TECHNICAL REPORT

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Title: An Assessment of JWST's Ability to Observe Bright Objects in the Solar System		Doc #: JWST-STScI-001375, SM-12 Date: 17 March 2008 Rev:	
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1.0 Abstract

The planetary astronomy community and NASA headquarters would like to understand JWST's ability to observe nearby, bright solar system planets because moving target capabilities have been approved and JWST instruments may suffer from saturation on these bright planets. We evaluated the capabilities of NIRCam, NIRspec, MIRI and FGS-TFI to determine if they can observe Mars, Saturn, Jupiter, Uranus, Neptune and Pluto without saturating. We have found that observing modes with the Webb Instruments do indeed exist to observe all the outer planets without saturating. However, these modes are limited in their wavelength range, and hence science capabilities. In some cases, new observing modes will be required to support the observations of these bright planets. Additional studies will be required to determine appropriate operational procedures for observing these bright planets.

2.0 Introduction

The JWST project has recently been funded to incorporate moving targets into its capabilities. The science drivers for the JWST solar system capability are the smaller bodies (KBOs and comets) which will require high sensitivity. However, the planetary astronomy community and NASA headquarters would like to understand JWST's ability to observe nearby, bright solar system objects given that JWST instruments may suffer from saturation. This study focuses on the simple question can we observe any of the planets in the outer solar system: Mars, Jupiter, Saturn in particular? If yes, what are the observing configurations that permit observations without saturation? We note that the inner planetary bodies (Mercury, Venus, Moon and Earth) are off limits to the solar avoidance zone requirements of the mission. The outer planets represent the most challenging bright object cases Webb will encounter. This study is a feasibility study of these bright object cases, not a detailed report on the type of science to be performed on planetary work. This study also does not outline or investigate the operations concept for carrying out solar system planetary studies and a future operations concept study may uncover additional constraints on such bright object observations.

The planet brightnesses that we adopted for the study are listed in the following two tables. The numbers in Table 2-1 (5 planets + pluto) are from a reflected solar spectrum only. The 2 µm numbers agree fairly well with actual ISO measurements for Mars, Jupiter, and Saturn (Table 2-2). The 10 µm fluxes in Table 2-1 certainly underestimate the actual fluxes because the thermal component is not included. The reflected solar flux was computed using the parameters in the table (radii, albedos, etc). The Pluto brightness is for full disk, not surface brightness. The reflected solar flux model assumed Earth-planet and Sun-planet distances are equal (i.e. planet is near quadrature – good for JWST observation).

Table 2-1: Estimated Surface Brightness of Reflected Solar Flux for Outer Planets and Pluto

Planet	Distance AU	Radius (km)	albedo	2 µm (Jy/□″)	4µm (Jy/□″)	10µm (Jy/□″)	Diam (arcsec)	Area ($arcsec^2$)
Mars	1.52	3397	0.2	101	30	5.4	6.2	30
Jupiter	5.2	71492	0.52	22	6.6	1.2	38	1129
Saturn	9.5	60268	0.47	6.0	1.8	0.3	17	238
Uranus	19.2	25559	0.51	1.6	0.47	0.09	3.6	10
Neptune	30.1	24766	0.41	0.5	0.16	0.03	2.2	4
Pluto	33.0	1150	0.55	5.5 mJy	1.6	0.3	0.05	0.009

Table 2-2: Full Disk IR Brightness Estimates for Mars, Jupiter, and Saturn

Wavelength	Mars		Jupiter		Saturn	
µm	Jy	Jy/□″	Jy	Jy/□″	Jy	Jy/□″
2	2600	81				
2.7-3	400	12.5	8000	7	330	1.5
4	1100	34				
5-6	12000	375	20000	18	280	1.3
10	90000	2810	40000	35	330	1.5
18	150000	4680	126000	112	1100	4.6

The fluxes in Table 2-2 are based on data from ISO and hence include the thermal emission from the planet. For Mars, we assume a diameter = 6.4 arcsec and measurements from Lellouch et al. (2000). The Jupiter observations used a 14x20 arcsec slit and we assumed a Jupiter diameter of 38 arcsec. Observed Jupiter fluxes were corrected to full disk by factor 4X (Encrenaz et al. 1999). Saturn used the same slit and we adopt a Saturn diameter of 17 arcsec. Full disk correction is ~1.1X (Encrenaz et al.

1999; de Graauw et al. 1997). We note that the angular diameters of the planets will vary over the course of the Earth's and planet's orbits. Mars, for example, can get as large as 20 arcsecond at opposition providing a potentially more challenging case. While noting such limitations of this study, we will limit the analysis to the numbers in Table 2-1 and Table 2-2.

Observing Bright Objects with JWST Science Instruments

3.0 NIRCam

3.1 Method

The planet is assumed to be positioned at the edges of the NIRCAM field, centered symmetrically across two readout strips to maximize the readout speed (Fig. 1).
The planet is enclosed in a square subarray with sides which are twice the diameter of the planet. With the exception of Jupiter, which marginally falls on 3 columns in the short wavelength channel, this is generally ok. "SUBARRAY (pix)" is the number of pixels in the square subarray. Half of SUBARRY is the number of pixels falling on each quadrant. This drives the readout time.

The readout time is assumed to be 20μs for each pixel, corresponding to 2 read/pixel. This is the minimum required to perform correlated double sampling. The number of pixels per quadrant multiplied by 20μs provides the minimum readout time.

During the readout, the signal will tend to saturate. We want the Saturation time to be longer than the readout time of the image.

The number of pixels that can be read before saturation (READ TO SAT), in other words, must be larger than SUBARRAY/2 pixels to be read. If this is not the case, we may still consider that a certain number of rows can be read before saturation. This envisions a "read by strip" mode where the subarray is reset and then a group of rows is read, shifting each time the location of the group. This mode is not foreseen for NIRCAM but could be implemented if necessary. The number of rows that can be read before reaching saturation is the ROWS TO SAT value.

In general, if the readout time is longer than the saturation time, the planet cannot be observed with a single shot in subarray mode. These cases are indicated in RED. Viceversa, if the saturation time is longer than the readout time, the planet can be observed (marked in GREEN). Values within ~20% are marked with ORANGE color.

3.2 Assumptions

I have considered two wavelengths of reference, 2 micron and 4 micron. The filters used are a broad, medium and narrow band centered in the vicinity of the two reference wavelengths, are assumed to be representative of the entire filter set in the short wavelength (SW) and long wavelength (LW) channels, respectively.
Other assumptions are

  1) NIRCAM sampling = 0.0317″/pix (SW); 0.0648″/pix (LW), corresponding to 995.13pix/□″ (SW) and 238.15/□″ (LW)
  2) Use 10σ sensitivity from Marcia spreadsheet.
  3) Saturation at 72,000 electrons
  4) The subarray is assumed to be square and with size double than the diameter of the planet. The minimal size is 64x64 pixels. Note that whereas a “generic” subarray size is not currently offered, nothing in the hardware prevents this possibility.

5) Data on the surface brightness and diameter of the planets are from Table 2-1 and Table 2-2.

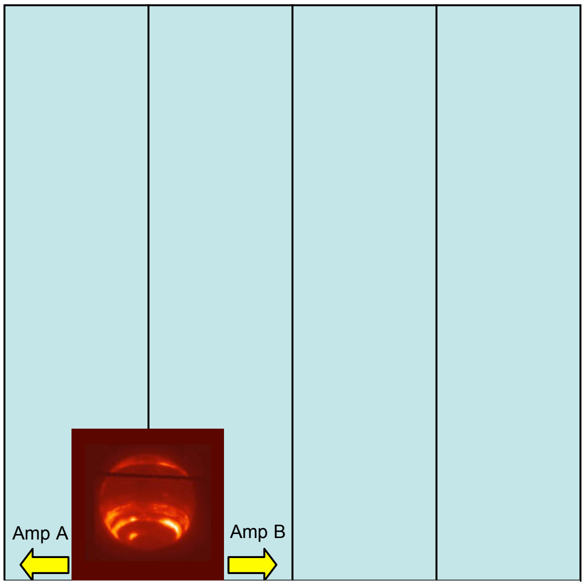

Figure 1

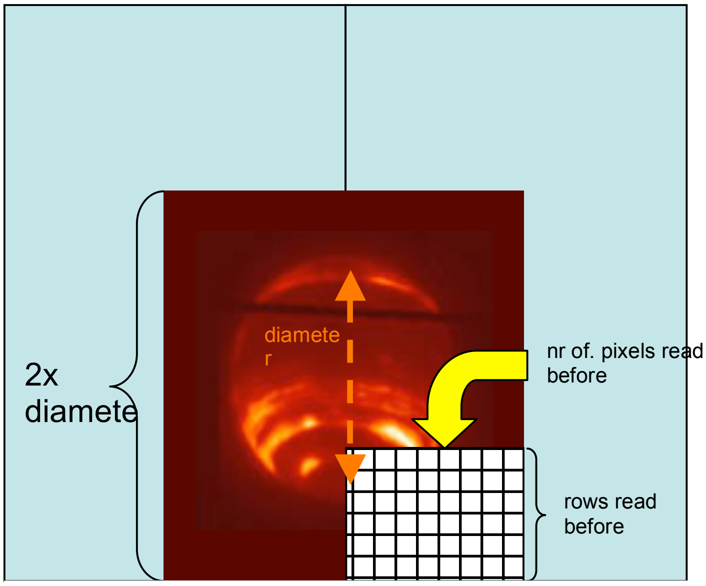

Figure 2

3.3 Results

The following tables illustrate the various cases. Uranus (Table 3-4), Neptune (Table 3-6) and Pluto (Table 3-6) can be observed with NIRCAM in broad, medium and narrow band filters. Mars (Table 3-1) and Saturn (Table 3-3) can be observed with NIRCAM in the LW channel using narrow band filters. Saturn is at the limit in the SW channel with narrow filter and LW channel with mid filter. All other cases require Mars or Saturn to be scanned in a new specialized "strip mode". Jupiter (Table 3-2) cannot be observed with any currently conceived subarray mode and would required the new "strip mode." Given that these bright planets are not science drivers for JWST, the inclusion of such a "strip mode," would seem unwarranted.

Table 3-1: NIRCam Results for Mars

Mars	2µm+F200W	2µm+F210M	2µm+F212N	4µm+F444W	4µm+F410M	4µm+F405N
Flux(Jy/_″)	101			30		
Flux(Jy/pix)	0.10			0.03		
Counts/s	4425134	1471661	121793	1208883	473303	42205
Sat.time (s)	0.016	0.049	0.591	0.060	0.152	1.706
Diameter (arcsec)	6.2					
Diameter (pix)	196			96		
1/2 subarray (pix)	76506			18309		
Readout time (s)	1.53	1.53	1.53	0.37	0.37	0.37
Reads to sat (pix)	813.5	2446.2	29558.4	2978.0	7606.1	85297.2
rows to sat (rows)	4.2	12.5	151.1	31.1	79.5	891.5

Table 3-2: NIRCam Results for Jupiter

Jupiter	2µm+F200W	2µm+F210M	2µm+F212N	4µm+F444W	4µm+F410M	4µm+F405N
Flux(Jy/_″)	22			6.6		
Flux(Jy/pix)	0.02			0.01		
Counts/s	963890	320560	26529	265954	104127	9285
Sat.time (s)	0.075	0.225	2.714	0.271	0.691	7.754
Diameter (arcsec)	38.0					
Diameter (pix)	1199			586		
1/2 subarray (pix)	2873946			687776		
Readout time (s)	57.48	57.48	57.48	13.76	13.76	13.76
Reads to sat (pix)	3734.9	11230.4	135700.1	13536.2	34573.3	387714.5
rows to sat (rows)	3.1	9.4	113.2	23.1	59.0	661.2

Table 3-3: NIRCam Results for Saturn

Saturn	2µm+F200W	2µm+F210M	2µm+F212N	4µm+F444W	4µm+F410M	4µm+F405N
Flux(Jy/_″)	6			1.8		
Flux(Jy/pix)	0.01			1.81E-03		
Counts/s	262879	87425	7235	72533	28398	2532
Sat.time (s)	0.274	0.824	9.951	0.993	2.535	28.432
Diameter (arcsec)	17.0					
Diameter (pix)	536			262		
1/2 subarray (pix)	575187			137651		
Readout time (s)	11.50	11.50	11.50	2.75	2.75	2.75
Reads to sat (pix)	13694.5	41178.0	497566.9	49632.6	126768.6	1421619.7
rows to sat (rows)	25.5	76.8	927.8	189.2	483.2	5418.9

Table 3-4: NIRCam Results for Uranus

Uranus	2µm+F200W	2µm+F210M	2µm+F212N	4µm+F444W	4µm+F410M	4µm+F405N
Flux(Jy/_″)	1.6			0.47		
Flux(Jy/pix)	1.61E-03			4.72E-04		
Counts/s	70101	23313	1929	18939	7415	661
Sat.time (s)	1.027	3.088	37.318	3.802	9.710	108.890
Diameter (arcsec)	3.6					
Diameter (pix)	114			56		
1/2 subarray (pix)	25794			6173		
Readout time (s)	0.52	0.52	0.52	0.12	0.12	0.12
Reads to sat (pix)	51354.4	154417.3	1865875.9	190082.3	485496.9	5444501.0
rows to sat (rows)	452.2	1359.7	16430.1	3421.5	8738.9	98001.0

Table 3-5: NIRcam Results for Neptune

Neptune	2µm+F200W	2µm+F210M	2µm+F212N	4µm+F444W	4µm+F410M	4µm+F405N
Flux(Jy/_″)	0.5			0.16		
Flux(Jy/pix)	5.02E-04			1.61E-04		
Counts/s	21907	7285	603	6447	2524	225
Sat.time (s)	3.287	9.883	119.416	11.167	28.523	319.864
Diameter (arcsec)	2.2					
Diameter (pix)	69			34		
1/2 subarray (pix)	9633			8192		
Readout time (s)	0.19	0.19	0.19	0.16	0.16	0.16
Reads to sat (pix)	164334.0	494135.4	5970802.8	558366.8	1426147.2	15993221.7
rows to sat (rows)	2367.9	7120.0	86033.8	16446.4	42006.5	471073.1

Table 3-6: NIRCam Results for Pluto

Pluto	2µm+F200W	2µm+F210M	2µm+F212N	4µm+F444W	4µm+F410M	4µm+F405N
Flux(Jy/_″)	0.28			0.081		
Flux(Jy/pix)	2.81E-04			8.19E-05		
Counts/s	12273	4081	338	3284	1286	115
Sat.time (s)	5.867	17.641	213.157	21.927	56.005	628.052
Diameter (arcsec)	0.050					
Diameter (pix)	2			1		
1/2 subarray (pix)	8192			8192		
Readout time (s)	1.64E-01	1.64E-01	1.64E-01	1.64E-01	1.64E-01	1.64E-01
Reads to sat (pix)	293335.5	882029.6	10657858.0	1096350.7	2800233.4	31402617.4
rows to sat (rows)	185974.7	559206.8	6757082.0	1420870.5	3629102.5	40697792.2

- Pluto brightness (Jy/square arcsec) has been derived from the full disk estimate (5.5mJy @ 2mic, 1.6mJy @ 4mic).
- Subarray size is 64x64 pixels at 2 micron and 4 micron

4.0 NIRSpec

Point source, bright source limits for NIRSpec has been estimated by Beck and Valenti from a technical note by Jakobsen (10 September 2007, "Observing Eclipsing Exoplanets with NIRSpec, Issue 1.0). We estimate a surface brightness limit by dividing by an estimated point spread function area as follows. The point source flux at 2.4 μm brightness limits are divided by the pixel area. The pixel size is 100 mas and hence the area is 0.01 square arcseconds. If we assume a Gaussian PSF and a 6 m diameter telescope, the PSF at 2.4 μm has a FWHM of 83 mas which gives a Gaussian area of 7.71 x10-3 square arcseconds which is smaller than the pixel area. Thus we use the pixel area instead of the PSF area by which to so use the pixel area. Table 4-1 below shows the point source and surface brightness limits for NIRSpec at 2.4 μm.

Table 4-1: NIRSpec Bright Object Limits: Point Source and Surface Brightness

Instrument/config	wavelength/ filter	resolution (lambda/delta-lambda)	Point source Flux limit mJy	Surface brightness Jy/□"
NIRSpec: 0.2" slit				
2048x2048	2.4 micron	100	1.4	0.1
2048x2048	2.4 micron	1000	25.8	2.6
2048x2048	2.4 micron	2700	78.0	7.8
2048x64	2.4 micron	100	37.3	3.7
2048x64	2.4 micron	1000	591.6	59.2
2048x64	2.4 micron	2700	2355.0	235.5
128x8	2.4 micron	100	5915.6	591.6
128x8	2.4 micron	1000	93756.2	9375.6
128x8	2.4 micron	2700	235504.9	23550.5

We compare the surface brightness flux limits in Table 4-1 to the surface brightnesses of the planets in the introduction at 2 microns (Table 2-1). The results of this comparison are summarized in Table 4-2. We find that all of the outer planets can be observed with some observing mode of NIRSpec.

Table 4-2: NIRSpec Results for all Planets

Instrument/config	wavelength/ filter	resolution (lambda/delta-lambda)	Planets
NIRSpec: 0.2" slit			
2048x2048	2.4 micron	100	Pluto
2048x2048	2.4 micron	1000	Pluto, Neptune, Uranus
2048x2048	2.4 micron	2700	Saturn, Uranus, Neptune, Pluto
2048x64	2.4 micron	100	Pluto, Neptune, Uranus
2048x64	2.4 micron	1000	Jupiter,Saturn, Uranus,Neptune, Pluto
2048x64	2.4 micron	2700	Mars, Jupiter, Saturn, Uranus, Neptune, Pluto
128x8	2.4 micron	100	Mars, Jupiter, Saturn, Uranus, Neptune, Pluto
128x8	2.4 micron	1000	Mars, Jupiter, Saturn, Uranus, Neptune, Pluto
128x8	2.4 micron	2700	Mars, Jupiter, Saturn, Uranus, Neptune, Pluto

5.0 MIRI

The MIRI Imager has 8 standard filters plus a neutral density filter (reduction 0.002 reduction). The saturation limits and brightness of Mars, Jupiter, and Saturn are given in Table 5-1 and are taken from G. Rieke's radiation model spreadsheet for MIRI assuming a well depth of 200,000 electrons. The saturation limits are given for 6 sec integrations that give 2 frames allowing for a nominal slope to be measured. Only 4 representative filters are listed. For these saturation limits, Mars cannot be observed with any filter. Jupiter and Saturn can only be observed with the neutral density filter. The saturation limits can be increased by a factor of 8 by using 1 frame and the standard 512x512 subarray. This allows for Saturn to be observed at F560W and F1000W, but not at longer wavelengths.

Table 5-1: Saturation limits for MIRI Imager

Filter	Saturation (6 sec) Jy/arcsec^2	Mars Jy/arcsec^2	Jupiter Jy/arcsec^2	Saturn Jy/arcsec^2
F560W	0.218	375(no)	18(no)	1.3(subarray)
F1000W	0.171	2810(no)	35(no)	1.5(subarray?)
F1800W	0.245	4680(no)	112(no)	4.6(no)
FND(13.5um)	102	3628(no)	69(yes)	2.9 (yes)

The MIRI medium resolution spectrometer integral field unit (MRS-IFU) and low resolution spectrometer slit (LRS-Slit) disperse the light of a source and, thus, allows for brighter sources to be observed. The saturation limits and brightness of Mars, Jupiter, and Saturn are given in Table 5-2 and are taken from G. Rieke's radiation model spreadsheet for MIRI assuming a well depth of 200,000 electrons. The saturation limits are given for 6 sec integrations that give 2 frames allowing for a nominal slope to be measured. For these saturation limits, Mars cannot be observed at any wavelength with either MRS-IFU or LRS-Slit. Jupiter can be observed for wavelengths shorter than around 10 microns with the MRS-IFU, but not with the LRS-Slit. Saturn can be observed at all wavelengths with the MRS-IFU and LRS-Slit. The saturation limits can be increased by a factor of 2 by using 1 frame and this increases the wavelengths that Jupiter can be observed with the MRS-IFU to around 14.5 microns.

Table 5-2: Saturation limits for MIRI MRS-IFU/LRS-Slit

Wavelength (micron)	Saturation (6 sec) Jy/arcsec^2	Mars Jy/arcsec^2	Jupiter Jy/arcsec^2	Saturn Jy/arcsec^2
6.4 (MRS-IFU)	63	817(no)	21(yes)	1.3(yes)
9.2 (MRS-IFU)	78	2367(no)	32(yes)	1.5(yes)
14.5 (MRS-IFU)	30	3862(no)	78(1 frame?)	3.2 (yes)
22.5 (MRS-IFU)	34	5731(no)	155(no)	6.3(yes)
7.5 (LRS-Slit)	5.3	1426(no)	25(no)	1.4(yes)

6.0 FGS-TFI

6.1 Bright-Object Capabilities

The Tunable Filter Imager (TFI) has been developed for two primary uses: (a) to provide narrow-band imaging of astronomical objects; and (b) to enable high-contrast imaging of faint objects in the vicinity of a much brighter source. Although the optical design has been optimized to ensure that the TFI is extremely sensitive, imaging of bright objects is supported through the use of subarrays, which can be read more rapidly than the full detector. A standard suite of subarrays has been defined for this purpose.

The TFI also has a neutral density filter (FND) in its Pupil Wheel, which has an "optical density" of 2; i.e., it transmits 1% of the incident light, or, equivalently, provides 5 magnitudes of attenuation. The FND is intended to support coronagraphic target acquisition of bright sources, but is not at present considered to be available for scientific imaging. In particular, there are no plans to calibrate it photometrically.

Table 6-1 lists the fundamental parameters associated with different readout formats for the TFI. Successive columns record the size of the readout region in pixels; the angular size of the region; the time required to read it out (the "frame time", t_f), and the saturation flux for an extended object, F_ν^{sat} at 2μm and 4μm, with and without the FND selected in the Pupil Wheel.

Table 6-1: Properties of the Standard TFI Subarrays

Readout Size	FOV	t_f [s]	F_ν^{sat} [Jy/ arcsec^2]		F_ν^{sat} w/ FND [Jy/ arcsec^2]	
		Note a)	2 μm	4 μm	2 μm	4 μm
2048 × 2048	2.2′ × 2.2′	10.50	0.54	0.44	53.51	43.75
512 × 512	33.3″ × 33.3″	2.621	2.14	1.78	214.05	174.98
256 × 256	16.6″ × 16.6″	0.655	8.56	6.99	856.20	699.94
128 × 128	8.3″ × 8.3″	0.164	34.25	28.00	3,424.81	2,799.75
64 × 64	4.2″ × 4.2″	0.041	136.99	111.99	1.37×10^4	1.12×10^4
32 × 32	2.1″ × 2.1″	0.010	547.96	447.96	5.48×10^4	4.48×10^4

a) Assuming pixels are clocked at 100 kHz through (1,4) amplifier(s) for (subarrays, full-frame).

The key assumptions that go into these calculations are:

- A conservative estimate (50,000 electrons) of the pixel "full well" depth is adopted.
- The TFIRAPID MULTIACCUM pattern with `NGROUP` = 2 is used, so that the effective exposure time is $2t_f$. This is equivalent to readout via the correlated double sampling (CDS) scheme.

- The bandwidth of the tunable filters is ν/100.
- The throughput of the OTE and TFI is given by the spreadsheet TF_Sensitivity_June07.xls.

6.2 Observing Bright Solar System Objects

The most straightforward observation strategy uses the standard operating concept[1], which is optionally supplemented by the use of the FND. In this approach, the smallest subarray of the standard suite that will accommodate approximately twice the diameter of the planet is selected. Table 6-2 summarizes the selection and the flux ratio $\boldsymbol{F_\nu^{planet} / F_\nu^{sat}}$, where the estimated surface brightness of reflected solar flux has been used for $\boldsymbol{F_\nu^{planet}}$, and both fluxes are in Jy/arcsec^2. Values of the ratio that are less than 1 indicate that the planet can be observed; values of the ratio that are less than 100 indicate that the planet can be observed if the FND is used.

Table 6-2: TFI Subarray Imaging of Planets

Planet	Diameter		Subarray	$F_\nu^{planet} / F_\nu^{sat}$		Remarks
	arcsec	Pixels		2 µm	4 µm	
Mars	6.2	95.4	256 × 256	11.80	4.29	Feasible with FND
Jupiter	38.0	584.6	2048 × 2048	41.11	15.09	Feasible with FND
Saturn	17.0	261.5	512 × 512	2.80	1.03	Feasible with FND
Uranus	3.6	55.4	128 × 128	0.047	0.017	Feasible
Neptune	2.2	33.8	128 × 128	0.015	0.006	Feasible
Pluto	0.05	0.77[a]	32 × 32	8.9×10^{-4}	1.2×10^{-4}	Feasible

[a] Since Pluto is less than a pixel in diameter, F_ν^{sat} for a point source has been used.

Table 6-2 shows that Uranus, Neptune, and Pluto can be observed by using standard operating procedures. These targets do not approach the saturation limit for extended objects. A target acquisition is required to center Pluto in the 32 × 32 subarray, but it is sufficiently point-like for the usual "target locate" algorithm to function adequately.

In contrast, Mars, Jupiter, and Saturn are all too bright to be observed in their respective subarrays. However, the factor of 100 increase in $\boldsymbol{F_\nu^{sat}}$ provided by FND permits all three targets to be observed with this straightforward approach. Jupiter has the least margin, but this could be improved by using a 1024 × 1024 subarray (which, however, is not part of the standard suite of subarrays).

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[1] Issues associated with guide-star availability and tracking moving objects are not considered here.

6.3 Evaluation of Alternate Observational Strategies

Observations of Mars, Jupiter, and Saturn with the TFI are enabled by the neutral density filter, but come at the expense of a substantial increase in the time required to provide photometric calibration of this new observing mode. The approach outlined for use with NIRCam is also available:

- Define a new series of subarrays that are approximately twice the diameter of the planet. This requirement is relaxed for Jupiter and Saturn to accommodate the positioning of the subarray (next point).
- Position these subarrays so that they can be read through two amplifiers. This cuts the “frame time” in half.
- Use the TFIRAPID MULTIACCUM pattern with `NGROUP`=2 to mimic a CDS readout.

Table 6-3: Planetary Observations with Specialized Subarrays

Planet	Subarray	t_{exp} [s]	F_ν^{planet} [Jy/arcsec^2]		F_ν^{sat} [Jy/arcsec^2]		$F_\nu^{planet} / F_\nu^{sat}$	
			2 µm	4 µm	2 µm	4 µm	2 µm	4 µm
Mars	190 × 190	0.361	101.0	30.0	31.09	25.41	3.24	1.18
Jupiter	1024 × 1024	10.486	22.0	6.6	1.07	0.87	20.56	7.59
Saturn	512 × 512	2.621	6.0	1.8	2.14	1.75	2.80	1.03

Table 6-3 provides an evaluation of this approach to observing Mars, Jupiter, and Saturn. Clearly, this strategy is insufficient to enable observations of these planets with the TFI, since it only provides modest reduction (factor of ~2) in the effective exposure time compared with the simpler approach described in Section 6.2.

Although the time required to readout a subarray could be reduced further (e.g., by reading in strips), the level of complexity required to implement these operations is unwarranted for an application that is not a science driver for the instrument or the JWST mission.

7.0 Conclusions

We have found that observing modes with the Webb Instruments do indeed exist to observe all the outer planets without saturating. However, these modes are limited in their science capabilities and, in some cases, will require adopting new procedures to carry out. NIRCam can observe Uranus, Neptune and Pluto using a subarray mode, that could be adopted. NIRCam can only observe Mars and Saturn at the longest wavelength, narrow band filter. NIRCam cannot observe Jupiter, unless a highly specialized “strip mode” is adopted, which seems unlikely given that the bright planets are not science drivers for the mission. While NIRSpec cannot observe all the planets in all its configurations, NIRSpec can observe all the planets in the highest spectral resolution and subarray modes currently planned. MIRI cannot observe Mars in any imaging or spectroscopic configuration. Jupiter and Saturn can be imaged in MIRI's neutral density filter, but this filter is not planned for calibration. The MIRI MRS/IFU can observe Jupiter and Saturn. Observations of the planets with orbits beyond Earth are possible with the FGS-TFI. Uranus, Neptune, and Pluto can be observed in imaging mode. Mars, Jupiter, and Saturn require the development of a new mode that uses subarray imaging through the neutral density filter. The photometric calibration of this mode is not currently planned, and would require a significant increase in the time devoted to calibrating the TFI.

These outer planets represent the brightest targets that may be observed with JWST and, thus, the most challenging for the bright object limit on the instruments. The more typical JWST solar system program will focus on the smaller, fainter objects such as Kuiper Belt Objects and distant comets that will require the enormous increase in sensitivity provided by JWST.

Although this report indicates that observations of the bright outer planets are possible in principle, a more detailed observing operations concept will be required to determine if there are feasible from an operational perspective. For example, while NIRSpec observing Jupiter is possible, can one design a feasible observing strategy to enables NIRSpec to observe Jupiter, without Jupiter crossing the FGS or NIRCam's line of sight.

8.0 References

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