

Overview of Space Health Threats and Technology Drivers

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Significant Challenges of Deep Space Missions

Human Space Exploration beyond Low Earth Orbit presents significant challenges to human health and performance

1. Loss of Van Allen Belt Radiation Protection
2. Communication delays (no real time support)
3. Training and proficiency issues
4. No resupply unless pre-positioned stores
5. Limited or no abort options for critical events

Human Spaceflight Experience

As of March 2017

Total spaceflight time: 136.4 crew-years

Persons who have flown in orbit: 552 (60 women)

Crew with Cumulative spaceflight in Low Earth Orbit

Over 800 days - 3

Over 700 days - 5

Over 600 days - 7

Over 500 days - 19 (2 US)

Over 400 days - 22 (2 US)

Over 365 days - 35 (6 US)

Crew with single mission duration over 1 year - 4

Significant Incidents and Close Calls in Human Spaceflight

LEGEND

Loss of Crew

Crew Injury/Illness and/or Loss of Vehicle or Mission

Related or Recurring event

STS-110	4/8/2002
STS-109	3/1/2002
STS-108	12/5/2001
STS-91	6/2/1998
Soyuz TM-9	2/11/1990
SRB Seal Events (1981-96)	
STS-51L (Challenger) 1/28/1986	
Other SRB gas seal anomalies: STS-2, 6, 41B, 41C, 41D, 51C, 51D, 51B, 51G, 51F, 51I, 51J, 61A, 61B, 61C, 42, 70, 71, 78	
STS-51F	7/29/1985
Soyuz 18-1(18a)	4/5/1975
Apollo 13	4/11/1970
Apollo 12	11/14/1969
Gemini 10	7/18/1966

Progress M-12M 8/24/2011 (44P)

EVA Incidents Summary (1965-2014)

13 EVAs resulted in crew injury:
Gemini 10, Apollo 17, Salyut 7
PE-1, Salyut 7 VE-3, STS-61-B
EVAs 1&2, STS-37, Mir PE-9,
STS-63, STS-97/4A, STS-100/6A
EVAs 1&2, STS-134/ULF6

Ascent Debris

STS-124 5/31/2008

STS-95 10/29/1998

Other significant ascent debris events have occurred on:

STS-116 and STS-125

Late Release Orbiter Tyvek Covers

STS-114, 115, 118, 119, 124, 126

STS-112	10/7/2002
STS-61C	1/6/1986
On-pad Abort Events (1984-93)	
STS-41D	6/26/1984
Soyuz T-10-1(T-10a)	9/26/1983
Other On-pad Abort Events: STS-51F, STS-55, STS-51, STS-68	
STS-1	4/12/1981
Apollo 1 (AS-204)	1/27/1967
Gemini 6	12/12/1965

SpaceShipOne 9/29/2004 16P

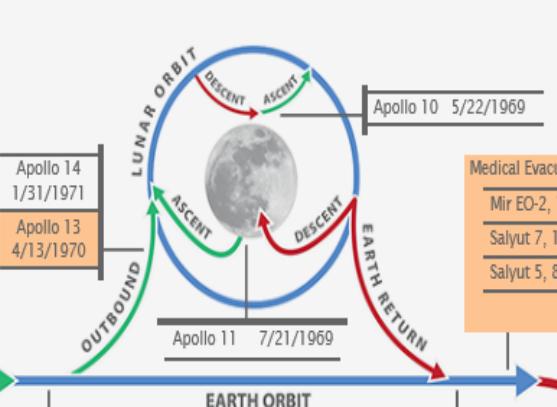
SpaceShipOne 5/13/2004 14P

SUBORBITAL FLIGHTS

X-15 3-65-97 11/15/1967

Apollo 14 1/31/1971

Apollo 13 4/13/1970



ISS Increment 38	12/1/2013	STS-95	10/29/1998
Soyuz TMA-18 (22S)	9/23/2010	STS-87	11/27/1997
ISS, Increment 17	4/30/2008	Mir	7/17/1997
ISS, Increment 15	6/10-6/18/2007	STS-83	4/6/1997
ISS, Increment 13	8/2006	STS-51	9/12/1993
ISS, Increment 10	2/2005	STS-44	11/24/1991
ISS, Increment 5&6 mid 2002-2/03		STS-21	1/9/1990
ISS, Increment 2-4 4/2001-3/2002		STS-9	12/8/1983
ISS, Increment 4	2/2002	STS-2	11/12/1981
ISS	8/2001	Soyuz 33	4/12/1979
STS-104	7/2001	Soyuz 23	10/16/1976
ISS, Increment 2	4/24/2001	Soyuz 21	8/24/1976
STS-99	2/2000	Soyuz 1	4/23/1967
ISS, Flight 2A.1	5/1999	Cosmonaut 8	3/16-3/17/1966
		Mercury MA-9	5/16/1963

Altitude Chamber	O2 Fire - Soviet 3/23/1961	Navy Chamber	11/17/1962
		M21-D21	7/30/1966

ASCENT **ENTRY** **CRUISE** **DESCENT**

SpaceShipTwo, PF04 10/31/2014

LAUNCH/GROUND

RESEARCH FACILITY

ATMOSPHERIC FLIGHTS

LANDING & POSTLANDING



SR-71 X-15 Soyuz 1 Apollo 1 Soyuz 11 Challenger Columbia SpaceShipTwo

Soyuz TM-5 9/6/1988

Soyuz T-11 10/2/1984

Soyuz 33 4/12/1979

Skylab 4 2/8/1974

Soyuz 11 6/30/1971

Crew Illness

Service/Descent Module (1961-2008) Separation Failures

Soyuz TMA-11 (15S) 4/19/2008

Soyuz TMA-10 (14S) 10/21/07 Crew: 3

Soyuz 5 1/18/69 Crew: 2

Voskhod 2 3/19/65 Crew: 1

Vostok 5 6/19/63 Crew: 1

Vostok 2 8/7/61 Crew: 1

Vostok 1 4/12/61 Crew: 1

TPS Entry Events (1981-2003)

STS-107 (Columbia) 2/1/2003

STS-51D 4/19/1985

STS-1 4/14/1981

Other significant STS TPS anomalies:

STS-6, 41B, 51C, 27, 28, 40, 42, 45

Most severe tile damage to date.

STS-134 6/1/2011

STS-108 12/7/2001

STS-90 5/3/1998

STS-37 4/11/1991

STS-51D 4/19/1985

Soyuz TM-7 4/27/89

STS-9 12/8/1983

STS-3 3/30/1982

Soyuz 36 7/31/80

Soyuz 23 10/16/76

Apollo 15 8/7/1971

Apollo 12 11/24/1969

Soyuz 5 1/18/69

Soyuz 1 4/24/67

Soyuz Landing Events (1967-1993)

Soyuz TM-15 2/1/93

Soyuz TM-14 8/10/92

Soyuz TM-12 10/10/91

Soyuz TM-7 4/27/89

Soyuz T-7 12/10/82

Soyuz 36 7/31/80

Soyuz 23 10/16/76

Soyuz 18-1(18a) 4/5/75

Soyuz 5 1/18/69

Soyuz 1 4/24/67

Significant Events in Human Spaceflight

Space Fatalities

Russian – 4 crew (2 Soyuz)

US – 15 crew (X-15, 2 Space Shuttles)

Mission Terminations/ Evacuations from Space

Russian - 3 missions terminated and 3 near terminations

Spacecraft Combustion Events

6 Salyut/ Mir, 4 Shuttle, 3 ISS

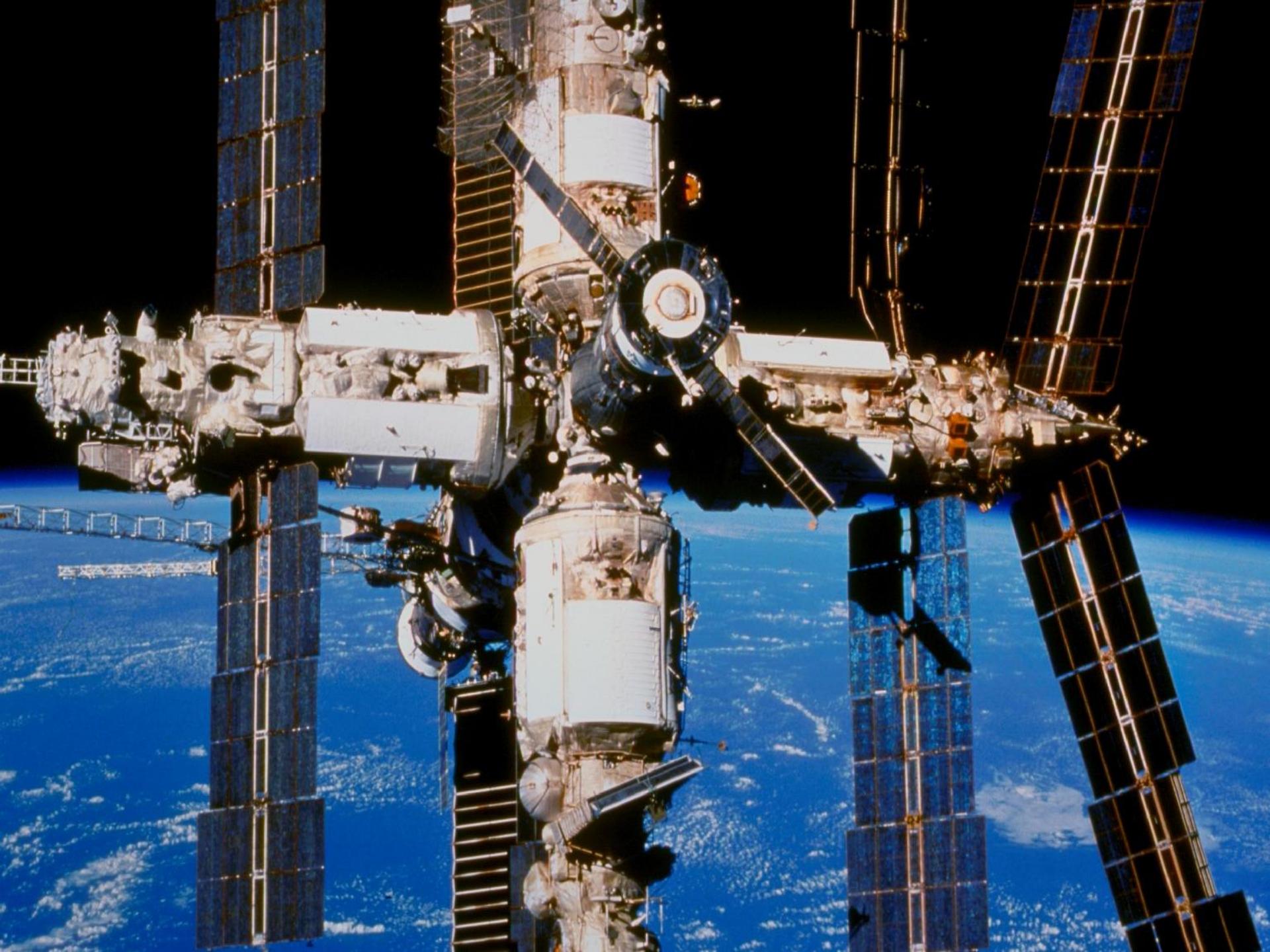
Medical Events in Space

Cardiac, Genitourinary, Neurologic, Behavioral

Performance Events in Space

Crew Coordination Errors during Robotics, EVA, Rendezvous & Docking, Reentry/ Landing





Spacecraft Environmental Events



Spacecraft Environmental Events

Combustion Events (6 Salyut/ Mir, 4 Shuttle, 3 ISS)

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/ Soyuz Test Project)

Water Contaminants

Formaldehyde (Mir)

Cadmium (ISS)

Spaceflight Related Performance Events

Impaired cognitive performance - described as “Space Stupids, Space Fog, Space Dementia, Mental Viscosity, Neurasthenia”

Crew Coordination Errors

Rendezvous and Docking Collision

Robotic Arm Collision

Missed Checklist Items

Lost tools on Spacewalks





Significant Incidents during Extravehicular Activity (1965-2011)

13 EVAs resulted in crew injury

13 EVAs terminated early due to crew injury or
systems issues

EVA Cut Glove – 6

40 EVAs resulted in Inadvertent Releases

Psychological Environment



In-Flight Behavioral Events

Acute Behavioral Change

STS 51B (1985) payload specialist **despondent when experiment failed**, crew concerned about **potential for dangerous behavior**

Acute Grief Reaction

Mir 18 Dezhurov's **mother died**, withdrew from crew for 1 week

Depression, Homicidal and Suicidal Thoughts

Salyut 7 - Valentine Lebedev 1988 211 day mission developed sour disposition from crew conflict, **contemplated killing his crew mate**

NASA Mir 3 – Blaha had fits of anger, insomnia and withdrawal, exacerbated by an excess workload. "He was hurting," Linenger recalls. "He was, in essence, **depressed**."

NASA Mir 5 – After the Progress collision with Mir, Lazutkin **contemplates suicide**

Crew-crew **interpersonal conflicts**

Soyuz 21 (1976), Soyuz T14 (1985), Soyuz TM 2 (1987)
personality incompatibility

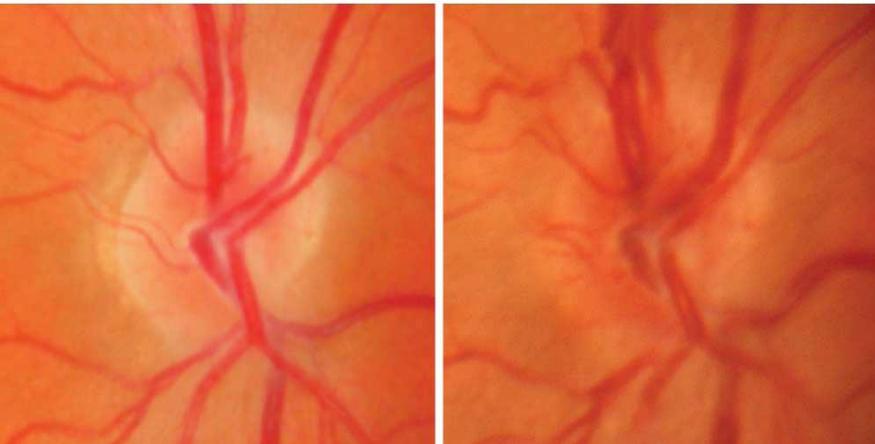
Crew- mission control team conflicts

Skylab 4 (Carr, Pogue, Gibson), NASA Mir 4 (Linenger)
Excessive workload and disrupted sleep rest cycle

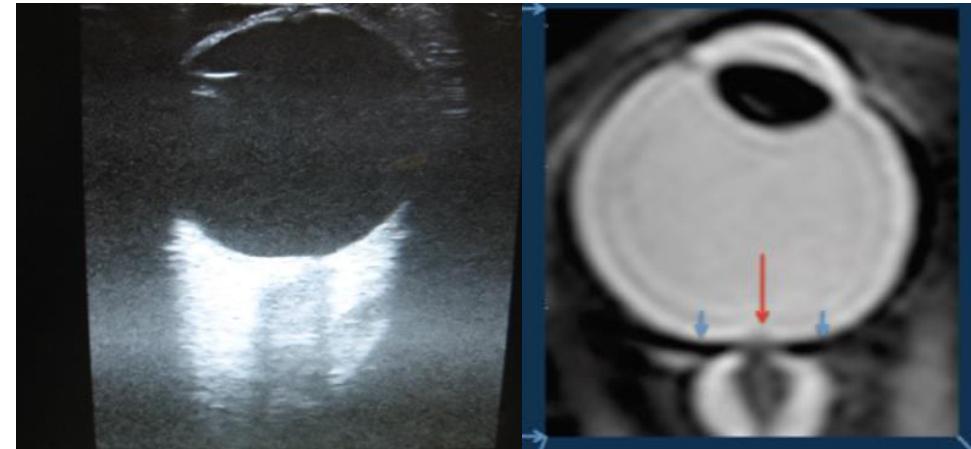


Ocular and Intracranial Findings in Astronauts after Long Duration Space Flight

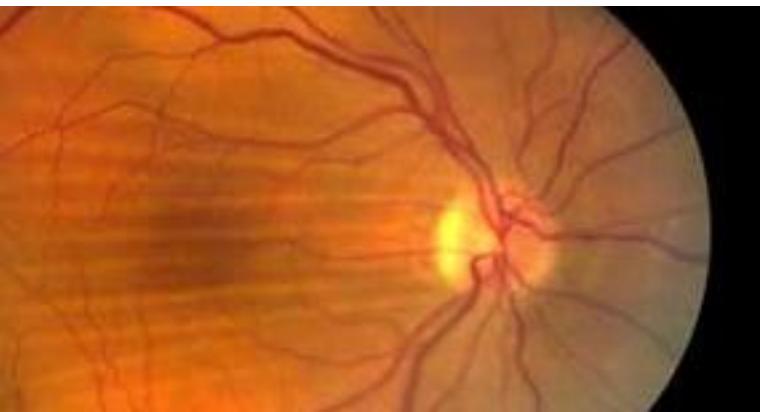
1. Optic Disc Edema



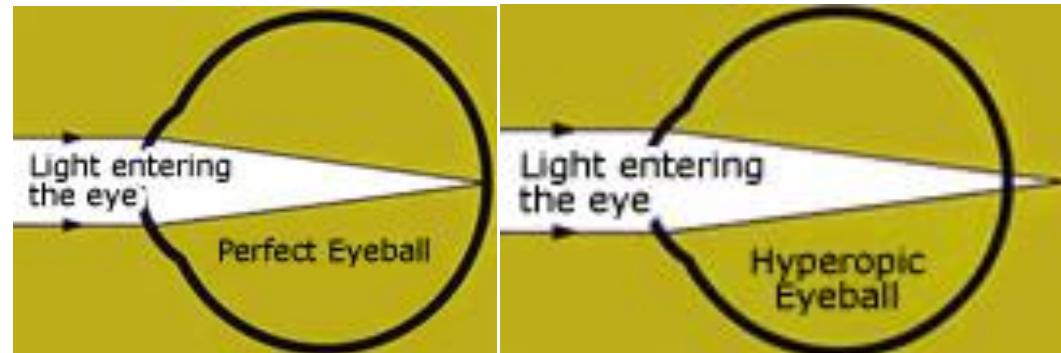
2. Globe Flattening



3. Choroidal Folds



4. Hyperopic Shifts





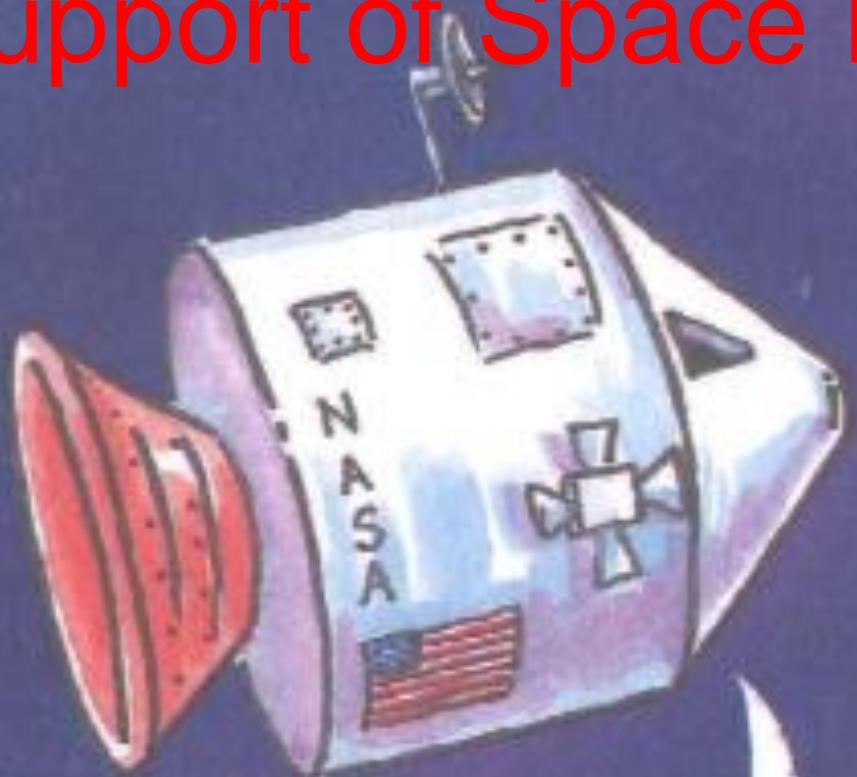
Update on Microgravity Associated Ocular Intracranial Syndrome

(AKA Visual Impairment Intracranial Pressure)

Summary of ISS Expeditions 1-48

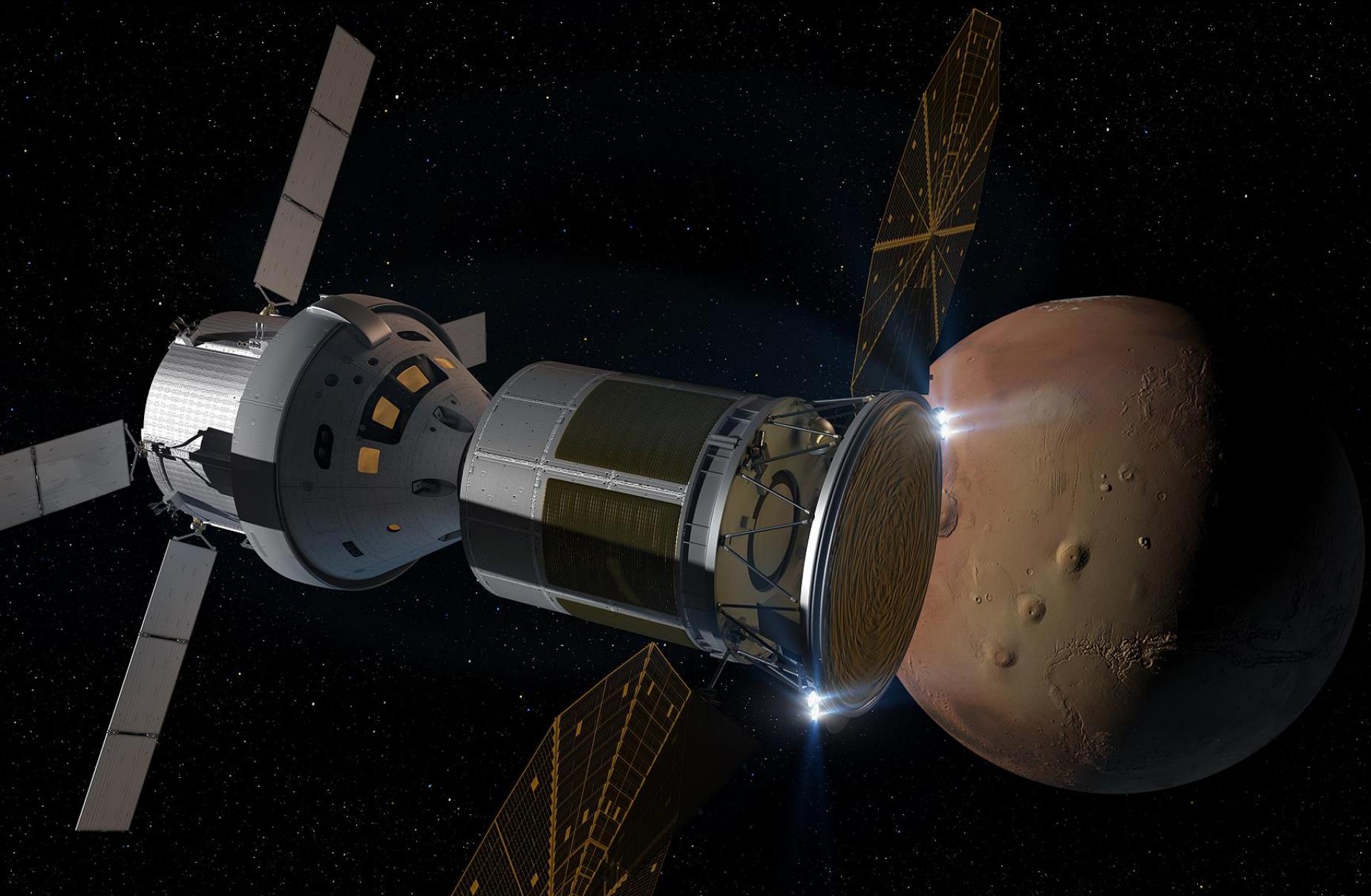
Clinical Condition	Cases	Astronauts Evaluated
Ocular Disc Edema (Grade 1 or greater)	10	64
Globe Flattening (MRI)	12	47
Choroidal Folds (OCT)	11	47
Cotton Wool Spots	7	64
Refractive Error >0.5 Diopter	9	47
Total astronauts	24	64

Technology Development in Support of Space Exploration



WHAT DO YOU MEAN
IT WON'T FLUSH

Key Drivers for Human Spaceflight Systems



Desirable Characteristics For Human Spaceflight Systems

Low Mass

Low Power

Minimal Size

Reliable

Autonomous/ semi-autonomous operation

Intuitive human interaction

Minimal Training

Minimal consumables, recyclable consumables

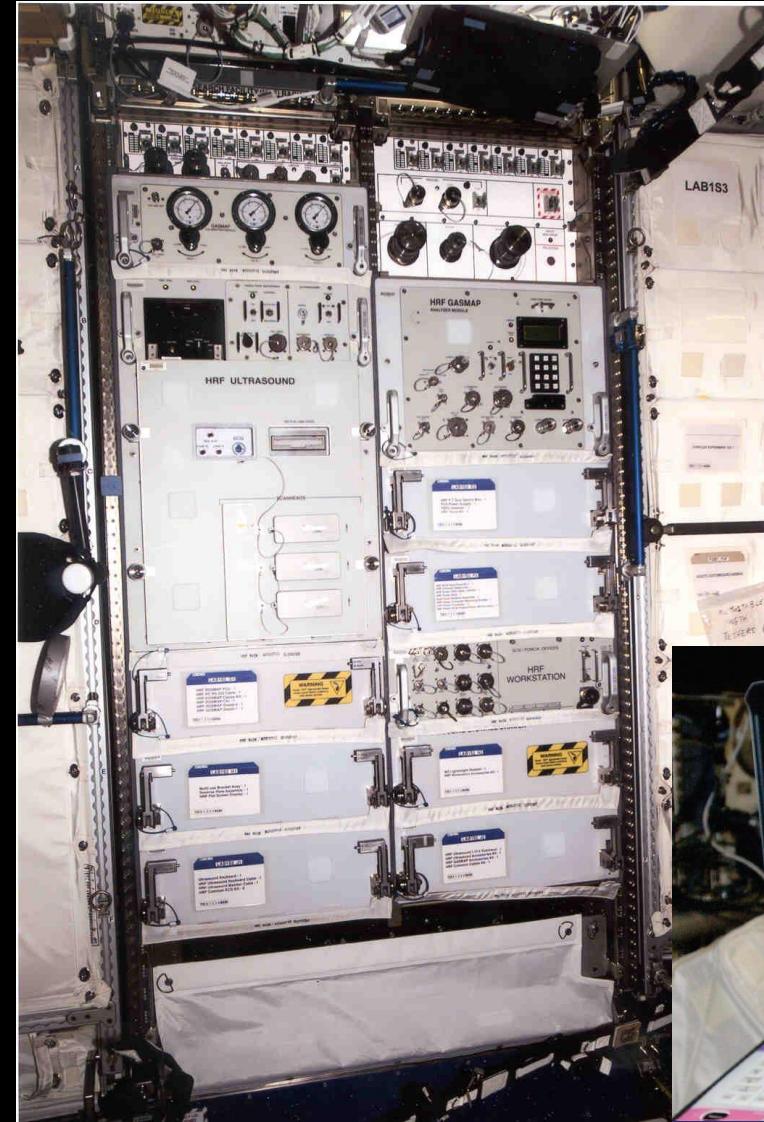
Module replaceable

Non-invasive application

Low toxicity, flammability, electromagnetic signature



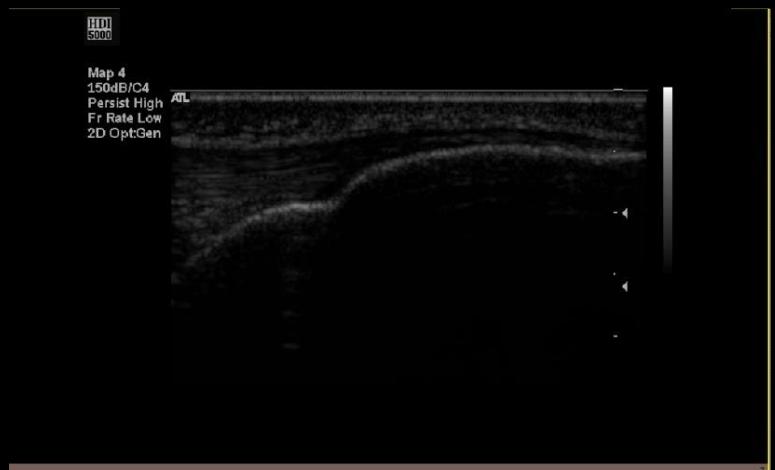
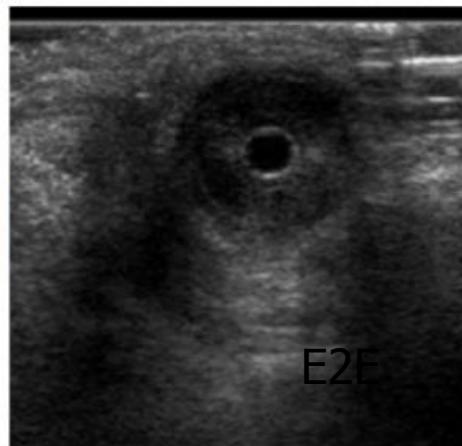
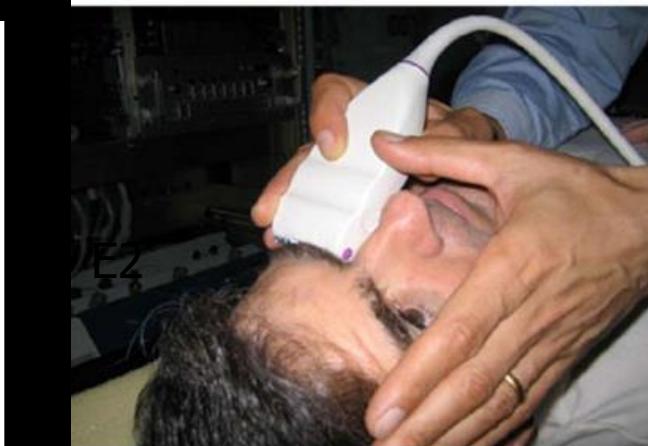
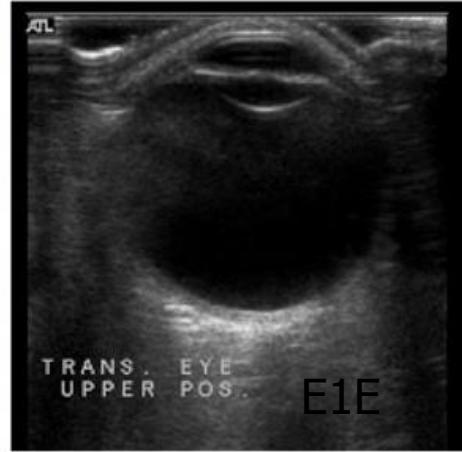
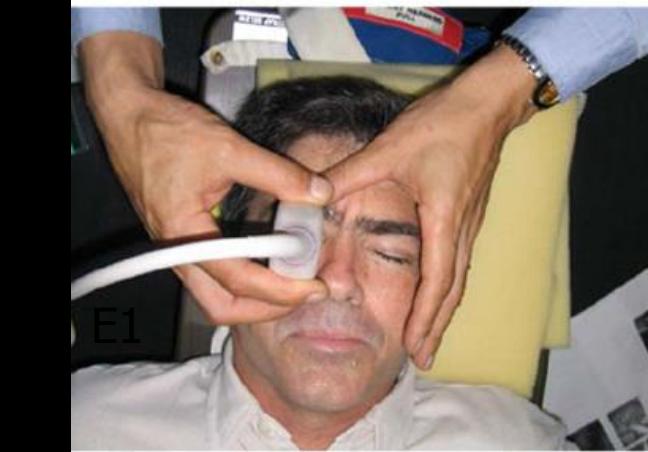
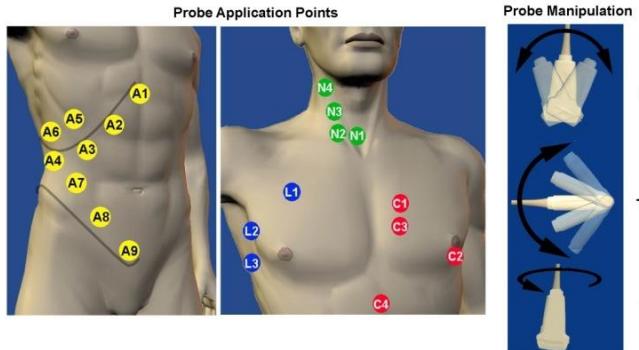
Evolution of Ultrasound Systems



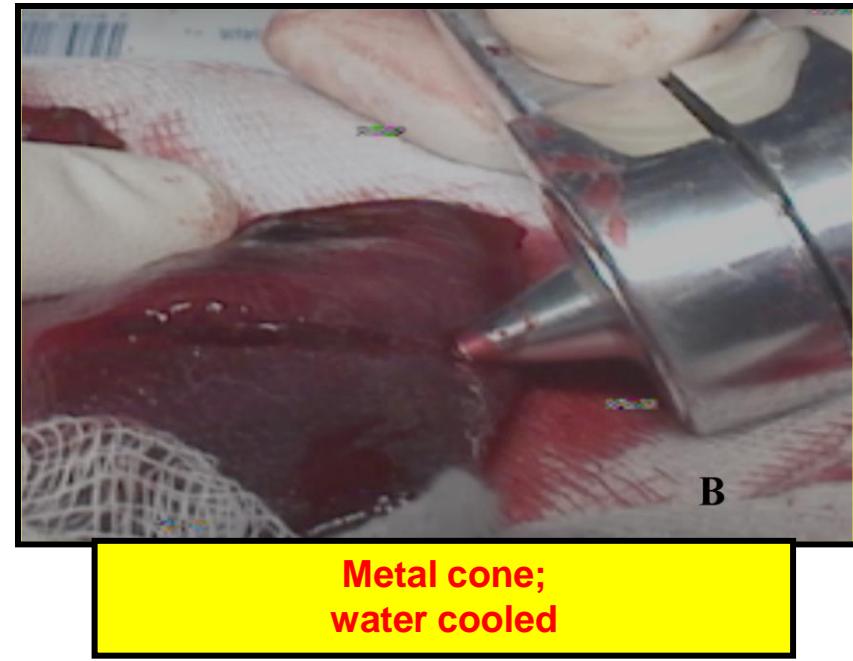
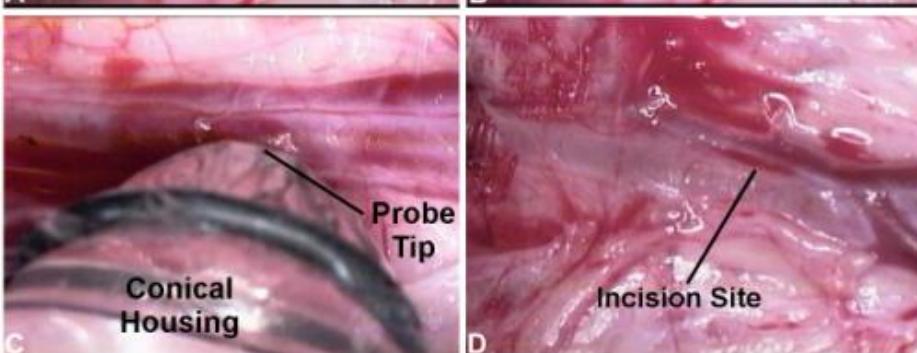
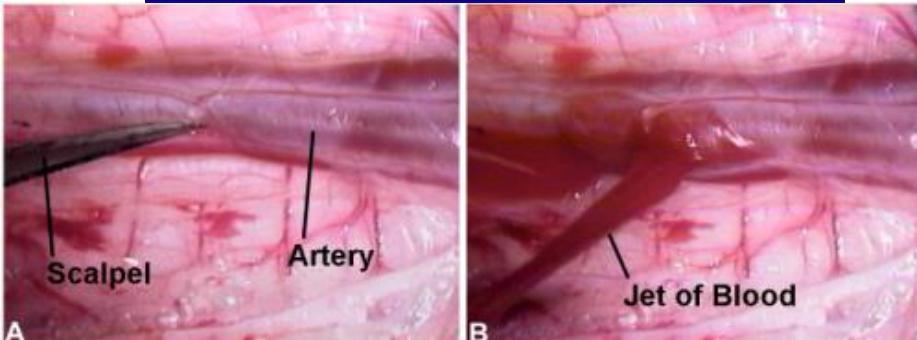
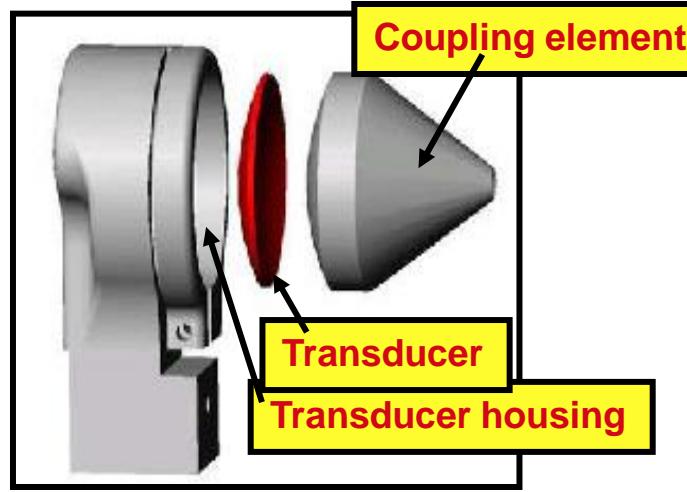
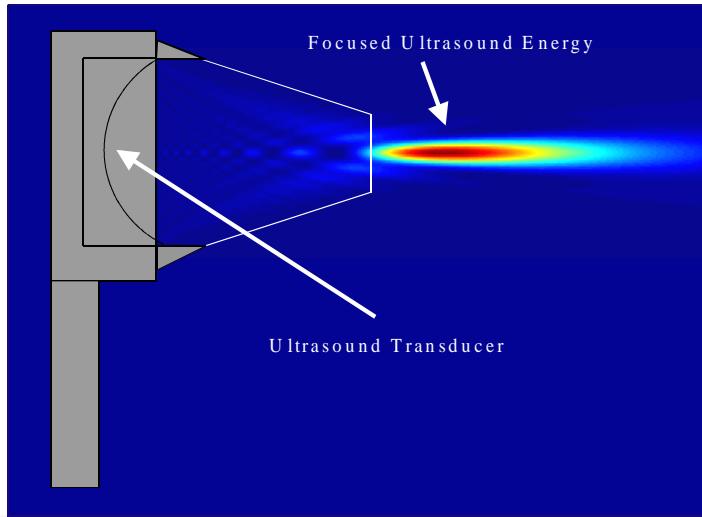
Just in Time Ultrasound Protocol

Cue Card and Reference Images

HRF Ultrasound Keyboard



HIFU Hemostasis without Occlusion of Punctured and Lacerated Vessels

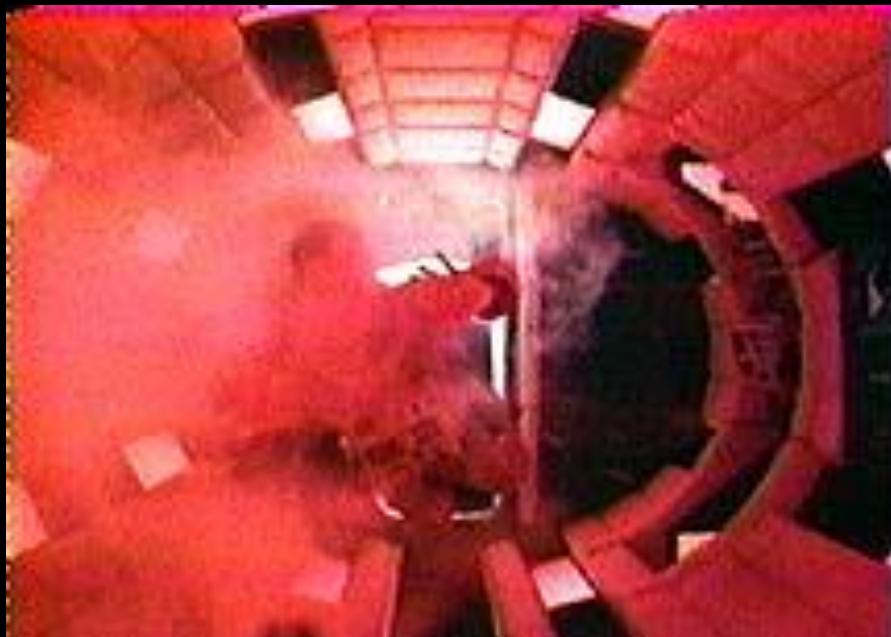


NASA recently sent a machine to
the International Space Station.

It converts URINE into DRINKING WATER.

HAL 9000

“I’m sorry Dave, I’m afraid I can’t do that”



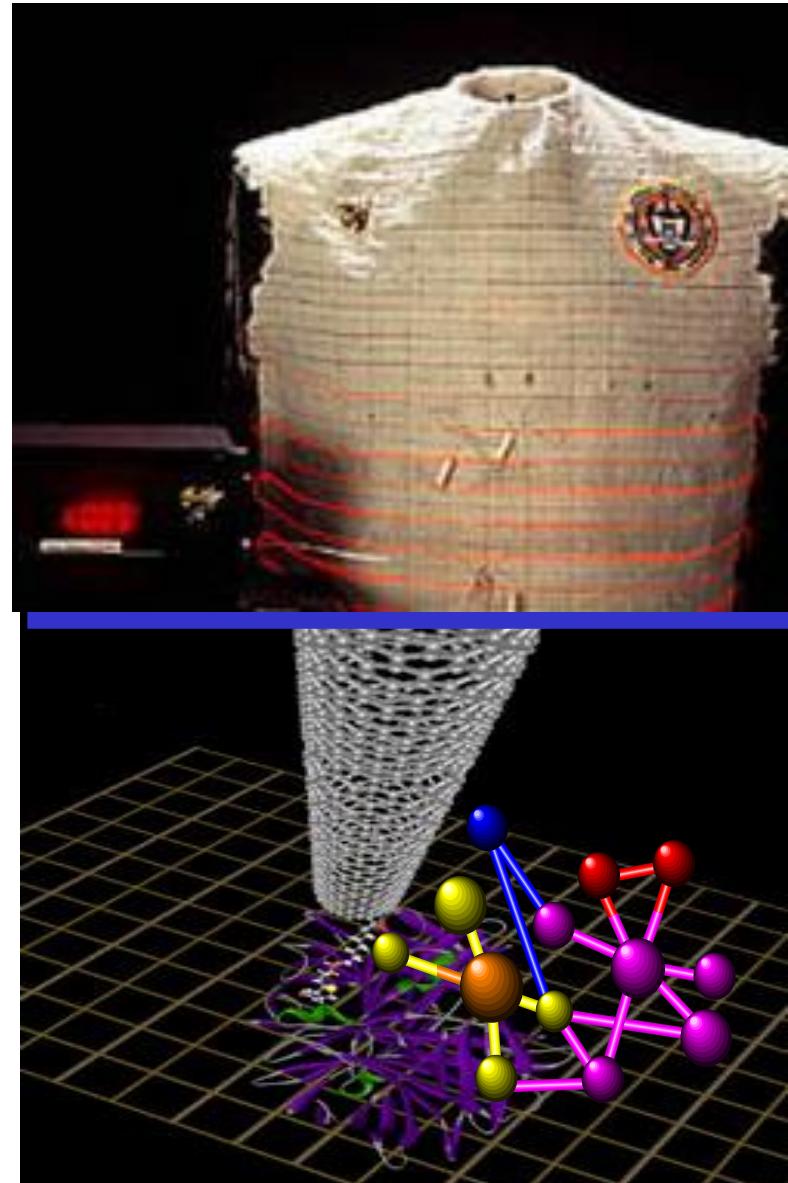
Future Space Health Care Systems

Wearable physiologic monitoring
particularly for high risk activities

Minimally/ non-invasive diagnostic
systems capable of evaluating
broad range of disease states

Health care system capable of
therapeutic intervention for a wide
range of illnesses and injuries

Precision Medicine Program to
individualize therapeutic and
preventive measures based on
knowledge of specific
environmental and genetic risk
factors



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