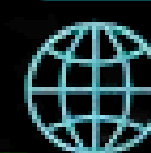


# LUNANET-SIM:

## AN OPEN-SOURCE, BROWSER-BASED 3D INTERACTIVE TESTBED FOR CISLUNAR DELAY-TOLERANT NETWORKING WITH VERIFIED HARDWARE INTEROPERABILITY

LUNAR-NODE  
BASE-1  
BASE-2  
R-1 R-2

### RESEARCH HIGHLIGHT



3D REAL-TIME  
CISLUNAR SIMULATION



RFC 9171 COMPLIANT  
DTN STACK

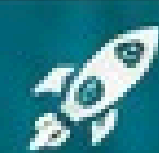


VERIFIED HARDWARE  
INTEROPERABILITY  
WITH AALYRIA'S HARDY



### THE CHALLENGE

- Reliable lunar communication is central to NASA's Artemis program and LunaNet.
- Today's DTN/LunaNet simulators are **expensive, non-interactive**, and require a **full Linux setup**.
- Hands-on research is out of reach for most students, educators, and independent researchers.



### OUR GOAL

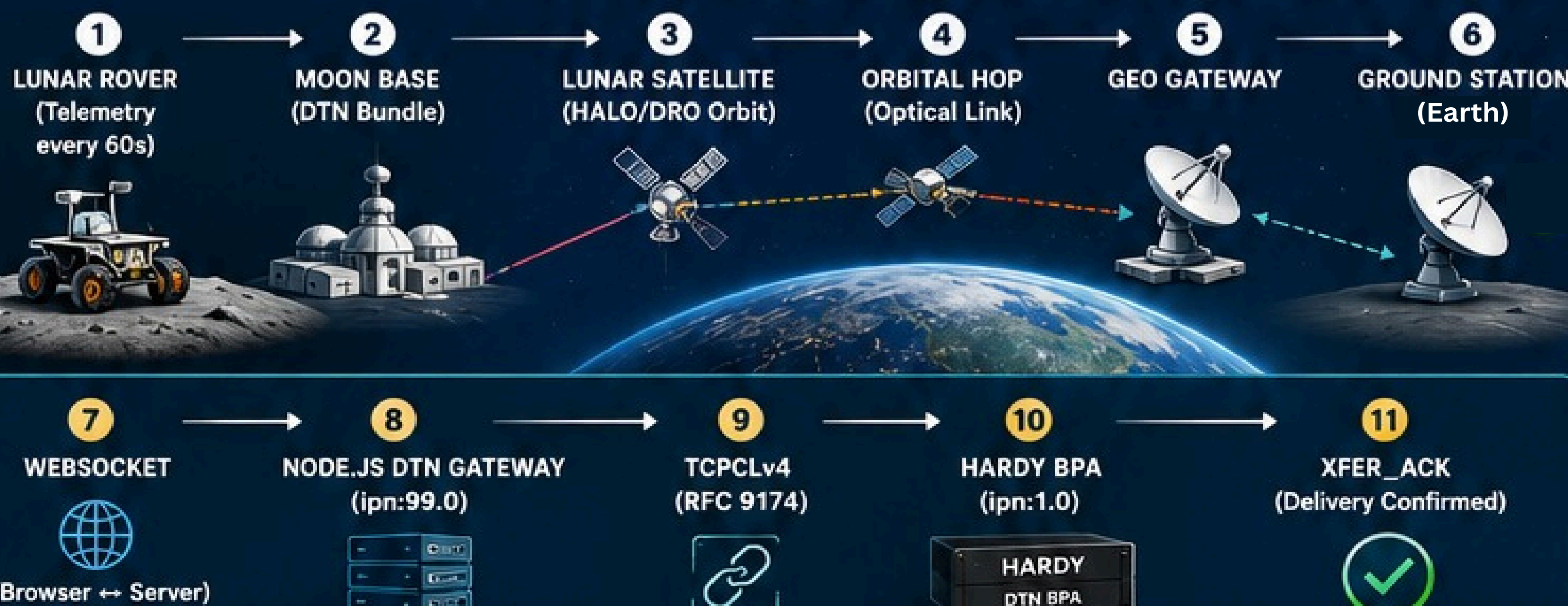
Build a 3D LunaNet simulator that visualizes cislunar communication in real time — and prove it isn't just a toy by validating it against Aalyria's Hardy, a production-grade DTN stack, through real hardware interoperability testing.



### METHODOLOGY

- 3D Visualization Layer** — CesiumJS on real astronomical data; satellites in true orbits, laser links, moon bases and rovers as live network nodes.
- Protocol Layer** — RFC 9171 DTN store-and-forward with priority-queued bundles. Routing via CGR (orbital pathfinding) and Greedy/Hierarchical protocols.
- Hardy Interoperability** — Node.js DTN gateway (TCPCLv4 from scratch) bridges WebSocket to a live TCPCLv4 session with Hardy BPA.
- Dashboard** — Clean, accessible UI to select nodes and study packet delivery live—no command line required.

### ARCHITECTURE & DATA FLOW (END-TO-END DTN PIPELINE)



### FEATURE HIGHLIGHTS

- Persistent TCPCLv4 session — single handshake, all bundles over one continuous connection
- 2 Routing Modes — CGR and Greedy/Hierarchical, switchable live
- Fault Injection — Solar flares (40% packet loss) and hardware blackouts
- Priority-Based Eviction — Priority 0 (Bulk) dropped first to preserve Priority 2 (Critical) traffic

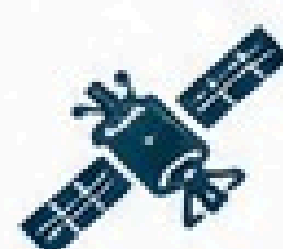
### KEY RESULTS



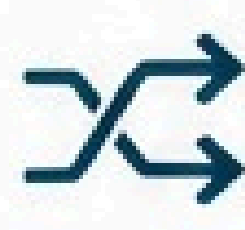
**100%  
PACKET DELIVERY  
RATIO**  
under nominal  
conditions



**PERSISTENT  
TCPCLv4 SESSION**  
single handshake,  
all bundles delivered  
over one continuous  
connection



**10-NODE  
EARTH-MOON  
TOPOLOGY**  
3 GEO + 5 cislunar +  
1 ground station,  
real orbits at real  
time and speed



**2  
SWITCHABLE  
ROUTING MODES**  
CGR and Greedy/  
Hierarchical,  
toggled live from  
dashboard



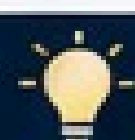
**FAULT  
INJECTION  
TESTED**  
solar flare events  
(40% packet loss)  
and hardware  
blackouts handled  
via DTN store-and-  
forward



**PRIORITY-BASED  
EVICTION**  
Priority 0 (Bulk)  
traffic is dropped  
first to preserve  
buffer space for  
Priority 2 (Critical)  
traffic

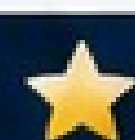


**FIRST VERIFIED  
TCPCLv4  
INTEROPERABILITY**  
between a browser-  
based cislunar  
simulator and  
Aalyria's Hardy BPA



### WHY IT MATTERS

As NASA works toward a sustained human presence on the Moon, a dependable LunaNet is essential — and so is the ability to study it. Today that ability is largely limited to official channels. LunaNet-Sim is **free, open-source**, and **runs entirely in a browser**, letting researchers and educators test real routing protocols like CGR and Greedy/Hierarchical, then validate results against production DTN hardware — no specialized lab required.



### KEY CONTRIBUTIONS

- First open-source, browser-based 3D interactive simulator of the NASA LunaNet architecture
- First verified TCPCLv4 hardware interoperability between a cislunar simulator and a production DTN stack (Aalyria's Hardy BPA)
- Full-stack pipeline: 3D visualization → WebSocket bridge → persistent TCPCLv4 session → XFER\_ACK-confirmed delivery
- RFC 9171-compliant DTN stack with CGR, Greedy routing, class-of-service priority queuing, preemptive buffer eviction, and fault injection



### RECOGNITION

- Reviewed and recognized by **Dave Israel**  
NASA LunaNet Architect
- Reviewed and recognized by **Rick Taylor**  
Tech Lead,  
Aalyria Technologies
- Invited to present at **IEEE STINT 2026**  
by **Juan A. Fraire**  
STINT Co-Founder, Inria

### SCAN TO WATCH THE DEMO



[www.linkedin.com/in/syed-talha-jamal](https://www.linkedin.com/in/syed-talha-jamal)

