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Designing a Frugal LEO Constellation with Integrated Orbital Micro Data Centers

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324 Satellites	$400–450M	70–90%	25 TFLOPS
LEO Constellation	Total CAPEX	Cost Reduction	On-Orbit Compute

Executive Summary

Maargin is building a Space Network to provide communications services for users, enterprises, satellites, aircrafts, and other space entities.

This white paper presents the technical architecture behind Maargin's low-cost LEO satellite constellation — designed to deliver broadband connectivity and on-orbit AI/ML compute for emerging markets at a **70–90% lower CAPEX** than existing mega-constellations.

Through five frugal design levers — higher-altitude 1,000–1,200 km orbits, 10–100 Gbps optical ISLs, SDR payloads, radiation-tolerant COTS electronics, and integrated 25 TFLOPS micro data centers — the 324-satellite constellation delivers a fully integrated connectivity and computing stack at **$400–450M total CAPEX**.

The Problem

Mega-constellations cost $5–10B+, locking out emerging markets. Over 2 billion people still lack reliable internet.

The Approach

Frugal engineering applied at constellation scale — higher altitude, COTS hardware, SDR payloads, orbital AI compute.

The Outcome

National broadband + orbital edge compute for India and partners at $400–450M CAPEX, $55–70M annual OPEX.

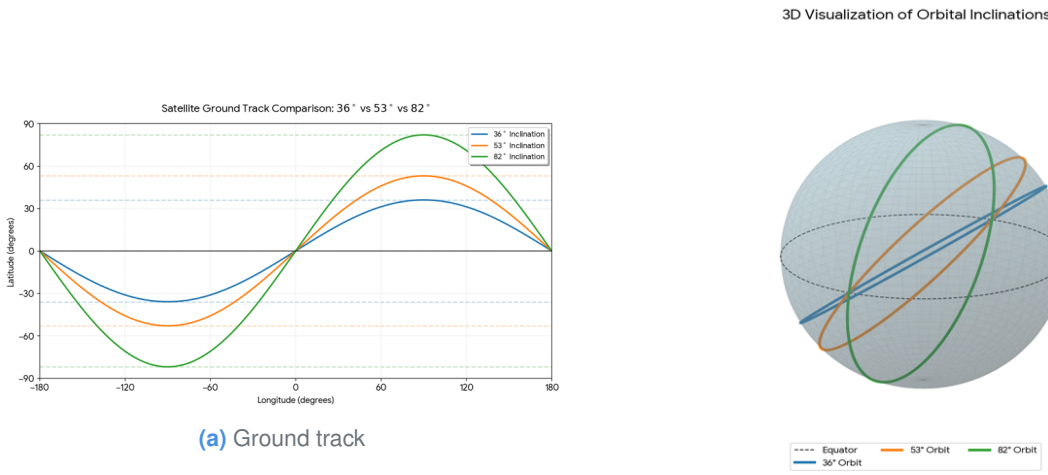
1 Constellation Design

Orbital Architecture

Maargin's three-shell Walker constellation at 1,000–1,200 km provides continuous coverage over India, UK/Europe, and polar regions from just 324 satellites.

Shell	Region	Altitude	Inclination	Satellites
Shell 1	Tropical / India	1000–1200 km	20–40°	144
Shell 2	Temperate / Europe	1000–1200 km	53°	144
Shell 3	Polar	1000–1200 km	$> 80°$	36
Total				**324**

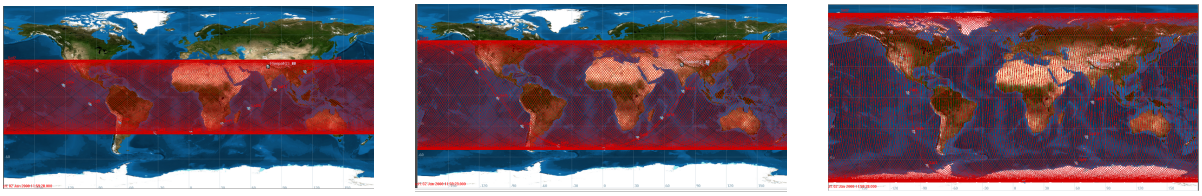
"Moving from 300 km to 1,200 km reduces the satellite count per shell by 89% — from 1,296 to 144 — cutting shell manufacturing cost from $520M to $60M."



(a) Ground track

(b) Orbital inclination

Figure 1: Orbital attributes for inclinations of 36°, 53°, and 82°.



(a) 36° **(b)** 53° **(c)** 82°

Figure 2: Ground tracks at various orbital inclinations.

Altitude	Satellites/Shell	Shell Cost	Launch Cost
300 km	1,296	$520M	$320M
600 km	484	$200M	$120M
1,200 km	**144**	**$60M**	**$36M**

2 Frugal Technology Stack

Optical Inter-Satellite Links

- **10–100 Gbps** bidirectional
- Max range **4,000 km**
- 1,550 nm wavelength
- **7–11 kg** (vs. 15–25 kg standard)
- **40–50%** weight reduction

Software-Defined Radio

- Development: **weeks** vs. 12–24 months
- NRE: **minimal** vs. $1M per design
- In-orbit reconfigurable
- Ku-band + Ka-band capable
- Remote software updates

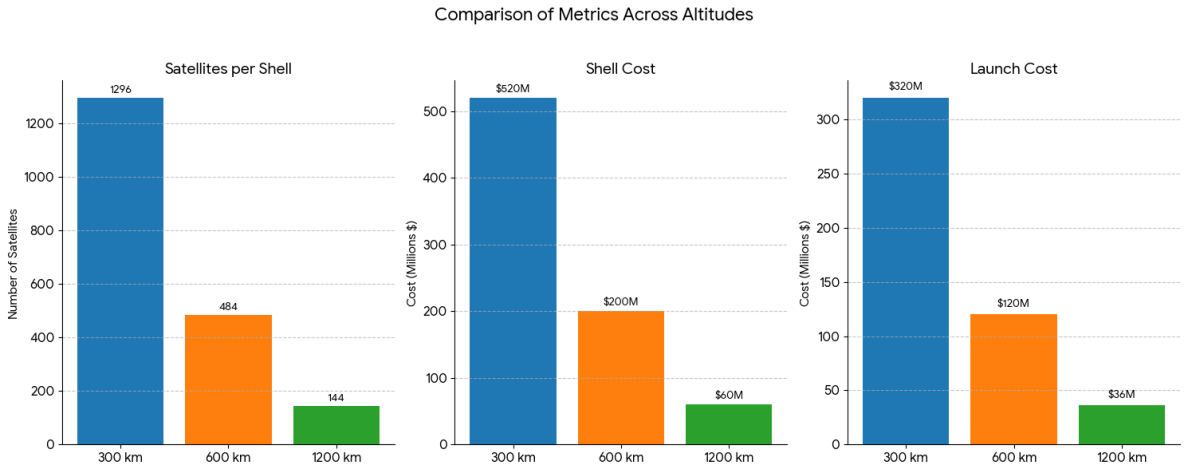


Figure 3: Satellite count, shell cost, and launch cost vs. altitude.

Radiation-Tolerant COTS

- Automotive/medical-grade COTS parts
- **$20–40k/sat** vs. $200k/sat
- **80–90%** cost reduction
- TID below 10 krad(Si) with shielding
- ECC + watchdog fault management

Compact Satellite Bus

- **200–250 kg** vs. 400+ kg standard
- Mfg. cost **$400–500k** vs. $1M
- **50%** mass reduction
- 400 W (comms) / 600 W (with compute)
- 6-year design life

3 Orbital Micro Data Centers

Compute modules deployed on ≈**108 satellites** — one-third of the constellation — forming a distributed orbital AI/ML fabric built atop the optical ISL network.

25 TFLOPS	2 TB	200 W	20–35 kg	108
Compute per node	Persistent Storage	Avg. Power Draw	Module Mass	Compute Satellites

Workload	Description
AI/ML Inference	Anomaly detection, workload management, traffic routing
Edge Processing	On-orbit data processing and results transmission
Comms Control	Autonomous routing, downlink prioritisation
Thermal Scheduling	Intensive compute during eclipse for peak radiative cooling

4 Economics

Phase 1 — Shell 1
$200M
Design, qualification, first shell + ground segment

Phase 2 — Shell 2
$100M
Recurring manufacturing & launch

Phase 3 — Shell 3
$100M
Full coverage polar shell

Cost Category	Amount (M$)
Satellite design, testing & qualification	80–100
Satellite manufacturing (340 units @ $400–500k)	136–170
Launch services ($1,000–1,500/kg)	80–100
Licensing, spectrum, ITU, legal	5–10
Ground stations (30 stations + backhaul)	60–100
Total CAPEX	**400–480**

Parameter	State-of-the-Art LEO	Maargin
Satellite mass	400+ kg	200–250 kg
Mfg. cost / satellite	$1,000,000	$300–400k
Shell deploy (manufacturing)	$520M	$60M
Shell deploy (launch)	$320M	$36M
Cost reduction	—	**88–90%**

Annual OPEX post-deployment: **$55–70M/year** (satellite replenishment, ground ops, backhaul, insurance).

5 Ground Segment & Performance

Ground Stations

System	Stations	Antenna
Starlink	150+	2.8–3.0 m
Amazon Kuiper	300	5.4 m
OneWeb	50+	2.4–3.5 m
Maargin	**28–30**	**2.5–3.0 m**

Performance

- Latency: **50–80 ms** RTT
- ISL add: 10–30 ms per hop
- Ka gateway: ≈**20 Gbps**/satellite
- **200–400** concurrent users/satellite
- 30° latitude swath at 1,200 km

Frequency plan: Optical ISLs at 1,550 nm (10–100 Gbps) · Ku-band 10.7–14.5 GHz (user terminals) · Ka-band 17.8–30.0 GHz (gateways)

6 Deployment Roadmap

Phase 1 anchored by IN-SPACe and sovereign co-investment. Phases 2–3 open to private operators and regional partners as risk is retired and demand is validated — a template adaptable to any emerging space nation.

Conclusion

> *"Maargin proves that frugal engineering can deliver national-scale broadband + orbital AI compute for under $500M — opening the space economy to the nations that need it most."*

Maargin's frugal LEO constellation delivers **70–90% CAPEX savings** versus state-of-the-art mega-constellations while maintaining competitive performance. The $400–450M total deployment cost makes sovereign space-based connectivity and orbital AI/ML compute accessible to emerging space nations.

The five-lever frugal architecture — orbit optimisation, SWaP-minimised payloads, COTS avionics with shielding, SDR-based software flexibility, and integrated orbital micro data centers — combined with a phased PPP deployment model provides a replicable template for any nation seeking sovereign LEO infrastructure.

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