



13503 - Searching for Satellites of Ceres: Support for the Dawn Mission

Cycle: 21, Proposal Category: GO

(Availability Mode: AVAILABLE)

INVESTIGATORS

<i>Name</i>	<i>Institution</i>	<i>E-Mail</i>
Dr. Britney E. Schmidt (PI) (Contact)	Georgia Institute of Technology	britneys@ig.utexas.edu
Dr. Jian-Yang Li (CoI) (Contact)	Planetary Science Institute	jyli@psi.edu
Dr. Lucy-Ann McFadden (CoI) (Contact)	NASA Goddard Space Flight Center	lucyann.a.mcfadden@nasa.gov
Dr. Christopher T. Russell (CoI)	University of California - Los Angeles	ctrussell@igpp.ucla.edu
Dr. Brian McLean (CoI)	Space Telescope Science Institute	mclean@stsci.edu
Mr. Max Mutchler (CoI) (Contact)	Space Telescope Science Institute	mutchler@stsci.edu

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) CERES	WFC3/UVIS	1	02-Apr-2014 21:04:00.0	yes
02	(1) CERES	WFC3/UVIS	1	02-Apr-2014 21:04:14.0	yes
03	(1) CERES	WFC3/UVIS	1	02-Apr-2014 21:04:26.0	yes
04	(1) CERES	WFC3/UVIS	1	02-Apr-2014 21:04:36.0	yes

4 Total Orbits Used

ABSTRACT

The existence of satellites, or lack thereof, around Ceres is of great interest to the Dawn mission, which is currently en route to Ceres and will arrive in February 2015. The Dawn spacecraft will orbit Ceres at altitudes of 1180 to 6400 km, well within the satellite stability region. The final opportunity for observations of Ceres with HST prior to Dawns arrival occurs in April 2014, when Ceres makes a close pass at opposition to Earth.

In addition to providing additional targets for exciting physical studies by the Dawn instruments, satellites, if there were any, would substantially affect Dawn's orbit planning in order to accommodate observations and ensure spacecraft safety. For example, detection of satellites would allow this program to derive a more accurate measurement of the mass of Ceres, which is important for the mission planners to determine the orbit of spacecraft. With the observation planning process already underway, early detection of satellites will provide sufficient time to adapt mission plans to be able to observe any satellites on ingress or during the mapping orbits. Timing is particularly important, since the spacecraft now has use of only two reaction wheels, which is already impacting mission design, and which prevents Dawn from conducting its own deep satellite search as was accomplished prior to arrival at Vesta. Because of this, an HST survey is critical for Dawn operations at Ceres. Since satellite detection could require a change to the mission's nominal orbital strategy and present risk from dust associated with any satellites, it is crucial to put Dawn in the best position to succeed.

OBSERVING DESCRIPTION

In April of 2014 Ceres will be at opposition and close to the Earth with a range of ~ 1.65 AU, spanning ~ 0.8 arcsec. Its Hill sphere has a radius of ~ 434 Ceres radii, or ~ 350 arcsec in diameter. As discussed by Toth (1999), the stability region is about $1/3$ of the classic Hill sphere, consistent with all binary systems reviewed in Richardson and Walsh (2006). Therefore the search within the stability region will be emphasized while most of the Hill sphere will be thoroughly searched. The stability region of the Hill sphere can be fully covered in each exposure using a 2K by 2K chip subarray, but the smallest subarrays are adequate for searching in close to Ceres with shorter exposure times. We will also have the ability to stack successive short subarray images to characterize the PSF and subtract it to enhance the contrast ratio and push down the detection limit close to Ceres. We will use a strategy that combines deep searches of inner and outer orbital regions while managing diffraction and saturation from the primary body. The long pass filter F350LP is selected for the search in order to cover the widest range of the spectrum and search for satellites with a variety of physical properties. In order to minimize the chance that any potential satellites hide in the diffraction spikes of PSF as well as CCD bleeding in saturated images, we propose to take images in four orbits separated by a few days, so that both the nominal roll angle of the telescope will change between the orbits, and also the motion of any satellites will have allowed them to move away from bad pixels, diffraction spikes, star trails, or PSF features. At the edge of Ceres' Hill Sphere, the orbital period is over 4 years, but it is likely objects this far out would have been discovered already unless they were smaller than 1 km. At the edge of the stable region, the orbital period is 340 days, and at Dawn's survey orbit height of 6500 km, the orbital period is 9.2 days. Within 1000 km, the orbital period is just over 12 hours. At these speeds, an inner satellite will move off of a bad pixel within 40 minutes, where at the edge of the stability region the same motion will take nearly 5.7 days. This drives our observing strategy, to allow for the satellites to move relative to individual pixels as well as to the diffraction spikes. Observations within a single orbit should allow a close satellite to move off of a bad pixel, making relatively quick exposures important. Alternatively, we will need to separate epochs by about 90 orbits to ensure

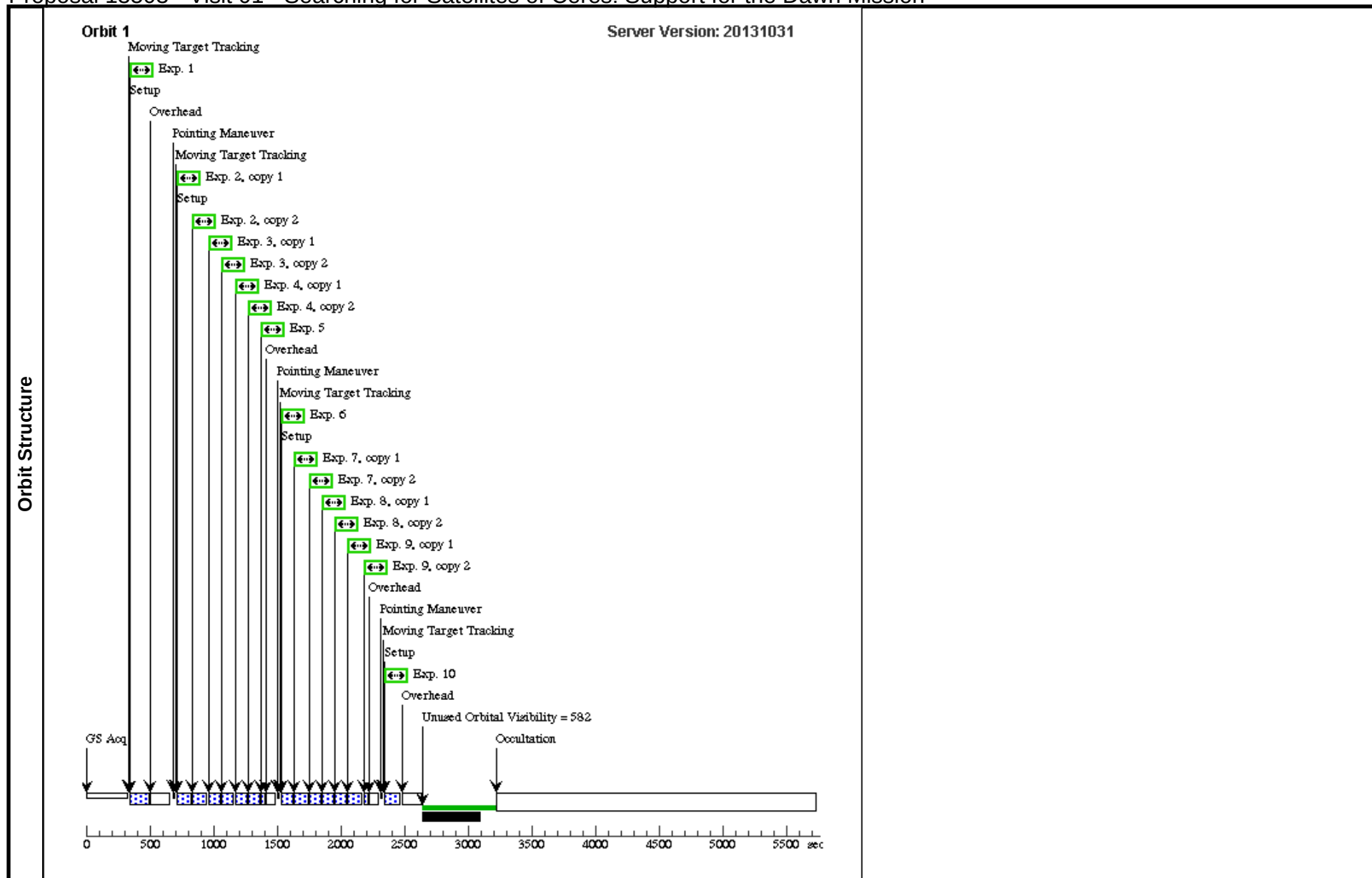
that satellites near the edge of the stable region have a chance to move out of a bad pixel. With 4 orbits of time, we can be certain that most satellites will not be able to hide among the various obscuring artifacts, and that satellites in close will have moved significantly around the chip, allowing for stacking to be an efficient method of search. We request 4 HST orbits to create multiple opportunities for an undiscovered satellite to be optimally placed for detection with WFC3. We would like to conduct our satellite search as Ceres is approaching Earth near its opposition in April 2014, in order to push the detection limit as low as possible. Because of the motion of the satellites within the inner Hill sphere, we will observe during 4 epochs spanning about 15 days. This will allow us to be confident in the detection of inner and outer satellites down to a limit of ~ 40 m.

ADDITIONAL COMMENTS

When our orbits are fully packed, the Visit Planner indicates no target availability in April (when Ceres is at opposition). By intentionally leaving several minutes unused in each orbit, the sequence becomes scheduleable near opposition on April 15. In visits 3 and 4 we use the WFC3 full frame, placing Ceres on each side of the chip gap to contain saturation and bleeding to one chip, for very deep searching on the other chip. We also invoke an off-nominal roll angle to manage the locations of obscuring artifacts (diffraction spikes, bleeding, chip gap) to avoid aligning them with Ceres' equatorial orbital plane. In Phase II we realized even our shortest F350LP exposures could saturate and bleed. So we added a short F555W exposure to each visit to ensure that we get one unsaturated image of Ceres as an astrometric reference for the deeper search frames. This was our original intent, and it does not alter our science goals or conflict with any other observing programs. We understand we can revise the exposure sequence within each orbit up until $\sim$ Feb 2014, so we may submit later versions as we further estimate the amount of saturation we will get with each exposure time.

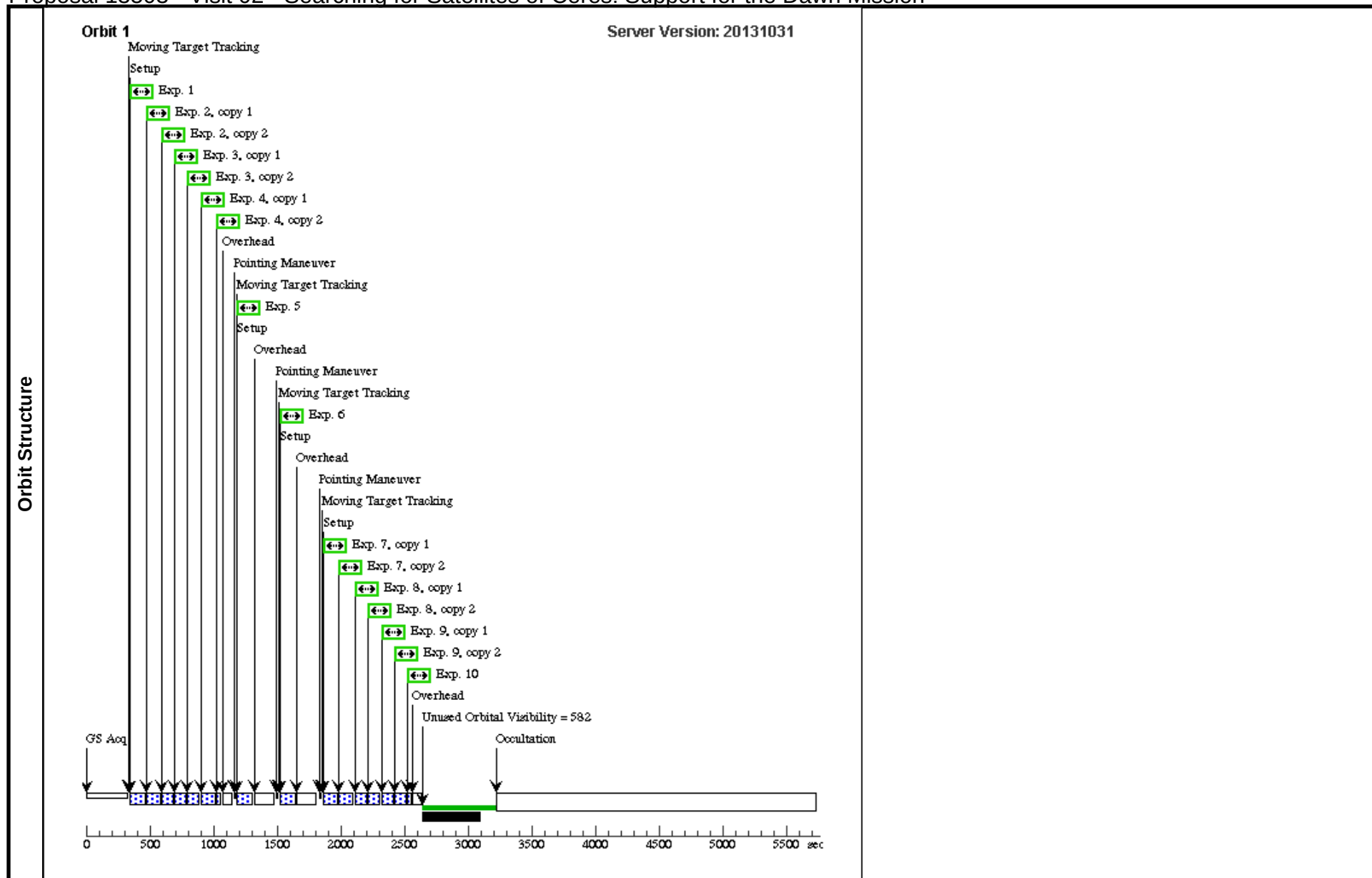
Proposal 13503 - Visit 01 - Searching for Satellites of Ceres: Support for the Dawn Mission

Visit	Proposal 13503, Visit 01, implementation Diagnostic Status: No Diagnostics Scientific Instruments: WFC3/UVIS Special Requirements: BETWEEN 14-APR-2014:00:00:00 AND 15-APR-2014:00:00:00 Thu Apr 03 01:04:47 GMT 2014									
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center			
	(1)	CERES	STD=CERES				EARTH			
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
	1		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP	CR-SPLIT=NO	POS TARG 8,8; GS ACQ SCENARI O BASE1B3		120 Secs (120 Secs) [==>]	[1]
	2		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=9			30 Secs X 2 (60 Secs) [==>(Copy 1)] [==>(Copy 2)]	[1]
	3		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A			5 Secs X 2 (10 Secs) [==>(Copy 1)] [==>(Copy 2)]	[1]
	4		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A			0.5 Secs X 2 (1 Secs) [==>(Copy 1)] [==>(Copy 2)]	[1]
	5		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F555W	CR-SPLIT=NO; FLASH=12; BLADE=A			0.5 Secs (0.5 Secs) [==>]	[1]
	6		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F555W	CR-SPLIT=NO; FLASH=12; BLADE=A	POS TARG 1,1		0.5 Secs (0.5 Secs) [==>]	[1]
	7		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A	POS TARG 1,1		0.5 Secs X 2 (1 Secs) [==>(Copy 1)] [==>(Copy 2)]	[1]
	8		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A	POS TARG 1,1		5 Secs X 2 (10 Secs) [==>(Copy 1)] [==>(Copy 2)]	[1]
	9		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=9	POS TARG 1,1		30 Secs X 2 (60 Secs) [==>(Copy 1)] [==>(Copy 2)]	[1]
	10		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP	CR-SPLIT=NO	POS TARG 9,9		120 Secs (120 Secs) [==>]	[1]



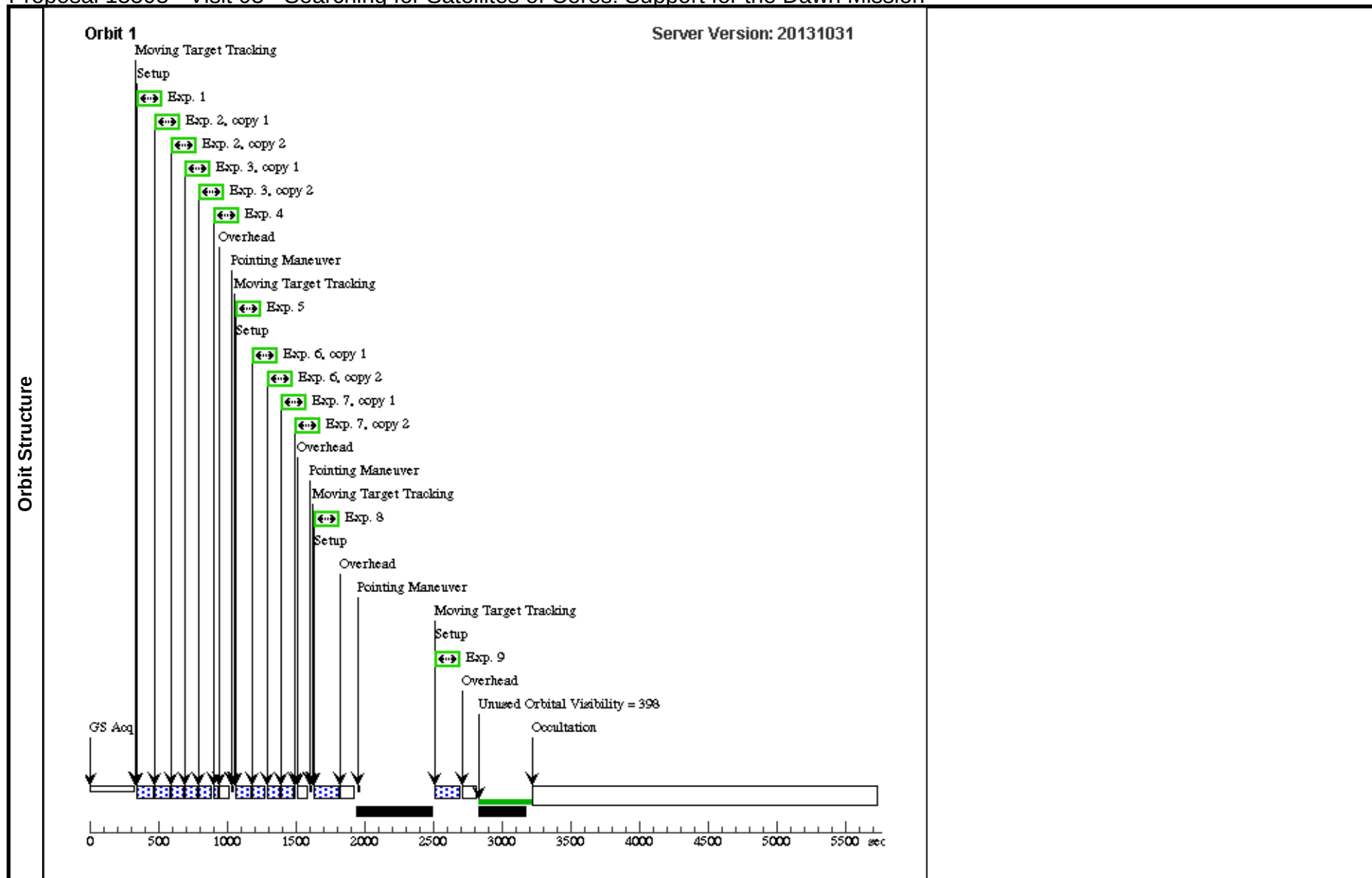
Proposal 13503 - Visit 02 - Searching for Satellites of Ceres: Support for the Dawn Mission

Visit	Proposal 13503, Visit 02, implementation										Thu Apr 03 01:04:50 GMT 2014
	Diagnostic Status: No Diagnostics										
	Scientific Instruments: WFC3/UVIS										
	Special Requirements: AFTER 01 BY 20 H TO 48 H										
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center				
	(1)	CERES	STD=CERES				EARTH				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit	
	1		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F555W	CR-SPLIT=NO; FLASH=12; BLADE=A	GS ACQ SCENARI O BASE1B3		0.5 Secs (0.5 Secs)		
									[==>]	[1]	
	2		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A			0.5 Secs X 2 (1 Secs)		
									[==>(Copy 1)]	[1]	
									[==>(Copy 2)]		
	3		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A			5 Secs X 2 (10 Secs)		
									[==>(Copy 1)]	[1]	
									[==>(Copy 2)]		
	4		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=9			30 Secs X 2 (60 Secs)		
									[==>(Copy 1)]	[1]	
									[==>(Copy 2)]		
	5		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP	CR-SPLIT=NO	POS TARG 8,8		120 Secs (120 Secs)		
									[==>]	[1]	
6		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-2K2C-SUB	F350LP	CR-SPLIT=NO	POS TARG 9,9		120 Secs (120 Secs)			
								[==>]	[1]		
7		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=9	POS TARG 1,1		30 Secs X 2 (60 Secs)			
								[==>(Copy 1)]	[1]		
								[==>(Copy 2)]			
8		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A	POS TARG 1,1		5 Secs X 2 (10 Secs)			
								[==>(Copy 1)]	[1]		
								[==>(Copy 2)]			
9		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A	POS TARG 1,1		0.5 Secs X 2 (1 Secs)			
								[==>(Copy 1)]	[1]		
								[==>(Copy 2)]			
10		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F555W	CR-SPLIT=NO; FLASH=12; BLADE=A	POS TARG 1,1		0.5 Secs (0.5 Secs)			
								[==>]	[1]		



Proposal 13503 - Visit 03 - Searching for Satellites of Ceres: Support for the Dawn Mission

Visit	Proposal 13503, Visit 03, implementation										Thu Apr 03 01:04:52 GMT 2014
	Diagnostic Status: No Diagnostics										
	Scientific Instruments: WFC3/UVIS										
	Special Requirements: AFTER 01 BY 5 D TO 7 D										
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center				
	(1)	CERES	STD=CERES				EARTH				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit	
	1		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F555W	CR-SPLIT=NO; FLASH=12; BLADE=A	GS ACQ SCENARI O BASE1B3		0.5 Secs (0.5 Secs)		
									[==>]	[1]	
	2		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A			0.5 Secs X 2 (1 Secs)		
									[==>(Copy 1)]		
									[==>(Copy 2)]	[1]	
	3		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A			5 Secs X 2 (10 Secs)		
									[==>(Copy 1)]		
									[==>(Copy 2)]	[1]	
	4		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=9			30 Secs (30 Secs)		
									[==>]	[1]	
	5		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=9	POS TARG 1,1		30 Secs (30 Secs)		
								[==>]	[1]		
6		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A	POS TARG 1,1		5 Secs X 2 (10 Secs)			
								[==>(Copy 1)]			
								[==>(Copy 2)]	[1]		
7		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A	POS TARG 1,1		0.5 Secs X 2 (1 Secs)			
								[==>(Copy 1)]			
								[==>(Copy 2)]	[1]		
8		(1) CERES	WFC3/UVIS, ACCUM, UVIS-CENTER	F350LP	CR-SPLIT=NO	POS TARG 0,-1		180 Secs (180 Secs)			
								[==>]	[1]		
9		(1) CERES	WFC3/UVIS, ACCUM, UVIS-CENTER	F350LP	CR-SPLIT=NO	POS TARG 0,2,5		180 Secs (180 Secs)			
								[==>]	[1]		



Proposal 13503 - Visit 04 - Searching for Satellites of Ceres: Support for the Dawn Mission

Visit	Proposal 13503, Visit 04, implementation										Thu Apr 03 01:04:53 GMT 2014
	Diagnostic Status: No Diagnostics										
	Scientific Instruments: WFC3/UVIS										
	Special Requirements: AFTER 01 BY 11.5 D TO 15 D										
Solar System Targets	#	Name	Level 1	Level 2	Level 3	Window	Ephem Center				
	(1)	CERES	STD=CERES				EARTH				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]		Orbit
	1		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F555W	CR-SPLIT=NO; FLASH=12; BLADE=A	GS ACQ SCENARI O BASE1B3		0.5 Secs (0.5 Secs)		
									[==>]		[1]
	2		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A			0.5 Secs X 2 (1 Secs)		
									[==>(Copy 1)]		
									[==>(Copy 2)]		[1]
	3		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A			5 Secs X 2 (10 Secs)		
									[==>(Copy 1)]		
									[==>(Copy 2)]		[1]
	4		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=9			30 Secs (30 Secs)		
									[==>]		[1]
	5		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=9	POS TARG 1,1		30 Secs (30 Secs)		
									[==>]		[1]
	6		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A	POS TARG 1,1		5 Secs X 2 (10 Secs)		
								[==>(Copy 1)]			
								[==>(Copy 2)]		[1]	
7		(1) CERES	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F350LP	CR-SPLIT=NO; FLASH=12; BLADE=A	POS TARG 1,1		0.5 Secs X 2 (1 Secs)			
								[==>(Copy 1)]			
								[==>(Copy 2)]		[1]	
8		(1) CERES	WFC3/UVIS, ACCUM, UVIS-CENTER	F350LP	CR-SPLIT=NO	POS TARG 0,-1		180 Secs (180 Secs)			
								[==>]		[1]	
9		(1) CERES	WFC3/UVIS, ACCUM, UVIS-CENTER	F350LP	CR-SPLIT=NO	POS TARG 0,2,5		180 Secs (180 Secs)			
								[==>]		[1]	

