7th International Space Sailing Symposium Report for OCT

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The aim of this report is to highlight our activities at Delft, the Netherlands, during our participation in the 7th International Symposium on Space Sailing (ISSS 2025), which I attended as a representative of Project Svarog, a student-led initiative at Imperial College London. We were given the opportunity to present our team's abstract on the feasibility of passive semi-major axis (SMA) gain in Low Earth Orbit (LEO) for a solar sail CubeSat, collaborating with team members including Shiki Vaahan, Piotr Fil, Herbie Christophers, Debdut Sengupta, Fatima Sajid, Madhav Rajeswar, Ian Poon, Rajveer Daga, Neil Pakrasi, and Defne Ertugrul. The symposium, hosted by Delft University of Technology, brought together experts from academia, industry, and space agencies to discuss advancements in solar sailing technology.

The main tasks I was involved in included:

- Preparing and submitting an abstract for the symposium's book of abstracts, focusing on our high-fidelity orbital simulations incorporating solar radiation pressure (SRP) and gravity-gradient torques, as well as the stratospheric demonstration of our solar sail prototype via the European Space Agency's (ESA) Balloon Experiment for University Students (BEXUS) program. This involved refining our Julia-based orbital propagator to test LEO trajectories and interplanetary escape paths, validating models against real-world conditions, and addressing challenges like incomplete deployment during BEXUS 34.

- refining and using our high fidelity Julia orbital propagator codebase to simulate various orbital trajectories relevant to our paper. We then used our plots and results to back up our claims/experimental testing results on stability analysis as well as choice of optimal trajectories.

- Presenting our work orally at the symposium, titled "Feasibility of Passive SMA Gain in LEO: Simulation and Stratospheric Demonstration of a Solar Sail CubeSat." This included discussing our mission concept for reaching the heliopause within 100 years using passive solar sailing, without gravity assists, and highlighting objectives like trajectory measurement up to 10 AU, visual deployment confirmation, and payload carriage. I also engaged in networking sessions with international experts, such as those from NASA, JAXA, and DLR, to gather feedback on our low-cost approach.

- Contributing to poster sessions and workshops, where I demonstrated our simulation results showing potential SMA growth in Sun-synchronous orbits (SSO) and discussed synergies with other presentations, such as those on solar sail attitude control and material degradation.

These main tasks specifically required me to compile technical data from our simulations and BEXUS tests, present complex orbital mechanics concepts accessibly, and incorporate feedback to refine our path toward a LEO technology demonstrator and eventual interstellar mission. Data collection involved reviewing symposium abstracts and running iterative simulations.

Figure 1: Group Photo

1 Context

Space sailing represents a revolutionary propulsion method that harnesses solar radiation pressure for fuel-free interplanetary and interstellar travel, making deep space exploration more accessible and cost-effective. Delft, the host city for ISSS 2025, is a hub for aerospace innovation, with Delft University of Technology leading research in advanced spacecraft dynamics. The symposium addressed multifaceted challenges in solar sailing, including material durability, trajectory optimization, and attitude control, amid growing interest from agencies like ESA and NASA. Many presentations highlighted inefficiencies in traditional chemical propulsion for high-delta-V missions, such as those to the outer Solar System, where solar sails offer a passive alternative.

Due to limited access to space for student teams, projects like ours face hurdles in testing large-scale sails, relying on educational opportunities like BEXUS for validation. Youth involvement in space technology is high but often unstructured, with low formal training in specialized fields like orbital mechanics. These challenges are compounded by inadequate frameworks for low-cost mission development and management. Project Svarog has been involved in advancing passive solar sailing through simulations and prototypes to enable missions beyond LEO, including escape trajectories to the heliopause.

The objectives of our presentation and participation aligned with the symposium's goals:

- Demonstrating feasibility of passive SMA gain in LEO without active control.
- Validating orbital models incorporating SRP, drag, and gravity-gradient effects.
- Promoting cost-effective CubeSat designs for interstellar exploration.
- Reducing mission complexity by leveraging spin-stabilization.
- Creating opportunities for visual and telemetry confirmation of deployment.

- Fostering international collaboration on solar sail applications.

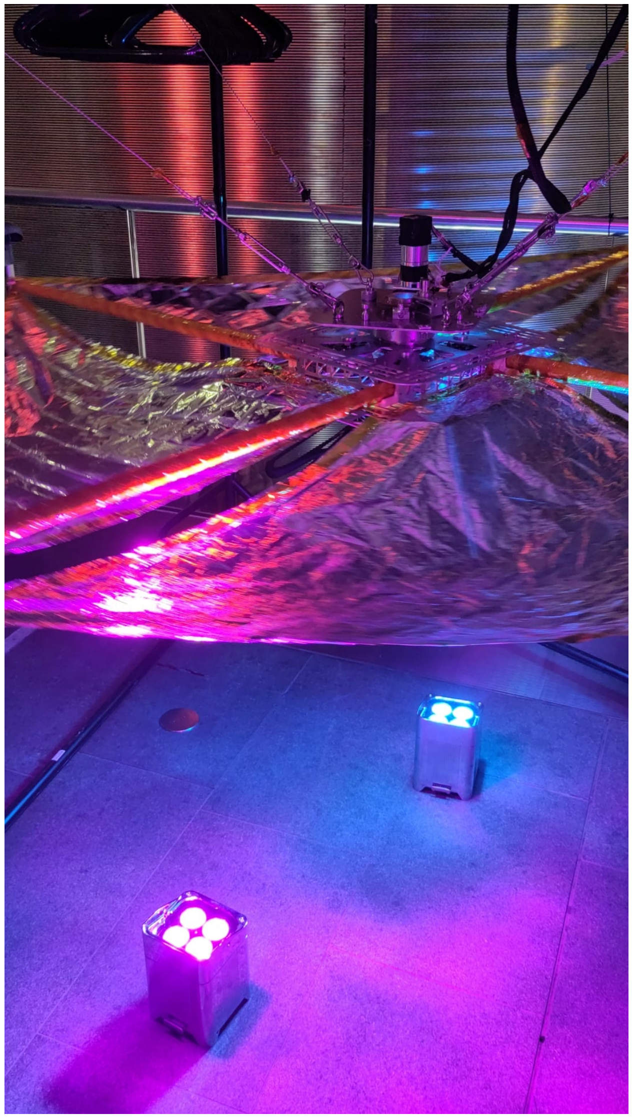

Figure 2: Project Svarog's Sail

2 Outcome

Project Svarog's presentation at ISSS 2025 contributes to a thriving ecosystem for solar sailing research, offering validated models and prototypes that enable low-cost missions for students and emerging space nations, while maintaining focus on sustainable, passive propulsion technologies.

2.1 Strengthening the framework for passive solar sailing simulations and testing.

A comprehensive orbital propagator in Julia was refined based on symposium feedback, providing tools for trajectory design in SSOs with inclinations around 98°. This includes Gauss Variational Equations for perturbations and models for SRP acceleration (a_{SRP}) and torque (τ_{SRP}).

The means to achieve this outcome include integrating BEXUS data into simulations, developing action plans for LEO demonstrators, and improving processes for high-fidelity modeling of nutation frequency (ω_n) and inertia tensors.

2.2 Promoting diverse mission opportunities and cost efficiencies.

Our work showcases solar sailing's potential for a range of applications, from LEO orbiting to interstellar escape, involving academic teams, agencies like ESA, and industry partners.

The means to achieve this outcome include raising awareness through presentations, creating incentives for low-mass designs (e.g., via spin-stabilization), and exploring partnerships for secondary payloads on interplanetary launches.

2.3 Establishing feasible trajectories and dynamics for passive sails.

Passive SMA gain is enabled by inertially-fixed orientations, with simulations showing potential altitude increases in SSOs despite drag.

The means to achieve this outcome include optimizing initial conditions (e.g., altitude and inclination), incorporating gravity-gradient torque (τ_{gg}), and ensuring stability through quaternion-based rotations.

2.4 Enabling collaborative and educational advancements in space technology.

The symposium fostered knowledge exchange, leading to refined prototypes and plans for future BEXUS flights or LEO launches.

The means to achieve this outcome include networking for feedback, investing in open-source tools, and designating student-led initiatives as key drivers for innovation, such as adapting our design for missions like solar polar orbits.

3 Reflection

This opportunity was an extremely enriching experience, especially during my time in Delft. I learned a lot from fellow presenters and committee members, who generously shared their expertise on solar sailing challenges. From the very beginning, I felt included and valued, which created an atmosphere where learning and growth were natural. The stimulating exchanges with experts from diverse backgrounds were invaluable. Their guidance not only improved my technical skills in orbital simulation but also provided valuable insights into the dynamics of international collaboration in space research.

Moreover, this symposium allowed me to experience things I could have never encountered otherwise. I gained a profound understanding of the global context of space exploration, which made me realize the importance of considering cost and accessibility when designing student-led missions in emerging fields like solar sailing. This aspect of my learning journey emphasized that successful projects aren't just about technical solutions; they must be sensitive to the needs and realities of interdisciplinary teams to truly make a positive impact. Additionally, I gained profound insights into the field and ongoing missions. I learned about the numerous challenges they are facing, both technically and logistically.

This experience was very helpful in showing me the need to consider many different factors in aerospace projects, with an approach that takes into account the broader context and involves multiple stakeholders. It was eye-opening to see how the traditional engineering approaches I learned until now need to be adapted and evolve to address the complex challenges in deep space exploration. In summary, this presentation gave me not only technical knowledge but also a full understanding of the challenges in real-world solar sailing projects, and I will cherish this experience forever.

Figure 3: Group Photo

4 Acknowledgements

I would like to express my deepest gratitude to the ISSS 2025 Organizing Committee, chaired by Jeannette Heiligers, for providing this platform that has allowed me to grow both professionally and personally. I would also like to thank my Project Svarog team members and mentors at Imperial College London for trusting and helping me through this whole experience. Last but not least the Old Centurion Trust Fund committee for making this opportunity possible in the first place.