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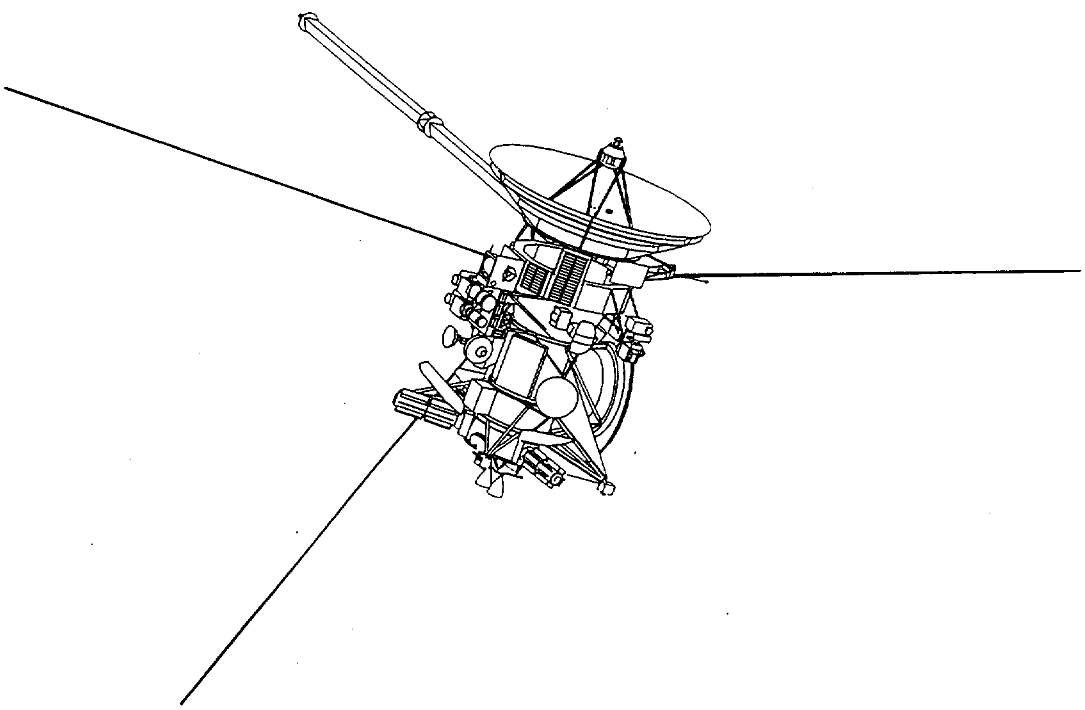
Cassini Program Environmental Impact Statement Supporting Study

Volume 1: Program Description



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GLOSSARY OF TERMS AND ACRONYMS

Acronyms and Abbreviations

AACS	Attitude and Articulation Control Subsystem
ACP	Huygens Aerosol Collector Pyrolyser
ASI	Italian Space Agency
CAPS	Cassini Plasma Spectrometer
CDA	Cosmic Dust Analyzer
CIRS	Composite Infrared Spectrometer
DISR	Descent Imager/Spectral Radiometer
DWE	Doppler Wind Experiment
EIS	Environmental Impact Statement
ESA	European Space Agency
GCMS	Gas Chromatograph/Mass Spectrometer
GPHS	General Purpose Heat Source
HASI	Huygens Atmospheric Structure Instrument
IDS	Interdisciplinary Science
INMS	Ion and Neutral Mass Spectrometer
ISS	Imaging Science Subsystem
JPL	Jet Propulsion Laboratory
LH_2	Liquid Hydrogen
LO_2	Liquid Oxygen
HAG	Dual Technique Magnetometer
MIMI	Magnetospheric Imaging Instrument
MMH	Monomethylhydrazine
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NTO	Nitrogen Tetroxide
PLF	Payload Fairing
PMS	Propulsion Module Subsystem

RADAR	Cassini Radar
RCS	Reaction control Subsystem
RHU	Radioisotope Heater Unit (same as LWRHU)
RPWS	Radio and Plasma Wave Science
RSS	Radio Science Subsystem
RTG	Radioisotope Thermoelectric Generator
SED	Saturn Electrostatic Discharges
SKR	Saturn Kilometr ic Radiation
SOI	Saturn orbit Insertion
SRM	Solid Rocket Motor
SRMU	Solid Rocket Motor Upgrade
SSP	Huygens Surface Science Package
UDMH	Unsymmetrical Dimethy1hydrazine
UVIS	Ultraviolet Imaging Spectrograph
V	Visible
VEEGA	Venus-Earth-Earth-Gravity-Assist
VVEJGA	Venus-Venus-Earth-Jupiter-Gravity-Assist
VIMS	Visible and Infrared Mapping Spectrometer

Units of Measurement

AU	Astronomical Unit(s)
cm	Centimeter(s)
cm/s	Centimeter(s)/Second
deg	Degree(s)
g	Gram(s)
in	Inch(es)
kg	Kilogram(s)
km	Kilometer(s)
km/s	Kilometer(s)/Second
lb-f	Pounds of force
mi	Mile(s)
N	Newton(s)
oz	Ounce(s)
s	Second(s)

Symbols

ΔV	Velocity Delta
$>$	Greater than

SECTION 1

OVERVIEW

1.1 PURPOSE OF THE ENVIRONMENTAL IMPACT STATEMENT SUPPORTING STUDIES

The National Aeronautics and Space Administration (NASA) is preparing an Environmental Impact Statement (EIS) for its proposed Cassini mission to Saturn. In support of this EIS, the Cassini Project at the Jet Propulsion Laboratory (JPL) has compiled three volumes of pertinent information. Volume 1 provides a summary description of the baseline Cassini Program (i.e., the proposed action), including mission objectives, baseline spacecraft, launch vehicle, and primary and backup mission designs. Volume 2 assesses the feasibility of potential spacecraft, mission, and power alternatives, then characterizes the technically viable options in terms of their impact on the spacecraft, mission objectives, and mission designs as delineated in the baseline. Volume 3 in its final form, will provide (1) estimates of the probability of an accidental Earth impact during the baselined Earth gravity-assist swingby, (2) the navigation strategies that have been designed to minimize that probability, and (3) estimates of the long-term (next 2000 years) impact probability for a disabled spacecraft. The preliminary version of Volume 3 summarizes the requirements of navigation strategies adopted by the Project to minimize accidental Earth impact. Launch vehicle safety and potential hazard environments will be addressed in the EIS. All three volumes are discussed in the Executive Summary.

1.1.1 Background

As mandated by the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 4321 et seq.), as amended, Federal agency action significantly affecting the quality of the human environment requires an Environmental Impact Statement. NASA's regulations for implementing NEPA require an EIS for development or operation of nuclear systems (CFR, 1993), and follow the Council on Environmental Quality regulations in U.S. CEQ, 1992, concerning consideration of 'alternatives'. These documents constitute the Cassini Project's support toward this effort.

1.2 CASSINI'S ROLE IN NASA'S EXPLORATION OF THE SOLAR SYSTEM

In pursuit of the goal of understanding the birth and evolution of the planetary system, NASA has developed a strategy that calls for an orderly progression from planetary reconnaissance, through exploration, to intensive study of each of the three regions of the solar system: the inner solar system (terrestrial planets), the primitive bodies (comets and asteroids), and the outer solar system (the gas giants and Pluto). Until recently, space missions to the planets in the outer solar system concentrated on flyby- or reconnaissance-type missions. With the launch of the Galileo mission to

Jupiter, NASA began its transition to more detailed, exploratory missions. The Cassini Mission to Saturn represents the next step in this more detailed exploration of the outer solar system, using orbiters and probes.

1.3 EXPLORATION'S BENEFITS TO SOCIETY AND THE NEED TO STUDY THE OUTER SOLAR SYSTEM

1.3.1 Exploration's Benefits to Society

Solar system exploration can be viewed as providing benefits to society on three time scales: short-term (years), mid-term (decades), and long-term (>100 years). In the short-term, there are distinct political, technological and economic benefits associated with such exploration. For instance, planetary missions provide a valuable opportunity to foster international cooperation. They also drive state-of-the-art technology development such as the miniaturization, improved speed, and greater reliability of electronic components.

The mid-term benefits consist of further technological, economic, and scientific advances. The commercial applications of technological developments that began in the short-term sometimes spawn whole new technologies in the mid-term. In a similar fashion, the multi-disciplinary application of space science findings can generate whole new insights into terrestrial phenomena. For instance, meteorologists have been able to improve their atmospheric models by testing their predictive capabilities against the real data gathered from other planets. Also, volcanologists and geophysicists have been better able to understand terrestrial geophysical phenomena as a result of trying to explain data gathered from planetary "laboratories" such as Io, Mars, Venus, and the icy satellites of the outer solar system. The benefits that society reaps from these advances in expanded knowledge are difficult to quantify, but it is notable that the study and understanding of many significant terrestrial problems (e.g., global climate change) have benefited from the techniques, theories, and/or perspectives arising from space exploration.

The long-term advantages are the most difficult to assess, but may prove to be the most valuable. These benefits fall into three general categories. First, solar system exploration provides us with a sense of our 'place' in the universe; 20th century space exploration may well be remembered more for having given us our first real look at the solar system in which we live than for any of the shorter term benefits discussed previously. Second, solar system exploration improves our understanding of the chemical and physical conditions needed to foster the development of life. And third, history suggests that the ultimate value of such exploration may well be something we cannot envision at the current time -- the serendipitous potential that makes exploration so exciting.

1.3.2 The Need to Study the Outer Solar System

While the inner solar system (the region including the Sun, Mercury, Venus, Earth, and Mars) tends to be the more accessible portion of our solar system, we cannot hope to reap all the many benefits of solar system exploration unless we investigate the less-accessible outer solar system as well. There are a couple of reasons for this. First, more than 99 percent of all non-Sun planetary material resides in the outer solar system. Most planet-sized bodies, including large moons, reside in the outer solar system. Hence, most of our solar system is, in a sense, the outer solar system.

Second, a large quantitative and qualitative difference exists between the outer solar system and the inner planets. Many of the materials that would melt and/or vaporize in the inner solar system are still preserved as a part of the planetary atmospheres, icy moons, and comets of the outer solar system where temperatures are much lower. Examination of such materials may reveal clues about the substances present during the solar system's formation and about the availability of the basic building blocks of life, such as the carbon-rich condensed material believed to be in cometary nuclei and icy satellites. In short, outer solar system exploration is key to answering some of the fundamental questions pertaining to the origins of life and our solar system.

SECTION 2

THE BASELINE SPACECRAFT AND ASSOCIATED LAUNCH VEHICLE CONFIGURATION FOR THE CASSINI SPACECRAFT

2.1 BASELINE SPACECRAFT DESCRIPTION

In the current baseline plan, CaSBini is a three-axis stabilized, probe-carrying orbiter (Figure 2-1), designed for scientific exploration of Saturn and its system, including the moons and rings. The spacecraft orbiter has a mass allowance of 2150 kg (4740 lb). This is the orbiter dry mass (i.e., without propellant) at launch, and includes approximately 335 kg (739 lb) of scientific instruments. Cassini's Huygens Probe and Probe support equipment for the exploration of Saturn's moon, Titan, add another 352 kg (776 lb); the spacecraft launch vehicle adapter will add an additional 190 kg (419 lb). The spacecraft orbiter will carry up to 132 kg (291 lb) of hydrazine for small maneuvers and the attitude and articulation control subsystem (AACS) applications, as well as up to 3000 kg (6614 lb) of bipropellant (monomethylhydrazine and nitrogen tetroxide) for larger maneuvers.

The spacecraft's most visible features include a cylindrical shell structure upon which the main electronics (located in the 12-sided electronics bus) and antenna are mounted, within which the primary bipropellant tanks are stacked, and from which the main engines are suspended. The baseline design includes three general purpose heat source, radioisotope thermoelectric generators (GPHS-RTGs or, simply, RTGs) that are supported by struts extending from the base of this cylindrical structure; the science instruments are supported by a boom and two palettes, or are attached directly to the main structure. (RTGs were used successfully on the Galileo and Ulysses missions.)

Inherent to the configuration are a variety of subsystems, including structure, radio frequency, antenna, power and pyrotechnics, command and data, attitude and articulation control, cabling, propulsion, temperature control, mechanical devices, the solid-state recorders, and more than a dozen mission-specific science subsystems. As much as possible, these subsystems have been designed to enhance the spacecraft's adaptability to future planetary missions. The Attitude and Articulation Control Subsystem (AACS), for instance, has been designed in a modular fashion with an expandable electronics bus to allow simple spacecraft configuration, as well as subsystem additions and/or deletions.

Only certain portions of the spacecraft are relevant to the assessment of those potential environmental impacts that are addressed in this report, i.e., the baselined RTGs used in the power and pyrotechnics subsystem and the Radioisotope Heater Units (RHUs) used in the temperature control subsystem. Other portions of the spacecraft which could potentially impact the environment, including launch vehicle propellants, will be addressed in NASA's EIS. Propellants are a significant source of potential environmental impact.

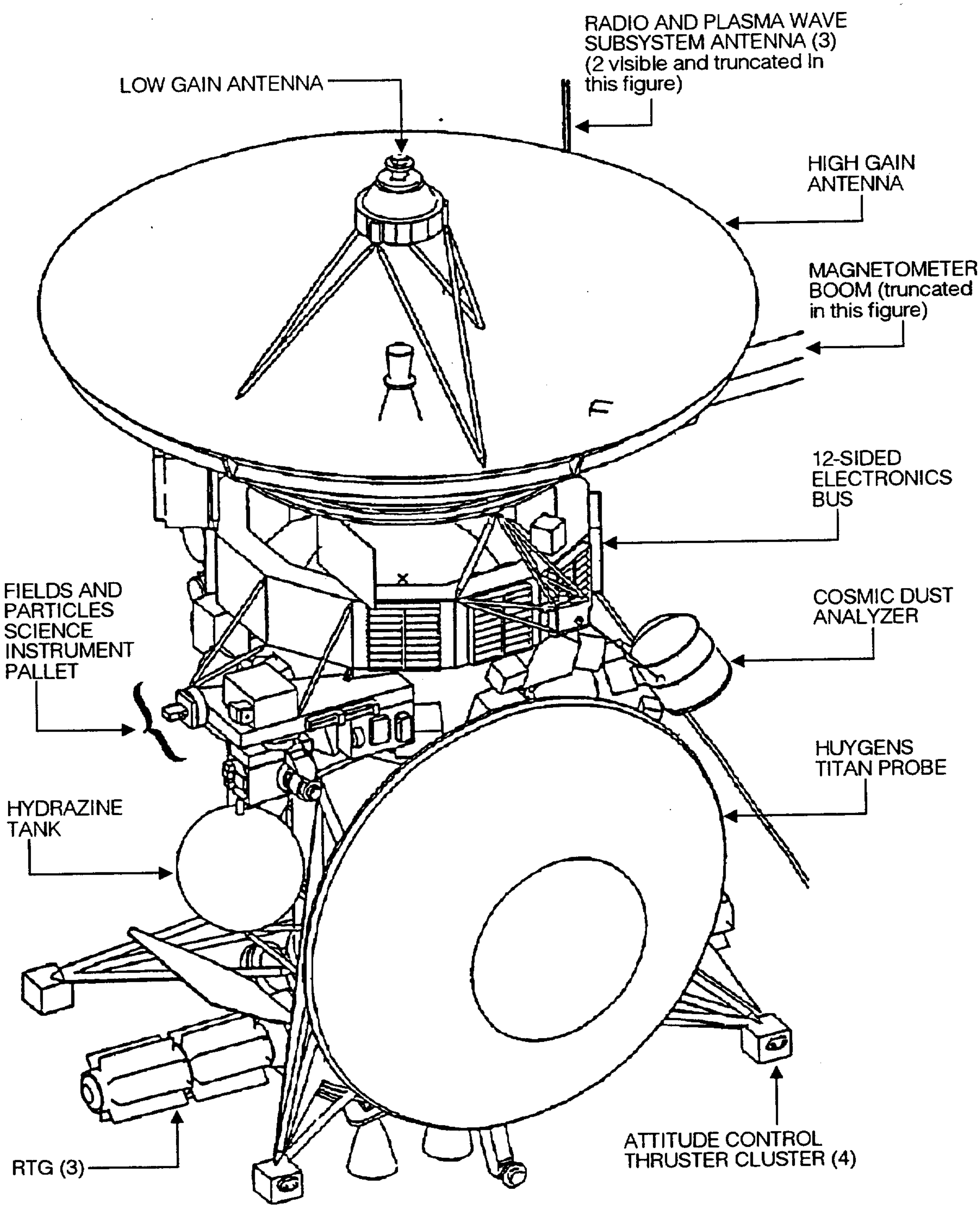

Figure 2-1. Cassini Spacecraft, Deployed Configuration

2.1.1 The Power and Pyrotechnics Subsystem

The power and pyrotechnics subsystem consists Of the spacecraft's electrical power source, its power conditioning and distribution elements, and the capability to initiate the electro-explosive devices needed to open propulsion valves, separate the spacecraft from the Centaur, and release the protective covers on the science instruments. The electrical bus on Cassini is designed to operate at approximately 30 volts dc (direct current).

In this baseline design, the Cassini spacecraft will get electrical power from three RTGs (Figure 2-2). The three RTGs will supply over 800 watts electrical at the beginning of the mission. Each of these RTGs contains approximately 10.8 kg (24 lb) of plutonium dioxide (PuO_2) fuel; about 80% of the plutonium is the Pu-238 isotope at the time of launch.) The baseline plan calls for using two completely new RTGs and one RTG that combines new fuel with an existing, unfueled (Galileo/Ulysses) converter; it also allows for using the common spare from the Galileo and Ulysses missions as a spare for the Cassini mission.

2.1.2 The Temperature Control Subsystem

To encompass the large range of thermal environments, the spacecraft developers are using a combination of active and passive components. These components include multilayer insulation blankets, sunshades, thermal coatings, louvers, radiators, electrical heaters, and one-thermal-watt RHUs. Because the spacecraft thermal design has not yet been completed, the number of RHUs required is still uncertain; the best current estimate is between 130 and 230. Each RHU is fueled with approximately 2.7 g (0.006 lb) of plutonium dioxide fuel. RHUs are used with the all-RTG design because they reduce the total amount of plutonium required on the spacecraft.

2.1.3 The Propulsion Module Subsystem (PMS)

The Propulsion Module Subsystem consists of two bipropellant tanks, a 490-N (110 lb-f) main engine and redundant main engine for trajectory and orbit changes, and sixteen 0.5-N (0.11 lb-f) monopropellant thrusters for attitude control and very small orbit changes. The bipropellant engines use nitrogen tetroxide (NTO) and monomethylhydrazine (MMH); the monopropellant thrusters burn hydrazine. The bipropellant tanks, capacity is 3000 kg. Pressures in both the bipropellant and monopropellant elements are maintained using helium.

2.2 BASELINE LAUNCH VEHICLE CONFIGURATION

The baseline launch vehicle for the Cassini mission is the Titan IV Solid Rocket Motor Upgrade (SRMU)/Centaur, an expendable U.S. Air Force launch vehicle. It consists of four basic components: core vehicle, solid rocket motors, payload fairing, and Centaur upper stage (Figure 2-3).

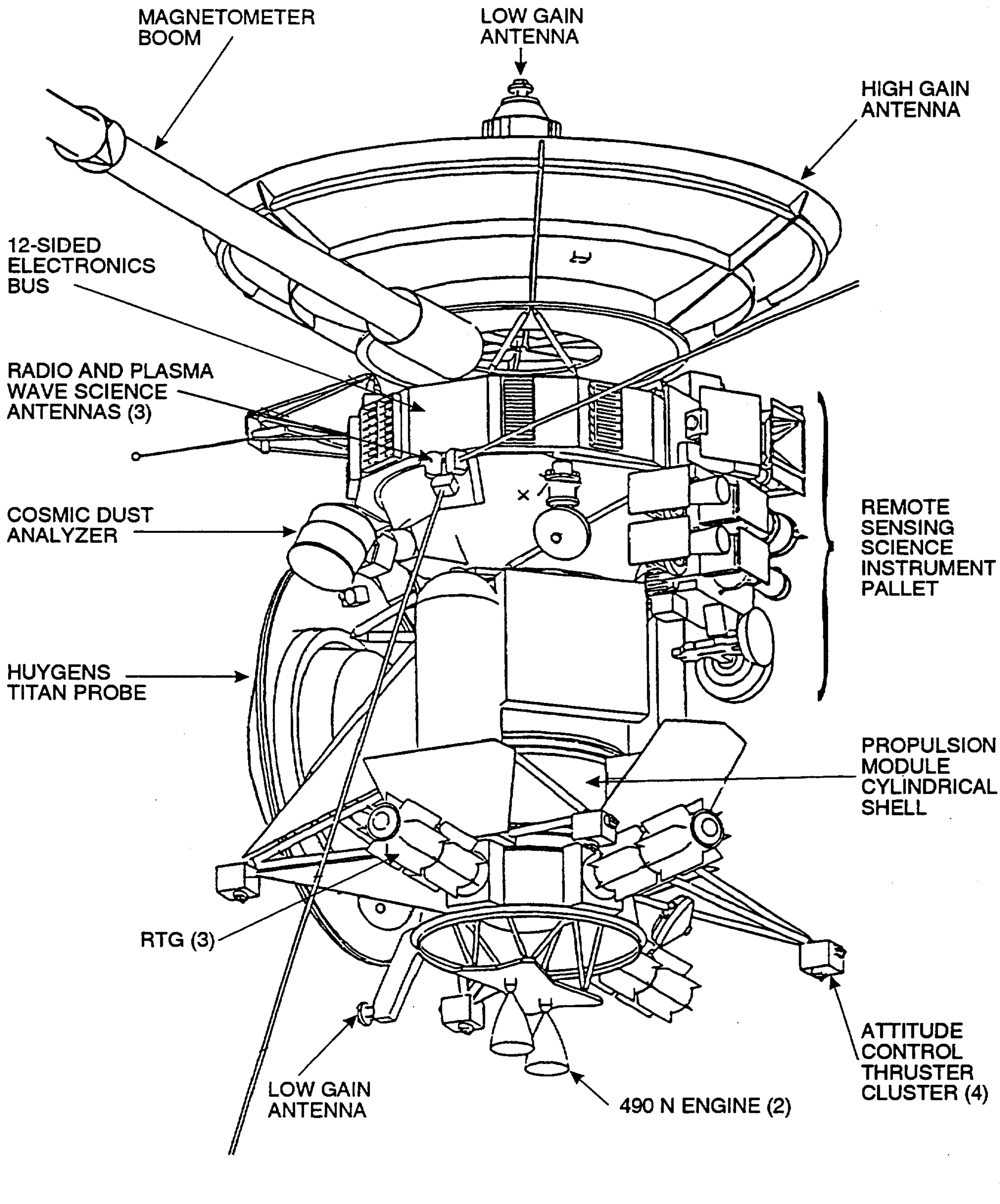

Figure 2-2. View of the Cassini Spacecraft and Its Three RTGs

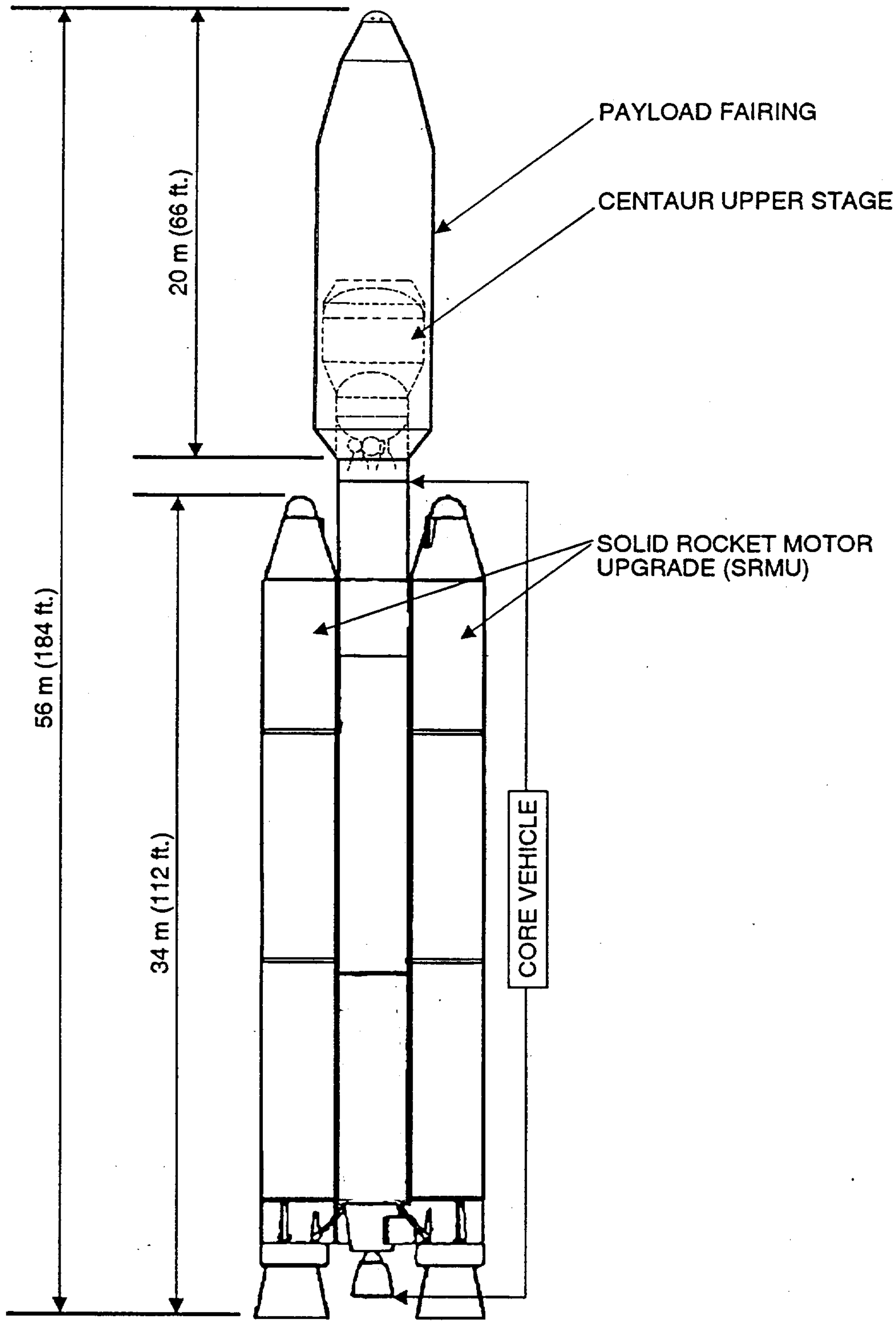

Figure 2-3. The Titan IV/Centaur Launch Vehicle

2.2.1 The Core Vehicle

The core vehicle consists of two stages with their associated airframes, structures, avionics, mechanical systems, and liquid propulsion systems (Figure 2-4). Stage 1 contains two bipropellant liquid rocket engines. One of the propellants, the oxidizer, is NTO; the other propellant, the fuel, is Aerozine 50, a 50/50 blend of unsymmetrical dimethylhydrazine (UDMH) and hydrazine. Stage 2 contains a single bipropellant engine virtually identical to the two used in Stage 1.

2.2.2 The Solid Rocket Motors

Two solid rocket motors strap onto the sides of the core vehicle and contribute to the initial boost stage of the launch vehicle as a whole (Figures 2-3 and 2-5). These three-segment, graphite composite-cased motors (Figure 2-5) provide a significant performance gain over the current seven-segment, steel-cased motors. (The current solid rocket motors, or SRMs, are being phased out and will not be available for the Cassini mission.)

2.2.3 The Payload Fairing

The payload fairing (PLF) is mounted on top of the core vehicle and encases the Centaur upper stage and spacecraft, thereby providing aerodynamic and thermal protection for these elements during ascent (Figure 2-6). The fairing is an all-metal structure composed primarily of aluminum and pieced together as three segments (Figure 2-7). Between 240 and 248 seconds after liftoff, the fairing segments uncouple and jettison from the rest of the launch vehicle.

2.2.4 The Centaur Upper Stage

The Centaur upper stage burns twice. The first burn supplements the Titan in lifting the spacecraft into the proper Earth orbit. The second burn boosts the spacecraft to the velocity needed to escape the Earth and injects it into the proper trajectory. The Centaur utilizes two liquid hydrogen (LH_2) /liquid oxygen (LO_2) combustion engines. The LH_2 and LO_2 are stored in two large tanks which comprise the bulk of the Centaur's internal volume. Mounted to these tanks are forward and aft adapters. The forward adapter provides mounting supports for avionics packages and the spacecraft's mechanical and electrical interfaces. The aft adapter provides the structural interface between the Centaur and the Titan. The Centaur configuration as a whole is illustrated in Figure 2-8.

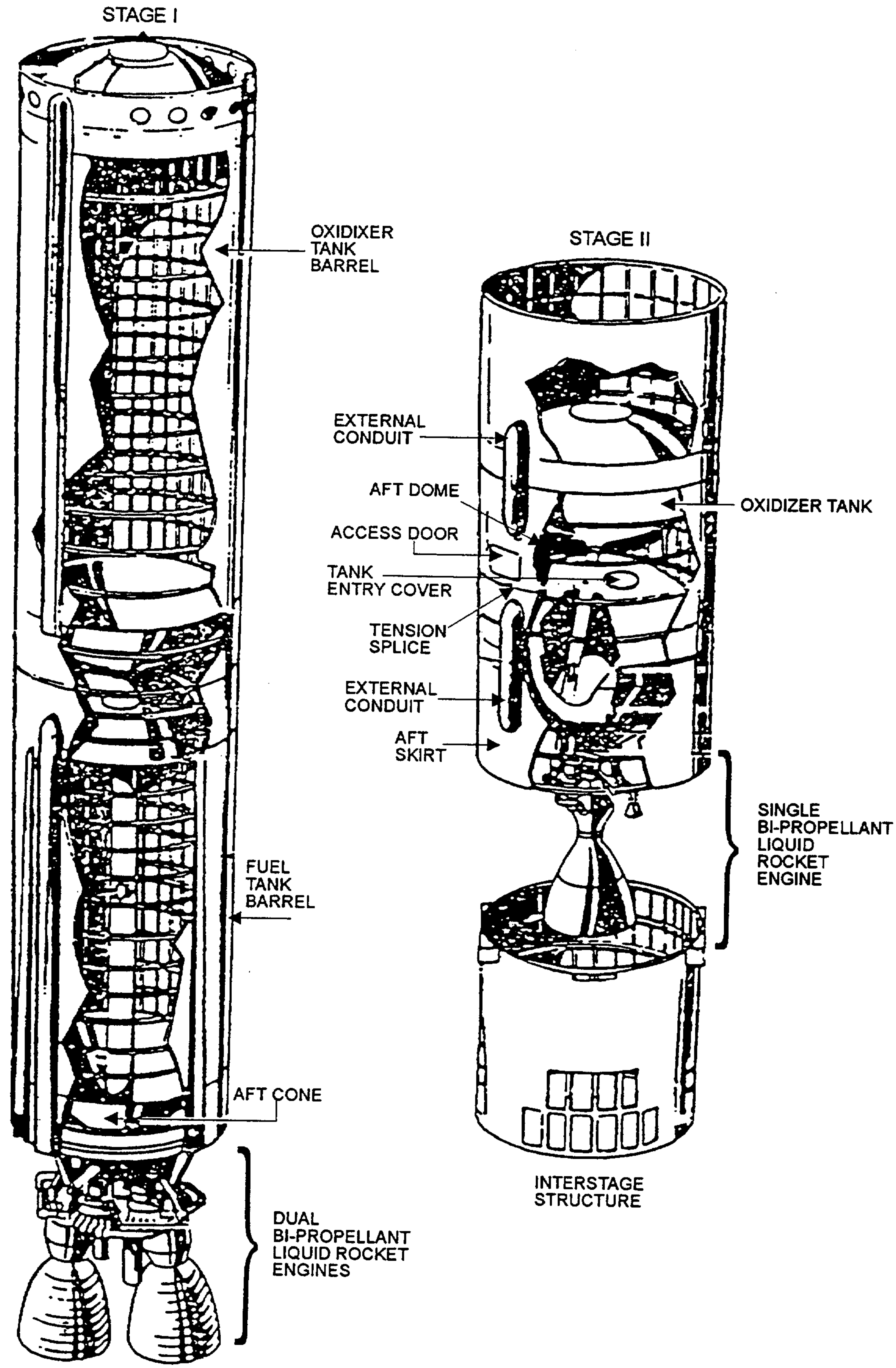

Figure 2-4. The Core Vehicle

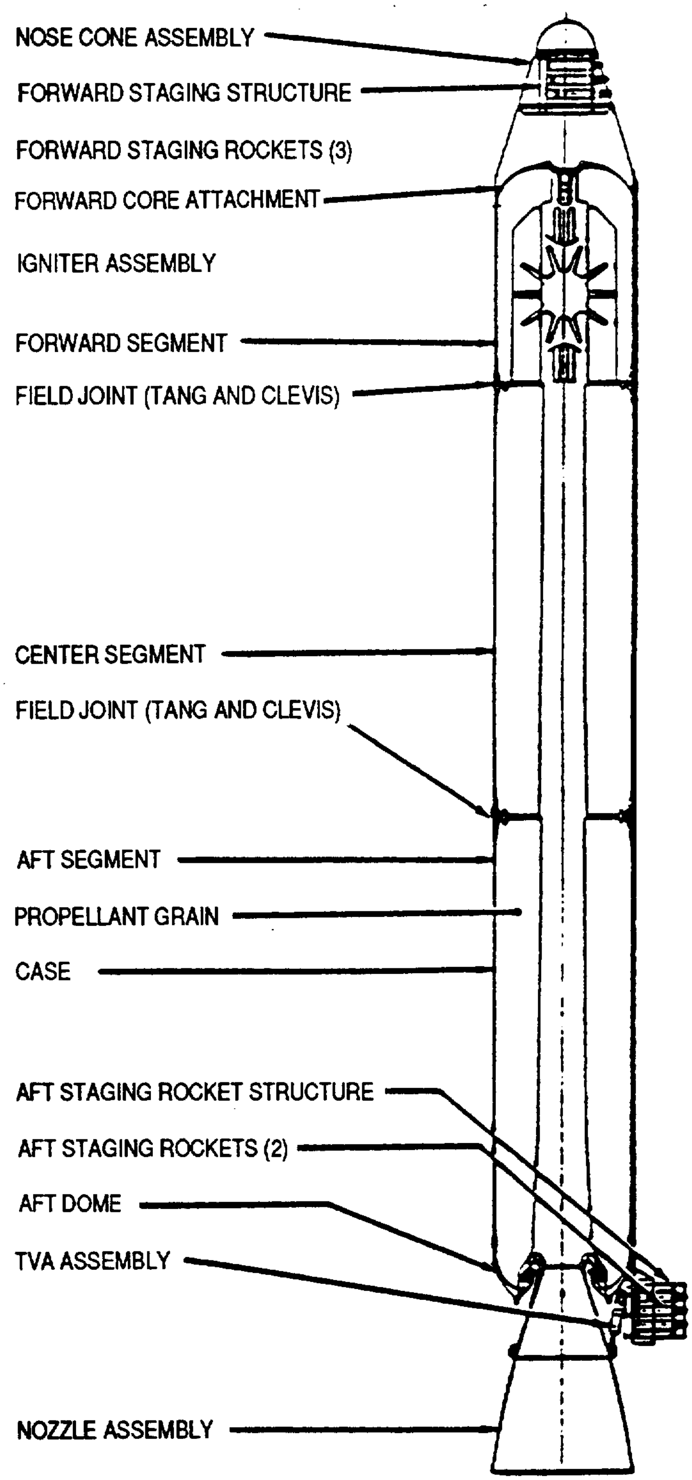

Figure 2-5. The Three-Segment SRMU

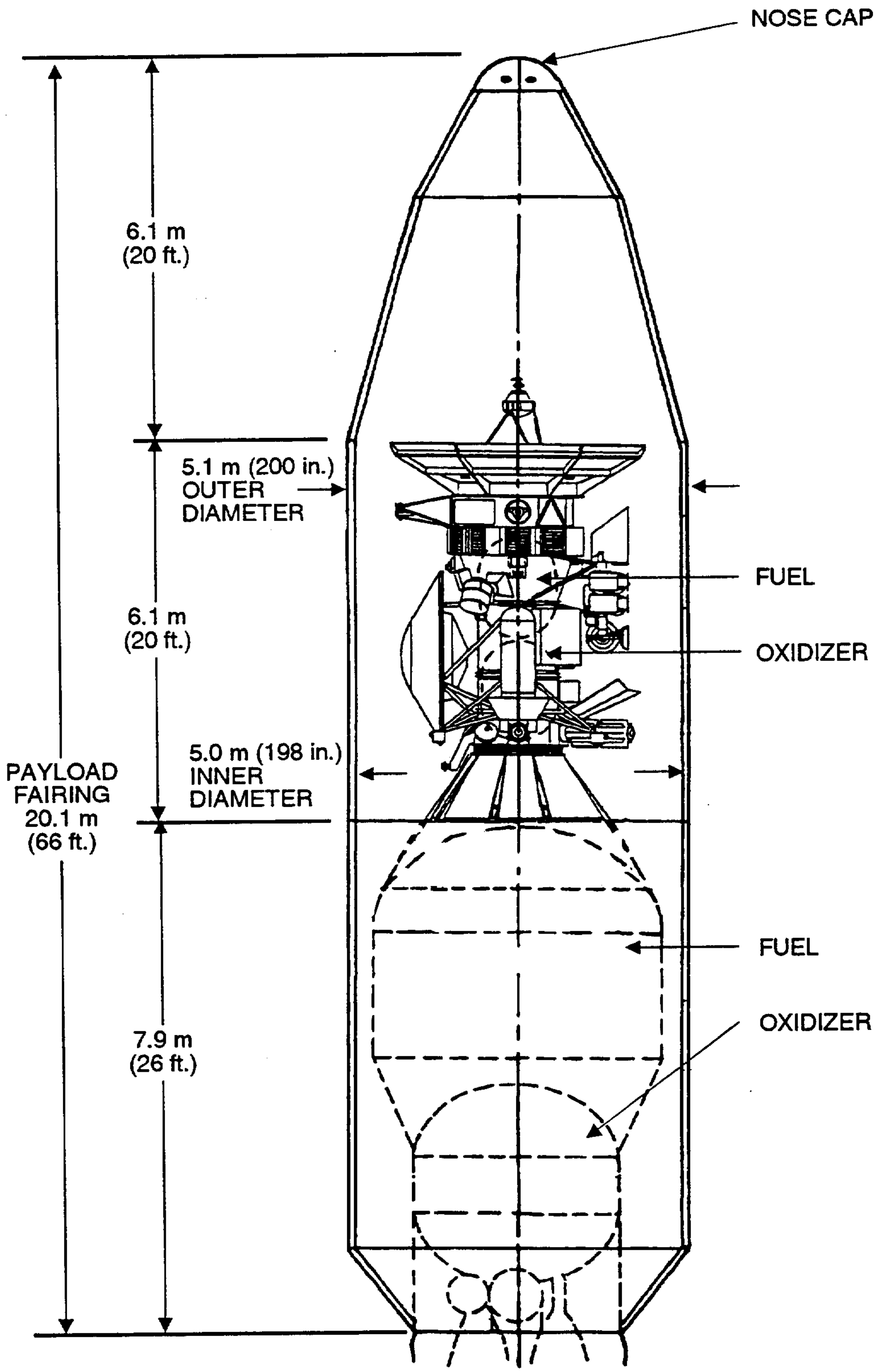

Figure 2-6. The Centaur and Spacecraft Within the Payload Fairing

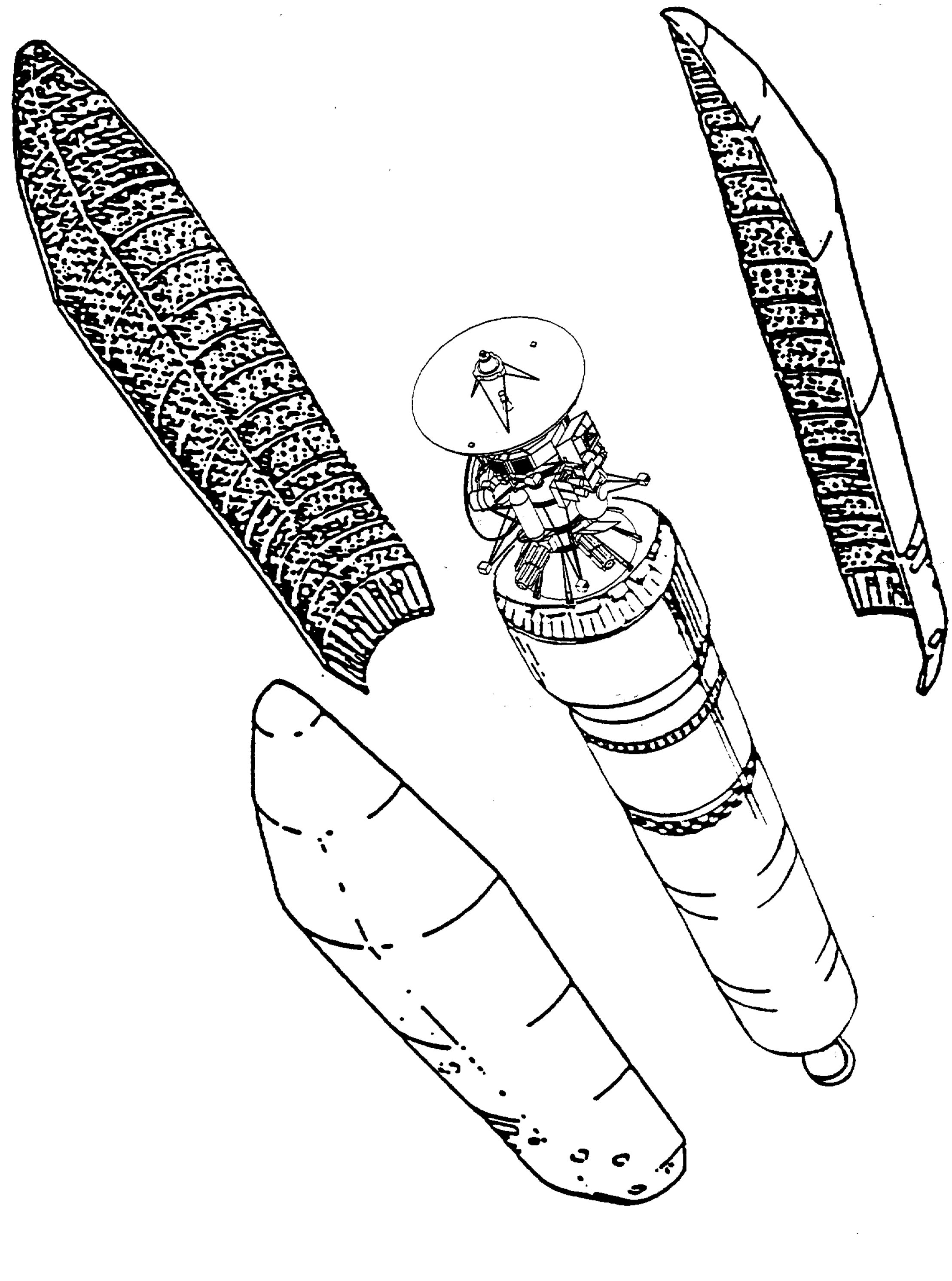

Figure 2-7. Payload Fairing Separation

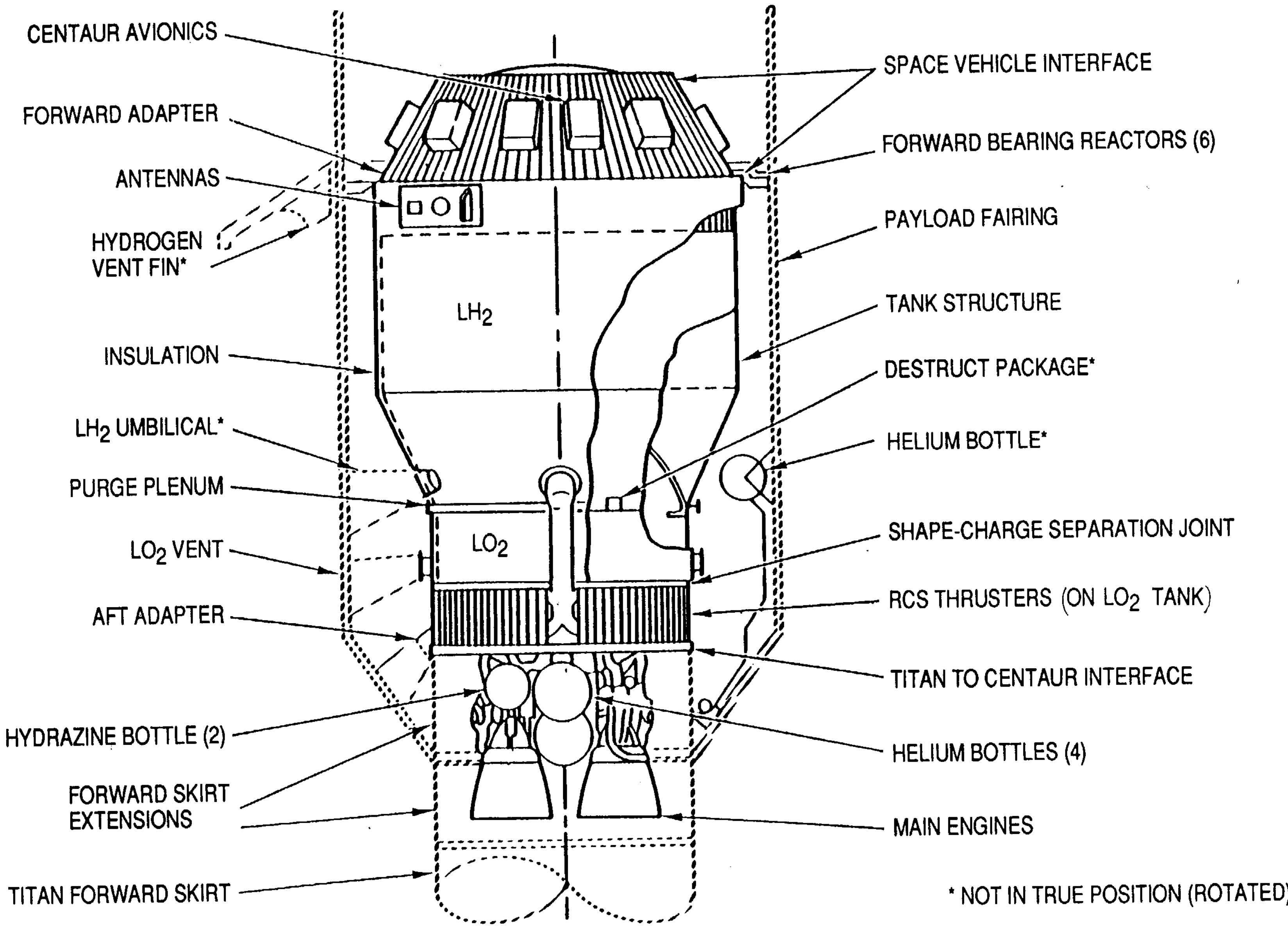

Figure 2-8. Centaur Configuration

SECTION 3

CASSINI MISSION DESCRIPTION

3.1 CASSINI MISSION OVERVIEW

Named after Jean Dominique Cassini (1625-1712), discoverer of the major division in Saturn's rings, the Cassini mission is a joint undertaking by NASA, the European Space Agency (ESA), and the Italian Space Agency (ASI) to explore the Saturnian system. Baselined for launch from Cape Canaveral Air Force Station in October 1997, this 10.7-year mission involves dispatching a probe (ESA's Huygens Probe) into the atmosphere of Saturn's largest moon, Titan, and then having the spacecraft continue on its four-year tour of the Saturn system. Delivery of the Probe is essential to an investigation of Titan's surface structure, as well as the chemical composition of and energy exchanges within its atmosphere. The tour will involve repeated gravity-assist swingbys of Titan to allow viewing of the Saturnian rings and satellite system from a variety of Sun angles and orbital inclinations. Radar mapping will be performed during the Titan flybys to augment the data from the other instruments and to provide information on Titan's surface topography.

The spacecraft will also be targeted for Close flybys of several of Saturn's icy satellites, where data obtained from the science payload will be used to derive a better understanding of the satellites, evolution and makeup. In-situ and remote imaging measurements of the magnetoshere and charged-particle environment of Saturn will also be accomplished from a variety of Sun/planet/spacecraft geometries.

3.2 CASSINI MISSION SCIENCE OBJECTIVES

Saturn is the second-largest planet in the solar system. It also has the most visible, impressive ring structure. As a result of these attributes, Saturn has been the subject of centuries Of telescopic observations, as well as the focus of the Pioneer 11, Voyager 1, and Voyager 2 flyby missions. Yet many questions about Saturn and its moons remain that, if answered, could possibly provide clues to how the solar system evolved and how life began on Earth. For instance, questions pertinent to how life began on Earth include:

- What chemical processes produced the atmosphere of hydrocarbons and other organic molecules unique to Saturn's largest moon, Titan? Do these hydrocarbons exist in liquid form on Titan's surface?

- Is the dark hemisphere of one of Saturn's icy moons, Iapetus, comprised of organic material? Is this material related to the organic material in Titan's atmosphere and to the dark material on comets, asteroids, and Phobos and Deimos, the dark moons of Mars?

Questions pertaining to the evolution of the solar system include:

- By what processes did Saturn acquire so much orbital debris? What processes organized the debris into the intricate structure of rings and embedded moonlets now surrounding it? What is the composition of this debris?

- How does the chemical and physical composition of Saturn compare with that of Jupiter?

- What is the nature of Saturn's magnetospheric interactions with dust and moonlets in the ring plane and what does it tell us about the interactions Of plasma, dust, and radiation at the beginning of the solar system?

The Cassini mission will endeavor to answer these and many other similar questions by pursuing five primary areas of study:

(1) investigation of Saturn;

(2) investigation o f Titan;

(3) investigation of Saturn's icy satellites;

(4) investigation of Saturn's rings; and

(5) investigation of Saturn's magnetosphere.

3.2.1 Investigation of Saturn

The previous flyby missions to Saturn have allowed only short-duration, remote measurements of the Saturnian system. Such measurements have been sufficient to give only a general determination of wind speeds in the planet's upper atmosphere. Cassini will investigate cloud properties and atmospheric composition, wind patterns and temperatures, Saturn's internal structure and rotation, and the planet's ionosphere. The mission will also involve high-inclination orbits so that these studies can be conducted in Saturn's polar regions as well as in its equatorial regions.

3.2.2 Investigation of Titan

Because Titan is enshrouded by dense clouds, little is known about its surface. Instruments carried by the Cassini spacecraft and Huygens Probe will provide a much better understanding of the abundance of elements and compounds that compose this moon's atmosphere, the distribution of trace gases and aerosols, winds and temperature, as well as its surface state and composition. In particular, the spacecraft's radar will be used to penetrate Titan's atmosphere and reveal its surface characteristics, just as the Magellan spacecraft has done at Venus.

3.2.3 Investigation of Saturn's Icy Satellites

Saturn's other moons are ice-covered bodies. Cassini will examine their physical characteristics and investigate their geological histories. These studies will consider how their surfaces have evolved over time, the composition and distribution of materials on their surfaces, their internal structure, and how they interact with Saturn's magnetosphere. Of particular interest is the half-dark, half-light moon, Iapetus. The light side of the moon is believed to be composed of ice, the dark side possibly of some organic material.

3.2.4 Investigation of Saturn's Rings

The Voyager flybys in 1980 and 1981 proved Saturn's ring system to be much more complex than previously realized, with intricate braiding" in some parts of the system. Cassini will permit detailed studies of ring structure and composition, dynamic processes, dust and micrometeoroid environments, and of interactions between the rings, magnetosphere, and satellites.

3.2.5 Investigation of Saturn's Magnetosphere

Saturn's magnetosphere is the region of space under the dominant influence of the planet's magnetic field. Cassini will carry instruments to study the configuration and dynamics of the magnetosphere; the nature, source, and fate of its trapped particles; and how it interacts with the solar wind, satellites, and rings. One particular phenomenon of interest is the Saturn Kilometric Radiation (SKR), a poorly understood, very low frequency, electromagnetic radiation that scientists believe is being emitted by the auroral regions in Saturn's high latitudes.

3.2.6 Investigations Necessary for Implementation of the Cassini Mission Science Objectives

The mission science objectives enumerated above are summarized in Table 3-1. The specific investigations associated with these objectives are delineated in Tables 3-2a, 3-2b, 3-2c, 3-3, and 3-4. In Tables 3-2b and 3-2c, a solid bullet indicates that a notable contribution is made toward that objective. Each of the objectives is addressed by one or more of the investigations; each investigation contributes in a major way to multiple objectives.

Table 3-1. Summary of Cassini Mission Science Objectives

TITAN OBJECTIVES	Determine abundances of atmospheric constituents including any noble gases), establish isotope ratios for abundant elements, constrain scenarios of formation and evolution of Titan and its atmosphere.
	Observe vertical and horizontal distributions of trace gases, search for more complex organic molecules, investigate energy sources for atmospheric chemistry, model the photochemistry of the stratosphere, study formation and composition of aerosols.
	Measure winds and global temperatures; investigate cloud physics, general circulation, and seasonal effects in Titan's atmosphere; search for lightning discharges.
	Determine the physical state, topography, and composition of the surface; infer the internal structure of the satellite.
	Investigate the upper atmosphere, its ionization, and its role as a source of neutral and ionized material for the magnetosphere of Saturn.
SATURN OBJECTIVES	Determine temperature field, cloud properties, and composition of the atmosphere of Saturn.
	Measure the global wind field, including wave and eddy components; observe synoptic cloud features and processes.
	Infer the internal structure and rotation of the deep atmosphere.
	Study the diurnal variations and magnetic control of the ionosphere of Saturn.
	Provide observational constraints (gas composition, isotope ratios, heat flux, etc.) on scenarios for the formation and evolution of Saturn.
	Investigate the sources and morphology of Saturn lightning, including Saturn Electrostatic Discharges (SED) and lightning whistlers.
RING OBJECTIVES	Study configuration of the rings and dynamical processes (gravitational, viscous, erosional, and electromagnetic) responsible for ring structure.
	Map composition and size distribution of ring material.
	Investigate interrelation of rings and satellites, including imbedded satellites.
	Determine dust and meteoroid distribution in the vicinity of the rings.
	Study interactions between the rings and Saturn's magnetosphere, ionosphere, and atmosphere.

Table 3-1, continued.

ICY SATELLITES OBJECTIVES	Determine the general characteristics and geological histories of the satellites.
	Define the mechanisms of crustal and surface modifications, both external and internal.
	Investigate the compositions and distributions of surface materials, particularly dark, organically rich materials and low melting point, condensed volatiles.
	Constrain models of the satellites' bulk compositions and internal structures.
	Investigate interactions with the magnetosphere and ring systems and possible gas injections into the magnetosphere.
MAGNETOSPHERE OBJECTIVES	Determine the configuration of the nearly axially symmetric magnetic field and its relation to the modulation of Saturn Kilometric Radiation (SKR).
	Determine current systems, composition, sources, and sinks of magnetosphere-charged particles.
	Investigate wave-particle interactions and dynamics of the day-side magnetosphere and the magnetotail of Saturn and their interactions with the solar wind, the satellites, and the rings.
	Study the effect of Titan's interaction with the solar wind and magnetospheric plasma.
	Investigate interactions of Titan's atmosphere and exosphere with the surrounding plasma.

Table 3-2. Saturn Orbiter Investigations of Saturn and Titan

Table 3-2a. Instruments

Acronym	Instrument	Acronym	Instrument
INMS	Ion and Neutral Mass Spectrometer	CDA	Cosmic Dust Analyzer
ISS	Imaging Science Subsystem	CIRS	Composite Infrared Spectrometer
RADAR	Cassini Radar	MAG	Dual Technique Magnetometer
RSS	Radio Science Subsystem	MIMI	Magnetospheric Imaging Instrument
VIMS	Visual and Infrared Mapping Spectrometer	RPWS	Radio and Plasma Wave Science
CAPS	Cassini Plasma Spectrometer	UVIS	Ultraviolet Imaging Spectrograph

Table 3-2b. Saturn Orbiter Investigations of Titan

INVESTIGATION	INMS	ISS	RADAR	RSS	VIMS	CAPS	CDA	CIRS	MAG	MIMI	RPWS	UVIS
TITAN												
Atmospheric abundances	●			●	●	●		●		●		●
Atmospheric chemistry and distribution of species; aerosols	●	●		●	●	●		●		●		●
Atmospheric circulation and physics		●		●	●			●			●	●
State and composition of surface; interior			●	●								
Upper atmosphere and relation to magnetosphere	●			●		●			●	●	●	●

● = Notable Contribution(s)

Table 3-2c. Saturn Orbiter Investigations of Saturn, Its Rings, Icy Satellites, and Magnetosphere

INVESTIGATION	INMS	ISS	RADAR	RSS	VIMS	CAPS	CDA	CIRS	MAG	MIMI	RPWS	UVIS
SATURN												
Atmospheric and cloud properties and composition		●		●	●			●				●
Synoptic features and processes; winds and eddies		●		●	●			●				
Internal structure and rotation of deep atmosphere				●	●			●	●		●	
Ionospheric diurnal variations and magnetic control				●		●			●	●	●	●
Physical and compositional properties and evolution		●		●	●	●		●				●
Lightning (SED, whistlers)		●									●	
RINGS												
Configuration and processes		●		●	●			●	●			●
Composition and particle size	●	●		●	●	●	●	●				●
Interrelation with satellites		●		●	●	●	●	●				●
Dust and meteoroid distribution		●			●		●				●	
Interactions with Saturn magnetosphere, ionosphere, and atmosphere	●	●		●		●	●		●	●	●	●
ICY SATELLITES												
Characteristics and geological histories		●			●			●				●
Mechanisms of modification		●			●	●	●					●
Composition and distribution of surface materials, especially dark, organic rich, and condensates		●			●			●				●
Bulk compositions and internal structures		●		●	●			●				
Interactions with magnetosphere and rings		●			●	●	●	●	●	●	●	●
MAGNETOSPHERE OF SATURN												
Configuration of magnetic field and relation to SKR									●		●	
Charged particle currents, compositions, sources, and sinks						●			●	●	●	●
Wave-particle interactions and dynamics						●			●	●	●	
Titan's interaction with solar wind and magnetospheric plasma	●			●		●			●	●	●	●
Interactions of Titan's atmosphere and exosphere with surrounding plasmas	●			●		●			●	●	●	●

● = Notable Contribution(s)

Table 3-3. Huygens Probe Investigations of Titan

Acronym	Instrument	Investigation
ACP	Aerosol Collector Pyrolyser	Clouds and aerosols in Titan's atmosphere
DISR	Descent Imager and Spectral Radiometer	Temperatures, atmospheric aerosols, and the surface
DWE	Doppler Wind Experiment	Wind
GCIVIS	Gas Chromatograph and Mass Spectrometer	Chemical composition of atmospheric gases and aerosols
HASI	Huygens Atmospheric Structure Instrument	Physical and electrical properties of Titan's atmosphere
SSP	Surface Science Package	Physical properties of Titan's surface

Table 3-4. Interdisciplinary Science (IDS)

Saturn Orbiter
Aeronomy and Solar Wind Interactions
Atmospheres
Magnetosphere and Plasma
Origin and Evolution
Rings and Dust
Satellites
Huygens Probe
Titan aeronomy
Titan atmosphere and surface
Titan chemistry exobiology

3.3 THE BASELINE CASSINI MISSION DESIGN

3.3.1 The Baseline Primary Mission Design

The baseline Cassini Mission is scheduled for launch within a 25-day period beginning October 6, 1997. Using the Titan IV/Centaur launch vehicle described in Section 2, the spacecraft will be injected into a 6.7-year VVEJGA (Venus-Venus-Earth-Jupiter-Gravity-Assist) trajectory to Saturn, as shown in Figure 3-1.

The first Venus swingby will occur in April 1998. The following December, a maneuver will occur to place the spacecraft on course for the second Venus swingby in June 1999. Due to the Earth's unique orientation relative to Venus during this time period, the spacecraft will be able to fly on to Earth in slightly under two months, where it will obtain another gravity assist in August 1999.

After flying past the Earth, the spacecraft will swing out toward Jupiter, passing through the asteroid belt. Due to limited propellant reserves, lack of adequate ground systems for support, and the absence of a readily accessible asteroid of appropriate size, an asteroid flyby along the way is not planned. In December 2000, the spacecraft will swing by Jupiter to obtain a fourth and final gravity assist.

For several months prior to arrival at Saturn in June 2004, the spacecraft will perform science observations of the Saturnian system as it draws nearer to its destination. The intensity and pace of observations will increase sharply during the last few days, prior to the execution of the Saturn Orbit Insertion (SOI) burn. The spacecraft's closest approach to the planet during the SOI phase, at about 1.3 Saturn radii, is the closest of the entire mission. Because this provides a unique opportunity for observing the inner regions of the ring system and magnetosphere, the roughly 1.5-hour orbital insertion burn will be delayed about 0.75 hours from its optimal point to permit such science observations.

After SOI, the spacecraft will swing out to the most distant point in its orbit around Saturn (about 200 Saturn radii), and then swing in again to achieve an encounter with Titan in November 2004 (Figure 3-2). About three weeks before Cassini's first flyby of Titan, the spacecraft will release the Huygens Probe, targeted for entry into Titan's atmosphere. Two days after Probe release, the Orbiter will perform a deflection maneuver to be in position to receive scientific information gathered by the Huygens Probe throughout its estimated 2.5-hour parachute descent to Titan's surface. The Orbiter can remain in position to receive information from the battery-powered probe for up to three hours, which would include data collected at the surface if the probe survives its landing. All data gathered by the probe will be stored on the Orbiter for later transmission to Earth.

The spacecraft will then continue on its tour of the Saturnian system, including multiple Titan swingbys for gravity assist and science acquisition. The Titan swingbys and Saturn orbits will be designed to allow maximum science coverage, including the acquisition of science data from Saturn's icy satellites. By the end of the four-year tour, the orbital inclination will have been increased from an initial value of 10.5 degrees to approximately 80 degrees, allowing investigation of the environment at high latitudes. In particular, the spacecraft will investigate the source of the unique Saturn Kilometric Radiation (Subsection 3.2.5). The 10.7-year nominal mission will then end in June 2008.

3.3.2 The Baseline Backup mission Design

In the event that a problem should arise with the spacecraft or launch vehicle, causing a delay in the launch date for the primary trajectory, a launch date for the backup trajectory has been scheduled for March 1999, around 17 months after the primary mission launch opportunity. The baseline Cassini backup mission would be able to fulfill scientific goals similar to the primary mission’s, including the four-year satellite tour. This longer cruise time increases the probability of spacecraft malfunction. The time in storage also provides opportunity for malfunction.

The baseline backup trajectory is a much longer, 9.8-year VEEGA (Venus-Earth-Earth-Gravity-Assist) trajectory. In this trajectory, the gravity-assist sequence begins with a June 2000 swingby of Venus, after which the spacecraft proceeds to Earth for a second gravity assist in August 2001. This second assist propels the spacecraft on a broad, sweeping arc through the asteroid belt. In August 2004, Cassini arrives back at the Earth for a third and final gravity assist. This assist catapults the spacecraft toward Saturn, allowing an arrival at the ringed planet in December 2008. The Probe delivery and tour portions of the mission are very similar to those described for the baseline mission, with the timetable shifted to reflect the 2008 arrival date. The different arrival date, however, is less desirable than that of the baseline primary. Aside from the four-year delay in science return compared with the baseline, it also offers a much less advantageous geometry of Saturn's rings, both as seen from the Earth and from the spacecraft.

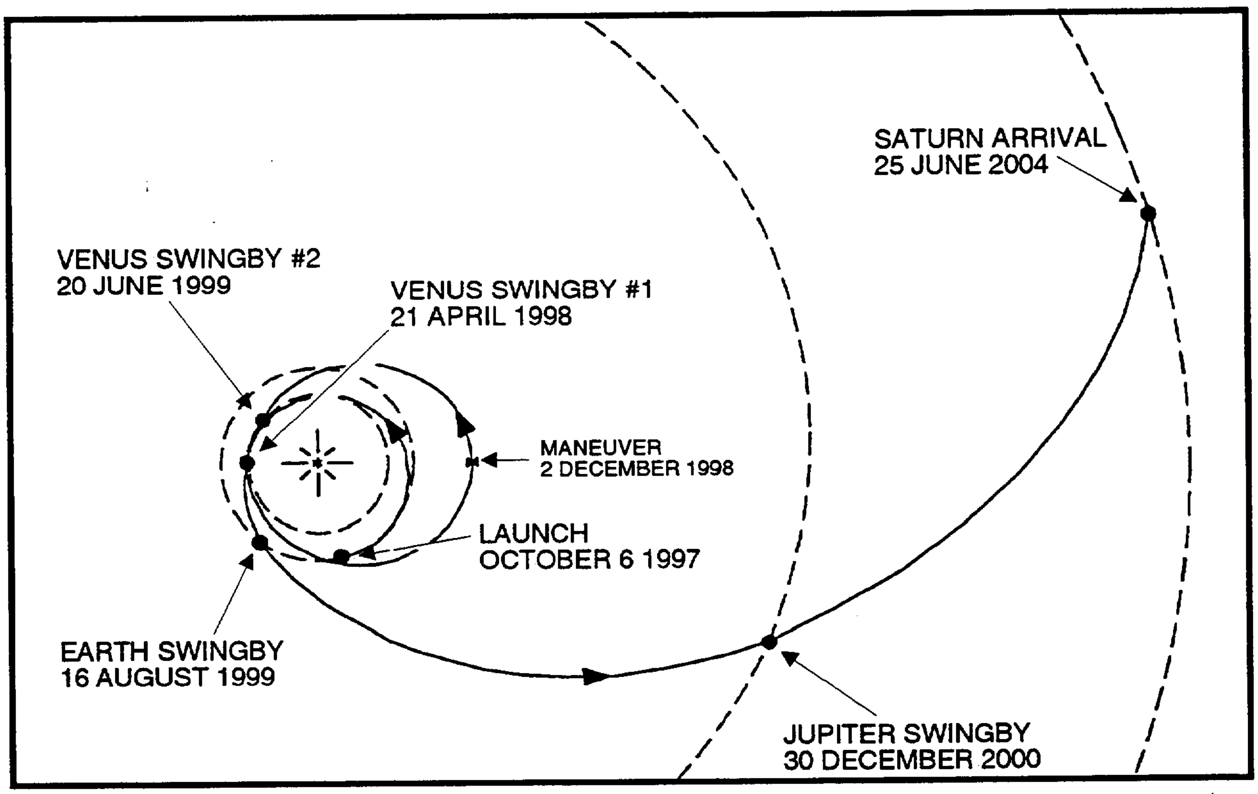

Figure 3-1. Cassini Interplanetary Trajectory, VVEJGA

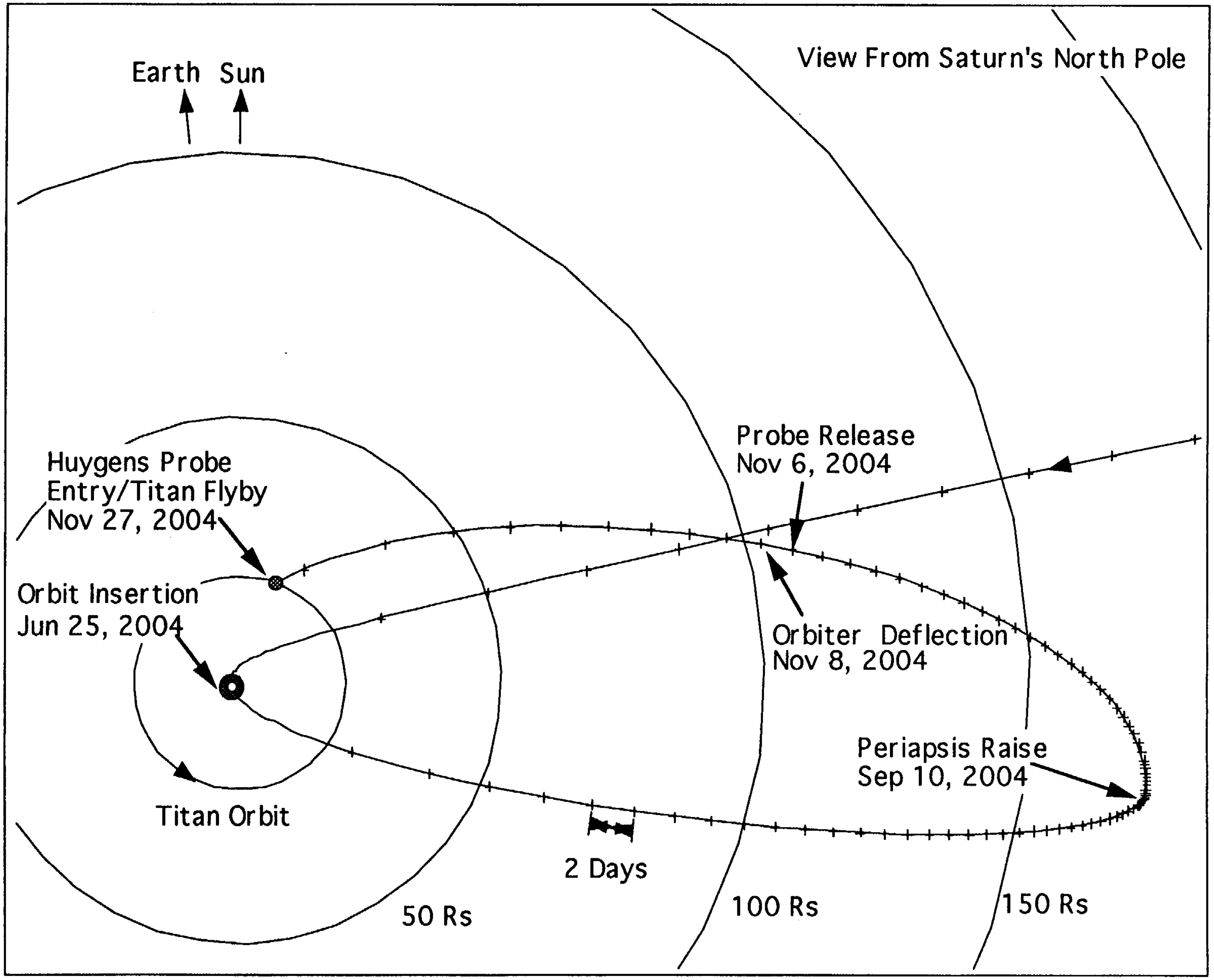

Figure 3-2. Cassini Saturn Arrival and Initial Orbit

APPENDIX A

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Cassini Environmental Impact Statement
Supporting Studies

Executive Summary

Volume 1 - Program Description

Volume 2 - Alternate Mission and Power Study

Volume 3 - Earth Swingby Plan

Earth Swingby Plan Supplement