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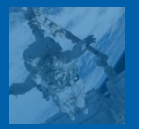

Descent Into the Void:

Soyuz-11 Depressurization

Leadership ViTS Meeting

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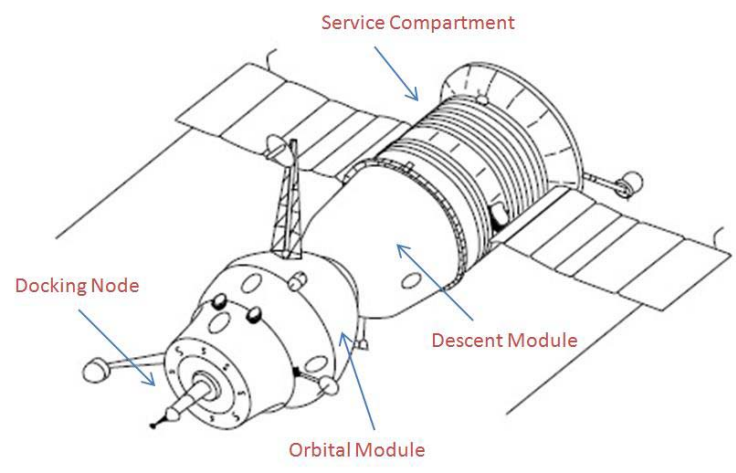
THE MISHAP

On June 6, 1971, three cosmonauts departed aboard Soyuz-11 on a month-long mission to pilot Salyut, Earth's first space station. Over the next 24 days on orbit, the crew performed more than 140 experiments in various scientific fields. On the day of their return, the descent capsule began its automated re-entry. Teams deployed to the descent site in Kazakhstan, arriving in time to observe the vehicle's flawless landing. When rescue squads opened the hatch, they found all three crew members still in their seats, lifeless.



The Mission

•*Soyuz*-11 would dock with the *Salyut* space station where the crew would spend 30 days performing scientific experiments.

•Two days before launch, the entire primary crew was replaced with a backup crew because physicians thought the primary flight engineer might have tuberculosis.

•The backup crew, assigned only four months before, had received significantly reduced training compared to previous and subsequent standards.

The Spacecraft (Nominal)

•*Soyuz*-11 was separated into three modules: orbital module, descent module, and service compartment.

•Upon re-entry, the descent module separated from the other two components when the descent module pyrotechnic bolts and the orbital module cartridges and bolts fired sequentially.

•The descent module was equipped with two ventilation/equalization valves (atmosphere intake and cabin exhaust, exposed to vacuum at orbital/descent module separation).

•On descent at 4 KM altitude (13,360 feet), valves were opened and seals ruptured pyrotechnically in order to allow cabin pressure to adjust.

WHAT HAPPENED?

The *Soyuz*-11 crew consisted of cosmonauts Dobrovolskiy, Patsayev, and Volkov.

Re-entry Preparations

•When the crew sealed the descent module in preparation for the return to Earth, the “hatch open” caution and warning panel light did not turn off.

•Ground control walked the crew through the hatch-closing process, and after several attempts to close the hatch, the light turned off.

•Onboard verification test indicated the cabin was properly sealed.

Depressurization Event Sequence

•Based on examination of the hatch and valves, officials determined that air leaked from one of the two ventilation/equalization valves, located behind the control panel.

•Although the crew would have been immediately aware of the leak, they had to determine its source, so they switched off radio transmitters to isolate the leak’s noise. Crew commander Dobrovolskiy’s body was found apparently attempting to cover the control panel with a checklist.

•The crew could not close the valve because it lacked a manual closure mechanism and was inaccessible.

•Within 40 seconds of depressurization during descent, the crew suffocated.

PROXIMATE CAUSES

Pyrotechnic powder traces found in the throat of the ventilation/equalization valve determined that the valve had malfunctioned. This was confirmed by analysis of the attitude control system, which indicated that the thrusters fired to counteract the force of gases escaping from the valve. Engineers later determined the 6 explosive cartridges and 6 explosive bolts that separated the orbital module from the descent capsule **fired simultaneously instead of sequentially (delay between the two)**; the resultant off-nominal shock jarred a ball joint in the valve loose, forcing the valve open and rupturing a seal at 105 miles altitude, versus the 2.7 miles altitude as designed.

UNDERLYING ISSUES

Design Flaws

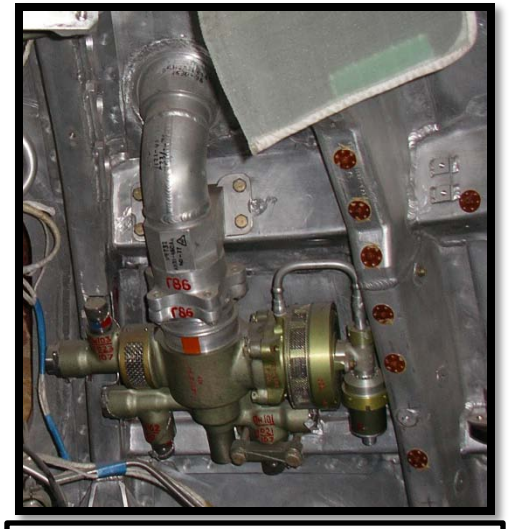
•Ventilation valve design did not meet the worst-case scenario of structural shock resulting from simultaneous firing of the orbital/descent module separation pyrotechnic system.

•Ventilation valves design was sensitive to the unanticipated higher shock loads from the explosive bolts firing simultaneously.

•Ventilation valves did not have associated alarms in the event that the seals somehow opened prematurely, so the crew spent precious seconds searching for the leak's source.

•Ventilation valves were placed behind the control panel – a location inaccessible to the crew.

•Ventilation valves lacked a backup closure procedure or mechanism, so once the crew members realized where the leak was coming from, they were powerless to correct the situation.



Redesigned Ventilation/Equalization Valve now provides relief for high pressure in the descent module and also functions to equalize pressure once parachutes have been deployed.

FOR FUTURE NASA MISSIONS

•Design engineers did not foresee *Soyuz*-11's failure mode: years of experience with high-altitude pressurized aircraft did not prepare design teams to test critical components versus pyrotechnic off-nominal shock events to uncover single-point failures.

•Complex systems can defeat attempts to ensure comprehensive human understanding of designs; design intent can be miscommunicated or misinterpreted as the design progresses through its life cycle.

•Hazard analysts may be more challenged to deduce or discover failure modes overlooked during design than by quantifying risk inherent to known scenarios.

•Recent experience with *Soyuz* and Space Shuttle re-entry has shown that pressure suit availability and usability is crucial.

•Columbia Crew Survival Report: "Future spacecraft must fully integrate suit operations into the design of the vehicle and provide features that will protect the crew without hindering normal operations."

The *Soyuz*-11 Crew in Flight