
SELF-STYLED MESSIAHS
FASTEST SHARKS IN THE SEA
ARCHAEOLOGY BY SATELLITE
NATIONAL GEOGRAPHIC
THE SPACE ISSUE
THE NEXT MOON SHOT
IN ORBIT WITH SCOTT KELLY
VOYAGER, 40 YEARS LATER
BEST ECLIPSE IN A CENTURY
AUGUST 2017

This Japanese spacecraft delivered nearly five tons of hardware and supplies to the space station in 2015. Lit up on Earth below, the Nile River flows into the eastern part of the Mediterranean Sea.

Space Odyssey

Astronaut Scott Kelly reflects on his yearlong journey aboard the International Space Station in this exclusive excerpt from his memoir, Endurance.


HTV5

For 340 consecutive days Scott Kelly was a living, breathing science experiment. Kelly (below, in a selfie taken on the space station with a view of Earth) was monitored to help researchers understand how the body reacts and adapts to the harsh conditions in space – with an eye toward future exploration of the solar system. After three space walks, 5,440 orbits around Earth, and some 144 million miles aboard the space station, he returned home in March 2016. Here he discloses the physical – and emotional – challenges of long-term space travel.

Looking down at the planet

from 200 miles in space, I feel as though I know the Earth in an intimate way most people don't—the coastlines, terrains, mountains, and rivers. Some parts of the world, especially in Asia, are so blanketed by air pollution that they appear sick, in need of treatment or at least a chance to heal. The line of our atmosphere on the horizon looks as thin as a contact lens over an eye, and its fragility seems to demand our protection. One of my favorite views of Earth is of the Bahamas (above), a large archipelago with a stunning contrast from light to dark colors. The vibrant deep blue of the ocean mixes with a much brighter turquoise, swirled with something almost like gold, where the sun bounces off the shallow sand and reefs. Whenever new crewmates come up to the International Space Station, I always make a point of taking them to the Cupola—a module made entirely of windows looking down on Earth—to see the Bahamas. That sight always reminds me to stop and appreciate the view of Earth I have the privilege of experiencing.

Sometimes when I'm looking out the window it occurs to me that everything

ALL PHOTOS: NASA

that matters to me, every person who has ever lived and died (minus our crew of six) is down there. Other times, of course, I'm aware that the people on the station with me are the whole of humanity for me now. If I'm going to talk to someone in the flesh, look someone in the eye, ask someone for help, share a meal with someone, it will be one of the five people up here with me.

This is my fourth mission to space, my second to the ISS, and I've been here for three weeks now. I'm getting better at knowing where I am when I first wake up, but I'm often still disoriented about how my body is positioned. I'll wake up convinced that I'm upside down, because in the dark and without gravity, my inner ear just takes a random guess on the position of my body in the small space. When I turn on a light, I have a sort of visual illusion that the room is rotating rapidly as it reorients itself around me, though I know it's actually my brain readjusting in response to new sensory input.

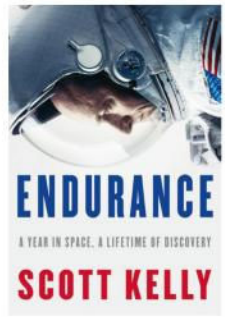
My crew quarters are just barely big enough for me and my sleeping bag, two laptops, some clothes, toiletries, photos of Amiko (my longtime girlfriend) and my daughters, a few paperback books. Without getting out of my sleeping bag, I wake up one of the two computers attached to the wall and look at my schedule. Much of today is to be taken up with one long task labeled DRAGON CAPTURE.

THE STATION IS SOMETIMES DESCRIBED as an object: "The International Space Station is the most expensive object ever created." "The ISS is the only object whose components were manufactured by different countries and assembled in space." That much is true. But when you live inside the station for days and weeks and months, it doesn't feel like an object. It feels like a place, a very specific place with its own personality and its own unique characteristics. It has an inside and an outside and rooms upon rooms, each of which has different purposes, its own equipment and hardware, and its own feeling and smell, distinct from the others. Each module has its own story and its own quirks.

From the outside the ISS looks like a number of giant empty soda cans attached to each other end to end. Roughly the size of a football field, the station is made up of five modules connected the long way—three American and two Russian. More modules, including ones from Europe and Japan as well as the United States, are connected as offshoots to port and starboard, and the Russians have three that are attached "up" and "down" (we call these directions zenith and nadir). Between my first time visiting the space station and this mission, it has grown by seven modules, a significant proportion of its volume. This growth is not haphazard but reflects an assembly sequence that had been planned since the beginning of the space station project in the 1990s.

Whenever visiting vehicles are berthed here for a time, there is a new "room," usually on the Earth-facing side of the station; to get into one of them I have to turn "down" rather than left or right. Those rooms get roomier as we get the cargo unpacked, then get smaller again as we fill them with trash. Not that we need the space—especially on the U.S. side, the station feels quite spacious, and in fact we can lose each other in here easily. But the appearance of extra rooms—and then their disappearance after we set them loose—is a strange feature most homes don't have.

Since before the space shuttle was retired, NASA has been contracting with private companies to develop spacecraft capable of supplying the station with cargo and, at some point in the future, new crews. The most successful private company so far has been Space Exploration Technologies, better known as SpaceX, which produces the *Dragon* spacecraft. Yesterday a *Dragon* launched



from a pad at Cape Canaveral. Since then *Dragon* has been in orbit a safe 10 kilometers from us. This morning our aim is to capture it with the space station's robot arm and attach it to the docking port on the station. The process of grappling a visiting vehicle is a bit like playing a video game that tests hand-eye coordination, except that it involves real equipment worth hundreds of millions of dollars. Not only could an error cause us to lose or damage the *Dragon* and the millions of dollars' worth of supplies on board, but a slip of the hand could easily crash the visiting vehicle into the station. An accident with a resupply ship has happened before, when a cargo spacecraft struck the old Russian space station Mir, though its crew was lucky enough not to have been killed by decompression when the *Progress* crashed into its hull.

These uncrewed spacecraft are the only way we can get supplies from Earth. The Russian *Soyuz* spacecraft has the capability to send three humans to space, but there is almost no room left over for anything else. SpaceX has had a lot of success so far with their *Dragon* spacecraft and Falcon rocket, and in 2012 they became the first private company to reach the ISS. Since then they have become one of our regular suppliers, along with the Russian *Progress* and Orbital ATK's *Cygnus,* and they hope to be ready to fly astronauts on the *Dragon* in the next few years. If they can pull that off, they will be the first private company to carry human beings to orbit, and that launch will be the first time astronauts leave Earth from the United States since the space shuttle was retired in 2011.

Right now *Dragon* is carrying 4,300 pounds of supplies we need. There is food, water, and oxygen; spare parts and supplies for the systems that keep us alive; health care supplies like needles and vacuum tubes for drawing our blood, sample containers, medications; clothing and towels and washcloths, all of which we throw away after using them as long as we can. *Dragon* will also be carrying new science experiments for us to carry out, as well as new samples to keep the existing ones going. Notable among the science experiments is a small population of live mice for a study we will be carrying out on how weightlessness affects bone and muscle. Each resupply spacecraft also carries small care packages from our families, which we always look forward to, and precious supplies of fresh food that we enjoy for just a few days, until it runs out or goes bad. Fruits and vegetables seem to rot much faster here than on Earth. I'm not sure why, and seeing the process makes me worry that the same thing is happening to my own cells.

We are especially looking forward to this *Dragon*'s arrival because another resupply rocket exploded just after launch back in October 2014. That one was a *Cygnus* flown by another private contractor, U.S.-based Orbital ATK. The station is always supplied far beyond the needs of the current crew, so there was no immediate danger of running out of food or oxygen when those supplies were lost. Still, this was the first time a rocket to resupply the ISS had failed in years, and it destroyed millions of dollars' worth of equipment. The loss of vital supplies like food and oxygen made everyone think harder about what would happen if a string of failures were to occur. A few days after the explosion, an experimental space plane being developed by Virgin Galactic crashed in the Mojave Desert, killing the copilot. These failures were unrelated, of course, but the timing made it feel as though a string of bad luck might be catching up with us after years of success.

BACK IN MY CREW QUARTERS I get dressed while reading and clicking through emails. Getting dressed is a bit of a hassle when you can't "sit" or

"stand," but I've gotten used to it. The most challenging thing is putting on my socks—without gravity to help me bend over, I'm using only core strength and flexibility to pull my legs up to my chest. It's not a challenge to figure out what to wear, since I wear the same thing every day: a pair of khaki pants with lots of pockets and strips of Velcro across the thighs, crucial when I can't put anything "down." I have decided to experiment with how long I can make my clothes last, the idea of going to Mars in the back of my mind. Can a pair of underwear be worn four days instead of just two? Can a pair of socks last a month? Can a pair of pants last six months? I aim to find out. I put on my favorite black T-shirt and a sweatshirt that, because it's flying with me for the third time, has to be the most traveled piece of clothing in the history of clothing.

Dressed and ready for breakfast, I open the door to my quarters. As I push against the back wall to float myself out, I accidentally kick loose a paperback book: *Endurance: Shackleton's Incredible Voyage,* by Alfred Lansing. I brought this book with me on my previous flight as well, and sometimes I flip through it after a long day on the station and reflect on what these explorers went through almost exactly a hundred years before. They were stranded on

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ice floes for months at a time, forced to kill their dogs for food, and nearly froze to death in the biting cold. They hiked across mountains that had been considered impassable by explorers who were better equipped and not half-starved. Most remarkable, not a single member of the expedition was lost.

When I try to put myself in their place, I think the uncertainty must have been the worst thing. They must have wondered if they could survive, and that doubt must have been worse than the hunger and the cold. When I read about their experiences, I think about how much harder they had it than I do. Sometimes I'll pick up the book specifically for that reason. If I'm inclined to feel sorry for myself because I miss my family or because I had a frustrating day or because the isolation is getting to me, reading a few pages about the Shackleton expedition reminds me that even if I have it hard up here in some ways, I'm certainly not going through what they did. It's all about perspective. I tuck the book back in with a few other personal items. Maybe I'll read a few pages before I go to sleep tonight.

DRAGON IS NOW IN ITS ORBIT 10 kilometers away from us, matching our speed of 17,500 miles per hour. We can see its light blinking at us on the external cameras. Soon SpaceX ground control in Hawthorne, California, will move it to within 2.5 kilometers, then 1.2 kilometers, then 250 meters, then 30 meters, then 10 meters. At each stopping point, teams on the ground will check *Dragon*'s systems and evaluate its position before calling "go" or "no go" to move on to the next stage. Inside of 250 meters we will get involved by monitoring the approach, making sure the vehicle stays within a safe corridor, is

Kelly was safely tethered to the space station during this seven-hour, 48-minute space walk to reconfigure a cooling unit in November 2015. Mere layers of a space suit shielded him from radiation and other hazards of space.

behaving as expected—and that we are ready to abort if required. Once it's close enough, my crewmate Samantha Cristoforetti will grapple it with the station's robot arm. This is a glacially slow and deliberate process, and this is one of the many things that's very different between movies and real life. In the films *Gravity* and *2001: A Space Odyssey,* a visiting spacecraft zips up to a space station and locks onto it; then a hatch pops open and people pass through, all over the course of about 90 seconds. In reality we operate with the knowledge that one spacecraft is always a potentially fatal threat to another—a bigger threat the closer it gets—and so we move slowly and deliberately.

Samantha will operate the robot arm from the robotics workstation in the Cupola. Terry Virts, the only other American on board, will be her backup, and I will be helping out with the approach and rendezvous procedures. Terry and I squeeze into the Cupola with Samantha, watching the data screen over her shoulder that shows the speed and position of *Dragon*.

Like me, Terry was a test pilot before joining NASA—in his case, with the Air Force. His call sign is Flanders, after the lovably square character

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Ned Flanders on *The Simpsons*. Terry has the positive attributes of Ned Flanders—optimism, enthusiasm, friendliness—and none of the negative ones. I've found him to be consistently competent, and I appreciate that as a leader he is a consensus builder rather than an authoritarian. Since I've been up here, he has always been respectful of my previous experience, always open to suggestions about how to do things better rather than getting defensive or competitive. He loves baseball, so there is always a game on somewhere on the station, especially when the Astros or the Orioles are playing. I've gotten used to the rhythm of the nine-inning games marking time for a few hours of our workdays.

Samantha is one of the few women to have served as a fighter pilot in the Italian Air Force, and she is unfailingly competent in everything technical. She is also friendly and quick to laugh, and among her many other qualifications to fly in space, she has a rare talent for language. She has native-level fluency in English and Russian (the two official languages of the ISS) as well as French, German, and her native Italian. She is also working on learning Chinese.

For some people who hope to fly in space, language can be a challenge. We all have to be able to speak a second language (I've been studying Russian for years, and my cosmonaut crewmates speak English much better than I speak Russian), but the European and Japanese astronauts have the added burden of learning two languages if they don't already speak English or Russian. For Samantha this wasn't a problem. In fact her Russian and English are both so good that she sometimes acts as an interpreter between cosmonauts and astronauts if we have to talk about something nuanced or complicated.

David Saint-Jacques, a Canadian astronaut at Mission Control in Houston, will talk us through the capture process, announcing *Dragon*'s position as it moves, controlled from the ground through each of its preplanned stops.

"Dragon is inside the 200-meter keep-out sphere," David says. The keep-out sphere is an imaginary radius boundary around the station, meant to protect us from accidental collisions. "The crew now has the authority to issue an abort." This means that we can shut down the process ourselves if we lose contact with Houston or if *Dragon* is outside the corridor.

"Houston, capture conditions are confirmed. We're ready for *Dragon* capture," Terry replies.

At 10 meters we inhibit the station's thrusters to prevent any unintended jolts. Samantha takes control of the robotic arm, using her left hand to control the arm's translation (in, out, up, down, left, right) and her right hand to control its rotation (pitch, roll, and yaw).

Samantha reaches out with the robot arm, watching a monitor that offers a view from a camera on the "hand," or end effector, of the arm, as well as two other video monitors showing data describing *Dragon*'s position and speed. She can also look out the big windows to see what she's doing. She moves the arm out away from the station—very slowly and deliberately. Closing the space between the two spacecraft inch by inch, Samantha never wavers or goes off course. On the center screen the grapple fixture on *Dragon* grows larger. She makes precise adjustments to keep the spacecraft and the robot arm perfectly lined up.

The arm creeps out slowly, slowly. It's almost touching the *Dragon*.

Samantha pulls the trigger. "Capture," she says.

Perfect.

The process of pressurizing the space between the *Dragon* and the station (the "vestibule") takes several hours and is important to do correctly. The danger that *Dragon* poses to the station is not over. A mistake in vestibule outfitting could cause depressurization—our air venting out into space. So Samantha and I work through the steps one by one.

We wait to open the ISS hatch that leads to the *Dragon* until the next morning. When Samantha slides it out of the way, an unusual and unmistakable smell hits me. Slightly burned, slightly metallic. This time it reminds me of the smell of sparklers on the Fourth of July: the smell of space. After a series of procedures we eventually open *Dragon*'s hatch, and our care packages are clearly marked and easily accessible, as are the mice and the fresh food. Terry and I distribute the packages to everyone, feeling a bit like Santa Claus.

I FINALLY OPEN MY care package in the privacy of my crew quarters. Inside is a poem and some chocolates from Amiko (she knows I crave sweets when I'm in space, though on Earth I don't have much of a sweet tooth); a pair of shoelaces for my workout shoes with toggle ties, because it's hard to tie laces without gravity; a bottle of Frank's hot sauce; a picture from my identical twin brother, Mark, showing twin redhead little boys giving the finger to the camera, with a note on the back that reads, "Hope the WCS is working up there!" (WCS stands for waste collection system, a space toilet); and a card from my daughters, Charlotte and Samantha, their distinctive handwritings gouged into the heavy paper by a black pen.

I put everything away, eat a piece of the chocolate, check my email again. I hang in my sleeping bag for a while, thinking about my kids, wondering how they are doing with me being gone. Then I go to sleep. □