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September 24, 1997

Final Environmental Impact Statement for the Cassini Mission

Solar System Exploration Division
Office of Space Science
National Aeronautics and Space Administration
Washington, DC 20546

June 1995

ABSTRACT

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DATE:	June 1995

This Final Environmental Impact Statement (FEIS) addresses the potential environmental impacts that may be associated with the implementation of the Cassini mission, a cooperative science effort planned by the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), and the Italian Space Agency (ASI). The mission would involve the use of the Cassini spacecraft, including an Orbiter and the detachable Huygens Probe, to conduct a 4-year scientific exploration of the planet Saturn, its atmosphere, moons, rings, and magnetosphere. The Huygens Probe would be released to collect data from the atmosphere of Saturn's largest moon, Titan.

The Proposed Action addressed in this FEIS consists of preparing for and implementing the Cassini mission. The Cassini spacecraft would be launched from the Cape Canaveral Air Station (CCAS) using the Titan IV (Solid Rocket Motor Upgrade [SRMU] or Solid Rocket Motor [SRM])/Centaur. The primary launch opportunity would be in October 1997 with contingency launch opportunities in December 1997 (secondary) or March 1999 (backup). The primary launch opportunity would place the spacecraft into a 6.7-year Venus-Venus-Earth-Jupiter-Gravity-Assist (VVEJGA) trajectory to Saturn. The secondary and backup launch opportunities would use an 8.8-year and a 9.8-year Venus-Earth-Earth-Gravity-Assist (VEEGA) trajectory, respectively. The amount of science return (i.e., data) from either contingency launch opportunity would be less than the return associated with the primary launch opportunity. In the event that the Titan IV (SRMU) were not available, a Titan IV (SRM) would be used. The launch opportunities would remain the same.

The alternatives to the Proposed Action evaluated in detail are a 1999 mission alternative, a 2001 mission alternative, and the No-Action alternative (i.e., cancellation of the mission). The 1999 mission alternative would involve dual Shuttle launches from the Kennedy Space Center (KSC) in which the first launch would predeploy an upper stage(s) into low Earth orbit, and a second launch, 21 to 51 days later, would deliver the Cassini spacecraft and the remaining upper stage(s). An on-orbit mating of the upper stage(s)

with the Cassini spacecraft would be followed by upper stage ignition and insertion of the Cassini spacecraft into its 9.8-year VEEGA interplanetary trajectory. A backup launch opportunity, with a 9.4-year VEEGA, would occur in August 2000. The science return from this alternative would be less than that expected for the 1997 primary launch opportunity in the Proposed Action.

The primary launch opportunity for the 2001 mission alternative would not require an Earth swingby. It would, however, require the spacecraft to be equipped with 20 percent larger propellant tanks and completing the development and flight testing of a high performance rhenium spacecraft propulsion engine. The Cassini spacecraft would be launched by the Titan IV (SRMU)/Centaur from CCAS into a 10.3-year Venus-Venus-Venus-Gravity-Assist (VVVGA) trajectory. An 11.4-year VEEGA backup launch opportunity for this alternative would occur in May 2002. The level of science return associated with this alternative would be reduced when compared with the return associated with the Proposed Action.

The only expected environmental impacts of the Proposed Action and of the 1999 and 2001 mission alternatives would be associated with the normal launch of the Titan IV (SRMU or SRM)/Centaur or the Shuttle. The impacts for the 1999 mission alternative would occur twice for the dual Shuttle launches. The impacts would primarily be short-term in nature affecting the air quality and water resources near the launch site.

The principal concern associated with the launch of the Cassini spacecraft would be a potential accident involving the three radioisotope thermoelectric generators (RTGs) used onboard the spacecraft to provide electrical power and the radioisotope heater units (RHUs) used to control the thermal environment onboard the spacecraft and the Probe. In the unlikely event that a launch accident causes sufficient damage to the RTGs, plutonium dioxide fuel contained within the RTGs could be released to the environment. Extensive U.S. Department of Energy (DOE) testing and evaluation programs have demonstrated the effectiveness of the RTGs and the RHUs to contain the fuel under a wide range of accident test conditions. Therefore, only small fuel releases are postulated if a launch accident occurred.

Representative launch accident scenarios were evaluated for the Proposed Action and the other mission launch alternatives. Of these accident scenarios, the accident environments sufficient to cause a release of plutonium dioxide fuel from the RTGs could occur in the CCAS/KSC region, limited areas under the vehicle flight path while over Africa, and indeterminate locations within the global area.

NASA has postulated two low probability accident scenarios that could occur during the interplanetary cruise portions of the VVEJGA and VEEGA trajectories. These scenarios would result in either a short-term or long-term inadvertent reentry of the Cassini spacecraft. The Proposed Action and the 1999 mission alternative have the potential for both a short-term and long-term inadvertent reentry. The 2001 alternative, because of its VVVGA trajectory, does not have the potential for a short-term inadvertent reentry. However, this trajectory would not rule out the possibility of a long-term inadvertent reentry.

No environmental impacts would be associated with the No-Action alternative. NASA, ESA, and ASI would experience adverse mission-specific impacts if the No-Action alternative is adopted. The science return specific to this mission would be lost, and the ability of the United States to enter into future international agreements for cooperative space activities could be impaired.

EXECUTIVE SUMMARY

This Final Environmental Impact Statement (FEIS) has been prepared in accordance with the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321 et seq.), as amended; the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA (40 CFR Parts 1500-1508); and the National Aeronautics and Space Administration's (NASA) policy and regulations (14 CFR Subpart 1216.3) to support the decision-making process concerning the Proposed Action and alternatives for NASA's Cassini space exploration mission.

PURPOSE AND NEED FOR THE ACTION

The Cassini mission is an international cooperative effort being planned by NASA, the European Space Agency (ESA), and the Italian Space Agency (AS[) to explore the planet Saturn and its environment. The mission would involve a 4-year tour of Saturn, its atmosphere, moons, rings, and magnetosphere by the Cassini spacecraft, which consists of the Orbiter and the detachable Huygens Probe. The Huygens Probe would be released from the Cassini Orbiter to descend by parachute through the atmosphere of Saturn's largest moon, Titan. During the descent, instruments on the Probe would directly sample the atmosphere and determine its composition. The Probe would also gather data on Titan's landscape.

The Cassini spacecraft would carry three radioisotope thermoelectric generators (RTGs) that use the heat from the decay of plutonium (Pu-238) dioxide fuel to generate electric power for the spacecraft and its instruments. The spacecraft would use radioisotope heater units (RHUs) (157 are planned), also containing plutonium dioxide, to generate heat for controlling the thermal environment onboard the spacecraft and several of its instruments. The U.S. Department of Energy (DOE) would supply the RTGs and RHUs to NASA.

NASA would provide the ground communications network and two scientific instruments for the Huygens Probe. ESA would provide the Huygens Probe, and ASI would provide major elements of the Cassini Orbiter's communications equipment and elements of several science instruments.

The Cassini mission is part of NASA's program for exploration of the solar system. The goal of the program is to understand the birth and evolution of the solar system. Initially, this program concentrated on flyby or reconnaissance-type missions to the outer solar system. With the launch of the Galileo spacecraft in 1989, the program began its transition to exploration-type missions to the outer planets using orbiters and atmospheric probes. The Cassini spacecraft would make remote and close-up measurements of Saturn, its atmosphere, moons, rings, and magnetosphere. This information could also provide significant insights into the formation of the solar system and the conditions that led to life on Earth.

ALTERNATIVES EVALUATED

The Proposed Action addressed by this FEIS consists of preparing for and implementing the Cassini mission to Saturn to conduct a 4-year scientific exploration of the planet, its atmosphere, moons, rings, and magnetosphere. NASA proposes to launch the spacecraft from Cape Canaveral Air Station (CCAS) (formerly Cape Canaveral Air Force Station [CCAFS]) in October 1997 using a Titan IV (Solid Rocket Motor Upgrade [SRMU]) and a Centaur upper stage (i.e., Titan IV (SRMU)/Centaur) to place the Cassini spacecraft into a 6.7-year Venus-Venus-Earth-Jupiter-Gravity-Assist (VVEJGA) trajectory to Saturn. The SRMU is the most recent upgrade of the solid rocket motor [SRM] used on the Titan IV. If the October 1997 launch opportunity were missed, a secondary launch opportunity exists in December 1997 using an 8.8-year Venus-Earth-Earth-Gravity-Assist (VEEGA) trajectory and a backup launch opportunity exists in March 1999 using a 9.8-year VEEGA trajectory. In the event that the Titan IV (SRMU)/Centaur were not available, a Titan IV (SRM)/Centaur would be used. The launch opportunities would remain the same.

The alternatives to the Proposed Action evaluated in detail are a 1999 mission alternative, a 2001 mission alternative, and the No-Action alternative (i.e., the cancellation of the mission). The 1999 mission alternative would entail dual Shuttle launches from the Kennedy Space Center (KSC), separated by 21 to 51 days, to deliver the Cassini spacecraft and the upper stage(s) into low Earth orbit. An on-orbit mating of the upper stage(s) and the spacecraft would be performed by astronauts followed by insertion of the spacecraft in March 1999 into its 9.8-year VEEGA interplanetary trajectory to Saturn. A backup launch opportunity, a 9.4-year VEEGA, occurs in August 2000. The 2001 mission alternative would use the Titan IV (SRMU)/Centaur to launch the Cassini spacecraft into a 10.3-year Venus-Venus-Venus-Gravity-Assist (VVVGA) trajectory to Saturn. The spacecraft would require 20 percent additional propellant, as well as completing development of and flight testing a high performance rhenium engine for spacecraft propulsion to accommodate the amount of maneuvering associated with the VVVGA trajectory. An 11.4-year VEEGA backup launch opportunity occurs in May 2002. The No-Action alternative would cancel the mission.

In developing the alternatives (i.e., the Proposed Action and the 1999 and 2001 missions), the available options for the following key components of the mission design were evaluated: launch vehicles, interplanetary trajectories, and power sources for spacecraft electrical needs.

Several criteria were used to evaluate the options: technological feasibility and availability of the option for implementing the mission at the earliest opportunity, impact of the option on the ability of the spacecraft to achieve the mission science objectives, and potential of the option for reducing or eliminating environmental impacts that could be associated with the mission. The evaluation provided the following results: (1) the Titan IV (SRMU)/Centaur is the most capable U.S. launch vehicle available to implement the mission; (2) the Cassini mission to Saturn requires planetary gravity-assist trajectories; and (3) the spacecraft requires the use of RTGs to satisfy the mission electrical power needs.

The overall result of the options evaluated indicates that implementation of the Proposed Action, with its three launch opportunities (i.e., primary in October 1997, secondary in December 1997, or backup in March 1999), provides the greatest opportunity to achieve the mission science objectives. The 1999 mission alternative and the 2001 mission alternative also are technically feasible and provide opportunities to achieve most of the science objectives planned for the mission but with less science return (i.e., data).

ENVIRONMENTAL IMPACTS

The only expected environmental impacts of the Proposed Action, as well as the 1999 and 2001 mission alternatives, would be associated with the normal launch of the Cassini spacecraft on the Titan IV (SRMU or SRM)/Centaur or the Shuttle. These impacts have been addressed in previous NEPA documents prepared by the U.S. Air Force (USAF) for its Titan IV launch operations at the CCAS (USAF 1986, USAF 1988a, USAF 1988b) and for the Titan IV using the SRMU (USAF 1990) and prepared by NASA for the Shuttle launches (NASA 1978, NASA 1979, NASA 1988b, NASA 1989b, NASA 1990). The evaluation of these alternatives also used other NEPA-related documentation, including the EIS for the Kennedy Space Center (KSC) (NASA 1979) and the KSC *Environmental Resources Document* (NASA 1994).

For the Proposed Action, the environmental impacts of a normal launch of the Cassini spacecraft on a Titan IV (SRMU or SRM)/Centaur would result from exhaust emissions (i.e., the exhaust cloud) from the two solid rocket motors (principally aluminum oxide particulates [Al_2O_3], hydrogen chloride [HCl], and carbon monoxide [CO]), which would have a short-term impact on air quality in the vicinity of the launch site; noise from the SRMUs or SRMs, which would not adversely impact the nearest unprotected person (or the general public); deposition of acidic SRMU or SRM exhaust products, largely on the launch complex itself, but which could reach nearby marsh and surface water areas where natural buffering would substantially reduce any impacts; and short-term impacts on stratospheric ozone along the launch vehicle's flight path from the SRMU or SRM exhaust products. No substantial long-term environmental impacts would be associated with a normal launch of the Cassini spacecraft for any of the launch opportunities.

The radiological concern associated with the mission is the potential release of some of the approximately 32 kg (71 lb) of plutonium dioxide (consisting of around 71 percent by weight Pu-238 at launch) in the RTGs and RHUs onboard the spacecraft. In the unlikely event that an accident were to occur during the launch of the spacecraft (i.e., from the time of ignition of the SRMUs or SRMs, through the insertion of the spacecraft into its interplanetary trajectory), the safety features incorporated into the RTGs and RHUs, in most cases, would limit or prevent any release of the plutonium dioxide fuel. However, in the unlikely event of a launch phase accident causing a release of plutonium dioxide fuel, no health effects (i.e., excess latent cancer fatalities [above the normally observed cancer fatalities]) would be expected to occur if members of the population were exposed to the released radioactive fuel.

For launch Phases 1 through 6 on the Titan IV (SRMU)/Centaur, four accident scenarios were identified as representative of the categories of failures that could release plutonium dioxide fuel to the environment. In addition, two postulated very low probability (i.e., much lower than the probabilities for Phases 1 through 6) accident scenarios that could occur during the interplanetary portions of the VVEJGA and VEEGA trajectories were identified as the short-term and long-term inadvertent reentry scenarios. The short-term scenario would involve the inadvertent reentry of the spacecraft into the Earth's atmosphere during a planned Earth swingby, and the long-term scenario would involve a spacecraft failure that leaves the spacecraft drifting in an Earth-crossing orbit and potentially reentering the Earth's atmosphere a decade to millennia later. Preliminary estimates for a Titan IV (SRM)/Centaur launch indicate that the radiological consequences and the risk would be similar to those for the Titan IV (SRMU)/Centaur.

Depending on the accident scenario, the CCAS/KSC regional area, limited portions of the African continent under the vehicle flight path, or indeterminate locations within the global area could be impacted by plutonium dioxide fuel releases. The CCAS/KSC regional area could be impacted if a Phase 1 accident were to result in a release. Areas outside the region (i.e., portions of the African continent; areas elsewhere around the world) could be impacted if an accident resulting in a release were to occur in Phase 5 or 6. Considering potential accidents that could result in a release across all launch phases, no excess cancer fatalities would be expected in the exposed population. No releases of plutonium from the RTGs to the environment are postulated if any of the representative accident scenarios occurred in Phases 2, 3, or 4.

During the interplanetary portions of the mission, postulated short- and long-term inadvertent reentry accident scenarios could result in releases of plutonium dioxide to the environment. However, NASA is designing the mission to avoid the potential for such accidents. The mission's design ensures that the expected probability of an inadvertent reentry would be less than one in a million. If such an accident were to occur, plutonium dioxide could be released in the upper atmosphere and/or scattered in indeterminate locations on the Earth's surface. Within the exposed population of 5 billion people, approximately 1 billion people (i.e., 20 percent or 1/5 of the population) would be expected to die of cancer due to other causes. The estimated fatalities that could result from an inadvertent reentry with release would represent an additional 0.0005 percent above the normally observed 1 billion cancer fatalities.

The principal method used in this document for characterizing the radiological impacts of each alternative evaluated is health effects risk. Health effects are expressed as the number of excess latent cancer fatalities (above the normally observed cancer fatalities) caused by exposure to the plutonium dioxide fuel. As used in this FEIS, health effects mission risk is the probability of an accident with a plutonium dioxide fuel release (i.e., the probability of an initiating accident times the probability of that accident causing a release of plutonium dioxide, since not all accidents would result in a plutonium dioxide release) multiplied by the consequences of that accident (i.e., the health effects that could be caused by the exposure of individuals to the plutonium dioxide), summed over all postulated accidents. Estimates of health effects mission risk, as discussed in this FEIS, represent the expectation latent cancer fatalities. The expectation health effects mission risk over all mission phases (i.e., the total or overall health effects mission risk) does not include contributions to risk from the long-term reentry scenario.

For the Proposed Action, the health effects mission risk considering all launch phases for the primary launch opportunity would be 8.4×10^{-7}. The health effects mission risk from the short-term inadvertent reentry accident during the Earth swingby portion of the primary launch opportunity's VVEJGA trajectory would be 1.7×10^{-3} and for the secondary and backup opportunities' VEEGA trajectories would be 1.8×10^{-3}. The total health effects mission risk (considering all launch phases and the Earth-Gravity-Assist trajectories) from the primary launch opportunity would be 1.7×10^{-3} and from the backup launch opportunity would be 1.8×10^{-3}. The health effects mission risks from the Cassini mission would be small and less than the total health risks faced by the public from construction and/or operation of large industrial projects.

The environmental impacts of a normal launch of the 1999 mission would be associated with the normal operations of the Shuttle. These Shuttle operations would result in temporary impacts on air and water quality near the launch site. Because this alternative would require two Shuttle launches, impacts would occur two times separated by 21 to 51 days.

During the second Shuttle launch for this mission alternative, certain accidents that may occur could result in a release of a portion of the plutonium dioxide from the RTGs to the environment. The local CCAS/KSC regional area could be impacted if a Phase 1 accident resulted in a release. Limited portions of the African land mass could be impacted by a Phase 2 accident, and Phases 3 and 4 accidents could impact indeterminate locations within the global area. In addition, releases could occur from an accident occurring during a short-term inadvertent reentry.

Potential failures and radiological consequences associated with the Earth swingby portions of the VEEGA trajectory would be expected to be identical to those analyzed for the VEEGA swingbys for the 1999 backup launch opportunity of the Proposed Action.

Using estimation methods similar to that for the Proposed Action, the health effects mission risk over all the mission launch phases for the 1999 mission alternative is 2.1×10^{-6}. The corresponding risk from a short-term inadvertent reentry during the Earth swingby portion of the VEEGA trajectories would be 1.8×10^{-3}, and the total health effects mission risk would be 1.8×10^{-3}.

The environmental impacts of a normal launch of the 2001 mission alternative would be similar to those estimated for the Proposed Action. The spacecraft with a high performance rhenium propulsion engine would be launched on the Titan IV (SRMU)/Centaur. The launch accident scenarios that could result in a release of plutonium dioxide fuel and the associated consequences and risks would be identical to those evaluated for the Proposed Action. The overall health effects mission risk from the launch phases is 8.4×10^{-7}. The primary launch opportunity of this 2001 mission alternative would not use the Earth for a gravity-assist (the trajectory is a VVVGA); subsequently, there would be no consequences and health effects mission risks associated with a short-term inadvertent reentry. Because there is no non-EGA backup launch opportunity for the 2001 mission alternative, the backup opportunity would use a VEEGA. The health effects mission risk from the backup short-term inadvertent reentry is 1.8×10^{-3}. The overall health effects mission risk from the primary opportunity is 8.4×10^{-7} and from the backup is 1.8×10^{-3}.

For all launch opportunities, should the spacecraft become uncommandable any time after injection into its interplanetary trajectory and before the final planetary gravity-assist, the spacecraft could eventually reenter the Earth's atmosphere a decade to centuries later (i.e., long-term inadvertent reentry scenario). The health effects mission risk of such an event is assumed to be similar (i.e., same order of magnitude) to that estimated for the short-term inadvertent reentry for the primary launch opportunity associated with the Proposed Action.

No environmental impacts would be associated with the No-Action alternative.

MISSION-SPECIFIC CONSIDERATIONS

The Proposed Action has the greatest potential to accomplish the mission and its scientific objectives. In addition, because the Proposed Action would ensure that adequate performance margins are available (e.g., spacecraft propellant available for maneuvers during the Saturn science tour), it would have the greatest likelihood to take advantage of both planned and unplanned opportunities for science return. The expected science return for the Proposed Action's December 1997 and March 1999 contingency launch opportunities would be less due to the later arrival time at Saturn. For similar reasons, the expected science return for the 1999 mission alternative using the two-Shuttle launch would be less than the return obtained from the Proposed Action.

Although the 2001 mission alternative would achieve most of the planned science objectives, it would not return as much science as the Proposed Action. The larger propellant tank and propellant load would reduce the overall mission performance, requiring the use of a specially developed rhenium spacecraft propulsion engine. Even with the use of this more efficient propulsion engine, the number of Titan flybys would be reduced from 35 to 21. Other trajectory adjustments would be necessary to conserve propellant. In addition to reducing the opportunity for obtaining the planned science return, the ability of the spacecraft to take advantage of unplanned discoveries would be limited. Because this alternative requires a longer flight time than the Proposed Action, and the launch would be delayed relative to the primary launch opportunity, the international partnerships formed to develop the Cassini spacecraft, Huygens Probe, and other space-related projects could be disrupted.

Because the No-Action alternative would cancel the mission, the science return would be lost, and the ability of the United States to enter into future international agreements for cooperative space activities could be impaired.

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ABBREVIATIONS AND ACRONYMS

A

a	Acre
AACS	Attitude and Articulation Control Subsystem
ACS	Active Cooling System
ADS	Automatic Destruct System
AGE	Aerospace Ground Equipment (Building)
AIAA	American Institute of Aeronautics and Astronautics
AIHA	American Industrial Hygiene Association
Al_2O_3	aluminum oxide
AMTEC	alkali metal thermoelectric converter
APSA	Advanced Photovoltaic Solar Array
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
ASRM	advanced solid rocket motor
AU	astronomical unit(s)

B

BACT	Best Available Control Technology
BEIR	biological effects of ionizing radiation
Bq	becquerel

C

ºC	degrees centigrade (Celsius)
CAA	Clean Air Act
CBCF	carbon-bonded carbon fiber
CCAFS	Cape Canaveral Air Force Station
CCAS	Cape Canaveral Air Station
CDF	cumulative distribution function
CDS	Command and Data Subsystem
CED	Committed Effective Dose
CELV	Complementary Expendable Launch Vehicle
CFR	Code of Federal Regulations
Ci	Curie
Cl_2	Chlorine
cm	centimeter
cm^3	cubic centimeters
Cm-244	Curium-244
CO	carbon monoxide
CO_2	carbon dioxide

CSA	concentrated solar array
CSD	Command Shutdown and Destruct
CSDS	Command Shutdown and Destruct System
CRAF	Comet Rendezvous Asteroid Flyby

D

dBA	decibels (A-weighted)
DCU	digital control unit
DEIS	Draft Environmental Impact Statement
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
DOT	U.S. Department of Transportation

E

EA	Environmental Assessment
ECFRPC	East Central Florida Regional Planning Council
EGA	Earth-Gravity-Assist
EJGA	Earth-Jupiter-Gravity-Assist
EIS	Environmental Impact Statement
EMC	electromagnetic compatibility
EPA	U.S. Environmental Protection Agency
ESA	European Space Agency
ESD	electrostatic discharge
ET	external tank

F

FCO	Flight Control Officer
FDEP	Florida Department of Environmental Protection
FDNR	Florida Department of Natural Resources
FEIS	Final Environmental Impact Statement
FGFWFC	Florida Game and Fresh Water Fish Commission
FMEA	Failure Mode Effects and Analysis
FOV	field-of-view
FR	Federal Register
FSAR	Final Safety Analysis Report
FSU	Florida State University
ft/s	feet per second
FTS	Flight Termination System
FVIS	fuel vapor incineration system
FWPF	fine weave pierced fabric

FWS Fish and Wildlife Service
FY fiscal year

G

g gram
GaAs gallium arsenide
GE General Electric Company
Ge germanium
GIS graphite impact shell
GPHS General Purpose Heat Source

H

H_2 hydrogen
H_20 water
ha hectare
HCI hydrochloric acid or hydrogen chloride
HNO_3 nitric acid
HTPB hydroxyl terminated polybutadiene

I

IAEA International Atomic Energy Agency
ICRP International Commission on Radiological Protection
IIP instantaneous impact point
INSRP Interagency Nuclear Safety Review Panel
ISDS inadvertent separation and destruct system
ITL Integrate Transfer and Launch
IUS Inertial Upper Stage

J

JGA Jupiter-Gravity-Assist
JPL Jet Propulsion Laboratory, California Institute of Technology
JSC Johnson Space Center, NASA

K

kg	kilograms
km/s	kilometers per second
km^2	square kilometers
KSC	Kennedy Space Center, NASA

L

LASEP	Launch Accident Scenario Evaluation Program
lb	pounds
LEO	low earth orbit
LH_2	liquid hydrogen
LILT	low (insolation) intensity and low temperature
LO_2	liquid oxygen
LWRHU	lightweight radioisotope heater units

M

MECO	Main Engine Cutoff
MET	mission elapsed time
mg/l	milligram per liter
MHW	Multi-Hundred-Watt
MIL-STD	Military Standard
MINWR	Merritt Island National Wildlife Refuge
mm	millimeter
MMH	monomethylhydrazine
MPa	10^6 pascals
mrem	millirem
m/s	meters per second
MSA	Metropolitan Statistical Area
MST	Mobile Service Tower

N

N	Newton
N_2H_4	hydrazine
N_2O_4	nitrogen tetroxide (NTO)
NAAQS	National Ambient Air Quality Standards
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCRP	National Council on Radiation Protection and Measurements
NEP	Nuclear Electric Propulsion
NEPA	National Environmental Policy Act

NESHAP	National Emissions Standards for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
NO_2	nitrogen dioxide
NO_X	nitrogen oxides
NOI	Notice of Intent
NRC	U.S. Nuclear Regulatory Commission
NSI	NASA standard initiator
NTO	nitrogen tetroxide (N_2O_4)

O

O_2	oxygen
O_3	ozone
OFW	Outstanding Florida Waters
OH-	hydroxide ion
OMS	Orbital Maneuvering System
OSSE	Outer Solar System Exploration Program
OSTP	Office of Science and Technology Policy
OVSS	oxidizer vapor scrubber system

P

P	probability
PAFB	Patrick Air Force Base, USAF
PAMS	Permanent Air Monitoring Station
PAM-S	Payload Assist Module - Special
PBAN	polybutadiene acrylonitrile
PCAD	Products of Combustion and Dispersion Air Quality Model
pCi/l	picocurie/liter
PD/NSC-25	Presidential Directive/National Security Council Memorandum #25
PEL	permissible exposure limits
PG	pyrolytic graphite
pH	measure of acidity of -log[H^+]
PHSF	Payload Hazardous Servicing Facility
PLF	payload fairing
PMS	propulsion module subsystem
ppb	parts per billion
ppm	parts per million
PQM-1	Preliminary Qualification Motor No. 1
PSAR	Preliminary Safety Analysis Report
psi	pounds per square inch
Pt	platinum
Pu	plutonium
PUO_2	plutonium dioxide

R

REEDM	Rocket Effluent Exhaust Dispersion Model
rem	roentgen equivalent man
RHU	radioisotope heater unit
ROD	Record of Decision
RTG	radioisotope thermoelectric generator

S

s	seconds
SAEF	Spacecraft Assembly and Encapsulation Facility
SAR	Safety Analysis Report
SCS	Soil Conservation Service, U.SDepartment of Agriculture
SEP	Solar-Electric Propulsion
SER	Safety Evaluation Report
Si	silicon
SiGe	silicon germanium
SNAP	Systems for Nuclear Auxiliary Power
SO_2	sulfur dioxide
SOI	Saturn Orbit Insertion
SR	State Route
Sr-90	strontium-90
SRB	solid rocket booster
SRM	solid rocket motor
SRMU	solid rocket motor upgrade
SSME	Space Shuttle main engines
STP	sewage treatment plant
STP	Solar-Thermal Propulsion
STS	Space Transportation System (Shuttle)
STS-IUS	Space Transportation System - Inertial Upper Stage
Sv	Sievert
SV	Satellite Vehicle
SVDS	space vehicle destruct system

T

TOMS	total ozone mapping spectrometer
TP	total phosphate

U

μCi	microcuries
$\mu g/m^3$	micrograms per cubic meter
UDMH	unsymmetrical dimethylhydrazine
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USAEC	U.S. Atomic Energy Commission
USAF	U.S. Air Force
UT	Umbilical Tower

V

VAB	Vehicle Assembly Building
VEEGA	Venus-Earth-Earth-Gravity-Assist
VIB	Vertical Integration Building
VVEJGA	Venus-Venus-Earth-Jupiter-Gravity-Assist
VVVGA	Venus-Venus-Venus-Gravity-Assist
VVVJGA	Venus-Venus-Venus-Jupiter-Gravity-Assist

W

W	Watt
WIND	Weather Information Network Display
WMO	World Meteorological Organization