



15500 - The Moons of Kuiper Belt Dwarf Planets Makemake and 2007 OR10

Cycle: 26, Proposal Category: GO

(JWST Initiative)

(Availability Mode: SUPPORTED)

INVESTIGATORS

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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) MAKEMAKE	WFC3/UVIS	1	06-Nov-2018 16:01:24.0	yes
02	(1) MAKEMAKE	WFC3/UVIS	1	06-Nov-2018 16:01:26.0	yes
03	(1) MAKEMAKE	WFC3/UVIS	1	06-Nov-2018 16:01:27.0	yes
04	(2) 2007OR10	WFC3/UVIS	1	06-Nov-2018 16:01:28.0	yes
05	(2) 2007OR10	WFC3/UVIS	1	06-Nov-2018 16:01:29.0	yes

<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>
06	(2) 2007OR10	WFC3/UVIS	1	06-Nov-2018 16:01:30.0	yes

6 Total Orbits Used

ABSTRACT

In two recent analyses of Hubble data, we discovered that both Makemake (the second-brightest trans-Neptunian Object behind only Pluto) and 2007 OR10 (the third largest TNO behind only Pluto and Eris) each have a faint satellite in orbit about them. With the addition of these satellites, all known TNOs with diameters unequivocally larger than 1000 km are known to have moons; these are the only two for which the satellite orbits have not been characterized. The presence of these satellites provides the opportunity to accurately characterize bulk properties of Makemake and 2007 OR10 for the first time, including their masses and densities. This is a remarkable opportunity to study two of the largest dwarf planets in the solar system, completing the census of bulk properties for TNOs with $D > 1000$ km. Hubble has been instrumental in characterizing the satellites of the other TNO dwarf planets, as its union of sensitivity and angular resolution make it uniquely capable of studying these faint, high-contrast systems. We request an 18-orbit program to accurately measure the orbital properties of these satellites and to derive the masses and densities of Makemake and 2007 OR10. Both Makemake and 2007 OR10 are targets of JWST Guaranteed Time Observations, and this HST program is required to provide orbital phasing information that will ensure that the JWST MIRI observations can resolve the systems.

OBSERVING DESCRIPTION

All visits will follow the same basic pattern, with small variations depending on the choice of filters. This pattern will be to start the visit with several short F350LP exposures followed by several longer exposures in a second filter after which we will repeat the F350LP exposures to finish the visit. The bracketing F350LP exposures will provide a baseline to correct for any possible lightcurve effects and allow us to work on one wide-band filter (F606W or F814W) at a time in the visits.

MK2: The initial set will be guided by the large acceptable orbit volume from Parker et al. (2016b) until there is sufficient new data to generate an preliminary orbit. Until these are done we cannot know with certainty if any given scheduled observation will detect MK2. According to our simulations, at least four out of seven visits are expected to be successful, we just cannot know which visits in advance. Also, success with this minimal number of orbits requires that they be scheduled over a short enough time range (~21 days) that the timing of all seven have to be decided at once and there can be no feedback to improve our odds. The successful observations will then be sufficient to get an initial orbit that will permit us to predict the location of MK2 during the rest of Cycle 25 and 26. After the first group are

Proposal 15500 (STScI Edit Number: 1, Created: Tuesday, November 6, 2018 at 4:01:31 PM Eastern Standard Time) - Overview
executed, the results will be collated into an orbit model. From that orbit will determine the most effective time to schedule the remaining visits for maximum orbit improvement in the remainder of Cycle 25 and/or Cycle 26. If the satellite is not recovered in these initial seven orbits, the subsequent four orbits can be re-allocated to other programs.

OR2: The discovery observations of OR2 do not suggest an orbit that spends a large fraction of its time at separations from the primary that would preclude detection. Thus, only three initial recovery observations are planned for OR2, which combined with the previous measurements will inform the four characterization orbits. If the satellite is not recovered in these initial three orbits, the subsequent four orbits can be re-allocated to other programs.

Proposal 15500 - Makemake Nail 01 (01) - The Moons of Kuiper Belt Dwarf Planets Makemake and 2007 OR10

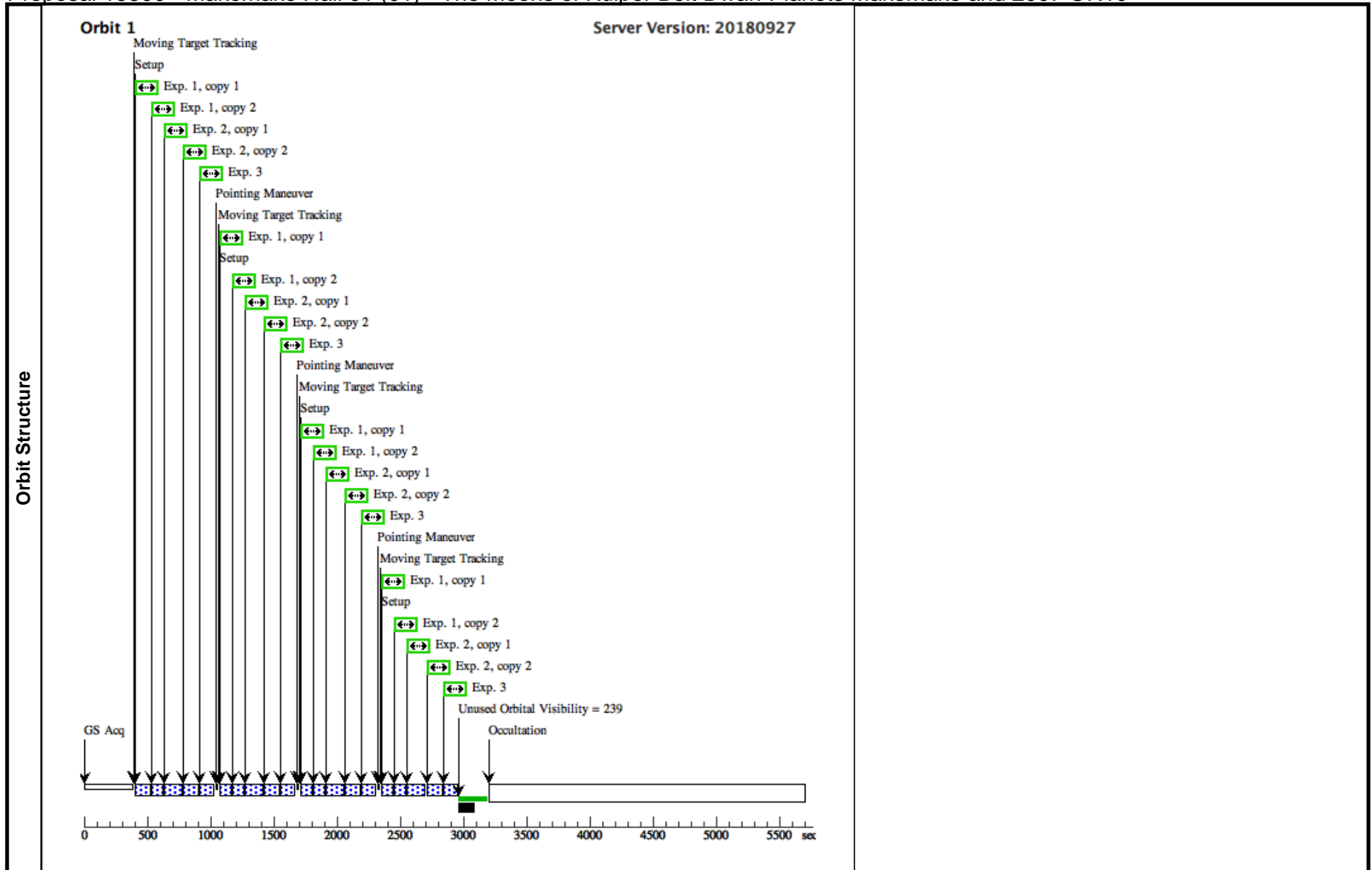
Tue Nov 06 21:01:31 GMT 2018

Visit	<p>Proposal 15500, Makemake Nail 01 (01), implementation</p> <p>Diagnostic Status: No Diagnostics</p> <p>Scientific Instruments: WFC3/UVIS</p> <p>Special Requirements: PCS MODE FINE; BETWEEN 01-MAR-2019:00:00:00 AND 02-MAR-2019:00:00:00; BETWEEN 10-FEB-2019:23:00:00 AND 11-FEB-2019:23:00:00; BETWEEN 23-JAN-2019:22:00:00 AND 24-JAN-2019:22:00:00</p> <p><i>Comments: This is a time-sensitive program measuring the orbital properties of Makemake's satellite. There are a series of possible start dates in 2019, and after Makemake Nail 01 executes, Makemake Nail 02 and Makemake Nail 03 must execute shortly thereafter with relatively tight timing constraints.</i></p>						
	Patterns	#	Primary Pattern		Secondary Pattern		Exposures
(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			(1-3)	
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center
	(1)	MAKEMAKE	STD=MAKEMAKE				EARTH
<p><i>Comments: Description=Dwarf planet Makemake and satellite Extended=NO</i></p>							

Proposal 15500 - Makemake Nail 01 (01) - The Moons of Kuiper Belt Dwarf Planets Makemake and 2007 OR10

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	Makemake F350LP	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=8	POS TARG 2,null	Pattern 1, Exps 1-3 i n Makemake Nail 01 (01) (1)	40 Secs X 2 (320 Secs) [==>(Pattern 1, Copy 1)] [==>(Pattern 1, Copy 2)] [==>(Pattern 2, Copy 1)] [==>(Pattern 2, Copy 2)] [==>(Pattern 3, Copy 1)] [==>(Pattern 3, Copy 2)] [==>(Pattern 4, Copy 1)] [==>(Pattern 4, Copy 2)]	[1]
2	Makemake F606W	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F606W	FLASH=9	POS TARG 2,null	Pattern 1, Exps 1-3 i n Makemake Nail 01 (01) (1)	70 Secs X 2 (560 Secs) [==>(Pattern 1, Copy 1)] [==>(Pattern 1, Copy 2)] [==>(Pattern 2, Copy 1)] [==>(Pattern 2, Copy 2)] [==>(Pattern 3, Copy 1)] [==>(Pattern 3, Copy 2)] [==>(Pattern 4, Copy 1)] [==>(Pattern 4, Copy 2)]	[1]
3	Makemake F350LP	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=8	POS TARG 2,null	Pattern 1, Exps 1-3 i n Makemake Nail 01 (01) (1)	40 Secs (160 Secs) [==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[1]

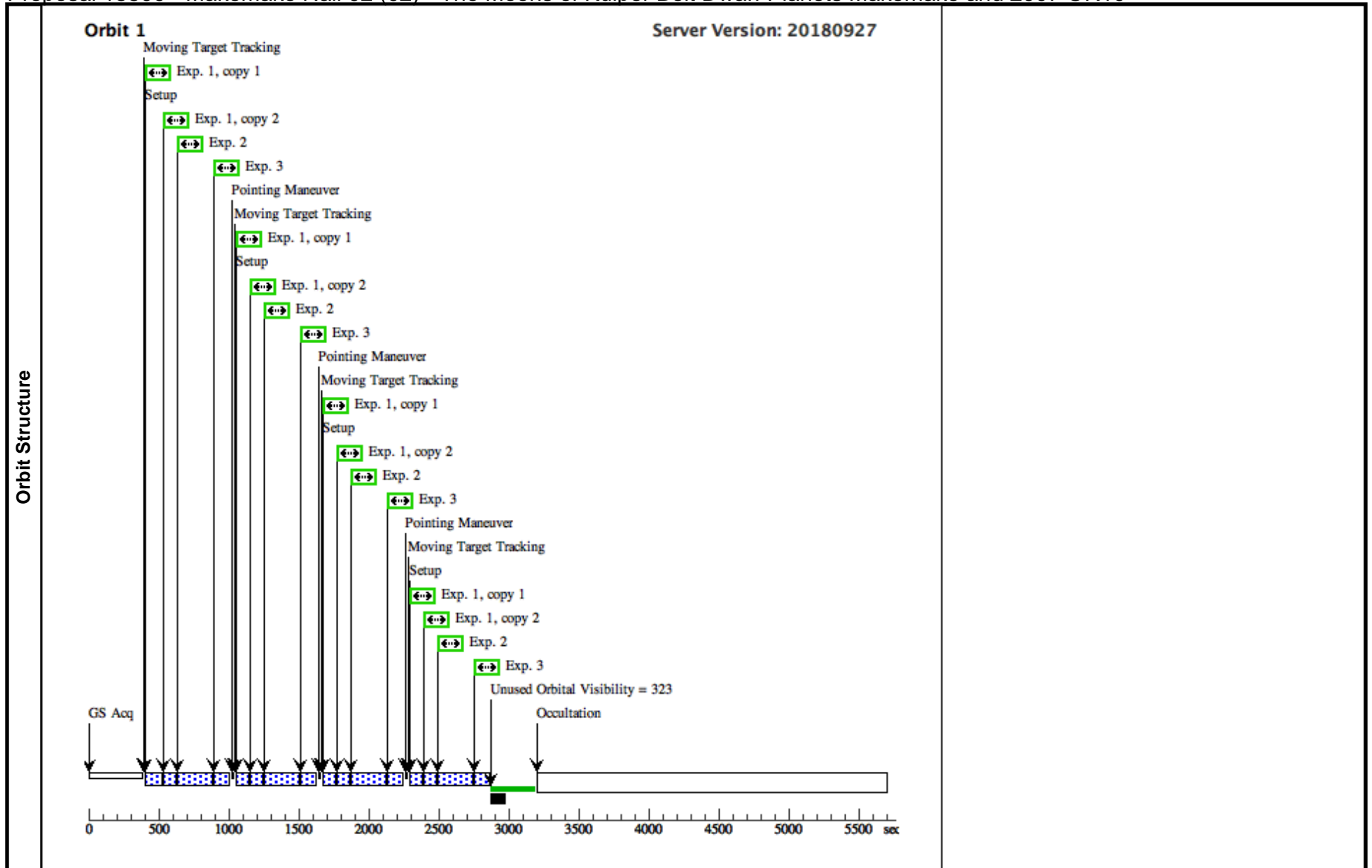
Exposures



Proposal 15500 - Makemake Nail 02 (02) - The Moons of Kuiper Belt Dwarf Planets Makemake and 2007 OR10

Tue Nov 06 21:01:31 GMT 2018

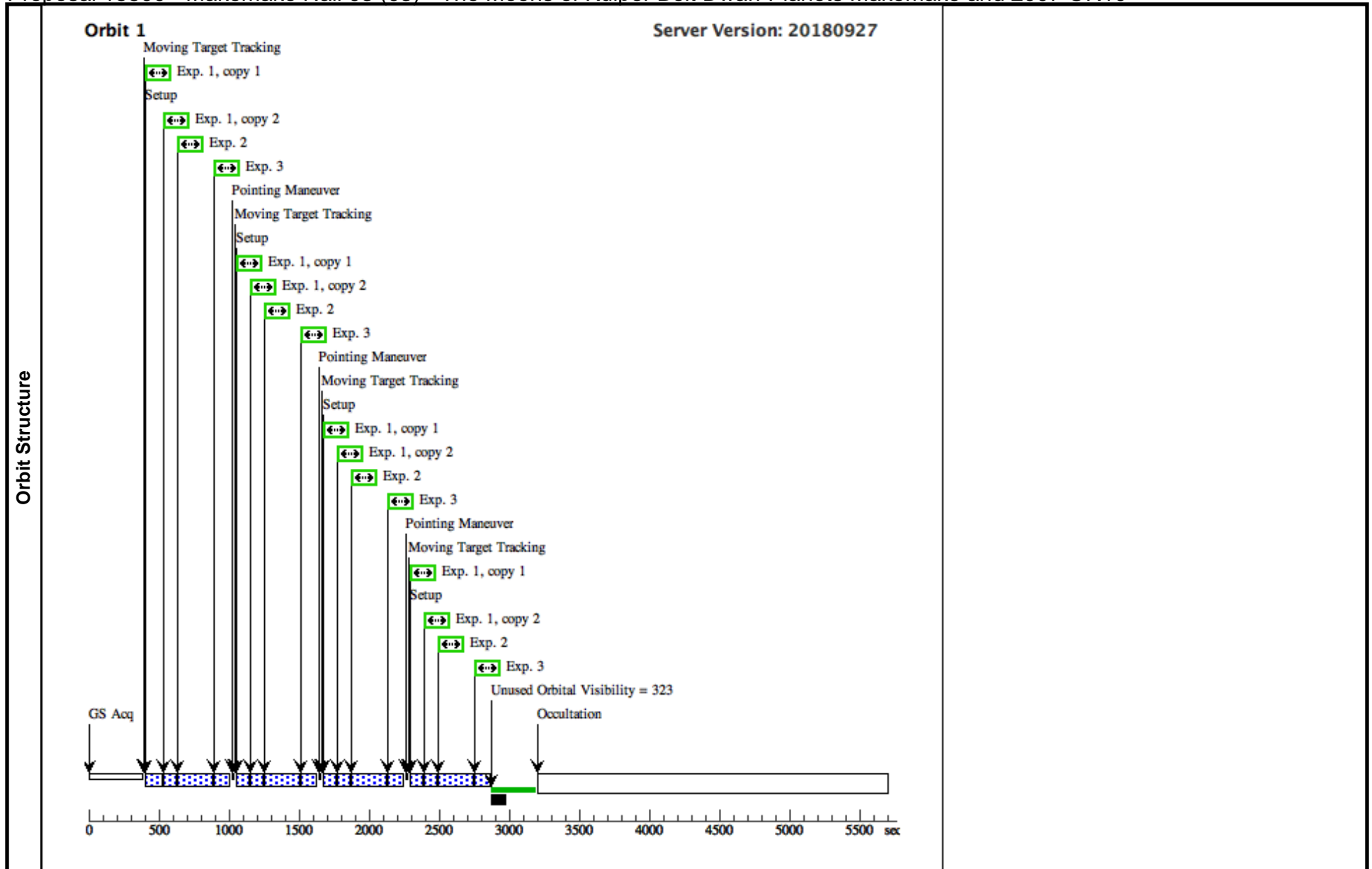
Visit	Proposal 15500, Makemake Nail 02 (02), implementation Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/UVIS Special Requirements: PCS MODE FINE; AFTER 01 BY 8.5 D TO 9.5 D									
	Patterns	#	Primary Pattern				Secondary Pattern			Exposures
		(1)	Pattern Type=WFC3-UVIS-DITHER-BOX 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						(1-3)
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center			
	(1)	MAKEMAKE	STD=MAKEMAKE				EARTH			
	<i>Comments: Description=Dwarf planet Makemake and satellite Extended=NO</i>									
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	Makemake F350LP	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=8	POS TARG 2,null	Pattern 1, Exps 1-3 in Makemake Nail 02 (02) (1)	40 Secs X 2 (320 Secs) [=>(Pattern 1, Copy 1)] [=>(Pattern 1, Copy 2)] [=>(Pattern 2, Copy 1)] [=>(Pattern 2, Copy 2)] [=>(Pattern 3, Copy 1)] [=>(Pattern 3, Copy 2)] [=>(Pattern 4, Copy 1)] [=>(Pattern 4, Copy 2)]	[1]
	2	Makemake F814W	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F814W	FLASH=7	POS TARG 2,null	Pattern 1, Exps 1-3 in Makemake Nail 02 (02) (1)	180 Secs (720 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]
	3	Makemake F350LP	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=8	POS TARG 2,null	Pattern 1, Exps 1-3 in Makemake Nail 02 (02) (1)	40 Secs (160 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]



Proposal 15500 - Makemake Nail 03 (03) - The Moons of Kuiper Belt Dwarf Planets Makemake and 2007 OR10

Tue Nov 06 21:01:31 GMT 2018

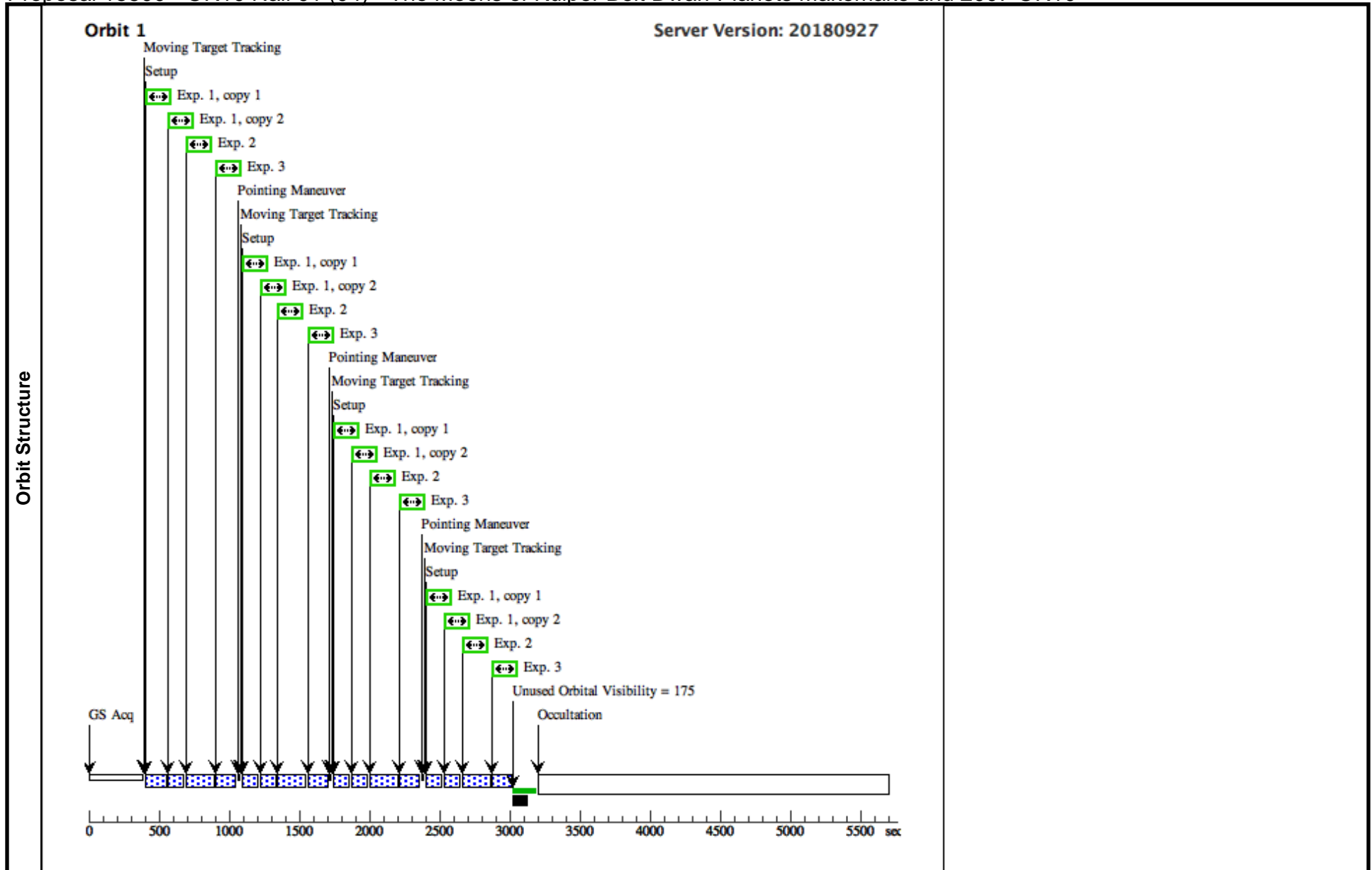
Visit	Proposal 15500, Makemake Nail 03 (03), implementation Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/UVIS Special Requirements: PCS MODE FINE; AFTER 01 BY 17.5 D TO 18.5 D									
	Patterns	#	Primary Pattern				Secondary Pattern			Exposures
		(1)	Pattern Type=WFC3-UVIS-DITHER-BOX 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						(1-3)
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center			
	(1)	MAKEMAKE	STD=MAKEMAKE				EARTH			
<i>Comments: Description=Dwarf planet Makemake and satellite Extended=NO</i>										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	Makemake F350LP	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=8	POS TARG 2,null	Pattern 1, Exps 1-3 in Makemake Nail 03 (03) (1)	40 Secs X 2 (320 Secs) [=>(Pattern 1, Copy 1)] [=>(Pattern 1, Copy 2)] [=>(Pattern 2, Copy 1)] [=>(Pattern 2, Copy 2)] [=>(Pattern 3, Copy 1)] [=>(Pattern 3, Copy 2)] [=>(Pattern 4, Copy 1)] [=>(Pattern 4, Copy 2)]	[1]
	2	Makemake F814W	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F814W	FLASH=7	POS TARG 2,null	Pattern 1, Exps 1-3 in Makemake Nail 03 (03) (1)	180 Secs (720 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]
	3	Makemake F350LP	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=8	POS TARG 2,null	Pattern 1, Exps 1-3 in Makemake Nail 03 (03) (1)	40 Secs (160 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]



Proposal 15500 - OR10 Nail 01 (04) - The Moons of Kuiper Belt Dwarf Planets Makemake and 2007 OR10

Tue Nov 06 21:01:32 GMT 2018

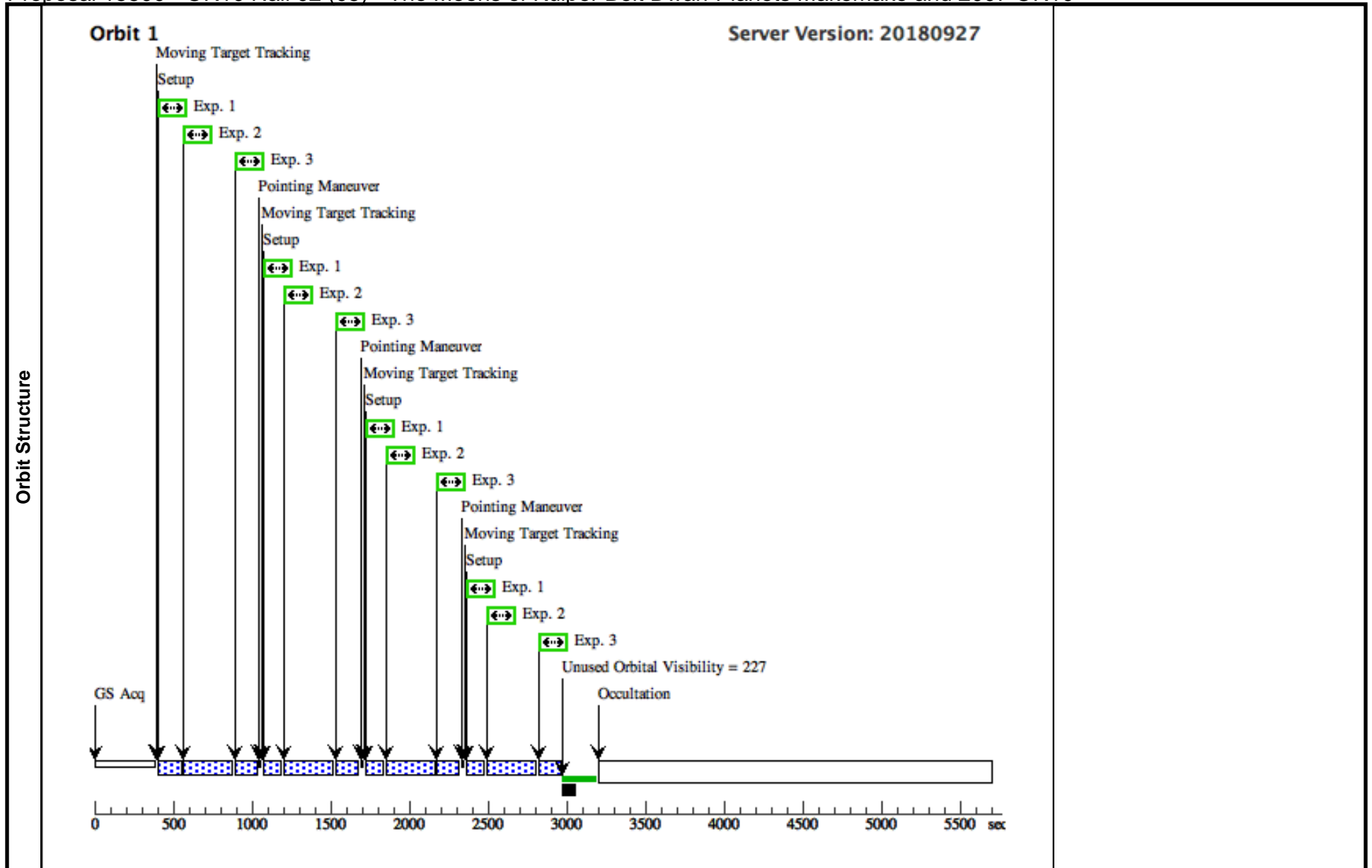
Visit	Proposal 15500, OR10 Nail 01 (04), implementation Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/UVIS Special Requirements: PCS MODE FINE; AFTER 15-JUL-2019:00:00:00 <i>Comments: This is a time-sensitive program measuring the orbital properties of 2007 OR10's satellite. There are a series of possible start dates in 2019, and after OR10 Nail 01 executes, OR10 Nail 02 and OR10 Nail 03 must execute shortly thereafter with relatively tight timing constraints.</i>									
	Patterns	#	Primary Pattern			Secondary Pattern			Exposures	
(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			(1-3)		
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center			
	(2)	2007OR10	TYPE=ASTEROID,A=66.8415689637 5929,E=0.5045718566367412,I=30.90 50913888484,O=336.8211090973072, W=206.618255615117,M=103.469246 9440252,EQUINOX=J2000,EPOCH= 13-JAN- 2014:00:00:00,EpochTimeScale=TDB					EARTH		
<i>Comments: Description=Dwarf planet 2007 OR10 and its satellite. Extended=NO</i>										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	OR10 F350 LP	(2) 2007OR10	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=6	POS TARG 2,0	Pattern 1, Exps 1-3 in OR10 Nail 01 (04) (1)	70 Secs X 2 (560 Secs) [=>(Pattern 1, Copy 1)] [=>(Pattern 1, Copy 2)] [=>(Pattern 2, Copy 1)] [=>(Pattern 2, Copy 2)] [=>(Pattern 3, Copy 1)] [=>(Pattern 3, Copy 2)] [=>(Pattern 4, Copy 1)] [=>(Pattern 4, Copy 2)]	[1]
	2	OR10 F606 W	(2) 2007OR10	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F606W	FLASH=6	POS TARG 2,0	Pattern 1, Exps 1-3 in OR10 Nail 01 (04) (1)	130 Secs (520 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]
	3	OR10 F350 LP	(2) 2007OR10	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=6	POS TARG 2,0	Pattern 1, Exps 1-3 in OR10 Nail 01 (04) (1)	70 Secs (280 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]



Proposal 15500 - OR10 Nail 02 (05) - The Moons of Kuiper Belt Dwarf Planets Makemake and 2007 OR10

Tue Nov 06 21:01:32 GMT 2018

Visit	Proposal 15500, OR10 Nail 02 (05), implementation Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/UVIS Special Requirements: PCS MODE FINE; AFTER 04 BY 6 D TO 7 D									
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures					
	(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		(1-3)					
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center			
	(2)	2007OR10	TYPE=ASTEROID,A=66.8415689637 5929,E=0.5045718566367412,I=30.90 50913888484,O=336.8211090973072, W=206.618255615117,M=103.469246 9440252,EQUINOX=J2000,EPOCH= 13-JAN- 2014:00:00:00,EpochTimeScale=TDB				EARTH			
	<i>Comments: Description=Dwarf planet 2007 OR10 and its satellite. Extended=NO</i>									
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	OR10 F350 LP	(2) 2007OR10	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=6	POS TARG 2,null	Pattern 1, Exps 1-3 in OR10 Nail 02 (05) (1)	70 Secs (280 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]
	2	OR10 F814 W	(2) 2007OR10	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F814W	FLASH=7	POS TARG 2,null	Pattern 1, Exps 1-3 in OR10 Nail 02 (05) (1)	250 Secs (1000 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]
	3	OR10 F350 LP	(2) 2007OR10	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=6	POS TARG 2,null	Pattern 1, Exps 1-3 in OR10 Nail 02 (05) (1)	70 Secs (280 Secs) [=>(Pattern 1)] [=>(Pattern 2)] [=>(Pattern 3)] [=>(Pattern 4)]	[1]



Proposal 15500 - OR10 Nail 03 (06) - The Moons of Kuiper Belt Dwarf Planets Makemake and 2007 OR10

Tue Nov 06 21:01:32 GMT 2018

Visit	Proposal 15500, OR10 Nail 03 (06), implementation Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/UVIS Special Requirements: PCS MODE FINE; AFTER 04 BY 18.5 D TO 19.5 D									
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures					
		(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		(1-3)				
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center			
	(2)	2007OR10	TYPE=ASTEROID,A=66.8415689637 5929,E=0.5045718566367412,I=30.90 50913888484,O=336.8211090973072, W=206.618255615117,M=103.469246 9440252,EQUINOX=J2000,EPOCH= 13-JAN- 2014:00:00:00,EpochTimeScale=TDB				EARTH			
	<i>Comments: Description=Dwarf planet 2007 OR10 and its satellite. Extended=NO</i>									
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	OR10 F350 LP	(2) 2007OR10	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=6	POS TARG 2,null	Pattern 1, Exps 1-3 in OR10 Nail 03 (06) (1)	70 Secs X 2 (560 Secs)	
									[==>(Pattern 1, Copy 1)] [==>(Pattern 1, Copy 2)] [==>(Pattern 2, Copy 1)] [==>(Pattern 2, Copy 2)] [==>(Pattern 3, Copy 1)] [==>(Pattern 3, Copy 2)] [==>(Pattern 4, Copy 1)] [==>(Pattern 4, Copy 2)]	[1]
	2	OR10 F606 W	(2) 2007OR10	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F606W	FLASH=6	POS TARG 2,null	Pattern 1, Exps 1-3 in OR10 Nail 03 (06) (1)	130 Secs (520 Secs)	
								[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[1]	
3	OR10 F350 LP	(2) 2007OR10	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=6	POS TARG 2,null	Pattern 1, Exps 1-3 in OR10 Nail 03 (06) (1)	70 Secs (280 Secs)		
								[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[1]	

