# LEO Relay to GEO + Starlink Mesh

Systems Block, Operating Modes, MECSAI Integration, and Handover Logic

Overview

This document defines the architecture, operating modes, and control interfaces for a space-only optical relay network that connects a low Earth orbit (LEO) relay node to a geostationary orbit (GEO) communication satellite and integrates with a LEO mesh network (such as Starlink) for data distribution. The design removes the need for terrestrial ground stations, enabling continuous optical connectivity between space-based assets.

System Block Diagram

Users	■	LEO Mesh Cells
	↑	
(LEO Mesh ISL Fabric)		
	↑	
LEO Relay Node	■	GEO Optical Payload
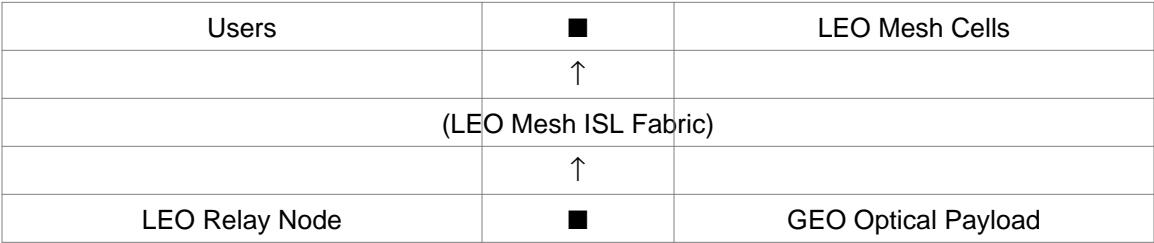
Operating Mode Table

Mode	Trigger	Action	Exit Criteria
M0 Safe	Fault or thermal anomaly	Lasers off, maintain clock	Fault clears
M1 Acquisition-GEO	GEO LoS detected	Beacon search and lock	Lock achieved
M2 Acquisition-LEO	LEO mesh LoS detected	Beacon search and lock	Lock achieved
M3 Coherent-Combined	Dual lock, low jitter	Phase combine, full rate	Jitter exceeds limit
M4 Non-Coherent	Phase unlock	Power combine, increase FEC	Stability restored

Handover Logic

A small Walker constellation ensures continuous link coverage between LEO and GEO nodes. Each handover is pre-briefed 120 seconds prior, initiates parallel acquisition 20 seconds prior, and finalizes a make-before-break switchover within 50 ms to maintain continuous optical routing.

MECSAI Integration Summary

The MECSAI controller supervises all relay operations, receiving telemetry such as SNR, jitter, rate, and handover states. It commands mode changes, rate/FEC overrides, and gate controls. Safety

interlocks prevent unsafe laser activation near exclusion zones and thermal limits.

Next Steps

- Develop ICD v0.1 signal dictionary and topic schema. - Produce Rate/FEC ladder performance curves. - Simulate handover traces with 4 LEO and 2 GEO nodes for validation.