



13668 - Deep Search for Small Satellites of Eris and Makemake

Cycle: 22, Proposal Category: GO

(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) ERIS	WFC3/UVIS	2	21-Apr-2015 21:02:35.0	yes
02	(1) ERIS	WFC3/UVIS	2	21-Apr-2015 21:02:37.0	yes
03	(2) MAKEMAKE	WFC3/UVIS	2	21-Apr-2015 21:02:39.0	yes
04	(2) MAKEMAKE	WFC3/UVIS	2	21-Apr-2015 21:02:41.0	yes

8 Total Orbits Used

ABSTRACT

Recent HST observations searching deeper than ever before have discovered a very distinct family of small, faint, circumbinary satellites around Pluto and Charon. Pluto has looked like the oddball of the Solar System many times in the past, with its inclined and eccentric transneptunian orbit, its enormous satellite Charon, and its volatile ice rich surface composition. But in each of these matters, subsequent discoveries revealed that Pluto was not unique, merely the first of an entirely new class of objects. This proposal aims to determine if Pluto's family of small faint satellites is also non-unique, through unprecedentedly deep imaging of Eris and Makemake, the two other most Pluto-like bodies in the Kuiper belt.

OBSERVING DESCRIPTION

We are observing (136199) Eris and (136472) Makemake looking for faint companions using observing procedures used successfully for the Pluto system.

Our proposed observations will improve on prior work in two fundamental ways. First, we plan a longer integration time that will get to a much fainter limiting magnitude. Each visit will take two orbits and we will take six ~ 730 -sec exposures (three per orbit) and two short navigation images. A single visit stack nets an aggregate exposure time of ~ 4400 seconds and will yield an optimal SNR of 14 for an object of $V=28$ (assuming a G8V spectrum and average zodiacal light and background). This improvement will get us one magnitude deeper for Makemake and Eris. We will dither by small integer pixel amounts between images within a visit to help remove any potential detector artifacts.

The second improvement comes from applying lessons learned while searching for faint satellites around Pluto. The biggest challenge to searching the inner regions is removing the confusion caused by the PSF of the primary and secondary objects (if present). The strategy used by Showalter and Buie was to take pairs of visits with controlled geometry. By design, Pluto and Charon were in the same relative position in raw pixel coordinates between the epochs and a difference of the two image stacks almost perfectly removes these two bright central objects. This technique led to the discovery of the fifth satellite around Pluto. That this new satellite is roughly $V=27$ attests to the sensitivity achieved. In the case of Pluto, the residual noise in the difference image is higher than any object on our list merely because the central object is not as bright. We can expect both changes to contribute to a much more thorough and deeper search than any done to date.

Our basic observational pattern will use four orbits per object grouped into two visits with two orbits each. Each visit will lead to a deep stack and the pair will be used to search for a satellite that moves relative to the primary. A key component of the observing strategy is to maintain useful sensitivity to the motion of any putative satellites between the two visits. If the interval is too short there will not be enough time for detecting the motion though our technique would still reveal the presence of a satellite. Our survey is designed to cover out to 20% of the Hill radius. Larger distances are not expected to be stable. This threshold sets the minimum velocity that we have to accommodate.

The time between visits is set to 2-3 days for Makemake and 3-4 days for Eris to ensure a minimum of 100 mas of satellite motion between visits at the outer edge of the stability region. We require a small roll between the two visits so that any object in the system will move relative to any PSF artifacts. This roll needs to be just a few degrees to facilitate the

observations. Making the roll offset too large will make the observations difficult to schedule.

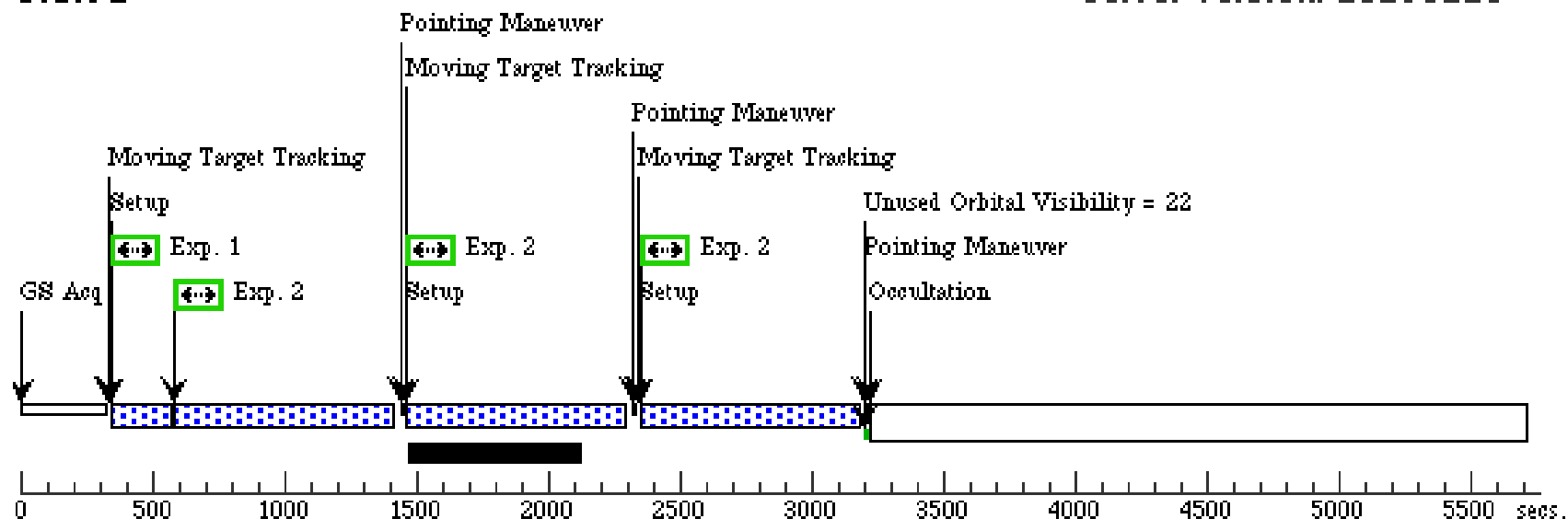
These observations are specifically designed to find new satellites but will not, by themselves, do a very good job of determining orbits. It will remain for later work to followup any objects discovered.

Proposal 13668 - Eris epoch 1 (01) - Deep Search for Small Satellites of Eris and Makemake

Visit	Proposal 13668, Eris epoch 1 (01), completed Wed Apr 22 01:02:43 GMT 2015									
	Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 10-NOV-2014:00:00:00 AND 20-FEB-2015:00:00:00; Period 7.89358 D AND ZERO-PHASE HJD2456934.0 <i>Comments: Each visit is designed to collect a deep integration (two orbits per visit) on the target. For Eris, there are additional timing constraints. This constraint ensures that the observations of the known satellite, Dysnomia, will serve to break the mirror ambiguity on its current orbit. Without the timing constraint we would only have a 25% chance of getting the desired observation. Basically, the constraint serves to get this visit at a particular orbital longitude. The additional loose timing constraint restricts the observations to occur somewhat near opposition. This ensures a useful motion of the target relative to the background stars while also giving the best image scale and target brightness.</i>									
Patterns	#	Primary Pattern				Secondary Pattern				Exposures
	(1)	Pattern Type=WFC3-UVIS-DITHER-LINE Coordinate Frame=POS-TARG Pattern Orientation=46.84 Purpose=DITHER Angle Between Sides= Number Of Points=3 Center Pattern=false Point Spacing=0.290 Line Spacing=								(2), (3)
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center			
	(1)	ERIS	STD=ERIS				EARTH			
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1	Navigation exposure 1	(1) ERIS	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO	PHASE 0.873 TO 0.127		80 Secs (80 Secs)	
									[==>]	[1]
	2	Long part 1	(1) ERIS	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO		Pattern 1, Exps 2-2 in Eris epoch 1 (01) (1)	720 Secs (2160 Secs)	
									[==>(Pattern 1)]	
									[==>(Pattern 2)]	[1]
									[==>(Pattern 3)]	
	3	Long part 2	(1) ERIS	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO		Pattern 1, Exps 3-3 in Eris epoch 1 (01) (1)	720 Secs (2160 Secs)	
									[==>(Pattern 1)]	
									[==>(Pattern 2)]	[2]
									[==>(Pattern 3)]	
	4	Navigation exposure 2	(1) ERIS	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO	POS TARG 0,0		80 Secs (80 Secs)	
									[==>]	[2]

Orbit 1

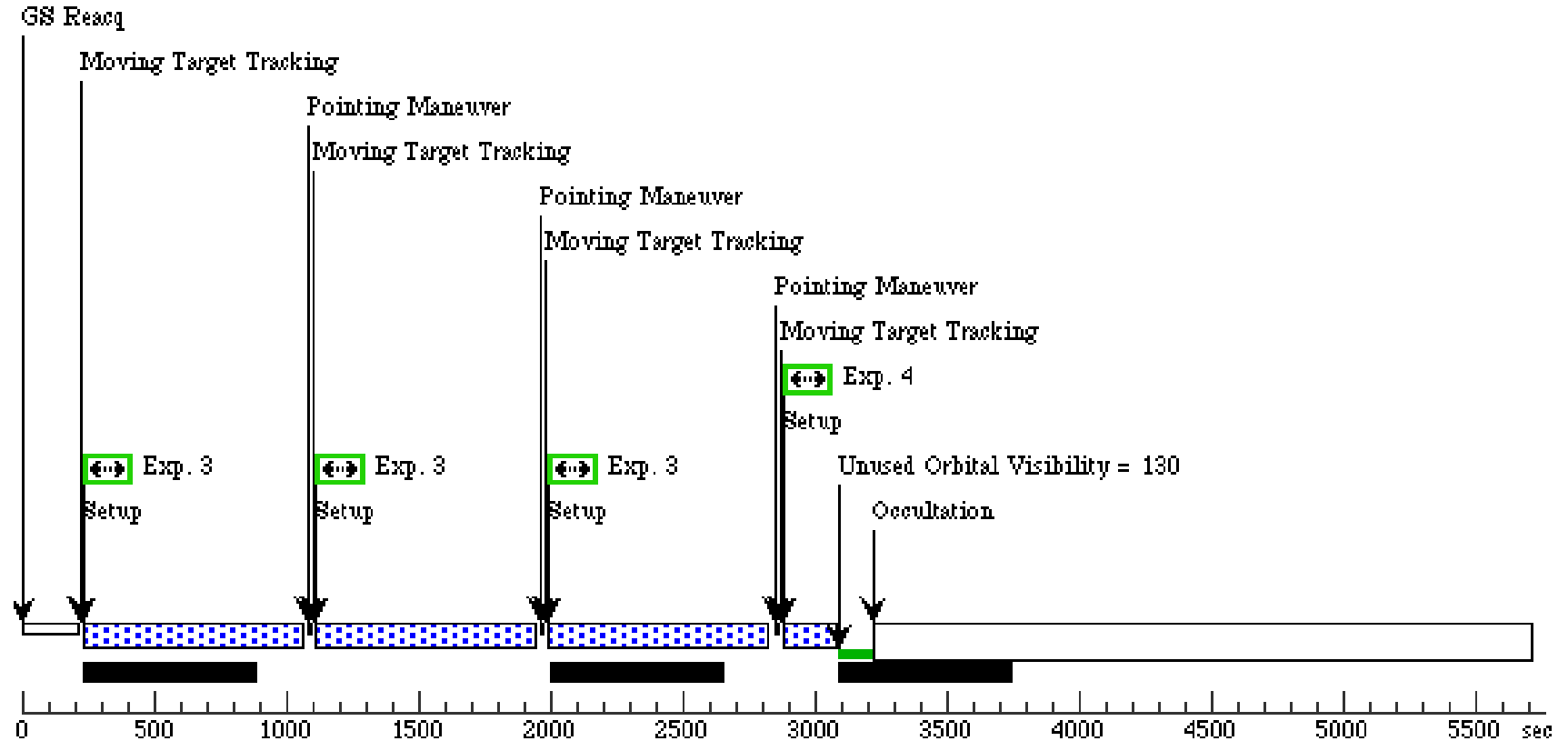
Server Version: 20150128



Orbit Structure

Orbit 2

Server Version: 20150128

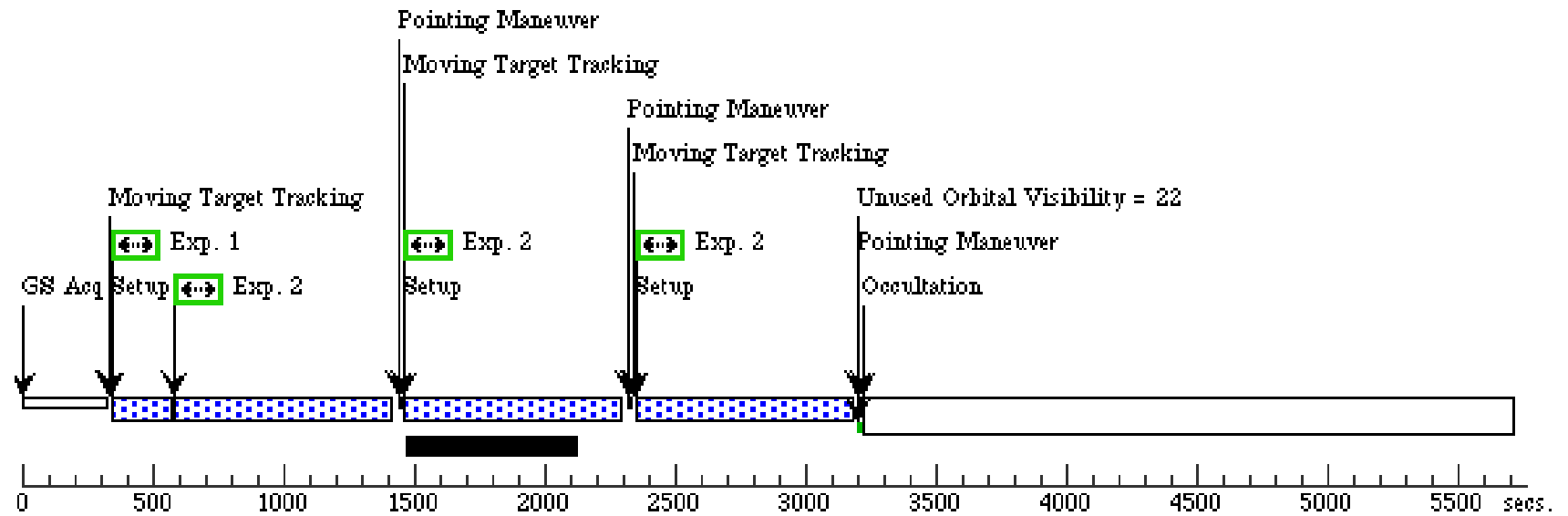


Proposal 13668 - Eris epoch 2 (02) - Deep Search for Small Satellites of Eris and Makemake

Visit	Proposal 13668, Eris epoch 2 (02), completed										Wed Apr 22 01:02:43 GMT 2015		
	Diagnostic Status: No Diagnostics												
	Scientific Instruments: WFC3/UVIS												
	Special Requirements: ORIENT 5D TO 6D FROM 01; AFTER 01 BY 3 D TO 4 D												
Comments: The second epoch is required to find a satellite moving relative to the primary object. The timing window is set to capture useful motion for an object at 20% of the Hill radius. Objects closer in will be moving faster. The relative roll is used to move the satellite system relative to the PSF between epochs. The minimal dithers are calculated for integer pixel shifts of the field (accounting for distortion) so that faint objects fall in the same place relative to a unit pixel in all images within a visit.													
Patterns	#	Primary Pattern					Secondary Pattern					Exposures	
	(1)	Pattern Type=WFC3-UVIS-DITHER-LINE Purpose=DITHER Number Of Points=3 Point Spacing=0.290 Line Spacing=					Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false					(2), (3)	
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center						
	(1)	ERIS	STD=ERIS	EARTH									
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit		
	1	Navigation exposure 1	(1) ERIS	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO			80 Secs (80 Secs)				
									[==>]		[1]		
	2	Long part 1	(1) ERIS	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO		Pattern 1, Exps 2-2 in Eris epoch 2 (02) (1)	720 Secs (2160 Secs)				
									[==>(Pattern 1)]				
									[==>(Pattern 2)]		[1]		
									[==>(Pattern 3)]				
	3	Long part 2	(1) ERIS	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO		Pattern 1, Exps 3-3 in Eris epoch 2 (02) (1)	720 Secs (2160 Secs)				
								[==>(Pattern 1)]					
								[==>(Pattern 2)]		[2]			
								[==>(Pattern 3)]					
4	Navigation exposure 2	(1) ERIS	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO				80 Secs (80 Secs)				
									[==>]		[2]		

Orbit 1

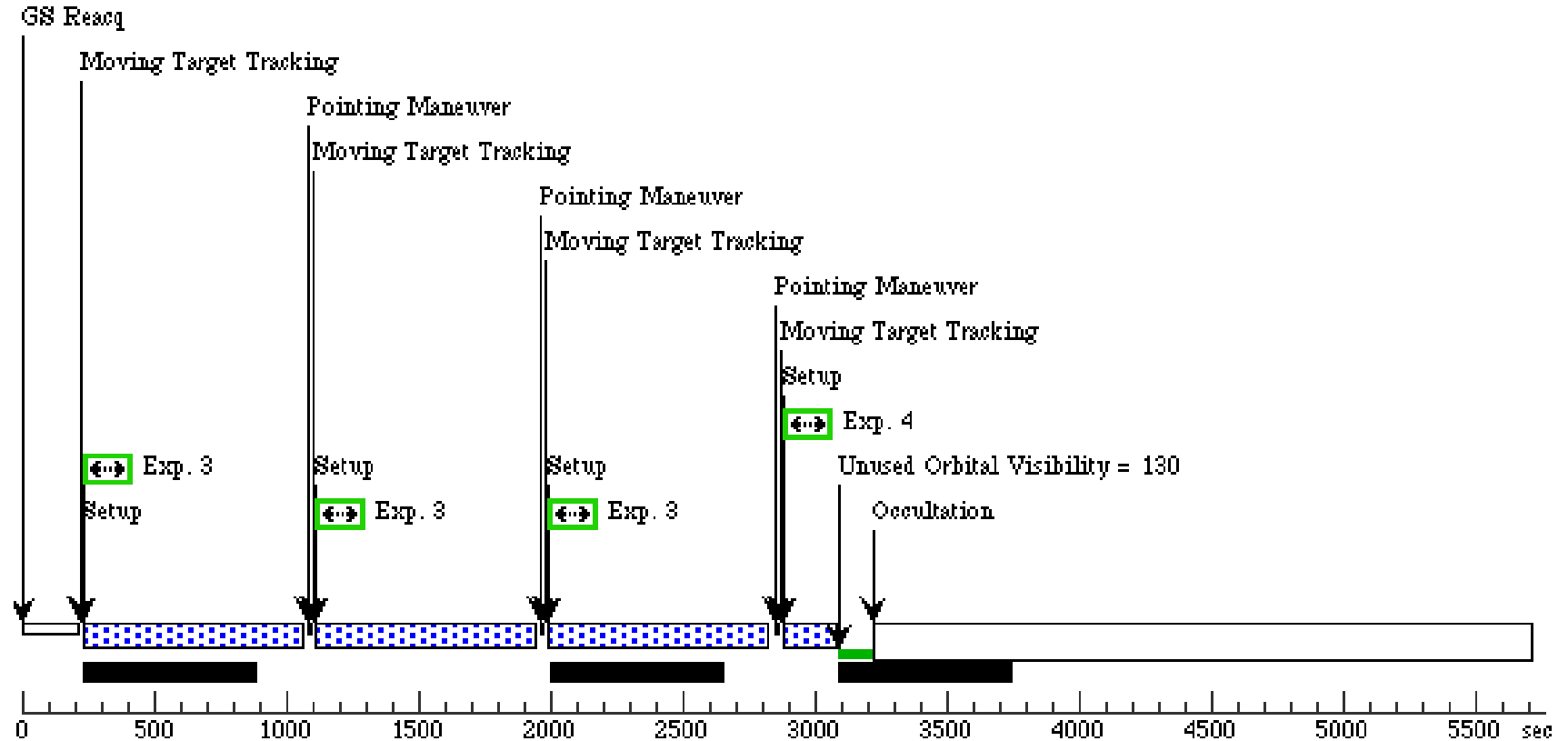
Server Version: 20150128



Orbit Structure

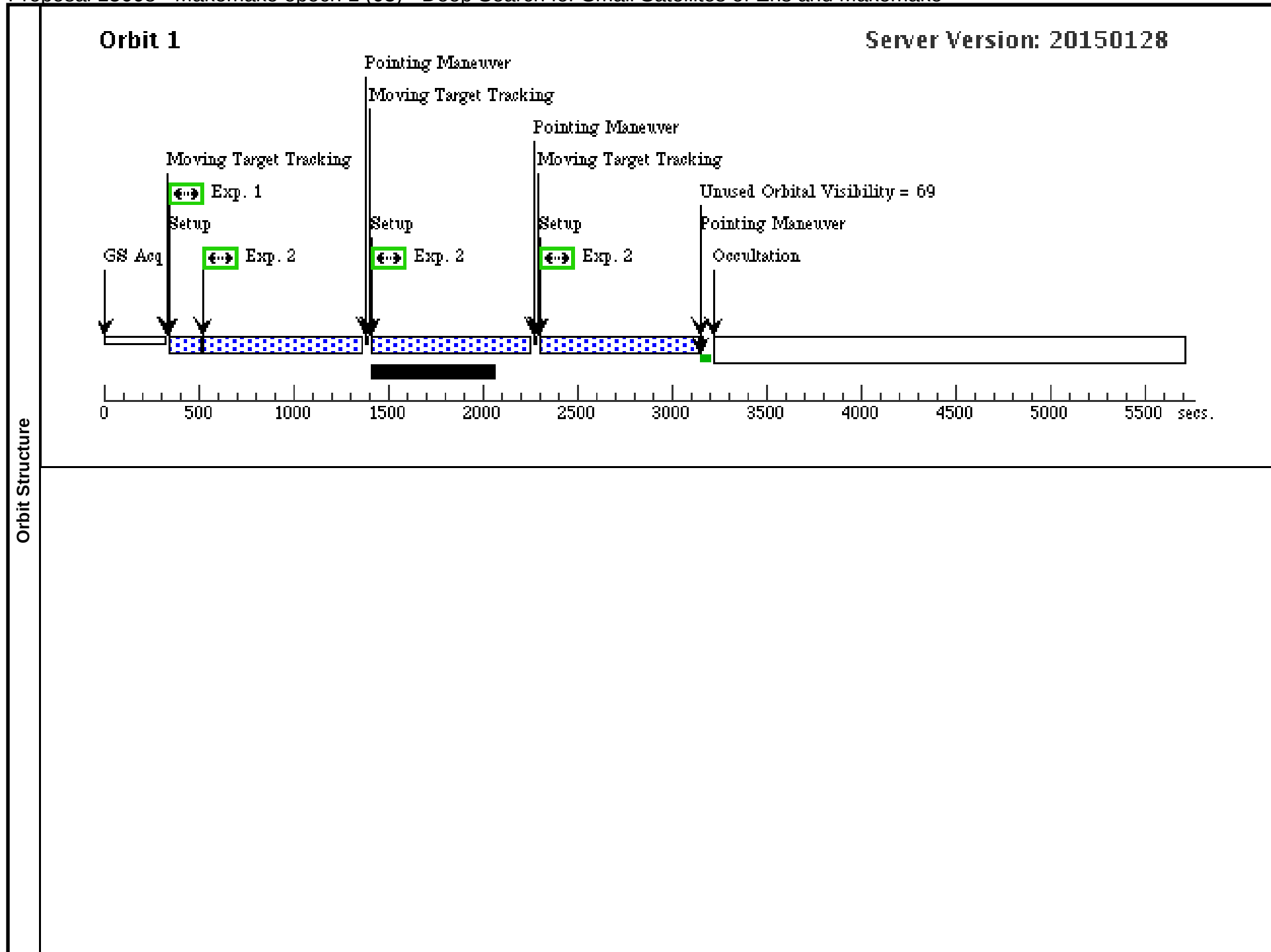
Orbit 2

Server Version: 20150128



Proposal 13668 - Makemake epoch 1 (03) - Deep Search for Small Satellites of Eris and Makemake

Visit	Proposal 13668, Makemake epoch 1 (03), implementation										Wed Apr 22 01:02:43 GMT 2015
	Diagnostic Status: No Diagnostics										
	Scientific Instruments: WFC3/UVIS										
	Special Requirements: ORIENT 149D TO 149 D; BETWEEN 01-MAR-2015 AND 01-JUN-2015										
Comments: Each visit is designed to collect a deep integration (two orbits per visit) on the target. The loose timing constraint restricts the observations to occur somewhat near opposition. This ensures a useful motion of the target relative to the background stars while also giving the best image scale and target brightness.											
Patterns	#	Primary Pattern				Secondary Pattern				Exposures	
	(1)	Pattern Type=WFC3-UVIS-DITHER- LINE Purpose=DITHER Number Of Points=3 Point Spacing=0.290 Line Spacing=				Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false				(2), (3)	
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center				
	(2)	MAKEMAKE	STD=MAKEMAKE								EARTH
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1	Navigation exposure 1	(2) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO; FLASH=10	GS ACQ SCENARIO BASE1B3		12 Secs (12 Secs)		
									[==>]		[1]
	2	Long part 1	(2) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO		Pattern 1, Exps 2-2 in Makemake epoch 1 (03) (1)	725 Secs (2175 Secs)		
									[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)]		[1]
	3	Long part 2	(2) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO		Pattern 1, Exps 3-3 in Makemake epoch 1 (03) (1)	725 Secs (2175 Secs)		
									[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)]		[2]
4	Navigation exposure 2	(2) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO; FLASH=10			12 Secs (12 Secs)			
								[==>]		[2]	



Proposal 13668 - Makemake epoch 2 (04) - Deep Search for Small Satellites of Eris and Makemake

Visit	Proposal 13668, Makemake epoch 2 (04), implementation										Wed Apr 22 01:02:43 GMT 2015
	Diagnostic Status: No Diagnostics										
	Scientific Instruments: WFC3/UVIS										
	Special Requirements: ORIENT 155D TO 155 D; AFTER 03 BY 2 D TO 3 D										
Comments: The second epoch is required to find a satellite moving relative to the primary object. The timing window is set to capture useful motion for an object at 20% of the Hill radius. The relative roll is used to move the satellite system relative to the PSF between epochs.											
Patterns	#	Primary Pattern					Secondary Pattern				Exposures
	(1)	Pattern Type=WFC3-UVIS-DITHER- LINE Purpose=DITHER Number Of Points=3 Point Spacing=0.290 Line Spacing= Coordinate Frame=POS-TARG Pattern Orientation=46.84 Angle Between Sides= Center Pattern=false									(2), (3)
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center				
	(2)	MAKEMAKE	STD=MAKEMAKE								EARTH
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1	Navigation exposure 1	(2) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO; FLASH=10	GS ACQ SCENARIO BASE1B3		12 Secs (12 Secs)		
									[==>]		[1]
	2	Long part 1	(2) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO		Pattern 1, Exps 2-2 in Makemake epoch 2 (04) (1)	725 Secs (2175 Secs)		
									[==>(Pattern 1)]		
									[==>(Pattern 2)]		[1]
									[==>(Pattern 3)]		
	3	Long part 2	(2) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO		Pattern 1, Exps 3-3 in Makemake epoch 2 (04) (1)	725 Secs (2175 Secs)		
								[==>(Pattern 1)]			
								[==>(Pattern 2)]		[2]	
								[==>(Pattern 3)]			
4	Navigation exposure 2	(2) MAKEMAKE	WFC3/UVIS, ACCUM, UVIS2	F350LP	CR-SPLIT=NO; FLASH=10				12 Secs (12 Secs)		
									[==>]		[2]

Orbit Structure

Orbit 1

Server Version: 20150128

