



## 18133 - Probing the TNO Density Transition with Mid-Size 2013 FY27

Cycle: 33, Proposal Category: GO

(Availability Mode: SUPPORTED)

### INVESTIGATORS

<i>Name</i>	<i>Institution</i>
<b>Prof. Darin Ragozzine (PI) (Contact)</b>	<b>Brigham Young University</b>
Dr. Benjamin Proudfoot (CoI) (Contact)	University of Central Florida Board of Trustees
Dr. Will M. Grundy (CoI)	Lowell Observatory
Dr. Scott Sander Sheppard (CoI)	Carnegie Institution of Washington

### VISITS

<i>Visit</i>	<i>Targets used in Visit</i>	<i>Configurations used in Visit</i>	<i>Orbits Used</i>	<i>Last Orbit Planner Run</i>	<i>OP Current with Visit?</i>
01	(1) 2013FY27	WFC3/UVIS	1	15-Dec-2025 13:00:30.0	yes
02	(1) 2013FY27	WFC3/UVIS	1	15-Dec-2025 13:00:31.0	yes
03	(1) 2013FY27	WFC3/UVIS	1	15-Dec-2025 13:00:32.0	yes
04	(1) 2013FY27	WFC3/UVIS	1	15-Dec-2025 13:00:33.0	yes
05	(1) 2013FY27	WFC3/UVIS	1	15-Dec-2025 13:00:33.0	yes

5 Total Orbits Used

### ABSTRACT

The density distribution of Trans-Neptunian Objects (TNOs) provides key insights into the composition and interiors of outer solar system bodies, with broad implications for planet formation and evolution. Only ~20 TNOs have measured densities which seem to fall into three categories: small TNOs have similar low densities and large TNOs have similar high densities. The "transition region" (diameters of 400-900 km) only has 5 known densities which show a surprisingly rapid transition between these two regimes. While the density-size relationship was thought to be linear, a recent

measurement breaks this trend, suggesting the need to explore other interpretations.

This proposal targets 2013 FY27, a rare TNO in the transition region with a known satellite and a diameter of ~760 km. Previous HST observations were insufficient to determine its orbit due to a small near edge-on orbit.

We propose a focused 5-orbit program to obtain precise relative astrometry of FY27 and its satellite to measure the density of FY27 and to determine the possibility of information-rich mutual events. Previous observations are used to design an optimal observing program, including iterative updates to the observing schedule using state-of-the-art orbit fitting and prediction tools. Success in these goals is only plausible with HST.

This program will add a valuable new data point to the poorly-understood density distribution of TNOs in the density transition, helping to resolve whether composition or porosity drives the transition. The resulting insights on composition and interiors have broad importance in astrometry through improved constraints on planet formation and evolution.

## **OBSERVING DESCRIPTION**

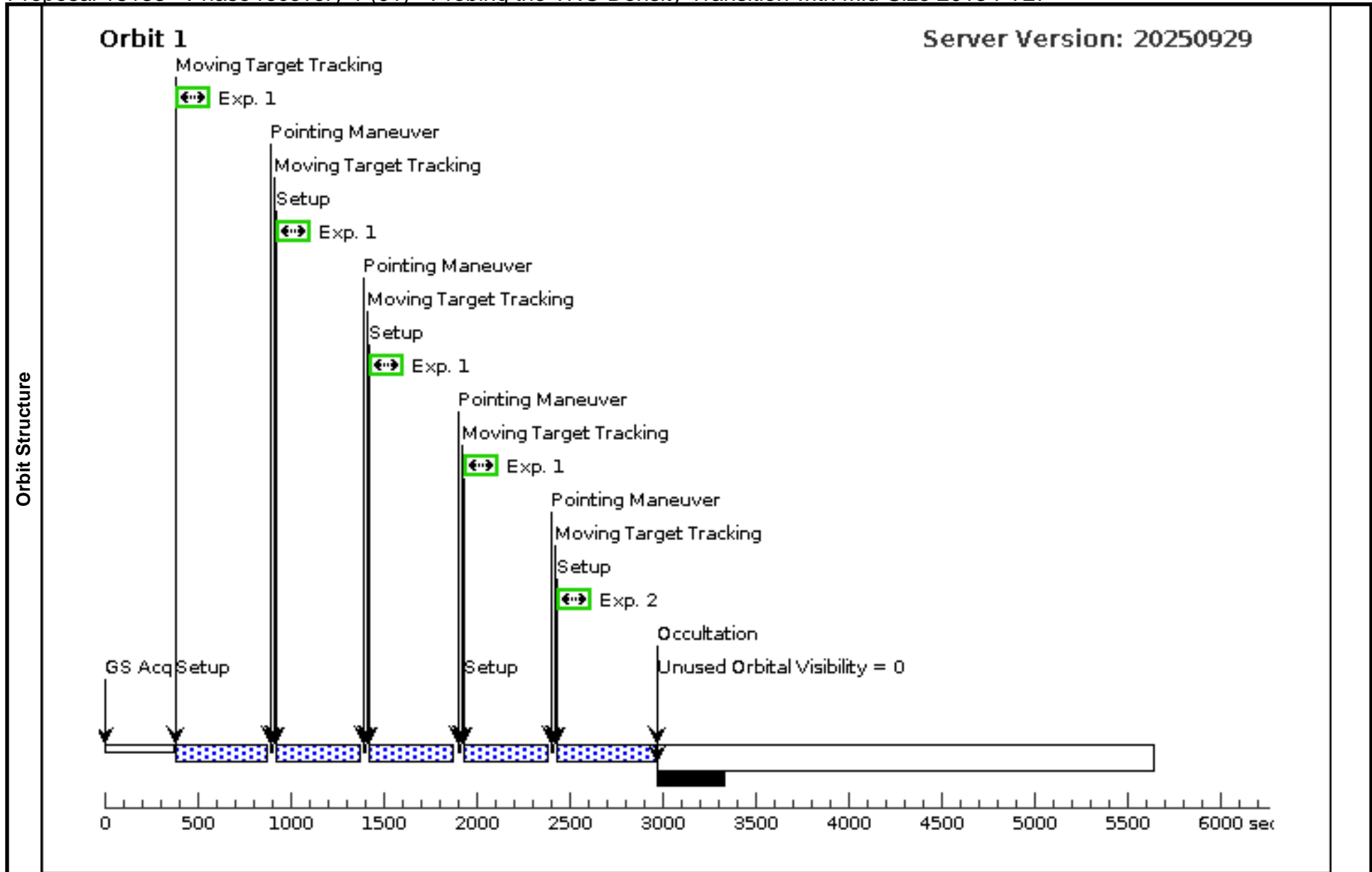
Our observations aim to recover and determine the orbit of 2013 FY27's satellite. Observations focus on high SNR and astrometric precision. Each single-orbit visit will consist of 5 F350LP exposures, each of ~420 seconds. The first 4 exposures will use the UVIS2-C512C-SUB aperture, which will limit data volume and reduce overheads. The last exposure will use the full UVIS2 aperture, pushing the final data buffer dump into Earth occultation. Observations will be dithered to optimally sample the PSF and provide resilience to per-pixel effects.

Our program relies on precise observation timing to fulfill our science goals efficiently. Since the orbit phase of the satellite is ~unknown, our first three observations will be dedicated to blindly recovering the satellite. These observations should take place in a sequence with 2.5 +/- 0.5 days between each visit. The first visit should be carried out soon after 2013 FY27 becomes visible, which allows us the maximum time to carry out our carefully planned sequence of observations. Visits 4 and 5 will remain on hold until preliminary analysis is able to predict optimal times to observe the satellite. If we accomplish our science goals before all visits are carried out, we will release allocated orbits back to STScI.

Proposal 18133 - Phase recovery 1 (01) - Probing the TNO Density Transition with Mid-Size 2013 FY27

Mon Dec 15 18:00:34 GMT 2025

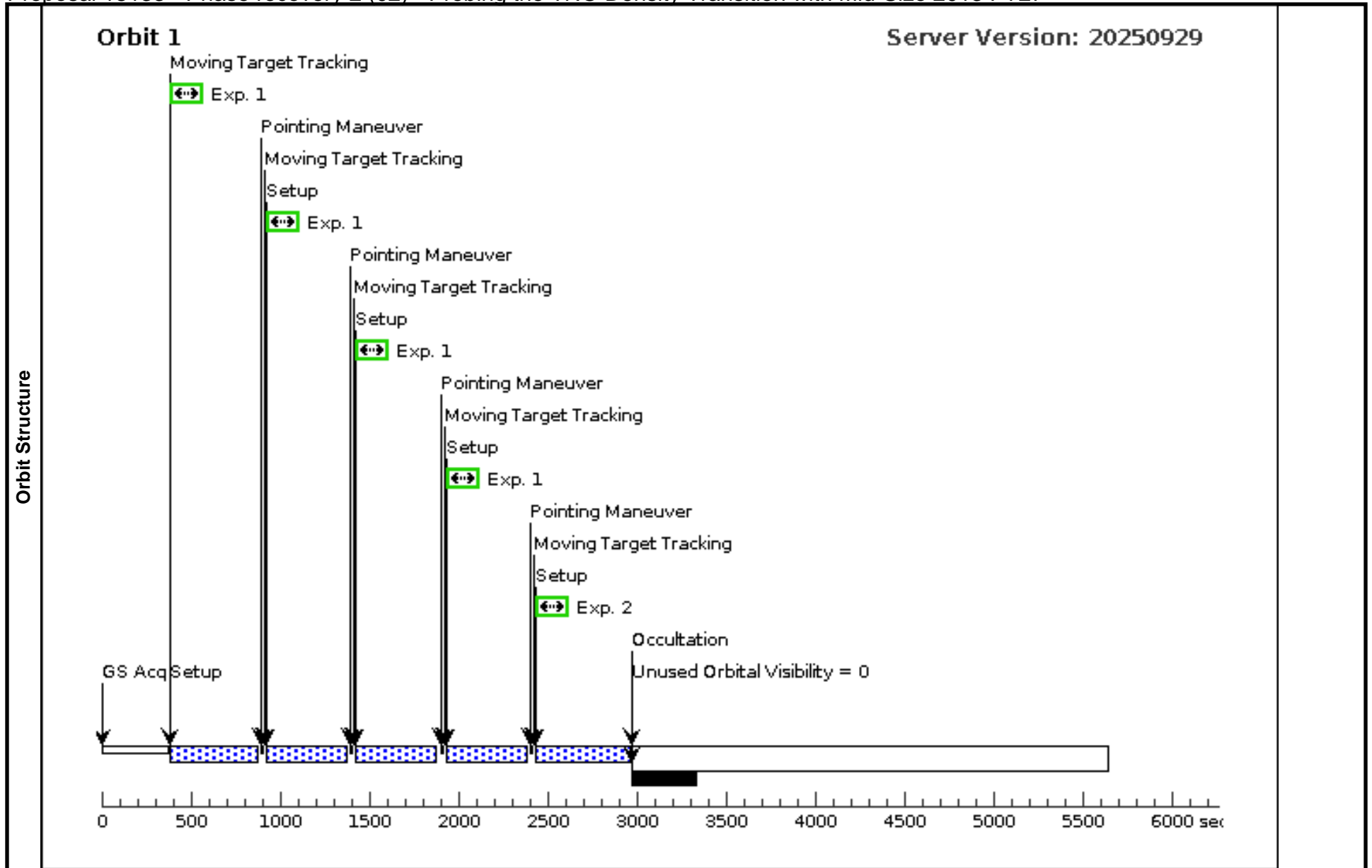
<b>Visit</b>	<b>Proposal 18133, Phase recovery 1 (01), completed</b> <b>Diagnostic Status: Informational</b> Scientific Instruments: WFC3/UVIS Special Requirements: ORIENT 285D TO 296.1 D; BEFORE 10-DEC-2025:00:00:00 <i>Comments: Should take place soon after target becomes visible.</i>									
	<b>Diagnosics</b> (Phase recovery 1 (01)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.									
<b>Patterns</b>	#	<b>Primary Pattern</b>			<b>Secondary Pattern</b>		<b>Exposures</b>			
	(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112			Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1)			
<b>Solar System Targets</b>	#	<b>Name</b>	<b>Level 1</b>	<b>Level 2</b>	<b>Level 3</b>	<b>Window</b>	<b>Ephem Center</b>			
	(1)	2013FY27	TYPE=ASTEROID,A=58.9936314534 8065.E=0.3916647205101159,I=32.99 057781326125 .O=187.1703133045093,W=138.60603 91018931,M=212.7151024578246,EQ UINOX=J2000,EPOCH=21-APR- 2017:00:00:00,EpochTimeScale=TDB				EARTH			
<i>Comments: Description=FY27 and satellite Extended=NO</i>										
<b>Exposures</b>	#	<b>Label</b>	<b>Target</b>	<b>Config,Mode,Aperture</b>	<b>Spectral Els.</b>	<b>Opt. Params.</b>	<b>Special Reqs.</b>	<b>Groups</b>	<b>Exp. Time (Total)/[Actual Dur.]</b>	<b>Orbit</b>
	1	(1) 2013FY27		WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP			Sequence 1-2 Non-Int in Phase recovery 1 (01)	420 Secs (1672 Secs) [==>418.0 Secs (Pattern 1)]	
								Pattern 1, Exps 1-1 in Sequence 1-2 Non-Int in Phase recovery 1 (01) (1)	[==>418.0 Secs (Pattern 2)] [==>418.0 Secs (Pattern 3)] [==>418.0 Secs (Pattern 4)]	[1]
	2	(1) 2013FY27		WFC3/UVIS, ACCUM, UVIS2	F350LP			Sequence 1-2 Non-Int in Phase recovery 1 (01)	420 Secs (418 Secs) [==>418.0 Secs ]	[1]



Proposal 18133 - Phase recovery 2 (02) - Probing the TNO Density Transition with Mid-Size 2013 FY27

Mon Dec 15 18:00:34 GMT 2025

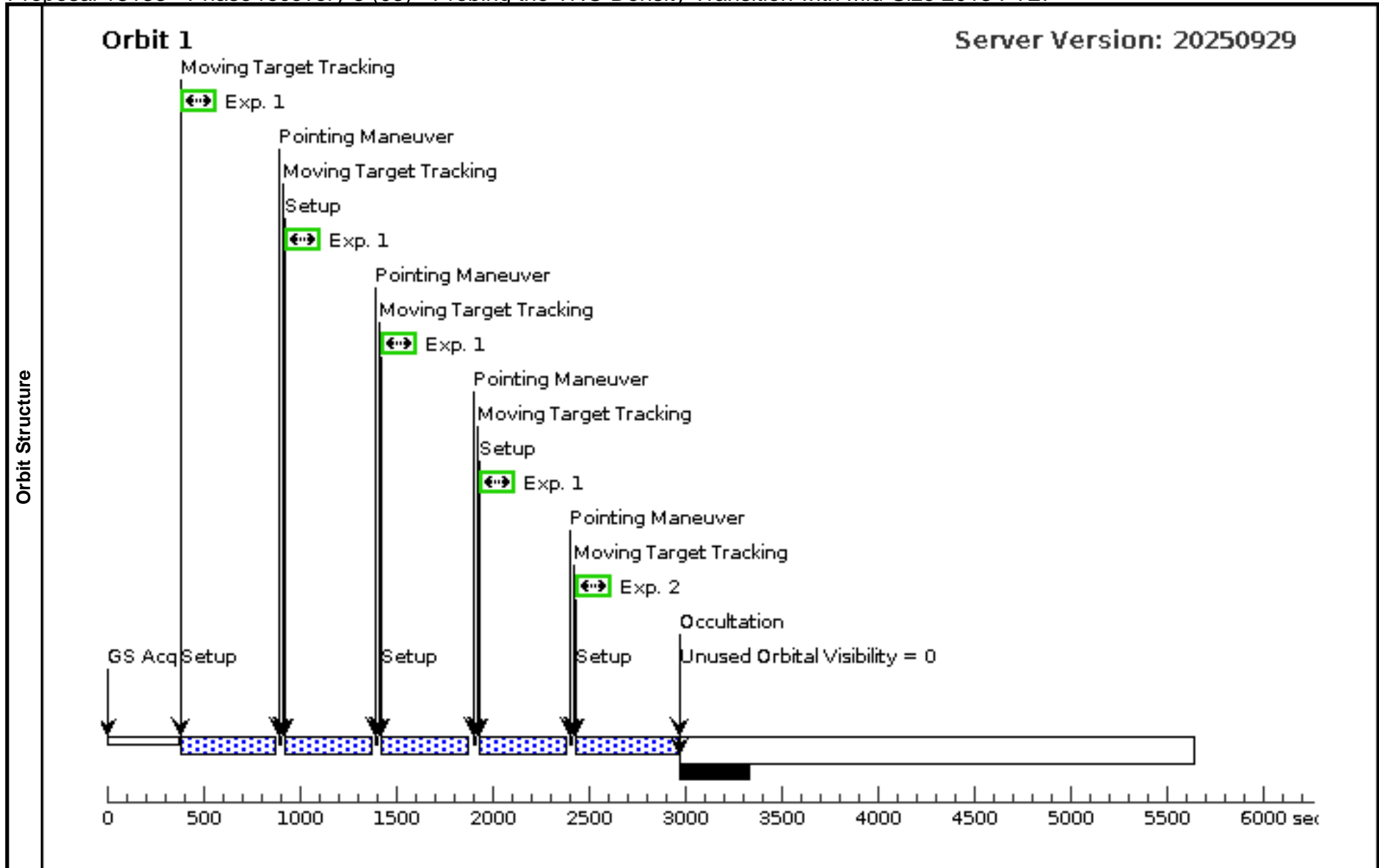
<b>Visit</b>	<b>Proposal 18133, Phase recovery 2 (02), completed</b> <b>Diagnostic Status: Informational</b> Scientific Instruments: WFC3/UVIS Special Requirements: ORIENT 285D TO 296.1 D; AFTER 01 BY 2 D TO 3 D <i>Comments: Should take place 2-3 days after Visit 1. The timing of this sequence is critically important for our science goals.</i>									
	<b>Diagnosics</b> (Phase recovery 2 (02)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.									
<b>Patterns</b>	#	<b>Primary Pattern</b>			<b>Secondary Pattern</b>		<b>Exposures</b>			
	(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112			Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1)			
<b>Solar System Targets</b>	#	<b>Name</b>	<b>Level 1</b>	<b>Level 2</b>	<b>Level 3</b>	<b>Window</b>	<b>Ephem Center</b>			
	(1)	2013FY27	TYPE=ASTEROID,A=58.9936314534 8065.E=0.3916647205101159,I=32.99 057781326125 .O=187.1703133045093,W=138.60603 91018931,M=212.7151024578246,EQ UINOX=J2000,EPOCH=21-APR- 2017:00:00:00,EpochTimeScale=TDB				EARTH			
<i>Comments: Description=FY27 and satellite Extended=NO</i>										
<b>Exposures</b>	#	<b>Label</b>	<b>Target</b>	<b>Config,Mode,Aperture</b>	<b>Spectral Els.</b>	<b>Opt. Params.</b>	<b>Special Reqs.</b>	<b>Groups</b>	<b>Exp. Time (Total)/[Actual Dur.]</b>	<b>Orbit</b>
	1	(1) 2013FY27		WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP			Sequence 1-2 Non-Int in Phase recovery 2 (02)	420 Secs (1672 Secs) [==>418.0 Secs (Pattern 1)]	
								Pattern 1, Exps 1-1 in Sequence 1-2 Non-Int in Phase recovery 2 (02) (1)	[==>418.0 Secs (Pattern 2)] [==>418.0 Secs (Pattern 3)] [==>418.0 Secs (Pattern 4)]	[1]
	2	(1) 2013FY27		WFC3/UVIS, ACCUM, UVIS2	F350LP			Sequence 1-2 Non-Int in Phase recovery 2 (02)	420 Secs (418 Secs) [==>418.0 Secs ]	[1]



Proposal 18133 - Phase recovery 3 (03) - Probing the TNO Density Transition with Mid-Size 2013 FY27

Mon Dec 15 18:00:34 GMT 2025

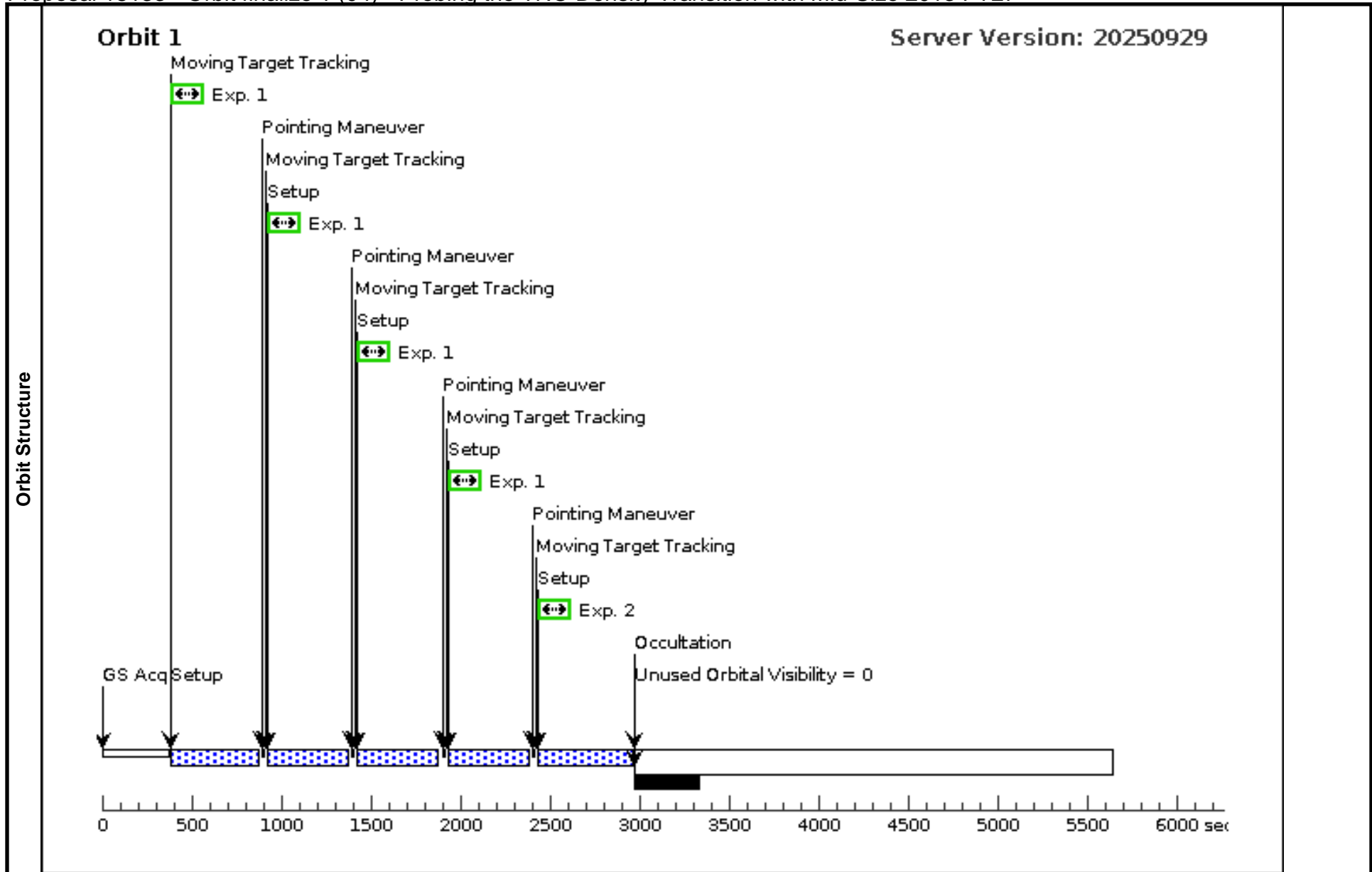
<b>Visit</b>	<b>Proposal 18133, Phase recovery 3 (03), completed</b> <b>Diagnostic Status: Informational</b> Scientific Instruments: WFC3/UVIS Special Requirements: ORIENT 285D TO 296.1 D; AFTER 02 BY 2 D TO 3 D <i>Comments: Should take place 2-3 days after Visit 2. The timing of this sequence is critically important for our science goals.</i>									
	<b>Diagnosics</b> (Phase recovery 3 (03)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.									
<b>Patterns</b>	#	<b>Primary Pattern</b>			<b>Secondary Pattern</b>		<b>Exposures</b>			
	(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112			Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1)			
<b>Solar System Targets</b>	#	<b>Name</b>	<b>Level 1</b>	<b>Level 2</b>	<b>Level 3</b>	<b>Window</b>	<b>Ephem Center</b>			
	(1)	2013FY27	TYPE=ASTEROID,A=58.9936314534 8065.E=0.3916647205101159,I=32.99 057781326125 .O=187.1703133045093,W=138.60603 91018931,M=212.7151024578246,EQ UINOX=J2000,EPOCH=21-APR- 2017:00:00:00,EpochTimeScale=TDB				EARTH			
<i>Comments: Description=FY27 and satellite Extended=NO</i>										
<b>Exposures</b>	#	<b>Label</b>	<b>Target</b>	<b>Config,Mode,Aperture</b>	<b>Spectral Els.</b>	<b>Opt. Params.</b>	<b>Special Reqs.</b>	<b>Groups</b>	<b>Exp. Time (Total)/[Actual Dur.]</b>	<b>Orbit</b>
	1	(1) 2013FY27		WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP			Sequence 1-2 Non-Int in Phase recovery 3 (03)	420 Secs (1672 Secs) [==>418.0 Secs (Pattern 1)]	[1]
							Pattern 1, Exps 1-1 in Sequence 1-2 Non-Int in Phase recovery 3 (03) (1)	[==>418.0 Secs (Pattern 2)] [==>418.0 Secs (Pattern 3)] [==>418.0 Secs (Pattern 4)]		
	2	(1) 2013FY27		WFC3/UVIS, ACCUM, UVIS2	F350LP			Sequence 1-2 Non-Int in Phase recovery 3 (03)	420 Secs (418 Secs) [==>418.0 Secs ]	[1]



Proposal 18133 - Orbit finalize 1 (04) - Probing the TNO Density Transition with Mid-Size 2013 FY27

Mon Dec 15 18:00:34 GMT 2025

<b>Visit</b>	<b>Proposal 18133, Orbit finalize 1 (04), implementation</b> <b>Diagnostic Status: Informational</b> Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 24-DEC-2025:06:00:00 AND 25-DEC-2025:06:00:00; BETWEEN 28-DEC-2025:00:00:00 AND 29-DEC-2025:12:00:00; BETWEEN 03-JAN-2026:00:00:00 AND 04-JAN-2026:00:00:00; BETWEEN 06-JAN-2026:18:00:00 AND 08-JAN-2026:06:00:00; BETWEEN 12-JAN-2026:18:00:00 AND 13-JAN-2026:18:00:00; BETWEEN 16-JAN-2026:12:00:00 AND 18-JAN-2026:00:00:00; BETWEEN 22-JAN-2026:12:00:00 AND 23-JAN-2026:12:00:00; BETWEEN 28-JAN-2026:06:00:00 AND 29-JAN-2026:18:00:00 Comments: Orbit to disambiguate between the final two remaining orbit solutions.									
	<b>Diagnosics</b> (Orbit finalize 1 (04)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.									
<b>Patterns</b>	<b>#</b>	<b>Primary Pattern</b>			<b>Secondary Pattern</b>		<b>Exposures</b>			
	(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112			Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1)			
<b>Solar System Targets</b>	<b>#</b>	<b>Name</b>	<b>Level 1</b>	<b>Level 2</b>	<b>Level 3</b>	<b>Window</b>	<b>Ephem Center</b>			
	(1)	2013FY27	TYPE=ASTEROID,A=58.9936314534 8065,E=0.3916647205101159,I=32.99 057781326125 ,O=187.1703133045093,W=138.60603 91018931,M=212.7151024578246,EQ UINOX=J2000,EPOCH=21-APR-2017:00:00:00,EpochTimeScale=TDB				EARTH			
Comments: Description=FY27 and satellite Extended=NO										
<b>Exposures</b>	<b>#</b>	<b>Label</b>	<b>Target</b>	<b>Config,Mode,Aperture</b>	<b>Spectral Els.</b>	<b>Opt. Params.</b>	<b>Special Reqs.</b>	<b>Groups</b>	<b>Exp. Time (Total)/[Actual Dur.]</b>	<b>Orbit</b>
	1	(1) 2013FY27	(1) 2013FY27	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP			Sequence 1-2 Non-Int in Orbit finalize 1 (04) [=>418.0 Secs (Pattern 1)] Pattern 1, Exps 1-1 in Sequence 1-2 Non-Int in Orbit finalize 1 (04) (1) [=>418.0 Secs (Pattern 2)] [=>418.0 Secs (Pattern 3)] [=>418.0 Secs (Pattern 4)]	420 Secs (1672 Secs)	[1]
	2	(1) 2013FY27	(1) 2013FY27	WFC3/UVIS, ACCUM, UVIS2	F350LP			Sequence 1-2 Non-Int in Orbit finalize 1 (04) [=>418.0 Secs ]	420 Secs (418 Secs)	[1]



Proposal 18133 - Orbit finalize 2 (05) - Probing the TNO Density Transition with Mid-Size 2013 FY27

Mon Dec 15 18:00:34 GMT 2025

<b>Visit</b>	<b>Proposal 18133, Orbit finalize 2 (05)</b> <b>Diagnostic Status: Informational</b> Scientific Instruments: WFC3/UVIS Special Requirements: AFTER 04 BY 2 D TO 365 D; BETWEEN 24-DEC-2025:06:00:00 AND 25-DEC-2025:06:00:00; BETWEEN 28-DEC-2025:00:00:00 AND 29-DEC-2025:12:00:00; BETWEEN 03-JAN-2026:00:00:00 AND 04-JAN-2026:00:00:00; BETWEEN 06-JAN-2026:18:00:00 AND 08-JAN-2026:06:00:00; BETWEEN 12-JAN-2026:18:00:00 AND 13-JAN-2026:18:00:00; BETWEEN 16-JAN-2026:12:00:00 AND 18-JAN-2026:00:00:00; BETWEEN 22-JAN-2026:12:00:00 AND 23-JAN-2026:12:00:00; BETWEEN 26-JAN-2026:06:00:00 AND 27-JAN-2026:18:00:00 Comments: Orbit to disambiguate between the final two remaining orbit solutions.									
	<b>Diagnosics</b> (Orbit finalize 2 (05)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.									
<b>Patterns</b>	<b>#</b>	<b>Primary Pattern</b>		<b>Secondary Pattern</b>		<b>Exposures</b>				
	(1)	Pattern Type=WFC3-UVIS-DITHER-BOX Purpose=DITHER Number Of Points=4 Point Spacing=0.173 Line Spacing=0.112		Coordinate Frame=POS-TARG Pattern Orientation=23.884 Angle Between Sides=81.785 Center Pattern=false		(1)				
<b>Solar System Targets</b>	<b>#</b>	<b>Name</b>	<b>Level 1</b>	<b>Level 2</b>	<b>Level 3</b>	<b>Window</b>	<b>Ephem Center</b>			
	(1)	2013FY27	TYPE=ASTEROID,A=58.9936314534 8065,E=0.3916647205101159,I=32.99 057781326125 ,O=187.1703133045093,W=138.60603 91018931,M=212.7151024578246,EQ UINOX=J2000,EPOCH=21-APR-2017:00:00:00,EpochTimeScale=TDB				EARTH			
Comments: Description=FY27 and satellite Extended=NO										
<b>Exposures</b>	<b>#</b>	<b>Label</b>	<b>Target</b>	<b>Config,Mode,Aperture</b>	<b>Spectral Els.</b>	<b>Opt. Params.</b>	<b>Special Reqs.</b>	<b>Groups</b>	<b>Exp. Time (Total)/[Actual Dur.]</b>	<b>Orbit</b>
	1		(1) 2013FY27	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP			Sequence 1-2 Non-Int in Orbit finalize 2 (05) [=>(Pattern 1)] Pattern 1, Exps 1-1 in Sequence 1-2 Non-Int in Orbit finalize 2 (05) (1) [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	350 Secs (1400 Secs)	[1]
	2		(1) 2013FY27	WFC3/UVIS, ACCUM, UVIS2	F350LP			Sequence 1-2 Non-Int in Orbit finalize 2 (05) [=>]	300 Secs (300 Secs)	[1]

