OSY-E PROGRAM
CLASS B TUG PROPULSION SELECTION
LAUNCH SEQUENCE AND EARLY LOGISTICS
REV A — FOR ATB REVIEW

1. PURPOSE

This document records the propulsion trade history, selection rationale, and initial deployment plan for the **Class B Tug**, the workhorse vehicle responsible for:

1. Ferrying OSY-E modules from LEO to GEO.
2. Supporting early OSY-E construction operations.
3. Conducting the first pod-retrieval cycles (25–50 pods).
4. Establishing the logistical backbone until OSY-E fuel production activates.

This document captures the decision-making process, defines the Phase 1–2 architecture, and provides ATB with a technical baseline for subsystem design.

2. MISSION REQUIREMENTS SUMMARY

The Class B Tug must:

- Operate between **GEO (station) and an elliptical orbit with perigee at 350–400 km**.
- Complete full **GEO → Elliptic → GEO cycles in under 7 days**.
- Retrieve **25–50 pods per mission** (1 t each).
- Perform **early OSY-E assembly transport**: ferrying modules delivered by Starship V3 from LEO to GEO.
- Operate independently before OSY-E fuel production exists.
- Support multiple cycles without excessive downtime.
- Fit within mass and volume interfaces deliverable by Starship V3.
- Use a propulsion system compatible with long-term OSY-E logistics.

These requirements are time-driven first, mass-driven second, and cost-driven third.

3. PROPULSION ARCHITECTURES CONSIDERED

3.1 Electric Propulsion (EP-Only: NEP / Hall / Nested Hall)

Considered systems:

- NEP ion engines
- Hall clusters
- Nested Hall HERMeS-style setups
- VASIMR low-power configurations

Key findings:

- Thrust-to-mass ratios are too low by multiple orders of magnitude.
- Even at 1 MW electric, transit times are **weeks to months**, not days.
- GEO–LEO elliptical insertion requires **km/s in hours**, not continuous low thrust.
- Excellent for later barge-class tugs, not for Class B.

Conclusion: **Rejected for primary propulsion. Retained only for stationkeeping and fine ops.**

3.2 Chemical Propulsion (Methalox, Hydrolox)

We evaluated:

- LOX/CH4 vacuum engines
- LOX/LH2 vacuum engines (RL10 class analogs)

Observations:

- Hydrolox gives strong Isp (~450 s) and workable mass fractions.
- Methalox is easier to store but takes a heavy dv penalty (~360 ss Isp).
- To meet the 7-day cycle with 25–50 pods, burns must be hour-scale, not tens of hours.
- Both require significant prop loads; hydrolox is acceptable, methalox marginal.

Conclusion: **Hydrolox is viable but suboptimal. Methalox marginal.**
Chemical-only is feasible but not ideal for long-term scaling.

3.3 Nuclear Electric Propulsion (NEP)

Evaluated 100 kW–1 MW class NEP systems.

Observed:

- Same limitations as EP-only: thrust is too low for 7-day cycles.
- Excellent long-term for barge and cargo hauling over weeks/months.
- Cannot handle early OSY-E logistics tempo.

Conclusion: **Rejected for Class B. Reserved for barge-class.**

3.4 Nuclear Thermal Propulsion (NTP)

Evaluated reactor sizes, thrust levels, Isp performance.

Key data:

- Isp: 850–900 s
- Thrust: tens of kN with compact reactor assemblies
- Mass fraction drastically improves vs chemical
- Burn durations: **hours** rather than days
- Fully compatible with 3–3.5 km/s mission dv
- Supports 7-day cycle with margin
- Compatible with Earth-delivered LH2 until OSY-E fuel capacity comes online
- Reactor mass within Starship V3 capability

Conclusion: **Only propulsion system meeting all mission constraints.**

Final selection: **NTP primary propulsion for Class B Tugs.**

4. CLASS B TUG - BASELINE DESIGN (BLOCK 0)

4.1 Mission Scale

- Pod capacity: **25 pods** (25 t).
- Dry tug mass (reactor, engine, tanks, avionics, RCS, structure): **20–25 t**.
- Total dry system: **45–50 t**.

4.2 Propellant Load

- Required dv: **3,500 m/s** after margin.
- At Isp ~900 s, mass ratio ~1.49.
- Tug departure mass ~75 t.
- LH2 propellant ~25 t per cycle.

4.3 Thrust Requirements

- Required thrust band: **20–50 kN** for hour-scale burns.
- Ensures GEO insertion and de-orbit burns occur within mission windows.
- Allows rapid departure and return legs (2–3 days each).

4.4 Propulsion Stack

- Primary: NTP engine cluster (single core or dual-mode configuration).
- Secondary:
  - Chemical trim engines (storable, low thrust)
  - NH3 or H2 RCS system
  - Optional: 10–50 kW electric thrusters for fine orbit shaping

4.5 Reactor + Shielding

- Compact reactor optimized for high thrust NTP.
- Forward shadow shield to protect avionics and pods.
- Rear thermal radiators sized for safe hot soak.

4.6 Docking and Capture Hardware

- Reinforced pod mount rail for 25-pod configuration.
- Hard dock interface with OSY-E core ring.
- Bots mountable for capture assistance.

4.7 Turnaround Operations

- LH2 top-off from Starship tankers (Phase 1).
- Quick-inspection cycle < 12 hours.

- Autonomous health monitoring with worker bot integration.

5. STARSHIP V3 BOOTSTRAP SEQUENCE (PHASE 1)

Goal: Deliver OSY-E Core + first tug + early power/robotics to GEO.

This architecture assumes **Starship V3 delivers modules to LEO**, and the Class B Tug **ferries them to GEO**.

5.1 Starship V3 - Flight 1
"OSY-E Core Delivery"

Delivered to LEO:

- OSY-E Core Module:
    - Central hub structure
    - Primary docking ring
    - Attitude control system
    - Comms backbone (Earth link, inter-sat, local net)
    - Initial power (small solar arrays + batteries)
    - Grapple fixtures and assembly hardpoints
    - Propulsion for LEO stationkeeping until tug arrival

Mission:

- Tug retrieves OSY-E Core from LEO.
- Ferries to GEO in first operational NTP burn series.
- Worker bots (arriving later) will mount and deploy additional components.

5.2 Starship V3 - Flight 2
"Power and Robotics Module"

Delivered to LEO:

- Phase 1 Power System:

    - Expanded solar wings
    - Additional batteries
    - Power distribution racks
- Robotics Package:
    - Assembly bots
    - Inspection drones
    - Modular tool bays
- Radiators for thermal management
- Structural expansion frames

Mission:

- Tug ferries this entire module to GEO.
- Worker bots assemble power arrays, expand OSY-E capability.

5.3 Starship V3 - Flight 3
"Tug + Cryo Depot Package"

Delivered to LEO:

- Class B Tug (Block 0), fully integrated
- Cryogenic LH2 Depot Module:
    - Multi-tank cluster
    - Lines, valves, chilldown equipment
    - Passive insulation + boil-off tolerant architecture
- Additional robotics units
- Utility racks for tug servicing

Mission:

- Tug ferries itself + depot module to GEO.
- Establishes the first operational OSY-E fuel resupply node.

- Initiates readiness for pod retrieval operations.

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6. EARLY LOGISTICS FLOW (PRE-FUEL PRODUCTION)

Cycle:

1. Starship tankers deliver LH2 to LEO.
2. Tug ferries LH2 tankage to GEO depot.
3. Tug refuels directly from depot.
4. Tug begins first pod cycles (25 pods → OSY-E).
5. OSY-E receives early water-processing modules on later Starships.
6. Once fuel production begins:
    - LH2/O2 can be made onsite
    - NTP cycles become more frequent
    - Chemical engines (hydrolox) for auxiliary tasks become practical
    - Tug 2 and Tug 3 assembly begins on-orbit

This allows OSY-E to enter its growth phase (Phase 1–4 major construction).

7. WHY THIS ARCHITECTURE IS SELECTED

7.1 Time Compliance

NTP is the only propulsion system capable of:

- 7 day GEO <-> LEO elliptical round trips
- 25–50 pod retrieval
- Early module ferry duty
- High-thrust hour-scale burns

All alternatives fail the time requirement.

7.2 Logistics Chain Compatibility

The NTP architecture integrates cleanly with:

- Early Earth-supplied LH2
- Later OSY-E water splitting
- Potential hydrolox chemical tugs
- Future thermal-electric upgrades
- All station assembly operations

7.3 Scalability

The solution scales cleanly:

- Block 0: First tug, ferry/assembly duty
- Block 1: Add Tug 2 and Tug 3
- Block 2: Expand pod capacity to 50
- Block 3: Add NEP / MPD hybrid thrusters for long-haul missions
- Block 4: Support OSY-M construction and Mars logistics

7.4 Safety and Control

- Reactor stays on tug, not OSY-E
- GEO operations keep Earth biosphere safe
- NTP is operational only in vacuum far from Earth
- Worker bots minimize EVA risk

8. NEXT STEPS FOR ATB

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1. Approve or request modifications to the Class B NTP baseline.
2. Approve the 3-launch bootstrap architecture for OSY-E Phase 1.
3. Begin subsystem-level ICD definition for:
    - NTP reactor and engine cluster
    - LH2 depot module
    - OSY-E docking and tug servicing architecture

- Power and thermal interfaces
- Pod capture hardware

4. Prepare Block 1/2 development schedule.
5. Initiate mass budget refinement for Starship V3 packaging.