Proceedings of the 2025 Winter Simulation Conference
E. Azar, A. Djanatliev, A. Harper, C. Kogler, V. Ramamohan, A. Anagnostou, and S. J. E. Taylor, eds.

COLLABORATIVE DEVELOPMENT OF A DISTRIBUTED LUNAR MISSION SIMULATION: A MULTI-TEAM DEMONSTRATION WITHIN SIMULATION EXPLORATION EXPERIENCE (SEE 2025)

Maziar Ghorbani[1], Anastasia Anagnostou[1], Nura T. Abubakar[1], Hridyanshu Aatreya[1], April Miller[1], and Simon J. E. Taylor[1]

[1]Dept. of Computer Science, Modelling & Simulation Group, Brunel University of London, Uxbridge, UK

ABSTRACT

The Simulation Exploration Experience (SEE) is an international industry–academic initiative that promotes the use of distributed simulation for space exploration. Each year, multiple university teams participate by developing simulations based on lunar mission scenarios. In SEE 2025, Brunel University of London collaborated with three other institutions to create a real-time, distributed simulation of a conceptual lunar mission. Using High-Level Architecture (HLA) standards and NASA's Distributed Observer Network (DON), five federates were developed to simulate a landing procedure, astronaut transport between facilities, inter-federate communications, and a laboratory tour. This abstract outlines the collaborative development effort, the roles of the participating universities, and the interoperable interactions between their systems.

1 INTRODUCTION

Inspired by volunteers from NASA, SISO, Pitch Technologies, and a global network of academic institutions, the Simulation Exploration Experience (SEE) advances modeling and simulation standards through open collaboration, student engagement, and cross-institutional interoperability in distributed systems (Ghorbani et al. 2024). In 2025, more than 10 universities from 8 countries participated in SEE, with around 60 students contributing to modeling and simulation, based on lunar mission scenarios. The final event showcased a live, real-time distributed simulation developed by four universities, demonstrating increased scale and technical integration across interoperable distributed systems.

2 SCENARIO OVERVIEW

The conceptual scenario focused on lunar infrastructure operations, using HLA-based federates to coordinate landing procedures, astronaut transport, inter-federate communications, and a laboratory tour.

Key scenario elements included:

1. The **Brunel University Lander federate** requested landing clearance from the **Spaceport federate**, initiating the lunar descent, and surface entry process.
2. The **FACENS Cable Car federate** transported astronauts between lunar infrastructure nodes, coordinating handovers with the Spaceport upon successful landing.
3. The **Embry-Riddle Aeronautical University Laboratory federate** received astronauts at its facility and provided a virtual tour, marking the scenario's final phase.
4. The **University of Central Florida Beacon federate** facilitated asynchronous communication and message acknowledgement across the simulation network.

All activities were visualized through NASA's Distributed Observer Network (DON), providing a shared 3D environment, and live-streamed broadcast on YouTube.

3 TECHNICAL AND EDUCATIONAL ACHIEVEMENTS

SEE 2025 successfully demonstrated:

- Distributed simulation across multiple teams via the SEE HLA Starter Kit Framework (Falcone and Garro 2016).
- Live control handoffs between federates representing infrastructure components and communications.
- Student-led design, development, and execution of interoperable simulation components across multiple time zones.

Figure 1 presents both the visualization of the scenario within DON 3.1 and a simplified interaction diagram showing key HLA publish/subscribe relationships between federates.

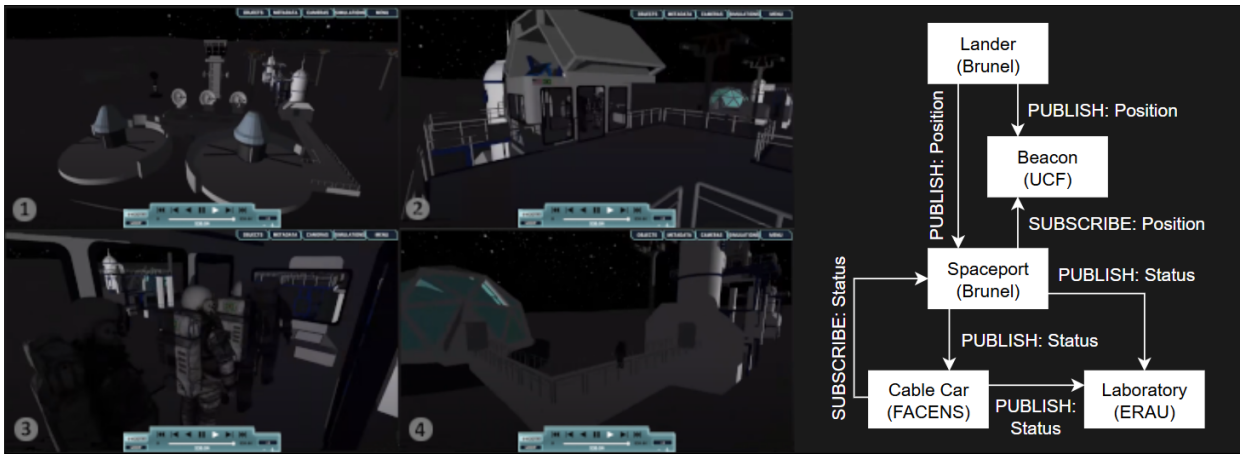

Figure 1: Left: Key stages of the scenario visualized in DON, including the lunar Spaceport, Cable Car, astronaut transfer, and laboratory tour. Right: Federate interaction diagram showing HLA-based publish/subscribe and their control flows.

4 CONCLUSION AND FUTURE WORK

SEE 2025 demonstrated the effectiveness of distributed simulation for space exploration, especially in educational contexts. The effort was led and delivered by student teams, demonstrating the strength of experiential learning and international collaboration, which are essential for future space missions.

A key lesson from SEE 2025 was the importance of starting collaborative development early and ensuring teams have access to simulation tools they are comfortable with. These practices significantly improve integration and system coherence across institutions.

Future efforts will focus on refining simulation architectures, supporting new team onboarding, and developing automation tools to enhance usability and scalability.

REFERENCES

Falcone, A., and A. Garro. 2016. "The SEE HLA starter kit: enabling the rapid prototyping of HLA-based simulations for space exploration". In *Proceedings of the 2016 Spring Simulation Multi-Conference (SpringSim): Modeling and Simulation of Complexity in Intelligent, Adaptive and Autonomous Systems (MSC/IAAS)*, 1–8: Society for Computer Simulation International https://doi.org/10.22360/SpringSim.2016.MSCIAASSPACE.001.

Ghorbani, M., A. Anagnostou, N. T. Abubakar, H. Aatreya, D. Curry, and S. J. E. Taylor. 2024. "Simulation Exploration Experience (SEE) Introductory Tutorial". In *Proceedings of the 2024 Winter Simulation Conference (WSC)*, 1368–1382: IEEE https://doi.org/10.1109/WSC63780.2024.10838847.