PhD in Modeling and Control of Space Systems
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PhD: Innovative Modelling, in-situ Identification and active Control methods for In-Orbit Manufacturing, Assembly and Operation of large antennas (MICIOMAO)

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Context & Motivation

Large aperture antennas are enabling not only for traditional communication services and radar, but also for new approaches of communication, remote sensing, deep space probing and power transfer spacecraft. Higher antenna aperture guarantees higher signal resolution and signal-to-noise ratio, while its accuracy drives its spatial resolution and sensitivity. While in the past, developing high aperture antenna was a technological challenge limited by the deployment of high stiffness and heavy components against launch constraints, recent advances in on-orbit autonomous manufacturing and assembly opened the door to the development of very large and light structures directly in space. However, if many works in literature focused on large antenna manufacturing in space as in [1], many engineering challenges such as surface accuracy, spacecraft stability, and deployment reliability, still impose a limit to the actual de-risking of these technologies. The proposed project has the ambition to propose the development of a European end-to-end in-orbit assembly scenario of a large antenna and demonstrate its key technological challenges with a small-scale experimental benchmark. By leveraging skills available in the team on modelling and control of large flexible structures [2, 3] and antenna technology [4, 5], this project will focus on:

- Manufacturing and assembly of a large lightweight antenna structure;
- Design an Attitude and Orbital Control algorithm that takes into account all gravitational, thermal, radiation, structural flexibility (including fuel sloshing effects) when assembling the antenna and which adapts accordingly to the variation of the spacecraft inertia;
- Propose a set of actuators and sensor to assure the alignment of each assembled module and to actively mitigate vibration after assembly;
- Propose an innovative in-situ identification of the antenna structure by directly using the diagnostic of the radio-frequency (RF) received/transmitted signal.

Objectives

The main objective of this study is to conceive and develop an end-to-end realistic scenario of in-orbit manufacturing, assembly and operation of a large antenna starting from the work presented in [6], with a focus on the high-fidelity modelling and active control of the large flexible structure during its construction, nominal operations and reconfiguration/maintenance phases. The research questions identified in this work together with the industrial partner (Thales Alenia Space), which correspond to the novelties brought by the project with respect to the state-of-the-art, are:

- How to robustly guarantee the spacecraft stability and attitude/orbital accuracy during the antenna construction with a validation in a multi-physics high fidelity simulator?
- Is it possible to actively control the alignment of the supporting structure of the multi-panel antenna and the vibration propagated through the spacecraft structure to the payload through a dedicated set of lightweight collocated sensors/actuators?
- Is it possible to exploit the radiation diagnostics of the radio-frequency signal to recover the antenna deformation (in-situ identification) and drive active control devices to recover a better signal/noise ratio?
- Is it possible to reorient the antenna by coping with stability and RF requirements by enabling a re-use of the same technology for a different mission purpose?
- Is it possible to provide a maintenance service to the antenna by using robots as shown in [6, 7]?
- Is it possible to demonstrate the proposed manufacturing process and stiffening with active control solutions in a small-scale laboratory experience?

Background

By using the recent developments on spacecraft control of in-orbit large flexible structures based on the Two-Input Two-Output Port (TITOP) multibody framework [2, 3] implemented in the SDTlib toolbox [8, 9], the ISAE-SUPAERO team will contribute to provide the building blocks for the development of the high-fidelity non-linear simulator and the simplified model used for control synthesis and formal analysis. In particular a recent study [10] developed with the European Space Agency (Contract ESA NO. 4000141060/23/NL/MGu) will contribute to give insight into the technical development of an efficient digital twin.

The RF advanced modelling, analysis and the related tools will be supported by Thales Alenia Space Research and Development Antenna Department [4, 5, 11]. With extensive experience in the modelling, design, optimisation, and measurement of reflectors, mesh reflectors, reflect/transmit arrays, and other EM surfaces, TAS in-house software enables efficient simulation of the radiation performance of large reflectors.

Candidate Profile

You have a strong background in dynamics, control theory, linear algebra, and aerospace telecommunication systems, demonstrated through an excellent undergraduate and/or master's degree performance. You are proficient in English, with excellent written and verbal communication skills. Prior research experience, such as participation in research projects, internships, or independent research work, is highly valuable.

Fundings

This PhD is a co-funded project (ESA, ISAE-SUPAERO, TAS) in the frame an OSIP initiative (`https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/The_Open_Space_Innovation_Platform_OSIP`).

Conditions of employment

Full-time employment for three years, including:

- A gross monthly salary and benefits in accordance to the ISAE-SUPAERO standard

- Receiving institutions: ISAE-SUPAERO (Toulouse, France), Thales Alenia Space (Toulouse, France), ESA-ESTEC (Noordwijk, The Netherlands)

Candidates are expected to start between the end of 2025 and the beginning of 2026.

Application

All applications should be compressed (.zip, 5MB max.) and submitted by email to the addresses below, including:

- Cover letter including a statement of purpose and previous experiences
- Detailed curriculum vitae
- Course grades transcripts
- Two recommendation letters

For more information regarding this position, please contact:

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