Guidance, Navigation and Control for Rendezvous on cislunar Near Rectilinear Halo Orbits

ISAE-SUPAERO

NICOLAS BAUDIN
INTERNSHIPS IN FRANCE INITIATIVE

Name of the hosting institution in France	ISAE-SUPAERO
Name of the host laboratory / research team	Space Advanced Concepts Laboratory (SACLAB)
Address	10 Avenue Edouard Belin 31055 Toulouse France
Website	https://www.isae-supaero.fr/en/
Name of the supervisor	Stéphanie Lizy-Destrez
Function	Associate Professor
Email	Stephanie.LIZY-DESTREZ@isae-supaero.fr

Internship offer

Topic of the internship (title)	Guidance, Navigation and Control for Rendezvous on cislunar Near Rectilinear Halo Orbits			
Proposed dates of the internship*	Start	2020-09-01	End	2021-03-01

* The supervisors have indicated the dates proposed are flexible and are able to be postponed, subject to COVID-19 border closures, until March 2021

Scientific and academic objectives of the internship (detailed description of the internship content, work expected from the intern and expected outcomes):

A Lunar Orbital Platform Gateway concept has been recently proposed by NASA as a pillar for future missions to the Moon surface. Such an infrastructure is also expected to take advantage of the complex nonlinear dynamics about the Lagrangian points of the Earth- Moon system to facilitate human exploration beyond the cislunar space. The assembly of this structure is expected to happen on orbit within the next decade, with the launch of the Gateway's first module scheduled for 2022. The platform will need to accomodate modular assembly, cargo delivery and crew exchange operational activities, all which rely critically on Rendezvous and Docking (RVD) operations with modules such as Orion. Near Rectilinear Halo Orbits (NRHOs) have been identified as suitable orbits to host the Gateway and to accommodate multiple mission staging. There is extensive experience with RVD in the two-body problem in Low Earth Orbits to various space stations or around quasi-circular Low Lunar Orbits. Despite that, no operational RVD has yet been performed in the vicinity of the Lagrangian points. The main goal of the internship is to contribute to a preliminary Guidance, Navigation and Control (GNC) system design for autonomous RVD operations on NRHOs. The system shall cover the range from the start of RVD, where relative measurements become available, until docking. Robust stability and performance of the closed loop GNC system shall be evaluated. The study case used for simulations is Rendezvous between the Orion spacecraft and the Gateway located in a cislunar NRHO about the second Earth-Moon Lagrangian point. The intern is expected to contribute to the development, testing, tuning and performance assessment of the GNC system. The student is expected to implement and prepare hardware in the loop simulations of the guidance algorithms to assess on-board feasibility. The candidate will be working under the supervision of Dr. Stéphanie Lizy-Destrez and Dr. Joël Bordeneuve-Guibé, associate professors, and Mr. Emmanuel Blazquez, PhD candidate. He/she will be provided with advanced astrodynamics tools in MATLAB and Python as well as Simulink models for the Guidance, Navigation and Control systems, developped in collaboration with the European Space Agency and Airbus Defence and Space. Objectives :

1. Contributing to the preliminary design of a GNC system for RVD operations on NRHOs
2. Assessing robustness and performance of the closed-loop GNC
3. Demonstrating the capabilities of the system in a Gateway-Orion RVD scenario
4. Preparing hardware in the loop simulations of the guidance algorithm

Expected profile of applicant

Level of study	Bachelor, Master, PhD
Discipline	Space Engineering, Control Systems
Required qualities, knowledge and skills	- Advanced Programming skills in MATLAB, SIMULINK and Python - Strong Background in applied mathematics and Algebra - Strong background in orbital mechanics and astrodynamics - Strong background in feedback control (preferably multivariable) - Initiative, critical thinking, adaptability - Any experience in research would be greatly appreciated - Programming skills in C \ C++ would be greatly appreciated

Toulouse, January 31st, 2020
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Guidance, Navigation and Control for Rendezvous on cislunar Near Rectilinear Halo Orbits

Supervisors: Stéphanie Lizy-Destrez, Joël Bordeneuve-Guibé, Emmanuel Blazquez
Duration: 6 months
Keywords: Guidance, Navigation, Control, Astrodynamics, Rendezvous, Circular Restricted Three-Body Problem

Job Description:

A Lunar Orbital Platform Gateway concept has been recently proposed by NASA as a pillar for future missions to the Moon surface. Such an infrastructure is also expected to take advantage of the complex nonlinear dynamics about the Lagrangian points of the Earth- Moon system to facilitate human exploration beyond the cislunar space. The assembly of this structure is expected to happen on orbit within the next decade, with the launch of the Gateway's first module scheduled for 2022. The platform will need to accomodate modular assembly, cargo delivery and crew exchange operational activities, all which rely critically on Rendezvous and Docking (RVD) operations with modules such as Orion. Near Rectilinear Halo Orbits (NRHOs) have been identified as suitable orbits to host the Gateway and to accommodate multiple mission staging. There is extensive experience with RVD in the two-body problem in Low Earth Orbits to various space stations or around quasi-circular Low Lunar Orbits. Despite that, no operational RVD has yet been performed in the vicinity of the Lagrangian points.

The main goal of the internship is to contribute to a preliminary Guidance, Navigation and Control (GNC) system design for autonomous RVD operations on NRHOs. The system shall cover the range from the start of RVD, where relative measurements become available, until docking. Robust stability and performance of the closed loop GNC system shall be evaluated. The study case used for simulations is Rendezvous between the Orion spacecraft and the Gateway located in a cislunar NRHO about the second Earth-Moon Lagrangian point.

The intern is expected to contribute to the development, testing, tuning and performance assessment of the GNC system. The student is expected to implement and prepare hardware in the loop simulations of the guidance algorithms to assess on-board feasibility.

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Objectives:

1. Contributing to the preliminary design of a GNC system for RVD operations on NRHOs
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Required skills

- Advanced Programming skills in MATLAB, SIMULINK and Python
- Strong Background in applied mathematics and algebra
- Strong background in orbital mechanics and astrodynamics
- Strong background in feedback control (preferably multivariable)
- Initiative, critical thinking, adaptability
- Any experience in research would be greatly appreciated
- Programming skills in C \ C++ would be greatly appreciated

References

1. Stephanie Lizy-Destrez, Laurent Beauregard, Emmanuel Blazquez, Antonino Campolo, Sara Manglativi, and Victor Quet, "Rendezvous Strategies in the Vicinity of Earth-Moon Lagrangian Points," *Frontiers in Astronomy and Space Sciences*, vol. 5, Jan. 2019.
2. Emmanuel Blazquez, Laurent Beauregard, Stéphanie Lizy-Destrez, Finn Ankersen, and Francesco Capolupo, "Rendezvous design in a cislunar near rectilinear Halo orbit," *The Aeronautical Journal*, pp. 1–17, Oct. 2019.
3. Thomas V. Peters, José F. Briz Valero, José A. Perez Gonzalez, Aurélien Cuffolo, and Alexander Cropp, "GNC for Lunar Ascent, Orbit Transfer and Rendezvous in Near-Rectilinear Halo Orbits," Washington D.C., United States, 2019, IAF.
4. JacobWilliams, David E Lee, Ryan J Whitley, Kevin A Bokelmann, Diane C Davis, and Christopher F Berry, "Targeting cislunar Near Rectilinear Halo orbits for human space exploration," p. 20, 2017.
5. Finn Ankersen, *Guidance, Navigation, Control and Relative Dynamics for Spacecraft Proximity Maneuvers*, Dec. 2010.
6. Chris D'Souza, Tim Crain, Fred Clark, and Joel Getchius, "Orion Cislunar Guidance and Navigation," in *AIAA Guidance, Navigation and Control Conference and Exhibit*, Hilton Head, South Carolina, Aug. 2007, American Institute of Aeronautics and Astronautics.
7. Sigurd Skogestad and Ian Postlethwaite, *Multivariable feedback control : analysis and design*, Wiley, Chichester, 2007.
8. Wigbert Fehse, *Automated Rendezvous and Docking of Spacecraft*, Cambridge University Press, Nov.2003.