INTERNATIONAL ASSOCIATION
FOR THE ADVANCEMENT OF
SPACE SAFETY

ISSF
INTERNATIONAL SPACE
SAFETY FOUNDATION

Space Safety Magazine©

Issue 5
Fall 2012

ISSF SPECIAL
The Case for Support

SPECIAL REPORT
Life Sciences in Microgravity

Falling Free from the Edge of Space

Commercial Human Spaceflight Safety in the 21st Century

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Cover pictures:
Sunita Williams, the woman who has logged the most EVA time "touching" the sun on her most recent spacewalk - Credits: NASA
Central Region of the Milky Way - Credits: NASA, ESA, SSC, CXC, and STScI

The International Space Safety Foundation Advisory Council

Dear Reader,

The International Space Safety Foundation (ISSF) is a recently established US based non-profit organization dedicated to furthering international cooperation and scientific progress in the field of space safety. The final aim of the Foundation is to pursue the advancement of space safety on a worldwide scale and to contribute to making space missions, vehicles, stations, extra-terrestrial habitats, equipment, and payloads safer for the general public, ground personnel, astronauts, and space travellers. Concurrently, the Foundation is seeking to promote measures for a sustainable orbital environment aimed to protect the integrity of space-based safety critical services, such as global navigation systems.


The BP Deepwater Horizon oil rig ablaze. - Credits: U.S. Coast Guard

As you know, we learn from failure not from success.

At 9:45 pm on 20 April 2010, during the final phases of drilling an exploratory well in the Gulf of Mexico, a geyser of seawater erupted onto the drilling oil-rig *Deepwater Horizon*, shooting 73 meters into the air. An eruption of a slushy combination of mud, methane gas, and water followed. The slushy material quickly transitioned into a stream of gas which then ignited into a series of explosions followed by a firestorm. After burning for approximately 36 hours, the oil-rig sank 1,500m below the level of the water. In the process, eleven people lost their lives, while a gigantic oil spill spawned an environmental disaster of epic proportion.

The findings of the Presidential Commission investigating the Deepwater Horizon disaster bear striking resemblances to those of the Shuttle Challenger and Columbia accidents, or more recently of the Fukushima nuclear power plant disaster. A disaster investigation typically addresses proposals for new regulations, to little effect if the underlying problem is a lack of critical thinking by industry. In this case however, the Presidential Commission on the Deepwater Horizon disaster made a truly visionary recommendation: *"The gas and oil industry must move towards developing a notion of safety as a collective responsibility. Industry should establish a 'Safety Institute' […] an-industry created, self-policing entity aimed at developing, adopting, and enforcing standards of excellence to ensure continuous improvement in safety and operational integrity offshore".*

Industry should stop thinking of safety as a matter for governments only and start looking seriously into self-regulation. This idea, which may sound revolutionary, is in fact the way maritime business has been operating for 350 years through the so-called Classification Societies (e.g. Lloyd's Register.)

Today's dynamic high-tech industry cannot be regulated any longer by static safety codes. Government should concentrate on identifying safety objectives and policies, leaving it to industry to find the most appropriate design and operational solutions. **The task of certification must be placed on industrial technical teams as excellent and competent as - although independent from - their design team counterparts.**

Promotion of serious self-regulation by the commercial spaceflight industry for both manned and unmanned operations is one of the centrepieces of the cooperation between the ISSF and the International Association for the Advancement of Space Safety (IAASS), which together aim to establish the International Institute for Space Safety (IISS).

The ISSF Advisory Council is the think-tank working on developing the safety institute. The Advisory Council, set up in early 2012, is currently focused on developing the ISSF research program, which is intended to sponsor general studies in support of global risk management, conceptual studies on innovative systems, development of dedicated equipment, as well as performance of detailed studies on specific topics. Particular attention has been devoted to space systems interoperability. ISSF is also active in communicating information to consolidate the safety culture, promoting at the same time the development of safe commercial spaceflight. Special attention has been focused on promoting the development of undergraduate and graduate educational programs.

The ISSF Advisory Council will support the so-called "ICAO for Space" initiative, a potential "Copernican revolution" in international civil space organization built around the common objectives of safety and sustainability by extending up to Medium or Geosynchronous Earth orbit the mandate of the UN International Civil Aviation Organization (ICAO) in order to regulate, for example, safety of GNSS services.

As Einstein noted some decades ago, *"The significant problems we have cannot be solved at the same level of thinking with which we created them."*

Best regards,

Simonetta di Pippo
ISSF Advisory Council Chair

Neil Armstrong and Sally Ride: Their Safety Legacy

By Merryl Azriel

This summer, two icons of spaceflight died: Neil Armstrong, the first man to set foot on the Moon, and Sally Ride, the first American woman in space and the first person to snag an orbiting satellite using a robotic arm. Among the less celebrated achievements of these remarkable individuals is their contribution to space safety. Armstrong and Ride were the only astronauts to serve on the presidential commission that investigated the explosion of the Space Shuttle Challenger on January 28, 1986. Armstrong was vice chairman of the proceedings and co-wrote its final report. This was Armstrong's second experience on an accident review board; he served as the only astronaut on the 1970 NASA investigation into the explosion of an oxygen tank aboard Apollo 13. With no casualties, Apollo 13 did not receive an independent investigation, although there were clear cultural as well as technological contributors to the incident.

The participation of two individuals who could themselves have been affected by a similar accident was a poignant reminder to everyone involved of what was at stake. "The two astronauts on the commission were terribly concerned about the lack of sensitivity at the Marshall Space Center to the risk," David Acheson, who was the commission's other report author, recently told the Daily Beast. "It was the shock of the two astronauts on the commission that really made us focus on the extraordinary obtuseness of the Marshall Space Center." At the time, Armstrong was already retired from the corps and had left NASA for business pursuits, but Ride was still an active astronaut. In a May 1986 interview she famously reported that neither she nor most other astronauts in the corps were willing to fly aboard the shuttle given their new-found insights into its manufacture. "I think that there are very few astronauts who are ready to fly again now," Ride told ABC at the time. By October, however, she appeared satisfied that appropriate steps were being taken and headlines across the country read *Sally Ride Willing to Fly Again*. "I think NASA has done a real good job studying the solid rockets, studying the redesigns and doing the testing that would be necessary to get the space program back," she told NBC's Today program.

> "The problem is, people forget"

Ride went on to be the only member to serve on both the Challenger and the Columbia commissions. As she memorably put it in a 2003 New York Times interview: "The problem is, people forget." The Columbia commission identified many of the same cultural problems at NASA as were found following the Challenger accident. Ride particularly criticized the attitude of managers in demanding proof of a risk before allocating resources to investigate it. The "Faster, Better, Cheaper" philosophy which had been introduced under NASA administrator Dan Goldin in the 1990's also came under her fire: "With human space flight, you'd better add the word 'safety' in there too."

When Sally Ride died of pancreatic cancer on July 23, 2012 at age 61 and Neil Armstrong died of complications following heart surgery on August 25, 2012 at age 82, in addition to their legacies as space pioneers, they left what will hopefully be a lasting impact on space safety. As Ride reminded us in 1986, space is still a risky business. "I think that we may have been misleading people into thinking that this is a routine operation," she said, "that it's just like getting on an airliner and going across the country and that it's that safe. And it's not."

Sally Ride (second from left) examines a solid rocket booster segment with other commission members at the Kennedy Space Center. - Credits: NASA

By Pedro Vaz Teixeira

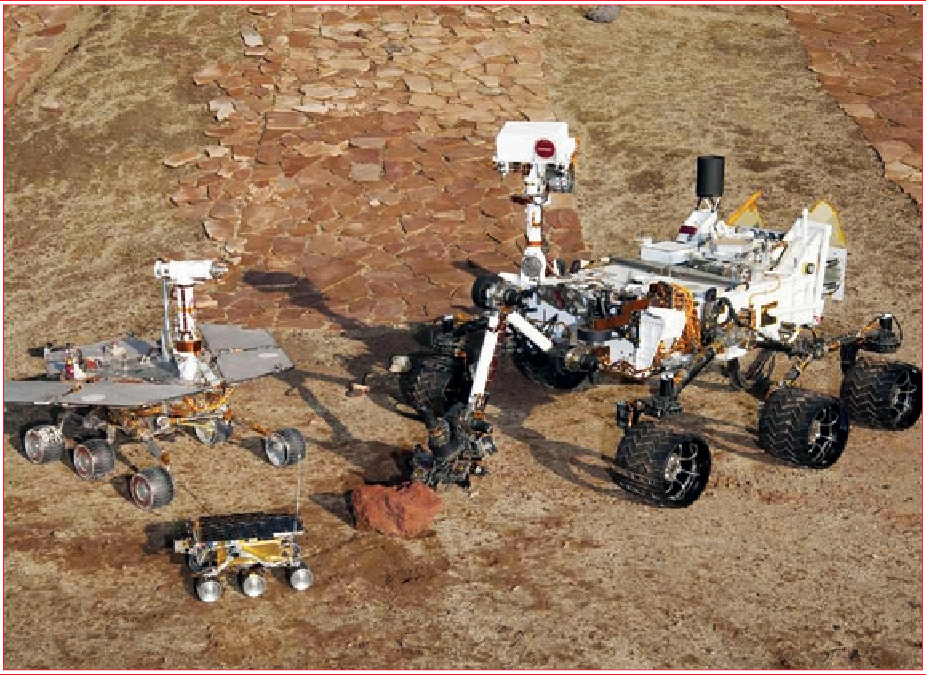
Curiosity: The Path to Success

On the 6th of August, the Mars Science Laboratory (MSL) Rover Curiosity performed a textbook landing on the surface of Mars - an amazing feat of engineering that made the news all around the world. We contacted Rob Manning, Chief Engineer for MSL, at the Jet Propulsion Laboratory (JPL) to find out more about the history behind the mission.

Long before working on MSL, Manning was Chief Engineer for Mars Pathfinder - NASA's first mission to Mars since the twin Viking missions of the 1970s. Whereas the Viking landers resorted to a powered descent to the surface, Pathfinder's lander pioneered the use of a new entry, descent, and landing (EDL) technique wherein a descent stage decelerated an airbag-covered lander to hover a few tens of meters above the surface before dropping it. After bouncing to a halt, the lander deflated the airbags and opened its 'petals', setting free Sojourner, NASA's first rover to the red planet. Sojourner was a pioneer in its own right, testing critical systems such as the rocker-bogie suspension and navigation algorithms, modified versions of which would later be used by Mars Exploration Rovers (MER) Spirit and Opportunity and MSL Curiosity.

> "Imagine a lander with a rover and a rocket lying on top"

After Pathfinder, Manning continued working on a Mars Sample Return (MSR) mission. "We were working on the Mars Sample Return project and I was in charge of a huge lander," Manning recalls. While Pathfinder had validated JPL's new approach to EDL, a sample return mission posed new and significant challenges. "At the time we were having all sorts of difficulties building a lander that can accommodate the very large masses of both the Mars ascent vehicle and a sample rover on the 'roof' of the lander," Manning explains. "Imagine a Viking- or Apollo-like lander with a rover and a rocket lying outside, on top. That was the architecture, and we were struggling on how to make that work."

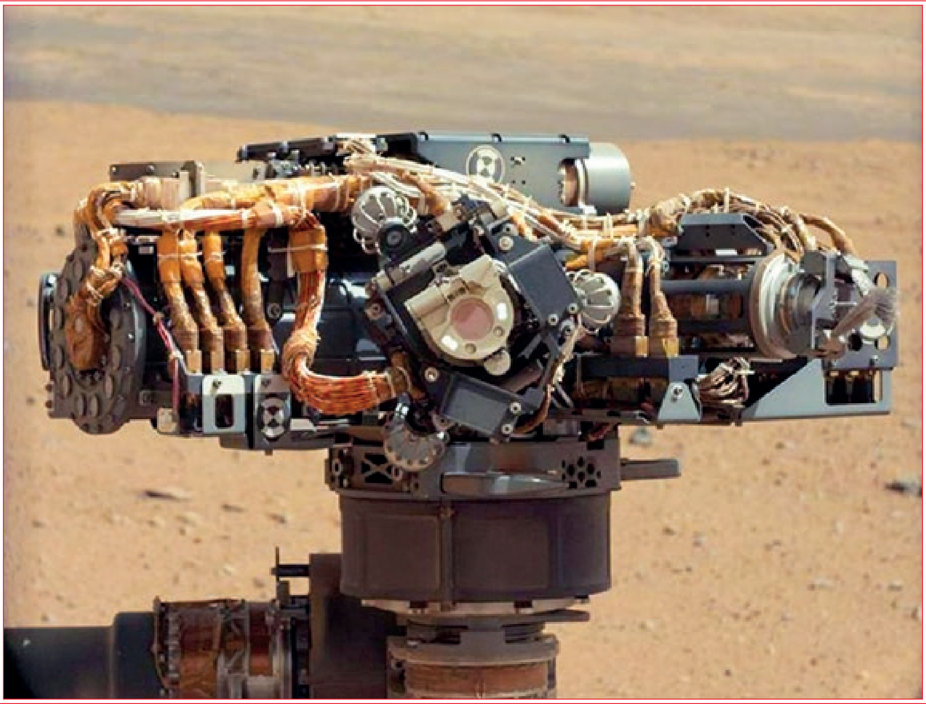


Three generations of Mars rovers: Sojourner (front), MER (left) and Curiosity. The vehicles shown are flight spares and test models for the actual Martian units, photographed in JPL's Mars Yard. - Credits: NASA/JPL-Caltech

A Helicopter Named Sky Crane

The MSR lander project was cancelled following the failure of both the Mars Climate Orbiter and the Mars Polar Lander in 1999. With the funding left from the failed projects, Manning gathered a team of experts to work on new EDL concepts: "Over the course of about two months we came up with a whole family of possible landing architectures for delivering a large rover to the surface of Mars." Among these concepts was the idea of moving from a solid to a more controllable (throttleable) liquid rocket system for the descent stage, allowing a rover to land directly on its wheels thereby making all-around airbags - and the lander itself - unnecessary. Still, this concept was considered to be too difficult with respect to some of the alternatives, and was not pursued further at that time.

After the twin MER probes were launched, Manning decided to resume the liquid rocket based descent stage concept they had come up with three years earlier. MER, like Pathfinder before it, relied on a descent stage that would slow the lander to approximately 0m/s of vertical speed before dropping the airbag-covered lander from a height of around 15 meters. The idea was now to lower a rover directly from the descent stage using a set of bridles. "The technique for lowering it down on the cable just a few meters above the ground [is] called the Sky Crane mode," Manning explains. "Originally it was called the helicopter mode and we changed it to Sky Crane after



The MAHLI imager, just one of the many tools on the Swiss Army knife known as Curiosity. Credits: NASA/JPL-Caltech/MSSS

we studied the Sky Crane helicopters." The helicopter in question - the Sikorsky S-64 "Sky Crane" heavy lift helicopter – has been used successfully since the 1960s for payload transportation and firefighting. The team decided to develop the concept, performing analysis and learning about multi-body dynamics. Soon they were able to use the rockets aboard the descent stage to control the velocities of the payload hanging below. "Everyone agreed at the time that it would be a great way to land if only you could control it safely, if only you can get the velocities under control," Manning recalls. "Well, we did: we landed at 0.75m/s vertically and 4cm/s horizontally...that's the slowest landing ever!"

> "MSL is the engineering equivalent of a Swiss army knife"

The Complexity of Success

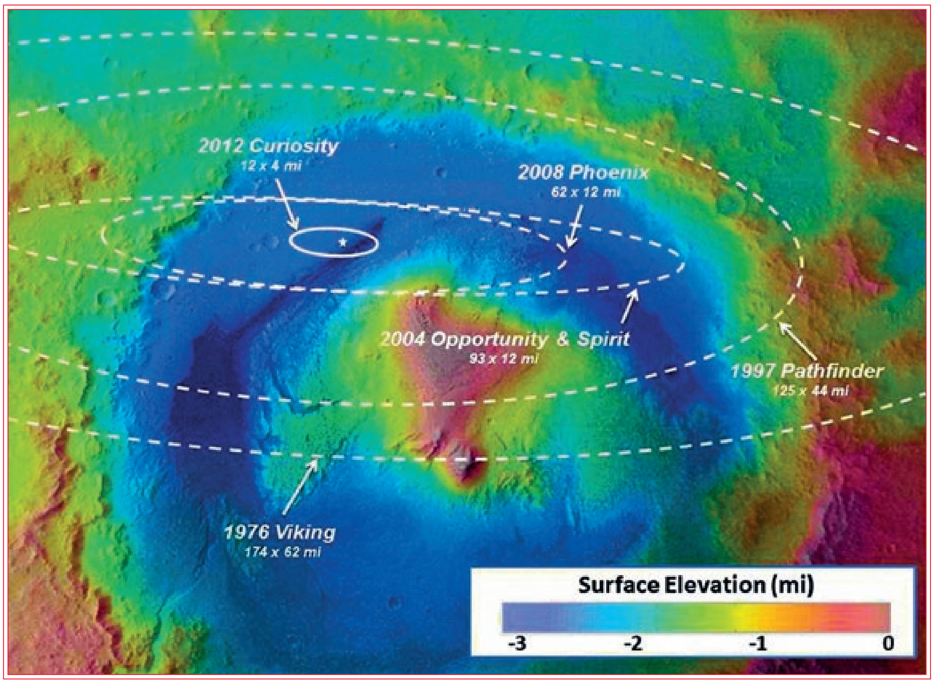
Despite having a solution to one of the most important technical challenges, success was still not guaranteed. From a management perspective, MSL represented a significant break with the past. While both Pathfinder and MER were developed by a relatively small and tightly integrated team, MSL required a different approach.

"Mars Pathfinder was a very tiny project by comparison. It was about one tenth the cost - including launch vehicle and operations - and it was done with a co-located team of people," Manning explains. "The paperwork was very light because the communication pathways between individuals were so tight; nearly everyone worked in one giant room."

With MER, the team once again took a co-located approach, this time having everyone working around the newly built testbed facility at JPL - the Mars Yard. "Our team revolved around our primary test venue, so we built a trailer park around it out of modular mobile offices," Manning recalls, "We all worked just next door to the testbed. I think that really enabled the project to be successful."

When work on MSL began around 2005, planned for a 2009 launch, it was considered one of NASA's 'big projects.' NASA, however, was unable to commit the appropriate level of resources early on due to the parallel efforts of the Phoenix lander and Mars Reconnaissance Orbiter, so the team tried to follow their previously successful approach of a small, co-located team. "The trouble was [the project] was just too big and [we] suffered the consequences by not being able to manage this complexity as well as the cost," recalls Manning.

The 2009 launch window slipped away, leading JPL to attempt a new approach. "What we failed to do with MSL in time was to organize ourselves in a big project manner," he says. "It is just like large corporations. A company is small and can be very efficient, ▸▸



Since the first Mars rover in 1976, landing accuracy of these vehicles has steadily improved. - Credits: NASA/JPL-Caltech/ESA

"Every mission we built has informed the others"

highly effective, very fast on its feet, and that's what everybody wanted this project to be. The trouble is, when projects or companies get very large, in order to manage the complexity you have to compartmentalize your organization into specialities, into discipline areas."

In the end, and as was elegantly shown on August 6th, the team adapted to the needs of a project of this scale, while taking it as an opportunity for organizational learning. "We learned what so many other people do - the challenges of going from a small company to a big company. Had we started off in the big company model, this project might have been easier. I don't think it'd be any less expensive, but it would have been a bit easier to build. But it was a fascinating experience and I think the most amazing thing of all was that the management - and certainly the team members - adapted."

MSL Flight Systems Chief Engineer Rob Manning at a NASA social in August.
Credits: NASA/Bill Ingalls

The Evolution of Planetary Exploration

The challenges of MSL were not limited to the EDL or management: in fact, the rover represents a completely new architecture when compared with previous missions. Unlike Pathfinder, most of the functionality required throughout the entire mission is now controlled by the rover itself. Unlike MER, MSL's ground capabilities are enormously complex. This means that in addition to being "good at launch, cruise, entry descent and landing, which includes being a pilot, a parachutist, and a precision helicopter pilot," the rover also must be "a rolling geo-chemist and an all-terrain vehicle with many, many different skills." Manning draws a comparison between the challenge posed by the new architecture and designing an elegant multi-purpose tool. "It is sort of the engineering equivalent of a Swiss Army knife," he explains. "Swiss Army knives have tools for particular functions. If you add more functionality and all sorts of strange things to it, what it does is it becomes heavy, cumbersome to use, it is not good at any of the things it was good at. Basically, you're overloading functions - you're putting too many functions in one place as opposed to diversifying and specializing." Finding the right balance required considerable effort from the engineers, who eventually managed to come out with a working system. According to Manning, "integration of that many functions into a single hub has turned out to be among one of the most complicated and difficult to manage attributes of this system."

Looking at the evolution of NASA's Mars program, Manning notes: "Pathfinder was a pathfinder for everybody, and we learned from the Viking folks, as well as Apollo. Then Spirit and Opportunity were pathfinders - huge pathfinders - for MSL." Even beyond Mars exploration, JPL's design solutions live on in later missions. "Every mission we have built has informed the others," Manning explains. "There's no doubt that our experiences on Viking and Pathfinder informed Stardust and Genesis. The experience in developing Mars Polar Lander - despite the fact we lost it - also helped inform MER. Even outside of Mars exploration, the Cassini spacecraft was absolutely essential for making Pathfinder a success, and Cassini was architecturally strongly motivated by our lessons from Voyager and then later on Galileo. They're all so highly coupled it is really stunning."

The successful landing of MSL is, of course, only the beginning. The roving laboratory, intended to operate for at least two years, aims to determine whether Mars is - or ever was - capable of harboring life. While doing so, it will also provide valuable information for a future human endeavour to the red planet. "MSL can offer a lot of information, particularly how we learn from the environment from the many instruments on board," Manning concludes. "I believe over time this could revolutionize our understanding of Mars and would really make a big difference in understanding what risks are posed to human beings when they eventually get to the surface of Mars."

By Michael J. Listner

Legal Issues of Space Debris Remediation

Almost 60 years of space activities have left a self-perpetuating debris environment that threatens to render the outer space environment useless, particularly in low-Earth orbit. Space debris ranges in size from infinitesimal fragments to intact satellites, rocket bodies, objects from extravehicular activities, and fragments from exploded rocket bodies and collisions.

Space debris can be addressed through mitigation and remediation. Mitigation includes practices such as limiting the number of objects released during normal operations, reducing long term presence of an object in orbit after end-of-life, and releasing of stored energy through passivation. Measures like these are recommended in the Space Debris Mitigation Guidelines promulgated by the United Nations (UN), which are non-binding upon member states of the UN and implemented as mandatory requirements by a few of the space-faring nations only. Remediation includes methodologies for removal of existing space debris, a topic that is that in its infancy and facing substantial technical, financial, political, and legal hurdles.

Artist's conception of rocket body explosion, an issue that can be prevented through intentional release of stored energy (passivation), one of the mitigation measures recommended by the UN. – Credits: ESA

The Legal Framework

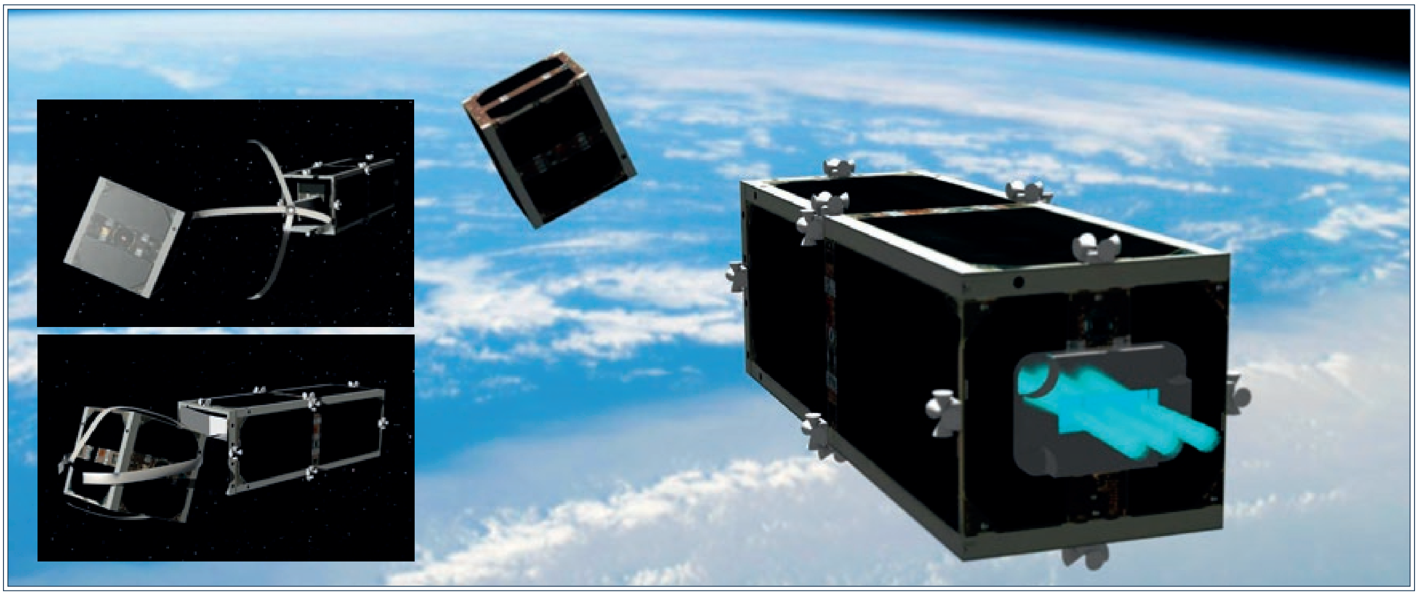
The issue surrounding cleanup of orbital space debris is rooted in Article VIII of the Outer Space Treaty (OST) where space objects, including non-functioning satellites, continue to belong to the country or countries that launched them. There is no right of salvage in space law, so even though a satellite may not be functioning it does not mean that it has legally been abandoned by the launching state. This is further complicated by the fact that international space law deems fragments and components of space objects as individual space objects in and of themselves, thereby requiring identification to determine the owner and either individual or blanket consent to remove such objects from orbit.

Besides ownership, there are licensing and compliance with International Traffic in Arms Regulations (ITAR) issues. Removal methodologies of intact derelict satellites may include the use of mechanisms that rendezvous with, attach to, and physically move a derelict from a stable orbit into either a graveyard orbit where it will not interfere with other space objects or into a less stable orbit, ensuring destructive reentry within a short period of time. Such methodologies require an intimate knowledge of the spacecraft, possibly triggering ITAR in the case of space objects belonging to the United States. ITAR issues could also arise if a derelict satellite registered to the United States is slated for removal by a foreign government, especially if this operation involves exporting spacecraft-related technical data outside the US. Before such exporting and subsequent satellite disposal could take place, licenses or other waivers would be required to address these issues.

> "Removal requires an intimate knowledge of the spacecraft, possibly triggering ITAR"

Disclosure of sufficient technical details regarding a derelict spacecraft could implicate intellectual property, including confidential and proprietary technical information as well as patents. Licensing, confidentiality, and nondisclosure agreements between the owners and former operators of the derelict satellites would have to be negotiated in order to protect the rights of the owners.

The issue of liability is also very relevant. Removal of space debris presents a risk, regardless of whether non-governmental or governmental organizations are performing the activity. Article VI of the OST requires that the country under whose jurisdiction that organization falls retain responsibility for their activities and any accidents incurred during their activities. The Liability Convention takes the issue of liability a step beyond Article VII of the OST, envisioning an event where a space object causes damage someplace other than the surface of the Earth,



Artist's conception of CleanSpace One, a debris removal cubesat mission. – Credits: Swiss Federal Institute for Technology

including outer space or another celestial body, and applies a fault standard which apportions responsibility based on the culpability of the actors involved.

A Definition of Space Debris

Another troublesome issue of space debris is finding a suitable legal definition. The term "space debris" is commonly used to describe both the veritable junkyard of expended space objects in orbit and naturally occurring objects such as asteroids and meteors. There have been proposals in the context of legally binding treaties and liability for space debris, but an acceptable legal definition for space debris is still missing.

While proposed definitions of space debris focus on the current problem of responsibility and liability for damages caused by them, they do not create a solution in terms of remediation. A strictly legal approach in the form of a treaty focused at the UN level has little chance of being implemented any time soon given the competing geopolitical interests of the various nations who make up the UN and the Committee on the Peaceful Uses of Outer Space (COPUOS).

A more practical approach to remediation of space debris is to apply a quasi-legal definition that directly addresses the problem of ownership. As mentioned above, one the primary issues of space debris removal is the absence of salvage rights because of the ownership issues related to Article VIII of the OST. To that end, a quasi-legal definition of space debris taking into account the economic value, historical value, and national security value of a space object would focus the impetus of space debris more on whether a space object should be expressly abandoned and disposed of than on liability.

Provisions of the Liability Convention and the Registration Convention incorporated into to a quasi-legal definition of space debris would bolster current international law and resolve issues of ownership and liability, especially in the context of the definition of "space object," which is similarly defined by both treaties. While there is debate about the definition of "space object" in the context of both treaties, the use of the term and a similar definition in the domestic space laws of some nations makes the case that the term as defined has customary legal precedent.

Historical Precedents and Future of Removal

A final legal hurdle that must be addressed is the legal act of removing space debris, which does not have sufficient precedent. The retrieval of a space object belonging to another nation, however, is not entirely without precedent. In February 1984, the commercial satellite Palapa B2, launched for the Indonesian government on Space Shuttle mission STS-41B, failed to reach geosynchronous orbit due to a malfunction of its perigee motor stage. While it was circling

> "The primary issue of space debris removal is the absence of salvage rights"

the Earth in a useless orbit, the satellite was purchased by Sattel Technologies of California from the insurance group that covered the loss. Sattel subsequently contracted NASA to retrieve the satellite, which it did in 1984. The satellite, renamed Palapa B2-R, was successfully re-launched in April 1990. After the relaunch, title of the satellite was transferred back to Indonesia.

To cement the debris removal concept in the current legal and policy environment more precedents are needed. The Swiss debris removal proposed mission CleanSpace One, slated to remove a Swiss cubesat for this very reason, may in the future provide the precedent to cement a customary rule allowing a nation to perform active removal of both their own and other nation's space debris, creating a legal and policy impact similar to those of Sputnik-1 on the issue of free access and navigation of outer space.

The issue of space debris removal is an unconventional one, still in its infancy, with unprecedented legal and policy implications. The solution will likewise require a clear legal definition of the problem, and will require unconventional means to achieve it.

By Andrea Gini

Falling Free from the Edge of Space

On August 16, 1960, US Air Force Captain Joseph William Kittinger left the safety of the ground for a historic flight, under the insignia of Project Excelsior. Seated inside an open gondola attached to a stratospheric balloon, he floated up to the stratosphere protected only by his pressurized suit.

In spite of a pressure suit malfunction, which might have cost him his life, he decided to proceed to an altitude of 31,333m – 20km higher than commonly flown by commercial airplanes – where he jumped from what was called "the highest step in the world." In a 4 minute and 36 second free fall, facilitated by a small stabilization drogue parachute, Kittinger reached the incredible speed of 988km/h and experienced temperatures as low as -70°C. At an altitude of 5,330m he opened his main parachute and proceeded to a safe landing in the New Mexico desert.

Captain Kittinger's undertaking – which preceded Gagarin's space flight by almost a year – set two remarkable records: highest parachute jump and fastest speed reached by a human being in the atmosphere outside a plane. To date, neither one of these two records have been surpassed.

Project Red Bull Stratos is a mission that aims to break both records at once. Captained by Felix Baumgartner – skydiver and BASE jumper renowned for the groundbreaking nature of his undertakings – Project Stratos is endorsed by Joseph Kittinger himself, who joined the team as Primary Advisor, Flight and Safety Operations, and Capcom.

Joe Kittinger preparing for his record-breaking mission. The plaque at the bottom reads: "This is the highest step in the world." - Credits: US Air Force

Bailing Out Through the Sound Barrier

Developed over more than five years by a team of scientists and engineers, as well as by physicians led by Dr. Jonathan Clark, Space Medicine Advisor to the National Space Biomedical Research Institute, Project Red Bull Stratos is not a stunt; it is a scientific study aimed at collecting data on human body performance during a descent from high altitude. Space Safety Magazine contacted Clark to get some insight into the scientific research behind the project.

Clark, who joined the team back in 2009, leads a medical team made up of all volunteers, which includes six physicians, an aerospace physiologist, a paramedic, and a critical care respiratory therapist. Their job is to deal with any of the life-threatening contingencies that could possibly happen during the mission. "I had been interested in spacecraft escape, and this project was something I was born to be a part of," says Clark. "I had qualified as a high-altitude military freefall parachutist and sports parachutist with over 300 parachute jumps. My experience with the survival lessons learned from the Columbia and other spacecraft mishaps has allowed me to ensure the highest commitment to safety for this project."

> "Project Red Bull Stratos is not a stunt; it is a scientific study"

The mission will take place in the upper stratosphere, from an altitude of about 36,576 meters, with a pressure of about 0.063 psi, and a -57°C temperature, environmental conditions that require a special suit. "The suits Joe Kittinger and Felix Baumgartner use are called escape suits," Clark explains. "Joe wore the David Clark MC3 partial pressure suit, which was state of the art in aircrew protection in the late 1950s to early 1960s. Felix wears the David Clark modified S1034 full pressure suit, with enhanced mobility."

Flying free with no stabilizer drogue chute, Baumgartner is expected to go supersonic 35 seconds into his fall, becoming the first man to break the

Felix Baumgartner before his 21,800 meter jump at the first manned test flight in Roswell, New Mexico, USA on March 15, 2012. - Credits: Jay Nemeth, Red Bull Content Pool

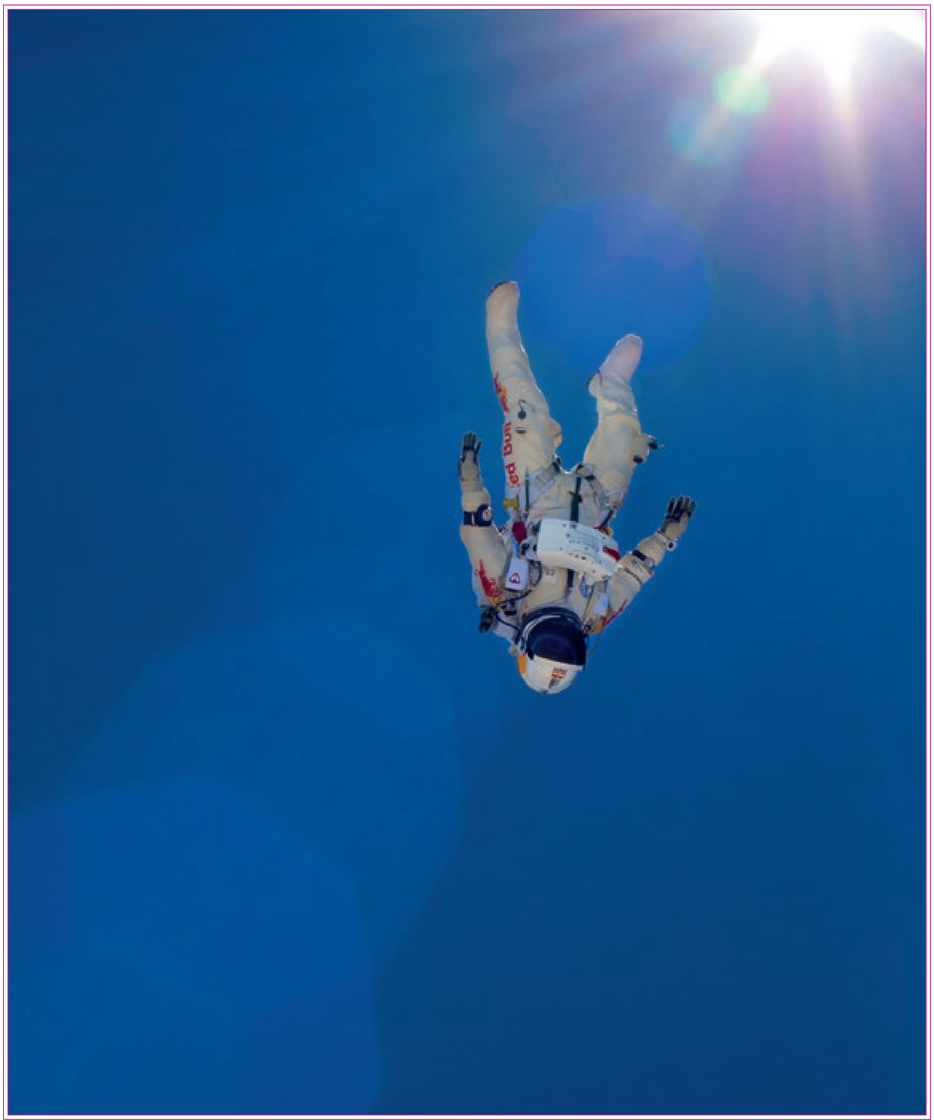
> "A driver for Felix's suit was mobility, which is also a driver for EVA suits"

sound barrier in the atmosphere outside of an aircraft. After a 5 minute and 35 second free fall, he will open his rectangular ram-air parachute, hopefully to land safely shortly after.

Pushing the Envelope

Current jet ejection seats are considered safe within a speed of Mach 3 and an altitude of 30,000m – the safe ejection envelope. The reasons for such limits come down to problems that the human body experiences at such speed and altitude. First, there are problems associated with acceleration. A free falling body tends to tumble, and is subjected to a flat spin; a prolonged spin of 180rpm or higher can cause unconsciousness or death. A small drogue parachute prevents this problem, allowing a free fall with minimal spin. Spinning can also be prevented with aerodynamic devices, such as fins or inflatable ballutes. One of the objectives of Project Stratos is to attempt a high altitude free fall without such devices. Felix Baumgartner hopes to be able to control spin with body position; a supersonic drogue can be triggered manually by Felix, or is triggered automatically if he encounters a spin generating over 3.5g for 6 consecutive seconds.

A second problem associated with acceleration is the reaction of the human body while passing through the transonic region. The shock-shock interaction, which occurs when two shock waves intersect, is a major concern for the Stratos jump. In spacecraft aerodynamics, this phenomenon affects heat transfer rate and pressure on the vehicle's surface. These variables might cause physical injury patterns related to shock wave damage or even breech of the pressurized suit from concussion waves; both problems were considered as major drivers during the equipment development.



Felix Baumgartner freefalling during a high altitude jump in Taft, California, on June 21, 2012. - Credits: Luke Aikins, Red Bull Content Pool

Finally, there are several problems associated with atmospheric pressure. "At 35,500m, atmosphere is about one per cent of the air pressure on the ground," Clark explains. "Above an altitude of 19,202 meters, water as a liquid spontaneously turns to vapor (gas) which results in a life threatening condition called ebullism." Ebullism happens when water turns into gas in a pressure condition below 47mmHg; it causes severe lung damage, but is survivable to a certain extent. "In addition, the risk of hypoxia, barotraumas, and decompression sickness are also a concern," adds Clark. Hypoxia is the sudden interruption of oxygen flow to tissues. Barotrauma is the expansion of gas filled cavities resulting in pulmonary over-inflation, collapsed lungs, and arterial gas embolism within seconds. Decompression sickness happens when nitrogen gas dissolved into tissues come out of solution into bubbles inside the body on depressurization, causing joint pain, paralysis, nervous system damage, and death.

"Escape suits operate in the Extravehicular Activity (EVA) bailout environment, but only in the upper stratosphere (40 km), not space (100 km)," Clark explains. "Escape suits have thermal protection to protect against the extreme cold. They use open loop life support supplied by consumables carried in the ejection seat or crew worn, like in Felix's suit. The life support consumables cover the period from exit to landing, which might be up to 15 minutes."

"I hope that the Red Bull Stratos project will be an inspiration"

The Legacy of Red Bull Stratos

While Project Red Bull Stratos approaches its conclusion, we wonder about possible spin-offs. "We are working with the NASA Crew Escape Office, which still has ACES suits in their inventory," says Clark, referring to the David Clark S1035 Advanced Crew Escape Suit (ACES) worn by Shuttle crew. "Commercial space companies providing crew transfer services to NASA can have access to those suits for contingencies, including stratospheric escape. I've been working separately with one commercial space company evaluating crew escape options, and they are following our progress closely."

"We are also working with the FAA Office of Commercial Spaceflight on crew protection," he adds. "Our physiologic monitoring system has been extensively tested in the David Clark suit, and could be used by NASA or commercial space companies to monitor acceleration loads during reentry and landing as well as other physiologic parameters, like heart and respiratory rate, skin temperature, and ECG. There is a follow-on project to evaluate this further."

There are also possible spin-offs to EVA suits: "A key driver for Felix's suit was mobility, which is also a driver for EVA suits," says Clark. "We worked with the suit manufacturer to get what we needed. During the ascent phase Felix has to sit in a capsule, which is similar to what the U-2 pilots have to do. Felix can adjust the suit for being seated in the capsule or standing/upright during exit and freefall. Thermal protection is also very important. We learned from the first jump from 21,818 meters that Felix's hands got cold, so we are working on enhanced thermal protection, which is also a concern during space walks."

Besides the suit, training is a huge part of the project and essential for mission success. "For every hour an astronaut spends in space doing a spacewalk, they spend 10 hours in training facilities, such as the neutral buoyancy lab," Clark explains. "I estimate that we have spent many more hours for Felix's preparations. He has done eight runs in the vacuum chamber and three runs in the thermal vacuum chamber, six jumps from 8,230 meters in the pressure suit and countless jumps from lower altitude. He has also done many hours in the vertical wind tunnel and six bungee jumps in the suit to practice step-offs. He also has had extensive work with Dr. Andy Walshe, Red Bull High Performance Director, to prepare Felix mentally and physically for the ordeal."

Clark accepted a leading role on the Red Bull Stratos team not only to protect Felix Baumgartner from the effects of high altitude, but also to establish new protocols for the benefit of future aviators and astronauts. "I find amazing that after a half-century of space research, no protocol exists to address ebullism, and I hope to change this. An ebullism prevention and treatment protocol will be an enduring legacy of the Red Bull Stratos mission." On a broader note, Clark makes a final remark: "I hope that the Red Bull Stratos project will be an inspiration to the next generation, those kids who are dreamers, seeing space diving go from science fiction to science fact."

Felix Baumgartner hugs Joe Kittinger right after the 29,610 meter manned test flight in Roswell, New Mexico, USA on July 25, 2012. - Credits: Predrag Vuckovic, Red Bull Content Pool

Dr. Jonathan Clark is an Associate Professor of Neurology and Space Medicine at Baylor College of Medicine. He served in the Navy and NASA as a flight surgeon, and was a Member of the NASA Spacecraft Survival Integrated Investigation Team following the Columbia accident.

SPECIAL REPORT

LIFE SCIENCES IN MICROGRAVITY

Sponsored by

KAYSER ITALIA

MUSCLE ATROPHY IN SPACE

BY ANDREA GINI

The human body has adapted over millions of years to work and operate within the gravity field. The musculoskeletal system is sized to act, jump, grip, grasp, carry loads, move, maintain balance, and use and define all the motor control strategies which are necessary for a safe life on Earth.

The absence of gravity makes working in a spacecraft physically undemanding. In a weightless environment, very little muscle contraction is needed to support the body and move around. Such effortless motion results in weakening of calf muscles, quadriceps and the muscles of the back and neck in a process called atrophy. An astronaut can experience a muscle mass loss as high as 5% a week.

aRED (top) and CHIBIS (bottom). aRED will be used in combination with Kayser Italia's ELITE S2 for the BICE Experiment selected by ESA in ILSRA-2009.
Credits: NASA

Even the heart is affected by atrophy. In space, blood pressure is about 100 mmHg throughout the body, with no differential between head and feet. When bodily fluids redistribute themselves in the new environment, astronauts appear to have swollen faces and thin legs. The lack of blood pressure gradient means less blood is needed, causing the body to excrete about 22% of its blood volume. The heart doesn't need to pump as hard to distribute the blood, therefore it atrophies

If one could remain in space forever, muscle loss would not be a problem, but when crewmembers return to Earth their bodies have to readjust to gravity. Most space adaptations appear to be reversible, but the rebuilding process is not necessarily easy. While blood volume is typically restored within a few days, muscle recovery takes about a month. Bone loss is even more problematic, taking up to three years to recover.

ZERO-G EXERCISE

The only way to minimize muscle atrophy in space is through intensive strength training exercise – up to 2.5 hours a day. But exercising in space is only effective if it entails some gravity-like resistive force. On ISS, this resistance is provided by strapping an astronaut to a treadmill with bungee cords. The straps are not particularly comfortable, so astronauts can only exercise with loads of 60-70% of their body weight. Astronauts can include squats, dead lifts, heel lifts, and various presses and curls in their routines using the Advanced Resistive Exercise Device (aRED), which can provide more than 270kg of resistance.

Even though these machines are partially effective in mitigating the effects of weightlessness on muscles, increasing loads on muscles and bones is not enough without taking care of fluid flows. Chibis aims to do just that. It is a Russian below-the-waist suit that applies suction to the lower body, simulating a gravity-like stress to the body's cardiovascular system. In the days before returning home, cosmonauts perform a preparatory training in the suit consisting of drinking 150-200 milliliters of fluids, followed by a sequence of progressive regimes of negative pressure (from -15 to -30 mmHg) for five minutes each while shifting from foot to foot at 10-12 steps per minute. This protocol induces the body's circulatory system to interpret the pressure differential between upper and lower body as a gravity-like force pulling the blood (and other liquids) down. The exercise prevents much of the loss of cardiovascular function and of muscle, and may also be effective in reducing bone loss.

INVESTIGATING UPPER LIMB ATROPHY

BY ANDREA GINI

The muscles of the upper limbs are also affected by the lack of gravity. The Italian Space Agency, with support from Kayser Italia, is currently promoting a wide program of microgravity experiments on the upper limbs. We contacted Dott. Valfredo Zolesi, president of Kayser Italia and principal investigator of the Hand Posture Analizer (HPA) facility, to know more about the research in this field.

"The upper limbs are the principal means of locomotion for crews living in a space station," explains Zolesi. "Fatigue can have a significant effect on the hands, affecting both on-board activities and EVAs. These are the main reason to study and characterize this phenomenon."

Kayser Italia developed Hand Posture Analyzer (HPA), a facility designed to investigate astronauts' upper limb performance during space missions. "The experiment consists of a Hand Grip Dynamometer (HGD) and a Pinch Force Dynamometer (PFD), which are crew operated tools designed to measure respectively hand grip and pinch force application."

The facility allows the ISS crew to run a protocol called CHIRO ("Crew's Health: Investigation on Reduced Operability"), to "investigate how hand grip control and precision lateral pinch force are influenced by reduced gravity, and to quantify the adaptive normalization during the mission."

Following on-screen instructions, the astronaut is requested to grip the HGD or to pinch the PFD as strongly as possible, exerting the so-called Maximum Voluntary Contraction (MVC), and holding it for a certain interval. The tests alternates between providing on-screen feedback on gripping/pinching strength to the subject and providing no feedback except the subject's own proprioceptive sense..

By conducting pre-flight, in-flight, and post-flight testing, the experiment enables researchers to characterize hand performance before, during, and after an ISS increment. "Over a six month mission, the hand grip MVC tends to decrease about 45%, while the pinch MVC remains stable," explains Zolesi. "There is no adaptation with time, no recovery, and HGD-MVC values decrease continuously in weightless conditions, a serious issue in missions longer than six months."

The HPA also features an instrumented glove that records how the hand reaches for and grasps an object. "The glove has 15 degrees of freedom, allowing the study of the position of single phalanxes," says Zolesi. "This is coupled with an inertial platform on the wrist, which measures motion control strategies during grasping and reaching tasks enabling the study of alteration in cognitive processes."

The experiment measures how the subject reaches for an object, grasps it, and moves it to a position indicated on-screen. "When we reach for an object, our brain evaluates the distance and weight of the object. The arm moves taking into account these evaluations. As soon as the hand approaches the target, the wrist decelerates and adjusts the grip in order to complete the action."

With the lack of gravity, hands experience a disabling effect. "The capability of hand grip is highly influenced by microgravity. This situation resembles the pathology of muscle atrophy or spinal cord injury. In this sense, if Earth is a normal environment for disabled people, Space is a disabling environment for normal people," concludes Zolesi.

The major application of this research is the ergonomics of crew user interfaces, but the same principles can be applied in rehabilitation of subjects on the ground with local trauma or central nervous system disorders. "A subset of the facility has been used in clinic on more than 200 elderly patients, and also to study the progress in Carpal Tunnel and in the Trapezium-Metacarpal Arthrosis."

(1) Zolesi et al, 2001. Hand Posture Analyzer (HPA): a set of portable instruments for upper limb posture analysis on the International Space Station, presented at AIAA Conference & Exhibit on ISS Utilization, Cape Canaveral, 2001.

(2) Zolesi et al, 2004. Short term microgravity effect on isometric hand grip and precision pinch force with visual and proprioceptive feedback, COSPAR.

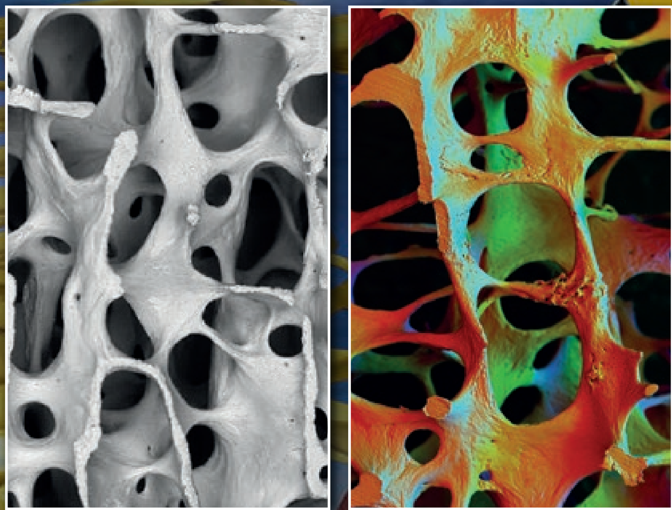
Italian astronaut Roberto Vittori uses the Hand Grip Dynamometer (HGD) of Kayser Italia's Hand Posture Analyzer (HPA). The HGD is a precision tool designed to measure hand grip's Maximum Voluntary Contraction (MVC).
Credits: NASA

MICROGRAVITY BONE LOSS ILLUMINATES OSTEOPOROSIS ORIGINS

BY TEREZA PULTAROVA

Microgravity and aging: what do they have in common? At first sight not much, but under the microscope or through modern analytical methods like quantitative computed tomography, the similarities become striking. Starting with the Gemini and Apollo missions in the 1960s, doctors noticed in post-flight exams that astronauts showed higher calcium levels in their urine and measured decreased mineral density in their bones. Does it ring a bell? Yes: decrease in bone density is a symptom of osteoporosis, a disease that affects more than 50% of the population over 50 years old.

Whereas osteoporosis is primarily caused by hormonal changes accompanying aging, in microgravity induced bone loss the lack of mechanical stimuli of the bones is the main culprit. The underlying mechanisms of the two phenomena on the molecular and cellular level are nevertheless identical. The medical community believes that detailed research enabled by long duration human spaceflight and the possibility of performing in vitro bone cell experiments aboard the International Space Station can shed some light on the origins of a disease responsible for 650,000 fractures each year in the European Union alone.



From left to right, low power scanning electron microscope image of a normal bone architecture in the third lumbar vertebra of a 30 year old woman vs osteoporotic architecture in the fourth lumbar vertebra of an 89 year old woman. The bone is heavily eroded in places by the action of osteoclasts and consists mainly of thin, fragile struts.
Credits: Alan Boyde, a.boyde@qmul.ac.uk

BONE LOSS IN MICROGRAVITY

The human body evolved within an environment of constant Earth gravity. The skeleton and the muscles serve as a powerful motion apparatus that enables us to stand upright and move against the power of gravity. Once gravity is eliminated, we can move effortlessly. Bones and muscles therefore start weakening as there is nothing forcing them to stay strong. Studies have revealed that astronauts lose approximately 1-2% of bone mass for every month they spend in space. Post-flight recovery of the lost mass can exceed twice the time of the flight itself.

Bone is an organic tissue that flexibly responds to external stimuli. During a period of increased exercise bone piles on mass, during decreased activity it weakens. It continuously rebuilds itself through resorption and formation, in a cyclic process known as remodeling. When resorption takes place, the bone calcium is excreted into the blood stream and then to the urine. Bone cells adapt to the variables of mechanical stress, and it is only this stress that makes them perform efficiently.

There are two types of cells responsible for this cycle - the osteoclasts and the osteoblasts. Osteoclasts secrete chemical substances that dissolve calcium and other minerals, degrading the bone. Small pits are created and then filled with osteoblasts that produce new bone material inside the pit by secreting calcium and proteins. The process of remodeling is fastest during puberty. At more advanced ages, bone loss compensation takes a significant amount of time.

In the 1970s, longer spaceflight missions began taking place thanks to the first space stations. At the same time, advancement in analytical technology helped researchers describe the bone loss process in greater detail. From the three Skylab missions of 29, 59, and 84 days, doctors learned how bone density loss is distributed throughout the body, proving that the most severe bone loss takes place in the heel while upper limbs remain almost unaffected.

This phenomenon was later confirmed and examined in greater detail by a study on 15 MIR cosmonauts, which proved that bone loss occurs first at the level of the lumbar spine and increases in the bones of the legs in the downward direction. Even after several months in space, the arms still remained unaffected. These studies also showed that the inner ▶▶

spongy trabecular bone is on average more affected than the outer hard cortical layer.

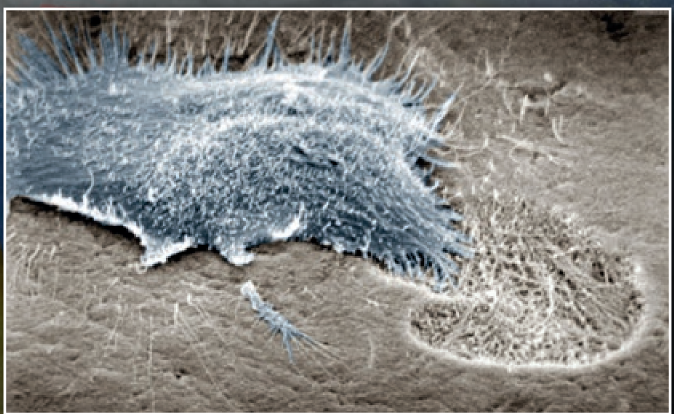
Several theories are trying to explain the reasons behind the uneven bone loss distribution during space flight. One of them assumes that whereas in terrestrial conditions legs are constantly bearing the biggest burden of our body weight, in microgravity astronauts predominantly use their hands and arms as the source of locomotion. Therefore legs become underused and the body doesn't feel the need to maintain their muscles and bones. On the other hand, arms experience a load increase and the body adapts accordingly. The same distribution of weakening applies also to muscles.

A second theory explains this phenomenon as being a consequence of the influence of weightlessness on the fluid distribution within the body. As there is no force pulling liquids towards the feet, fluids shift towards the head, causing redistribution of minerals within the body. The kidneys then react to the above average volume of liquid in the upper body by excreting it as urine. Along with urine, minerals are eliminated as well.

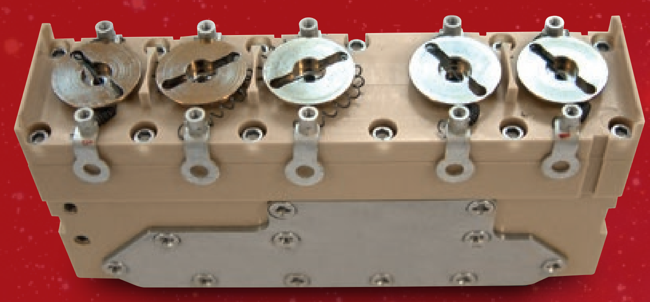
MICROGRAVITY RESEARCH

Recent results have demonstrated that nutrition and sufficiently resistive exercise can noticeably improve astronauts' bone health. Research has shown that boosting vitamin K can help (1), as can use of the bisphosphonate family of osteoporosis drugs that interrupts the remodeling process by preventing mineral resorption. Current ISS study Pro K is investigating whether an increased ratio of consumption of potassium to animal protein can reduce bone mineral losses. The increased resistive capability of ISS' new aRED exercise device is also providing a boost for bone density since it doubled the resistive exercise capability of its predecessor (2).

JAXA's Medaka Osteoclast study, scheduled to launch aboard the SpaceX Dragon this year, will make use of the recently delivered aquatic habitat to study the fresh water fish medaka's bone response to microgravity. Such a study is only possible with the increased potential for transporting samples from ISS offered by Dragon, since the fish will be evaluated Earth-side for changes in gene expression.



Scanning electron micrograph showing osteoclast resorbing bone.
Credits: Prof. Tim Arnett, University College London



Kayser Italia's Stroma Experimental Unit, designed to study the bone marrow stromal cell differentiation and mesenchymal tissue reconstruction in microgravity through a fully automated protocol of BMSC cell activation, incubation and growth on a solid support, and fixation. The STROMA EU, which hosted five experiments since 2003, can host different supports allowing cultures such as BMSC, osteoclasts and umbilical vein endothelial cells.
Credits: Kayser Italia

Another route to understanding microgravity's impact on bone is to examine cellular level mechanisms in *in vitro* studies. The primary targets for *in vitro* work are osteoclasts that are responsible for breaking down existing bone, osteoblasts that produce new bone, and bone marrow mesenchymal stem cells that produce both osteoblasts and osteoclasts. Current studies focus on whether microgravity causes these cells to respond differently on a molecular level than their Earth-bound relatives.

Although this may lend insight into space-based bone loss, there is an alternative school of thought that hypothesizes space is a better analog for cellular development than ground based cell cultures due to the fact that *in vivo* cells enjoy a buoyant growth environment in the body due to supporting bodily fluids that nearly mimic zero-gravity effects (3). This buoyancy allows cells to grow in a three dimensional matrix. Lab based cultures, however, can only grow in two dimensions.

Much of the culture research in space has looked at equipment such as Kayser Italia's Stroma and Oclast Experimental Units (see box), supporting cell activation, incubation and three dimensional growth, and fixation in a self-servicing, fully automated environment.

(1) Vico, L. and C. Alexandre. 2012. Zero Gravity: Bad to the Bones, Scientific American and ESA, Looking Up, 2008

(2) Smith, et al, 2012. Benefits for bone from resistance exercise and nutrition in long-duration spaceflight: Evidence from biochemistry and densitometry. JBMR, 27(9).

(3) Uhran, M.L. 2011. Positioning the International Space Station for the Utilization era. AIAA, Inc.

RADIATION PROTECTION ON LONG DURATION SPACEFLIGHT

BY ROBERTO BATTISTON

Human exploration of space is among the most ambitious goals of mankind. This ambition, however, is not supported by our evolutionary DNA code.

Space, unfortunately, is a very hostile environment for man. Long duration missions to low Earth orbit (LEO) already require a technological marvel like the International Space Station (ISS). Exploration of the solar system beyond LEO poses much more difficult challenges, requiring the best of our technology and ingenuity to overcome them.

EARTH SHADOW PROTECTION

Protection from the effects of ionizing radiation, both short-term Solar Particle Events (SPE) and long-term Galactic Cosmic Rays (GCR), is a major issue. SPE are rare but very intense outbursts of ionizing particles from the Sun. Their energy is in the 1-100 MeV range but their flux can be so intense that they produce doses highly dangerous to astronaut health. GCR are a low but steady flux of high energy particles, peaking around 1 GeV, including all kinds of stable nuclei from protons to iron.

Exposure to ionizing radiation is seldom an issue on Earth: the effects of nuclear plant accidents or usage of nuclear weapons are the most extreme, but infrequent cases. On our planet we are well protected from the effect of cosmic radiation. The planet itself completely shields us over half of the solid angle, a phenomenon known as Earth shadow. The atmosphere acts as a massive shield equivalent to the thickness of 3.3 meters of aluminum. The Earth dipole magnetic field acts as a powerful deflector with 50 Tm bending power. The combined effect of Earth Shadow, atmosphere, and geomagnetic field contributes to almost eliminate the impact of GCR.

PROTECTION IN LEO

The situation changes substantially in LEO: the protection of the atmosphere is lost and the radiation dose absorbed by astronauts due to GCR increases nearly two orders of magnitude. But residence in LEO rarely exceeds six months, so by simply returning home, the absorbed dose can be maintained below professional exposure limits. The Apollo missions to the Moon lasted only about ten days and therefore did not present a health hazard from the point of view of total absorbed radiation. But an exploration mission, involving two to three years in space, represents a very significant step from the point of view of radiation protection: both the duration and the intensity of exposure to radiation are increased at the same time, reaching and sometimes exceeding current career limits.

Space radiation hitting cell DNA.
Credits: NASA

This issue has been known since the time of Werner von Braun. Several studies attempted during the last 40 years to find practical ways to protect astronauts from the sudden, very intense, low energy SPE and from the continuous flux of penetrating, high energy Galactic Cosmic Rays. Passive shielding works well for SPE, but is problematic for GCR: high energy hadrons can be shielded only using extremely heavy shields of a couple meters thickness, an approach used for ground based particle accelerators. Passive shields of a few centimeters thickness compatible with space usage have a tendency to increase the dose deposited by GCR due to secondary production.

The use of intense magnetic fields enveloping the spacecraft and deflecting charged cosmic radiation has been considered by various authors. This approach appears likely to be the most effective, although technologically challenging, active protection method. The power required to deflect most of the GCR requires magnetic fields on the order of magnitude of 1 Tesla extending over about 10 meters. Strong, large volume magnets in space, however, can only be based on superconductivity due to basic power and mass considerations.

ACTIVE MAGNETIC SHIELDING

Detailed analysis and accurate Monte Carlo simulations are required to identify realistic magnetic configurations that would optimize mass of the support structures needed to counter the large magnetic forces that are present within an active shield. Such a detailed analysis was started for the first time in 2011 in a ESA study (1) that will continue over the next three years within the frame of the recently approved FP7 Superconducting Radiation Space Shield (SR2S) project (2).

Earlier studies were based on the use of toroidal fields created by radially mounted coils. The ESA study considered alternative coil configurations based on an innovative *Double Helix* (DH) (3) design which is more promising from the point of view of the structural mass needed to counter the strong magnetic forces. The study shows that using different coil designs can significantly vary the weight/bending power with, for instance, up to a 30% reduction for a design based on DH coils and 4 Tesla meter (Tm) bending power.

The ESA study also yielded important results in understanding the interplay between active and passive shielding effects. Although intuitively, one might expect increased shielding mass to automatically reduce radiation, it turns out that is not the case. High energy particles produce secondaries which tend to increase the flux of charged particles. This phenomenon mandate the use of low mass coil materials and careful choice of structural materials to ensure attempts to protect against radiation are not achieving the opposite effect.

The study analyzes the merits of an active shield which could be built using existing state of the art technology. An active shield based on a 4 Tm Double Helix multicoil design around a spacecraft's habitable module would be able to reduce the GCR dose by nearly 40% with respect to the deep space dose, taking it below the current dose yearly limit of 50 rem/yr for Blood Forming Organs (BFO). This active design would have the advantage of effectively shielding astronauts from the lower energy SPE.

Magnetic shielding could offer a crew protection similar to that of Earth's magnetosphere.
Credits: NASA

Matroschka is an ESA-Roscosmos experiment co-developed by Kayser Italia. Named after Matryoshka nested dolls, the experiment uses a realistic human torso of polyurethane material and natural bones that simulates the densities of human tissues in order to establish the relation between radiation doses at the skin surface and at different locations inside a realistic human torso.
Credits: ESA

Future work within the FP7 SR2S program will deal with improved superconducting magnets able to reach higher field strengths, will study better shield materials and will provide detailed thermal and structural analyses. NASA has recently started similar work supported by the NASA Institute for Advanced Concepts (NIAC) and in close collaboration with the ESA and SR2S team.

There is consensus among experts that optimized combinations of passive and active shields, based on magnet technologies that are either available today or will be available within the next decade, should be able to reduce the absorbed radiation dose well below current limits.

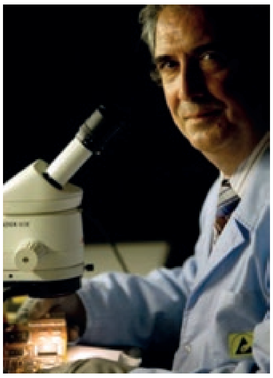
(1) R. Battiston *et al., An Active Radiation Screen Design Based on Superconductive Double-Helix Solendoids*, Proceedings of the 5th IAASS Conference *"A Safer Space for a Safer World"*, Versailles, France 17-19 October 2011 (ESA SP-699, January 2012); ARSSEM report http://arxiv.org/abs/1209.1907

(2) *Space Radiation Superconductive Shield (SR2S)*, approved under the call FP7-SPA-2012.2.2-02

(3) C.L. Goodzeit et al., The double-helix dipole a novel approach to accelerator magnet design, IEEE Trans. Appl. Supercon, 13, 2, 1365 – 1368, (2003); R. B. Meinke, Modulated double-helix quadrupole magnets, IEEE Trans. Appl. Supercon, 13, 2, 1369 – 1372, (2003)

Roberto Battiston is professor of physics at the University of Perugia and President of the INFN Committee on Astroparticle Physics. Deputy spokesperson of the AMS experiment on the ISS, he has coordinated the ESA Study for Active Radiation Shields for Space Exploration (ARRSEM Report) and currently coordinates the SR2S FP7 program aimed to improve the technology for superconductive radiation shields.

KAYSER ITALIA: THE COMPANY



Kayser Italia is a Small-Medium Enterprise (SME), a private independent aerospace system engineering company owned by Dr. Valfredo Zolesi's family. It was incorporated in 1986, and since 1995 it is 100% Italian property. The company is located in the countryside of Livorno, in the region of Tuscany, 20km south of the international airport of Pisa and 90km from Florence. In a modern building, the company has 5,000m^2 of property, organized into offices, meeting rooms, conference room, laboratories, a clean room, a manufacturing, inspection, and integration area, and an User Support Operation Center (USOC) to support the execution of experiments by astronauts onboard the International Space Station (ISS). The working area is surrounded by a property of 22,000m^2 of Mediterranean woodland. From its beginning up to 2012, Kayser Italia has participated in more than 50 space missions with 80 payloads and experiments, all of them completed with full scientific, technical, economic, and programmatic success. The staff consists of 40 highly specialized engineers, with expertise in electronics, aeronautics, mechanics, thermodynamics, physics, computer science, optics, and molecular biology. Their design and manufacturing capabilities, joined with a deep engineering background, have allowed the company to participate both as prime contractor as well as sub-contractor for many European Space Agency (ESA) and Italian Space Agency (ASI) programs, especially in the area of life science (biology and human physiology).

The payloads developed by Kayser Italia have been flown on the Russian capsules Bion, Foton, Progress, and Soyuz, on the Space Shuttle, on the Japanese HTV, on the European ATV module, and of course on the ISS. In 2011 an incubator was flown with the Chinese Shenzhou 8 capsule. In 2012 the flight of an ESA Transport container is planned with SpaceX Dragon.

Kayser Italia is certified ISO 9001, and its personnel is qualified to manufacture and inspect electronic circuits and harness in accordance with ESA standards. The company supports grants and partnership programs with universities and research institutes and is actively involved in the promotion of the integration process between large and Small-Medium Enterprises working in space.

Looking forward to the next 25 years of successes.

Dr. Ing. Valfredo Zolesi
President
Kayser Italia

ISSF

INTERNATIONAL SPACE SAFETY FOUNDATION

THE CASE FOR SUPPORT

International Space Safety Foundation Case For Support

After losing radio contact with ground control, Space Shuttle Columbia reentered the Earth's atmosphere disastrously in 2003. The shuttle burned up on reentry and disintegrated over Texas, killing all seven crew members. Small bits of shuttle debris were spread over a wide area of Texas, including shuttle engines full of highly toxic chemicals. Fortunately, no others were harmed, but the risk of a fatal crash with air traffic was estimated by Federal Aviation Administration to be as high as 1/100 for civil aviation and 1/1000 for commercial aviation.

The Space Shuttle Columbia break up over Texas in 2003

Space Travel: Entering A New Dimension

Over a century ago we witnessed the world's first flight—12 seconds that defied belief at that time. Today, our skies have grown almost as busy as our roads. Each day there are 28,537 commercial flights, 27,178 private planes, 24,548 air taxi flights, 5,260 military flights, and 2,148 cargo flights either taking off or landing at the 19,990 airports in the U.S. Thus there are about 87,000 flights in the United States a day and 64 million in a year.[1] In 2007, the U.S. alone saw more than 769 million passengers enplaned on scheduled airlines traveling across the country and across the world.[2]

By contrast, there are only a handful of people in space at any one time—astronauts who might have been launched from one of only a dozen spaceports around the world. The number of unmanned spacecraft is also few. To date, only about 500 people have flown into space. While the volume of travel is currently low, the potential for growth is unprecedented.

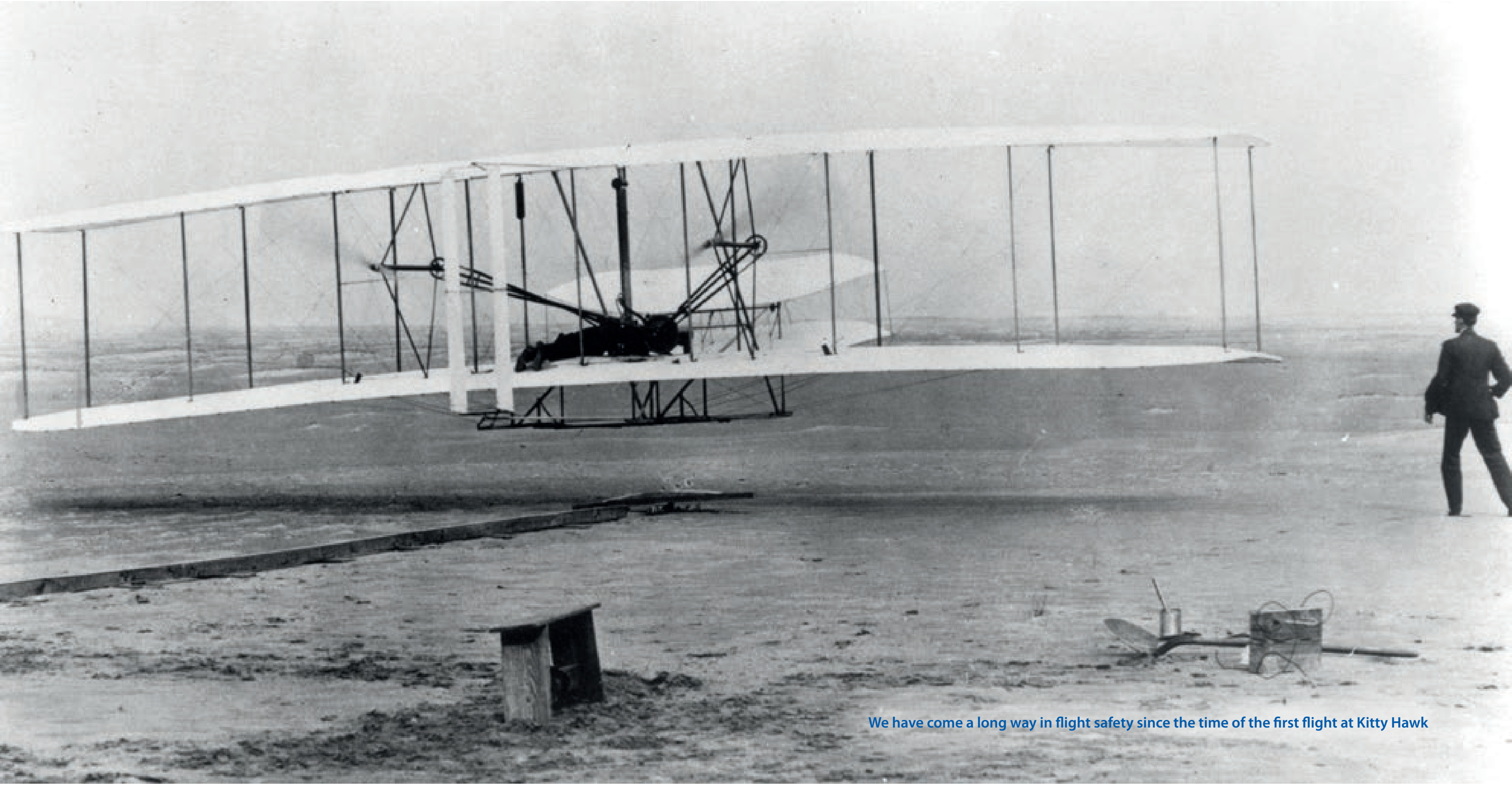
Far from being science fiction, space travel is a booming industry. In 2004, *SpaceShipOne*, the first private manned aerospace craft, reached space. And while many dream of an adventure in space, for some it is a reality. In 2001, Dennis Tito, a businessman from California, became the world's first space tourist when he paid $20 million to be launched into space aboard a Russian rocket. Five others have since followed, with more hopeful space tourists awaiting their opportunity. *Virgin Galactic* and other members of the Commercial Space Flight Federation have been taking reservations from paying passengers eager to venture into space since 2005 and have unveiled the spacecraft that will take them there. Infrastructure is being developed to launch space tourism excursions with the construction of private spaceports across the world—*Spaceport America*, the first new-built commercial spaceport, with a capital investment of a quarter billion dollars, is on the way to completion. The terminal area was inaugurated in October 2011.

With advancements by world governments and private enterprises, plans in motion for commercial spaceflight and space tourism will mark a dramatic change in the number of spacecraft being launched and with it a substantial increase in the volume of space traffic.

Airplanes, just like spacecraft, were once the exclusive domain of governments. At the start of commercial air travel, flight was risky, costly, and accessible only to the rich. Now that air travel has been brought to scale, our skies are busier and managing flight has become much more organized and subject to international standards. The result is airline travel that is impressively safe. If the right leadership and steps are taken today, the same will happen for the space industry tomorrow.

1 National Air Traffic Controllers Association, accessed January 2009 http://www.natca.org/mediacenter/bythenumbers.msp

2 US Bureau of Transportation Statistics, National Transportation Statistics accessed January 2009 http://www.census.gov/compendia/statab/



We have come a long way in flight safety since the time of the first flight at Kitty Hawk

Public acceptance of aviation as a safe and fast method of transportation is rarely questioned today, thanks to the strict safety standards that ensure the well being of the crew and passengers and people on the ground. Such standards are the results of accumulated experience as well as of technical progress in which private research played a fundamental role since the very beginning. In the rare event that an accident occurs, protocols and procedures for responding to an emergency are in place: when an airliner went down in the Hudson River early in 2009, all 155 people survived without injury thanks in part to the safety standards that guide the airline industry.

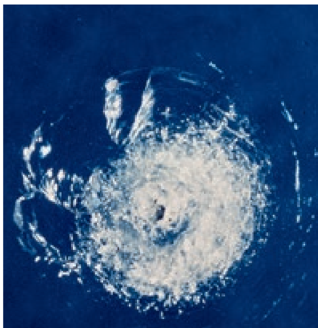
Despite various regulatory oversight responsibilities shared by government agencies in the United States and "space treaties" among international organizations, there is not yet in place an extensive, coordinated international program that tracks and manages space travel and commerce to ensure the safety of those in the industry and of the general public. The dangers and potential for accident in space is unprecedented.

Danger of Orbital Accidents

Today, more than 21,000 pieces of space debris ranging in size from large, derelict satellites to a few inches (10cm) are circling the Earth. There are tens of millions more uncatalogued space debris objects greater than 1 mm in size.

At speeds reaching 27,400 km per hour, even the smallest bits of space debris can cause serious harm to spacecraft; larger

NASA's 2006 post-flight inspection of the space shuttle Discovery STS-114 found 41 impacts on the vehicle caused by orbital debris, the largest of which left a crater in one of the shuttle's windows. NASA estimated that it was caused by a particle with a diameter of just 0.22 mm. This impact was among the largest ever recorded.



Space debris impact on Space Shuttle window
Credits: NASA

Space debris impact on Space Shuttle blanket
Credits: NASA

Space debris reentry
Credits: Kristhian Mason

ATV reentering the atmosphere
Credits: D.Ducros / ESA

Each year, nonfunctioning satellites come crashing back to Earth uncontrollably. The only way to control these falling satellites is to shoot them down. When China shot down one of its satellites in 2007, the explosion left large amounts of debris orbiting the planet, posing risk to spacecraft. In 2006, 270 passengers on board an airliner above the Pacific had a lucky escape when the wreckage of a blazing Russian satellite narrowly missed their aircraft. In early 2008 the United States shot down a missile containing toxic fuel. The explosion created small pieces of broken-up satellite that fell into Earth's atmosphere, posing risk to the environment and to human life. In 2009, an Iridium commercial satellite and a defunct and out of control Russian Cosmos satellite crashed, destroying both spacecraft and creating a deadly shower of debris in low Earth orbit.

ones threaten the lives of astronauts and can cause catastrophe. A fragment of about two thirds of a pound (300 grams) can destroy an airplane at cruise altitude and speed. As recent history shows, an object as seemingly insignificant as a paint chip can cause significant damage.

The United Nations Committee on the Peaceful Uses of Outer Space has, after over a decade of debate, adopted guidelines to limit space debris, but there remains far more to be done to ensure human safety. As space travel advances, there will be an exponential increase in space traffic and more discarded debris. More objects in orbit will mean greater chance of collisions in space. The first dramatic collision took place in 2009 between the US Iridium 33 satellite and Cosmos 2251, a Russian communication satellite that ceased active operations in 1995.

Risk of Accidents on Ground

Approximately one cataloged piece of space debris has fallen to Earth every day for the last 40 years.[3] Right now, there are several hundred spacecraft in Low Earth Orbit that will reach end of life, no longer be able to maintain orbit, and destructively re-enter the atmosphere in the coming decades—exact numbers are not tracked. Sometimes a satellite can be lost at the very beginning of, or during operations and become a public safety hazard.

Between 10 percent and 40 percent of the mass of these spacecraft are projected to survive re-entry in the form of fragments. As the number of objects hitting land increases, the risk of human injury and damage to aircraft and property becomes greater.

It is not just spent satellites or fragmentary remains of craft that fall to Earth. Hazardous materials and poisonous substances, including noxious gases and radioactive materials, carried inside spacecraft that fail to burn up on reentry fall on Earth and have the potential to cause serious damage to public health and safety and the environment. USA-193, also known as NRO launch 21, was an American military spy satellite launched on December 14, 2006. The satellite malfunctioned shortly after deployment, and was intentionally destroyed 14 months later on February 21, 2008, by a modified SM-3 missile fired from the warship USS Lake Erie, stationed west of Hawaii. According to Federal Emergency Management Agency (FEMA) reports the satellite contained

> *"We have rules of sea and we have rules of flying over territories and countries, but once you get into space those rules are not established."*
>
> *Richard Stuart, founder, CEO, and President of ARES Corporation/Board President, International Space Safety Foundation*

3 NASA

hazardous materials that could have survived reentry: half a ton of frozen hydrazine and beryllium.

Since the beginning of space travel, ten space failures have dispersed radioactive material to the Earth's surface and oceans—but pollution from rocket fuel and contamination from fallen space debris are increasing concerns.

Accidents also occur at launch sites, where nearly 200 people (35 since 2000) have been killed by rocket explosions during processing, test, launch preparations, and launches.

Frontier Environment

In the extremes of space, there are no mutual aid provisions and travel patterns are not coordinated. Each country has its own unique technologies and systems—from space suits and vehicles to terminology. Were there to be an accident on a space flight, there is no universal method to transmit distress and no international code of conduct for responding to a call for help in space. Preliminary (and uncoordinated) efforts to create international standards for exploration on the Moon are underway and initial efforts have demonstrated how application of these standards could save lives.

Safety of Future Space Exploration

The space industry needs a "quantum leap" in the area of safety. People around the world are at risk from spacecraft launch and reentry operations as well as falling space debris. We need to act now to protect the safety of citizens of all nations, to reduce the impact on our environment, foster safe human space travel and increase international cooperation for the benefit of all space exploration.

We need protocols in place to reduce the risks to public safety. We need effective rules and commitments for tracking and reducing existing space debris and limiting future debris. We need to substantially advance system safety through dedicated studies. We need to set industry standards for space equipment design, and we need standard operating procedures in the air and on the ground. In essence, we need the same innovations in safety for the space industry that we have for commercial aviation—black boxes, traffic management rules, and quality monitoring programs such as Flight Operational Quality Assurance and the Aviation Safety Action Program.

THE GUGGENHEIMS AND AIR SAFETY

On any given day, more than 87,000 flights are in the skies in the United States. Public acceptance of aviation as a safe and fast method of transportation is rarely questioned today; however, regular, safe passenger service on airlines was not a reality until aeronautical engineering programs were established and reliable aircraft engines and instruments were developed. Between 1925 and 1930, philanthropists Daniel and Florence Guggenheim invested more than $2.6 million (the equivalent of $31 million in 2008) in research and educational activities to develop airplane safety that ultimately led to safer air travel and paved the way for a nascent commercial air flight industry.

Flight was extremely risky, plagued by accidents and fatalities. In the early days of scheduled transportation from 1922 to 1925, one pilot was killed for every 10,000 hours of flying. According to the Flight Safety Foundation, if the world had the same accident rate now, there would be several hundred serious air transport accidents a year. Certainly, one or two would occur every day somewhere around the world. Safety has been improved dramatically, and today the air transport industry has a very low accident rate. Today, taking a plane is a journey safer than catching the bus or crossing the street, due in part to the vision of people like the Guggenheims and those committed to aviation safety that have continued their work.


Jumbo Jet Airliner

Pilot Neil Armstrong with X-15
Credits: NASA

International Space Station
Credits: NASA

Priority Actions to Advance Space Safety

The diversified efforts of government agencies, the military, commercial firms and private entrepreneurs have enabled limited access to space. However, present codes of conduct and current methods of coordination are insufficient to insure a safe and sustainable use of space. Now is the time to establish an enhanced process for space safety and to develop an international, cooperative culture for advancing this cause.

It is critical to undertake three priority actions:

1. Develop through advanced education and training a space industry workforce more knowledgeable of space safety engineering and management;
2. Research and develop innovative safety practices and effective tools; and
3. Help to establish a minimum set of global voluntary standards for improving space flight safety, reducing space debris, and implementing international space traffic management.

International Space Safety Foundation

Recognizing the urgent need to advance safety practices in the rapidly increasing use of space, the International Association for the Advancement of Space Safety (IAASS) was formed in 2004. This organization spurred new research, published unique books, articles and opinion pieces, and began to work with the space agencies, space industries, and private space entrepreneurs to advance the field.

In the United States, a group of dedicated safety experts from the private, commercial, government, and academic sectors of the space industry saw the need for American leadership in this critical new field. Inspired in part by the impact on aviation flight safety achieved by the Guggenheims and by Jerome Lederer, the group formed the International Space Safety Foundation in 2008. The Foundation's mission is quite simply to enhance access to space for future generations. Its vision is a safe space for people on Earth, for the environment, and for explorers and astronauts in space.

The International Space Safety Foundation is the only organization in the United States that is dedicated entirely to furthering policies of international cooperation and scientific progress in the field of space safety. The Foundation is a non-governmental organization operated by an independent Board of Directors with knowledgeable and experienced representatives from each sector of the space industry and supported by a think-tank of experts, the Advisory Council.

The International Space Safety Foundation cooperates closely with IAASS in undertaking and promoting conferences, workshops, research, education and training, and development of space safety standards.

The Foundation seeks to engage all segments of space program management, policy makers, and elements of engineering and operations to advance space safety research,

The spectacular ignition sequence of a Delta IV Heavy
Credits: Vandenberg Air Force Base

The Multi Purpose Crew Vehicle
Credits: Lockheed Martin

to push the use of improved technologies and inherently safe systems solutions, and to promote independent certification processes, design and verification methods. The Foundation is independent of the space agencies, government regulatory agencies, space enterprise, private space flight industries, and specific aerospace interests. The Foundation joins all of these entities, as well as space-related foundations, in the quest to make the future of space safe.

A Plan for Success

The Foundation has set forth an ambitious plan to address the challenge of human and environmental safety and to improve access to space. The plan encompasses three strategies to significantly improve space safety. It will **catalyze space safety private and academic research** to ensure safe access to, use of, and transit through space and to safeguard any space object operating in space and preserve the Earth's environment and human safety on the ground and in aircraft; **advance knowledge and application of space safety** by building expertise in the field among the broader space industry workforce through advanced education and comprehensive training.

The Foundation is seeking an initial funding of $1 million that will launch efforts to create an international space safety institute to advance knowledge and application in the space safety field, and to fund a focused research program. The Foundation will seek to leverage, where possible, the initial funding through joint projects with partner organizations and foundations, including the IAASS.

Catalyze Space Safety Voluntary Standards and Certification

The Foundation will establish an international institute for space safety whose mission will also include promoting the development of voluntary standards and independent safety certification processes in support of commercial and private space flight companies. The Institute will seek to support regulatory bodies at national and international levels for the civil use of space. These efforts are not intended to directly support military or defense space programs, although the civil space voluntary safety standards could benefit non-civil programs. The Institute will network a group of internationally renowned advisors and system and subsystem analysts to test, evaluate, and independently certify the safety of private spacecraft.

Advance Knowledge and Application of Space Safety

The Foundation will advance safer design and the development of dedicated safety equipment by awarding research grants for key space safety projects and building the knowledge and capacity of the field by supporting publications, monographs, conferences, workshops, training sessions, and web-based seminars. Already the Foundation has provided support for the publication of **Safety Design for Space Systems** (recently translated into Chinese) and its follow-on project, **Space Safety Regulation and Standards**.


Edward H. White II, pilot of the Gemini 4 spacecraft
Credits: NASA

Award Innovation and Leadership

The Foundation will provide incentive awards and other recognition to thought leaders encouraging the field of space safety. Awards to be developed will be targeted to innovative practitioners to increase their education and professional development and carry out key research and development projects.

Fund Raising

We are seeking funds to support creation of an International Space Safety Institute, carryout key research, publish key books, training materials and monographs, provide awards for outstanding efforts in the field and other related activities. Support will be obtained by means of:

a. Exceptional Donors – individuals, institutions, or corporations that make substantial grants to build our endowment base
b. Members – corporations or institutions that make annual donations:
    1. Benefactor: $25,000 or more
    2. Patron: $15,000 - $24,999
    3. Contributor: $10,000 – $14,999

Join Us

Advancing space safety is critical to environmental health and human safety on Earth and to increased viability for all space programs, manned and unmanned. Space safety can also contribute to the growth of a multitude of new space industries, from space communications to space tourism, from geomatics to clean hypersonic transport. Together, we must place a premium on safety.

Significant investment is needed in the programs and research that will catalyze space safety innovation and voluntary standards, and advance knowledge and application of space safety. We invite you to join us in the quest.

By investing now in the work of the International Space Safety Foundation, commercial space companies will help develop and expand research and development activities critical to improving space safety, support educational and training programs as well as conferences and workshops related to space safety improvements, and spark innovation and leadership in the field. Your leadership in building a safe and science-based approach to space safety will help expand horizons, increase the opportunities, and preserve viability for future generations of explorers.

We particularly invite interested organizations and corporations to contact us, to see how you can be a part of the foundation by being a **sponsor**, **patron**, or **benefactor** by providing either annual support or an endowment grant to the Foundation. We are also looking for people to help support our initiative to create new educational programs in space safety, to carry out research projects in the field, to support training programs, to serve on committees, to join our board, or to advance our case in other ways.

Visit our website to learn more, ask questions, and get involved!

www.spacesafetyfoundation.org

By Merryl Azriel

Tai Chi: Taking Wellness to Space

On June 26, video of the first female taikonaut performing Tai Chi in space made its appearance online and on television. The routine demonstrated by Liu Yang was specially developed for the taikonauts by their trainer Tong Faizhou, the goal being "to regulate their breathing and relax their body and muscles and bones." The image of the graceful movements being performed in such a foreign environment caught the fancy of many spectators around the world, not least because Tai Chi is such a quintessentially Chinese exercise and so very different from the cycling, treadmilling, and weight lifting exercises we are used to seeing from astronauts in space. With rapid space developments from China in recent years, and India pushing along, it may be time to consider what these countries and their eastern traditions may bring to the table in terms of care for astronauts of any origin.

Liu Yang, China's first female taikonaut, performing her Tai Chi routine aboard Tiangong-1 in June. - Credits: Central China Television

To explore this topic, Space Safety Magazine spoke with Judit Jaenchen and Hemil Modi, two graduate students from the International Space University working with noted space physiology researcher Dr. Gilles Clément. Jaenchen, an avid meditator and Kung Fu practitioner herself, investigated the potential physiological and psychological benefits of meditation in space. Modi, civil engineer and yoga practitioner from India, performed clinical research into the benefits of yoga with applications for space. Both were encouraged by the sight of Tai Chi, an ancient martial art sometimes known as "meditation in motion," brought to space. The discipline is widely seen on Earth as a healthful gentle exercise, promoting stress reduction, mind-body connection, and limber joints.

"Eastern approaches to spaceflight are as old as their philosophy," noted Modi. "The first and only Indian cosmonaut, Wing Commander Rakesh Sharma, practiced yoga before and during his space flight." Although the lack of a controlled experiment made it impossible to isolate the effect of such exercises, Sharma's condition was noted to be very good mentally and physically throughout his flight.

"I am not surprised that the Chinese are looking into this," says Jaenchen. "For them the traditional Chinese medicine approach is a natural thing to believe in, and it all comes down to the flow of chi, the inner energy all humans have." According to Jaenchen, meditation has the potential "to help astronauts face physiological and psychological issues during space flight missions, increasing their mental and physical health." She noted that there is a barrier in the western world to exploring meditation, as much of the philosophy that accompanies traditional meditative disciplines seems to run counter to the scientific approach. "I am trying to build a bridge," says Jaenchen, "by linking the practice of meditation to concrete, measurable health benefits such as changes in heart rate, breathing, and brain activity." The available literature shows that meditative techniques seem to have potential positive effects on nausea, headache, and insomnia. "These are all serious issues astronauts have," she says. "[The Eastern approach] needs to be investigated to see if it works in space."

> "Eastern approaches to spaceflight are as old as their philosophy"

"With the future of human space flight extending towards long duration flights like the ones to asteroids and Mars, the merits or demerits of such holistic approaches should be considered while designing the next generation of human spaceflight training programs," adds Modi. "We all know our astronauts are our finest resource in space and we all want them in top condition to take humankind forward."

By Joseph Pelton

Taking Potentially Hazardous Asteroids Seriously

When I explain to people that I meet every day that I am involved with the study of space safety, the first response they make is: "Just what is space safety?" The problem is that everyone, even within the field of space safety, has their own definition.

Some people think of astronaut safety. Others think about the design of safer launchers, spacecraft, or satellites. Others in the field of satellite telecommunications think about possible conjunction of spacecraft or space debris hazards. Yet others think about nuclear materials and toxic materials such as hypergolic fuels used in space missions which might expose people to risk. Recently, space traffic management and space situational awareness have been hot topics. Just a very few think about Near Earth Objects (NEOs), Potentially Hazardous Asteroids (PHAs), and other dangers from space such as cosmic radiation or coronal mass ejections (CMEs).

The International Space Safety Foundation (ISSF) and the International Association for the Advancement of Space Safety (IAASS) are concerned with "all of above." We are truly concerned about these safety issues and risks and even more. These are physical hazards from space that are remote in terms of likelihood but potentially devastating in scope. As Space Writer Leonard David has said about potentially hazardous asteroids in near earth orbits: "They are nasty and mean and can mess up Planet Earth big time."

So what should we do to assess just how big a risk is posed by Near Earth Objects? How can the general public start to grasp even what we are talking about? Apollo 8 Astronaut Rusty Schweickart, who for years headed the B16 Foundation, is a brilliant spokesperson on this subject, but people he has reached have generally been space scientists and perhaps a few sci-fi zealots. How can we reach a wider audience and give them a realistic view of the dangers within a scientifically accurate framework?

> "PHAs are nasty and mean and can mess up Planet Earth big time"
> L. David

Artist's concept of a catastrophic asteroid impact with the early Earth. An impact with a 500-km-diameter asteroid would effectively sterilize the planet. – Credits: Don Davis, NASA

One possible answer is the so-called Torino Impact Hazard Scale, or Torino Scale for short. The Torino Scale is a method to categorize the impact hazard associated with asteroids, comets and other near-Earth objects (NEOs). It ranges from 1, routine discovery of NEO with low impact probability, to 10, certain collision of catastrophic proportion.

At Unispace III in Torino, Italy, the assemblage agreed to adopt the Scale that combined an assessment of "likelihood" degree of devastation that wayward meteorites of various sizes could create if they impacted our planet..

Almost everyone in the world understands what the Richter Scale is and its progressive levels of impact as measured on a logarithmic scale from 1 to 10. Likewise we understand categories of hurricanes from 1 to 5. The Torino Scale for Potentially Hazardous Asteroids can help the general public understand that especially Category 8 to 10 PHAs are the most important to avoid if we possibly can. We need to involve the United Nations, the general press, and major news web sites to get out the word on the Torino Scale.

This general understanding of the Torino scale can help us build con- ▶▶

No Hazard	0	The likelihood of collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bolides that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.
Normal	1	A routine discovery in which a pass near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to re-assignment to Level 0.
Meriting Attention by Astronomers	2	A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to re-assignment to Level 0.
	3	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of localized destruction. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by the public and by public officials is merited if the encounter is less than a decade away.
	4	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional devastation. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by the public and by public officials is merited if the encounter is less than a decade away.
Threatening	5	A close encounter posing a serious, but still uncertain treat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.
	6	A close encounter by a large object posing a serious, but still uncertain treat of global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.
	7	A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain treat of global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not a collision will occur.
Certain Collisions	8	A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per serveral 1000 years.
	9	A collision is certain, capable of causing unprecedented regional devastation for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 10,000 years and once per serveral 100,000 years.
	10	A collision is certain, capable of causing a global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average between once per 100,000 years, or less often.

The Torino Impact Hazard Scale.

sensus to invest in two important things. One is to acquire better means of space situational awareness. These enhanced systems would go well beyond the capabilities of NASA's Wide Field Infra-Red Survey Explorer (WISE) in order to provide a comprehensive understanding of the 20,000 to 45,000 asteroids out there that could impact Earth in very unwelcome ways in coming decades, centuries, or even millennia. The other investment would be to create improved systems to actually address the threat of "killer asteroids."

There have been efforts first advocated by Arthur C. Clarke that turned into NASA's Earth Guard as well as the European Commission's latest effort known as "NEOShield." These programs are aimed at developing tools to deal with an asteroid that is found to be on a collision path with our planet. At this stage these are programs with extremely modest funds and with no real sense of urgency. If we discover we have a potential threat that is a Number 9 or 10 on the Torino Scale and it is too late—then it will indeed be TOO LATE.

> "Category 8 to 10 PHAs are the most important to avoid if we possibly can"

The ISSF and IAASS will in future months and years be trying to raise public understanding through advancing wider knowledge of the Torino Scale.

Joseph N. Pelton is President of the International Space Safety Foundation, IAASS Chairman of the Academic Committee and Former Dean, International Space University.

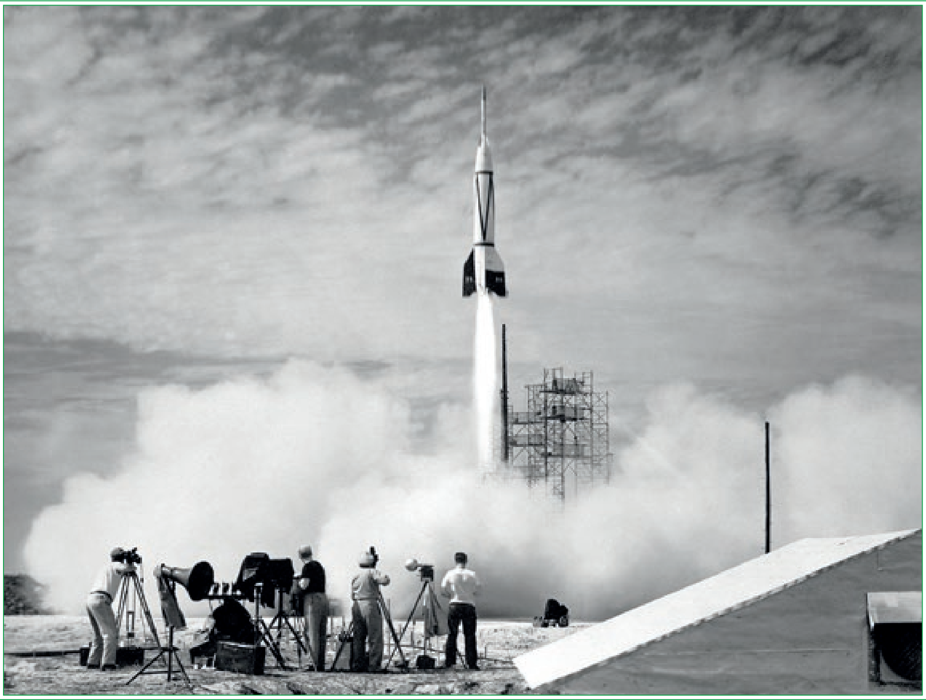
Commercial Human Spaceflight Safety in the 21st Century

By Tommaso Sgobba and Andrea Gini

Unmanned suborbital flights have been routine since the beginning of the space age, with sounding rockets covering a wide range of apogees even higher than the altitude of the Shuttle and ISS orbits. Nowadays suborbital spaceflight is living a new season due to an emerging human spaceflight industry which is proposing crewed vehicle configurations substantially similar to early government programs.

The commercial vehicles currently in development follow one of two basic configurations with different risk levels: launcher/capsule and aircraft-type. The requirements for the launcher/capsule configuration have been in place for more than 50 years and have been successfully proven in manned orbital space flights. The aircraft-type, on the other hand, presents safety requirements that have a well-established technological basis in the aeronautical engineering field. Still, the requirements related to the most safety-critical parts of the flight, like inadvertent or untimely release from the carrier, are not reflected in any current civil aviation type regulation.

> "Self-regulation promotes a higher level of safety as a business case"



The first launch from Cape Canaveral, Florida, in July 1950. The Bumper 2, a two stage suborbital rocket based on a German V-2, reached an altitude of about 400km, higher than the ISS' orbit. Credits: NASA

The X-15 experimental rocket powered aircraft was air launched from a B-52 aircraft at 13,500m and a speed of about 800km/h. - Credits: NASA

Self-Regulation: Safety as Business Case

In 2004, the US private spaceflight industry welcomed the Commercial Space Launch Amendment Act (CSLAA) which postponed until December 23, 2012 or until an accident occurs, the ability by the Federal Aviation Administration (FAA) to issue safety standards and regulations except for aspects of public safety. The Congress has recently extended the original deadline to October 1, 2015.

The CSLAA requires that a prospective space tourist shall be debriefed about the risks of spaceflight and sign an informed consent agreement. It can be reasonably expected that the average space flight participant will not have the necessary background and technical experience to truly grasp the risk of space flight. Due to the fact

The flight configuration of SpaceshipTwo below the belly of the WhiteKnightTwo mothership resembles those of the X-15. - Credits: Virgin Galactic

that there is no such thing as "absolute safety," and that the acceptable risk is generally the one defined by government standards and regulations, an operator would have a hard time defending his vehicle risk level and demonstrating the thoroughness of the information he passed to the customer in case of litigation following an accident. A set of well-defined safety regulations, and a certification of compliance with them, not only serves the interests of the customer, but also protects the industry from tort liability, by implicitly or explicitly defining the acceptable risk level at the current state-of-art.

An alternative to government regulation is self-regulation, which promotes a higher level of safety as a business case. Formula 1 car racing presents a good example. In the first three decades of the Formula 1 World Championship, inaugurated in 1950, a racing driver's life expectancy was about two seasons. Total risk was accepted by pilots, racing teams, and the public. The deaths of Roland Ratzenberger and Ayrton Senna on live TV during the Imola Grand Prix of 1994 forced the car racing industry to look seriously at safety, or risk being banned forever. In the days after the Imola crashes the Fédération Internationale de l'Automobile (FIA) established the Safety Advisory Expert Group to identify innovative technologies to improve car and circuit safety, and mandated their implementation and certification testing. Thanks to this effort, Formula 1 car racing evolved into a safe, self-regulated, multibillion dollar business funded by sponsorships and global television rights.

> "Self-regulation is seen as a way of complementing government regulations"

Nowadays the need for self-regulation is seen as a way of complementing government regulations. An example comes from the oil industry. The Presidential Commission that investigated the Deepwater Horizon oil spill in the Gulf of Mexico on April 2010, which killed 11 workers and caused an environmental catastrophe, recommended the establishment of an independent safety agency within the Department of the Interior and that "the gas and oil industry must move towards developing a notion of safety as a collective responsibility." According to the report, "Industry should establish a 'Safety Institute' [...] an-industry created, self-policing entity aimed at developing, adopting, and enforcing standards of excellence to ensure continuous improvement in safety and operational integrity offshore."

This self-regulation model may be applied to the human commercial spaceflight industry to overcome the drawbacks of the traditional approach of the early space industry.

"Mission First" and Fly-Fix-Fly

When the era of manned spaceflight started during the Cold War, the mission objective was national prestige. This objective evolved along with the relationship between the U.S. and U.S.S.R. – from a technology supremacy propaganda tool up to the Moon landing, to a tangible sign of political goodwill and mutual acceptance culminating with the Soyuz-Apollo docking in 1975. After the collapse of the ▸▸

Soviet Union, spaceflight cooperation with the Shuttle-Mir missions and the International Space Station became a means to prevent a feared migration of technical skills towards rogue States.

In time of war, mission accomplishment takes precedence over considerations of personal and even collective safety, so mission accomplishment – not safety – had been the driving force behind the development of Cold War era space systems due to the strong original imprint of the military and political attitudes of space programs.

Nowadays the situation has not changed much: private actors are preaching their own version of "mission first," taking the development of commercial human spaceflight as mission.

This is truly a self-defeating attitude, since no commercial industry can prosper by treating safety as secondary to commercial goals, costs, or profits. The air transport, nuclear, and pharmaceutical industries are examples of successful industries with a deeply-rooted safety culture.

The public may accept certain risks as unavoidable – like those associated with driving a car for example – but will not tolerate those failures which are within the reach of current knowledge and technologies to prevent, and which are caused by economic pressure or by a lack of sufficient management or regulatory attention. Public acceptance of failures and risks will eventually dictate the fate of a business. There is no evidence that the general public would have more tolerance for accidents in space projects brought about, for example, by inadequate testing of a new commercial aero-spacecraft, while at the same time hundreds of millions of dollars are spent on lavishly appointed space tourism facilities.

Prior to the 1940s, flight safety consisted basically of trial-and-error. The term fly-fix-fly was associated with the approach of build a prototype aircraft, fly it, repair and modify it if need be, and then fly it again. For complex and critical systems such an approach is simply impossible. From 1952 to 1966 the United State Air Force (USAF) lost 7,715 aircraft in non-combat operations, with 8,547 casualties. Most accidents were blamed on pilots, but many engineers argued that safety had to be designed into aircraft just like any other functional or physical feature related to performance.

The aviation Flight Safety Foundation, headed by Jerome Lederer, conducted seminars that brought together engineering, operations, and management personnel. The term "system safety" was first used in 1954 by the aviation safety pioneer C.O. Miller in a paper published in one of those seminars. The concept of fly-fix-fly that seems to be favoured again by some parts of the emerging spaceflight industry should be obsolete: it may constitute a potential threat to the industry if used in lieu of development testing and without designing upfront safety into the system. "If you believe that safety is expensive, try an accident," were the wise words of Lederer.

> "Public acceptance of failures and risks will eventually dictate the fate of a business"

Artist's conception of the Apollo-Soyuz Test Project (ASTP), the first international docking of the U.S.'s Apollo spacecraft and the U.S.S.R.'s Soyuz spacecraft in space. - Credits: NASA

Prescriptive Requirements vs. Safety Case

Use of prescriptive requirements is an old-fashioned way to pursue safety. The modern approach revolves around building safety cases.

A prescriptive requirement is an explicitly required design solution for an implicit safety goal. The RMS Titanic accident illustrates how a prescriptive requirement can sometimes dramatically fail by obsolescence. In the early hours of 15 April 1912, the RMS Titanic struck an iceberg on her maiden voyage from Southampton, England, to New York, USA and sank. A total of 1,517 people died in the disaster because there were not enough lifeboats available. Alexander Carlisle, one of the managing directors of the shipyard that built the Titanic, had suggested during the construction some minor modifications to give Titanic the potential of carrying 48 lifeboats, providing more than enough seats for everybody on board. But in a cost cutting exercise, the customer (White Star Line) decided that only 20 would be carried aboard thus providing lifeboat capacity for only about 50% of the passengers on the maiden voyage. This decision, which may seem a careless way to treat passengers and crew on-board, was in line with the Board of Trade regulations, which stated that all British vessels over 10,000 tons had to carry 16 lifeboats. The regula-

The death of Roland Ratzenberger (pictured on his last day at Imola) and Ayrton Senna prompted FIA to establish a safety regime based on self-regulation. - Credits: Sgozzi/Wikimedia

tions were clearly out of date in an era where the size of ships had reached up to 45,000 tons.

The safety-case regime, on the other hand, is based on the principle that the regulatory authority sets the broad safety criteria and goals to be attained, while the system developer proposes the most appropriate technical requirements, design solutions, and verification methods for their fulfilment.

A safety-case is documented in the Safety Case Report that typically includes:

a) the summary description of the system, and relevant environment and operations,
b) identified hazards and risks, their level of seriousness, and applicable regulatory criteria/requirements,
c) identified causes of hazards and risks,
d) description of how causes of hazards and risks are controlled and
e) a description of relevant verification plans, procedures, and methods.

This regime recognizes that the regulatory authority has the role and responsibility to define the safety objective, while the developer/operator has the responsibility to propose a valid technical solution due to its in-depth knowledge of the system design and operations.

This approach was developed by the USAF to address safety in the military missile program. In the early development of the Atlas and Titan ICBMs in the 1950s there was no safety program. Within the first 18 months of operations, four out of 71 Atlas F missiles blew up in their silos during operational testing. On August 9 1965, fire in a Titan II silo in Searcy, Arkansas, killed 53 people. The USAF then developed system safety assessment and management concepts, leading to the establishment of a major standard, MIL-STD-882, and System Safety Engineering as a discipline. Thanks to safety-cases, it is possible to remove or control hazards in new systems so as to minimize their safety risk before they enter into operation.

> “If you believe that safety is expensive, try an accident”
>
> J. Lederer

Bureaucrats vs. Engineers

The commercial human spaceflight industry must develop a safety approach for the 21st century.

There are two key elements in a mature approach to space safety: independent self-regulation under government oversight and safety requirements for use in a safety-case regime. Finally, we should note that knowledge drives safety. While prescriptive requirements can be easily verified by technical bureaucrats, a safety case regime requires that both the design team and the safety certification team have a deep knowledge of how the system works in order to understand the relevant hazards and how to control them.

The last of Titanic's lifeboat is rescued by the Carpathia. The RMS Titanic carried lifeboats for about half of its passengers, an arrangement in line with the Board of Trade regulations at the time. - Source: National Archives, Northeast Region, NYC

The Red Stuff: The True Story of the Russian Race for Space

By Andrea Gini

The DVD cover, autographed by Leo de Boer.

The history of US human spaceflight has been narrated over and over again from a wide array of media. Since its inception, NASA's human space program has been a public feat, where everything, including all the launch failures, were witnessed and reported, then collected in articles, books, documentaries, and movies. The Soviet space program, on the other hand, has always been shrouded in secrecy. There was no publicity before each flight and mainly propaganda after. Accidents like the Nedelin catastrophe were completely concealed, while others, like the death of the crews of Soyuz 1 and 10, were stripped of their most gruesome details. When the Soviet Union collapsed, these stories started to surface. One of the first films that attempted to fill in the gaps was "The Red Stuff - The True Story of the Russian Race for Space," a collection of interviews with the surviving first generation of Soviet cosmonauts. Space Safety Magazine met with the film's director, Leo de Boer, to learn more about his remarkable documentary.

The idea came about in the early 2000s, when de Boer was visiting Russia for one of his movies. "A friend took me along to celebrate 'cosmonaut-day' in Star City, just outside Moscow," says de Boer. "There I met some of the first cosmonauts like Titov, Nikolaev, and Leonov, who had all been members of the first group of cosmonauts trained together with Yuri Gagarin. I was impressed by their stories and was able to convince people at Dutch TV to put up the money to make this film."

Everyone agreed with the proposal, with a notable exception: "The only person who refused to be filmed was Valentina Terehkova – the first woman in space," says de Boer. "She was married once to cosmonaut Andrian Nikolaev. Rumour has it that some political pressure also stimulated their marriage, as it was turned into a propagandistic 'space' fairy-tale of the two heroes. They divorced later and Valentina told me she did not want to be in the same film with her ex-husband."

Fear is Not an Option

Cosmonauts and space authorities were generally cooperative, with some exceptions: "As I found out, the cosmonauts were not eager to talk openly about all subjects," de Boer says. The early Soviet space program achieved some incredible "firsts" by taking significant risks. Were the cosmonauts willing to talk about the risks they were exposed to and about their fears? "The topic 'fear' was never addressed," says de Boer. "For decades these men had to play the role of Soviet Heroes. And fear – or even hesitation – had no place in that image. I think they have actually been trained to not feel it any more, if that's at all possible."

> "The topic 'fear' for was never addressed"

The movie's coverage of the ill-fated flight of Soyuz 1, which ended with the death of Vladimir Komarov, is poignant. "I think Komarov was sacrificed for political reasons," says de Boer. "Everyone knew that his capsule was not ready. They had made the bottom of his spaceship heavier to improve stability during re-entry in the atmosphere. To compensate this gain of weight, they had made the landing-parachutes bigger. But the space for the parachute was still the same – so they had to use wooden hammers to get it inside the small space. Not surprisingly the parachutes did not open upon reentry."

Group photo of the first cosmonaut group. On the top: Feoktistov, Bikovski, Jegorov, Bjeljajev, Popovich and Komarov. On the bottom: Leonov, Terehkova, Kamanjin, Gagarin, Nikolajev and Titov. - Credits: RIA Novosti

Alexei Leonov during his spacewalk, Voskhod 2, March 1965

> **“For younger generations, cosmonauts are associated with a period they are trying to forget”**

“I had heard the story of the collective letter written by the group of cosmonauts to protest against the forced flight of Vladimir Komarov in 1967,” adds de Boer. “It’s also mentioned in Yuri Gagarin’s biography. The political pressure to have the flight ready in time for the 50th anniversary of the Soviet Union was enormous. Everyone on the team knew the spaceship would not be ready, but Brezhnev insisted the ship be in outer space during the commemoration. So the team collectively wrote this protest-letter, which was handed over personally to Brezhnev by Gagarin himself, as Yuri was considered untouchable for the possible consequences. The letter disappeared in the bottom drawer of Brezhnev’s desk and Komarov was launched in the faulty spaceship. When he re-entered the Earth’s atmosphere his parachutes didn’t work and the spaceship crashed onto the surface.”

To date, the existence of this letter remains a mystery: “When I asked the cosmonauts individually about this letter, they denied the existence of it,” says de Boer. “As I found out later they had agreed among each other not to speak to me about it. No idea if they were still afraid of the political consequences or that they didn’t want to bring out in public this dreadful story that throws a dark shadow on the role of politics in this story of the Soviet Heroes of Space.”

The Red Stuff also documents the death of the Soyuz 11 crew during reentry due to a failure in the capsule equalization valve. “This gripping story is told by the widow of one of them, Vera Patchaeva, who was present in the control room during the landing of the capsule,” de Boer says. “Her story is illustrated by authentic archive footage of the capsule being opened and doctors frantically trying to save the cosmonauts.”

Forgotten Heroes

While most of the first US astronauts are still highly regarded celebrities, the first generation of cosmonauts are mostly forgotten: “For the older generation in Russia – who still grew up in the Soviet system, they are probably still heroes,” explains de Boer, “but of course their Soviet heroism is very much linked to the period of communist repression in Russia. For the younger generation they are associated with a period that they are trying to forget, while internationally I’m quite sure that these pioneers of space, who took the risks and pushed the envelope inside out time and again, are still highly admired.”

Of all the cosmonauts he interviewed, de Boer was most impressed by Alexei Leonov. “He was the first man to leave his capsule in outer space and make a space walk. When he tried to get back into his spaceship, he found his space-suit had swollen so much that he no longer fit in the hatch. It took him a lot of effort, and skilful creativity, to get back inside.”

“Back on earth he wrote a children’s book about his little trip into space. And he himself did the illustrations for that. I think Leonov was truly touched by his space-experience, almost up to the level of a religious experience. To me he was the most human – the least ‘machine-like’ – of all the cosmonauts I have met.”

Komarov’s wife Valentina cries over her husband’s grave during the funeral. - Credits: RIA Novosti

Russian Satellite Launch Failure Leads to Proton Suspension

With the world's attention focused on the successful landing of the Mars Science Laboratory on August 6th, little attention was given to the launch of a Proton-M rocket from the Baikonur Cosmodrome in Kazakhstan. The two satellites it carried, Telkom-3 and Ekspress-MD2, were subsequently lost when they failed to reach transfer orbits due to a burn failure of the Breeze-M upper stage.

Russian Space Agency Roscosmos suspended the launches of Proton-M rocket carriers with Breeze-M boosters until an investigative board determines the cause of the failure. The failure of the Breeze-M for this launch adds to its list of failures since the end of 2010, including the loss of the Ekspress-AM4 in August 2011, as well as three navigation satellites in 2011.

Source: Michael J. Listner

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

Jon Collins.

Jon Collins, Safety Innovator, Dead at 77

Jon Collins, risk management innovator and recipient of the da Vinci Lifetime Achievement Award for Space Safety, died on August 10, 2012. He is survived by his wife Nancy and four children.

Jon forwarded research in probabilistic applications in dynamics and mechanics, including launch and reentry safety analyses of the Apollo Service module and several missile weapons systems. He introduced the concept of a debris footprint and convinced NASA to perform flight safety risk analysis on the Space Shuttle. His groundbreaking analyses included modeling of explosions, evaluating glass breakage hazards and structural response due to the shockwaves, and determining the trajectories and impact distribution of burning and non-burning debris.

His work since has become the basis for risk management guidelines in space agencies around the globe.

Source: Merryl Azriel

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

JAXA astronaut Aki Hoshide during the third Expedition 32 EVA. - Credits: NASA

Extra Spacewalk Restores ISS Power

On Wednesday 5th September, astronauts Suni Williams of NASA and Akihiko Hoshide of JAXA accomplished their primary spacewalk objectives – on their second attempt – with a little help from a toothbrush. They completed the installation of a power unit on the station's truss. This was their second spacewalk in a week, following an unsuccessful excursion on August 30, and lasted 6 hours and 28 minutes.

On the August 30th spacewalk, which proved to be the 3rd longest space station spacewalk in history at 8 hours and 17 minutes, Williams and Hoshide failed to install the MBSU due to a faulty bolt during the reinstallation process. This time, the pair managed to solve the issue by clearing the bolt hole obstruction with the makeshift tools of a toothbrush, wire cleaner, and nitrogen gas.

Source: Maria Fischer

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

NASA Prepares for Safety Certification of Commercial Carriers

With the Commerical Crew Integrated Capability (CCiCap) program winners announced, NASA is wasting no time getting to work on the next item on its commercial crew checklist: a safety certification process. On August 8, NASA announced details of the process, to be governed by Certification Products Contracts, that will run in parallel with crew capsule developments by SpaceX, Boeing, and Sierra Nevada.

"Hazard reports form the basis of getting through the NASA safety review process, and so those hazard reports are very important," said deputy commer crew program manager Brent Jett. "We want to engage early so that you can use those hazard reports and identification and analysis to influence your design to eliminate those hazards to the maximum extent possible."

Source: Merryl Azriel

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

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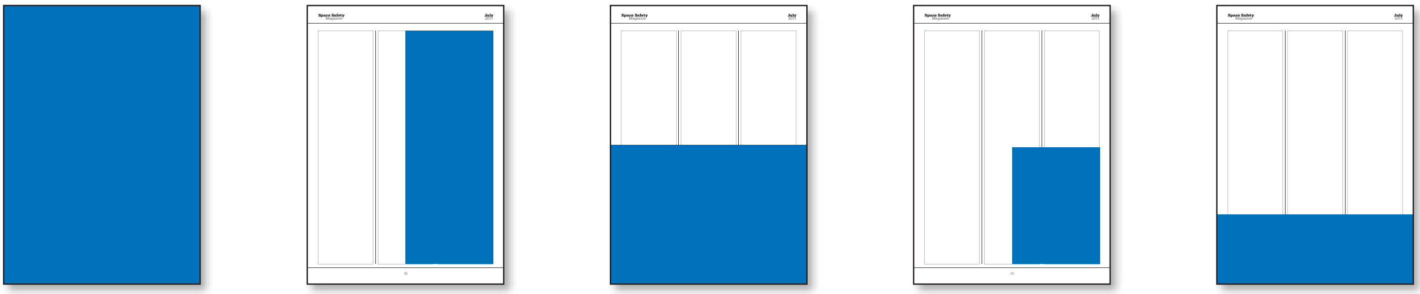

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