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Issue 6
Winter 2013

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Remembering Columbia

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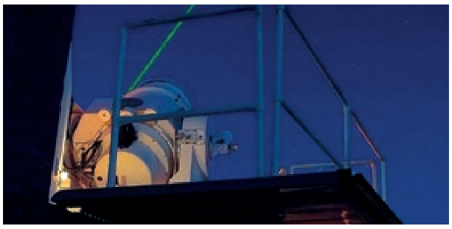
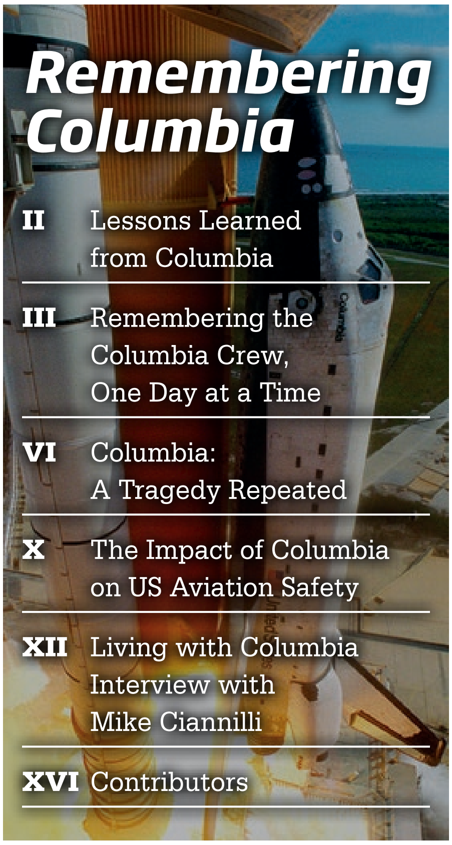
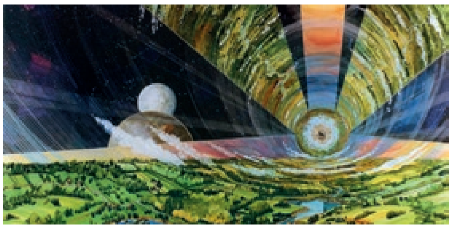




Remembering Columbia



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The Columbia Disaster and Space Program Safety

This issue is dedicated to one of the most tragic events in human spaceflight: the loss of Space Shuttle Columbia and its crew. As you will learn from the Special Report "Remembering Columbia," the Shuttle was destroyed upon reentry by a flux of super-heated air coming through a breach in the reinforced carbon-carbon left wing leading edge that caused degradation of structural properties of the wing itself. The crew was left with no chance of survival when the cabin broke apart at an altitude of approximately 42,672m.

The Columbia Accident Investigation Board (CAIB) determined that the breach had been caused by the impact of the Shuttle left wing with a piece of foam coming off the External Tank's (ET) bipod fitting 81.7 seconds after launch.

As in all previous fatalities in human spaceflight, the Columbia disaster was not an accident at all. The ET was defective by design, and the phenomenon of debris shedding was well known. According to the CAIB, damage caused by debris has occurred on every Shuttle flight, and STS-107 was the seventh time that a release of foam from the bipod ramp had been recorded.

The organizational failures that led NASA to downplay or dismiss all accident precursors as "acceptable risks" are well documented in the CAIB Report. The event that doomed Columbia was noticed during the second day of the ill-fated mission, upon reviewing launch camera photography. Mission Control Center even told the crew that there was "absolutely no concern for entry" because the phenomenon had been seen before.

The general feeling was that a chunk of low density foam insulation could not cause much damage. In fact, the impact of the acceleration component to the relative velocity of the two bodies was completely underestimated: the foam shredded the reinforced carbon-carbon panel like it was made of paper when Columbia literally rammed into it at 3,000km/h.

According to Bryan O'Connor, who at the time was NASA Associate Administrator, Office of Safety and Mission Assurance, a major cause of the Columbia disaster was complacency. "The hardware had been talking to us, and what we had believed at the time to be rational risk management looked in retrospect more like rationalization of inconvenient warnings."

LeRoy E. Cain, STS-107 entry flight director, realizes the loss of Columbia. – Credits: NASA

With Columbia we lost much more than the crew and an orbiter; we lost an entire space program and a large part of its engineering knowledge. The Space Shuttle was a highly complex and innovative vehicle, designed to ferry back-and-forth to LEO a crew of up to eight people and large military payloads. A set of wrong assumptions about its reliability and the need to satisfy a wide array of mission profiles, including the never utilized ability to fly into polar orbit from Vandenberg Air Force Base, led to an unsafe and vulnerable design.

We are witnessing the beginning of a new and promising era in human spaceflight, the commercial era.

The focus of commercial space is very much on cost-cutting, while vague assurances are made about safer vehicles. Sometimes safety is even presented as a stubborn obstacle to industry development and progress. The commercial human spaceflight industry needs to remember that the primary goal of the Shuttle Program was cutting the cost of transportation to orbit by an order of magnitude, a goal at which it failed miserably. As with the supersonic Concorde, the Shuttle was doomed by being both expensive and unsafe. Being expensive made it in turn unaffordable to undertake any further development or safety modification. But being expensive to operate did not stop either the Shuttle or Concorde from operating for about 30 years; what ultimately ended these programs was their inadequate safety. We hope that the emerging commercial operators will keep alive the lessons learned from Columbia, making sure not to fall into the same illusory tradeoff of cost for safety.

Andrea Gini
Editor-in-Chief

By Merryl Azriel

Space Politics, the European Way

Politics and space activities have always been inextricably bound, to a large extent due to the scope and cost of system development that up until the past few years, only a governmental body could imagine taking on. But governments are notoriously whimsical, as elected officials bend and sway to catch the elusive approval of their constituents in the never ending drive to achieve reelection. The steady tattoo from governments in recent years has been cost-cutting, and space agencies are among those feeling the squeeze.

Within this context, the European Space Agency (ESA) is something like the story of the little engine that could. A conglomerate of distinct states, each with their own priorities and competing interests, many with their own space agencies, the intergovernmental body has become the glue that is holding many space initiatives together – and picking up pieces that would otherwise fall through the cracks. While individual members certainly have their own political and budgetary woes, the agency altogether seems to be holding its own better than many of its partner agencies. Here is a look at the most recent developments in the management of the improbable success story that is ESA.

ESA in 2012

Even as its member states dealt with ongoing financial woes surrounding the Eurozone crisis in 2012, ESA jogged along very nicely with progress in its Gallileo, GMES, ATV, astronaut, launch, and – to a certain extent – space situational awareness programs. ESA welcomed Poland as its 20th member state last year. ESA survived the loss of NASA's collaboration on the upcoming ExoMars mission, and made overtures to the ambitious and growing Chinese space program. These successes laid a strong foundation for two critical meetings that took place at the end of 2012: the Council Meeting at the Ministerial Level and the Ninth Space Council with the European Union.

ESA is holding its own better than its partner agencies

Council Meeting at the Ministerial Level

ESA has an advantage in managing its funds in that, unlike NASA, its budgets cover multiple years and generally provide resource allocation to each project through its completion. This means that funding priorities can't be changed by mercurial politicians quite as quickly, but it also means that financing decisions may pile up for a while, become fraught with political considerations along the way. The process also leaves ESA vulnerable to nations in crisis – which describes a goodly portion of Europe over the past four years – who may have trouble meeting financial commitments that once seemed within reach.

This past November, ESA's Council Meeting at the Ministerial Level met to determine the next three year budget, in the process deciding several of the aforementioned accumulated issues. Two of those issues were directly affected by developments in the United States: the future of Arianespace

ESA's latest Council at the Ministerial Level held in Naples. – Credits: ESA

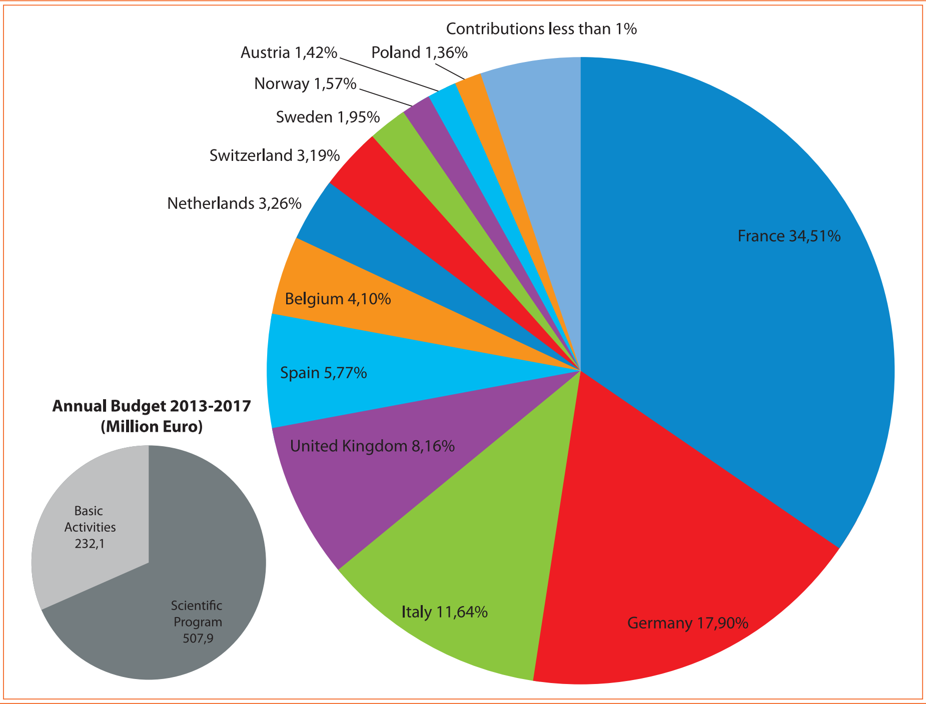
In August 2012, Ariane 5 launched with its largest payload ever, totaling 10,183kg.
Credits: ESA/CNES/Arianespace/Optique Video du CSG

and of NASA's Space Launch System service module.

Arianespace has been hanging in limbo for some time with its two major nationalities at loggerheads over the best direction for the company responsible for launching roughly half of the world's spacecraft. Before the advent of "new space," Arianespace, United Launch Alliance, and Starsem more or less had the launch market divvied up among the three of them. But several SpaceX successes in 2012 have gotten these companies pretty worried. Arianespace officials went so far as to snipe at SpaceX capabilities, with CEO Jean-Yves LeGall declaring that "SpaceX speaks a lot, but they don't launch a lot. That is a fact," just before Space-X successfully demonstrated the Dragon resupply vessel. The swipe prompted SpaceX CEO Elon Musk to retaliate in a subsequent speech with "there's really no way for that vehicle [Ariane 5] to compete with Falcon 9 and Falcon Heavy. If I were in the position of Ariane, I would really push for an Ariane 6." ESA decided not to push for Ariane 6 this year, instead siding with Germany in recommending development of the Ariane 5ME (for mid evolution), an upgrade to the current launch vehicle that could accommodate two large satellites. Theoretically, the Ariane 5 ME is to use componentry that will be easily transferred to the Ariane 6, a more modular and nimble launch vehicle in conception. The delay in development of Ariane 6 could have significant consequences for market competition in an evolving launch environment. It is also questionable whether a focus on accommodating larger satellites will pay off, since standard orbital capabilities are fitting into smaller and smaller packages, with active discussions ongoing as to the possibility of replacing some standard Earth observation and perhaps even telecommunition satellites with CubeSats or the like.

> Some view it as demeaning for Europe to serve a NASA contractor

The Ministerial Council also made the call to support NASA's Orion crew capsule, accepting an offer to provide that vehicle's Service Module based on the European Automated Transfer Vehicle (ATV) design. The move was expected but somewhat controversial, with some viewing it as demeaning for Europe to serve as a contractor to NASA. But let's face it, while ESA does not have the budget or capabilities of NASA at this time, it seems to be stepping up more and more to shoulder responsibilities its big brother in space can't handle – ExoMars comes to mind. This seems to be one of those times. With the agreement, ESA has secured itself a spot in the future of crewed space exploration beyond the International Space Station. European astronauts may soon find themselves welcome in spacecraft the world over due to ESA's ballet-like balance of multinational interests and formation of strong and aggressive bonds with space contingents in Russia, China, and anywhere else they can finagle a way in.



ESA member contributions for 2013-2017 as adopted by the 234th Council Meeting on November 21, 2012. Inset: Annual ESA budget for 2013-2017.

ESA's third Automated Transport Vehicle Edoardo Amaldi departs the International Space Station in September.
Credits: NASA

ESA's ministers managed to retain a budget on the scale of its prior plan; it does not include expansions many wanted, but avoided cuts widely feared. However, setting the budget may turn out to be easier than meeting it. There are increasing rumblings of trouble collecting payments from some European nations who have gotten caught in the recent economic morass. Spain in particular has garnered attention for receiving a public ultimatum from ESA to confirm contributions to the upcoming budget. If struggling members are unable to meet their contributions or cannot obtain legislative confirmation of commitments, ESA's budget could start to look a lot different.

The Ninth Space Council

Everyone knows that ESA is the crux of Europe's space presence, but a long-simmering familial struggle with the European Union (EU) is heating up. Those outside of Europe may be forgiven for not realizing that ESA is not actually the space arm of the EU. Its membership is comprised of 20 member states, of which two – Switzerland and Norway – are not EU members at all. ESA also counts Canada as an associate member. Seven members of EU have chosen not to participate in ESA, while the European Union itself is an associate member of ESA, contributing over 20% of the agency's finances.

France and Belgium favor ESA as an EU agency, Germany and the UK favor the status quo

Most space aficionados would conflate European Space with the European Space Agency, and to a large extent they would be correct. But in 2012 some of the political rumblings underpinning ESA's funding model began to burble to the surface, promising future negotiations and developments that may alter the institution's operation. The key question is the current and future relationship between ESA and the European Union.

As with other nationalities, cost is a major concern for Europe, and there are increasing signs that the European Union wants to flex its muscles as both a European space strategist and financier of a fifth of ESA's budget. EU sees itself as possessing a "shared competency" in space along with ESA and individual state agencies, despite not having much to show for that competency. EU's particular complaints relating to ESA are a lack of transparency, demonstrated by the closed door Ministerial Council sessions in November; use of EU funds to benefit non-EU ESA members Norway, Switzerland, and Canada whose participation "poses an obvious problem in general, and an even more acute problem when it comes to security and defense matters," according to a November proposal to the EU entitled "Establishing appropriate relations between the EU and the European Space Agency"; and objections to ESA's geographic return policy which promises to ensure space spending occurs in individual member states in proportion to their investment rather than following EU's contracting policy of purchasing based on best-value alone.

The Ninth Space Council between ESA and EU ministers was held on December 11 and showed where battlelines in this fight are likely to fall. France and Belgium came out in favor of ESA becoming an EU agency, Germany and the UK in favor of retaining the status quo, and most other nations were not yet willing to commit to one side or the other. In Europe, France and Germany are the biggest players in space activities, with Italy bringing up third place; France and Germany are usually on different sides of the fence no matter what the question is. The United Kingdom's position is interesting in that the nation increased its commitment to space spending in 2012, almost solely enabling ESA's role in Orion Service Module development. The UK is also seen as keeping the EU at arm's length, a trait not likely to endear it to EU ministers or to forward its position in favor of status quo.

Space Councils are a yearly event, but this conversation will likely not stay on the backburner for another twelve months. Whether increased participation – some might say interference – from the EU in European space activities is likely to endanger ESA's ability to satisfy its diverse constituents or weaken its international partnerships remains to be seen.

Where does all this leave ESA? With a lot of talking – and maybe some flying – left to do.

The ExoMars rover, initially a collaboration between ESA and NASA is now being carried forward by ESA and Russian Space Agency Roscosmos. – Credits: ESA

By Hubert Foy

Building the World's First Automated Space Debris Tracker

EOS Satellite Laser Ranging and Space Debris Tracking Station at Australia's Mount Stromlo Observatory in Canberra. - Credits: EOS

Since the launch of Sputnik I in 1957, more than 6,000 spacecraft have been successfully sent into Earth orbit. Each launch – whether successful or not – contributes to the release of human-made debris in Earth orbit. This "space junk" consists of expired spacecraft, spent rocket bodies, mission related objects, and fragmentation debris. A majority of debris remains in orbit indefinitely, but their orbits drift due to the effect of Earth's atmospheric drag, a force that extends far into space.

Debris poses a real collision threat to deployed spacecraft. NASA's Debris Office estimates that as many as 300,000 objects larger than 1 centimeter are present in low Earth orbit alone. The U.S. Space Surveillance Network, consisting of 29 optical telescopes and radar sensor sites worldwide, currently tracks about 20,000 human-made space objects as big as a baseball (10 centimeters in diameter) or larger, each capable of destroying a satellite. The only protection against this larger debris is to alter the trajectory of a spacecraft to avoid a collision, a maneuver that can be expensive in terms of fuel and mission downtime.

> The Cosmos-Iridium accident showed that satellite collision is a reality

In 2009, five different NASA robotic spacecraft, as well as the Space Shuttle and the ISS, conducted collision avoidance maneuvers. The destruction of the operational U.S. Iridium 33 communication satellite after a collision with the decommissioned Russian Cosmos 2251 spacecraft in 2009 showed that collision is not just a statistical probability: it is a reality. The incident underscores the inadequacy of current measures and capabilities to detect and predict ▸▸

Artist's impression of the tracking station during operations. - Credits: EOS collisions, and the importance of improving precision orbit determination and prediction.

Using the reflection of laser light to measure the distance of space debris from a ground-based station is one possible way to improve debris tracking accuracy. The Australian company Electro Optic Systems (EOS) is developing the world's first automated laser tracking technology that would track potentially damaging debris as small as a few centimeters. Once a debris object is tracked, satellite operators would be able to enact a collision avoidance maneuver.

Automated Laser Tracking System

A consortium of scientists and design engineers at EOS developed the automated laser tracker project in 2010 with an AUD 4.04 million (USD 3.6 million – 2010 exchange rate) grant from the Australian Space Research Program. The project is aimed at upgrading EOS' current manned tracking capability at Australia's Mount Stromlo Observatory in Canberra to reduce operation cost. Professor Yue Gao, Head of Laser Research and Development Division at EOS Space Systems Pty Ltd, is one of the chief designers. Space Safety Magazine contacted Prof. Gao to get some insight into the research and development behind the project.

> "A high energy laser system can tell the range, azimuth, and elevation from a single station"

Prof. Gao, who joined EOS in 1994, has worked on projects and systems for space, military, and scientific applications. He was project manager and chief investigator of the laser ablation study for space debris deorbiting. He has led investigations on different studies related to solid state laser systems, laser guide star for adaptive optics, and space debris tracking systems. "On EOS laser projects I have worked as a project manager and chief designer of the laser systems, and one of the system designers for the whole tracking system," he adds.

"EOS is developing the capability of fully remote and automated operation of a high performance tracking station, responsive space debris orbit determination, and space debris crash de-confliction," explains Prof. Gao.

The automated tracking system offers prospects of a technology breakthrough that could determine debris orbits in space with sufficient accuracy to improve situational awareness of space assets and allow cost-effective mitigation of debris risk.

"EOS currently has two laser systems located in Australia, one Satellite Laser Ranging (SLR) and one laser system for monitoring space debris," says Prof. Gao, adding that the team at EOS is not aware of any competitors to the project at the moment, although other countries such as China and Germany have been pursuing this technology in the last few years.

EOS has a long standing reputation in space surveillance and monitoring services. Almost all of the critical components for the tracking system, including the laser, telescope, timing systems and control systems were developed in-house by EOS. According to Prof. Gao, "these new features are expected to achieve most of the performance milestones in late 2013." He then adds that "they can significantly reduce the cost of providing debris protection to satellites and would ease the integration of the capability into the operational processes of key users."

"The tracking technology is a combination of high pulse energy and high repetition rate laser system with Electro-Optic technology that can determine space debris orbit with a range accuracy of 1.5 meters in a second or so," Prof. Gao explains. "It can provide three dimensional data, azimuth, elevation, and range from a single tracking station, and can provide high orbit determination and prediction accuracies."

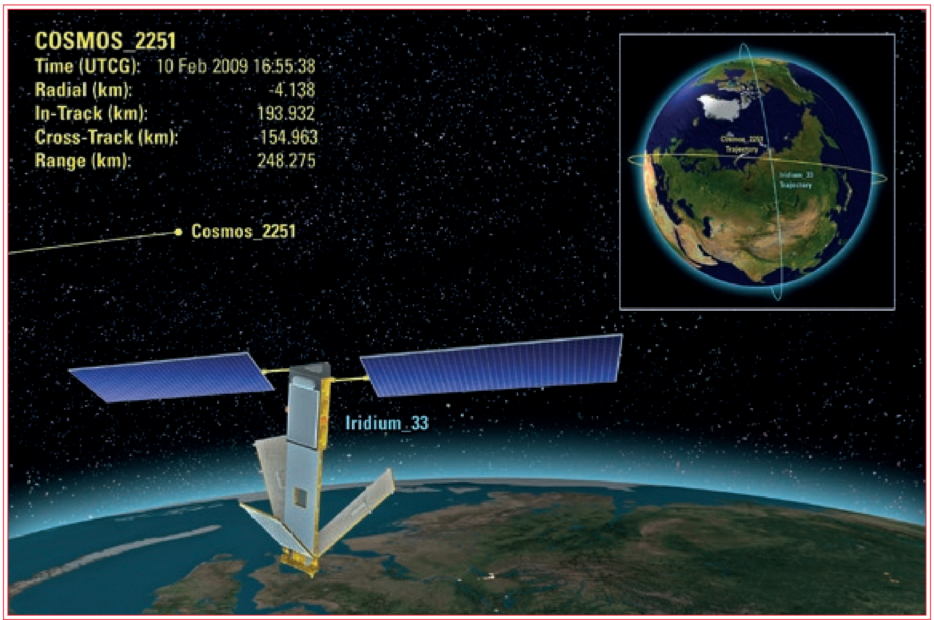


Illustration of the Cosmos-Iridium collision of 2009. The upper right plot shows trajectories of Iridium 33 (blue) and Cosmos 2251 (yellow) at time of collision. - Credits: Analytical Graphics, Inc. (www.agi.com)

Tracking and Monitoring Debris

Current ground-based debris surveillance and monitoring systems, including the automated laser tracking system, have their advantages and disadvantages. A ground-based sensor tracking a space object and determining its position at a given time is referred to as observation. For a single pass of the object in space as it flies in its trajectory, a collection of observations from different sensors constitute a track.

The U.S. Joint Space Operations Center (JSpOC), which gathers ground-based observations of space debris from the Space Surveillance Network, determines how many tracks of

NASA's Satellite Laser Ranging Network uses lasers to measure distances from ground stations to satellite borne retro-reflectors to the millimeter level. – Credits: NASA

data are nominally required to determine each object's orbit primarily based on the object's type, size, and rate of change of its orbit. Because the orbits of debris objects are not stable, the level of positional accuracy obtained with current ground-based tracking systems are inadequate to sufficiently predict in-orbit collision with a degree of certainty.

Ground-based systems are capable of tracking space objects only when the ground area is dark while the object must be illuminated by the sun. This requirement limits the debris-observation window to less than 4 hours for every 24-hour period: usually after sunset and before sunrise. Debris observation is further limited by inclement weather. In order to observe a large debris population in a short period of time, multiple ground stations located around the world are required, a costly proposition. Prof. Gao acknowledges those limitations and explains how they can be mitigated in a laser system.

"Although ground-based laser tracking is negatively affected by the atmosphere, it is mitigated in the technology. The ultimate performance of this technology relies on the ability to focus a laser beam accurately on the space debris," Prof Gao says. "The current laser system is ground based. But atmospheric turbulence does deteriorate the laser beam quality and reduce the system link budget. An adaptive optics system helps to overcome this."

Debris that presents a small profile, either due to actual size or distance from Earth, poses bigger technical challenges. According to Prof. Gao, "there have been difficulties for the current VHF-band radar-based space surveillance system to track objects smaller than 10 centimeters and achieve high orbit determination accuracy due to the fundamental limit of the radar wavelength." He adds that "conventional optical tracking through telescopes cannot tell the range from a single station. However, a high energy laser system can tell the range in addition to the azimuth and elevation from the single station."

Unlike ground-based radar tracking that have limited 'mobility,' ground-based laser tracking has good 'mobility', can move quickly and can thus track targets in any direction.

Laser technology is already used to monitor large objects in space. Ground-based Satellite Laser Ranging (SLR) is currently used to track satellites equipped with retro-reflectors.

> "A combination of radar and laser tracking offers a cost effective and full spectrum solution"

That technique involves the firing of laser pulses through a telescope at passing satellites and measuring the time taken for the pulses to return to Earth. The Australian EOS SLR facilities at Mount Stromlo in Canberra and the Moblas in Western Australia are part of a global network of over 40 observatories using laser light to measure distances to orbiting satellites.

According to Prof. Gao, SLR is, however, not suitable for tracking space debris because its energy level is too low and the retro-reflectors essential for the method to work are completely lacking on debris objects. "Generally speaking, the lasers used for SLR have pico-second pulse width and generate relatively low pulse energy. The laser systems used for SLR are not suitable for tracking space debris," he clarifies.

Looking Forward

Radar tracking has its own advantages, such as the capability of tracking a large number of targets, large data volume, and operating day and night in all weather, Prof. Gao says. "Honestly, laser tracking is never going to take over or supersede radar based systems."

According to Prof. Gao, "active laser tracking is complementary to optical and radar based systems." He adds that "an optimum combination of radar and laser tracking capabilities offers a cost effective and full spectrum solution because each does what they are good at." For example, "radar based monitoring system is good for 24/7 surveillance and maintaining a large volume of objects and orbits." For high interest and potential conjunction objects, "radar can hand over to the laser tracking system for a high precision tracking and orbit update."

Looking forward, Prof. Gao explains how the international aerospace community may benefit from the technology. "Now our laser based tracking system can provide 1.5 arcsecond angular accuracy, better than 5 meter orbital determination accuracy and better than 200 meter predicted orbital accuracy (after 24 hours)," he says. "With the improved orbit predictions, the close approach can be identified, avoidance maneuvers can be conducted, and collision avoided altogether. So space assets can be well protected."

By Tereza Pultarova

What if There IS Life on Mars? Interview with Margaret Race

As prospects of a Mars sample return mission or even a manned mission to Mars are becoming increasingly realistic, the danger of biological invasions from space or, on the other hand, the danger of contaminating other celestial bodies with terrestrial microbes attracts more of the scientific community's attention.

There are obviously reasons to worry. There are many examples from the past when a microbe, plant, or animal virtually harmless in its original habitat caused havoc when transferred to another continent, like rabbits in Australia or recently, a germ decimating the population of North American bats. Even the indigenous inhabitants of America suffered the consequences of being exposed to European diseases such as smallpox or measles.

There is no doubt that if such a newcomer was a completely alien entity to the terrestrial environment, the consequences would be impossible to predict. To understand what is being done to prevent a possible outbreak of "space fever," or an invasion of "space parasites," Space Safety Magazine interviewed one of the leading experts in the field.

Margaret Race is an ecologist and a planetary protection expert from the Search for Extra-Terrestrial Intelligence Institute (SETI). Based in California's Silicon Valley, SETI Institute is a nonprofit organization that aims to explore, understand, and explain the origin, nature, and prevalence of life in the universe.

> "We want to avoid exposure to anything that might be biohazardous to Earth life"

Margaret Race, planetary protection expert from the Search for Extra-Terrestrial Intelligence. - Photo courtesy of Margaret Race

Space Safety Magazine: You started your career as a biologist studying invasive species in terrestrial environments. What drew your attention to space?

Margaret Race: In general, my research has focused on ecological disruptions, exotic species, and environmental management. My dissertation in ecology focused on an east coast mud snail that was introduced to San Francisco Bay after the Gold Rush (it came inside barrels of oysters shipped on the TransContinental Railroad!). Later, I worked on the environmental impact reviews at the University of California in Berkeley for the first deliberate outdoor release of a genetically engineered organism. At the time it represented the ultimate in potentially 'invasive' species (or so I thought). Years later, I began working with NASA's Planetary Protection Office in analyzing the biosafety concerns associated with bringing back Martian materials and helping to develop scientific protocols for the testing of samples from Mars. In case there is anything living in these samples, special care must be taken to prevent the contamination of Earth, while also protecting the samples from earthly contamination that would detract from their scientific value.

SSM: It is a well known fact that invasive species on Earth can cause havoc in ecosystems where they don't belong. But talking about a possible space contamination probably takes the whole issue another step further. What are the biggest concerns?

MR: From the beginning of the space era, the Outer Space Treaty (1967) has required that launching nations take steps to minimize harmful cross contamination during exploration. Not only do we want to avoid false positives in our search for extraterrestrial life (don't bring life from Earth that could be mistaken for an extraterrestrial discovery), we also want to avoid uncontained exposure to anything that might be biohazardous to Earth life — whether to astronauts during future missions, or to biota on Earth exposed to materials brought back for study. Current international policy requires taking a conservative approach to space missions, including the special handling and testing of materials from other planets, especially when they come from places like Mars with potentially habitable conditions. As there is a level of uncertainty involved, we simply have to be extra careful. The US National Research Council, when asked about the Martian sample return, indicated that although the risks are likely to be extremely low, they cannot be assumed to be zero. Therefore it is crucial to proceed with strict containment and quarantine until rigorous scientific testing indicates that it is no longer needed.

SSM: How is the current prevention program structured? What type of measures does it include?

MR: In the US, all missions are reviewed by the NASA Planetary Protection Officer long before launch. Missions are assigned to a planetary protection category that indicates how stringent the controls will be. These are consistent with international policy under the Outer Space Treaty, and based on where the mission is going and what it will be doing. For example, robotic orbiter missions have different requirements than landers, and also different from missions with instruments that would dig into the subsurface. Different planetary bodies also have more or less stringent controls. The criteria are based on the habitability and perceived prospects for finding extraterrestrial life. The Moon's ability to harbor life has already been ruled out by past studies and research, so the measures are less strict for lunar missions. Currently, Mars has the strictest planetary protection controls. Once a mission is assigned its initial level of controls, it is designed and monitored to ensure it meets the planetary protection requirements at all stages.

SSM: Are there greater concerns for invasive species being brought from space to Earth or from Earth to an extraterrestrial body?

MR: Both are important. In general, missions returning materials to Earth undergo more scrutiny. They also include constraints on their outbound leg; a round trip mission therefore would be extra scrutinized for both forward and back contamination. However, if a mission is coming back from a location that is essentially non-habitable, only few, if any, planetary protection requirements apply. For example, the Stardust mission that returned samples from a comet's tail, the Genesis mission that returned particles of solar wind, and certain asteroid missions have had no Earth return constraints, because none of those locations was deemed habitable.

SSM: Are planetary protection issues gaining importance with improving prospects for a Mars sample return mission?

Artist's conception of a Mars Soil Sample Return Mission. - Credits: NASA JPL

> "We can sterilize outgoing spacecraft but we obviously can't sterilize humans"

MR: Planetary protection considerations have been important all along. A complete draft protocol for handling and testing Martian samples has already been developed and reviewed through a process that involved multiple workshops and studies over a period of about four years. It was completed in 2002 when NASA thought samples would be returned from Mars by around 2008. At this point, the draft protocol will be updated when a specific future mission is planned.

SSM: What are the biggest concerns for a Mars sample return?

MR: The main concern will be to keep materials contained until a complete battery of scientific tests will be done to determine whether or not there are indications of Martian microbes in the rocks, pebbles, and dust. In addition, we have to make sure that we keep the returned samples in pristine condition throughout the testing process so as not to detract from their scientific integrity and value. Finally, there is a need to make sure that a complete battery of biohazard tests is done prior to any release of pristine materials outside of the bio-containment lab.

SSM: The return of Apollo 11 from the Moon represents a precedent when it comes to preventive measures regarding possible contamination of terrestrial environment during human missions. How would these measures stand up to today's standards?

MR: During the Apollo program, there was an elaborate quarantine for all parts of the missions because we didn't know whether the Moon harbored alien life. The good news is that we know today from extensive studies that the Moon is lifeless, so strict quarantine and planetary protection measures are no longer required for lunar missions. However, when humans are involved in future missions to Mars, it will be far more difficult. We can sterilize ▸▸

Apollo 11 crew are visited by US President Richard Nixon while quarantined in a special Mobile Quarantine Facility. Quarantine was abandoned after Apollo 14. - Credits: NASA

outgoing robotic spacecraft and equipment to prevent forward contamination via the transfer of 'hitchhiker' microbes from Earth to other planets, but obviously, we can't sterilize humans before launch. And humans bring with them their complete set of microbes — so some level of forward contamination cannot be avoided.

SSM: How would planetary protection measures affect possible future manned missions to Mars? What are the current presumptions regarding such a mission and is anything going on in that area?

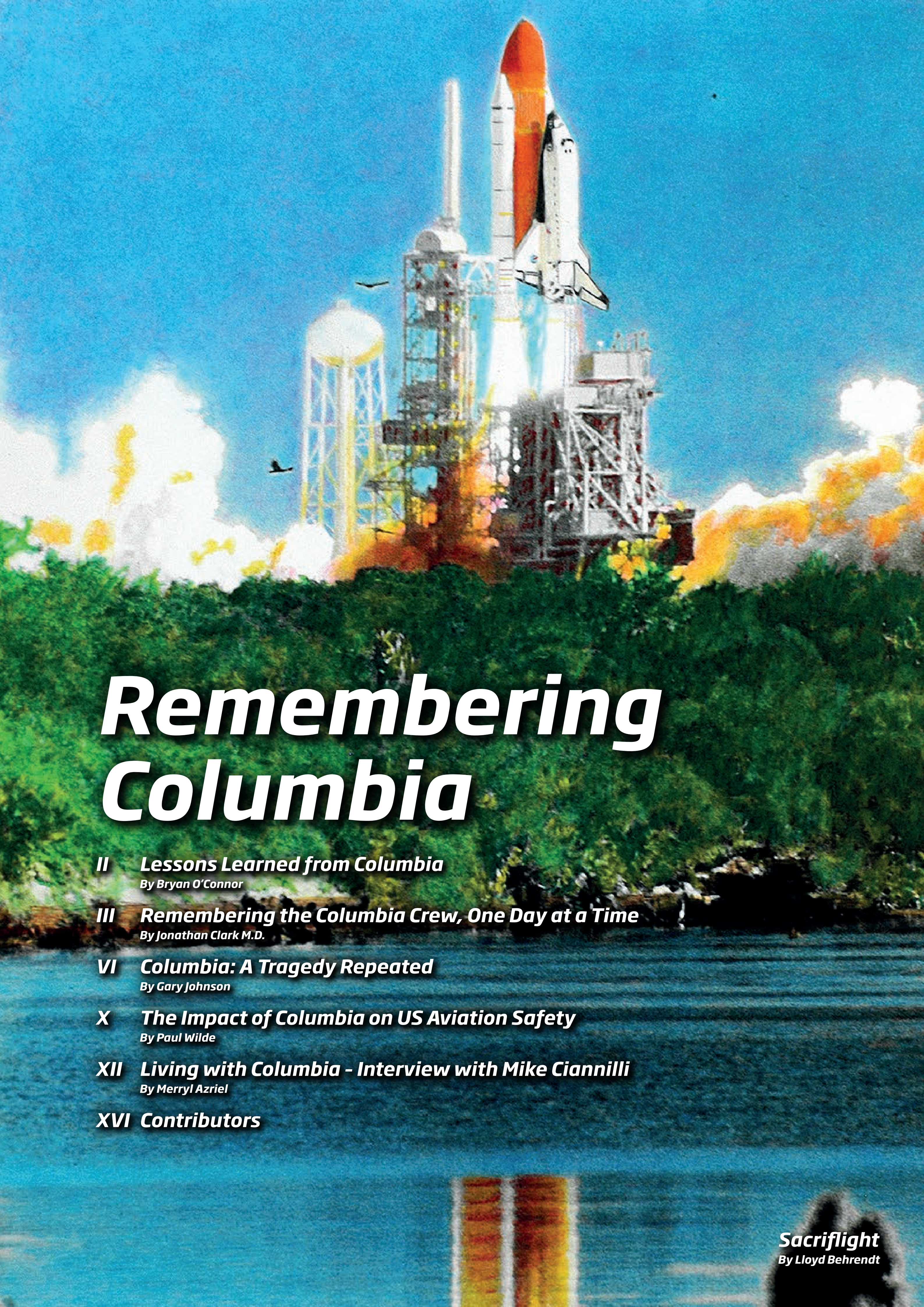
MR: When human crews are involved in long duration missions to Mars, it will require development of an entirely new set of planetary protection protocols. Since astronauts haven't gone onto a planetary surface since Apollo days, it's like starting from scratch in many ways. Long duration human missions to Mars will require significant updates in infrastructure, technology, and operations, with planetary protection considerations applying to all aspects of the mission. NASA has recently begun updating its earlier Design Reference Architecture for future Mars human missions, and planetary protection is viewed almost like a 'new' complication — since human missions in Earth orbit over the past 40 years have not had to contend with planetary protection constraints or activities on planetary surfaces.

SSM: Ethical questions also arise when extraterrestrial life is discussed; can you outline what are the biggest issues in that regard?

MR: Making sure that we do responsible research and exploration. In addition, there are potential ethical questions associated with the 'meaning' of any verified discovery of extraterrestrial life. Scientists discuss the scientific significance of discoveries drawing from their varied disciplines. In Astrobiology, we want to know if there is 'other' life out there, whether it is based on DNA or like life as we know it, and whether it behaves and evolves in ways we are familiar with. Other types of significance and 'meaning' are discussed by philosophers, ethicists, and theologians. What would it mean if there is a distinctly different 'other' life discovered? Would it represent a 'second genesis' of theological importance? What should be the relationship between humans and verified extraterrestrial organisms? What environmental management policies would apply to planets with verified, distinct extraterrestrial life? All lines of ethical thinking are important to consider, but each is done by specialists in different disciplines. Each informs the others, so it is very cross-disciplinary. People have begun to question the potential ethical issues ahead in space exploration, just as we do with activities on Earth. In many ways, the ethical questions are similar to those associated with new and emerging technologies like synthetic biology, nanotechnology, artificial life, and so on. All have potentially challenging complexities in scientific, policy, and societal realms. It almost makes planetary protection seem simple!

"All lines of ethical thinking are important to consider"

The Genesis sample return capsule on the ground in Utah. Missions like Genesis, which returned particles of solar wind, face less stringent requirements in terms of planetary protection. - Credits: NASA/JPL



Remembering Columbia

Sacriflight
By Lloyd Behrendt

Lessons Learned from Columbia

By Bryan O'Connor

*This photograph was taken aboard Columbia during STS-107; it was developed after the crew's death from film recovered in the wreckage.
From top left: David M. Brown, William C. McCool, and Michael P. Anderson.
From bottom left: Kalpana Chawla, Rick D. Husband, Laurel B. Clark, and Ilan Ramon.
Credits: NASA*

It is with a cautionary note that I propose some of my personal lessons learned from the tragic loss of the crew of Space Shuttle Columbia. I have spent ten years comparing stories with others who were part of or close to the Shuttle program in the years leading up to the loss of Columbia and her crew... so I admit to being less than a reliable independent eye witness. That said, I will offer a few lessons that have driven me nearly every day since that sad Saturday in February 2003 in my jobs as a spaceflight safety advisor both in and out of NASA. They fit into three distinct but related categories: Flight Test, Complacency, and Checks and Balance.

Flight Test

Shortly after the last Shuttle flight, STS-135 in July, 2011, I shared a short elevator ride with one of the world's best test pilots, Maj. Gen. Joe Engle. I asked him, "Joe, could you tell me what you believe was the biggest lesson learned from the Space Shuttle Program?" Without pause, he answered: ***"You don't know what you've got 'til you fly it!"***

When I hear people talk about flying a very short flight test program with the next human spaceflight system development, and then declaring it "operational," I cringe. The fact is that the Shuttle never was purely "operational." In retrospect, it was a 30-plus year flight test program during which NASA performed a variety of operational mission objectives. It would have been good for us to periodically remind ourselves and our stakeholders of that fact before, not just after the big accidents.

Complacency

"The greatest of faults is to be conscious of none."
Thomas Carlyle (1795 - 1881)

Success, or more honestly, the perception of success, fosters complacency. And we all know what comes of complacency. To be sure, through the 1990s the Shuttle program had experienced a long run of "successful" missions. We were bringing back the crews, we were accomplishing the mission objectives, and managing the cost and schedule relatively well considering the complexity of the program. Most importantly, we believed we were putting the right attention on the decreasing number of technical issues we experienced in flight. But when, after the accident, we donned the corrective lenses of the mishap analyst, it became clear that we had been fooling ourselves in some catastrophic ways. The hardware had been talking to us, and what we had believed at the time to be rational risk management looked in retrospect more like rationalization of inconvenient warnings. It was not a coincidence that we found ourselves under a great deal of pressure to meet impossible schedules and to cut costs even to the point of planning for privatization.

Checks and Balance

"Devil's Advocate (Roman Catholic Church): An official whose duty is to point out [to the Pope] defects in the evidence upon which a demand for beatification or canonization rests... [in order to] bring out the whole truth."
Webster's International English Dictionary, 2nd Edition

An enlightened high performing organization includes humility as a critical criterion for promoting its best and brightest to leadership positions. And to aid these humble leaders, it espouses some form of devil's advocacy as an important component of its high stakes decision-making. After the Columbia loss, NASA learned – or re-learned – that a competent, adequately-resourced technical authority and a respected safety advisor provide necessary checks and balance for the decision maker as he/she strives to "bring out the whole truth" of the inevitable technical challenges.

When all is said and done, NASA and the aerospace community learned much from the Columbia loss, but I believe most of the lessons fall into one or more of the three categories I've listed. They should be continuous considerations for any future human spaceflight endeavor.

Remembering the Columbia Crew, One Day at a Time

By Jonathan Clark M.D.

Dear Rick, Willie, Mike, KC, Dave, Laurel, and Ilan,

I can't believe it's been ten years since I last saw you guys. We really miss you a lot. A day doesn't go by without thinking of you all. At first it was mostly tears, but now it's about happier thoughts, all the good times we had. You would be amazed at how all of us pulled together after losing you all. It was hard on everyone, families and friends. We all changed forever, but I like to think that overall, it's been in a good way. I have to confess that I feel responsible for what happened to you all. I worked a shift in Mission Control for STS-107 the week before you were coming home and learned about the foam strike and the debate about what it might mean. I should have done something.

Laurel, after the accident our son Iain asked why you didn't bail out. He knew you had done a lot of parachute jumps and all the crew had the right equipment and had practiced it before. I told him that you were too high and going too fast and that it probably wouldn't work out. Then he said he was going to become a scientist and invent a time machine and go back and warn you all. I realized then that I had to focus the rest of my career making it safer for those following in your footsteps.

There was a big investigation by the Columbia Accident Investigation Board (CAIB) and they did a really great job finding out what happened and getting the Shuttle back to flying safer than it's ever been. NASA had wanted the section done by the Crew Survival Working Group to be removed from the CAIB report because they thought the Columbia families wouldn't like it. We all got together and discussed it and sent the CAIB a note, and here is part of what it said:

Jonathan Clark, NASA flight surgeon at the time of Columbia, his wife Laurel, STS-107 mission specialist, and their son Iain. Courtesy of Jonathan Clark

Laurel Blair Salton Clark
Mission Specialist

Laurel achieved an undergraduate degree in zoology before earning her doctorate of medicine. She joined the Navy as a submarine and diving medical officer, eventually becoming a Naval Flight Surgeon before serving with the Marines as Group Flight Surgeon. She became an astronaut candidate in 1996; STS-107 was her first spaceflight mission. The launch of Columbia took place just six weeks after Laurel's whole family survived a crash that destroyed their family plane. Laurel was never one to sidestep a challenge, as her husband related after her death: "One of Laurel's favorite quotes was: "A ship in harbor is safe – but that is not what ships are for."

William "Willie" Cameron McCool
Pilot

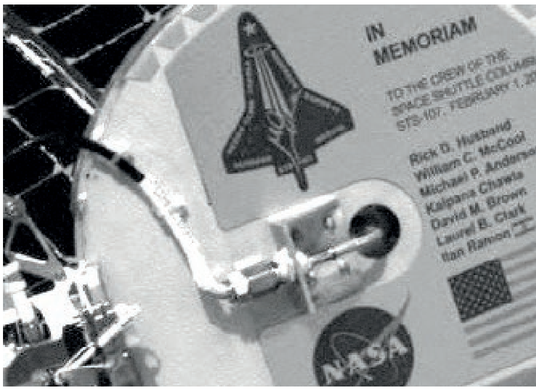
A Navy man before joining NASA, Willie attended the Naval Academy, accumulating degrees in applied science, computer science, and aeronautical engineering, even as he deployed as a Navy pilot, and later, test pilot. He was selected as an astronaut in 1996. Unlike many astronauts, Willie loved exercising in space. "I'll tell you, there's nothing better than listening to a good album and looking out the windows and watching the world go by while you pedal on the bike," he said while aboard Columbia. STS-107 was his only space mission.

David McDowell Brown
Mission Specialist

An athletic man, David was a four year collegiate varsity gymnast and circus acrobat, unicyclist, and stilt walker, before graduating with a degree in biology and achieving his doctorate in medicine. He joined the Navy as a flight surgeon. In 1988 he became the first flight surgeon in a decade to be selected for pilot training. David began astronaut training in 1996. STS-107 was his first and only mission. Before taking off, he told his girlfriend what to do if something went wrong: "I want you to find that person that made the mistake, and I want you to tell that person that I hold no animosity. I died doing what I loved."

Kalpana "KC" Chawla
Mission Specialist

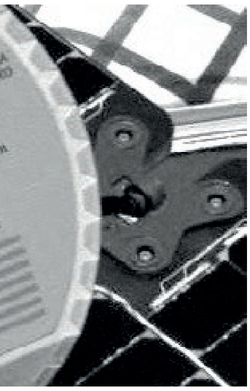
Born in Karnal, India, KC moved to the United States after undergraduate school, proceeding to obtain her doctorate in aeronautical engineering. She began her career at NASA Ames, researching computational fluid dynamics relating to aircraft air flows. She was selected as an astronaut candidate in 1995. Her first flight took place in 1996 aboard Columbia STS-87 as mission specialist and prime robotic arm operator. KC loved flying and was a licensed pilot and flight instructor of commercial land and sea planes and gliders. She was an inspiration to young girls in her birth country, where her achievements were much celebrated as the first Indian-born woman to fly in space.



In discussion with the Columbia spouses we were entirely unified in our desire to ensure that all the lessons learned from this mishap be applied to prevent this type of accident from happening again. We discussed the crew survival section and our desire is to ensure this information is made available to learn all we can from it. A fundamental aspect of every aerospace mishap investigation is the understanding of crew survivability issues and there is much still to learn about survival during upper atmospheric reentry. As sensitive as this issue is, it is essential that the facts related to crew survival be disseminated to ensure the next generation of spacecraft are afforded the maximum protection. This is particularly apparent with the upcoming Orbital Space Plane and future commercial spacecraft. Perhaps the greatest legacy of the Columbia crew will be these enduring lessons applied to future human space endeavors.

In 2004 NASA created a follow on group to look at crew survival issues, which was called the Spacecraft Crew Survival Integrated Investigation Team, and I was a member. We looked at all the space mishaps including Columbia, and really came up with a better understanding of how to make it safer for human spaceflight. In 2008 we published our report "Columbia Crew Survival Investigation Report." I've also been involved with the International Association for the Advancement of Space Safety, which was created in 2004, and they are dedicated to making it safer to fly in space.

In 2009 I wrote an article "Crew Survival Lessons Learned from the Columbia Mishap" and kept thinking about what our son Iain had said, "Why didn't the crew bail out from the Shuttle?" Based on what we had learned from the Columbia mishap, the final breakup was below 140,000 feet (42,672m). In 2009 I joined a team that wanted to expand the stratospheric bailout envelope above 100,000 feet (30,480m), which



A memorial plaque mounted on the back of the high gain antenna on the Mars rover Spirit. Credits: NASA

was what the Shuttle Advanced Crew Escape Suit (ACES) was certified to. The mission was called Red Bull Stratos. It was an aggressive flight test program, with many aerospace experts and an international team.

We built a pressurized capsule, used a pressure suit based on the Shuttle ACES suit, and used large helium balloons to get to the stratosphere. We tested in the vertical wind tunnel, vacuum chamber, thermal-vacuum chamber, and made many test jumps before setting off to the stratosphere. We learned all we could from the manned stratospheric balloon flights conducted by the United States and Russia in the 1950s and 1960s that supported their impending manned space programs. We studied the US Navy Strato-Lab mission, which tested the Project Mercury pressure suit, the US Air Force Project Excelsior stratospheric parachute jumps, which showed that a jump from 102,800 feet (31,333m) was survivable, and the Russian high altitude balloon parachute program "Volga" which used a pressurized capsule modeled after the Vostok spacecraft. We developed new medical procedures to deal with the hazards of space, like exposure to vacuum.

After two unmanned flights to test the balloon systems, in 2012 we flew three manned flights into the stratosphere, and on 14 October 2012, 65 years to the day after Chuck Yeager broke the sound barrier in the X-1, we successfully accomplished the highest stratospheric freefall parachute jump from 128,100 feet (39,045m), achieving human supersonic flight without an aircraft at 837 miles per hour (374.3 meters/second), or Mach 1.27. Sonic booms were heard on the ground from a human breaking the sound barrier in freefall. We never gave up, despite the risk, to show that anything is possible if you believe it can be done.

Rick, Willie, Mike, KC, Dave, Laurel, and Ilan we miss you all so much, but it warms our hearts to know that your legacy will endure in making it safer for the next generation of space flyers. Our sorrow and grief will pass, and we will meet up with you on the path ahead.

Michael P. Anderson
Payload Commander

A physicist, Michael began his career as an Air Force Communication Electronics Officer. He rose to Director of Information System Maintenance before taking up pilot training and becoming an aircraft commander and instructor pilot. He was selected as an astronaut candidate in 1994. His first mission was STS-89, the eighth Shuttle-Mir docking mission. His second and final flight was aboard STS-107. Before his flight, Michael's minister asked him what would happen if the shuttle were to not make it back. "Don't worry about me," he responded, "I'm just going higher."

Rick Douglas Husband
Commander

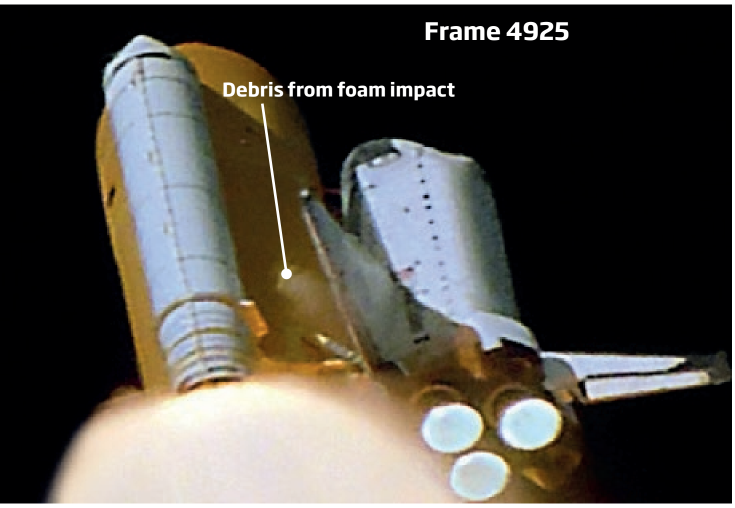
A mechanical engineer by education, Rick joined the Air Force and became a test pilot before being selected as an astronaut candidate in 1994. After completing his initial training, Rick served as Chief of Safety for the Astronaut Office. He first flew to space aboard Discovery STS-96 in May 1999 , the first Shuttle mission to dock with the International Space Station. His second space mission was STS-107. For Rick, being an astronaut was a lifelong dream, and he loved every minute of it.

Ilan Ramon
Payload Specialist

An Israeli-born citizen and son of Holocaust survivors, Ilan became a career fighter pilot in the Israeli Air Force, where he was known as the youngest pilot to participate in Operation Opera, the mission that destroyed the Iraqi nuclear reactor Osiraq. Ilan was selected as the first Israeli astronaut and began training with NASA in 1998. STS-107 was his only spaceflight. His diary was recovered from the wreckage of Columbia; on the last legible page of the journal, he wrote "I have become a man who lives and works in space."

Columbia: A Tragedy Repeated

By Gary Johnson



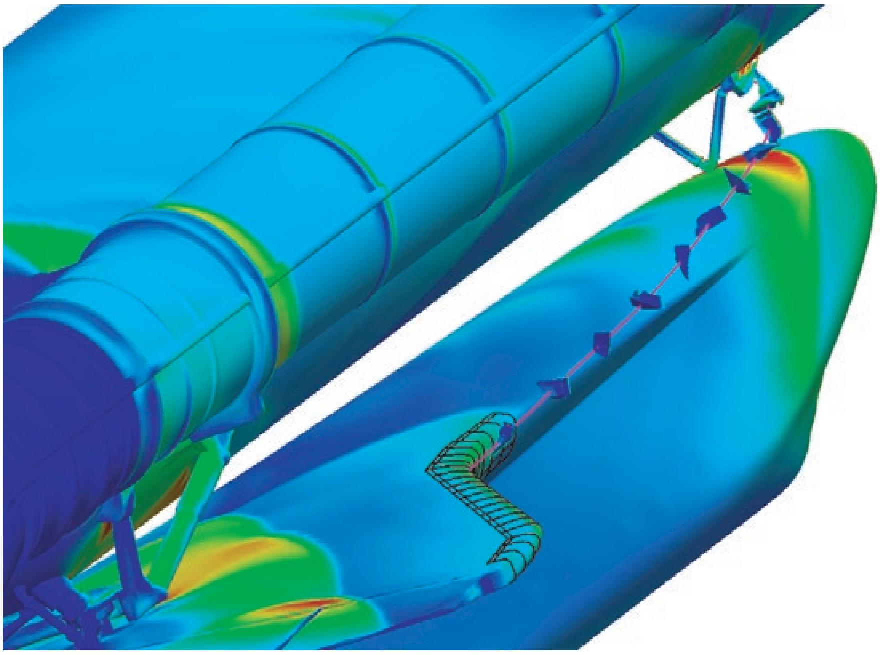
A color enhanced, de-blurred still frame of the foam strike, derived from video recording. Credits: NASA

The Space Shuttle Columbia STS-107 was launched on January 16, 2003 at 10:39 a.m. Eastern Standard Time. At 81.7 seconds after launch, when the Shuttle was at about 20,000m and traveling at Mach 2.46 (2,655km/h), a large piece of insulating foam came off the External Tank (ET) left bipod ramp area, close to where the orbiter attaches to the ET. The foam impacted under the leading edge of the left wing at 81.9 seconds. This incident was not seen by anyone on the ground or in the Kennedy Space Center (KSC) Firing Room or Johnson Space Center (JSC) Mission Control Center (MCC); there was no onboard indication to the crew. The impact was detected the next day during the detailed review of all launch camera photography that is conducted after every Shuttle launch. The analysis revealed that the debris was approximately 53-68cm long and 30-45cm wide, tumbling and moving at a relative velocity of 670-922km/h at the time of impact. Neither the crew nor MCC were aware that on flight day two an Air Force Command review of radar tracking data detected an object drifting away from the orbiter, that subsequent analysis suggested may have been related to the foam strike. On flight day eight, MCC emailed the crew that post-launch photo analysis showed External Tank foam had struck the orbiter's left wing during ascent. MCC stated there was "absolutely no concern for entry" because the phenomenon had been seen before. MCC also emailed a short video clip of the foam strike. Columbia continued its 16 day mission without further incident – until Entry Interface.

MCC stated there was "absolutely no concern for entry"

On-orbit Photo Request

On the second day of the mission, the Intercenter Photo Working Group Chair contacted the Shuttle Program Manager for Launch Integration at KSC to request imagery of



A trajectory analysis that used a computational fluid dynamics approach to determine the likely position and velocity histories of the foam. (Ref [1] p61) - Credits: NASA

Columbia's left wing on-orbit. The Program Manager agreed to explore the possibility – this was the first imagery request of the mission. A Debris Assessment Team (DAT) was formed with NASA and contractor engineers. DAT contractor engineers prompted a NASA Shuttle manager to make a second imagery request. The Department of Defense (DoD) Manned Space Flight Support Office began implementing the request, albeit with the assurance from MCC that this was merely information gathering, not a formal request for action. The first formal DAT meeting was held on January 21^{st}, five days into the mission. Without additional on-orbit pictures, the DAT was restricted to using a mathematical modeling tool called Crater, that predicts the depth to which debris will penetrate a Thermal Protection System (TPS) tile. Crater was suitable for small debris impacts, on the order of 49cm^3 – versus 19,665cm^3, the estimated size of the bipod ramp foam. Crater was classified as a "conservative" tool based on its projections of ice projectile damage to RCC turning out to be more severe than that achieved experimentally. Because foam is less dense than ice, the DAT used a *qualitative* extrapolation of the test data and *engineering judgment* that a foam impact angle of up to 21° would not penetrate the RCC.

The assumptions and uncertainty incorporated in this analysis were never fully presented to the Mission Management Team (MMT). The DAT assigned the NASA Co-Chair to pursue a request for imagery of the vehicle on-orbit – constituting the third request for imagery – by going through the Engineering department rather than through Shuttle Program Managers. The imaging request was viewed by Shuttle Program Managers as a non-critical engineering desire rather than a critical operational need. Seven days into the mission, a NASA Headquarters Safety and Mission Assurance (S&MA) manager called a JSC S&MA manager for the Shuttle Safety

A frame from a tape recording taken by the crew 4 minutes before the breakup. Credits: NASA

Columbia reentered the atmosphere with a breach in the reinforced left wing leading edge

Program and the Associate Administrator (AA) for S&MA, to discuss a potential DoD imaging request. The JSC manager for Shuttle Safety program said he was told this was an "in-family" event – meaning it was normal and nothing to worry about. The AA for S&MA stated that he would defer to Shuttle management in handling such a request. Despite two safety officials being contacted, safety personnel took no actions to obtain imagery. After discussion with other MMT members, the Shuttle Program Manager cancelled the DoD imagery request. The MMT had concluded this was not a safety-of-flight issue, apparently confusing the notion of foam posing an "acceptable risk" with foam not being a "safety-of-flight" issue. MMT members were making critical decisions about TPS damage tolerance based on little or no knowledge.

Sequence of Reentry Events

Columbia reentered the atmosphere with a breach in the Reinforced Carbon-Carbon (RCC) left wing leading edge near Panel 8. This breach allowed super-heated air, estimated to be about 2,760°C, to penetrate behind the TPS, destroying the insulation that protected the leading edge support structure and melting the aluminum wing spar. This resulted in thermal degradation of structural properties of the left wing. At Entry Interface (EI) plus 555 seconds, video from the ground shows pieces of material shedding from the orbiter, which continued to fly its pre-planned flight profile. Later, over the Dallas-Fort Worth, Texas area at about 60,960m, the increasing aerodynamic forces caused catastrophic damage to the left wing. At EI+613s, when the super-heated air had penetrated to the outside of the left wheel well, and destroyed the four hydraulic sensor electrical cables, controllers on the ground saw the first anomalies in telemetry data. At EI+727s, Mission Control noted an increase in left wheel well hydraulic line temperatures. At EI+790s, the two left main gear outboard tire pressure sensors began trending upward, then off-scale low. At EI+834s, a sharp change in the rolling tendency of the orbiter occurred along with additional shedding of debris. In an attempt to maintain attitude control, the orbiter responded with a sharp change in aileron trim, likely due to wing deformation. At EI+917s, the data ▶▶

The shuttle flight control room in Houston's Mission Control Center at JSC right after flight controllers lost contact with the Space Shuttle Columbia. Credits: NASA

According to CAIB, destruction of the crew module took place over a period of 24 seconds, beginning at an altitude of approximately 42,672m and ending at 32,000m. Credits: NASA

showed a significant increase in positive roll and negative yaw, an indication of increased drag on and lift from the damaged left wing. The flight control system attempted to compensate for this increased left yaw at EI+921s by firing two aft right yaw Reaction Control System (RCS) jets continuously. By EI+927s, the third RCS yaw jet began firing continuously and at EI+928s the fourth and last right yaw RCS jet began firing continuously. It is probable that hydraulic pressure to the aero control surfaces was lost at EI+928s when hot plasma burned through all four hydraulic lines in the area of the left wheel well. This loss of control and beginning of orbiter pitch-up marks the transition from a controlled glide to an uncontrolled ballistic entry with orbiter aero-thermal breakup at EI+970s.

Failure of the crew module resulted from the thermal degradation of structural properties, which resulted in a rapid catastrophic structural breakdown rather than an instantaneous explosive failure. Separation of the crew module assembly from the rest of the orbiter likely occurred at the interface with the payload bay. The crew module, pressurized compartment, and outer forebody separated at EI+1004s. Debris assessment indicates that cabin depressurization probably occurred when the lower cabin structure impacted the forebody structure. Increasing aero-thermal loads resulted in the total destruction of the crew module and forebody by EI+1021s. From data and analysis it appears that the destruction of the crew module took place over a period of 24 seconds, beginning at an altitude of approximately 42,672m and ending at 32,000m. The death of the crew was due to blunt force trauma and hypoxia (Ref [1] pp 70-77; [2] pp 1-63, 72).

Death of the crew was due to blunt force trauma and hypoxia

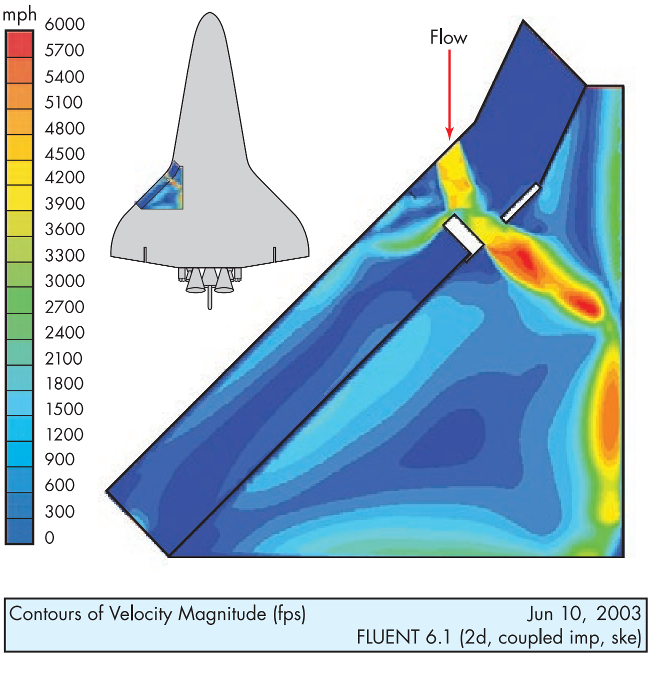
The Aftermath

NASA commissioned the Columbia Accident Investigation Board (CAIB) to "conduct a thorough review of both the technical and the organizational causes of the loss of the Space Shuttle Columbia and her crew on February 1, 2003." To capture lessons learned for future vehicle design, the Space Shuttle Program (SSP) commissioned the Spacecraft Crew Survival Integrated Investigation Team (SCSITT). "The SCSIIT was asked to perform a comprehensive analysis of the accident, focusing on factors and events affecting crew survival, and to develop recommendations for improving crew survival for all future human space flight vehicles," (Ref [2] p xix).

"The physical cause of the loss of Columbia and its crew was a breach in the Thermal Protection System on the leading edge of the left wing, caused by a piece of insulating foam," CAIB reported. CAIB found that the design of the orbiter left no possibility for a crew to survive given the resulting conditions. Once the breach occurred, the crew's fate was sealed.

But there were plenty of opportunities before the breach occurred to have prevented this tragedy. CAIB cited "the organizational causes of this accident," stretching back before the Shuttle program even began: "original compromises that were required to gain approval for the Shuttle, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization of the Shuttle as operational rather than developmental, and lack of an agreed national vision for human space flight." CAIB particularly called out a NASA culture that accepted mission success over engineering understanding, the stifling of differences of opinion, and evolution of an informal chain of command (Ref [1], p 9).

The same organizational causes were cited with reference to the Challenger accident. "By the eve of the Columbia accident, institutional practices that were in effect at the time of the Challenger accident – such as inadequate concern over deviations from expected performance, a silent safety program, and schedule pressure – had returned to NASA," (Ref [1], p 101). Sally Ride, who was on both the Rogers Commission Challenger



Computational fluid dynamics analysis of the speed of the superheated air as it entered the breach in RCC panel 8 and travels through the wing leading edge spar. The darkest red color indicates speeds of over 6,400 km/h; temperatures likely exceeded 2,760 degrees Celsius (Ref [1] p69) - Credits: NASA investigation and the Columbia Accident Investigation Board, stated she was surprised at how similar the cause factors were for both accidents. The tile losses went directly against the Space Shuttle's original design requirements that precluded foam-shedding by the External Tank. Engineers stated that had they known in advance that the ET was going to produce the debris shower that occurred during Columbia's first launch in 1981, they would have had a difficult time clearing it for flight. As we now know, from 1981 until the accident there was ET foam shedding to various degrees on every flight (Ref **[1]** p 122). The CAIB noted that while there is a process for conducting hazard analysis when the system is first designed, and a process for re-evaluating them when a design is changed or a component is replaced, no process addressed the need to update a hazard analysis when anomalies occur.

The CAIB identified 14 In-Flight Anomalies (IFAs) that had significant TPS damage or major foam loss. "Space Shuttle Program personnel knew that monitoring of tile damage was inadequate and that clear trends could be more readily identified if monitoring was improved, but no such improvements were made," CAIB stated. The process for closing IFAs was not well documented and appeared to vary. Had the correct information been available, it may have led to a concern by NASA management and engineering about ascent debris damaging RCC (Ref **[1]**; **[3]**).

Space Shuttle Return to Flight

The Space Shuttle was grounded following the loss of Columbia and did not return to flight until July 26, 2005. In the intervening two and a half years, the ET TPS was redesigned and capabilities for detecting an impact were installed: video cameras on the solid rocket boosters and ET feedline, high speed cameras at the launch site, aircraft mounted cameras and radar, and an impact sensor mounted on the backside of the wing's RCC and nose cap. The crew of STS-114

A view of Columbia taken at approximately 7:57 a.m. CST upon reentry as it passed by the Starfire Optical Range at Kirtland Air Force Base, New Mexico. Note debris coming from the left wing (bottom). Credits: SOR/NASA

There were plenty of opportunities to prevent this tragedy

was instructed to inspect their vehicle for damage and equipped with a limited repair kit to deal with the damage if they found it.

Meanwhile, NASA was working on its safety organization. The agency established the NASA Engineering Safety Center (NESC) at the Langley Research Center, charged with providing independent engineering safety assessments and testing, and funded by the Headquarters Office of Safety and Mission Assurance to assure independence (Ref **[5]**, p xxiv). A Chief Safety Officer for Space Shuttle was established, and S&MA began using analytical tools for risk characterization and trade studies. S&MA developed the capability to support real-time operations and for rapid team response to significant events or anomalies, as well as detailed Shuttle Probabilistic Risk Assessment models. S&MA and the SSP made a concerted effort to maintain and continually improve the risk-based decision making process. This effort was carried out through the end of the Space Shuttle Program and in that time avoided the decline and atrophy that occurred post-Challenger (Ref **[4]**).

References

[1] Columbia Accident Investigation Board, Report Volume 1, August 2003.
[2] NASA/SP-2008-565 "Columbia Crew Survival Investigation Report".
[3] NASA JSC Safety and Mission Assurance Qualification Training Program, Columbia Case Study Course No. BA-601, by Gary W. Johnson/SAIC, February 2008.
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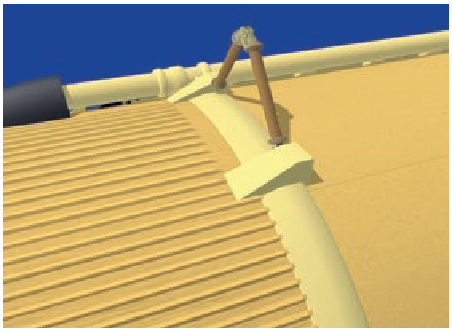
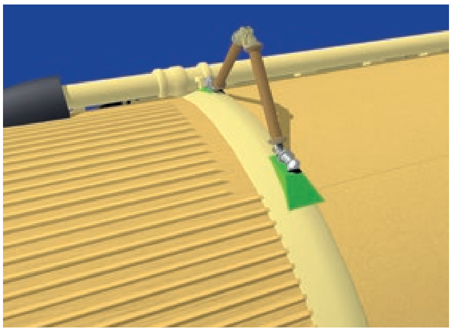
[5] NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond, Volume 1, Revision 1.1, November 20, 2003.





Left: the External Tank's bipod fittings covered by foam ramps, as flown on the Space Shuttle Columbia. Center and right: the redesigned fitting. Credits: Lockheed Martin/NASA Michoud

The Impact of Columbia on US Aviation Safety

By Paul D. Wilde, Ph.D., P.E

Columbia changed my personal and professional life dramatically. The morning of the accident a fellow Federal Aviation Administration (FAA) employee called me from the Cape; he said the orbiter was 30 minutes overdue and suggested I pack my bags. Within a week I was in Houston, meeting Admiral Gehman and the rest of the Columbia Accident Investigation Board (CAIB) members.

As the leader of the flight safety analysis team for the Office of Commercial Space Transportation, I was one of two FAA employees selected as an investigator on the Independent Analysis Team (IAT). The CAIB put so much value on independent analyses that we had an IAT inside the CAIB, which was itself an independent safety organization. Mostly I worked on the technical analysis of the accident performed by "Group 3" and directed various independent analyses funded by the CAIB, such as the foam impact analysis performed at the Southwest Research Institute (SwRI) and the public risk study. As an example of CAIB thoroughness, the SwRI analysis supplemented at least three other technically separate analyses performed by Boeing, NASA, and the Sandia National Laboratory. For six solid months, the CAIB worked seven days a week, starting with an all-hands staff meeting every morning except Sunday, at 0700.

Responsibility for Public Safety

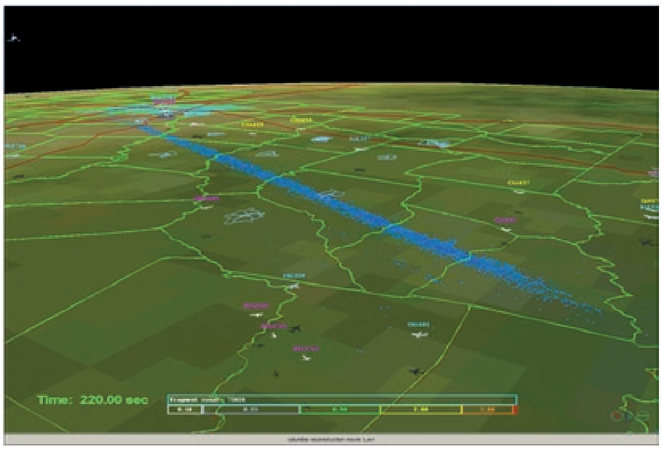
I was fully engaged in figuring out what happened to Columbia and why it happened when Bryan O'Connor called me into his office on his last day as an Ex-Officio Member of the Board. He recommended investigating the public safety implications of the accident, specifically to see if it was "a miracle" that no one was hurt on the ground. He wanted to know the public safety implications of the accident; this concern was highlighted when NASA Administrator Sean O'Keefe testified before the US Senate on May 14, 2003 that "stunningly, in as much as this was tragic and horrific through a loss of seven very important lives, it is amazing that there were no other collateral damage happened as a result of it. No one else was injured."

Mr. O'Connor's recommendation started me on a more challenging quest than I had realized. My first step was to speak with Steve Wallace, Director of the FAA's Office of Accident Investigation and a CAIB member, about the potential public safety implications, which he agreed were of interest. However, the CAIB was still entirely focused on the cause of the accident, so not much energy went into a public safety investigation until after NASA briefed the CAIB about the Probabilistic Risk Assessment (PRA) for the STS program, which was almost ready for publication just prior to the accident. Toward the end of that briefing, I asked about the potential applications of the PRA to public safety. The response was that NASA would not apply PRA insights to any public safety applications because the United States Air Force (USAF) and FAA were responsible for public safety during launch and reentry, respectively. As an FAA employee, it was clear to me that at least some people at NASA had the wrong impression about responsibility for public safety during reentry. After the PRA briefing, Steve Wallace agreed that the public safety issues demanded a thorough investigation. And they got one.

Danger Below Columbia

CAIB directed an independent study of the public risks posed by Columbia, which was performed by ACTA Inc. and documented in Volume II of the CAIB final report. The results demonstrated a 10-30% chance of one or more casualties on the ground given that the ▶▶

O'Connor recommended investigating if it was "a miracle" that no one was hurt



Simulation of Columbia Breakup to Compute Probability of Impact on Aircraft. Credits: ACTA inc accident happened when and where it did. Thus, the absence of serious injuries to people on the ground due to the Columbia accident was the statistically expected outcome, not "a miracle" by risk analysis standards. However, the populous city of Houston would have been hit if that fateful reentry was delayed one orbit. The probability of casualty was much higher, 89-98%, if the same debris field fell on Houston, with two casualties expected.

CAIB published preliminary results on the conditional risks to aircraft: the expected number of plane impacts from Columbia was approximately 0.03 based on estimated air-traffic nearby. A subsequent FAA study used the actual commercial aircraft trajectory data at the time of the accident to compute between 0.003 and 0.1 expected collisions of Columbia debris with commercial aircraft [see AIAA 2005-6506].

The highest probability of impact to any individual aircraft was between 1 in 1,000 and 1 in 100, depending primarily on the uncertainty associated with how many small fragments survived to aircraft altitudes but were unrecovered. The consequences of an aircraft impact with Columbia debris was highly uncertain, but the fact that over half the recovered debris was under 0.5 kg and extremely low density materials suggested that many would have been benign even if they had impacted.

A Public Safety Policy

CAIB published a section on public safety (10.1) in Volume I that called out NASA for failing to follow public risk standards already in place at other flight institutions. "FAA and U.S. space launch ranges have safety standards designed to ensure that the general public is exposed to less than a one-in-a-million chance of serious injury from the operation of space launch vehicles and unmanned aircraft," reported CAIB. "NASA did not demonstrably follow public risk acceptability standards during past orbiter reentries." The findings concluded that NASA needed "a national policy for the protection of public safety during all operations involving space launch vehicles." Columbia became a part of this policy development, with the recovered debris from the orbiter used to facilitate realistic estimates of the risk to the public during orbiter reentry.

In 2005, NASA issued range safety policy NPR 8715.5 that included public risk acceptability criteria for all launches and reentries. This policy regarding collective public risk associated with Space Shuttle entries required an evaluation of entry trajectories from the ISS orbit inclination of 51.6 degrees and the collective public risk associated with each trajectory. This policy allowed the Space Shuttle Program to "continue to use Kennedy Space Center as its primary landing site, and establishes a public safety risk threshold to be used when considering alternate landing sites."

Columbia streaking over the Very Large Array radio telescope in Socorro, New Mexico. Credits: NASA

Houston would have been hit if reentry was delayed one orbit

Columbia's Aviation Legacy

The impact of the Columbia accident on aviation safety cannot be overstated. In the wake of the accident, multiple US agencies collaborated to develop consensus based aircraft protection standards and models to characterize aircraft vulnerability to launch and reentry debris. Columbia prompted NASA and the FAA to develop and implement a real-time mishap response system to alert aircraft and rapidly clear potentially threatened airspace during subsequent Shuttle reentries [see AIAA 2010-1349].

The FAA is currently expanding the real-time aircraft warning system, based on containment for debris that exceeds aircraft hazard thresholds, to more efficiently integrate launch and reentry vehicles into the US national airspace without compromising safety. The FAA continues to sponsor tests and analyses to produce more refined aircraft vulnerability models. These tests and analyses are part of the ongoing efforts to ensure no space vehicle debris collision will cause an aircraft accident the way the foam strike destroyed *Columbia*.

Physical Test to Simulate Foam Impact on Columbia's Wing Leading Edge. An air gun is used to launch a 757g foam piece into a Reinforced Carbon-Carbon test article at a speed of 234 m/s, with a 20 degree angle of incidence. Inset: the test article a fraction of a second after being impacted. Credits: Rick Stiles/ CAIB

Living with Columbia

Interview with Mike Ciannilli

By Merryl Azriel


Mike Ciannilli with his long-time charge, the orbiter Columbia. Courtesy: Mike Ciannilli

On February 1, 2003, Mike Ciannilli was a contractor for NASA. He worked as a test project engineer, responsible for the engineering systems coming together in the firing room. He was assigned to Space Shuttle Columbia, which seemed fitting somehow. Ciannilli had a long love affair with Columbia, dating from his middle school days, when he made a replica of the ship for his school science fair. At the time of the STS-107 mission, he was monitoring issues during processing flow in the turnaround between landing and launch and he manned the launch countdown. When he talks about listening to your vehicle, it's clear he still hears the rumbles and creaks of Columbia, a decade after she disintegrated before his and everyone's eyes.

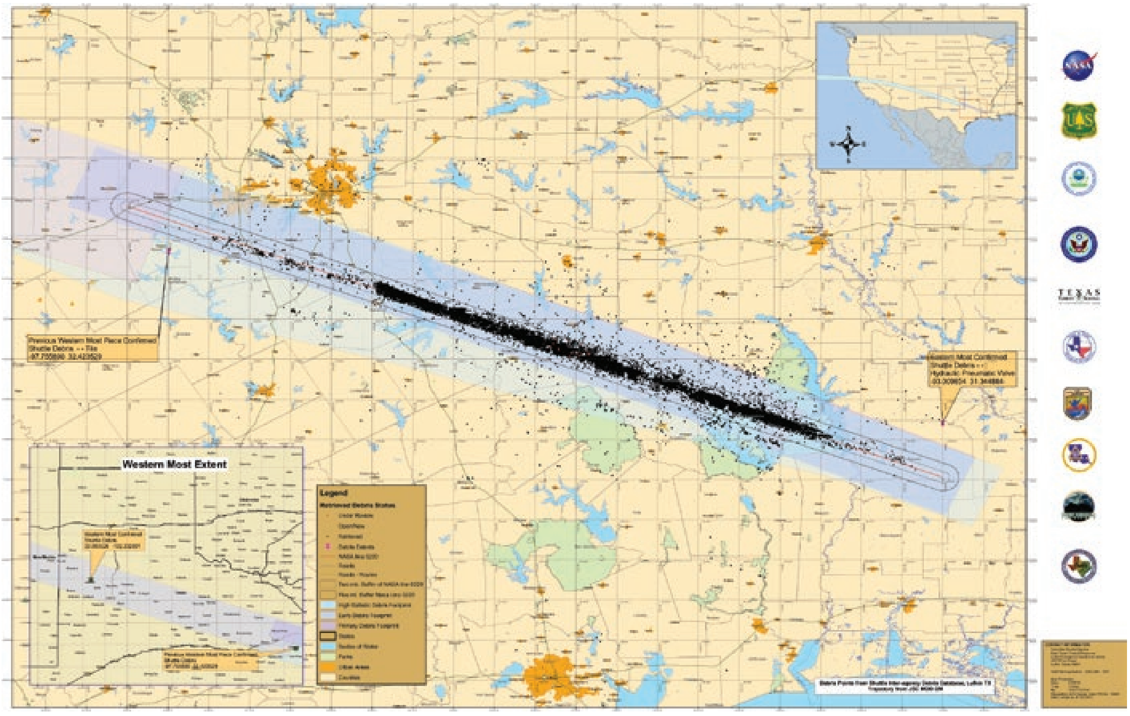
"Columbia was always personally very special to me"

The Search

Mid-February 2003 found Ciannilli in the middle of Texas, overflying Columbia's final flight path again and again. His job was to look out the helicopter doors, watching for signs of anything that might be a piece of the shuttle. When he spotted something promising, the copter would land while he attempted to identify the bit, bringing it aboard if it looked to be a likely match. "We'd do our initial identification, put it on board, and then launch up again. It was a lot of long days, flying every single day, for weeks on end."

He was far from alone on this search. "We had to pull off what in the end was the largest search in American history," Ciannilli says, describing the 420x16km stretch that comprised Columbia's flight path. If it wasn't for the "thousands of volunteers – the American Indian tribes, volunteer firefighters and policemen, and everyday people that came down," he says, with something of wonder still in his voice, the job would have been nearly impossible. Ciannilli's respect for those volunteers is palpable: "These folks came on buses from around the country, lived in tents in freezing rain conditions. They worked twelve hour plus days through very, very rough conditions and then their reward at night was to sleep in a small tent in freezing rain." Ciannilli describes how incredible it was to interact with these volunteers, who simply felt that this was something they owed to their country. "And these folks did it with a smile, you'd walk around they'd be thanking you for the experience."


Members of a US Forest Service team walk a Columbia recovery search grid. Credits: NASA



The debris field in East Texas spread over 5,179 km^2. The search covered 700,000 acres. Source: CAIB Report, p 45

When you wonder if space really matters to people, Ciannilli says, think of these volunteers. “When you see these folks come down and put their life on hold to help out the nation’s space program, it becomes very real what space means to people.”

“It was an extremely bittersweet emotional experience,” says Ciannilli, “I never want to have to do it again, but you can’t imagine not living through the experience because of the amazing people that you met and the amazing spirit of those people. They wanted to bring Columbia home.”

After several weeks, Ciannilli became the Air Operations lead: “I was helping organize the flights at that point and trying to coordinate the scheduling.” They did not finish the search until May 2003, nearly four months after the accident. By the time he got back to Cape Canaveral, the Columbia Accident Investigation Board was well on its way to producing what is now known as the CAIB Report. It is still one of the defining accident reports of modern spaceflight, what Ciannilli describes as “an awesome tool,” one he recommends everyone, especially anyone involved in spaceflight, read and reread.

Curating the Remains

While Ciannilli, his colleagues, and volunteers were out hunting for pieces, a reconstruction team was hard at work at the shuttle landing facility, trying to figure out where those pieces fit. “They were reconstructing Columbia as best they could and they did a really amazing job of putting her back together,” says Ciannilli. When the CAIB Report was delivered to US President Bush in August 2003, the remains of Columbia were turned over to NASA, who moved them from the shuttle hangar to the Vehicle Assembly Building.

"I never want to have to do it again, but you can't imagine not living through the experience"

Four years later, Ciannilli gained custody of Columbia when he was appointed Project Manager of the Columbia Research and Preservation Office. “It was and is humbling,” he says. “Columbia was always personally very special to me.”

Managing the office gives Ciannilli something of a pulpit from which to deliver the message of Columbia. He recently convinced NASA to require all new co-ops and employees at Kennedy Space Center to tour the Columbia Office “I’m a huge believer in know your history, remember your history, and understand your history. I think you really need to educate your folks on the reality of what happened.”

He’s also proud of the work the office is able to do in helping to continue research based on the shuttle. The office has an active loan program that allows researchers to borrow artifacts for study. “It’s really interesting because they’ll take a look at a piece and you can watch the wheels turning. They can see so much into it.” The office also works with educational institutions: “A university or a high school can apply to have a piece of Columbia sent to them and they can use it in the classroom for an engineering forensics class or engineering analysis class. Hopefully it inspires the younger folks to study and have Columbia be the catalyst to help that conversation.”

Listening to Your Vehicle

The discussion turns to the lessons learned from Columbia, and for a moment Ciannilli seems not to know where to start. “There’s a bunch,” he says, and proceeds to list some of the big ones: keep your models and tools up to date, understand your materials, guard against the off-nominal becoming normal, continually question and revalidate your design, and of course, institute a culture of open communication. But one thing that Ciannilli comes back to again and again is listening to your vehicle.

“People say that the vehicles become alive. They become personalities,” explains Ciannilli. “I can tell you how Atlantis behaves and how Columbia starts up in the morning.” These quirks, much like those you might be familiar with from your family automobile, can provide important clues to changes in spacecraft behavior – clues that may not be present in more formal types of data. "The vehicle's talking to you, the hardware's talking to you – listen to it," urges Ciannilli. "Things are happening and they often start as very small things. Understand what's happening." He specifically notes the issues shuttle managers faced relating to tile incidents. "Even the last few years, we didn't really understand carbon-carbon, its strengths and its weaknesses." Accepting tile incidents as normal without understanding the source of the incidents was a clear pre-Columbia failure.

Ciannilli gets animated when he describes what the shuttle program could have been like had the Columbia accident never occurred. "Our plan was to fly space shuttle to 2020 or 2025 even," he says, describing the extension program and the upgrades to cockpit, engines, instrumentation, computers, GPS, and "a whole host of systems," that were already underway at the beginning of 2003. Even after the accident, technically the shuttles were in excellent condition, possibly the best they'd ever been. "The incidents between flows were being significantly reduced, the crews were reporting on orbit the vehicles were performing better and better every flight," Ciannilli recalls. But political winds blew NASA down a different path.

"For 30 years we had a tremendous database." Ciannilli notes with pride. Unfortunately, that database moves to the shelf now, as new vehicles come in with quirks and personalities yet to be discovered. In some ways, new vehicles can advance safety systems, with enhanced opportunities for designing in safety factors that cannot be retrofitted to an existing vehicle. But in other ways, the loss of familiarity can be a stumbling block. "It's kind of like buying a new car," explains Ciannilli." You're gonna have new features and you don't know how it's going to perform."

"But," he says, "you can never keep flying the same vehicle forever."

Mike Ciannilli in back of a helicopter during Columbia aerial search operations in Texas. Courtesy: Mike Ciannilli

"The vehicle's talking to you – listen to it"

Standing up to Say Something's Wrong

Ciannilli observed clear changes in NASA's communication culture following release of the CAIB report. "After the accident it definitely improved a lot and I think it got better as time went on after the accident - more improvements were put in place and the culture was established," he recounts. But, he says, that fear of standing up to say something is wrong will never go away entirely. "It's human nature," says Ciannilli. "If you're going to a flight readiness review, a launch readiness review, any kind of environment it's gonna be difficult at times for folks to come forward."

That's where Ciannilli hopes the memory of Columbia can help. "I say this at the end of every tour I give of the Columbia room: if you're ever sitting at a flight readiness review, or a launch readiness review, or anything and you have that feeling in your stomach, you feel there's something not right... If you ever need that courage, think back to this room. Think back to your time here with Columbia. And that might be the one little extra piece of encouragement that will help get you out of your seat."

Safety in Any Industry

Clearly, Ciannilli hopes that the lessons of Columbia and Challenger will be carried forward into the next generations of spacecraft development and developers. "The practices, what's good to do, the safety checks that are important what kind of redundancy is important and necessary, a lot of that is transferrable," says Ciannilli, despite the differences in design and approach. And, Ciannilli emphasizes, these lessons are not isolated to NASA or even commercial crew: "aircraft, cars, submarines, it's all the same in a lot of ways."

Ciannilli advises those developers to "keep looking for the risks that are out there, capture them in your processes, promote them in your training, instill them in your culture, and then keep revisiting them." And most importantly, he says, act on them. "It's like a parent, you know. You tell your kids certain things to do or not to do, but if you don't do them yourself in a very visible way it's not going to be taken seriously."

"I don't care if you're a technician turning a wrench or if you're the CEO," he admonishes. "Be the example of that culture and let others see how serious you are."

Keeping the Message Alive

"As time gets removed, as time goes on, memories kind of fade, like old family stories," says Ciannilli. "After a while the stories don't have quite the same effect."

In many ways, remembering Columbia – and Challenger before it – is very much a personal responsibility. Ciannilli talks about he and others from that time trying to transfer their experiences to new employees – employees who were in middle school or high school when the crew of STS-107 died. "They don't have the personal connection that we have that lived it." Ciannilli sees the Columbia room as a critical component in that communication. "They walk through the Columbia room and you can just see the impact it has. It becomes real for them, as close as it could be. And hopefully they take that into their career and it really means something in their future decision making processes."

Ciannilli is also clearly excited about the new research that results from studying Columbia's remains. "It's definitely pushing the bounds of knowledge for the upper atmosphere and the effects there." While researchers commonly publish their ▶▶

Recovery volunteers camp in a warehouse in Texas after a day of searching for debris. Credits: NASA

findings, there is no formal mechanism to incorporate new materials and structural knowledge back into the next generation of space vehicles. "It's a treasure trove for the folks that do want to learn about it," says Ciannilli.

"We do our best to keep it going and the best way you really can do that is passing down from one generation of engineer to the next." So the Mercury engineers talk to Gemini and Apollo engineers who talk to the Space Shuttle engineers: "Tribal knowledge I call it." But Ciannilli acknowledges that keeping it going is a constant challenge. "There's a tremendous amount of experience that we don't have any more," both from NASA layoffs at the end of the shuttle program and the aging of engineers with those decades of experience. "You can't replace the thousands and thousands that aren't here anymore, but you try the best you can to get as much of the knowledge across that we learned and pass that on to the next folks."

"As time goes on, memories fade"

"The STS-107 mission was a mission of education and research," Ciannilli concludes. "I always say that what we do is, in their name, continue that mission, continue that research, and continue the education, so Columbia in a way still flies. And so do they, in spirit."

Mike Ciannilli has launched a website, Columbia.nasa.gov, as a one stop shop for everything Columbia, including a place to share your memories of Columbia with the community. He urges anyone who thinks they may have a piece of Columbia or Challenger to give him a call. "Having any of Columbia or Challenger is a felony, so they don't want to do that," says Ciannilli. "But if they do find something, we thank them so much and want them to contact us. We want to bring all of Challenger and Columbia home."

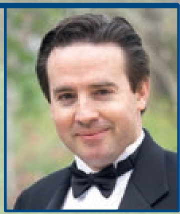
Reconstruction of Columbia debris in the hangar at Kennedy Space Center. Credits: NASA

Contributors

Credits: NASA

Bryan O'Connor

Bryan O'Connor was Shuttle pilot on STS-61B in 1985. After the loss of Challenger, he was given a number of safety and management assignments. In 1991, he commanded STS-40. In 1993 he became Director of the NASA Space Station Redesign team and, in 1994, Director of the Space Shuttle Program. In June 2002 he became NASA Associate Administrator, Office of Safety and Mission Assurance (OSMA). In 2004, following the Shuttle Columbia accident investigation conclusion, his title changed to NASA Chief, Safety and Mission Assurance and his functional responsibilities enlarged. Bryan O'Connor is recipient of the IAASS Jerome Lederer Space Safety Pioneer Award 2011.



Courtesy: P. Wilde

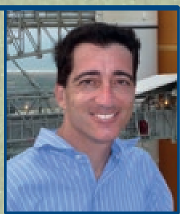
Paul Wilde

Dr. Paul Wilde is a founding fellow of the IAASS with 20 years experience in safety standards development, launch and reentry safety evaluations, explosive safety analysis, and operations safety. Currently a technical advisor for the Chief Engineer in the US Federal Aviation Administration's Office of Commercial Space Transportation, he preformed leading roles for multi-organization projects in high-profile situations, such as investigation of public safety issues and the foam impact tests for the Columbia Accident Investigation Board, flight safety evaluations for the maiden flights of the ATV, Atlas V, Delta IV, Falcon 9-Dragon, Spaceship 1, Titan IVB, and the development of US standards on launch and reentry risk management. He received the NASA Exceptional Achievement Medal and is a licensed professional engineer in Texas.

Credits: Red Bull Stratos

Jonathan Clark

Dr. Jonathan Clark is an Associate Professor of Neurology and Space Medicine at Baylor College of Medicine and teaches operational space medicine at BCM's Center for Space Medicine. He was a Member of the NASA Spacecraft Survival Integrated Investigation Team from 2004 to 2007 and Constellation EVA Systems Project Standing Review Board from 2007 to 2010. From 1997 to 2005 he worked at NASA as a Space Shuttle Crew Surgeon. He served 26 years active duty in the US Navy as a Naval Flight Officer, Flight Surgeon, and Military Freefall parachutist. Dr. Clark is Medical Director of the Red Bull Stratos Project. His professional interests focus on the neurological effects of extreme environments and crew survival in space.



Courtesy: M. Ciannilli

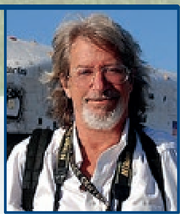
Michael Ciannilli

Mike Ciannilli is NASA Test Director, Project Manager of the Columbia Research and Preservation Office, and Project Manager of the Space Shuttle Challenger Office at Kennedy Space Center. He started his career as a systems engineer supporting the Fuel Cells Orbiter group, later moving on to serve as a test engineer for the orbiter Columbia, which was his position on February 1, 2003. Ciannilli took a hands-on role in recovering Columbia's debris and he's still the individual to call when someone uncovers a new debris candidate. Five years after the loss of STS-107, Ciannilli took over as curator of the Columbia room, where he continues to share the lessons of Columbia with anyone who will listen.

Courtesy: G. Johnson

Gary Johnson

Gary W. Johnson is an Aerospace Safety Consultant, currently working for J&P Technologies. He worked for NASA on the major manned programs from Apollo on since 1964. He served as Manager for the Sequential Subsystem for the Apollo CSM, Lunar Module, and Skylab CSM; member of ASTP Working Group 4; first Space Shuttle flight Orbit Flight Control Team Electrical, General Instrumentation, and Lighting (EGIL) flight controller; Mission Operations Directorate Systems Division Mechanical and Payload Systems Branch Chief and Guidance and Propulsion Systems Branch Chief; Deputy Director, SR&QA Office; NASA/Mir Program Joint Safety Assurance Working Group Co-Chairman; deputy director of Russian Projects SR&QA; and NASA Co-Chairman of the International Space Station Program Joint American Russian Safety Working Group.



Credits: Jim Siegel, Celebration News.

Lloyd Behrendt

Lloyd Behrendt is an artist and photojournalist who has collected more than 300 launches on film since Apollo 14. His work is based on black and white photographs transformed into original oil paintings. His book "Birds of Hope... A Primer for the Future" depicts the coexistence of Central Florida's man-made "space birds" with the natural, winged creatures living in the area, and shares the story of how rockets have saved their feathered neighbors. According to Behrendt, the decision to represent Columbia's fated launch was an attempt "to represent the accomplishments of the STS program and to memorialize the precious sacrifices of those lost over the years as we have explored the harsh and sometimes unforgiving environment of space."

Credits: Jtesla16/Wikimedia

By Carmen Felix

To the Stratos and Beyond Interview with Felix Baumgartner

On October 14th 2012, Felix Baumgartner became the first human to break the sound barrier during a free-fall from an altitude of of 39 km. Space Safety Magazine contacted him to learn more about the safety aspects of a project that has changed the perception of what is possible in terms of crew escape and rescue.

A Dream to See the World from Above

Space Safety Magazine: You became the skydiver to achieve the highest parachute jump and the first human to break the sound barrier outside a vehicle. Is this something you anticipated when you began skydiving?

"I didn't know whether I'd broken the sound barrier until I landed"

Felix Baumgartner: From the time I was a child, I wanted to see the world from above. My grandmother gave me a coin commemorating the Moon landing when I was just a little boy, and men like Neil Armstrong and Joe Kittinger were my heroes. My biggest personal dreams were to be a skydiver and to fly helicopters, and I made my first skydive as soon as I was legally old enough: age 16 in Austria. Setting a new altitude record was always in the back of my mind, but it took 20 years of progressively more difficult challenges to be ready for the mission we completed on October 14.

SSM: What was your personal involvement in the design of your spacesuit for this mission?

FB: The suit was custom-tailored to my measurements, and I personally went to David Clark Company for fittings and to discuss what was needed – especially the mobility necessary for skydiving. Then once a prototype suit was created I provided feedback, and throughout our testing and training I continued to give my input on all the equipment I wore. For example: it wasn't possible to look up to see my parachute lines in the helmet, so we added mirrors to the gloves. And, just the opposite, it was difficult to look down and see a landing site over my chest pack, so the team equipped the chest pack with a release I could use to swing it out of the way at low altitudes. Adjustments that may seem like ▸▸

Felix jumps into the void from an altitude of 39km. About 40s later, Felix became the first human to break the sound barrier in freefall.
Credits: Red Bull Content Pool

Baumgartner sits in his capsule during preparations for the final Red Bull Stratos flight. – Credits: Jörg Mitter/Red Bull Content Pool

"We all wanted the jump to succeed, but we also agreed that the risk had to be acceptable"

fine-tuning can make a big difference when you're in the air.

SSM: While we are waiting for the data to be published, what can you report about your personal experience of the transition to supersonic speed? What was different with respect to an ordinary high velocity free-fall?

FB: I couldn't sense how fast I was going – there aren't any visual markers in the sky to give your brain a point of reference. And I didn't know whether I'd broken the sound barrier until I landed and the crews told me that they'd heard my sonic boom. But what was different from other free-falls was how long a period I fell (and accelerated) with no control because the air was so thin. The air wasn't dense enough to work against, so it felt like a very long time before I could use my skydiving skills to stabilize myself. Fortunately, I had trained hard for just such a situation. The team had always warned me that I could spin, and my test jumps from 71,581 feet (about 21,800m) in March and 97,145.7 feet (29,610m) in July gave me a taste of what a free-fall in a near vacuum would be like.

SSM: One of the risks and possible scenarios that did not occur during the actual jump was falling unconscious. How was the team prepared to address this problem?

FB: My parachute rig included a drogue stabilization parachute that would have deployed if I had experienced 3.5Gs for six continuous seconds. And my reserve parachute was equipped with a CYPRES automatic activation device that would have fired if necessary as I approached the ground. Finally, the medical team had established clear protocols on how to treat me if I had landed in an unconscious state. Every contingency was well thought out.

An Acceptable Risk

SSM: During the jump, you reported to the ground that the visor was not working properly and you were experiencing fogging. Luckiy, you retained some visibility, but what would have happened if you'd been completely blind?

FB: It was built into our protocols that if I couldn't see, I couldn't jump — I would have had to come down in the capsule, because I needed to be able to see the horizon to stabilize myself. However, even if I had jumped and then fogged or iced over, the automatic deployment devices in my parachute rig would have protected me — but it would have been much more difficult to stop my spin or have a perfect landing.

SSM: Issues like heating and communication that occurred during your ascent could have resulted in a

"This mission has resulted in new protocols and procedures that could save lives"

decision to abort the mission. What was your position regarding that and what drove the decision to continue?

FB: Because this was a well-planned flight test program, we had carefully crafted our procedures so that we knew what to do if difficulties arose. Naturally we all wanted the jump to succeed, but we also agreed that the risk had to be acceptable. Ultimately, whether or not to jump was my call. Working with Mission Control enabled me to troubleshoot and consider the risks, and I decided to go ahead with the jump.

Looking Beyond Stratos

SSM: What is the legacy of Project Stratos? What are the major outcomes of this endeavor for science and future technologies?

FB: It's hard to sum up the results of Red Bull Stratos in a few sentences. I think most members of our team would say the biggest impact was proving that a human being could successfully pass through the transonic zone and break the speed of sound in freefall. There were a lot of people – even experts – who doubted it, and hopefully the dynamics of that experience will point toward solutions for high-altitude bailout in emergencies.

In terms of equipment, I understand that organizations throughout the aerospace industry are interested in the modifications made to my pressure suit and parachute rig to facilitate a high-altitude, high-speed parachute jump. I think we made some true advances there. This mission also brought together an incredible medical team whose collaboration has resulted in new protocols and procedures that could save lives. Throughout the entire five years of program development, we were learning. Now the team is going to be sharing their insights and findings to benefit programs on the horizon.

It's exciting to see just how much the jump has inspired kids around the world, too. If Red Bull Stratos has helped spark young people to take an interest in science, or to follow their dreams in other ways, that's a legacy to be proud of.

SSM: Will you do it again?

FB: This project was very fulfilling, and I'm happy that we were able to gather even more data than we had originally anticipated to further advancements in aerospace safety. I feel like we accomplished what we set out to do, and now it's time for me to move to other challenges. I hope that the next generation can take what we learned and expand on it.

SSM: What is next for you?

FB: I've probably gone as far as I can go with parachuting, but I still love that feeling of seeing the world from above, and I'm the kind of person who is always looking to take my skills to the next level. I'm ready to pursue my other passion – that second dream I've had since I was a kid, flying helicopters. I have already been flying as a commercial helicopter pilot, and now that I have more time I'm really looking forward to flying in ways that will be useful, like piloting mountain rescues.

Baumgartner celebrates the successful completion of his record breaking jump.
Credits: Predrag Vuckovic/Red Bull Content Pool

Under Pressure: A Brief History of Pressure Suits Part 1

By Phillip Keane

For the most part of our history, we have not ventured too far outside of a very specific set of environmental conditions, optimal for human life. It wasn't until we began to explore the depths of the oceans in the 18th century, and then began to explore higher altitudes in the 20th century that we noticed the effects of pressure on human physiology. These new environments introduced variations in temperature and pressure that were far in excess of our comfort zone, up to the point of being fatal to those not properly equipped.

Pressure

Pressure, in hydrostatic terms, is the force exerted on a body from a column of fluid of a certain height. This principle applies to air as well as water. The pressure acts perpendicular to the body from all directions. So in any fluid, the pressure experienced is proportional to the product of ρgh, where ρ is the density of the fluid, g is the gravity and h is the height of the column of fluid. At sea level, the pressure exerted by the atmosphere above is equal to 1 atm, or 101.1 bar. As we traverse skywards, the height of the air column acting on the body decreases, and therefore so does the pressure experienced.

The opposite can be said for when the human body descends beneath the ocean surface: pressure increases as the depth increases, and because water is much denser than air, the pressure increases proportionally faster with respect to depth. As mentioned previously, we operate best in a very narrow margin of atmospheric conditions, and outside of these conditions, we need to bring a suitable environment with us to survive, and this is where the story of the pressure suit begins.

Humans operate best in a very narrow margin of atmospheric conditions

Siebe, Gorman & Co. Ltd. bolted diving helmet. – Credits: David L. Dekker www.divescrap.com

Diving

Although underwater diving and high altitude flight involve different extremes of the pressure spectrum, it is worth mentioning them both from a historical perspective, as the development of altitude suits, and later on, the space suit, both share a common design heritage to underwater diving equipment.

The very first aviation pressure suits resembled diving suits, as they were largely just modified versions of the sub-aquatic equipment. The most obvious commonality between the two types of suit is the need to create a fluid-tight seal, be it for water or for air, and George Edwards was the first to design a diving suit with a bolt-on helmet that prevented ingress of water. Previous designs relied on a helmet that was held in place purely by its own weight, which frequently resulted in the deaths of divers from drowning.

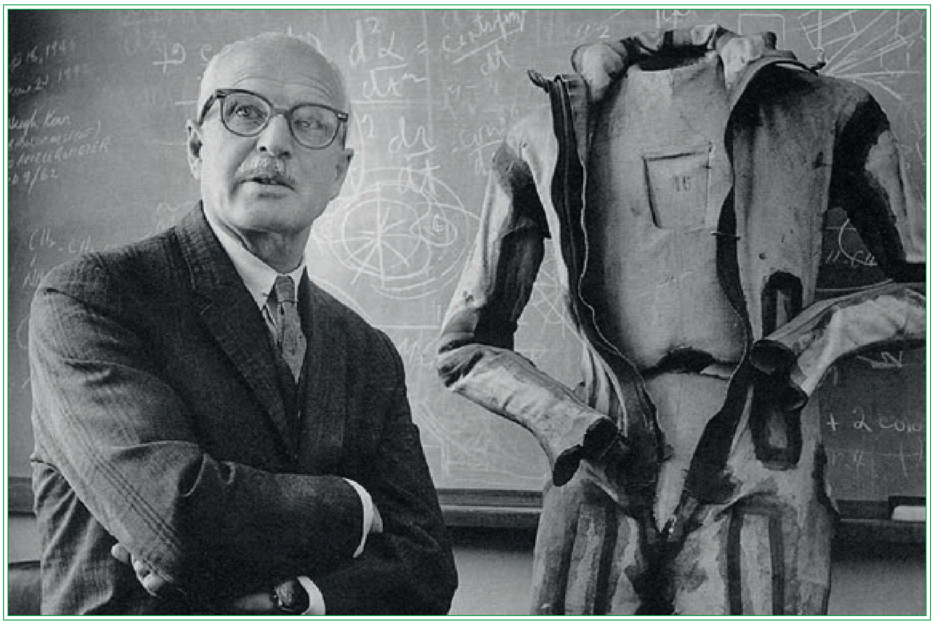
Development History

World War I saw the first widespread use of fighter craft in combat, and consequently pilots were subjected to high g-loads as well as exposure to altitudes above 4,572m as they strove to avoid enemy fire. Pilots reported loss of vision during high g maneuvres as well as headaches, dizziness, and fatigue. It was realized by medics that most of these symptoms were related to lack of oxygen at altitude, although the effects of acceleration were not realized until much later on.

The first conceptual pressure suit was designed after World War I by Fred Sample, an engineer from Florida, US. On 16th July 1918 he was awarded the patent for his "suit for aviators", that featured a bolt-on helmet, an oxygen hose that connected to a tank fitted on the back, and an inflatable gas-bladder which provided mechanical counter pressure to the lungs (much like the partial-pressure suits later designed). It was intended for pilots and mountain climbers. The suit was never manufactured, although it shared similarities with designs implemented in the late 1940's and 50's.

The first pressure suit ever manufactured was designed in 1931 by Evgeniy Chertovsky, a Soviet engineer working for the Aviation Medicine Institute in Leningrad. It was designed to protect the crew of Russian High-Altitude balloon experiments, but due to a catastrophic fire on the test balloon in 1935, it was never put to use.

Wiley Post in his full pressure suit.
Credits: US Air Force



Canadian Wilbur Rounding Franks with his "Franks Flying Suit," the first G-suit, with water filled bladders. – Credits: University of Toronto Archives/Jack Marshall Photography

The 1930's are often seen as a Golden Age for aviation, with various parties competing to achieve higher altitudes and faster speed records. Two such gentlemen were the Swiss physicists August Piccard and his associate Charles Knipfer, who on May 27th 1931 became the first human beings to reach the stratosphere using a balloon and pressurized gondola.

Meanwhile, in Massachusetts, USA, another daredevil explorer had his eye on the altitude record. Mark Edward Ridge, who had previous experience in skydiving, had realized that the weight of a pressurized gondola would affect the performance of the balloon, and came to the conclusion that in order to survive at these altitudes he would be better off surrounding himself with pressurized air in a more lightweight and close-fitting form.

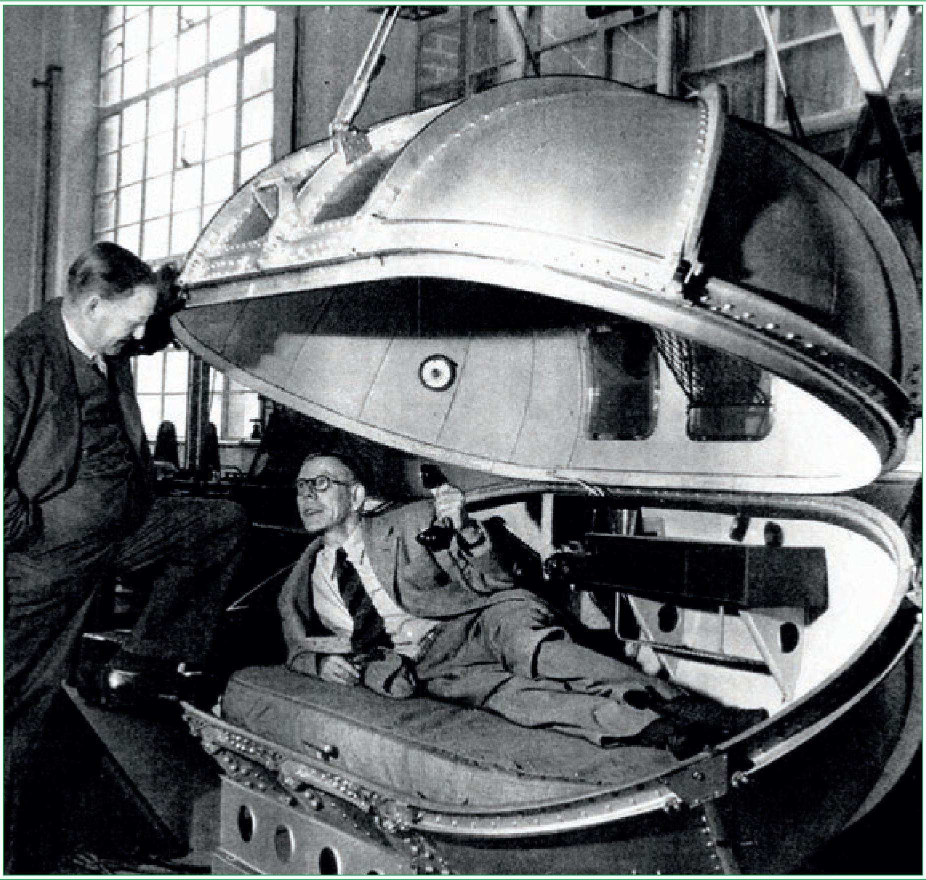
Ridge first turned to the US military for funding, but was refused assistance, so he then approached Dr. John Scott Haldane, a professor at Oxford University, UK. Haldane had previous experience working with pressure chambers as a researcher investigating the effects of decompression sickness in divers. Haldane also had experience of high altitude, as he led an expedition to the summit of Pikes Peak in Colorado, US, to investigate the effects of low pressure at high altitude.

Haldane had previously worked with Sir Robert Davis from Siebe Gorman & Company, an equipment manufacturer for deep sea divers. Ridge and Haldane approached the company with the Ridge design, and SG&C modified one of their diving suits to enable it to offer protection in a low pressure environment. This suit, made from rubber and canvas, was the first full pressure suit in history.

The first aviation pressure suits were modified versions of sub-aquatic equipment

The Ridge pressure suit was never tested in flight, but on November 16th 1933, Ridge became the first person to test a suit in an altitude chamber.

The honour of first flight in a pressure suit goes to an aviator by the name of Wiley Post. Post had already won several flight endurance awards and had realized that he could fly a lot faster at higher altitude, due to decreased air resistance. This reduced air resistance also meant that the piston engines of the time could not breathe enough oxygen to sustain combustion. This situation changed with the advent of the supercharger and other forced air induction systems. On August 30th 1934, Post became the first person to test an operational pressure suit in flight.



Winston Churchill's Personal Pressure Chamber was fitted to his personal aircraft, maintaining pressure at an equivalent of 1524m which enabled the ailing Prime Minister to travel above 2438m. – Credits: LIFE Magazine

During the remainder of the 1930's, several countries were developing their own suit designs in parallel, with a variety of different results. The German company Drager was working on hard-shelled full-pressure suits, but the lack of mobility provided by the metal suit rendered it useless for aviation. The lack of mobility caused by the pressurized suits ballooning was a design challenge that engineers would attempt to overcome for decades after.

World War II and G-suits.

One name that resonates through the history of aero medicine is that of Harry Armstrong, a physician in the US Air Force who investigated formation of gas bubbles in the blood and the necessity for prebreathing, examined toxic hazards in aircraft, and defined the point in the atmosphere known as Armstrong's Line: the altitude at which unconfined water on the human body would boil at body temperature.

As first observed during WWI, pilots

In 1934 Wiley Post became the first person to test a pressure suit in flight

were suffering from effects of blood pooling in the legs and from organ shifts inside the abdominal cavities. Armstrong discovered that by applying pressure at the extremities and at the chest that these effects could be prevented. There were several different concepts being tested at the time, all of which required a pressurized fluid contained within bladders positioned within the suit. The Canadians opted for water filled bladders, and the Australians, British, and Americans opted for pneumatic systems. Some systems required hand pumping for pressurization, while others used compressed air of the engine superchargers. It was during this period that the legendary David Clark

US Air Force pilot being equipped with air-bladder type anti-G suit. – Credits: US Air Force

company entered into the pressure suit business with the "T-1 model," and they have remained at the forefront of pressure suit design ever since.

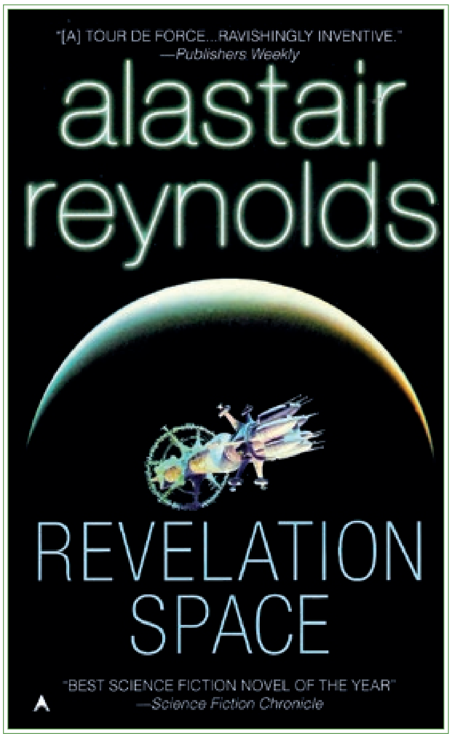
At the end of the war, a new paradigm was about to emerge. With the invention of the jet engine by Frank Whittle and with developments in rocketry by the Germans, human endurance was about to be pushed to new extremes, never before experienced. The seeds of the Space Age had been sown, and the pressure suit manufacturers would be forced to change with the times.

To be continued in Part 2: The Jet Age, The Cold War, Apollo, and beyond.

The "Tomato Worm," one of the few full-pressure suits developed during WWII for US Air Force pilots. – Credits: US Air Force

By Andrea Gini

Looking Far Into the Future Interview with Alastair Reynolds



Revelation Space was Reynolds' first commercial success. According to the author, part of its success was due to the strength of the cover. – Credits: Ace

Science fiction has always allowed us "to peak" into a potential future, to reflect how it could be. Many science fiction authors have made significant contributions to science, like Arthur Clark who conceived using geostationary satellites to provide global telecommunication long before it was possible, or Isaac Asimov whose three laws of robotics are seriously considered in today's developments in the field of Artificial Intelligence.

Alastair Reynolds is a British science fiction author famous for his five part space opera "Revelation Space," published between 2000 and 2007, and for his newly inaugurated 2012 trilogy "Poseidon's Children," opening with the novel "Blue Remembered Earth." Space Safety Magazine sat down with Reynolds to discuss the possible role of space safety in the future of human space exploration.

From Science to Science Fiction

Reynolds' fascination with science dates back to his childhood, when Mr. Spock and Doctor Who were his role models of scientists. When he was 17 he saw Cosmos, a famous TV series by Carl Sagan: "That was when I realized that I was going to become scientist." He then worked hard at school to get the qualifications to go to university. After he got his degree in physics and astronomy at Newcastle University, he moved to Scotland where he got a PhD in optical observation of binary stars. "I didn't really have a clue of what I was going to do afterwards," he recalls. He applied to the European Space Research and Technology Center (ESTEC) in the Netherlands, where he got his first job in 1991.

"In parallel with that, I was writing science fiction in my spare time," says Reynolds. After taking a postdoc at Utrecht University, he came back to ESTEC as a contractor. In 2000, Reynolds published "Revelation Space," his first breakthrough. "My book just came at the right time: it was included on a list of the '100 most influential science fiction novels since 1945', it had a cover that worked really well… and they liked it! In 12 years, it sold well over 100,000 copies. "

With a contract for a book a year to honor, he was struggling to keep up with his daytime job. In 2004, Reynolds resigned from his job in ESTEC to become a full time writer.

Respect for Science

The stuff that I most like writing is far future science fiction, where there is respect for scientific principles," says Reynolds. "It doesn't have magic in it, like wizards, reincarnation, or 'the force': it's all about nature as we understand it, what it will do to us, and what

"Science fiction can give us an idea that the future may actually be worth living"

are we going to be like as species or individuals."

Despite his solid space engineering background, Reynolds prefers leaving science in the background. "For me it has to be about the characters and human situations to grab the readers," he says. Creating characters is an organic process: "There are things about them that I won't really 'discover' until the process itself brings the character to life." He perfected the process over time: "I cringe at some things in my early novels: 'Why did I write that? What was I thinking?'" Reynolds concludes that in a novel you can get many things wrong, "but if you get the character right, the readers will forgive you anything."

For Reynolds, research is a continuous process of reading scientific articles, books, magazines, and just letting them soak in. "I don't do any ▸▸

Carl Sagan, one of Reynold's earliest role models. – Credits: NASA/Cosmos Studios conscious research for a particular book," he explains. "When I need to pull out some facts, I know where to look. To me research is just living life."

A Future Worth Living

Some of Reynolds' earlier works were characterized by a dystopian view of the future. "I have grown bored with that, and I started thinking I would rather like something more utopian, optimistic and forward thinking," he says, adding that his turning point was the approach of the 40th anniversary of the Moon landing. "[In 2008] suddenly people were remembering what has been achieved," he recalls. Besides the technological achievements, Apollo brought "a sense of optimism in terms of where we could go in the solar system, and more general optimism about scientific progress, technological progress, and the future."

According to Reynolds, one of the roles of science fiction is to give hope and inspiration: "It can give us an idea that the future may actually be worth living," he explains. He describes himself as a "natural optimist," who thinks that the human race has the means, the intellect, and the wisdom to overcome the worst of problems. "I think we will become more intelligent about the way we manage the climate, the way we manage energy sources, to improve the civilization without consuming every last drop of carbon in the planet."

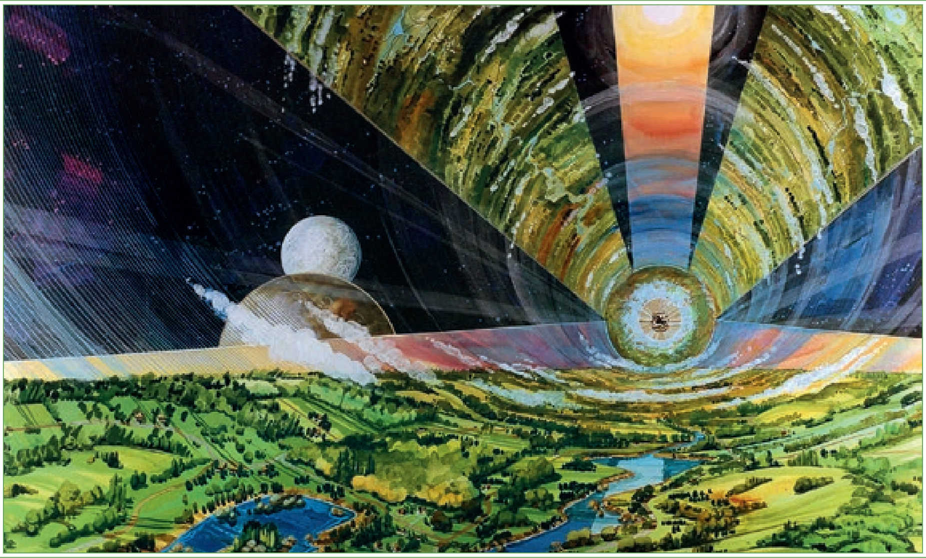
With this premise, he started to work on a new trilogy. In the first book of the series, "Blue Remembered Earth," he envisioned a 22nd century where Africa is the main economic power and leader in the exploration of the Solar System. "My story begins with a wealthy African family. Their grandmother was an important figure in space exploration in the 21st century. She was one of the first people to land on Mars, but she didn't stop there: she went all over the solar system, planting flags and also developing technology, like a ballistic catapult, that can be used to launch things to orbit from Africa rather than using the [old world's] space elevator."

> "The whole idea that spaceflight can be made risk free to me is a non-starter"

"The book is about generational conflicts within this family in terms of a secret left by this old lady," he says. The lady dies in a space station leaving behind a cryptic message that could have a significant impact on the history of this future society.

The universe described is as realistic as possible: "The space elevator is allowed, because it's plausible technology, as well as ion drive and even fusion. They don't have infinite energy capability; they have a commercial space line going between Earth and Mars, but it still takes from 3 to 6 weeks to get to Mars."

Artist's conception of the Space Elevator, one of the "plausible technologies" used by Reynolds in his works. – Credits: Pat Rawlings / NASA



A space colony like the ones envisioned by Gerard K. O'Neil and popularized by science fiction writer Arthur C. Clarke in "Rendezvous with Rama" may one day allow humans to permanently colonize the Solar System. – Credits: Rick Guidice, NASA Ames Research Center

The Risk of Safety

The society described in the trilogy is a very safe one. "By that time every object has become networked. People are directly networked through implants. The system knows where everyone is all the times, so you can't really have an accident, because of this pervasive, infinitely quick and flexible monitoring system. I think it's almost inevitable."

The control is distributed, so the Government decides what level of control it hands over. "If you are going to have an accident, the system will detect the likelihood of that accident ahead of time, and try to prevent that from happening. If it can't, it will immediately mobilize medical assistance." There is very little violence, because the system is tracking people over time and weapons are forbidden.

How would a society grown inside such a sanitized world cope with spaceflight, which holds inherent risks? "By the time the book is set, 2162 AD, routine spaceflight is as risk free now as air travel in the present day," says Reynolds. "Even travel across the solar system is essentially risk free."

But as they approach the margins of the solar system, explorers start once again to face authentic risk. "In the next book I will try to get into the psychology of this population, going from extreme situations of zero-risk to a position where you can actually die." This will create a different view about how to run a society: "A group of people thinks that the elimination of risk is actually a bad thing because it creates a sense of complacency, it makes people very lazy and dependent on machine systems, so they get rid of all that and accept risk as a sort of balance."

Nowadays, the acceptance of risk in contemporary human spaceflight is a recurring topic of discussion. "If we want to do anything interesting in the next 50 years, we must accept the high degree of personal risk," says Reynolds, adding that most astronauts in the Shuttle era said they would accept a higher level of risk just to do something significant in space. "Look at the risks that were accepted by the Apollo astronauts," he explains. "The total 'all-up' Apollo system was virtually untested when they went to the Moon. There had only been a handful of tests for the whole system in one piece, they kept changing things between missions. The astronauts were prepared to go to the Moon knowing that their return was dependent on a single point of failure. The whole idea that spaceflight can be made risk free to me is a non-starter."

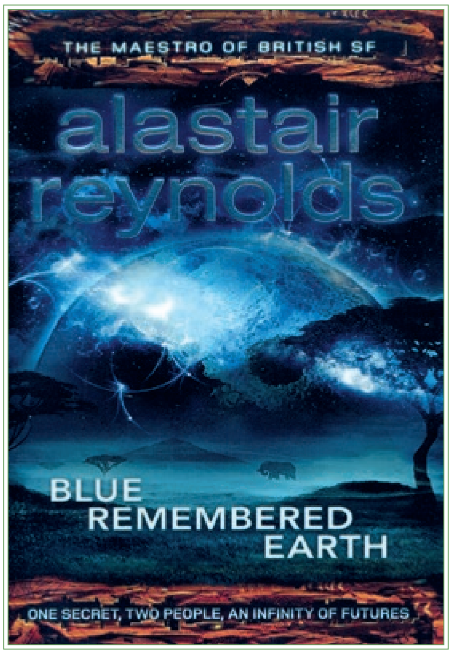
When does the Future Start?

According to Reynolds, going back to the Moon would be the necessary starting point for future exploration. "We barely learned how to survive on the Moon," he says. "[Astronauts] were having problems with contamination of lunar dust. Who knows what it would take to design, say, a lunar space suit that could function over and over again? That would be a significant technical challenge, and I think that would be worth doing. And I think the Moon is far enough away that you are isolated, but you are not completely beyond the possibility of rescue if all goes wrong."

> "I would really like to go to Mars, but definitely with a return ticket"

"I would like to see human presence on Mars, but it has always been 30 years in the future since I was a kid, and we don't seem to get any closer to it. I am also excited by things like asteroid or Venus flybys that could be done with a modest extension of current technology."

Some are seriously discussing one way trips to Mars. "That would be my personal definition of hell: you would never feel the wind over your face again, you'll never see a blue sky, you'll never hear bird songs again... I would really like to go to Mars, but definitely with a return ticket."



Blue Remembered Earth, the latest novel from Reynolds, is the first book of a trilogy. Credits: Victor Gollancz Ltd.

Dreamliner Battery Woes Have ISS Implications

On January 16, the US Federal Aviation Administration (FAA) grounded all Boeing 787 Dreamliner airplanes pending investigation into the safety of its batteries. The move came after a series of incidents in which the Dreamliner's Lithium ion battery packs instigated fire-related hazards aboard the luxury jet.

The ISS is slated to use Lithium ion batteries from the same manufacturer as Boeing's Dreamliner. "Although the cells are made by the same manufacturer who made the batteries for the Dreamliner, they are of different capacity and construction," says NASA Johnson's Battery Group Lead for Safety and Advanced Technology Dr. Judith Jeevarajan. "A very strong technical team will be looking into" the Dreamliner issues, she says.

Source: Merryl Azriel

Read the full story:
http://bit.ly/DreamlinerBattery

Breeze-M Explosion Leaves Debris Legacy

Left tumbling for two months after a launch failure, a Proton Breeze-M exploded on October 16th, creating a new debris cloud in a 264km x 1512km at 49.9° inclination elliptical orbit. The incident followed a prior August 6th shutdown of another Proton Breeze-M stage shortly after the start of the third of its four planned maneuvers resulted in the loss of the two spacecraft it was carrying, Telkom 3 and Express MD2.

The explosion occurred at perigee for the Breeze-M rocket body, which was still carrying a tank full of fuel. It is likely that the breakup was due to atmospheric heating. Debris were initially crossing the International Space Station orbit at almost right angles in its 50.2° inclination orbit. The intersection of the two orbits occurs where debris are at about the same altitude as the ISS (405- 425km), thus creating a serious potential threat.

Source: Guillaume Houdu

Read the full story:
http://bit.ly/BreezeMExplodes

The Russian Proton-M upper stage has been troubled by a rash of failures in recent months. – Credits: Roscomos

NASA and Roscosmos Agree to Year-long ISS Mission

NASA, the Russian Federal Space Agency (Roscosmos), and their international partners have selected two veteran spacefarers for a one-year mission aboard the International Space Station in 2015. This mission will include collecting scientific data important to future human exploration of our solar system. NASA has selected Scott Kelly and Roscosmos has chosen Mikhail Kornienko.

Kelly and Kornienko will launch aboard a Russian Soyuz spacecraft from the Baikonur Cosmodrome in Kazakhstan in spring 2015 and will land in Kazakhstan in spring 2016. The goal of their yearlong expedition aboard the orbiting laboratory is to understand better how the human body reacts and adapts to the harsh environment of space. Data from the 12-month expedition will help inform current assessments of crew performance and health and will validate and determine better countermeasures to reduce the risks associated with future exploration.

Source: NASA

Read the full story:
http://bit.ly/YearOnISS

The first commercial resupply mission took place when the SpaceX capsule Dragon was captured by the ISS Canadarm2 on October 10. - Credits: NASA

First Commercial Resupply Mission Complete, Leaves Anomaly Investigations

SpaceX's first cargo delivery to the International Space Station (ISS) in October was troubled by several anomalies. The rocket's computer shut down one of the first stage's Merlin 1C engines 79 seconds into the flight following a sudden loss in pressure in the combustion chamber. While berthed to the ISS, one of Dragon's three flight computers failed, possibly following a radiation hit. Radiation may have also been the cause of anomalies on one of three GPS units, the Propulsion and Trunk computers and Ethernet switch; all units recovered after been reset.

The Dragon capsule suffered problems with one of the Draco thrusters during reentry. It also suffered a loss of all three coolant pumps after splashdown, a failure that affected the Glacier freezer used to return scientific samples, like urine and blood, from the ISS. The temperature rose from -95°C up to -65°C, exceeding the temperature limits for some sample.

Source: Andrea Gini

Read the full story:
http://bit.ly/Falcon9Anomaly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