

# MBSE Approach Applied To Lunar Surface Exploration Elements

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# Overview



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- **Study Main Objective:**

- Design and optimize the GNC related operations keeping into the decision loop the overall system context and the health of the main subsystem.

- **Main Approach:**

- Define the design box of the autonomous GNC exploiting STRATA MBSE framework.

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MBSE: Model Based System Engineering  
STRATA: Strategic Layers  
GNC: Guidance, Navigation and Control

# Methodology Overview

- MBSE Software
  - Vitech Genesys 7.0
- MBSE Methodology
  - MBSE STRATA Methodology
  - Main advantages:
    - ❖ Strong links between the different design domains.
    - ❖ Database with all the instances of the model.
    - ❖ Easy export on Excel.

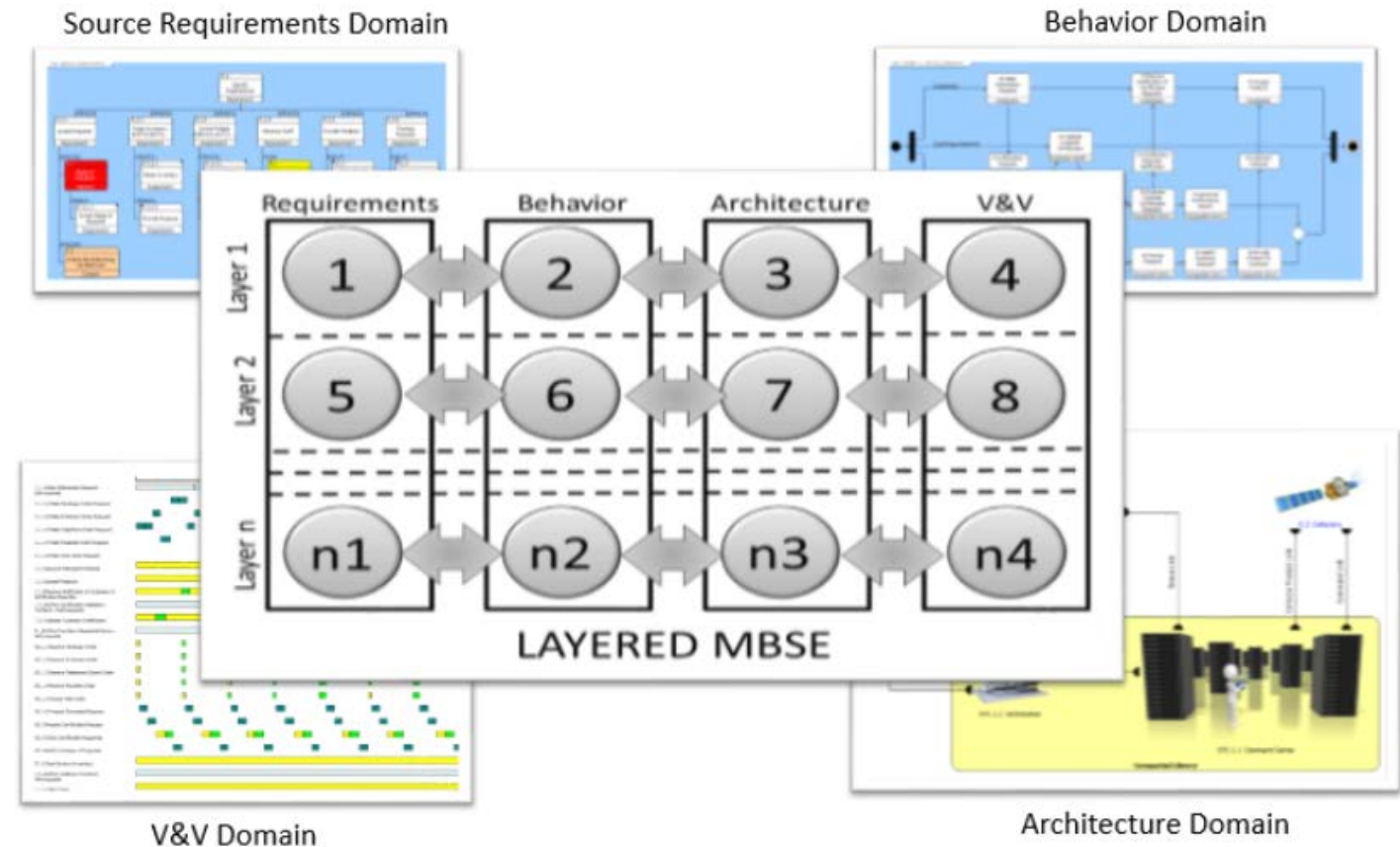
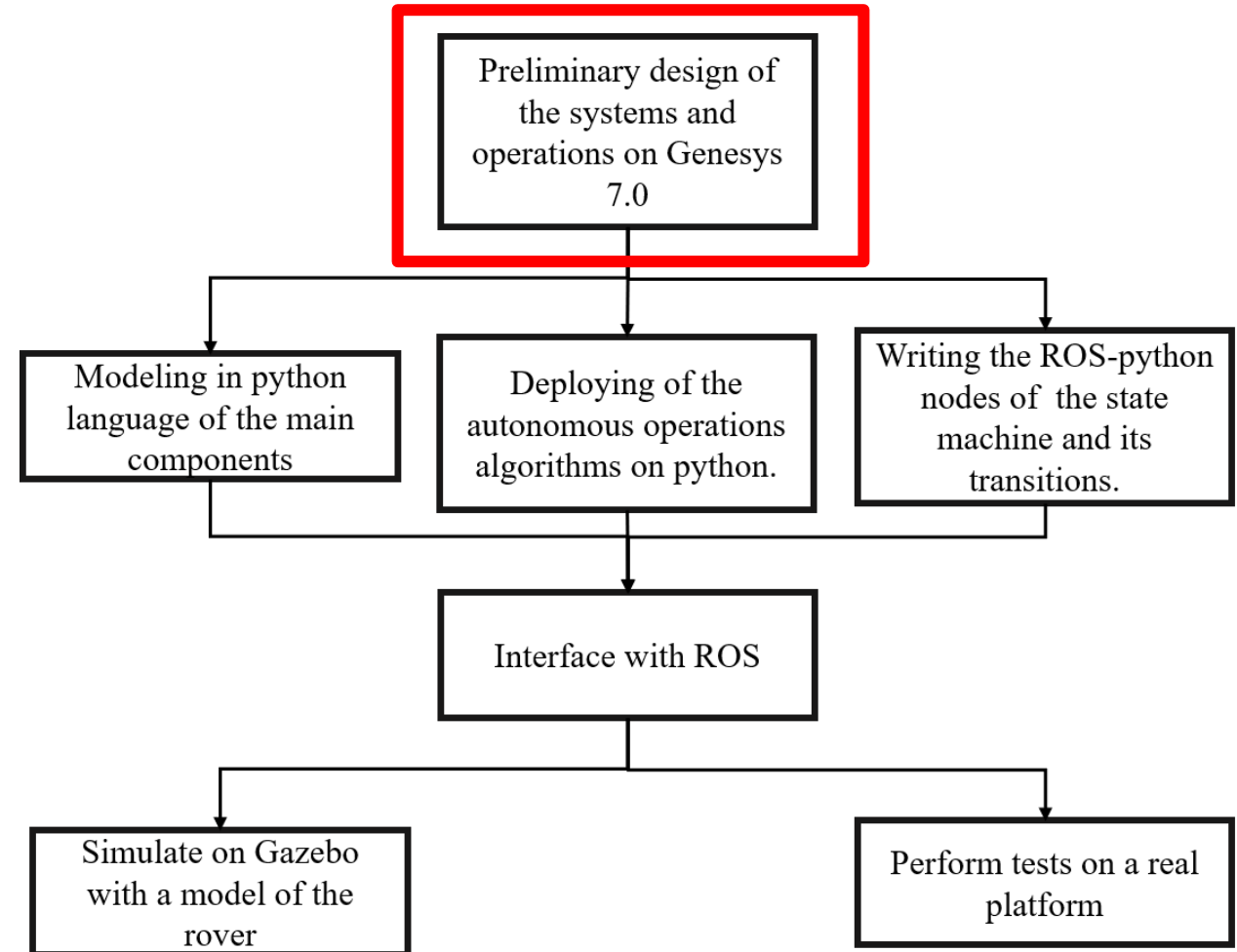


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# Methodology Overview

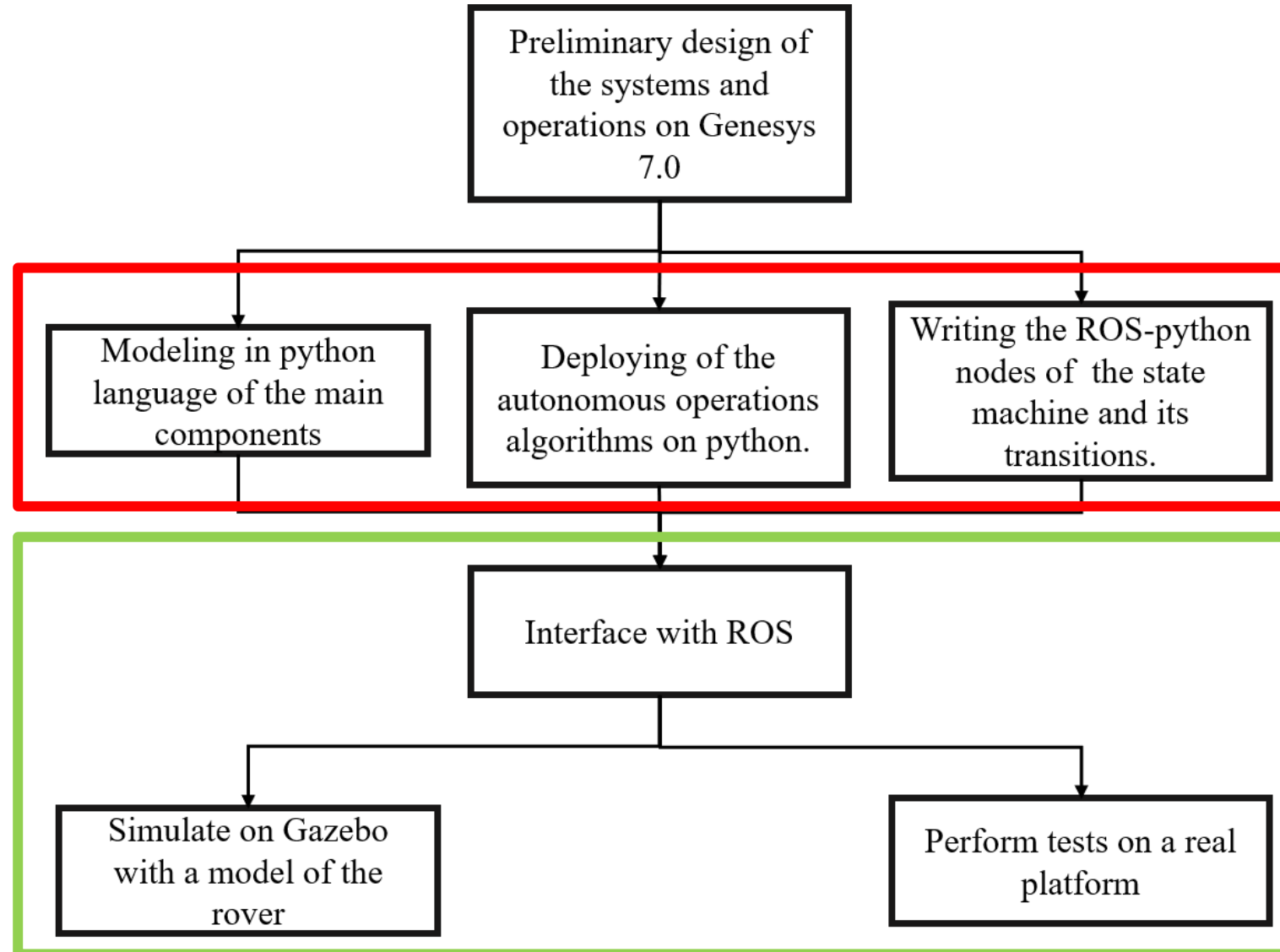


- Detailed at an early stage:
  - Requirements
  - Constraints
  - Boundaries
- Helps defining the risks and the contingency situations at an early stage:
  - Better definition of:
    - ConOps
    - Functions
    - Components
      - Constraints
      - Concerns
      - Sizing laws
  - Fault universe of interest



ConOps: Concept of Operations

# Methodology Overview



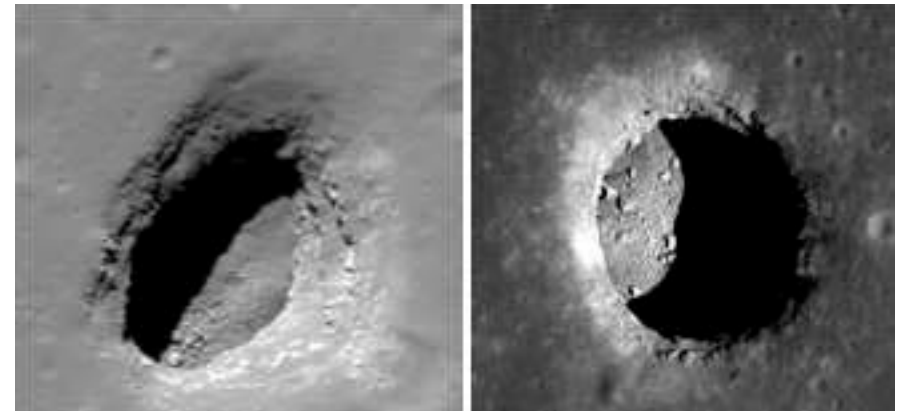
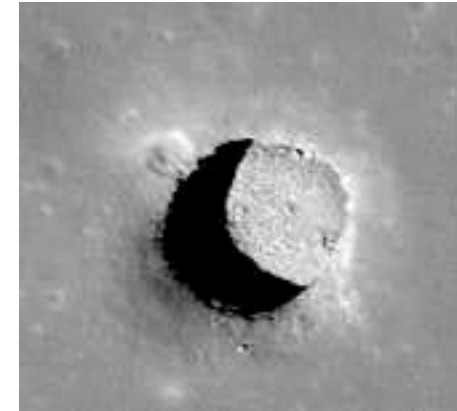
# Mission Overview



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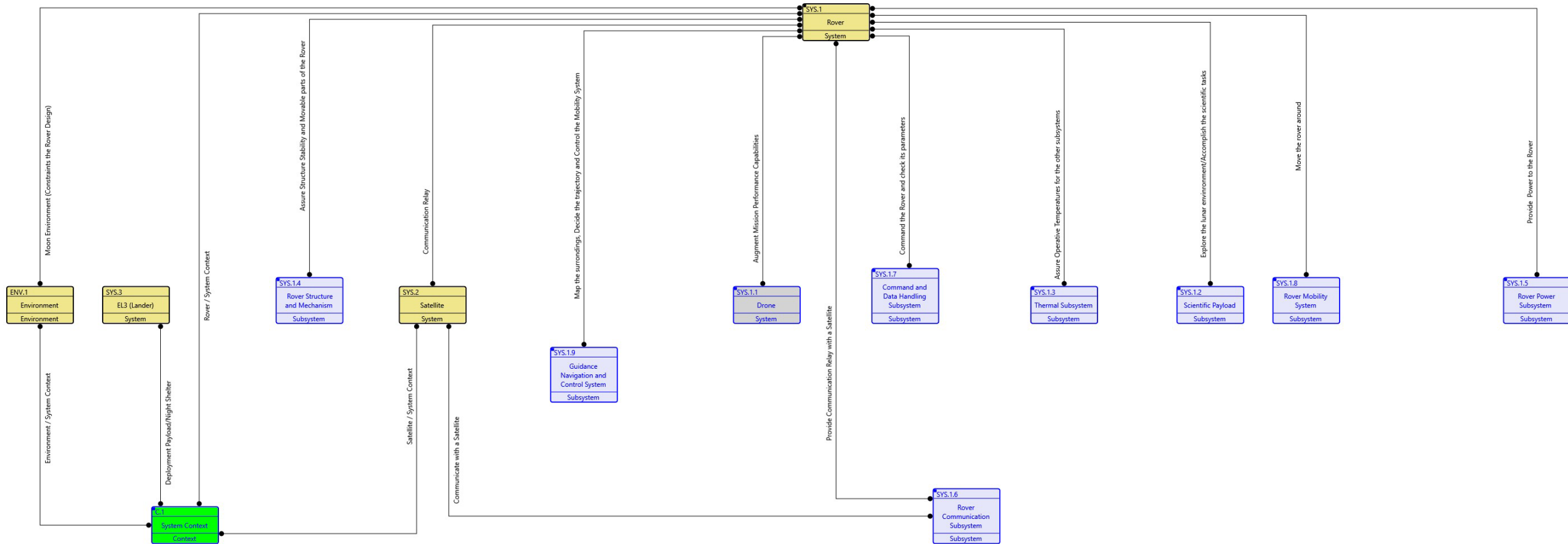
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- Exploration of the lunar lava tubes
  - Marius Hills
  - Mare Tranquillitatis
  - Mare Ingenii
- High-level Requirements:
  - Assess the safety inside the lava tubes for next mission;
  - Map the environment outside and inside the lava tubes;
  - Communicate with Earth.





# Actors

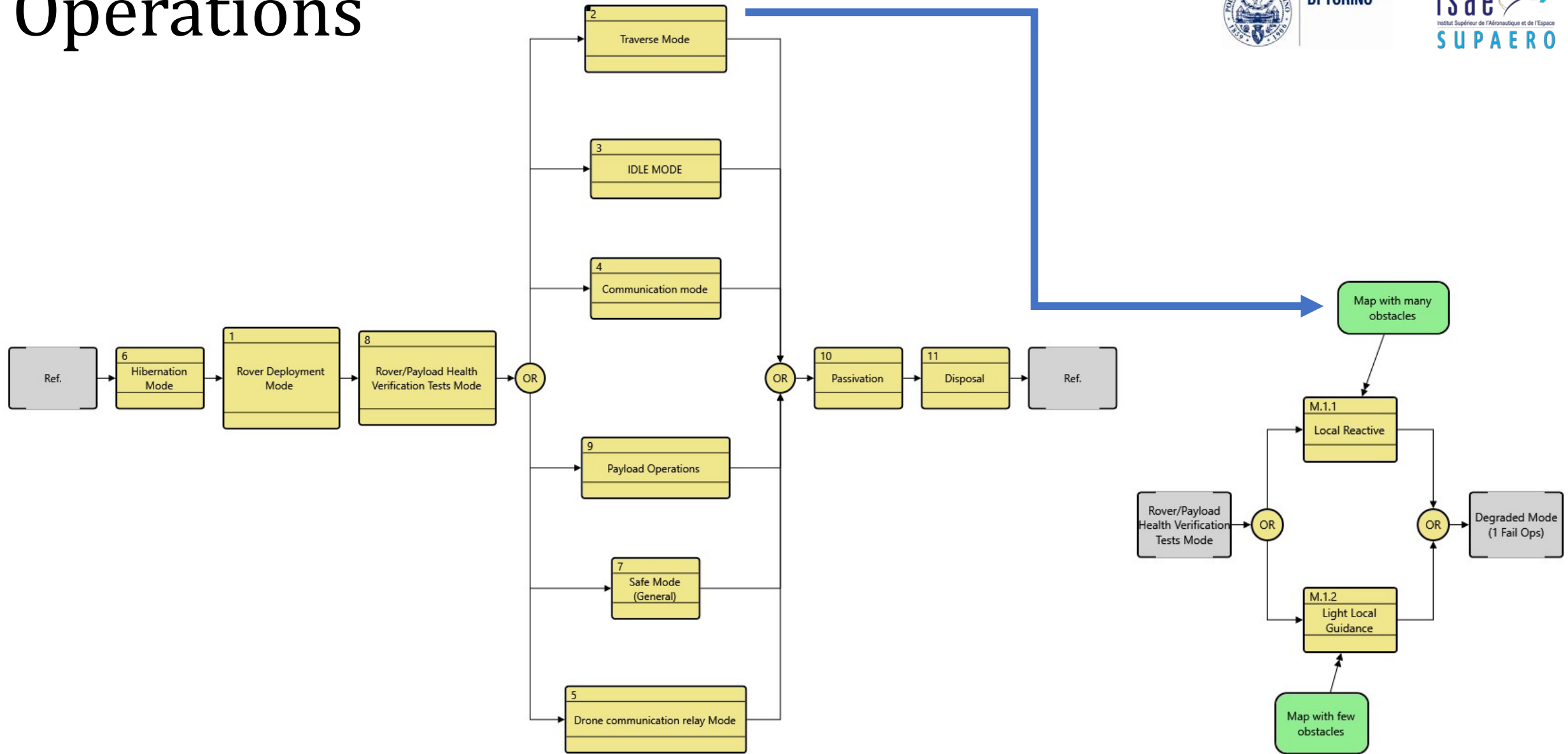


# Operations



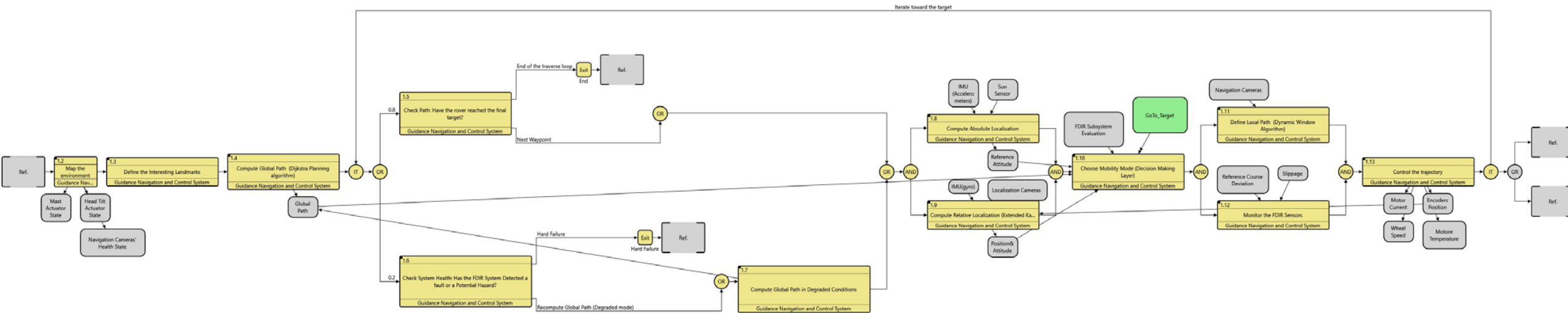
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# Nominal Flow of Traverse Mode



- Map environment
- Define interesting landmarks
- Generate global path
- Check path
- Check system Health

- Compute absolute localization
- Compute relative localization
- Generate local path
- Monitor the FDIR sensors
- Control trajectory

FDIR: Failure Detection  
Identification and Recovery

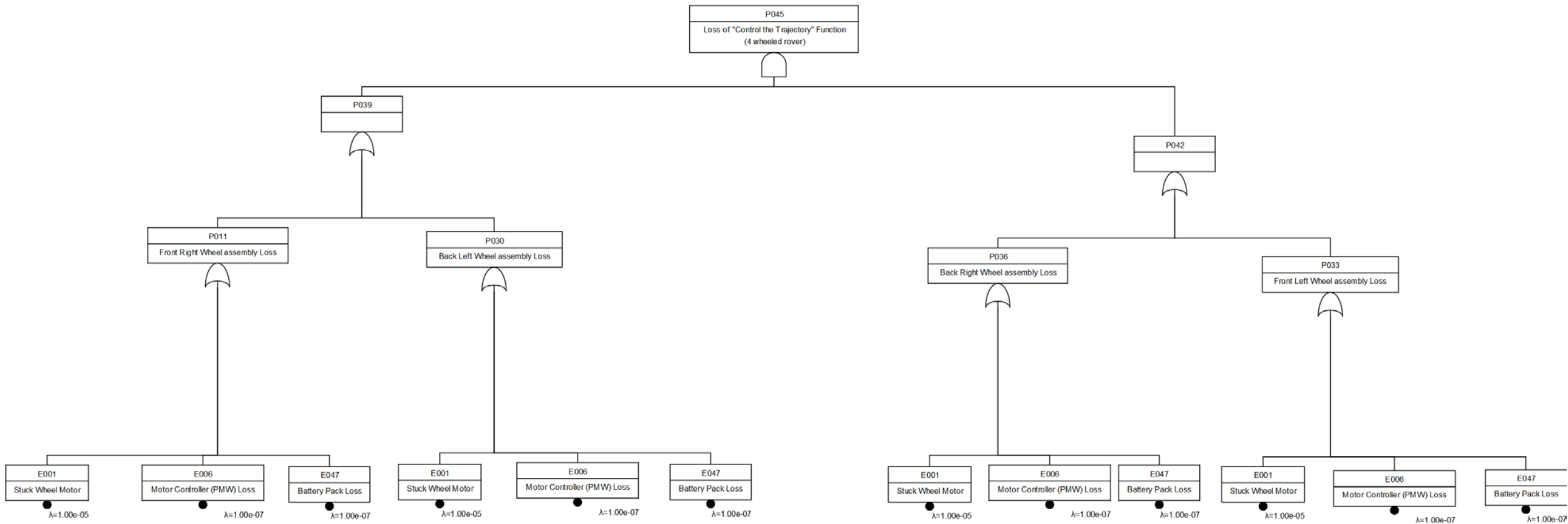
# GNC's Faults



- Traverse mode typical faults:
  - Goal errors;
  - System-related errors.
    - Most interesting for our study.
- For each function we can define:
  - Contingency situations;
  - fault trees;
  - recovery procedure;
  - Degraded mode procedures.



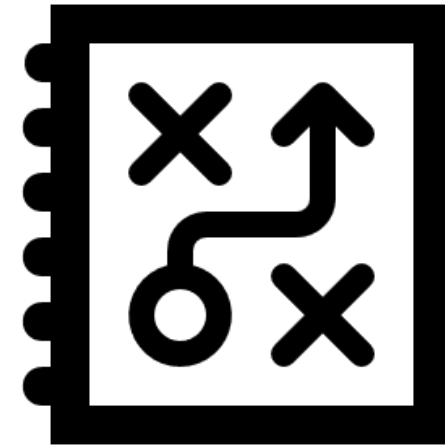
# GNC's Faults



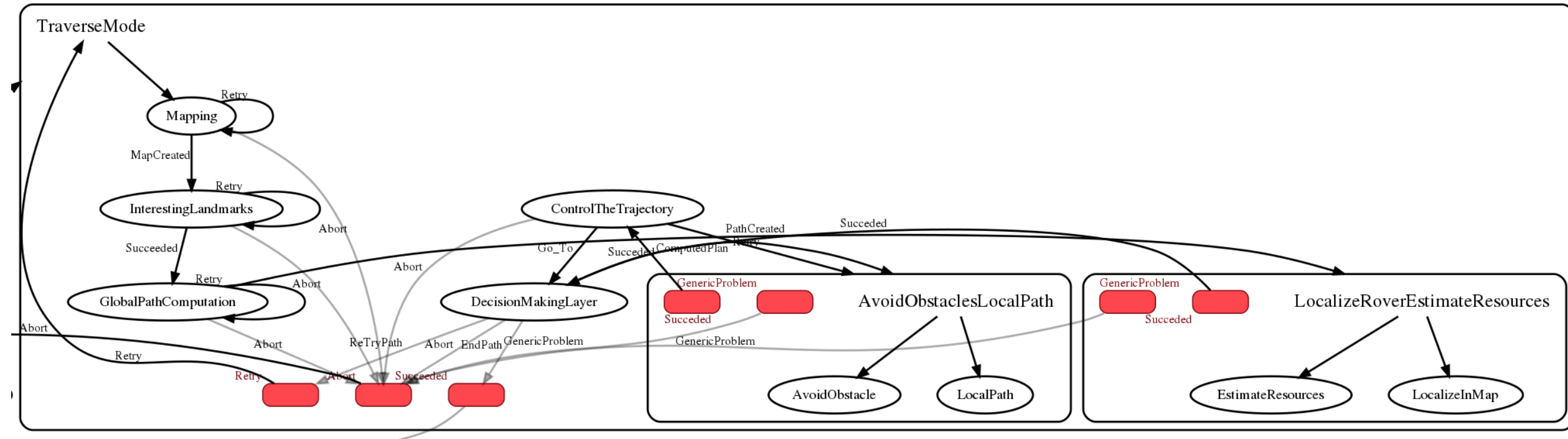
# Python, ROS and Test



- Outputs of Genesys 7.0:
  - Critical operations.
  - Transitions between the functions;
  - Parameters to observe;
  - Expected impact on the operational level not only on component or subsystem level.
- ROS is used to test the operational scenarios derived from the mission analysis.



# Python, ROS and Test



Nominal traverse mode as a ROS-SMACH state machine

# Advantages of MBSE



- The overall STRATA approach was, and is, really helpful to understand:
  - The constraints for the various components;
  - The contingency situations;
  - Understand the logical interfaces and physical links between the subsystems and the components.
- It is useful for the verification of the expected behaviours of the architecture in the different scenarios, both nominal and degraded.
  - It is possible to define different test cases defined by:
    - Essential Functions;
    - Essential Component;
    - Observable parameters.



# Conclusions and Future Work



- Three main branches for the systems under study:
  - The mission analysis with Genesys 7.0;
  - The study of failures and fault with FMECA and FTA;
  - The study of the GNC subsystems and traverse mode operations in nominal and contingency situations.
- The aim is the creation of a comprehensive design framework to study the autonomy of surface robotics systems starting from mission analysis up to effective testing.

# Thank you for your kind attention

## Q&A

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