



Down to Earth

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At night, when the sky is open to its deepest secrets, human beings dream of escaping Earth's gravity to travel to other worlds of adventure and discovery. The common link amongst all cultures and civilizations is the sky overhead—blue by day and black by night. Incorporated into our art and our science throughout history, the celestial bodies of sun, moon and star, have driven religious practices, social structure, wars, maritime and agricultural operations, and calendars, and that's just for starters. What really makes human beings unique is, perhaps, not just that we dream (for we do not know much about the sleeping patterns of monkeys, dogs, cats or fish), but that we actually try to move that dream into reality. This happened fifty years ago, on October 4, 1957, when Sputnik-1 became the first human-made object to leave Earth's gravity.

Anniversary dates are important to us as human beings, because they mark from where we have come while giving us time to reflect. A half century of accomplishment takes our collective breath away as we contemplate what it was like before, amazed at our inventiveness, all the while knowing that life will never be the same again. We are also re-invigorated to keep moving forward in spite of setbacks from accepting the great challenges of the human spirit which are invariably accompanied by great risk. We somehow know, perhaps intuitively, that the greatest risks can generate the greatest rewards. To deny ourselves the opportunity to seek out the greatest challenges will make us less than we can be. And we will never have a great dream.

As we mark the milestones in our space journey as human beings, we can still look into the night sky and have dreams of discovering life on another planet, or create images of dancing among the stars. Space exploration certainly is not restricted to technology or just to the sciences of astronomy and celestial mechanics. Both our artistic and our scientific souls can explore the universe, unimpeded by gravity. Also, in a sense, we are pushing the envelope on more than our artistic and scientific knowledge and technological skills. We are learning more about ourselves and our relationships to each other, especially politically and ideologically, as the sky above us becomes more accessible to rockets and their payloads from many countries.

From the human reaction to spaceflight, we learned that we need the United Nations and a treaty to promote the peaceful uses of space. Some wish that the "rocket" had never been invented, but like the wheel, there is both good and ill-advised use of inventions, especially with vehicles capable of escaping Earth's gravity. And where would we all be if it were not for communication satellites for television, cellular phones and the internet? There is, however, an uncelebrated advantage of spaceflight and this one, in common with the sky above us, has a universal effect on

human evolution. This is the field of Space Medicine, borne of the dream of human spaceflight and classic tales such as Jules Verne's From the Earth to the Moon.

Imagine a healthy adult human being—I mean a *really* healthy adult, either male or female. Now imagine that this person has traveled somewhere for a week. When examined on return, our traveler now cannot walk a straight line with the heel of one foot against the toe of the other foot. Pushed ever so gently from one side, the person falls to the other side. Pushed from the back, the person falls forward. Curiously, the traveler's arms do not try to break the fall and others try to catch the body that is falling like a rock. If this person had traveled to the same place for many weeks, there might be a crack in one of the bones of the leg or wrist. Also, the traveler could be quite nauseated and may even start filling up bags with the last ingested meal. On standing, our traveler could experience what we in neurology refer to as the "weak, faint and dizzies". Simply put, the traveler might actually pass out while attempting to stand up suddenly.

Where is this place that changes a human being from normal to someone who warrants further medical investigation? Who would travel to such a destination that is so hostile to the health of a human being? More importantly, can this person recover to become normal again? The place is outer space and the travelers are cosmonauts (Russian or Soviet Union trained and flown), astronauts (US program), spationauts (French program), taikonauts (Chinese trained and flown) and other "-nauts" destined to ride a rocket towards the stars. All of us, both men and women, are as fit as possible before we fly but within a couple of days in space have the earliest bodily changes of how life will be without gravity. As physicians, we recognize that the signs and symptoms seen in returning space travelers are also present in diseases such as spinal cord injury, Parkinson's disease, multiple sclerosis, stroke, and osteoporosis. The difference is that from the modest short and slightly longer duration spaceflights to date, we do recover, for the most part, to re-adapt to living with Earth's gravity.

Questions of survivability are still being asked by those who bravely dream of human spaceflight. In the early days of flinging men and the occasional woman off the surface of the planet, NASA and the former Soviet Union needed to prove that spaceflight was safe—that an astronaut or cosmonaut could survive the explosive launch and the fiery re-entry through Earth's dense atmosphere. One year after Sputnik-1, the National Aeronautics and Space Administration (NASA) was formed by the United States of America and given the task of launching a person safely into space and ensuring an equally safe mission and return. Given this mandate, NASA decided to space-qualify human beings, beginning with the original 7 astronauts in the Mercury program and continuing through the Gemini, Apollo, Apollo-Soyuz, Skylab and Space Shuttle missions to the present day International Space Station.

Intuitively, human beings (as we are known to each other) are not pieces of hardware that can be shaken to the point of disintegration on a vibrating table. We also fare poorly if exposed to extremes of temperature, rigorous sudden accelerations and decelerations and vacuum. It is one thing to space-qualify hardware and equipment, and quite another issue to apply the same standards to flesh and bone.

Predating Sputnik-1, science fiction was remarkable in suggesting what human beings could endure, blasting off into and living in space without one bit of corroborating medical evidence. Wildly imaginative, science fiction writers even to

this day, assume that human beings are more like super heroes and therefore invincible to the forces of nature and the unknown. Warp speed, beaming up human beings, and artificial gravity are for many human beings expectations that do not even approach reality. When it comes to space and science fiction, blue and/or green screen techniques give the human body great powers of ability and survival. No wonder there is a large part of the population of Earth who would like to experience spaceflight. Who wouldn't go into space if it makes one incredibly strong with a view out the windows unparalleled on Earth? Is this the truth?

It is obvious that human beings cannot survive the extremes of explosions and fires given the safety and protection of current technology if we fail to be removed expeditiously from impending doom. To date the most public of accidents with experimental human spaceflight have been in the US program, first with the launch pad fire of Apollo 1 in 1967, killing three astronauts, followed by two in the Space Shuttle program—Challenger in 1986, and Columbia in 2003—killing seven crewmembers each. Accidents with loss of life in the former Soviet Union program also occurred, including three cosmonauts in 1971 from de-pressurization during re-entry.

The former Soviet Union and now, Russia, have been studying the effects of spaceflight on human beings for decades, with international participants including French scientists and guest cosmonauts such as the first Austrian, Franz Viehbock, and British citizen, Helen Sharman. After their orbit of the Earth, both Yuri Gagarin in 1961 and Valentina Tereshkova in 1963 each proved their prowess by being ejected while still in their seats from their Vostok vehicles at 7000 meters and then at 4000 meters parachuting free of their seats to Earth. The record for the longest stay in space also goes to the Russian program with the flight of 437 days, 17 hours, 58 minutes for Valeri Polyakov in 1994 to 1995. Does their survival mean that human beings are now space-qualified? Is there more to this than preserving only a space traveler's life or does a non-flying Earthling gain from Space Medicine and allied research?

When I am asked what I consider to be the greatest spin-off from human spaceflight for Earth dwellers, I know it has to be something concrete about human beings that cannot be achieved by robotic systems. It needs to be something beyond the philosophical passion of the Earth from space although I know that the sight of the turquoise atmosphere and pastel Earth colours against the light sucking black of the broader universe profoundly affected my view and my photography. I am reminded of an early 16th century wood engraving also known as the Flammarion woodcut that shows a shepherd poking his body through where the sky and the Earth touch, thus revealing the secrets of the cosmos. If we were to stop instead of only pausing at the sight of a different world and perspective, we would not evolve our thoughts. To me, the gift of spaceflight is the world beyond what we know—a world of unknown possibility and opportunity. This is the world of Space Medicine.

On Earth, the all pervasive force of gravity affects every system in our body, either directly or indirectly and over the millennia this is the context in which we have constructed the basis of clinical medicine. For the first time in our lives as human beings, we have the unique opportunity to move into a world where only one thing has changed. By lessening the force of gravity, spaceflight challenges our previously held theories that are rooted in assumptions of gravity, such as blood distribution in the lungs. But observations in the apparent weightless environment of outer space

pale in comparison with the richness of studying the recovery of the human body on return.

All bona fide medicine on our planet is studied *after* a person already has signs and or symptoms of a disease process. It is virtually impossible to study human beings before, during and on recovery from a disease state. Our medical knowledge is limited to studying disease after it has happened. We ethically cannot produce in human beings on Earth, the changes we see in returning astronauts. Spaceflight, it seems, has opened up a new world of discovery of how our bodies will function in response to one physical change both as we enter and live in space, and then as we ultimately return to live in gravity's influence once more. For the first time, we can study how each physiological system interacts to coordinate a return from being "Earth abnormal" and "space normal" to being "Earth normal" once again. This is the new wave of space exploration.

Some examples include the loss of bone and bone matrix or osteoporosis. All astronauts, both men and women, will suffer from the effects of this, especially after long term spaceflights. Who wants to really break a leg when putting the first foot on Mars? How about the ability to ward off infections? There are increasing data that show bacteria grow bigger and that the human immune system is not as robust during weightlessness. In space, we need two fewer liters of blood in our circulation because of blood volume shifting into our hearts up from our legs where it is innocently held by gravity in our veins on Earth. This inevitably causes a change in how our heart and blood vessels regulate the flow of blood through our bodies. All of this has to be restored to "Earth normal" or we will not be able to function under the influence of gravity.

Most impressive for me were the changes in my nervous system when I landed after my spaceflight. In just over eight days in space, I had lost many of the reflexes that my body uses to combat the force of gravity. If there had been a bag of gold at the end of the stretcher, I would not have been able to do a sit-up to grab it. I banged into door frames and staggered around corners. It was as if a precision-guided laser had carved out a specific area of my brain that dealt with keeping me upright and safe from being drawn into the centre of the Earth. Prolonged standing without my inflatable trousers to keep the blood flowing up from my legs to my head made me feel decidedly faint. This was the edge of where the Earth touched the sky and I was poking my head into a new world of discovery.

When the blue day sky unveils the clear black of night, I look at the cosmos with a new eye and new insight. In this Earth exploration phase of being an astronaut, I am thrilled to explore and photograph this planet, moving my dreams into reality. Other generations will succeed me in the adventure of spaceflight and the wealth of medical discoveries still to be made. Perhaps these will be in laboratories on the Moon, or even on Mars. As human beings, we will certainly continue to celebrate our milestones as benchmarks of how we have grown and from where we have come. The greatest memories will always come from the greatest dreams.