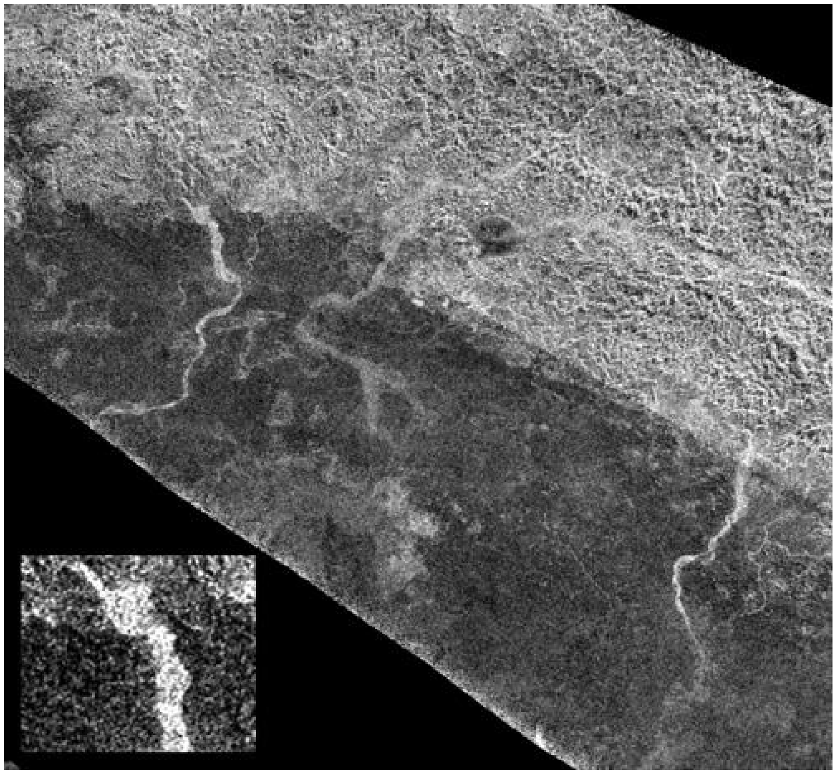
C A S S I N I



T I T A N 0 9 1 T I (T 4 6)
MISSION DESCRIPTION

November 3, 2008

Jet Propulsion Laboratory
California Institute of Technology

Cover image: Xanadu's Channels - August 8, 2008. On the final flyby of Cassini's original four-year tour, its radar mapper captured these unusual channels on Titan at the edge of Xanadu, the widest seen in this area. (For a radar image of Xanadu see Xanadu: Rivers Flowed onto a Sunless Sea). These might be active rivers carrying methane or debris, or they might be dry riverbeds similar to earthly arroyos.

Past Cassini radar images have revealed different types of channels on Titan's surface (see Titan's Rain Drains to the Plains and Huygens Landing Site Similarities). They vary from bright to dark in radar (rough to smooth), and from fan-shaped to braided to meandering. Some drain into lakes, others disappear. Some of these channels may be several hundred meters, or feet, deep.

This image, taken from the flyby on May 28, 2008, shows the border of Xanadu as the bright-dark boundary running from the upper left to lower right. Southward from that boundary is an unusual set of channels. While these are brighter (more roughly textured) than the surrounding terrain, some are only slightly brighter, and some are as wide as 5 kilometers (about 3 miles) -- about the size of the River Thames at its mouth east of London. They appear to flow out of the rough region of Xanadu. Careful inspection reveals smaller tributaries that wind through the brighter and apparently rougher terrain to the north. A close-up of one of the widest channels is shown at the lower left.

Scientists think that many of the channels on Titan are carved by methane deposited on the surface from strong but infrequent rainstorms. A bright channel may be dry, with the rough riverbed of icy particles (like those seen at the Huygens landing site) producing the radar brightness. The darker channels in this image resemble the dry lakes seen in the north polar area of Titan, so they may be dry as well, with their smoother (radar-dark) surfaces caused by finer-grained sediment deposits on the channel floors.

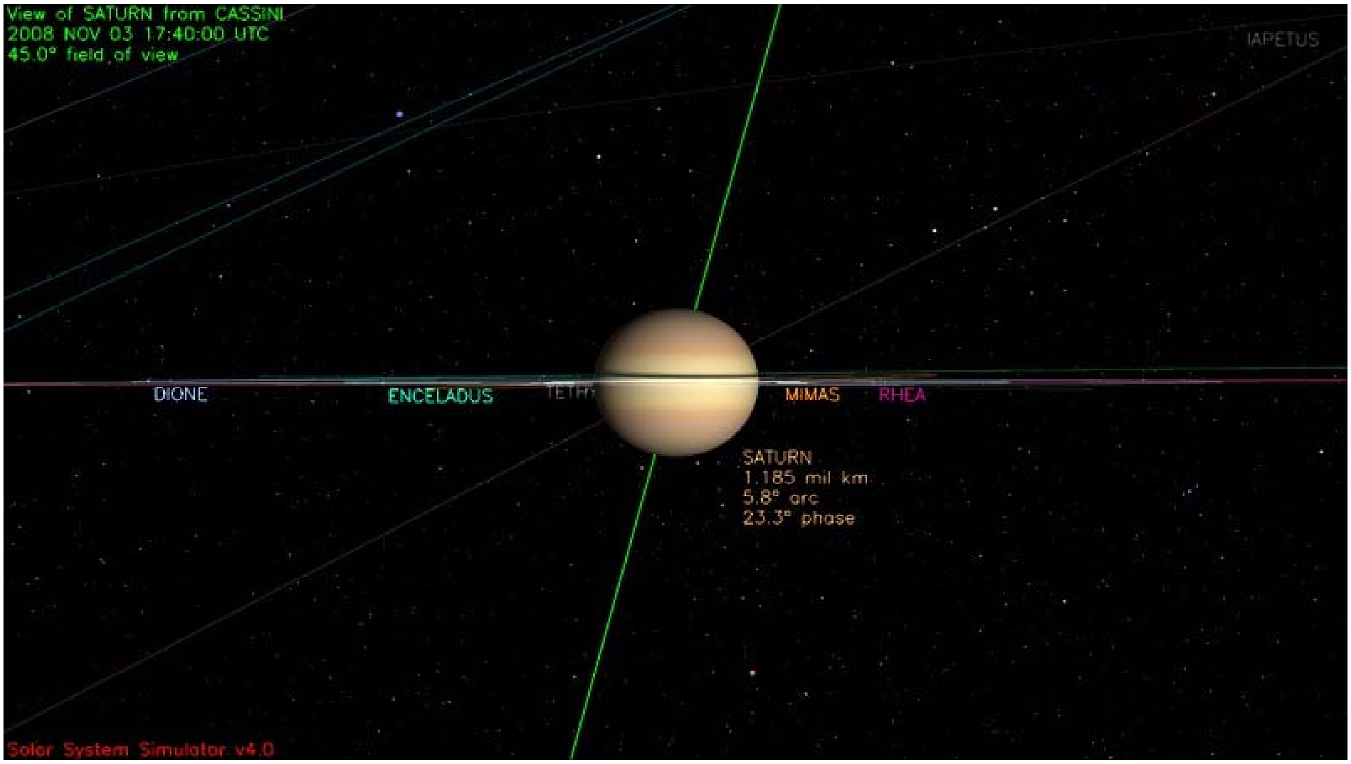
This image shows an area located at 15 degrees south latitude and 121 degrees west longitude. It is about 450 kilometers (280 miles) across, and has approximately 1 kilometer (0.62-mile) resolution. North is up.   Credit: NASA/JPL

1.0 OVERVIEW

After a 95 day hiatus since its previous visit, Cassini once again approaches Saturn's largest moon for the mission's forty-seventh targeted encounter with Titan. The closest approach to Titan occurs on Sunday, November 3, at 2008-308T17:35:23 spacecraft time at an altitude of 1100 kilometers (~680 miles) above the surface and at a speed of 6.3 kilometers per second (14,000 mph). The latitude at closest approach is 3.5 degrees S and the encounter occurs on orbit number 91.

This encounter is set up with two maneuvers: an apoapsis maneuver on October 17, and a Titan approach maneuver, scheduled for October 29. T46 is the tenth in a series of outbound encounters and the second Titan encounter in Cassini's Solstice Mission. It occurs roughly three days after Saturn closest approach.

Titan is directly between Cassini and Saturn at the time of closest approach, so the images show the view of Saturn from the spacecraft 5 minutes after closest approach, and then the view of Saturn at the time of closest approach.



ABOUT TITAN

If Titan were a planet, it would likely stand out as the most important planet in the solar system for humans to explore. Titan, the size of a terrestrial planet, has a dense atmosphere of nitrogen and methane and a surface covered with organic material. It is Titan that is arguably Earth’s sister world and the Cassini-Huygens mission considers Titan among its highest priorities.

Although it is far colder and lacks liquid water, the chemical composition of Titan’s atmosphere resembles that of early Earth. This, along with the organic chemistry that takes place in Titan’s atmosphere, prompts scientists to believe that Titan could provide a laboratory for seeking insight into the origins of life on Earth. Data from the Huygens probe, which touched down on Titan’s surface in January 2005, and the Cassini orbiter has shown that many of the processes that occur on Earth also apparently take place on Titan – wind, rain, volcanism, tectonic activity, as well as river channels, and drainage patterns all seem to contribute in shaping Titan’s surface. However, at an inhospitable -290 degrees Fahrenheit (-179 degrees Celsius), the chemistry that drives these processes is fundamentally different from Earth’s. For example it is methane that performs many of the same functions on Titan that water does on Earth.

The Huygens probe landed near a bright region now called Adiri, and photographed light hills with dark river beds that empty into a dark plain. It was believed that this dark plain could be a lake or at least a muddy material, but it is now known that Huygens landed in the dark region, and it is solid. Scientists believe it only rains occasionally on Titan, but the rains are extremely fierce when they come.

Only a small number of impact craters have been discovered. This suggests that Titan’s surface is constantly being resurfaced by a fluid mixture of water and possibly ammonia, believed to be expelled from volcanoes and hot springs. Some surface features, such as lobate flows, appear to be volcanic structures. Volcanism is now believed to be a significant source of methane in Titan’s atmosphere. However, there are no oceans of hydrocarbons as previously hypothesized. Dunes cover large areas of the surface.

The existence of oceans or lakes of liquid methane on Saturn's moon Titan was predicted more than 20 years ago. Radar and imaging data from Titan flybys have provided convincing evidence for large bodies of liquid. With Titan's colder temperatures and hydrocarbon-rich atmosphere, these lakes and seas most likely contain a combination of liquid methane and ethane (both hydrocarbons), not water.

The Cassini-Huygens mission, using wavelengths ranging from ultraviolet to radio, is methodically and consistently revealing Titan and answering long-held questions regarding Titan's interior, surface, atmosphere, and the complex interaction with Saturn's magnetosphere. While many pieces of the puzzle are yet to be found, with each Titan flyby comes a new data set that furthers our understanding of this world as we attempt to constrain scenarios for the formation and evolution of Titan and its atmosphere.

Planning for T46

This is a particularly exciting period for Cassini scientists. The spacecraft will make close flybys of icy moons Enceladus and Titan within three days. For Cassini's navigators, though, executing the planned trajectory proved to be challenging for a number of reasons. According to Cassini's Navigation team, "E6/T46 is unique even among the three double flybys since it is almost a pi-transfer (E6 ~periapsis, T46 ~ apoapsis) without an Orbit Trim Maneuver (OTM) in between." In other words, the Nav team's plan was to dramatically change the spacecraft's orbit orientation without using many OTMs, while at the same time having the science teams rely on the spacecraft encountering these two moons at precisely determined times and distances. As of early October best-available predictions showed that the E6 flyby altitude would be 15 km lower and occur 0.26 sec later than planned. It looked like one of the flybys would not come off precisely as planned, and that the science at closest approach for one of these encounters would suffer.

Both flybys have compelling science. Radio Science made the case that we must target T46 as originally planned due to the sensitivity (in both altitude and timing) of their occultation and bi-static experiment at closest approach. The Radio Science pointing designs are part of the S45 background sequence and cannot be updated at this late stage. On the other hand, imaging teams pointed out that E6 presents the last opportunity for lit viewing of Enceladus's tiger stripes and the "skeet shoot" planned by ISS is unique in its implementation.

After discussing different options, the flight team decided that the best choice for preserving E6 and T46 science was to perform a so-called "live update" of the E6 pointing vectors. In the live update process, Cassini's Nav team provides the most up-to-date orbital determination, allowing science teams and Science Planning to see how changes in the spacecraft's trajectory would affect science observations. If the changes are significant, the science teams can change how they point towards their target, and these new instructions can be sent up to the spacecraft in advance. Cassini hadn't planned on a live update for E6, but the flight team rallied to preserve the unique science opportunities for both flybys.

1.1 TITAN-46 SCIENCE HIGHLIGHTS

- **RSS** : – There are only five Radio Science atmospheric occultations in the entire extended mission; two of them occur on this flyby. RSS observations on T46 include ionospheric/atmospheric occultations and bistatic surface scattering on both the ingress and egress sides. The T46 egress atmospheric occultation will be the first to probe the mid northern-latitude of Titan (~34 degrees). The ingress occultation probes mid-southern latitude (~40 degrees). Combined with results from eight other latitudes probed during previous prime mission flybys, the occultations will shed more light on latitudinal variability of the electron density profile of the ionosphere, temperature/pressure profile, extinction profile, and small scale-structure of the neutral atmosphere. Bistatic surface scattering will be observed at low southern latitudes on the ingress side (25-30 degrees; ~90-110 degrees west longitude) and low northern latitude (25-30 degrees; ~200-220 degrees west longitude) on the egress side. The incidence angle for both sides is close to the Brewster angle range for likely surface compositions. Same- and cross-polarized components of the mirror-like surface echo, if detectable, provide valuable information about the dielectric constant and physical state of the surface region probed.

- **ISS** will acquire a regional mosaic of Titan's leading hemisphere at mid-southern latitudes, including coverage of Hotei Arcus. The instrument will also continue to monitor clouds.
- **CIRS** will scan and integrate on Titan's northern limb, concentrating on far-IR wavelengths to map and identify condensates and aerosols in the winter stratosphere.
- **UVIS** will obtain an image cube of Titan's atmosphere at EUV and FUV wavelengths by sweeping its slit across the disk. These cubes provide spectral and spatial information on nitrogen emissions, H emission and absorption, absorption by simple hydrocarbons, and the scattering properties of haze aerosols. This is one of many such cubes gathered over the course of the mission to provide latitude and seasonal coverage of Titan's middle atmosphere and stratosphere.
- **MAG:** T46 is a flank-in flyby with a minimum altitude of 1100 km. This geometry is adequate for studies of the draping of the external magnetic field around Titan on the nightside hemisphere. T46 takes place in Saturn's near-noon sector (10.5 hours SLT), where Titan could be found in the magnetosheath if the solar wind pressure is high.
- **MIMI:** The instrument will study energetic ion and electron energy input to Titan's atmosphere.
- **RPWS** will measure thermal plasmas in Titan's ionosphere and surrounding environment, search for lightning in Titan's atmosphere, and investigate the interaction of Titan with Saturn's magnetosphere. The RPWS objectives are to study the density and temperature of ionospheric electrons and to look for plasma waves that participate in the interaction of Saturn's magnetosphere with Titan. RPWS will also look for evidence of lightning from Titan's atmosphere.

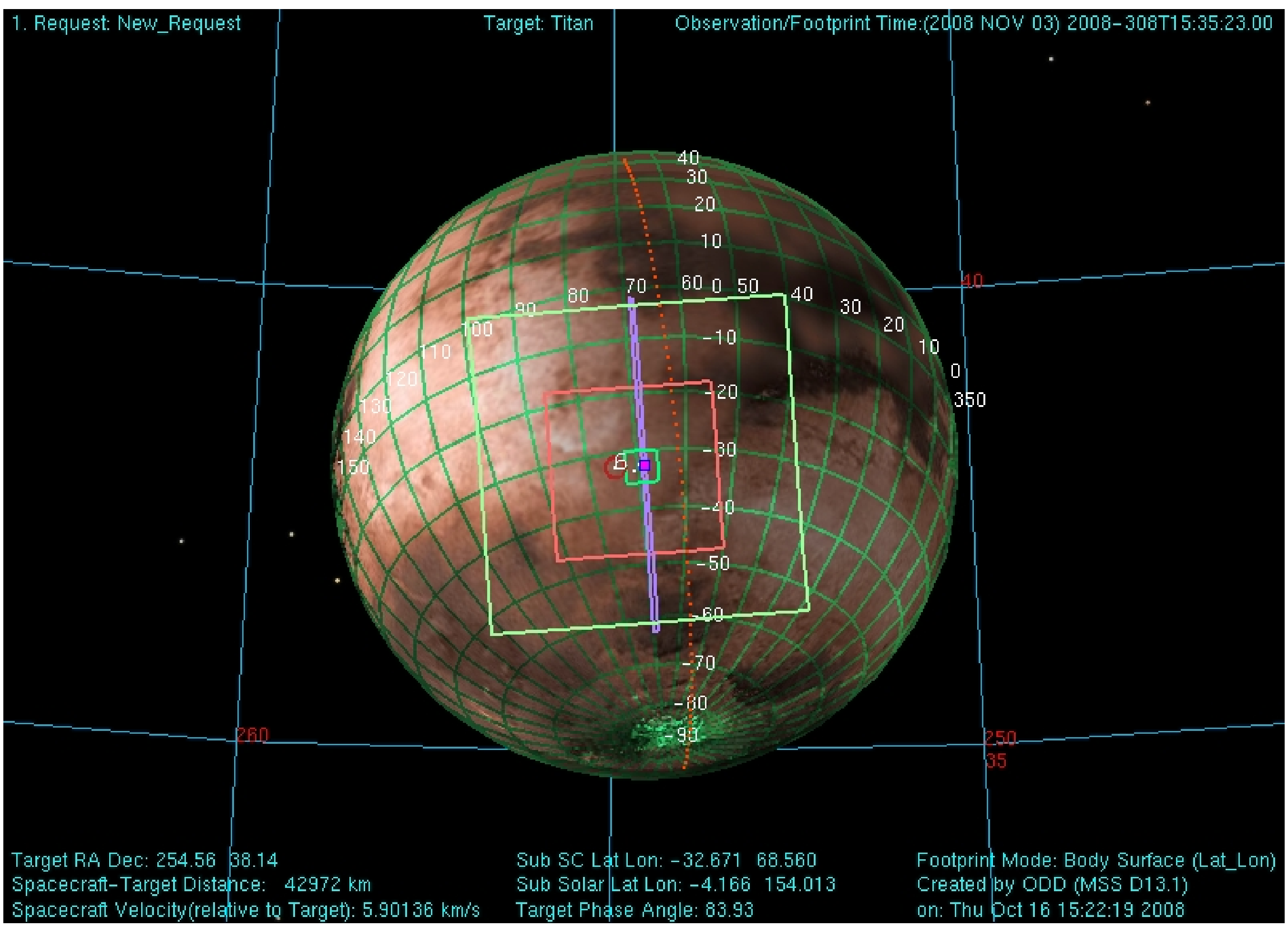
SAMPLE SNAPSHOTS

Three views of Titan from Cassini before, during, and after closest approach to Titan are shown below. The views are oriented such that the direction towards the top of the page is aligned with the Titan North Pole. The optical remote sensing instruments' fields of view are shown assuming they are pointed towards the center of Titan. The sizes of these fields of view vary as a function of the distance between Cassini and Titan. A key for use in identifying the remote sensing instruments fields of view in the figures is listed at the top of the next page.

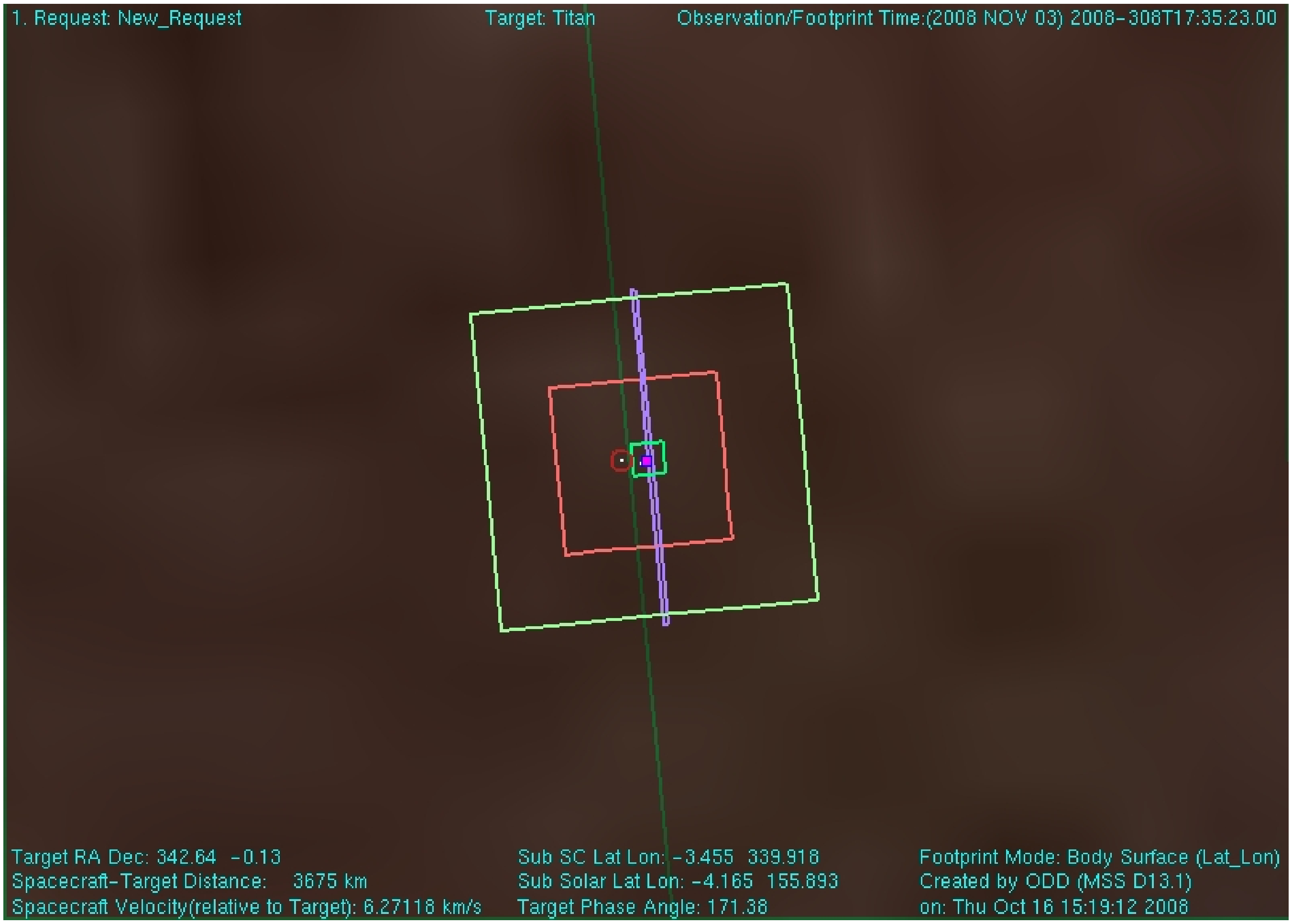
Key to ORS Instrument Fields of View in Figures

Instrument Field of View	Depiction in Figure
ISS WAC (imaging wide angle camera)	Largest square
VIMS (visual and infrared mapping spectrometer)	Next largest pink square
ISS NAC (imaging narrow angle camera)	Smallest green square
CIRS (composite infrared spectrometer) – Focal Plane 1	Small red circle near ISS_NAC FOV
UVIS (ultraviolet imaging spectrometer)	Vertical purple rectangle centered within largest square

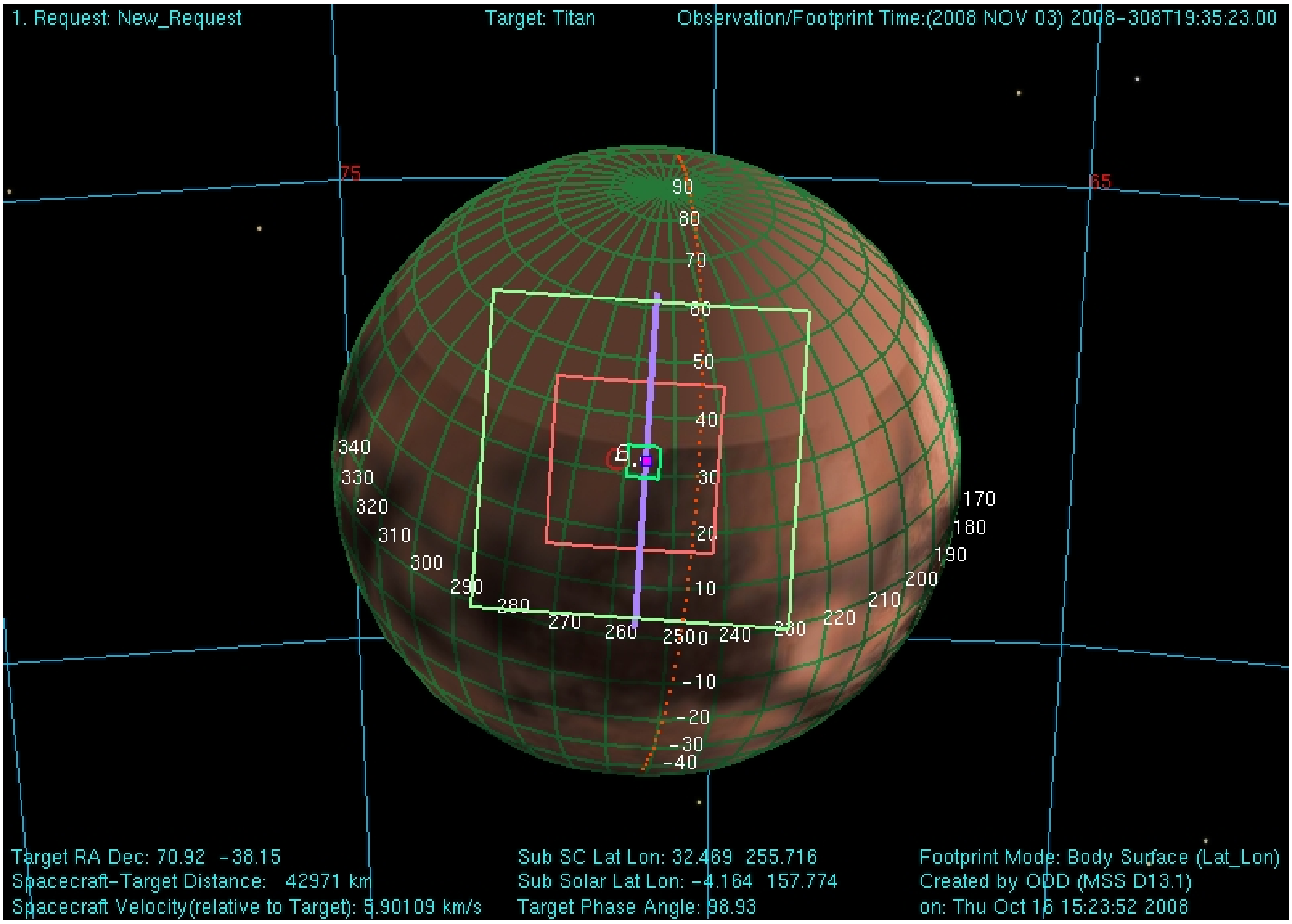
View of Titan from Cassini two hours before Titan-46 closest approach



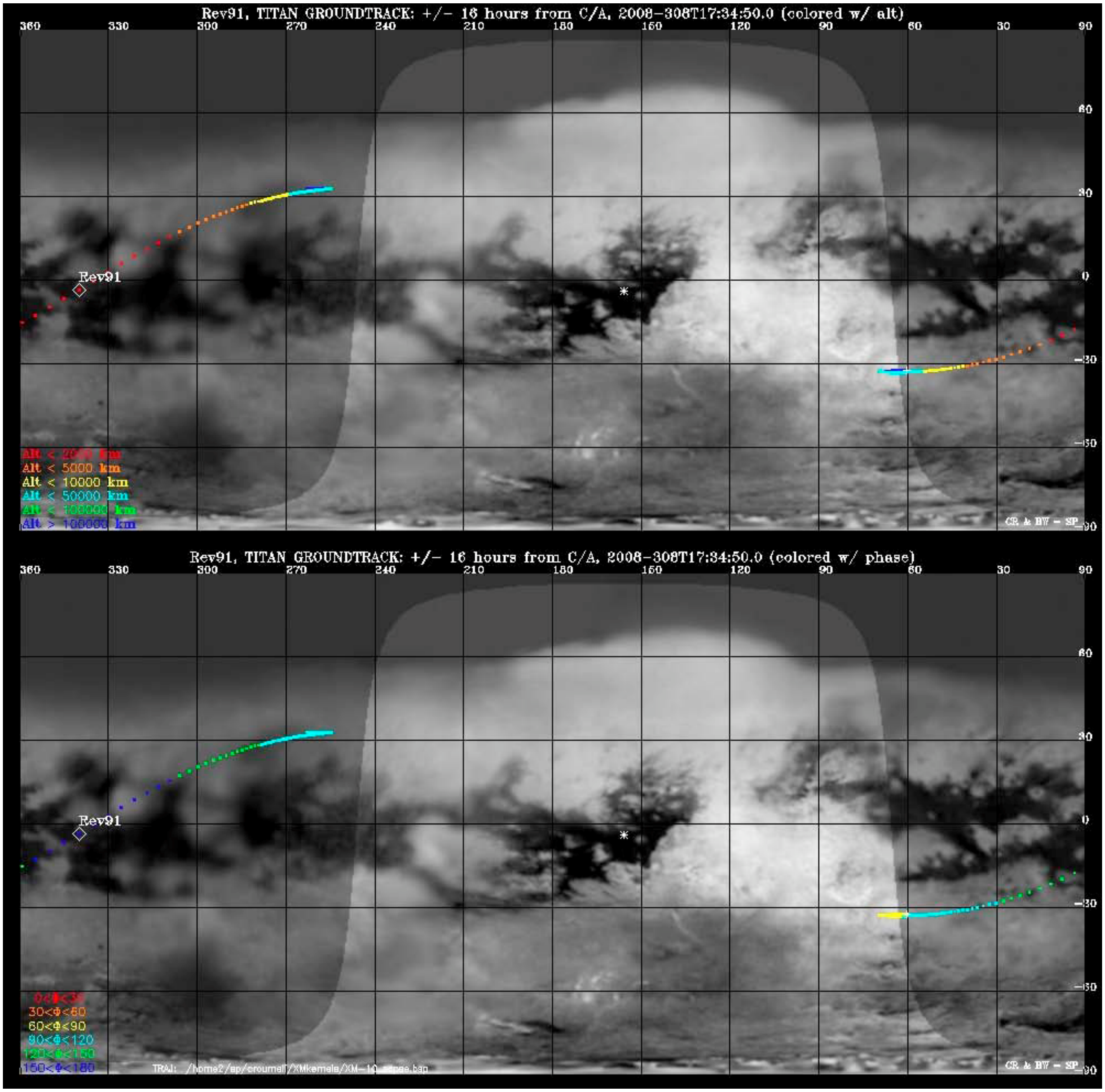
View of Titan from Cassini at Titan-46 closest approach



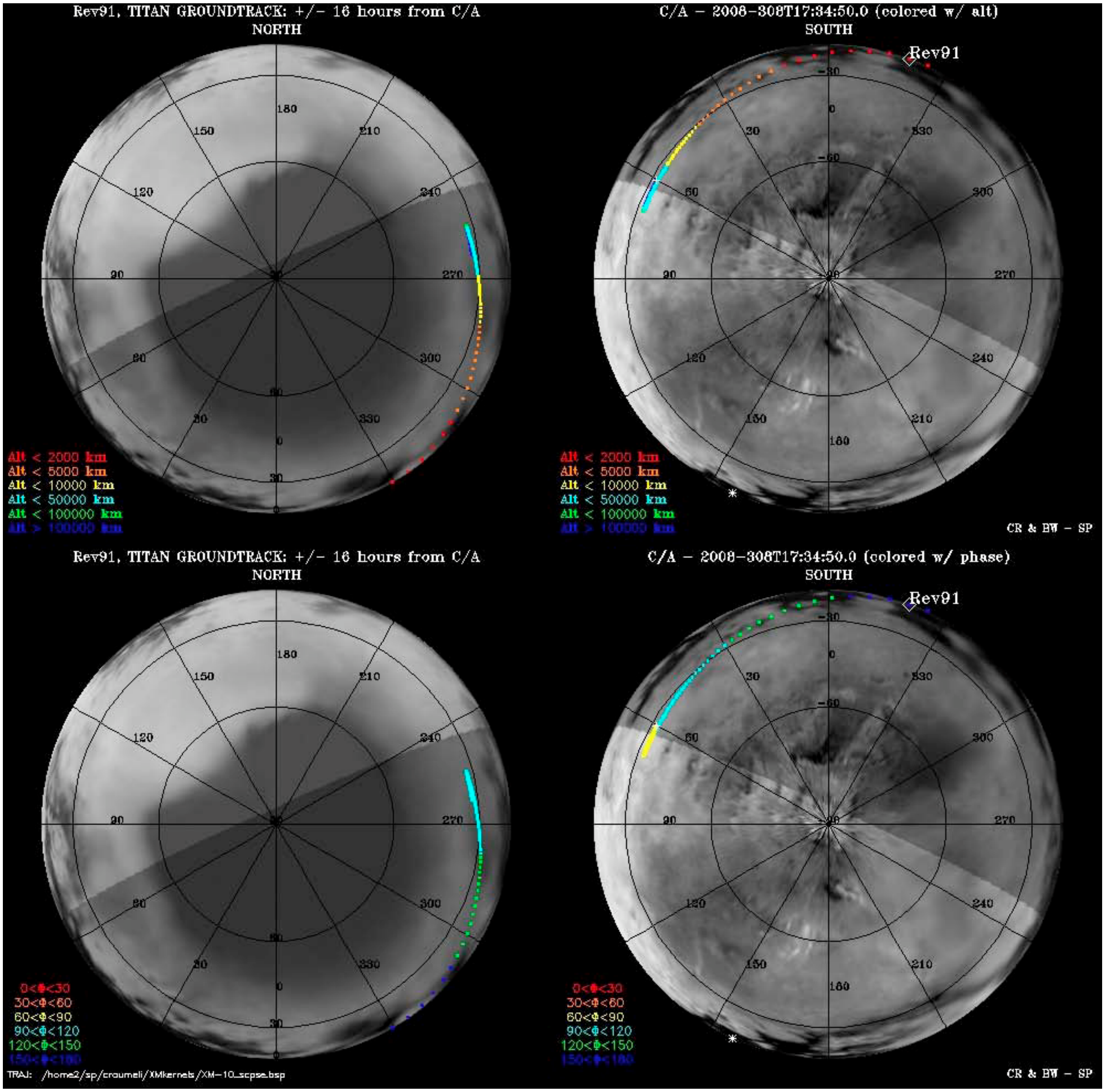
View of Titan from Cassini two hours after Titan-46 closest approach



Titan Groundtracks for T46: Global Plot



Titan Groundtracks for T46: Polar Plot



The T46 timeline is as follows:

Cassini Titan-46 Timeline - October 2008

Colors: yellow = maneuvers; blue = geometry; pink = T46-related; green = data playbacks

Orbiter UTC	Ground UTC	Pacific Time	Time wrt T46	Activity	Description
292T20:21:00	Oct 18 21:44	Sat Oct 18 01:44 PM	T46-15d21h	Start of Sequence S45	Start of Sequence which contains Titan-46
303T10:37:00	Oct 29 12:00	Wed Oct 29 04:00 AM	T46-05d07h	OTM #169 Prime	Titan-46 targeting maneuver.
304T10:37:00	Oct 30 12:00	Thu Oct 30 04:00 AM	T46-04d07h	OTM #169 Backup	
307T19:22:00	Nov 02 20:45	Sun Nov 02 12:45 PM	T46-22h13m	Start of the TOST segment	
307T19:22:00	Nov 02 20:45	Sun Nov 02 12:45 PM	T46-22h13m	Turn cameras to Titan	
307T20:02:00	Nov 02 21:25	Sun Nov 02 01:25 PM	T46-21h33m	New waypoint	
307T20:02:00	Nov 02 21:25	Sun Nov 02 01:25 PM	T46-21h33m	Deadtime	15 minutes 33 seconds long; used to accommodate changes in flyby time
307T20:17:33	Nov 02 21:40	Sun Nov 02 01:40 PM	T46-21h18m	Titan atmospheric observations-CIRS	Obtain information on the thermal structure of Titan's stratosphere.
308T02:35:23	Nov 03 03:58	Sun Nov 02 07:58 PM	T46-15h00m	Titan atmospheric observations-CIRS	Obtain information on CO, HCN, CH4.
308T08:35:23	Nov 03 09:58	Mon Nov 03 01:58 AM	T46-09h00m	Titan surface observations-ISS	Global map
308T12:35:23	Nov 03 13:58	Mon Nov 03 05:58 AM	T46-05h00m	Titan surface observations-ISS	Regional map
308T14:05:23	Nov 03 15:28	Mon Nov 03 07:28 AM	T46-03h30m	Transition to thruster control	
308T14:06:23	Nov 03 15:29	Mon Nov 03 07:29 AM	T46-03h29m	Titan atmospheric observations-CIRS	Obtain information on surface & tropopause temperatures, and on tropospheric CH4.
308T16:07:23	Nov 03 17:30	Mon Nov 03 09:30 AM	T46-01h28m	Turn cameras to new waypoint	
308T16:09:23	Nov 03 17:32	Mon Nov 03 09:32 AM	T46-01h26m	New Waypoint	
308T16:09:23	Nov 03 17:32	Mon Nov 03 09:32 AM	T46-01h26m	Titan surface measurements-RSS	Bistatic scattering measurments at three radio wavelengths to determine the physical properties of Titan's surface, including reflectivity, dielectric constant, and roughness.
308T17:21:23	Nov 03 18:44	Mon Nov 03 10:44 AM	T46-00h14m	Titan atmospheric observations-RSS	RSS ingress/egress occultation of Titan's atmosphere and ionosphere
308T17:35:23	**Nov 03 18:58**	**Mon Nov 03 10:58 AM**	**T46+00h00m**	**Titan-46 Flyby Closest Approach Time**	**Altitude = 1613 km (~1002 miles), speed = 6.3 km/s (14,000 mph); 49 deg phase at closest approach**
308T17:54:23	Nov 03 19:17	Mon Nov 03 11:17 AM	T46+00h19m	Titan surface measurements-RSS	Bistatic scattering measurments at three radio wavelengths to determine the physical properties of Titan's surface, including reflectivity, dielectric constant, and roughness.
308T18:51:18	Nov 03 20:14	Mon Nov 03 12:14 PM	T46+01h16m	Turn cameras to new waypoint	
308T19:04:23	Nov 03 20:27	Mon Nov 03 12:27 PM	T46+01h29m	New Waypoint	
308T19:04:23	Nov 03 20:27	Mon Nov 03 12:27 PM	T46+01h29m	Transition off of thruster control	
308T18:08:16	Nov 03 19:31	Mon Nov 03 11:31 AM	T46+00h33m	Ascending Ring Plane Crossing	
308T19:26:23	Nov 03 20:49	Mon Nov 03 12:49 PM	T46+01h51m	Titan atmospheric observations-UVIS	Several slow scans across Titan's visible hemisphere to form spectral images
309T02:35:23	Nov 04 03:58	Mon Nov 03 07:58 PM	T46+09h00m	Titan atmospheric observations-ISS	Photometry
309T03:35:23	Nov 04 04:58	Mon Nov 03 08:58 PM	T46+10h00m	Titan atmospheric observations-CIRS	Obtain information on CO, HCN, CH4.
309T08:13:33	Nov 04 09:36	Tue Nov 04 01:36 AM	T46+14h38m	Titan surface observations-ISS	monitoring for surface/atmosphere changes; attempt to see surface color variations; monitor limb hazes, 1-3 km/px
309T09:13:33	Nov 04 10:36	Tue Nov 04 02:36 AM	T46+15h38m	Deadtime	14 minutes 26 seconds long; used to accommodate changes in flyby time
309T09:28:00	Nov 04 10:51	Tue Nov 04 02:51 AM	T46+15h53m	Turn to Earth-line	
309T10:08:00	Nov 04 11:31	Tue Nov 04 03:31 AM	T46+16h33m	Playback of T46 Data	Goldstone704m