18427 - Post-periastron Evolution of Ejecta and Jet-precession in the R Aqr Symbiotic System

Cycle: 34, Proposal Category: GO

(UV Initiative)

(Availability Mode: SUPPORTED)

INVESTIGATORS

Name	*Institution*
Dr. Margarita Karovska (PI) (Contact)	**Smithsonian Institution Astrophysical Observatory**
Mr. Warren J. Hack (CoI)	Eureka Scientific Inc.

VISITS

Visit	*Targets used in Visit*	*Configurations used in Visit*	*Orbits Used*	*Last Orbit Planner Run*	*OP Current with Visit?*
01	(1) V-R-AQR	WFC3/UVIS	3	07-Aug-2026 16:00:16.0	yes
02	(1) V-R-AQR	WFC3/UVIS	3	07-Aug-2026 16:00:18.0	yes

6 Total Orbits Used

ABSTRACT

We propose HST/WFC3 observations of the interacting symbiotic system R Aqr, as a followup to the HST archival observations obtained during the recent periastron (with the next periastron expected in about 40 years). Our principal goal is to use the HST unique high-angular resolution UV-optical imaging capability to obtain a detailed post-periastron time-lapse study of the new ejecta and jet/counter-jet propagation, and especially of the jet evolution and precession, at scales close to the binary itself, about 5 AU, to the extended jet-interaction region within 4000 AU from the central binary. The results will have a great impact on the understanding of other wind accreting, jet-producing systems (e.g., interacting binaries, YSOs, PN, AGN), whose close accreting and jet-forming environments cannot be currently resolved.

OBSERVING DESCRIPTION

We request a total of 6 orbits, in 2 visits, scheduled within a couple of weeks from each other. The HST high-angular resolution in the spectral regions (filters) that we selected is critical for achieving the science goals of this project. It is very important to have the images at different filters obtained close in time because the R Aqr periastron related outburst and jet structures evolve rapidly, The visits need to be scheduled as close together as possible to keep the orientation as similar as possible due to the HST orbit. This will minimize the errors in combining the exposures and allow us to recover the highest angular-resolution possible to study the origin of the jet of this active system.

We also prefer that the observations are scheduled during Spring-Summer 2027 when the Mira is in the vicinity of (or at) its optical minimum (June-July 2027). The primary component should have a magnitude of V less than 10.5 mag based on the 2023-2026 light curves. This period around the Mira-star minimum starts roughly in April-2027 and goes through September 2027. This will allow the secondary and faint emission components in the core of this system to remain visible without the effects of saturation from the primary.

The variable nature of the emission from R Aqr will require us to monitor the light curve and spectra closely, using ground based photometry and spectroscopy. Depending on when the observations are scheduled, we may need to adjust the exposures accordingly; specifically, in the month before the actual observations are taken.

We plan to carry out most of the HST WFC3/UVIS imaging of R Aqr using the 4-point dither mode in several filters centered on spectral lines and the nearby continuum. This approach will allow us to reach 0.025"/pixel, and will also assist in cosmic ray removal. Combining the dithered images will result in improvement of the sampling of the PSF and will allow us to further enhance the (nominal 0.04") resolution using deconvolution techniques such as Richardson-Lucy or EMC2 reaching 0.025". This will nearly double the number of pixels covering the regions of interest. We also plan several long exposures to image the fainter outer lobes (about 20 arcseconds from the center) and determine their morphology and evolution when compared to the archival HST observations in the past decade. Most of the selected filters were used previously, including in the 2023 WFC3/UVIS observations. This will allow direct comparison and study of the dynamical evolution and proper motions of individual structures (inner jet, knots and blobs, outburst structures etc.).

The images obtained in the spectral lines will provide information on the ionization state, temperature, and density of the gas. The full list of filters we plan to use can be found in the original Phase 1 proposal description. The F343N filter, for example, will provide the [NeV] line intensity and indicate whether temperatures significantly higher than 10^5 K are present. The Mg IIλ2800\AA\ line has a resonant scattering

component and will provide information on the ionization state of the gas. The [OII]λ3726\AA\ line serves as a density indicator. Furthermore, the [SII]λ6731\AA/Hα ratio will allow us to identify shocked vs. ionized gas emission. The [O III]4363\AA/5007\AA\ ratio gives the temperature which further constrains the shock speed and the ionizing spectrum. The F658N filter will provide an estimate of the [NII] emission and will allow us to calculate the [S II]/[N II] ratio, while also providing density diagnostics where the ratio gets suppressed in the inner regions of R Aqr. The Hα/Hβ ratio will map the intrinsic reddening, i.e. dust regions/shells along the jet and counter-jet, and perpendicularly to the jet (eg, in the orbital plane).

The exposure times used in this proposal are based on the online WFC3 ETC calculations as verified by the 2023 WFC3 observations of R Aqr. We optimize the efficiency of the observing time by using subarray readouts (1024x1024 readout) to minimize the overheads, while still providing a >=40"x 40" field of view. Our observations also include post-flash exposure in order to partially remediate the effects of charge-transfer inefficiency due to the age of the detector.
This proposal was generated using the latest APT based on the desired exposure times to avoid saturation and on the use of dither patterns, and makes the most efficient use of the observing time.

A reduced gyro mode will not have any significant impact as long as the target is in the HST field-of-regard when the observations need to be taken. This will not require any explicit roll constraints for our observations.

Visit

Proposal 18427, Visit 01 Fri Aug 07 20:00:19 GMT 2026

Diagnostic Status: No Diagnostics

Scientific Instruments: WFC3/UVIS

Special Requirements: BETWEEN 01-MAR-2027:00:00:00 AND 01-AUG-2027:00:00:00

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(2)	Pattern Type=SPIRAL	Coordinate Frame=POS-TARG		(1), (2), (3), (4), (5), (6), (7), (8), (11)
	Purpose=DITHER	Pattern Orientation=46.86		
	Number Of Points=4	Angle Between Sides=		
	Point Spacing=0.145	Center Pattern=false		
	Line Spacing=			

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	V-R-AQR	RA: 23 43 49.4634 (355.9560975d)		V=10+/-3.0	Reference Frame: ICRS
		Dec: -15 17 4.18 (-15.28449d)			
		Equinox: J2000			

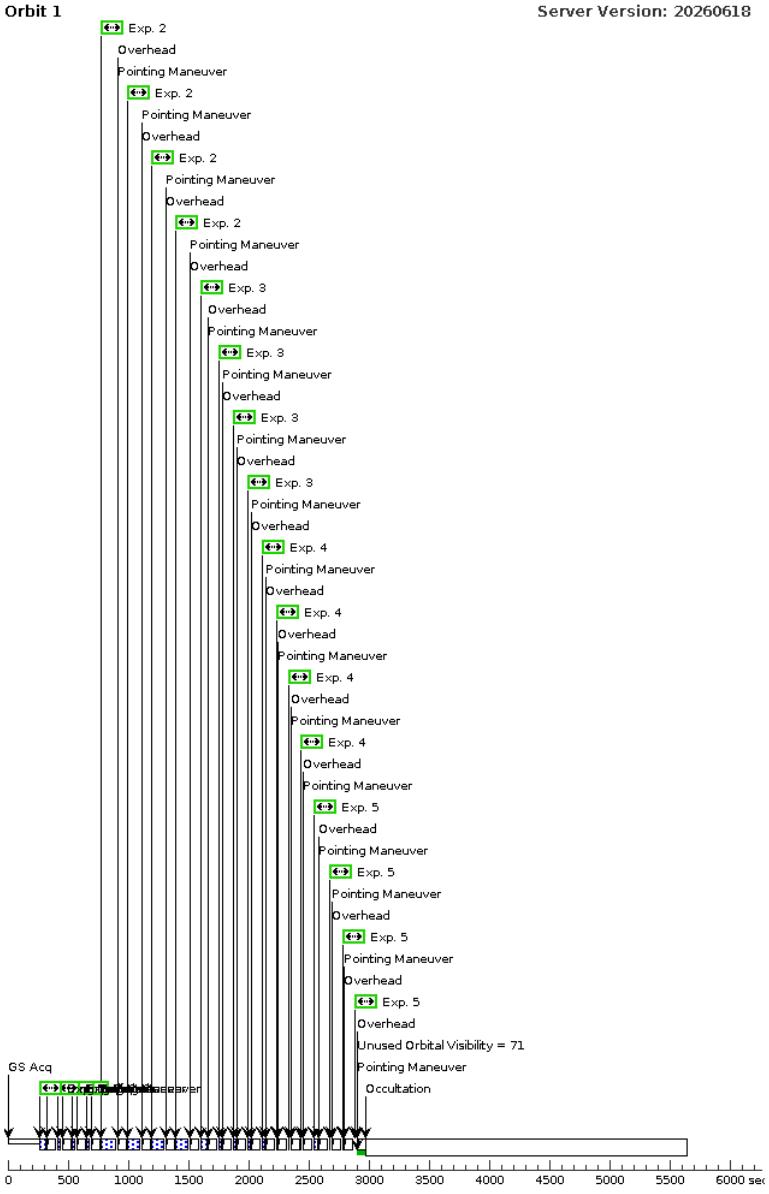
Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[ACCRETION DISK, INTERACTING BINARY, JET, SYMBIOTIC STAR]

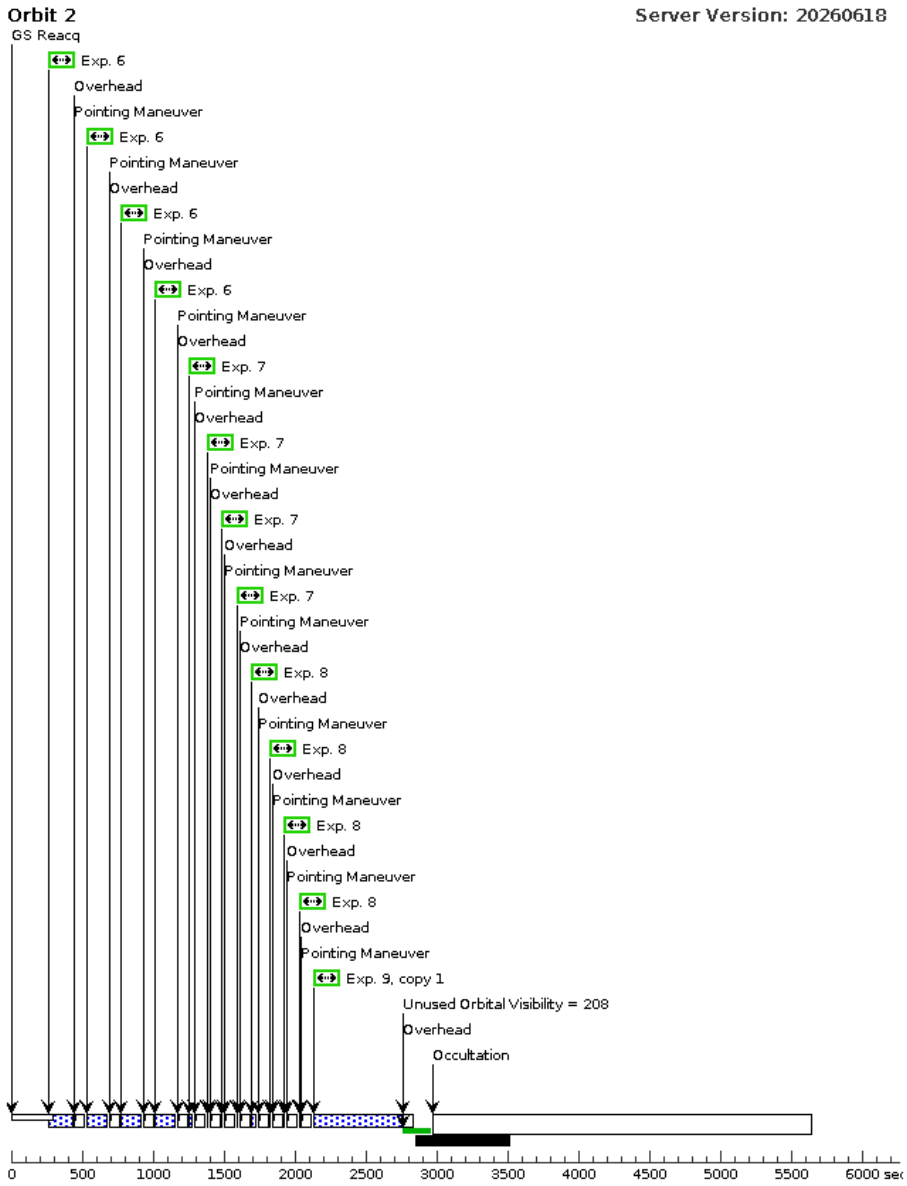
Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	(WFC3UVIS.im.780074)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F502N	FLASH=20		Pattern 2, Exps 1-1 in Visit 01 (2)	20 Secs (80 Secs)	
								[==>(Pattern 1)]	***[1]***
								[==>(Pattern 2)]	
								[==>(Pattern 3)]	
								[==>(Pattern 4)]	
2	(WFC3UVIS.im.832643)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F373N	FLASH=20		Pattern 2, Exps 2-2 in Visit 01 (2)	100 Secs (400 Secs)	
								[==>(Pattern 1)]	***[1]***
								[==>(Pattern 2)]	
								[==>(Pattern 3)]	
								[==>(Pattern 4)]	
3	(WFC3UVIS.im.1720362)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F487N	FLASH=20		Pattern 2, Exps 3-3 in Visit 01 (2)	20 Secs (80 Secs)	
								[==>(Pattern 1)]	***[1]***
								[==>(Pattern 2)]	
								[==>(Pattern 3)]	
								[==>(Pattern 4)]	
4	(WFC3UVIS.im.780078)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F656N	FLASH=20		Pattern 2, Exps 4-4 in Visit 01 (2)	2 Secs (8 Secs)	
								[==>(Pattern 1)]	***[1]***
								[==>(Pattern 2)]	
								[==>(Pattern 3)]	
								[==>(Pattern 4)]	
5	(WFC3UVIS.im.780140)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F658N	FLASH=20		Pattern 2, Exps 5-5 in Visit 01 (2)	5 Secs (20 Secs)	
								[==>(Pattern 1)]	***[1]***
								[==>(Pattern 2)]	
								[==>(Pattern 3)]	
								[==>(Pattern 4)]	
6	(WFC3UVIS.im.832644)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F280N	FLASH=20		Pattern 2, Exps 6-6 in Visit 01 (2)	140 Secs (560 Secs)	
								[==>(Pattern 1)]	***[2]***
								[==>(Pattern 2)]	
								[==>(Pattern 3)]	
								[==>(Pattern 4)]	
7	(WFC3UVIS.im.780079)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F673N	FLASH=20		Pattern 2, Exps 7-7 in Visit 01 (2)	4 Secs (16 Secs)	
								[==>(Pattern 1)]	***[2]***
								[==>(Pattern 2)]	
								[==>(Pattern 3)]	
								[==>(Pattern 4)]	
8	(WFC3UVIS.im.780074)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F547M	FLASH=20		Pattern 2, Exps 8-8 in Visit 01 (2)	1 Secs (4 Secs)	
								[==>(Pattern 1)]	***[2]***
								[==>(Pattern 2)]	
								[==>(Pattern 3)]	
								[==>(Pattern 4)]	
9	(WFC3UVIS.im.780074)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F280N	FLASH=20			600 Secs X 2 (1200 Secs)	
								[==>(Copy 1)]	***[2]***
								[==>(Copy 2)]	***[3]***

	10	(WFC3UVIS.im.780074)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F502N	FLASH=20		500 Secs X 2 (1000 Secs) *[==>(Copy 1)]* *[==>(Copy 2)]*	 ***[3]***
	11	(WFC3UVIS.im.1720366)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F343N	FLASH=20	Pattern 2, Exps 11-11 in Visit 01 (2)	90 Secs (360 Secs) *[==>(Pattern 1)]* *[==>(Pattern 2)]* *[==>(Pattern 3)]* *[==>(Pattern 4)]*	 ***[3]***

Orbit Structure

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Pointing Maneuver
Exp. 6
Pointing Maneuver
Overhead
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Pointing Maneuver
Overhead
Exp. 6
Pointing Maneuver
Overhead
Exp. 7
Pointing Maneuver
Overhead
Exp. 7
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Exp. 7
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Exp. 7
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Overhead
Exp. 8
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Exp. 8
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Pointing Maneuver
Exp. 8
Overhead
Pointing Maneuver
Exp. 9, copy 1
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Occultation
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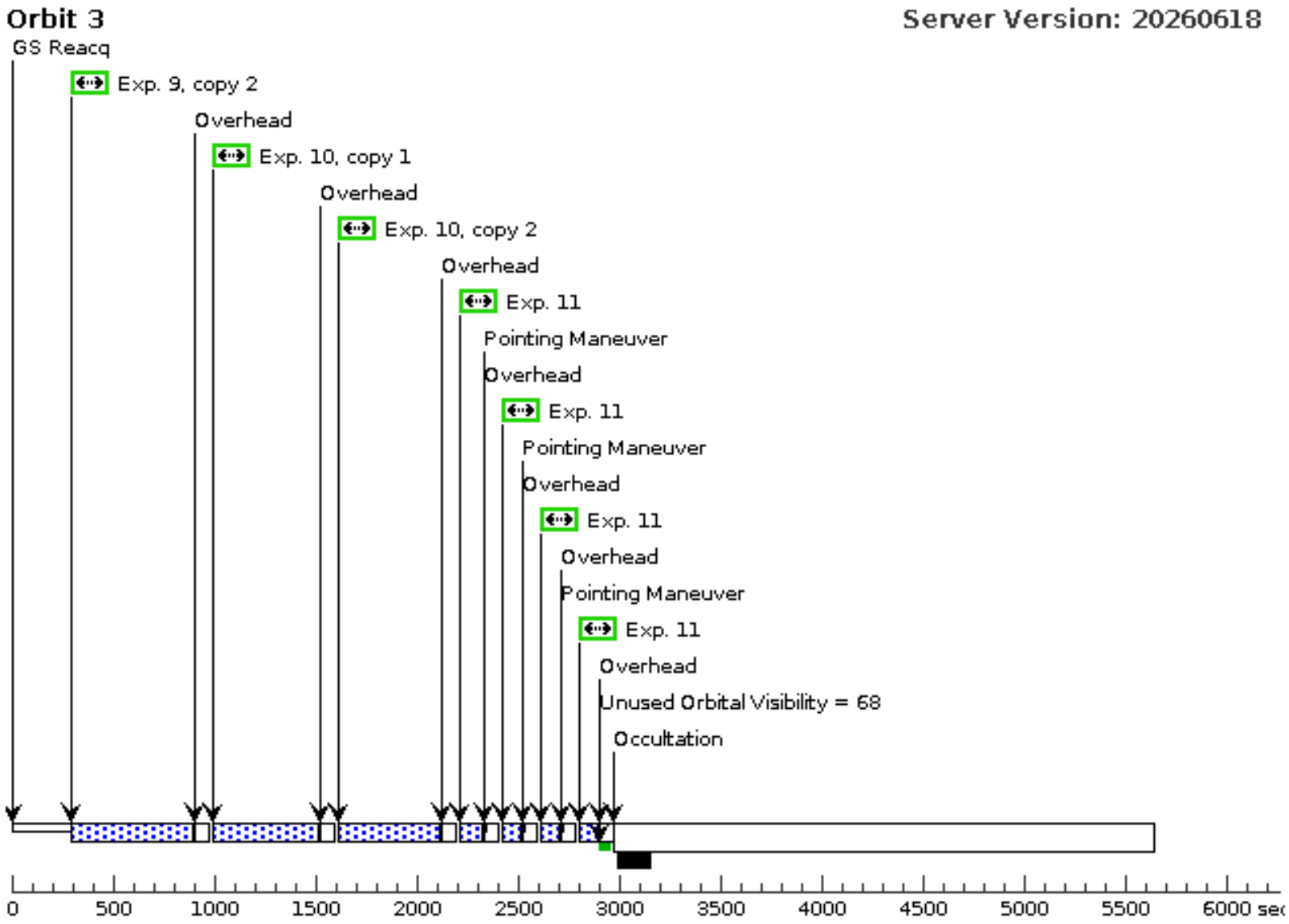
6000 sec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Exp. 10, copy 2
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Exp. 11
Overhead
Unused Orbital Visibility = 68
Occultation
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Visit

Proposal 18427, Visit 02 Fri Aug 07 20:00:19 GMT 2026

Diagnostic Status: Warning

Scientific Instruments: WFC3/UVIS

Special Requirements: AFTER 01 BY 0 H TO 14 D

Diagnostics

(Exposure 7 (Pattern 2, Exps 7-7 in Visit 02)) Warning (Form): POS TARG & PATTERN should be used carefully with WFC3 quad filters to avoid placing the target on the vignetted part of the field of view or moving it to another quadrant.

Patterns

#	Primary Pattern		Secondary Pattern	Exposures
(2)	Pattern Type=SPIRAL	Coordinate Frame=POS-TARG		(2-4), (7)
	Purpose=DITHER	Pattern Orientation=46.86		
	Number Of Points=4	Angle Between Sides=		
	Point Spacing=0.145	Center Pattern=false		
	Line Spacing=			

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous
(1)	V-R-AQR	RA: 23 43 49.4634 (355.9560975d)		V=10+/-3.0	Reference Frame: ICRS
		Dec: -15 17 4.18 (-15.28449d)			
		Equinox: J2000			

Comments: This object was generated by the targetselector and retrieved from the SIMBAD database.
Category=STAR
Description=[ACCRETION DISK, INTERACTING BINARY, JET, SYMBIOTIC STAR]

Exposures

#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit
1	(WFC3UVIS.im.780074)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F656N	FLASH=20			575 Secs X 2 (1150 Secs)	
								[==>(Copy 1)]	***[1]***
								[==>(Copy 2)]	
2	(WFC3UVIS.im.780079)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F763M	FLASH=20		Pattern 2, Exps 2-4 in Visit 02 (2)	1 Secs (4 Secs)	
								[==>(Pattern 1)]	
								[==>(Pattern 2)]	***[1]***
								[==>(Pattern 3)]	
								[==>(Pattern 4)]	***[2]***
3	(WFC3UVIS.im.780075)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F336W	FLASH=20		Pattern 2, Exps 2-4 in Visit 02 (2)	20 Secs (80 Secs)	
								[==>(Pattern 1)]	***[1]***
								[==>(Pattern 2)]	
								[==>(Pattern 3)]	***[2]***
								[==>(Pattern 4)]	
4	(WFC3UVIS.im.780140)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F275W	FLASH=20		Pattern 2, Exps 2-4 in Visit 02 (2)	240 Secs (960 Secs)	
								[==>(Pattern 1)]	***[1]***
								[==>(Pattern 2)]	
								[==>(Pattern 3)]	***[2]***
								[==>(Pattern 4)]	
5	(WFC3UVIS.im.780074)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F673N	FLASH=20			620 Secs X 2 (1240 Secs)	
								[==>(Copy 1)]	***[2]***
								[==>(Copy 2)]	
6	(WFC3UVIS.im.832644)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS2-C1K1C-SUB	F373N	FLASH=20			600 Secs X 2 (1200 Secs)	
								[==>(Copy 1)]	***[3]***
								[==>(Copy 2)]	
7	(WFC3UVIS.im.1720362)	(1) V-R-AQR	WFC3/UVIS, ACCUM, UVIS-QUAD-SUB	FQ437N	FLASH=20		Pattern 2, Exps 7-7 in Visit 02 (2)	160 Secs (640 Secs)	
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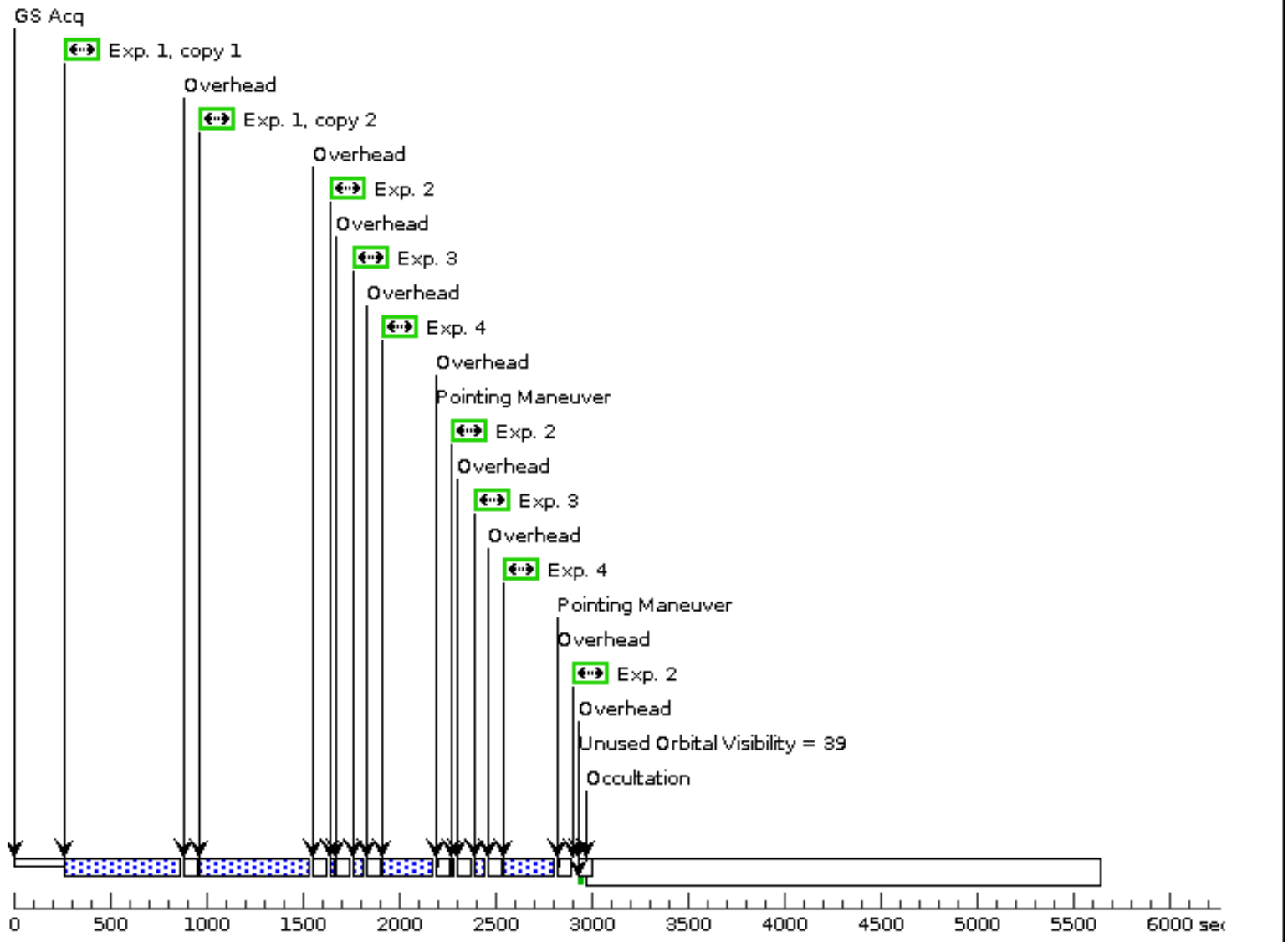
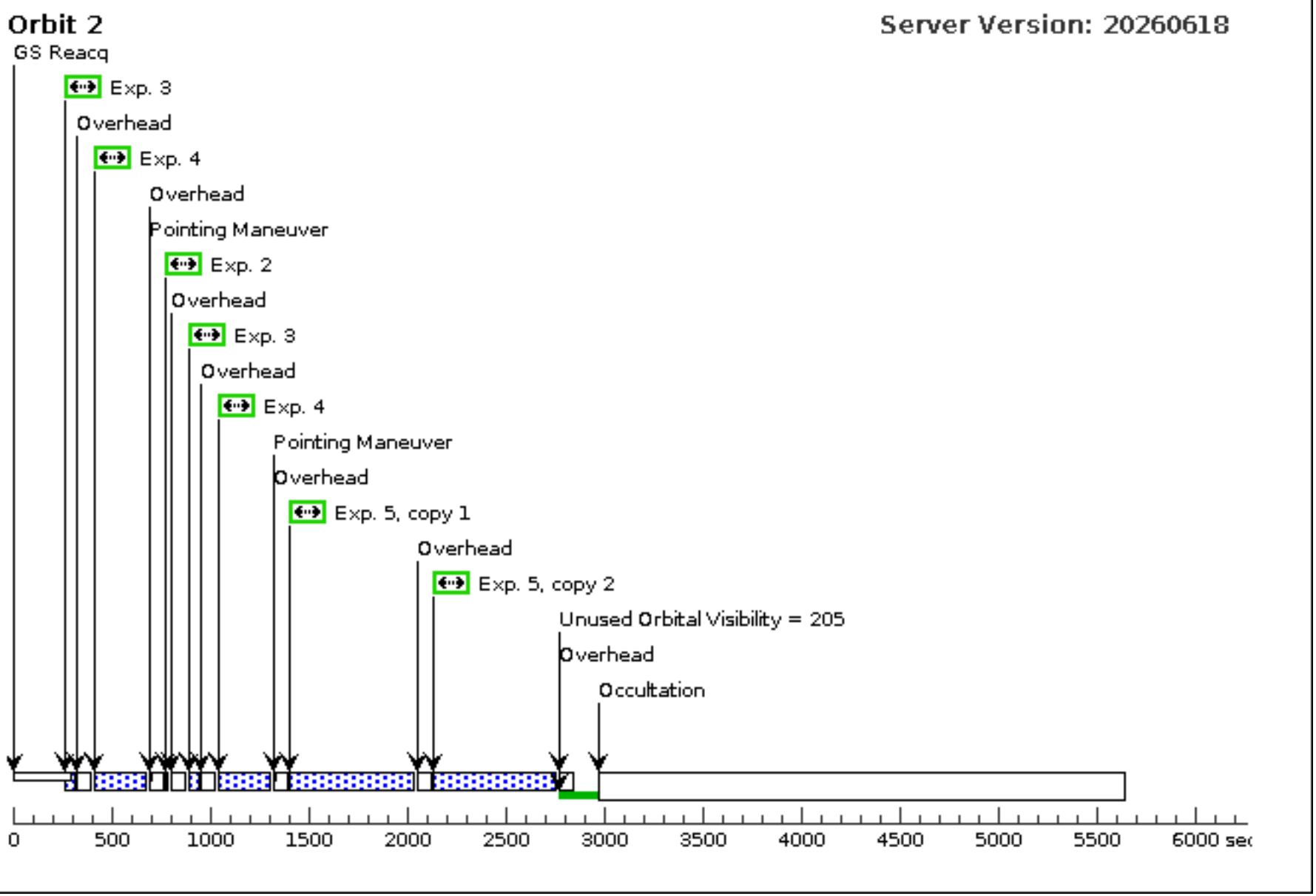
Orbit Structure

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Exp. 4
Overhead
Pointing Maneuver
Exp. 2
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Exp. 3
Overhead
Exp. 4
Pointing Maneuver
Overhead
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Overhead
Exp. 5, copy 2
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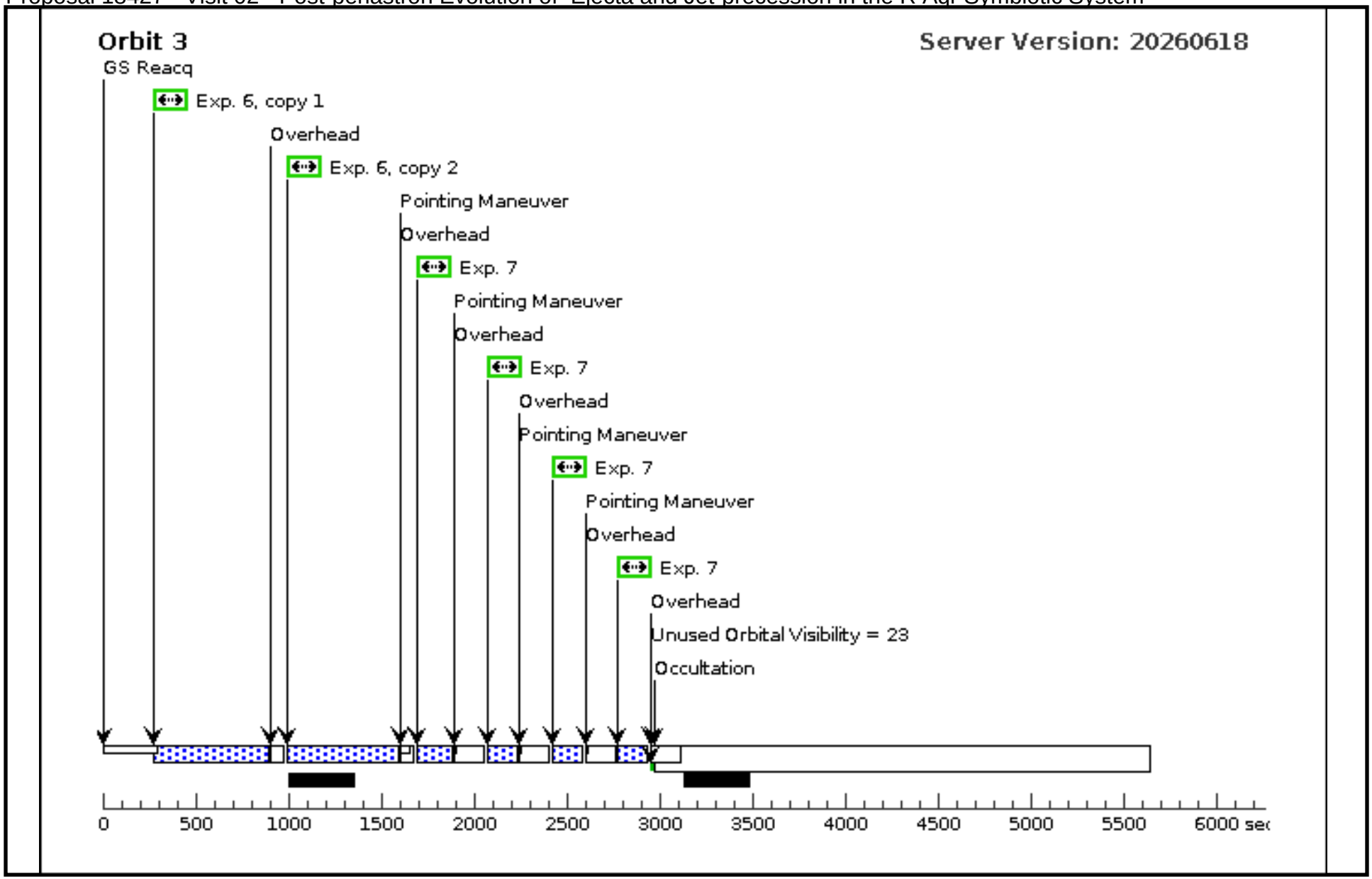
6000 sec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Overhead
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Pointing Maneuver
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Pointing Maneuver
Overhead
Exp. 7
Overhead
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6000 sec