RACING THROUGH SPACE

HUMAN ACHIEVEMENT REACHES A PINNACLE ON THE INTERNATIONAL SPACE STATION

BY ADAM MORGAN & MELISSA MATHEWS

Imagine you're a NASCAR racer zipping around the racetrack at 200 miles per hour (mph), but – just to make it more interesting — you are also building your car during the race. That would be a challenge, right?

Mission Specialist Soichi Noguchi moves along an International Space Station truss during the first STS-114 spacewalk. During this excursion, he and fellow spacewalker Steve Robinson worked on one of the Station's control moment gyroscopes.

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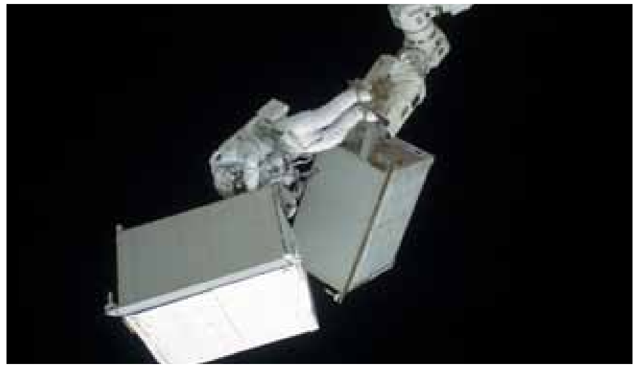

Anchored to a Canadarm2 mobile foot restraint, European Space Agency astronaut Christer Fuglesang, STS-128 mission specialist, participates in the mission's second session of extravehicular activity (EVA) as construction and maintenance continue on the International Space Station. During the six-hour, 39-minute spacewalk, Fuglesang and NASA astronaut John "Danny" Olivas (out of frame), mission specialist, installed the new Ammonia Tank Assembly on the Port 1 Truss and stowed the empty tank assembly into the Space Shuttle Discovery's cargo bay.

Now imagine you're flying 220 miles above the Earth, traveling at speeds of 17,500 mph and orbiting the Earth every 90 minutes. But this time, you're building your house at those speeds. Oh yeah, did I mention you're also living in the house while you're building it? Now that's a challenge.

Well, that is exactly what has been happening over the past 10 years on the International Space Station (ISS). Fifteen nations from five major space agencies have been working together to design and build what has been coined "one of the greatest engineering feats of all time."

Recently recognized by the National Aeronautics Association with the 2009 Collier Trophy "for the design, development, and assembly of the world's largest spacecraft, an orbiting laboratory that promises new discoveries for mankind and sets new standards for international cooperation in space," the ISS is an undertaking in a class by itself. It shatters the mold as an engineering, scientific, management, and diplomatic achievement.

"Nothing this complex has ever been attempted before – plain and simple," said Joy Bryant, vice president and program manager for Boeing's International Space Station program.

As the largest spacecraft ever built, its "wingspan" is larger than a 747, yet it travels at Mach 25. Its pressurized cabin area is the size of a five-bedroom house but stores three times as much, because all surfaces – top, bottom, and sides - are utilized in the weightlessness of space.

Over the next four issues of *Ad Astra,* we will tell the amazing story of the International Space Station. Starting with this overview, we will highlight the many successes as well as the many challenges of one of NASA's, no – mankind's, most ambitious projects. Keep an eye out for the next three installments in the series including an in-depth look at how engineers and astronauts overcome obstacles 220 miles above Earth with limited logistical opportunity, bringing 15 nations together with a common goal, as well as the impact of the International Space Station on the future of space exploration.

WHERE DID IT ALL START?

Inhabited space stations go back as far as the early 1970s when The Soviet Union launched the world's first space station, Salyut 1, in 1971 - a decade after launching the first human into space. The United States was not far behind with the launch of its Skylab in 1973.

In his 1984 State of the Union speech, U.S. President Ronald Reagan directed NASA to build a permanently-crewed space station. "America has always been greatest when we dared to be great," he told Congress. "We can reach for greatness again. We can follow our dreams to distant stars, living and working in space for peaceful economic and scientific gain." He invited international participation.

Russia (then the Soviet Union) began constructing Mir in 1986. It was the world's first consistently inhabited long-term research station in space. Russia planned to follow the Mir space station with a Mir 2 in the 1990s, while the United States planned to build a station called Freedom – an effort that included partnering with space agencies in Europe, Canada, and Japan. Funding difficulties brought the U.S.-led international team and the Russians together in 1993 to build a combined station – the International Space Station.

Conceived as an international undertaking from the beginning, the ISS was designed, built, and launched from locations spanning the globe.

Space exploration is "one area of human endeavor in which we are indisputably continuing to lead the world," said U.S. President Bill Clinton in 1993. Science and technology partnerships, he said, "are the keys to our future as a people, to our standard of living, to our quality of life as well as to our ability to continue the American tradition of exploring frontiers."

Russian cosmonauts Oleg Kotov and Maxim Suraev (out of frame), both Expedition 22 flight engineers, participate in a session of extravehicular activity (EVA) as maintenance and construction continue on the International Space Station. During the spacewalk, Kotov and Suraev prepared the Mini-Research Module 2 (MRM2), known as Poisk, for future Russian vehicle dockings.

Fifteen separate cultures, values, and sources of expertise pulled together to create our largest adventure into space to date. At its peak, the development effort involved more than 100,000 dedicated people across the United States and around the world. The complex assembly phase spanned about a decade and provided no opportunity to pre-assemble or fit-check interfaces on the ground. Despite this, all hardware and software has been integrated and activated on-orbit flawlessly.

"Hardware integration has been one of our biggest challenges," said Mark Mulqueen, vehicle director for Boeing's International Space Station program. "Given the cost and effort involved in launching a piece of hardware into space, there simply has been no room for error. This is an area where meticulous requirements planning and thorough coordination was essential. The fact that these large, complicated pieces have come together flawlessly on-orbit is a testament to the great teams of engineers working across the globe."

IMAGE CREDIT: NASA

Cosmonaut Yury Lonchakov, Expedition 18 flight engineer, participates in a session of extravehicular activity (EVA) to perform maintenance on the International Space Station.

To prepare for the project, space shuttles flew to Mir from 1995 to 1998 with U.S. astronauts serving on board the Russian station as researchers for as long as six months.

A Russian Proton rocket launched the first ISS module from Baikonur Cosmodrome in Kazakhstan on November 20, 1998. The module was a Russian-built and United States-funded unit called Zarya. The second module, Unity, was built by the United States and was launched aboard NASA's Space Shuttle Endeavour from Kennedy Space Center on December 4, 1998. The two were joined together in orbit.

Innovation has been a key factor in every aspect of the ISS development. Breakthroughs in round-the-clock multinational virtual design and construction took advantage of the latest communications and design software, forever changing international technical collaboration. Quality and attention to detail had to be perfect. Physical tolerances, for example, could not exceed three one thousandths of an inch or risk an air leak. Since the major components could not be fit checked first on the ground, there was simply no room for error.

Boeing is NASA's prime contractor for the design, development, integration, testing delivering, and now sustaining all the U.S.-built elements of the ISS. The U.S elements include three connecting modules, or nodes; a laboratory module; truss segments; four solar array modules; three mating adapters; a cupola; and an unpressurized logistics carrier. Boeing developed the thermal control system; life support system; guidance, navigation, and control system; data handling systems; power systems; and communications and tracking systems.

"Boeing and its heritage firms have had a leading role in every U.S. crewed spacecraft to date," added Bryant. "The International Space Station work gave us an opportunity to harness that expertise and push ourselves to the next level as an aerospace firm."

Boeing also integrates vehicle elements provided by the international partners. International partner components include: a Canadian-built 55-foot-long robotic arm and mobile servicing system used for assembly and maintenance tasks on the space station; a pressurized European laboratory called *Columbus* and logistics transport vehicles; a Japanese laboratory called *Kibo,* with an attached exposed exterior platform for experiments, as well as logistics transport vehicles; and two Russian research modules, an early living quarters called the *Zvezda Service Module* with its own life support and habitation systems, logistics transport vehicles and *Soyuz* spacecraft for crew return and transfer.

"GO FOR RESEARCH"

The International Space Station is, in every sense, now an orbiting laboratory and, as NASA literature puts it, "It's GO for research." The ISS has integrated over 20,000 kg of hardware and software, supporting over 200 unique research investigations by more than 1,500 scientists – all while ISS assembly and construction was still underway.

"There are great expectations and initiatives underway for even more improved scientific return now that ISS assembly is complete," added Bryant.

In 2005, the U.S. Congress authorized NASA to establish the American segments of the station as a National Laboratory, and encouraged NASA to open research opportunities to other federal entities, as well as private researchers. The full capability of initial ISS resources are in place – and the crew complement has grown from two or three

NASA astronaut John "Danny" Olivas, STS-128 mission specialist, participates in the mission's third and final session of extravehicular activity (EVA) as construction and maintenance continue on the International Space Station. During the seven-hour, one-minute spacewalk, Olivas and European Space Agency astronaut Christer Fuglesang (out of frame), mission specialist, deployed the Payload Attachment System (PAS), replaced the Rate Gyro Assembly #2, installed two GPS antennae and did some work to prepare for the installation of Node 3 next year.

members to six. Astronauts, previously busy with the assembly phase, will now be able to devote significantly more of their time to research.

The ISS laboratories provide unique environments to conduct research. Three primary environmental differences open the door for continued research. The absence of gravity, i.e., the "microgravity" environment offers unique conditions that impact fundamental research of biological cells, fluids and materials behavior. The vacuum and radiation environments differ from our earthly environment. Additionally, the ISS allows remote sensing of 90 percent of the world's population from a relatively low altitude. Research completed on-board the ISS is vitally important to improving life here on Earth as well as creating a foundation to continue our nation's space exploration mission.

Experiments are designed by investigators on the ground, housed on orbit in "racks," or external pallets, and maintained by ground operators and/or the astronauts in space. Some of the most interesting and critical experiments on space station can't be contained in racks or test tubes, however. Key experimental subjects are the astronauts themselves, who function as floating guinea pigs (if guinea pigs had MDs, PhDs, and cooler aviator call signs). One of the primary questions the spacefaring community must answer if it is to venture beyond low Earth orbit is how exploration will affect the human body. Hazards like zero gravity, which wreak havoc on muscles and bones, and radiation have to be understood and conquered before NASA and its partners plan more ambitious missions. International Space Station astronauts, then, poke and prod themselves to test specific countermeasures – such as a load-bearing exercise – and send the data back to researchers on the ground.

BUILDING A PARTNERSHIP

The only thing more complex than the engineering that went into building the International Space Station is the diplomacy behind it. The five primary space agencies representing 15 countries signed agreements to build and operate the space station on January 29, 1998, along with several bilateral agreements between individual agencies. Together, the agreements represented an intricate web of contributions and barters that built the structure flying in space today.

"Each of the partners… has a specific and important role to play," said President Clinton's science adviser, Dr. Jack Gibbons, at the signing ceremony at the U.S. State Department in Washington. Canada would draw on its technical strength – robotics – to "provide critical robotic capabilities for assembly and operation of the station." Europe would contribute a pressurized laboratory and cargo craft to re-boost and re-supply the station. Japan, likewise, would contribute an experimental module and cargo spacecraft. Russia and the U.S. would provide infrastructure modules and crew transportation.

The agreements – and the strength of the partnership – were put to the test when, on February 1, 2003, the Space Shuttle Columbia disintegrated on re-entry to Earth's atmosphere, killing all seven

Backdropped by Earth's horizon and the blackness of space, the unpiloted Japanese H-II Transfer Vehicle (HTV) approaches the International Space Station. Once the HTV was in range, NASA astronaut Nicole Stott, Canadian Space Agency astronaut Robert Thirsk and European Space Agency astronaut Frank De Winne, all Expedition 20 flight engineers, used the station's robotic arm to grab the cargo craft and attach it to the Earth-facing port of the Harmony node.

astronauts and grounding the shuttle program for two and a half years. On orbit, two astronauts and a cosmonaut aboard the space station grieved for their colleagues, as their own mission hung in the balance.

Without the space shuttle to service the space station, how would it survive?

The partnership came together, and – with a sense of determination and innovation not seen in the space program since Apollo 13 – came up with solutions. Further assembly of the station would be put on hold, until the shuttle could once again ferry up the giant parts. Crew would be transported on the much smaller, but reliable, Russian Soyuz. The crew size would be reduced from three to two, to cut down on the need for food, water, and other consumables.

The partnership quite literally saved the International Space Station. But despite its obvious benefits, there were technical challenges that came with internationalization. Engineers were responsible for integrating all the elements, whether U.S. or foreign-made, and getting them ready for flight.

"Here's the kind of situation we were dealing with," explained Mulqueen. "Because of the nature of the ISS agreements, an Italian aerospace company may have built a NASA element that had to integrate seamlessly with a piece of Russian hardware. This was new territory for space programs."

But internationalization also made the space station program, well, more fun. Suddenly, astronauts and engineers were also expected to be linguists and diplomats. During spacewalks, astronauts and cosmonauts would have to switch seamlessly between English and Russian as they communicated with mission control in either Houston or Moscow. U.S. astronauts became connoisseurs of freeze-dried Russian space fare.

The diplomacy and cross-cultural exchanges may someday prove to be one of the most significant by-products of the International Space Station, but today the space station's *raison d'etre* continues to be hardcore science and technology.

Nearly a decade after its first residents climbed on board, the International Space Station is nearly complete and ready to enter

The International Space Station is featured in this image photographed by an STS-130 crew member on space shuttle Endeavour after the station and shuttle began their post-undocking relative separation. Undocking of the two spacecraft occurred at 7:54 p.m. (EST) on February 19, 2010.

its most exciting phase. In the U.S., the Obama administration just proposed supporting research on the station through the end of the decade, five years longer than originally envisioned. The International Space Station can now reach its true potential as a laboratory and exploration test bed. With six astronauts representing as many languages, cultures, research priorities, and national ambitions living and working together, the story of the International Space Station is really just beginning.

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Melissa Mathews writes about science, technology and aerospace through her communications firm, The Mathews Group. She is a former NASA spokesperson and a big fan of the International Space Station. She lives in Arlington, Va.

Astronaut Nicole Stott, Expedition 20 flight engineer, participates in the STS-128 mission's first session of extravehicular activity (EVA) as construction and maintenance continue on the International Space Station. During the six-hour, 35-minute spacewalk, Stott and astronaut John "Danny" Olivas (out of frame), mission specialist, removed an empty ammonia tank from the station's truss and temporarily stowed it on the station's robotic arm.