



## 12889 - Accurate Cosmology from Gravitational Lens Time Delays

Cycle: 20, 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) HE0435-1223	WFC3/IR	4	28-Jun-2012 21:37:58.0	yes
02	(3) HE1104-1805	WFC3/IR	6	28-Jun-2012 21:38:29.0	yes
03	(2) WFIJ2033-4723	WFC3/IR	9	28-Jun-2012 21:39:21.0	yes

19 Total Orbits Used

## **ABSTRACT**

Measuring cosmological parameters with a realistic account of the systematic errors is currently one of the principal challenges of physical cosmology. We have shown that a detailed analysis of the gravitational lens B1608+656, including systematic errors, measures the time-delay distance to 5% precision, corresponding to the Hubble constant ( $H_0$ ) to 7%. Combined with WMAP this yields flatness to 2% and the dark energy parameter  $w$  to 18%, comparable to BAO measurements. The results are made possible by deep HST/ACS images, showing the Einstein ring with high signal-to-noise ratio that allowed us to determine accurately the mass distribution of the deflector. We propose to extend our work to 4 additional lenses (1 archival) with exquisite time-delay measurements from the Cosmograil collaboration. New, deep WFC3/IR F160W images are needed for 3 systems to characterize fully their Einstein rings. With 5 systems in total, we will measure  $H_0$  to 3.8%, i.e., similar in precision to current distance-ladder results (3.3%). Combining these two independent measurements with upcoming Planck data yields 2.5% precision on  $H_0$ , 0.5% on flatness and 13% on  $w$ . Furthermore, studying more lenses is the only way to test if unknown systematic errors are present in our approach. We will do this by performing blind analysis of each system and comparing the measurement scatter with estimated errors. With dozens of accurate time delays currently being measured by Cosmograil, the method has the potential to reach within 3 years 2% on  $H_0$  fully independent of the local ladder (and  $<0.3\%$  on flatness). Eventually, PS1, DES, and LSST will discover hundreds of lenses, making 1% on  $H_0$  attainable.

## **OBSERVING DESCRIPTION**

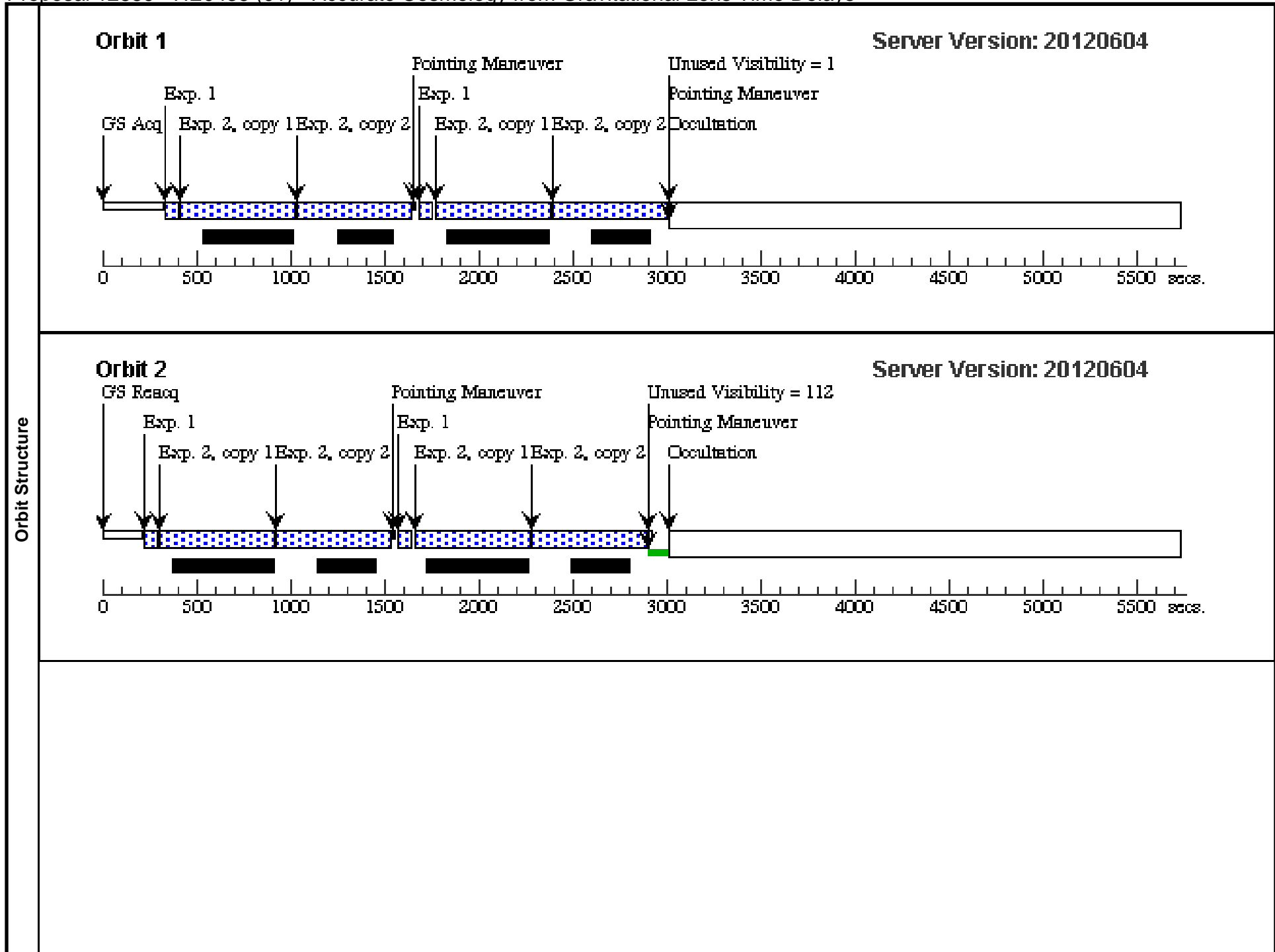
We will use several 4-point dither patterns with parallelogram shapes, which each has  $n+1/2$  pixel shifts. These parallelogram patterns will have minimal overlap to avoid areas of persistence. The pixel shifts between the parallelograms are  $m+1/4$  for two parallelograms and  $m+1/3$  for three parallelograms, which will allow us to effectively reject cosmic rays and hot pixels and optimize the sampling of the PSF.

In order to fully sample the dynamic range and avoid non-linearities at the 5 brightest pixels at the location of the lensed quasars, we will split each orbit into sequences of short and long exposures at the dither pattern positions.

Proposal 12889 - HE0435 (01) - Accurate Cosmology from Gravitational Lens Time Delays

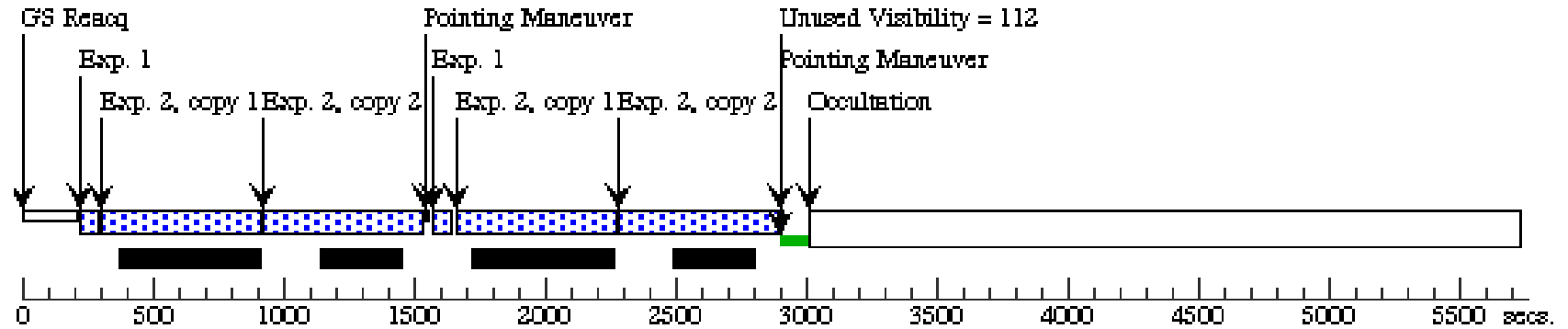
Fri Jun 29 01:39:41 GMT 2012

Visit	<b>Proposal 12889, HE0435 (01)</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/IR Special Requirements: SCHED 100%; ORIENT 27D TO 82 D; ORIENT 289D TO 312 D									
	Patterns	#	Primary Pattern	Secondary Pattern	Exposures					
	(1)	Pattern Type=LINE Purpose=DITHER Number Of Points=2 Point Spacing=9.132 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=138.212 Angle Between Sides= Center Pattern=false	Pattern Type=BOX Purpose=DITHER Number Of Points=4 Point Spacing=7.431 Line Spacing=4.740	(1-2)					
Fixed Targets	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous				
	(1)	HE0435-1223	RA: 04 38 14.9000 (69.5620833d) Dec: -12 17 14.40 (-12.28733d) Equinox: J2000		V=18.6+/-0.3	Reference Frame: HST				
Exposures	#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
	1	shortR	(1) HE0435-1223	WFC3/IR, MULTIACCUM, IR	F160W	NSAMP=15; SAMP-SEQ=RAPID			Pattern 1, Exps 1-2 in HE0435 (01) (1)	[==>(Pattern 1,1)] [==>(Pattern 1,2)] [==>(Pattern 1,3)] [==>(Pattern 1,4)] [==>(Pattern 2,1)] [==>(Pattern 2,2)] [==>(Pattern 2,3)] [==>(Pattern 2,4)]
	2	long600	(1) HE0435-1223	WFC3/IR, MULTIACCUM, IR	F160W	NSAMP=12; SAMP-SEQ=STEP100		Pattern 1, Exps 1-2 in HE0435 (01) (1)	[==>(Pattern 1,1, Copy 1)] [==>(Pattern 1,1, Copy 2)] [==>(Pattern 1,2, Copy 1)] [==>(Pattern 1,2, Copy 2)] [==>(Pattern 1,3, Copy 1)] [==>(Pattern 1,3, Copy 2)] [==>(Pattern 1,4, Copy 1)] [==>(Pattern 1,4, Copy 2)] [==>(Pattern 2,1, Copy 1)] [==>(Pattern 2,1, Copy 2)] [==>(Pattern 2,2, Copy 1)] [==>(Pattern 2,2, Copy 2)] [==>(Pattern 2,3, Copy 1)] [==>(Pattern 2,3, Copy 2)] [==>(Pattern 2,4, Copy 1)] [==>(Pattern 2,4, Copy 2)]	[1] [2] [3] [4]



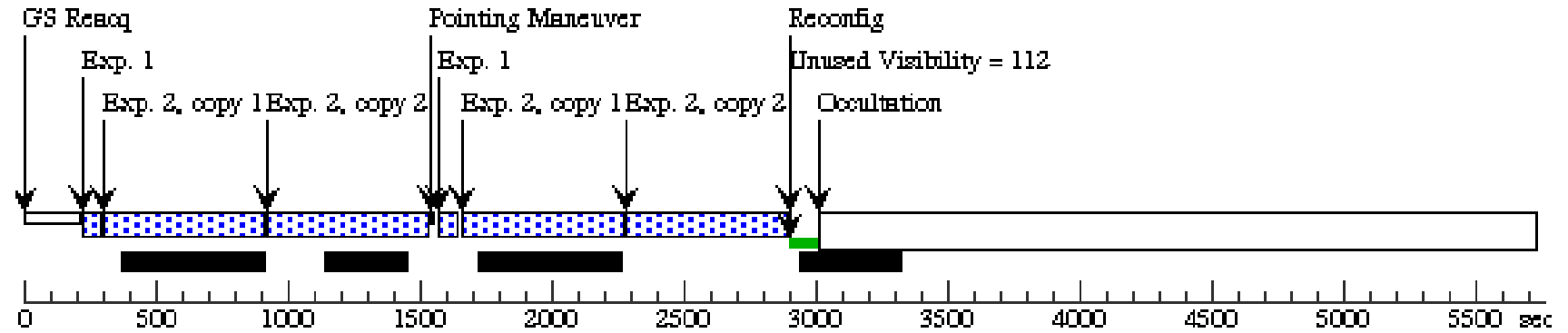
Server Version: 20120604

**Orbit 3**



Server Version: 20120604

**Orbit 4**



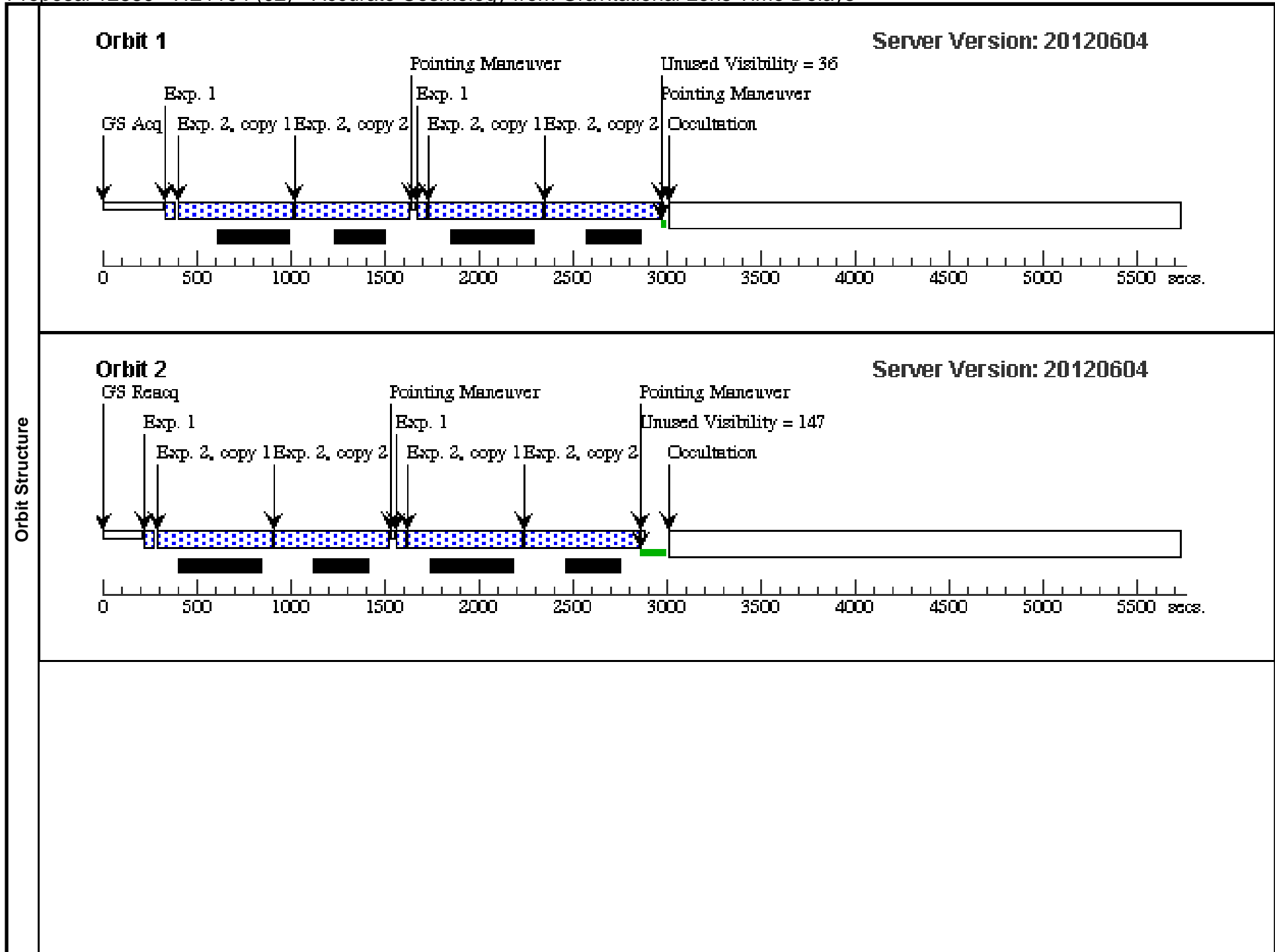
Proposal 12889 - HE1104 (02) - Accurate Cosmology from Gravitational Lens Time Delays

Fri Jun 29 01:39:47 GMT 2012

<b>Visit</b>	<b>Proposal 12889, HE1104 (02)</b> <b>Diagnostic Status: No Diagnostics</b> Scientific Instruments: WFC3/IR Special Requirements: SCHED 100%; ORIENT 350D TO 49 D; ORIENT 97D TO 157 D; ORIENT 201D TO 217 D					
	<b>Patterns</b>	<b>#</b>	<b>Primary Pattern</b>	<b>Secondary Pattern</b>	<b>Exposures</b>	
	(2)	Pattern Type=LINE Purpose=DITHER Number Of Points=3 Point Spacing=10.601 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=138.212 Angle Between Sides= Center Pattern=false	Pattern Type=BOX Purpose=DITHER Number Of Points=4 Point Spacing=8.574 Line Spacing=5.470	(1-2)	
<b>Fixed Targets</b>	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>	<b>Targ. Coord. Corrections</b>	<b>Fluxes</b>	<b>Miscellaneous</b>
	(3)	HE1104-1805	RA: 11 06 33.4500 (166.6393750d) Dec: -18 21 24.20 (-18.35672d) Equinox: J2000		V=16.4+/-0.3	Reference Frame: HST

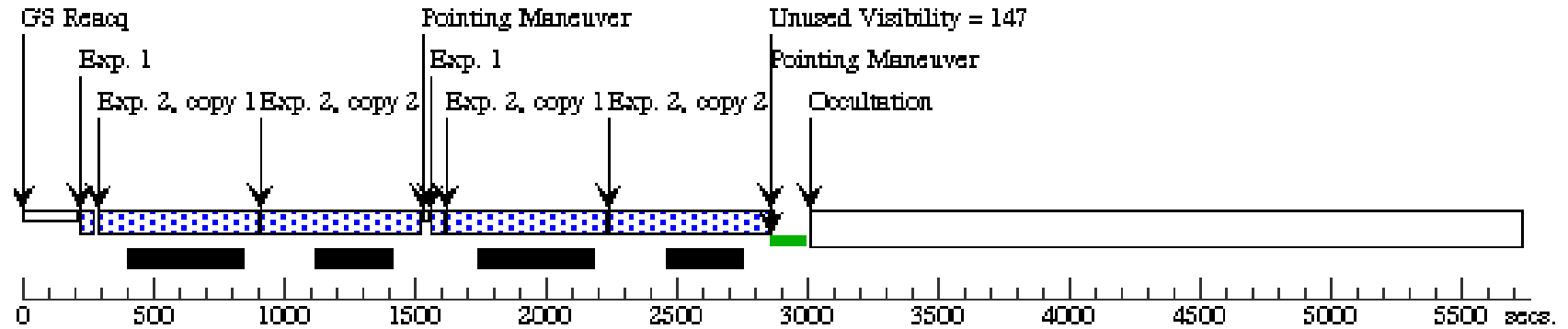
Proposal 12889 - HE1104 (02) - Accurate Cosmology from Gravitational Lens Time Delays

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit
Exposures	1	vshortR	(3) HE1104-1805	WFC3/IR, MULTIACCUM, IR	F160W	NSAMP=9; SAMP-SEQ=RAPID	Pattern 2, Exps 1-2 in HE1104 (02) (2)	[==>(Pattern 1,1)]	[1]
								[==>(Pattern 1,2)]	
								[==>(Pattern 1,3)]	[2]
								[==>(Pattern 1,4)]	
								[==>(Pattern 2,1)]	[3]
								[==>(Pattern 2,2)]	
								[==>(Pattern 2,3)]	[4]
								[==>(Pattern 2,4)]	
								[==>(Pattern 3,1)]	[5]
								[==>(Pattern 3,2)]	
								[==>(Pattern 3,3)]	[6]
								[==>(Pattern 3,4)]	
	2	long600	(3) HE1104-1805	WFC3/IR, MULTIACCUM, IR	F160W	NSAMP=12; SAMP-SEQ=STEP100	Pattern 2, Exps 1-2 in HE1104 (02) (2)	[==>(Pattern 1,1, Copy 1)]	
								[==>(Pattern 1,1, Copy 2)]	[1]
								[==>(Pattern 1,2, Copy 1)]	
								[==>(Pattern 1,2, Copy 2)]	
								[==>(Pattern 1,3, Copy 1)]	
								[==>(Pattern 1,3, Copy 2)]	[2]
								[==>(Pattern 1,4, Copy 1)]	
								[==>(Pattern 1,4, Copy 2)]	
								[==>(Pattern 2,1, Copy 1)]	
								[==>(Pattern 2,1, Copy 2)]	[3]
								[==>(Pattern 2,2, Copy 1)]	
								[==>(Pattern 2,2, Copy 2)]	
								[==>(Pattern 2,3, Copy 1)]	
								[==>(Pattern 2,3, Copy 2)]	[4]
								[==>(Pattern 2,4, Copy 1)]	
								[==>(Pattern 2,4, Copy 2)]	
								[==>(Pattern 3,1, Copy 1)]	
								[==>(Pattern 3,1, Copy 2)]	[5]
								[==>(Pattern 3,2, Copy 1)]	
								[==>(Pattern 3,2, Copy 2)]	
								[==>(Pattern 3,3, Copy 1)]	
								[==>(Pattern 3,3, Copy 2)]	[6]
								[==>(Pattern 3,4, Copy 1)]	
								[==>(Pattern 3,4, Copy 2)]	



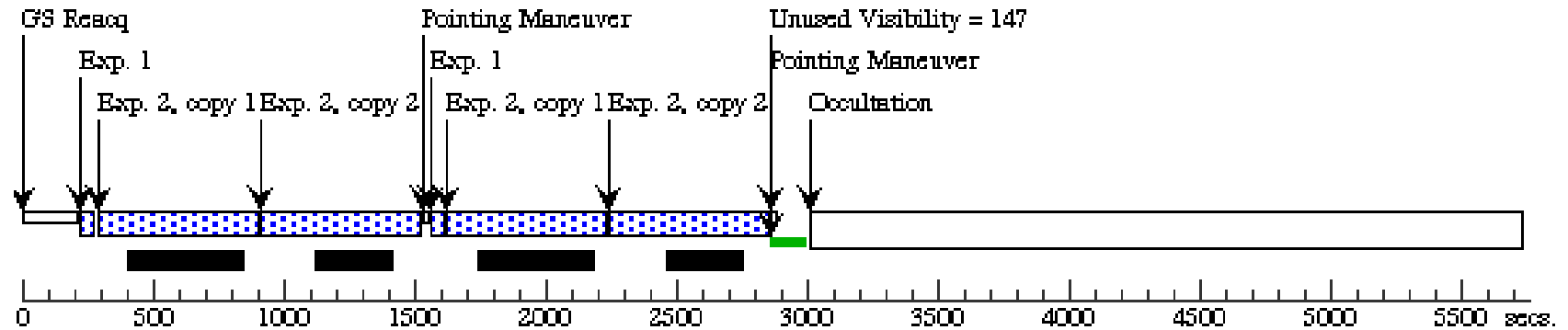
Server Version: 20120604

**Orbit 3**



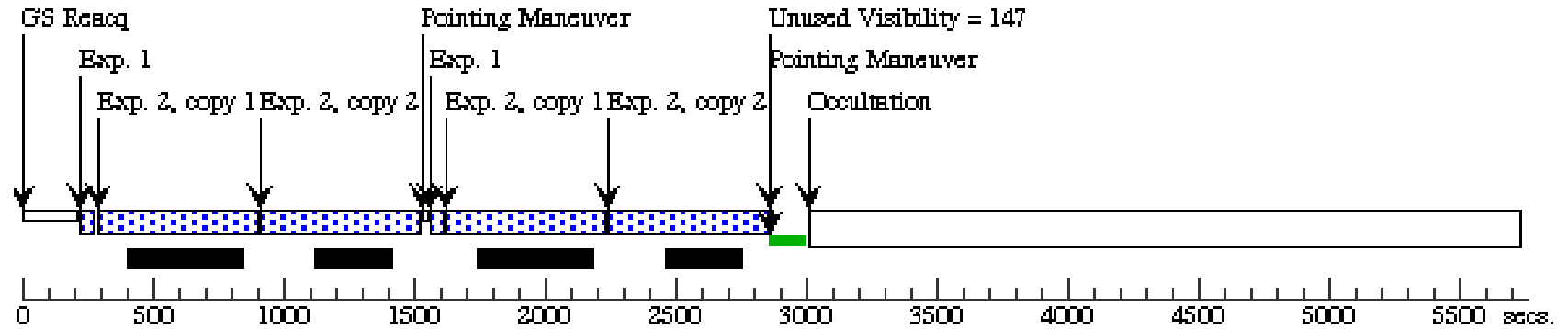
Server Version: 20120604

**Orbit 4**



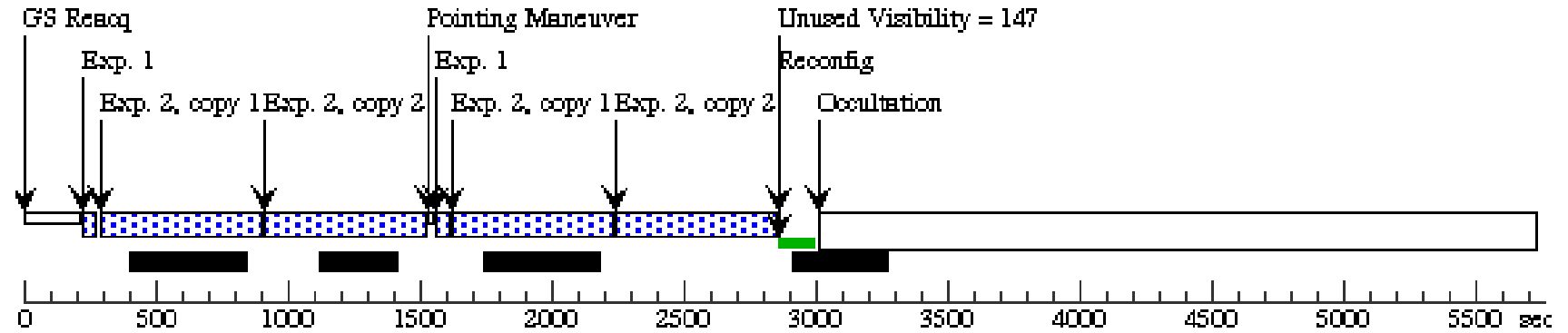
Server Version: 20120604

**Orbit 5**



**Orbit 6**

Server Version: 20120604



Proposal 12889 - WFI2033 (03) - Accurate Cosmology from Gravitational Lens Time Delays

Fri Jun 29 01:39:53 GMT 2012

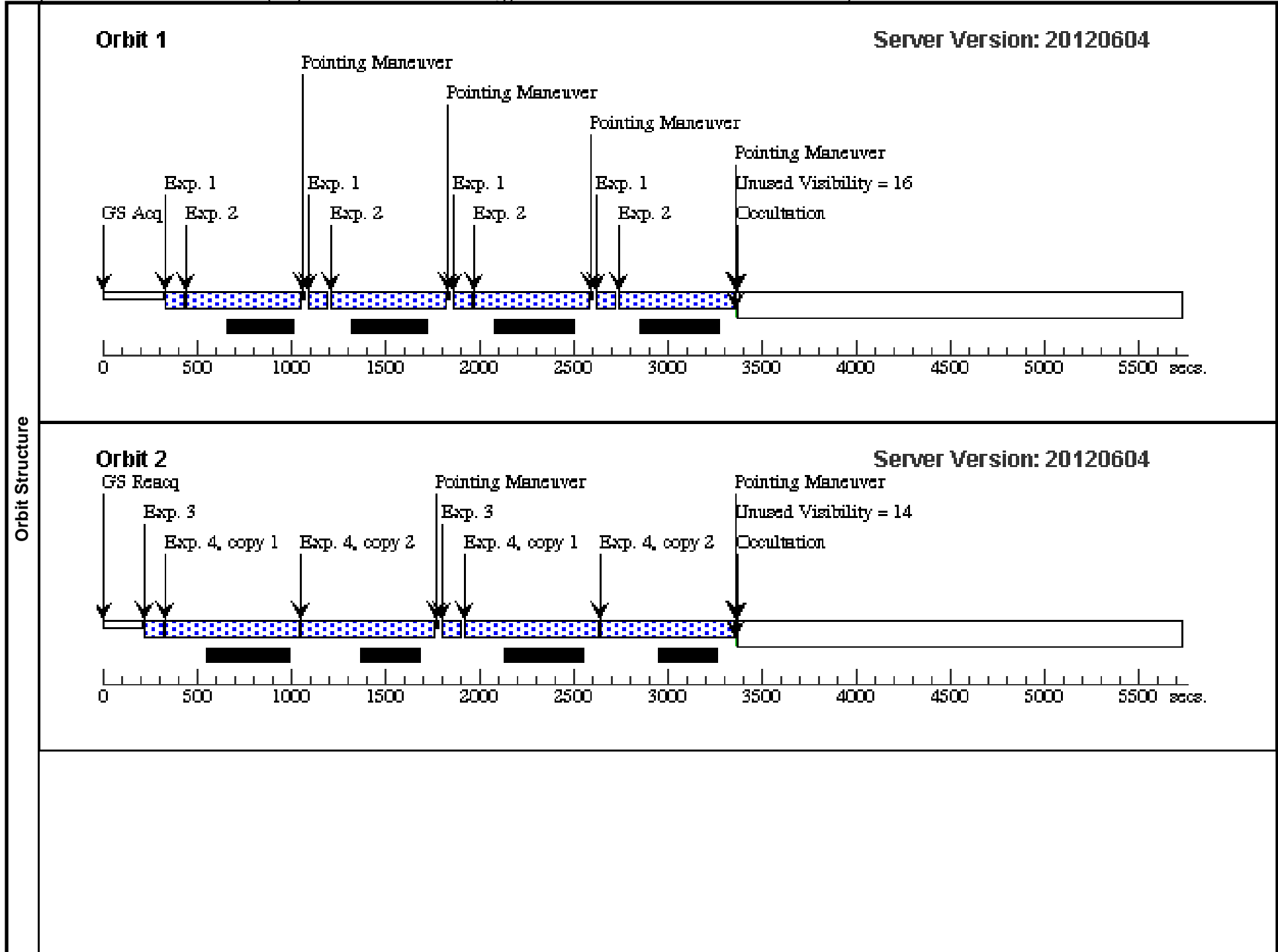
<b>Visit</b>	<b>Proposal 12889, WFI2033 (03)</b> <b>Diagnostic Status: Warning</b> Scientific Instruments: WFC3/IR Special Requirements: ORIENT 2D TO 12 D; ORIENT 36D TO 128 D; ORIENT 210D TO 276 D					
	(WFI2033 (03)) Warning (Orbit Planner): LONG SU LIKELY TO INTERSECT THE SAA					
<b>Diagnosics</b>						
<b>Patterns</b>	<b>#</b>	<b>Primary Pattern</b>		<b>Secondary Pattern</b>		<b>Exposures</b>
	(3)	Pattern Type=BOX Purpose=DITHER Number Of Points=4 Point Spacing=7.431 Line Spacing=4.740	Coordinate Frame=POS-TARG Pattern Orientation=198.528 Angle Between Sides=74.653 Center Pattern=false			(1-2)
<b>Fixed Targets</b>	(4)	Pattern Type=LINE Purpose=DITHER Number Of Points=2 Point Spacing=6.588 Line Spacing=	Coordinate Frame=POS-TARG Pattern Orientation=138.212 Angle Between Sides= Center Pattern=false	Pattern Type=BOX Purpose=DITHER Number Of Points=4 Point Spacing=7.431 Line Spacing=4.740	Coordinate Frame=POS-TARG Pattern Orientation=198.528 Angle Between Sides=74.653 Center Pattern=false	(3-4), (5-6)
	<b>#</b>	<b>Name</b>	<b>Target Coordinates</b>	<b>Targ. Coord. Corrections</b>	<b>Fluxes</b>	<b>Miscellaneous</b>
(2)	WFIJ2033-4723	RA: 20 33 42.0800 (308.4253333d) Dec: -47 23 43.00 (-47.39528d) Equinox: J2000		V=18.5+/-0.3	Reference Frame: HST	

Proposal 12889 - WFI2033 (03) - Accurate Cosmology from Gravitational Lens Time Delays

#	Label	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time/[Actual Dur.]	Orbit	
Exposures	1	shortS	(2) WFIJ2033-4723	WFC3/IR, MULTIACCUM, IR-FIX	F160W	NSAMP=7; SAMP-SEQ=STEP2 5	POS TARG -9.485,5 .328	Pattern 3, Exps 1-2 in WFI2033 (03) (3)	[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[1]
	2	4long	(2) WFIJ2033-4723	WFC3/IR, MULTIACCUM, IR-FIX	F160W	NSAMP=12; SAMP-SEQ=STEP1 00	POS TARG -9.485,5 .328	Pattern 3, Exps 1-2 in WFI2033 (03) (3)	[==>(Pattern 1)] [==>(Pattern 2)] [==>(Pattern 3)] [==>(Pattern 4)]	[1]
	3	shortS	(2) WFIJ2033-4723	WFC3/IR, MULTIACCUM, IR	F160W	NSAMP=7; SAMP-SEQ=STEP2 5		Pattern 4, Exps 3-4 in WFI2033 (03) (4)	[==>(Pattern 1,1)] [==>(Pattern 1,2)]	[2]
									[==>(Pattern 1,3)] [==>(Pattern 1,4)]	[3]
									[==>(Pattern 2,1)] [==>(Pattern 2,2)]	[4]
									[==>(Pattern 2,3)] [==>(Pattern 2,4)]	[5]
	4	long700	(2) WFIJ2033-4723	WFC3/IR, MULTIACCUM, IR	F160W	NSAMP=13; SAMP-SEQ=STEP1 00		Pattern 4, Exps 3-4 in WFI2033 (03) (4)	[==>(Pattern 1,1, Copy 1)] [==>(Pattern 1,1, Copy 2)] [==>(Pattern 1,2, Copy 1)] [==>(Pattern 1,2, Copy 2)]	[2]
									[==>(Pattern 1,3, Copy 1)] [==>(Pattern 1,3, Copy 2)] [==>(Pattern 1,4, Copy 1)] [==>(Pattern 1,4, Copy 2)]	[3]
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									[==>(Pattern 2,3, Copy 1)] [==>(Pattern 2,3, Copy 2)] [==>(Pattern 2,4, Copy 1)] [==>(Pattern 2,4, Copy 2)]	[5]
	5	shortS	(2) WFIJ2033-4723	WFC3/IR, MULTIACCUM, IR-FIX	F160W	NSAMP=7; SAMP-SEQ=STEP2 5		Pattern 4, Exps 5-6 in WFI2033 (03) (4)	[==>(Pattern 1,1)] [==>(Pattern 1,2)]	[6]
									[==>(Pattern 1,3)] [==>(Pattern 1,4)]	[7]
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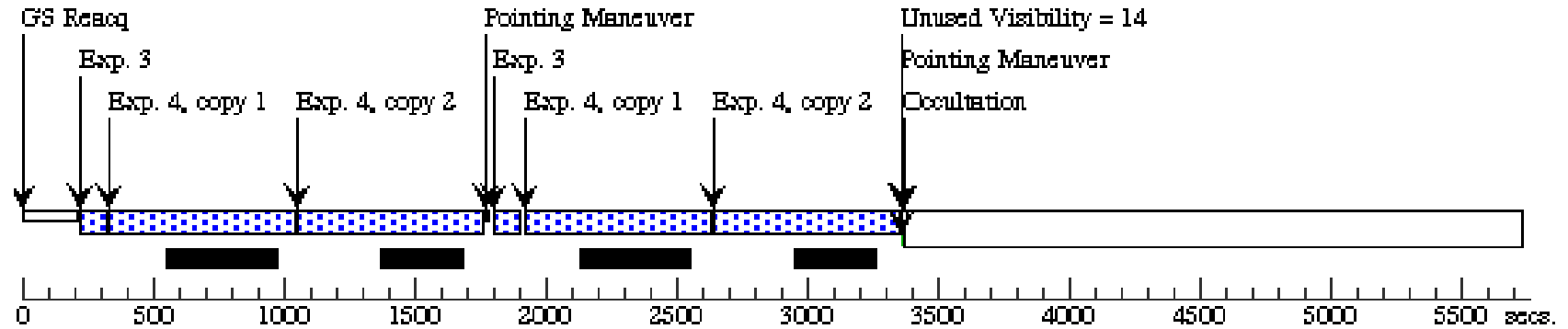
Proposal 12889 - WFI2033 (03) - Accurate Cosmology from Gravitational Lens Time Delays

6	long700	(2) WFIJ2033-4723 WFC3/IR, MULTIACCUM, IR-FIX F160W	NSAMP=13; SAMP-SEQ=STEP1 00	Pattern 4, Exps 5-6 in WFI2033 (03) (4)	<p>[==&gt;(Pattern 1,1, Copy 1)]</p> <p>[==&gt;(Pattern 1,1, Copy 2)]</p> <p>[==&gt;(Pattern 1,2, Copy 1)]</p> <p>[==&gt;(Pattern 1,2, Copy 2)]</p> <hr/> <p>[==&gt;(Pattern 1,3, Copy 1)]</p> <p>[==&gt;(Pattern 1,3, Copy 2)]</p> <p>[==&gt;(Pattern 1,4, Copy 1)]</p> <p>[==&gt;(Pattern 1,4, Copy 2)]</p> <hr/> <p>[==&gt;(Pattern 2,1, Copy 1)]</p> <p>[==&gt;(Pattern 2,1, Copy 2)]</p> <p>[==&gt;(Pattern 2,2, Copy 1)]</p> <p>[==&gt;(Pattern 2,2, Copy 2)]</p> <hr/> <p>[==&gt;(Pattern 2,3, Copy 1)]</p> <p>[==&gt;(Pattern 2,3, Copy 2)]</p> <p>[==&gt;(Pattern 2,4, Copy 1)]</p> <p>[==&gt;(Pattern 2,4, Copy 2)]</p>	<p>[6]</p> <hr/> <p>[7]</p> <hr/> <p>[8]</p> <hr/> <p>[9]</p>
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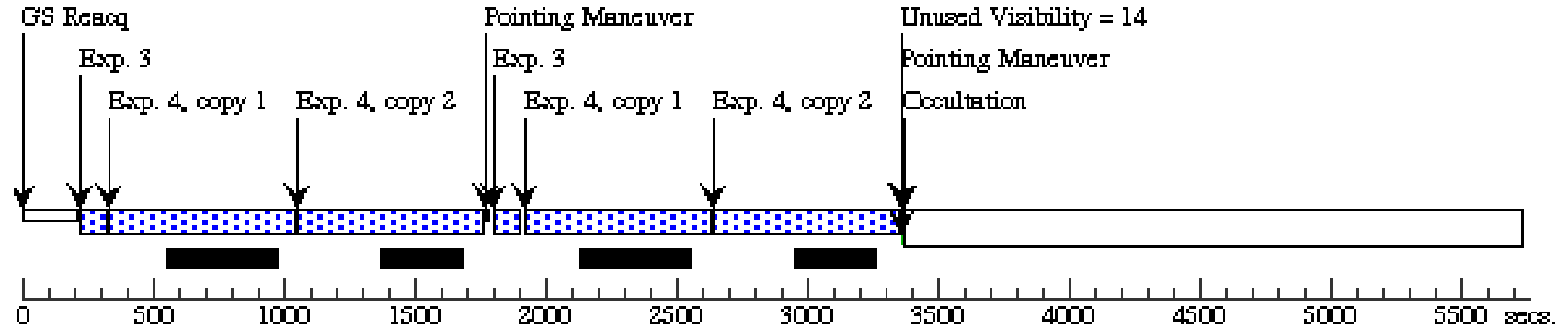
**Orbit 3**

Server Version: 20120604



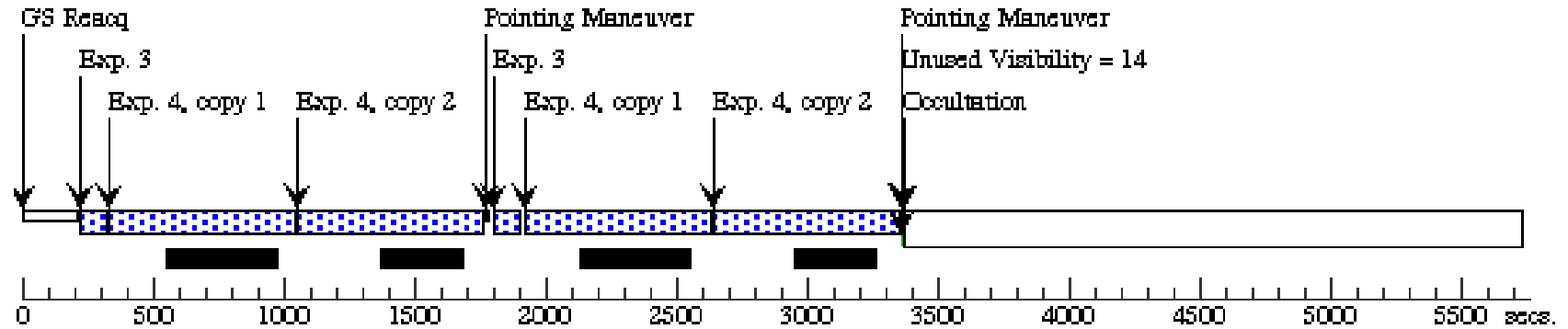
**Orbit 4**

Server Version: 20120604



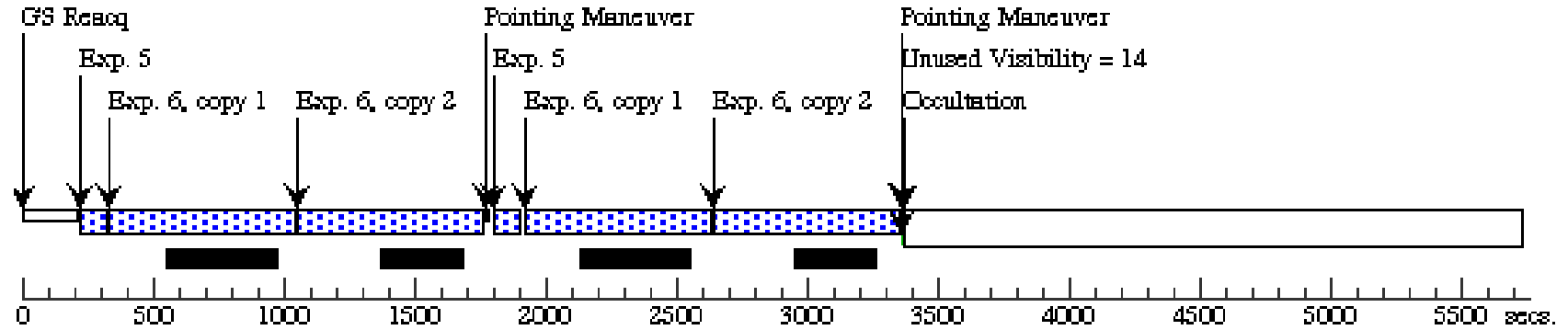
**Orbit 5**

Server Version: 20120604



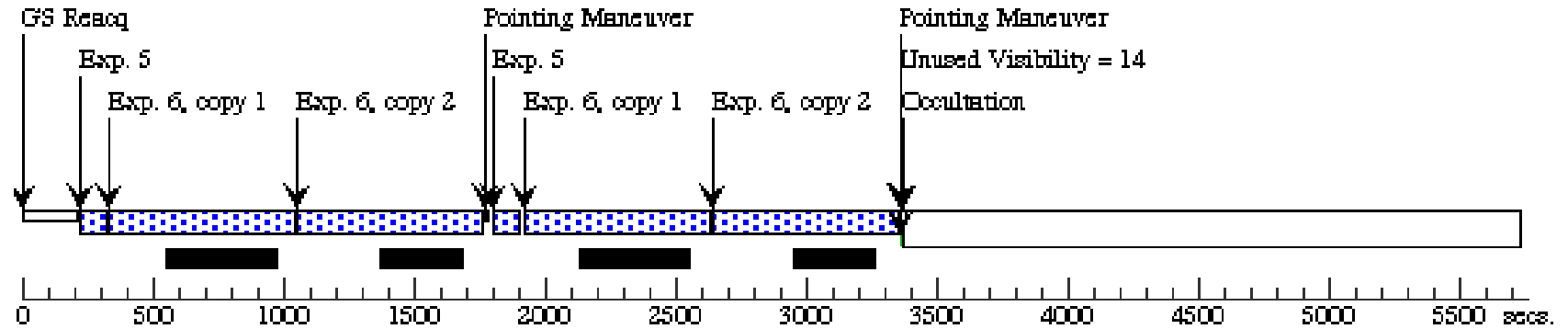
**Orbit 6**

Server Version: 20120604



**Orbit 7**

Server Version: 20120604



**Orbit 8**

Server Version: 20120604

