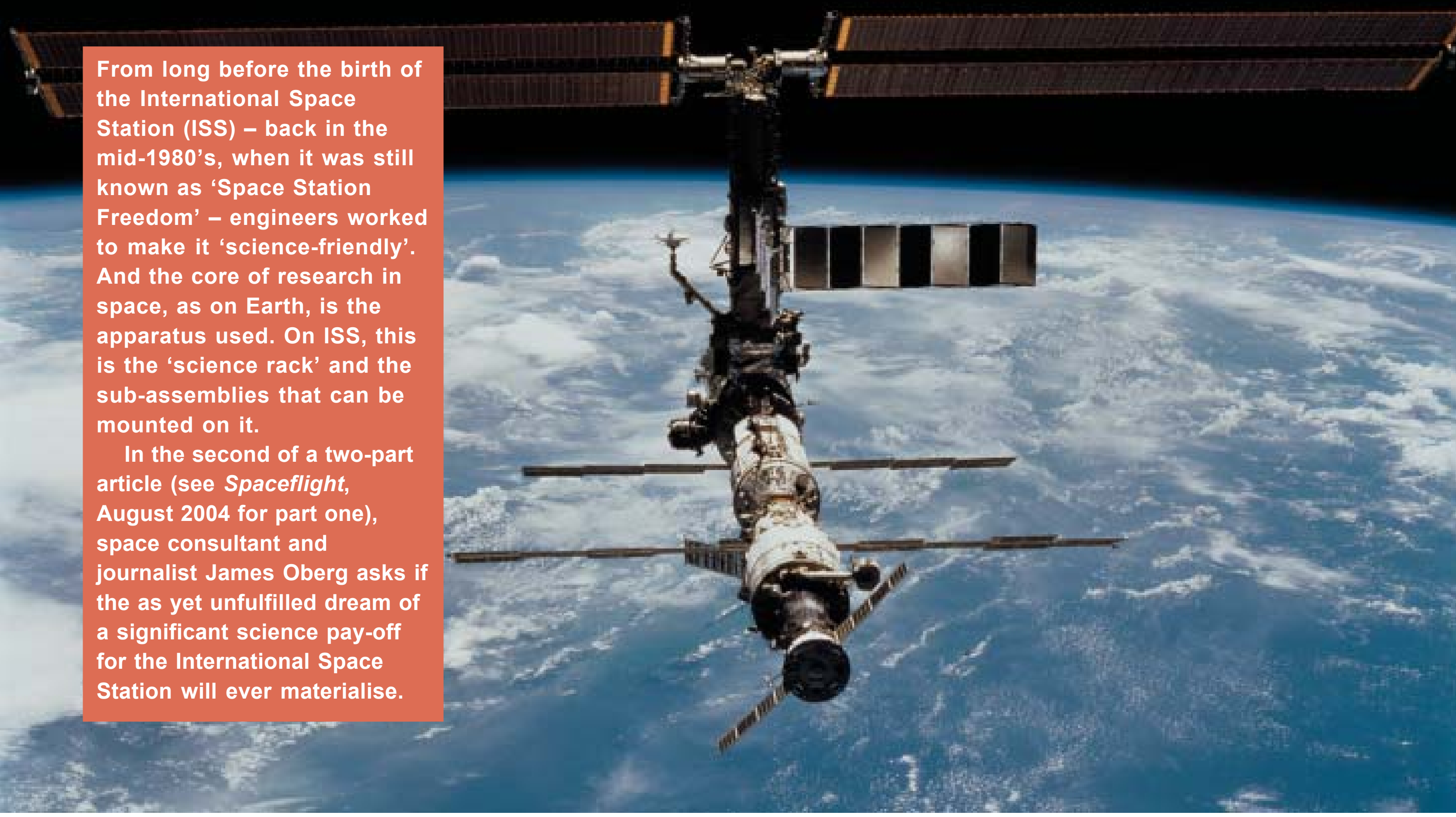
Science of uncertain returns

by James Oberg



From long before the birth of the International Space Station (ISS) – back in the mid-1980's, when it was still known as 'Space Station Freedom' – engineers worked to make it 'science-friendly'. And the core of research in space, as on Earth, is the apparatus used. On ISS, this is the 'science rack' and the sub-assemblies that can be mounted on it.

In the second of a two-part article (see *Spaceflight*, August 2004 for part one), space consultant and journalist James Oberg asks if the as yet unfulfilled dream of a significant science pay-off for the International Space Station will ever materialise.

Are Space Station science priorities being eroded?

Science equipment on previous space stations would be bolted to any available work surfaces, usually installed pre-launch as the cylindrical module was being assembled. Then the modules were closed up, shipped to the launch site, and rocketed into space. Visiting astronauts and cosmonauts would dock with the facility, enter through a small tunnel, and operate the equipment as best they could. By the time it was launched, years had usually gone by since it was designed – and as years more went by in orbit, the equipment usually became quickly obsolete, or stopped working altogether. But then it continued to take up precious space inside the small pressurised modules.

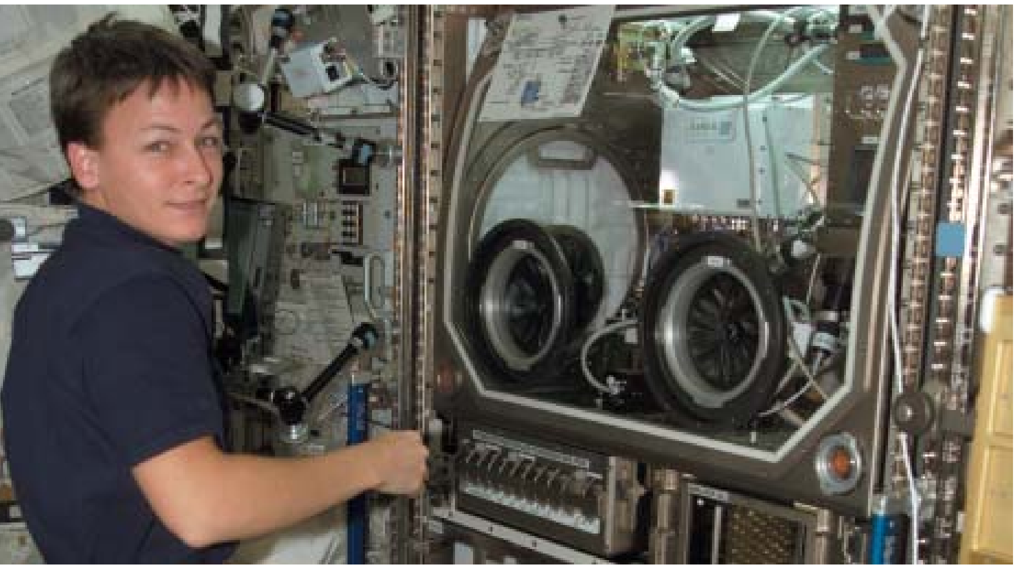
US designers were determined to learn from experience and improve on this frustrating history. Their best design innovations evolved into the US Laboratory module installed on the ISS in early 2001. And the key to this improvement is the doorway.

Because of the need for docking Apollo and Soyuz type 'space capsules' to earlier space stations such as Salyut, Skylab and Mir, the transfer tunnel was kept small, rarely much more than 50 cm in diameter. People could pass through it, perhaps carrying small boxes of supplies, or portable devices. But the Station itself was the classical 'ship in a bottle' – if anything couldn't be broken down into pieces small enough to fit through the hatch, they could never be brought aboard (or removed) once the module was in space.

The solution was a bigger door and despite the additional operational problems this entailed, its advantages were numerous. The doorways on the US modules are square, 130 cm on a side with rounded corners. Their outer rim contains mating mechanisms to hold and seal two facing doorways together to provide a module-to-module interface.

This portal was too large for an Apollo or Soyuz type earth-to-space transfer craft to carry a matching unit, and it couldn't be built strong enough to actually dock to a heavy Space Shuttle. The solution was to perform the gently module-to-module matings with the Shuttle's Remote Manipulator System, the Canadian built robot arm. These were either carrying a new module to be added permanently, or carrying the special logistics modules (built by Italy) brought up inside the Shuttle's cargo bay and hooked up to the ISS after the Shuttle had already docked to the small-diameter transfer tunnel.

So when the temporary logistics module was mated with such a large door, big boxes of supplies could quickly be passed into the ISS. More critically, standardised science racks – the size of home refrigerators – could be loaded onto the Station and, as needed, those aboard could be moved into the logistics



Peggy Whitson, Expedition Five flight engineer, works near the European-built Microgravity Sicence Glovebox in Destiny during July 2002. *All photos: NASA*

module for return to Earth. New racks, or just insertable subsections, could be manufactured on Earth and sent into space fairly quickly, as technology evolved.

From the beginning of design work, common utilities had been provided. Utilidors were the first hardware installed inside the empty hull of the US Lab (photo). Once racks were mechanically installed (the 'bottom' edge is inserted into a hinge slot and the entire unit is then rotated back into position), the crew must manually make the required connections to utility feeds. Aside from power and data communications, the individual feedlines also include water and both input gases and output vacuum.

The author visited a 'clean room' at NASA's Johnson Space Center where one flight-qualified rack for medical research was being checked out. Rails inside the frame guided sub-modules to mate with pin-stabilized spring-mounted "floating plugs" for power and data.

NASA scientists explained that each full rack (and there are slots for 24 of them in the 'Destiny' science laboratory) weighs up to 800 kg in a volume of 1.6 m^3. Most have a 3 kw feed at 120 Vdc, although five slots allow 6 kw, sometimes on prime and backup feeds that can be combined into one 12 kw feed. Data comes out on a MIL-STD-1553B payload bus, plus a high-rate optical fibre link. All the racks have access to an 802.3 Ethernet LAN with a 10 Mbps transfer rate, plus selectable video feeds to seven VTRs or to the video downlink processor.

This infrastructure is impressive, but it comes with a price, and it's more than just time and money. Because the facilities must reach a certain stage of completeness before any real research can plug into it, the Station assembly sequence was very 'front-end-loaded' toward piling up hardware that really wouldn't be utilised to any significant degree for several years. Science operations had a much lower priority than assembly and check-out of the support infrastructure.

Although some science has always been manifested for the long-term 'Expedition' crews, it has always been mostly symbolic – as well as useful 'dry runs' for the science gear. On a typical activity schedule for a three-person crew, with perhaps 50 hours of useful work per week per person, about two and a half full crewmembers are allocated to Station maintenance, repair and assembly, and checkout of new equipment. Perhaps 20 hours a week – and often only half that much – was assigned to science work.

The lack of any progress towards improving this figure – less than 20 percent of the crew time originally promised for a seven-person crew – led to a 'space team' crisis in mid-2002 when the Space Station science community essentially revolted.

This uprising was sparked by the late-2001 release of conclusions of a special ad hoc group called the "International Space Station Management and Cost Evaluation Task Force", chaired by former Martin Marietta chief A. Thomas Young. NASA had set up Young's panel following its realisation that completing the space station would probably cost about US$5 billion more than originally expected. The panel said that NASA should get used to the three- person crew limit, and a reduction in the Shuttle flight rate to four per year. Not until NASA got its finances in order – and it was clear that costs were totally out of control – should NASA even begin to plan on a larger crew for the Station.

This outraged many scientists involved with research on the Station and, in June 2002, they sent an 'open letter' with 528 signatures to NASA Administrator Sean O'Keefe. "We, the space science community, want to express our serious concern about this issue," the letter stated (this was the language of open revolt among scientists).

Of particular concern was "the lack of crew time to conduct the science due to the downsizing of the crew from seven to three astronauts/cosmonaut [which] seriously limits the majority of hours needed for scientific study." They also expressed concern over "the loss of critical scientific equipment and operational laboratory modules."

The signatories, calling themselves "the ISS Science Community", concluded: "We have yet to realise the full potential of an operational Space Station not only for the current scientific advances but also to inspire both young and old in learning more about the sciences and gravity based processes in biology and physics. These opportunities are very near, the major investment has been made, it is now only for all of us to focus our priorities to achieve the scientific and social return on this investment."

O'Keefe responded positively: "Research must be the primary focus of the International Space Station. NASA is currently moving as fast as is practicable on a five-point reform and revitalisation plan for ISS to put the effort on course and use this unique laboratory for world-class research."

"In particular," he continued, "we will determine crew size driven by the research and operations requirements. From that analysis we'll get a true picture of what it will take for the partnership to field and operate required capabilities." He went on to promise that "achieving US Core Complete in early 2004, and the accommodation of partner elements by the end of 2006, will provide an impressive on-orbit capability for research. We need to ensure that the International Space Station realises its potential as a world-class research facility."

But in August, after several months of deliberations, yet another ad-hoc external NASA advisory committee called the Research Maximization And Prioritization (ReMAP) Task Force made its in-depth assessment public. NASA may originally have intended for this panel of scientists to merely give a prioritised list of proposed Station experiments, and then NASA could begin cancelling proposals from the bottom of the list, blaming the selection on other scientists. But these were scientists, after all, and NASA didn't get exactly what it seems to have expected.

In its Executive Summary, the group first professed their faith in the goodness of the Space Station programme. "The ISS has unique features not available on any other vehicle," it stated. Further, "the committee was unanimous in the view that the ISS is unprecedented as a laboratory and is the only available platform for human tended research on long-duration effects of microgravity".

But the panel rejected NASA's apparent acquiescence to the Young task force's cost-cutting recommendations. Its first recommendation was that "NASA must resolve the upmass and crew research time issues", and further that "NASA should increase science priority and productivity on ISS". It further urged NASA to restart work on habitat space for an expanded crew.

The grim alternative was stated bluntly: "If enhancements to ISS beyond US Core Complete are not anticipated, NASA should cease to characterise the ISS as a science driven programme." Since this was precisely the terminology that NASA Administrator O'Keefe was using to describe ISS, this second group of scientists had joined forces with the original letter-writers.

But even by the end of 2002, NASA officials had come up with no plans to either fund or design the extra modules needed to increase the Station's crew size from the level that even NASA's own scientists found intolerable. And after 1 February 2003, the trend was if anything in the opposite direction.

NASA's own public relations officials struggled to put a positive spin on the 'revolt of the space scientists' and spokesmen seem often to get confused when boasting about the value of research aboard the Space Station. One glaringly circular argument was issued in March 2003: "Whether it's by being repairmen or being experiments themselves, the Expedition Six crew continues to demonstrate the benefits of having humans in space." These justifications are distinctly circular – humans are useful for space research because they allow us to show how to use humans for space research.

The 'repair' justification does have somewhat more substance, and a good example is the research facility commonly called the 'glovebox'. Designed to isolate potentially hazardous activities from the cabin atmosphere (a requirement for a human space facility), the unit has a clear plastic chamber with neoprene gloves to allow manual manipulation of the isolated apparatus and samples. It has hosted numerous different materials processing experiments, amounting to about a third of all scientific research performed on ISS.

On 20 November 2002, within days of the end of her space tour, Expedition Five Science Officer Peggy Whitson was changing a tape on the unit's video recorder when she heard a 'click' – a circuit breaker cutting power. A Shuttle mission was about to deliver a new crew, and during her handover to Don Pettit, both scientists ran connectivity tests. They isolated the problem to one of two electronic panels for distributing electricity. These panels were returned to Earth on the shuttle that delivered Pettit and his team mates, and were subsequently returned to the ISS aboard an unmanned Russian spacecraft early in February. After the unit was restarted, it exhibited signs similar to those that preceded previous failure. Pettit spent many hours troubleshooting the circuits to discover the cause of the original circuit breaker trip, and by the end of February had it safely operating.

And the glovebox was the key to much of the science capability of the Station. A genuine example of ISS science operations at their best has been the Zeolite Crystal Growth experiment. Early in January, Expedition Six Commander Ken Bowersox unloaded zeolite samples that had been completed two days earlier in a test furnace. He then reconfigured the furnace for another round of tests. First he had to manually twirl each of the 19 new sample tubes to reduce the number of bubbles in them, and then he installed the samples in the ZCG furnace to begin a scheduled 15 day processing run.

On the ground, the Center for Advanced Microgravity Materials Processing at Northeastern University in Boston sent commands to initiate mixing of the samples. One sample appeared to jam, and Bowersox was called to help. He used a hand drill to mix the sample and begin processing.

Kenneth Bowersox, Expedition Six mission commander, inserts an experiment cartridge in the autoclave for the Zeolite Crystal Growth (ZCG) experiment in Destiny, and (inset) view of a bubble formed as a result of the experiment.

According to background information from NASA's Payload Operations Center, zeolites are used in many manufacturing processes on Earth, including virtually all the world's petrol production and upgrading. So improving zeolites could make petrol production more efficient or lead to ways of storing clean-burning hydrogen for fuel. Zeolites can also be applied to detergents, optical cables, gas and vapour detectors for environmental monitoring. The potential value of the ISS experiments is the ability to grow higher-quality crystals, 100 to 500 times larger than normal, and to test the crystallization process in "slow motion" without being rushed by the effects of gravity. These are returned to Earth for analysis.

This kind of crew-supported experiment – and there are others that are equally exciting and promising – make the frustrations of the Space Station even more poignant because they highlight how much good work the Station might still be able to do, if completed and fully utilised. But as 2003 went by, NASA still did not come up with any serious proposals to satisfy these fundamental problems.

Perhaps it will work. The as-yet-unfulfilled dream of a significant science payoff for the multi-billion-dollar ISS continues to inspire many people within the project.

In a general comment that perhaps had unintended wider implications for the entire ISS programme Don Pettit, Science Officer for Expedition Six (Nov 2001 – April 2002) said: "Scientific efforts legitimise the exploration; without that, you are simply wandering around."