



18006 - Geophysical Characterization of the Distant Ocean World Makemake

Cycle: 33, Proposal Category: GO

(Availability Mode: SUPPORTED)

INVESTIGATORS

<i>Name</i>	<i>Institution</i>
Dr. Benjamin Proudfoot (PI) (Contact)	University of Central Florida Board of Trustees
Prof. Darin Ragozzine (CoI)	Brigham Young University
Dr. Will M. Grundy (CoI)	Lowell Observatory
Dr. Bryan Jason Holler (CoI)	Space Telescope Science Institute

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	22-Oct-2025 12:01:17.0	yes
02	(1) MAKEMAKE	WFC3/UVIS	1	22-Oct-2025 12:01:18.0	yes
03	(1) MAKEMAKE	WFC3/UVIS	1	22-Oct-2025 12:01:19.0	yes
04	(1) MAKEMAKE	WFC3/UVIS	1	22-Oct-2025 12:01:20.0	yes

4 Total Orbits Used

ABSTRACT

Recent JWST observations have revealed that the trans-Neptunian object (TNO) Makemake has a prominent IR excess indicating the existence of Enceladus-style hotspots on its surface. This makes Makemake possibly one of the Solar System's most distant ocean worlds. Unfortunately, little is known about many of the basic properties of Makemake, making high-fidelity geophysical investigations almost impossible. To solve this, we propose an investigation to measure the mass, density, and pole-axis orientation of Makemake via astrometric tracking of its small satellite, nicknamed MK2. Measuring mass and density will help to constrain the ongoing radiogenic heating of Makemake and provide firm footing for

Proposal 18006 (STScI Edit Number: 6, Created: Wednesday, October 22, 2025, 11:01:21AM Eastern Standard Time) - Overview models of Makemake's interior structure. Determining Makemake's pole-axis orientation will provide critical context for interpreting the JWST thermal measurements and could help to constrain the geographical extent of any hotspots. Leveraging over a dozen orbits from past HST programs, we require just 4 well-timed HST orbits to complete our investigation, which will revolutionize our knowledge of Makemake and enable high-fidelity geophysical modeling of this distant ocean world.

OBSERVING DESCRIPTION

Our observations call for 4 single-orbit visits to image the Makemake system using the WFC3/UVIS instrument. During each visit, images will be acquired using the UVIS2-C512C-SUB aperture, paired with the F350LP filter to optimize astrometric precision. Exposure times are chosen to optimize SNR and schedulability, with 10+ dithered images taken during each visit. This allows us to remain robust to unlucky cosmic ray hits.

Scheduling of observations is important to the goals of our program. The timing windows input into the Phase II are somewhat flexible, and can be changed if needed. If more observing windows are needed, we can provide them, although these are our "optimal" windows. We would prefer if each visit is at least 18 days apart, although this is not strictly necessary.

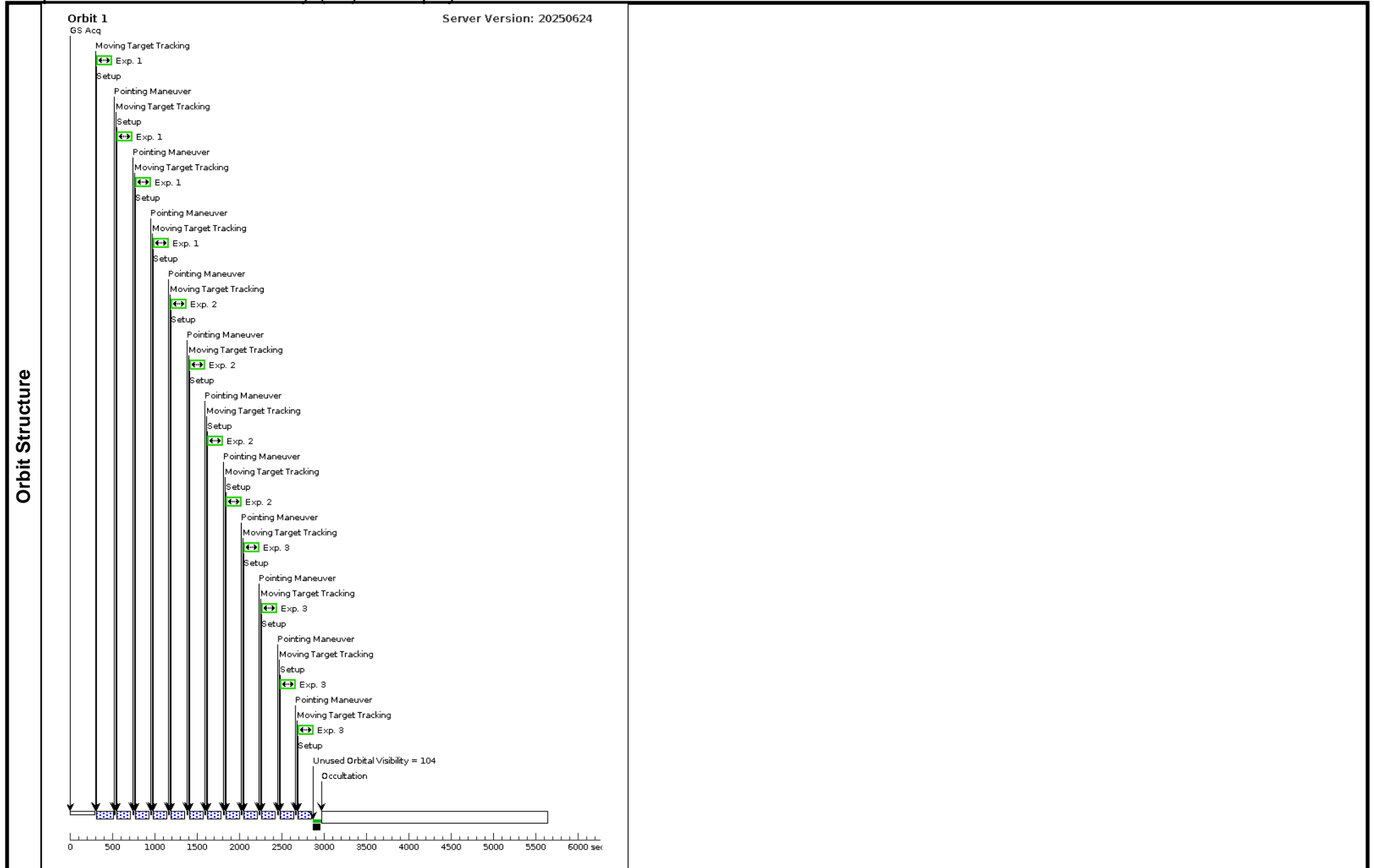
Since poorly oriented diffraction spikes can degrade the astrometric quality of our observations, we request observations avoid orients where the diffraction spikes are aligned with the satellite's orbit. Inputting these a priori is difficult/time-consuming since the position of the satellite and orient ranges change in time. Once preliminary scheduling windows based on "betweens" are identified, we can further input the orients which are allowed. We will also check for bright nearby stars that could degrade image quality.

Proposal 18006 - Period verify (01) - Geophysical Characterization of the Distant Ocean World Makemake

Wed Oct 22 16:01:21 GMT 2025

Visit	Proposal 18006, Period verify (01), implementation Diagnostic Status: Informational Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 01-DEC-2025:00:00:00 AND 02-DEC-2025:00:00:00; BETWEEN 07-DEC-2025:16:00:00 AND 11-DEC-2025:00:00:00; BETWEEN 16-DEC-2025:16:00:00 AND 19-DEC-2025:20:00:00; BETWEEN 25-DEC-2025:16:00:00 AND 29-DEC-2025:00:00:00; VISIBILITY INTERVAL NO GYRO BIAS UPDATE ON MOVING TARGET									
	Diagnosics (Period verify (01)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.									
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), (2), (3)			
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center			
	(1)	MAKEMAKE	STD=MAKEMAKE				EARTH			
<i>Comments: Description=Makemake</i>										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) MAKEMAKE	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=7	GS ACQ SCENARIO ONEB1OR	Sequence 1-3 Non-Int in Period verify (01)	120 Secs (480 Secs)	
								Pattern 1, Exps 1-1 in Sequence 1-3 Non-Int in Period verify (01) (1)	[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[1]
	2	(1) MAKEMAKE	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=7		Sequence 1-3 Non-Int in Period verify (01)	120 Secs (480 Secs)	
							Pattern 1, Exps 2-2 in Sequence 1-3 Non-Int in Period verify (01) (1)	[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[1]	
3	(1) MAKEMAKE	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=7		Sequence 1-3 Non-Int in Period verify (01)	120 Secs (480 Secs)		
							Pattern 1, Exps 3-3 in Sequence 1-3 Non-Int in Period verify (01) (1)	[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[1]	

Proposal 18006 - Period verify (01) - Geophysical Characterization of the Distant Ocean World Makemake



Proposal 18006 - Mirror break (02) - Geophysical Characterization of the Distant Ocean World Makemake

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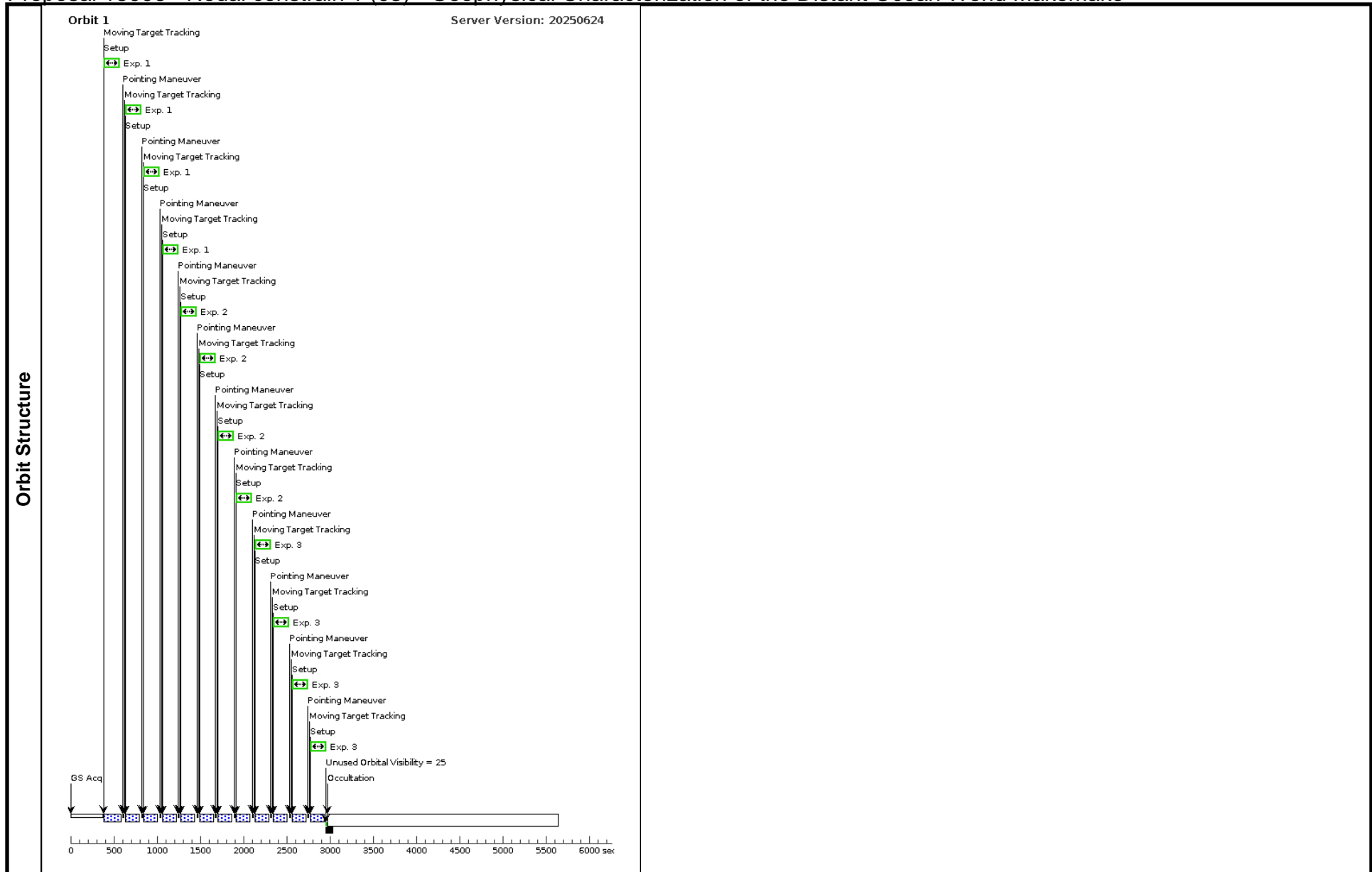
Visit	Proposal 18006, Mirror break (02), implementation Diagnostic Status: Informational Scientific Instruments: WFC3/UVIS Special Requirements: AFTER 01 BY 10 D TO 365 D; BETWEEN 16-DEC-2025:08:00:00 AND 17-DEC-2025:16:00:00; BETWEEN 18-DEC-2025:20:00:00 AND 20-DEC-2025:08:00:00; BETWEEN 25-DEC-2025:04:00:00 AND 26-DEC-2025:08:00:00; BETWEEN 28-DEC-2025:00:00:00 AND 29-DEC-2025:08:00:00; BETWEEN 03-JAN-2026:08:00:00 AND 04-JAN-2026:16:00:00; BETWEEN 05-JAN-2026:20:00:00 AND 07-JAN-2026:08:00:00; VISIBILITY INTERVAL NO GYRO BIAS UPDATE ON MOVING TARGET										
	(Mirror break (02)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.										
Diagnosics											
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), (2), (3)	
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center				
	(1)	MAKEMAKE	STD=MAKEMAKE				EARTH				
<i>Comments: Description=Makemake</i>											
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1	(1) MAKEMAKE	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=7	GS ACQ SCENARIO ONEB1OR	Sequence 1-3 Non-Int in Mirror break (02)	120 Secs (480 Secs)		[1]
								Pattern 1, Exps 1-1 in Sequence 1-3 Non-Int in Mirror break (02) (1)	[=>(Pattern 1)]		
									[=>(Pattern 2)]		
								[=>(Pattern 3)]			
2	(1) MAKEMAKE	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=7		Sequence 1-3 Non-Int in Mirror break (02)	120 Secs (480 Secs)		[1]	
								[=>(Pattern 1)]			
								[=>(Pattern 2)]			
								[=>(Pattern 3)]			
3	(1) MAKEMAKE	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=7		Sequence 1-3 Non-Int in Mirror break (02)	120 Secs (480 Secs)		[1]	
								[=>(Pattern 1)]			
								[=>(Pattern 2)]			
								[=>(Pattern 3)]			
								[=>(Pattern 4)]			

Proposal 18006 - Nodal constrain 1 (03) - Geophysical Characterization of the Distant Ocean World Makemake

Wed Oct 22 16:01:21 GMT 2025

Visit	Proposal 18006, Nodal constrain 1 (03), implementation Diagnostic Status: Informational Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 12-APR-2026:00:00:00 AND 17-APR-2026:00:00:00; BETWEEN 21-APR-2026:04:00:00 AND 26-APR-2026:04:00:00; BETWEEN 03-APR-2026:04:00:00 AND 07-APR-2026:20:00:00; BETWEEN 25-MAR-2026:00:00:00 AND 30-MAR-2026:00:00:00; BETWEEN 16-MAR-2026:00:00:00 AND 20-MAR-2026:20:00:00; BETWEEN 07-MAR-2026:00:00:00 AND 12-MAR-2026:00:00:00; VISIBILITY INTERVAL NO GYRO BIAS UPDATE ON MOVING TARGET									
	(Nodal constrain 1 (03)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.									
Diagnosics										
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), (2), (3)				
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center			
	(1)	MAKEMAKE	STD=MAKEMAKE				EARTH			
<i>Comments: Description=Makemake</i>										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1		(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=7		Sequence 1-3 Non-Int in Nodal constrain 1 (03)	120 Secs (480 Secs)	[1]
								Pattern 1, Exps 1-1 in Sequence 1-3 Non-Int in Nodal constrain 1 (03) (1)	[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	
	2		(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=7		Sequence 1-3 Non-Int in Nodal constrain 1 (03)	120 Secs (480 Secs)	
							Pattern 1, Exps 2-2 in Sequence 1-3 Non-Int in Nodal constrain 1 (03) (1)	[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]		
								Sequence 1-3 Non-Int in Nodal constrain 1 (03)	120 Secs (480 Secs)	[1]
								Pattern 1, Exps 3-3 in Sequence 1-3 Non-Int in Nodal constrain 1 (03) (1)	[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	

Proposal 18006 - Nodal constrain 1 (03) - Geophysical Characterization of the Distant Ocean World Makemake



Proposal 18006 - Nodal constrain 2 (04) - Geophysical Characterization of the Distant Ocean World Makemake

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Visit	Proposal 18006, Nodal constrain 2 (04), implementation Diagnostic Status: Informational Scientific Instruments: WFC3/UVIS Special Requirements: AFTER 03 BY 9 D TO 365 D; BETWEEN 12-APR-2026:00:00:00 AND 17-APR-2026:00:00:00; BETWEEN 21-APR-2026:04:00:00 AND 26-APR-2026:04:00:00; BETWEEN 03-APR-2026:04:00:00 AND 07-APR-2026:20:00:00; BETWEEN 25-MAR-2026:00:00:00 AND 30-MAR-2026:00:00:00; BETWEEN 16-MAR-2026:00:00:00 AND 20-MAR-2026:20:00:00; BETWEEN 07-MAR-2026:00:00:00 AND 12-MAR-2026:00:00:00; VISIBILITY INTERVAL NO GYRO BIAS UPDATE ON MOVING TARGET									
	(Nodal constrain 2 (04)) Informational (Form): The Visit Planner and Spike may produce different schedulability results.									
Diagnosics										
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), (2), (3)			
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center			
	(1)	MAKEMAKE	STD=MAKEMAKE				EARTH			
<i>Comments: Description=Makemake</i>										
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	(1) MAKEMAKE	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=7		Sequence 1-3 Non-Int in Nodal constrain 2 (04)	120 Secs (480 Secs)	[1]
								Pattern 1, Exps 1-1 in Sequence 1-3 Non-Int in Nodal constrain 2 (04) (1)	[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	
	2	(1) MAKEMAKE	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=7		Sequence 1-3 Non-Int in Nodal constrain 2 (04)	120 Secs (480 Secs)	
							Pattern 1, Exps 2-2 in Sequence 1-3 Non-Int in Nodal constrain 2 (04) (1)	[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]		
3	(1) MAKEMAKE	(1) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2-C512C-SUB	F350LP	FLASH=7		Sequence 1-3 Non-Int in Nodal constrain 2 (04)	120 Secs (480 Secs)	[1]	
							Pattern 1, Exps 3-3 in Sequence 1-3 Non-Int in Nodal constrain 2 (04) (1)	[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]		

Proposal 18006 - Nodal constrain 2 (04) - Geophysical Characterization of the Distant Ocean World Makemake

