Landsat 5 Decommission Plan Overview to LST

February 12, 2013

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Objectives of Landsat 5 Decommission

- **Objectives of Landsat 5 Decommission**
  - Safely lower the spacecraft to a disposal orbit which
    - Removes it as a credible threat to the 705 EOS Fleet
    - Minimizes the time to re-enter the atmospheric
  - Render all sources of energy onboard either depleted or incapacitated to the extent allowed by the spacecraft design
    - All kinetic energy sources disabled
    - All chemical energy sources (hydrazine) exhausted
    - All electrical systems disabled or incapacitated to the maximum extent

Basis for L5 Decommission Objectives

- **Given the mission's current status, USGS directed the L5 FOT to decommission the satellite**
  - The failure of IRU redundancy has created an unacceptable risk
- **The FOT follows applicable guidelines from:**
  - the *National Space Policy of the United States* and
  - the *U.S. Government Orbital Debris Mitigation Standard Practices*
- **From the National Space Policy:**

  Preserve the Space Environment. For the purposes of minimizing debris and preserving the space environment for the responsible, peaceful, and safe use of all users, the United States shall:

  - Continue to **follow the United States Government Orbital Debris Mitigation Standard Practices**, consistent with mission requirements and cost effectiveness, in the procurement and operation of spacecraft, … in space;
  - Require the **head of the sponsoring department or agency to approve exceptions** to the United States Government Orbital Debris Mitigation Standard Practices **and notify the Secretary of State**

Basis for L5 Decommission Objectives

- **From the *U.S. Government Orbital Debris Mitigation Standards:***

  4. Post Mission Disposal of Space Structures

  4.1.a) Atmospheric reentry option: Leave the structure in an orbit in which, using conservative projections for solar activity, atmospheric drag will limit the lifetime to **no longer than 25** years after completion of mission. …If a space structure is to be disposed of by reentry into the Earth's atmosphere, the risk of human **casualty will be less than 1 in 10,000**.

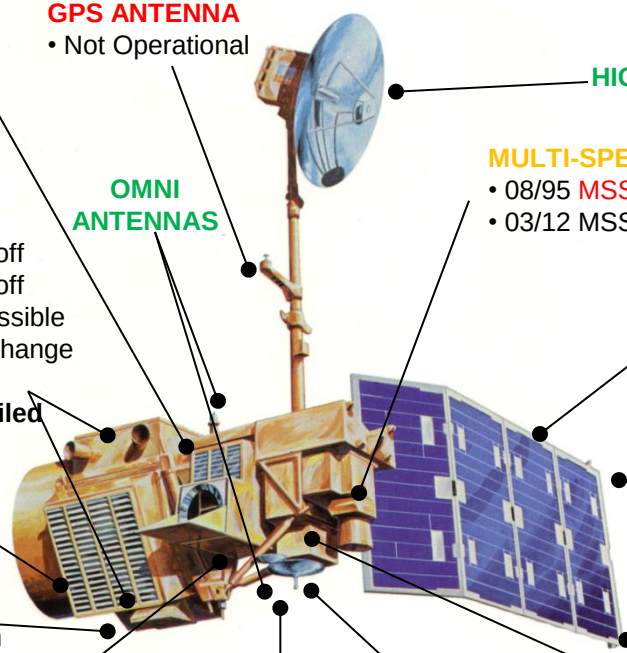
  Because of fuel gauging uncertainties near the end of mission, a program should use a maneuver strategy that ***reduces* the risk of leaving the structure near an operational orbit regime**.

  2. Minimizing Debris Generated by Accidental Explosions

  2.2) Limiting the risk to other space systems from accidental explosions after completion of mission operations: **All on-board sources of stored energy** of a spacecraft or upper stage **should be depleted or safed** when they are no longer required for mission operations or **post mission disposal**. Depletion should occur as soon as such an operation does not pose an unacceptable risk to the payload…

Landsat 5 Flight Segment Status

(AFTER NEARLY 3 DECADES OF CONTINUOUS OPERATION)



GPS ANTENNA
- Not Operational

HIGH GAIN ANTENNA

COMM & DATA HANDLING MODULE
- **S-band XMTR-A Failure 8/85**

OMNI ANTENNAS

MULTI-SPECTRAL SCANNER
- 08/95 MSS Band 4 failure MSS Deactivated
- 03/12 MSS reactivated (all 4 bands) Band 4 deactivated 5/12

ACS MODULE (no auto safe hold)
- 07/03 FHST#1 Degradation turned off
- 10/92 Skew wheel SEU tack anomaly
- 11/92 Earth Sensor 1 degraded turned off
- 02/02 Earth Sensor 2 degraded turned off
  ES1&2 Intermittent operations possible
- 08/09 Gyro-C SEU anomaly no status change
- 09/09 Gyro A&B Prime configuration
- **11/12 Gyro B Anomaly – Declared Failed**

SOLAR ARRAY DRIVE / PANELS
- 01/05 Primary Solar Array Drive failure
- Nominal Solar array panel degradation (12/04)
- 11/05 Redundant Solar Array Drive failure
- 3/06 Power pitching (+/-20) initiated

PROPULSION MODULE
- 3/84 Primary Thruster D failure

COARSE SUN SENSORS
Operational but useless without solar panel drives

POWER MODULE
- 05/04 Battery-1 failure. Removed from power circuits, depleted
- 10/07 Battery-2: Cell short still operational but usually offline

X-BAND ANTENNA

WIDEBAND COMM. MODULE
- 07/88 Ku-band TWTA Prime failure (OCP)
- 07/92 Ku-band TWTA Redundant failure (OCP)
- 08/87 X-band TWTA Prime failure (OCP)
- 03/06 X-band TWTA Redundant anomaly
- 12/09 X-band TWTA Redundant failure (OCP)
- 01/10 X-band TWTA Prime successfully re-activated
- 11/11 X-band TWTA Prime ops suspended
- 06/12 X-band TWTA Prime Failed (OCP)

THEMATIC MAPPER
- 10/94 Power Supply 1 stuck switch
- 06/02 TM switched to bumper mode
- 06/12 TM Ops ended due to loss of wideband comm capability

DIRECT ACCESS S-BAND
- 03/94 Side-A FWD Power Sensor failure
- 03/12 Side-B DASB reactivated

USGS

Basis for Plan Development

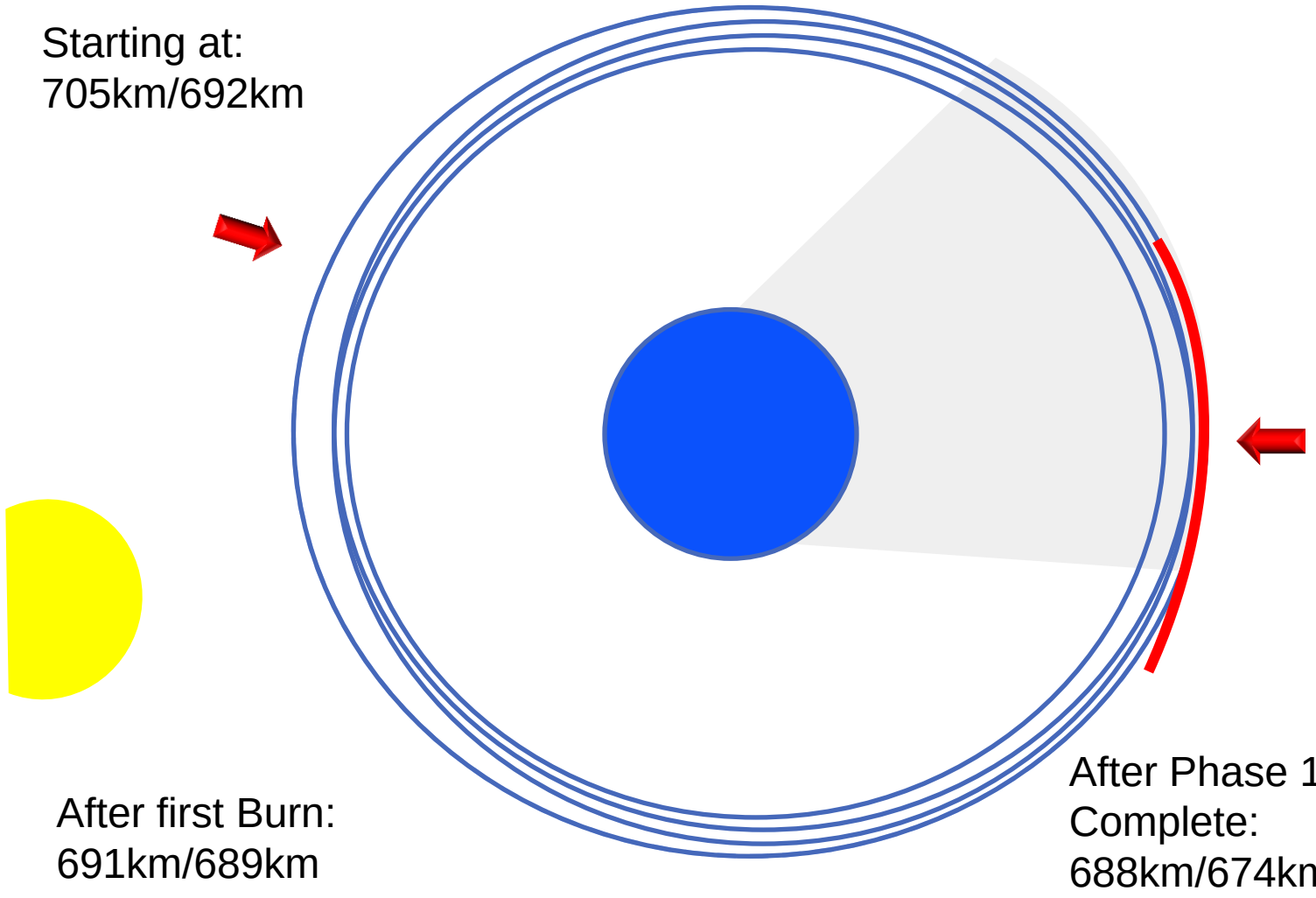
- **Development Philosophy for Satellite Decommission Plan**
  - Reuse of lessons learned from L4 and UARS decommissioning
  - Use SOP wherever possible
    - Maneuver planning and execution
    - Flight Dynamics (FD) products
    - Contingency responses
  - Multi-level reviews for new processes and analysis
    - Numerous in-house reviews
    - Reviews with L5/MMS Subject Matter Experts (SMEs)
    - External Engineering Peer Review
- **The FOT has developed a four-phase plan to accomplish the decommissioning of Landsat 5**
  - Phase 1: Remove L5 as a credible threat to the 705 EOS Fleet
  - Phase 2: Lower the L5 orbit perigee to minimize the time to reentry
  - Phase 3: Render the Spacecraft Passive
  - Phase 4: Closeout the Landsat 5 Mission Operations Center (MOC)

Phase 1: Scheduling and Execution of Initial Orbit-Lowering Maneuvers

- **The first two maneuvers were intended to essentially remove Landsat 5 as a credible threat to the *705 EOS Fleet***
- **After receiving AtP, the FOT began the planning and scheduling of the maneuver**
  - 3-4 weeks out:
    - Model burn sequence
    - Schedule TDRS and GN contacts
  - 1-2 weeks out:
    - Begin collision analysis risk assessment (CARA) screening process
    - Hold FOT script reviews and rehearsals
  - 1 week out:
    - Implement decommission maneuver spacecraft configuration
    - May run no-burn attitude slew to verify scripts and power model
- **Execute initial orbit lowering maneuvers**
  - Two 21-minute burns targeted to lower SMA by 17.5km

Phase 1 Maneuvers

Starting at:
705km/692km

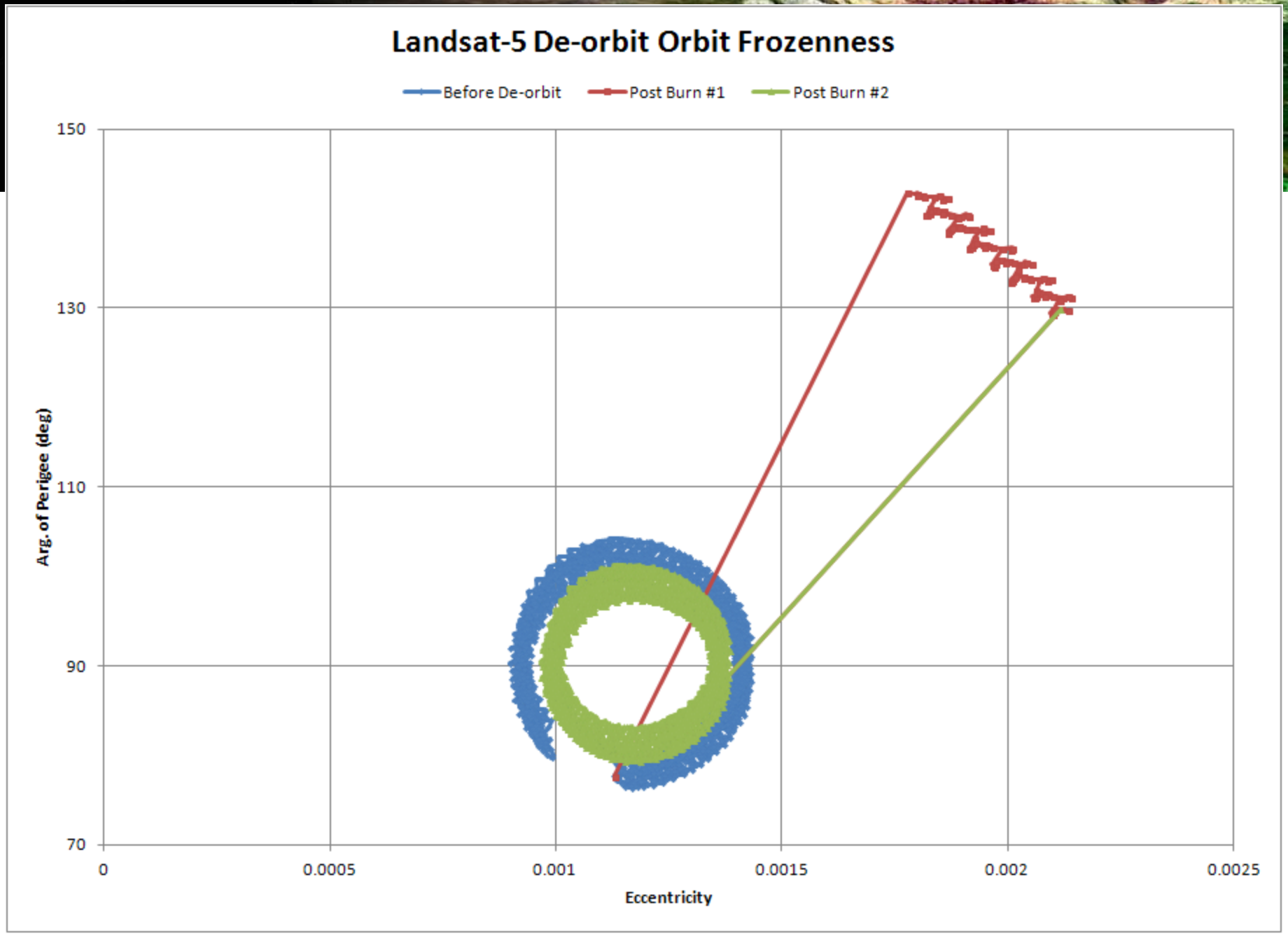


After first Burn:
691km/689km

After Phase 1
Complete:
688km/674km

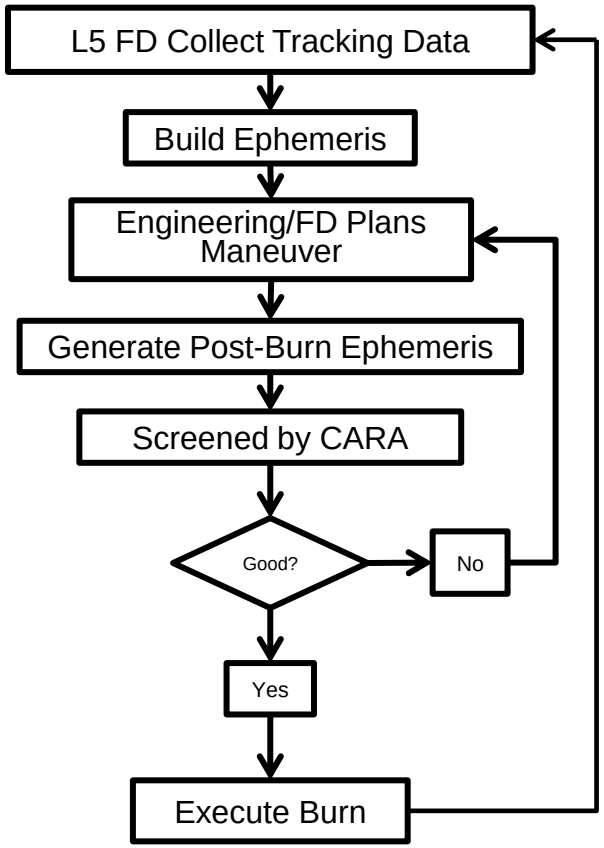
Phase 1 Flight Dynamics Analysis

	Apogee Height*(km)	Perigee Height*(km)	SMA (km)	Delta-V (m/sec)
	707	691	7077.5	
Burn #1	699	675	7065.6	6.28 (4.635)
Burn #2	685	668	7054.6	5.866 (4.561)


Landsat-5 De-orbit Orbit Frozenness
Before De-orbit
Post Burn #1
Post Burn #2
150
130
110
90
70
Arg. of Perigee (deg)
0
0.0005
0.001
0.0015
0.002
0.0025
Eccentricity

Phase 2 Maneuver Procedure

- **As the argument of perigee will now be in constant motion, the orbit angle of each burn will vary**
- **The procedure will be:**
  - L5 FD collects tracking data and builds a predicted ephemeris product
  - FD and Ops Engineering create a maneuver plan
    - Maneuver duration is determined by Engineering based on past thruster performance
    - Maneuver location is determined by FD
  - FD builds a predicted post-burn ephemeris product and delivers it to CARA for screening
  - Burn is executed
- **This will be repeated until remaining fuel/pressurant is exhausted**
  - Latch valves will remain open through end of mission

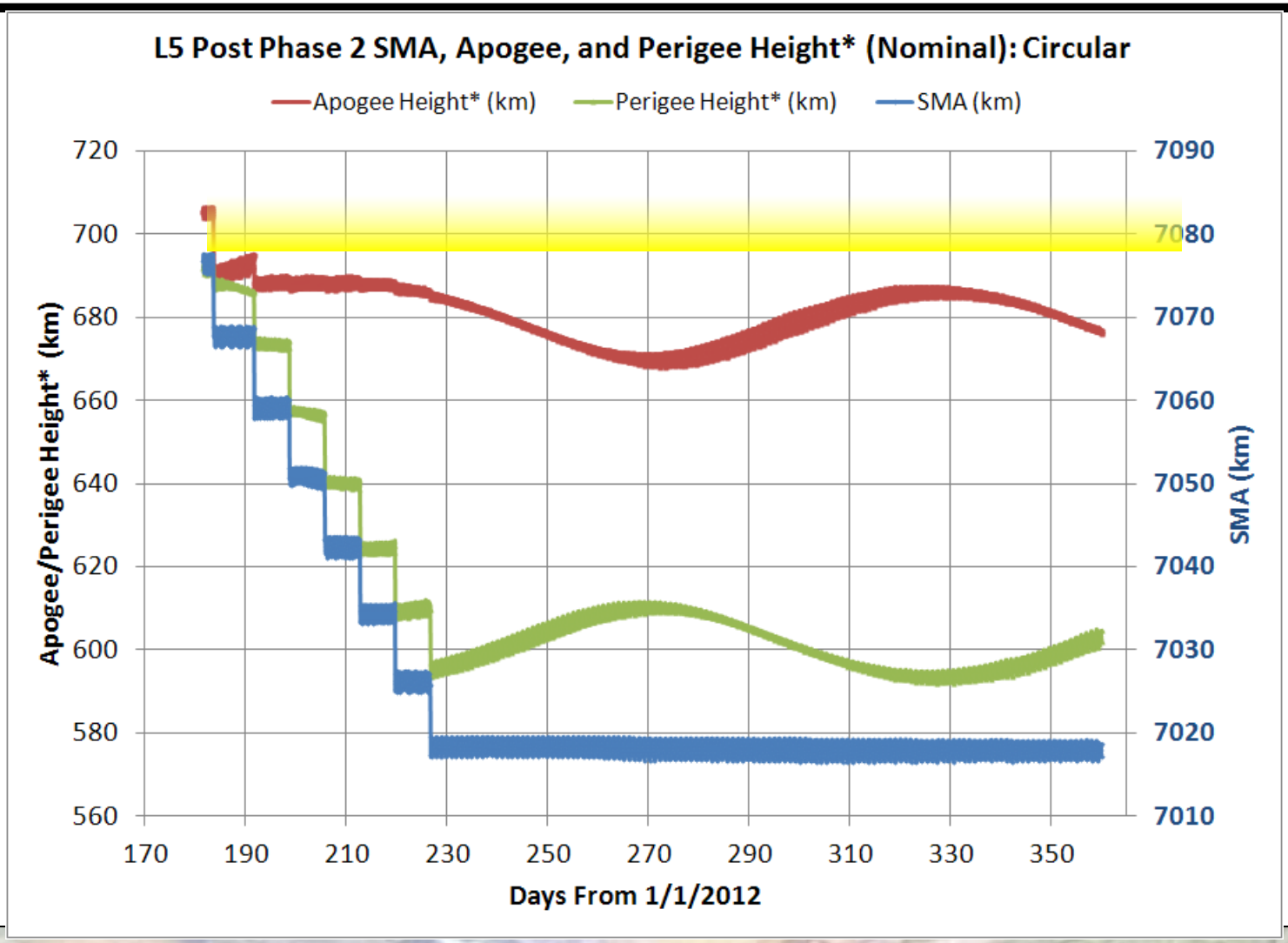


Phase 1&2 Flight Dynamics Analysis

	Apogee Height*(km)	Perigee Height*(km)	SMA (km)	Delta-V (m/sec)
	705	692	7077.65	
Burn #1	691	689	7069	4.64
Burn #2	688	673	7060	4.56
Burn #3	688	657	7052	4.49
Burn #4	688	640	7044	4.43
Burn #5	688	623	7035	4.36
Burn #6	687	608	7027	4.31
Burn #7	685	597	7019	4.25
Total ΔV				**31.04**

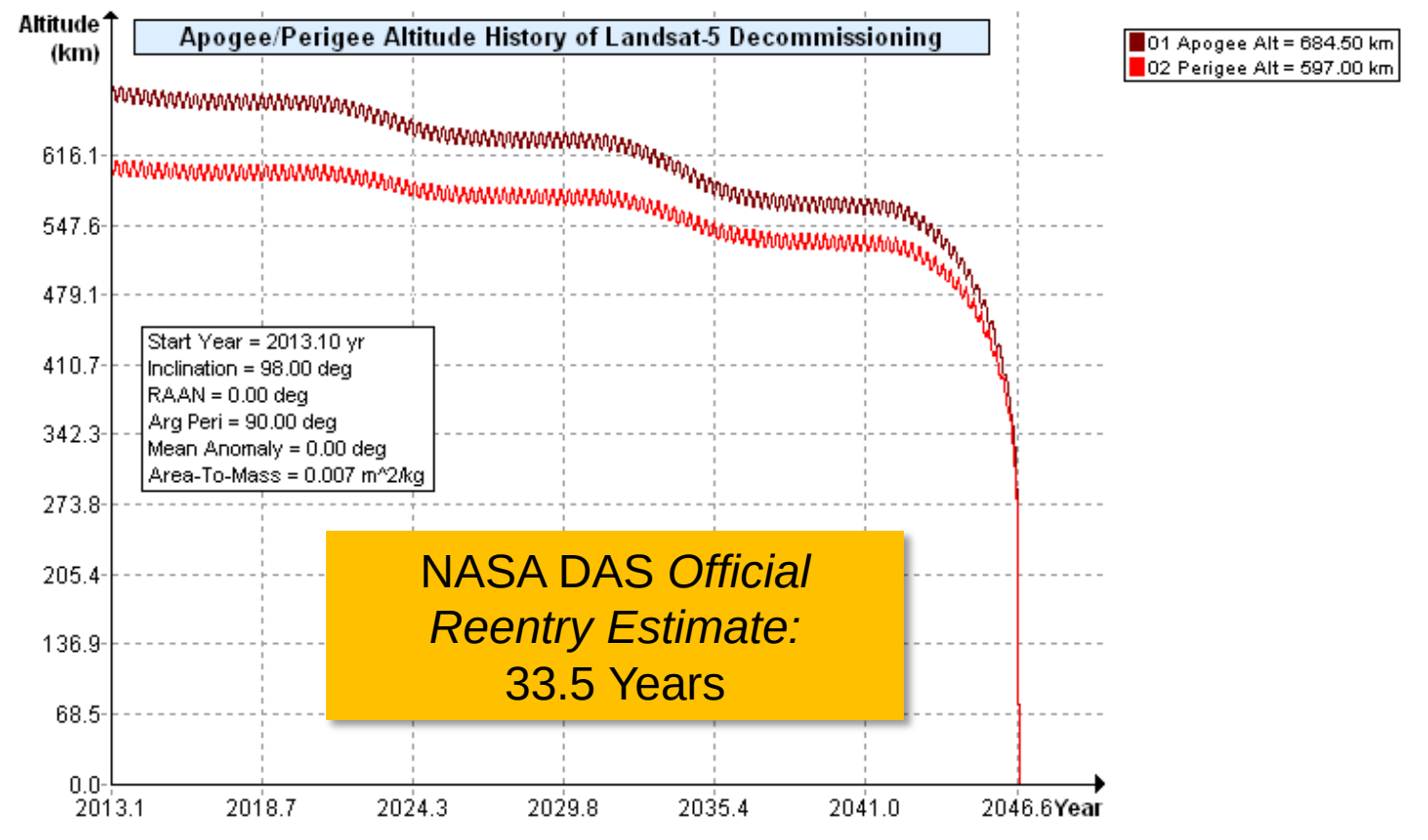
Note: This table contains notional burns meant to represent the total Δ-V expected

Phase 2 Flight Dynamics Analysis



Disposal Orbit

- Given 31.05 m/sec of remaining delta-V, the resulting disposal orbit of Landsat 5 will be 696km/587km



Lifetime +0 sigma (years)	79.2	82.9
Lifetime +2 sigma (years)	47.6	48.6

Phase 3: Passivation of Landsat 5

- **Primary Objectives:**
  - Comply with U.S. Government Orbital Debris Mitigation Standard Practices by depleting and disabling all sources of onboard energy
    - Chemical: Hydrazine
    - Electrical: Batteries, RF sources
    - Kinetic: Reaction Control Wheels, Gyros, Payloads
  - Identify those systems that cannot be disabled and devise a methodology to minimize the risk of reactivation.
- **After completion of orbit lowering maneuvers, the FOT will complete the decommissioning process by:**
  - Disabling all sources of stored energy
    - 1 battery must remain online (hardware constraint)
  - Maximizing “potential load” demand on the spacecraft bus
  - Configuring the spacecraft to minimize the possibility/opportunity to capture and store energy
  - Hobble flight software’s (FSW) ability to save the spacecraft
  - Shutting down the spacecraft transmitter
    - It isn’t possible to disable Landsat 5’s receivers

Phase 4: Decommission of Landsat 5 MOC

- **The FOT will**
  - Complete a report on the Landsat 5 decommission process and final status
  - Identify equipment/software/data of historical value and transfer those items to either another USGS mission or the EROS Center in Sioux Falls
  - Identify equipment and software of utility to other USGS missions and transfer those items as appropriate
  - Coordinate excess of remaining equipment
    - Anyone need a microVAX?
  - Discontinue any contracted h/w s/w support
  - Discontinue any contracted L5 Flight Operations Team support