ISS End-of-Life Disposal Plan

Aerospace Safety Advisory Panel Briefing
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Background

- **Environmental Impact Statement (EIS) outlines ISS decommissioning hazards and available options**
  - Controlled re-entry chosen as only viable option w.r.t. safety, technical difficulty, and economy
- **Previous ISS de-orbit plans used the CEV (lunar variant) vehicles**
  - ISS de-orbit planning is heavily dependent on vehicle capabilities
- **Currently pursuing options with other vehicles**
  - Vehicle limitations and / or availability issues necessitate solutions utilizing vehicle combinations or modifications
    - Modified Progress option
    - ATV & Progress combinations
    - Recently started discussions with ESA about a dedicated de-orbit vehicle

Deorbit Strategic, Tactical, & Execute Plans

- **Strategic Planning (~1 yr)**
  - Assure required propellant reserves
  - Configure ISS for de-orbit controllability
  - Natural decay to lowest phase-repeat altitude to set up ocean ground track
  - Dock final deorbit vehicle(s)

~6000 kg prop

- **Tactical Plan (4 days)**
  - Begin from 270 km phase repeat orbital altitude
  - Propulsively lower perigee (and set up proper argument of perigee) over 4 days
  - Set up high Ballistic Number ("trimmed profile") and use propulsive attitude control
  - Optimize apogee and phase propulsively on final day
  - Drop penultimate perigee to minimum controllable altitude

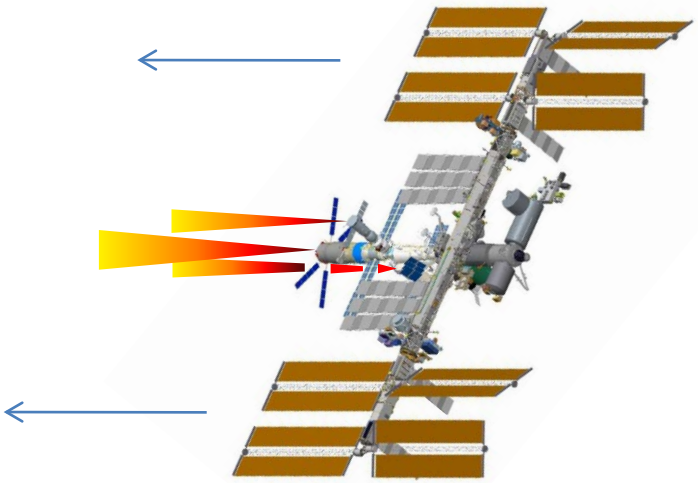
>2000 kg prop

- **Execute (1 orbit)**
  - Must drop as deep as possible into atmosphere in one orbit
    - Ensuring capture of high-speed, high-Ballistic Number fragments after rupture
  - Final long burn places ISS on trajectory to reach capture altitude

ATV With Radial Progresses Option

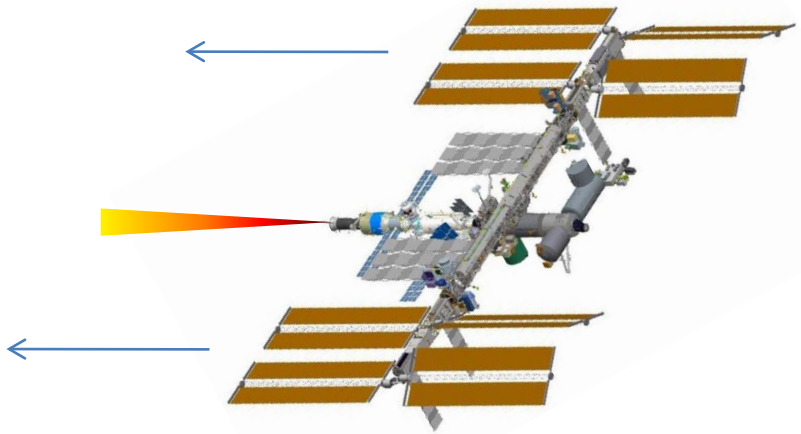
- **ATV provides continuous 195kgf burn**

- **Radial Progresses**
  - Provide additional ΔV and pitch control due to ATV off-c.g. thrust vector
  - Achieve tactical phasing
    - Radial Progresses fire together for 10 m/sec/day for 4 days to set up final phasing and orbit shaping, augmented by some of ATV prop
  - Augment ATV final deboost



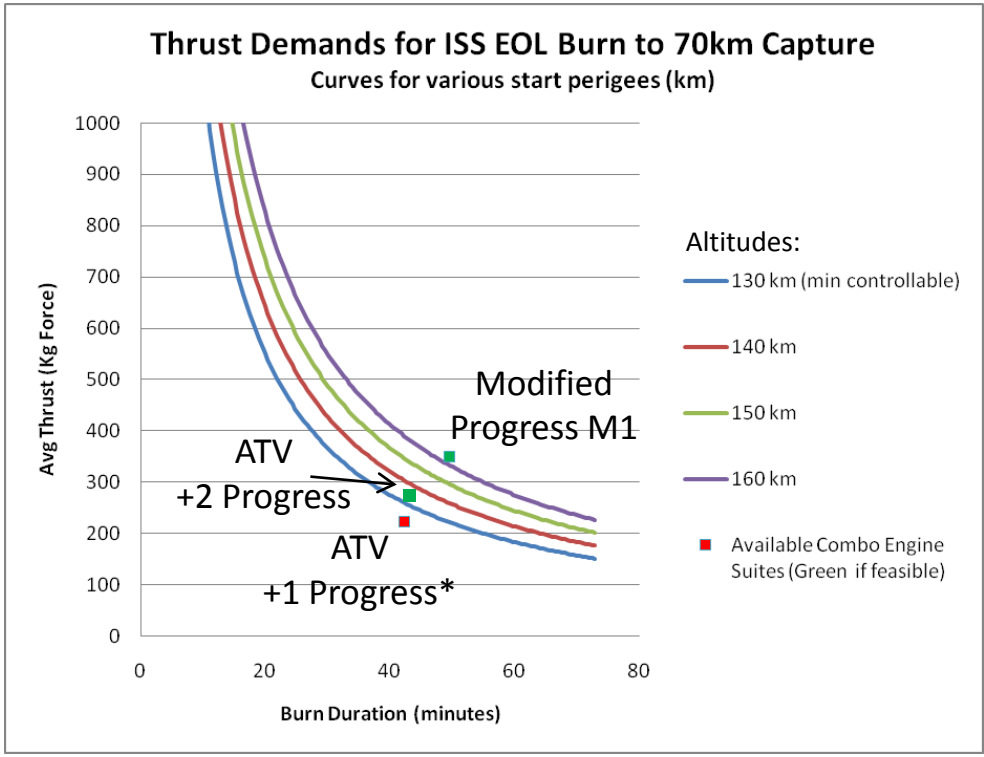
Modified Progress Option

- **Require a modified Progress to allow the engine to burn through the entire propellant supply of Service Module (SM), Progress, and some of FGB in a single high-thrust burn**
  - Valves will be needed to allow resupply and SM high pressure propellant to be burned in main engine without OMS prop system blowback
  - Modify current Progress engine (ablative 300 kgf engine limited to 900 seconds) with a Service Module-type 315 kgf film-cooled engine, allowing indefinite burns
- **Currently in initial discussions with RSC-E to assess feasibility of modifications**



Options Summary

- **ATV with Radial Progresses**
  - Pros
    - Fewer mods to existing vehicles
  - Cons
    - Less margin = longer footprint
    - Three vehicles needed (1 ATV + 2 Progress)
    - More difficult phasing and setup due to low-thrust mid-rings
    - ATV availability past Vehicle #5 uncertain
- **Modified Progress**
  - Pros
    - Single-vehicle, single partner process
    - Mods can be iteratively made and tested on future Progress vehicles with minimal weight penalty during routine ISS ops
    - Such mods to the fleet have potential value in contingency scenarios
    - More margin
      - Can also begin set-ups at higher more controllable altitudes
  - Cons
    - Feasibility still in discussions with Russians



Notes:

- *ATV +1Progress is marginally acceptable when including aerodynamic drag effects

Early Termination Plan

- **First response to an early evacuation of the ISS scenario is to boost ISS to a higher altitude to provide time to address the issue**
  - Additional vehicles will be flown to either supply additional propellant to keep the ISS in orbit so that a plan to re-crew the ISS can be implemented
  - Additional vehicles can also be flown to execute the nominal end-of-life deorbit plan

- **Early termination will only occur if**
  - A catastrophic event causes an early evacuation of the ISS . . . AND
  - ISS cannot still maintain control . . . AND
  - The event is also preventing additional vehicles to dock to ISS

Summary

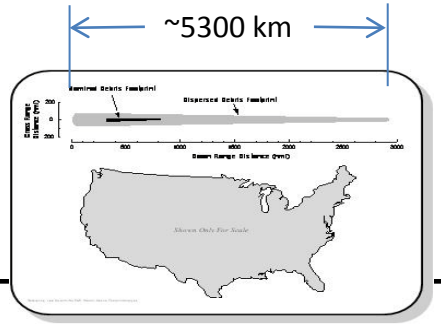
- **For the nominal EOL scenario, both vehicle options must use Progress for propulsive attitude control or additional thrust**

- **Pursuing a slightly modified Progress as the baseline plan**
  - Simplest, likely most cost efficient, and highest-margin
  - Could also be implemented in iterative phases and tested
  - Would also benefit contingency scenarios

- **In discussions with ESA for a dedicated EOL de-orbit vehicle**
- **First response to a contingency scenario is to boost ISS to a higher altitude to provide time to address the issue or launch vehicle(s) to execute the nominal EOL plan**
  - Other options are available if the first response is not feasible depending on the systems that are available

Back Up Material

Optimal Placement



Note: Not to scale.
ISS and red debris footprint is for illustrative purposes only.