The Cassini Live Update Process

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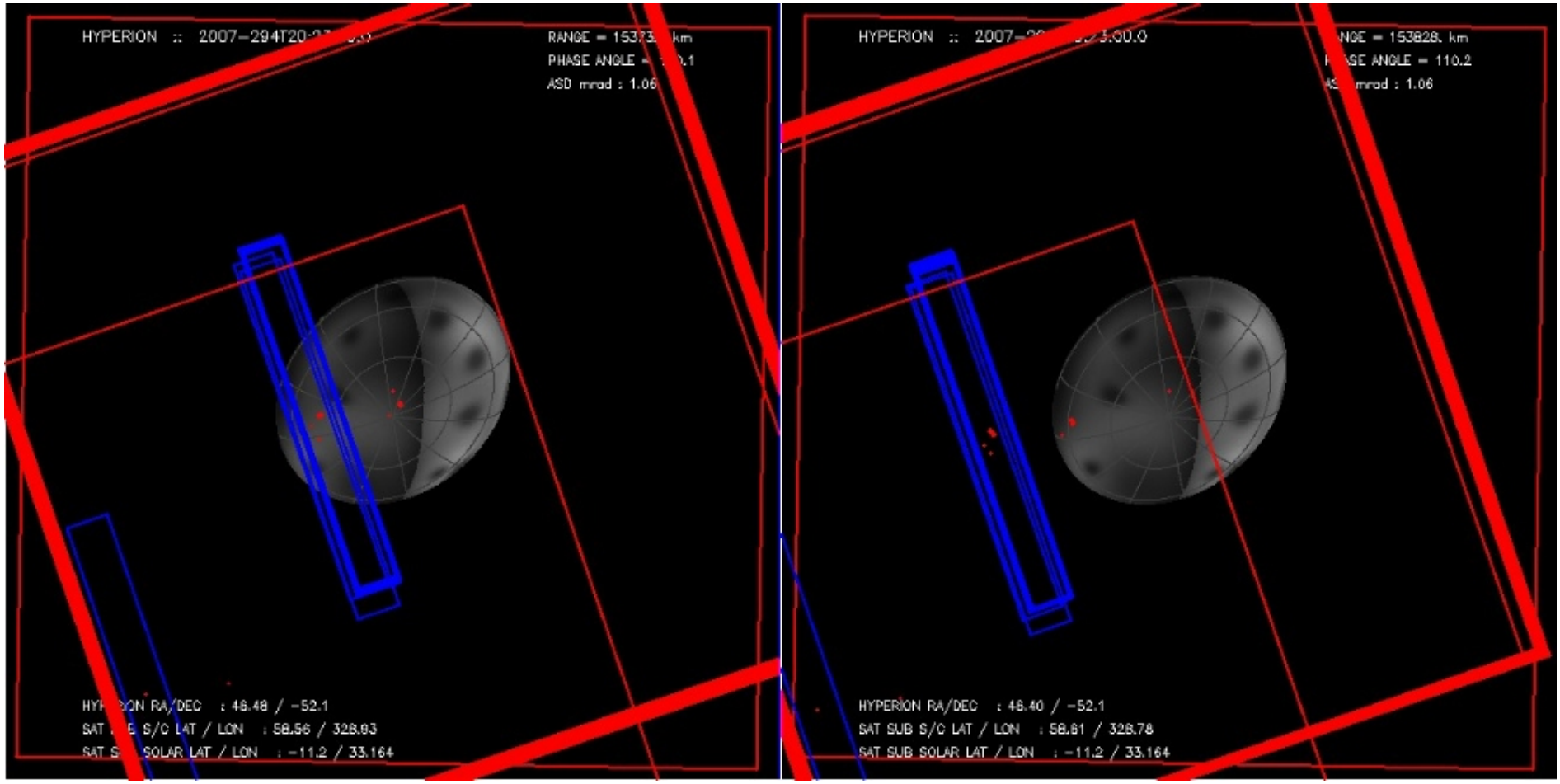


What is a Live IVP Update, Live Moveable Block, and LUB?

- **A Live IVP Update is an update of the pointing vectors after the sequence has already been uplinked to the spacecraft.**
  - When the science teams created their original pointing designs, the AACS team ran those commands through the software tool KPT/IVP and created a set of IVP vectors to match.
    - The science teams command “point the narrow angle camera at Rhea, with the -X axis of the spacecraft as close to the RAM direction as possible
    - The AACS vector describes where Rhea is and the RAM direction
- **A Live Moveable Block (LMB) is an update to the start time of a set of commands, AND the IVP vectors, after the sequence has been uplinked. The delta time between the commands inside the moveable block remains unchanged.**
  - A Live Moveable Block must be planned during the sequence implementation as the necessary deadtime must be available on each side of the block to “move” the commands into.
  - Radio Science must use Live Moveable Blocks when they do limbtrack observations, which can only be created by a carefully coordinated creation of commands and vectors, so updating the vectors alone is worthless. In addition their IVD files cannot be overlaid once onboard.
    - RSS LMB’s thus do NOT have a default uplinked to the spacecraft; they are built as a minisequence and uplinked just before execution. However, a default LMB is built using the reference trajectory
- **A Live Update Block (LUB), is when Radio Science needs the Live Update of their commands and vectors, but they don’t move the start time.**

Why do a Live IVP Update

- **We do a live update when the accuracy of the pointing designs of the science teams, designed to the reference trajectory many months in advance, will not be met by the actual trajectory.**

  - The bulk of this difference comes from the deviations based on the predicted maneuver orbit determination [OD] solutions vs. actual.

    - Cancelling maneuvers sometimes necessitates a live update - for example a maneuver targeting Titan may be cancelled because we meet Titan pointing requirements however we do not meet requirements for other nontargeted bodies

  - The science teams typically design to 2.4 mrad of error although they can/should increase that design margin when we know ahead of time that it is insufficient

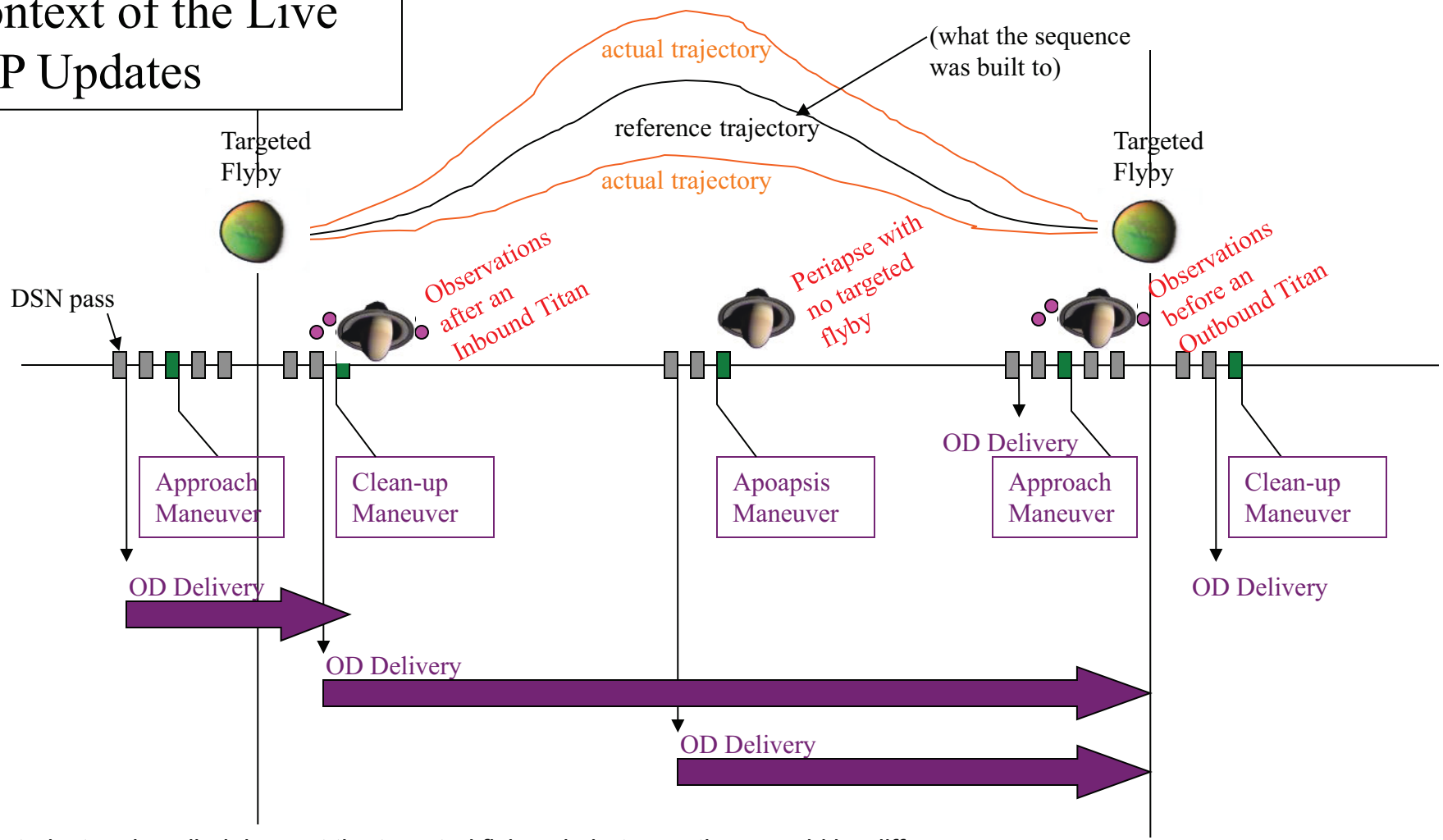
    - Smaller bodies (“rocks”) will often be missed with errors much smaller than 2.4 mrad
    - Larger bodies (e.g. Tethys) will not be missed altogether but the desired feature may be missed

When do we do a Live IVP Update

- **Typically, Live IVP Updates are done near periapsis and are known about during the sequence generation**
  - The BURPT program (Brad's Update Required Predicter Tool) is run on the planned observation to determine which may not meet pointing requirements based on predicted OD uncertainties
- **There two types of unplanned Live IVP Updates.**
  - One is found when a new OD is delivered during sequence execution and Science Planning runs the remaining observations through a program (Brad's Update Targeting Tester) to see if any observations are no longer working as intended.
  - The second is when an OTM is cancelled. It's possible that overall it is better to simply update a few vectors for a few observations instead of doing an entire maneuver. These have become more common.

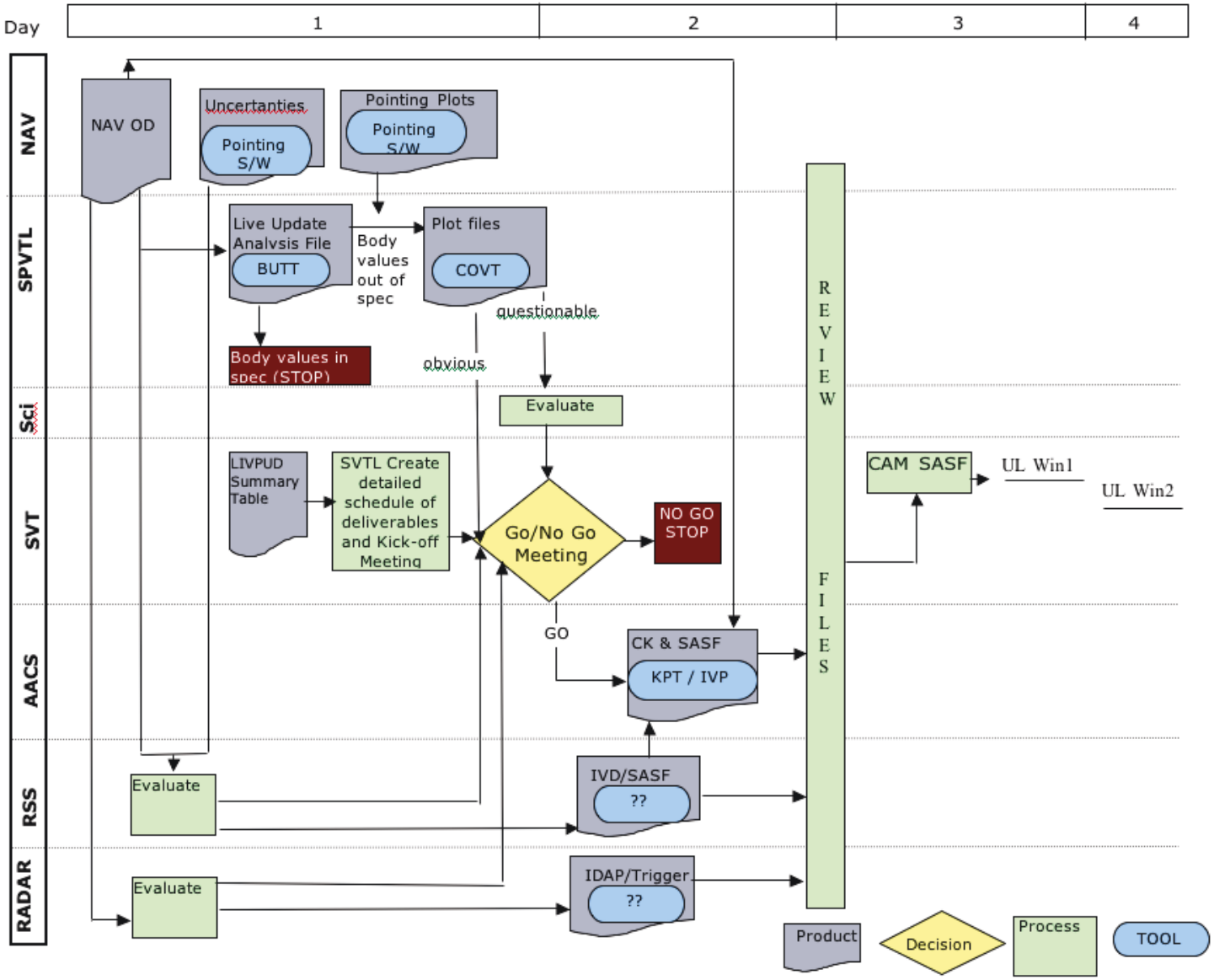
Note: it's important to understand the location of observations relative to the Nav OD deliveries, and how long those deliveries are good for.

Context of the Live IVP Updates



- The trajectory is nailed down at the targeted flybys, in between there could be differences.
- Maneuvers are scheduled for targeted encounters: - 3 days (approach), +3 days (cleanup), plus the apoapsis maneuver. The OD Delivery is typically a day before the maneuver.
- The clean-up OD Delivery is good through to the next targeted flyby, and the Apoapsis maneuver OD is better. The -3D (approach) OD is only good through the flyby.
- Depending on outbound vs inbound targeted, then the ability to use an existing OD delivery will be very easy (observations before an outbound Titan)… or very hard (observations after an inbound Titan)…

Process Description (diagram)



BURPT output

TARGET	REV	OBSERVATION	START TIME	RANGE km	TATF days	TAOTM days	x_del km	error mrad	UPDATE REQd	ASD mrad			
RHEA	74	UVIS_074RH_ICYLON001_PRIME	2008-183T19:40:00	943236.4	34.46	36.97	1487.55	1.13	---	0.8	OTM-157	69TI-3	2008-146T11:28:00
SATURN	74	CIRS_074RI_TEMPL13LP001_PRIME	2008-183T20:30:00	941824	34.5	37	1454.46	1.11	---	64.1	OTM-157	69TI-3	2008-146T11:28:00
SATURN	74	CIRS_074RI_CWLEOOCC001_PRIME	2008-184T00:00:00	987835.9	34.64	37.15	1346.45	1.01	---	61.11	OTM-157	69TI-3	2008-146T11:28:00
SATURN	74	CIRS_074RI_TEMPL10LP001_PRIME	2008-184T04:15:00	1037841.5	34.82	37.32	1236.62	0.91	---	58.16	OTM-157	69TI-3	2008-146T11:28:00
SATURN	74	ISS_074RI_SPKLFMOV001_PRIME	2008-184T07:00:00	1066988.6	34.94	37.44	1161.83	0.85	---	56.57	OTM-157	69TI-3	2008-146T11:28:00
SATURN	74	CIRS_074RI_TEMPU06LP001_PRIME	2008-185T11:50:00	1242564.1	36.14	38.64	808.76	0.66	---	48.57	OTM-157	69TI-3	2008-146T11:28:00
SATURN	75	CIRS_075RI_SUBMU14LP001_PRIME	2008-186T02:55:00	1250429.8	36.77	39.27	812.16	0.68	---	48.26	OTM-157	69TI-3	2008-146T11:28:00
SATURN	75	CIRS_075RC_COMP001_PRIME	2008-186T16:55:00	1208150.9	37.35	39.85	918.28	0.72	---	49.95	OTM-157	69TI-3	2008-146T11:28:00
SATURN	75	VIMS_075RF_FMOVIE002_PRIME	2008-187T00:55:00	1161584.8	37.68	40.19	1020.31	0.77	---	51.96	OTM-157	69TI-3	2008-146T11:28:00
SATURN	75	CIRS_075RI_SUBMU40MP001_PRIME	2008-188T02:23:00	886214.8	38.74	41.25	1545.69	1.23	---	68.12	OTM-157	69TI-3	2008-146T11:28:00
SATURN	75	CIRS_075SA_NADIROCC001_PRIME	2008-188T18:30:00	573554.4	39.41	41.92	2292.15	2.89	YES	105.38	OTM-157	69TI-3	2008-146T11:28:00
SATURN	75	CIRS_075SA_NADIROCCB001_PRIME	2008-189T00:10:00	422870.7	39.65	42.15	2791.45	5.32	YES	143.15	OTM-157	69TI-3	2008-146T11:28:00
SATURN	75	VIMS_075RI_COMPHIDRK001_PRIME	2008-189T01:00:00	398388.8	39.69	42.19	2922.82	6.08	YES	152.02	OTM-157	69TI-3	2008-146T11:28:00
ENCELADUS	75	CIRS_075EN_ORSSECLN001_PRIME	2008-189T04:30:00	328922.2	39.83	42.33	3518.01	2.78	YES	0.77	OTM-157	69TI-3	2008-146T11:28:00
SATURN	75	RSS_075SA_OCCIN001_PRIME	2008-189T08:17:07	180364.9	39.99	42.49	4436.82	34.89	YES	341.06	OTM-157	69TI-3	2008-146T11:28:00
SATURN	75	CIRS_075SA_NADIROCC002_PRIME	2008-189T20:19:00	440279.4	40.49	0.01	2435.46	4.43	YES	137.45	OTM-158	69TI+P	2008-189T11:07:00
SATURN	75	VIMS_075RI_COMPLOLIT001_PRIME	2008-190T00:05:00	541459.6	40.65	0.17	2020.31	2.76	YES	111.65	OTM-158	69TI+P	2008-189T11:07:00
SATURN	75	VIMS_075RB_BMOVIE4001_PRIME	2008-190T03:05:00	613972.6	40.77	0.29	1798.91	2.09	YES	98.42	OTM-158	69TI+P	2008-189T11:07:00
DIONE	75	UVIS_075DI_ICYLON001_PRIME	2008-190T13:35:00	1041712.8	41.21	0.73	1312.41	0.73	---	0.53	OTM-158	69TI+P	2008-189T11:07:00
SATURN	75	CIRS_075RI_TEMPL17LP001_PRIME	2008-191T02:40:00	1010429.4	41.75	1.27	964.57	0.72	---	59.74	OTM-158	69TI+P	2008-189T11:07:00
SATURN	75	CIRS_075RI_TEMPL17LP002_PRIME	2008-191T07:30:00	1063812.6	41.96	1.47	872.05	0.64	---	56.74	OTM-158	69TI+P	2008-189T11:07:00
SATURN	75	VIMS_075RI_LATPHASE001_PRIME	2008-191T08:45:00	1076388.4	42.01	1.53	856.59	0.63	---	56.07	OTM-158	69TI+P	2008-189T11:07:00
SATURN	75	CIRS_075SA_FIRMAPA002_PRIME	2008-192T02:37:00	1206534.9	42.75	2.27	657.15	0.51	---	50.02	OTM-158	69TI+P	2008-189T11:07:00
SATURN	75	UVIS_075SA_AURORA001_PRIME	2008-192T13:37:00	1244770.9	43.21	2.73	611.25	0.5	---	48.48	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	CIRS_076SA_FIRMAPB002_PRIME	2008-193T02:37:00	1251786.2	43.75	3.27	622.89	0.52	---	48.21	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	UVIS_076SA_AURORA001_PRIME	2008-193T13:37:00	1225702.1	44.21	3.73	679.08	0.54	---	49.24	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	CIRS_076SA_FIRMAPC002_PRIME	2008-194T02:22:00	1157225.8	44.74	4.26	793.06	0.6	---	52.15	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	UVIS_076SA_AURORA002_PRIME	2008-194T13:22:00	1062062.1	45.2	4.72	922.38	0.68	---	56.83	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	UVIS_076SA_AURORA003_PRIME	2008-195T02:22:00	898893.5	45.74	5.26	1137.8	0.9	---	67.16	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	CIRS_076RI_SUBMU45MP001_PRIME	2008-195T12:22:00	726134.2	46.16	5.68	1382.81	1.32	---	83.17	OTM-158	69TI+P	2008-189T11:07:00
ENCELADUS	76	CIRS_076EN_ORSSECLNX001_PRIME	2008-196T02:07:00	486017.4	46.73	6.25	2116.46	1.24	---	0.52	OTM-158	69TI+P	2008-189T11:07:00
JANUS	76	CIRS_076JA_ORSJANUS001_PRIME	2008-196T06:00:00	261925.8	46.89	6.41	2621.15	3.93	YES	0.36	OTM-158	69TI+P	2008-189T11:07:00
RHEA	76	CIRS_076RH_FP1SECLN001_PRIME	2008-196T06:29:00	516478	46.91	6.43	2706.18	2.25	YES	1.47	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	VIMS_076RI_HIPHASE001_PRIME	2008-196T10:00:12	166229.4	47.06	6.58	3313.08	30.79	YES	371.41	OTM-158	69TI+P	2008-189T11:07:00
MIMAS	76	CIRS_076MI_ORSSECLN001_PRIME	2008-196T11:41:00	225836.7	47.13	6.65	3265.1	13.07	YES	0.92	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	ISS_076SA_SPOLRMOV001_PRIME	2008-196T17:00:00	315330.8	47.35	6.87	2117.3	6.38	YES	192.51	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	UVIS_076SA_AURORA004_PRIME	2008-197T03:05:00	594854.7	47.77	7.29	1243.89	1.5	---	101.59	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	CIRS_076SA_COMPSIT001_PRIME	2008-197T11:00:00	761910.9	48.1	7.62	949.25	0.86	---	79.26	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	CIRS_076SA_FIRMAPA001_PRIME	2008-198T03:07:00	1006114.9	48.77	8.29	640.74	0.48	---	59.99	OTM-158	69TI+P	2008-189T11:07:00
SATURN	76	CIRS_076SA_FIRMAPB001_PRIME	2008-199T02:06:00	1200012.5	49.73	9.25	442.95	0.34	---	50.29	OTM-158	69TI+P	2008-189T11:07:00
SATURN	77	UVIS_077SA_AURORA001_PRIME	2008-200T03:06:00	1252485.5	50.77	0.06	436.66	0.36	---	48.18	OTM-159	~APO	2008-199T16:36:00
SATURN	77	UVIS_077SA_AURORA002_PRIME	2008-201T02:06:00	1165341.8	51.73	1.02	544.98	0.41	---	51.79	OTM-159	~APO	2008-199T16:36:00
SATURN	77	VIMS_077RI_COMPLODRK001_PRIME	2008-202T01:50:00	919873.8	52.72	2.01	744.58	0.58	---	65.63	OTM-159	~APO	2008-199T16:36:00
SATURN	77	CIRS_077RI_VTMPU37MP001_PRIME	2008-202T04:50:00	874777.4	52.84	2.13	780.83	0.63	---	69.02	OTM-159	~APO	2008-199T16:36:00
SATURN	77	VIMS_077RI_HIRESHIPH001_PRIME	2008-203T08:05:00	231086.1	53.98	3.27	1668.79	8.38	YES	264.13	OTM-159	~APO	2008-199T16:36:00
SATURN	77	ISS_077RF_HIRESFRNG002_PRIME	2008-203T09:05:00	202389.2	54.02	3.31	1766.37	11.26	YES	302.69	OTM-159	~APO	2008-199T16:36:00
DIONE	77	VIMS_077DI_ORSDIONE001_PRIME	2008-203T10:40:00	290806.4	54.09	3.38	1885.16	6.47	YES	1.92	OTM-159	~APO	2008-199T16:36:00
SATURN	77	ISS_077RI_RDHRCOMP001_PRIME	2008-203T12:00:00	163225	54.14	3.43	1875.74	18.2	YES	378.59	OTM-159	~APO	2008-199T16:36:00
SATURN	77	ISS_077RF_HIRESFRNG001_PRIME	2008-204T01:50:00	542265.6	54.72	4.01	713.49	0.97	---	111.48	OTM-159	~APO	2008-199T16:36:00
SATURN	77	CIRS_077RI_SHADLMP001_PRIME	2008-204T02:50:00	567153.6	54.76	4.05	682.2	0.88	---	106.57	OTM-159	~APO	2008-199T16:36:00

Summary table

Name	TARGETS (# OBS) (rocks NOT included generally***)	Instruments or LMB epoch name	START TIME**	END TIME**	Previous OTM	OTM date	OD available THIS COLUMN is the OD for the update!	Uplink	NOTES.
S42	LMB	LMB_E075_Saturn_RSS_Occ_Ing	2008-189T08:17	2008-189T10:28	OTM-159 APO	2008-175:00:24	doy 174	187, 188	
S42 UD1	SATURN (7) ENCELADUS	VIMS, CIRS CIRS	2008-188T18:30 (to be extended due to Saturn vector)	2008-190T10:35	OTM-159 APO	2008-175T00:24	doy 174	187, 188	Same OD as last S41 live update
S42 UD2?	SATURN (2) JANUS* RHEA MIMAS	ISS, VIMS CIRS CIRS CIRS	2008-196T06:00 (to be extended due to Saturn vector)	2008-196T20:00	OTM-159 APO	2008-175T00:24	doy 174	194, 195	Combine w/UD1 if no special OD Special OD helpful?
S42 UD3?	SATURN (3) DIONE	ISS, VIMS VIMS	2008-203T08:05 (to be extended due to Saturn vector)	2008-203T15:50	OTM-159 APO	2008-175T00:24	doy 174	201, 202	Combine w/UD1&2 if no special Ods Special OD helpful?
S42 UD4?	SATURN TETHYS (2)	ISS CIRS	2008-210T10:45 (to be extended due to Saturn vector)	2008-210T16:30	OTM-160 T45-3	2008-209T08:36	OTM159 doy 174	208, 209	Combine w/UD1&2&3 if no special OD OTM-160 OD out doy 208: too late
S42 UD5?	SATURN (4) MIMAS	CIRS, ISS, VIMS, RSS ISS	2008-217T06:45 (to be extended due to Saturn vector)	2008-218T02:35	OTM-162 APO	2008-216T16:15	OTM160 doy 208	215, 216	OTM-162 OD out doy 215: too late

* Pointing plots not generated for small bodies

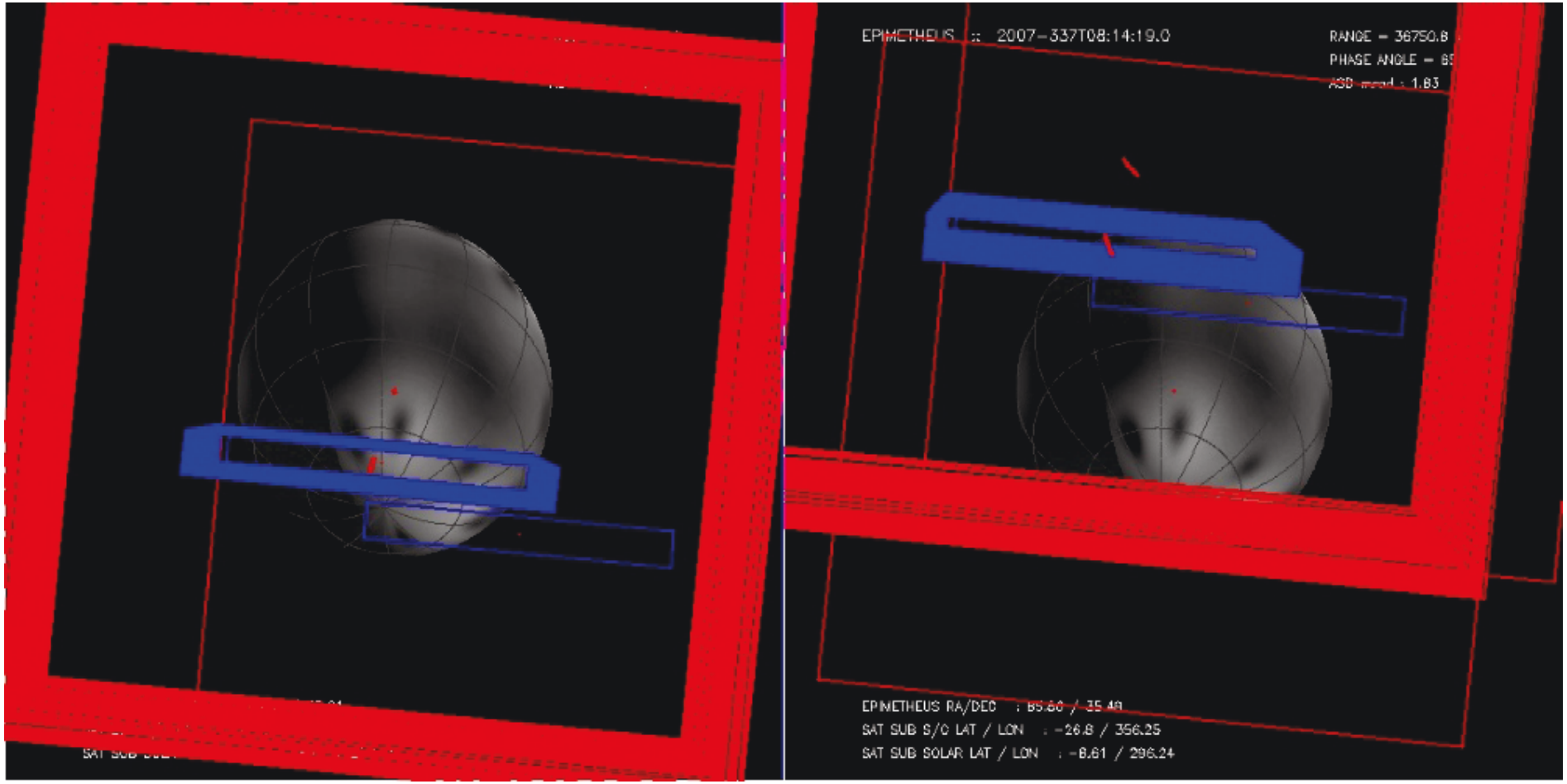
** Start time and end time need to be extended if Saturn vector being updated; use nearest earth-pointed 10 minute quiescent period.

*** during SSUP the SP runs a "get_rocks" script to find rock observations not called out in the SPASS; these vectors may be added to existing updates at that time

BUTT output

TARGET BODY	OBSERVATION	START	END	ERROR (mrad)	UPDATE
ENCELADUS	UVIS_053EN_ICYATM010_PRIME	2007-333T01:30:00	2007-333T05:00:00	0.135571	----
MIMAS	ISS_053MI_PHOTOM001_PRIME	2007-336T18:14:00	2007-336T19:45:00	0.350177	----
MIMAS	RADAR_053MI_SCATTRAD001_PRIME	2007-337T00:00:00	2007-337T03:35:00	1.61306	----
EPIMETHEUS	ISS_053EP_GEOLOG001_PRIME	2007-337T07:54:49	2007-337T08:33:49	2.97618	YES
TITAN	CIRS_053TI_FIRNADCMP001_PRIME	2007-338T09:59:50	2007-338T14:06:50	0.0491496	----
TITAN	ISS_053TI_PHOTOMWAC001_PRIME	2007-338T14:06:50	2007-338T15:06:50	0.0493571	----
TITAN	UVIS_053TI_EUVFUV001_PRIME	2007-338T15:06:50	2007-338T18:36:50	0.0500992	----
TITAN	CIRS_053TI_FIRNADMAP001_PRIME	2007-338T18:36:50	2007-338T21:36:50	0.0514279	----
TITAN	CIRS_053TI_FIRLMBINT001_PRIME	2007-338T21:36:50	2007-338T22:51:50	0.0535708	----
TITAN	CIRS_053TI_FIRLMBAER001_PRIME	2007-338T22:51:50	2007-338T23:16:50	0.0555848	----
TITAN	CIRS_053TI_FIRLMBT001_PRIME	2007-338T23:16:50	2007-338T23:51:50	0.0639315	----
TITAN	VIMS_053TI_HIRESNAC001_PRIME	2007-338T23:51:50	2007-339T02:06:50	0.0646029	----
TITAN	ISS_053TI_REGMAP001_PRIME	2007-339T02:06:50	2007-339T04:06:50	0.0548798	----
TITAN	CIRS_053TI_FIRNADMAP002_PRIME	2007-339T04:06:50	2007-339T05:06:50	0.0549699	----
TITAN	ISS_053TI_GLOBMAP001_PRIME	2007-339T05:06:50	2007-339T08:06:50	0.0550231	----
TITAN	VIMS_053TI_GLOBMAP003_PRIME	2007-339T08:06:50	2007-339T09:06:50	0.0550125	----
TITAN	CIRS_053TI_FIRNADCMP002_PRIME	2007-339T09:06:50	2007-339T11:06:50	0.0549859	----
TITAN	ISS_053TI_MONITORNA001_PRIME	2007-339T11:06:50	2007-339T13:06:50	0.0548985	----
TITAN	VIMS_053TI_GLOBMAP002_PRIME	2007-339T13:06:50	2007-339T14:06:50	0.0547788	----
TITAN	CIRS_053TI_MIDIRTMAP002_PRIME	2007-339T14:06:50	2007-339T23:43:50	0.0547102	----
TELESTO	ISS_053TL_SATELLORB003_PRIME	2007-330T07:05:30	2007-330T07:11:00	0.0852665	----

COVT output



Red = Imaging science narrow angle camera field of view
Blue = Composite infrared science camera field of view

Observation results

Epimetheus
Imaging science
narrow angle camera
field of view

LATE AND LIVE UPDATE: HISTORY LIST

History table

Live UD #	Cancelled UD #	Sequence	Year	DOY(s)	date	target(s)	# of vectors	file name	OD used	planned?	Notes
29		S31	2007	162-163	11-12 Jun	Atlas, Rhea	3 polys	n0312a	OTM-114	N	Atlas (retargetable) 8.9 mrad. Rhea <2, CIRS
	- (LUB)	S31	2007	178	27-Jun	RSS occ IVD's	-	n0311b	OTM-117	Y	B/G miniseq uplinked
	18	S31	2007	178-179	27-28 Jun	Tethys, Rhea	-	-	OTM-117	Y	less than 0.5 mrad
-(LUB)		S32	2007	178	27-Jun	RSS occ IVD's	-	n0320c	OTM-120	Y	
	19	S32	2007	201-204	20-23 Jul	Helene, Hyperion	-	-	OTM-120	Y	
30		S33	2007	241-242	29-30 Aug	Rhea	2 polys	n0331a	OTM-123	Y	
	20	S34	2007	292-301	19-28 Oct	Hyperion, many more	-	-	doy 277	Y	extra OD after CDS FSW U/L
-(LMB)		S34	2007	297	24-Oct	RSS occ IVD's	-	n0344e	doy 277	Y	Epoch shift 13 seconds
	21	S35	2007	320-321	16-17 Nov	Rhea, Saturn	-	-	OTM-132	Y	
31		S35	2007	337	3-Dec	Epimetheus, Mimas	3 polys	n0355a	OTM-135	Y	Mimas small error, Epimetheus nearly 3 mrad
-(LMB)		S36	2007	353	19-Dec	RSS occ IVD's	-	n0361d	OTM-138	Y	Epoch shift 13 seconds
	22	S36	2008	3	3-Jan	Dione	-	-	OTM-141	Y	Error 4.2 mrad; preemptively cancelled due to holiday weekend work
	23	S36	2008	13-19	13-19 Jan	Saturn + 4 sats	-	-	080109AP	Y	max error 0.68 mrad
-(LMB)		S36	2008	15	15-Jan	RSS occ IVD's	-	n0362d	080109AP	Y	Epoch shift 15 seconds
	24	S37	2008	27-29	27-29 Jan	Saturn	-	-	OTM-143	Y	max error 1.3 mrad
	- (LMB)	S37	2008	27	27-Jan	RSS occ IVD's	-	n0372c	OTM-143	Y	B/G miniseq uplinked, despite 17 second epoch shift
32		S37	2008	39-40	8-9 Feb	Saturn, Dione	7 polys, 5 conics	n0374a	OTM-144*	Y	Preliminary OTM OD delivered early for us. Dione error over 7 mrad
-(LMB)		S37	2008	39	8-Feb	RSS occ IVD's	-	n0371e	OTM-144*	Y	Epoch shift 1 min 24 sec
	25	S38	2008	51-52	20-21 Feb	Saturn, Janus	-	-	OTM-144	Y	max error 1.2 mrad (0.86 Janus)
33		S38	2008	59-66	28 Feb-6 Mar	Saturn, Dione, Tethys	73 polys, 10 conics, 2 rotate	n0382a	080221AP	Y	Pre-T41 OD delivered extra for us. Saturn error 32 mrad
-(LMB)		S38	2008	62	2-Mar	RSS occ IVD's	-	n0380f	080221AP	Y	Epoch shift 8 min 4 sec