Significant Incidents in Human Spaceflight

WHAT IS IT?

Human spaceflight grew out of the Cold War between the United States and the Soviet Union. Competitive struggles laid the groundwork with advances in high altitude flight, rocketry, and human performance. Human spaceflight reached its first defining success more than half a century ago, when Cosmonaut Yuri Gagarin became the first man to orbit the Earth in April 1961. In November 2000, a multi-national crew moved aboard the International Space Station. By November 2011, the former Cold War rivals had collaborated to surpass 10 years of continuous presence in space. Now a new record of continuous space habitation is established daily.

The Significant Incidents and Close Calls in Human Spaceflight chart presents a visual overview of major losses and close calls spanning the history of human spaceflight. It heightens awareness of the risks that must be managed as human spaceflight continues to advance.

HOW DOES IT WORK?

Events on the chart are organized by flight phase and ordered chronologically within each phase. Each event is represented by a small box which includes the mission name, date, a brief description of the incident and any significant result, such as injury or loss of life.

Three types of important events are highlighted: loss of crew, crew injury, and related or recurring events. Events with one or more crew fatalities are considered a loss of crew and highlighted in red. Crew injury or illness and/or loss of vehicle or mission is designated by orange shading. Related or recurring events are grouped together and set apart by yellow shaded boxes. These events have occurred repeatedly, are similar in nature, and may continue to occur today.

WHY DO WE HAVE IT?

The Significant Incidents and Close Calls in Human Spaceflight chart is maintained by NASA Johnson Space Center's Flight Safety Office to raise awareness of lessons that have been learned through the years. It is a visible reminder of the risks inherent in human spaceflight. It is intended to spark an interest in past events, inspire people to delve into lessons learned, and encourage continued vigilance. It can aid in developing "what-if" scenarios and in ensuring the lessons of history are incorporated into new designs. It is being distributed as widely as possible in the hope that future accidents may be prevented.

WHAT IS THE BONDARENKO STORY?

Two fatal events, the Soviet altitude chamber oxygen fire and the Apollo 1 terminal countdown demonstration test, highlight the importance of sharing information. On March 23, 1961 Soviet cosmonaut Valentin Bondarenko lost his life after being severely burned in an altitude chamber fire. The incident occurred during a routine training exercise, when Bondarenko attempted to throw an alcohol swab into a waste basket, but hit the edge of a hot plate instead. The oxygen-rich environment quickly ignited. Rescue efforts were thwarted because internal pressure prevented rescuers from opening the chamber's inwardly swinging hatch for several minutes. By the time the pressure was released and the hatch could be opened, Bondarenko had been hopelessly burned. He died hours later.

Six years later, three U.S. astronaut's lives were lost in a fire during the terminal countdown demonstration test. During the test, the Apollo crew module contained an oxygen-rich atmosphere. An electrical short caused a fire that spread quickly throughout the cabin. Again, rescue efforts were delayed due to the buildup of pressure behind an inwardly opening hatch. Unlike the Soviet altitude chamber oxygen fire, the crew did not die due to burns from the fire, but from cardiac arrest caused by smoke inhalation. However, in both the Bondarenko tragedy and the Apollo 1 incident, high levels of oxygen caused the fires to spread rapidly, and pressure against inward opening hatches slowed rescue efforts. Neither cabin was equipped with effective fire-suppression equipment.

Information about the Bondarenko incident was not known in the U.S. until 1986 – more than 20 years later. Would access to this information have led to design changes that saved lives? Although that question can never be answered, these events underscore the importance of sharing information in the effort to prevent future tragedies.

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Legend

Loss of Crew	Crew Injury/Illness and/or Loss of Vehicle or Mission	Related or Recurring event

SR-71 | X-15 | Soyuz 1 | Apollo 1 | Soyuz 11 | Challenger | Columbia

Launch/Ground

STS-110 4/8/2002
STS-109 3/1/2002
STS-108 12/5/2001
Incorrect adjustments to the controller software resulted in SSME underperformance.
Crew: 7

STS-91 6/2/1998
Main engine pressure chamber sensor failed. If it occurred later, logic error may have triggered at RTLS.
Crew: 6

Soyuz TM-9 2/11/1990
DM insulation torn loose on ascent; contingency EVA repair.
Crew: 2

SRB Seal Events (1981-1996)

STS-51L (Challenger) 1/28/1986
SRB seal failure.
Crew: 7 **Loss of Crew**

Other SRB gas sealing anomalies: STS-2, 6, 41B, 41C, 41D, 51C, 51D, 51B, 51G, 51F, 51I, 51J, 61A, 61B, 61C, 42, 71, 70, 78

STS-51F 7/29/1985
Temperature sensor problems resulted in SSME1 shutdown at T+5:45.
Crew: 7 Abort To Orbit

Soyuz 18-1(18a) 4/5/1975
Electrical fault caused premature firing of half of the 2nd stage separation bolts, resulting in the inability to fire the remaining ones. Staging failure resulted in abort sequence being used at T=295 seconds.
Crew: 2 Loss of Vehicle/Mission

Apollo 13 4/11/1970
2nd stage center engine shutdown due to pogo oscillations.
Crew: 3

Apollo 12 11/14/1969
Lightning strike on ascent.
Crew: 3

Gemini 10 7/18/1966
1st stage oxidizer tank exploded at staging. No discernable effects. Nominal ascent.
Crew: 2

ISS Cargo Mission Failures (2011-2016)
Progress M-12M (44P) 8/24/2011
Anomaly in fuel pressurization system led to shutdown of 3rd stage engine. Vehicle failed to reach orbit.
Crew: 0 Loss of Vehicle/Mission
Other ISS Cargo Mission Failures:
Progress M-27M & MS-04, Cygnus CRS Orb-3, Dragon CRS SpX-7.

STS-117 6/8/2007
Thermal blanket damage. EVA performed to repair damage.
Crew: 7

STS-114 5/26/2005
- Bird strike on External Tank.
- Loss of foam from External Tank PAL ramp.
- TPS gap filers protruding. Removed during third mission EVA.
- ET forward separation bolt NSI ejected causing damage to adjacent orbiter structure and TPS.

Crew: 7

STS-93 7/23/1999
- At T+5 a short on AC1 Phase A resulted in loss of SSME1 Controller A and SSME3 Controller B.
- SSME3 H_2 leak: early LOX depletion and shutdown.

Crew: 5

Ascent Debris
STS-124 5/31/2008
3,500 refractory bricks blown away from flame trench wall during liftoff.
Crew: 7
STS-95 10/29/1998
Drag chute door separated during launch and impacted main engine bell.
Crew: 7
Other significant ascent debris events have occurred on:
STS-116 and STS-125
Late Release Orbiter Tyvek Covers
STS-114, 115, 118, 119, 124, 126

STS-112 10/7/2002
T-0 umbilical issues resulted in none of the system A pyrotechnic charges firing.
Crew: 6

STS-61C 1/6/1986
System configuration errors resulted in inadvertent drain back of 14,000 lbs of LOX prelaunch, which would have resulted in a Trans-Atlantic Abort Landing.
Crew: 7

On-pad Abort Events (1984-1993)
STS-41D 6/26/1984
Following a pad abort, LH_2 leaked from SSME3, resulting in a fire at the base of the orbiter.
Crew: 6
Soyuz T-10-1 (T-10a) 9/26/1983
Pad booster fire/explosion. Capsule Escape System used.
Crew: 2 Loss of Vehicle/Mission
Other On-pad Abort Events:
STS-51F, STS-55, STS-51, STS-68.

STS-1 4/12/1981
SRB ignition pressure wave caused TPS and structural damage.
Crew: 2

Apollo 1 (AS-204) 1/27/1967
Crew cabin fire (electrical short + high pressure O_2 atmosphere).
Crew: 3 **Loss of Crew**

Gemini 6 12/12/1965
Main engine shutdown. Booster left unsecured on pad. Crew elected not to eject. Launched 3 days later.
Crew: 2

Suborbital Flights

Ascent / Entry

X-15 3-65-97 11/15/1967
Electrical short and crew error led to loss of control at 230,000 feet. First U.S. spaceflight fatality.
Crew: 1 **Loss of Crew**

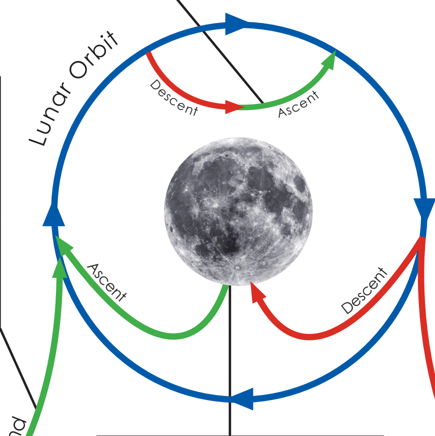
SpaceShipOne, 16P 9/29/2004
Uncommanded vehicle roll. Control regained prior to apogee.
Crew: 1

SpaceShipOne, 14P 5/13/2004
Flight computer unreponsive. Recovered by rebooting.
Crew: 1

Earth Orbit

Ascent / Outbound / Earth Return / Entry / Descent

EVA Incidents Summary (1965-2014)
12 EVAs resulted in crew injury:
Gemini 10, Apollo 17, Salyut 7 PE-1, Salyut 7 VE-3, STS-61-B EVAs 1&2, STS-37, Mir PE-9, STS-63, STS-97/4A, STS-100/6A EVAs 1&2, STS-134/ULF6
See the Significant Incidents in EVA Operations Graphic and Interactive Version for more details. (spaceflight.nasa.gov/outreach/readersroom.html)



Apollo 10 5/22/1969
Switch misconfiguration resulted in lunar module control problems.
Crew: 2

Apollo 14 1/31/1971
Multiple failed docking attempts. Contingency procedures developed to mitigate risk of recurring docking anomaly. Docking successful.
Crew: 3

Apollo 13 4/13/1970
Explosion due to electrical short. Loss of O_2 and EPS.
Crew: 3 Loss of Mission

Apollo 11 7/21/1969
Engine arm circuit breaker knob broke off. Circuit breaker successfully reset allowing ascent.
Crew: 2

Medical Evacuations (1976-1987)
Mir EO-2, 1987, Crew: 2
One replaced early due to medical condition.
Salyut 7, 1985, Crew: 3
One returned with visiting crew due to medical condition.
Salyut 5, 8/25/1976, Crew: 2
Early return of crew due to health effects from suspected toxic gases in space station.
Crew Illness

ISS Increment 38 12/11/2013
ITCS configuration errors resulted in near freezing and potential rupture of water-to-ammonia heat exchanger.
Crew: 6

Soyuz TMA-18 (22S) 9/23/2010
First attempt to separate from ISS failed; ISS crew succeeded in bypassing faulty sensor.
Crew: Soyuz 3, ISS 3

ISS, Increment 17 4/30/2008
Freon 218 leaked from SM AC.
Crew: 3

ISS Increment 15 6/10-6/18/2007
Power switch failures caused loss of ISS propulsive attitude control capability.
Crew: 10

ISS, Increment 13 8/2006
Triol coolant leak in SM.
Crew: 3

ISS, Increment 10 2/2005
Potential acid preservative aerosol escape from Russian urinal.
Crew: 2

ISS, Increment 5&6 mid-2002-2/03
Formaldehyde periodically exceeded long-term limits.
Crew: 3-10

ISS, Increment 2-4 4/2001-3/2002
Freon 218 leaked from SM AC.
Crew: 3

ISS, Increment 4 2/2002
MetOx regeneration caused noxious air.
Crew: 3

STS-104 7/2001
EMU battery leaked hazardous KOH. Discovered during EMU checkout.
Crew: 5

ISS 8/2001
Extremely high methanol levels in FGB air sample on Increment 2.
Crew: 3

ISS Increment 2 4/24/2001
Failure of all U.S. command and control computers on ISS.
Crew: 10

STS-99 2/2000
High bacterial count in postflight sample after GIRA installed to removed iodine.
Crew: 6

ISS, Flight 2A.1 5/1999
Crew sickened in FGB; likely a result of high localized CO_2 levels due to poor ventilation.
Crew: 7

STS-95 10/29/1998
Preflight sterilization process chemically altered the Low Iodine Residual System resulting in contaminated drinking water.
Crew: 7

STS-87 11/21/1997
Spartan satellite deployed without proper activation. Recapture with RMS unsuccessful. Later captured by EVA crew.
Crew: 6

Mir 7/17/1997
Accidental unplugging of computer power cable led to loss of attitude control and loss of power.
Crew: 3

STS-83 4/6/1997
Failure of fuel cell number 2 resulted in MDF being declared. The 15-day mission was shortened to 3 days.
Crew: 7 Minimum Duration Flight
Loss of Mission

STS-51 9/12/1993
Both port-side primary and secondary SUPER*ZIP explosive cords fired, resulting in containment tube failure and damage in the payload bay.
Crew: 5

STS-44 11/24/1991
Failure of IMU 2 caused MDF to be declared. 10-day mission shortened to 7 days.
Crew: 6 Minimum Duration Flight

STS-32 1/9/1990
Erroneous state vector up-linked to flight control system, causing immediate and unpredictable attitude control problems.
Crew: 5 Loss of Attitude Control

STS-9 12/8/1983
Two GPCs failed during reconfiguration for entry. One GPC could not be recovered.
Crew: 6

STS-2 11/12/1981
- Failure of fuel cell resulted in a MDF being declared.
- The fuel cell failure also resulted in hydrogen in the drinking water leading to crew dehydration.

Crew: 2 Mission Terminated

Soyuz 33 4/12/1979
Main engine anomaly caused final rendezvous abort.
Crew: 2 Loss of Mission

Soyuz 21 8/24/1976
Separation from Salyut failed; ground command succeeded in opening latches.
Crew: 2

Soyuz 1 4/23/1967
Failures in attitude control and electrical power systems resulted in a loss of mission. The launch of the intended docking target, Soyuz 2, was scrubbed.
Crew: 1 Loss of Mission

Gemini 8 3/16-3/17/1966
Stuck thruster caused loss of control and led to 1st U.S. emergency de-orbit.
Crew: 2 Emergency De-orbit

Mercury MA-9 5/16/1963
Electrical faults caused loss of some systems and need to perform manual entry. Also experienced high $PPCO_2$ levels in suit during entry operations.
Crew: 1 Manual Entry

Mir Collision Events (1994-1997)
Mir 6/25/1997
Progress M-34 collided with Mir. Spektr pressure shell ruptured. Spektr module isolated. Cables through hatchway impeded hatch closing.
Mir Crew: 3 Collision
Mir 8/30/1994
Progress M-24 collided with Mir during second docking attempt.
Mir Crew: 2 Collision
Mir 1/14/1994
Soyuz TM-17 collided twice with Mir during undocking.
Crew: Soyuz 2, Mir 3 Collision

Fire/Overheating Events (1971-2008)
ISS, 10/10/2008, Crew: 3
ISS, 9/18/2006, Crew: 3*
ISS, 3/2005, Crew: 2
Mir* 2/26/1998
Overheating BMP beds produce health-threatening level of CO.
Crew: 2
Mir* 2/24/1997
Chemical oxygen generator (SFOG) failure resulted in fire.
Crew: 5
Mir, 10/1994, Crew: 6
STS-40, 6/1991, Crew: 7*
STS-35, 12/1990, Crew: 7*
STS-28, 8/1989, Crew: 5*
STS-6, 4/1983, Crew: 4*
Salyut 7, 9/1982, Crew: 3
Salyut 6, 1979, Crew: 3
Salyut 1, 6/1971, Crew: 3
*toxic byproducts released

Docking Anomalies
STS-133 2/26/2011
Experienced significant misalignment between orbiter and ISS during post-capture free drift due to gravity-gradient-induced motion.
Crew: 6
STS-130 2/10/2010
Experienced significant misalignment between orbiter and ISS during post-capture free drift due to gravity-gradient-induced motion.
Crew: 6
Soyuz T-8 4/22/1983
Loss of rendezvous antenna prevented docking.
Crew: Soyuz 3 Loss of Mission
Skylab 2 5/26/1973
Multiple failed automatic docking attempts resulted in manual docking to Skylab.
Crew: 3
Soyuz 10 4/23/1971
Automatic docking system failed. Manual docking with Salyut not achieved.
Crew: 3 Loss of Mission

Soyuz TM-5 9/6/1988
Two de-orbit attempts failed. Crew confined to DM due to OM being jettisoned prior to 1st de-orbit attempt. Crew prevented erroneous firing of SM separation pyrotechnics.
Crew: 2

Soyuz T-11 10/2/1984
Partial failure of atmospheric entry control system.
Crew: 3

Soyuz 33 4/12/1979
Backup engine burned 25 seconds too long on de-orbit. Ballistic entry.
Crew: 2

Skylab 4 2/8/1974
Incorrect circuit breakers opened, resulting in the loss of the automatic control.
Crew: 3

Soyuz 11 6/30/1971
Pyrotechnic system failure resulted in crew module rapid depress.
Crew: 3 **Loss of Crew**

Gemini 5 8/29/1965
Erroneous entry data uplinked; crew manually corrected entry flight profile.
Crew: 2

Gemini 4 6/7/1965
Erroneous entry data uplinked; crew manually corrected entry flight profile.
Crew: 2

Voskhod 2 3/19/1965
Automatic descent system malfunctioned. Issues with manual entry resulted in off-target, rough terrain landing. Delayed crew recovery.
Crew: 2

Mercury MA-7 5/24/1962
Pitch horizon scanner failed, resulting in manual entry and off-target landing. Delayed crew recovery.
Crew: 1

Mercury MA-6 2/20/1962
False landing-bag indicator light led to entry with retropack in place as a precaution.
Crew: 1

Service/Descent Module Separation Failures (1961-2008)
Soyuz TMA-11 (15S) 4/19/2008
Ballistic, high *g* entry and landing over 400 km short of intended target.
Crew: 3 Crew Injury (1)

Soyuz TMA-10 (14S)	10/21/2007	Crew: 3
Soyuz 5	1/18/1969	Crew: 2
Voskhod 2	3/19/1965	Crew: 1
Vostok 5	6/19/1963	Crew: 1
Vostok 2	8/7/1961	Crew: 1
Vostok 1	4/12/1961	Crew: 1

TPS Entry Events (1981-2003)
STS-107 (Columbia) 2/1/2003
TPS damage from ascent debris strike resulted in loss of crew and vehicle on entry. Similar bipod ramp foam loss occurred on STS-7, STS-32, STS-50, STS-52, STS-62, and STS-112
Crew: 7 **Loss of Crew**
STS-51D 4/19/1985
TPS burn-through on left outboard elevon.
Crew: 7
STS-1 4/14/1981
Right-hand main landing gear door warped due to entry heating.
Crew: 2
Other significant STS TPS anomalies:
STS-6, 41B, 51G, 27*, 28, 40, 42, 45
*Most severe tile damage to date.

Research Facility

Altitude Chamber O_2 Fire - Soviet 3/23/1961
Alcohol wipe hit hot plate and started fire in oxygen-rich test chamber.
Crew: 1 **Loss of Crew**

Navy Chamber 11/17/1962
Fire started in a 100% oxygen environment at 5 psi. Four officers injured.
Crew: 4 Crew Injury (4)

Atmospheric Flights

Ascent / Cruise / Descent

M21-D21 7/30/1966
D21 drone collided with M21 during launch, causing M21 breakup. Crew survived breakup but one was lost after water landing.
Crew: 2 **Loss of Crew (1)**

SR-71 1/25/1966
Loss of control at high speed and altitude.
Crew: 2 **Loss of Crew (1)**

SpaceShipTwo, PF04 10/31/2014
Vehicle breakup during powered flight.
Crew: 2 **Loss of Crew (1)**

SpaceShipOne, Flight 11P 12/17/2003
Left main landing gear collapsed.
Crew: 1

Landing and Postlanding

Soyuz TM-25 8/17/1997
Landing rockets fired at heat shield separation rather than at landing.
Crew: 3

Apollo ASTP 7/24/1975
N_2O_4 in crew cabin. Crew hospitalized for 2 weeks.
Crew: 3 Crew Injury

Mercury MA-7 5/24/1962
RCS depletion at 80,000 ft.
Crew: 1

STS-134 6/1/2011
Brief fire observed between the left main landing gear tires during runway rollout.
Crew: 7

STS-108 12/17/2001
Violation of minimum landing weather requirements.
Crew: 7

STS-90 5/3/1998
Hard, fast landing due to human factors and rogue wind gust. Hardest shuttle landing.
Crew: 7

STS-37 4/11/1991
Several factors contributed to a low-energy landing 623 feet prior to the threshold of the runway at the backup landing location.
Crew: 5 Low Energy Landing

STS-51D 4/19/1985
Right brake failed (locked up) causing blowout of inboard tire and significant damage to outboard tire.
Crew: 7

STS-9 12/8/1983
A. Two APUs caught fire during rollout.
B. GPC failed on touchdown.
C. Incorrect flight control rechannelization on rollout.
Crew: 6

STS-3 3/30/1982
Pilot induced oscillation during derotation. Stronger than predicted winds contributed.
Crew: 2

Soyuz 15 8/28/1974
Descended through an electrical storm during night landing.
Crew: 2

Apollo 15 8/7/1971
Landed with only 2 of 3 parachutes.
Crew: 3

Apollo 12 11/24/1969
Harder than normal splashdown knocked loose a camera. The camera knocked lunar module pilot unconscious.
Crew: 3

Mercury MR-4 7/21/1961
Inadvertent hatch pyrotechnic firing. Capsule sunk. Astronaut nearly drowned.
Crew: 1 Loss of Capsule

Soyuz Landing Events (1967-1993)
Soyuz TM-15 2/1/1993
Rolled down hillside.
Crew: 2
Soyuz TM-14 8/10/1992
Hard landing impact. Hatch jammed, requiring cosmonauts to use tools to pry open.
Crew: 3
Soyuz TM-12 10/10/1991
Hard impact. News team reported capsule as "very dented."
Crew: 3
Soyuz TM-7 4/27/1989
Double-impact "hard landing."
Crew: 2 Crew Injury (1)
Soyuz T-7 12/10/1982
Landed on hillside and rolled downhill. One cosmonaut thrown from seat.
Crew: 2
Soyuz 36 7/31/1980
Landing rockets failed to fire resulting in ~30 *g* impact.
Crew: 2
Soyuz 23 10/16/1976
Landed on frozen lake during blizzard. Delayed recovery.
Crew: 2
Soyuz 18-1 (18a) 4/5/1975
After ascent abort, capsule landed on snowy slope above cliff. Parachute snagged and prevented fall.
Crew: 2 Crew Injury
Soyuz 5 1/18/1969
Landing rockets failed to fire, resulting in a hard landing.
Crew: 1 Crew Injury
Soyuz 1 4/24/1967
Main and reserve parachutes failed.
Crew: 1 **Loss of Crew**

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The JSC SMA Flight Safety Office maintains the Significant Incidents and Close Calls in Human Spaceflight graphic to provide continuing visibility of the risks inherent with space exploration and to provide engineers with a summary of past experience. It is hoped this information will be used to learn from the past and make present and future missions safer.

Abbreviations and Acronyms

AC	Air Conditioner
APU	Auxiliary Power Unit
BMP	Microimpurities Removal System (Russian)
CDRA	Carbon Dioxide Removal System
CMG	Control Management Gyroscope
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DM	Descent Module
EMU	Extravehicular Mobility Unit
EPS	Electrical Power System
EVA	Extravehicular Activity
FGB	Functional Cargo Block (Russian)
FSO	Flight Safety Office
GIRA	Galley Iodine Removal Assembly
GPC	General Purpose Computer
GPS	Global Positioning System
H_2	Hydrogen
IMU	Inertial Measurement Unit
ISS	International Space Station
ITCS	Internal Thermal Control System
KOH	Potassium Hydroxide
LH_2	Liquid Hydrogen
LOC	Loss of Crew
LOV	Loss of Vehicle
LOX	Liquid Oxygen
MDF	Minimum Duration Flight
MetOx	Metal Oxide
MMOD	Micro-Meteoroid Orbital Debris
N_2O_4	Nitrogen Tetroxide
NSI	NASA Standard Initiator
O_2	Oxygen
OM	Orbital Module
OSMA	Office of Safety & Mission Assurance
PAL	Protuberance Air Load
PASS	Primary Avionics Software System
$PPCO_2$	Partial Pressure of Carbon Dioxide
RCS	Reaction Control System/Subsystem
RMS	Remote Manipulator System
RTLS	Return to Launch Site
SFOG	Solid Fuel Oxygen Generator
SMA	Safety & Mission Assurance
SM	Service Module
SRB	Solid Rocket Booster
SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
STS	Space Transportation System
TPS	Thermal Protection System
U.S.	United States

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