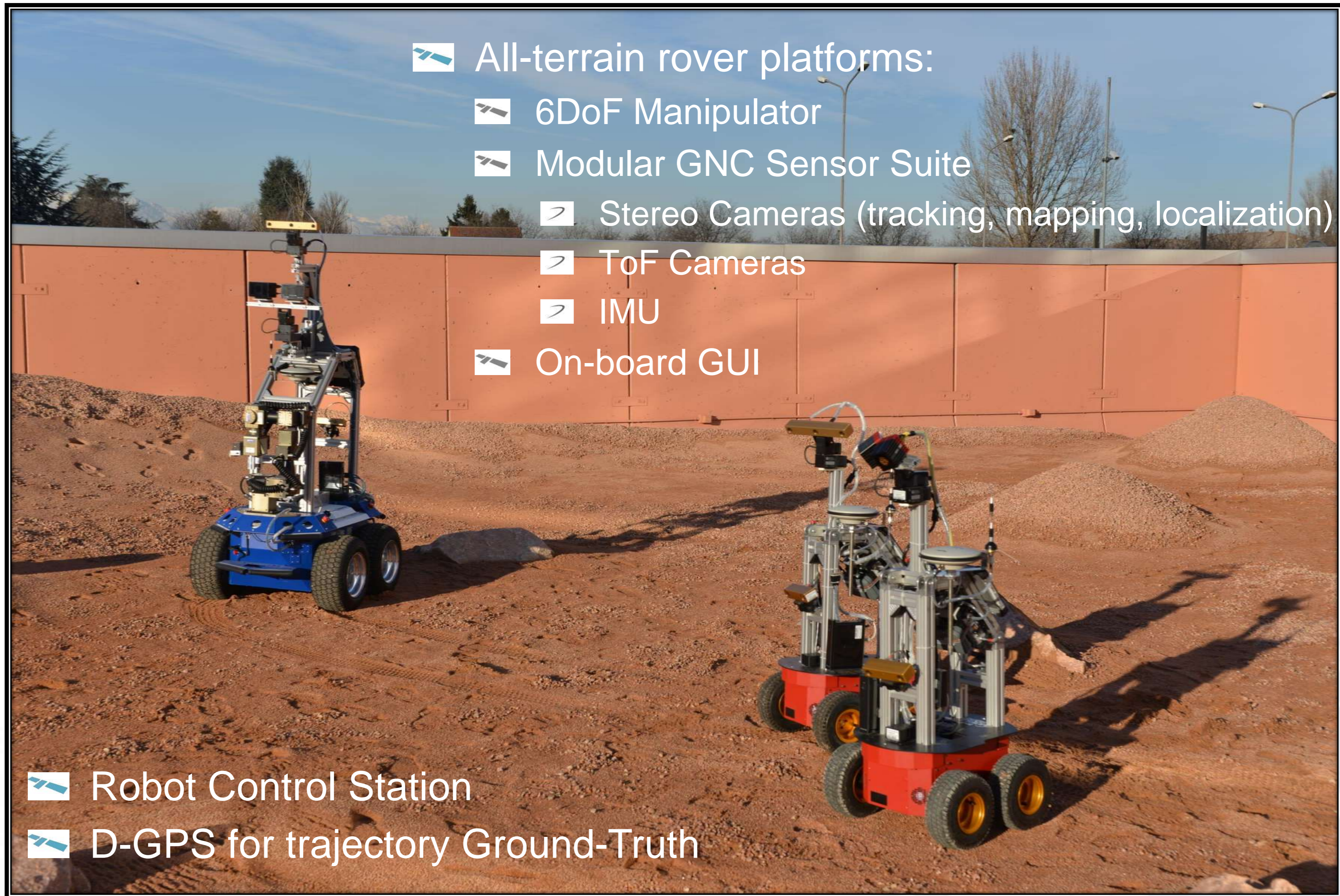
- All-terrain rover platforms:
  - 6DoF Manipulator
  - Modular GNC Sensor Suite
    - Stereo Cameras (tracking, mapping, localization)
    - ToF Cameras
    - IMU
  - On-board GUI

- Robot Control Station
- D-GPS for trajectory Ground-Truth

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GNC – Continuous Navigation

- Perception in motion
- DEM and NavMap Generation
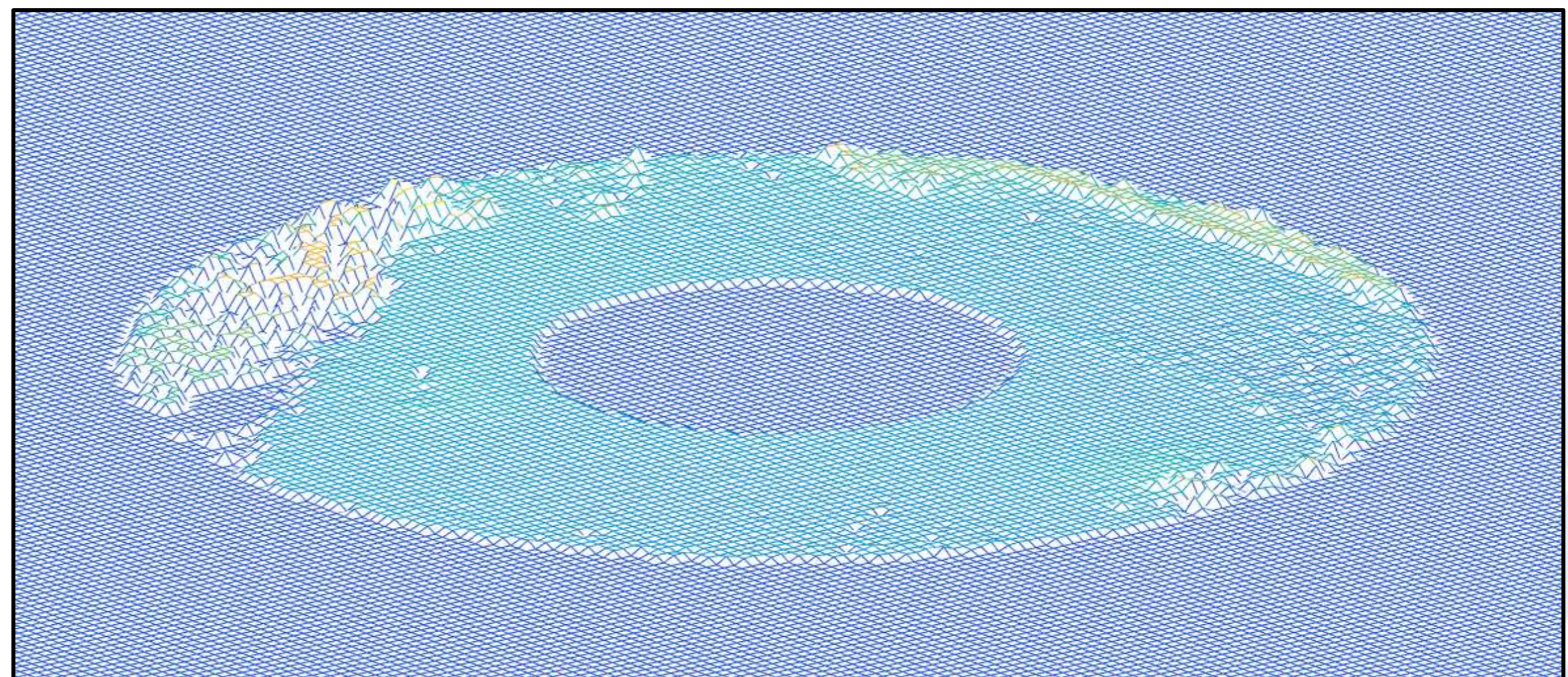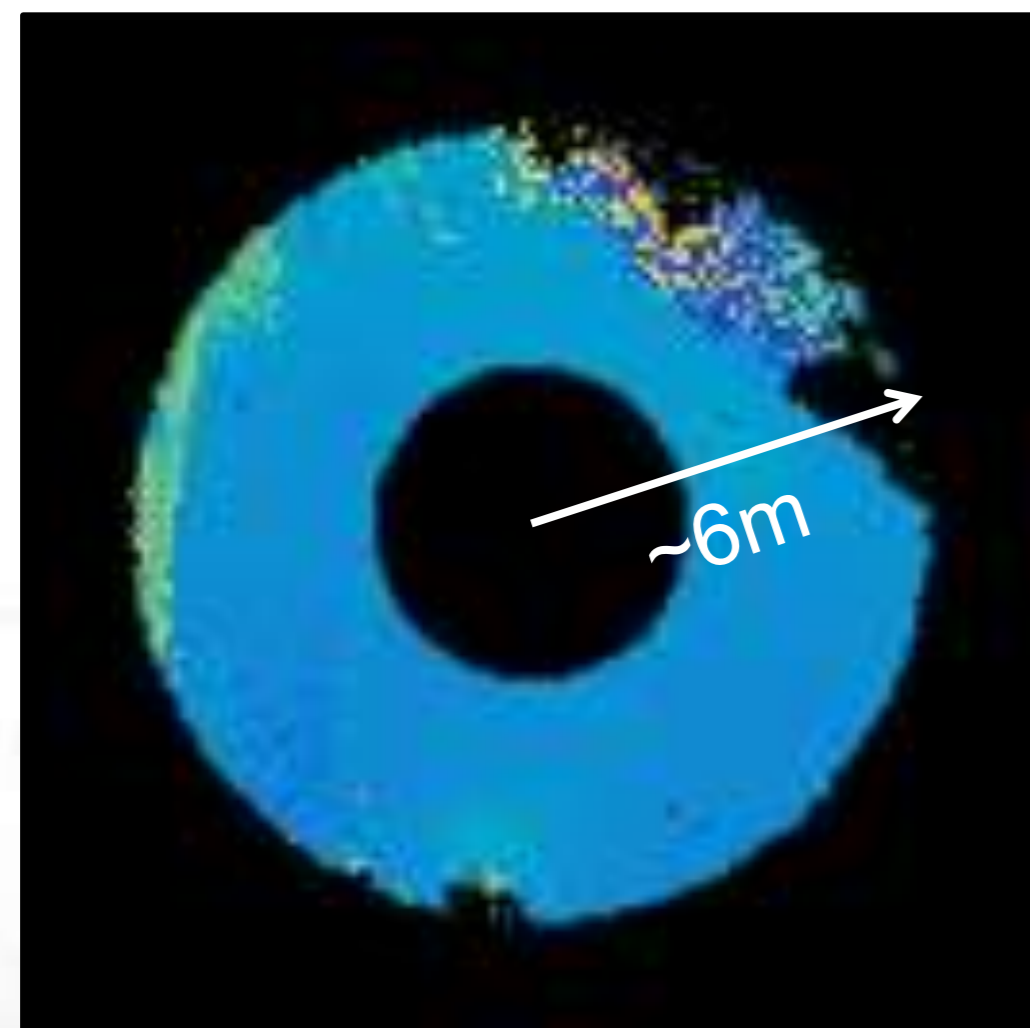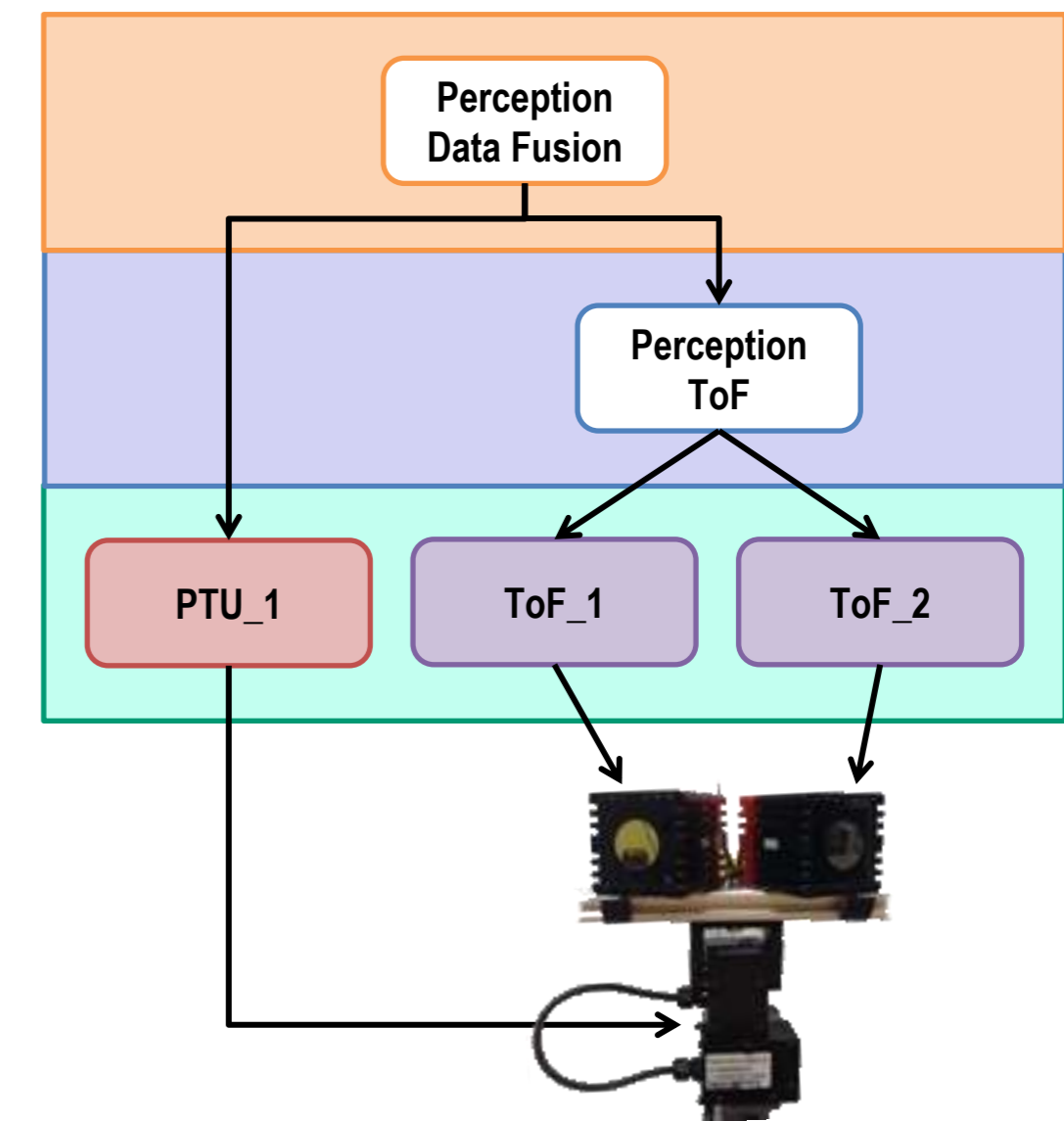- Fast Path Planning / Re-Planning
- Reliable Localization
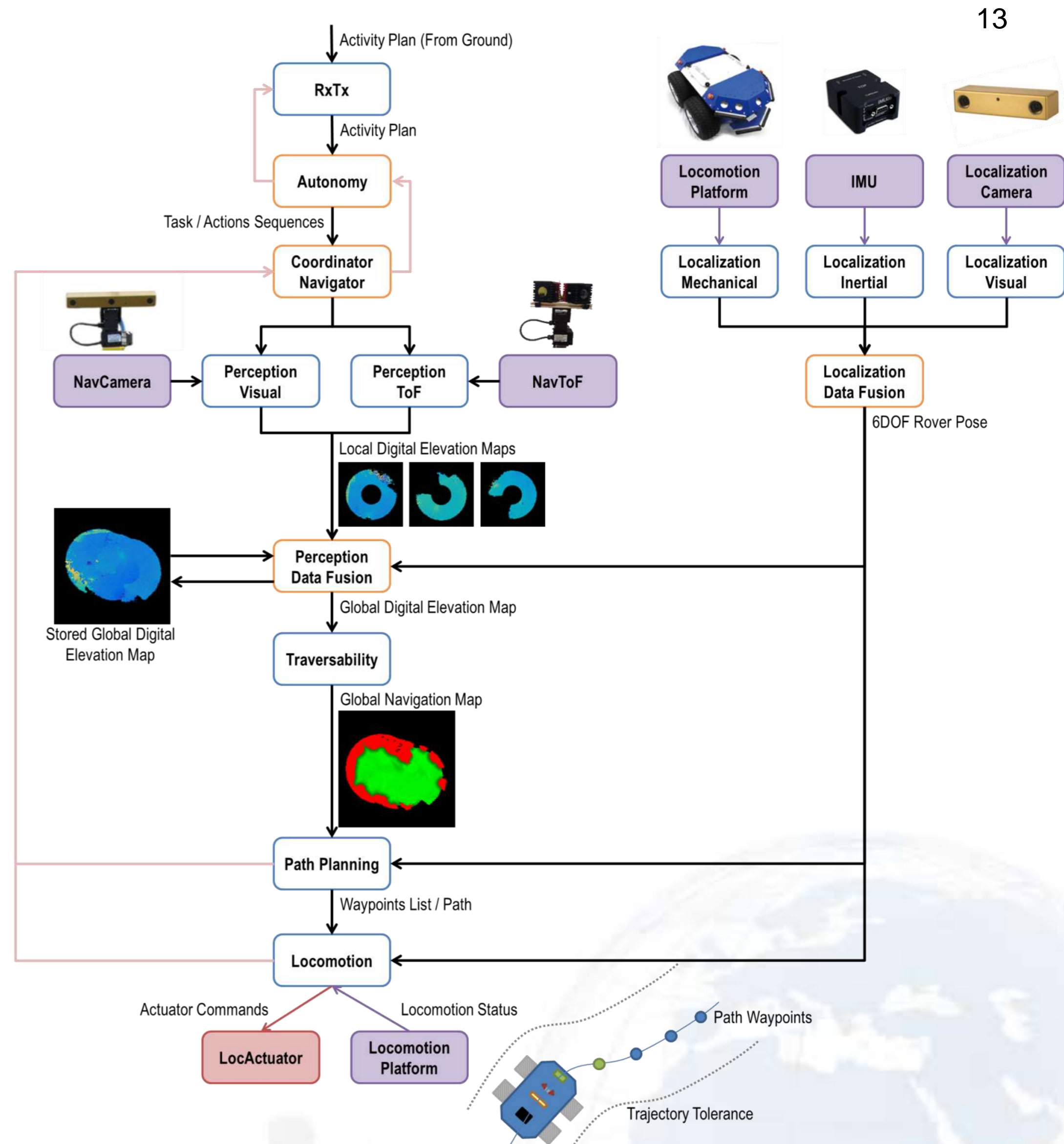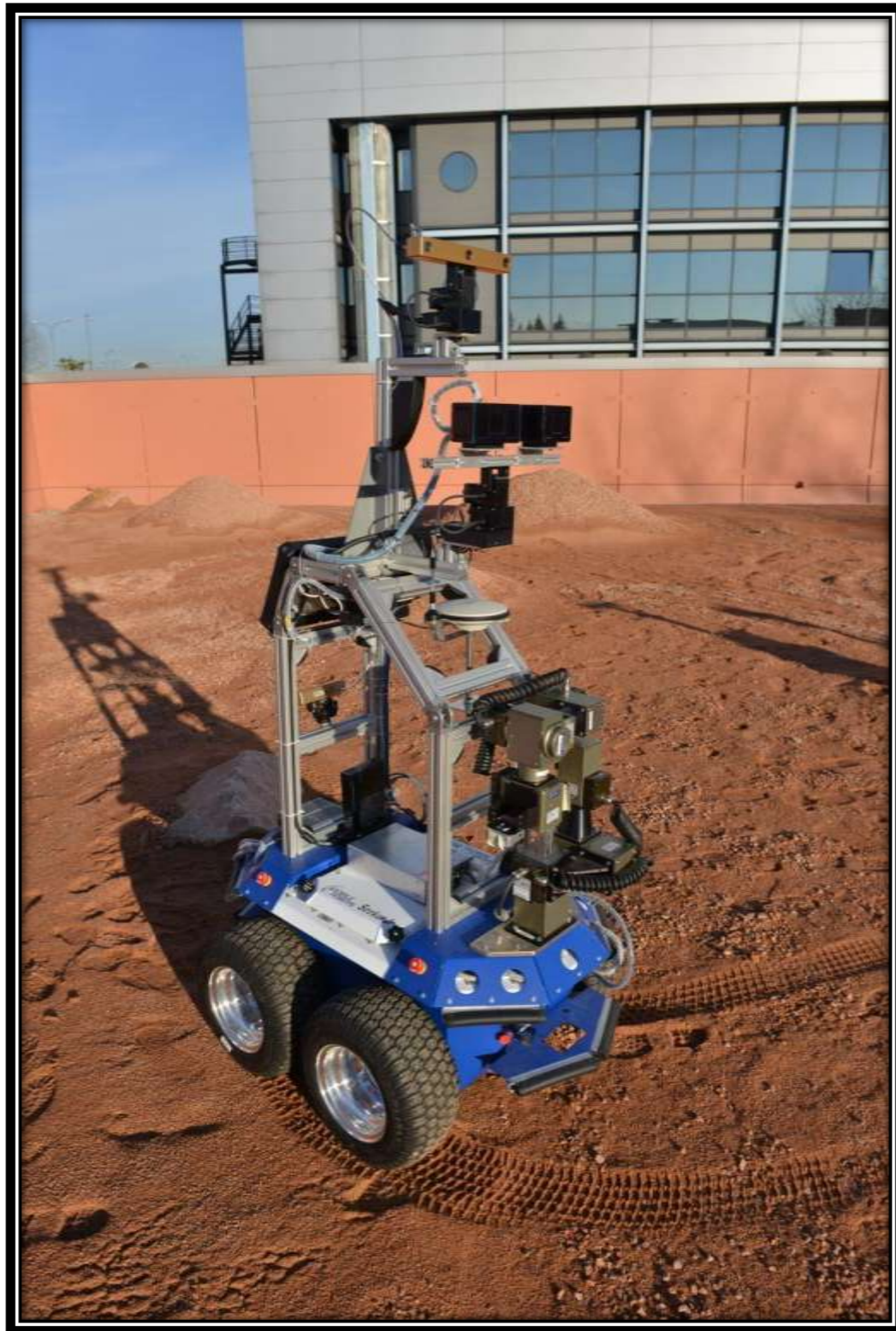
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GNC – DEM Generation with Double ToF Sensor

- ⤳ Multiple Point Cloud Acquisition
- ⤳ Point Cloud Re-Projection
- ⤳ Noise Filtering
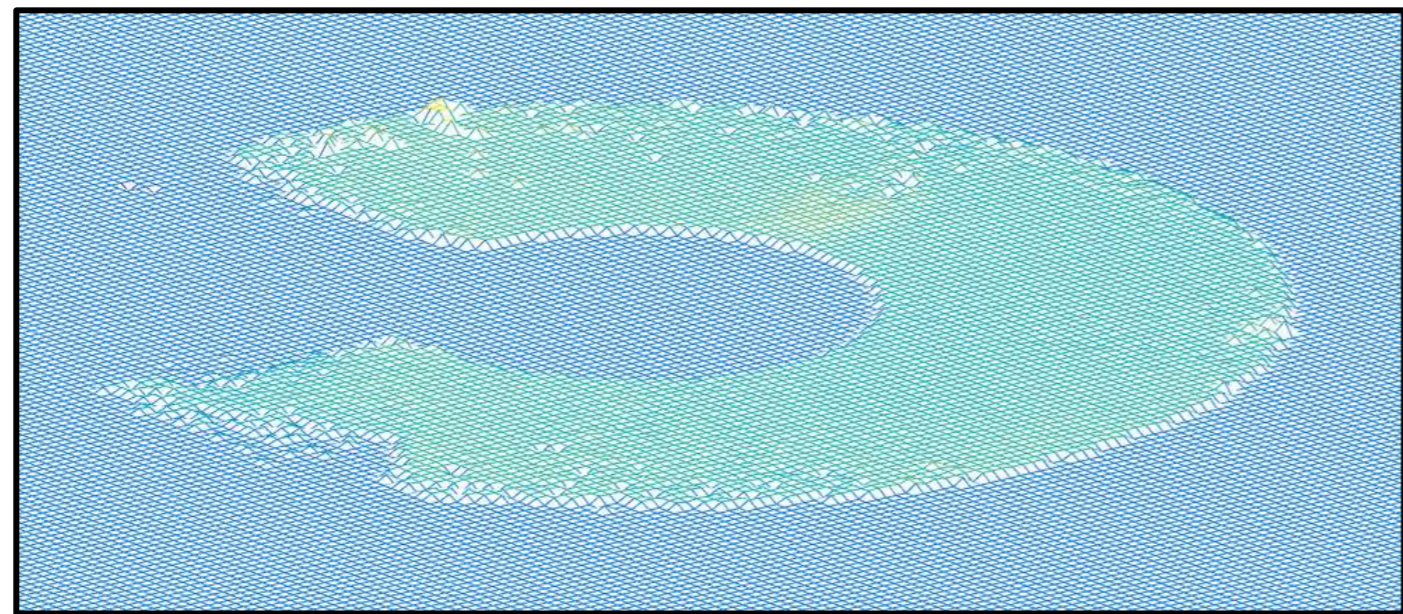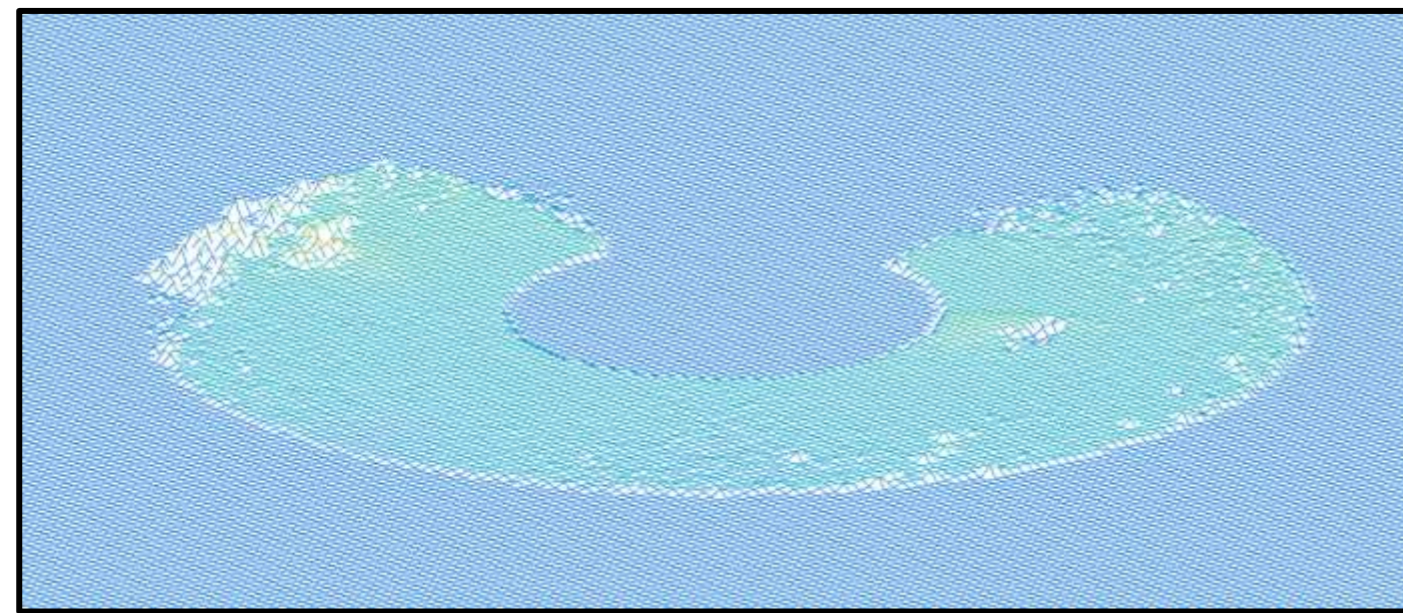- ⤳ Confidence Filtering
- ⤳ Adjustable DEM Spatial Resolution

~6m

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GNC – DEM Fusion

Local DEM 1

Local DEM 2

Local DEM 3
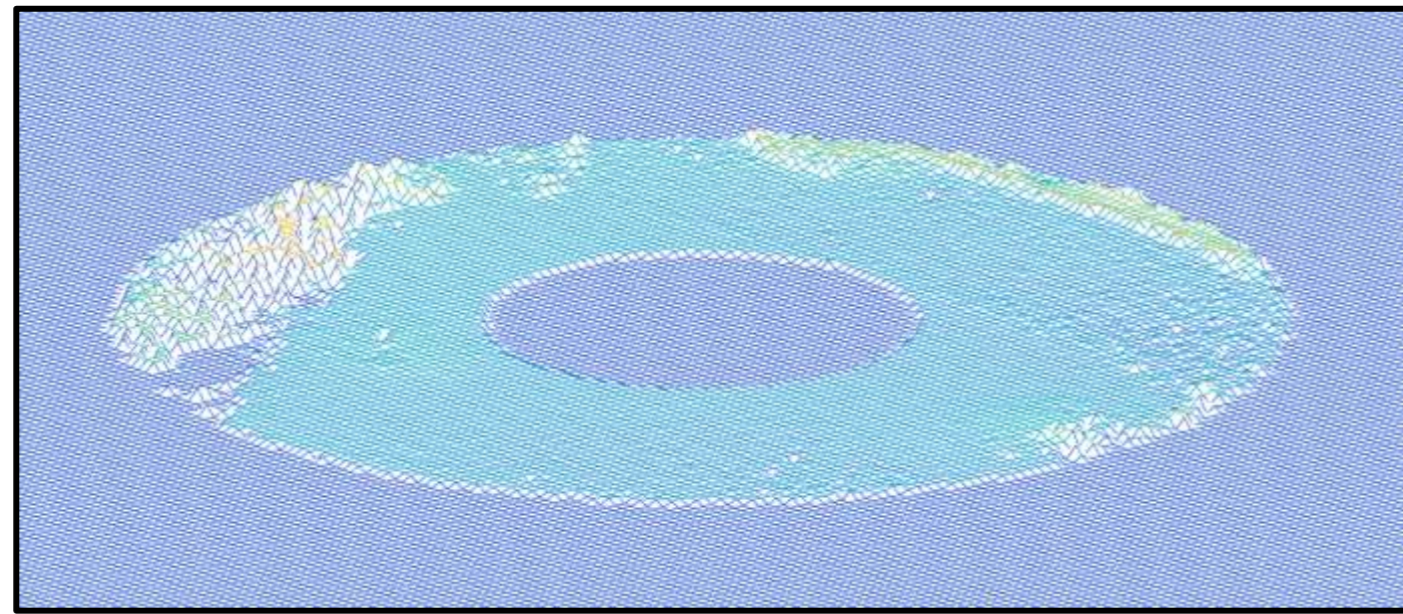
- Merge DEMs from Different Sensors Sources over time
  - Weighted on sensor reliability
- Noise Filtering
- Distant Region Reconstruction
- Robot Occlusion Compensation
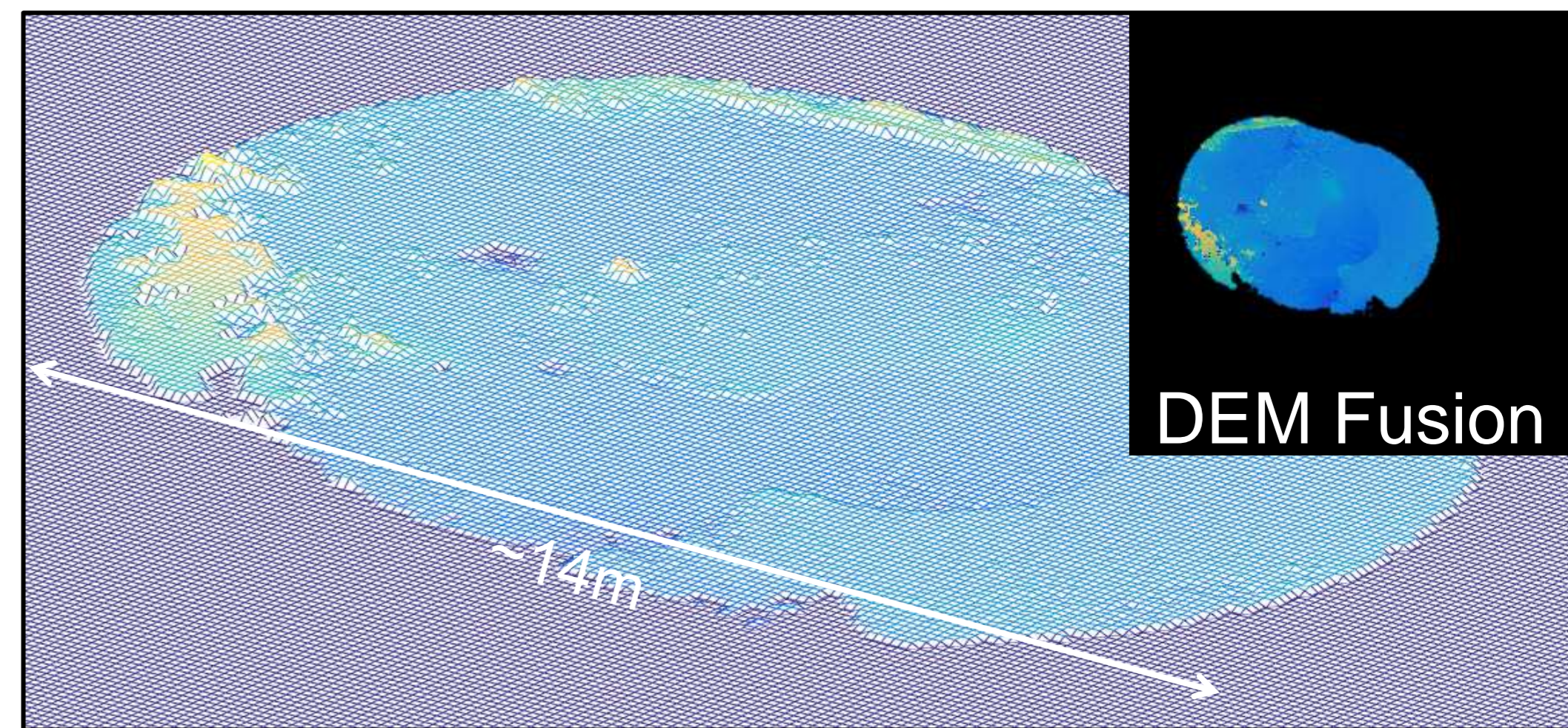
DEM Fusion

~14m

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GNC – Relative Localization

- Localization Data Fusion from Wheel Encoders + IMU + Visual Odometry

- Visual Odometry based on Stereo Vision and OpenSource Libraries

- Tests Results:

  - Synthetic Data Set: overall 6D accuracy better than 2%

  - ROXY outdoor facility: overall 6D accuracy better than 5%
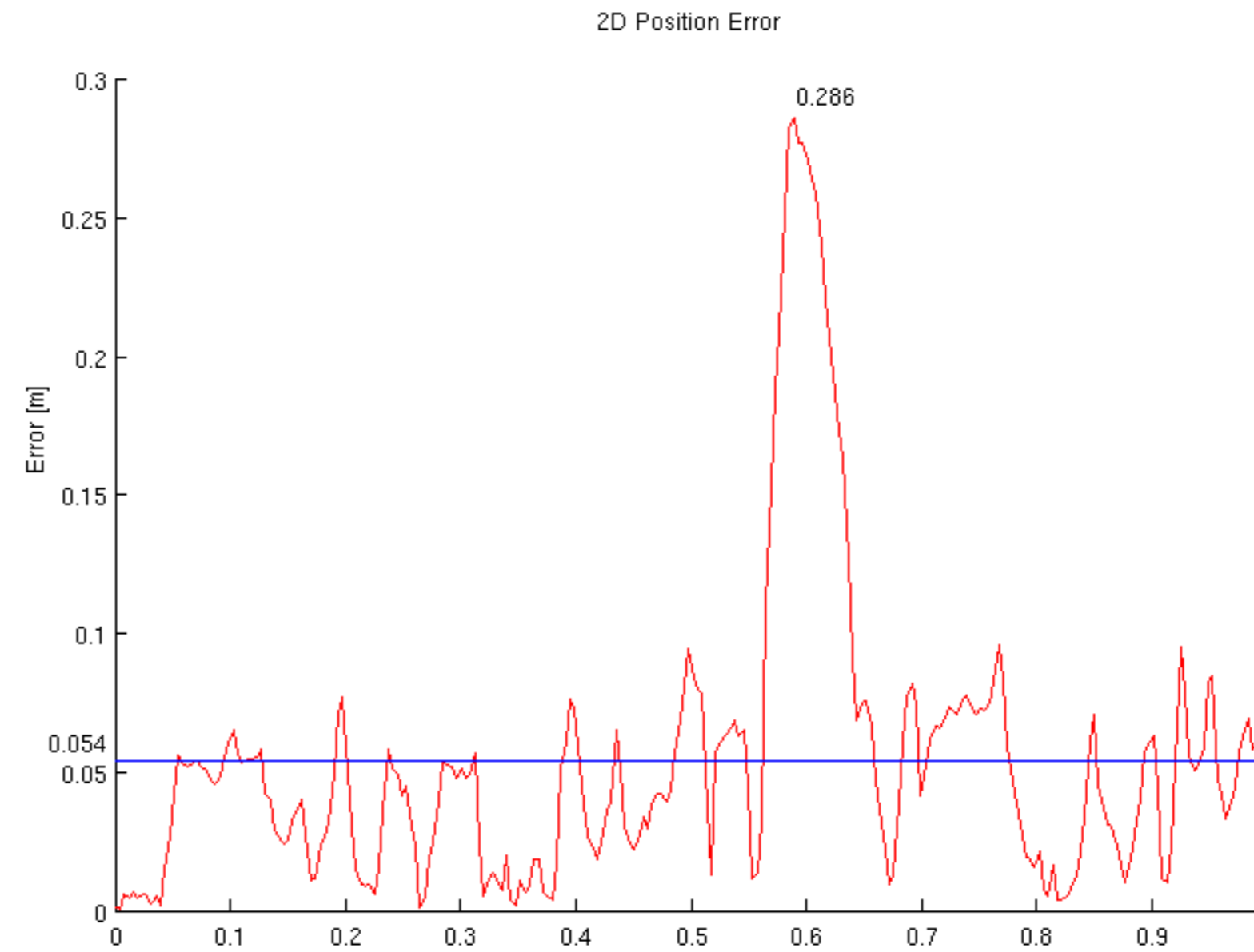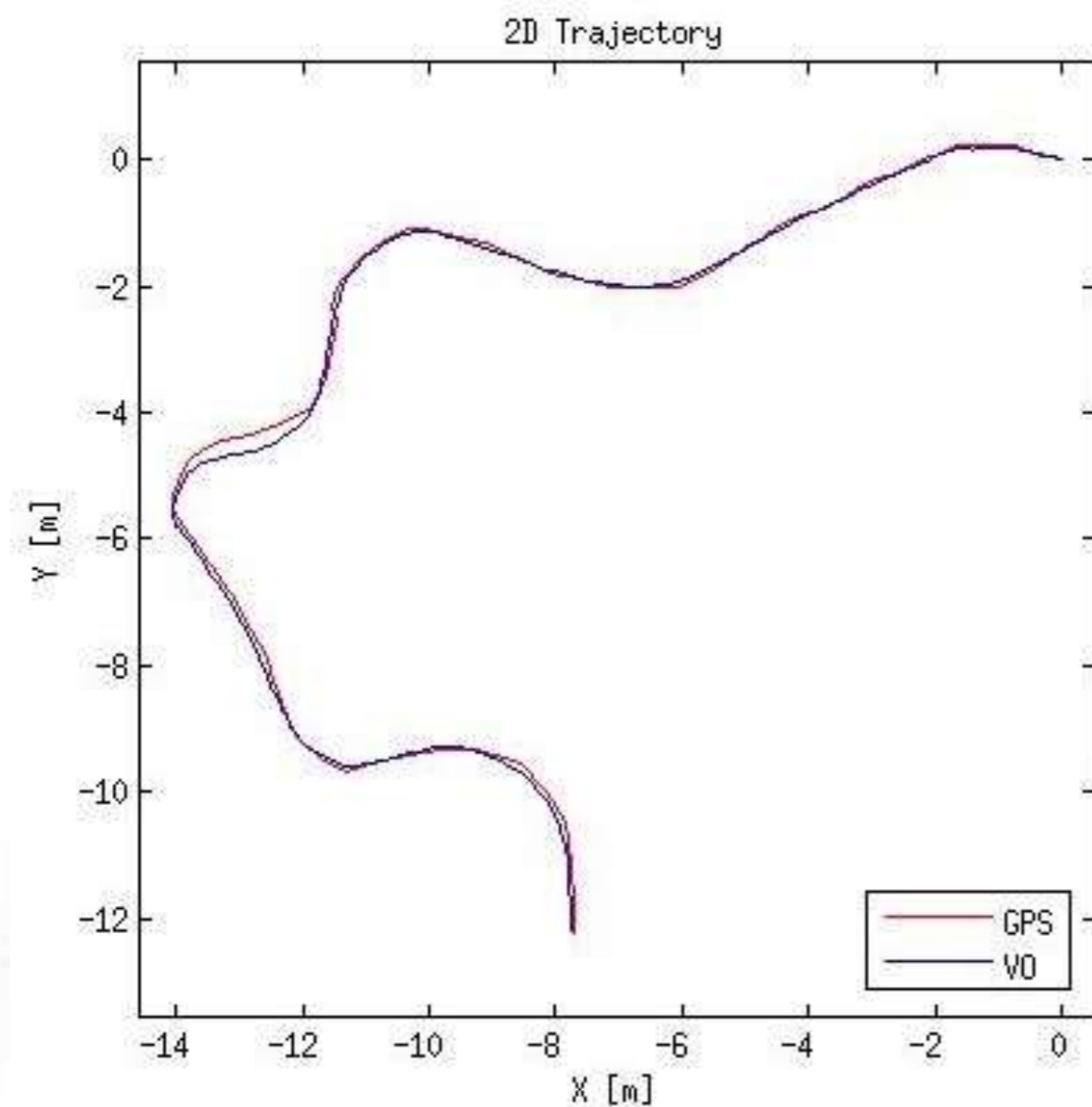
2D Trajectory

2D Position Error

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GNC – Visual Tracking

- Track a selected object in the scene
- Monocular Vision for 2D tracking
- Stereo Vision for 3DOF position estimation
- Machine Learning algorithm to build object model

- Use Cases:
  - Rover Guidance
  - Localization w.r.t an unknown object
  - RDV&D (medium range)
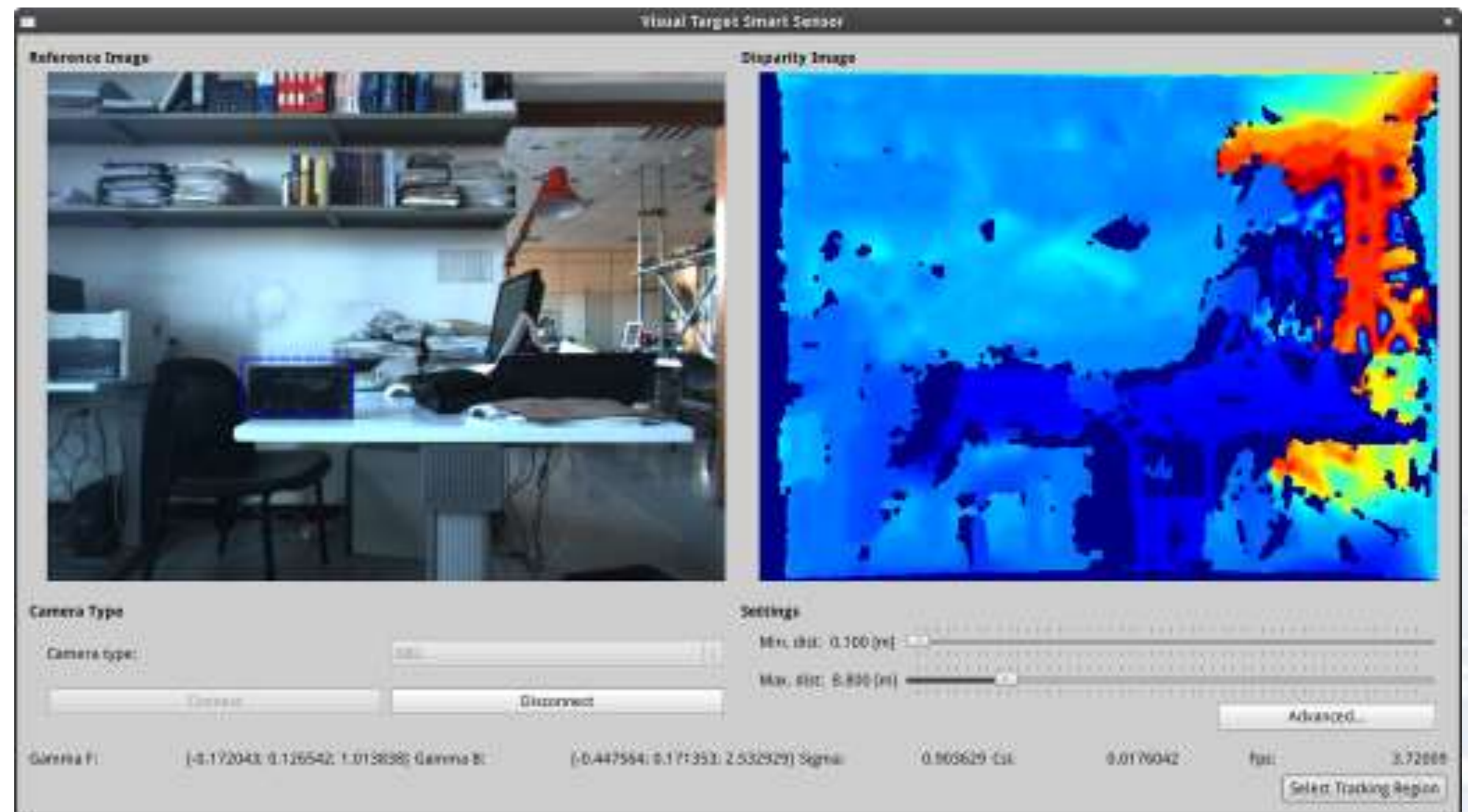
Visual Target Tracking GUI

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GNC – Marker Tracking

- Track Single or Multiple Marker Tables
- 6DOF Pose Estimation

- Use Cases:
  - Visual Servoing
  - Rover Guidance
  - Localization w.r.t. a Known Object (e.g. Lander, Rover)
  - RDV&D (Short Range)

Marker Tracking GUI

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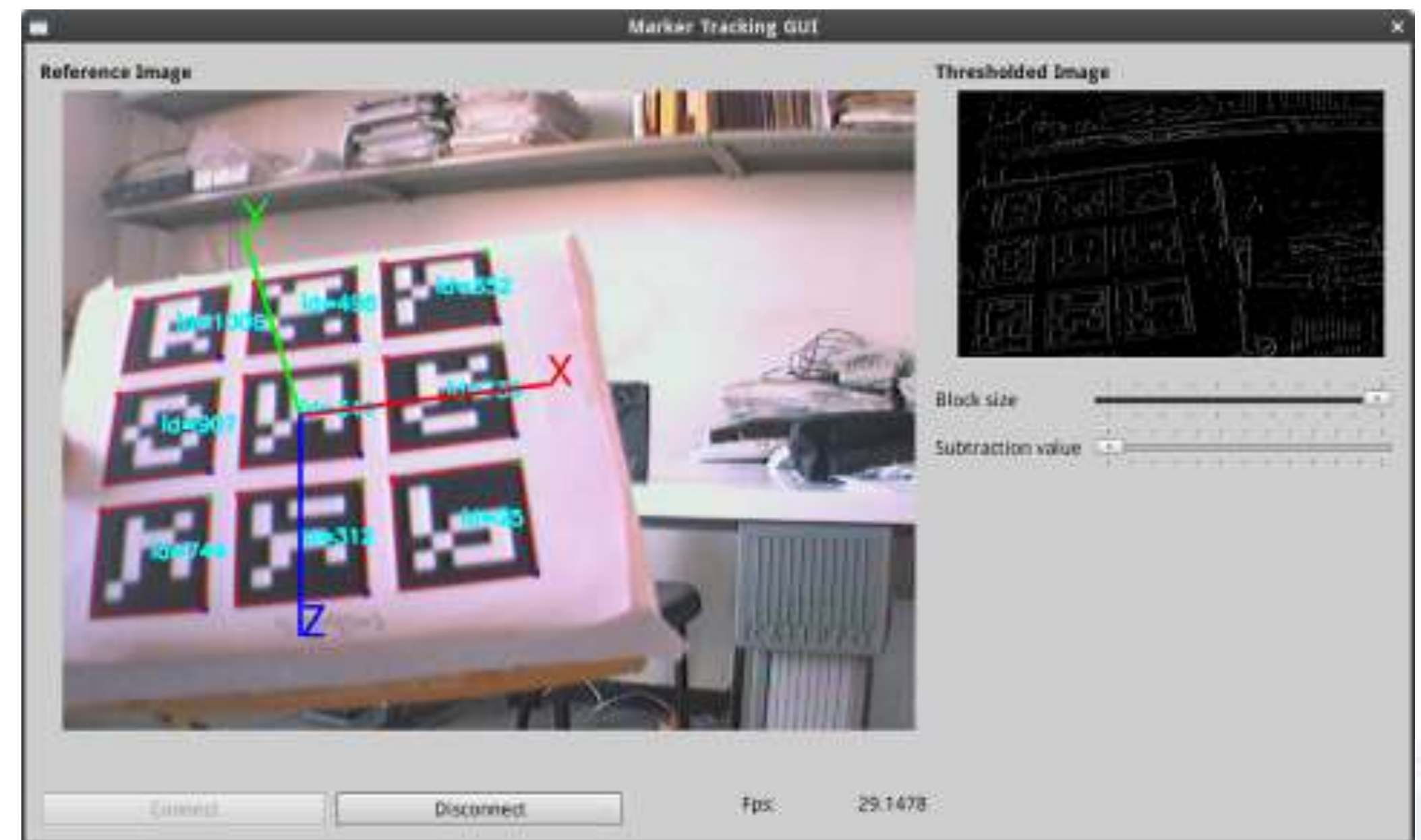
Manipulation – Visual Servoing

- Uses the visual feedback of marker tracking to control the arm approaching an object

- Use Cases:

  - Sample/Object Identification and Handling

  - Structured Environment Interaction (e.g. lunar infrastructures maintenance)

  - RDV&D Capture/Berthing Phase

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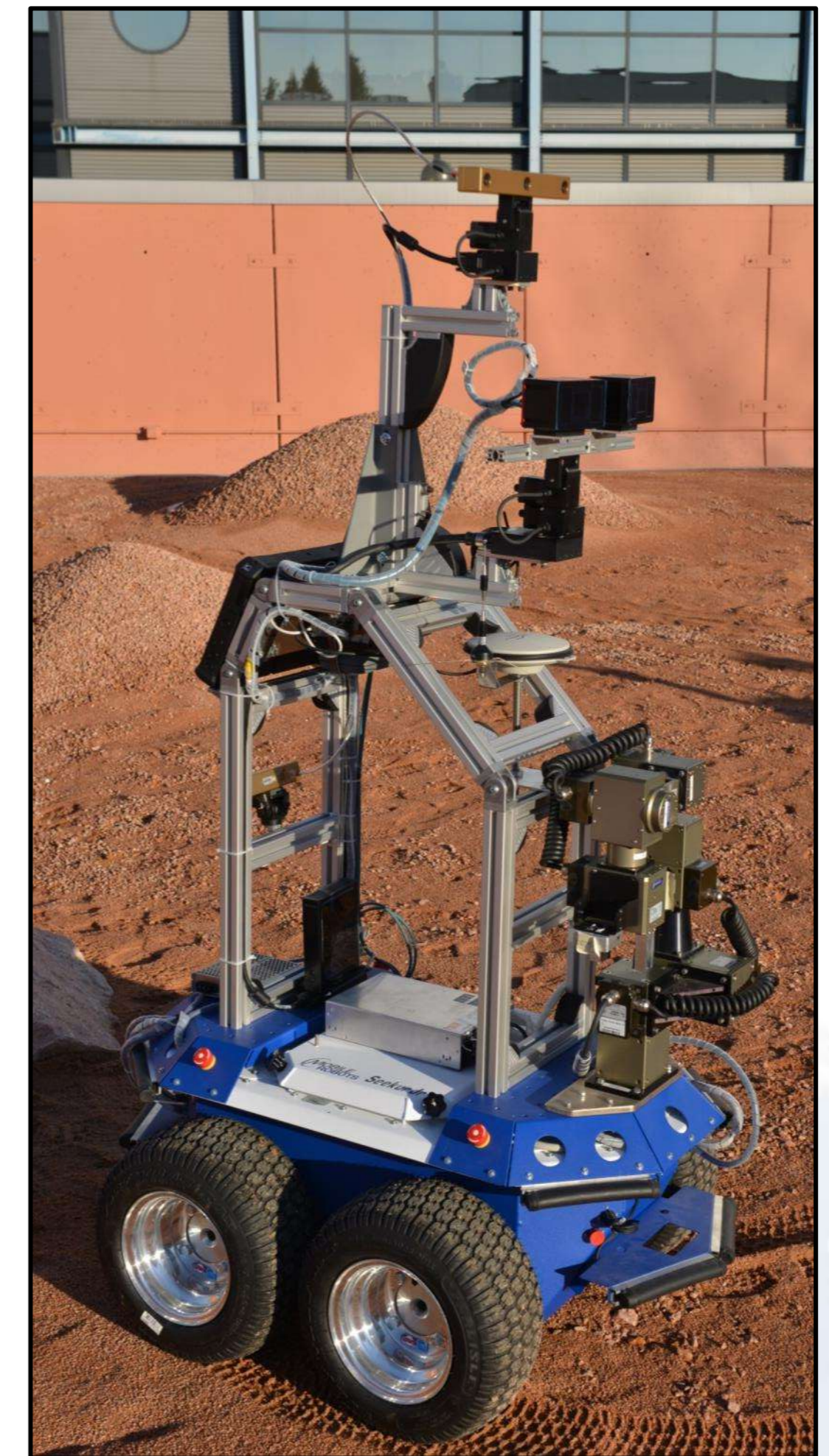
STEPS2 Robotics Team – Thank You

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Contacts and References

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➤ Geiger A., Ziegler J., Stiller C. (2011), StereoScan: Dense 3D Reconstruction in Real-time. *Intelligent Vehicles Symposium 2011.*

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