Guidance, Navigation, and Control of In-Orbit Assembly of Large Antennas

Event : ESA Clean Space Industry Days

Date : 18th October 2023

INNOVATING SOLUTIONS

Introduction

Introduction to IOANT

Project Overview

Study technologies to enable IOA of large antenas

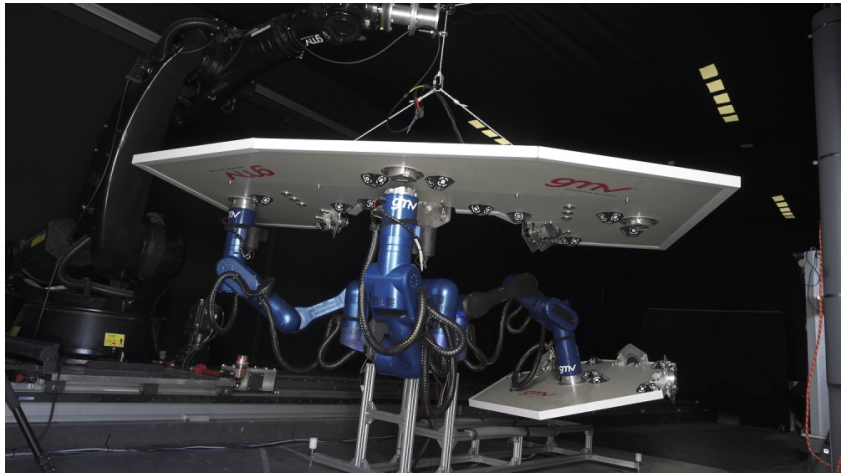
- Focus on a few key technologies
- Reach TRL 4/5

Address main challenges to GNC and System

- Large variation of properties (MCI/Flexibility)
- System logistics and propellant consumption
- Autonomy

Two phases

- Phase 1: Design, implementation and Simulink campaign
- Phase 2: Scaled tests in ground facilities



Introduction to IOANT

Phase 1

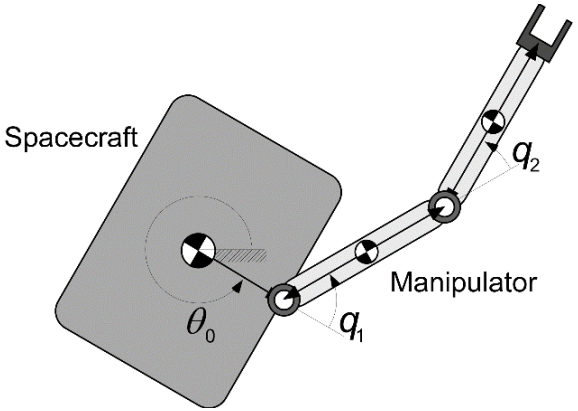
Target key technologies

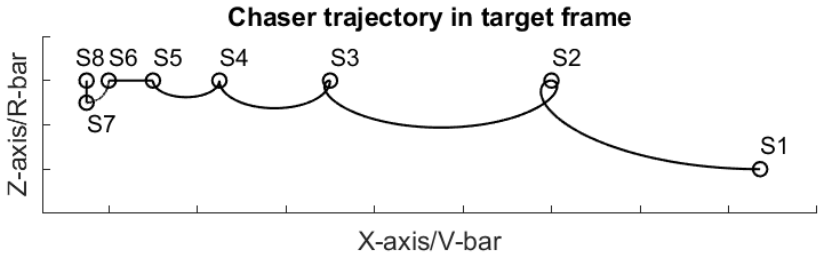
- Platform-manipulator coordinated controllers
- On-board trajectory planning and optimization
- Controllers adaptable/scheduled with MCI and flexible properties
- System Identification (SYSID)

Definition of:

- System
- Scenario
- Requirements

Detailed design, validation and verification of GNC





Case Study

Case Study

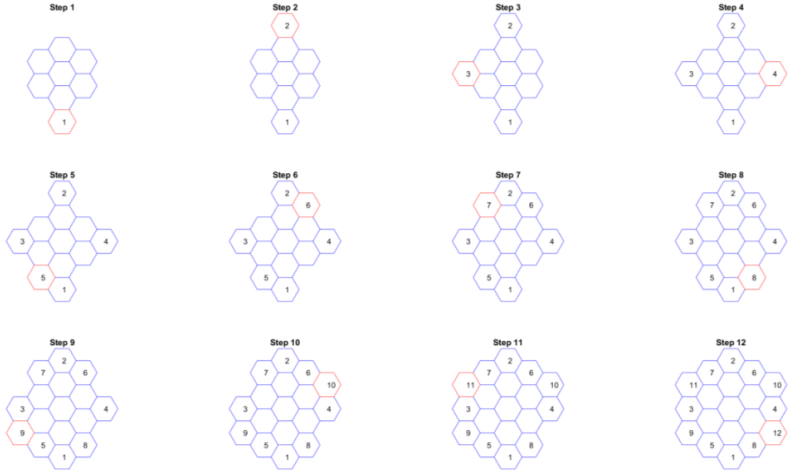
Proposed System

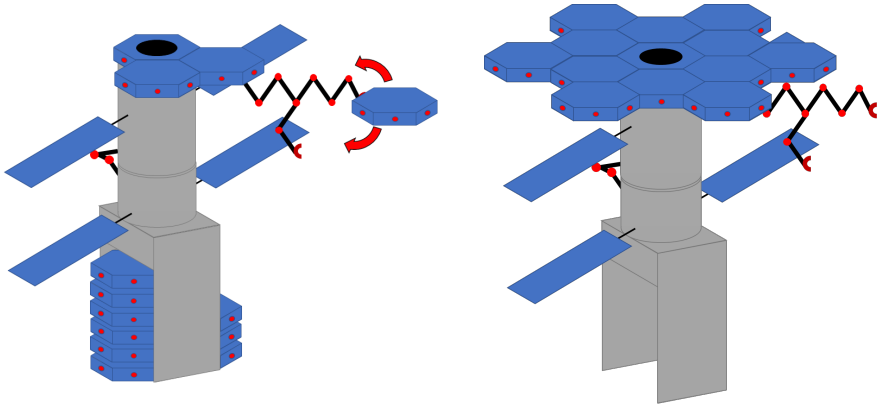
Goals

- Assembly of an antenna larger than Ø20 m
- Scalable
- Technically feasible with current or in development technologies

Components

- Central Module
- Transport Tug
- Stacks of segments
- Multi-Arm Relocatable Manipulator (MARM) from MIRROR





Case Study

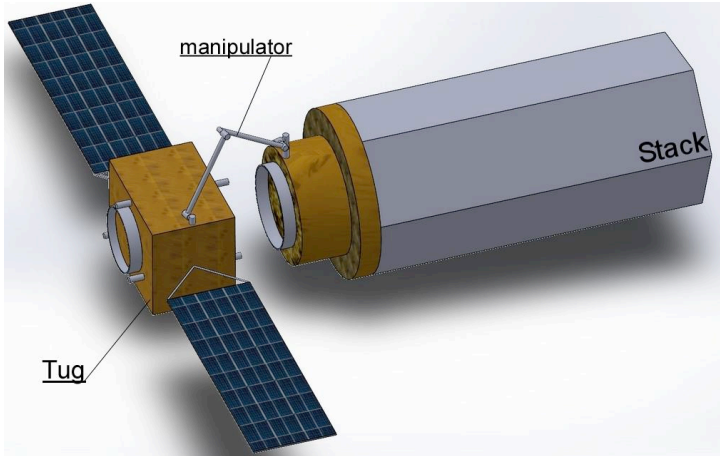
Proposed System

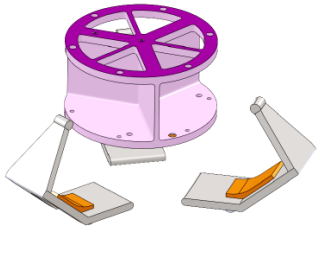
Tug

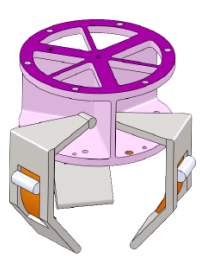
- Equipped with manipulator for berthing
- Equipped with berthing interfaces
- Performs transportation and rendezvous
- Capture interfaces based on CAT/MICE

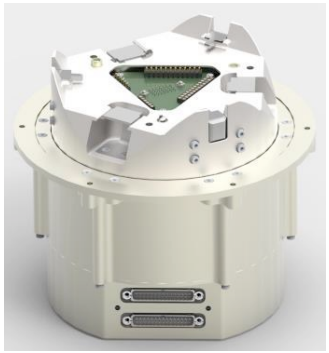
Central Module

- Centralices antena equipment
- Antenna is assembled using hexagonal pieces and SIROM







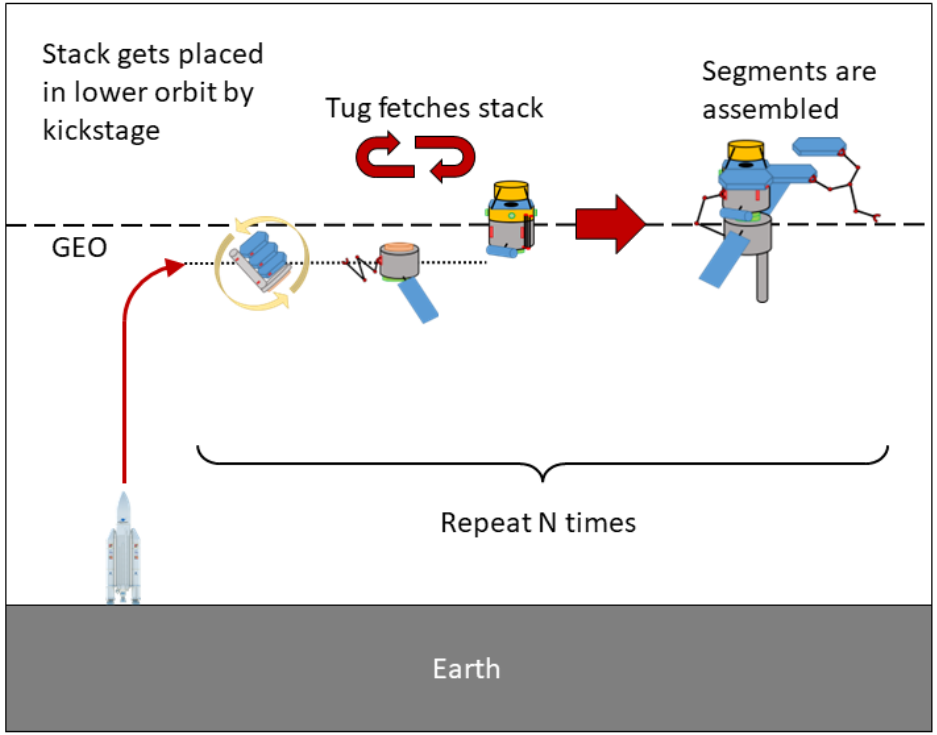


Case Study

Proposed Scenario

Mission Launch Strategy

1. Central Module and Tug placed in GEO
2. Stack of reflectors placed 250km below GEO
3. Launches of stacks performed sequentially
4. Tug captures stack and docks to Central Module
5. Stack sent to graveyard orbit
6. Process is repeated until al stacks are attached



Case Study

Rendez-vous and assembly operations

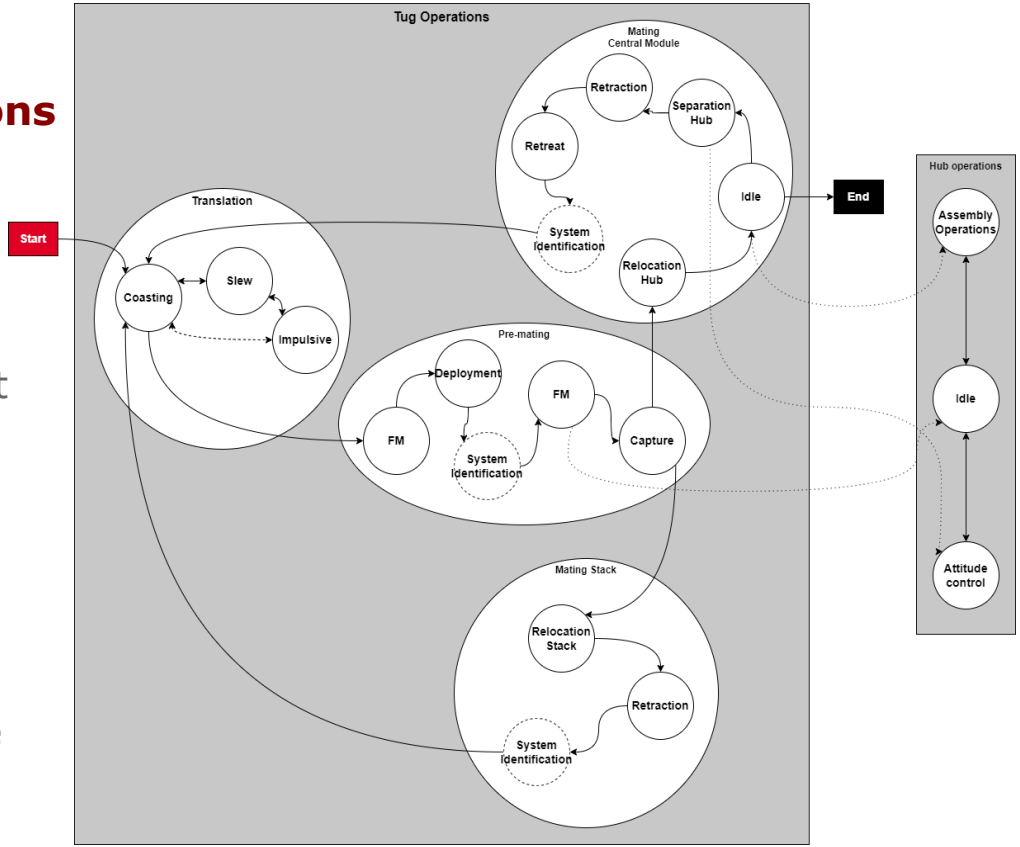
Orbital Translational operations
- Initial orbit to few hundreds meters

Pre-mating
- Final approach and preparations for capt

Mating with stack

Mating with Tug
- Capture and Separation

Assembly Operations
- Assembly onto Central Module using the MARM



GNC

Proposed GNC

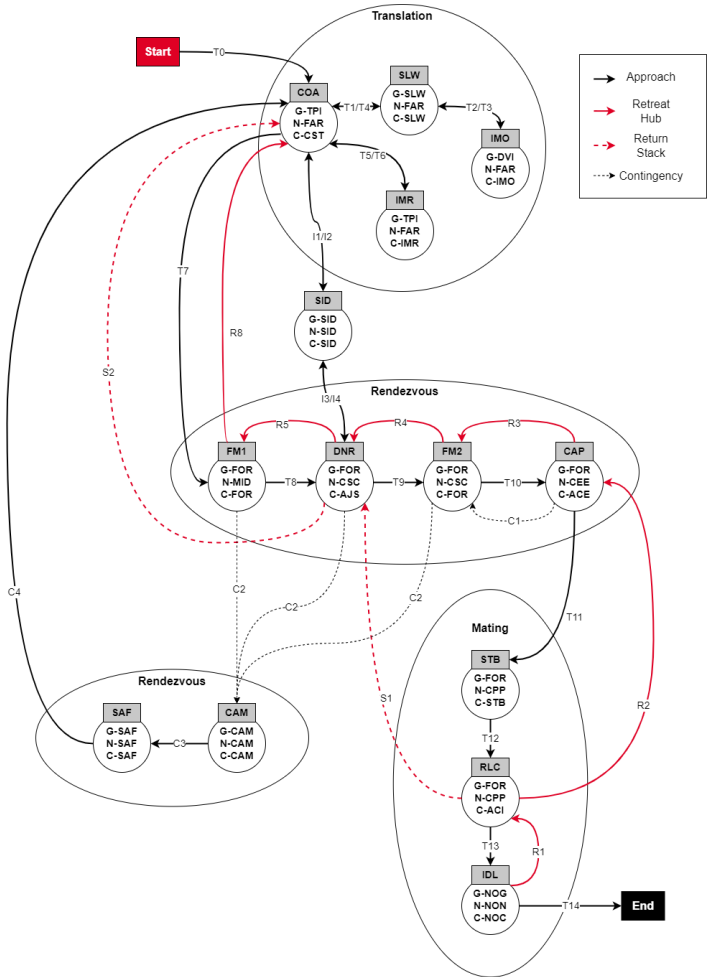
Rendez-vous and assembly operations

Focuses of the study

- Tug GNC: rendez-vous operations
- Central Module ADCS: assembly operations

GNC Modes

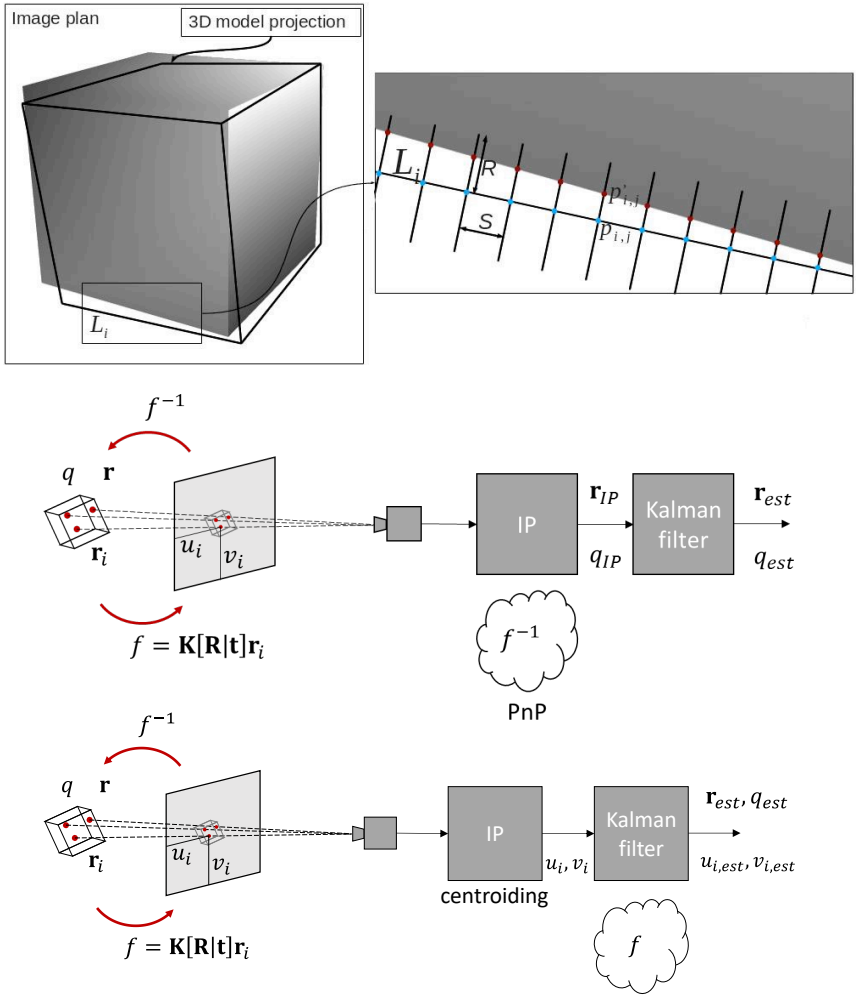
- E3 autonomy (event driven)
- Allows different transitions depending on target
- Can be executed forwards and backwards
- Reduced number of modes



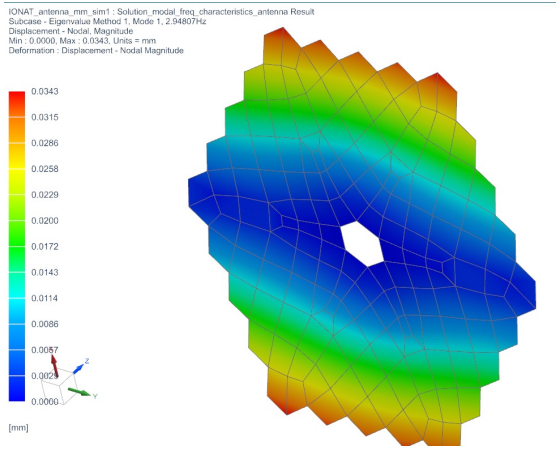
Proposed GNC

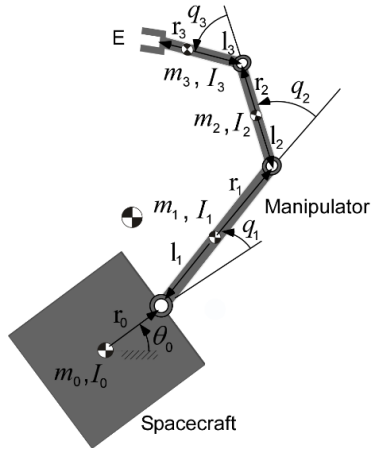
Navigation

- Inertial attitude, estimation of the spacecraft attitude (star trackers and gyroscope)
- Orbit estimation based on initial state and measured maneuvers
- Relative state estimation
  - Far-range (relative GNSS sensors)
  - Mid-range (navigation cameras and range estimation)
  - Close-range (navigation cameras and estimation of the relative pose between vehicles)



Proposed GNC





Control

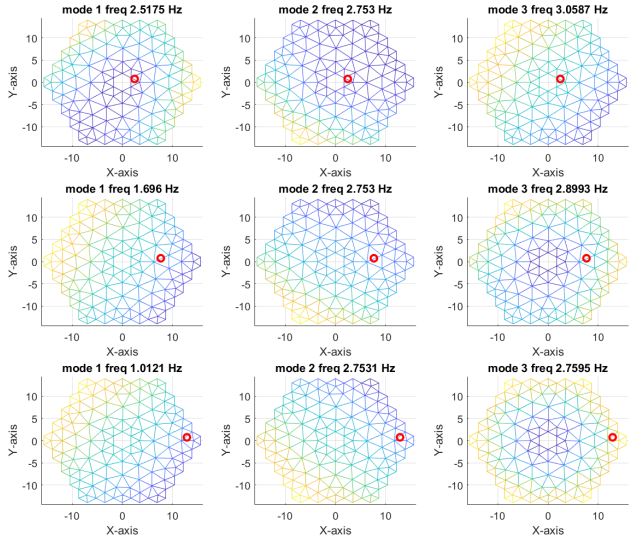
Variation of MCI and flexible properties
-> Need for a robust and versatile system

Key Aspects

- AOCS of antenna while MARM assembles pieces, which introduces disturbances and alters its dynamical properties
- Tug and robotic manipulator coordinated control laws
- System Identification

How is it achieved

- Adaptable gains for changes in MCI
- Adaptable filters (low-pass/notch) for changes in the flexible properties
- Model-based PD/H∞ control loops for phases which use robotic manipulators

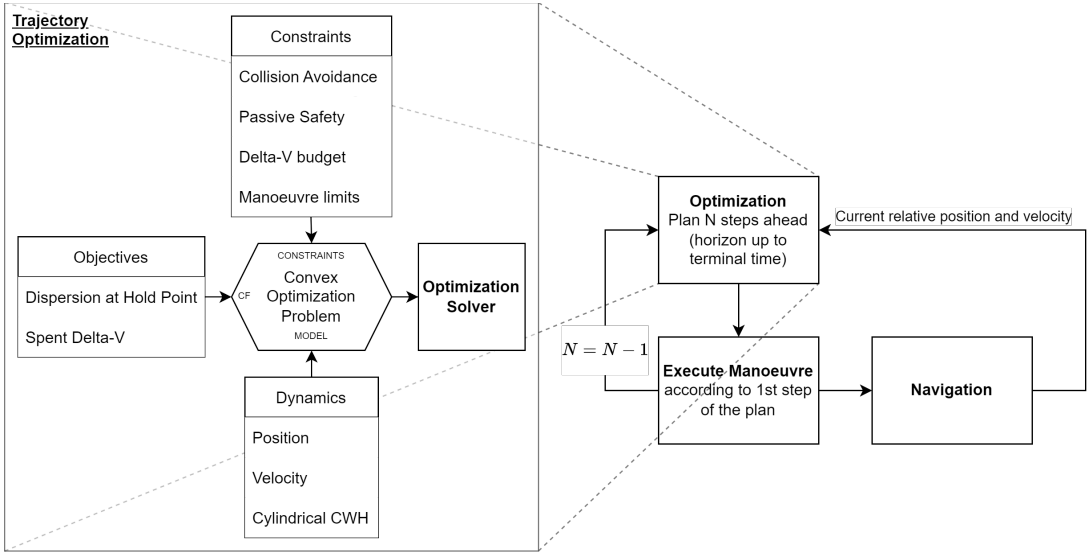


Proposed GNC

Translational Guidance

Model Predictive Control

- Reduce propellant consumption
- Maximize the number of trips/Reduce mission cost
- Manoeuvres computed with up-to-date info -> safer trajectories
- Closed-loop guidance -> improved disturbance rejection and dispersion reduction



Conclusions and future work

Conclusions and Future Work

Conclusions and status

From phase 1, close to test campaign

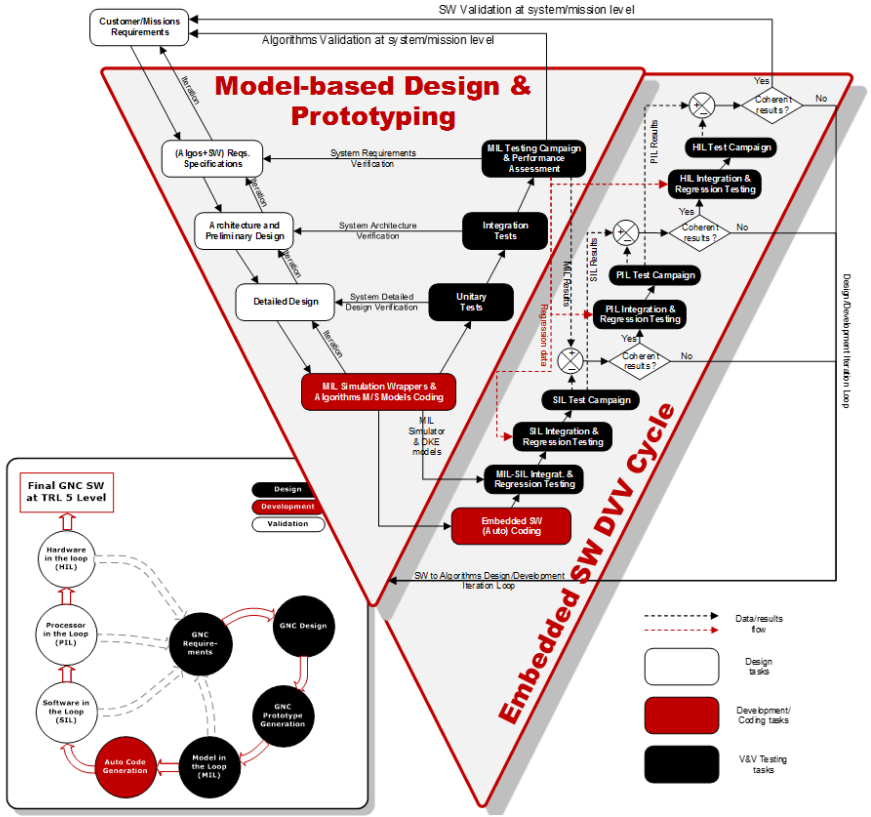
- System and mission tailored to specific target antenna
  - Several aspects applicable to all IOA missions
- All target technologies are covered and feasible
- Series of needs, problems, and potential solutions of IOA missions identified
- Operations defined to assemble the antenna
  - Concept of operations
  - GNC modes
  - Algorithms

Conclusions and Future Work

Future Work to reach TRL 4/5

End of Phase 1

- Implementation of the GNC functions into a Simulink model
- Performing a Validation and Verification campaign (Monte Carlo)
- Conclusions and update of requirements

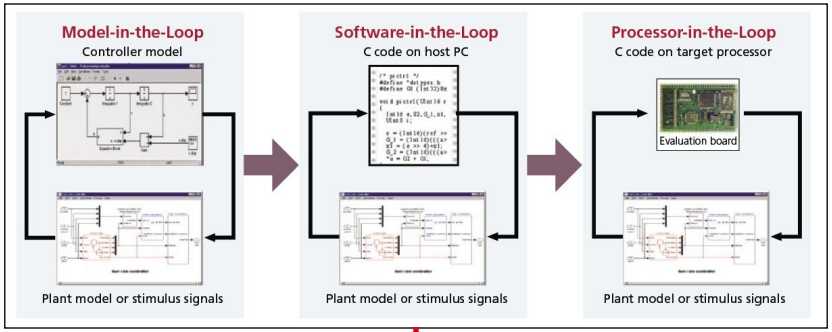


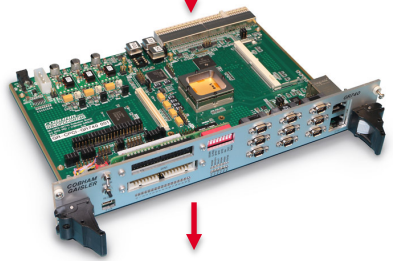
Conclusions and Future Work

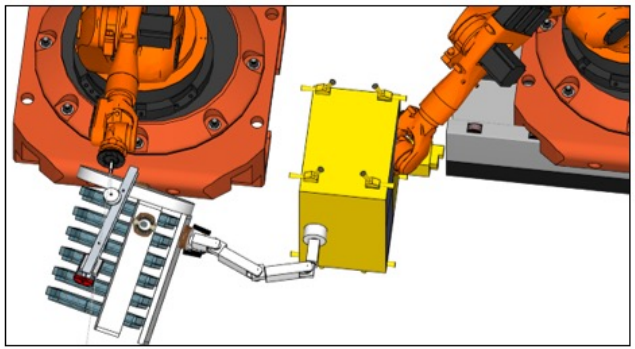
Future Work to reach TRL 4/5

Phase 2

- Design, setup, manufacture and breadboard scaled End-to-End Proof of Concept in an experimental facility
- Adaptation Phase 1 functions, conversion to C code using MIL->SIL->PIL autocoding
- Test campaign in a ground facility, scaling the results back to the original scenario







Thank you

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