Cassini Mission

Deep Space Telecommunications Into the Next Century

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S1101<'1" ABSTRACT

in late 1997 an unmanned spacecraft will begin a 7 year voyage to the vicinity of the planet Saturn Upon arrival it will tour the Satur nian system for nearly 4 years. This mission, which is named *Cassini* in honor of a French-Italian astronomer, Jean Dominique Cassini, is an international cooperative mission of NASA, ESA, and the Italian Space Agency. NASA is providing the tracking network and the orbiter spacecraft. ESA is providing the Huygens Probe and ASI is responsible for the spacecraft's radio antenna as well as portions of 3 scientific instruments.

This paper will describe the scientific object ives of'the missions and then show the designs of the telecommunications assemblies and systems that make this tremendous accomplishment possible,

At the present time early 1996 the designs of the Cassini Systems and subsystems arc complete. Fabrication of flight and spare hardware is under way. The system test program is about to begin leading to the launch, less than 2 years away. But the launch is just another beginning. The 7 year voyage is filled with activities to enable the spacecraft to safely arrive at Saturn in mid 2004 11 is then that the real excitement of discovery begins once again

1 .ONG ABSTRACT

]n late 1997 an unmanned spacecraft will begin a 7 year voyage to the vicinity of the planet Saturn. Upon arrival it will tour the Saturnian system for nearly 4 years. This mission is named *Cassini* in honor of a French-ltalian astronomer, Jean Dominique Cassini. A variety of scientific instruments will probe, sample, observe and listen to the environment of the planet, its rings, some of its icy moons and its largest moon Titan.

Cassini is an international cooperative mission of NASA, ESA, and the Italian Space Agency. NASA is providing the tracking network and the orbiter spacecraft. ESA is providing the Huygens Probe and ASI is responsible for the spacecraft' s radio antenn a as well as portions of 3 scientific instruments

The task of capturing on Earth the enormous amount of information collected by the 3 dozen scientific instruments is a formidable one Stations of NASA's Deep Space Network, arc scheduled to provide reception of the vital planetary scientific information as well as spacecraft health monitoring during the entire mission.

The spacecraft is carrying a 4 meter diameter antenna, which together with 2 smaller lower gain antennas provide all communications paths with Earth for radio command, radio navigation and radio telemetry. This large antenna also provides the reception of information from the Huygens]'robe dining its descent to the Titan surface. In addition, this antenna is used by the Titan mapping RADAR of the orbiter which has the capability to pierce the veil of haze of Titan and produce images of the surface.

At X-Band the electronics of the Radio Subsystem provides multiple telecommunications functions. Commands beamed from Earth, radio tracking signals to determine spacecraft position and velocity, as well as engineering and scientific information for Earth bound observers arc all processed within this subsystem.

Radio Science observation use the X-Band capability of the Radio Subsystem but also utilize S-Band and Ka-Band to search for gravitational waves in the universe, study the atmosphere, rings, and gravity fields of Saturn anti its moons

Designed as part of the 4 meter antenna is a 5-beam feed array. This array enables the Ku-Band mapping RADAR to collect Titan imaging, altimetry, and surface radiance information during close flybys over the 4 year tour.

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In late 1997 an unmanned spacecraft will begin a seven year voyage to the vicinity of the planet Saturn Upon arrival it will tout' the Saturnian system for nearly four years, This mission is named ***Cassini*** in honor of the French-Italian astronomer, Jean Dominique Cassini, who in 1676 first observed the division in the rings of Saturn, that is now known as the Cassini division. Dutch astronomer Christian Huygens observed that the rings are separate from the planet after Italian astronomer Galileo Galilei first observed the rings in 1610. Huygens was also the discoverer of the large moon Titan.

Now nearly four centuries later a joint U S.- European mission is being prepared to conduct a multispectral, orbital surveillance of Saturn, and to investigate Titan. This spacecraft will be the fourth to visit this planet, having been proceeded by Pioneer 11 and Voyagers I and 2..

Prior to its arrival at Saturn, the spacecraft will be used in attempts to detect gravitational waves in the universe.

Then upon arrival in mid 2004, observations will begin to achieve the science objectives as shown in 'Table _

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Science Objectives

Titan
- Atmospheric constituent abundance
- Distributions of trace gases and aerosols
- Winds and temperatures
- Surface state and composition
- Upper atmosphere

Saturn
- Ground properties/atmospheres composition
- Winds and temperatures
- Internal structure and rotation
- Saturn's ionosphere
- origin and evolution of Saturn

Saturn Rings
- Structure and composition
- Dynamical processes
- Interrelation of rings and satellites
- Dust/micrometeoroid environment

Icy Satellites
- Characteristics and geological histories
- Mechanisms of surface modification
- Surface composition and (distribution
- Bulk composition and internal structure
- Interaction with magnetosphere

Magnetosphere
- Configuration and current systems
- Particle composition, sources, and sinks
- Dynamics of the magnetosphere
- Interaction with solar wind, satellites, and rings
- Titan's interaction with solar wind and magnetosphere

Mission Design

THE MACHINE

The Cassini Spacecraft is a three-axis-stabilized spacecraft. The main body of the spacecraft is formed by a stack consisting of a lower equipment module, upper equipment module, and the High Gain Antenna (HGA). Attached to this stack are the remote sensing pallet, the fields and particles pallet, and the Huygens Probe system. The spacecraft electronics bus is part of the upper equipment module and earl-iersthe electronicsto support the spacecraft data handling, including the command and data subsystem (CDS) and the radio frequency subsystem. The spacecraft is several stories tall and weighs a total of 5,500 kilograms (the hardware weighs 2,500 kilograms and the propellant tanks are loaded with 3,000
kilograms of propellant),

The equipment includes:

Engineering Subsystems: Antenna, Radio, CDS, At tit ude and Articulat ion Control (AACS), Power, and Propulsion

Orbiter Instruments:
- imaging Science Subsystem (1SS)
- RADAR
- Radio Frequency Instrument Subsystem (RFI S)
- Ion & Neutral Mass Spectrometer (INMS)
- Visual & infrared Mapping Spectrometer (VIMS)
- Composite infrared Spectrometer (CIRS)
- Cosmic Dust Analyzer (CDA)
- Radio and Plasma Wave Science (RPWS)
- Cassini Plasma Spectrometer (CAPS)
- Ultraviolet imaging Spectrograph (UVIS)
- Magnetospheric imaging Instrument (M1h41)
- Dual Technique Magnetometer (MAG)

The 12 science instruments can be grouped into 3 larger groups: optical Remote Sensing, (CIRS, 1SS, UVIS, and V]MS), l~iclds/l)articlcs/Waves (CAPS, CDA, INMS, MAG, MIMI, and RPWS) and Microwave Remote Sensing (RADAR and RSS).

Huygens Probe Instruments:

carries

The probe ~~carriers~~ accelerometers to measure drag as well as instruments to measure temperature and pressure It will also carry an instrument to measure the structure and physical properties of the atmosphere, an aerosol collector and pyrolyzer to examine clouds and suspended particles, a gas chromatograph and mass spectrometer, a Doppler wind experiment arid a descent imager and spectral radiometer to take pictures of Titan's clouds and surface

THE FLIGHT

The Cassini Spacecraft is planned to be launched with a Titan IV Centaur in October, 199'7 and the trajectory to Saturn utilizes two gravity-assist flybys of Venus (in April 1998 and June 1999), then one each of Earth (in August 1999) and Jupiter (in December 2000) arriving at Saturn 7 years later in late 2004.

Immediately after separation of the spacecraft from the Centaur, the spacecraft's AACS points the spacecraft's HGA towards the Sun. At this point, with its high gain antenna pointed towards the Sun, the spacecraft is transmitting real time telemetry via one of the two low gain antennas, and is awaiting instructions from the ground.

Shortly after the launch sequence is complete, the spacecraft will playback the telemetry that was recorded in the Solid State Recorder (SSR) up to that moment, and interleave it with real time telemetry. The total data volume (about 10 Mbits) is transmitted via one of the two low gain antennas.

While inside the Earth's orbit around the Sun, the heat from the Sun requires the spacecraft High Gain Antenna (HGA) to be pointed directly at the Sun so that the high-gain antenna shades most of the spacecraft. During this time, communications with the spacecraft will use one of the two low-gain antennas (LGA1 or LGA2 depending on the launch epoch) on the spacecraft. The Antenna Subsystem provides two low gain antennas which allow one or the other to receive/transmit X-Band from/to the Earth when the spacecraft is sun pointed.

Following the Earth flyby, the spacecraft will be on a trajectory that will encounter Jupiter in December, 2000. Six months after the Earth flyby, the spacecraft will turn to point at Earth and subsequent communications will use the spacecraft HGA.

Two years prior to Saturn Orbit Insertion, the instruments will be turned on, calibrated, and science data will be collected. During the approach to Saturn in late June 2004, the spacecraft will conduct science activities prior to the execution of the Saturn Orbit Insertion (S01) maneuver. The closest approach altitude during SOI is 0.3 Saturn radii, its closest approach to the planet during the entire mission.

The probe is released from the Orbiter 21 to 22 days before the first Titan flyby, anti flies directly into Titan's atmosphere, where it collects data for up to 2 1/2 hours before reaching the surface. Two days after Probe release, the Orbiter performs a deflection maneuver to place it on the propt] trajectory 10 collect and record probe data for later playback to the Earth; to avoid impacting Titan, and to obtain the proper gravity assist to meet the tour design.

The Orbiter then continues on a tour of the Saturnian system, including multiple c1osc Titan flybys for gravity assist and science acquisition The planned tour duration is 4 years, which follows the 7 year cruise to arrive at Saturn.

THE MEASUREMENTS

Cassini's principal mission objective is to send a suite of instruments to Saturn to:

1. collect scientific data about Saturn, its rings, its satellites (including Titan)
2. collect scientific data about Saturn's fields and particle environments, and interactions
3. study the atmospheres and ionosphere's of Saturn and Titan
4. study the gravity fields of Saturn anti its satellites
5. detect gravity waves during the interplanetary cruise phase
6. perform general relativity tests and study the solar corona via solar conjunction experiments
7. Huygens probe will collect and beam data to the Orbiter during its descent and for a short time on Titan's sul-face,

The Titan flybys and Saturn orbits will be designed to maximize science coverage and provide numerous Sun and Earth occultations of both targets. The Cassini Spacecraft will operate in a mode of alternately facing towards Saturn and its sat ellites taking data and turning towards Earth and transmitting the downlink telemetry.

On a typical day in the Cassini tour, the spacecraft will be in Downlink Fields, Particles, and Waves (DFPW) mode from 9 to 12 bouts, depending on the duration of the Deep Space Network (DSN) pass. Much of the time the spacecraft will transition into and out of the Optical Remote Sensing (ORS) mode before and after the DFPW mode. This results in a split of time between the pointing instruments and the scanning instruments of roughly 15 houJs a day and 9 hours a day.

Data Management Scenarios:

Measurements from all Orbiter instruments will be stored on the Solid State Recorders (SSRs) as these are collected and then relayed to Earth via the Radio and High Gain Antenna (HGA).

A Set of 3] telemetry modes has been defined to accommodate different engineering and science activities and the changing telecommunications capability during the Cassini mission. Each telemetry mode represents a unique configurate ion of data sources, rates, and destinations for telemetry data gathered and distributed by the CDS. Data arc muted either to the SSR for temporary storage or to the RFS for transmission to the ground or both.

There arc 5 sources of data:

Engineering data from the Spacecraft Subsystems
Science housekeeping data from the instruments
Scientific data from the instruments
Playback data from the SS1{
Probe data

The 31 telemetry modes have been grouped into 7 categories:

Real time engineering
Playback plus Real-time Engineering
1'1 obc Checkout
l'lobe operations
Science and Engineering Record
Real-time Engineering plus Science Playback
Ground Instrument Checkout

The science and engineering record modes will be used for science data collection when the orbiter 1 IGA is turned off the Earth line for- remote sensing, RADAR, and INMS observations and during radio science experiments.

Downlink Telemetry Link Scenarios:

The Venus-Earth portion of cruise contains some of the most difficult conditions for telemetry reception. Limited use of 70 meter ground stations is required to achieve a 20 bps downlink telemetry l-ate while the 34 meter ground antennas are required to provide X-hand uplink.

At the beginning of the Venus-Earth subphase, the spacecraft is sun-pointed and communicating through LGA1 at a rate of 1 pass per week. After the Earth flyby on August 16, 1999, the DSN coverage demands drop, since the Sun angle drops low enough to allow continuous Earth point and the use of the I] GA.

The long period of (outer-) cruise from Earth to Saturn will be a period of fairly low activity. This is evidenced by long periods of low DSN tracking, typically only one pass per week. However, at L+436 days, the spacecraft is near a solar opposition and can point its HGA towards the Earth for a period of 25 days and still keep the Pmbc battery temper-ature within a reasonable range. This provides a high data rate window in which maintenance activities will be able to resume at full speed, the instruments will be able to perform a checkout.

Uplink Command Link Scenarios:

During the LGA coverage, uplink commanding of at least 8 bps can be accomplished with the DSN's 34 meter stations. While the 70 meter DSN stations will not have the capability to uplink X-Band until the year 2001.

For all of cruise and tour when on the HGA, the uplink rate will be constant at 500 bps. During the Launch and most of the Inner Cruise Phase, the spacecraft will be on the low gain antennas. The uplink rate when on a low gain antenna will be between S and 63 bps, except near Earth when 500 bps can be used. The times when LGA uplink can be 500 bps is limited by range and EPS angel.

During the SOI subphase, the range to Earth is shout 10 AU (for July 1, 2004, arrival), The SOI data volume per pass for specific configurations is shown in Table 6.2

Table 6,2 X-hand Data Rates

Antenna Configuration	X-Band Data Rates	Data Volume Returned
N. Hemisphere 70 meter full pass	35,6/83,0 kbps	2.90 Gbits
N. Hemisphere 70/34 meter 9 hour array	83.0/124 4 kbps	3,70 Gbits

The science community has indicated that 1 0 Gbit per day for low activity periods and 4.0 Gbits per day for the high activity periods would be adequate to accomplish their goals.

During the tour, expected data rates for the spacecraft's HGA and 19 Watt X-Band transmitter arc on the older of 14 Kbps to 166 Kbps. These rates vary due to the assumed telecom confidence level, the ground station configuration and the Earth's motion around the Sun (which affects the transmission range), and Saturn's motion around the Sun (which affects the declination of the spacecraft as seen from Earth). Earth's motion is by far the dominant geometric factor and is evident in the sinusoidal nature of the link's performance, Since the link performance varies significantly with time, multiple data rates must be used to maintain acceptable science data return.

During the tour two data rates will be used for each pass. Two data rates arranged in a step fashion provides a substantial improvement over only onc rate pcr pass (a 20% increase). the data rates in each pass will be chosen by the telecommunications team to maximize the total data return for that pass. All stations usc the higher rate about twice as much as the lower rate.

When the downlink capability is more than tbc SSR capacity of 3.6 Gbit, the SSR maybe filled between passes, and fields, particles and waves (FPW) data recorded on the space that is freed up during the downlink. This allows more than 3.6 Gbit to be recorded and played back in a single day.

Radio Science Experiments:

Gravitational wave experiments will be performed while enroute to Saturn near at least three oppositions, with X-Band and Ka-Band uplinks, and X-hand and dual frequency Ka-Band downlink.

Solar conjunction experiments will be conducted while enroute to Saturn, near at least two solar conjunctions X-Band and Ka-Band uplinks and X Band and dual frequency Ka-Band downlinks will be used for the general relativity experiment the solar corona study requires both X-Band uplink and simultaneous X-Band and S-Band downlink or simultaneous X-hand and Ka-Band downlink.

'J'here ai c two types of radio science flybys: occultation flybys and gravity field determination flybys

The occultat ion expel-imcnt will determine chai act crist ics of the Titan atmosphere by ti ansmit ting S-Band, X-hand, and potentially Ka-Band signals through the atmosphere toward the Earth. During occultation periods the DSN site must be chosen to provide radio link during a specific time, Some cases will require more than onc DSN site to provide complete coverage of an occult at ion event.

During gravit y field passes, X and Ka signals will be t ransmitted towai d Earth for a period of 2 hours on either side of closest approach. Tracking coverage will be continuous throughout the pass.

International Cooperation

Cassini is an international cooperative mission of NASA, the European Space Agency (ESA), and the Italian Space Agency (ASI). NASA is providing the tracking network, the orbiter spacecraft, the launch vehicle, and overall project management. Cassini's NASA/European partnership provides an example of an undertaking whose scope and cost would not likely be affordable by any single nation.

In Europt, fourteen nations are participating in the technological development of the Huygens Titan probe, and scientists from twelve European nations are members of Cassini's scientific team. The U.S. is supplying the batteries and two science instruments for Huygens.

The Italian Space Agency is developing the orbiter's high-gain antenna, as well as assemblies for the Radio Science investigations, the Titan Mapping RADAR, and the Visual anti Infrared Mapping Spectrometer.

Telecommunication System Design

The challenge was to design a system that met simultaneously many requirements. In pal-titular, the Cassini spacecraft will be up to 1.5 billion Kilometers from Earth when it arrives at Saturn. A large volume of science data will have to be collected and transmitted to Earth (up to 4 Gigabits per day). This requires from the spacecraft a very large High Gain Antenna (4 m in diameter) and very precise pointing to Earth (O. 18 degrees). It also requires on Earth a Deep Space Network (DSN), with very large antennas (up to 70 m in diameter), very low receiving system noise temperatures (25 Kelvin or better), very sophisticated receivers and decoders capable of processing very week signals. As an example, the average signal power received on Earth will be about 10^{-16} W when the spacecraft is at Saturn. The DSN also provides 24-hours-per-day coverage with 3 different sites: Goldstone, California; Canberra, Australia; and Madrid, Spain.

Another challenging period is during the interplanetary cruise, when the spacecraft will be close to the Sun, so it has to use the HGA reflector as a sun-shield. This means the spacecraft will have to point away from Earth (at times up to 170 degrees), so we have to use Low Gain Antennas with a wide beam, but with low gain. This means that telemetry data rates during cruise may drop down to 20 bps or less.

The Telecom System allows us to navigate the spacecraft, to command it, to transmit science data and engineering telemetry from it anti to perform numerous Radio Science experiments with it, in addition, our HGA will allow the Radar mapping of Saturn's largest moon, Titan.

For navigation, the Telecom system must support both two-way tracking and ranging. Tracking is performed by having the spacecraft receiver lock up to an RF signal from Earth and transmitting a phase-coherent signal back to Earth. The ground station then processes the 2-way data to measure the Doppler shift on the spacecraft signal, thereby measuring the spacecraft velocity. Ranging is pcl-formed by sending a series of square waves to the spacecraft transponder, which demodulates them from the uplink signal and re-modulates them onto the downlink. When the ground receives the ranging signals, it cor-relates them with a replica of the ranging signals that were sent, which allows it to measure the round-trip light time of the ranging signals. This gives the distance to the spacecraft. The navigation must be very precise. For example, when the Cassini spacecraft is in its Saturn tour phase, it must flyby Titan with an accuracy of 1 () km, which at 1.5 billion kilometers from the Earth is remarkable. Also, the Cassini mission makes use of the gravity of Venus, Earth and Jupiter to accelerate and change direction. This allows the spacecraft to fly with only 3,000 kilograms of propellant, instead of 28,000 (which is a savings of 933%). Another way to consider this is that it would take about 5 times more launch energy for a direct trajectory than for the gravity-assist trajectory Therefore, the gravity assists are necessary, but must be executed precisely: for example, the spacecraft will fly by Venus at an altitude of 300 km, plus or minus 25 km

The Earth must be able to send commands to the spacecraft every day of the mission. This means that the spacecraft receiver and command detector- unit must be able to acquire a signal even during an emergency at maximum range (1 5 billion km), through a Low-Gain Antenna So the receiver had to be able to lock to very weak uplink signals from Earth (down to 10^{-17} W) During normal operations at Saturn, the spacecraft will use it s 1 IGA and the ground station will upload sequences of' commands to the spacecraft's thi ee dozen instruments, where a higher command d at a rate is required. As a result, our Command I Detector Unit can process command data rates from 7.7 bps up to 500 bps.

As for telemetry, there wiii be a large range of data rates. Wc will transmit up to 1 50 kilobits per second during high activity science periods at Satu n, and wc also will drop d own to 20 bps during interplanetar y cruise. Wc must be able to semi telemetry whether the spacecraft is receiving commands 01 not, whether ranging signals are being sent from Earth and need to be re-modulated on the downlink, anti whether the downlink RF frequency is phase-iockcd to an uplink from 1 Earth or not.

Radio Science obser vat ions present many challenges. First, Radio Science occultation experiments require simultaneous transmission at t hr cc frequencies(s-, X- and Ka-band) all driven by an lJitra-Stable oscillator with very stringent frequency stability requirements. The three frequencies arc needed for better resolution of the Saturn rings, at mosphere, etc. in addition, Cassini will conduct several gravity-wave experiments, and the spacecraft must be able to receive both an X-Band uplink and a Ka-band uplink, and generate an X-band downlink phase coherent with the X-band uplink, a Ka-band downlink phase-cohclcnt with the Ka-band uplink, anti a Ka-band signal phase-cohcl-cnt with the X-band signal '1'here will also be expel-imcnts in celestial mechanics and tests of relativity.

in addition, the 1 IGA is used to support Radar mapping of Titan at Ku-band. The HGA had to simultaneously meet requirements for S-, X-, Ka- and Ku-band, which complicated the design t remendously.

Onc obvious complexity is the need to limit inter-subsystem interference: for example, the S-band downlink signal transmitted by the spacecraft must not damage the Huygens Probe Receivers, also built at S-hand (although at slightly different fi equencies). This challenge has been addressed carefully through design and analysis and will be also subject to extensive tests pre-launch. Another complex aspect was the need to per form many of the functions descr ibed above with a minimum set of equipment. In particular, command, tracking, ranging and telemetry all use the spacecr aft transponder at each function must not interfere with any of the others.

Antennas

The Cassini high gain antenna is a four-meter diameter Cassegrain reflector antenna provided by the Italian Space Agency (ASI), which is funding Alenia Spazio (AI .S) for its delivery. The high gain antenna operates at S-, X-, Ku-, and Ka-bands and includes a hyperbolic/shaped frequency selective subreflector (FSS) system. The X-, Ku-, and Ka-band feeding systems (an X/Ku/Ka-band corrugated horn and Ku-band fan beam arrays) are placed in the cassegrain configuration and the S-band feed is placed at the antenna primary focual point, so that the FSS system is reflective at X-, Ku-, and Ka-bands and transparent at S-band.

The Cassini high gain antenna will be used for a variety of purposes throughout the mission. Telecommunications at X-band occur-s throughout. The high gain antenna will be sun-pointed in the tally part of the tour, to shade the rest of the spacecraft, during which time the low gain antennas will be used for telecommunications Radio science experiments use the high gain antenna at S-, X-, and Ka-bands, for both gravitationsl wave experiments during flight and for occultation experiments at Saturn. While in the saturnian system, the Huygen's probe, provided by the European Space Agency (ESA), will be inserted into the atmosphere of Saturn's moon Titan, and the antenna will receive signals transmitted back by the probe ot the spacecraft at S-band. And finally, the high gain antenna has also been designed for SAR (Synthetic Aperture Radar) radar mapping of Saturn's moon Titan at Ku-band to penetrate the haze that envelopes it

The four-meter diameter high gain antenna weighs approximately 100 kg. Mechanical design considerations are driven by the fact that the high gain antenna must survive launch and maintain structural stability over the 4 to 10 A.U. flight distance without degradation in performance. The antenna is a composite structure with a back stiffening reinforcement net work of ribs, rings, and a diaphragm. The main reflector dish is a thin, lightweight sandwich construction using graphite epoxy facesheets and an aluminum honeycomb core, while the stiffening components are made of a thicker sandwich construction. All the members are attached to one another with composite clips. Six graphite epoxy struts with titanium end-fittings support a kevlar sandwich construction deck plate, which supports the FSS screens and the S-band feed and the low gain antenna 1 (LGA1), All the feeds are aluminum Three titanium interface points are provided to the spacecraft support bipeds. Finally, the antenna is painted white with a proper thermal coating so that it may act as an effective sun shield.

The Cassini Low Gain Antenna 1 (GA 1) is mounted on top of the S-band feed and pointed in the forward direction. The field of view of LGA1 is unobstructed by the spacecraft. It consists of a cylindrical waveguide with several external corrugations shaped to minimize the amount of back radiation. LGA1 is aluminum and serves as the primary telecommunication link at near- earth distances.

The Cassini Low Gain Antenna 2 (GA2) is located below the Probe Relay Antenna facing the -X direction of the spacecraft, The field of view for LGA2 is partially obstructed by the Probe and the spacecraft thruster clusters. LGA2 is also fabricated out of aluminum and consists of a cylindrical waveguide with two choke rings to help minimize the back radiation. It will be used as a back-up for LGA 1.

Radio Frequency Subsystem

The Radio Frequency Subsystem (RFS) provides the telecommunications facilities for the Spacecraft and is used as part of the Radio Science instrument.

For telecommunications it produces an X-hand carrier at 8.4 GHz, modulates it with data received from CDS, amplifies the X-band carrier power to produce 20 Watts from the Traveling Wave Tube Amplifiers (TWTAs), and delivers it to the Antenna Subsystem (ANT) from ANT, the RFS accepts X-band ground command/data signals at 7.2 GHz, demodulates them, and delivers the commands/. data to CDS for storage and/or execution.

The Ultrastable Oscillator (USO), the Deep Space Transponder (DST), the X-Band Traveling Wave Tube Amplifier (TWTA), and the X-band Diplexer are those elements of the RFS which are used as part of the radio science instrument. the DST can phaselock to an X-band uplink anti generate a coherent downlink carrier with a frequency translation adequate for transmission at X-, S-, or Ka-band. The DST has the capability of detecting a ranging modulation signal and of modulating the X-band downlink carrier with the detected ranging modulation signal. Differential One-Way ranging (DOR) tones can also be modulated onto the downlink. The DST can also accept the reference signal from the USO and generate a non-coherent downlink carrier.

Radio Frequency Instrument Subsystem

The flight Radio Science instrument consists of the Radio Frequency Instrument Subsystem (RFIS). The main assemblies of the RFIS are the Ka-band Exciter, the Ka-band TWTA, the Ka-band Translator, and the S-band Transmitter. The RFIS receives UHF and X-band reference signals from the RFS which may be selected to be either coherent with the X-band uplink carrier or derived from the RF'S Ultrastable Oscillator; from these reference signals the RFIS produces an S-band and/or a Ka-band downlink carrier signal. The RFIS also provides a two-way Ka-band transponding function via the Ka-band Translator.

Current Status

With a launch date slightly more then 1 1/2 years away, the Huygens Probe, the orbiter spacecraft subsystems, and the scientific instruments arc all in the final phases of flight fabrication and environmental tests. Build up of the flight spacecraft is underway and initial application of electrical power has occur-red.

What remains in the complete integration of the Probe and the science instruments onto the spacecraft, then thermal and dynamics tests oft he entire stock. Following successful completion of these tests, the spacecraft and its supporting equipment will be shipped to Florida where it will be readied for its launch in October 1997, the end of our one phase of the mission.

nut the launch is just another beginning. The seven year voyage past Venus, Earth and Jupiter is filled with activities to enable the spacecraft to safely arrive at Saturn in mid 2004. It is then that the real excitement of discovery begins once again

Conclusion

This paper has presented the mission objectives, the mission design and then the telecommunications designs needed to meet the mission objectives. The telecommunication features arc:

- Long flight time
- Internation cooperation
- Multiple usage r.f. subsystems

Wc await the 21st century for the results of this exciting voyage for Earth bound observers.