National Aeronautics and Space Administration

ISS EVA 23 Lessons Learned

Date of Mishap: July 16, 2013

Chris Hansen, Chairman – Mishap Investigation Board

Manager, EVA Office, Johnson Space Center

NASA Johnson Space Center, September 26th, 2019

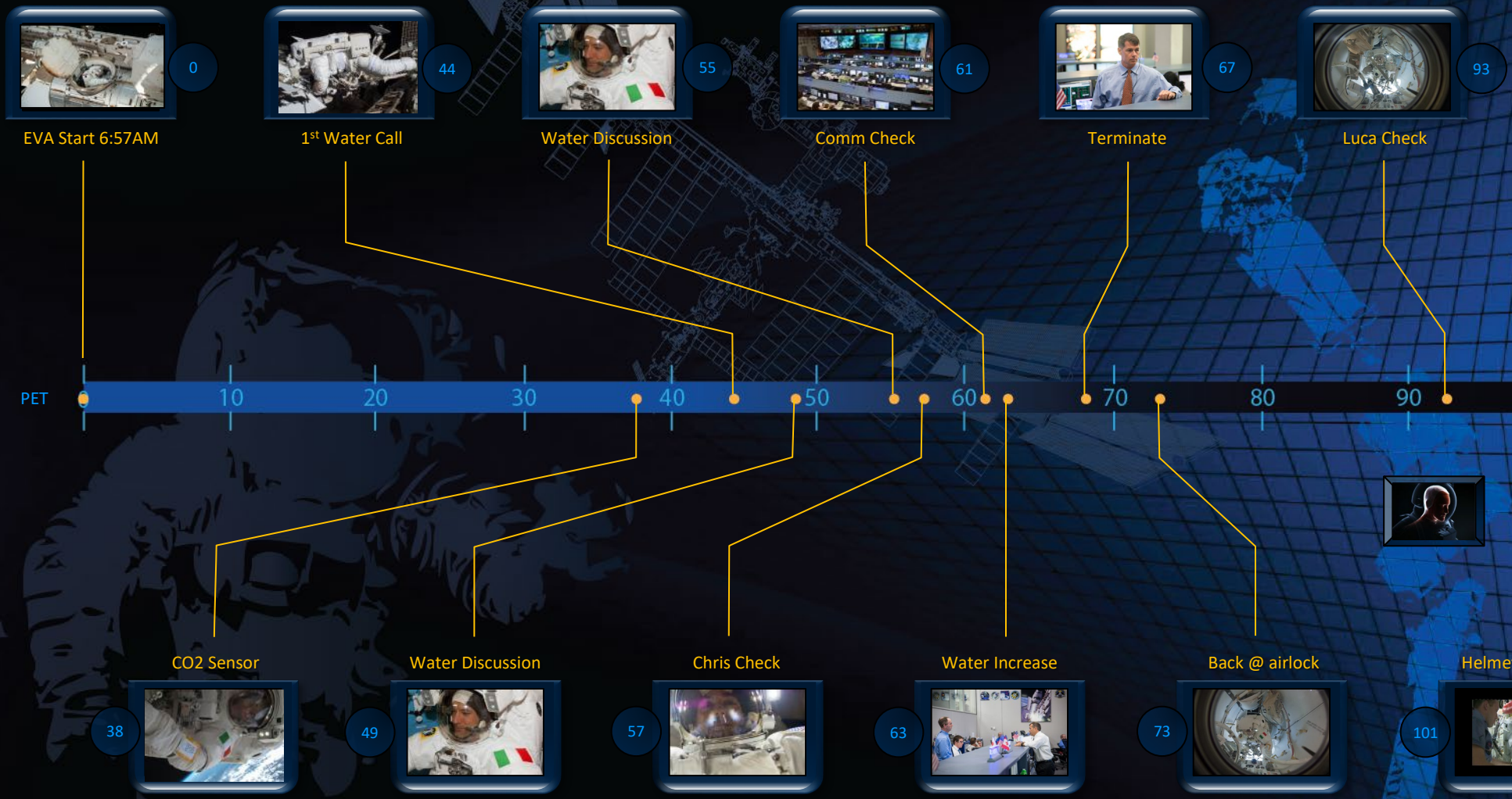
Today's Discussion

- **Chris Hansen**
  - Description of EVA 23 close call, what happened? (EVA 23 Movie)
  - EVA 22, what did we miss?
  - Key findings from mishap investigation, what can we learn?
  - EVA Recovery Team
  - Summary of the hardware investigation findings, why did the suit fail?
  - Lessons learned
- Conclusions

Mishap Summary

- DATE: July 16, 2013
- TIME: 1241 GMT (0741 CDT)
- LOCATION: Outside ISS, on orbit during US EVA 23
- BRIEF DESCRIPTION:
  - Roughly 44 minutes into EVA 23, ESA Astronaut Luca Parmitano reported water inside his helmet on the back of his head. The EVA ground team, Luca and his spacewalking partner Chris Cassidy were unable to identify the water's source. As they continued to work, the amount of water in Luca's helmet increased and eventually migrated from the back of his head onto his face. EVA 23 was terminated early and the crew safely returned to the Space Station. What started as a normal EVA day on ISS became one of the most serious mishaps in the history of Spacewalking.

Timeline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EVA Start 6:57AM
44
1st Water Call
55
Water Discussion
61
Comm Check
67
Terminate
93
Luca Check
PET
10
20
30
40
50
60
70
80
90
100
CO2 Sensor
38
Water Discussion
49
Chris Check
57
Water Increase
63
Back @ airlock
73
Helmet Removal
101

Post EVA 23

- Ground teams were unaware of the serious danger Luca was in during the spacewalk until a crew debriefing that took place several hours later where he described his harrowing experience
- It was later learned that during Luca's return to the airlock, water in his comm system was causing intermittent failures, preventing him from communicating with the ground teams or his partner
- Almost 1.4 liters of water was determined to have entered Lucas's helmet by the end of the EVA 23
- Luca's calm reaction to a very dangerous situation possibly saved his life
- The suit failure that occurred on EVA 23 was a shock to the Spacewalking team, but could it have been prevented?

EVA 22 – one week earlier…

- EVA 22, Luca's first EVA, began with Chris and Luca one week earlier on July 9th, 2014
- The EVA was completed with no issues, however, during repress Luca noticed water in his helmet
- When his helmet was removed, almost ½ liter of water was discovered
- Subsequent conversations led to an assumption that water had leaked from Luca's drink bag during his time in the airlock, so the drink bag was replaced prior to EVA 23
- Later investigation determined that the drink bag was not the source of the water in Luca's helmet, but other possible failures were not investigated, and EVA 23 proceeded on time one week later

Summary of Findings

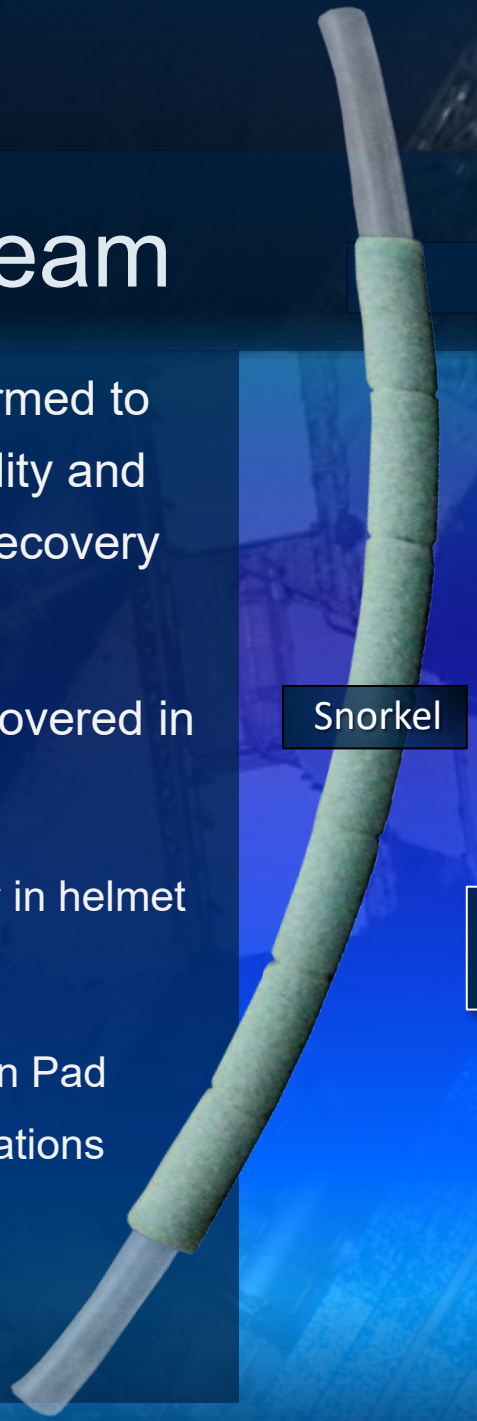
- The causes for this mishap evolved from:
  - Inorganic materials causing blockage of the drum holes in the suit water separator resulting in water spilling into the vent loop
  - The NASA team's lack of knowledge regarding this particular failure mode
  - Misdiagnosis of this suit failure when it initially occurred on EVA 22

Root Causes Of Real-time Mishap

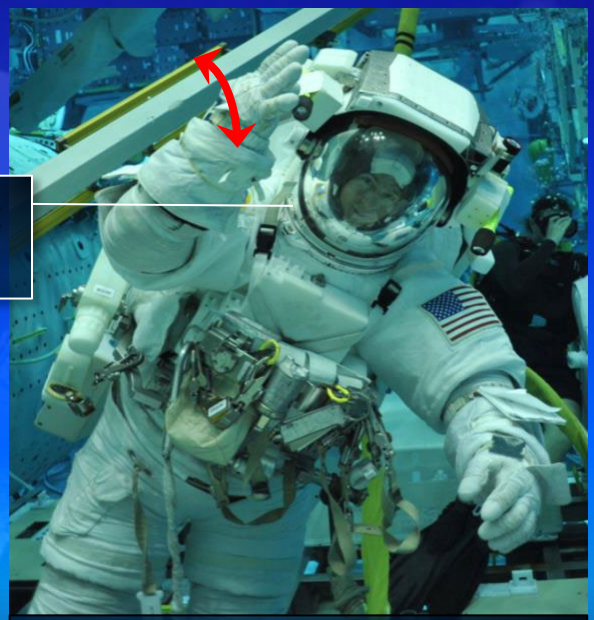
- The root causes of the mishap were:
  - Program emphasis was to maximize crew time on orbit for utilization
  - ISS Community perception was that drink bags leak
  - Flight Control Team's perception of the anomaly report process as being resource intensive made them reluctant to invoke it
  - No one applied knowledge of the physics of water behavior in zero-g to water coming from the PLSS vent loop
  - The occurrence of minor amounts of water in the helmet was normalized

EVA Recovery Team

- EVA Recovery Team initially formed to regain contingency EVA capability and later focused on planned EVA recovery and root cause determination
- Contingency EVA capability recovered in September 2014
  - Operational response to water in helmet developed
  - Snorkel and Helmet Absorption Pad (HAP) developed as risk mitigations



Helmet Absorption Pad



Loss of Comm Signals

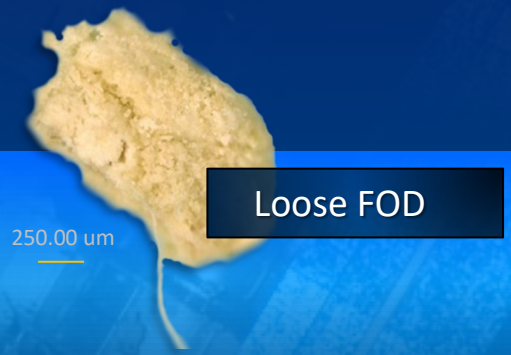
Summary of Investigation Findings

- Numerous suit components were replaced and tests were performed to determine anomaly was in the suit's fan pump water separator (FPS)
- Silica-based contamination in the water separator blocked holes resulting in water back-flowing into the ventilation loop
  - Silica quantity and precipitation in the water separator never seen before
  - Water separator is basically a centrifuge which facilitates precipitation of contaminants

Drum Hole Contam

FPS Removed; FOD in Bore

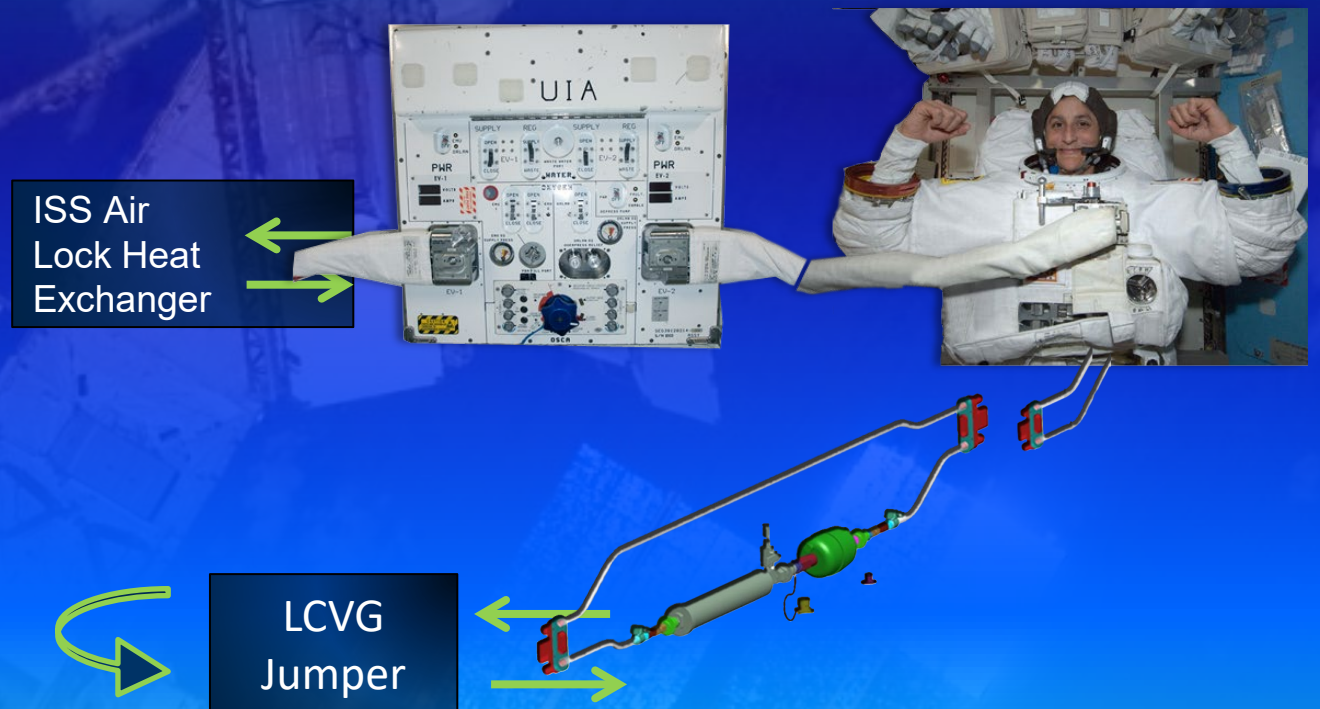
Water Separator Drum



Loose FOD

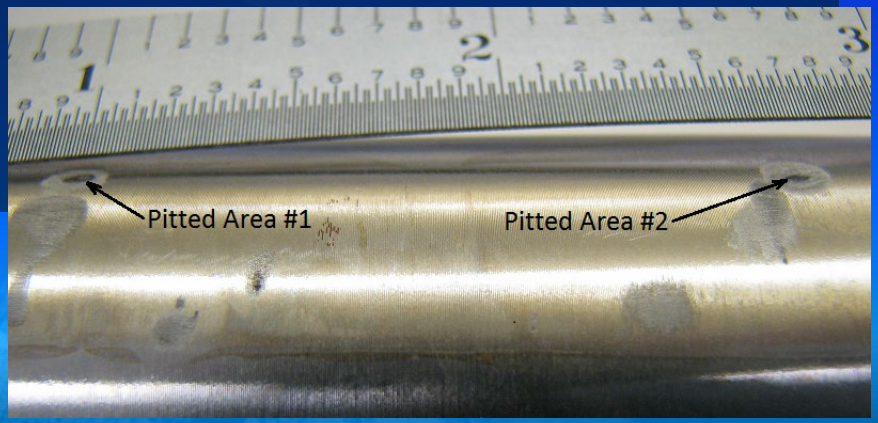
Silica Source

- Ion exchange beds found to be source of silica
  - Suit coolant loop is “scrubbed” with an ion exchange bed every 90 days and before/after a series of EVAs
  - Removes contaminants like nickel that shed from the suit and Airlock heat exchanger



Ion Bed Contamination

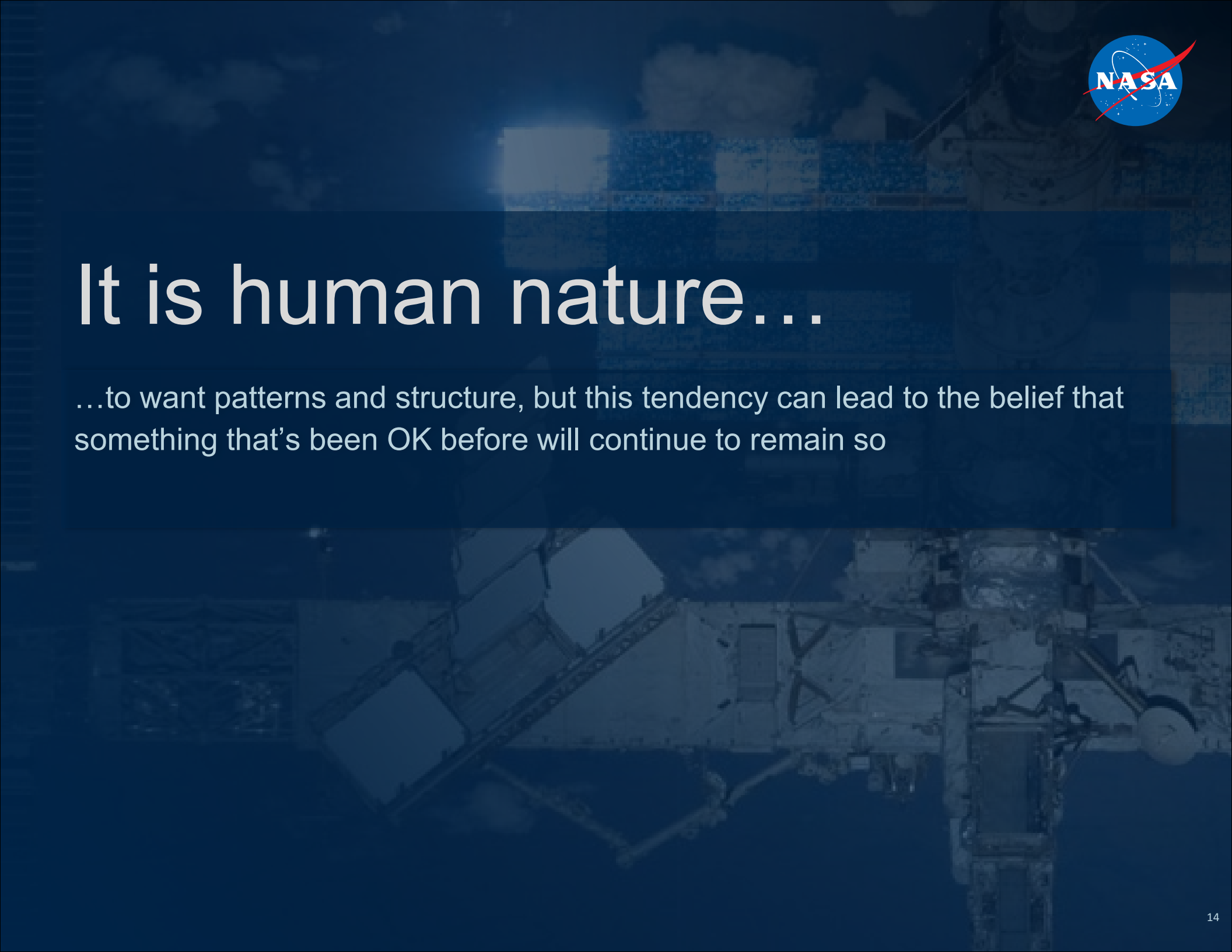
- Premature saturation of Ion Beds and subsequent use with Luca's suit resulted in release of high concentration of silica into water loop
  - Ion bed saturation resulted from insufficient quality of water used during ground processing
  - Multiple ion beds used on-orbit were later found to have been contaminated
    - » Anomalous water condition likely spanned 8+ years
  - Lot of ion beds built in December 2013 corroded due to water contamination



Suit Design History

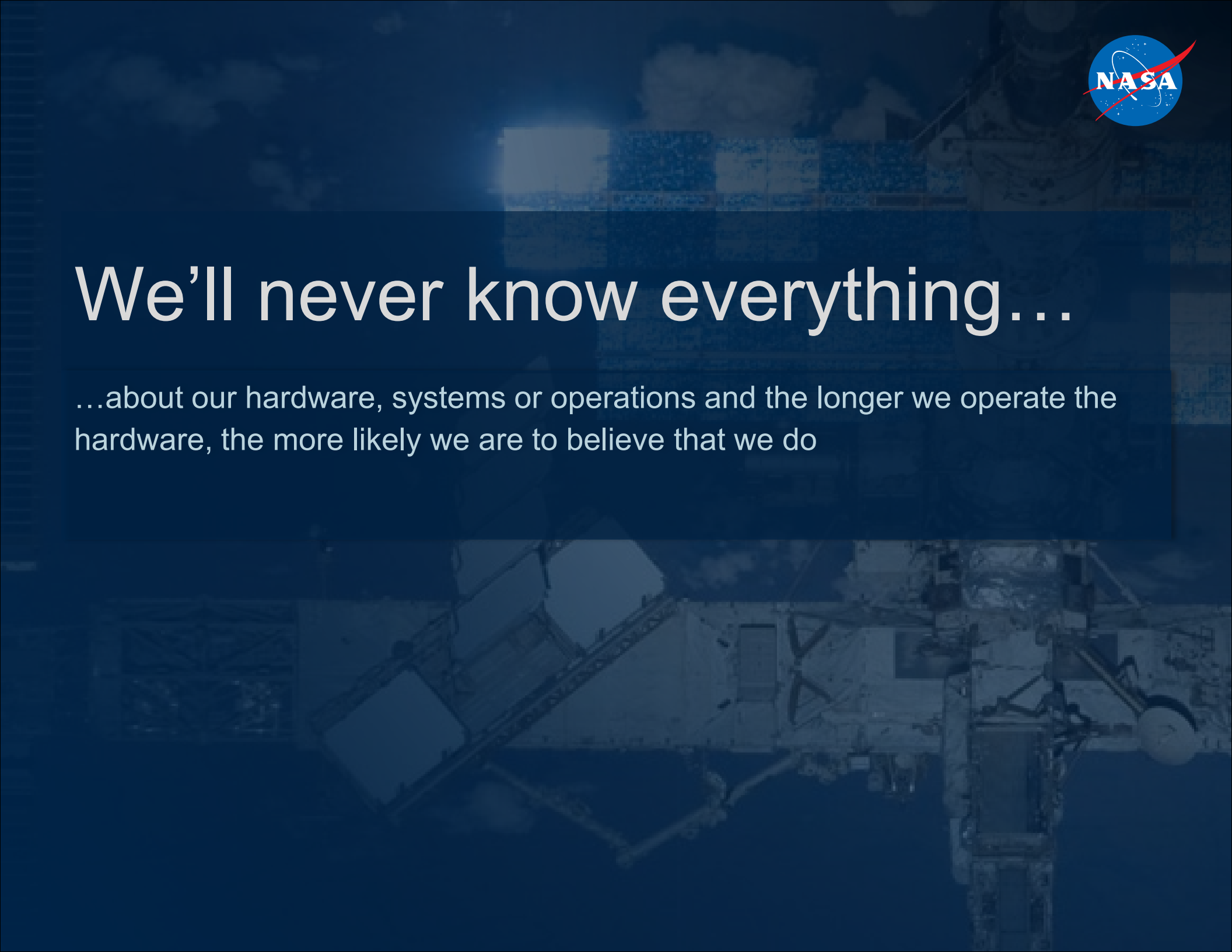
1982	1995	2000	2003	2007	2008
Suit certified for a **single** Shuttle mission	Certified for **25 EVAs** over 180 day period to support ISS assembly	Certification extended to **1** year	Certification extended to **2** years	Certification extended to **3** years	Certification extended to **6** years with in-flight maintenance and additional ground "Mega" processing

Likelihood of encountering contamination in water lines was significantly lower during Shuttle era



It is human nature…

…to want patterns and structure, but this tendency can lead to the belief that something that's been OK before will continue to remain so

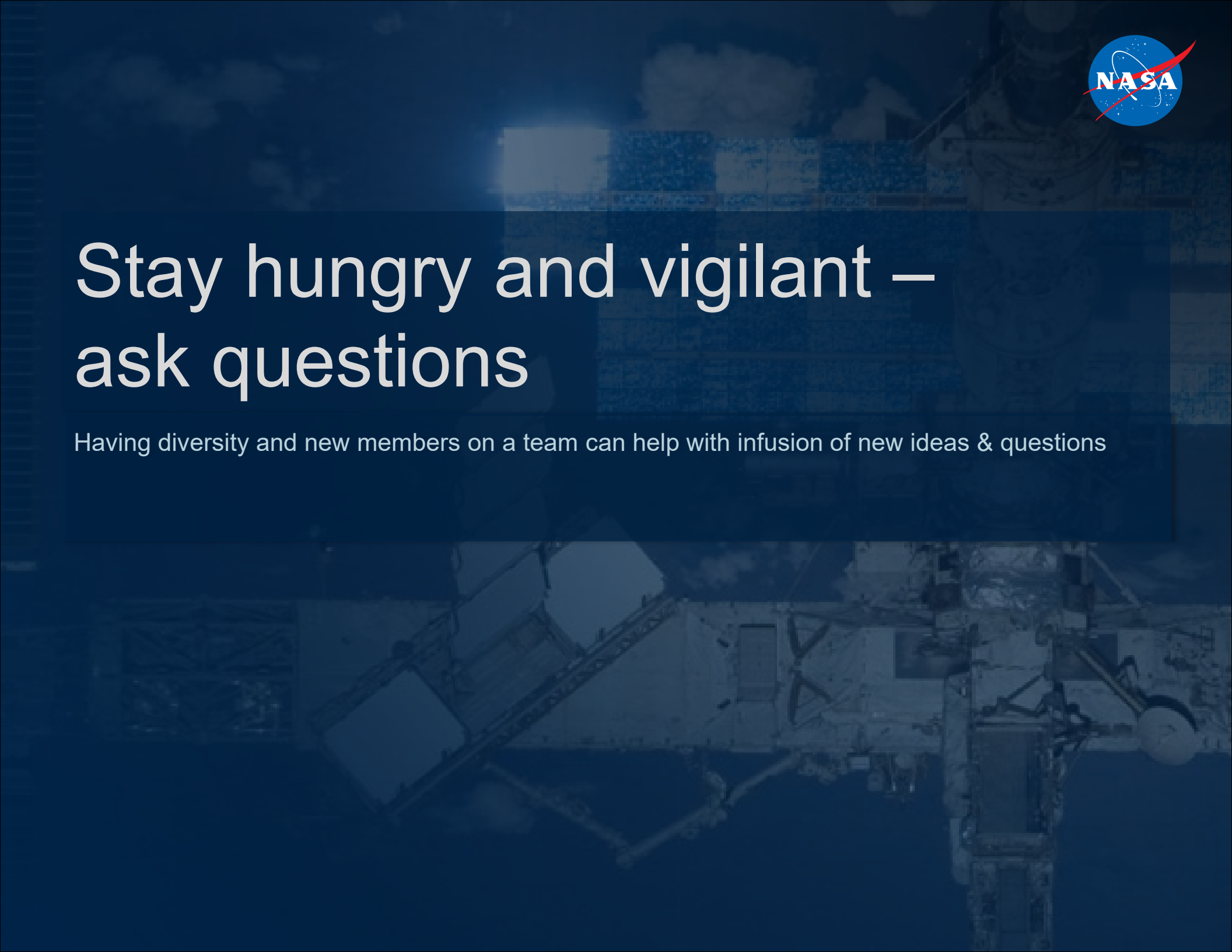


We'll never know everything…

…about our hardware, systems or operations and the longer we operate the hardware, the more likely we are to believe that we do

Don’t assume

Don’t assume something is safe because we’ve done it before



Stay hungry and vigilant – ask questions

Having diversity and new members on a team can help with infusion of new ideas & questions

Gaps in data and theories present risk

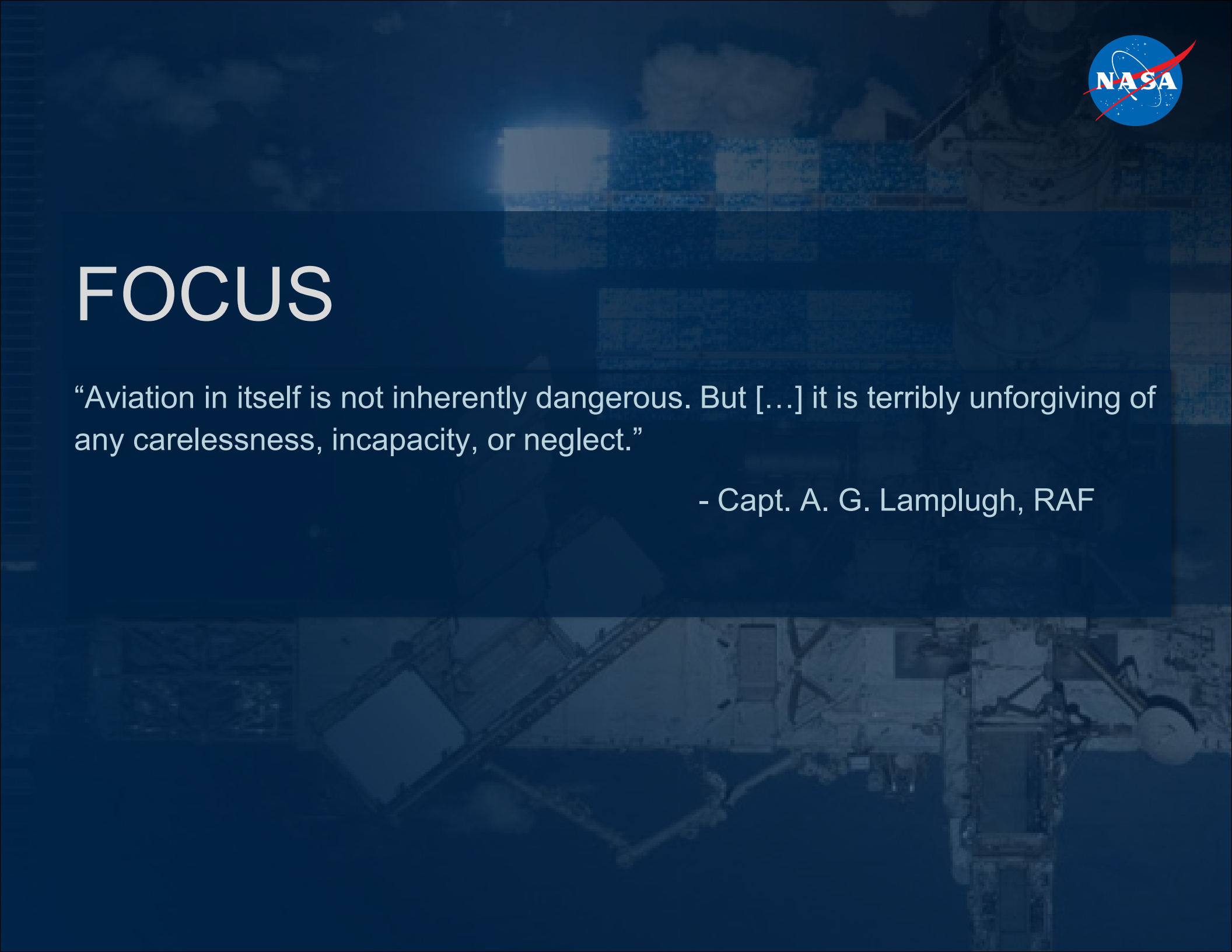
- If you don’t have the full data set, understand where gaps exist and what risks this presents
- Be aware of what you know as fact versus what you’re assuming or inferring

Anyone in *any* organization

…(engineering, safety, ops, program, etc) could have had a considerable impact in preventing the EVA 23 mishap

It can happen to you

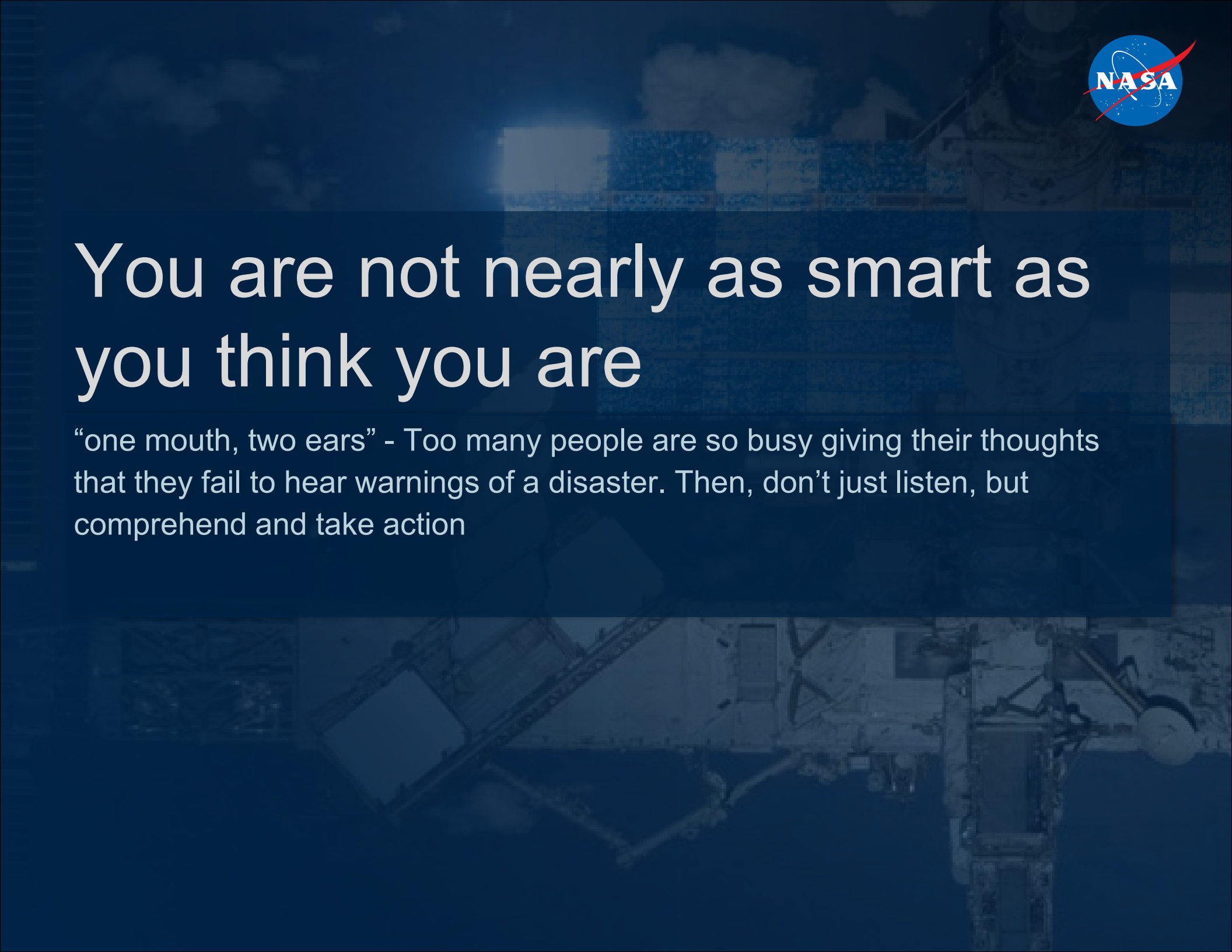
Nobody is smart enough to avoid all problems. A preoccupation with failure results in high reliability organizations



FOCUS

“Aviation in itself is not inherently dangerous. But […] it is terribly unforgiving of any carelessness, incapacity, or neglect.”

- Capt. A. G. Lamplugh, RAF



You are not nearly as smart as you think you are

“one mouth, two ears” - Too many people are so busy giving their thoughts that they fail to hear warnings of a disaster. Then, don’t just listen, but comprehend and take action

Question conventional wisdom

“People in groups tend to agree on courses of action which, as individuals, they know are stupid.”

- Dr. David Aiken

Use your imagination

Apollo 1 was referred to by Frank Borman as a failure of imagination. They couldn’t imagine a ground test could be hazardous. Keep vigilant and have an active imagination of possible hazards.

Conclusion

- NASA considered this close call an extremely serious wake up call and took action
- As individuals, we must also take action to prevent future, similar mishaps
- ISS has a long successful history, similar to the suit Program's history
- We can't let our Programs successes lull us into assuming we have all the answers for the future

A full copy of the public report can be downloaded at:
http://www.nasa.gov/sites/default/files/files/Suit_Water_Intrusion_Mishap_Investigation_Report.pdf

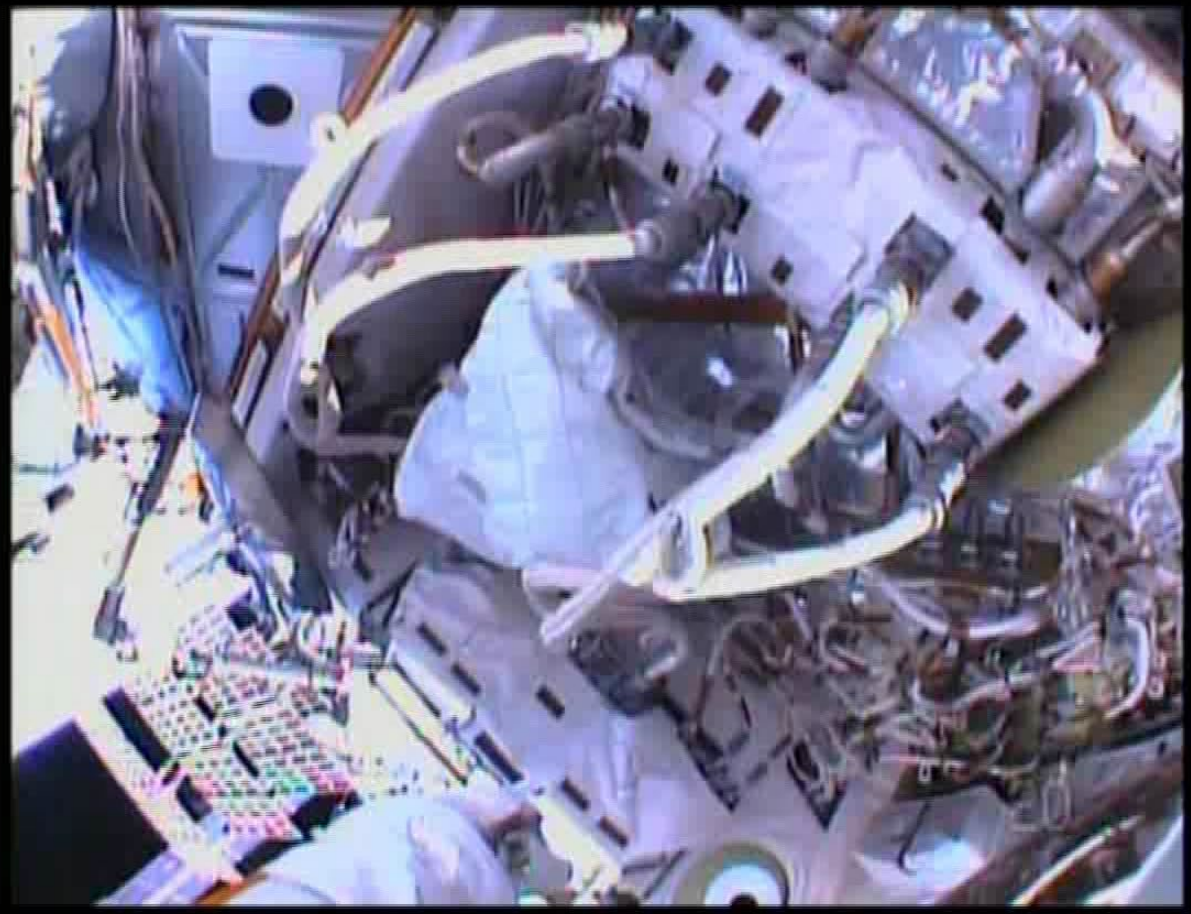
Questions

BACK

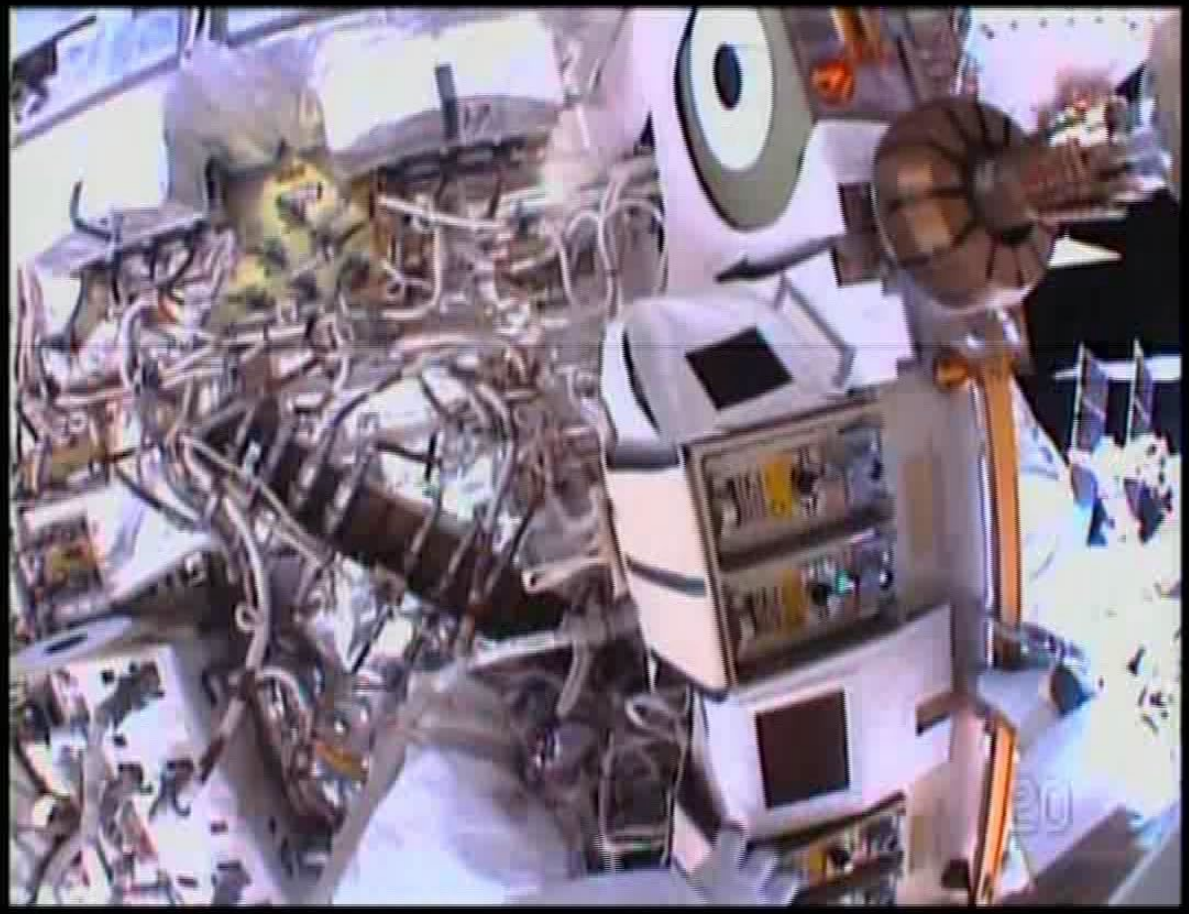
EVA Start

BACK

CO_2 Sensor



1st Water Call



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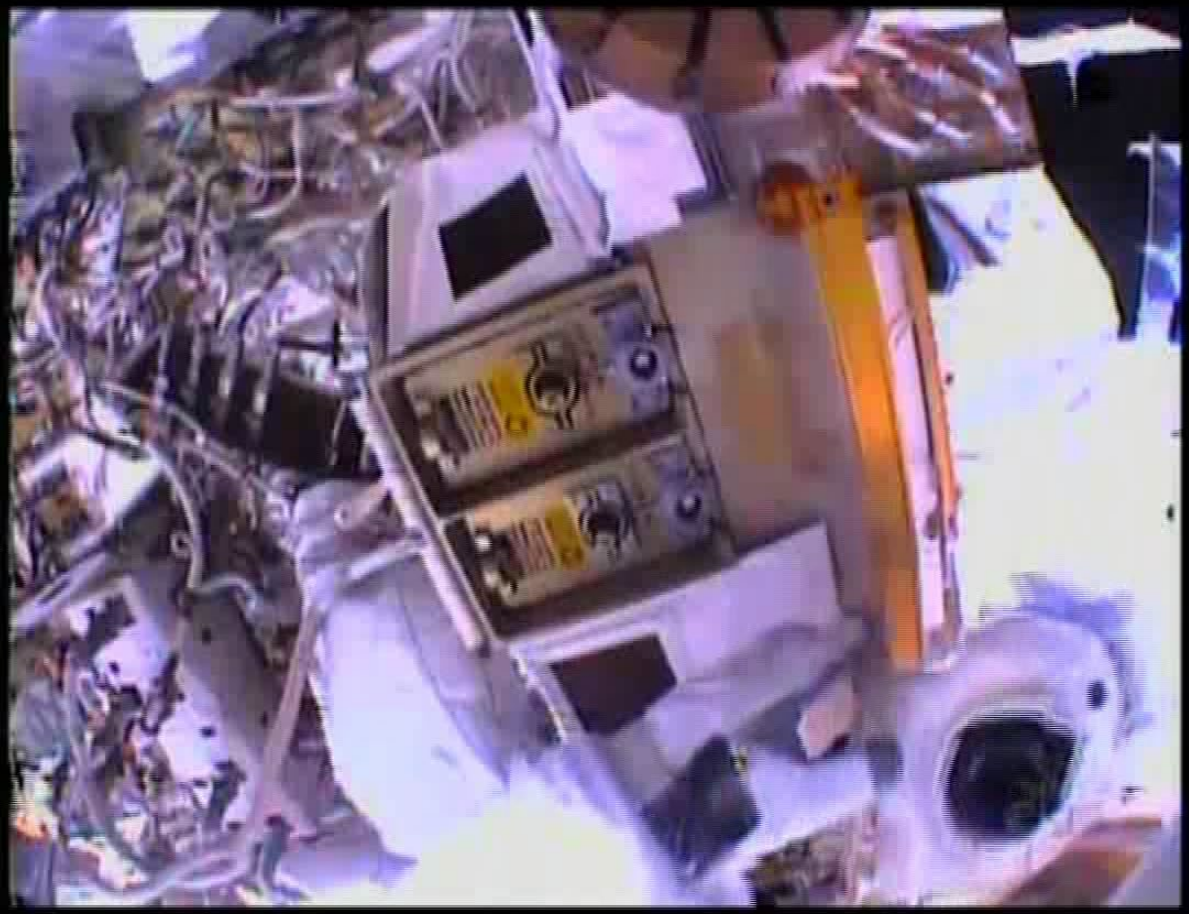
Water Discussion



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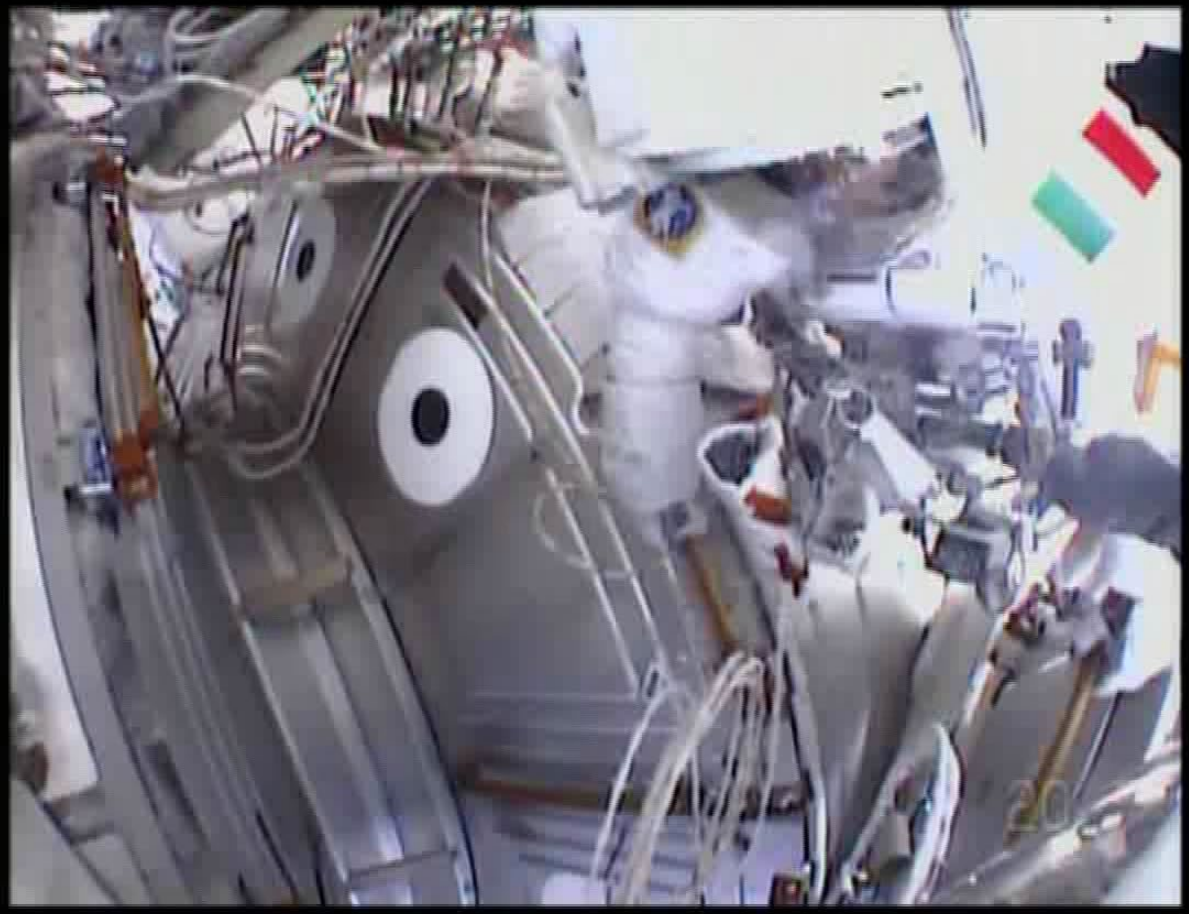
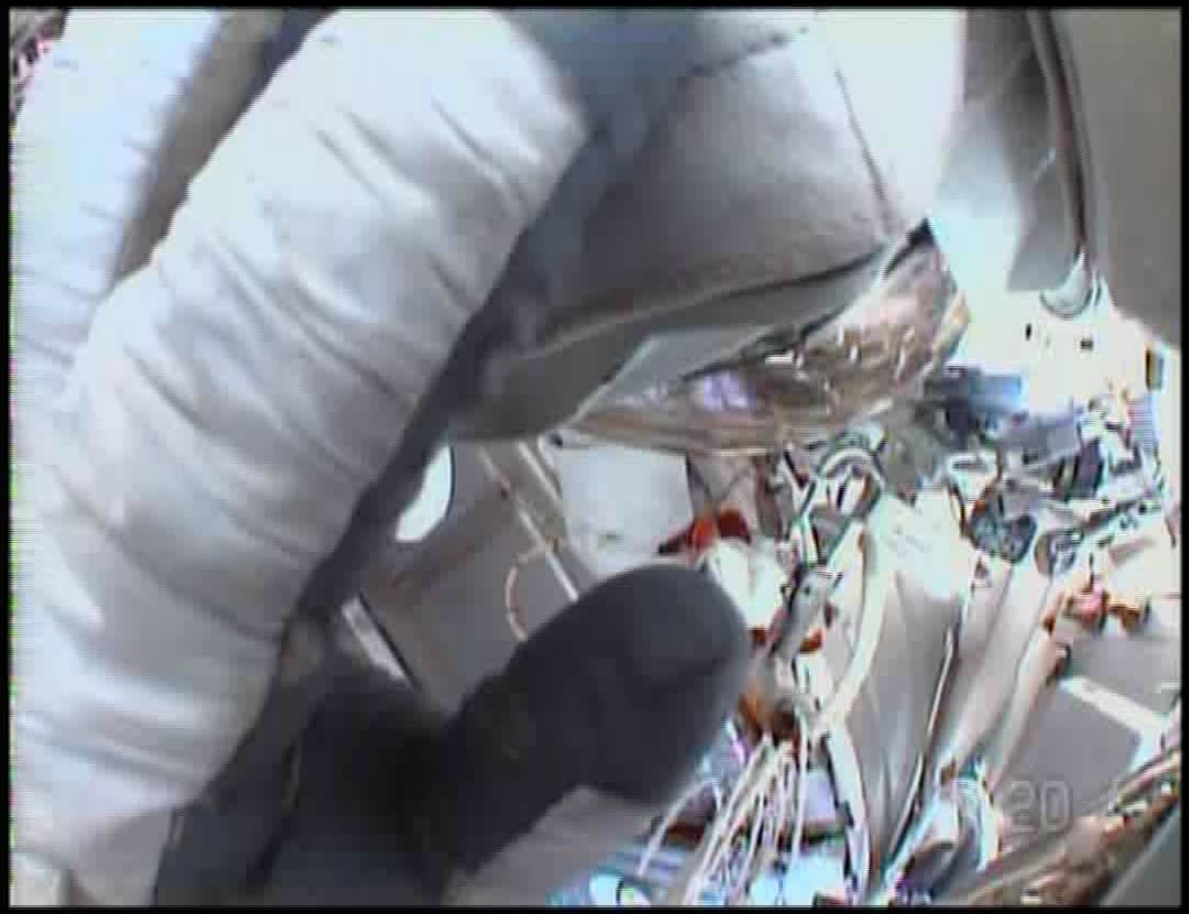
Water Discussion



EV1/EV2



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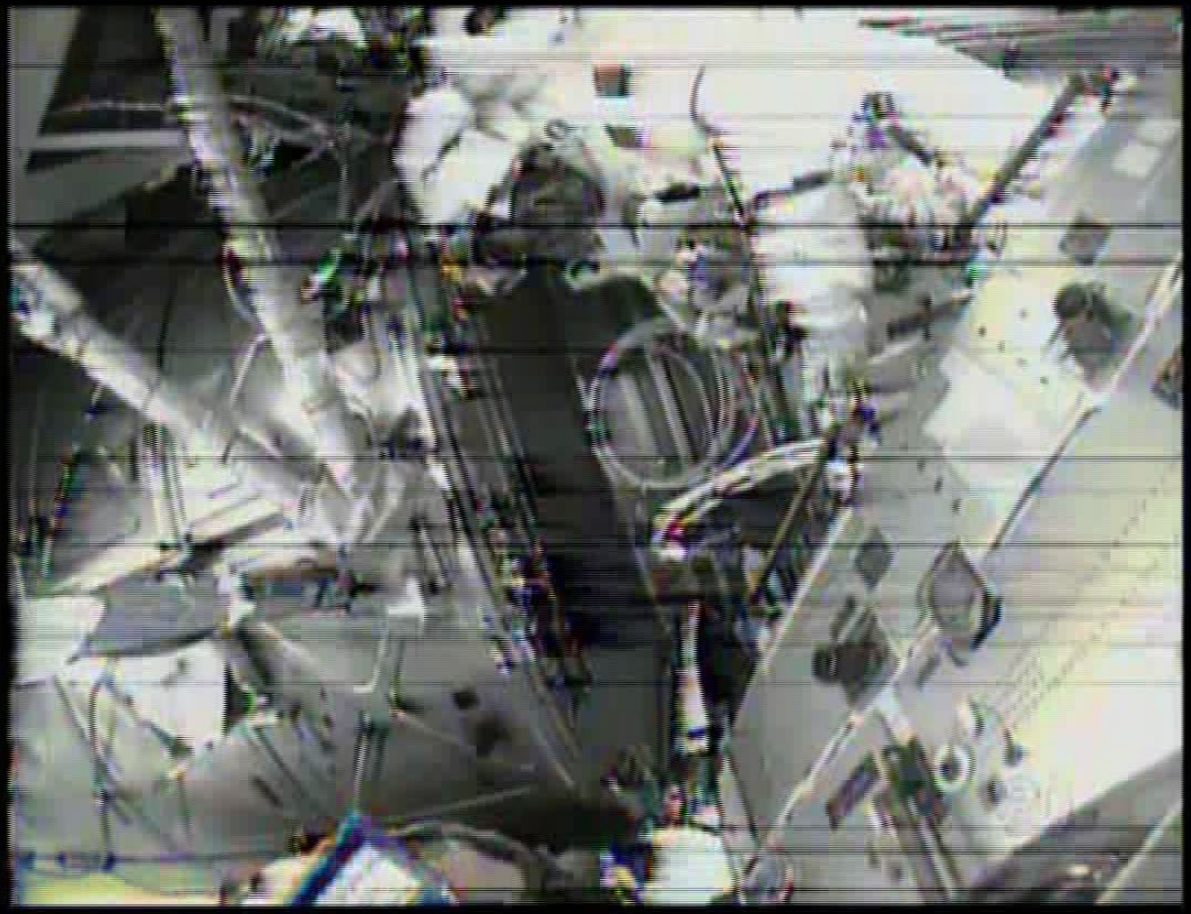
Comm Check

Water Increase



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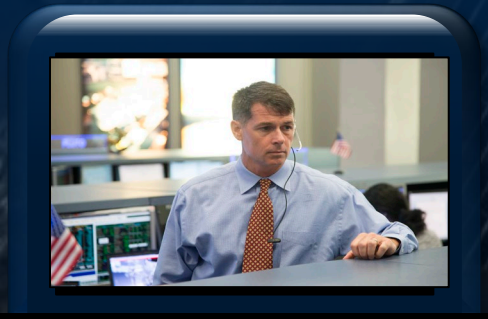
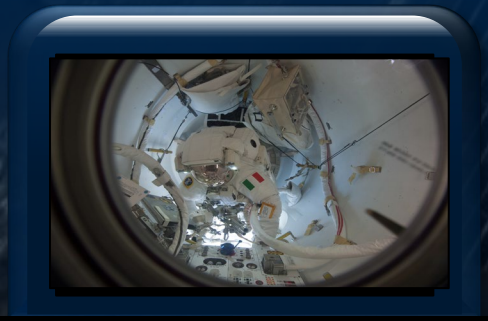
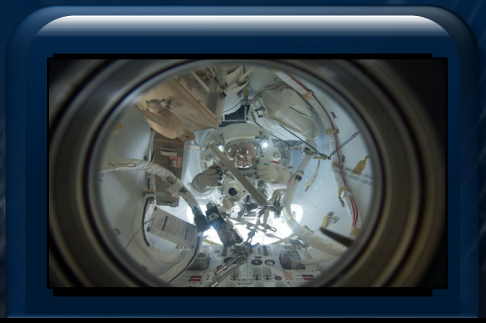
Terminate



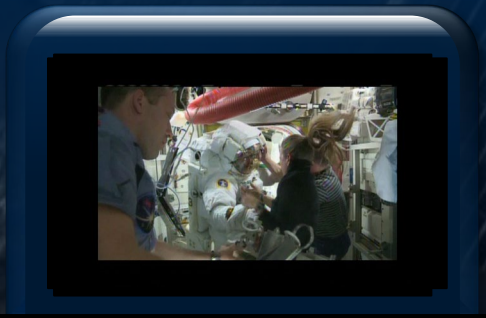
Back @ Airlock



Luca Check



Helmet Removal



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Water Dynamics