Space Stations

Osher, Fall 2024

Howard Seltman

Outline

- Week 1: Science and Science Fiction Background
- Week 2: Early Space Stations
- Week 3: Mir, ISS Planning and Construction
- **Week 4: ISS Operations**
- Week 5: China, Science & Tech Summary, and the Future

Overview of the ISS

- Zarya, the first module was launched in November 1988
- Occupied in November 2000 after launch of Zvezda, the third module
- Construction until 2011 with 36 U.S. and 6 Russian flights
- Construction took 161 spacewalks
- Russian, US, Canadian, European and Japanese portions
- 14 pressurized modules and a truss
- $150 billion to build
- $2-3 billion per year to maintain (mostly transport costs)
- Space-X charges $88 million per seat
- In 2014 Russia charged $76 million per seat

Overview [0:39 NatGeo]

https://www.youtube.com/watch?v=Ei-TcECJVXU

So you want to be an astronaut [1:52 NASA]

https://www.nasa.gov/humans-in-space/astronauts/become-an-astronaut/

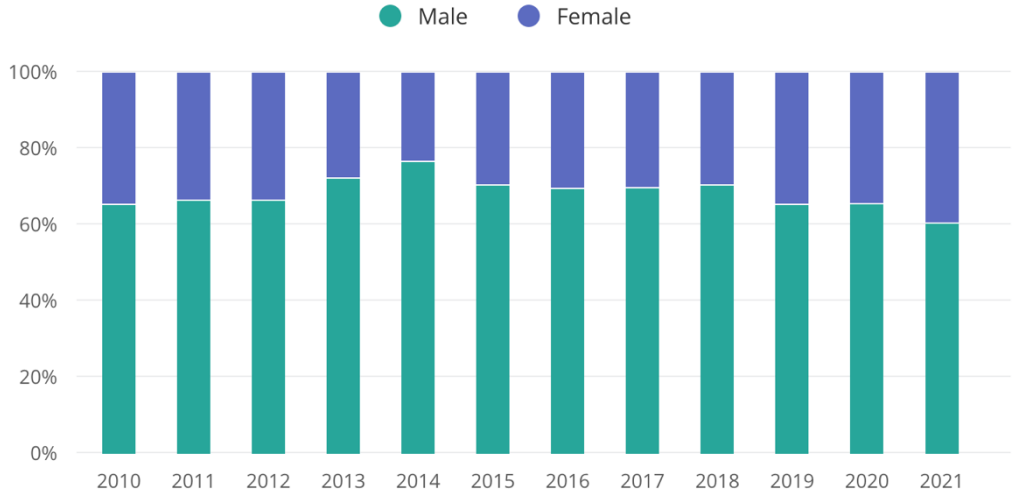
Becoming an astronaut

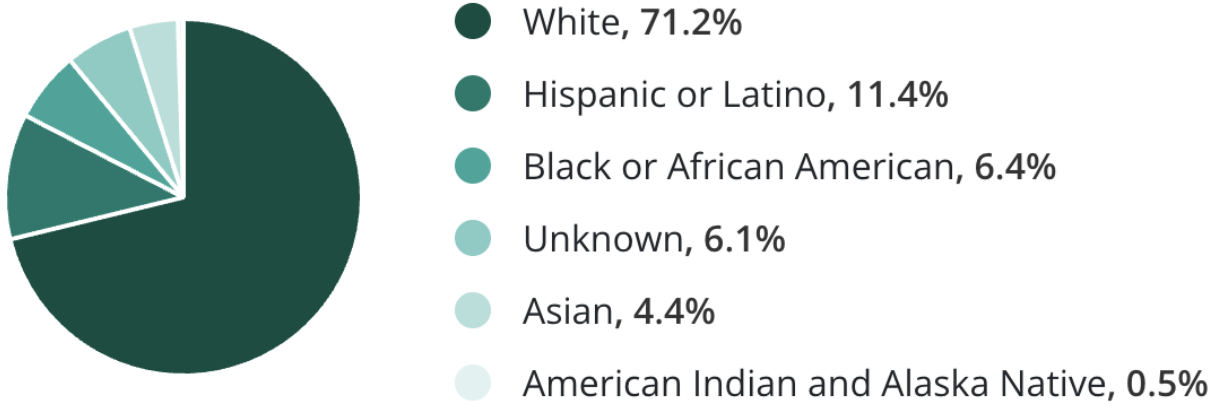
“I remembered the paragraphs I had written and rewritten as if my life depended on them. The main reason I want to be an astronaut is that it is the most challenging and exciting job I can imagine. I want to play an integral part of humankind’s boldest endeavor ever, and truly feel that I would be an asset to the human space program.... The entire world needs spaceflight to advance scientific discoveries in medicine, engineering, science, and technology. Just as the Apollo program resulted in countless tangible benefits that improved the daily lives of all individuals, the human space program is necessary if we are to continue our great history of technological achievement. It would be an honor to be a part of any discovery made as a result of the human space program.”

— Endurance: My Year in Space, A Lifetime of Discovery by Scott Kelly

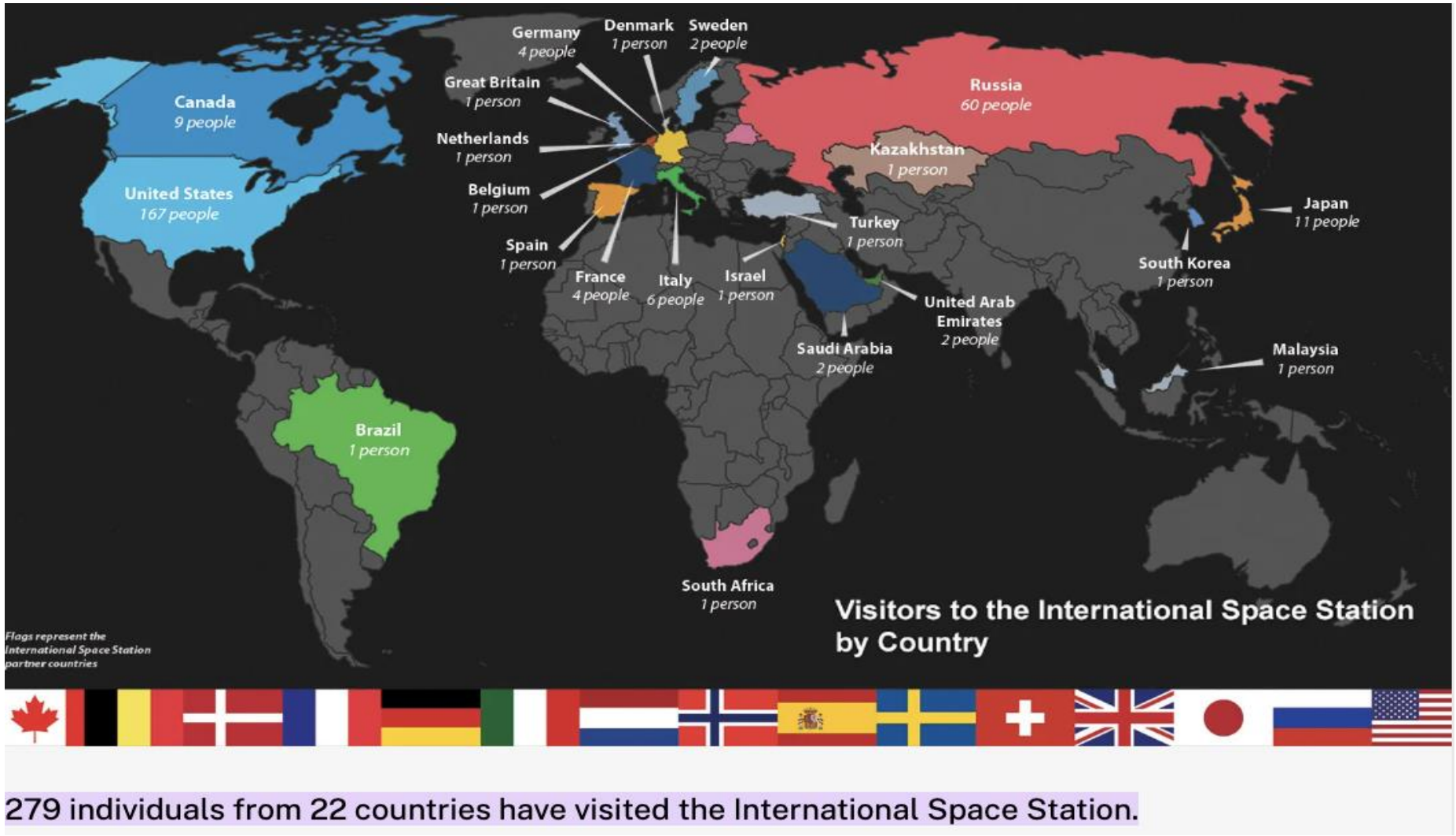
Who are the astronauts?

- Must have STEM masters, MD, DO, or be a test pilot
- Two-year training includes SCUBA certification, military water survival (inc. 3 lengths of a 25-meter pool in a flight suit), altitude training, microgravity training, ISS systems training, emergency procedures, robotic skills, Russian language, etc.
- GS-11 to GS-14 ($94,000 - $285,000)
- Currently 18 women and 28 men
- Don Petit, age 69, returned to Earth September 23, 2024





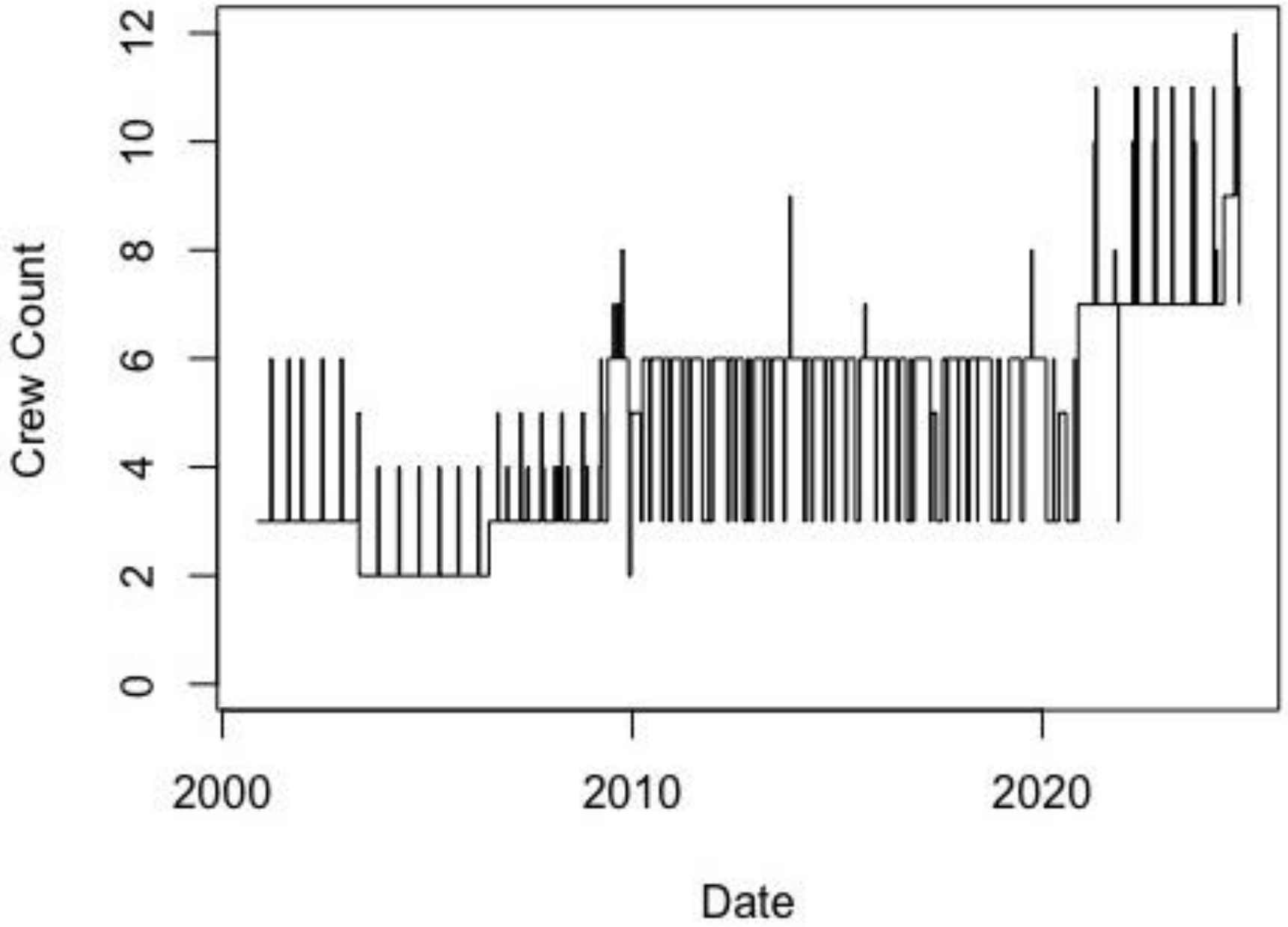
All station visitors



279 individuals from 22 countries have visited the International Space Station.

US 167, Russia 61, Japan 11, Canada 9, Italy 6, France 4, Germany 4, UAE 2, Saudi Arabia 2
Across 403 flights

Number living on the ISS over time



Astronaut careers

- Frank Rubio: 371 consecutive days on the ISS (8 over 200 days)
- Peggy Whitson: 675 days on the ISS in 3 intervals (6 over 380 days)
- Oleg Kononenko and Nikolai Chub had a single ISS stay of 374 days
- Kononenko: visited five times (record 1,110 days in space)
- 84 people on the ISS twice, 36 three times, 5 four times
- Typical example: Catherine (Cady) Coleman
  - Airforce ROTC
  - PhD in Chemistry -> Air Force research chemist
  - 24 years as an astronaut
  - Two shuttle flights and one ISS stay
  - Total 180 days in space
  - Other jobs: capcom, labeling, public relations, shuttle repair commission, etc.

What to take

- Food and clothing are provided
- Change underwear ever other day, socks and shirts every week, pants every month: old to trash
- Since Gemini, FAA regulations, §1214.604, allow for a Personal Preference Kit (PPK) of items for use as mementos, not to be sold, and approved by NASA (but kept private)
- Current limit for personal items is 3.3 pounds (1.5 kg)
- Most common items are musical instruments and cameras
- Small flags, t-shirts, jewelry are common

Mission training

- 18 to 24 months
- Main and backup crews
- EVA certification no longer required
- EVA practice in Neutral Buoyancy Tank
- Use and repair of station equipment
- Training on scientific apparatus
- Robotics training
- Survival and emergency preparedness
- Strength and cardiovascular training, stress management, etc.
- Cross-cultural communications and teamwork

Soyuz training at Star City [ESA 4:48]

https://www.esa.int/ESA_Multimedia/Keywords/Description/Training_at_Star_City/(result_type)/videos_p

Sharing Space by Cady Coleman

“Every astronaut has to accept that part of the job is living and working in close quarters with a group of people you many not know ahead of time and didn’t get to choose – and learning to trust those people with the success of the mission and with your life. It’s like one of those reality shows in which a group of total strangers get stranded on an island and have to depend on one another to survive.”

Crew conflict

- While no major public conflicts have been reported, astronauts have acknowledged minor disputes or frustrations due to cultural differences in work pace or expectations
- Cosmonaut Valery Ryumin wrote in his journal during a particularly difficult period on board the Salyut 6 space station: "All the conditions necessary for murder are met if you shut two men in a cabin measuring 18 feet by 20 and leave them together for two months."
- Scott Kelly's *Endurance*

  "I was most concerned about Lisa [Nowak], whom I had known longer than most of my colleagues, about fifteen years, since we were in test pilot school together at Pax River. She was a technically brilliant flight engineer. But lately she had become obsessive about small details that didn't seem to matter much, like what she was going to have for lunch that day. She could become hyperfocused and had trouble letting things go, even if they were irrelevant. On Earth this wasn't a problem, but on a spaceflight, every member of the crew was crucial to its success, and these peculiarities of Lisa's personality began to concern me."

Isolation from loved ones: Scott and Amiko Kelly

[Amiko 2:51]

Often […] I'm asked what I miss about Earth. […] I mention rain, spending time with my family, relaxing at home. Those are always true. But throughout the day, from moment to moment, I'm aware of missing all sorts of random things that don't even necessarily rise to the surface of my consciousness.

I miss cooking. I miss chopping fresh food, the smell vegetables give up when you first slice into them. I miss the smell of the unwashed skins of fruit, the sight of fresh produce piled high in grocery stores. I miss grocery stores, the shelves of bright colors and the glossy tile floors and the strangers wandering the aisles. I miss people. I miss the experience of meeting new people and getting to know them, learning about a life different from my own, hearing about things people experienced that I haven't. I miss the sound of children playing, which always sounds the same no matter their language. […] I miss drinking from a glass. I miss setting things down on a table and having them stay there. I miss the sudden chill of wind on my back, the warmth of sun on my face. I miss showers. I miss running water in all its forms…

https://www.youtube.com/watch?app=desktop&v=TyOpx6hVvOg

Sharing Space by Cady Coleman

"Slowly I open my eyes. *I'm still here*. That miraculous fact hits me the moment I wake up, every morning, floating. *I'm in space and I'll be in space tomorrow and the next day and the next – for six whole months*. *I LIVE here*. It's a kind of bubbly, never-get-old feeling that floods my body and banishes any notion of going back to sleep."

Sharing Space by Cady Coleman

“I loved seeing the different continents – each with its distinctive colors – coming closer and closer until they were right above my head, and then I’d spin around and watch then recede into the distance. Whether I was tracing the tangled threads of the Nile delta, or marveling at the vastness of Australia, or learning to distinguish the particular shades of red and gold that told me which desert was which, I never got tired of watching. The oceans were infinite varieties of blue. Within the outlines of each landmass, the planet sparkled and pulsated with life.”

Sharing Space by Cady Coleman

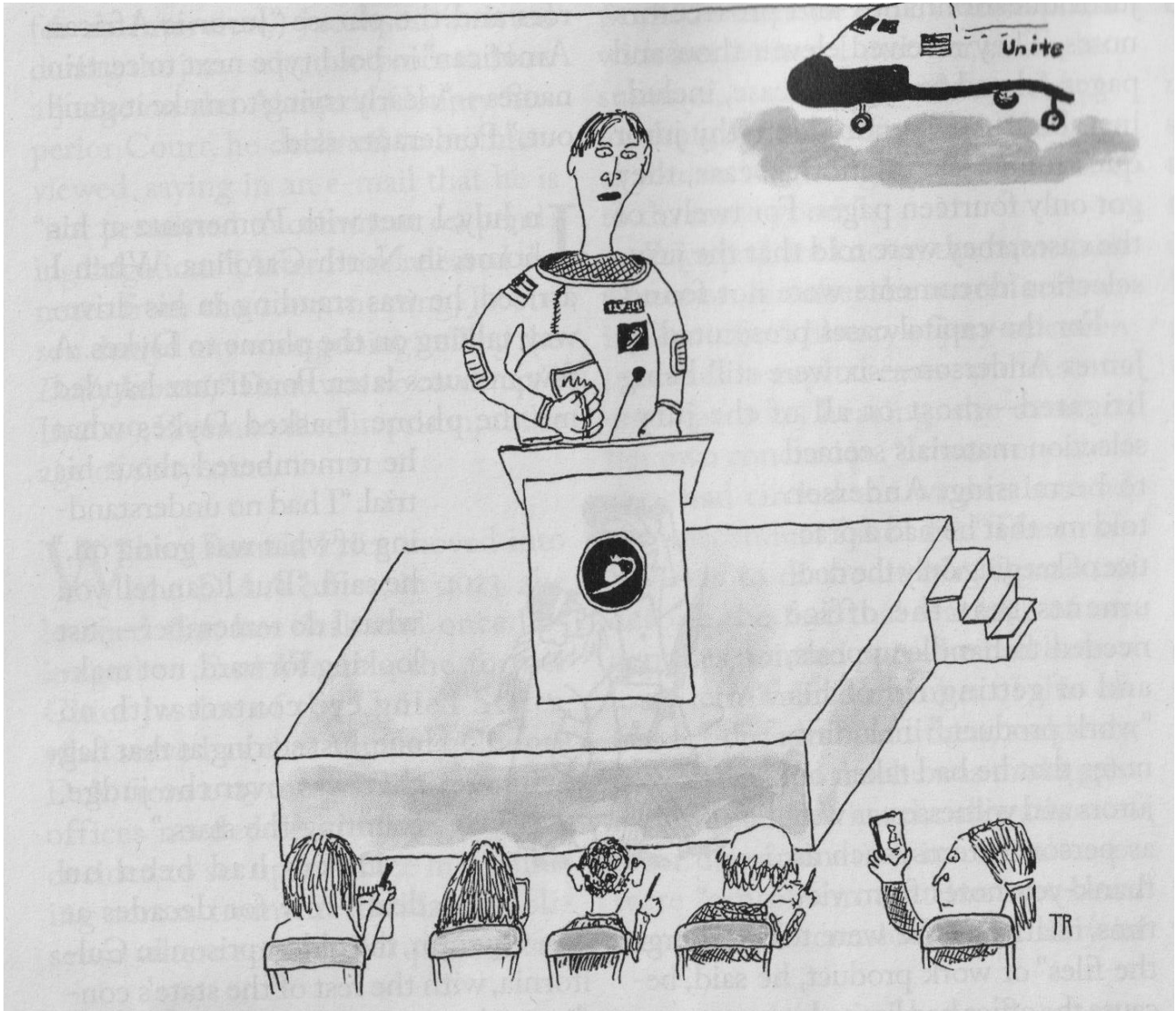
“Even though I was one of only six human beings *not* on the planet, I felt so connected to the billions of people down there. More important, it was startlingly clear to me how connected they all could be to one another. If only they knew that, I often thought, how much easier it would be to solve the challenges that we face here on Earth. From space, you see very few national borders or political boundaries separating humans from one another. You understand -- not as an abstract ideal, but as a visceral, obvious reality – that we are one human family sharing a precious, life-supporting planet.”

Sex and reproduction in space

- No one has claimed to have joined the “250-mile-high club”, including Jan Davis and Mark Lee (STS-47)
- NASA now forbids married couples in space together
- Vague confirmations of masturbation
- Newton’s third law is a problem
- Free floating fluid is a problem
- Shift of body fluids towards the head is a problem
- [Erectile dysfunction persists in rats after one year]
- Lack of privacy and packed schedules/fatigue are problems
- A number of cellular abnormalities occur during embryogenesis
- Results vary by species, some developing normally and others abnormally

Some needs to keep a crew alive

- **1.5 pounds of oxygen per person per day**
  - Maximum per day produced by electrolysis is about 12 pounds
  - 12 pounds of O_2 can come from 13.5 pounds (1.7 gallons) of water
- **5 pounds of food per person per day**
- **Removal of about 2 pounds of CO_2 per person per day**
- **10 pounds of water per person per day**
  - 98% can be recycled: need 2 pounds per person per day
- Sabatier reactor (2010-2017): waste $H_2 + CO_2 \rightarrow H_2O + CH_4$
- Resupply ships can carry 5,000 to 17,000 pounds
- Space-X cargo costs about $27,000 per pound



"This has been a historic mission, which for me personally has represented the culmination of a lifetime of preparation and research in a ceaseless quest to expand mankind's knowledge of the cosmos. But, to answer your question, yes, I sometimes pee in the suit."

ISS toilet [2:40 ESA]

https://www.esa.int/ESA_Multimedia/Videos/2015/04/International_Space_Station_toilet_tour

Water recovery: 2011-2017

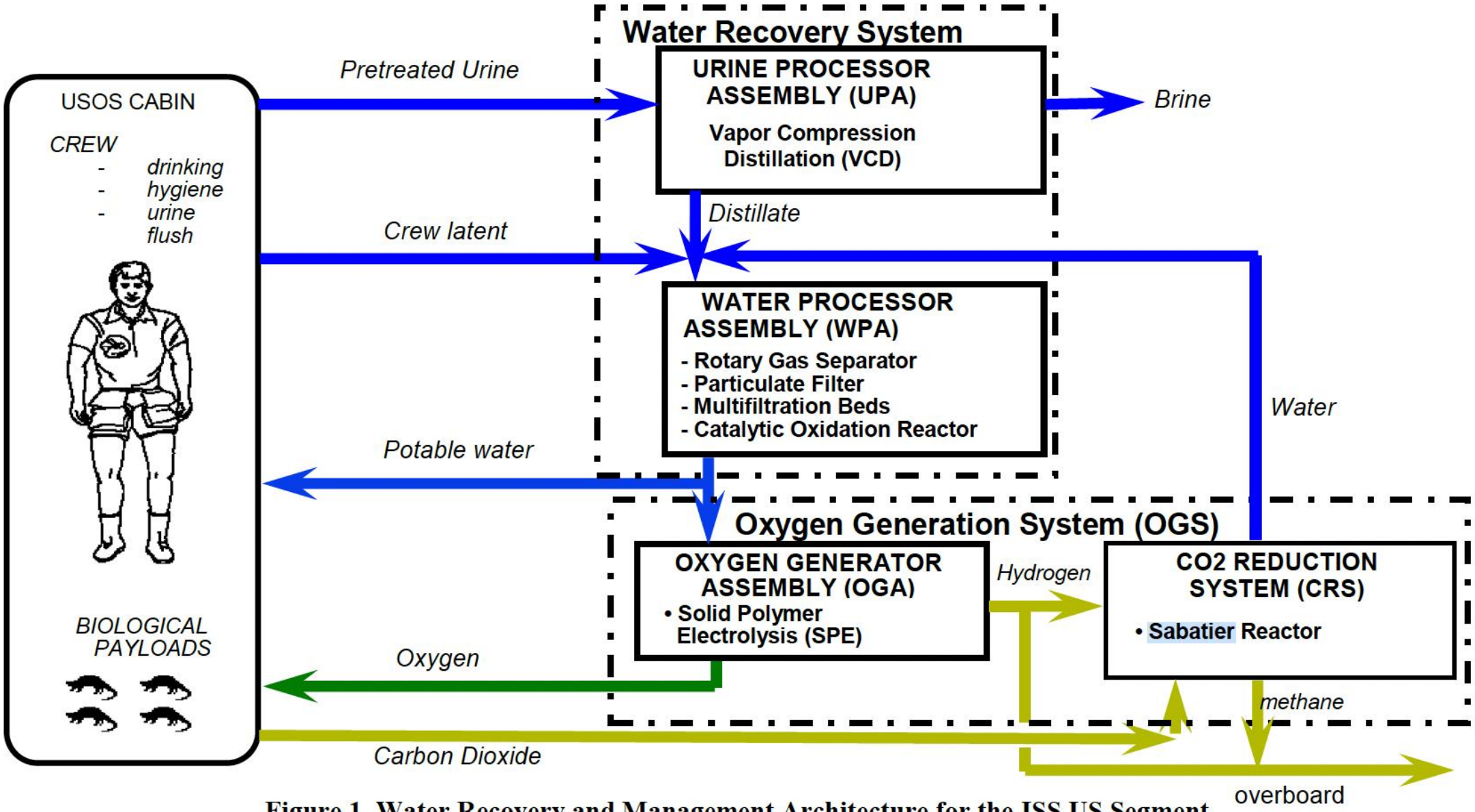


Figure 1. Water Recovery and Management Architecture for the ISS US Segment

Stretch

TikTok in space [1:53]

https://www.tiktok.com/@astrosamantha/video/7138792793492704517

Health effects

- Decreased bone density and increased chance of renal stones
- Decreased muscle mass, strength, and endurance
- Space adaptation syndrome
- Fluid movement to the upper body and head
- Space-Associate Neuro-ocular Syndrome (SANS)
- Cardiac deconditioning, increased arrythmias
- Fatigue, stress, and decreased mental performance
- GI discomfort, altered microflora, impaired absorption
- Loss of auditory acuity from noise exposure
- Callouses move from bottom to top of feet
- 50x radiation exposure (40 chest x-rays a month)
- On a 6-month tour, age 0.007 seconds less than us
- 2016 *Human Spaceflight Ethics and Obligations* testimony

Space tourists

- $20-$30 million to Russia for 6-12 days through Space Adventures
- Typically, 6 months training in Russia
- Dennis Tito, American businessman and former JPL scientist
- Mark Shuttleworth, South African entrepreneur
- Gregory Olson, American entrepreneur, engineer, and scientist
- Anousheh Ansari, Iranian-American entrepreneur and engineer
- Charles Simonyi, Hungarian-American software engineer
- Richard Garriott, British American entrepreneur and game designer
- Guy Laliberté, Canadian businessman and poker player
- Yusaku Maezawa, Japanese entrepreneur and art collector
- Yozo Hirano, production assistant to Maezawa
- (Sarah Brightman, singer and actress)

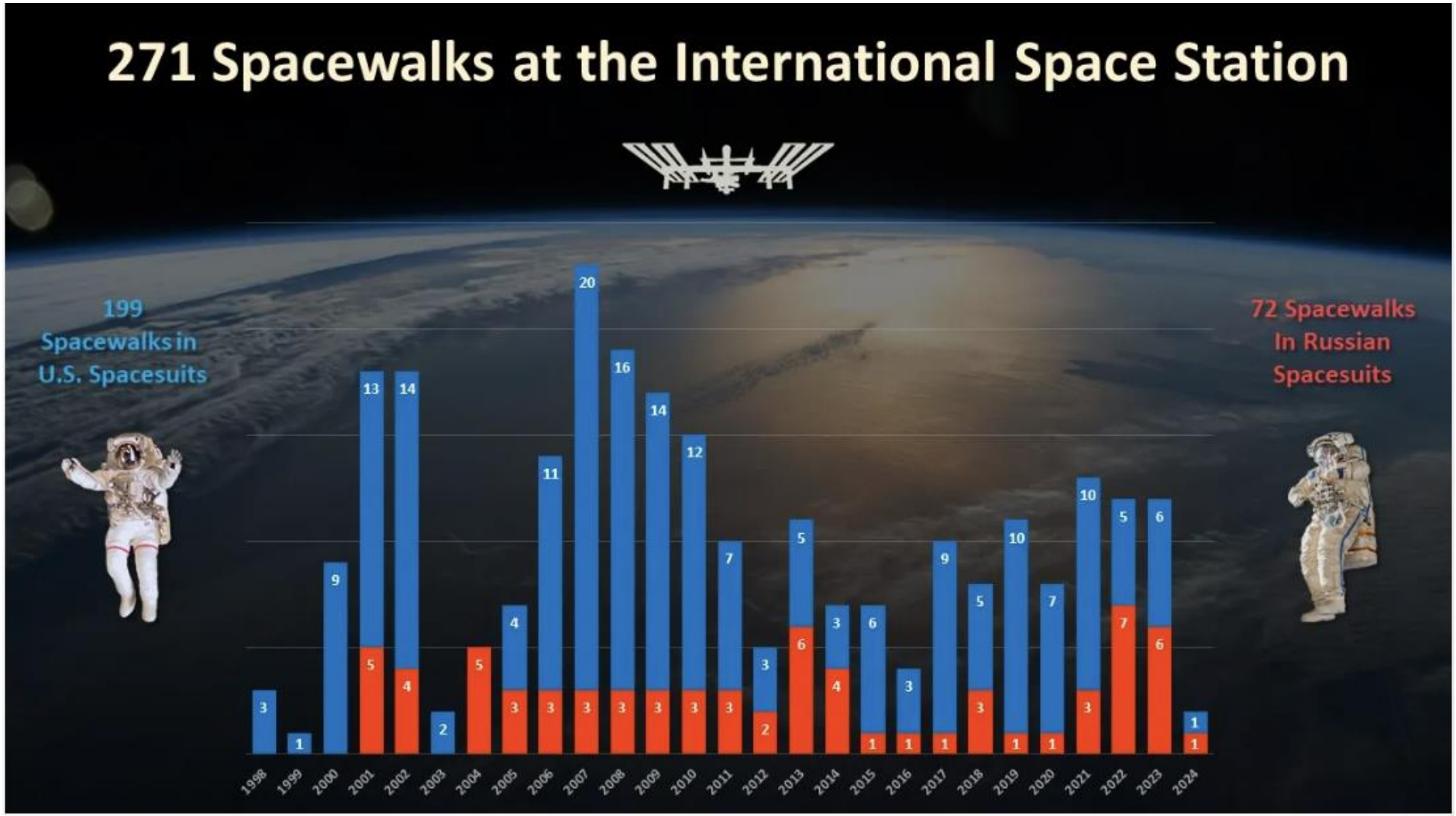
Extra-vehicular activity [5:42 DeepSpaceCourier]

- EVA needed for assembly, repair, installation of new equipment, and experiments

https://www.youtube.com/watch?v=x1XtAp8ItOk

Russian Orlan space suit

ISS spacewalks



There have been 271 spacewalks at the International Space Station since December 1998.

NASA

EVA tools [NASA 6:37]

https://www.nasa.gov/extravehicular-activity-and-human-surface-mobility/spacewalking-tools/

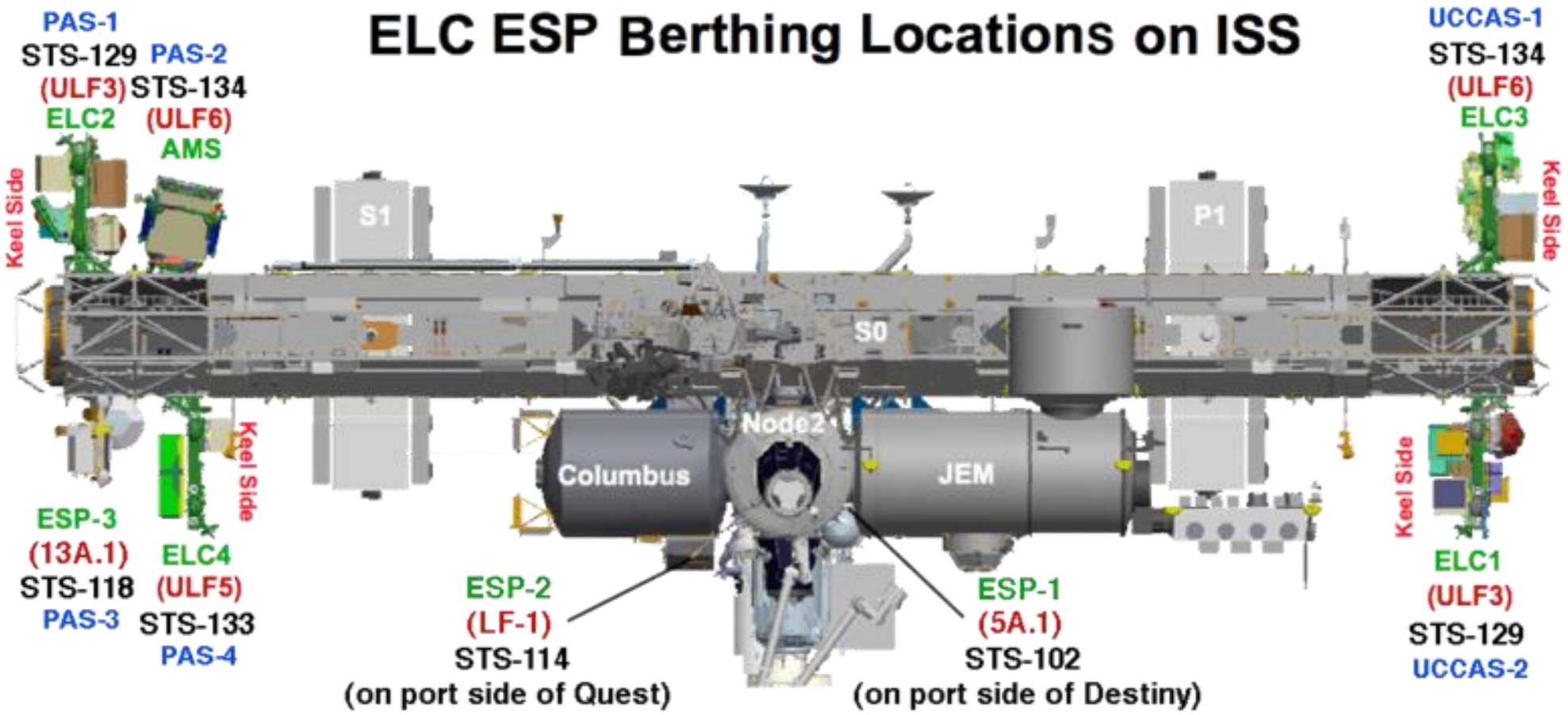
Spacewalk #264 6/9/2023 [NASA 11:00]

To install IROSA: ISS roll-out solar array

https://www.youtube.com/watch?v=wS4z42KaeGk

Repairs

- Orbital Replacement Units: pumps, tanks, antennas, batteries, etc.
- ExPRESS Logistics Carriers (ELCs): small pallets
- External Stowage Platforms (ESPs): large pallets



Dextre repairs [CSA 3:13]

https://www.youtube.com/watch?v=Wc3yCDRnxRk

Incidents and accidents

- EVA ended early due to suit damage or malfunction: 2001, 2004, 2007, 2008, 2013, 2016, 2021, 2022, 2024
- Attitude control lost: 2004, 2021, 2023
- Emergency EVA: 2001, 2006
- Shelter in Soyuz: 2009, 2012, 2015, 2021, 2024
- 2018: Air leak in Soyuz return vehicle
- 2019: Blood thinners used to treat jugular vein clot
- 2022: Soyuz emergency rescue ship’s cooling loop hit by micrometeroid; new ship sent up 2 months later
- Multiple times: Broken oxygen generation and CO_2 removal equipment

Inflatable module

- Real estate mogul Robert Bigelow founded Bigelow Aerospace in 1999, with a goal of developing the first commercial space station
- His other interests include ufology including the study of cattle mutilations and interdimensional shape-shifters, and proof of life after death
- In 2013 he announced an inflatable space hotel by 2022 with a 3 day stay costing $5 million
- In 2016 BEAM (Bigelow Expandable Activity Module) was berthed on the ISS and expanded. It is still used as a storage module.
- Bigelow Aerospace went out of business in 2021

Space station “culture”

- *Visual Displays in Space Station Culture: An Archaeological Analysis*, by Walsh, et al., **Current Anthropology**, 62:6, 2021

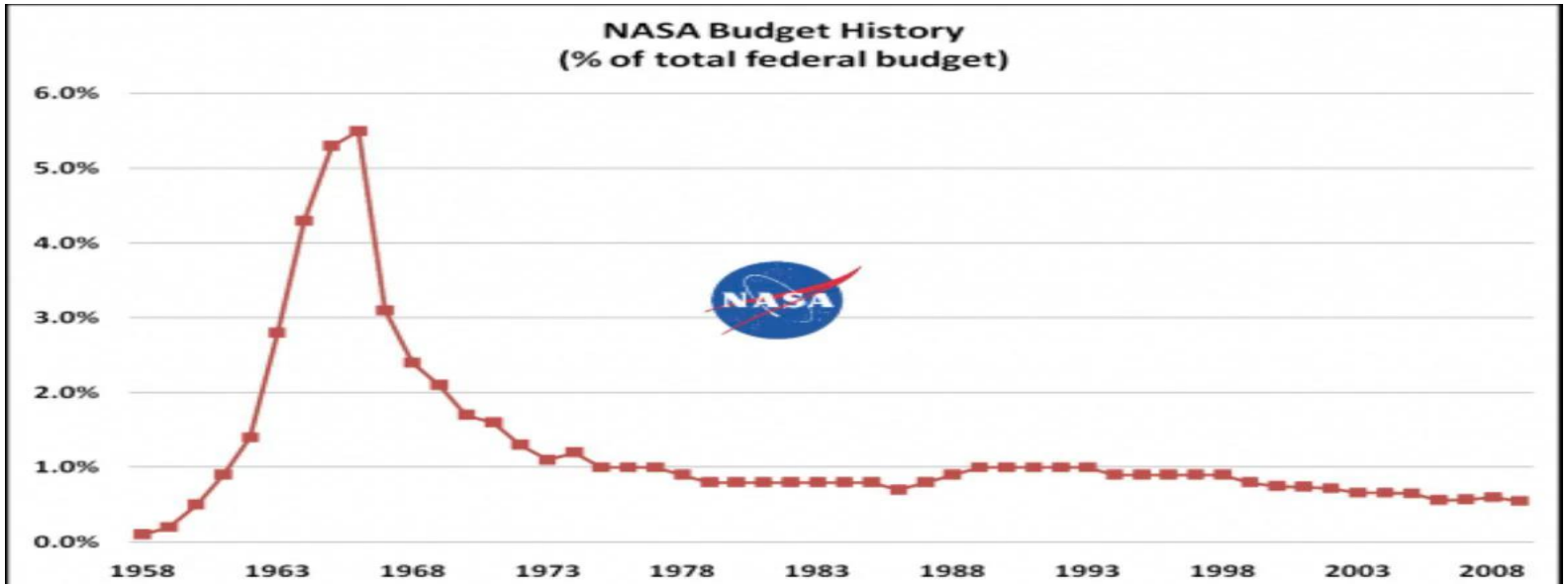
  We offer an archaeological analysis of the visual display of “space heroes” and Orthodox icons in the Russian Zvezda module of the International Space Station (ISS). This study is the first systematic investigation of material culture at a site in space. The ISS has now been continuously inhabited for 20 years. Here, focusing on the period 2000–2014, we use historic imagery from NASA archives to track the changing presence of 78 different items in a single zone. We also explore how ideas about which items are appropriate for display and where to display them originated in earlier Soviet and Russian space stations starting as early as the 1970s. In this way, we identify the emergence and evolution of a particular kind of space station culture with implications for future habitat design.

Leaks

- 2018: Small hole in Soyuz initially suspected to be sabotage, repaired with epoxy and patches
- 2020:
  - Vestibule of life support module Zvezda (launched in 2000) next to the docking port
  - After months of searching, floating tea leaves were used to identify the location
  - Patched with Kapton tape and sealant
  - Sealed off from the rest of the station most of the time
  - Cause and danger are major disagreement between Roscosmos and NASA
  - Major theory is a problem with internal and external welds
  - Loss as high as three and a half pounds of air per day
  - US closes a hatch between the US and Russian sides when the affected hatch to the docking port is open
  - Russians rule out catastrophic disintegration; US does not

Comments and Questions

NASA Budget Over Time

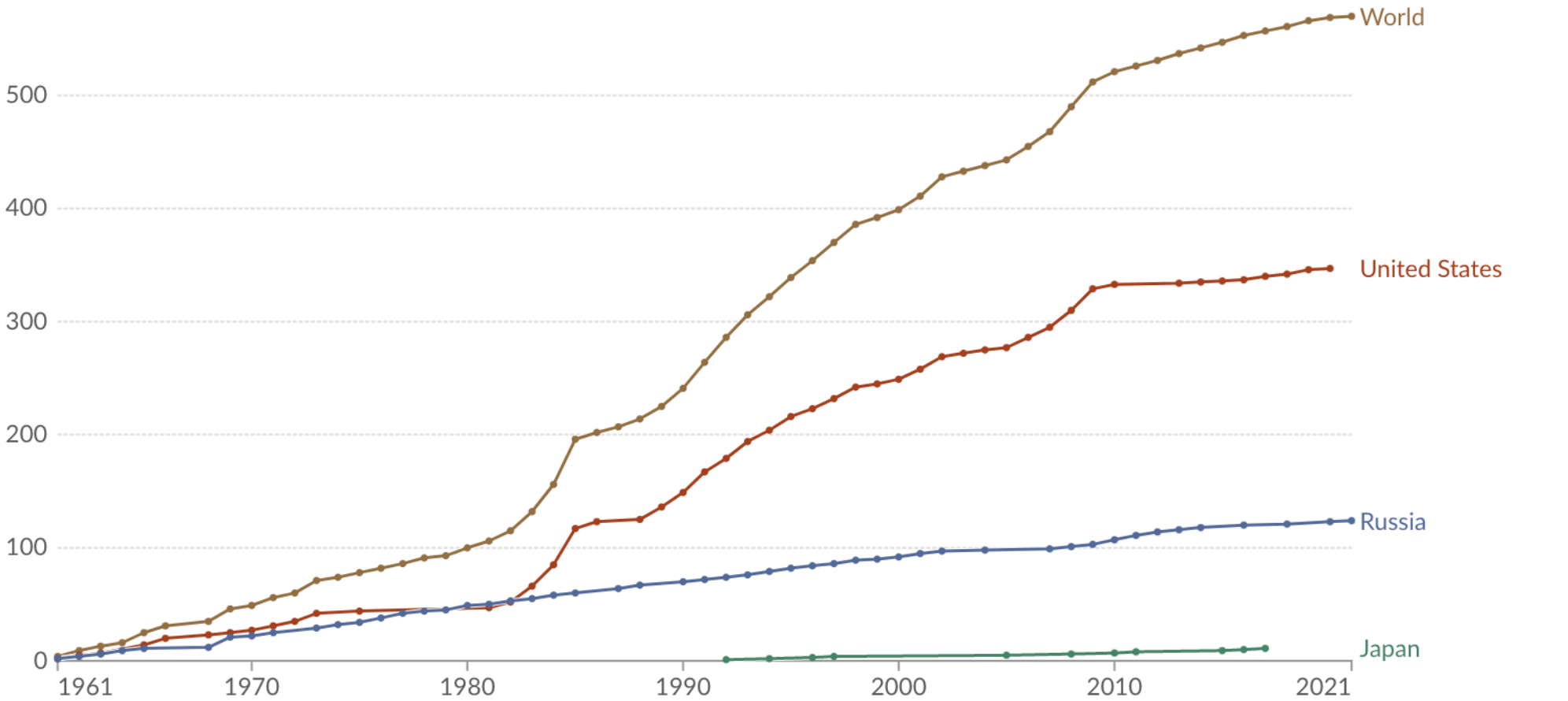


Cumulative number of people who have been to space, 1961 to 2021

Our World in Data

Table | Map | Chart

Edit countries and regions | Settings



1961 2021

Data source: CSIS Aerospace Security Project (2022) – Learn more about this data

OurWorldinData.org/space-exploration-satellites | CC BY

Note: For individuals who went to space multiple times, only the first visit is counted. Country-level data is assigned according to the individual's nationality.

Scott Kelly on exercise

If I don’t exercise six days a week for at least a couple of hours a day, my bones will lose significant mass—1 percent each month. We’ve had two astronauts break their hips after long-duration spaceflights, and since the risk of death after hip fracture increases with age, bone loss is one of the biggest dangers my year in space will pose to my future health. Even with all this exercise, I will lose some bone mass, and it’s suspected that bone structure changes permanently after long-term spaceflight (this is one of the many medical questions Misha’s and my year will help to answer).

Our bodies are smart about getting rid of what’s not needed, and my body has started to notice that my bones are not needed in zero gravity. Not having to support our weight, we lose muscle as well. Sometimes I reflect that future generations may live their whole lives in space, and they won’t need their bones at all. They will be able to live as invertebrates. But I plan to return to Earth, so I must work out six days a week.

Sharing Space by Cady Coleman

"… we sat through a charming series of ceremonial welcome events that the U.S. astronauts affectionately referred to as the Funny Hat Ceremony. The guys were presented with the aforementioned hats, which were very grand looking, in black and gold, but apparently women don't get funny hats. Instead, I was given a ceremonial burgundy velvet jacket that I still wear today to black-tie functions. There were dancers, tea and presents. I received a Russian nesting doll with my picture on the outside and a huge box of chocolates with our crew picture on the lid."

Sharing Space by Cady Coleman

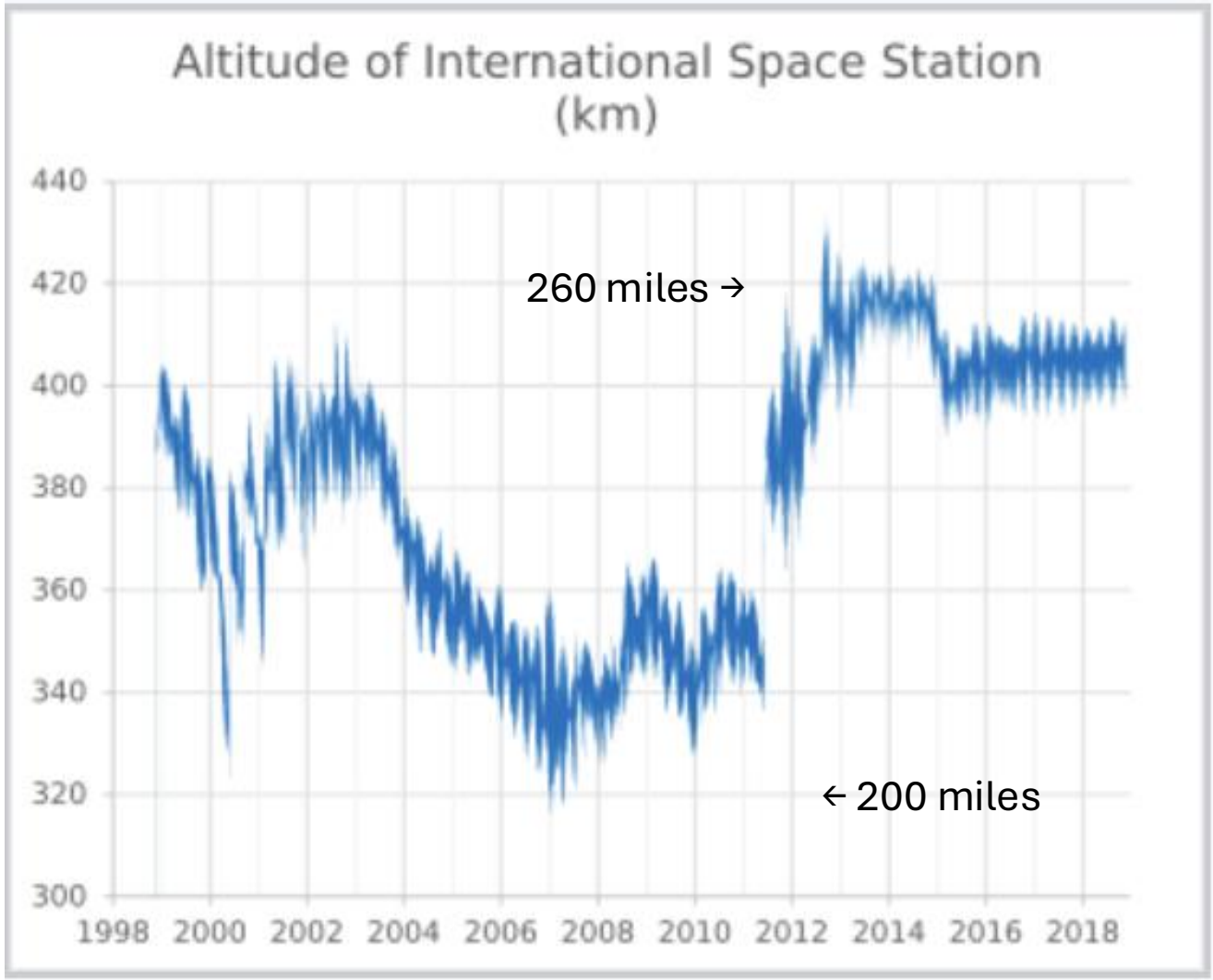
“Gravity sucks! When I tried to walk to the helicopter, the world seemed to swing wildly back and forth every time I took a step. Luckily, it’s standard procedure to have someone support you on each side until your vestibular system recalibrates, likely sometime over then next day or two.”

Debris avoidance (Scott Kelly)

- With six hours' notice, the space station can move itself out of the way of oncoming orbital debris. The Air Force tracks the position and trajectory of thousands of objects in orbit—mostly old satellites, whole or in chunks. As with everything else, NASA has an abbreviation for these adjustments: PDAM, or predetermined debris avoidance maneuvers, which means firing the station's engines to adjust its orbit. We've had two of this type since I've been up here. Today, however, is different. With only two hours' notice, a PDAM will not be possible. Mission control directs me to close and check all the hatches on the U.S. segment of the space station. I trained to do this in my preparations for this mission, and I run through the procedure in my mind in order to complete the steps properly and—most important—quickly. Even the hatches that were already closed need to be checked, like the unused berthing ports for visiting vehicles. With the hatches closed, if one module is hit, the others might survive—or at least their contents won't be sucked out into the vacuum of space. There are eighteen hatches on the U.S. segment that must be closed or checked. While I'm working through the hatches as efficiently as I can, I get a call from mission control.
- I get back to checking that the hatches are closed. Luckily there are no serious issues with any of them—I don't have the time to fix any problems. I collect the items from the U.S. segment that we will need most if a collision destroys that part of the station: the defibrillator, the advanced life support medical kit, my iPad with important procedures on it, my iPod, and a bag of personal items.
- Ten minutes before potential impact we make our way to the Soyuz, which Gennady has prepared for flight in case we have to detach from the station. It's orbital night now and dark in the Soyuz as we each slide into our seats. It's cramped and cold and loud. "You know," Gennady says, "it will really suck if we get hit by this satellite." "Da," Misha agrees. "Will suck." Only four other times in fifteen years have crews had to shelter in place as we are now.

How high are they?

- Above around 420 miles (700 km) the Van Allen belt particles are dangerous
- Below around 180 miles (300 km), drag is more of a problem
- Higher orbit is more expensive to achieve



How to see the ISS

- Many websites and apps tell you when and where
  - Heaven's Above Pro app
  - Spot the Station app
  - https://spotthestation.nasa.gov/
- Very bright, some structure, especially with binoculars
- Just before sunrise or after sunset (longer in the summer)
- Transit usually takes several minutes
- Best when elevation is >20 degrees
- Travels west to east

Launch from Baikonur (From Kelly's *Endurance*)

- "Pre-launch rituals are weird. Cosmonauts suit up and enter a room separated by glass from family, administrators and the press. In sequence each astronaut spends 15 minutes in a Soyuz seat for a pressure check, then they openly and in sequence speak to their families and say goodbye.
- "The Sokol suits are designed for sitting in the fetal position while launching in the Soyuz, not for walking, so the three of us waddle along like hunched penguins with as much dignity as we can. We are carrying cooling fans that blow air into our pressure suits, like the Apollo astronauts in the old NASA footage.
- "The three of us walk up to three small white squares that have been painted on the asphalt, labeled with our positions on the Soyuz: commander for Gennady, flight engineer for Misha, flight engineer 2 for me. We step into our little boxes and wait for the head of the Russian space agency to ask us each in turn, again, if we are ready for our flight. It's sort of like getting married, except whenever you're asked a question you say, 'We are ready for the flight' instead of 'I do'."

Launch from Baikonur

- “After a while, the bus slows, then comes to a stop well before the launchpad. We nod at one another, step off, and take up our positions. We’ve all undone the rubber-band seals that had been so carefully and publicly leak-checked just an hour before. I center myself in front of the right rear tire and reach into my Sokol suit. I don’t really have to pee, but it’s a tradition: When Yuri Gagarin was on his way to the launchpad for his historic first spaceflight, he asked to pull over—right about here—and peed on the right rear tire of the bus. Then he went to space and came back alive. So now we all must do the same. The tradition is so well respected that women space travelers bring a bottle of urine or water to splash on the tire rather than getting entirely out of their suits.”
- “It’s night, but we wouldn’t be able to see anything out our windows even if it were broad daylight. The capsule is encased in a metal cylinder, called a fairing, which protects it from aerodynamic stress until we are out of the atmosphere. Inside, it’s dark and loud and we are sweaty in our Sokol suits.”

Communications and computers

- Radio communications for telemetry, communications with mission control and return of scientific data
- Russia: direct communication and Luch data relay satellites
- US: Tracking and Data Relay Satellite System (TDRSS) in geostationary orbit
- US side has ~100 modified commercial Windows or Linux laptops
  - Linux for command and control
  - Windows for procedures, science, email, video chat, and entertainment
  - Wireless LAN via Wi-Fi: 2019 upgrade from 10/3 Mbits/sec (download/upload) to 600 Mbits/sec with internet access
- Russian side has Russian PCs with Russian OSs

Power and thermal control

- Six Russian solar arrays, 28 volts DC
- Eight truss solar arrays, 160 volts DC
- Six of eight rollout solar arrays installed
- Bifacial: direct and Earth-reflected light
- Two degrees of freedom to follow the sun
- Rechargeable NiH2 batteries replaced by lithium ion in 2016
- DC-to-DC converters supply 28 and 124.5 volts throughout the station
- Plasma contactors discharge static electricity
- Thermal control
  - Water inside, heat exchangers, ammonia outside with radiators

An astronaut’s day in space

•An average day on the station starts with breakfast, personal hygiene, housecleaning and checking the daily schedule on a laptop computer.

•Next, blood samples are drawn for analysis later in the day and a daily conference is conducted with Mission Control to make sure everyone knows what is scheduled throughout the day.

•A routine air quality check is taken and the crew begins work on allotted experiments.

•Later, another air quality check is done and the crew hits the treadmill and exercise bike for a two-hour daily exercise regimen. The entire crew then meets for lunch in the Zvezda Service Module.

•After lunch, the crew receives a one-hour break and then it’s back to work, doing routine maintenance on the station, conducting research and working on experiments.

•Afterward, the cabin’s air pressure is checked and the crew does a few more laps on the treadmill.

•Next, tasks are finished, experiments cleaned and station systems checked.

•The crew then eats and has another daily planning conference to prepare for the next day.

•Finally, the crew has free time to get ready for bed and rest for the next busy day ahead.

Scott Kelly’s twin study

I WAKE UP early in the morning, six a.m., and float out of my CQ, through the lab and Node 1, turning on lights as I go. I turn right, into Node 3, where I go into the WHC. I don’t start it up, though—today is a science sample collection day. The process of urination is going to be even more complicated than usual. I grab a urine collection bag, clear plastic with a condom attached to one end. I put the condom on, then wrap it in mesh bandages to prevent leaks. As I urinate, I have to push with enough force to unseat the valve on the bag to allow the urine to flow in—without the valve there, of course, it would just come floating back out. But it’s hard to push with enough force to open the valve without pushing so hard the urine leaks from the condom—and this is exactly what happens. Urine soaks the gauze, then quickly forms droplets that float out to the walls. I’ll have to clean them up later. After I finish peeing, I remove the condom while trying not to liberate more urine. I use sample tubes with plungers to draw out three samples, initial them, mark them with the date and time, and scan their barcodes into the system. Then I head down to the Japanese module to put the tubes into one of the freezers. I will go through this process again and again, every time I urinate for the next twenty-four hours.

With the pee sample done, I head into Columbus for my blood draw. Like most astronauts on ISS, I know how to draw my own blood. At first I told the instructors in Houston that I wouldn’t be able to stick a needle in my own vein, but with some help I agreed to give it a try and quickly got the hang of it. Gennady joins me in Columbus to help, right on time, though I told him last night he didn’t need to. I clean the site on my right arm, which I’ve found to be a better vein. Using my left hand, I pierce the skin and slip the needle in. There is a brief flash of red in the tube holder, an indication that I hit the vein, but when I connect the vacuum tube, there’s no blood. I must have gone right through. Having ruined that one for today, I will have to try again on the left side. Because this is my only remaining arm, I suggest Gennady give it a try for me. Gennady grabs another butterfly needle and connects it to the tube holder. After cleaning the site on my left arm, he takes aim and slides the needle perfectly into the vein. But the needle isn’t properly connected to the tube holder, so blood escapes, flowing out into globs in the air that wobble and then resolve themselves into crimson spheres, traveling out in every direction. Gennady quickly reseats the connection while I reach out to grab some of the blood spheres with my hand before they can float farther away. The ones I missed I’ll have to track down and clean up later. Luckily, I’m mostly alone on the U.S. segment, so no one will encounter a gory surprise before I can get to it. Gennady changes out the tubes over and over until he’s drawn ten tubes of blood. I thank him for his help, and he goes back to the service module to have breakfast. I put the tubes in the centrifuge for half an hour, then put them in the freezer along with the other samples. Later in the day, I will take a fecal sample; tomorrow, saliva and skin. I will go through this whole process every few weeks for the rest of the year.

Table 8-2. Medical Events Among Seven Astronauts on MIR, March 14, 1995 through June 12, 1998

Note: **Data from the Russian Space Agency indicate that there were 304 in-flight medical events on board the space station *Mir* from February 7, 1987 through February 28, 1998. The numbers of astronauts at risk or the incidence per 100 days was not reported.**

Event	Number of Events
Musculoskeletal	7
Skin	6
Nasal Congestion, irritation	4
Bruise	2
Eyes	2
Gastrointestinal	2
Psychiatric	2
Hemorrhoids	1
Headaches	1
Sleep disorders	1

Table 8-3. Medical Events and Recurrences Among Astronauts of All Nationalities on Mir, March 14, 1995, through June 12, 1998.

Event	Number of Events
Superficial injury	43
Arrhythmia	32
Musculoskeletal	29
Headache	17
Sleeplessness	13
Fatigue	17
Contact dermatitis	5
Surface burn	5
Conjunctivitis	4
Acute respiratory infection	3
Asthenia	3
Ocular foreign body	3
Globe contusion	2
Dental	2
Constipation	1

Music in space [CollectSpace 2:15]

https://www.youtube.com/watch?v=EB5kbZrb4TY

Debris avoidance and attitude control [6:00 NatGeo]

https://www.youtube.com/watch?v=Ei-TcECJVXU

Incidents and accidents

- 2001: EVA to remove debris blocking Progress supply ship
- 2004: Russian EVA ended early due to cooling malfunction
- 2004: US EVA ended early due to oxygen flow switch malfunction
- 2004: Attitude control lost during EVA with 2-person crew
- 2006: Antenna not retracted after Progress docking; cut with EVA
- 2007: US EVA cut short due to hole in one glove layer
- 2008: Reduced EVA activity due to high CO_2 levels
- 2009: Quick retreat to Soyuz due to 2.7 inch fragment of US rocket
- 2009: US EVA ended early due to high CO_2 levels
- 2012: Quick retreat to Soyuz due to debris
- 2013: US EVA cut short due to water in the helmet
- 2015: Quick retreat to Soyuz due to debris from old Soviet satellite
- 2016: US EVA ended early due to water in the helmet
- 2018: Air leak in Soyuz return vehicle
- 2019: Blood thinners used to treat jugular vein clot
- 2021: New Russian module computer glitch with severe attitude disturbance
- 2021: Docked Soyuz engine test fired too long
- 2021: Retreat to spacecraft due to Russian anti-satellite missile test
- 2022: Russian EVA ended early due to battery problems
- 2022: Soyuz emergency rescue ship's cooling loop hit by micrometeroid; new ship sent up 2 months later
- 2023: Russian radiator leak bypassed with EVA
- 2024: US EVA ended early due to water leak
- 2024: Shelter in emergency vehicles after Russian commercial satellite breakup