Federal Aviation Administration

Physiological, Operational & Environmental Risks in Manned Commercial Space Flights

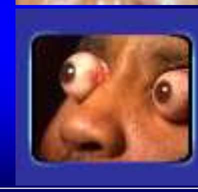
Presented at: *30th ICOH*

By: *Melchor J. Antuñano, M.D., M.S.*

Director, Civil Aerospace Medical Institute

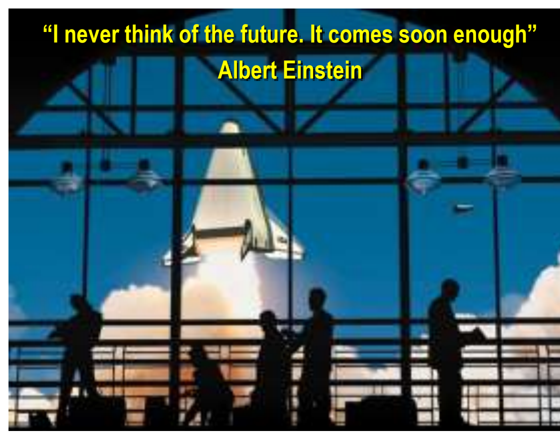
Date: *2012*

Open your Eyes to See New Possibilities



Commercial Space Flight

Federal Aviation Administration



Origins of Commercial Space Operations in the US

- September 9, 1982, Space Services Inc. conducted the first commercial space launch (Conestoga I). There were no statutes, policies, or regulations in the U.S. governing commercial space operations
- February of 1984 President Reagan issued an executive order assigning to the DOT the responsibility to oversee all U.S. commercial space operations (1984 Commercial Space Launch Act)
- The Commercial Space Launch Act was amended and recodified to become CFR, Title 49, Subtitle IX

Commercial Space Flight

Federal Aviation Administration

- November 1995, the DOT transferred such responsibility to the FAA and the Office of Commercial Space Transportation **(AST)** was created
- October 1998, Congress expanded AST's role to include licensing of reentries and reentry sites

FAA AST MISSION

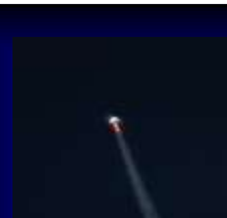
- Issue licenses for commercial space operations including commercial launch sites, reentry operations, reentry sites
- Promote, encourage, and facilitate the growth of the U.S. commercial space industry
- Carry out this responsibility consistent with public health and safety, safety of property, and the national security and foreign policy interests of the United States

Populations Impacted by Commercial Space Flights

Crews

Passengers

Suborbital Commercial Space Flights



June 21, 2004 - Mike Melvill flew SpaceShipOne to an altitude of 328,491 ft and set a world-record for the first manned suborbital flight onboard a private space vehicle

September 29, 2004 - Mike Melvill completed the first of the two official suborbital flights (337,500 ft) required to win the “Anzari X Prize”

Commercial Space Flight

Federal Aviation Administration

October 4, 2004 - Brian Binnie became the 434th human to fly into space after reaching an altitude of 367,442 ft and winning the Anzari X-Prize:

- Surpassed the altitude (354,200 ft) reached by Joe Walker onboard an X-15 on August 22, 1963
- 47 years after the launch of the Russian Satellite “Sputnik”

Commercial Space Flight

Federal Aviation Administration

SpaceShipTwo will be capable of carrying 2 pilots and 6 passengers on a 3-hour suborbital flight (including 4 minutes of microgravity) for about $200K

Sir Richard Branson (founder of Virgin Atlantic Airways) has established a space tourism company named “Virgin Galactic”

SpaceShipTwo will be capable of carrying 2 pilots and 6 passengers on a 3-hour suborbital flight (including 3-4 minutes of microgravity).

Commercial Space Flight

Federal Aviation Administration

In April 2011 VG published an announcement for pilot-astronaut candidates (550 applicants)

Southwest Research Institute

February 28, 2011

Signed multi-million dollar contracts to fly researchers aboard Virgin Galactic’s SpaceShipTwo and XCOR’s Lynx to conduct scientific research (including biomedical)

Commercial Human Space Flight Update

Federal Aviation Administration


Will take a pilot and a passenger on a suborbital flight that includes three minutes of microgravity for about $100,000 per passenger
LYNX


Goddard
SPACE TOURISM
UP AND AWAY
In the latest bid to rocket tourists into orbit, the secretive Blue Origin unveils a flying pod. Is your space voyage sooner than you think?


DCX


Test Vehicle 2
Mach 1.2 at 45K ft in August 2011


Armadillo Super-MOD Vehicle
$225K NASA CRuSR Contract in 2010


$250K NASA CRuSR Contract in 2010
Masten
SPACE SYSTEMS


Copenhagen Suborbitalis


Orbital
Commercial
Space Flights


$278M NASA COTS 2006
$1.5B NASA CRS 2008
$75M NASA CCDev2 2011
FALCON 9 / DRAGON:
NASA's Choice to Resupply the Space Station

SpaceX has plans to become the world's largest producer of rocket engines in less than five years, manufacturing more units per year than any other single country

SpaceX's will invest $30 million into a Southern California launch site which is projected to:

- generate more than 10,000 new jobs
- serve as an economic stimulant

Commercial Human Space Flight Update

Federal Aviation Administration

Orbital Sciences Cygnus

$278M NASA COTS 2006

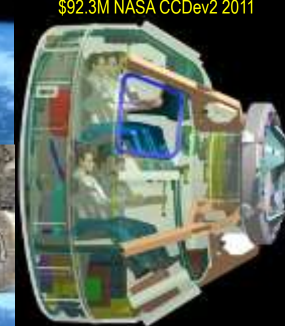
$175M NASA COTS 2007

$1.9B NASA CRS 2008

Boeing CST-100

$18M NASA CCDev1 2010

$92.3M NASA CCDev2 2011

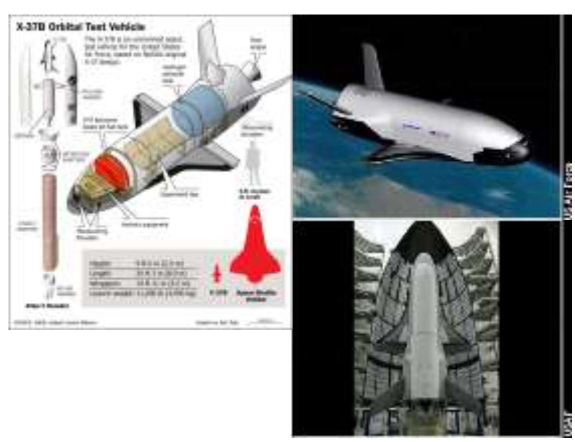



Sierra Nevada Dream Chaser
$175M NASA COTS 2007
$80M NASA CCDev2 2011


Excalibur
Almaz


Energia
Kliper


Shenzhou


X-37B Orbital Test Vehicle

COMMERCIAL ORBITAL FLIGHTS
(Soyuz TMA Launch Vehicles)

Space Adventures
Russian Aviation Space Agency (Rosaviakosmos)
Rocket Space Corporation Energia (RSC Energia)

- Dennis Tito (April 2001)
- Mark Shuttleworth (April 2002)
- Greg Olsen (October 2005)
- Anousheh Ansari (September 2006)
- Charles Simony (April 2007)
- Richard Garriott (October 2008)
- Charles Simony (April 2009)
- Guy LaLiberte (2009)

Space Adventures Proposal

Space tourists may have the option of performing a spacewalk for an additional multi-million dollar fee

Space Adventures Proposal

Circumlunar flights is another option for an estimated fee of $100 million by 2015-17 (James Cameron???)

Commercial Spaceports


Oklahoma
Spaceport


SpacePort America – New Mexico


Commercial Human Space Flight Update
Federal Aviation
Administration

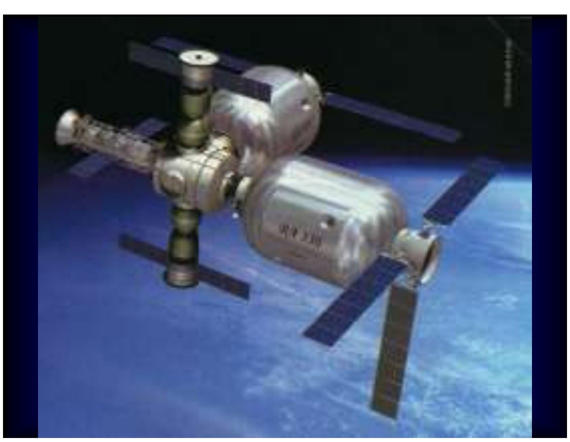

Blue Origin Private Spaceport - Texas
Future Challenges in Commercial Aviation & Space Transportation
Federal Aviation
Administration

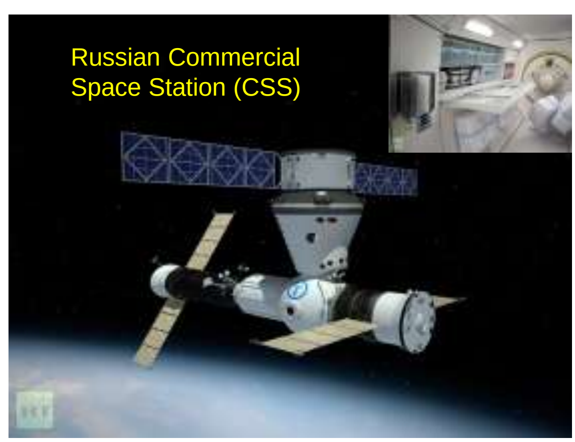

Singapore Spaceport


Commercial Space Stations
Future Challenges in Commercial Aviation & Space Transportation
Federal Aviation Administration


Robert Bigelow (founder of Bigelow Aerospace) announced his decision to sponsor a $50 million "America's Space Prize" competition to build and fly a private spacecraft capable of carrying no less than 5 people into orbit
Safety and Survivability Issues in Civil Aviation
Federal Aviation Administration


• Genesis I – 2006 – Magadascar Cockroaches and Mexican Jumping Beans
• Genesis II – July 2007 – Cockroaches and scorpions
• Galaxy – Late 2008 – Larger module with a LSS
• Sundance – Ready for visitors by 2012?

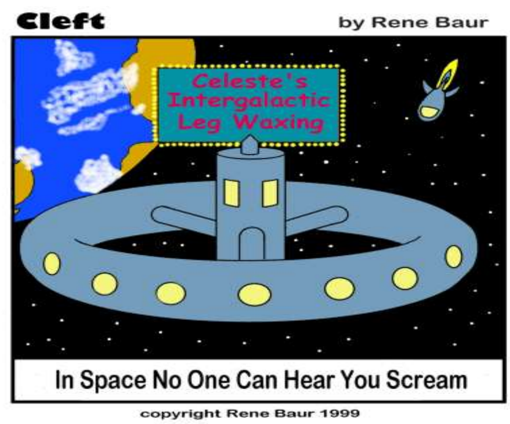



Russian Commercial Space Station (CSS)

Russian firms unveiled their plans to build an orbiting hotel with room for seven guests by 2016

A 5-day stay at the hotel is expected to cost about US$ 160,000. The whole trip, including a two-day transfer to the CSS on the Soyuz space ship will cost about US$ 800,000

Other plans include flying tourists to the dark side of the moon and, by 2030, to Mars



Regulatory Oversight

At the present time, the U.S. is the only country that has established licensing requirements for manned commercial space operations

The U.S. Commercial Space Launch Amendments (CSLA) Act of 2004 (H.R. 5382)

Requires space passengers to be fully informed about all of the potential risks of participating in space flights allowing them to fly at their own risk

What potential risks should be disclosed?

What is an appropriate/sufficient full-disclosure of potential risks that would:

- **Minimize liability for the operator?**
- **Not produce excessive fear among prospective space participants?**

An operator must present this information in a manner that can be readily understood by a space flight participant with no specialized education or training, and must disclose in writing:

(1) For each mission, each known hazard and risk that could result in a serious injury, death, disability, or total or partial loss of physical and mental function.

(2) That there are hazards that are not known.

(3) That participation in space flight may result in death, serious injury, or total or partial loss of physical or mental function.

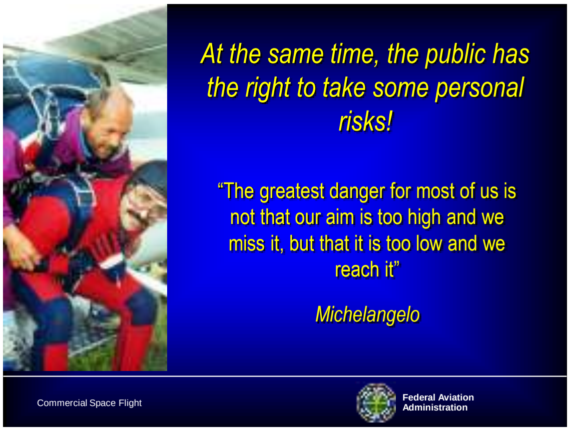
Why is Risk Disclosure Important?

Passenger Safety & Liability Issues

The problem is that we live in a litigious society where the safety of space passengers is a critical issue that the manned commercial space transportation industry must address proactively and comprehensively.

Commercial Space Flight

Federal Aviation Administration


At the same time, the public has the right to take some personal risks!
"The greatest danger for most of us is not that our aim is too high and we miss it, but that it is too low and we reach it"
Michelangelo
Commercial Space Flight
Federal Aviation Administration


Always be prepared to deal with risks in disguise!
Commercial Space Flight
Federal Aviation Administration


RISK MANAGEMENT
Perception vs Reality


Skill and Experience may not be Enough to Eliminate all Risks
Following Safety Procedures and Using Personal Protective Equipment is Always a Good Idea!


Risks in Space

Is it Risky to Fly in Space?

Yes, but risks vary

Suborbital
vs
Orbital

Yes, but risks vary

Short Flights
vs
Long Flights

RISK FACTORS FOR THE OCCUPANTS OF SPACE VEHICLES

1. *PHYSIOLOGICAL/INDIVIDUAL FACTORS*
2. *EXTERNAL ENVIRONMENTAL FACTORS (Flight Environment)*
3. *OPERATIONAL FACTORS (Vehicle and Flight Operations)*

RISK FACTORS FOR THE OCCUPANTS OF SPACE VEHICLES

1) INDIVIDUAL FACTORS:

- Unidentified or undisclosed pre-existing medical conditions
- Unexpected inflight medical emergencies (acute illnesses or trauma)
- Self-imposed stress (alcohol and drug use/abuse, nicotine addiction, self-medication, fatigue, dehydration, poor fitness, extreme overweight)

RISK FACTORS FOR THE OCCUPANTS OF SPACE VEHICLES

1) INDIVIDUAL FACTORS:

- Space motion sickness
- Unknown or undisclosed pregnancy
- Undisclosed use of medications
- Disruptive passengers

Do we know *all the Medical Risks of Flying in Space?*

NO!

We have very limited medical experience and knowledge on individuals with significant medical problems who have flown in space

Most of the medical and physiological data collected to date are based on the effects of space flight on generally normal and healthy individuals (career astronauts and cosmonauts)

Until now most people who have flown in space are healthy career astronauts aged 35 to 50 years old

Due to medical privacy regulations and career considerations individual medical data from career astronauts is not available for study by the scientific community

What Medical Data is Available to the Public?

Inflight Medical Events Among U.S. Astronauts

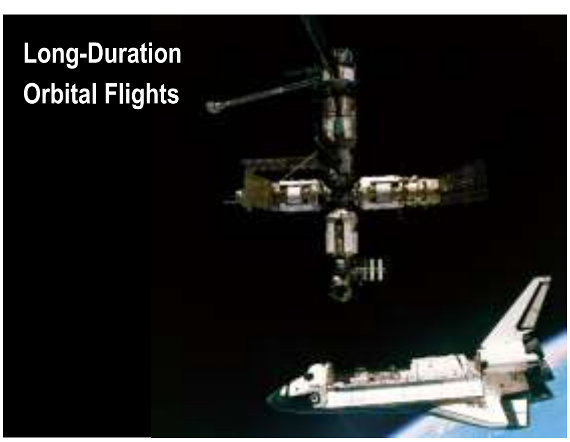
106 Space Shuttle Missions (Apr 1981 – Dec 2001)
607 Astronauts (521 men and 86 women)
5,496 Flight Days

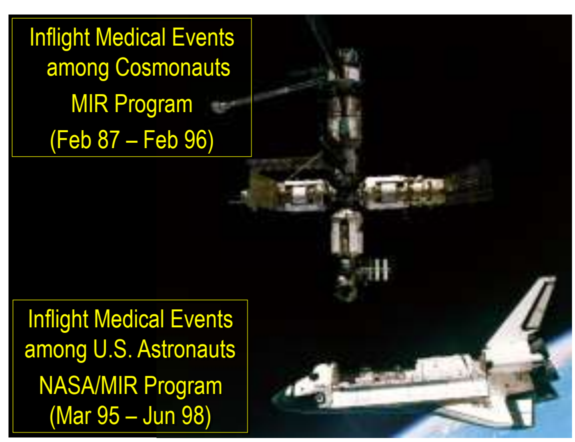
- *98.1% of men and 94.2% of women reported 2,207 medical events or symptoms during flight:*
  - Space adaptation syndrome (39.6%)
  - Nervous system and sensory organs (16.7%)
  - Digestive system (9.2%)
  - Injuries and trauma (8.8%)
  - Musculoskeletal system and connective tissues (8.2%)

- Skin and subcutaneous tissue (8%)
- Respiratory system (4.5%)
- Behavioral signs and symptoms (1.8%)
- Infectious diseases (1.3%)
- Genitorurinary system (1.5%)
- Circulatory system (0.3%)
- Endocrine, nutritional, metabolic & immunity disorders (0.1%)

194 events due to injury (including 14 fatalities)

SOURCE: Jon Clark, MD, Space Medicine Liaison, National Space Biomedical Research Institute, Baylor College of Medicine, Personal Communication, 2007





Inflight Medical Events Among U.S. Astronauts during the NASA/MIR Program (Mar 95 – Jun 98)

MEDICAL EVENT	FREQUENCY
Musculoskeletal	7
Skin	6
Nasal congestion, irritation	4
Bruise	2
Eyes	2
Gastrointestinal	2
Hemorrhoids	1
Psychiatric	2
Headaches	1
Sleep disorders	1

Inflight Medical Events Among Cosmonauts during the MIR Program (Feb 87 – Feb 96)

MEDICAL EVENT	FREQUENCY
Arrhythmia/conduction disorder	128
Superficial Injury	36
Musculoskeletal	29
Headache	24
Sleeplessness	19
Tiredness	14
Contact dermatitis	7

SOURCE: Jon Clark, MD, Space Medicine Liaison, National Space Biomedical Research Institute, Baylor College of Medicine, Personal Communication, 2007

Conjunctivitis	6
Laryngitis	6
Asthenia	5
Erythema of face, hands	4
Acute respiratory infection	3
Surface burn, hands	3
Glossitis	3
Dry nose	2
Heartbrun /gas	2
Foreign body in eye	2
Dry skin	2
Hematoma	1
Constipation	1
Eye contusion	1
Dental caries	1
Wax in ear	1

FAA's philosophy is different than NASA's on the determination of medical fitness for flight

We authorized a routine Class 2 Airman Medical Certificate issued by an Aviation Medical Examiner (AME) and reviewed by the Aerospace Medical Certification Division at CAMI

What is the minimum "Right Stuff" for passengers in commercial space flights?

Commercial Space Flight

Federal Aviation Administration

Flying in space is not like taking a role coaster ride

FAA Office of Aerospace Medicine

February 11, 2005

- The "Guidance for Medical Screening of Commercial Aerospace Passengers" was released to the public during the 8th FAA Commercial Space Transportation Forecast Conference.
- This was the culmination of a team effort that started in July 1998.

"FAA Recommended Guidelines for Medical Screening of Commercial Space Passengers"

Main Risk Factors Relevant to the Development of Guidelines for Medical Screening of Commercial Space Passengers

- Exposure to acceleration/deceleration
- Exposure to decreased barometric pressure
- Exposure to microgravity
- Exposure to radiation (solar and cosmic)

Medical Conditions that may Contraindicate Passenger Participation in Suborbital or Orbital Space Flights

Any deformities (congenital or acquired), diseases, illnesses, injuries, infections, tumors, treatments (pharmacological, surgical, prosthetic, or other), or other physiological or pathological conditions that may:

1) Result in an in-flight death
2) Result in an in-flight medical emergency
3) Interfere with the proper use (don and doff) and operation of personal protective equipment
4) Interfere with in-flight emergency procedures or emergency evacuation
5) Compromise the health and safety of the passenger or other space vehicle occupants, and/or the safety of the flight

Other Considerations

- Some medical conditions may be cleared for space flight following special medical assessments in simulated spaceflight environments including the use of a zero-G aircraft, a high performance aircraft, a hypobaric (altitude) chamber, or a human centrifuge
- Using a flexible approach that applies aerospace medicine knowledge and experience-based medical risk analysis, it may be possible to permit special medical accommodations for prospective participants who have certain pathologies (including disabilities)

Other Guidance

- No conclusive data exist concerning the potential adverse physiologic and pathologic effects of space flight on <u>infants or young children</u>
- Operators may wish to establish a <u>minimum age</u> for passengers participating in space flights

- Because of the potential hazards of space flight (including exposure to solar and cosmic galactic radiation, acceleration, and microgravity), <u>it is highly recommended that a female of child-bearing age be offered a pregnancy test</u>
- <u>Operators may wish to consider excluding pregnant women from participating in space flights</u>, until more medical information becomes available to assess the actual risks of space flight for pregnant women and their unborn children

Controversial Consideration

- There may be some individuals suffering <u>terminal medical conditions</u> who may wish to participate in a space flight before they pass away
- Operators will have to decide whether or not such individuals will be allowed to participate in a space flight
- This will be a very difficult decision to make due to a number of significant ethical and legal implications

IAA Study Group 2.6

"Medical Safety Considerations for Passengers on Short-Duration Commercial Orbital Space Flights"

The final report contains a list of medical conditions that could be adversely impacted by exposure to the operational and environmental risk factors in orbital space flights

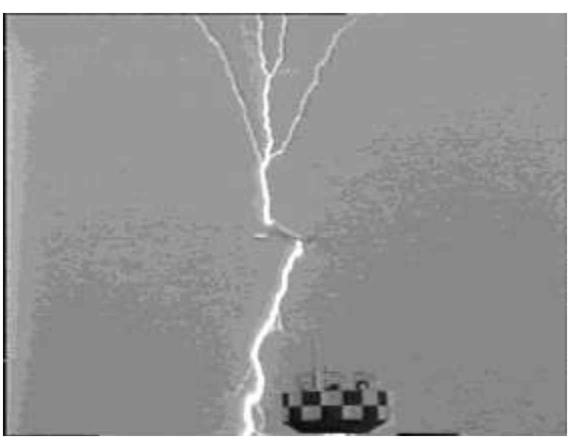
RISK FACTORS FOR THE OCCUPANTS OF SPACE VEHICLES

2) EXTERNAL ENVIRONMENTAL FACTORS:

- Weather (during the atmospheric phase of flight)
- Wildlife strikes
- Barometric pressure and decompression
- Ambient temperature extremes
- Ionizing and non-ionizing radiation
- Microgravity/weightlessness
- Space debris (natural and human-made)

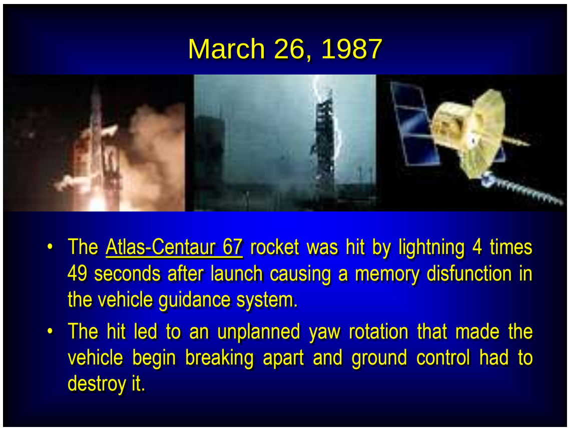
Commercial Space Flight — Federal Aviation Administration

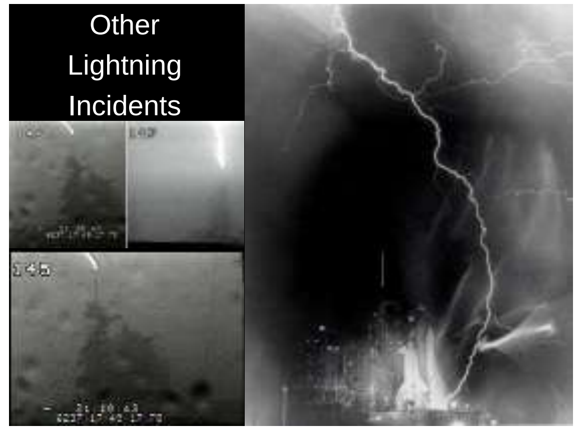
Weather-Related Risks



November 14, 1969

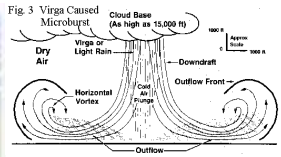
Apollo 12 experienced major electrical disturbances after been hit by lightning 36.5 and 52 seconds after lift off


March 26, 1987
The Atlas-Centaur 67 rocket was hit by lightning 4 times 49 seconds after launch causing a memory disfunction in the vehicle guidance system.
The hit led to an unplanned yaw rotation that made the vehicle begin breaking apart and ground control had to destroy it.


Other Lightning Incidents


STS-117 Hail Storm Damage


January 28, 1986
Space Shuttle Challenger explodes 73 sec after launch killing Christa McAuliffe, Dick Scobee, Michael Smith, Ellison Onizuka, Judith Resnik, Ronald McNair and Gregory Jarvis.



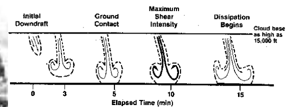
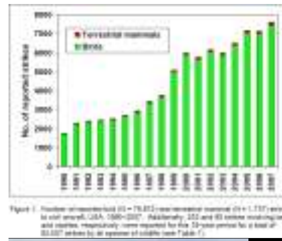


Fig. 4 Lifecycle of a typical Microburst.



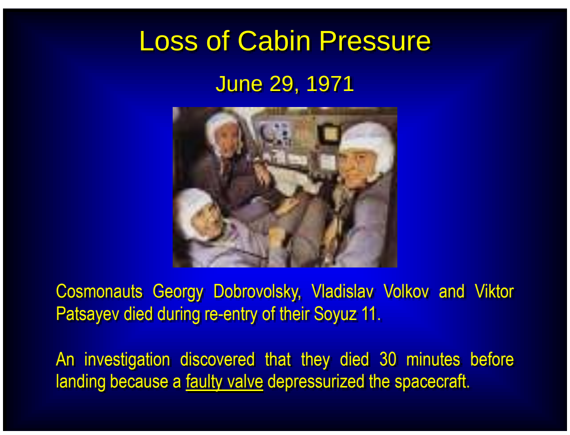
Bird Strikes

July 2005

Space Shuttle external tank was hit by a turkey vulture during launch


161


INFLIGHT DECOMPRESSION


Loss of Cabin Pressure
June 29, 1971
Cosmonauts Georgy Dobrovolsky, Vladislav Volkov and Viktor Patsayev died during re-entry of their Soyuz 11.
An investigation discovered that they died 30 minutes before landing because a faulty valve depressurized the spacecraft.


June 25, 1997
A Progress M-34 spacecraft crashed into the Spektr module while maneuvering for a docking. The collision damaged one of Spektr's solar arrays and punctured the hull, depressurizing the module. The module was sealed off from the rest of the station to prevent depressurization of the entire Mir space station.


SpaceShipOne test pilots did not use pressure suits


Space Debris Risks
Future Challenges in Commercial Aviation & Space Transportation
Federal Aviation Administration

The USAF Space Command uses 30 radar and optical sensors to track about 10,000 man-made objects as small as 10 cm. (baseball) flying in LEO or low-earth orbit (below 2,000 km) at about 17,500 mph

About 84% of these objects travel below 800 km

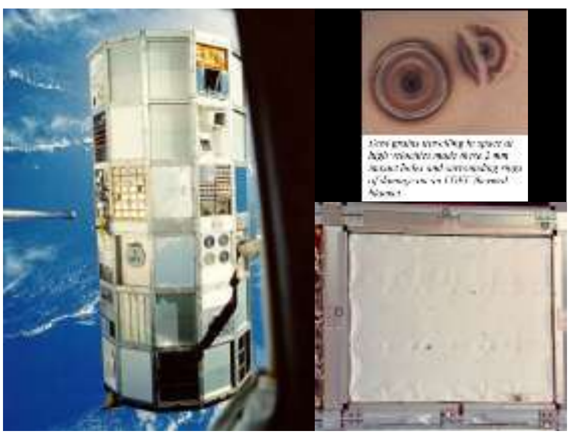
A 1999 study estimated there are ~4 mill pounds of space junk in LEO

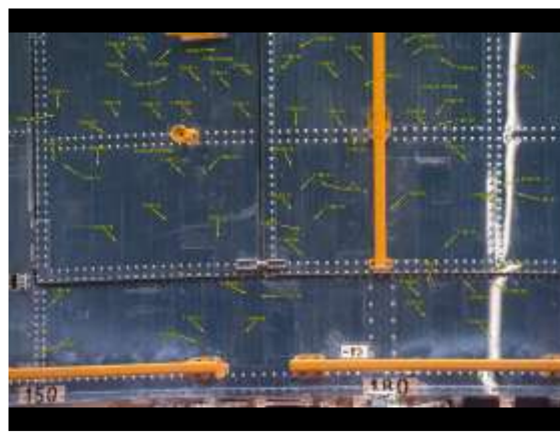
~110,000 objects are larger than 1 cm

LEO GEO GEO Polar

ASAT TEST
Xichang Space Center, China
January 11, 2007

Visualization using the data tracks available on March 1, 2007





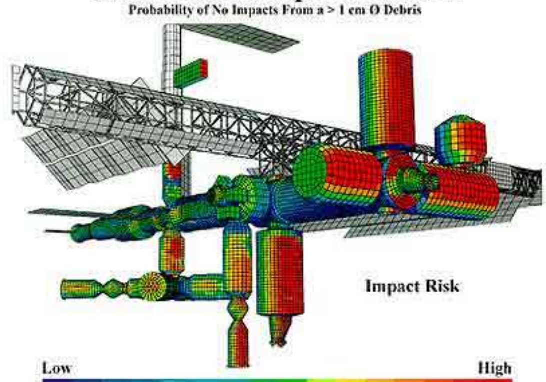
Space debris will be a risk factor for the occupants of orbital space vehicles

A speck of paint from a satellite dug a pit in a space shuttle window nearly ¼ inch wide

NASA has replaced more than 80 shuttle windows due to debris impacts

International Space Station

Probability of No Impacts From a > 1 cm Ø Debris



Impact Risks in LEO

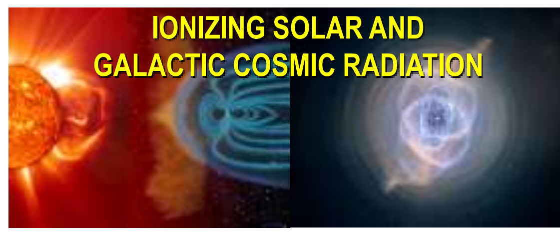
- 18% chance that a debris impact would force abandoning of ISS (when 100% completed)
- 9% chance of penetration that would lead to loss of station and/or its crew
  - Installation of 23 ISS debris shields will ↓ these odds to 14% and 8% respectively
  - Installation of 22 Kg of shields on Progress and Soyuz spacecraft will ↓ these odds to 8% and 5% respectively

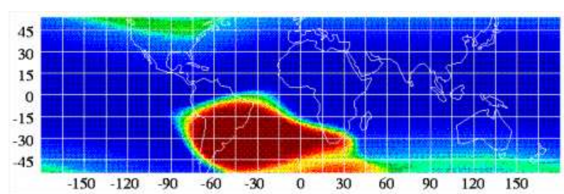
Final Report: of the International Space Station Independent Safety Task Force
February 2007


Space debris could become a concern for the safety of people on the ground

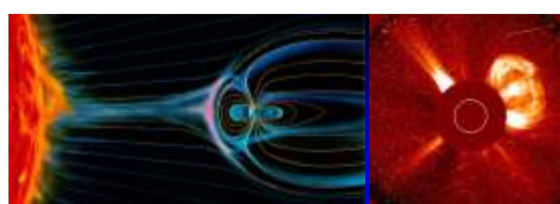
January 1997 – A 580 pound tank from the 2nd stage of a Delta 2 survived reentry and crashed in Georgetown, Texas

January 2001 – A 140 pound payload assist module of a Delta 2 crashed in Saudi Arabia





The main sources of ionizing radiation in space are <u>geomagnetically trapped radiation</u>, <u>solar particle event radiation</u>, and <u>galactic cosmic radiation</u>



IONIZING SOLAR AND

The main sources of ionizing radiation in space are <u>geomagnetically trapped radiation</u>, <u>solar particle event radiation</u>, and <u>galactic cosmic radiation</u>

Galactic Cosmic Radiation (GCR)

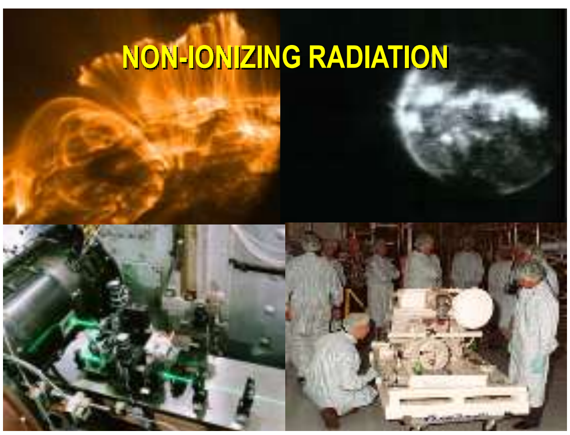
- Originates outside the solar system
- Solar Cycle Dependent
  - Highest during Solar Minimum
- Extremely High Energy
  - Very Penetrating
  - Hard to Shield
- Fully Charged Atomic Nuclei
  - Protons
  - Biologically Most Damaging
- Highest Levels in open magnetic field areas (aka low cutoff zones)

Space radiation is more damaging than radiation typically encountered by ground-based workers

Experimental evidence indicates that space radiation is more effective at causing the type of biological damage that ultimately leads to cancer than the gamma or x-rays commonly encountered on Earth.

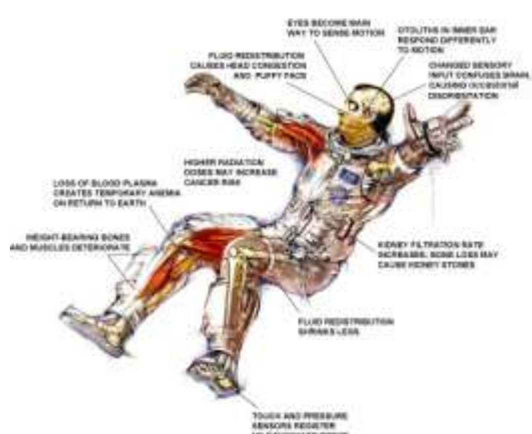
Animal experiments show evidence of biological damage unique to high-energy heavy ions encountered in space.

Damage to the central nervous system similar to that associated with aging.



Physiological Effects of Exposure to Microgravity

- Cardiovascular
- Musculo-skeletal
- Neurovestibular
- Hematologic & immunologic



a. Fluid distribution on Earth
b. In microgravity fluids redistribute
c. Kidneys eliminate fluids
d. Returning to Earth

The physiological changes resulting from exposure to microgravity depend upon the total duration of the exposure, and can vary in magnitude from individual to individual

RISK FACTORS FOR THE OCCUPANTS OF SPACE VEHICLES

3) OPERATIONAL FACTORS (Vehicle and Flight Operations):

- Type of acceleration profile (take off/launch, cruise, landing) and relative position of the occupants during acceleration exposure
- Type of flight profile (ascent rate, maximum altitude, descent rate, duration of the flight)
- Cabin/suit pressurization profile
- Noise/vibration exposure during flight

HIGH-INTENSITY NOISE

Noise is produced by rocket propulsion systems, thrusters, hydraulic and electrical actuators, cabin air conditioning and pressurization systems, cockpit advisory and alert systems, communications equipment, motors, fans, pumps, transformers, oscillators, etc

Noise can also be caused by the aerodynamic interaction between ambient air (boundary layer) and the surface of the space vehicle during the atmospheric portion of the flight

VIBRATION

Vibration is transmitted throughout the entire body

Vibration is transmitted throughout the entire body

Vibration exposure usually occurs during the launch and atmospheric entry phases of a space flight, or while using the thrusters

Other sources of inflight vibration include motors, pumps, and other mechanical equipment

RISK FACTORS FOR THE OCCUPANTS OF SPACE VEHICLES

2) OPERATIONAL FACTORS (Vehicle and Flight Operations):

- Breathing air (composition, contaminants, CO_2 removal, volume per occupant)
- Cabin/suit temperature and humidity
- Impact/crash exposure (structural integrity or crashworthiness, occupant restraint systems, personal protective equipment, emergency evacuation systems, etc.) and survival

FAA Office of Aerospace Medicine

(August 2003 to November 2004)

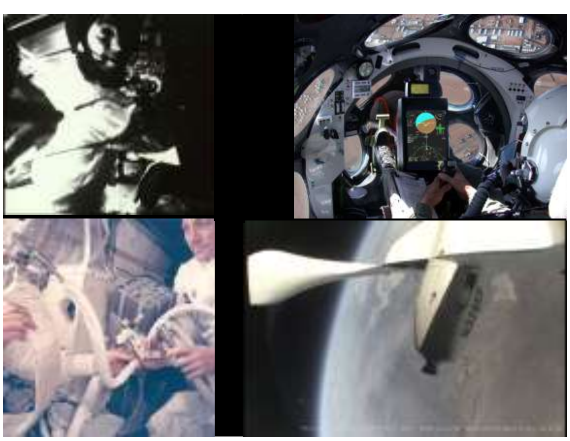
The Civil Aerospace Medical Institute (CAMI) worked on and produced an internal report on “Minimum Environmental Control & Life Support Guidelines for Manned Commercial RLVs”

CABIN AIR

April 1970

- Apollo-XIII
- Lovell/Haise/Sweigert
- Explosion in service module
- Limited O_2/Mission aborted
- Dehydration – UTI – Fatigue - $\uparrow CO_2$

- In the sealed cabin environment of a space vehicle there are several potential risks including the presence of biological, chemical and particulate contaminants
- Carbon dioxide released by all occupants during exhalation could accumulate and become a breathing hazard especially during sleep due to lack of convective air circulation
- Breathing 100% oxygen (instead of a gas mixture) at sea level pressure for prolonged periods of time could cause reduced vital capacity, respiratory disturbances, heart problems, blindness, and loss of consciousness



- *Odors are known to cause symptoms such as nausea, nasal congestion, coughing, headaches and irritability*
- *The most common sources of odor onboard a space vehicle are sweat, food, and organic waste*

TEMPERATURE

The lack of an atmosphere in space exposes space vehicles to extremely cold and hot ambient temperatures that vary depending upon the effective surface area of the vehicle that is directly exposed to radiant heat coming from the sun

A space vehicle is exposed to high levels of aerodynamic heat produced during the atmospheric entry

These temperature extremes represent a potential hazard for all vehicle occupants, who must rely on the proper operation of the cabin heating, air circulation, and cooling systems

These systems must maintain the right balance between air temperature, air velocity, barometric pressure, and humidity

HUMAN TOLERANCE TO DECELERATION (250 G/sec)

+ Gz: 25 Gs for 0.1 sec
- Gz: 15 Gs for 0.1 sec

+ Gx: 83 Gs for 0.04 sec
  45 Gs for 0.1 sec
  25 Gs for 0.2 sec
- Gx: 45 Gs for 0.1 sec (full harness)
  25 Gs for 0.2 sec (full harness)

± Gy: 11-20 Gs for 0.1 sec (full harness)

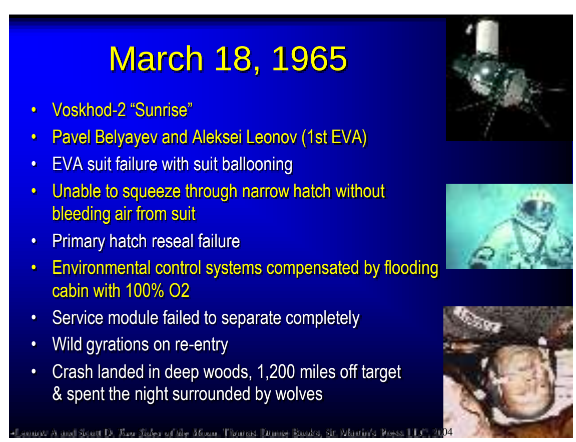
Commercial Space Flight — Federal Aviation Administration


CAMI
SLED TEST


ARNOULD
Vancouver
CANADA
"You want me to do what?"


Commercial Space Flight
Federal Aviation Administration


NTSB reported that the current failure rate of slides in the U.S. is about 30%
Commercial Space Flight
Federal Aviation Administration


March 18, 1965
Voskhod-2 "Sunrise"
Pavel Belyayev and Aleksei Leonov (1st EVA)
EVA suit failure with suit ballooning
Unable to squeeze through narrow hatch without bleeding air from suit
Primary hatch reseal failure
Environmental control systems compensated by flooding cabin with 100% O2
Service module failed to separate completely
Wild gyrations on re-entry
Crash landed in deep woods, 1,200 miles off target & spent the night surrounded by wolves

RISK FACTORS FOR THE OCCUPANTS OF SPACE VEHICLES

2) OPERATIONAL FACTORS (Vehicle and Flight Operations):

- Physical hazards (electrical, chemical, thermal) of the cabin
- Injuries due to accidental contact with internal structures or objects especially during microgravity
- Inflight fire (fire retardant materials, toxic materials, fire suppression systems)


January 27, 1967
Apollo 1 Astronauts Gus Grissom, Edward White and Roger Chaffee died
when a fire blazed their command module during a ground test at KSC.


LIMITED MEDICAL INTERVENTION
CAPABILITIES DURING FLIGHT