Incidents in Human Space Flight
"Having a Bad Day in Space"

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DISCLOSURES

The presenter has consulting relationships with:

- Disney World Corporation
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- Xtreme Space Inc.
- Orbital Outfitters Inc.
- Space Medicine Associates
- Science Applications International Corporation
- Universities Space Research Association
- Wyle Laboratories

“The only thing we learn from history is that we learn nothing from history.”

George Bernard Shaw paraphrasing Georg W. Hegel

Outline

- Human Spaceflight Experience
- Hazards of Spaceflight
- Fatalities in Training and Space Operations
- Launch and Landing Events
- Medical Evacuation and Close Calls
- Medical Events in Active Astronauts
- Spacecraft Environmental Events
- Behavioral and Neurologic Issues
- Performance Challenges In Spaceflight
- Events and Concerns during Spacewalks
- Summary

Human Space Experience as of Dec 2006

Total spaceflight time:

29,875 crew-days (81.8 crew-years)

Persons who have flown in orbit: 451

Cumulative spaceflight record:

Sergei Krikalyov (Russia) - 803.4 days single

Single mission spaceflight record:

Valeri Polyakov (Russia) – 437.7 days

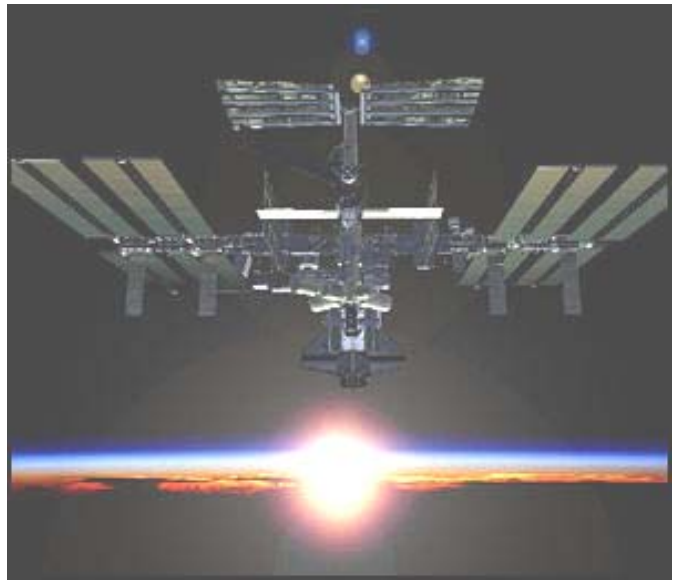
(678 days total)

Spacewalk Time:

Total spacewalk time: 110 crew-days

Anatoliy Solovyov (Russia) – 77:41 (16 EVAs)

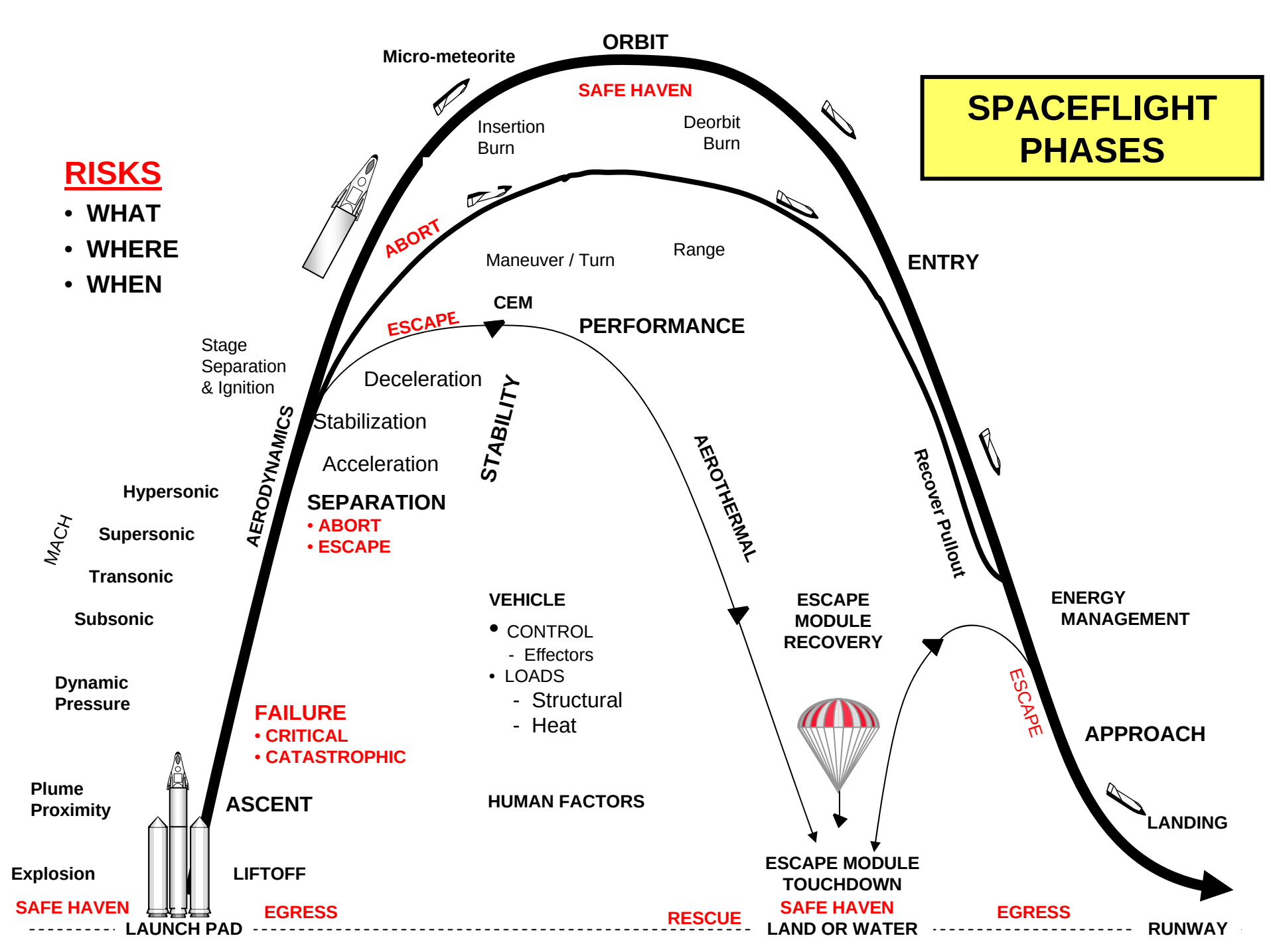
Hazards of Spaceflight



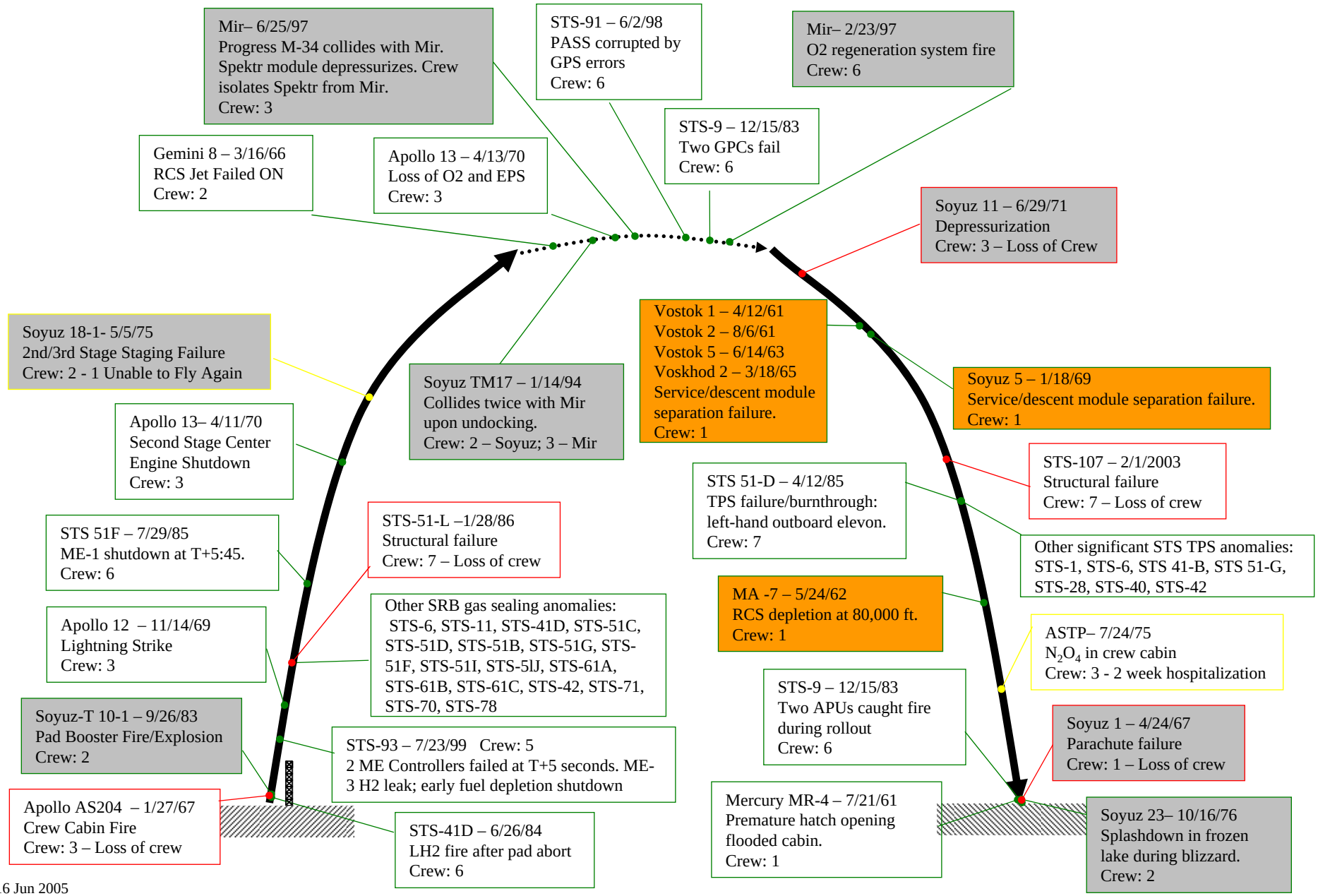
Space Environment
- Reduced Gravity
- Radiation
- Vacuum
- Debris

Space Craft Environment
- Isolation and confinement
- Noise
- Life support environment
- Waste management and sanitation

Space Mission Environment
- Launch and entry gravitational forces
- Extra-Vehicular Activity (EVA)
- Planetary Surface Operations
- Mission and Science Activities
- Communication availability, bandwidth, and time delay
- Circadian rhythm, crew schedule, and workload

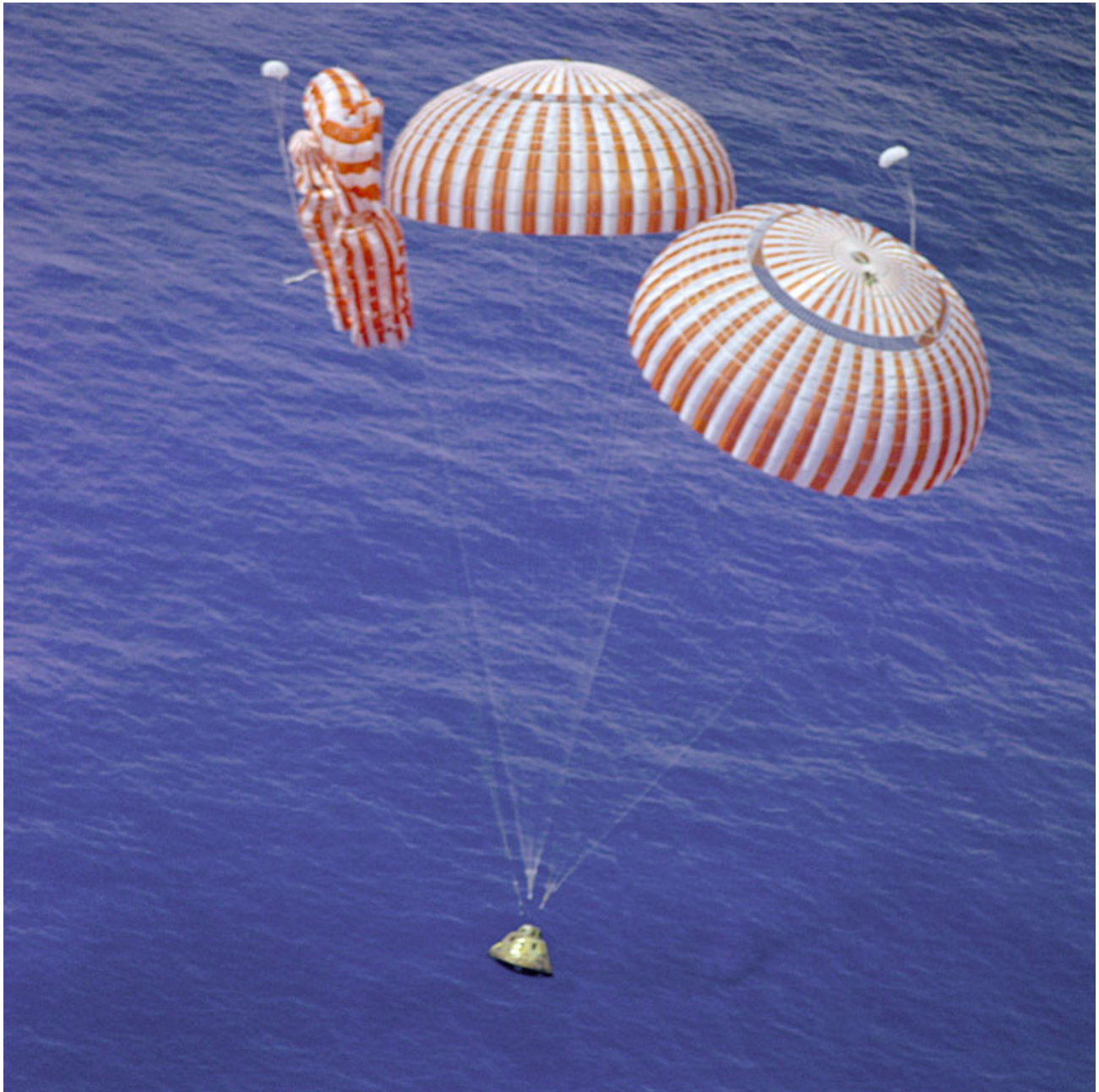

SPACEFLIGHT PHASES
RISKS
• WHAT
• WHERE
• WHEN
ORBIT
Micro-meteorite
SAFE HAVEN
Insertion Burn
Deorbit Burn
ABORT
Maneuver / Turn
Range
ENTRY
ESCAPE
CEM
PERFORMANCE
Stage Separation & Ignition
Deceleration
Stabilization
Acceleration
AERODYNAMICS
STABILITY
AEROTHERMAL
Recover Pullout
SEPARATION
• ABORT
• ESCAPE
MACH
Hypersonic
Supersonic
Transonic
Subsonic
Dynamic Pressure
VEHICLE
• CONTROL
- Effectors
• LOADS
- Structural
- Heat
ESCAPE MODULE RECOVERY
ENERGY MANAGEMENT
ESCAPE
APPROACH
FAILURE
• CRITICAL
• CATASTROPHIC
Plume Proximity
ASCENT
HUMAN FACTORS
LANDING
Explosion
LIFTOFF
ESCAPE MODULE TOUCHDOWN
SAFE HAVEN
EGRESS
RESCUE
SAFE HAVEN
EGRESS
LAUNCH PAD
LAND OR WATER
RUNWAY

Significant Incidents and Close Calls in Human Spaceflight



16 Jun 2005

If It Can Fail, It Will



Training and Ground Operations Fatalities

Russian Space Program

- 1 Fatality – (23 March 1961) Pilot Cosmonaut died in fire in pure oxygen simulator run
- 1 Fatality – 27 March 1968 - Cosmonaut Yuri Gagarin dies at age of 34 -- Crash of MiG-15 trainer
- 1 Fatality – (11 July 1993) Pilot Cosmonaut drowned during water survival training in the Black Sea

U.S. Space Program

- 3 Fatalities – (27 Jan 1967) Apollo 1 pad fire
- 4 Fatalities in T-38 aircraft, 1 (1964), 2 (1966) 1 (1968)

Space Fatalities

Russian Space Program

- 1 Fatality – Soyuz 1 (21 Apr 1967) power, communication and attitude control problem and parachute entanglement during reentry
- 3 Fatalities – Soyuz 11 (29 Jun 1971) crew cabin decompression from relief valve opening during reentry

U.S. Space Program

- 1 Fatality – (1967 Nov 15) X-15 Flight 191, after reaching peak altitude (81 km), entered flat spin at Mach 5, began high frequency pitch oscillations, disintegrated
- 7 Fatalities – (28 Jan 1986) Challenger STS 51-L launch breakup following SRB O-Ring burn through
- 7 Fatalities – (1 Feb 2003) Columbia STS 107 breakup during entry from foam damage to wing leading edge

X-15 Mishap

X-15 Mishap

X-15 Flight 191 (1967 Nov 15) Air Force test pilot Major Michael J. Adams

During ascent an electrical anomaly distracted the pilot and X-15 began gradual heading drift at maximum altitude of 266,000 feet (81 km).

Attitude flight display misinterpreted and within 30 seconds the X-15 was descending at right angle to the flight path.

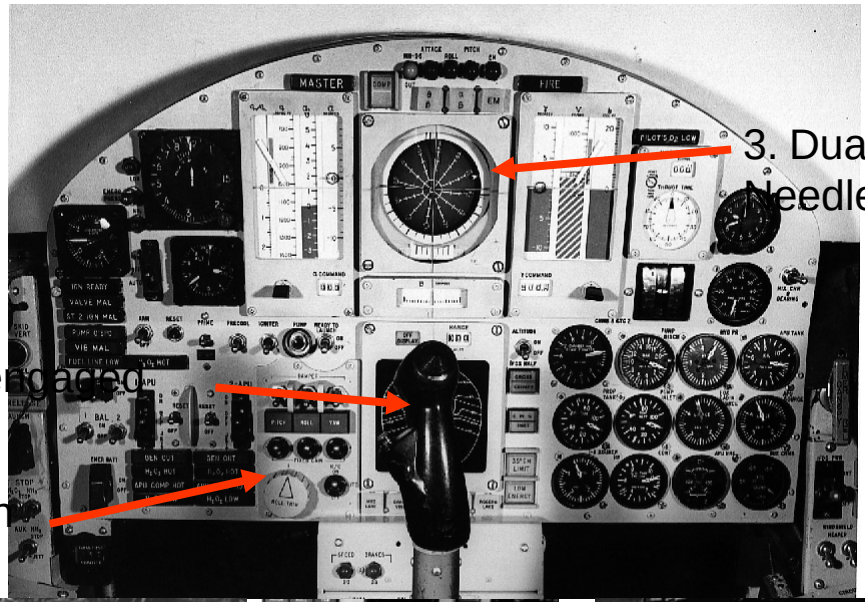
At 230,000 feet the X-15 entered a Mach 5 spin, and there were no recommended supersonic spin recovery procedures.

At 118,000 feet he recovered from spin then went into a Mach 4.7 inverted dive (40-45 deg).

Adaptive flight control system became saturated as X-15 came out of the spin, and began a rapidly increasing pitch oscillation motion, descending at 160,000 feet per minute.

With dynamic pressure increasing the X-15 experienced in excess of 15 g positive and negative vertical (Gz) and 8 g lateral (Gy) and underwent structural breakup 65,000 feet at Mach 3.93.

Human Factors related to X-15 Crash

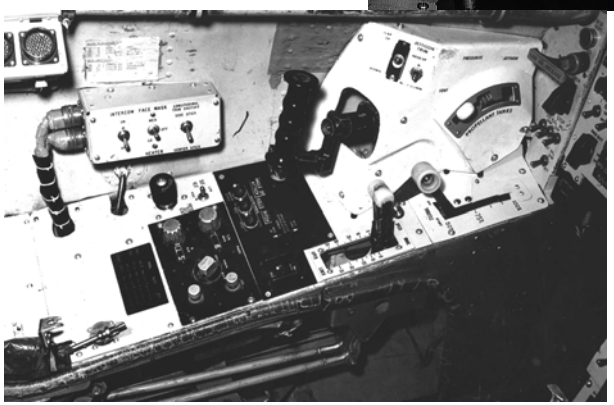


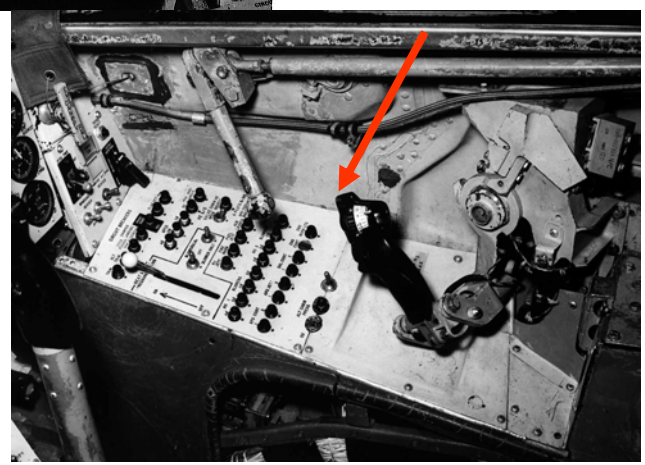
3. Dual use of same Guidance Needle (Roll Angle Vs Sideslip)

1. FCS Dampers Disengaged

2. Auto Blending of RCS and Aero Controls Ceased

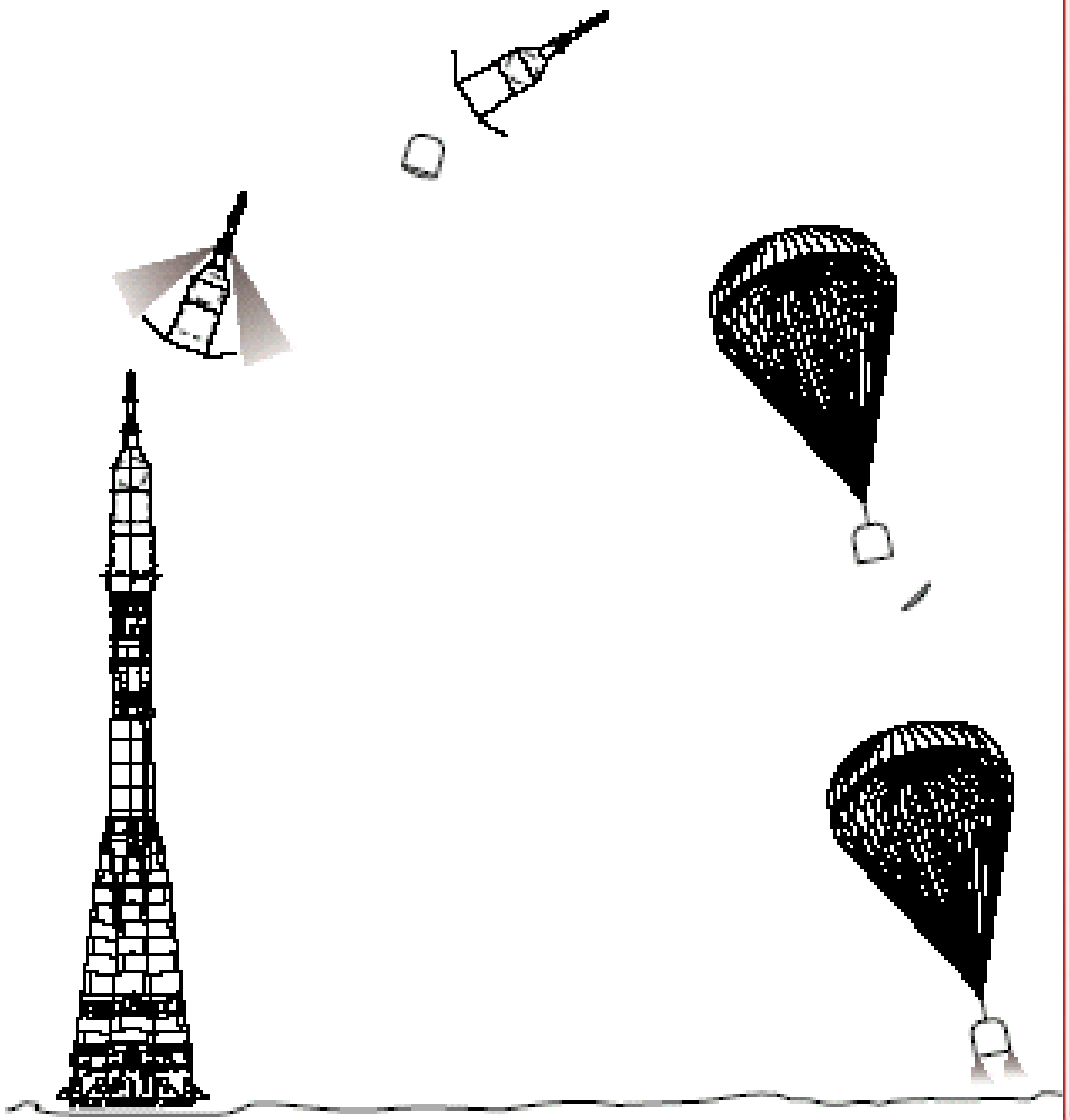
4. Nose manually driven away from Flight Path





5. FCS Gain driven away from optimum by Electrical Transients
6. Control Surface deflections excessive as Dynamic Pressure Increased during Entry
7. Structural Capability Exceeded

Soyuz Launch Escape System



Russian Pad and Launch Aborts

Soyuz-18A (April 5, 1975)

V. Lazarev, O. Makarov

Third stage booster separation failure, crew experience injuries from 20.6 G reentry, capsule rolled down hill, parachute snagged tree before capsule came to edge of a cliff

Soyuz T-10A (Sept 27, 1983)

V. Titov, G. Strekalov

Explosion 90 sec before launch, LES activated, crew experiences 14-17 G x 5 s, unharmed

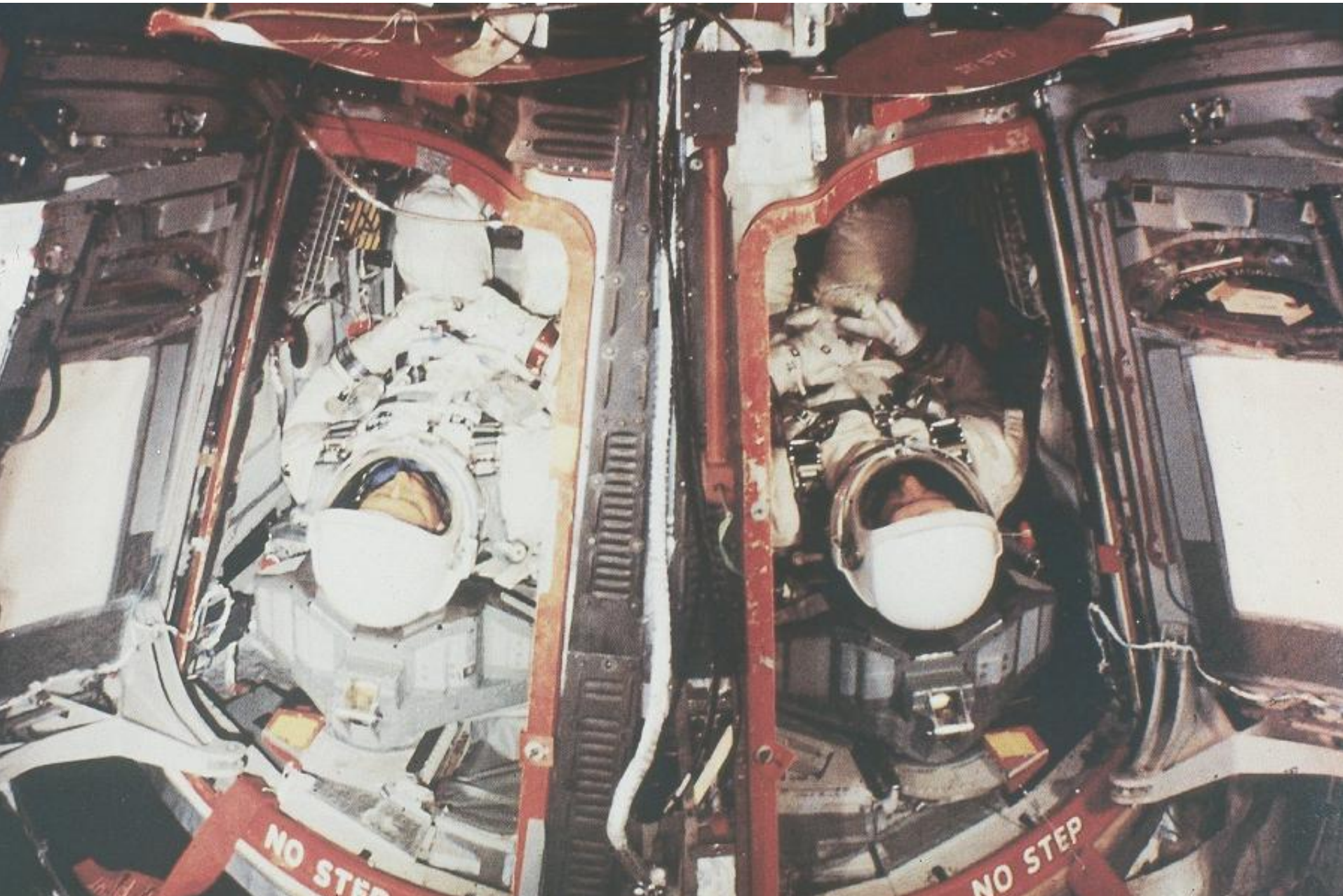
U.S. Pad and Launch Aborts

Gemini 6 – Main Engine Shut down

STS 41D - Launch Pad Fire

STS 51 F – Abort to Orbit

Remember the bears (Gemini VI) 12/12/65

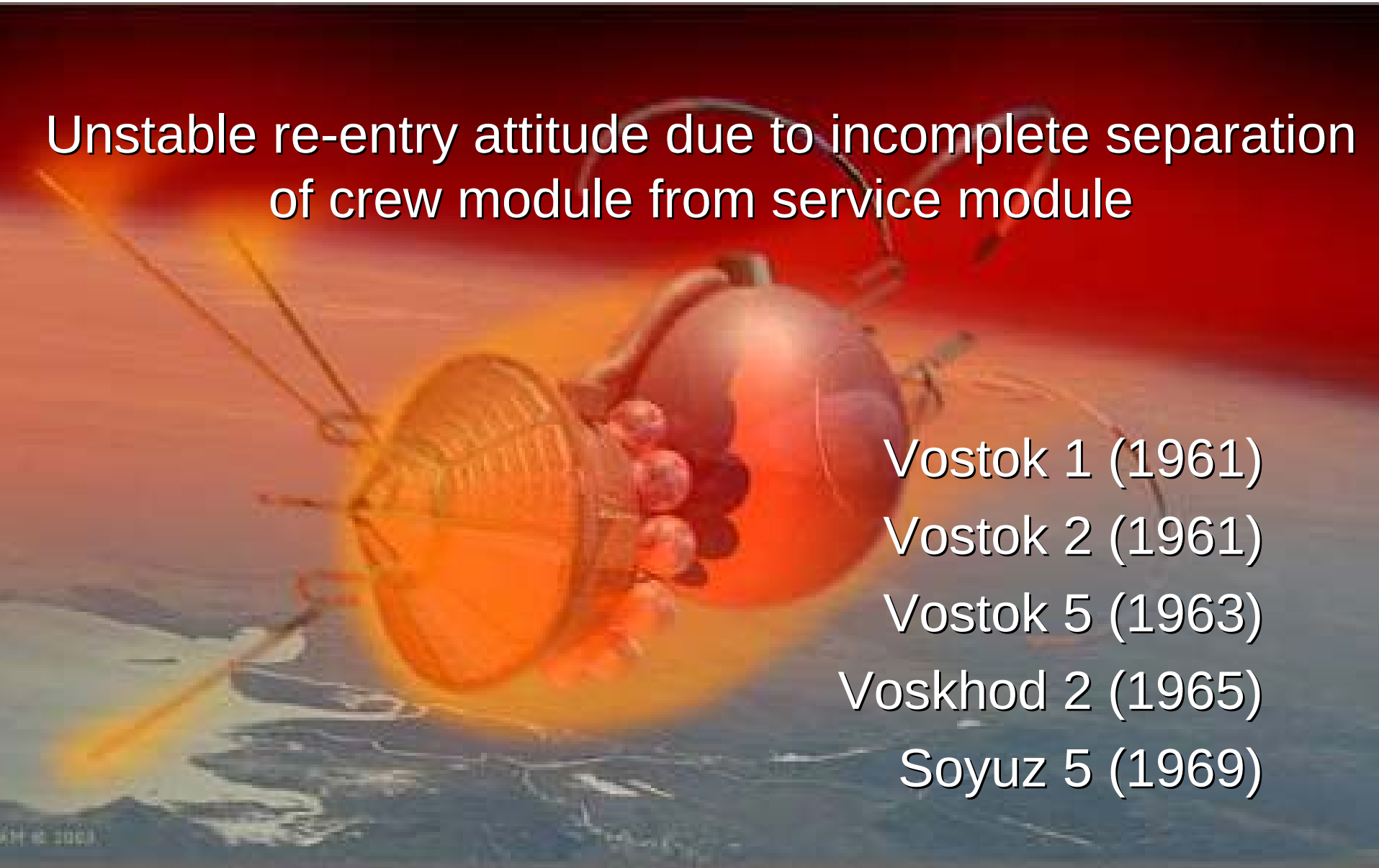


STS-41D (STS 12)
Space Shuttle Discovery
June 26, 1984
Pad Fire/ Launch Abort

Sensor detected out of sequence start of Space Shuttle Main Engine (SSME) which resulted in an abort shutdown about 4 seconds before Solid Rocket Booster (SRB) ignition.

After the abort, a hydrogen fire occurred on the starboard body flap for about 12 minutes. The aft base heat shield water deluge system was repeatedly activated.

Spacecraft Re-entry Events



Unstable re-entry attitude due to incomplete separation of crew module from service module

Vostok 1 (1961)

Vostok 2 (1961)

Vostok 5 (1963)

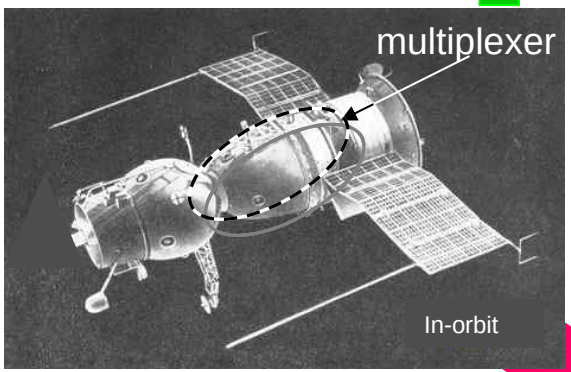
Voskhod 2 (1965)

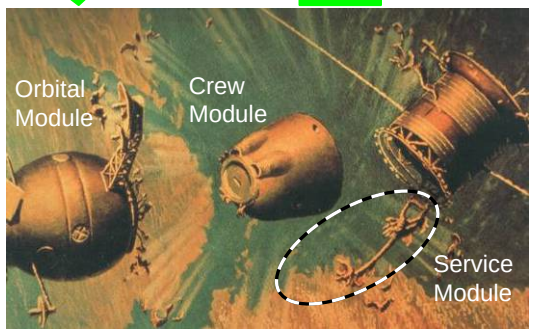
Soyuz 5 (1969)

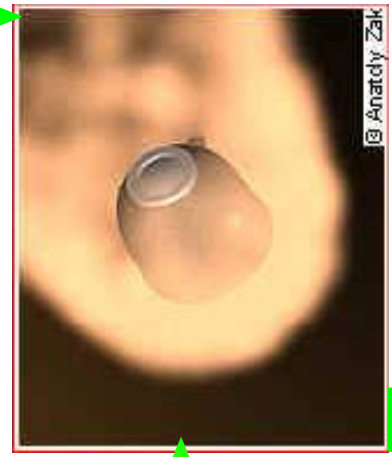
Re-entry of Soyuz 5 (18 Jan 1969)

Unstable entry attitude due to off-nominal spacecraft configuration: multiplex connector failed to disconnect as commanded.

Nominal process…







Entry G forces reversed, cosmonaut hanging in the straps

Service module finally separated and re-entry vehicle righted

Failure of soft-landing rockets resulted in hard landing and cosmonaut broke his teeth

Landing Events

Soyuz 23 (16 Oct 1976)

Reentry when unable to dock with Salyut 5 space station when rendezvous system failed.

Landed at night in a snowstorm, in -20 deg C weather, on the surface of Lake Tengiz.

Recovery crews did not find the capsule until the next morning, and were surprised to find the crew alive.

On Orbit Close Call

Debris Impact with Vehicle (potential cabin depressurization):

Vladimir Lyakhov and Aleksandr Aleksandrov aboard Soyuz T-9 in 1983, prepared to evacuate after hearing a loud crack; investigation revealed a 3.8 mm impact crater on a window

Medical Evacuation from Space

Salyut 5 space station (1976) - abandoned by Volynov and Zholobov 49 days into 54 day mission for intractable headaches following probable combustion event (crew return on Soyuz 21)

Salyut 7 space station (1985) - Vasyutin evacuated 56 days into 216 day mission for fever and urinary infection (crew return on Soyuz T-14)

Mir space station (1987) Laveikin evacuated 6 months into 11 month mission for cardiac irregularity (crew return on Soyuz TM-2)

Medical Evacuation Close Calls

Dental abscess treated with analgesics for 10 days, evacuation planned when symptoms resolved (Russian)

Facial and upper airway contact dermatitis after crewmember's head went into ethylene glycol ball, deorbit considered but treated on orbit (Russian)

Acute abdominal pain (suspected appendicitis) with deorbit plan in progress when kidney stone passed (Russian)

Medical Events in Active U.S. Astronauts

- Appendicitis (2)
- Diverticulitis
- Choledocholithiasis (3)
- Pancreatitis (2)
- Gastroenteritis/colitis
- Duodenal ulcer
- Inguinal hernia (4)
- Lower GI bleeding
- Ureteral calculus (14)
- Ovarian cyst
- Malignant melanoma
- Ventricular tachycardia
- Atrial fibrillation
- Severe allergic reaction
- Severe epistaxis
- Cervical disc herniation with spinal cord impingement
- Bacterial tenosynovitis in hand
- Pneumonia (2)
- Corneal ulcer
- Retinal detachment (2)
- Cataracts requiring intraocular lens replacement (3)
- Sudden severe hearing loss (2)

Spacecraft Environmental Events

Spacecraft Environmental Events

Combustion Events (4 Russian, 4 Shuttle)

Toxic Atmosphere (crew symptomatic)

- Carbon monoxide (Mir) 600 ppm measured
- Ethylene glycol (Mir) 75 ppm measured
- Carbon Dioxide (Salyut, Apollo 13, STS 96)
- Nitrogen Tetroxide (Apollo 18)

Water Contaminants

- Formaldehyde (Mir)
- Cadmium (ISS)

Acute Behavioral Events

Acute Behavioral Change

Payload specialist despondent when experiment failed, crew concerned about potential for dangerous behavior

Acute Grief Reaction

Mir 18 – Crewmember's mother died, mission control did not tell him, when he eventually found out he withdrew for 1 week

Depression

NASA Mir 3, Salyut 7

Crew-Crew Interpersonal Conflicts

Soyuz 21, Soyuz T14, Soyuz TM 2

Crew-Ground Control Team Conflicts

Skylab 4, NASA Mir 4

Spaceflight Associated Neurologic Issues

Space Motion Sickness

Perceptual Illusions

Headache - reported by 67% of astronauts

Retinal Burn (Space Tourist)

Elevated Intraocular Pressure (IOP) - in all normal individuals measured, ocular hypertensives, and glaucoma patient

Papilledema and visual loss (long duration crew)

Impaired cognitive performance - anecdotal reports, called “Space Stupids, Space Fog, Space Dementia”

Post Flight Concerns

- Disequilibrium and Ataxia
- Earth Readaptation Syndrome
  - (Mal de Debarquement, G state flashbacks)

Performance Challenges In Spaceflight

Piloted Entry and Landing

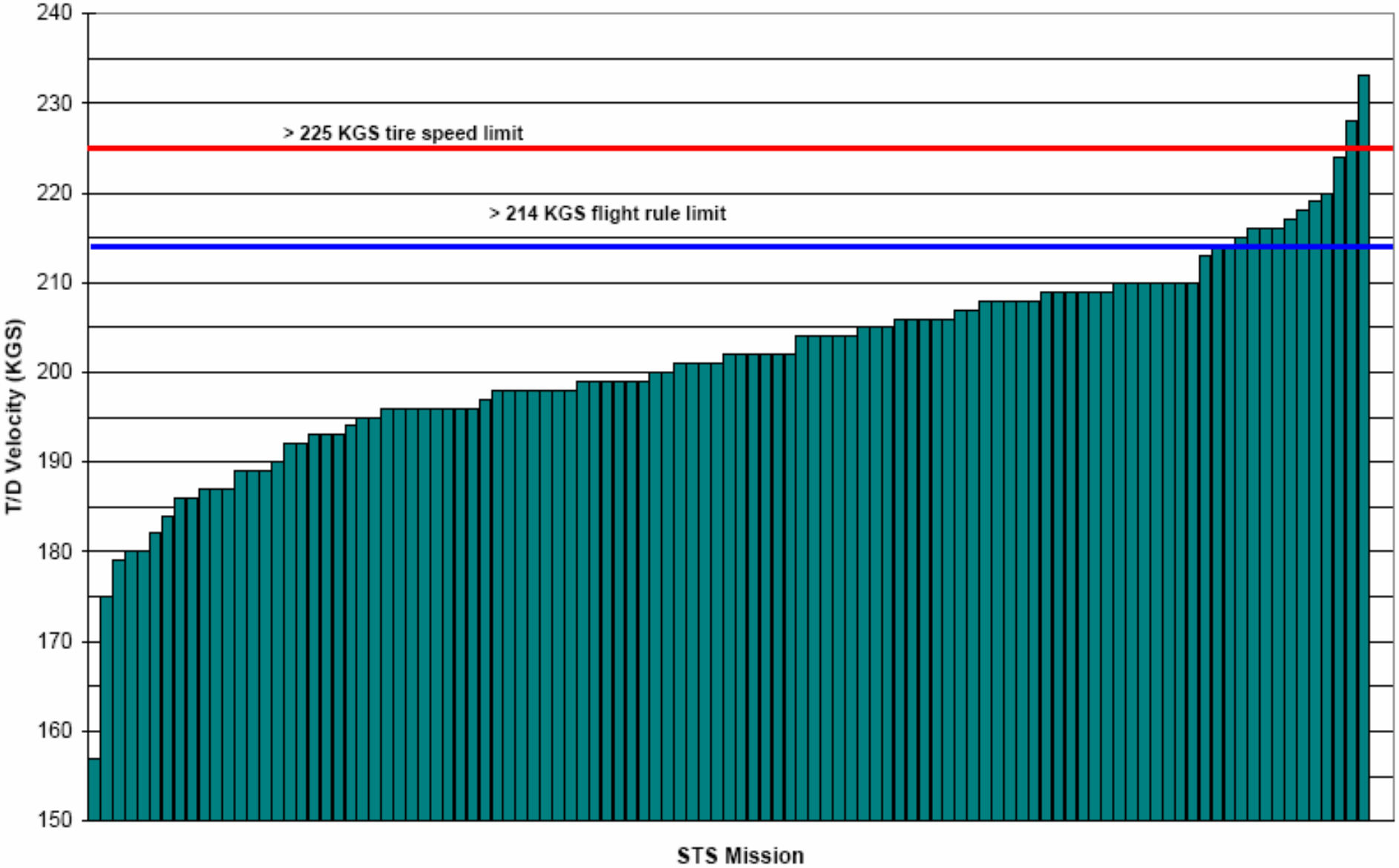
Robotic Operations

Rendezvous & Docking

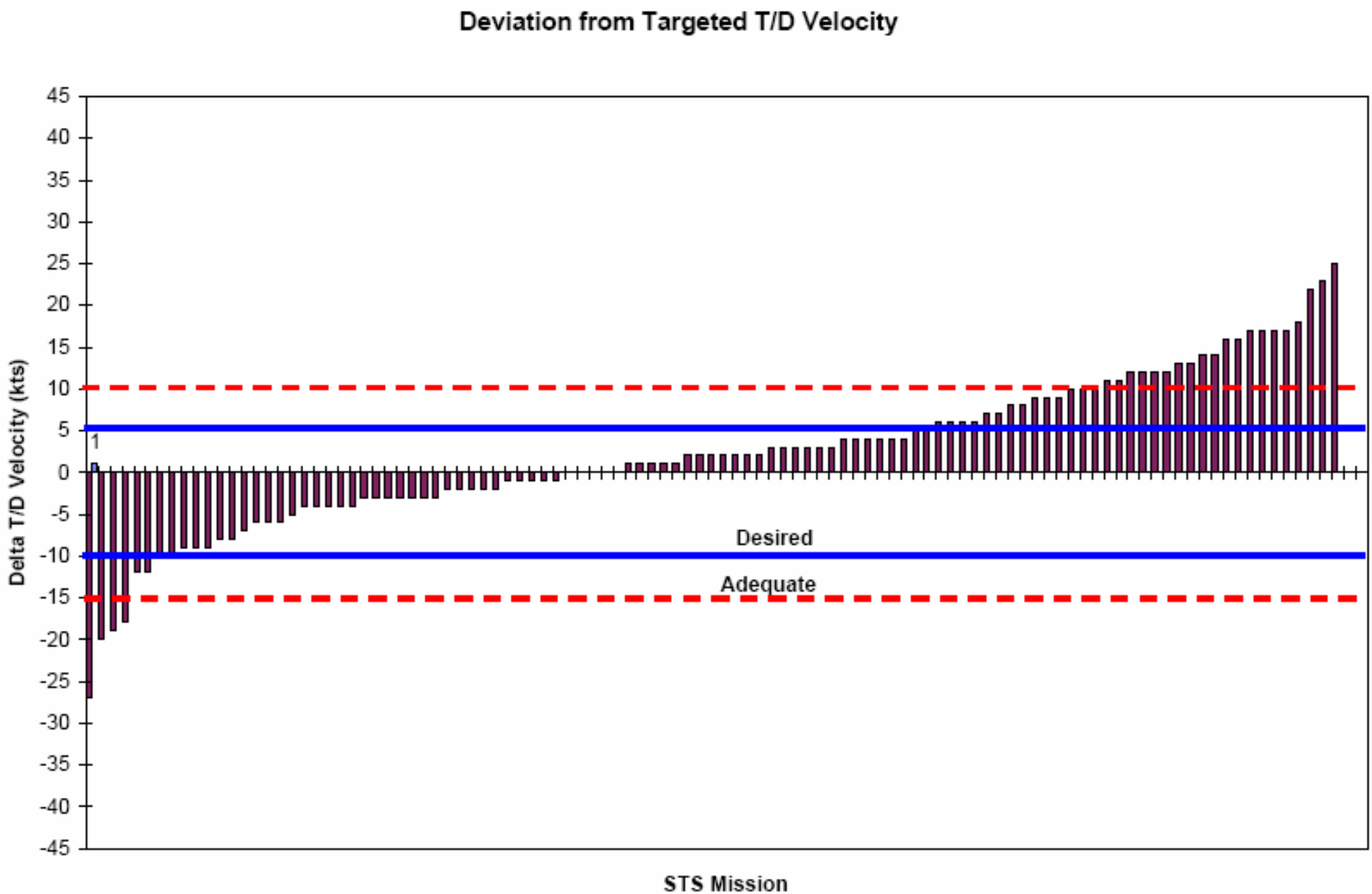
Spacewalks

Emergency Egress and Escape

Shuttle Landing Performance



Shuttle Landing Performance



Loss of Spacecraft Vehicle Control

X-15 flight 191

Gemini VIII

Apollo 10 Lunar Module

Apollo 13 Command and Service Module

STS 25 (51-L)

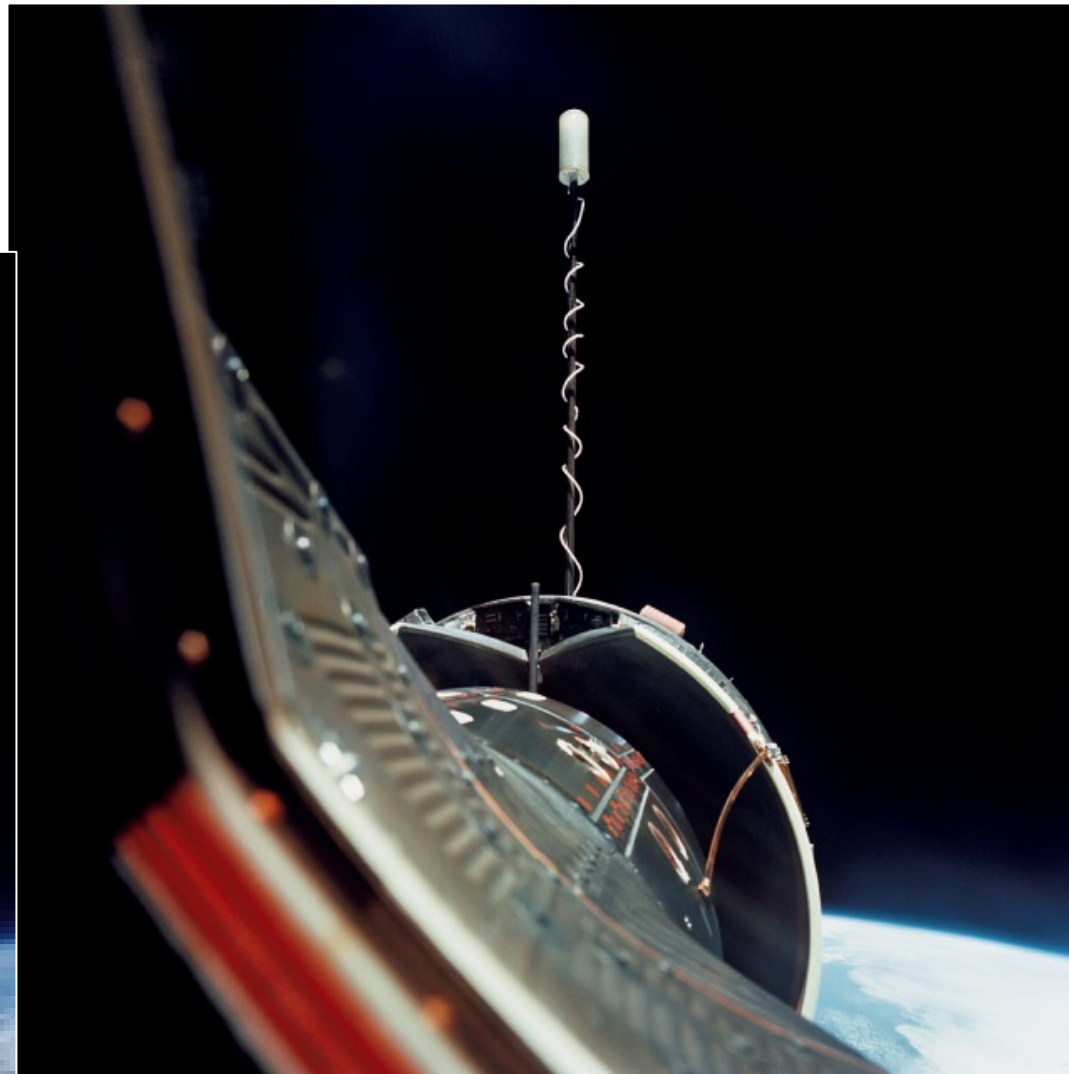
STS 32

Mir following Progress M-34 Collision

STS 107

Space Ship One (X Prize qualifying flight)

Gemini-Titan 8



Gemini-Titan 8

Launched March 16, 1966

MET 06:33:16 Docked with Agena Target Vehicle

MET 07:00 (approx) Initially imperceptible roll

MET 07:15:12 Emergency Undock from Agena

MET 07:16 160 deg/sec

MET 07:17:30 300 deg/sec for 46 sec

MET 07:22:40 60 deg/sec

MET 07:25:30 Vehicle control attained

MET 10:03:48 Reentry burn

MET 10:41:26 Splashdown

Loss of Vehicle Control - Lunar Module

Apollo 10 Lunar Module (LM) “Snoopy” checkout ascent stage 15 km above the lunar surface

Cernan suddenly exclaimed, "Son of a bitch!" Snoopy seemed to be throwing a fit and lurching wildly. Stafford yelled that they were in gimbal lock.

Crew were testing the abort guidance system (AGS), not the primary guidance system (PNGS) they were used to.

The abort system had two basic control modes, "attitude hold" and "automatic." In automatic, the computer would take guidance and start looking for the command module (not what the crew wanted).

In correcting for a minor rate-gyro disturbance, the crew had each switched the spacecraft to the automatic mode, resulting in frantic gyrations.

Loss of Vehicle Control - Shuttle

STS 32 - Erroneous state vector entered into onboard flight software by mission control flight team which had been on 12 hour night shifts for an extended period. Erroneous data command was repeatedly rejected, but controller overrode it.

While the crew slept the Shuttle made 5 complete rotations at up to 3 degrees/second.

The uplinked command error occurred just before normal communication loss between relay satellites and Shuttle.

Attitude control problems continued for 10 minutes while the vehicle was out of communication with the ground coverage.

Space Ship One Roll Anomaly

Space Ship One flight 16P

29 Sept 2004

Apogee 337,700 feet (103 km)

Asymetric thrust at high mach/ low AOA resulted in right roll of 190 deg/sec at 60 seconds into rocket burn.

Pilot Mike Melville reduced roll to 140 deg/sec with aerodynamic control but needed reaction control jets to overcome roll

Vehicle control regained just prior to apogee

Crew Coordination Related Medical Event

Apollo 18 (Apollo Soyuz Test Project)

- Crew performed landing checklist out of sequence.
- Cabin pressure relief valve was opened prior to drogue chute deployment.
- Crew manually deployed drogue chutes which caused capsule to sway, and reaction control system (RCS) fired to counteract motion.
- The opened pressure relief valve drew in toxic gases from the thrusters.
- Crew finally armed the automatic system 30 seconds later and RCS thruster terminated, but cabin was flooded with toxic Nitrogen Tetroxide.

- At splashdown, the capsule inverted (called Stable 2), and Brand became unconscious from fumes.
- Stafford managed to get free and climb back up and get an oxygen mask over Brand's face, who began to recover.
- When the command module flipped back upright, Stafford opened the vent valve, and fresh air dissipated the remaining fumes disappeared.
- Crew hospitalized for two weeks with chemical pneumonitis.

Progress-Mir Collision

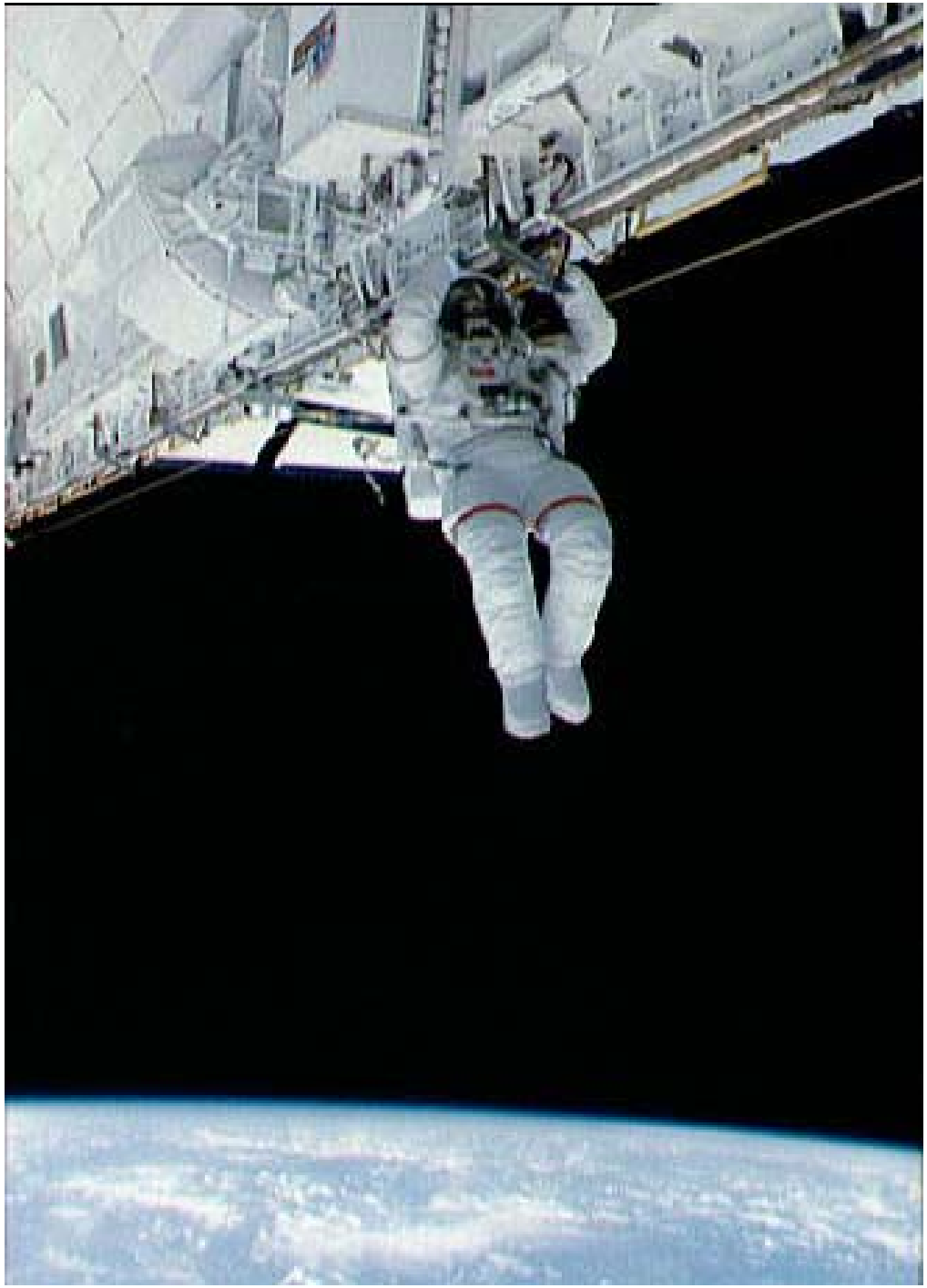
Progress-Mir Collision

Crew perform manual rendezvous and dock Progress re-supply ship to Mir space station using video (no direct view)

Radar shut down to avoid interference with docking camera video (no range/rate info)

Mission control overrode crew concerns about fatigue (slam shift, lack of sleep) and task proficiency (4 months since training) and lack of adequate video image (camera field of view required frequent attitude changes)

Near miss on Progress 33, Collision on Progress 34



Spacewalk Issues

Performance and Health Issues during EVA

- Thermal Injury – Gemini 9
- Separation from space craft – Salyut 6 PE-1
- Suit leak in Vacuum - STS 37
- Contact with Toxic Substances - STS 98
- Inability to perform tasks
  - Unable to see for 5 minutes (antifog in eyes) – STS 100
  - Unable to open airlock hatch during ingress - Salyut 6 EO-3
  - Excruciating pressure point pain due to boot fit - STS 98
  - EVA delayed due to SMS (Apollo 9, Skylab 3)
- Vomiting in space suit (STS)
- Falls (Apollo 15,16,17) and Injury (Apollo 17)
- Radiation
- Light Glare/ Darkness
- Life Support System failure
- Worksite injury (crush, electrical)
- Hypobaric space suit pressure (DCS)
- Micrometeoroid/ orbital debris (MMOD)

Summary

Hazards of the space environment, vehicle environment, and mission architecture present significant challenges to human performance and mission success

Spontaneous medical events occur in astronauts despite extensive selection and screening

On orbit countermeasures and medical capabilities have not eliminated significant events in space or need for evacuation

Human errors have contributed to events in space that have affected crew health and mission success

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