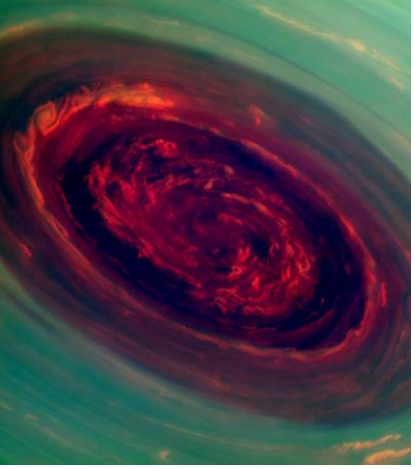
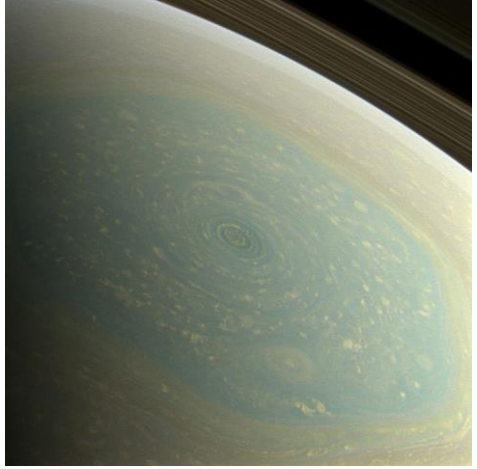
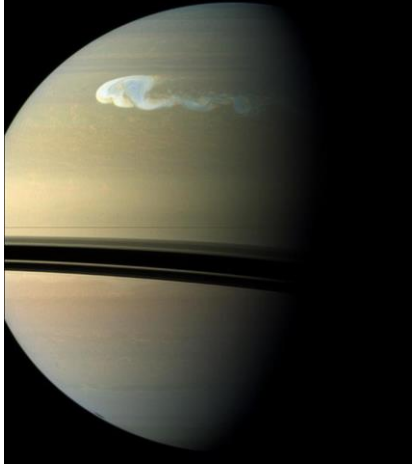


Science Planning & Sequence Team
CASSINI

SATURN TARGET WORKING TEAM

Rev 226 Segment Legacy Package

Segment Boundary: November 23, 2015 – November 25, 2015
2015-327T05:14 – 2015-329T06:08 (SCET)

Integration Began 02/09/2015
Segment Delivered to S91 Sequence 04/03/2015
Lead Integrator was Shawn Brooks

Legacy Package Assembled by Kyle Cloutier

Table of Contents

*** N.A. = Slide present but content not available.**

Segment Overview and Final Products

Segment Summary

- Rev 226 is an EQ-2 periapse segment. Saturn science included VIMS north hemisphere mapping, UVIS EUV/FUV atmospheric observations, and multiple limb observations by CIRS and ISS. UVIS also performed a stellar occultation.
- Unique science included a Tethys flyby. All ORS instruments observed, working to constrain the color and surface properties of the “Pac-Man” region.
- The spacecraft turned HGA-to-RAM for protection during the Janus/Epimetheus ring plane crossing. CDA and RPWS collected data.
- The last downlink included Radio Science, who probed the solar corona ahead of solar conjunction.

Final Sequenced SPASS

Request	Riders	Start (SCET)	Start (Epoch)	Duration	End	Primary	Secondary	Comments
SATURN_226 Segment		2015-327T05:14:00		002T00:54:00	2015-329T06:08:00			
SP_226SA_WAYPTTURN327_PRIME		2015-327T05:14:00		000T00:30:00	2015-327T05:44:00	ISS_NAC to Saturn	NEG_X to NSP	
NEW WAYPOINT		**2015-327T05:44:00**		**000T20:48:45**	**2015-328T02:32:45**	**ISS_NAC to Saturn**	**NEG_X to NSP**	
VIMS_226SA_NHEMMAP001_PRIME	C, I	2015-327T05:44:00		000T11:00:00	2015-327T16:44:00	ISS_NAC to Saturn	NEG_X to NSP	
UVIS_226SA_EUVFUV001_PRIME	C, I	2015-327T16:44:00		000T03:16:00	2015-327T20:00:00	ISS_NAC to Saturn	NEG_X to Sun	
CIRS_226TE_TETHYS001_PIE	E, I, M, U, V	2015-327T20:00:00		000T03:30:00	2015-327T23:30:00	ISS_NAC to Tethys	NEG_X to NSP	Collaborative Rider(s): ISS, UVIS. Pick up and drop off at the WP: ISS_NAC to Saturn, NEG_X to NSP
CIRS_226SA_LIMBINT002_PRIME	I, M, U, V	2015-327T23:30:00		000T02:47:00	2015-328T02:17:00	CIRS_FPB to Saturn	NEG_X to NSP	Observe limb at lowest phase angle (Northern Hemisphere)
SP_226DR_RAMAVOID328_PRIME	M	2015-328T02:17:00		000T00:15:45	2015-328T02:32:45	XBAND to Dust_RAM	NEG_X to 113.804/70.618	
NEW WAYPOINT		**2015-328T02:32:45**		**000T01:42:15**	**2015-328T04:15:00**	**XBAND to Dust_RAM**	**NEG_X to 113.804/70.618**	
MP_226DR_DUSTHAZRD001_PRIME	M	2015-328T02:32:45		000T01:18:39	2015-328T03:51:24	XBAND to Dust_RAM	NEG_X to NSP	
Periapse R = 2.532 Rs, lat ...		2015-328T03:14:08		000T00:00:01	2015-328T03:14:09			
SP_226SA_WAYPTTURN328_PRIME	M	2015-328T03:51:24		000T00:23:36	2015-328T04:15:00	ISS_NAC to Saturn	NEG_X to Sun	
NEW WAYPOINT		**2015-328T04:15:00**		**000T09:44:00**	**2015-328T13:59:00**	**ISS_NAC to Saturn**	**NEG_X to Sun**	
CIRS_226SA_LIMBINT001_PIE	E, I, M, U, V	2015-328T04:15:00		000T06:00:00	2015-328T10:15:00	CIRS_FPB to Saturn	NEG_X to Sun	PIE
ISS_226SA_LIMBSCAN001_PRIME	C, U, V	2015-328T10:15:00		000T03:15:00	2015-328T13:30:00	ISS_NAC to Saturn	NEG_X to Sun	
SP_226EA_DLTURN328_PRIME		2015-328T13:30:00		000T00:29:00	2015-328T13:59:00	XBAND to Earth	POS_X to 341.3/-16.9	
NEW WAYPOINT		**2015-328T13:59:00**		**000T03:20:00**	**2015-328T17:19:00**	**XBAND to Earth**	**POS_X to 341.3/-16.9**	
SP_226EA_G70METNON328_PRIME	R	2015-328T13:59:00		000T03:00:00	2015-328T16:59:00	XBAND to Earth	POS_X to 341.3/-16.9	
SP_226SA_WAYPTTURN428_PRIME		2015-328T16:59:00		000T00:20:00	2015-328T17:19:00	NEG_Y to 84.054/-1.202	POS_Z to 174.9/-33.0	
NEW WAYPOINT		**2015-328T17:19:00**		**000T02:04:00**	**2015-328T19:23:00**	**NEG_Y to 84.054/-1.202**	**POS_Z to 174.9/-33.0**	
UVIS_226ST_EPSORI001_PIE		2015-328T17:19:00		000T01:39:00	2015-328T18:58:00	UVIS_FUV to 84.054/-1.202	POS_Z to 174.9/-33.0	
SP_226EA_DLTURN428_PRIME		2015-328T18:58:00		000T00:25:00	2015-328T19:23:00	XBAND to Earth	NEG_X to NEP	
NEW WAYPOINT		**2015-328T19:23:00**		**000T10:45:00**	**2015-329T06:08:00**	**XBAND to Earth**	**NEG_X to NEP**	
SP_226EA_C70METSEQ328_PRIME	C, E, R	2015-328T20:03:00		000T07:40:00	2015-329T03:43:00	XBAND to Earth	NEG_X to NEP	CAPS.NEG_X to 40.6/83.5 (NSP) or NEP.EOS.

Gap 1

Gap 2

Gap 3

Final Sequenced SMT and Data Volume

DATA VOLUME SUMMARY --- TRANSFER FRAME OVERHEAD INCLUDED (80 BITS PER 8800-BIT FRAME)

			OBSERVATION_PERIOD							DOWNLINK_PASS							
			P4						P5	RECORDED		PLAYBACK					
DOWNLINK PASS NAME	Start doy hh:mm	End doy hh:mm	START (Mb)	SCI (Mb)	HK+E (Mb)	TOTAL (Mb)	CPACTY (Mb)	MRGN (Mb)	OPNAV (Mb)	SCI (Mb)	ENGR (Mb)	TOTAL (Mb)	CPACTY (Mb)	MARGN (Mb)	NET_MARGN (Mb)	(%)	CAROVR (Mb)
SP_226EA_G70METNON328_PRIME	328 13:59	328 16:59	614	2620	149	3383	3322	-60	0	29	18	3368	679	-2690	0	0%	2689
SP_226EA_C70METSEQ328_PRIME	328 20:03	329 03:43	2689	195	13	2897	3322	425	0	136	45	3078	2501	-578	0	0%	577

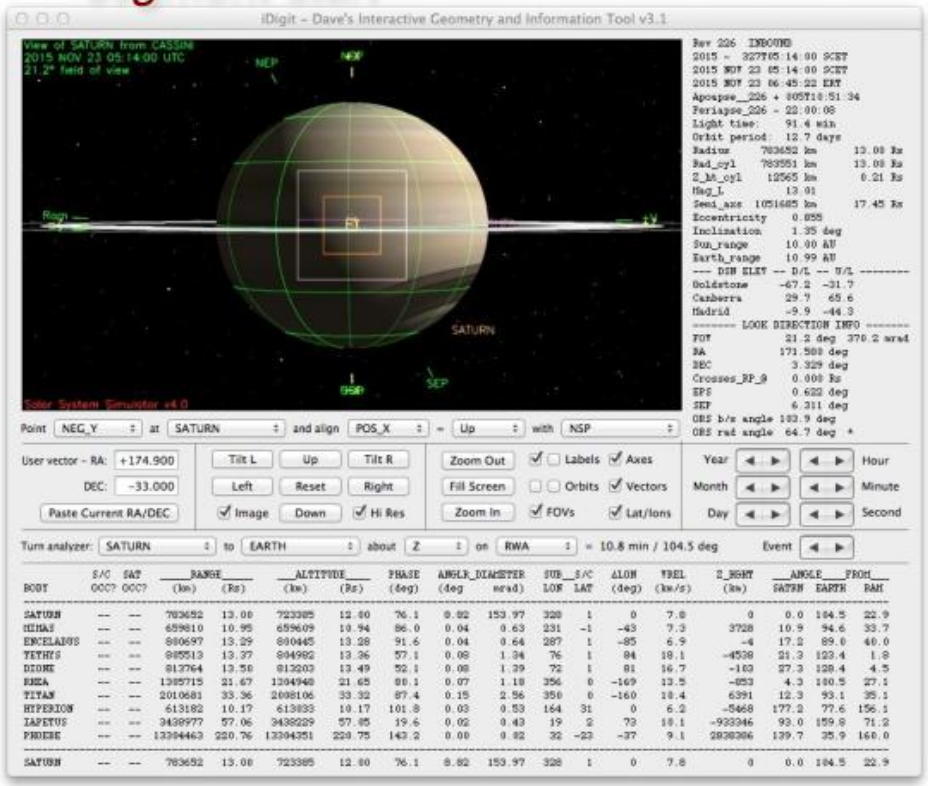
DATA VOLUME REPORT --- TRANSFER FRAME OVERHEAD NOT INCLUDED

Event	Start doy hh:mm	End doy hh:mm	CAPS (Mb)	CDA (Mb)	CIRS (Mb)	INMS (Mb)	ISS (Mb)	MAG (Mb)	MIMI (Mb)	RADAR (Mb)	RPWS (Mb)	UVIS (Mb)	VIMS (Mb)	PROBE (Mb)	ENGR (Mb)	TOTAL (Mb)
OBSERVATION_NOR	327 02:44	328 13:59	0.0	199.5	307.3	34.5	758.8	31.3	107.9	0.0	115.2	329.7	712.0	0.0	147.3	2743.6
SP_226EA_G70METNON328_PRIME	328 13:59	328 16:59	0.0	5.7	0.0	1.1	0.0	2.7	9.2	0.0	9.8	0.0	0.0	0.0	0.0	28.4
DAILY TOTAL SCIENCE	327 02:44	328 16:59	0.0	205.2	307.3	35.6	758.8	34.0	117.0	0.0	125.0	329.7	712.0	0.0	147.3	
OBSERVATION_NOR	328 16:59	328 20:03	0.0	5.8	0.0	1.1	0.0	2.7	9.4	0.0	10.0	164.1	0.0	0.0	12.8	206.0
SP_226EA_C70METSEQ328_PRIME	328 20:03	329 03:43	0.0	14.5	60.3	2.8	0.0	6.8	23.5	0.0	25.1	1.8	0.0	0.0	0.0	134.7
DAILY TOTAL SCIENCE	328 16:59	329 03:43	0.0	20.2	60.3	3.9	0.0	9.5	32.8	0.0	35.1	166.0	0.0	0.0	12.8	

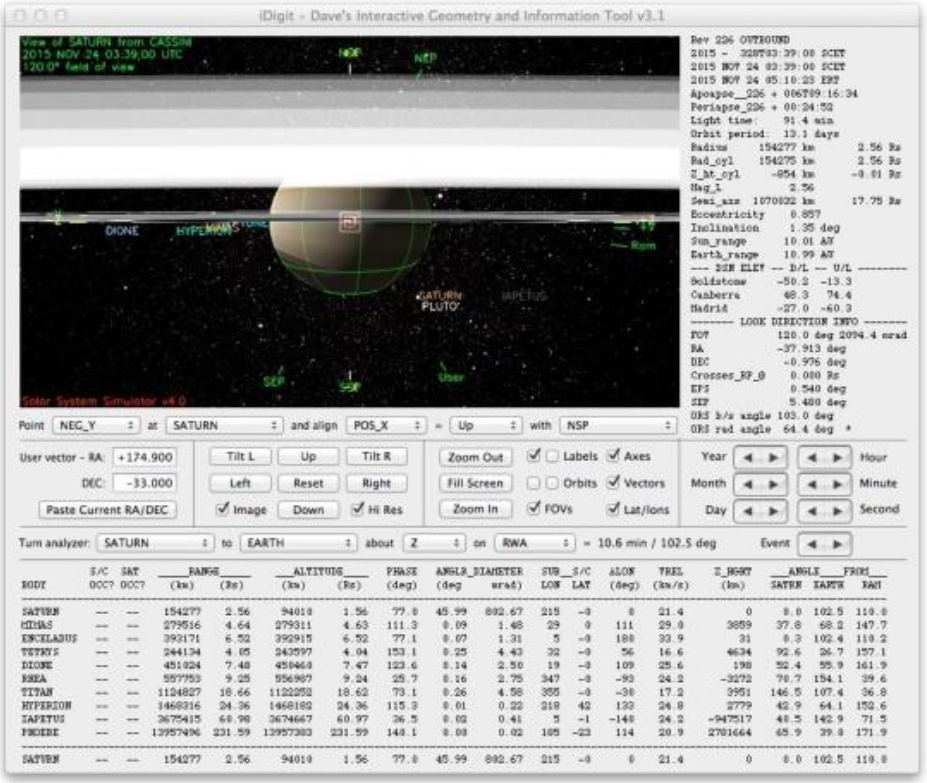
* NOTE: Negative SSR (P4) Margins did not result in data loss due to compression/under-utilization.

Segment Geometry (1 of 2)

segment start 2015-327T05:14



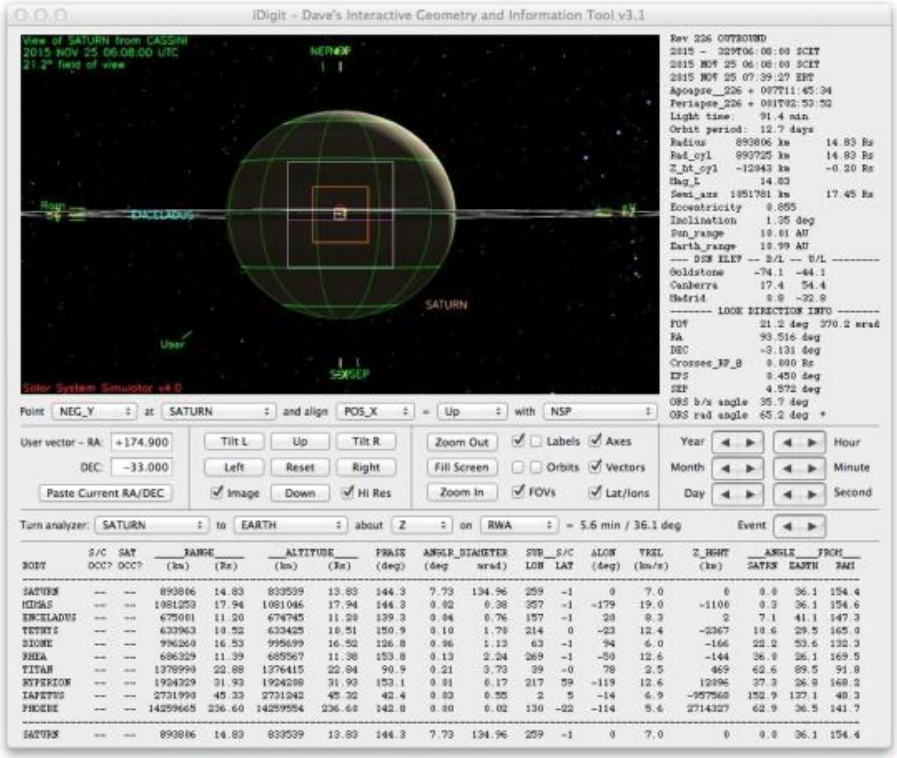
	Saturn Range	Phase Angle	Sub-S/C Lat.
Segment Start	13.0 R_{Sat}	76.1°	1°
Periapse	2.5 R_{Sat}	66.2°	0°
Segment End	14.8 R_{Sat}	144.3°	-1°



(just after) periapse

(Periapse: 2015-328T03:14:08)

Segment Geometry (2 of 2)



	Saturn Range	Phase Angle	Sub-S/C Lat.
Segment Start	13.0 R_{Sat}	76.1°	1°
Periapse	2.5 R_{Sat}	66.2°	0°
Segment End	14.8 R_{Sat}	144.3°	-1°

segment end 2015-329T06:08

Solar Geometry – ORS Boresight Concerns

No ORS Boresight Solar Constraints on Science Pointing Noted.

Daily Science Highlights

DOY 327 (23 November 2015): Several science activities fell on the first day of the `Saturn_226` periapse segment, which began with an 11-hour mapping of Saturn's northern hemisphere from the equatorial regions to the poles led by Visible and Infrared Mapping Spectrometer. Following this observation, Ultraviolet Imaging Spectrograph mapped the planet in the ultraviolet to study the distribution of hazes and organic compounds high in Saturn's atmosphere.

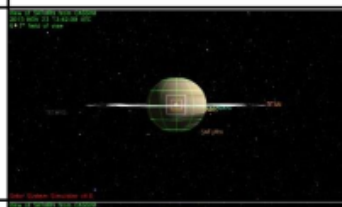
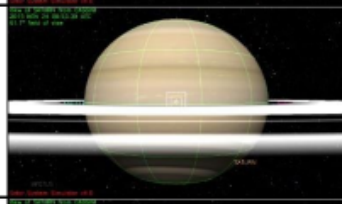
Just as Tethys passed in front of Saturn from Cassini's vantage, the full suite of optical remote sounding instruments were trained on Tethys during an ~18,000 km equatorial flyby. They began by observing the day-lit western boundary of Tethys' "Pac-Man" region (a region marked by its distinct color and thermal anomaly located at low latitudes on Tethys' leading hemisphere), and then continued to observe across Tethys' night-side trailing hemisphere, finishing at the eastern boundary of the anomalous region. These observations will better constrain the color and surface properties both inside and outside of the anomalous region, and across both the eastern and western anomaly boundaries.

DOY 328 (24 November 2015): As this day began, the Composite Infrared Spectrometer is sounding Saturn's limb at multiple latitudes in the mid-infrared to obtain information about the atmosphere's thermal structure. Afterwards, Cassini flew past the tenuous Janus/Epimetheus ring with its main engine cover closed and its high gain antenna oriented to shield the spacecraft from any errant ring particles as a precaution. In this configuration, the spacecraft flew through periapse before swinging around to the planet's night-side. The Cosmic Dust Analyzer and the Radio and Plasma Wave Science instrument took advantage of this ring passage and Cassini's location near the equator to measure the dust flux from the ring and obtain high resolution measurements of plasma waves at the magnetic equator.

With the spacecraft safely past the Janus/Epimetheus ring, CIRS continued its limb sounding of Saturn, expanding on the latitude coverage just obtained. The Imaging Science Subsystem then turned to image Saturn's limb at high phase angles. And after a brief, three-hour downlink, UVIS observed the occultation of *epsilon* and *zeta Orionis*, the center and leftmost stars in Orion's Belt respectively, by Saturn to probe Saturn's uppermost atmosphere. During the subsequent downlink, RSS utilized the spacecraft's radio signal as a probe of the solar corona ahead of the solar conjunction period that began two days later when Saturn and Cassini appear to pass behind the Sun from Earth's vantage point.

Segment Integration Planning

Timeline Gaps and Suggested Observations

Gap	Start	End	Duration	Phase angle	Range	Sub-S/C Lat.	Snapshot (mid-gap)
1	2015-327T07:24:00	2015-327T20:00:00	000T12:36:00	73.8° – 46.8°	12.1 – 6.0 R_s	1°	
	Suggested observations: VIMS N. Hemisphere mosaic, ISS						
2	2015-327T23:30:00	2015-328T02:17:00	000T02:47:00	27.9° - 43.4°	4.0 - 2.7 R_s	1° to 0°	
	Suggested observations: VIMS N. Hemisphere plume mosaic, ISS						
3	2015-328T10:05:00	2015-328T13:30:00	000T03:25:00	152.4° - 155.6°	5.8 - 7.7 R_s	-1°	
	Suggested observations: VIMS S. Hemisphere 5.2-μm plumes						

Initial SMT and Data Volume

Beginning of Integration:

DATA VOLUME SUMMARY --- TRANSFER FRAME OVERHEAD INCLUDED (80 BITS PER 8800-BIT FRAME)

			OBSERVATION_PERIOD							DOWNLINK_PASS							
			P4						P5	RECORDED		PLAYBACK					
DOWNLINK PASS NAME	Start doy hh:mm	End doy hh:mm	START (Mb)	SCI (Mb)	HK+E (Mb)	TOTAL (Mb)	CPACTY (Mb)	MRGN (Mb)	OPNAV (Mb)	SCI (Mb)	ENGR (Mb)	TOTAL (Mb)	CPACTY (Mb)	MARGN (Mb)	NET_MARGN (Mb)	(%)	CAROVR (Mb)
SP_226EA_G70METNON328_PRIME	328 13:59	328 16:59	0	1564	138	1702	3322	1620	0	36	18	1756	679	-1077	1355	38%	1076
SP_226EA_C70METNON328_PRIME	328 20:53	329 06:08	1076	219	16	1312	3322	2010	0	202	55	1569	2923	1354	1355	46%	0

- We have 1.3 Gb of data volume available for new requests.
  - Assumes MAPS instruments at nominal data rates.

DATA VOLUME REPORT --- TRANSFER FRAME OVERHEAD NOT INCLUDED

Event	Start doy hh:mm	End doy hh:mm	CAPS (Mb)	CDA (Mb)	CIRS (Mb)	INMS (Mb)	ISS (Mb)	MAG (Mb)	MIMI (Mb)	RADAR (Mb)	RPWS (Mb)	UVIS (Mb)	VIMS (Mb)	PROBE (Mb)	ENGR (Mb)	TOTAL (Mb)
OBSERVATION_NOR	327 05:14	328 13:59	0.0	61.8	135.7	33.6	297.3	58.2	100.2	0.0	423.3	367.5	72.0	0.0	136.9	1686.5
SP_226EA_G70METNON328_PRIME	328 13:59	328 16:59	0.0	5.7	0.0	1.1	0.0	5.3	9.2	0.0	14.0	0.0	0.0	0.0	0.0	35.3
DAILY TOTAL SCIENCE	327 05:14	328 16:59	0.0	67.4	135.7	34.7	297.3	63.6	109.4	0.0	437.3	367.5	72.0	0.0	136.9	
OBSERVATION_NOR	328 16:59	328 20:53	0.0	7.4	0.0	1.4	0.0	6.9	11.9	0.0	18.3	171.6	0.0	0.0	16.3	233.8
SP_226EA_C70METNON328_PRIME	328 20:53	329 06:08	0.0	17.4	86.4	3.3	0.0	16.5	28.3	0.0	43.3	4.9	0.0	0.0	0.0	200.2
DAILY TOTAL SCIENCE	328 16:59	329 06:08	0.0	24.8	86.4	4.7	0.0	23.4	40.2	0.0	61.5	176.5	0.0	0.0	16.3	

	CAPS (Mb)	CDA (Mb)	CIRS (Mb)	INMS (Mb)	ISS (Mb)	MAG (Mb)	MIMI (Mb)	RADAR (Mb)	RPWS (Mb)	UVIS (Mb)	VIMS (Mb)	PROBE (Mb)
TOTAL RECORDED (OPNAV data not included)	0.0	92.2	222.1	39.4	297.3	87.0	149.6	0.0	498.9	544.0	72.0	0.0

Waypoint Selection

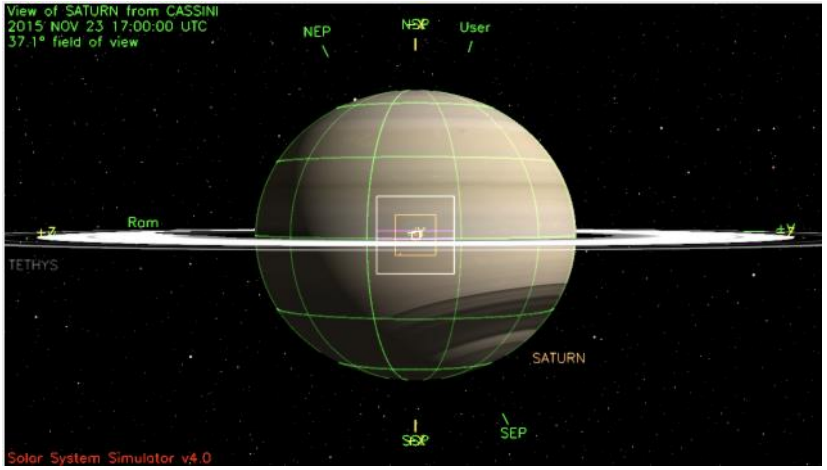
Standard

OBS_NAME	START	END	POS_X_2_NSP	POS_X_2_NEP	NEG_X_2_NSP	NEG_X_2_NEP	POS_Z_2_NSP	POS_Z_2_NEP	NEG_Z_2_NSP	NEG_Z_2_NEP	NEG_X_2_SUN	NEG_Z_2_EARTH
SP_226NA_OBSERV327_NA	2015-327T05:14:00	2015-328T02:17:00	**BAD**	**BAD**	OK	**BAD**	**BAD**	**BAD**	**BAD**	**BAD**	OK	OK
SP_226NA_OBSERV328_NA	2015-328T04:05:00	2015-328T20:53:00	**BAD**	**BAD**	OK	**BAD**	**BAD**	**BAD**	**BAD**	**BAD**	OK	**BAD**

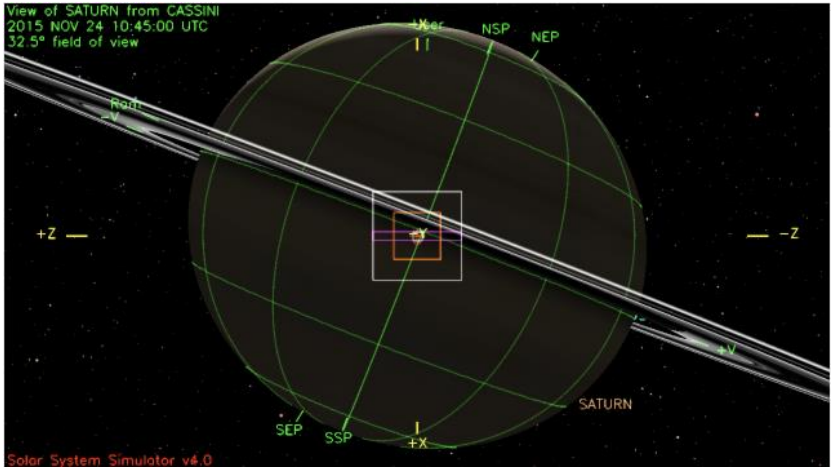
- Owing to the dust hazard, all standard waypoints for the segment were deemed "***BAD***".
- The above waypoint analysis was performed considering observation periods before and after the dust hazard separately.
- Because of the proximity of Saturn, there is minor heating even for the five waypoints designated as "OK". The heating is at acceptable levels.
- `waypt_widget` predicts 0.3K of CIRS heating at the proposed dust ram attitude. (We can look to reduce this, but at the expense of turn time.)

Waypoints Chosen

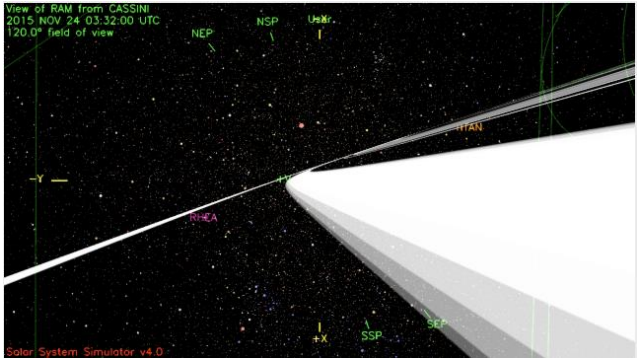
Waypoint 1 (2015-327T05:44 – 328T02:32:45):
NAC to Saturn, NEG_X to NSP



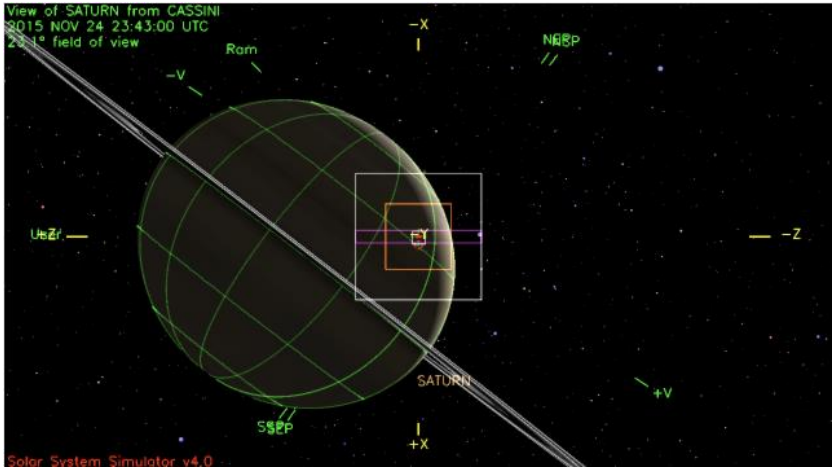
Waypoint 3 (2015-328T04:15 – 328T17:19):
NAC to Saturn, NEG_X to Sun



Waypoint 2 (2015-328T02:32:45 – 328T04:15):
XBAND to Dust_RAM, NEG_X to 113.804/70.618
Dust Hazard avoidance: Janus/Epimetheus ring crossing.



Waypoint 4 (2015-328T17:19 – 329T06:08):
NEG_Y to 84.054/-1.202, POS_Z to 174.9/-33.0



Notes

- Pointing:
  - There is a RAMAVOID turn – `SP_226SA_RAMAVOID328_PRIME,` – starting at 2015-328T02:17:00, implemented to mitigate the dust hazard posed by the Janus/Epimetheus ring on this day.
  - The YGAP prior to the final downlink in this segment was deleted, as it is the final downlink in the sequence. Since the Project has changed the bias strategy at the sequence transition to include a beginning-of-sequence bias, as opposed to an end-of-sequence bias, a YGAP associated with this downlink was deemed superfluous. SCO was consulted and concurred. Eliminating this YGAP allowed us to extend the downlink for extra data playback capacity.
  - Probably owing to the dust hazard during this segment, there were no identified RBOT-friendly waypoint attitudes that were acceptable. The Saturn TWT opted to use safe waypoints that better facilitated the implementation of the science observations in this segment. These waypoints have minor CIRS heating, but nothing in excess of 1.6°K over nominal.
  - The CIRS PIE `CIRS_226SA_LIMBINT001_PIE` was shifted 15 minutes later in order to accommodate the DOY 328 dust hazard and the turn from the hazard avoidance attitude. The duration remains at six hours.
  - The UVIS PIE occultation on DOY 328 does not comply with the rule requiring 20 minutes of margin before and after periapse stellar occultations. However, the Saturn TWT felt that this would not be a problem, as the waypoint is (almost) identical to the UVIS observation, obviating the need for any large turns to acquire the target star.

- Data Volume:
  - Sufficient margin exists to tolerate a loss of 90 minutes of DSN coverage off either the front or back end of the DOY 328 DSS-43 pass (including `vcut` compression).

- DSN:
  - A three-hour DSS-14 pass has been added on DOY 328 to provide additional data playback capacity.
  - The final downlink (and the only one in the strawman DSN plan for this segment) has been extended (on the front end) to a duration of 10 hours and 45 minutes for additional playback capacity. To make room in the timeline for this, the preceding YGAP was deleted (see above under 'Pointing' notes).
- Resource checker:
  - *none*

- Opmodes:
  - The `RSS2RWAF` opmode is implemented at 2015-328T13:59:00 to accommodate an RSS solar conjunction experiment rider on the SPST downlinks. No other instrument teams are impacted in this opmode.

- Special Activities:
  - *none*

Liens

Sequence Liens (should all be SPLAT items):

- There are two observations that will require at least one 20-minute quiescent period owing to the large slews (> 60°) required to track their targets over the course of the observation:
  - `CIRS_226TE_TETHYS001_PIE` – Tethys covers ~150° of sky during this observation
  - `CIRS_226SA_LIMBINT001_PIE` – Saturn covers ~80° of sky during this request

  SPLAT items have been entered into CIMS for these two requests.