System Safety Challenges to Human Commercial Space Flight

FAA Recommended Practices

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Space Flight Risk to Human Space Flight

Mission Phase 1: Pre-launch Preparations

**FIRE**

- **Apollo 1, U.S.A., 1967**
  - Astronauts Gus Grissom, Ed White and Roger Chaffee are sealed into their command module for a routine ground test. When a fire suddenly erupts in the cockpit, the men are unable to open the complex escape hatch in time. **DEATHS: 3**

**TRAINING ACCIDENT**

- **Lunar Landing Trainer Vehicle Crash, U.S.A., 1968**
  - Astronaut Neil Armstrong, rehearsing for his historic moon mission, must eject to safety when his training vehicle malfunctions. **EJECTING FROM THE LLTV**

**ROCKET MALFUNCTION**

- **Nedelin Disaster, U.S.S.R., 1958**
  - With 30 minutes remaining before a test launch of Russia's new R-16 missile, hundreds of technicians and military officers work near the launch pad. Suddenly a rocket engine ignites prematurely. The missile explodes. **DEATHS: 126 estimated**

Mission Phase 2: Liftoff and Ascent

**VEHICLE BREAKUP**

- **Space Shuttle Challenger, U.S.A., 1986**
  - Cold weather causes rubber seals in the booster rockets to become leaky. As the shuttle ascends, escaping flames lick across the huge external fuel tank. When the tank explodes, the orbiter disintegrates. After falling for nearly 3 minutes, the crew cabin crashes into the ocean. **DEATHS: 7**

**EXTERNAL FUEL TANK EXPLOSION SHATTERS SHUTTLE**

Mission Phase 3: The Vacuum of Space

**FIRE**

- **Apollo 13, U.S.A., 1970**
  - A damaged oxygen tank explodes, crippling the spacecraft. Quick action by the astronauts and by Mission Control allows the use of the moon lander as a lifeboat. Astronauts James Lovell, Fred Haise and Jack Swigert return home safely.

**ONBOARD EXPLOSION**

- **Lunar Module Aquarius**

**SPACE STATION MIR, U.S.S.R., 1997**

- A jet flame breaks out from an oxygen generator, burning for about 14 minutes. Mir's three crewmen are cut off from one of their two Soyuz escape vehicles. The crew use extinguishers to control the fire. They wear oxygen masks to prevent suffocation in the thick smoke.

**DECOMPRESSION**

- **Voskhod 2, U.S.S.R., 1965**
  - After his historic first-ever spacewalk, cosmonaut Alexei Leonov attempts to return to his capsule. He discovers that his spacecraft has unexpectedly ballooned out, preventing him from entering the hatch. His heart racing, Leonov reduces pressure in his suit until he is able to enter the ship.

**Soyuz 11, U.S.S.R., 1971**

- Cosmonauts Georgi Dobrovolski, Viktor Patsayev and Vladimir Lebedev undock their Soyuz craft from the Salyut 1 space station. Sections of their vehicle, not needed for the return home, are blasted away by explosive bolts. The shock jars open a valve, allowing all the breathable air to escape into space. Automatic systems return Soyuz 11 to Earth. When rescuers open the hatch, they discover that the crew has suffocated. **DEATHS: 3**

**PARACHUTE FAILURE**

- **Soyuz 1, U.S.S.R., 1967**
  - The first flight of the new Soyuz spacecraft did not go well. Several serious failures forced an early end to the mission. Cosmonaut Vladislav Komarov attempted a risky manual egress. A malfunctioning parachute does not slow the vehicle, and Komarov crashes to the ground at about 86 mph (140 km/h). **DEATHS: 1**

Mission Phase 4: Re-entry and Landing

**HEAT SHIELD FAILURE**

- **Space Shuttle Columbia, 2003**
  - At launch, the shuttle's heat shield tiles are damaged by falling debris. The damage is not considered serious and the 16-day scientific mission proceeds as planned. When the crew of seven attempts to return home, the heat of re-entry burns through the damaged heat shield. The vehicle is torn apart. **DEATHS: 7**

**PARACHUTE FAILURE**

- **Soyuz 1, U.S.S.R., 1967**
  - A stuck maneuvering thruster sends the capsule reeling at a dizzying rate. Astronauts Neil Armstrong and David Scott are seconds away from blacking out when they manage to shut down the malfunctioning rocket engines and stop the spin using engines needed for the descent to Earth.

**GEMINI 10, 1966**

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Technical Challenges

• Extreme Energies associated with all space flight;

• Environmental extremes
The next step

• Space flight no longer for a select few

• Commercial space flight offering the experience for the general public
FAA Authority

• Regulates to protect public safety
• Prohibited by law to introduce new regulations
  – No On Orbit Authority
  – Or occupant safety

• FAA anticipating new rule making authority around 2017
The Challenges to Safety and establishing a system safety process for commercial human space flight:
Specific technical challenges

- Extreme temperatures
- Radiation
- Orbital debris
- Physiological
- Microgravity

- All of which impose hazards to the occupant
Airline Approach The holy Grail

- Design
- Manufacturing
- Operations
FAA Approach

- Organized by major program functions
Performance Based Requirements

• NO Plans

• No Analyses without a recommendation on use of results.
Spiral development

• Wide variety of designs, operations and capabilities introduces new issues.
• How to write a requirement that envelopes all possible designs present and future?

1.1.1 Atmospheric Conditions
a. The vehicle should provide atmospheric conditions to all occupants adequate to protect them from serious injury and allow safety-critical operations to be performed.

b. The flight crew or ground controllers should be able to monitor and control the following atmospheric conditions in the inhabited areas:
Challenges to Regulations

• No authority to impose standards
• Constrained by current law
• Regulations originally built with best of intentions but did not validate or verify
  – Confusion on how to meet
  – FAA expectations have been changing

• New HSF regs following a more traditional route