

Significant Incidents in Extravehicular Activity

Jonathan B. Clark M.D., M.P.H.
jbclarkmd@outlook.com

Sawan Dalal

Foundation for Aerospace Safety and Training
Houston TX

U.S. SKC Program Spacesuit Medical Series

Objectives

Gain familiarity with
EVA incidents and
injuries

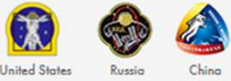
Cover selected cases of
EVA Terminations,
Incidents, and Injuries



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Significant Incidents & Close Calls in Human Spaceflight: EVA Operations

INADVERTANT RELEASES EVA HOURS SUIT GUIDE ACRONYMS THE TEAM FSO TOOLS ABOUT HELP



	#	%
Loss of Crew	0	0
+ Crew Injury	15	4
⊘ Early Termination	14	3
⚠ System Issue	57	13
📄 Operational Issue	43	10

429 total spacewalks through 1/25/2020.
94 (22%) experienced significant incidents and/or close calls.

All hours represent EVA hours, not crew member hours.

Voskhod 2 3/18/1965	⚠
Gemini 4 6/3/1965	⚠
Gemini 9 6/5/1966	+ ⚠
Gemini 10, EVA 1 7/19/1966	+ ⊘ ⚠
Gemini 10, EVA 2 7/20/1966	📄 ⚠
Gemini 11, EVA 1 9/13/1966	⊘ 📄 ⚠
Apollo 11, EVA 1 7/20/1969	⚠
Apollo 12, EVA 2 11/2/1969	⚠

1960s

25 hours = 24 U.S. + 1 Russia
18 EVAs = 16 U.S. + 2 Russia

Apollo 15, EVA 2 7/31/1971	⚠
Apollo 15, EVA 3 8/1/1971	📄 ⚠
Apollo 16, EVA 1 4/21/1972	📄 ⚠
Apollo 16, EVA 2 4/22/1972	⚠
Apollo 16, EVA 3 4/23/1972	⚠
Apollo 17, EVA 1 12/11/1972	+ 📄 ⚠
Skylab 2, EVA 2 6/7/1973	⚠
Skylab 3, EVA 3 9/22/1973	⚠
Skylab 4, EVA 1 11/22/1973	📄
Skylab 4, EVA 2 12/25/1973	⚠
Skylab 4, EVA 3 12/29/1973	⚠
Skylab 4, EVA 4 2/3/1974	⚠
Salyut 6 PE-1, EVA 1 12/20/1977	📄
Salyut 6 PE-3, EVA 1 8/15/1979	⚠

1970s

121 hours = 116 U.S. + 5 Russia
32 EVAs = 29 U.S. + 3 Russia

Salyut 7 PE-1, EVA 1 7/30/1982	+ 📄
STS-41B, EVA 1 2/7/1984	⚠
STS-41C, EVA 1 4/8/1984	⚠
STS-41C, EVA 2 4/11/1984	📄 ⚠
Salyut 7 PE-3, EVA 6 8/8/1984	+ ⚠
STS-51 D 4/16/1985	📄
STS-51 I, EVA 2 9/1/1985	📄
Mir, PE-2, EVA 1 4/11/1987	📄

1980s

145 hours = 69 U.S. + 77 Russia
33 EVAs = 13 U.S. + 20 Russia

Mir, PE-6, EVA 1 7/17/1990	📄
Mir, PE-8, EVA 3 1/26/1991	📄
STS-37, EVA 1 4/7/1991	+ 📄 ⚠
STS-37, EVA 2 4/8/1991	📄
Mir, PE-9, EVA 6 7/27/1991	+ 📄 ⚠
Mir, PE-10, EVA 1 12/20/1992	📄 ⚠
Mir, PE-13, EVA 1 4/19/1993	⚠
STS-57, EVA 1 6/25/1993	📄 ⚠
Mir, PE-14, EVA 3 9/28/1993	⊘
Mir, PE-14, EVA 4 10/22/1993	⊘ ⚠
STS-61, EVA 2 12/5/1993	⚠
STS-63, EVA 2 2/9/1995	+ ⊘ ⚠
STS-80, EVA 1 11/29/1996	⊘ ⚠
STS-86, EVA 1 10/1/1997	⚠
STS-88, EVA 1 12/7/1998	📄
STS-96/2A.1 5/27-6/6/1999	⚠

1990s

557 hours = 231 U.S. + 326 Russia
107 EVAs = 35 U.S. + 71 Russia

STS-97/4A, EVA 1 12/3/2000	+ ⚠
STS-98/5A, EVA 1 2/10/2001	📄
STS-98, EVA 2 2/12/2001	+ ⚠
STS-100/6A, EVA 2 4/22/2001	+ ⚠
STS-100/6A, EVA 3 4/24/2001	+ ⚠
ISS Exp-P U.S. EVA Ops 5/19/2004	⚠
RS EVA 9A 6/24/2004	⊘ 📄
RS EVA 10 8/3/2004	📄
RS EVA 13 3/28/2005	⚠
STS-121/ULF1, EVA 2 7/10/2006	📄
STS-116/12A, EVA 1 12/12/2006	📄
STS-118/13A.1, EVA 3 8/15/2007	⊘ 📄
STS-120/10A, EVA 3 10/30/2007	⚠
RS EVA 20A 7/10/2008	📄
STS-126/ULF2, EVA 2 11/20/2009	⊘ 📄
STS-126/ULF2, EVA 4 11/24/2009	⊘ 📄
RS EVA 21A 3/10/2009	📄
STS-125HST, EVA 4 5/17/2009	⊘ 📄
STS-127/21A, EVA 3 7/22/2009	⊘ 📄
STS-128/17A, EVA 3 9/5/2009	📄

2000s

900 hours = 755 U.S. + 144 Russia + 1 China
144 EVAs = 113 U.S. + 30 Russia

STS-130/20A, EVA 1 2/1/2010	⚠
STS-130/20A, EVA 2 2/14/2010	📄 ⚠
STS-130/20A, EVA 3 2/17/2010	⚠
U.S. EVA 15 8/7/2010	📄 ⚠
U.S. EVA 16 8/11/2010	📄 ⚠
STS-134/ULF6, EVA 1 5/20/2011	⚠
STS-134/ULF6, EVA 3 5/25/2011	+ ⚠
U.S. EVA 18 8/30/2012	⚠
U.S. EVA 22 7/9/2013	⚠
U.S. EVA 23 7/16/2013	⊘ ⚠
U.S. EVA 24 12/21/2013	📄
U.S. EVA 25 12/24/2013	📄 ⚠
U.S. EVA 32 10/28/2015	📄
U.S. EVA 35 1/15/2016	⊘ ⚠
U.S. EVA 38 1/6/2017	📄
U.S. EVA 41 3/30/2017	⚠
U.S. EVA 42 5/12/2017	⚠
U.S. EVA 46 10/20/2017	⚠
U.S. EVA 53 3/29/2019	📄

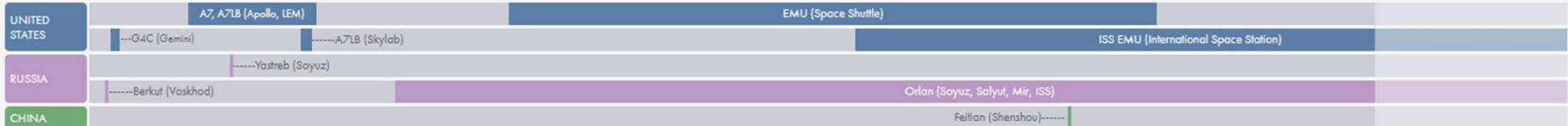
2010s

558 hours = 400 U.S. + 158 Russia
88 EVAs = 63 U.S. + 25 Russia

U.S. EVA 62 1/15/2020	📄
U.S. EVA 62 1/15/2020	+ ⚠
U.S. EVA 63 1/20/2020	+ ⚠
U.S. EVA 64 1/25/2020	📄

2020s

44 hours = 44 U.S.
7 EVAs = 7 U.S.



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<https://sma.nasa.gov/SignificantIncidentsEVA2018/>

NASA Official: [Gail Skowron](#) Infographic Editor: [Faisal Ali](#) Technical Questions? [Click here](#)

Significant Incidents during Extravehicular Activity (1965-2019)

429 total EVAs/ spacewalks through 1/25/2020

2350 EVA hours (1639 US, 711 Russian) - EVA hours, not crewmember hours

94 (22%) experienced significant incidents and/or close calls

15 EVAs resulted in crew injury

14 EVAs terminated early

System Issue – 57

Operational Issue – 43

Inadvertent Releases of Items – 67 (tools, cameras, covers)

Gemini-2, Salyut/Mir-2, Shuttle-7, Shuttle ISS Assembly- 28, ISS-28

Source: Significant Incidents & Close Calls in Human Spaceflight: EVA Operations



BRCA



Significant Incidents during Extravehicular Activity (1965-2019)

15 EVAs resulted in crew injury (1 with both eye and musculoskeletal)

Eye irritation – 9 (visor antifog solution, LiOH)

Musculoskeletal – 6 (contusion, pain, numbness)

Thermal – 2

14 EVAs terminations (none during Apollo program)

2 terminated for cut gloves

3 for high CO₂

2 for inadequate thermal control

6 for EVA systems failures

1 vehicle system failure (airlock)

Handrail Hit from Debris, cut EVA glove



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Extravehicular Activity Terminations

- GT10 EVA 1 (1966) LiOH leak with eye irritation**
- GT11 EVA 1 (1966) excess workload, overheating, visor fogging**
- Mir PE14 EVA 3 (1993) Orlan DMA suit cooling system failure**
- Mir PE14 EVA 4 (1993) Orlan DMA O2 flow issue**
- STS 63 EVA 2 (1995) crew excessively cold, eye irritation**
- STS 80 EVA1 (1996) airlock hatch jammed**
- ISS RS EVA 9A (2004) premature O2 depletion due to switch configuration**
- STS 118/13A.1 EVA 3 (2007) cut glove during EVA**
- STS 126/ULF2 EVA 2 (2008) high CO2 during EVA**
- STS 126/ULF2 EVA 4 (2008) high CO2 at end of EVA**
- STS 125 HST EVA 4 (2009) EVA glove palm bar tear**
- STS 127/ 2JA EVA 3 (2009) high met rate resulting in high CO2**
- ISS US EVA23 (2013) water in helmet**
- ISS US EVA35 (2016) water in helmet**

Gemini EVA Issues

Gemini 9: suit damage, skin burns

Gemini 10 EVA 1: **EVA terminated** for eye irritation from lithium hydroxide exposure affecting both crew

Gemini 11 EVA 1: **EVA terminated** for excess workload, overheating and visor fogging

Sources:

Significant Incidents & Close Calls in Human Spaceflight: EVA Operations
Walking to Olympus: An EVA Chronology (Portree and Treviño 1997)

Apollo EVA Issues

No Apollo EVAs were terminated early but falls occurred with minor injuries, workload often was at crew limit, dust was a major problem

Apollo 15 EVA 2: drink bag failed, fingernail pain from glove fit, dust covered EMU difficult to fit PLSS connectors

Apollo 16 EVA 1: slip and fall, trip over cable, dust in everything

*Apollo 17 EVA 1: contusions from extracting stuck core sample, showered by dust while driving, “hayfever attack” post doffing

Sources:

Significant Incidents & Close Calls in Human Spaceflight: EVA Operations

Walking to Olympus: An EVA Chronology (Portree and Treviño 1997)

Apollo 16 EVA 1

Crewmembers: John Young, Charlie Duke

Young tripped over a heat flow cable

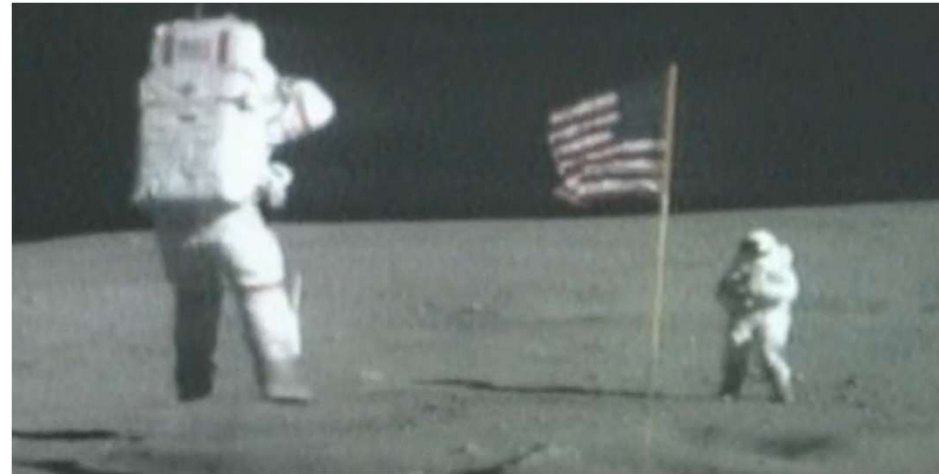
Young jumped and saluted the US Flag

Duke grew 1.5 inches in height, had difficulty with ingress suit

Duke jumped up 4 feet, but due to high center of gravity he landed hard on his PLSS

No injuries but Suit/ PLSS not tested for impact loads

Dust problems post EVA



Sources:

Significant Incidents & Close Calls in Human Spaceflight: EVA Operations
Walking to Olympus: An EVA Chronology (Portree and Treviño 1997)
NASA Apollo 16 EVA 1: <https://youtu.be/CgUC3a8AA3w> (8:35)

Apollo 17 EVA 1

Crewmembers: Eugene Cernan, Harrison Schmitt

Lunar core sample drilling

Cernan: high workload and O2 consumption,
bruised arms and burst fingernail vessels

Schmitt: fell while drilling, dust exposure doffing
spacesuit resulted in reactive airway attack in LM

Crew covered in dust when Lunar Rover fender
broke off

Sources:

Significant Incidents & Close Calls in Human Spaceflight: EVA
Operations

Walking to Olympus: An EVA Chronology (Portree and Treviño 1997)

NASA Apollo 17 EVA 1 <https://youtu.be/4w2nvzgRrBs> (1:45:40)





“Dust represents the single largest technical challenge to prolonged human presence on the Moon.”

*Harrison Schmidt
Apollo 17 Astronaut
March 2005*

“... one of the most aggravating, restricting facets of Lunar surface exploration is the dust and its adherence to everything no matter what kind of material, whether it be skin, suit material, metal, no matter what it be and its restrictive friction-like action to everything it gets on.”



*Gene Cernan
Commander, Apollo 17
December, 1972*

Salyut/ Mir EVA Issues

Salyut 7 PE-1 EVA 1: numb hand from tool use

Salyut 7 PE-3 EVA 6: injured hands, cooling pump failure

Mir, PE-9 EVA 6: helmet fogging, bruising of hand, elbow, and shoulder from Mir assembly

Mir PE-14 EVA 3: cooling system failure, **EVA terminated**

Mir PE-14 EVA 4: O2 flow system issue, **EVA terminated**

Sources:

Significant Incidents & Close Calls in Human Spaceflight: EVA Operations

Walking to Olympus: An EVA Chronology (Portree and Treviño 1997)

Early Shuttle EVAs

STS-41C, EVA 2: urine containment failure, helmet fogging

STS-37 EVA 1: palm bar punctured glove with minor contusion, eye irritation

STS-63 EVA 2: “unacceptably cold”, eye irritation, **EVA terminated**

Sources:

Significant Incidents & Close Calls in Human Spaceflight: EVA Operations

Walking to Olympus: An EVA Chronology (Portree and Treviño 1997, Ta and Treviño 2016)

STS-63 EVA 2

Crewmembers: Michael Foale, Bernard Harris

Purpose: 1st EVA Developmental Flight Test to evaluate enhanced EMU thermal capability in cold

What happened:

- Shuttle payload in shadow 15 minute cold soak

- Payload mass handling evaluated

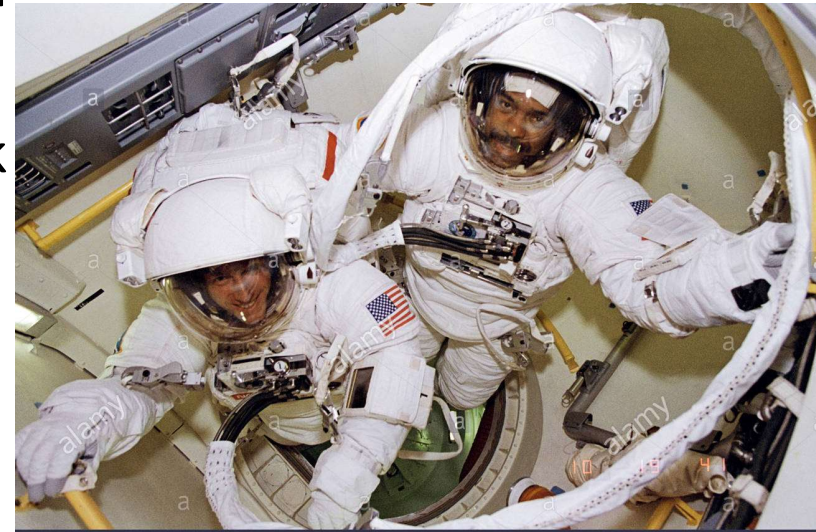
- EMU/gloves with thermal modifications + temp sensors

- Foale: glove temp -6 degrees C

- Harris: feet cold in contact with Shuttle (surface temp -148 degrees C)

- Cold rated at 3/8 “unacceptably cold”

- Eye irritation post helmet doffing



Shuttle and ISS Assembly EVAs

STS-97/4A EVA 1: eye irritation from anti-fog

STS-98 EVA 1: ammonia exposure during coolant line disconnect

STS-98 EVA 2: boot fit too tight, severe foot pain

STS-100/6A EVA 2 and 3: eye irritation from leaking drink bag + anti-fog

ISS RS EVA 9A: O2 tank depletion due to wrong switch position, **EVA terminated**

STS-118/13A EVA 3: cut glove noticed, **EVA terminated**, cause unknown

STS-126/ULF2 **EVA 2 and 4**: high CO2 levels, **EVA terminated**

STS-125 HST EVA 4: tear in glove noticed, **EVA terminated**

STS-127/2JA EVA 3: high CO2 levels due to high metabolic rate, **EVA terminated**

Sources:

Significant Incidents & Close Calls in Human Spaceflight: EVA Operations

Walking to Olympus: An EVA Chronology (Ta and Treviño 2016)

STS 98 EVA 1

Crewmembers: Thomas Jones, Robert Curbeam

Purpose: connect Destiny to ISS power/cooling lines

Ammonia exposure with crystals on suit

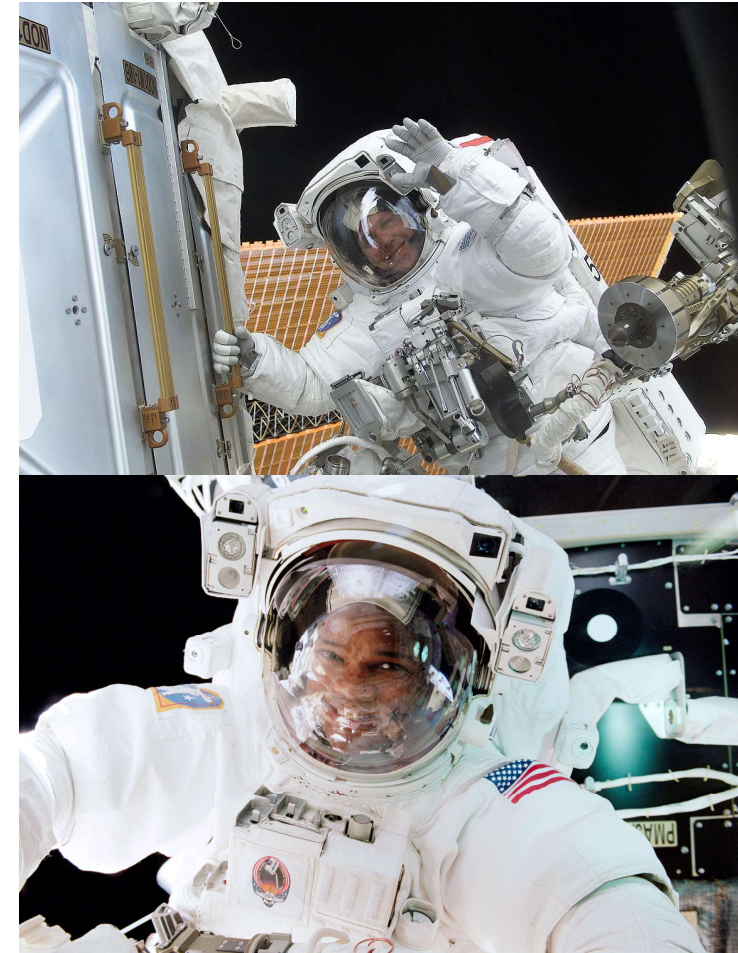
Decontamination via “Bakeout” hanging out in sunlight allowing crystals to vaporize

Risk/Injury:

- Inhalation in confined environment

- Rhinorrhea, scratchy throat, chest tightness, cough, dyspnea, and eye irritation.

- Self-limited though concentrated exposure can result in severe resp distress and full thickness burns



Source: Padappayil RP, Borger J. Ammonia Toxicity. [Updated 2021 Feb 6]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan-.



Later Shuttle ISS Assembly and ISS EVAs

STS-130/20A EVA 1 and 3: water noticed in helmet and boots

STS-130/20A EVA 2, US EVA 15 & 16: exposure to ammonia from disconnect spray, “bakeout required”

STS 134/ULF6 EVA 3: eye irritation from anti-fog

U.S. EVA 22: water in EMU helmet, no termination, precursor to EVA 23

*U.S. EVA 23: significant water in helmet, **EVA terminated**

U.S. EVA 35: water in helmet, **EVA terminated**

U.S. EVA 42: 1 Service & Cooling Umbilical failed, very high temps during depress

2020: US EVA 62 and 63: eye irritation

Sources:

Significant Incidents & Close Calls in Human Spaceflight: EVA Operations
Walking to Olympus: An EVA Chronology (Ta and Treviño 2016)

EVA 23: “The Most Dangerous EVA in US History”

Crewmembers: Luca Parmitano and Chris Cassidy

Timeline

- 44 min into EVA water reported on back of head
- Unable to find source, continued working
- Water migrated from back of head onto face
- Impaired visibility and difficulty breathing
- Communication issues
- Relied on manual feel of tether to return to airlock

Risks:

- Asphyxiation/ drowning, impaired vision, communication failure



Figure 5. Extravehicular Mobility Unit (EMU) With Water in Helmet During Post-EVA 23 Screening Test



Figure 3. ISS Crew Members removing Luca Parmitano's helmet after EVA 23



Figure 2. Drink bag used inside EMU during spacewalks

Source: MISHAP INVESTIGATION BOARD SUMMARY OF EXTRAVEHICULAR ACTIVITY 23: LESSONS LEARNED FROM A SPACEWALK CLOSE CALL (Hansen & Cassidy 2014)

EVA 23: Response

ISS EVA 23 Suit Water Intrusion High Visibility Close Call Mishap Investigation Board

Root Cause Analysis determined main causes of mishap:

- 1) Inorganic materials causing blockage of drum holes in EMU water fan pump separator -> water spilling in ventilation loop
 - JSC Building 7 cooling loop ion filter bed processing shortcoming -> contaminants in filters before EMU sent to ISS
- 2) NASA team lack of knowledge regarding this failure mode
- 3) Misdiagnosis of suit failure when it occurred on EVA 22

Action plan: addressed all of above with reports/new standards

Sources:

ISS EVA Suit Water Intrusion High Visibility Close Call Report (Hansen 2013)

MISHAP INVESTIGATION BOARD SUMMARY OF EXTRAVEHICULAR ACTIVITY 23: LESSONS LEARNED FROM A SPACEWALK CLOSE CALL (Hansen & Cassidy 2014)

Failure Analysis Results and Corrective Actions Implemented for the Extravehicular Mobility Unit 3011 Water in the Helmet Mishap (Steele 2015)

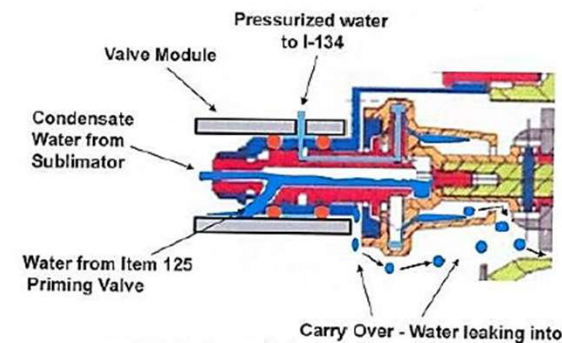


Figure 3-18. Water Separator Spinning Drum and Pitot Components



Figure 3. Blocked water separator drum holes.

EVA Incident Summary

The interaction between human, vehicle and spacesuit systems, mission objectives, and the space environment can have health consequences and affect mission success

Crew health concerns:

Thermal Issues - Heat exposure/ skin burn, cold exposure (↓performance)

Toxic exposure (lithium hydroxide, ammonia)

Eye irritation with temporary blindness (drink bag droplet + visor antifog)

Lunar dust exposure with temporary reactive airway and suit joint issues

Spacesuit activity associated musculoskeletal pain and minor trauma

System failures with EVA termination (ECLSS sensor, O2 tank depletion)

Workload exceeding ECLSS capability (visor fogging, overheating, ↑CO2)

References

- Significant Incidents & Close Calls in Human Spaceflight: EVA Operations (Johnson et. al 2020)
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- NASA Apollo 17 EVA 1 <https://youtu.be/4w2nvzgRrBs> (1:45:40)
- NASA Evidence Report: RISK OF INJURY AND COMPROMISED PERFORMANCE DUE TO EVA OPERATIONS (Chappell et. al 2017)
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- Padappayil RP, Borger J. Ammonia Toxicity. [Updated 2021 Feb 6]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK546677/>
- ISS EVA 23 Suit Water Intrusion High Visibility Close Call Report (Hansen 2013)
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