SDC Master Plan: GEO Space Data Center Clusters + Nuclear-Electric Tug Fleet

Architecture • Operations • Maintenance • Finance • Compliance

NASA-Style Technical Implementation & Finance Plan (v1.1)

Date: 2025-10-12

Project: SDC & COMMS

Table of Contents

1. Executive Summary

We propose three modular SDC clusters in GEO, each composed of five compute modules, one Servic
Module (SBM), one Autonomous House Module (AHM) providing solar-primary with fission baseload po
and electrolyzers, and one COMMS module. A six-node LEO optical mesh replaces ground stations, providing DTN custody and low-latency optical routing to ISS and Artemis Gateway.

A nuclear-electric tug fleet (NEP) provides LEO⇄GEO⇄NRHO logistics, relocations, life-extension docking, and emergency response. SBM robots perform regular SDC, AHM, COMMS, and tug maintena
with <48-hour turnarounds, enabled by standardized cartridges, quick-disconnects, and shared spare
across tugs and SDCs.

This master plan details architecture, maintenance, shared nuclear components for spares reduction, launch/deployment, compliance anchors, and a 10-year financial strategy targeting a $5B raise and $15–30B valuation.

2. System Architecture Overview

Each GEO SDC cluster integrates compute, servicing, power, and comms into a repairable, upgradabl platform. Clusters are cross-linked via optical/Ka links and routed using DTN with custody and priorities. The LEO mesh maintains continuous line-of-sight to the clusters and provides relay access to ISS and Gateway, eliminating ground ingress costs.

The tug fleet executes bulk delivery, relocation, plane changes, and Gateway logistics. EOL plans avoid Earth re-entry, with Jupiter atmospheric disposal or heliocentric graveyard. The same NEP power-conversion cartridge and thermal components are used fleet-wide.

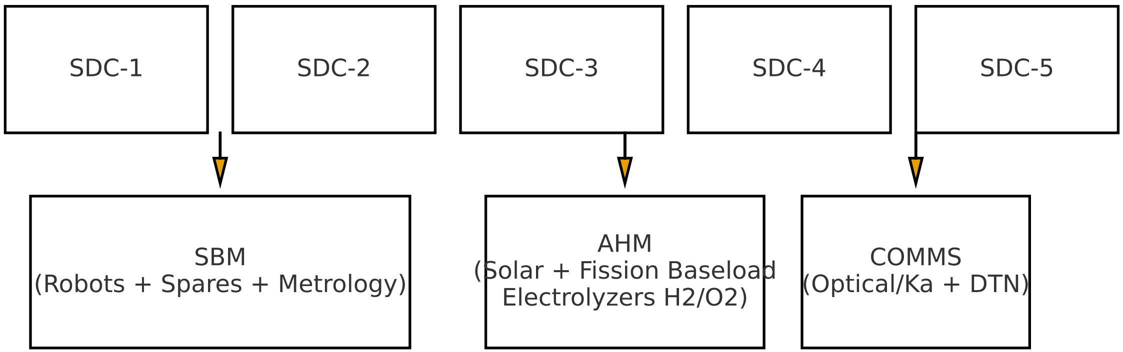


Figure 1. SDC Cluster Block Diagram (5 Compute + SBM + AHM + COMMS)

3. SDC Cluster Design (Compute, SBM, AHM, COMMS)

Compute: Five independent SDC modules (40–60 kW IT each) connect to redundant DC buses and liq cooling loops. Hot-swap compute sleds and network fabrics enable online upgrades.

SBM: Houses robots, spares racks, metrology, end-effectors, torque tools, borescopes, fluid handling carts, and leak-check instrumentation. Provides power/thermal/data umbilicals for visiting tugs and internal modules.

AHM: Solar arrays sized for sunlit full load; fission baseload (50–150 kWe) ensures eclipse ride-through and drives electrolyzers for H_2/O_2 production (station-keeping trim and contingency life support). Thermal loops are sectionalized with patchable radiators.

COMMS: Optical/Ka terminals with DTN BPv7 and priority classes; custody routing policies for fading links; time distribution per AFS roadmap.

Robotic serviceability and sectionalized systems drive lifetime beyond 12–15 years.

4. LEO Mesh & ISS/Gateway Comms

Six LEO nodes at ~53° alternating inclination maintain at least one active crosslink to a GEO cluster, with optical routing between nodes. The mesh provides relay access to ISS; GEO COMMS modules extend relay to Artemis Gateway (NRHO). DTN custody protects data across fades/eclipses a supports priority classes for critical traffic.

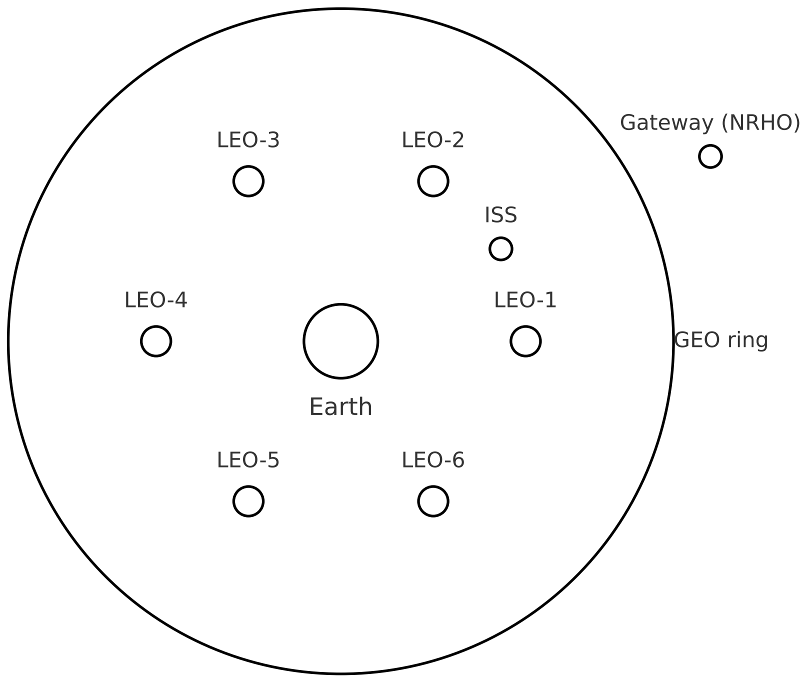


Figure 2. Six-Node LEO Mesh (53° alternating) with GEO SDC Links and Relays to ISS and Artemis Gateway

5. Nuclear-Electric Tug Fleet (Design, Lifespan, EOL)

Design: NEP core with reactor + Brayton/Stirling conversion; Hall/ion propulsion clusters (N+2 heads); Xe/Kr primary propellent; water utility loop. Docking per IDSS/NDS; optical/Ka comms. Sectionalized radiators and swap-ready power-conversion cartridges.

Lifespan: 12 years firm; 15 years with mid-life cartridge + thruster-head swap; stretch to ~20 years with careful throttling and radiator health. SBM robots execute 48-hour turnarounds (filters, seals, cathodes, head swaps, converter swap, fluids, test).

EOL: never re-enter; Jupiter disposal or heliocentric graveyard. Optionally donate a retiring tug to planetary defense (kinetic/tractor).

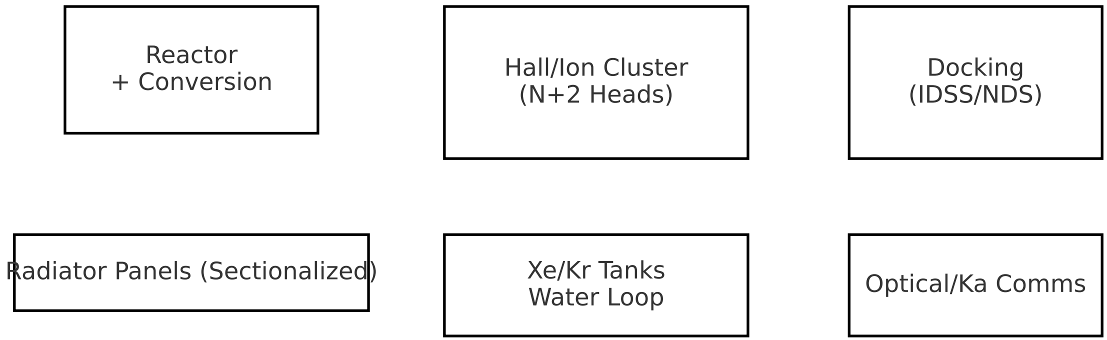


Figure 3. NEP Tug Conceptual Block Diagram

6. Maintenance at the SBM: Robots & 48-Hour Turnarounds

Standard dock: IDSS/NDS hard-mate; power/data/thermal umbilicals; Xe/Kr, water, coolant QDs; robot keep-out volumes enforced by interlocks.

Robot task library: thruster head/cathode swaps; valve/pump module replacement; converter cartridg swap; radiator patch/isolations; avionics card swaps; fluids top-off; metrology (LIDAR/IR); vibration trending.

Turn sequence (<48h): Dock → health scans → swap kits → fluid service → functional tests → leak checks → mass/prop updates → undock window.

Kits: A (per-visit), B (quarterly), C (mid-life). Spares depth: N+2 thruster heads per tug distributed across clusters; 1 converter spare per two tugs.

7. Nuclear Commonality & Spares Unification

AHM and NEP tugs share the same power-conversion cartridge, pumps, valves, filters, quick-disconnects, radiator tiles, and controller cards. This halves spare SKUs and allows any SBM to service any tug or AHM.

Benefits: smaller total spares mass; simpler training; faster turnarounds; fewer unique failure modes; higher system availability.

8. Launch & Deployment (Starship Clustered)

Starship baseline: average loaded cost ~$667/kg to LEO (assumption). Clustered manifests pack multiple LEO relays and tugs per launch; GEO transfer via commercial services or staged NEP boosts. Deployer uses dual ESPA-Grande rings with a central spine.

Separation choreography: phased releases with 10–20 m/s offsets; autonomous fan-out; radiator deployments; nuclear start only after phasing checks.

9. Standards & Compliance (LNIS/ICSIS/SCaN/LCRNS)

Optical Links & Routing (LNIS §5.2.4): handshake timing under fades; QoS telemetry hooks; reroute thresholds.

DTN Usage (LNIS §7.3): custody transfer + priorities; optical/RF convergence settings.

PNT/Timing (LNIS §8): AFS receiver plan + PPS/10 MHz distribution (gap to close).

Interoperable Relay (ICSIS §4.6): cross-provider continuity tests; message/timing integrity (ICSIS §5.4).

SCaN-MOCS: ground tier largely removed; retain spectrum artifact registers and preflight checks; LCRNS: PAT time, tracking stability, custody success KPIs.

Change-detection: daily spec watches with delta routing to MECSAI for action tracking.

Compliance threads are integrated into MECSAI via MCP Agent for continuous alignment.

10. Financial Plan (Build/Deploy/OPEX + Revenues)

Build: ~$740M (3 clusters, 6 LEO relays, 6 tugs incl. I&T/SE/PM/contingency).

Launch/Transfer: ~300–360*M→Totalinitialdeployment* 1.04–1.10B.

OPEX steady state: ~$19–23M/yr; reduced by AHM baseload + electrolyzer logistics.

Revenues: Tug services ($10–18M/yr each; 6 tugs → $60–108M/yr); SDC clusters ($40–80M/yr each; 3 clusters → $120–240M/yr).

Capital strategy: R&D grants ($200–400M), Angels ($50–100M), VC ($0.9–1.4B cumulative), Project Finance ($1.5–2.0B), IPO ($2.0–2.5B) targeting $5B total.

11. Risk Register & Mitigations (Selected)

Nuclear licensing timeline → start NEPA/NSRP early; common safety case family for tugs/AHM.

AFS/time distribution gap → fund receiver + PPS distribution NRE early; run timing sanity checks in DTN.

Optical link intermittency → LNIS 5.2.4 tests; custody priorities; mesh diversity; telemetry for QoS.

Supply chain (Xe/Kr, cartridges) → pooled spares, supplier dual-source, clustered launch cadence.

Capital timing → tranche plan, service-backed project finance, IPO post EBITDA-positive with >3x backlog.

12. Milestones & KPIs

T-12 mo: NEP conversion hot-fire endurance; optical mesh SW TRL-6.

T-6 mo: LEO demo (1 tug + 1 relay), SBM robotic turnaround in orbit.

T-0: Cluster-1 GEO acceptance, LEO mesh live, first revenue tows.

+12 mo: Two service cycles, tug utilization >60%, station-keeping subscriptions signed.

KPIs: PAT time, tracking stability, DTN custody success, time-tag RMS; financial: utilization, $/kg delivered, on-dock hours, fault-free days.

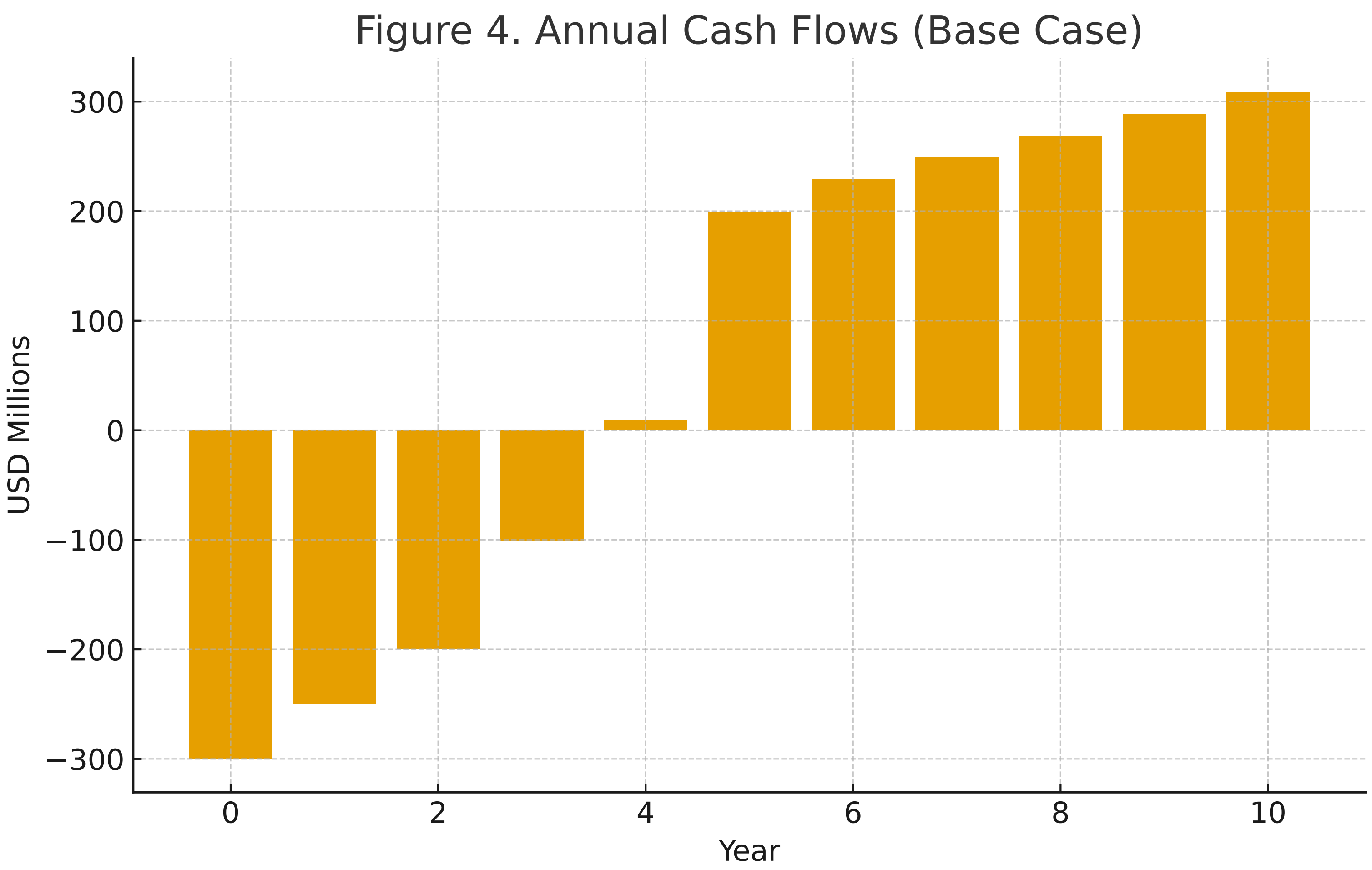
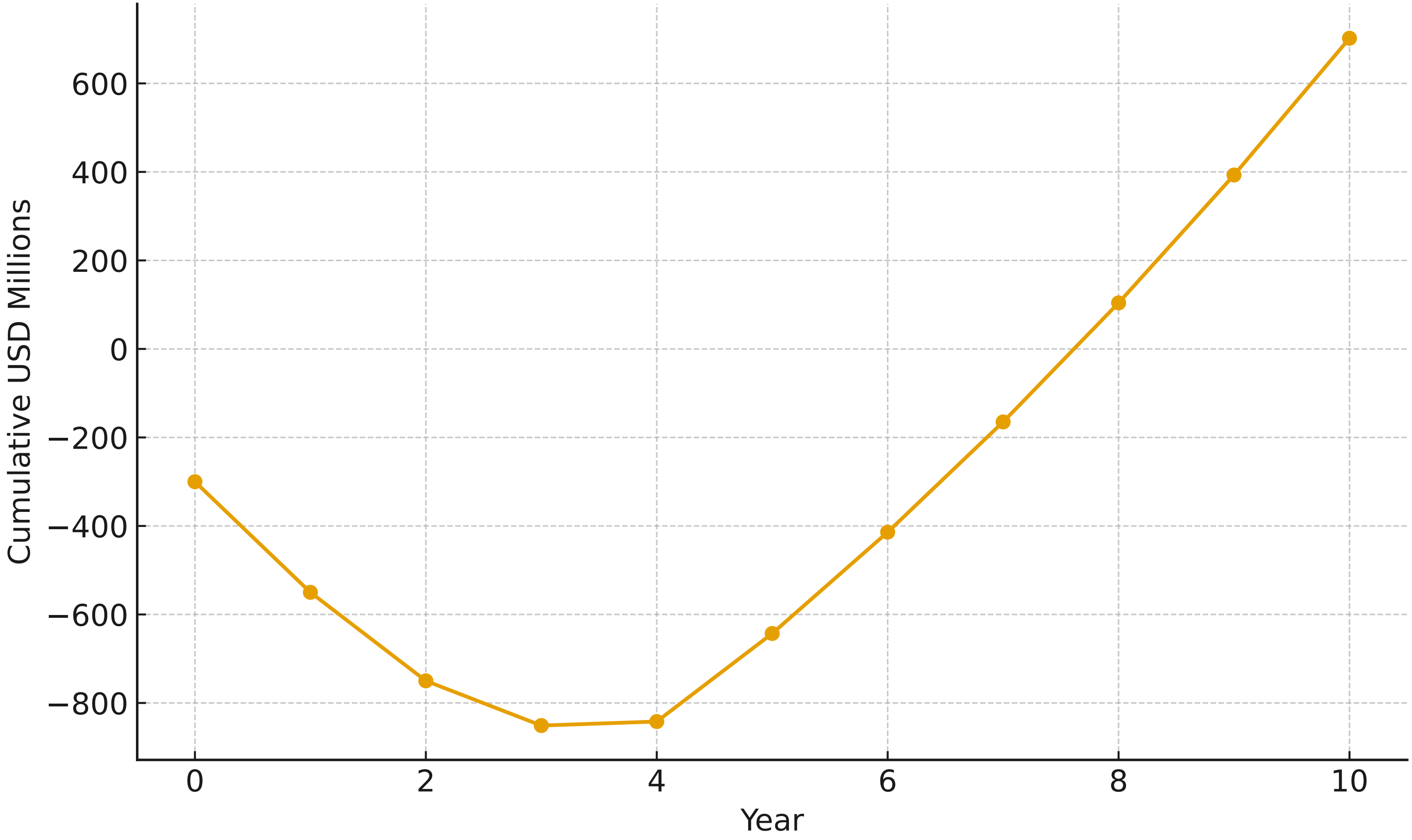


Figure 4. Annual Cash Flows (Base Case)
USD Millions
Year
300
200
100
0
−100
−200
−300
0
2
4
6
8
10

Figure 5. Cumulative Free Cash Flow (Base Case)



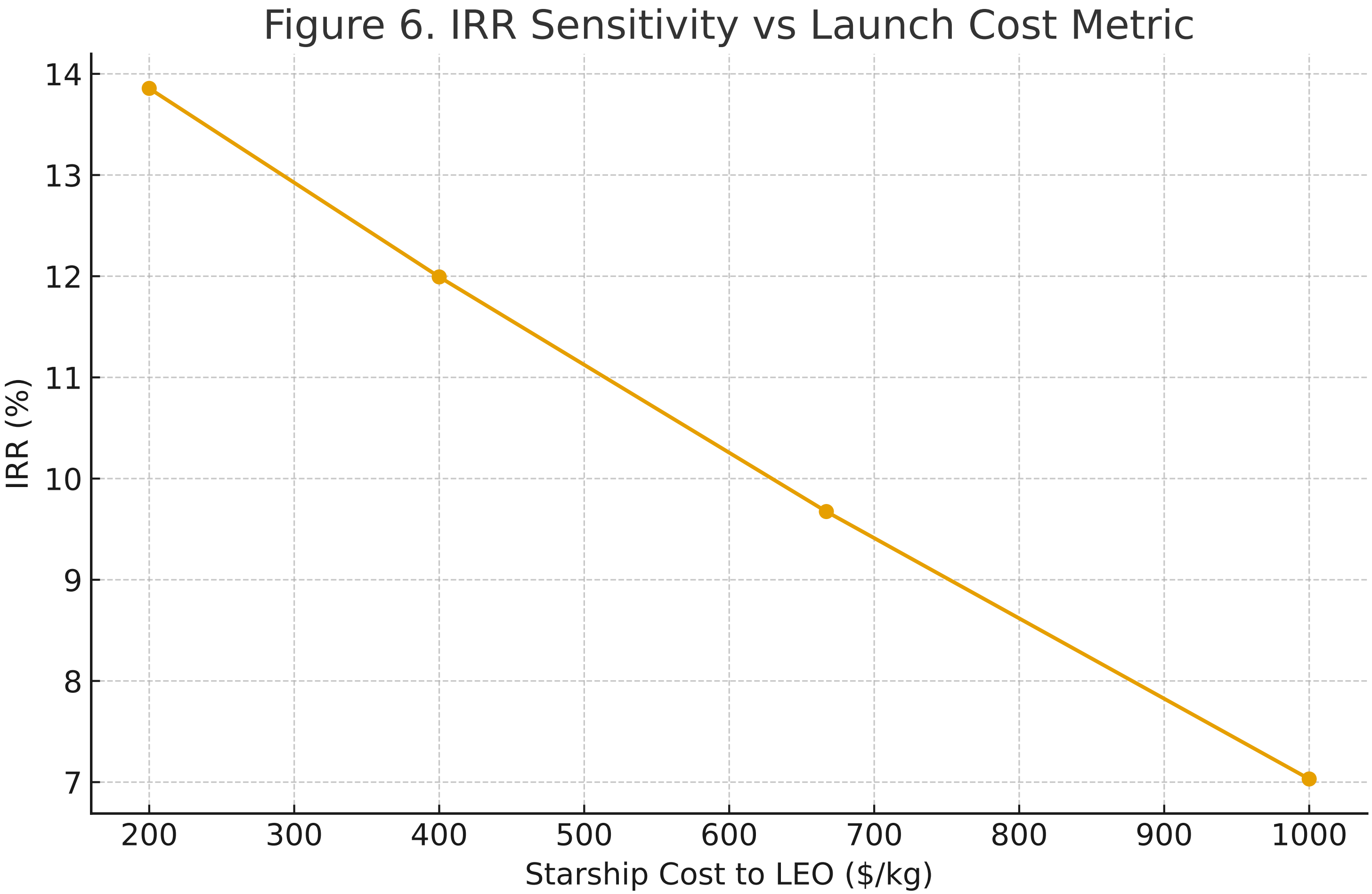
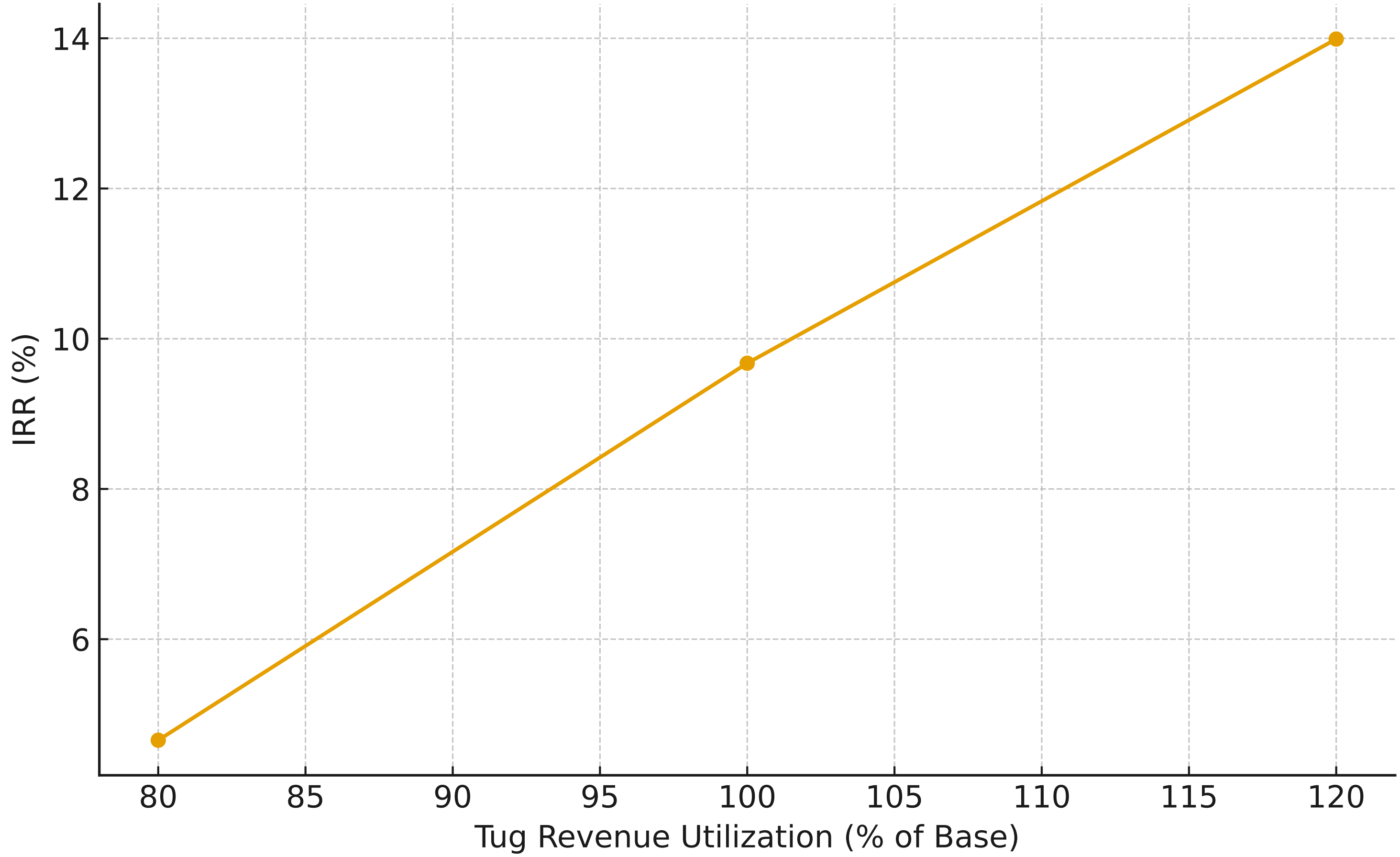


Figure 6. IRR Sensitivity vs Launch Cost Metric
IRR (%)
14
13
12
11
10
9
8
7
200
300
400
500
600
700
800
900
1000
Starship Cost to LEO ($/kg)

Figure 7. IRR Sensitivity vs Tug Utilization



Finance Annex — Metrics

Discount Rate: 10%

Base-Case NPV (10-Year): $-14.5M

Base-Case IRR (10-Year): 9.7%

Sensitivity Summary:

- Launch $/kg (200/400/667/1000) materially shifts IRR/NPV;
- +/-20% tug utilization changes IRR by several points;
- Push contracts to subscriptions to stabilize cashflows.

All figures illustrative; replace with vendor quotes for formal budgets.

Appendix A — Interfaces & ICD Summary

Docking: IDSS/NDS active (tug) to passive (SBM/SDC).

Utilities: power (5–15 kW), data (GbE), Xe/Kr, water, coolant; color-coded QDs with keying.

Thermal: bypass loops to route tug heat into SBM radiators; leak-back thresholds and acceptance tests.

Electrical: dual DC buses, converter cartridge pinout, inverter stage interface.

Comms: Ka/optical terminals; DTN BPv7 stack; custody and priority class mapping.

Appendix B — Maintenance Checklists (Excerpt)

Per-visit: filters/strainers, seals, quick borescope, leak-back, telemetry review.

Quarterly: 1 thruster head + 2 cathodes, valve kit, filter set, pump vib trending.

Mid-life: power-conversion cartridge swap, 2 thruster heads, pump module, radiator tile.

Functional tests: converter load, thruster low-throttle ignition, comms/optics BIST, star-tracker alignment.

Appendix C — Mass & Power Budgets (Placeholders)

Per SDC Compute: 40–60 kW IT, liquid loop 5–8 kWth rejection.

SBM: 5–10 kW ops; robot peaks 2–3 kW during torque tasks.

AHM: 50–150 kWe fission baseload; electrolyzer 20–60 kW variable; radiator reserve 10%.

COMMS: 2–6 kW average per link set. Tug (NEP): 50–100 kWe class (Midi), 15–25 t dry mass class.

Appendix D — Finance Assumptions & Formulas

Launch: Starship average loaded $/kg assumption; LEO→GEO transfer priced per kg; clustered launch amortizes integration.

Cashflows: CapEx schedule years 0–4; OPEX from year 3; revenue ramp years 3–10.

NPV/IRR: standard discounted cashflow; sensitivity to launch $/kg and tug utilization.

Replace placeholders with vendor quotes for formal budget lock.