EPFL-Skoltech On-orbit Servicing, Debris & Proximity Operations Workshop

About the workshop

The EPFL and Skoltech Space Centers are co-organizing the On-orbit Servicing, Debris & Proximity Operations Workshop on March 4th, 2021. It will gather international perspectives from industry, government, and academia interested in sustainable space logistics, to share their ideas and future visions of the field. One impact of the new logistics in space is orbits have become more crowded. On-orbit servicing, space debris, life extensions and disposal are all deeply connected to this trend.

*Workshop Schedule (**UTC+3** ! This corresponds to a **14h start (CET)**, or **8h (EST)**)*

Start time (UTC + 3)	Duration	Activity	Presenter/Lead
15:45	**00:15**	Online room open for attendees – presenters may test	
16:00	**00:10**	**Workshop opening**	Prof. Jean-Paul Kneib, EPFL Space Center director Prof. Anton Ivanov, Skoltech Space Center director
16:10	**00:15**	*On-orbit services to enable a thriving new space economy*	Hannes Bartle, EPFL PhD student, ClearSpace engineer
16:30	**00:10**	*Space-Based Observation on Space Debris*	Mohamed Abbas and Ahmed Elgohary, Skoltech Space Center master's students
16:40	**00:15**	*Smallsat Orbit Delivery Service Based on Russian Privately-Developed Mini Upper Stage*	Dmitry Oliferowicz, Chief Marketing Officer, Orbital Express
16:55	**00:10**	*Scheduling Optimization and Technical Challenges of Multi-Target On-Orbit Servicing*	Sung Wook Paek, EPFL Space Center postdoctoral researcher
17:05	**00:15**	*On-Orbit Servicing for Proliferated Low Earth Orbit Constellations*	Michael Luu, MIT Engineering Systems Laboratory, PhD candidate
17:20	**00:15**	Discussion and margin	
17:35	**00:30**	**Coffee break**	
18:05	**00:15**	*On the Satellite Formation Flying Mission for Graphic Image Demonstration in the Sky*	Shamil Biktimirov, Skoltech Space Center PhD candidate
18:20	**00:25**	**Keynote talk**: Space Logistics Modeling and Optimization for Space Exploration and On-Orbit Servicing	Prof. Koki Ho, Georgia Institute of Technology
18:45	**00:10**	*On the Design and Optimization of a Sustainable Asteroid Resources Based Supply Chain for Ensuring a Martian Colony Growth*	Serena Suriano, master's student at Politecnico di Milano, visiting student at Skoltech Space Center
18:55	**00:15**	*Generating Sustainable Space Mission Concepts by Reusing Robust Design Patterns*	Anne-Marlène Rüede, EPFL Space Center PhD student
19:10	**00:10**	*Low Energy Stable-Manifold Trajectories to the Earth-Moon Halo Orbits*	Salman Ali Thepdawala, Skoltech Space Center master's student
19:20	**00:10**	*Technology Combination Analysis Tool (TCAT): Institutional Interests and Future Developments*	Flavio Brancato, EPFL Space Center engineer
19:30	**00:15**	Discussion and margin	
19:45	**00:10**	**Concluding remarks. Main workshop closing**	Prof. Anton Ivanov, Skoltech Space Center director
19:55	**00:35**	Interactive session – joint research Objectives Trees *(separate sign-up required, see below)*	Marc-André Chavy-Macdonald, EPFL Space Center postdoctoral researcher
20:30		Finish	

Presentation abstracts

On-orbit services to enable a thriving new space economy

Hannes Bartle
ClearSpace SA, EPFL

Commercial space business is booming and while the number of satellites in orbit grows, new markets are evolving that require safe and cost-effective solutions. ClearSpace is one of a few companies that wants to shape the future of on-orbit servicing and debris removal. The first mission of the company, ClearSpace-1, is the first of its kind in removing an actual piece of space debris. It will be presented how ClearSpace tackles the complex system engineering through the use of MBSE and what challenges there are for these types of missions from a communication point of view.

Space-Based Observation on Space Debris

Mohamed Abbas, Ahmed Elgohary
Skoltech Space Center

Space debris has become a great threat to the future of spaceflight as the probability of collisions occurring is not only continually rising, but there have been several collision events that have damaged the international space station and other highly-valued satellites. Therefore, obtaining orbital information of debris is a must to protect the normal operations of spacecrafts and for the success of future active removal missions. Almost all the observations for space debris are currently made by ground-based optical and radar systems; however their accuracy is limited due to some problems like discontinuous observations, and weather dependency. For that, we are trying to conduct a feasibility study for space based optical observation using formation of satellites over the region of interest

Smallsat Orbit Delivery Service Based on Russian Privately-Developed Mini Upper Stage

Dmitry Oliferowicz
Orbital Express

Orbital Express is a team of space industry professionals developing a solution for orbit delivery of customer payloads (smallsats and their components). At the center of our business model is a mini upper stage. We plan to use Russian rockets and provide precise orbit insertion of payloads using our stage. It can also be used for in-flight qualification of spacecraft components and for science missions. Our vision includes using the platform for science missions to the Moon and beyond. The inaugural launch is slated for 2023. We are partnered with Roscosmos and several Russian space hardware manufacturers.

Scheduling Optimization and Technical Challenges of Multi-Target On-Orbit Servicing

Sung Wook Paek
EPFL Space Center

The scheduling of on-orbit servicing (OOS) in general could be viewed as a traveling salesman problem even though the MEV-1 mission in 2019, the first OOS demonstration, was dedicated to one target satellite. This presentation surveys high-level optimization approaches as well as technical challenges in multiple-agent OOS operations.

On-Orbit Servicing for Proliferated Low Earth Orbit Constellations

Michael Luu
MIT Engineering Systems Laboratory

On-Orbit Servicing (OOS) endeavors for GEO are already underway. Servicing in LEO presents unique challenges and value propositions. Environmental considerations, propulsion methods, and servicing schemes are reviewed.

On the Satellite Formation Flying Mission for Graphic Image Demonstration in the Sky

Shamil Biktimirov
Skoltech Space Center

The study investigates mission design and relative motion control aspects of satellite formation flying for graphic image demonstration in the sky. The subject of the study is an LEO formation comprising small satellites equipped with sunlight reflectors. The mission design procedure proposed in the work covers the target orbit selection method, a solar reflector sizing approach, and formation's orbital configuration design. The centralized impulsive formation control algorithm is proposed for satellites' relative motion control. It is utilized for formation deployment after launch, formation keeping to maintain the image geometry, and formation reconfiguration to change the demonstrated images. For the latter, an optimization problem is formulated and solved to maximize the minimum remaining level of fuel over the formation satellites for each reconfiguration maneuver. The problem is addressed by precomputed maneuvers analysis.

<u>Keynote talk:</u> Space Logistics Modeling and Optimization for Space Exploration and On-Orbit Servicing

Professor Koki Ho
Georgia Institute of Technology

As human and robotic space exploration architectures become increasingly complex, we often need multiple coordinated missions to achieve an overarching campaign objective. This talk will discuss a set of novel approaches to model and optimize such complex space missions from the logistics perspective. Multiple applications of space logistics modeling will be discussed including cislunar space exploration, on-orbit servicing, and mega-scale satellite constellations.

Prof. Koki Ho is an Assistant Professor of Aerospace Engineering and the director of the Space Systems Optimization Group at the Georgia Institute of Technology (Georgia Tech). Prior to joining Georgia Tech, he was an assistant professor at the University of Illinois at Urbana-Champaign (2016-2019) and a visiting researcher at the Jet Propulsion Laboratory (2015). Dr. Ho earned his Ph.D. at MIT and his bachelor's and master's degrees at the University of Tokyo. He is the recipient of the NSF CAREER Award (2020), the NASA Early Career Faculty Award (2019), the DARPA Young Faculty Award (2019), and the Luigi Napolitano Award (2015), and he is a co-author of one of the most downloaded Acta Astronautica articles. Prof. Ho currently serves as the Chair of the AIAA Space Logistics Technical Committee.

On the Design and Optimization of a Sustainable Asteroid Resources Based Supply Chain for Ensuring a Martian Colony Growth

Serena Suriano
Politecnico di Milano, Skoltech Space Center

The development of a colony on Mars needs a large amount of metallic materials. To provide it, a supply chain based on the extraction of metals from metallic asteroids is explored. The carbonaceous asteroids are considered for the propellant production. The asteroids are selected to respect the DV limits imposed by the spacecraft. Different supply chains are computed through a multi objective genetic algorithm that minimizes the mission dv, maximizes the mass of materials extracted and the mass of propellant produced on the asteroids. Several solutions are obtained having as input several mining rates. By associating a spacecraft to each element of the pareto front, the total quantity of extractable material is computed. Finally, the possibility of using the metallic material through additive manufacturing is examined.

Generating Sustainable Space Mission Concepts by Reusing Robust Design Patterns

Anne-Marlène Rüede
EPFL Space Center

On-orbit servicing capabilities support long-duration missions, and the subsequent development of a cis-lunar economy. However, it is still a challenge to understand when, where and how to use in-orbit servicing and design the infrastructure accordingly. In this presentation, the fundamentals of a pattern language composed of solutions to recurring design problems will be presented.

Low Energy Stable-Manifold Trajectories to the Earth-Moon Halo Orbits Dmitry Oliferowicz

Salman Ali Thepdawala
Skoltech Space Center

Orbits around Lagrange points in three body system, such as the Earth-Moon or Sun-Earth, offer significant advantage for various space missions. This presentation will discuss the use of space manifold dynamics to design transfer trajectories from Low Earth Orbit (LEO) to the L1/L2 Halo orbits of the Earth-Moon system. In this case, space manifold dynamics would encompass stable and unstable manifolds that would embody a general notion of the idea of an attractor or repellor in the case of orbits around Lagrange points.

Technology Combination Analysis Tool (TCAT): Institutional Interests and Future Developments

Flavio Brancato
EPFL Space Center

The European Space Agency is trying to extend the European capability to go to multiple destinations by 2023-2025 and is also investigating which roadmap they should follow beyond 2025. In the short-term, the target mission will be either in orbit around Earth either around another celestial body. TCAT aims to contribute to the delineation of a roadmap, identifying the missing building blocks for the optimal performance of some predetermined scenarios. In particular to deliver in various nodes several kinds of services and to help to optimize and maximize the use of space transportation solutions in order to better suit the customer needs.

Interactive session: joint research Objectives Trees

Facilitator: Marc-Andre Chavy-Macdonald
EPFL Space Center

This interactive session will attempt to connect the different presentations' research objectives via a structured workshop to rapidly create linked Objectives Trees. It will use the online tool Mural. Participants will try to formulate their research objectives in a defined syntax at several levels of abstraction, and connect them logically. They will then interactively connect them to each other. The aimed-for outcomes are:

(1) clarification of research objectives,
(2) a "common mental model" of the topics seen today, and
(3) identification of gaps and common objectives, leading to future joint research projects.

This interactive session is intended for active participants (researchers in, or entering the field) not observers, plus Skoltech Winter School participants. A separate tool and specialized rooms will be used, and it will not be recorded. Presenters are signed up by default; for others **please sign-up here:** https://forms.gle/1ErsjBLuEKuWtFwq6