Preliminary Design Review (PDR) — Draft

Executive Summary

A conceptual model of a liquid-propellant rocket engine (LRE) and a cryogenic fuel tank has been developed for orbital launch vehicle applications. Key objectives: increase specific impulse up to 350–450 s, minimize boil-off losses ≤ 0.2%/day, reduce structural mass by 15–25%, ensure operational safety and certification readiness.

Mission & Requirements

Application: first and upper stages of orbital launch vehicles. Main parameters: chamber pressure 20 MPa, nozzle expansion ratio 30/60, T/W ~80 N/kg, boil-off LH■ ≤ 0.2%/day, LOX tank operating pressure 2–3 bar, LH■ 2.5–3.5 bar.

System Architecture

Engine: LOX+RP-1 (first stage), LOX+LH■ (upper stage). Tank: cylindrical body with ellipsoidal domes, possible common bulkhead configuration.

Preliminary Design

Engine: Pc=20 MPa, Isp 320–330 s (SL, RP-1), 450 s (vac, LH■). Cooling: regenerative. Materials: Ni, CuCrZr, aluminum. Tank: materials Al-Li 2195/2050 or CFRP+liner, insulation MLI (30–40 layers) + vacuum shell. Boil-off ≤ 0.2%/day, Proof 1.25–1.5×, Burst >2×.

Risks & Mitigations

Technical: H■ permeation (CFRP) → metallic liner; FSW fatigue → additional testing. Economic: high cost of CFRP → baseline Al-Li. Systemic: slosh-instability → optimization of baffles.

Verification & Validation

Hydro- & cryoproof tests, He-leak ≤ 10■■ std·cc/s, cryo-vibration cycles, slosh tests, flight demonstrator.

Conclusion & Next Steps

The concept meets modern requirements. Next steps: extended CEA sweep, CFD modeling of slosh and cooling, prototype tank demonstration.

Trade-off: Al-Li vs CFRP

Criterion	Al-Li (2195/2050)	CFRP + metallic liner
Mass	Baseline (1.0)	0.7–0.85×
Technology maturity	High	Medium (LOX/methane), Low (LH■)

Hermeticity	Reliable	Risk of H■ permeation
Manufacturing	FSW, orthogrid	Filament winding, autoclave, liner adhesion
NDI/repair	Easier	More complex (delam, impacts)
NRE cost	Lower	Higher (qualification required)

Cryogenic Engine and Tank Schematic