

JSC S&MA FLIGHT SAFETY OFFICE

Significant Incidents and Close Calls in Human Spaceflight: EVA Operations

July 27, 2016

S&MA Engineering Contract
Product 7, Delivery 1
JS-2016-028
NNJ13RA01B

SAIC[®]



Significant Incidents and Close Calls in Human Spaceflight: EVA Operations

A Product of the JSC S&MA Flight Safety Office

	#	%
Loss of Crew	0	0
Crew Injury	12	3
Early Termination	14	4
System Issue	52	13
Operational Issue	36	9

391 total spacewalks through 7/27/2016.
110 (28%) experienced significant incidents and/or close calls.

All hours represent EVA hours, not crew member hours.

Voskhod 2	3/18/1965	<ul style="list-style-type: none"> Suit ballooning impeded operations and made airlock ingress difficult. Workload exceeded cooling capacity.
Gemini 4	6/3/1965	<ul style="list-style-type: none"> Difficulty closing hatch after EVA. Workload exceeded cooling capacity.
Gemini 9	6/5/1966	<ul style="list-style-type: none"> Difficulty maneuvering. Multiple areas of suit damage caused a thermal burn on the crew member's back. Workload exceeded cooling capacity.
Gemini 10	7/19/1966	<ul style="list-style-type: none"> EVA terminated early due to eye irritations from lithium hydroxide being blown into helmets when suit fans were run simultaneously.
Gemini 10	7/20/1966	<ul style="list-style-type: none"> Umbilical blocked view of instruments and caused inadvertent shutdown of Gemini radio. Dislodged sharp-edged electric discharge ring.
Gemini 11, EVA 1	9/13/1966	<ul style="list-style-type: none"> EVA terminated early due to fatigue. Workload exceeded cooling capacity.
Apollo 11, EVA 1	7/20/1969	<ul style="list-style-type: none"> Difficulty passing through the LEM hatch.
Apollo 12, EVA 2	11/20/1969	<ul style="list-style-type: none"> Lunar dust abraded the EMU.

Apollo 15, EVA 2	7/31/1971	<ul style="list-style-type: none"> Drink bag would not dispense water. Rover front wheel steering failed. Dust made EMU fittings difficult to operate. Hand pain from gloves pressing against fingernails.
Apollo 15, EVA 3	8/1/1971	<ul style="list-style-type: none"> Radio antenna broke – taped back in place. Difficulty navigating back to the LEM.
Apollo 16, EVA 1	4/21/1972	<ul style="list-style-type: none"> Crew member slipped and fell on the PLSS after jumping. Lunar dust problems (jammed connectors, accelerated wear, scratches). Tripped over cable to heat-flow sensors.
Apollo 16, EVA 2	4/22/1972	<ul style="list-style-type: none"> EMU radio antenna broke.
Apollo 16, EVA 3	4/23/1972	<ul style="list-style-type: none"> Temporary LRV navigation failure.
Apollo 17, EVA 1	12/11/1972	<ul style="list-style-type: none"> Minor contusions from extracting stuck core sample. One LRV fender brake off, which resulted in the crew getting showered by dust while driving.
Skylab 2, EVA 2	6/7/1973	<ul style="list-style-type: none"> Primary EVA heat exchanger module suffered minor clogging during the EVA, leading engineers to design a new module to serve as a backup.
Skylab 3, EVA 3	9/22/1973	<ul style="list-style-type: none"> Water cooling system failed.
Skylab 4, EVA 1	11/22/1973	<ul style="list-style-type: none"> Difficulty keeping umbilicals separated.
Skylab 4, EVA 2	12/25/1973	<ul style="list-style-type: none"> Cooling water leak resulted in ice forming.
Skylab 4, EVA 3	12/29/1973	<ul style="list-style-type: none"> Cooling water leak resulted in ice forming.
Skylab 4, EVA 4	2/3/1974	<ul style="list-style-type: none"> Cooling water leak resulted in ice forming.
Salyut 6 PE-1, EVA 1	12/20/1977	<ul style="list-style-type: none"> Safety tether not secured, but umbilical in place.
Salyut 6 PE-3, EVA 1	8/15/1979	<ul style="list-style-type: none"> Primary pressure bladder punctured.

Salyut 7 PE-1, EVA 1	7/30/1982	<ul style="list-style-type: none"> Tool use resulted in wrist ring pressing on wrist and numbing hand.
STS-41-B, EVA 1	2/7/1984	<ul style="list-style-type: none"> Slidewire bracket pip-pin pulled free.
STS-41-C, EVA 1	4/8/1984	<ul style="list-style-type: none"> Hardware configuration difference prevented EVA crew member from capturing satellite. Resulted in satellite losing sun-lock and tumbling. Low temperature of MMU led to false low-nitrogen reading.
STS-41-C, EVA 2	4/11/1984	<ul style="list-style-type: none"> EMU urine containment failure. EMU helmet fogging. Small trash bag lost due to inadvertent release of MWS lock.
Salyut 7 PE-3, EVA 6	8/8/1984	<ul style="list-style-type: none"> One spacesuit experienced a failure of the cooling water pump. Physician reported the hands of the EVA crew were injured.
STS-51-L, EVA 2	9/11/1985	<ul style="list-style-type: none"> EMU helmet fogging due to suit temperature adjustments. Difficulty in handling satellite due to lack of visual cues between EVA astronauts. Accidentally reused lithium hydroxide canisters from first EVA.
Mir, PE-2, EVA 1	4/11/1987	<ul style="list-style-type: none"> Incorrect switch setting resulted in temporary suit pressure decrease.

Mir, PE-6, EVA 1	7/17/1990	<ul style="list-style-type: none"> Procedural error damaged airlock hatch, preventing closure. Backup airlock used.
Mir, PE-8, EVA 3	1/26/1991	<ul style="list-style-type: none"> Inadvertent kick knocked Kurs antenna off. Not noticed until subsequent EVA.
STS-37, EVA 1	4/7/1991	<ul style="list-style-type: none"> Palm bar punctured glove and caused minor contusion. Eye irritation in one crew member.
STS-37, EVA 2	4/8/1991	<ul style="list-style-type: none"> Recommended against EVAs on consecutive days due to fatigue and time constraints.
Mir, PE-9, EVA 6	7/27/1991	<ul style="list-style-type: none"> Heat exchanger of one Orlan suit ran out of water, resulting in helmet fogging. Other cosmonaut guided crew member back. Crew member had bruises on hands, elbows, and shoulders.
Mir, PE-10, EVA 1	12/20/1992	<ul style="list-style-type: none"> Heat exchanger of one Orlan suit failed to work, requiring use of umbilical for cooling. Umbilical limited translation range. Crew member conducted portions of EVA alone.
Mir, PE-13, EVA 1	4/19/1993	<ul style="list-style-type: none"> Orlan suit ventilation problems.
STS-57, EVA 1	6/25/1993	<ul style="list-style-type: none"> Cold to point of experiencing hand pain. Almost lost un tethered piece of IUS tilt table equipment.
Mir, PE-14, EVA 3	9/28/1993	<ul style="list-style-type: none"> EVA terminated early due to Orlan suit cooling system failure.
Mir, PE-14, EVA 4	10/22/1993	<ul style="list-style-type: none"> EVA terminated early due to Orlan suit oxygen flow system problem.
STS-61, EVA 2	12/5/1993	<ul style="list-style-type: none"> One EV experienced radio problems.
STS-63, EVA 2	2/9/1995	<ul style="list-style-type: none"> EVA terminated early when EV became "unacceptably cold." One EV experienced eye irritation, likely from anti-fog agent.
STS-80, EVA 1	11/29/1996	<ul style="list-style-type: none"> EVA terminated early. Loose screw jammed airlock hatch latch mechanism, preventing operation.
STS-96/2A.1	5/27-6/6/1999	<ul style="list-style-type: none"> SAFER NSI (pyro) inadvertently fired on orbit, resulting in pyrotechnic isolation valve opening and loss of gaseous nitrogen. Condition identified post-landing.

STS-97/4A, EVA 1	12/3/2000	<ul style="list-style-type: none"> Crew member experienced eye irritation, likely from anti-fog agent used in helmet.
STS-98/5A, EVA 1	2/10/2001	<ul style="list-style-type: none"> EV2 was sprayed with ammonia and required decontamination procedure (aka "bakeout").
STS-100/6A, EVA 1	4/22/2001	<ul style="list-style-type: none"> EV1 experienced eye irritation in both eyes. Attributed to leaking in-suit drink bag and anti-fog agent used in helmet.
STS-100/6A, EVA 2	4/24/2001	<ul style="list-style-type: none"> EV1 experienced eye irritation in both eyes. Attributed to leaking in-suit drink bag and anti-fog agent used in helmet.
ISS-9, EVA 1 (1st attempt)	5/19/2004	<ul style="list-style-type: none"> EVA canceled due to EMU cooling loop contamination, resulting in temporary loss of ISS U.S. EVA capability.
ISS-9, EVA 1	6/24/2004	<ul style="list-style-type: none"> EVA terminated early due to misconfigured valve depleting Orlan suit oxygen supply at start of EVA.
ISS-9, EVA 3	8/3/2004	<ul style="list-style-type: none"> CMGs saturated during EVA. ISS went into free drift. No IVA crew.
STS-121/ULF1.1, EVA 2	7/10/2006	<ul style="list-style-type: none"> EV1's SAFER left tower latch was bumped into the unlatched position, resulting in the left tower disengaging from the EMU. EVA was suspended until latch could be re-engaged by EV2.
STS-116/12A.1, EVA 1	12/12/2006	<ul style="list-style-type: none"> EV1's SAFER HCM inadvertently deployed during airlock egress. EV2 re-stowed HCM on second attempt. SAFER NSI (pyro) accidentally fired.
STS-118/13A.1, EVA 3	8/15/2007	<ul style="list-style-type: none"> EVA terminated early due to cut glove.
STS-120/10A, EVA 3	10/30/2007	<ul style="list-style-type: none"> One EMU unusable after EVA due to degraded sublimator.
ISS-17, EVA 1	7/10/2008	<ul style="list-style-type: none"> Jettisoned Soyuz thruster cover collided with U.S. radiator.
STS-126/ULF2, EVA 2	11/20/2008	<ul style="list-style-type: none"> One EV experienced high carbon dioxide levels. EVA terminated early.
STS-126/ULF2, EVA 4	11/24/2008	<ul style="list-style-type: none"> One EV experienced high carbon dioxide levels. EVA terminated early.
ISS-18, EVA 2	3/10/2009	<ul style="list-style-type: none"> EVs working close to rotating port Service Module solar array. Solar arrays should have been parked for EVA.
STS-125/HST, EVA 4	5/17/2009	<ul style="list-style-type: none"> Tear in palm of EMU glove noticed when EVA was near completion. EVA terminated early.
STS-127/2JA, EVA 3	7/22/2009	<ul style="list-style-type: none"> One EV experienced high carbon dioxide levels. EVA terminated early.
STS-128/17A, EVA 3	9/5/2009	<ul style="list-style-type: none"> EMU camera and light detached from helmet, but held captive by electrical cable.



United States Russia China

STS-130/20A, EVA 1	2/11/2010	<ul style="list-style-type: none"> EV2 observed water droplets in helmet and sensed water at feet.
STS-130/20A, EVA 2	2/14/2010	<ul style="list-style-type: none"> EV2 exposed to ammonia from leaking quick-disconnect.
STS-130/20A, EVA 3	2/17/2010	<ul style="list-style-type: none"> EV1 observed water droplets in helmet.
ISS-24, EVA 2	8/7/2010	<ul style="list-style-type: none"> EV1 exposed to ammonia from leaking quick-disconnect and experienced difficulty actuating quick-disconnect.
ISS-24, EVA 3	8/11/2010	<ul style="list-style-type: none"> EV1 exposed to ammonia from leaking quick-disconnect and experienced difficulty actuating quick-disconnect.
STS-134/ULF6, EVA 1	5/20/2011	<ul style="list-style-type: none"> Carbon dioxide sensor failure resulted in reduced EVA timeline.
STS-134/ULF6, EVA 3	5/25/2011	<ul style="list-style-type: none"> One EV experienced eye irritation, likely from anti-fog agent.
ISS-32, EVA 1	8/30/2012	<ul style="list-style-type: none"> EV2 experienced elevated EMU water cooling loop temperatures.
ISS-36, EVA 1	7/9/2013	<ul style="list-style-type: none"> Crew member observed the presence of water in the EMU helmet.
ISS-36, EVA 2	7/16/2013	<ul style="list-style-type: none"> 1 to 1.5 liters of water entered the EMU ventilation loop and collected in the EMU helmet. EVA terminated early.
ISS-38, EVA 1	12/21/2013	<ul style="list-style-type: none"> After returning to the airlock, an EMU feedwater switch procedural error resulted in water flooding the sublimator rendering EMU no-go for EVA.
ISS-38, EVA 2	12/24/2013	<ul style="list-style-type: none"> Crew members experienced difficulty disconnecting ammonia fluid lines and reported seeing ammonia flakes escaping a valve.
ISS-46, EVA 2	1/15/2016	<ul style="list-style-type: none"> EV1 observed water in helmet. EVA terminated early.

1960s: 25 Hours = 24 U.S. + 1 Russia
18 EVAs = 16 U.S. + 2 Russia

1970s: 121 Hours = 116 U.S. + 5 Russia
32 EVAs = 29 U.S. + 3 Russia

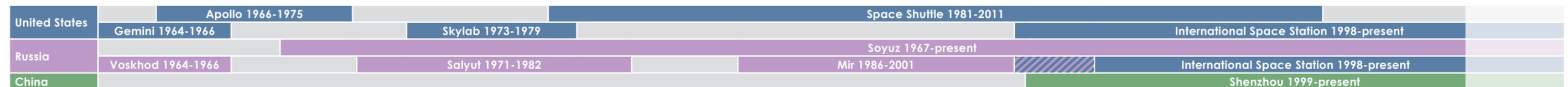
1980s: 145 Hours = 69 U.S. + 77 Russia
33 EVAs = 13 U.S. + 20 Russia

1990s: 557 Hours = 231 U.S. + 326 Russia
107 EVAs = 36 U.S. + 71 Russia

2000s: 900 Hours* = 755 U.S. + 144 Russia
144 EVAs* = 113 U.S. + 30 Russia

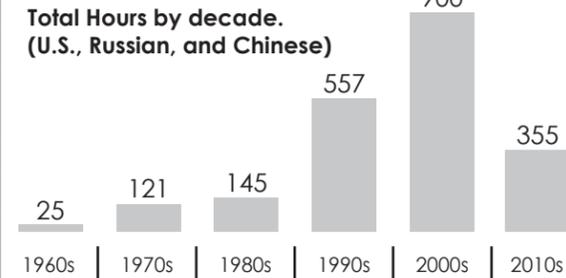
2010s: 355 Hours = 234 U.S. + 121 Russia
57 EVAs = 37 U.S. + 20 Russia

* Total hours and EVAs include 1 Chinese EVA with a duration of 1 hour.



43 EVAs with Inadvertent Releases

Mission ID	EVA	# lost	Year
Gemini 4	1	1	1965
Gemini 10	1	1	1966
Salyut 7	1	1	1983
STS-41-B	2	1	1984
STS-41-C	2	1	1984
STS-41-G	1	1	1984
STS-51-A	2	2	1984
STS-51-1	1	1	1985
Mir	PE-13	1	1993
STS-88/2A	1	4	1998
STS-88/2A	2	3	1998
STS-96/2A.1	1	1	1999
STS-103/HST	3	1	1999
STS-101/2A.2a	1	1	2000
STS-92/3A	3	1	2000
STS-100/6A	2	1	2001
STS-104/7A	3	1	2001
STS-102/5A.1	1	2	2002
ISS-4	RS 6	1	2002
ISS-11	US 13	1	2005
ISS-12	US 4	1	2005
ISS-13	RS 16	1	2006
STS-121/ULF1.1	3	1	2006
STS-115/12A	1	1	2006
STS-115/12A	2	1	2006
STS-116/12A.1	1	1	2006
STS-116/12A.1	3	1	2006
ISS-14	RS 17A	3	2007
ISS-15	RS 18	1	2007
STS-120/10A	4	2	2007
ISS-16	US 13	4	2007
ISS-16	US 14	1	2008
STS-124/1J	2	1	2008
STS-126/ULF2	1	1	2008
ISS-24	RS 25	4	2010
ISS-25	RS 26	1	2010
ISS-26	RS 27	1	2011
STS-133/ULF5	1	1	2011
ISS-28	RS 29	1	2011
ISS-35	RS 32	1	2013



The JSC Flight Safety Office created this graphic to highlight the risks of space exploration and to provide engineers with a summary of past experience. The chart depicts incidents during EVAs in orbit and on the lunar surface, which caused or could have caused injury, death, or the loss of the mission. Our goal is to encourage everyone to learn from the past to make present and future missions safer.

Event Criteria

Incidents on the chart meet one or more of the following criteria:

1. Resulted in loss of life or could have resulted in loss of life under different conditions or circumstances (e.g., close calls, accidental crew detachment, water in helmet, EVA operations in thruster keep-out zone, failure to constrain/inhibit Ku Band operations...).
2. Resulted in injury or temporary incapacitation of a crew member, or otherwise compromised the crew member's ability to perform critical tasks, such as self-rescue (e.g., frost bite, anti-fog agent in eyes).
3. Resulted in the potential for critical or catastrophic damage to spacecraft (e.g., damaged hatch seal, damage to wiring harness, damage to suit, jettisoned equipment collision, or inadvertent release).
4. EVA aborted or terminated early to protect the crew.
5. Unique significance based on expert opinion (e.g., precursor events and minor events related to subsequent, more significant events, such as water-in-suit events, planetary protection, etc.).

Acronyms

CMG	Control Moment Gyroscope	MWS	Mini-Workstation
EMU	Extravehicular Mobility Unit	NASA	National Aeronautics and Space Administration
EVA	Extravehicular Activity	NSI	NASA Standard Initiator
EV	EVA Crew Member	PE	Principal Expedition
FSO	Flight Safety Office	PLSS	Primary Life Support System
HCM	Hand Control Module	RCC	Reinforced Carbon-Carbon
HST	Hubble Space Telescope	S&MA	Safety and Mission Assurance
ISS	International Space Station	SAFER	Simplified Aid for EVA Rescue
IUS	Inertial Upper Stage	SAIC	Science Applications International Corporation
IVA	Intravehicular Activity	STS	Space Transportation System
JSC	Johnson Space Center	ULF	Utilization Logistics Flight
LEM	Lunar Excursion Module	U.S.	United States
LRV	Lunar Roving Vehicle		
MMU	Manned Maneuvering Unit		

This quick-reference sheet is a product of the JSC S&MA Flight Safety Office (FSO). Our reports assemble and clarify the best-available data from multiple sources to help S&MA decision makers develop a fully informed and integrated perspective of key factors involved in the risk-based decision process. For further information, please contact:

Nigel Packham, Ph.D., NASA

Manager, Flight Safety Office

JSC Safety & Mission Assurance Directorate

Nigel.Packham-1@nasa.gov

Bill Stockton, SAIC

Task Order Lead, FSO Team

Science Applications International Corp.

William.P.Stockton@nasa.gov

