17540 - Fragmented Asteroid 331P/Gibbs

Cycle: 31, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

Name	*Institution*
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VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) 331P	WFC3/UVIS	4	27-Jun-2024 10:01:11.0	yes
02	(1) 331P	WFC3/UVIS	2	27-Jun-2024 10:01:12.0	yes

6 Total Orbits Used

ABSTRACT

Extraordinary asteroid 331P/Gibbs consists of a rapidly rotating primary body about 1.6 km in diameter, a debris trail, and an embedded chain of 19 fragments, evidently all produced by a breakup in 2012. It is the best and most accessible example of rotational instability in the asteroid belt. HST observations in the 2015 - 2018 period have established the basic properties, revealing that one fragment has a large amplitude lightcurve consistent with a contact binary, that the fragments combined carry about 1 percent of the mass of the primary, and have an incredibly small (10 cm/s) velocity dispersion. Here, we propose follow-up observations with HST to define the fragment dynamics by extending the observational arc from 3 to 8 years. The new data will allow accurate orbital elements to be computed for each resolved object and, from these, accurate determination of the time and

speed of release from the primary. The degree to which the release times are staggered, the speeds of release, and speed-size correlations, will enable the first comparisons with numerical models of asteroid rotational breakup. The longer astrometric arc will yield sensitive limits to non-gravitational acceleration, as might be caused by the sudden exposure and sublimation of previously buried asteroid ice. If present, ice could spin-up the primary by sublimation torques, rather than radiation (YORP) torque as presently assumed; this new mechanism would have implications for rotational destruction timescales across the asteroid belt. These high resolution, high sensitivity observations lie far beyond the realm offered by even the largest ground-based telescopes, requiring the use of HST.

OBSERVING DESCRIPTION

We request 6 orbits divided into two separate visits in order to determine the positions and morphology of the fragment train in 331P. These 6 orbits should be divided into visits of 4 and 2 orbits, one coinciding with the Earth crossing the projected orbit plane of 331P and the other about two months later. The later visit benefits from smaller geocentric distance and brighter apparent magnitudes, hence requires only 2 orbits to reach comparable sensitivity. We will combine the images from within each visit to reveal the (very faint) 19 fragments. The need for 2 visits is to remove ambiguity in the fragment identifications resulting from ephemeris uncertainties caused by the extrapolation from the previous HST observations, as described below. We request observations at two epochs in Cycle 31. As discussed below, we have selected these epochs in order to maximize differences in the perspective as seen from HST, in order to set the strongest constraints on the orbits. One important perspective is obtained as the Earth passes through the projected orbit plane of 331P, when the out-of-plane distribution is uniquely revealed. Our basic observing strategy is to take multiple long exposures (280 s) using WFC3 and the wide bandpass filter F350LP. We will use the F350LP filter because it provides a 1.6x sensitivity advantage relative to other commonly used WFC3 broadband filters for a target with a solar-type spectrum. This matters because most of the identified fragments are exceedingly faint (V > 27) and data from 4 orbits must be combined to detect and measure a majority of them with confidence. We used the on-line exposure tool to calculate the signal-to-noise ratio (SNR) for various target fragments, using the absolute magnitudes from Table 2 of Jewitt et al. 2021) and assuming a G2V Kurucz solar spectrum model. We will reach the SNR indicated in Table 1 given 4 orbits at the April plane-crossing and 2 orbits with the more favorable geometry in July. We will dither the exposures to mitigate the effects from bad pixels, cosmic rays, and the inter-chip gap. The orbital visibility for a solar system target near the ecliptic plane is 54 min (Section 6.3 of the HST Primer document). In each orbit, we will take 8 exposures of 280 s using the C512C subarray of WFC3 (to save readout time) and perform a 2-point dither pattern to mitigate hot pixels and cosmic ray hits, obtaining 4 exposures at each dither point. This provides a total exposure time of 2240s = 37 min. We will average the exposures obtained at each dither point rejecting hot pixels and cosmic ray hits, and determine the component distance and brightness by least-squares-fitting of the two PSFs sub-sampled at an even smaller pixel scale to each of the two stacked images individually. This method can measure distances with uncertainties under 0.04 arcsec. The timing of the two visits is specified in order to maximize the observational

leverage on the locations of the fragments in three dimensions. Visit 1 (4 orbits): The Earth passes through the projected orbit plane of 331P on UT 2024 April 27, offering a unique view of the out-of-plane distribution of fragments. Observations within a plus/minus3 day window about this date negate the effects of projection into the orbit plane and provide a model-free measure of the out-of-plane positions of fragments and the perpendicular profile of the debris trail (consisting of particles 10 cm and larger). Visit 2 (2 orbits): The most negative orbit plane angle is attained on UT 2023 July 23, about 80 days after the plane crossing, roughly coinciding with the minimum geocentric distance (when image scale 60 km pixel-1). Off-plane observations on this date therefore provide a complement to the in-plane data from April 27 and benefit from a more favorable geometry requiring only 2 orbits to reach comparable SNR. The apparent rates of motion in late April are under 30 arcsec hr-1, which are easily within Hubbles tracking capabilities. This rate of motion is also slow enough to keep a single pair of guide stars within the FGS pickles for an entire visibility window. The ephemeris uncertainty of primary body 331P is < 1 arcsec, which is negligible compared to the WFC3 field-of-view of 162 x 162 arcsec. The length of the fragment train is, from our analysis of archival data, still < 40 arcsec in Cycle 30, fitting comfortably within the field of view. Ephemeris uncertainties are of no concern to this observation. We understand that the need in Cycle 31 for a gyro-gap is uncertain. A gyro-gap, if such exists, will not undermine the goals of this proposal. We also understand that we may have essentially no control over the spacecraft roll angle, which means we will not be able to optimize the orientation of the dust tail on the CCD (i.e., to orient the tail along the longest dimension of the detector). However, the field-of-view of the camera is large enough that we should obtain excellent data on a portion of the tail, no matter what spacecraft roll angle is used. As described above, we request that the observations for Visit 1 be obtained as close as possible to UT 2024 April 27. Dates within 3 days of 2024 April 27 are sufficient to remove the effects of projection. The requested date of Visit 2, when the geocentric distance is minimized, is UT 2023 July 23 plus/minus 10 days.

Proposal 17540 - Visit 01 - Fragmented Asteroid 331P/Gibbs

Visit

Proposal 17540, Visit 01, completed Thu Jun 27 14:01:13 GMT 2024

Diagnostic Status: Warning

Scientific Instruments: WFC3/UVIS

Special Requirements: BETWEEN 13-MAY-2024:00:00:00 AND 13-MAY-2024:06:00:00; BETWEEN 13-MAY-2024:19:00:00 AND 14-MAY-2024:10:00:00; BETWEEN 15-MAY-2024:05:00:00 AND 15-MAY-2024:06:00:00; BETWEEN 15-MAY-2024:18:00:00 AND 17-MAY-2024:08:00:00

Diagnostics

(Visit 01) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

(Visit 01) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

(Visit 01) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

(Visit 01) Warning (Orbit Planner): ORBITAL VISIBILITY OVERRUN

(Visit 01) Informational (Form): The Visit Planner and Spike may produce different schedulability results.

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(1)	Pattern Type=LINE	Coordinate Frame=POS-TARG		(1)
	Purpose=DITHER	Pattern Orientation=45		
	Number Of Points=4	Angle Between Sides=		
	Point Spacing=0.2	Center Pattern=false		
	Line Spacing=			

Solar System Targets

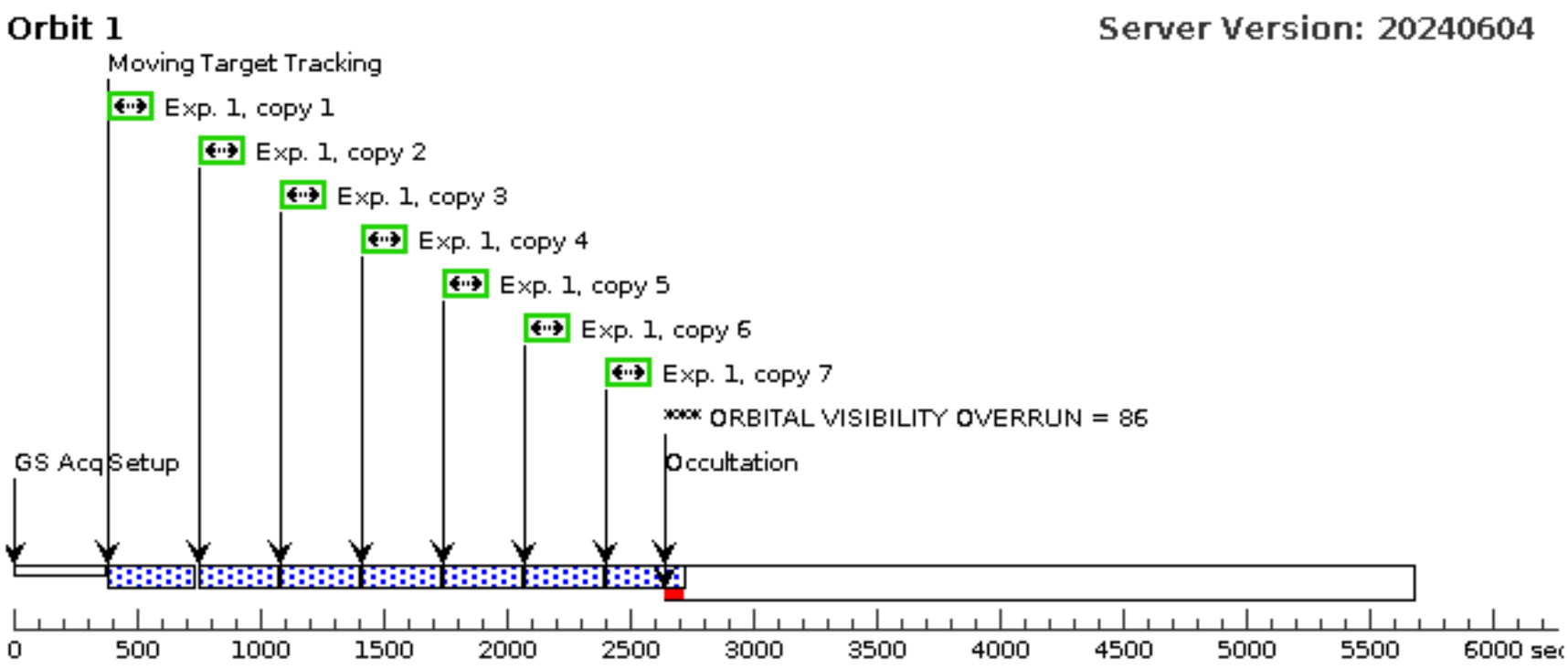
#	Name	Level 1	Level 2	Level 3	Window	Ephem Center
(1)	331P	TYPE=ASTEROID,A=3.00516932707 0824,E=0.04162092936179756,I=9.73 8048614887637 ,O=216.8567409364987,W=177.86529 13669414,M=234.3925641937084,EQ UINOX=J2000,EPOCH=20-AUG- 2013:00:00:00,EpochTimeScale=TDB				EARTH

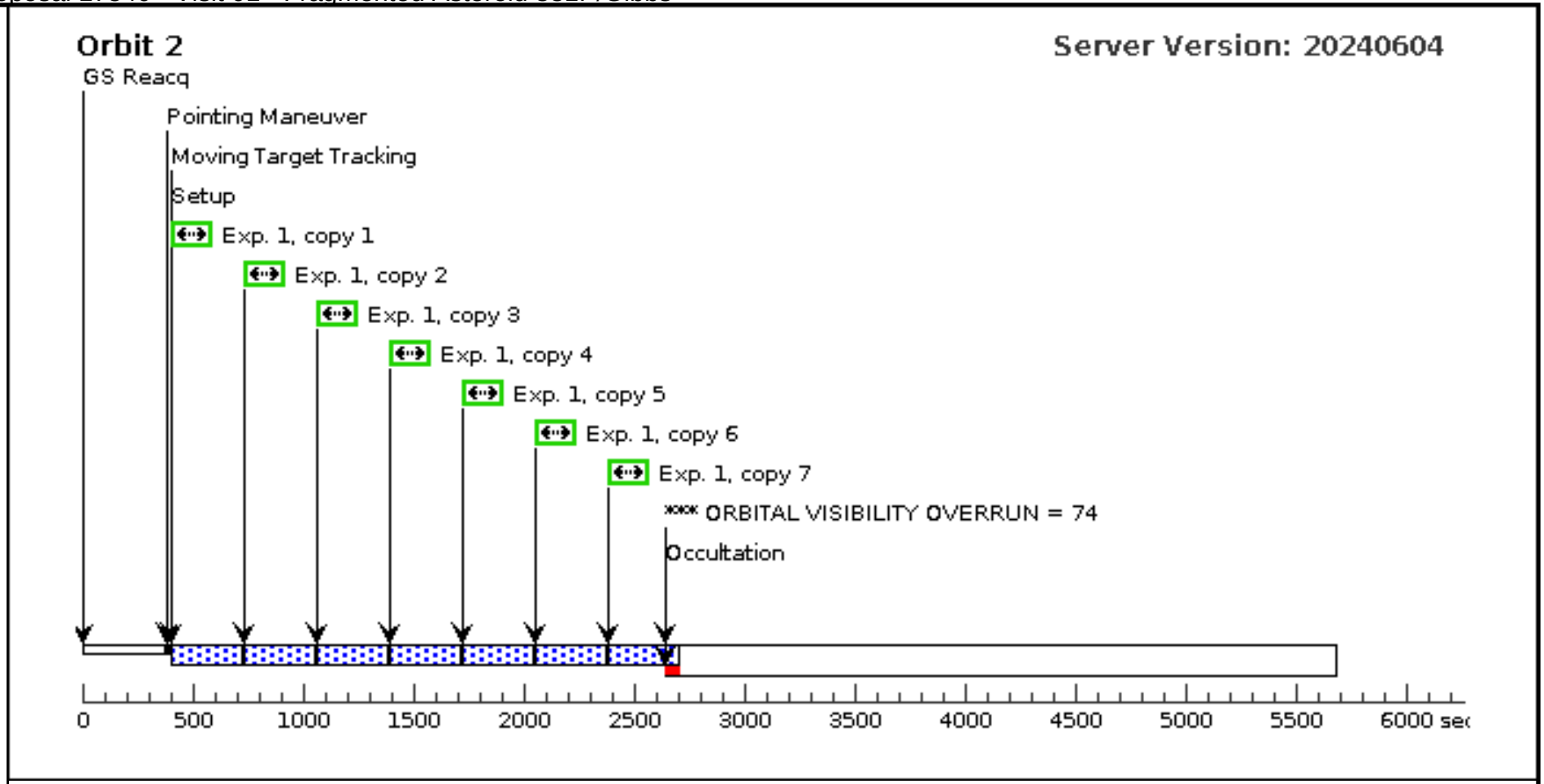
Comments: Description=Disintegrating asteroid
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1		(1) 331P	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP			Pattern 1, Exps 1-1 in Visit 01 (1)	280 Secs X 7 (7840 Secs)	
								[==>(Pattern 1, Copy 1)]	
								[==>(Pattern 1, Copy 2)]	
								[==>(Pattern 1, Copy 3)]	
								[==>(Pattern 1, Copy 4)]	***[1]***
								[==>(Pattern 1, Copy 5)]	
								[==>(Pattern 1, Copy 6)]	
								[==>(Pattern 1, Copy 7)]	
								[==>(Pattern 2, Copy 1)]	
								[==>(Pattern 2, Copy 2)]	
								[==>(Pattern 2, Copy 3)]	
								[==>(Pattern 2, Copy 4)]	***[2]***
								[==>(Pattern 2, Copy 5)]	
								[==>(Pattern 2, Copy 6)]	
								[==>(Pattern 2, Copy 7)]	
								[==>(Pattern 3, Copy 1)]	
								[==>(Pattern 3, Copy 2)]	
								[==>(Pattern 3, Copy 3)]	
								[==>(Pattern 3, Copy 4)]	***[3]***
								[==>(Pattern 3, Copy 5)]	
								[==>(Pattern 3, Copy 6)]	
								[==>(Pattern 3, Copy 7)]	
								[==>(Pattern 4, Copy 1)]	
								[==>(Pattern 4, Copy 2)]	
								[==>(Pattern 4, Copy 3)]	
								[==>(Pattern 4, Copy 4)]	***[4]***
								[==>(Pattern 4, Copy 5)]	
								[==>(Pattern 4, Copy 6)]	
								[==>(Pattern 4, Copy 7)]	

Orbit Structure




Orbit 2
Server Version: 20240604
GS Reacq
Pointing Maneuver
Moving Target Tracking
Setup
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Exp. 1, copy 2
Exp. 1, copy 3
Exp. 1, copy 4
Exp. 1, copy 5
Exp. 1, copy 6
Exp. 1, copy 7
*** ORBITAL VISIBILITY OVERRUN = 74
Occultation
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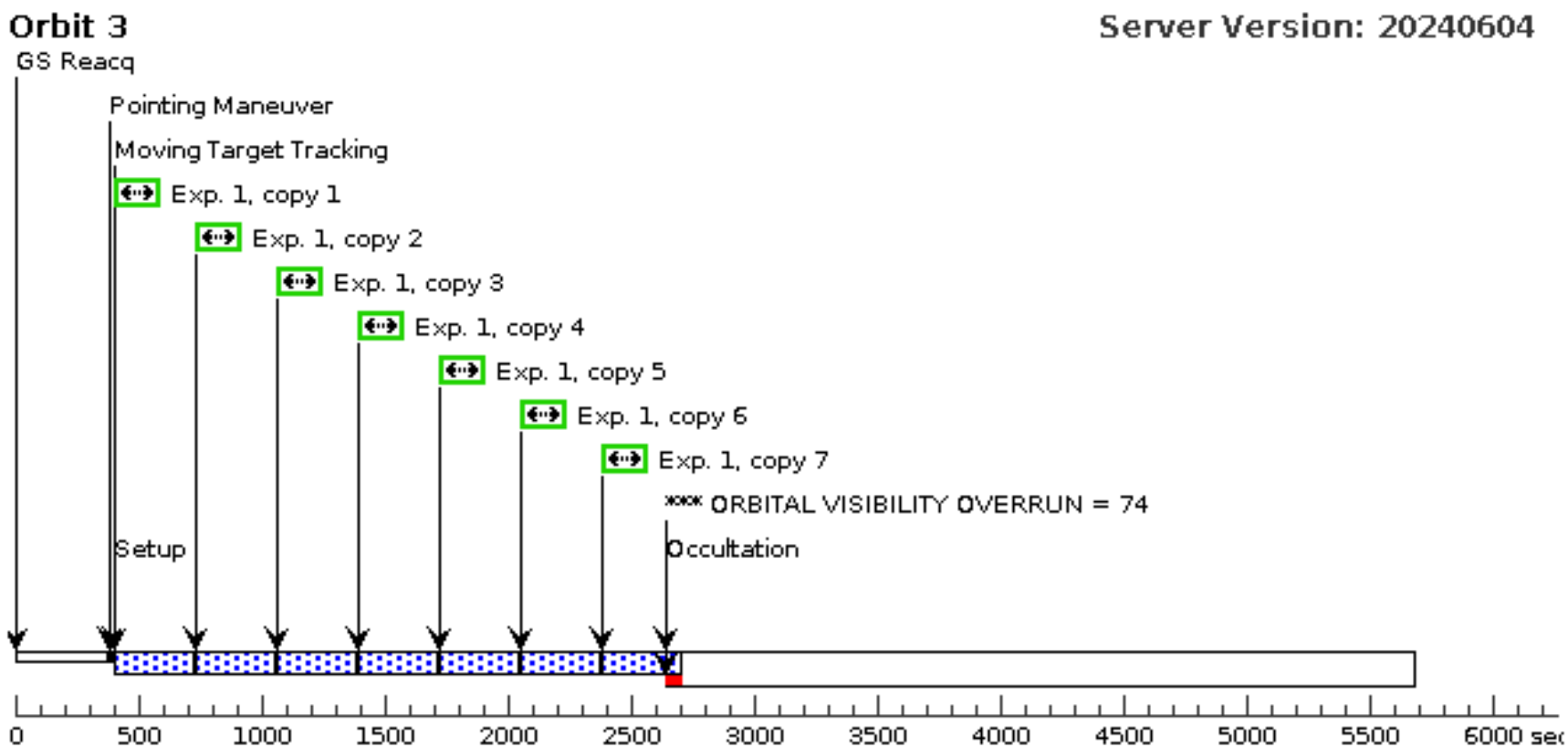
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000 sec


Orbit 3
Server Version: 20240604
GS Reacq
Pointing Maneuver
Moving Target Tracking
Exp. 1, copy 1
Exp. 1, copy 2
Exp. 1, copy 3
Exp. 1, copy 4
Exp. 1, copy 5
Exp. 1, copy 6
Exp. 1, copy 7
*** ORBITAL VISIBILITY OVERRUN = 74
Setup
Occultation
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1000
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2000
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3000
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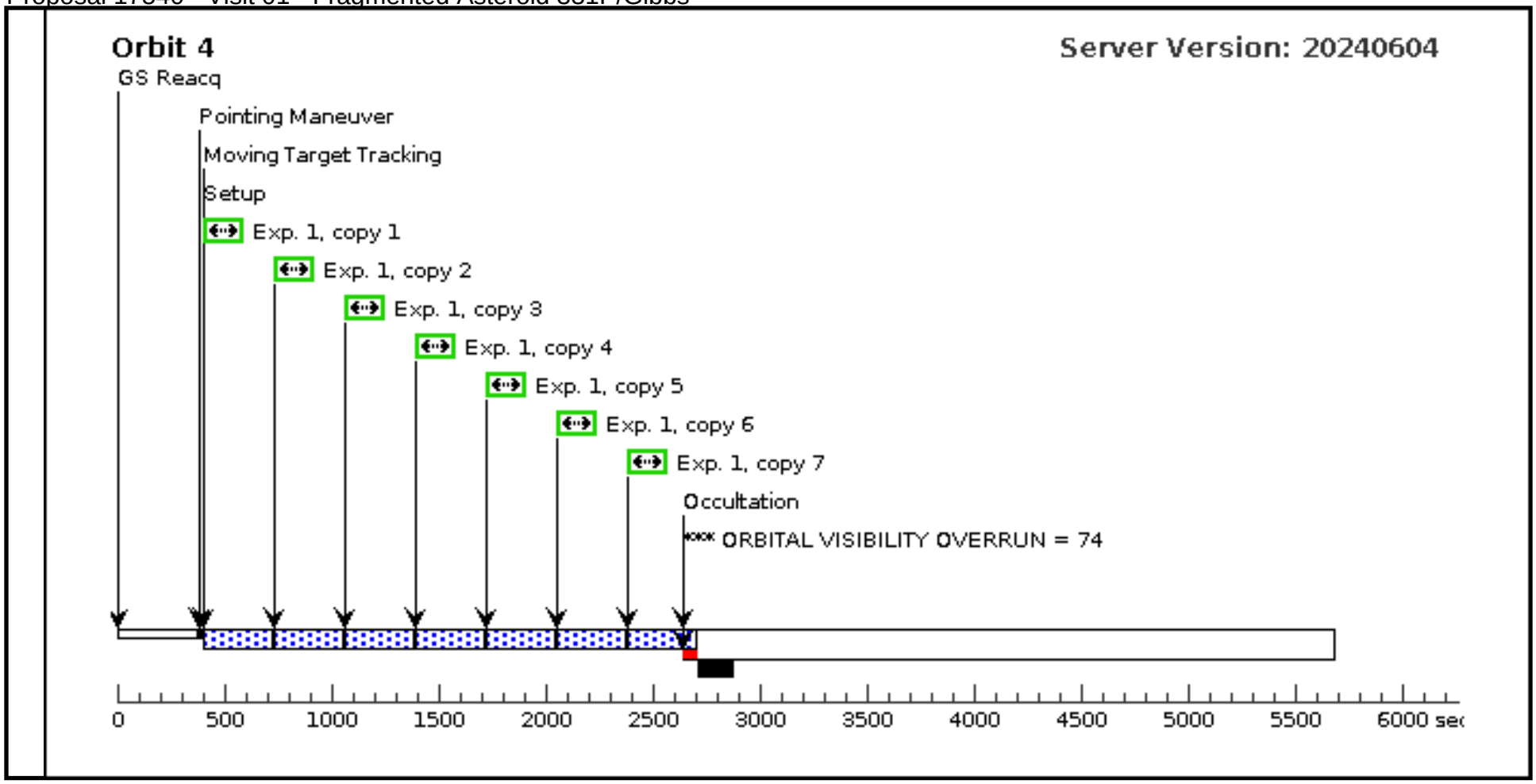
4000
4500
5000
5500
6000 sec


Orbit 4
Server Version: 20240604
GS Reacq
Pointing Maneuver
Moving Target Tracking
Setup
Exp. 1, copy 1
Exp. 1, copy 2
Exp. 1, copy 3
Exp. 1, copy 4
Exp. 1, copy 5
Exp. 1, copy 6
Exp. 1, copy 7
Occultation
*** ORBITAL VISIBILITY OVERRUN = 74
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000 sec

Visit

Proposal 17540, Visit 02, implementation Thu Jun 27 14:01:13 GMT 2024

Diagnostic Status: Informational

Scientific Instruments: WFC3/UVIS

Special Requirements: BETWEEN 13-JUL-2024:00:00:00 AND 30-JUL-2024:00:00:00; BETWEEN 30-JUL-2024:18:00:00 AND 02-AUG-2024:00:00:00

Diagnostics

(Visit 02) Informational (Form): The Visit Planner and Spike may produce different schedulability results.

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(2)	Pattern Type=LINE	Coordinate Frame=POS-TARG		(1)
	Purpose=DITHER	Pattern Orientation=45		
	Number Of Points=2	Angle Between Sides=		
	Point Spacing=0.4	Center Pattern=false		
	Line Spacing=			

Solar System Targets

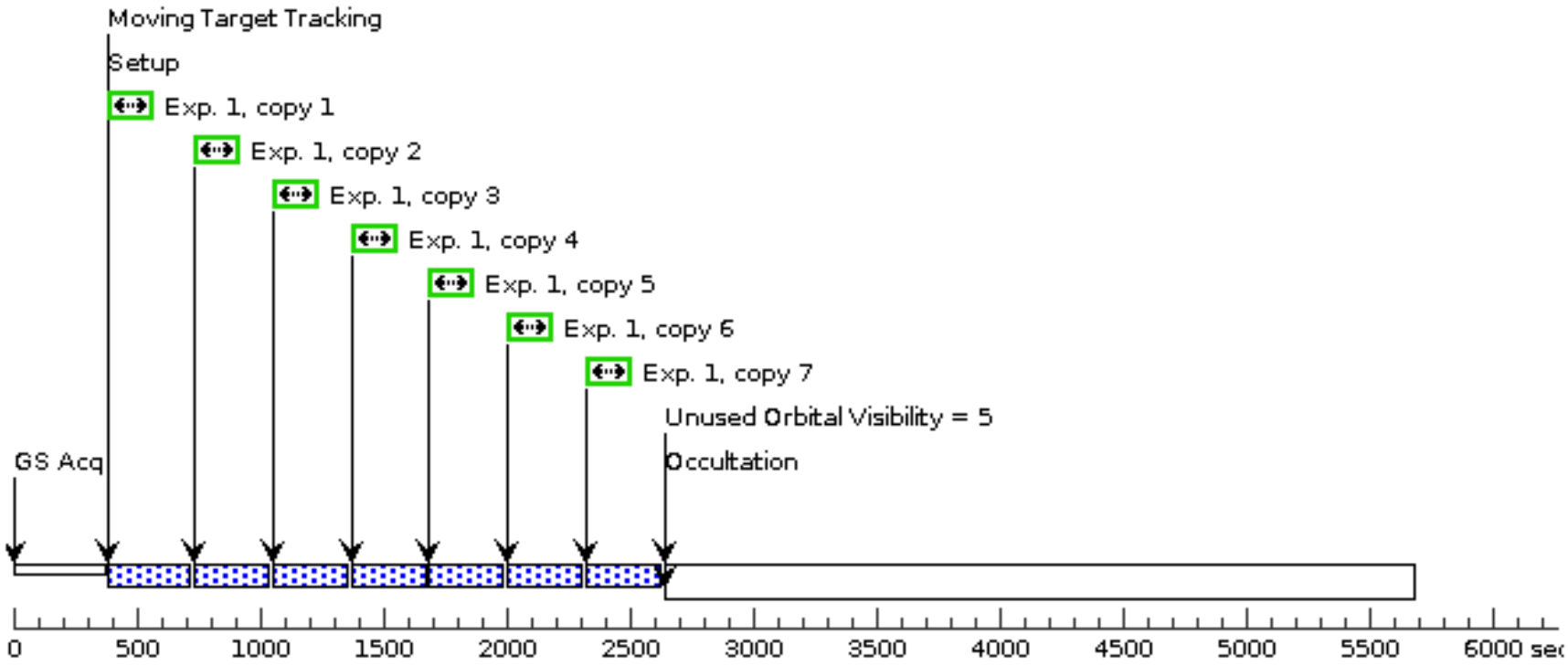
#	Name	Level 1	Level 2	Level 3	Window	Ephem Center
(1)	331P	TYPE=ASTEROID,A=3.00516932707 0824,E=0.04162092936179756,I=9.73 8048614887637 ,O=216.8567409364987,W=177.86529 13669414,M=234.3925641937084,EQ UINOX=J2000,EPOCH=20-AUG- 2013:00:00:00,EpochTimeScale=TDB				EARTH

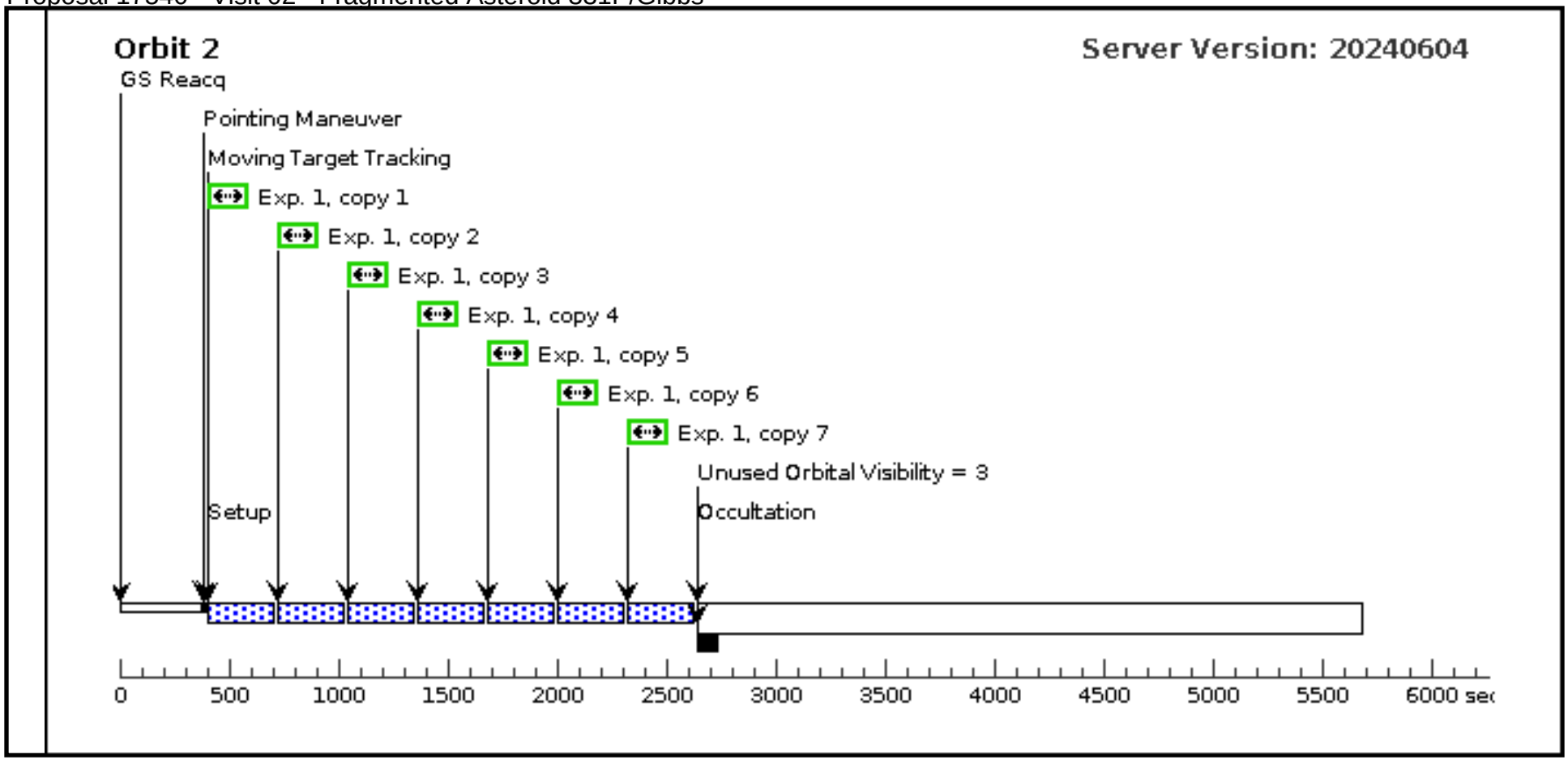
Comments: Description=Disintegrating asteroid
Extended=YES

Exposures

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1		(1) 331P	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP			Pattern 2, Exps 1-1 in Visit 02 (2)	280 Secs X 7 (3752 Secs)	
								[==>267.0 Secs (Pattern 1, Copy 1)] *[==>267.0 Secs (Pattern 1, Copy 2)]* *[==>267.0 Secs (Pattern 1, Copy 3)]* *[==>267.0 Secs (Pattern 1, Copy 4)]* *[==>267.0 Secs (Pattern 1, Copy 5)]* *[==>267.0 Secs (Pattern 1, Copy 6)]* *[==>267.0 Secs (Pattern 1, Copy 7)]*	***[1]***
								[==>269.0 Secs (Pattern 2, Copy 1)] *[==>269.0 Secs (Pattern 2, Copy 2)]* *[==>269.0 Secs (Pattern 2, Copy 3)]* *[==>269.0 Secs (Pattern 2, Copy 4)]* *[==>269.0 Secs (Pattern 2, Copy 5)]* *[==>269.0 Secs (Pattern 2, Copy 6)]* *[==>269.0 Secs (Pattern 2, Copy 7)]*	***[2]***

Orbit Structure




Orbit 2
Server Version: 20240604
GS Reacq
Pointing Maneuver
Moving Target Tracking
Exp. 1, copy 1
Exp. 1, copy 2
Exp. 1, copy 3
Exp. 1, copy 4
Exp. 1, copy 5
Exp. 1, copy 6
Exp. 1, copy 7
Unused Orbital Visibility = 3
Occultation
Setup
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000 sec