# CubeSat Mission Benefits and Integration of High Thrust, High ΔV Green Propulsion

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# MPS-130 Program Status

- **CubeSat Mission Benefits and Integration of High Thrust, High ΔV Green Propulsion**
  - Selected for award: Nov 2015
  - Negotiations ongoing
  - Contract award: early-mid May 2016

  - 12-15 (with schedule margin) month program to deliver 1U flight unit
  - Program efforts are focused on qualification details
    - Rigorous analysis
    - Hot fire test
    - Qualification tests
    - Final build and acceptance tests
  - Optimization of the catalyst bed heater and thrust chamber for cost and performance

- **This program effort removes a significant barrier to customer use: NRE costs**

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# MPS-130 Overview

- **Aerojet Rocketdyne MPS-130 Modular CubeSat Propulsion System provides total impulse: approximately 1.4× hydrazine, 2× condensables, 10× cold gas**
- **MPS-130 enables low altitude CubeSat missions, 25-year de-orbit capability at altitudes up to 800 km, deterministic re-entry, and deployment to LEO from GTO launch vehicles**
- **Propulsion-enabled CubeSats offers increased mission capability per unit cost**
- **Lowers cost of access to orbits that cannot be reached as secondary payloads**
- **Expands range of mission capabilities above other conventional propulsion solutions**

1U MPS-130
Modular CubeSat
Propulsion Systems

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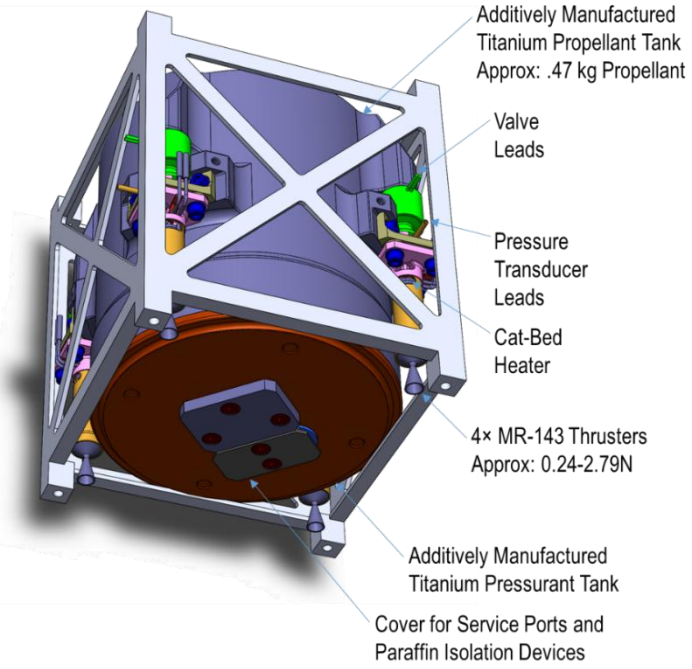
# MPS-130 System Properties

- **Tipping Point effort qualifies the 1U configuration**
- **AR also working parallel efforts to provide additional (2U) configurations**
  - Increased $\Delta V$
  - Interface electronics
  - Enables larger CubeSat configurations… 12U, 24U…

| System Properties | 1U Configuration (this effort) | 2U Configuration (in work) |
|---|---|---|
| System Dry Mass (kg) | 1.7 | 2.0 |
| Usable Propellant Mass (kg) | 0.5 | 1.3 |
| Total System Mass (kg) | 2.2 | 3.3 |
| Dimensions (cm) | 10 × 10 × 11.4 | 10 × 10 × 22.4 |
| Operating Temperature (C) | -5 to 50 | |
| Heater Power per Thruster (W) | TBD | |
| Valve Power per Valve (W) | <4 at startup / <1 for operation | |
| Valve Voltage (Vdc) | 6-8 at startup / 1-2 for operation | |

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# Hazards Class of Green Propellants

- **High density Isp green propellants complement volume constrained CubeSats**
  - Lower toxicity
  - Very low vapor pressure
  - No SCBA required
  - Reduced launch, range, and operations costs

| Hazard | N2H4 (reference) | Green Propellants | | |
|---|---|---|---|---|
| | | AF-M315E (HAN) | LMP-103S (ADN) | Hydrogen Peroxide |
| **Flammability (C)** | 53 | 106 | 11 (methanol) | Non-flammable |
| **Vapor pressure (psi)** | 0.28 | Not measurable | 147(ammonia) | 0.097 |
| **Toxicity - TLV / TWA (ppm)** | 0.01 | N/A No vapor | 25 (ammonia) | 1 |
| **Toxicity - $LD_{50}$ (mg/kg)** | 57 | 550 | 350 (ammonia) | 1518 |
| **Transportation Hazard Classification** | 8 corrosive<br>3 flammable<br>6.1 poisonous | 1.4S w/packaging<br>1.3C w/o packaging | 1.4S w/packaging<br>1.3C w/o packaging<br>1.1 open container | 5.1 oxidizer<br>8 |
| **Corrosive** | yes | no | no | yes |
| **$I_{sp}$ (sec) - Theoretical** | 242 | 266 | 252 | 161 |
| **Density (g/cc)** | 1.01 | 1.47 | 1.24 | 1.45 |

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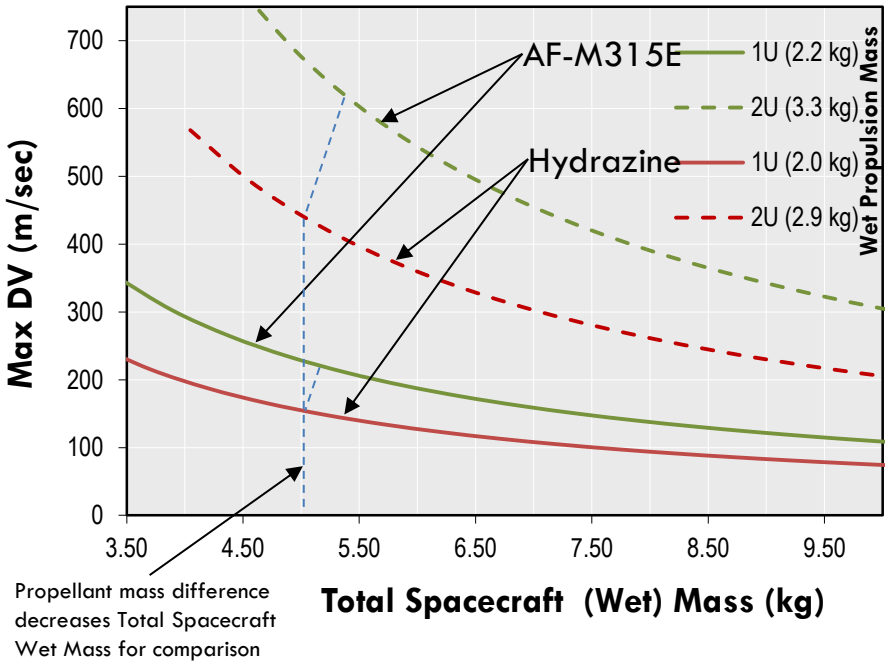
# Enabling ΔV Capability

- **1U MPS-130 Configuration**
  - ~ 0.5 kg of propellant
  - Nominally 2 year mission life
  - Primary propulsion
  - 3-axis attitude control

- **2U MPS-130 Configuration**
  - ~ 1.3 kg of propellant

AF-M315E approx. 40% increase in density Isp




- **Enabled High ΔV Missions**
  - Independent orbit raising from ISS / Upper Stage drop-off
  - Constellation deployment/sparing
  - Low LEO drag make-up
  - Proximity ops / formation flying
  - De-orbit capability

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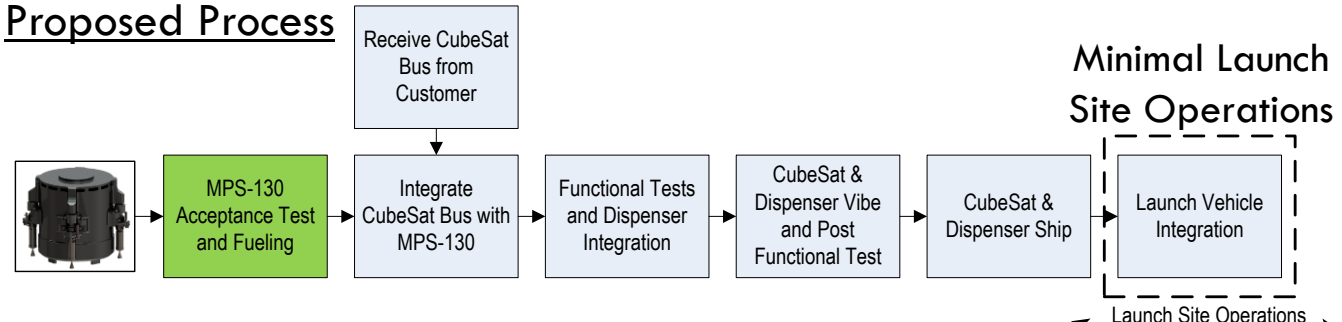
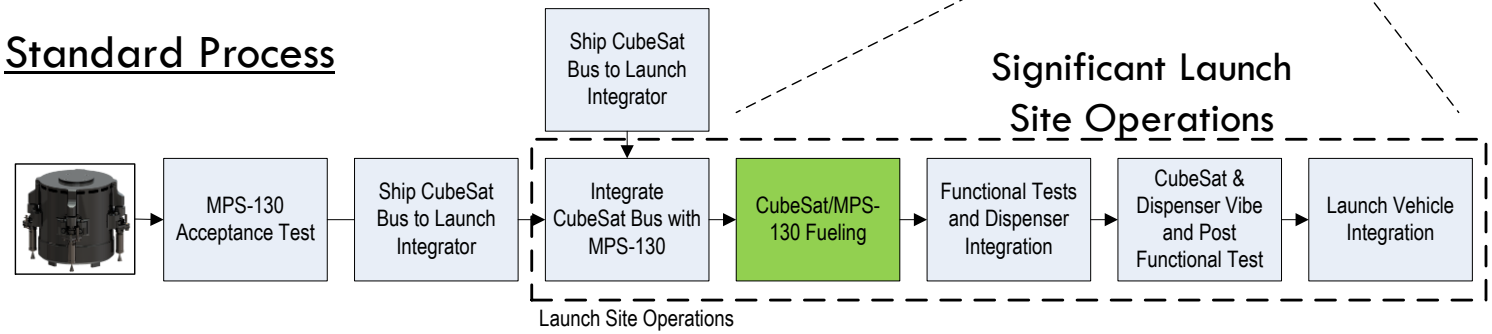
# Integration Options

- **Most small business / CubeSat customers do not have capabilities to handle high performance propellants**
  - Green propellants currently require explosive facility certification
  - Green propellants require shipping certification for HMC 1.4S
- **AR is working to make this process easier and cost effective**
  - Proposed Process




  - Standard Process

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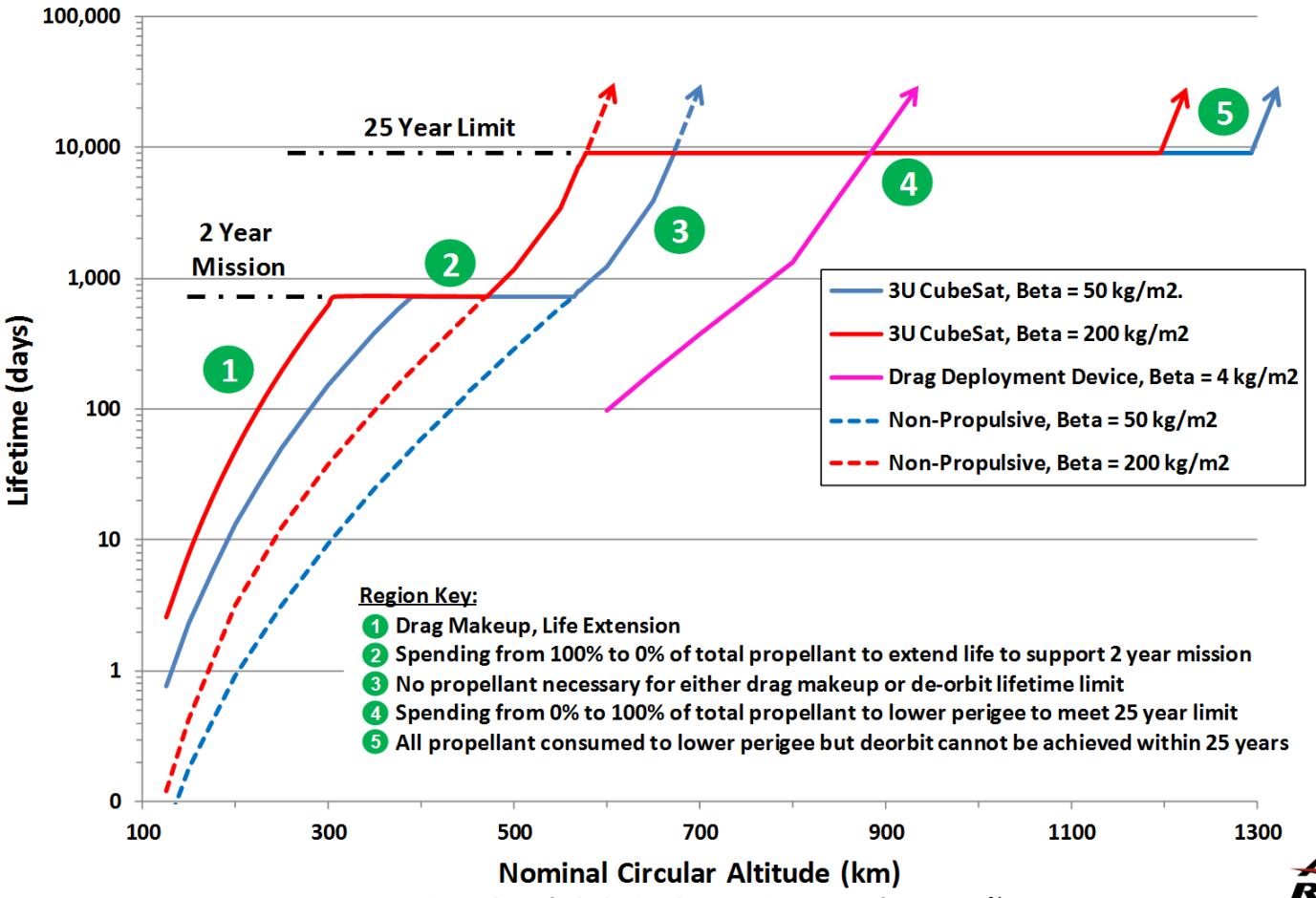
# LEO Mission Capabilities – 3U @ Solar Max

- **Increased mission life at low altitudes & de-orbit from higher altitudes**

| 3U CubeSat | | 6U CubeSat |
|---|---|---|
| β = 50 & 200 | Ballistic Coefficient (kg/m²) | β = 50 & 200 |
| 4 | Satellite Dry Mass (kg) | 10 |




*Curves shown for hydrazine, AF-M513E increases performance 40%

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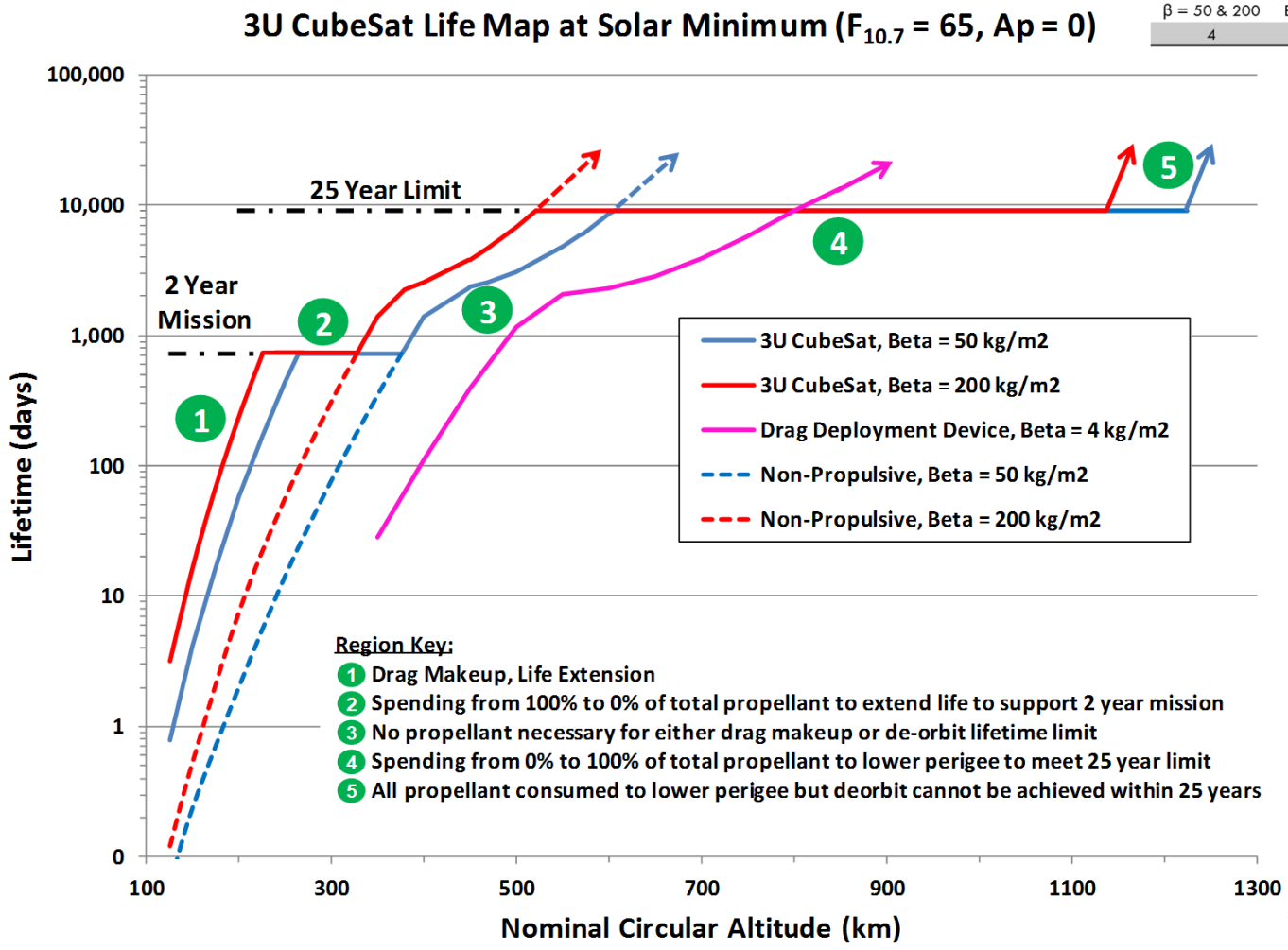


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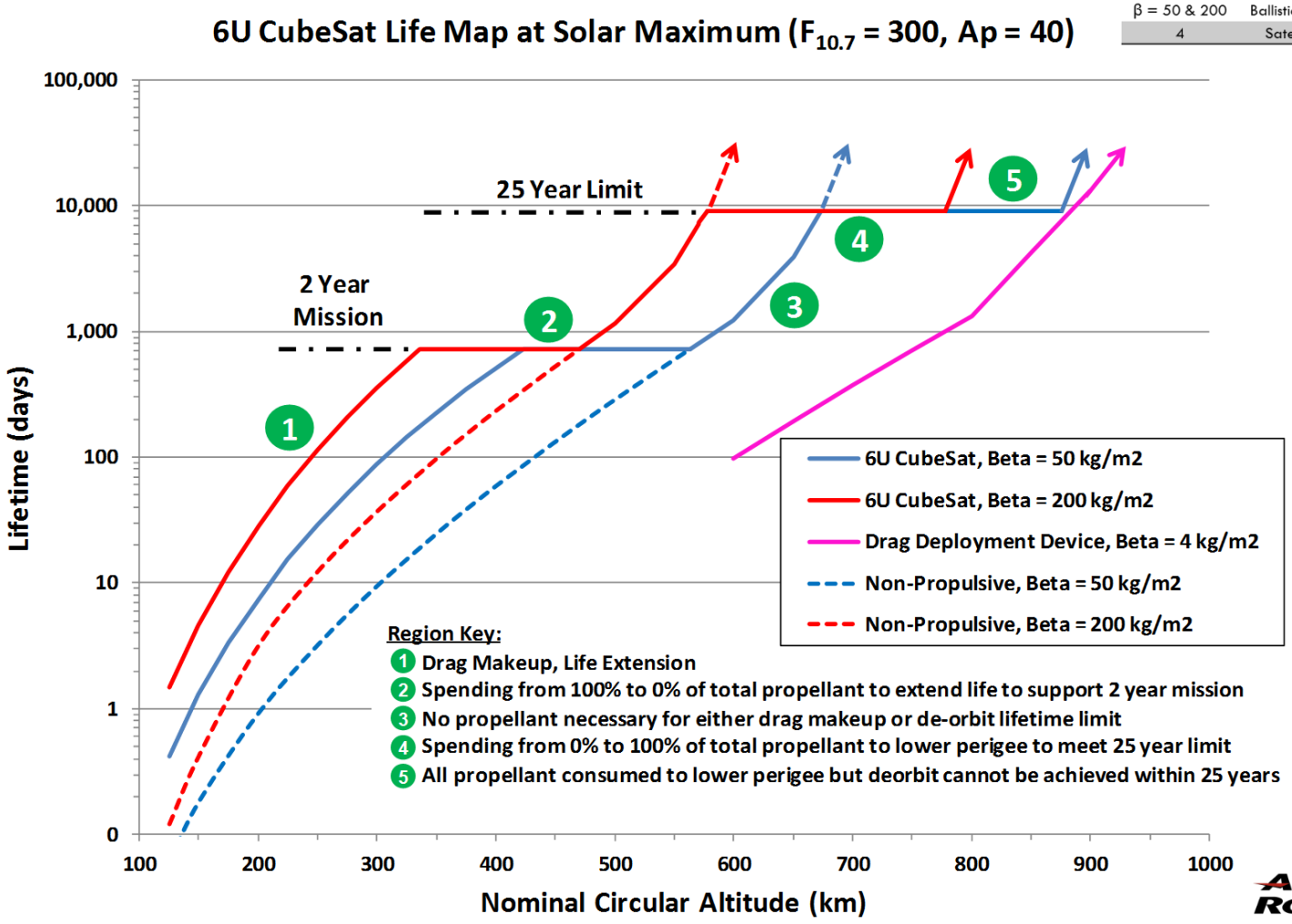


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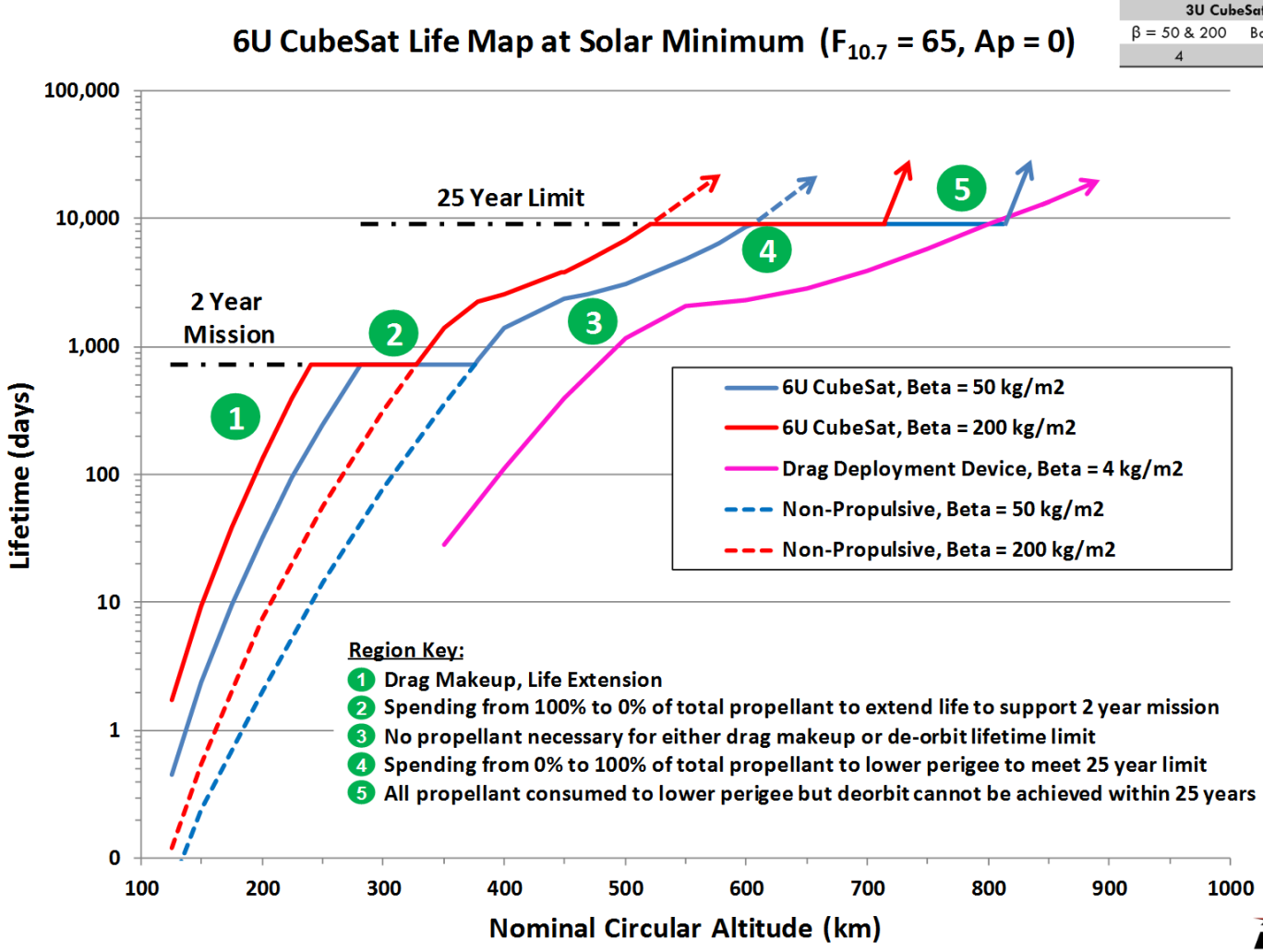


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# LEO De-Orbit Capabilities

- **Deterministic de-orbit from circular LEO orbits up to 800 km and 350 km, for 3U and 6U CubeSats, respectively (to ~500 nm dia.)**

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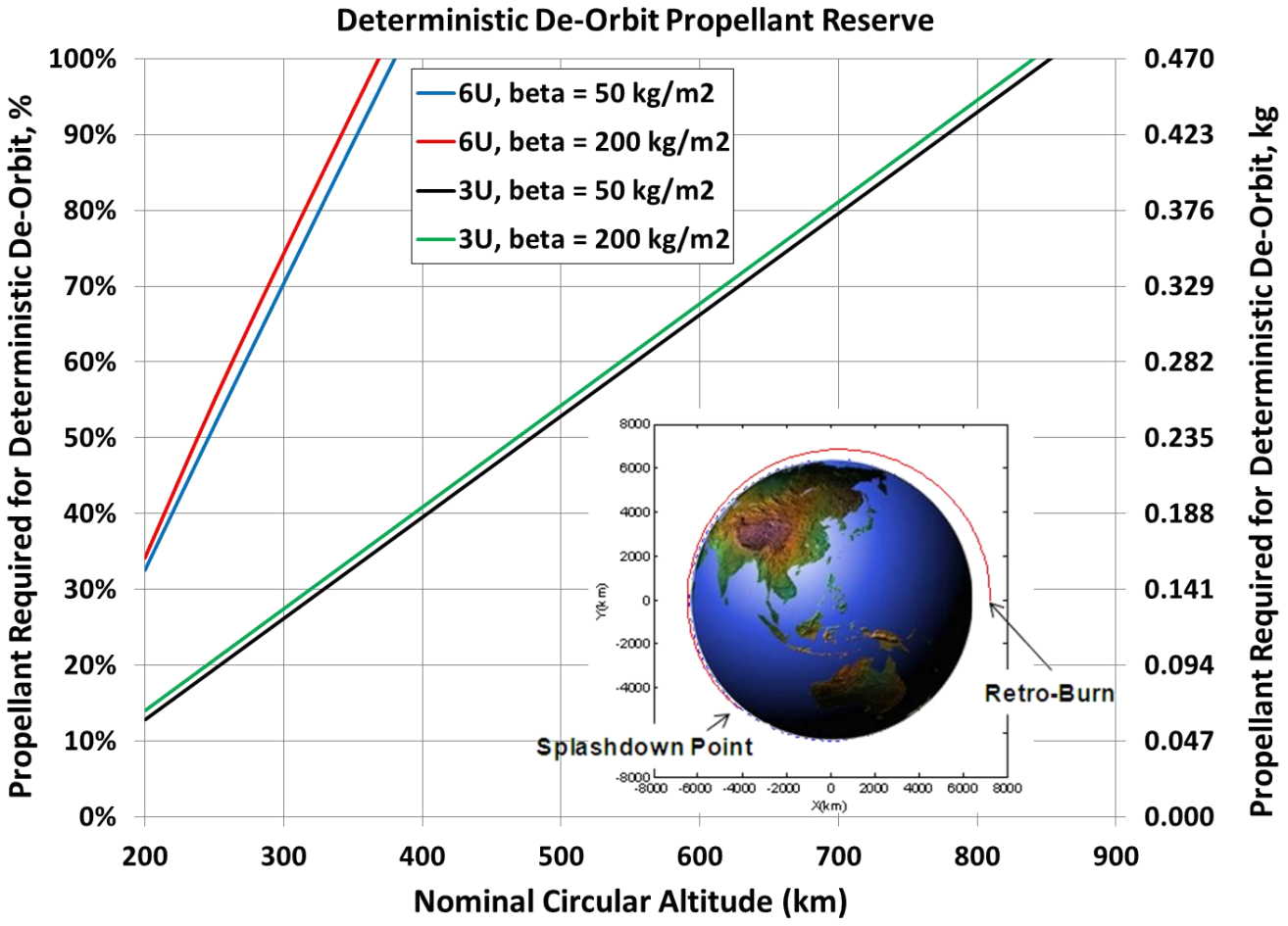
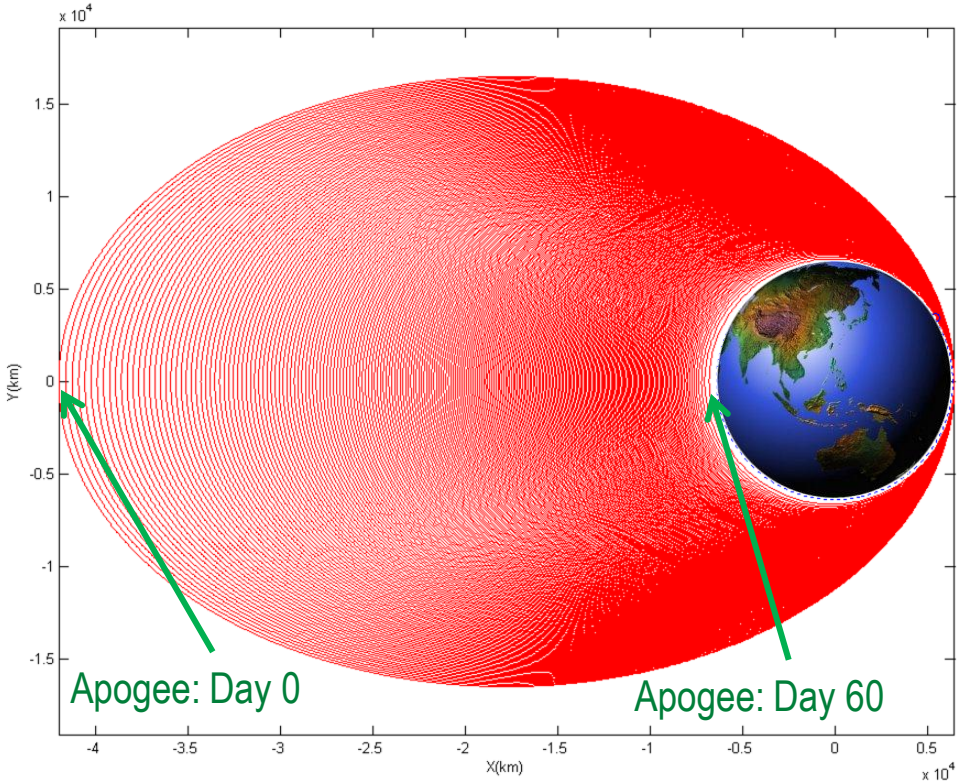


# GTO Mission Capabilities

- De-orbit from GTO by providing retro-propulsive capability to reduce the perigee of a typical GTO orbit.
- Shown to the right is a typical orbit trace from GTO down to LEO, where the orbit can be circularized.
- For a wide range of ballistic coefficients (20-200 kg/m2), the MPS-130 lowers apogee to LEO altitudes within 60 days, minimizing transit time through the radiation belts.

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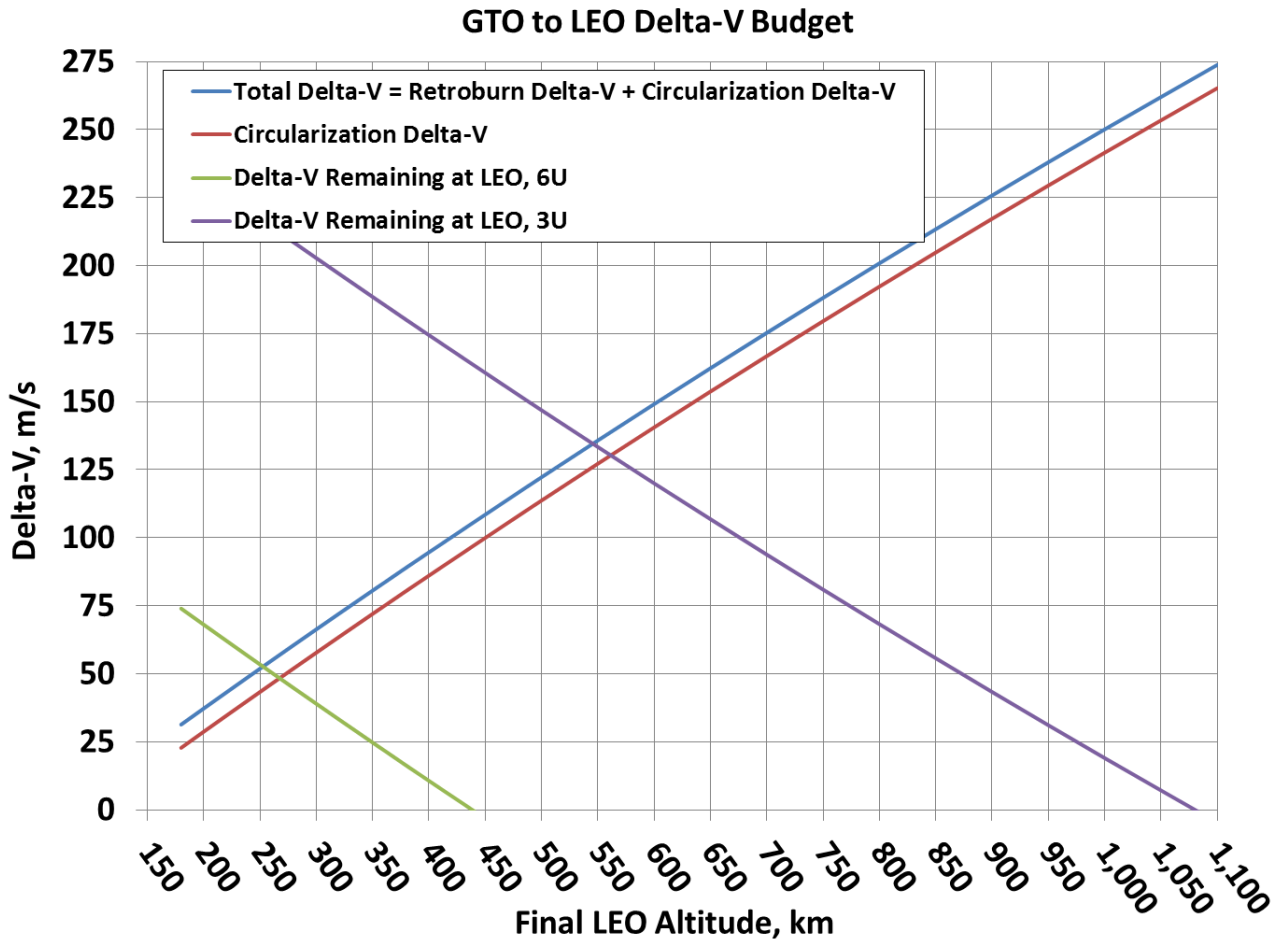
# GTO to LEO Mission Capabilities

- **High ballistic coefficients (200 kg/m$^2$) can be moved from GTO to LEO for a relatively small amount of ΔV, leaving significant ΔV available after circularization at LEO altitude**

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# Summary / Conclusions

- **Current Capabilities:**
  - General ΔV available for:
    - Independent orbit raising from ISS / Upper Stage
    - Constellation deployment/sparing
    - Low LEO drag make-up
    - Proximity ops / formation flying / attitude control / orbit maintenance
    - De-orbit capability
  - Life extension at low LEO altitudes, de-orbit within 25 years at high altitudes
  - Deterministic re-entry from up to 800 km for 3U, and 350 km for 6U
  - Enables rideshare on GTO LVs for insertion to LEO within 60 days

- **What's Ahead:**
  - Development is proceeding with potential first flight with NASA in the 2018 timeframe / Pathfinder Technology Demonstration (PTD) Mission
  - Parallel flight opportunities welcome
  - Options that increase total impulse

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