

The Bridge to Space

by Mike Combs

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To my precious wife Sandra. Thanks for the encouragement.

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Prologue

1981: A hopeful view of the future

Bruce Franklin was an extremely bright, brown-haired seventeen year old who had just been seized by an optimistic vision of tomorrow. He had finished reading Gerard O'Neill's "The High Frontier" and now his young mind was ablaze with visions of giant space habitats housing thousands of humans, solar power satellites beaming cheap, clean, plentiful, eternal energy to the Earth, and mines on the Moon and the asteroids, relieving the Earth of humanity's voracious need for resources.

Bruce, like the author, had been getting bugged lately by all the persistent talk about "limits to growth", and how over-population would inevitably result in shortages of energy and material resources. A teenager living in the '80's does not want to hear about how the standard of living is doomed to sink lower and lower beginning in the next century. The proposals in the book not only seemed to provide an alternative to this miserable future, but also fitted in neatly with Bruce's own personal philosophy that to every problem there lies a solution, and that it was no heresy at all to look for that solution in the world of technology.

He was particularly fascinated by a piece of technology called a mass-driver which the book described. It was a kind of stretched out electric motor, a linear electric catapult. The book had outlined two uses for this device. One was as a reaction engine which could literally use anything for fuel (it was even proposed that ground-up pieces of Space Shuttle external tanks could be used). The other was as a catapult to launch ore off of the moon. Since the moon had no atmosphere and low gravity, it was suggested that ore mined from the moon be simply launched from the surface into space through the mass-driver instead of burning up rocket fuel to lift it.

Bruce was intrigued by the design. The ore was loaded into a "bucket" which was ringed with super-conducting magnetic coils. The mass-driver itself consisted of a series of electromagnetic coils. Electric-eye devices sensed the position of the bucket and controlled the pulsing of current through each driver coil so as to continuously accelerate the bucket down the mass-driver. Accelerations of well over 1000 gravities were possible. Toward the end of the mass-driver, the coils begin to decelerate the bucket, allowing the ore to fly out. The bucket re-circulates back to the beginning of the mass-driver and the process begins again.

Bruce was not only very bright, but inventive as well. He was always taking things apart, tinkering, and building things from construction kits. He was invariably referred to as a "gifted student", and his future career direction toward some kind of engineering profession was already well established. It occurred to him to actually attempt building some sort of model illustrating the principle of the mass-driver.

Mass-driver Model Mark 1 consisted of a glass tube with small coils of wire wrapped around it at regular intervals. The wires led off to a nine-volt battery and a disk with short lengths of bare wire

exposed around the circumference, like the numbers on a clock face. By running another wire around the edge of the disk, he could sequentially energize each coil. A penny nail placed in one end of the glass tube could be accelerated down its length, flying out the far end. He learned how to most efficiently sweep the wire around the contacts with an accelerating movement until he could make nails hit the wall with a most impressive whack. Sometimes they would even stick. His father teased him that he had invented the world's most complicated hammer.

Mass-driver Model Mark 2 was a much larger, sturdier affair built in the backyard. The framework was made out of three old plumbing pipes Bruce had scrounged from behind the tool shed. He wound each electromagnetic coil by hand from varnished wire unwound from almost a dozen transformers. There was no way he could recreate the electric-eye bucket position sensing mechanism, nor could he equip his bucket with superconducting coils. However, he had an idea that would make use of two electric starter brushes he had pulled from a car in the junkyard. He arranged two dotted lines of electrical contact strips down the inside of his mass-driver. When the bucket was placed in one end, the starter brushes would connect a circuit, creating current flow not only in the bucket coil, but in the mass-driver coil ahead of it. The one magnetic field would attract the other and the bucket would move. As soon as the bucket came abreast of that coil, that circuit was interrupted and it was the next coil pulling. There would be no deceleration and re-circulation of the bucket, so it was more like an electric cannon. Bruce was interested to see how far he could shoot the bucket through the air.

Bruce hooked up his connectors to three fully-charged car batteries and, with a pause for drama's sake, placed the bucket into his model. The model promptly spit the bucket back out at him. To his chagrin, he realized he had wound the bucket coils the wrong way such that the two magnetic fields being produced were repelling each other, not attracting. Wanting desperately to avoid laboriously re-winding the bucket coils, he hit on the idea of remounting the starter brushes angled the other way, so he could essentially turn the bucket around and use it backwards. With high anticipation, he once again placed the bucket in.

There was a THUMP as the contraption recoiled. The bucket made an audible WHOOSH as it sailed away. He had inclined his mass-driver less than ten degrees from the horizontal, but was astonished to see the bucket disappear from view.

After taking a few seconds to get a fix on landmarks near the horizon, Bruce turned and hopped onto his rusting bicycle to scour the cattle fields and highway birms where his electrically launched payload must have come down. He looked until the daylight began to fail his eyes, but to no avail. He supposed that the bucket may have simply crashed into some dense weeds out of sight, or may have rolled beneath something which it hadn't occurred to him to look under. Perhaps he had badly misjudged the direction his projectile had taken. But he couldn't shake the rather awe-inspiring feeling that the bucket had gone much, much farther than he had ever thought possible.

"Man," he thought to himself as he pedaled homeward to a cold supper, "A guy could do things with this."

Chapter

1

Evacuation

November of 2000 found Jacob Tanner nearing the fulfillment of a childhood dream. For as long as

he could remember, he had fantasized about flying into space. He had taken NASA's advice to all aspiring astronauts: stay in school, study math, study science. He threw himself into his class work, resolving to excel at everything he did, so that he might be worthy. After two unsuccessful tries, Jacob finally made it into the Space Shuttle Astronaut Corp. Seven years of intensive training later, and here he was at last: lying on his back in the orbiter mid-deck, waiting to thunder off into the heavens.

This was the most exciting moment in his life. But in a way, his present location was a bit on the dull side. There were no windows to see out of from the shuttle's mid-deck. Nothing much to look at but storage lockers. He had to admit that Ruby's presence sure improved the scenery down here, though. The thirty-five-year-old mission specialist sat to his right, a bit above his position. She had delicate, pixieish features and the most adorable dimples. When they were all suiting up, Jacob was amused to note she had not tied up her long, scarlet hair into a ponytail. Soon they would all be in zero gravity, which meant Ruby's lovely, flowing red tresses had that "Brillo-pad" look in store. It would be just the thing for some good-natured ribbing later on.

Jacob then realized he shouldn't be too hard on his fellow astronaut. During the months this shuttle crew had trained together, Ruby and he seemed to connect in a very special way. They were both the "space rookies" of the crew, and this had started the close bond between them. For some time now he had been planning to wait until the mission was completed, and then see if the relationship could be advanced to a new, more intimate level.

They were about fifteen minutes from launch when Jacob began hearing disturbing things through the earphones in the flight cap he wore under his helmet. CapCom was advising the flight crew of a sudden drop in hydrogen fuel pressure. That certainly didn't sound good. Their pilot, Commander Chapman, was convinced thermal stresses from the fuel loading had caused the External Tank to split a seam. Jacob got a sinking feeling none of them were going anywhere today.

Then there was a sudden cry from the Commander. "Evacuate! C'mon! We've got to get out of here!!"

Almost immediately, Chapman and his co-pilot were dashing in from the flight deck, and over to the hatch. It was dawning on Jacob that the fuel leak must be serious enough for there to be a danger of fire. A feeling of unreality gripped him as he unfastened his restraint and joined the rest of the crew at the hatch. Ruby glanced at him, concern on her face. Jacob tried to give her a reassuring look.

The hatch was open, but the "white room" was not yet back to the orbiter. It swung toward them on its long arm, ponderously, agonizingly slow. As they looked downward, they could plainly tell where the split seam in the External Tank was located, as it billowed out heavy, white vapors. The rupture was below them, fairly close to the orbiter.

The white room still had not reached them. Ruby began to dance up and down with impatience. "Hurry...hurry...hurry...hurry..."

She trailed off, and placed a hand over her mouth, eyes wide. Her voice had a ridiculous elfin quality to it. Ruby sounded like a chipmunk. Jacob tried to think when he had heard a human voice with that peculiar resonance before. Then he knew: the last time he had been around a prankster who had put a helium balloon to his lips, inhaled, and then spoke with the light gas passing over his vocal cords.

What could be causing it? At the same time, each member of the crew realized the air around them was filled with odorless hydrogen gas. It was the one gas lighter than helium, even less of it would produce the same munchkin voice. Lighter than air, it was rising upward to where they stood. A chill went through Jacob which was unrelated to the spill of super-cold fuel. If the surrounding air was that

saturated with hydrogen, the slightest spark would touch off an inferno of Hindenberg proportions.

The white room arrived at last, and the crew leapt into it. They scrambled through the walkway and into the gantry tower. Soon they were at a cage hanging from a pulley on a cable which lead down to the distant ground below. This sliding cage had been conceived by NASA as the quickest way for a shuttle crew to get away from the launch pad in an emergency. If they could only slide away down the cable, they would be deposited near a sturdily-armored vehicle which could take them even further away. The crew piled into the cage.

Jacob had trained on this procedure, but it had seemed like a silly amusement ride at the time. Now, hopefully, it was going to save everyone's butts. Chapman threw the brake lever up, and they began to soar down away from the gantry.

The cage descended on the cable with increasing speed, but the Commander was not about to apply brake just yet. Suddenly, the space shuttle behind them transformed itself into a blazing fireball. They all looked back in shocked astonishment as the concussion dashed the gigantic brown fuel tank open. Tons of liquefied hydrogen and oxygen mingled, vaporized, and then ignited. Pent up energy sufficient to hurl a multi-ton vehicle into space was released all at once.

The shock wave struck their bodies. The sensation was akin to the peculiar feeling one gets in the middle of one's chest when standing near a parade when the big bass drums come by, only a hundred times more severe. Jacob felt his heart was going to burst. The astronaut's bodies jerked with the motion of the passing concussion like marionettes being yanked by some spiteful puppeteer.

Now a vast, pale wall of nearly-invisible blue flame was bearing down on them. When it touched them, everything and everyone instantly burst into blazes. Their orange flight suits only prolonged the torment. Man and woman alike erupted with high-pitched shrieks of agony. Then the flame silenced them all forever.

By the time the cage crashed into a barrier on the ground, there were no survivors in it. Only gruesome remains for a miserable pathologist to study in an attempt to make sense of it all for a nation seeking answers to yet another Space Shuttle disaster.

Chapter

2

A general dissatisfaction **with the current state of affairs**

Now it was January of 2001, and the "end of the millennium" hysteria was beginning to die down somewhat. It was so unfair; the world had had to go through it twice. Despite no shortage of experts lecturing on television talk shows and in Sunday supplement articles, there were still many who believed 1999 was the last year of the Twentieth century. December of 1999 had been even more tumultuous than last month, as every "end of the world" fanatic crawled out from whatever place such kooks resided. When 2000 dawned on the world and Judgment day was clearly not yet at hand, the devotees of Armageddon explained that there had merely been a slight error, and December 31st, 2000, the truly last day of the millennium, was the day of dread. This date came and passed free of global doom also, and the Earth, except for the much more minor social tremors which occur at the end of each century, could

be relatively peaceful until the year 3000 AD. Not that even the most skeptical thought humanity could possibly go on that much longer.

Bruce Franklin had just completed what many considered to be the crowning achievement of his career: a magnetic levitation mass transit system connecting New York with Chicago. This engineering feat was possible thanks to Bruce's development of the first practical nuclear drilling machine. Looking like a giant sharpened pencil with tank treads jutting out at five different angles, the device did not so much drill as melt its way through the earth. The conical nose of the machine was the world's hottest operating nuclear reactor, and glowed yellow-hot when activated. Soil and rock were liquefied, pushed aside, and left to cool, forming a very strong tunnel wall of solidified magma.

Once a tunnel was created from New York to Chicago, the acceleration and deceleration portions were mounted with magnetic coils nearly as big around as the tunnel itself. This was really no different from the mass-driver technology which was Bruce's engineering forte. For the entire distance, the floor of the tunnel was covered with an electrically conducting aluminum trough. Then all of the air in the entire tunnel was pumped out, leaving a vacuum.

The maglev vehicles, equipped with the latest superconducting coils which operated at liquid nitrogen temperatures, were accelerated well above the speed of sound by the acceleration coils. A principle called dynamic magnetic levitation caused a repulsion between the vehicle magnets and the curved aluminum trough, generating lift.

Since there was no air drag and no friction due to wheels or sliding surfaces of any kind, it had proved to be the most energy-efficient method of transportation ever devised. The energy cost of a maglev trip was less than one-fifth of the cost for any other form of transportation. To top it all off, most of the energy put into accelerating the vehicles was recovered at the end during the deceleration phase. Acceleration Inc., the new multinational corporation which had funded the venture, was able to undersell planes, trains, and automobiles by a substantial amount. There was simply no other means of moving people so quickly, quietly, comfortably, and energy efficiently on Earth.

Bruce had worked long and hard on the project, and now considered his part of it to be over. There were already ambitious plans to make another tunnel from Chicago to Los Angeles, along with a vast, arcing bypass south of Chicago, so both coasts could be linked non-stop by maglevs. But the construction principles were already well established, and Bruce would leave them to it.

He needed to unwind, and decided taking in a movie would be just the thing. Inevitably, "2001: A Space Odyssey" was in re-release this year. Bruce had fond childhood memories of this movie, and promptly went.

He sat in the theater, and once again became immersed in Kubrick and Clarke's vision of the dawn of the 21st Century. The giant, rotating, Space Station 5. The Aries shuttle, making a trip to the moon seem no more incredible than an international air flight. The sprawling Clavius moonbase. The expedition to Jupiter. And of course HAL, the conversant Artificial Intelligence.

Prior to coming to this film, Bruce had watched a number of news stories comparing the 2001 of the movie with the real 2001. The reality was far from being so grand. There were only a couple of spindly space stations, and they were nothing like the colossal spinning wheel of this venerable cinema classic. If anything, the world seemed even further away from a future in space than it did in the late sixties when 2001 premiered. With last month's destruction of a shuttle orbiter and the launch pad, and the loss of all crew, it was now obvious that the American space effort was stuck in yet another hiatus which could easily prove as lengthy as the one which followed the Challenger disaster of 1986.

The questions were asked and re-asked; Why no moonbases, Why no Jupiter expeditions, Why no PCs which could speak like a human, and not just parrot programmed phrases. There were theories put forth: Lack of funding, Lack of quality education, Lack of will.

Bruce walked out of the theater surrounded by a dozen conversations on the meaning of the film's ending, and stepped into the night air. He glanced upward at a nearly full moon which had not been touched by humans in thirty years, and asked "Why?" himself.

Then, he resolved to do something about it.

Chapter

3

Selling the crazy idea

Bruce was sitting with his co-worker and best friend Reggie Deitrich in the foyer to the office of Elisabeth Anderson, president of Acceleration Inc. Reggie had jet black hair and eyes, was of medium height and build, and had a cleft in his chin so deep it made everyone wonder if he had to Q-tip it out every morning.

Bruce knew he would only key himself up by mentally rehearsing a presentation which he already knew by heart, so he instead tried to relax himself by studying the Acceleration logo on the wall. It was one of those three-inch-thick backlit affairs with a halo of light surrounding each heavily back-slanted letter. The slant of the corporate logo was, he supposed, intended to convey a feeling of rapid acceleration. People get paid to come up with stuff like this, he mused to himself.

Bruce was mildly nervous, but otherwise quite chipper despite the early hour. Reggie hated that about him. Bruce was, as they say, bright-eyed and bushy-tailed even before the crack of dawn. It always took time and massive doses of caffeine for Reggie to get started in the morning. Bruce wouldn't even touch a cup of coffee, simply bouncing out of bed fully alert and ready for his day. Bruce attributed the difference between them to their differing lifestyles.

It was interesting to compare these two men: Reggie the reveler who never missed a party, Bruce the type-A personality who accumulated vacation time until his employer would kick him out the front door. Not that Reggie wasn't a crack engineer in his own right. Merely that he saw it as a means to an end. For Bruce, building new things was his reason for living. The contrast between the pair, between the cut-up and the straight-lace, was remarkable. More remarkable still was that not only did the two work together effectively, they genuinely liked each other as well.

In addition to still being groggy at this time of morning, Reggie was also pessimistic about the presentation ahead of them. Although he had worked with Bruce on every detail, the scale of their proposal still staggered him. He was afraid it would stagger Elisabeth too, to no good affect. Still, Bruce was the darling boy of Acceleration right now. His innovations had made the Chicago to New York maglev route possible. Acceleration Inc. would not exist in its present form if not for that. If there was anyone who could successfully get this through, it might be Bruce.

Brent, Elisabeth's male-model-perfect secretary, ushered them into the office. The decor was chrome and glass. Elisabeth greeted them both warmly. She had a wide face surrounded by dense blonde curls. It was obvious from her hairstyle and outfit that she rejected the notion a female had to be

man-like to succeed in corporate America.

"Well, Bruce, word is you have a proposal even bigger, and doubtless more expensive too, than the New York to Chicago run. OK. Make your pitch, and make it a good one."

While Bruce moved to the wall-sized monitor at the side of the office, Reggie settled down on a couch. The couch was one of those ghastly creations of white vinyl which did not so much support you as surround you. Sinking into its shapeless mass, Reggie felt like a foreign body being engulfed by a white blood cell.

The monitor came to life with an illustration of a slightly curved horizon with a long, straight line hovering over it. Two short vertical lines connected the ends with the land beneath. Bruce began his presentation.

"Acceleration Inc. has successfully used magnetic flight to reduce the cost of traveling across America to a small percentage of its former value. Our proposal is to now apply the same technology to space travel."

"We are still waiting for a space transportation system capable of sending people and cargo into low Earth orbit for a price per kilogram which would make space development economically feasible. We have taken rocket technology about as far as it can go and it's simply not the answer. If rockets can't do it, then what?"

"If we relate the cost in energy of lifting a kilogram into orbit to the cost of the electricity required for an electric motor to do the job, the requirement would only be about 9 kilowatt hours. Even subtracting for efficiency losses, the price for a ticket into space would still be less than a dollar per kilogram. For comparison, there has not been a rocket built yet which has achieved less than five thousand dollars per kilogram."

Bruce paused at this point and became somber. "Issues of efficiency and cost aside, I think the events of last November drive home the point that rockets are not only a very expensive way of getting into space, they're a very dangerous way, too. It's asking a lot to expect someone sit on top of several hundred tons of high-energy explosives while you light it up."

"The most perfect space transportation system would be an elevator which could lift you into space. This theoretical structure has been called an orbital skyhook. A satellite in geosynchronous orbit would play out cable in two directions: one towards the Earth, and the other away from it."

A small window at the upper right of the monitor began to illustrate the principle with a graphic. "As long as the masses being reeled out from both ends were equivalent, the entire structure would continue to move with the Earth. You keep unwinding cable until one end reaches the ground. Secure it, and now you can ride an elevator car to geosynchronous orbit. In addition to that, you can launch yourself to other planets by going beyond the orbit level to where centrifugal force would sling you off when you let go. Now this may sound suspiciously like getting something for nothing, but what you are really doing is tapping into the angular momentum of the Earth. But we could launch payloads for hundreds of thousands of years before detecting even the slightest slow-down in the Earth's rotation rate. Or perhaps forever. Returning ships could save themselves from having to burn up fuel by rendezvousing with a point on the cable matching their velocity, and then riding down, giving up their momentum to the Earth."

"This would be the most ideal means of accessing space. There's just one minor flaw: It can't be built with any engineering material known or theorized. There is nothing we have from which we can make a cable capable of supporting its own weight, let alone anything else, for the many thousands of kilometers necessary. However, there is a way to build a system that can be made with existing materials

and which would launch payloads with electricity, not rocket fuels."

"Our proposal is to build a high-altitude hot-air balloon borne space launcher on the coast of Brazil near the equator. It may seem beyond belief that we can build such a massive structure in the upper atmosphere, but I assure you our computer simulations indicate it is possible."

Bruce put his finger on the wall-sized monitor and dragged it downward diagonally. His moving finger-tip drew a "rubber band" box in red. When he pulled his finger back, the box and its contents expanded to fill the screen. The thin, dimensionless line paralleling the Earth could now be seen to have close, evenly spaced dots at the top. He repeated the process and the dots were resolved into spheres, each of which was one-half transparent, the other half white. The globes were all tilted at the same angle, and one could look through the transparent hemisphere to see that the interior of the other half was dark. A V-shaped support, almost edge-on in this view, was mounted on the horizontal axis of each sphere to suspend a thin line at the bottom. Bruce chose one of the half-opaque bubbles, and enlarged it further.

"The key to the enterprise is these supporting balloons. They are basically solar-powered hot-air balloons about a mile in diameter." Elisabeth raised her brows at this, but Bruce continued.

"One side is transparent, allowing sunlight into the interior. The other is black on the inside so as to absorb the light and convert it into heat with the greatest efficiency. This light-absorbing hemisphere is white on the exterior. This minimizes infra-red radiation, again to maximize the heat in the interior. Each balloon rotates once every 24 hours, tracking the sun." The balloon began to rotate like a wheel on the V-shaped support. "Thus the transparent side faces towards the Earth at night. This reduces the loss of heat due to infra-red as there is a certain amount of IR flux coming up from the Earth. Don't get me wrong: thermally, the system will still lose ground at night, but not as bad as if the clear portion was pointing at the cold of space. There is also a thin disk of aluminized mylar less than a kilometer in diameter suspended underneath each balloon. This reflects a certain portion of the infra-red back into the balloon when it is pointed downward. At night, there will be a certain amount of slack in the anchoring tethers at both ends, but the system will definitely stay aloft."

Bruce now drew a small red box on the thin line beneath the balloon. The view inside the window exploded to fill the screen. The mass-driver could now be seen as an open framework supported by suspension cables coming down from the balloon pivot points. Magnetic coils, about the same proportions as a man's wedding band, were spaced at regular intervals.

"The mass-driver is about three meters in diameter and boosts small vehicles to orbital velocity with an acceleration of ten G's. I know that sounds like a lot, but any reasonably healthy individual can easily tolerate ten G's for the minute and a half it would take for a launch. I would eventually like to double the length of the launcher, reducing the acceleration to five G's in order to open up the service to the elderly, and those with heart conditions. But that's a long term projection."

Reggie squirmed uncomfortably in the embrace of the couch. Bruce seemed to have side-stepped any specific mention of the linear dimensions. It might be better to just hit the subject head on than to save it for last.

"Launcher altitude is twenty four kilometers. In terms of air density, that puts it above 15/16ths of the atmosphere. Air pressure is down to less than one pound per square inch. Air drag is going to be extremely low. At this altitude the sonic booms produced by accelerating vehicles will be very mild, even for cities directly beneath the launcher. Cities near military bases carrying out artillery training have had to contend with far worse."

"These are the chief advantages of this system against any ground-based mass-driver launcher.

With a ground-based system, you have the problems of sea-level sonic booms and punching your way through the densest part of the atmosphere. Energy loss would be very high, and the payloads would even require an ablative heat shield. The launch capsules would be like a meteor in reverse. By placing our launcher near the top of the atmosphere, we avoid all these difficulties."

He pointed at the display, and now the point of view soared back and upward. The display became a map.

"Ideally, any space launcher should be built as close to the equator as possible. This is in order to take maximum advantage of the Earth's rotation. We believe the best location would be here in southern Brazil. Brazil has the best industrial infrastructure in South America, and a good resource base. We would anchor the far end of the launcher on the peak of Pico da Bandeira, one of the mountains of the Great Escarpment on Brazil's south-east coast. Pico da Bandeira is almost three kilometers high, so it would save us that much length in anchoring tether. Placing the exit of the launcher over a mountain which slopes down to the seashore is also ideal for sonic boom dissipation. The starting end would be less than four hundred kilometers north of Rio de Janeiro, a little over 400 kilometers north east of São Paulo (that's the tenth largest city in the world by the way) and around 700 Km from Brasília, the national capital. All of these cities have excellent international airports."

"Launcher operations could be carried out from Belo Horizonte, Minas Gerais state capital and the nearest major city. In 1999, Belo Horizonte overtook Rio as the nation's second-most powerful economy (after São Paulo). Other favorable factors include a large bauxite mine located midway between Rio and São Paulo. That's a critical factor, as aluminum is a major component of the mass-driver coils, structural members, and also the anchoring tethers. Hydro-electric dams at the Furnas Reservoir and other nearby water works provide abundant electricity to the region."

Now the monitor displayed a rotating graphic of a bullet-shaped vehicle. It had short, stubby fins which projected back from the flat rear of the craft.

"We have designed three vehicle models. One is a fuel tanker. The other is for cargo which would include satellites, and consumables for space station Alpha. The third is a passenger vehicle capable of life-support for the less-than-an-hour trip to Alpha. Our current design is a two-seater, but we have long range plans for four and six seaters which are simply stretches of the original design. Now, let's step through the process of sending passengers into orbit."

The monitor continued to illustrate Bruce's concepts. "Passengers would ride an elevator car up the tether cable at the launch end to the boarding station." The boarding station was a pressurized globe about four stories tall. At the base was a receiving station with large grapplers for transferring launch vehicles from the tether to a storage garage on the lowest level of the globe. The elevator linked up to a docking ring not unlike that of a space station. There was a lobby, an airlock leading out to the mass-driver, a depot for the "buckets" that the launch vehicles fit into, and on the top level, an observation lounge with windows.

"There they would board a launch vehicle. The launch vehicle would back up into a bucket, latch in, and then cycle out through the airlock." The lip of the bucket which now surrounded the bullet-shaped craft slanted, extending the curve of the nose backward. It was a flush, aerodynamic fit. "The bucket and vehicle are accelerated at 10 G's to orbital velocity. Once the proper speed is attained, the last few coils of the launcher apply a decelerating force, and the bucket is yanked back and away from the vehicle. By the way, when we do this, we retrieve most of the energy put into accelerating the bucket in the first place. The vehicle exits the launcher. The bucket travels back up the mass-driver to the station, is serviced, recharged with more liquid nitrogen, and stored for a future launch. By now, the launch vehicle is most of the way into low Earth orbit. Forty five minutes later, 180° around the Earth, four small

hydrogen/oxygen rocket motors fire, and circularize the orbit. The ship then rendezvous with a low orbit space station."

"On the return leg, the same vehicle is lowered from the station on a tether. The lower it goes, the greater the gravity on it vs. the station, and the tether comes to be under tension. At a well-timed point, the cable attachment releases the capsule, and it heads into a new, lower orbit which grazes the upper atmosphere. The station, on the other hand, gains the orbital energy the capsule has lost. This will help the space station save on orbital maintenance fuel. The vehicle re-enters the upper atmosphere, decelerating like the space shuttle. Incidentally, the belly of the craft is composed of titanium: a very high temperature alloy. No messy silica heat tiles. At a certain altitude, a steerable parachute deploys. Under computer control, the craft is guided to the landing field, and the landing gears drop. The landing field is circular. Runways run radially in all directions, so approaching craft can always land into the wind. Passengers or cargo are offloaded. The vehicle is towed to the tether at the beginning of the launcher. It's then re-fueled, sent back up the tether, and the whole process begins again."

Bruce turned around from the monitor to face Elisabeth. "I'm convinced this new century will see a mass migration off of the Earth into free space. This is the transportation system which will make it possible."

Chapter

4

Potshots

Elisabeth was obviously very impressed. "This is a pretty staggering concept. Let me play Devil's advocate, and try to shoot it down. Lord knows I would sooner have it all come tumbling down in theory than in actuality. I don't much like the idea of this gigantic space launcher crashing down on the heads of several hundred Brazilians." Bruce smiled encouragingly.

"OK, what about weather?" she began. "If the balloons are solar heated, then what about cloudy days?"

"The mass-driver and its support balloons will be above the Troposphere, above the cloud layer, and above storms," Bruce replied. "The only part of the system down in the weather is the support tethers at both ends, and they have a very low cross-sectional area. Winds will push them around some, but not a lot. Remember we are building fairly close to the equator, an area known as the "doldrums", so there are no hurricanes."

"How about lightning strikes, then?" Elisabeth held a hand up in front of her. "I know, I know, it's above the weather. Actually, I was thinking more about strikes on the tether cables."

"It's interesting: no lightning will be possible in the presence of an electrical conductor linking the cloud layer with the land. The cloud layer will literally be grounded. So the areas immediately around the tethers will be the only places on Earth where you can stand and be one hundred percent safe from lightning."

"Meteors?"

"Well, there're not much more odds of the launcher being struck than a shopping mall, and you certainly wouldn't hesitate to build a mall over the possibility. I know it's in the upper atmosphere, but

most meteors begin to disintegrate at even higher altitudes. It's not as big a target as one might think."

"How will the launcher stay straight?" Elisabeth wanted to know.

"There will be lasers running down its length for data communication. Those lasers will also be used for guidance," Bruce answered. "Sensors will detect deviations from straight and correct them by signaling the yardarms to apply the appropriate forces. It's not a major problem. There is some wind at this altitude, but remember air pressure is one sixteenth sea-level. So a sixteen kilometer per hour wind would apply no more force than a one kilometer per hour wind here at the surface."

"What if an airplane crashes into it?"

"Private aircraft don't fly this high, and we can certainly control local commercial jet traffic. A jet would be more likely to hit a balloon than any other part. Balloon repair is viewed as ongoing maintenance. Some will fail anyway due to age or defects."

"Earlier I showed you the schematics for three launch vehicles. We have designed a fourth vehicle for repairs. A repairman would ride the vehicle out on the launcher to the area of the deflated balloon, and repair it on-site. Oh, that assumes the balloon has folded itself evenly over the mass-driver. Our simulations indicated that as a balloon deflates, it could either fall pretty much evenly over both sides of the mass-driver, or slip over to one side and hang straight down from the bottom. If it does the former, then the weight is distributed rather uniformly along a substantial length of the mass-driver, and the stress loads are tolerable. If the balloon hangs straight down from its supports, on the other hand, then the load stress is too concentrated in one area. Explosive bolts will fire, and the balloon is jettisoned rather than risking structural damage to the mass-driver."

"But let's assume for the sake of argument," Bruce continued, "that against all odds, an aircraft plowed right into the mass-driver itself. The launcher would not crash into the ground. The entire structure is at neutral buoyancy. Even if the launcher were severed, the two ends would merely drift around close by. Jet engines would be used to maneuver the ends back together so repairs could be implemented. A plane severing a tether would be the worst-case scenario, but extremely unlikely. The tethers have lots of "give", and present a very narrow target. A wing strike would certainly bring down the plane, but not the launcher. I'm not sure even a direct strike would sever the cable, and I doubt if a pilot could manage that even if he were deliberately trying."

"Let's talk about that, then. What about terrorism?"

"There's a lot of redundancy built into this design. A terrorist would have to destroy major portions of the launcher in order to bring it down. Any one bomb (or half a dozen bombs for that matter) wouldn't do any damage which couldn't be fixed. We can certainly institute the same kinds of precautions with regard to luggage as is common in any air terminal. Besides, bombs are not very effective at high altitudes. Still, assuming he could somehow smuggle a bomb aboard, an insane individual could certainly blow up a vehicle, himself, and anyone else riding with him. But operations would only be halted temporarily for repairs, and then resumed, probably within a week. The very worst terrorist scenario my staff was able to come up with involved a group with access to a cruise missile. They off-load the explosives and send it straight down the line, puncturing most or all of the balloons simultaneously. I suppose we could always put an installation of Patriot missiles at either end of the launcher. In the long run, maybe even particle or laser beams. Personally, I don't give the cruise missile scenario much credence. I don't see the missile staying on course for very long after slamming into the first five or six balloons."

"What you said about lasers got me thinking. What about fanatics armed with a high-powered

laser?"

Bruce paused for thought. "Even a really high-wattage laser would only punch small holes in the balloons. To really do any real damage, terrorists would have to sweep the laser down the row. It would have to be a very slow sweep, a fast one would not put enough heat into any one spot to burn through. Yeah, a sweep slow enough to deflate any balloons would take many hours. A daylight attack would be rather fruitless. The white sides of the balloons would face towards the Earth, and the white color would reflect away much of the energy. A nighttime attack would be highly visible."

"It's a safe investment," Bruce insisted, "and a very profitable one as well. Our projections are, in the short term, to under-sell Ariane by a factor of two and the Space Shuttle by a factor of three. The space-launching world will beat a path to Acceleration's door. Once we have launched an amount of people and payload equal to around ninety Space Shuttle launches (and we can do that surprisingly fast), we will have reached the break-even point. Everything from that point on is pure profit."

Elisabeth was leaning forward in her chair. "What you are proposing is pretty incredible. You say each of these balloons is a mile in diameter. There seem to be an awful lot of them. Just how long is this thing supposed to be?"

Reggie could hear a stock sound-effect in his head. It was the one of the dropping bomb whistling down lower and lower. Next would come the stock explosion sound-effect.

Bruce hesitated only briefly. "A little over three hundred and ten kilometers," he answered. Elisabeth's eyebrows shot up. "I know, it's a lot, but the elements are just the same components endlessly repeated. This makes it well suited to automation. I foresee factories with no human workers whatsoever. In one end goes bauxite ore and energy, and out the other comes mass-driver components and tether cable day in and out."

"And how much is this little enterprise going to set me back?"

Thin-lipped, Bruce gave her the answer. "Forty-five billion."

Boom.

Elisabeth sagged back into her chair and blanched noticeably. "There's no way. There's simply no way."

"Oh come on, Elisabeth," Bruce implored, "This is the biggest, highest stake venture there can be in the world. You can't expect it to come cheap."

"No way. I mean there is physically no way to get that kind of venture capital together." Elisabeth was shaking her head solemnly.

Reggie was ready to leave the office to start work on something a little bit more doable. Bruce, however, was standing there, thinking furiously. Suddenly, he strode over to the giant monitor and stabbed his finger at the end of the launcher. A small, red, two-sided arrow appeared above his fingertip. He pushed in on the end of the launcher graphic, and it telescoped. He pushed it down to two thirds of its former length.

"OK. The length is now a little over two hundred kilometers. Call it about thirty billion. In order to still achieve orbital velocity, acceleration will now have to be twenty G's. You can still launch supplies, fuel, and satellites. And I suppose you could still launch people if they were young, in good health, and specially trained and conditioned."

"Still can't do it."

Bruce whirled back to the screen, and savagely crushed the launcher down further still. "There. Length is one hundred kilometers with a price tag just a hair over fifteen billion. Acceleration is now thirty G's. You can still launch raw materials and fuel. I guess you could also launch specially-made satellites with circuitry and components hardened to withstand the G forces."

Elisabeth looked at the display thoughtfully. She appreciated that the one single biggest cost of any major space activity was the fuel. If Acceleration Inc. could provide fuel to low Earth orbit at a lower cost, it could be quite a coup. The communications satellite launch industry was quite lucrative also.

"It would be tempting if the money could be raised, but it can't," she explained. "Not even a multinational corporation like Acceleration could raise that kind of capital. A combination of multinationals might, but that would get us in trouble with the anti-trust laws. We could try to seek some kind of special exemption from the government, but...I just don't know."

"OK, Liz, I'm going to try to scare you with the standard boogie man: The Japanese. After beating our pants off in steel, automobiles and electronics, they are now merrily trashing our aerospace industry. It is so typical that we make plans, abandon them, then they pick them up and follow through. Then, when we belatedly decide we did want the technology after all, we buy it from them. And we wonder why we have a trade imbalance. One of the best things Acceleration has done is to wrest leadership in magnetic flight back from the Japanese and the Germans. The Japanese still have much expertise in magnetic flight, though. They also have absorbed every American study ever published on moon bases, Solar Power Satellites, and space habitats. They sit poised and ready to spring into action as soon as the price for a pound of cargo to orbit declines to a certain critical level. The Japanese may chose to try pushing it to that level with some scheme very similar to the one I have just outlined."

Elisabeth stared thoughtfully at the image of the launcher, hovering at the edge of the atmosphere. "I'm sitting here feeling like Queen Isabella listening to Columbus explain why she should part with her jewels. But then I remember what came after, what she was remembered for financing." She paused, turning to look at Bruce who was looking back hopefully. "I've always thought of myself as a CEO with vision. Maybe I've got just enough vision to say YES."

"It also occurs to me that now I have to buy that vacation home in Rio which I keep trying to talk myself into, just so I can watch the first launch for myself," she added with a smile.

Later, as Bruce and Reggie were making their way out of Elisabeth's office, Reggie was clapping Bruce on the back jubilantly. Reggie was stoked for the first time that morning, but Bruce by contrast appeared sullen.

"Man, I can't believe you pulled that one off. We're going to South America! And I sure can't fault you for the location you picked. Have you looked at that map? Every weekend," Reggie fell into a sign-song rhythm, "we can goooo to Riooo de Janeiroooo...."

"*You* can if *you* want to," Bruce replied morosely. "I'm the one who wants to live long enough to retire in high Earth orbit, remember?"

"You seem pretty glum for a guy who just sweet-talked a pretty lady out of fifteen billion dollars!"

Bruce turned to look at his friend. "I wanted to build something which would launch *humankind* out into space, not just machines."

"They can ride the space shuttle, or maybe that aerospace plane they keep talking about," Reggie

said encouragingly. "A whole lot is going to be done in space that wouldn't have been done without the cheap fuel and re-supply we're going to provide."

"True. But I still want this launcher to be for the people. So anyone who wants to go can go. I can only hope that once we've started this project it's something which I can fight for later on and win."

Chapter

5

The christening

Bruce was sitting at his CAD/CAM station working out the final details of the balloon structure. They had a press conference set for the next day and Bruce didn't want even the tiniest detail to be undeveloped.

Specifically, he was finalizing the design of a critical link in the system: the rotating anchoring structures at the axis of each balloon which the mass-driver was supported by. The balloons were composed of hexagonal panels of a highly durable fabric, each one a little over a football field in size. At each "pole", the center hexagon was made of aluminum, not the fabric the rest of the balloon was composed of. The stress loads on the pivot points amounted to the weight of over a mile of mass-driver, too much for even the tough balloon fabric to withstand. But Bruce was still concerned. He feared the stress would cause tears in the seams between the aluminum hexagonal panel and the surrounding fabric panels. Now he was expanding the aluminum portion of the "poles" with a dozen additional hexagonal panels in an outward branching "snowflake" pattern. This had the effect of increasing the length of the aluminum-to-fabric seam many times over, distributing the load evenly over a much wider area.

Satisfied with the new stress projections, Bruce began to move his finger up to the "save" button when he felt a small, hard object hit him in the back of the neck.

"Bulls-eye!"

Bruce spun around, and saw Reggie. He was standing a short distance down the hallway leading into the lab, holding an elaborate, home-made model of the launcher which was poking all the way into the room. It was an eight meter long assemblage of plastic soda straws, tape, and toy balloons. It was obvious the balloons had at least a certain amount of helium in them. Reggie did not so much support the model as push it around. The entire length hung suspended more or less straight in the air.

The balloons were the kind which were white, but became almost transparent when inflated. Reggie had even gone to the bother of dipping each inflated balloon into some kind of ink, so that one half was jet black. All in all, it was a very impressive simulation of the real thing.

"That is absolutely incredible! How many hours did you spend on this?"

"Oh, less than a hundred," Reggie casually replied, and then carefully guided his model the rest of the way into the CAD/CAM lab. "You like it? I built it mostly for fun, but partly for the press conference tomorrow. Computer simulations are fine, but this will get the concept across in a very concrete way that something on a monitor just can't. The hardest part was achieving neutral buoyancy. I used the electronic scales in the Calibration Lab to weigh lengths of straw, bits of Scotch tape and an empty balloon before I came up with a formula of three quarters helium to one quarter air. Still wasn't very even at first, though. You'll find a dime or penny taped here and there along its length. Oh, but here's the best part."

Reggie produced a small length of red crayon minus the surrounding paper. It was just under a centimeter long, and well sharpened. It also looked like a bit of the diameter had been shaved off by carefully honing. Reggie slowly swung the ponderous length of his model around until it pointed at the far wall. He inserted the crayon segment into the first soda straw, placed the end to his lips, and blew. With a whoosh and a thwack, the projectile shot out and hit a poster on the wall which said "K.I.S.S.: Keep It Simple, Stupid". The wax bullet fragmented, and left an ugly scarlet smear. Bruce started to comment that he hoped this demonstration was not a premonition of things to come, but then thought better of it.

"A definite crowd pleaser," Bruce enthused. "You'll surely steal the show at the press conference tomorrow."

"Hey, speaking of which, have you come up with a name for this contraption yet?" Reggie asked.

"Name?" Bruce blinked. "I hadn't really stopped to think about giving it a name. I've just been calling it the space launcher."

"That's the problem with you die-hard engineering types: no imagination, no show-business sense. That's why you have to surround yourselves with creative types like myself to bail you out any situation requiring poetic inspiration. Let's see," Reggie perched on the edge of a desk and rolled his eyes upward, "a name.....Space gun?"

"A gun is a weapon."

"Star-shooter, then?"

"Still has gun-type connotations."

"Space rifle!"

"You know, this all illustrates perfectly that sex fixation I've been warning you about."

Reggie paused briefly enough to shoot him a quick dirty look, and then resumed his musings. "Well, what is this thing really going to wind up looking like once it's up there?"

Bruce stopped to visualize. "A gigantic pearl necklace, strung across the sky."

"Well 'sky pearls' is not going to cut it. Think."

"It will span the very heavens itself," Bruce supplied grandly.

"Span.....bridge.....Sky Bridge? No, I think there's a resort called that."

"I don't care, I like it!" Bruce said eagerly. "I like the associations with the word 'bridge'. A bridge is what gets you from here to...there," he intoned reverently.

"The Sky Bridge it is, then. You're welcome," Reggie added.

"So tell me," Bruce asked with a smile, "which one of those prima-donna network anchors are you going to shoot with one of your little red crayons tomorrow?"

"Well, that all depends."

"On what?"

"On whether or not you can put me in touch with a curare supplier."

* * *

Then next morning saw Bruce and Reggie heading down the hallway towards the conference room where the reporters lay in wait. Bruce carried his speech notes. Reggie had his lengthy Sky Bridge model in tow. As Bruce rounded a corner, he saw into the room and could hear the buzz of conversation from the crowd of journalists and photographers packed within. He felt his stomach begin to clench. Then he heard a sharp exclamation from behind him.

"Ghuy' cha' !"

Bruce had heard this phrase out of Reggie before, and recognized it as a Klingon curse. However, it was usually spat out venomously at errant electrons in a circuit, rebellious code in a program, or feuding metals which would not alloy properly. This was more like a wail of despair.

Bruce turned around to see Reggie standing there holding his eight meter long model, and looking with dismay at a right angle turn in the hallway with less than two meters clearance.

Chapter

6

Try not to slouch in front of the cameras,

OK?

Reggie's model was still a big hit with the reporters, even though they had to crowd out into the hallway to see it. First, however, came the multimedia presentation.

Unlike Elisabeth Anderson, Bruce was now dealing with an audience not intimately familiar with the technology of magnetic acceleration. So it was necessary to start at the very beginning. He lectured briefly on mass-driver theory, and then started an old movie showing Gerard O'Neill's first attempt to demonstrate his mass-driver model. The model was about two yards long. The grad students assisting O'Neill dipped the bucket into the liquid helium which they used to achieve superconductivity in those days. The bucket was then pulled out and, still trailing heavy mists, placed into the mass-driver model. After a brief delay, the switch was thrown to energize the mass-driver coils. The bucket...

Did nothing.

There was a small explosion of laughter from the gathering in the movie. It was a laughter induced by high expectations followed by an anti-climax. The audience watching the movie chuckled along with them.

"Oh, that's Freeman Dyson laughing the hardest, by the way," Bruce interjected. This provoked additional chuckles from the more scientifically literate members of the gathered press. Indeed, the image of the tall, homely father of the Dyson Sphere could be seen laughing good-naturedly at his friend and colleague.

"As soon as the bucket was taken out of the liquid helium, it immediately began freezing ice crystals out of the moisture in the air due to its extreme cold. That process continued after it was placed in the mass-driver, essentially freezing the bucket in place."

Reggie shifted self-consciously in his seat on the stage. Why the hell was Bruce showing footage of the mass-driver model failing? Was he trying to jinx the public acceptance of this project which was so desperately needed?

By now the assistants in the movie were setting up for the next try. The bucket was in place. The model was energized and the bucket...

Was at the other end of the mass-driver. There had been no motion detectable to anyone in the audience. The workers and attendees in the movie broke into applause.

"Now this is interesting, watch this." Bruce used his hand control, and the movie backed up to a point before the firing and froze. A small indicator at the lower left of the screen flashed the word 'bookmark'. "This is the frame immediately prior to the firing. Now I'm going to advance to the very next frame." In the next still image, the bucket was at the end of the model. There was no intervening blur showing the bucket actually moving from the one point to the other. "As you can see, the acceleration and deceleration of the bucket took place between the taking of one frame of film and the other, a process which takes only one twenty-fourth of a second." There was an impressed murmur from the audience.

Bruce then outlined the Sky Bridge concept, using the same multi-media show as he used in Elisabeth Anderson's office. He then took questions from the press. They posed all of the same questions that Elisabeth did, plus a few more she had been too intelligent to ask:

"Dr. Franklin, what about collisions between vehicles flying out of this launcher and flocks of birds?" asked a young video journalist.

"Birds don't fly this high. Remember, this is the upper atmosphere we're talking about."

"Won't all these launches in the upper atmosphere contribute to the destruction of the ozone layer?" an Asian female wanted to know.

"No. In fact, this will be the only space transportation system in the world that won't. There are no rockets involved in the escape from the Earth's atmosphere. It's all done with magnetic fields."

"What about earthquakes?" came from a portly newspaperman.

Bruce couldn't help but chuckle a little at this one. "Well, it's hard to see how vibrations on the ground can effect a structure residing in the upper atmosphere. The only connection with the ground is the anchoring tethers. I suppose an earthquake would induce some wave motion in the cables, but those waves would dampen out well before traveling twenty four kilometers straight up."

"Dr. Franklin, will the balloons completely eclipse the sun?" asked a silver haired woman.

"Hmmm. With a diameter of one mile, and at a distance of twenty four kilometers, each balloon will subtend..." Bruce pecked at his notebook-sized PC on the podium, and began to mutter of arctangents, "Ummm...call it a degree. The sun is like, what, one half a degree? So I guess it will. Now keep in mind that's only for certain areas directly below the launcher. There are no major cities to speak of lying directly beneath. And that would only be for certain times of day, and certain seasons. I think the effect would be much like a partly cloudy day. Remember," Bruce added with a smile, "this is equatorial South America. I don't think any of the residents will complain about a spot of shade every so often."

"Still, some would view this structure as an eye-sore," she persisted.

"I don't think so, not personally. I've described the outside of the absorbing hemisphere of each

balloon as being bright white, but please bear in mind that this is the side which will always be turned away from the sun. So visualize it more like the gray underbelly of a cumulus cloud. Even from relatively nearby Belo Horizonte, Sky Bridge will be close to the horizon, and fairly well hidden by haze even on a clear day. I just don't see most people having a problem with it."

The "eye-sore" issue did raise its head several times once the project was set in motion. Some inhabitants of the few minor towns and villages which did lay directly beneath the future site of the launcher took exception to Bruce's "no major cities to speak of" remark. It was an unfortunate coincidence that Belo Horizonte was Portuguese for "Beautiful Horizon". Demonstrators with placards saying "Don't spoil our Beautiful Horizon" lay ahead.

* * *

After the conference, Reggie button-holed Bruce. "Why did you show them that part of that movie footage where the mass-driver didn't work right at first?"

"Because I don't want the public to have unreasonable expectations. The simple fact of the matter is that anything which is new never works right the first time!"

Chapter

7

Building the mammoth thing

There were some minor demonstrations against the Sky Bridge project. But the nation of Brazil in general, and the city of Belo Horizonte in particular, realized this project would make their home a hub of travel. Just the money being spent on the way into and out of the country could amount to billions in the long run. The government was only too happy to smooth the way, financially, legally, and socially. The land grants were generous and inexpensive.

As on any construction project, it started with the laying of the foundation. In this case, however, the foundation was balloon number one, sent aloft with the first tether trailing under it late in the year of 2001. The first and last balloons, the ones supporting the anchoring tethers, would both be filled with helium. It would not have been economically feasible to have filled all of the balloons with helium. But for the first and last ones, the helium provided the extra buoyancy needed to support the weight of the tethering cables. The first balloon also had to support the additional weight of the boarding station.

Sky Bridge was built in sections ten balloons long. That made each segment over ten miles in length. On a clear sunny day, the balloons on a completed section would be half-filled with air from enormous banks of ducted fans. As the solar heating began, each balloon would expand somewhat further, and begin to haul the segment aloft. As it ascended, and the surrounding air pressure dropped, each balloon expanded completely. In fact, each had to bleed off large volumes of air in order to avoid over-expansion. Small vehicles mounted with eight jet engines pointing in various directions guided each section into place. Metal arms controlled via telepresence made the necessary connections, and Sky Bridge grew.

The sight of a section lifting off of its skinny, ten mile long concrete pad, and climbing into the heavens was awe inspiring. The scale of the spectacle was simply beyond human grasp. Bruce never tired of going up to the roof of the many-storied automated balloon manufacturing plant to witness the

event.

Even before Sky Bridge was completed, Acceleration Inc. began to see additional business opportunities come out of the project. Astronomers were interested in using the boarding platform for making observations. Those who studied the infra-red spectrum were especially keen on the idea. IR was absorbed by water vapor in the atmosphere. The astronomers were already building their observatories on mountain peaks to get above as much of the wetter parts of the atmosphere as possible, but had taken that about as far as they could.

Local providers of data via microwave links asked if they could mount microwave reflectors on the bottom of the mass-driver. It was a cheaper location than on a satellite, and much higher than any mountain.

A variety of meteorologists wanted to do studies of the upper atmosphere from the boarding station.

One entrepreneur proposed the building of an entire pleasure resort in the upper atmosphere using the solar balloon technology. He would enthuse grandly about how spectacular the view would be from the window in each room. He did have to admit no one would be able to step outside to enjoy this view, however. He was largely regarded as a crackpot, and pretty much ignored by Acceleration Inc.

Bruce's creation continued to grow. The sight of Sky Bridge overhead was impressive from any nearby location, but none more so than near the middle of the structure where it seemed to bisect the vault of heaven. If one was directly underneath, each balloon was almost twice the apparent diameter of the sun or moon. It was easily visible in the daytime, though it looked washed-out with blue mist, much like the daytime moon or very distant mountains. But Bruce most enjoyed looking at it shortly after dusk or before dawn. Then, when the land was darkened, and the sky was a deep blue-black, Sky Bridge would glow in the rays coming from the sun beyond the horizon. At various times, the atmospheric filtering of the sunlight would color the launcher gold or rose. At night, as the tension in the anchoring tethers eased and they would start to bow slightly, the crew would run the aircraft warning lights up each cable. It was interesting to watch the red flashes of light arcing upward, seemingly to infinity.

It was also interesting to climb up onto one of the two enormous concrete anchoring slabs, lean over the guardrail surrounding the pit leading down to the massive take-up reel, and place one's ear to the anchoring tether. The sounds that unceasingly echoed up and down the twenty four kilometer length of cable could soon create a most eerie mood.

By the winter of 2003, Sky Bridge was complete.

Chapter

8

Launcher Control

It was the day of the first launch of cargo from Sky Bridge. They had performed numerous tests which involved accelerating an empty bucket, decelerating it, and bringing it back to the boarding station, but this would be their first acceleration of cargo into low Earth orbit, and they had a paying customer. NASA was purchasing their launching services for the lofting of a load of carbon granules to space station Alpha. The carbon would supply their air filters for over a year. The next launch the following

week would be fuel. But the fuel would be a very high-mass launch. It had been decided that this first test launch should be the much lower-mass raw carbon. After careful data analysis of both launches, the schedule called for daily launches, and ultimately, hourly launches. But they had to prove the mammoth thing worked first.

Reggie and Bruce walked out of the fierce South American sun, and into the air conditioned coolness of Acceleration's Launcher Control in Belo Horizonte. Many people were erroneously calling it Launch Control. It was impossible to keep some of the old space program vocabulary from slipping into their lexicon. The popular press seemed to enjoy the resonances between this enterprise and the space program as it was in its earlier days. This "Mission Control room" was quite a bit smaller than NASA's in Houston, and required only a tiny fraction of the controllers. But it was built along the same lines, and seemed no less impressive.

They were introduced to Casandra Morris, Director of Operations for Launcher Control. She was a small woman with large, round glasses, and long, dark-brown hair which she kept wound in a pony tail down her back.

"The Cargo Bullet has been backed into the Bucket and latched in. The combined vehicle is now cycling through the air lock," announced one of the technicians seated at a nearby console.

Bruce frowned with annoyance. After arguing with Reggie on the subject of avoiding gun-derived terminology, he was now dismayed to see the term "bullet" come into universal use among press and staff alike when referring to the launch vehicles. It was, he supposed, inevitable. The launch capsules resembled nothing so much as a rifle bullet. Similar function leads to similar form. He realized he just had to accept it.

The countdown began. The press, kept in a room behind large picture windows which overlooked the control room, began to stir. Bruce was tempted to step outside and look up at the launcher, then realized this was a silly impulse. The bucket and bullet would be quite invisible from this distance. All the facts were here in front of him on the giant computerized displays, and the remote camera feeds.

Before he hardly realized it, they had reached the end of the countdown. The mass-driver coils were firing sequentially, and the bucket with its carbon laden bullet inside was accelerating down the length of the launcher. The velocity indicator showed it approaching and then exceeding mach one with astonishing swiftness...

* * *

Juscelino was on his knees working in his backyard garden when he heard a distance-muffled, but very distinct <whump> from above. He had heard a sound like it before, the sound made when a military jet breaks the sound barrier. But it was a sound he had never heard here, so far from any military air base. Then he remembered today was the day of the first launch. He glanced upward at the offending object, almost straight overhead here. The realization sank in that it was a sound he would eventually have to hear day in and out, and which he would have to get used to if he wanted to remain in this house which he loved so.

"Oh well," he wearily thought to himself, "I suppose one can get used to almost anything with time". It was better than living next to the airport like his idiot brother Alvares.

* * *

In Launcher Control there was much shouting and back-clapping. The bucket had been snapped back, and the bullet had continued on its path out of the launcher and into space. The technology had

performed flawlessly.

Reggie grabbed Bruce by the back of his collar and pulled him close to shout in his ear so as to be heard over the jubilant cries. "Hey, buddy! What was that you were saying about nothing new working right the first time?"

Bruce could only grin, and then duck away from a nearby champagne bottle which had just launched a projectile of its own.

* * *

The next day's launch payload was fuel. Although to be exact, it was nothing more than a tanker bullet loaded down with plain water. A company called Orbital Fuels Inc. had created an ingenious fuel depot in low Earth orbit. There, they had a Space Shuttle External Tank which had been donated to them by NASA. To this, OFI had added a large solar cell array. The array always faced the sun, and was arranged so as to permanently shadow the tank. The ET was outfitted with two compressors and many square meters of heat radiators which were also eternally shaded from the sun's warming rays.

The plan was for the tanker bullet to dock with the depot, and disgorge its contents into a small holding tank. The water was then electrolyzed into hydrogen and oxygen. These gases were run through separate compressors and heat radiators until they liquefied. The resulting cryogenic fuel was then routed to the two separate tanks inside the ET for storage.

As things progressed, more and more space shuttles would stop at this depot, and drop off space craft attached to boosters with empty fuel tanks. The boosters would gas up, and then lift their payloads to their destinations. It was considered much safer than having large amounts of volatile liquid rocket fuel in the cargo bay of the shuttle, or inside the tanker bullet. Water did not require elaborate cryonic systems in order to keep it from vaporizing while in transit. It was also cheaper in the sense that the water was much denser than the resulting hydrogen/oxygen fuel. A ton of H₂O molecules could be delivered to orbit with less tankage than if they were separated from the start, and every pound saved was money earned. But what made the entire project most appealing to Bruce was that it tapped the energy of the sun in space in order to make the fuel. He saw it as the first step towards using the resources of space in order to further space development.

The first tanker-bullet launch was also without flaw. The stresses on the mass-driver had been as high as predicted, but well within spec. OFI enjoyed a thriving business, and eventually expanded, building a second depot in geosynchronous orbit. There, the twenty-four-hour-a-day sunlight permitted fuel manufacture around the clock. Ships at GEO could fuel up for the return leg back down to lower orbits, while other ships would re-fuel and head upwards for points beyond.

Consumables and raw material supply to Alpha and a host of other new stations now being built continued to provide big business. A renaissance of space activities began as projects too expensive to mount before suddenly became affordable.

Bruce waited until after a particularly favorable consortium stock report meeting to press Elisabeth on the subject of expanding Skybridge. There was some launching of satellites taking place, but only those which had been specifically designed from the start for high G-loads. Bruce successfully seduced her with the market for a much broader range of satellite designs.

Sky Bridge began to grow once again.

Chapter

9

Spiderman

Mark Fairbanks sat in the repair bullet and waited for the airlock to finish its cycle. His hand came up and bumped against the clear faceplate of his pressure-suit helmet. Mark had a long beard and a bad habit of stroking it when distracted. The helmet always frustrated this mannerism. Not that he disliked his pressure suit, mind you. It was visually indistinguishable from the space suits the astronauts wore, a fact he took great pleasure in.

It was only slightly less complicated than the NASA suits. Temperature control was required. Although there was one small pressurized oxygen tank for emergency use, the back pack was primarily an air compressor. Its function was to pull in the thin air at Sky Bridge altitude, and bring it up closer to sea-level pressure so it was much more breathable. Although some CO₂ scrubbing did take place, stale air was, for the most part, simply pushed out of the suit. The pressure suit was not quite hermetic, but in appearance was no different looking than an actual space suit.

When alone in the suiting-up room, Mark would sometimes admire how he looked in the mirror, encased in the white purity of his suit. He would pose with helmet thrown jauntily under one arm, and his long, curly hair framed by the enormous collar seal. Mark had always wanted to be an astronaut, and this was as close as he was going to get. Closer than most dare devils without a physics degree, anyway.

His legs were beginning to ache. He was tall, gangly in fact, and the cramped cockpit of the repair vehicle he sat in did not seem to have enough room for his long, slender legs. His single seat was crowded on both sides by equipment lockers and massive tool boxes.

Finally the outer door swung open, and the repair bullet plus its surrounding bucket began to roll out of the airlock. An endless expanse of three silvery levitation strips and dull-gray driver coils now lay before him. For a short moment his craft sat there, poised at the beginning of the mass-driver. Then the magnetic fields from the first driver coil gripped the bucket's fields, and the capsule began to accelerate.

Mark's vehicle repeatedly interrupted light beams aimed at photo sensitive cells, causing the coils ahead to continuously urge the craft forward. It was a modest acceleration: scarcely more than half a G. But he didn't have far to go. The hoops of the driver coils ahead expanded and whipped past him at an increasing rate. He moved in and out of shadows as the tiny vessel passed beneath the giant balloons. As he gradually picked up speed, the eddy-current-induced magnetic fields in the three aluminum levitation strips near the bottom of the mass-driver began to repel, lifting the vehicle. Soon after, the deceleration cut in. The bullet landing gear had no sooner retracted through the slots in the bottom of the bucket than they had to drop back downward again to touch down on the curved levitation strips. Now the repair bullet was gliding into the darkness under a deflated balloon which was draped limply over the mass-driver. This balloon was his destination. The vehicle slowly came to a stop.

Mark watched the canopy rise about two and a half feet. Then the nose of the craft swung out and downward on a hinge. Repair bullets were the only Sky Bridge vehicles with this design feature. Constrained by the surrounding mass-driver, the canopy was not able to rise fully, and the lowering of the nose facilitated the repairman exiting the vehicle. Mark lifted his toolbox, and clambered out.

He casually stood upon a narrow strip of aluminum not much more than half a meter wide, twenty four kilometers above the ground. After a brief stretch, he began to shine his wrist light around to illuminate the dark, flaccid fabric surrounding him. The only other light came up from the thin strip of the Earth which could barely be glimpsed between the shifting folds of material hanging for hundreds of

meters below. He spoke the computer commands which would instruct a compressor to pump air into the balloon. He did this not in a vain attempt to inflate it, but merely to locate the tear.

He snapped the infra red goggles onto his helmet and peered downward, hoping that the leak would be on the inside. Those on the outside of a draped balloon were a real bitch to fix. It could almost never be done on-site.

His scans were rewarded. There, in IR, was the unmistakable plume of solar-heated air gushing out from a gash in the fabric. The tear didn't look to be more than five hundred meters down, and was probably no more than a meter long. A cinch to fix. He issued the verbal command to the repair bullet's computer which instructed it to back up a bit. He followed his vehicle, walking along the curved trough of the levitation strip, and then stopped it directly above the tear. Mark then fastened his safety line to the cable attachment just below the nose of his craft.

Next came the part that always made him feel like a spider. He leaned back on his line while touching a control. An enormous spool inside the repair bullet reeled out line, lowering him from the mass-driver. He went down, down, between the slowly undulating walls of fabric. This was where his rappelling experience came in handy. As he approached the wound in the balloon he slowed his descent and stopped level with it.

In no time at all the tear was patched, and he was being reeled back up on the line. Once on the mass-driver, he sat on a coil and waited for the balloon to re-inflate. It always took a long time.

Eventually, the balloon became an enormous deformed spheroid, but this was enough for solar heating to begin to create buoyancy. The mile-wide clear-and-white mass began to lift up and off of the driver. The thin aluminized-mylar disk beneath the balloon was in tatters. Repairing it was generally not deemed worth the risk to the repairman. Even in a torn state, it still helped to reflect some heat back into the balloon at night.

With the raising of the balloon, surrounding vistas were revealed for the first time since Mark had exited the vehicle. The mass-driver was a fairly open framework composed of only a few slender girders, so there was little to obstruct the surrounding view. The repair had gone by quickly. So, as he often did, Mark took some time out to enjoy the scenery.

It was like the view from a high-flying passenger jet, only instead of being constrained by a tiny porthole it was panoramic. A bluish cast covered the distant Earth, not just on the horizon, but directly underneath as well. Mark could see sinuous rivers which sometimes caught the sun's light and shone dazzlingly. Cities revealed themselves as geometrically perfect crystals. Farmlands also had a kind of patchwork perfection. The clouds welling up beneath him were those puffy kind which looked as solid as sculpted marble. It was interesting to think that as the inhabitants of the remote land below looked upward at the underbellies of these clouds, he was looking downward upon their tops.

He began to daydream of flying among those brilliantly white clouds. In addition to rappelling, base jumping, and skydiving, he also enjoyed hang gliding. He had brought his hang glider (here called an asa delta) with him to Brazil, and occasionally took it to Rio De Janeiro over the weekends in order to leap off of the giant granite slab mountains which overlooked that sprawling metropolis. How Mark would have loved to leap from here with his trusty hang glider overhead! It seemed like it would surely take him days to glide back down to the distant land. Alas, it could never be. There was no way his glider could fit into the repair bullet, even when disassembled.

Then he was suddenly struck with a vision of himself skydiving off of Sky Bridge. Or would it be base jumping? Whatever, it might come close to the world record. He would have to look up the facts on

the skydive of Captain Joseph Kittinger who had jumped from a high-altitude helium balloon in a pressure suit of his own. Even if it was no good for getting into Guinness, it would still be a unique experience. His pressure suit was, after all, equipped with a parachute behind the backpack. It was a contingency for any misstep sans safety line.

How would he do it? His first visualization was a swan dive. Then he re-thought that. It would be better to jump off backwards. It would be interesting to see Sky Bridge soar away above him. There would be plenty of time to turn around and look at the ground, for sure.

He was halfway tempted to do it now, and just say he had slipped, that's all. But in a short while he stood up and began to make his way back to the repair bullet.

Perhaps another time.

Chapter

10

A plea for ten G's

By the middle of 2005 the Earth was ringed with uncountable communication satellites in a variety of orbits. Most all of them had been built from components and materials delivered into space cheaply and reliably by Sky Bridge. Now everyone had those wrist communicators which they had been promised for so many years. The wristcoms were made possible by satellites which were giants compared to those launched back in the days of crackling rockets roaring off of launch pads. The long-prophesied picture phones were also in every home, and would soon be on the wristcoms as well.

The consortium's profits were growing almost embarrassingly huge, and Acceleration Inc.'s share of it was not small. Now Bruce was pressing Elisabeth to extend Sky Bridge to the originally designed length of three hundred and twenty kilometers. This would permit orbital speeds to be obtained with no more than ten G's of acceleration. Most humans would find this gravity level tolerable for the eighty seconds required. Then Acceleration could bring the passenger bullets on-line, and begin launching people, not just fuel and cargo.

"We're doing just fine with the current market," Elisabeth insisted. "I know our cash flow is rather enormous at the moment. But the only way you could convince me to sink more money into expansion is if you could prove beyond a shadow of a doubt that the passenger market is going to be bigger than all the markets we have now put together."

"It will, Liz," Bruce said with determination.

"I'm sorry, Dr. Franklin. Your thousands of emigrants heading out for the new frontier are not terribly real for me. I'm sorry. It's a beautiful dream. It may even come true some day in the far future. But I cannot convince the consortium to sink yet another fifteen billion into Sky Bridge over anything not in the very near future."

This remark stung Bruce, even though Elisabeth had delivered it as tactfully as she knew how. Bruce could respect her position. He realized that not everyone was consumed by the same dream he was, nor felt the urgency about it which he did.

It was, strangely enough, Bruce's 'standard boogie man' who came to his rescue. The Japanese

were keenly interested in building resort hotels in Earth orbit. Their market projections indicated it as a potential multi-billion dollar industry. The venture could get off to a limited start with nothing more than one, small, zero-G station dedicated to lodging. This was by virtue of the fact that there was a market of extremely wealthy people willing to spend millions in order to be among the first to vacation in space. For the venture to succeed, however, they had to follow on a few years later with a more mass market; say anyone who could presently afford a trip to Australia, or an African safari.

The attractions of a holiday in space were easy to see. Zero gravity afforded an amusement which could not be bought on Earth for any price. The view certainly couldn't be beat. And none could deny that the prestige associated with having actually done it would be a significant factor.

The Japanese had firm designs for these space resorts. They even had a heavy lift launch vehicle in development which would haul the station components up. But they hoped to send paying customers up on Sky Bridge, saving themselves from the additional expense of developing some kind of aerospace plane. They had the money, and the guaranteed market to convince the consortium the expansion was worth doing.

Sky Bridge continued to grow...

Chapter

11

Man-rating: First attempt

It was the fall of 2006. The day of the first test launching of a manned passenger bullet broke clear and sunny. This suited Bruce just fine. He always seemed even more chipper on a sunny day.

The first two humans up would be Doctors Reggie Deitrich and Bruce Franklin, of course. They met that morning in the suiting-up room. The suiting up room was an area of the Launcher Control building normally used by the Sky Bridge repairmen for getting into their pressure suits when called up for a repair job. This morning, Bruce and Reggie used it to climb into their space suits.

Bruce leaned in close to his friend so as not to be overheard by the surrounding reporters and whispered, "You sure look like hell, I must say."

"Uughhh." Reggie blinked bleary red eyes, and murmured, "Blame it on Rio."

True to his word, Reggie had not missed a single weekend without hopping a jet to Rio De Janeiro. Reggie had always lived to party, but at the rate he was now going, Bruce didn't give him much odds on making it past fifty.

The space suits they were squirming into were nearly identical to the ones used by NASA. The press was eating this up. For the older members of the press corps, this whole affair was like the glory days of Mercury, Gemini and Apollo all over again. In no time, Reggie was whistling the theme to "The Right Stuff" for their benefit.

Bruce had argued vigorously against wearing space suits. No paying passengers would be wearing space suits, he insisted. Casandra had then made an attempt to appeal to his sense of logic. She now described the suits as a contingency against a possible malfunction on the mass-driver which Reggie and Bruce might possibly repair without having to come back down again. Bruce was unsure about the logic

of this argument, but finally relented.

Bruce went along with Casandra more often than not because over the past several months he had come to have the greatest respect for her abilities. She had a quick mind which grasped and retained all of the details, missing nothing.

Both men picked up the portable PC's they would use to monitor launcher functions, and then walked from the room. They were loaded into a van and driven to the elevator boarding platform.

The elevators which rode up the first tether on Sky Bridge looked a great deal like the larger and fancier cable cars found at ritzy ski resorts. There were some differences. An air compressor mounted underneath maintained internal pressure while the car ascended. The heaters were more elaborate. There were places to stand and admire the view, but also places to sit down.

Bruce, Reggie, and four cameramen boarded the elevator car. The door swung down on its rubber gaskets. In short order the car began to climb the twenty four kilometer cable to their destination.

The engineers both appreciated that the view afforded by this ascent would be part of the attractiveness of launching from Sky Bridge. It had even been seriously proposed that Acceleration offer bargain-rate tickets merely for the ride up to the boarding station and back.

As the group was lofted upwards, nearby features dropped away, and more distant vistas came into view. In time, the surrounding hills and valleys took on the appearance of some elaborately sculpted model covered with fine green velvet. Soon the land below began to take on a bluish color, and still they climbed.

The colossal balloons of Sky Bridge were now growing more rapidly in the tinted windows overhead. In time, the mass-driver itself could be seen. The elevator car now began to slow as it approached the spherical boarding station suspended at the beginning of the launcher. A tiny communications dish jutted out from the side of the globe, pointing downwards. The bottom of the station was a mass of giant grapplers and pipes leading away from the massive air compressor.

With a muffled bump and a clang, the car docked with the belly of the boarding station. The passengers now ascended a corkscrew stair-case, and headed in.

There was a dome-shaped observation lounge on the top level complete with binocular telescopes and muzak. Someday soon, passengers waiting for their scheduled bullet would sit there in comfort. But Reggie and Bruce had already enjoyed the view of the impossibly-distant horizon from those panoramic windows, and headed without detour to the passenger boarding level.

After a short wait, their passenger bullet slid out of the tunnel leading out from the storage garage. The two-man craft was silver on the nose and belly. These surfaces on the hull were where the highest temperatures would be experienced on re-entry and were left bare, unpainted metal in order to aid in heat dissipation. The rest of the capsule was painted glossy white except for a black, triangular area leading from the base of the window to a point near the nose.

The vehicle glided to a stop next to them as its transparent canopy hissed up. The cameramen shot the two space-suited figures as they climbed into the needle-nosed craft. The canopy swung back down and sealed. As the two passengers buckled in, the bullet began to move off on its three small landing gear and left the boarding platform.

They entered the area where the buckets were stored and prepped. Now moving backwards on a spur track, the bullet climbed up into one. As they backed in, each landing gear folded forward as it

rolled up the short ramp leading to the lip of the bucket. Then the wheels dropped back down again through openings in the bottom. Contact points at the rear of the bullet mated together with those in the bucket. The gear now extended fully once again, and the entire affair raised up into the air a couple of centimeters. The combination of bullet and bucket then moved forward towards the open inner-door of the airlock.

Once they were stopped inside the lock, the inner-door dropped and latched. The sea-level-pressure air inside was slowly spewed out into the surrounding thinness. Reggie opened his laptop PC. When the small screen was raised, the PC always played the opening bars of the original Star Trek theme. Reggie was also using an unusual screen saver. It was not the extremely popular, full-motion-video, three hundred and sixty degree pan through the forest with the babbling brook, nor was it any one of an infinity of rotating three dimensional fractals. It looked like nothing better than the old moving starfield of the last century until one watched it long enough to catch the USS Enterprise whooshing by at random intervals.

"We're nearly equalized now," Reggie began a running commentary for the controllers down at Belo Horizonte. "OK, now the outer door is opening."

The vehicle rolled out into the launcher and stopped. The mass-driver formed a pattern of converging straight lines and repeating hoops stretching out before them far beyond the range of human vision. The accelerating coils were spaced fairly far apart, but created the illusion of a solid tunnel beyond several hundred meters. It was hard to see more than the first balloon which lie ahead.

Bruce tried to analyze his feelings at this historic moment. He was a bit nervous certainly, but more than anything else, he felt ready. Ready to prove that his creation could indeed launch men into space. Safely, that is.

Cassandra's voice came to them over their helmet speakers. "Bullet One, this is Belo Horizonte. All diagnostics read green for launch."

"Roger that," Reggie replied. "All systems green for launch". Bruce had to smile. Reggie was in his glory.

Bruce recited the very short countdown. "...3...2...1...energize!"

Reggie glanced at his companion quizzically, but returned his gaze forward almost immediately as they went off. The men were pressed back into their seats by ten times the normal force of gravity. The coils of the mass-driver soared past at a constantly increasing tempo until they blurred into invisibility.

They heard a whir and a thump which indicated that the landing gear had retracted. Now they were riding solely on magnetic fields. It was for the good: any kind of wheel would soon fly apart at the speeds they were approaching.

A faint roar began to build as air, even as thin as at this altitude, protested at being rent through. Now there was a distant whining sound, increasing in pitch. Bruce searched for an explanation, and finally decided it might be the magnetic tugs of each passing driver coil, now raised in frequency to where they produced waves of audible sound.

The mass-driver was now a ghostly, shimmering gray tunnel around them through which they could easily see the supporting balloons flying by overhead. The balloons' passage also had an ever-accelerating rhythm, like the coils before. The sunlight streaming in through the clear canopy strobed madly as mile-long shadows passed by too quickly to count.

"Acceleration profile nominal," Reggie struggled to get out. "All systems functioning normally."

Although they could not yet see the end of the launcher, they knew bucket-vehicle separation was near. Then a powerful decelerating force was on them with a shocking brutality. As both men were thrown against their restraining harnesses with almost unbearable pressure, they realized something was horribly wrong. Some sensation of deceleration was expected at this point, as the bullet pushed its way through the thin air and was slowed somewhat as a result. But nothing like this. Their heads were bent forward at an extremely painful angle and their arms stood grotesquely straight out in front of them. A dark tunnel of ebony sparkles was flowing in front of their eyes when suddenly the crushing forces were gone.

Under normal circumstances, an imaginary observer suspended in mid-air near the end of the launcher could never hope to see a bullet come soaring out. The vehicle would pass and be gone before the image could register on any retina. Such an observer today, however, would have witnessed the craft exit the mouth of the launcher no faster than a car on the freeway, and then almost immediately begin to plummet towards the craggy slopes of Pico da Bandeira far below.

"Jesus, what happened?" Reggie asked groggily. The bullet was in a slow tumble. Shafts of sunlight and shadow swung sickeningly through the tiny cockpit.

Bruce tried to shake the dark flashes from his eyes. Then a popping in his ears made him realize the roaring sound which he heard was not blood rushing through his ears as he had first thought, but an escape of air from somewhere in the craft. "Visors down!" he barked, already sounding faint in the thinning air. Both men slapped their helmet faceplates down.

The head engineer grabbed his laptop PC from its new location wedged under the front of the canopy, and scanned the system read-outs. None of the indicators were flashing red. Then he noticed that the display which should have shown the bucket being pulled back up the length of the launcher was static. The bucket should now be getting recalled back towards the boarding station, but there was no indicator showing its location on Sky Bridge. He looked up and saw, to his mortification, that the bucket was still with them.

The view in the extreme left and right parts of the window should by now have been unblocked. But there instead was the lip of the bucket, still tightly gripping their vehicle. Reggie was now looking at it too with dazed disbelief. Somehow, the contact points must have jammed.

"Launcher Control, the bucket is still with us," Reggie reported, "I say again: we have exited the launcher with the bucket still attached".

In Belo Horizonte, Casandra came out of her seat, and felt herself walking with dream-like slowness to the station directly ahead of her position. There she stood, stiffly erect, looking over the shoulder of the seated console operator at every reading. The Head Controller finally decided there was nothing she could do but continue to claw at the top of the chair in front of her, and await the outcome.

Bruce seized the manual control stick which he had insisted be installed for the man-rating tests. He carefully watched Earth and sky pass across the windshield, and then fired control jets to stop the dizzying tumble they were in. That done, he then pitched the nose of the craft straight up. He hit the engines full blast, then almost immediately cut the thrust. He did this again and again, pounding the throttle, snapping it back and then pounding again.

"What the hell are you trying to do?" Reggie demanded loudly. "Afraid we haven't had about enough already?"

"You don't understand. With this bucket all over us, we can't deploy the chute." He turned to look at his friend. "If I can't shake this thing loose, we're going to hit the water like a brick...and then sink like one too."

Chapter

12

Highway encounter

Bruce continued to hammer at the throttle. They remained in the bucket's stubborn grip.

"Save us some fuel," Reggie insisted. "Maybe we can fire the engines at the last second to cushion our fall. Maybe we won't drown if we can just survive the impact."

"Wouldn't do any good," was the tight-lipped reply. "Minus the weight of the bucket, maybe. But this thing weighs tons".

Reggie had helped his partner to design the driver bucket, and knew he was right. It contained two massive coil windings and dewars full of liquid nitrogen. Besides, the bullet's four tiny rocket engines were designed only for adjusting the orbit once it was out of the atmosphere, and didn't have that much thrust.

Bruce kept up the pogo-like maneuver, and was finally rewarded with the bucket slipping off and tumbling away. Now he righted the craft, and deployed the steerable parachute.

"Casandra, he did it!" Reggie exclaimed. "We're shook loose, and flying free now." The two men could hear the crew in Launcher Control rejoice briefly, but soon grow quiet again, realizing a difficult part still lie ahead. Bruce had to land, and they were too many kilometers from the runway to return and land there. They were precisely over the coast. The seemingly limitless blue expanse of the South Atlantic lay to their left, the gray mountain peaks and green hills of Brazil lay right.

"Go to splash-down procedures," Cassandra instructed.

"No," Bruce suddenly said. "We've got a hull breach here somewhere. If I put us down in the soup, this bullet will sink."

There was a pause on the other end. Then the voice of Launcher Control came back to them. "Our people inform me that you guys can float in those space-suits."

"Huh-uh," Bruce said skeptically, "Virgil Grissom almost drowned because they told him he could float in his space suit. No way. Try to find me a small airstrip. If you can't, I can put this thing down on a road anywhere."

Casandra fumed at Bruce's stubbornness, but remained silent.

* * *

Meanwhile, the bucket crashed down onto the slopes of Pico da Bandeira kilometers below. It rolled and bounced madly for almost half a minute, and finally came to rest in a shallow depression near the sands of the shore. There it laid, a still, twisted wreck which spewed vapors.

* * *

In the skies above, Bruce was slowly turning their tiny craft towards the land.

"Bruce, what's the deal, man?" Reggie asked.

"The technical reason for this screw-up could be somewhere in this bullet," he explained. "I'll be damned if I'm going to splash it somewhere, and then have it sink to where it can't be recovered for months."

"So you gamble with both our lives!"

"Reggie!" Bruce erupted, turning to face his friend sharply. Then, softening somewhat, he continued. "Trust me on this. I know what I'm doing."

"Like I have a choice. I notice they put that stick on your side."

Cautiously, so they wouldn't swing forward under the parachute and stall, Bruce began to fire the engines. He did this partly to keep them level so they might clear the jagged peaks of the Great Escarpment ahead, but also to burn off as much fuel as possible before landing.

Soon they were beyond the slate-colored mountains, and proceeding into the lush, green interior of the nation. Plagued by a nightmare vision of plunging headlong into the thick Brazilian forest, Bruce was now scanning the verdant land ahead for some kind of road. Soon he had one. It was broad but sinuous. Gear dropping, they descended toward it.

The traffic was frighteningly dense. Bruce tried to dip down low enough to be seen in windshields, and then climbed slightly. He had the attention of the drivers now. While unsure what the heck that they were looking at, they sensibly backed off, and Bruce had the opening they needed to land.

Touchdown. Now he steered the front landing gear, trying to keep up with the curves in the road. He began to apply brake cautiously. The parachute angled back until it became a drogue. The vehicle finally braked to a halt.

The canopy rose. Bruce and Reggie emerged, and removed their helmets. They stood on the road taking in their surroundings.

"Do I really have to kiss the ground? I think there's motor oil here," Reggie quipped.

A helicopter from Launcher Control approached. The pilot looked down to see many vehicles stopped in the road. The lead vehicle stood out somewhat though, seeing as how it looked like something from the twenty-second century. Indeed, the two space-suited men standing beside it looked as though they had just pulled in from Mars.

As the chute billowed in the breeze behind them, the engineers were surrounded; first by travelers who shouted to them in Portuguese, then later by reporters who kept asking them what it felt like to be alive.

They were alive.

Chapter

13

Caught in the act

The next day, Bruce, Reggie and Casandra were already delving into failure analysis. Reggie had his own theories as to where things had started to go wrong.

"Where did you get off saying 'Energize' when the countdown reached zero?"

Bruce smiled warily, and answered. "Well, it had occurred to me earlier that 'ignition' wasn't right since we weren't setting fire to rocket fuel. The process starts with the energization of the first coil in the driver..."

"Well, 'energize' is not appropriate," Reggie lectured. "That's what you say when you want to beam somewhere. What you say in a situation like this is 'engage'. C'mon, say it with me." He thrust his pointing hand forward, and intoned with his best Yorkshire accent, "Engage!"

"Sounds like another case of the cultural schism between Classic Trek and Next Generation to me," Casandra opined. "Now," she added good-naturedly, "if we could get back to the problem at hand..."

It was obvious why they had not made it into low Earth orbit. The bucket, instead of peeling away from the passenger bullet as soon as the decelerating magnetic fields began to act upon it, had instead clung on, slowing the bullet along with it. Those decelerating forces had been calculated to bring the bucket to a complete halt, but not with the weight of the vehicle inside. They emerged from the launcher, but with only a tiny fraction of the velocity needed to climb beyond the atmosphere.

The contact points between bucket and bullet had mysteriously frozen together. In fact, they had stuck with such strength that one of the points in the bullet had tore off, and was later found in the mangled remains of the bucket. It was this structure being torn loose from the hull which had caused the rupture, depressurizing the vessel. Further analysis revealed that the contact points had been affected by a phenomena known as vacuum welding.

Most metals we come into daily contact with reside at the bottom of a flowing ocean of oxygenated air. Every metal surface we see is covered with at least a thin coating of oxidized metal. This layer is the only thing keeping any one piece of metal from instantly bonding to another which comes into contact with it. Any breaks occurring in the coating are immediately renewed by the oxygen in the surrounding air. In a vacuum, however, this renewal of the oxide layer does not occur. Two metal surfaces coming into contact can instantly bond tighter than if they had been deliberately spot-welded together.

The phenomena was normally only associated with space engineering. But Sky Bridge was at an extremely high altitude. The surrounding air was so thin that they were experiencing only slightly less trouble in this regard than a designer of spacecraft.

A graphic of a bucket-to-bullet contact point was rotating on the CAD/CAM monitor before the trio. The bucket portion of the mechanism was shaped like a popsicle. The bullet portion looked like the mold which had formed the popsicle.

"Gosh, no wonder we have a vacuum welding problem here. Look at all that surface area!" Bruce rubbed his chin thoughtfully. "You know, I don't remember designing the cargo bullet contact points to look like that."

"That's because you didn't," Reggie replied, and split the screen in order to display both side-by-side. The contact points for the cargo bullet had the same diameter as those for the passenger version. But these, by contrast, were shallow hemispheres. They were about the same proportions as the

dome on the bottom of a Coke can.

"Dammit, now why are they different?" Bruce was fuming. "Zoom in on the signature". Reggie complied. "Hey, somebody get Don Jamison's sorry butt in here!" Bruce demanded.

"I think he's back to working on the Chicago to Los Angeles maglev run," Casandra stated.

"Then let's get him on the vid. I've got a bone to pick with that man."

Shortly later, Don Jamison was on the videophone looking somewhat mystified. Bruce was piping through a graphic of the longer contact points in addition to his own scowling face.

"Recognize your baby?"

"Well, yes," the man on the screen responded, "I was involved somewhat in the design of the..."

"Your baby almost killed us yesterday," Bruce stated flatly. "Now answer me one question: Why are the contact points for the passenger bullet and bucket designed differently than those for the cargo vehicle?"

"Well..," Don began to stammer, "The vehicle is a different design..."

"So you had to re-invent the wheel," the Head Engineer interrupted. "Have you ever heard of a little saying that goes 'If it ain't broke, don't fix it'? If there's anything I can't stand, it's an engineer who approaches every new job as though nothing like it has ever been done before. I don't like designs which are different just to be different! STANDARDIZE STANDARDIZE STANDARDIZE!"

The designer looked out at them from the screen sullenly. "I don't believe in torturing people," Bruce added, "so I'll tell you now that you *do* still have your job." Now Don's eyes widened as he realized for the first time he possibly could have lost his position over this.

"Now you can get back to what you were doing," Bruce said dismissively. The screen darkened. Bruce heaved a sigh, and then turned to the task of replacing the passenger bullet contact points with the same design which had successfully pushed thousands of tons of cargo into space.

* * *

Then next morning, when Bruce approached the door to his office, he saw that a small cartoon had been taped there. He was fairly sure it was from Reggie. Whenever Reggie saw a cartoon which tickled his fancy, he would always save it to an optical drive on his PC which was solely dedicated to the task.

This one depicted a man who has grabbed some unfortunate individual by the back of the neck. He is pushing the poor man's face down towards a benchtop on which lies some kind of small plastic widget. The man-handler is shouting, "Oh, just look at what you designed! Bad engineer! BAD, BAD engineer!!" A short distance away stands a third man, hands on hips, who is looking on skeptically. His word balloon reads, "What a moron! Hey Bob, you'll never break him that way! You've gotta catch him in the act!"

Bruce smiled. It was the first time in a couple of days.

Chapter

14

High dive

Far above the Earth, Mark Fairbanks spun around slowly as the take-up reel in his repair bullet pulled him back up to the mass-driver. He had just established that the balloon to which he had been dispatched was too badly damaged to be repaired on site. He had merely placed temporary fasteners on the fabric so that the balloon could not slip over and hang straight down. When a deflated balloon did that, it always triggered the automatic jettison system, and no one enjoyed taking responsibility for a mile of balloon fabric fluttering downward to land on God knows what.

He had spent less than one half of the time budgeted for this trip out onto Sky Bridge. If he was serious about an illicit sky dive off the launcher, now was the time. Did he have the nerve?

His repair bullet was stopped only a short distance from the far edge of the limp balloon. He walked along one of the levitation strips until he was well clear of the shifting fabric. He stood and looked out at the impossibly distant horizon, and then downward towards the twenty four kilometer drop at his feet. Summoning up his resolve, Mark turned, composed himself, and then took a deliberate, skillful back-dive off the launcher.

The air was so thin and his pressure-suit so thick that there was no immediate sensation of rushing air. The mass-driver above him seemed to be leaping straight upward to the heavens. The linear structure contracted in width, although its length would never cease to span his face plate. The driver soon became a one-dimensional line with no discernible features. In a surprisingly short length of time, it was no longer visible at all. Now even the balloons were getting smaller with the rapidly increasing distance. As they receded, Mark could see more of the blue-black color which dimmed the sky straight above. The almost impossibly-dark hue impressed on one that Sky Bridge was a good part of the way into space.

But Earth was where he was heading. Mark swung his arms and legs so as to roll over on the upward rush of air, now slowly becoming an invisible, supporting force beneath him. It would have been a mistake for him to stay on his back until the balloons shrank to nothingness. He would have reached the Earth before that could happen. Mark was just starting to admire the downward view when he suddenly remembered he had not yet radioed his situation to the controllers on the ground. If the fall had been accidental, he surely would not have hesitated to call them.

"Belo Horizonte, come in please." He tried to sound like a man in control of himself, while at the same time deliberately injecting a tiny amount of panic into his voice.

"Belo here, go ahead," came the voice of Casandra back at him.

Casandra was back on shift now! Mark suddenly felt the odds of him getting away with this stunt without penalty had just dropped considerably. Nothing got away from that woman.

"Uhh, guys, I kind of tripped and fell. I was between making safety line attachments. I'm coming down."

There was a considerable pause at the other end. Were they buying it?

"Understood. There's nothing either of us can do at this point. If you've been careful with your chute folding and stowage, then there shouldn't be any kind of problem. Just don't miss your deployment altitude."

"I promise you I won't. Will signal when deployed, and then again after I've landed."

"Roger," Casandra replied. "We're tracking you all the way down. Good luck."

That out of the way, Mark could now observe the land below in silence. Some rather large cumulous clouds were looming up below him. He had dropped quite a ways into the atmosphere already. He was plowing into thicker and thicker regions of air, and so had probably already slowed somewhat from his maximum velocity. He couldn't wait to find out from the controllers what his top speed had been.

With the denser air he now had even better control over his attitude. He angled his body so as to steer himself towards a cleft in the billowing white cloud immediately below him. He thought it might be good for a rush. The cloud layer was coming up at him with increasing speed, and he was beginning to question if he was going to make it. Then he was suddenly diving downward through a vertical valley of puffy whiteness. Gray mists whipped past him on either side with breath-taking speed. Then he broke through and out.

Bullseye.

A short while later, Mark noticed something by its absence. The soft, omnipresent hum of the air compressor in his back pack had been getting steadily quieter, and could no longer be heard at all now. He had descended to an altitude where the air was probably quite breathable, but made no motion to remove his helmet. He certainly would never have dreamed of sky-diving from a plane without his crash helmet.

The repairman began to divide his attention between the enlarging landscape below and the altimeter on the wrist of his suit. When he reached the proper height, he pulled the rip-cord, realizing the next few seconds would probably determine whether or not he would pay for this little stunt with his life.

There was a satisfactory jerk, and Mark looked upwards. The parachute had deployed perfectly. He was almost home free.

"Parachute is out and looking good," he reported.

Free fall was pure exhilaration. After chute deployment, however, came the slightly lazy, contemplative part of the experience. Swinging gently beneath the canopy, his plummet now slowed, Mark went back to observing the land below.

Green rolling hills abounded. River snaked around from several directions. But there were also suburbs and shopping centers. Highways flowed with tiny dots which methodically traced their curves with seemingly perfect precision.

Soon Mark was beginning to see enough detail below to worry him. There seemed to be an awful lot of development where he was headed. He didn't much like the idea of coming down on someone's roof, or worse, snagging his chute on a street light. He began to tug on the control lines fitfully.

He was coming down into a well-booked pleasure resort. Now a blue, sparkling rectangle was between his feet. The pool! Mark quickly decided it would be better to go into the pool than to come down on top of the crowd surrounding it. Oh well, at least there was no way he could fracture two metatarsals this time.

He knifed down into the clear water. He came to the top, threw off his helmet, and was treated to the high pitched squeals of several women and girls plus the outraged shouts of a few men. His parachute

covered half the pool area, and there was now a steady stream of people working their way out from under it. Mark's Portuguese was still a bit thin, yet he recognized a few of the words being shouted towards him as the kind seldom used in polite company.

Encumbered by his bulky pressure suit, he laboriously kicked and stroked his way over to one edge of the pool next to where a slender, dark-haired young woman sat in a lounge chair. There was a tall drink beside her, a batidas by the look of it. The spectacle of Mark's unconventional arrival seemed to have left the young lady rooted to the spot. The dare devil heaved up from the water, and thrust his elbows over the edge of the pool to cling there. His beard dripped water onto the cement as his face broke into an enormous smile.

"Are you buying the next round?" he asked her.

* * *

His next encounter with a slender, dark-haired female was decidedly less pleasant. Casandra Morris had her suspicions. The tiny woman stood before the gangly repairman and mercilessly grilled him on every point of the incident. Mark sensibly stayed as close to the truth as he could short of revealing that it had been a deliberate jump.

She was aware of the death-defying theme which ran throughout all of Mr. Fairbanks' recreational activities. But when she stopped to consider it, what other personality type could be paid to clamber all over a structure built twenty four kilometers up in the atmosphere? Casandra knew what he had done, but had no proof. So there the matter lay.

Chapter

15

Man-rating: Second attempt

Bruce got out of his car, and walked towards the Launcher Control building. He glanced upward at the thin, patchy haze which hung above. The cloud layer looked like it had been painted on glass. This was the day they would try another manned launching from Sky Bridge.

He entered the building, and found he had to push his way past a mass of reporters in the halls. Now that the first man-rating attempt had ended in near tragedy, public interest in the goings on here in Brazil had reached a fevered pitch. The engineer plowed his way to the suiting-up room. Reggie was already there and halfway into his suit. By contrast with the last time, he looked well-rested and alert. Bruce was pleased Reggie was giving this attempt the seriousness it deserved.

Soon the men were on an elevator car heading upwards. It was interesting to look out the windows as they penetrated the thin haze above the Earth. A seemingly infinite plane of slightly fuzzy gray slid down, around, and past them. Now that they were above it, they could see slight undulations in the semi-transparent fog. It was as though they were ascending above some vast, gray, sluggish sea. The car climbed far beyond it towards the launcher waiting for them at the top of the thin cable.

* * *

Meanwhile, inside the recesses of the boarding station above them, a grappling arm swung a launcher bucket out of its storage garage and over to a large electromagnet. The insulated dewars

surrounding each of the two large coils in the bucket had just been refilled with liquefied nitrogen. Now the whipping fields of the electromagnet induced electrical currents in those coils. The electrons would now circle around the bucket unceasingly, generating a powerful magnetic field for as long as the superconducting state remained in effect.

* * *

Shortly thereafter, the manned bullet was placed into the bucket, and now it sat poised at the beginning of the launcher. Tension seemed even higher this time around. Again, Bruce had the honor of reciting the countdown.

"...5...4...3...2...1...energize."

Reggie scowled, but had no opportunity to complain as both men were suddenly pressed back into their seats with a force equal to ten times their normal weight. The muted roar of passing air and the high-pitched singing of the rapidly passing driver coils had just begun when there was a sharp pop and then a steady hissing. Reggie struggled to turn his leadened head towards the sound. He could see just the edge of a white plume which curved back, dancing chaotically in their slip-stream.

"Houston, we have a problem," the engineer said in a subdued, strangulated cry. "We must have split a seam. We're losing nitrogen."

"Roger that," came the reply from Casandra down at Belo Horizonte. "We show a rapid drop in nitrogen pressure." Their instruments also indicated a drop in bucket coil temperature as the liquefied air boiled and escaped, carrying heat energy with it. But Casandra knew that when the nitrogen ran dry, this trend would rapidly reverse itself. Standing now, she reached out for the back of the chair in front of her, making the technician occupying it secretly wish she would go pick on some one else's chair for a change

* * *

Juscelino and his wife sat in lounge chairs they had set up in the backyard, and were looking up at the space launcher which hovered overhead. Being out here was a bit silly; they could see nothing but a string of balloons at this distance. They were getting far more information concerning this second manned launch attempt on the small TV Delores had set up in the back doorway. But it was still pleasant to lie back and sip maté, and interesting to realize that two men were up there trying to do what no one had ever done before. The near-fatal mishap on the first attempt only made it more exciting.

Suddenly, a thin white line began to slowly trace itself a straight path along the bottom of the balloons. It looked something like the contrail of a high altitude jet, but Juscelino had paid enough attention to this whole affair to know that neither jet engines nor rockets had anything to do with how these vehicles were propelled.

He turned to Delores and gravely stated, "Looks like the Yankees are having troubles again."

* * *

In the bullet, Bruce and Reggie could hear the last of the nitrogen coolant venting out of the bucket. It hadn't taken long in the low pressure air which surrounded them. The special ceramic-metal alloys in the bucket coil windings began to rise in temperature and to lose their super-conducting abilities. Now the dense electrical currents in the coils began to encounter resistance to their circular flowing, causing the temperature to rise still further. It was a snowballing effect which would eventually cause all current flow to cease. Even now, the men could feel their acceleration begin to slack off as the bucket's magnetic field diminished, leaving the mass-driver coils with less and less to grab on to.

As their speed and field strength began to fall, the magnetic induction levitation effect which suspended their craft began to fail. "The landing gear are going down," Reggie reported. "We're dropping." With a screech, the gears contacted the now-useless levitation strips. They were rolling on wheels now, and not very quickly at that.

Slowly, gradually, the vehicle came to a protracted halt.

"Well, that certainly was an anti-climactic end to this whole trip," Reggie declared with disgust.

Bruce scowled and spoke into his helmet mike. "Launcher Control, Franklin here. What's our next step?"

"Standby Bullet Two," came the reply from the ground. Then there was a lengthy silence which the two men spent regarding each other soberly.

* * *

Cassandra Morris began asking questions of the young technician operating the console before her. "Simon, the repair bullets are designed to go out to specific locations on the launcher. Can we send one out to them?"

"The repair bullets are one-seaters, remember," the tech responded. "To pick up both men, we would have to make two trips."

"I don't really care much for that idea," she stated. "The man left behind would have to wait over an hour for the next capacitor charging. I feel like every minute I leave someone up there, the more dangerous it is for them."

"Another point which occurs to me," Simon added, "Is that the repair bullets have a pretty cramped cockpit. The repairmen just barely fit in wearing their pressure suits. The space suits Franklin and Deitrich are wearing have even larger backpacks. I don't know if I can guarantee they could get the canopy down and latched once they got in."

"We can't afford to waste that much time. Can we send the alternate passenger bullet out to them, instead?"

"We would have to use the same acceleration and deceleration programs which we use to drive the repair bullets," the man said thoughtfully. "I think they're just subroutines in the main repair bullet program. We wouldn't want to run the repair bullet preparation code, just the repair bullet movement codes."

"Can you pull out the acceleration and deceleration subroutines, and run them separately from the main program?" she asked.

"Ummm... I think I can," Simon said, studying his monitor. "Yes...yes I can."

"Do it". She had come dangerously close to saying "Make it so". Reggie was definitely beginning to rub off on her.

* * *

"With bucket field strength at zero, there's nothing we can do to move your bullet," Cassandra told the stranded engineers. "We're going to have to send another passenger bullet out to get you. We have an alternate bullet on standby. It's fully prepped, but we're going to have to wait for the mass-driver capacitors to re-charge. That's going to take," a slight pause, "a little under an hour."

"How are we going to get from the one vehicle to the other?" Bruce wanted to know.

"You've got space suits. You can walk."

"Easier said than done," Bruce muttered, looking around them. He turned to Reggie and said, "The other bullet is going to pull up to us from behind, so you know what that means. We're going to have to clamber back over the top of this thing."

They slid down and latched their faceplates, and then manually opened a vent to equalize the air pressure in the cramped little cabin. Now they could hear a faint, continuous hiss in their helmets as the life support system in their back packs kicked in. Pressure remained good, but the suits felt stiffer now. The canopy popped up, and got no farther than about two and a half feet before striking the top of the mass-driver. One at a time, they laboriously wiggled their way out of the tiny craft.

As soon as he had a chance to get out and look at their situation, Reggie knew Bruce had been right about having to climb over the top of their bullet. There was no way they could walk around it. The highest levitation strip was too far beneath the curved hull of the space capsule to stand on. Bruce pushed the canopy back down. Reggie stooped to give him a boost up onto the nose of the craft, then took Bruce's outstretched hand to climb up with him.

The most hazardous part of this maneuver was that there was no place for them to attach the three-meter safety lines which hung in coiled loops from the waist of both suits. Trying not to think about the fact that they were twenty four kilometers above the Earth, the two men cautiously crept over the smooth, curving topside of the passenger bullet.

Reggie was the first to slip over the back-side of the vehicle. He wasted no time at all in attaching his safety line to a small loop mounted on a girder.

Bruce was shifting around to drop down as well when Reggie said, "Hey, no. Why take any chances? Throw me your line, and let me secure it first". Bruce complied.

"Are you sure you're making those attachments correctly?" Bruce asked.

"The latches are idiot-proof."

"In that case, my question is: Did you verify that personally?"

Reggie turned to look up at the Head Engineer, and saw an uncharacteristically devilish grin on his face.

"Ah, abuse," Reggie calmly concluded, and then helped his companion down from the vehicle.

* * *

After nearly an hour of waiting for the capacitors to charge and their ride to arrive, the two men were very bored. The views of the titanic balloons overhead and the landscape below, as fantastic as they may be, were static and could only remain interesting for so long.

Reggie was sitting at the bottom of a driver coil, casually swinging his legs over an inconceivable drop. He was whistling through his third repetition of "Wouldn't You Like to Fly in My Beautiful Balloon?". He had earlier been trying to play a MOD file on his PC for the old melody, but the air up here was so thin that it could scarcely be heard. Earlier than that, he had folded up his "Emergency Capsule Evacuation Procedures" checklist into a paper airplane. He tossed it from the launcher, only to see it drop straight downwards more or less like a rock. Again: thin air.

Bruce had preferred Reggie's MOD-playing PC to Reggie's whistling. The air being blown between his lips was rasping over his helmet mike and making a sound in Bruce's headphones which was setting him on edge. Hoping to provoke a conversation, so that the symphony of twentieth-century pop would cease, Bruce asked his companion a question.

"Reggie, when Sky Bridge is routinely sending thousands of people into space, and the price for space activities drops to next to nothing, what would you like to do?"

"Go back to the states, and get a decent Pizza. They just don't know how to make them right down here."

"No," he persisted. "I mean what would you like to do in space?" Reggie began to leer at the mere thought of his reply, prompting Bruce to hastily re-word his question. "I mean, what would you like to build in space?"

"Oh gee, I don't know," the engineer casually said, cocking his head to one side. "Oh, I know!" Now he broke into song, paraphrasing another oldies pop tune. "I want to be - the owner of - the first bar on the moon."

"Be serious," Bruce chided.

"I am serious. The way I figure it, in one-sixth gravity it won't hurt so bad when you fall off your stool and hit the floor."

"Oh, well," Bruce said, shaking his helmeted head sadly. "But I guess you know my dream."

"Yeah, yeah," Reggie responded. "Sun-sats and space habitats."

"You bet. You'll have to admit we can't keep on burning fossil fuels forever. Past a certain point, the green-house effect will get so bad that L. A. will become a harbor. Solar Power Satellites could provide the Earth with cheap, clean, plentiful energy without end. With Sky Bridge providing inexpensive access to space, we can mount mining expeditions to the moon and the asteroids. Those mines will make things like SPS possible. Once we are out there using local resources, space habitats will soon follow. Before this century is out," Bruce continued earnestly, "there could come a time when there are more humans living in space than on Earth."

"Everything you just said," Reggie pointed out, "is chapter and verse straight out of 'The High Frontier'".

"That's right," Bruce agreed. "And to think it was written back in the 1970's."

"Your problem," Reggie suggested, "is that you worship Gerard O'Neill."

"Let's just say I'm one of his disciples," Bruce acquiesced. Then he became wistful. "One of the great regrets of my life is that I never got to meet him personally. I hate to sound immodest, but I am famous now."

"I always preferred to be notorious," Reggie interjected.

Bruce continued without pausing. "Right now I can ask for and receive an audience with the most noted scientists and engineers in the world. Nobel prize winners, even. But I didn't become anyone well-known, anybody of note, until after Gerry's death before the turn of the century. Gerry was always surrounded by people who put many demands on his time, and I didn't feel I could just walk up and impose upon him. It's funny," he added contemplatively, "I've heard he felt the same way about Einstein."

"Uh-oh. Look out. Now he's using the names Gerard O'Neill and Albert Einstein in the same sentence," Reggie said derisively.

"I am convinced," Bruce insisted, "that those two names will go down in the history books side by side. Einstein: the father of relativity. O'Neill: the architect of.....the future. I wish I could have spoken to him."

"Do you know what I wish?" Reggie asked softly.

"No, what?"

"I wish we didn't have to wear these space suit helmets," Reggie said while peering downwards. "This would be a great place to hang out and spit on people's heads."

Despite his irritation at Reggie's juvenile remark, Bruce could not restrain himself from chuckling at the ludicrousness of it. At this height, they would be lucky to spot a shopping mall, much less a shopper. Bruce gave up on trying to share with his good friend, and lapsed into silence. In time, the whistling resumed.

Chapter

16

A bullet with their names on it

Down at Launcher Control, Casandra watched the capacitor voltage indicators climb up to the required levels. The empty passenger bullet could now be dispatched to the two stranded men. On a display at the front of the control center, a locator indicating the vehicle's position on the launcher began to creep forward.

"Acceleration profile normal," Simon reported from the station in front of her. "Nearing the half-way point. Deceleration commencing at...". Suddenly the young man's voice trailed off in mid-sentence. He stared at his displays in disbelief.

"What is it?" Casandra asked with growing concern.

"The bullet isn't decelerating! Oh God. It's continuing to accelerate!"

"Check your software!"

"Read-outs indicate deceleration program running normally, but the velocity indicator keeps going up!"

"Re-sequence the command stack," she suggested tightly.

"It's not doing anything!" the panicky tech exclaimed, his hands flying over the controls.

The location indicator continued to crawl across the screen at a visibly faster rate. The velocity reading now showed a speed well above mach 1.

Casandra thought furiously for a moment before saying "Break and switch to acceleration program". The operator turned to look up at her, aghast. "Do it!" she commanded.

Simon complied. The locator continued to move from left to right, but now seemed to be slowing somewhat. The command issued was having the opposite effect that it should.

"That did it! Velocity indicator dropping!"

"Increase driver coil current density to maximum". Cassandra dropped down to where her head was even with that of Simon's. "Will it be enough to....."

"No," the console operator replied sickly. "The bullet will still have a high velocity when it reaches the men. There's nothing more we can do to slow it down."

The Head Controller suddenly stood erect, and shouted to the screen at the front of the room. "Reggie, Bruce, we can't stop it! Get out of there!!"

"What?" Bruce asked uncomprehendingly.

"The bullet! We can't stop the bullet!"

The two men on the launcher looked at each other incredulously, and then bolted to their feet. They could see the bullet now. It grew as they watched, alternately shining and dimming as it passed through mile-long shadows from the balloons overhead. When the sun shone on it, smaller shadows from the mass-driver coils rippled over its nose at maniacal speed. That nose pointed straight at where they stood. The craft was barreling towards them far faster than any runaway freight train.

"Get out of there!!" Casandra yelled to them.

Reggie looked around at the empty air surrounding them. "Where?" was his plaintive cry.

"NOW!!!"

The pair jumped from the mass-driver. Before they could even come to the end of their three-meter safety lines, the unstoppable bullet collided with their stalled craft. The full load of rocket fuel exploded instantly.

The blast was strangely muffled in the thin air. They could feel the concussion, but felt the impact of small debris even harder. It peppered the backs of their space suits, and bounced off of their helmets. Suddenly they were at the end of their safety lines, and their fall was brought to a jerking halt. A pale blue flame enveloped the men. They could feel a portion of the heat even through the thick fabric of their suits and the heavily tinted face plates of their helmets. Flaming wreckage fell all around them.

Then it was over. The shrapnel-like fragments had passed, and the smoke and vapors quickly vanished into the rarefied atmosphere around them. Pieces of wreckage tumbled downward until they were out of sight. The men dangled above a drop to terrible to contemplate.

"We're still alive!" Bruce jubilantly reported to the ground. Then he realized Reggie was alive, but in trouble. The young engineer had a wide-eyed expression, and his mouth gaped spasmodically. Bruce immediately realized Reggie's space suit had been punctured by some of the flying debris, and that he was now struggling to breath the almost non-existent air at this altitude.

The rip was visible on Reggie's left side. It looked to be about four centimeters long. The emergency tank in his backpack would be discharging at the highest rate now, but would be unable to maintain pressure with a tear in the suit that big.

Bruce began trying to swing himself on his line so he could cross the less than one meter distance

separating them. Grabbing his friend's flailing arm, he then immediately began yanking at the pouch on the hip of his space-suit for the suit repair patches. Clutching Reggie with his legs now, the Head Engineer struggled to peel the adhesive backing off of a patch. It was difficult work in the suit gloves. His thick, clumsy fingers finally managed to get the backing free, and Bruce slapped the patch over the tear. He furiously tamped it down all over. Soon Reggie was looking somewhat less distressed, as his backpack slowly won its battle to bring the pressure in the suit back up to normal levels.

"OK now," Reggie panted. He lifted his head to look up, and then said, "Oh my God."

Bruce followed his friend's gaze. Even before looking, he had fully expected to see the mangled remains of both bullets lodged in the damaged mass-driver above them. But the backdrop to this scene of burnt destruction looked like something out of a "giant blob" horror movie.

The balloon immediately above them had doubtless been riddled by the debris which had sprayed out from the explosion like pellets from a shotgun blast. Now, rapidly deflating, it was undulating and creeping down towards them like some impossibly vast, half-transparent amoebae.

The reflective disk of mylar plastic beneath the balloon was torn away from its supporting ring by the descending mass. The almost incomprehensible scale of the balloon's collapse lent the twisting fabric a surreal kind of slow motion movement. It was like watching gossamer fall through water. Walls of material were dropping all around, and darkness descended on them.

The two men tried to assay the damage to each other's space-suit before the light failed them entirely. Both suits were streaked with dark soot. Reggie's did not appear to have any more tears. But when he turned Bruce around on his line to look at his backpack, Reggie could not keep himself from softly exclaiming "Uh-oh."

"What is it?"

"Well, your main tanks look fine, but your emergency oxygen cylinder is laid wide open."

"Then we're just going to have to hope I won't need it," Bruce stated evenly.

Reggie began to turn him back around. Then Bruce...

...suddenly dropped out of sight!

"Bruce!!!" Reggie cried.

Bruce was plummeting Earthward rapidly. The undulating walls of descending material around him now seemed to be shooting upward. Then he *saw* more than *felt* his outstretched hand make sliding contact with the balloon fabric. A drowning man will clutch at straws, and this falling man began to frantically clutch at the thin material. Somehow, he finally managed to get a grip on the deflating balloon.

Still dangling from the bottom of the mass-driver above, Reggie was enheartened to see Bruce grab ahold of the balloon. But the balloon was still collapsing, and he watched as it took his companion down further and further. Eventually, Bruce was gone from his sight.

Without any discernible jerk Bruce could feel, the material he was holding on to seemed to reach its lowest point and stop. Despite his chill, the scent of sweat was now strong in the confined space of his suit. His situation was precarious in the extreme. He was suspended twenty four kilometers above the ground, holding onto nothing but the remains of a deflated balloon. The mass-driver was now the better part of a mile overhead. There was absolutely no way humanly possible that he could climb back up.

Bruce began to climb.

* * *

Reggie was almost going crazy thinking about the fate of his dear friend. For a while he stared at the frayed safety line which had failed Bruce. Then, thinking at last of the dangerous position he himself occupied, the engineer climbed up the three meters of his own line, and clambered back onto the damaged mass-driver. The balloon material was draped over the framework for almost as far as he could see, and gave the mass-driver the appearance of a long, straight mine shaft. Reggie briefed Launcher Control on what had happened.

Suddenly there was a familiar voice on the communications channel. "Quit talking about me... like I'm not here... if you would please," Bruce panted.

"Bruce!" Reggie exclaimed. Then he felt somewhat foolish while recalling that he and his companion did not communicate with sound waves through the thin atmosphere here, but through the same radio system which linked them with Belo Horizonte.

Bruce's climb was already becoming a struggle. His legs and feet were of little use. The pressure in his suit gloves seemed to resist his efforts to close his fingers as tightly as possible. He could feel a slickness in the fingertips which he knew was blood seeping from around his abused nails. His faceplate, already darkened by soot, was now beginning to fog up from his exertions, so that it was getting more and more difficult to see. Fighting off thoughts of death, he continued his slow, agonizing ascent.

At one point he stopped, beyond exhaustion and overburdened with the hopelessness of his situation. He wondered if he shouldn't just let go, and begin the maddeningly long drop to the ground far below. But he couldn't bring himself to give in. Looking upward, he saw a tatter of fabric waving freely, and realized he was close to one of the tears in the balloon. He suddenly realized if he could just get up to it and wiggle through, he could climb inside the balloon and have rest. His energy levels renewed by a visible goal, he continued to grab fabric and pull himself upwards.

Chapter

17

Wouldn't you like to die in your beautiful balloon?

Bruce finally made it to the tear in the balloon fabric. It seemed just long enough for him to make his way through. At first, the hump of his backpack frustrated his efforts to climb in, but eventually he tipped over into the interior of the damaged balloon.

He found himself rapidly sliding downward in darkness. The black interior of the solar balloon devoured the light greedily and left none for his eyes. Bruce could not see where he was tumbling to. For a while he worried about sliding over another tear as big as the one which he had crawled in through. If he did, he would surely slip out before he could grab onto the slick material, and then would begin his long plummet to the ground.

Shortly, however, he came to rest. Bruce found himself thrashing about blindly in a small pile of tiny bits of junk. He identified it as pieces from the explosion which had penetrated the skin of the balloon into

the interior, and then slid down to the lowest point just as he had. He lay still in the pitch blackness, and relaxed, free at long last of the requirement to cling on for dear life. His overstressed muscles ached horribly, but began to untense.

On the mass-driver, Reggie continued to peer downward even though his friend had disappeared from sight some time ago. He had not heard Bruce cry out, and hoped this was a good sign. Then the voice of the engineer came over his headphones.

"Reggie, Cassandra, I'm OK for now. I managed to climb inside of the balloon. I'm alright."

"Bruce, what happened?" Reggie asked.

"A piece of debris from the collision must have hit my safety line. All that twisting around caused it to give way."

* * *

Down in Launcher Control, Casandra tried desperately to come up with a way of rescuing both engineers. Reggie was no problem. The capacitors were already recharging, and she had just ordered another bullet to be prepped. The deceleration and acceleration programs seemed to be working correctly again. Even if there was another reversal of function, now that they knew what to do, they could be ready for it.

Rescuing Bruce from his position near the bottom of a deflated balloon was another matter. No aircraft or rocket could help. Even if it were possible for a helicopter to fly at the altitude required, it couldn't come close enough to rescue the stranded engineer without getting its blades fouled in the balloon's limp fabric. Bruce could not climb up. There was no way Reggie could climb down more than a kilometer to him, even assuming he had a safety line that long.

Then it suddenly hit her. "Start prepping the repair bullet now," she called out. Then turning to Simon, Casandra asked, "Which of the balloon repairmen is on shift now?"

"Fairbanks," came the reply.

"Tell him to suit up, and prepare for ascent. I have a job for him."

* * *

Bruce was sitting alone in darkness when Cassandra's voice came to him. "Bruce, we've got a plan for getting you out of there. The balloon repairmen have lines they can rappel down to get at and fix deflated balloons. I'm going to send a repairman up to you. He's going to lower himself down to where you are, get you, and then lift you back up to the mass-driver. So you just sit tight and don't worry until help arrives."

"Roger that. Sitting tight."

After 'sitting tight' for ten or twenty minutes, Bruce found his mental attitude had completely reversed. He knew soon he would be on his way back up to the mass-driver and, shortly later, back down to the surface. He no longer feared dying on this day. The ebony interior of the balloon which at first seemed so scary was now rather comforting, actually. The darkness and warmth were positively womb-like. There was even a slow swaying motion as the feeble winds at this altitude gently pushed the limp balloon around. Bruce supposed he was in the world's largest hammock, and felt his biggest worry now was the potential embarrassment of being found asleep by his rescuer.

* * *

Up on the mass-driver, Reggie was just beginning to relax when he noticed every once in a while he could feel a curious tingling sensation through his boots. At first he worried it might be some kind of electrical discharge. The amounts of current which could be run through the driver coils was impressive, and with all of the damage the collision had caused, an electrical short was not entirely out of the question. He was just opening his mouth to ask Launcher Control if there was anything about the capacitor charging which looked funny when another explanation suddenly occurred to him. In the rarefied air which surrounded him, there could be tremendous sounds which would hardly carry through his helmet to his ears at all. He might simply be feeling sound vibrations through his feet. He walked a short distance over to a driver coil and pressed his helmet to it. He was instantly privy to the most astonishing sounds of groaning metal and popping joints.

"Uh, Belo, I'm hearing the awfulest lot of stressed metal sounds. I don't mean to be an alarmist, but are you sure this thing isn't about to come apart?"

Bruce could hear Reggie's comment perfectly well through his suit radio, and it shattered his tranquil state. The collision had done some damage, but the launcher was in a state of neutral buoyancy. There shouldn't be any kind of inordinate stress loads on the mass-driver just because of some structural damage.

Then the explanation suddenly hit him. It was the balloon in which he lay! It was no longer providing lift to this section of the driver. But that by itself should not be a problem. The design was redundant enough that the loss of one or two balloons was never a catastrophic failure. The mass-driver could even support the dead weight of a collapsed balloon provided that...

He felt his heart begin to race as he asked, "Reggie, is this balloon draped over the mass-driver, or is it hanging straight down?"

"What? It's hanging over the driver as far as I can make out."

"Is it hanging evenly?" Bruce inquired frantically. "Is there more or less as much material hanging over one side as the other?"

"Well, it's pretty hard for me to tell from in here," Reggie replied. "What difference does it make?"

Cassandra felt a horrible sinking sensation when she saw where Bruce was headed.

The engineer explained, "Reggie, if the balloon is uneven then it could slip until it hangs straight down. Remember, a limp balloon hanging down from its supports is too much weight concentrated in too little area. If the balloon falls straight down.....it'll be automatically jettisoned!"

In Launcher Control, Cassandra quickly found herself frustrated in an attempt to determine how evenly the balloon had fallen over the mass-driver. None of the sensors seemed to have been designed with such an intent in mind. None of the cameras mounted on the launcher were at an angle where much of the limp balloon could be seen from the outside.

"Oh, come on people," she cried out. Her tiny fist pounded on the head-rest of the seat before her. "I can't believe that with all of this hardware and software at our disposal, we can't answer a simple little question like this. Don't we have any long-range video from the ground where we can get a good look at this thing?"

"What about...," the tech in the seat she was pummeling meekly began, "...what about CNN?"

There was a moment of silence. Without another word, Simon began twisting a dial on his console. The main viewscreen at the front of the room switched through several different satellite channels before stopping on CNN. Sure enough, they were showing live pictures of the section of the launcher with the damaged balloon. Every network on the planet was by now giving live coverage of the life-or-death struggle taking place high in the skies above Brazil. CNN Headline News had been showing this view ever since the balloon's deflation. The picture was washed out with blue haze and jittered up and down from time to time, but was remarkably clear nonetheless, considering the distance.

"Genius," the Head Controller whispered quietly. She gave the little tech a pat on the arm. "Bruce, Reggie, we can see the balloon now. It's about two-thirds over one side and one-third over the other."

"That's not good," Bruce said worriedly. "Reggie, can you tell if it's slipping any?"

Bruce's partner looked, and realized he could now see the light at the end of the tunnel. In the present case, however, this was not a good thing. When he first climbed back up onto the mass-driver, Reggie had observed that the limp fabric hanging over the framework of the driver formed a dark tunnel for almost as far as he could see. But now, in one direction, the edge of the deflated balloon was clearly visible. It was definitely closer than it had been. Indeed while he watched, it jerked and drew back towards him even further.

"Bruce, the balloon is definitely slipping."

"Reggie, you've got to secure this thing, and keep it from going any further!"

Reggie frantically began looking around for something jagged which he could use to penetrate the balloon material, and snag it against something. In all this mess from the crashed bullets, there had to be something. He yanked a promising-looking piece of mangled metal out from the wreckage, and began jabbing it through the balloon fabric. He was trying to twist the fragment around to wedge it against an I-beam when the balloon lurched and began to slip rapidly. Reggie could feel the mass-driver heave beneath his feet. The twisted piece of metal suddenly levered around and was flung from his grasp. Reggie watched as one of the legs of the V-shaped balloon support arced over the top of the mass-driver and down, the massive aluminum I-beam bending like taffy. The balloon continued to slide downwards, and didn't stop until it hung straight down from the bottom of the space launcher.

"Bruce, I tried my best, but the balloon just kept slipping! It's hanging straight down now!"

Reggie's report only confirmed what Bruce had already suspected. He had earlier felt a faint sinking feeling which told him he was dropping lower still.

The limp, mile-long balloon swung slowly in complete silence. Perhaps there was still hope. The automatic jettison function had not kicked in immediately. Bruce squeezed his eyes shut, clenched his fists, and pleaded to the strain gauges in this part of the driver to hush their piezoelectric complaining to the control microprocessors.

Reggie was making similar prayers up on the mass-driver when he saw a faint yellow flash from below. He also heard a muffled pop. The explosive bolts had fired. Reggie saw the attachment point for the deflated balloon snap away downward from him.

"BRUCE!!!"

Reggie's sudden exclamation made Bruce fear the worst. Shortly there was no mistaking it. The sudden lightness, the sickly sensation in his stomach, the fluttering in the material around him, all told him what was happening.

He was falling twenty four kilometers down to the Earth.

Chapter

18

Plummet

Mark Fairbanks slipped beneath the upper torso of his pressure suit which hung on the supporting rack behind him. He thrust himself upwards and was in. He had help this time. Technicians on both sides began latching the seal between the upper and lower parts of his suit, and then immediately turned to the task of getting his gloves on and sealed.

There was a constant staccato of camera flashes and shifting illuminations from video cameras as the reporters pressed in as closely as they could. The questions they shouted out to him were a meaningless babble. Mark was starting to wonder how he was going to get past them.

A tech tossed him his helmet from half-way across the suiting-up room. He caught the helmet smartly, and began pushing his way through the crowd. The pressure-suited repairman ran down the hallway with his helmet held beneath one arm. It was good to be ahead of the pack of reporters dogging him, but he had to admit he was secretly enjoying certain aspects of this. Soon he would descend on his web to rescue the trapped designer far above, and then he would be a hero.

Mark was out the door and heading towards the van which was waiting to take him to the launcher. He glanced up at Sky Bridge, and then stopped dead in his tracks. His press entourage skidded to a halt behind him.

The image of Sky Bridge was very dim, filtered by the haze which covered the sky today. But one could still see the damaged balloon had now separated from the launcher and was very slowly falling away. The reporters surrounding Mark looked at this spectacle in silence for a second or two. Then they scattered to video cameras, to telephones, and to news vans. The repairman stood there alone, watching the mile long strip of balloon fabric languidly descend towards the Earth.

He felt for the engineer in that balloon, now surely condemned to death. But he couldn't keep himself from feeling cheated somehow either.

"Oh well," he thought to himself, "At least I had my fifteen minutes."

* * *

The material of the deflated balloon pressed cloyingly all around Bruce. He was the human nucleuse of a comet bound for Earth. Reggie was silent. Casandra was silent. No one had anything to say.

Bruce lay at the bottom of the plummeting balloon and reflected on his life. Not a bad one all in all. A few accomplishments here and there of which he could be proud. Still, he wished he could have lived to see the first humans launched into space from Sky Bridge. He even found himself concerned that this tragic death would doubtless set the program back many months.

He began to wonder how much more time he had. He knew enough about free-falling to know one did not accelerate continuously all the way down. Instead, a body accelerated until it reached a speed

where the resistance of the air drag equaled the weight of the body. That speed would never be exceeded. This was called the terminal velocity. All the up-and-down maneuvers professional sky divers did were accomplished by varying their body position so as to control their wind resistance. This altered their velocity, and enabled them to match speeds with other sky divers. The suits designed for the sport were even loose and baggy precisely in order to increase the air drag.

Bruce had a sudden realization. His air drag must be incredible. He was after all, trailing over a mile of fluttering balloon fabric. What would the resistance be for such a staggeringly long drogue? It was true he only had a sensation of falling for a brief period right at the beginning. Right now, he had no impression of accelerating downward, only of lying in a rippling sack, suspended by upward-rushing winds. He had come to his terminal velocity rather quickly, he now realized. It would even decrease somewhat as he entered into the thicker parts of the atmosphere. He felt his spirits buoyed up by a new-found hope. There was a chance...just the slimmest chance...he might survive this after all.

The engineer then began to notice the interior of the balloon was not as pitch black as he had originally thought. Now that his eyes were well dark-adapted, he could see there was a faint light up above him. It brightened and dimmed with the undulations of the balloon material. Bruce began to wonder if by some chance he had happened to come to rest near the border between the dark, light-absorbing half of the balloon and the clear, light-admitting half. It occurred to him that if this were true, and if he could get to the transparent part, he could see out. He then began to question if he really *wanted* to see out. It might be easier on his nerves if he did not watch the ground as it rushed up at him. But in the end he decided he wanted to see out. It had nothing to do with macho notions about staring death in the face. Bruce was of the inquiring, analytical personality type. He knew he wouldn't feel quite so out of control of the situation if he could at least know what was going on. For him, not knowing was definitely worse than knowing. Bruce began to roll towards the light.

It was not as easy a matter as he had thought it would be. The fabric in which he was ensnared pressed tightly around his body on all sides. He felt like a man who had been foolish enough to step out onto a pool cover, and had immediately plunged beneath the surface with the plastic sheet cold and cloying, sealing his body off from the air above. But with a laborious rolling motion, Bruce began to make slow, steady progress. At one point he found himself afflicted with a sudden worry that perhaps the light did not come from the clear area of the balloon at all, but from another tear. He could be rolling towards a hole which would dump him to the ground. He resolved to be cautious, but to continue.

The light around him continued to brighten until it became dazzling. Though he now had his eyes tightly shut, Bruce knew he had arrived. The thin fabric of the solar-heated side of the balloon had transitioned to the tough, clear plastic of the transparent half. He could feel the difference, even through his thick space-suit gloves. Now he could look out at the brilliantly-lit Earth which he approached. The ground was obscured behind a high, thin layer of semi-transparent haze. The view did not seem to be changing very rapidly. This was both reassuring and nerve-wracking. It gave support to Bruce's hope that his terminal velocity was not deadly high. But it also made him wonder when this ordeal was ever going to end.

Now there was a visible enlargement in the scene below. It was in the layer of water vapor which hung above the land. Suddenly, before he had hardly realized it, he was breaking through that thin layer and the details of the landscape below it were abruptly thrown into sharp, sickening contrast.

Bruce was plummeting downward like a meteor with a long, lazy tail. Many thousands of eyes down in Brazil were turned upward towards him, watching his long, long fall with open horror. Many cameras were pointed up as well, so millions more watched with concern on their televisions. And still he fell.

The designer had dropped to a level where he was sure the air was breathable. He briefly considered taking off his helmet but then thought better of it. His head was about to need all the protection it could get. Now Bruce could see he was falling towards rain forest. Giant trees reached up at him.

This is it...

There was a snapping, popping crash, and a stunning blow across his hips and left thigh. It felt like he had bounced off a tree branch. Bruce was pitched over onto his back. Blow after blow assailed him. Luckily, his space suit backpack now seemed to be taking the brunt of the impacts. His head rattled around inside of his helmet until he was convinced one or the other would surely break.

Then stillness. Silence. He had stopped. Somehow, he had survived. For the longest time Bruce lay still in the hammock created by the deflated balloon, content to merely savor life and consciousness and existence itself. Then he began to move limbs experimentally. Nothing seemed to be broken. His body was covered with bruises and his head with bumps, but he was fairly sure he would be able to walk away from this balloon without help.

Finding a way out did not prove difficult. The material all around him was now in tatters with tree branches poking through. He picked one of the longer tears, and slid out through it. He was in a tree, only about six or eight feet from the ground. Wincing as he used bruised muscles, Bruce made his way down to the forest floor.

He removed his helmet and dumped it to the ground. The damp smell of the rain forest immediately wafted to his nose. He looked up at the tree in which this part of the balloon was snagged. Bruce realized part of what he owed his life to was the fact that the balloon catching on the tree limbs had made his halt a much more gradual one. He hated to reflect on his fate had he come down on a road or a parking lot.

The sounds of approaching vehicles could now be heard. Suddenly he was surrounded by reporters who gaped at him open-mouthed. Bruce realized to his chagrin that they had come not to interview him, but to stare at and photograph his mangled remains. In short order, however, they got over their initial shock at having a live subject, and the barrage of questions began.

Even now, Bruce already knew that the headlines for next week's assortment of grocery check-out-line tabloids would all be variations on the same theme: Man Falls 24 Kilometers...And Lives! / Survives! / Walks Away Unharmed! etc.

Soon Casandra arrived in an Acceleration Inc. van. She stared at the engineer in his soot-darkened space-suit. The man looked like he had been to Hell and back. Bruce's first temptation was to pick the little woman up in a fierce hug. He suspected it was probably her quick thinking and actions which had kept a bad situation from being far worse. But Bruce and Casandra mutually agreed to settle for a handshake.

"Nice to see you alive," she said quietly.

The pair headed out of the woods to the nearby road. The view was surreal in the extreme. The balloon fabric blanketed the landscape all around. It draped entire forests. Traffic was backing up on the road. Two police officers climbed a small hill in search of the edge of the balloon, intending to drag it off of the road. On reaching the crest of the hill, they looked with despair at the sight of nearly a mile of fabric stretching off towards the horizon. The officers doubled back, and began directing cars to simply roll over the thin material. Acceleration had quite a clean-up job on their hands.

* * *

The van delivered them back to Launcher Control in Belo Horizonte. They had been there quite a while when news arrived that Reggie had completed the trip back down from Sky Bridge, and was on his way to Launcher Control. Bruce wasn't surprised he had beat his friend back. He did, after all, take the direct express route.

The van containing Reggie pulled up. The lightly-charred, space-suited engineer hopped out, and began trotting over to the pair. Casandra suddenly bolted to him and threw herself all over the slightly abashed man. Reggie dropped his helmet and held on to her.

"Oh God, Reggie, I thought I was going to lose you again!"

Bruce stood there dumb-founded. Reggie glanced at him sheepishly over her shoulder. Bruce had no idea. He had always assumed Reggie left for his weekly trips to Rio De Janeiro alone, and, knowing Reggie, had probably spent each weekend with a different woman. Now Bruce was no longer so sure.

* * *

The next week, the trio found themselves once again in the Failure Analysis Lab. Investigation of the wreckage indicated the rupture in the bucket which leaked out their nitrogen coolant had been caused by thermal stress. The passenger bullet was the first bullet to have an electric heater. A significant amount of heat from the bullet had leaked out into the bucket, causing a huge thermal differential. The solution to this problem was as simple a matter as beefing up the insulation around the passenger bullet. This certainly would not take any longer than the repairs to the damaged portion of the mass-driver.

The reason behind the mysterious reversal of the deceleration and acceleration functions came up during a bug hunt through the control programs. They had sent off the second passenger bullet with the same codes which were normally used to send the repair bullets out to specific locations on the launcher. It was the first time that this had been done. It was also the first time the repair bullet deceleration subroutine had been run separately from the repair bullet driver program. One of the things the driver program did was reset a sign-bit in the master control processor. After any run of code, this bit could have been left high or low depending on the circumstances of the bullet movement. Unfortunately, the resetting code was in the main part of the bullet driver program, not in the individual acceleration and deceleration subroutines. Since they were not prepping a repair bullet, but a passenger bullet instead, this code had not been run, and the sign-bit had not been reset prior to deceleration. Positive became negative and vice versa. The deceleration and acceleration functions became swapped. Reggie cut the sign-bit reset code from the main repair bullet driver program and pasted it near the beginning of the acceleration and deceleration subroutines.

Reggie waited for Bruce to angrily demand the name of the programmer. When the request was not forthcoming he asked, "What, no calling out on the carpet for the man responsible? And I had bought tickets to this performance."

"The programmer had no way of knowing the repair bullet driver subroutines would ever get run independently of the main program," the head engineer explained. "The way he had it written worked perfectly well for normal procedures. I wouldn't scream at anyone for not having a God-like ability to see into the future, only for bad engineering practices."

Chapter

19

Third try's a charm?

On the morning of the third launch attempt, Bruce awoke to leaden skies. There was a solid gray overcast. This would not affect today's attempt in the slightest. In fact, one of the advantages of Sky Bridge over rocket launches was that it was not bound to the vagaries of what the rocket people called "launch conditions". But Bruce longed for sunshine nonetheless.

Launcher Control reported all systems go. The major damage to the superstructure of Sky Bridge had been repaired. There were a number of coils in the area of the collision which were still non-functional, but this was not a problem. A number of spare coils sat near the end of the launcher, and only engaged to make up for coils which were down. There were more than enough of these redundant coils to make up the difference.

In no time, Bruce and his partner were suited up and ascending in the elevator car. At one point Reggie noticed Bruce was banging around on his PC with an annoyed expression on his face.

"What's the matter?" Reggie inquired.

"My PC is making an annoying, high-pitched, whining sound," Bruce complained.

"Yeah, and so's the user, so what's a guy to do?"

Bruce sullenly let the witticism slide. Noting that something seemed to have Bruce down this morning, Reggie persisted in trying to bring a smile to his friend's face.

"Hey, did you see what Time is calling you now?"

"No, what?"

"The Man Who Fell to Earth."

"Ha ha."

The car was approaching the dark underside of the solid cloud layer. Gradually, they became surrounded by dim blankness. Suddenly the elevator ground to a halt. They bobbed briefly, and then were still, surrounded by a silent gray nimbus.

"Hang on guys," came the voice of Casandra over their helmet speakers. "We're tracking the problem down now."

Bruce gazed out a window at nothingness. He noticed one of the cameramen in the car with them was pointing a camera directly at his face. He tried to change his expression from glum depression to one of grim determination. He had a ghastly vision of the elevator car suddenly plunging downward to the boarding platform several kilometers below. But he knew this was a silly fear. There were at least three or four independent braking mechanisms in the car's pulley system which would work when nothing else in the system would. Then the motors whined back to life, and they resumed their climb.

"Hey, look at it this way," Reggie chirped. "We've had our malfunction of the day. It can't be anything else but smooth sailing from here on out."

Bruce had a hard time sharing in his companion's cheerfulness. Then the dark, colorless fog surrounding them gradually began to brighten. It slowly transformed from drab gray to a brilliant white. Blue skies and a dazzling sun suddenly appeared overhead. The car was ascending upwards above a limitless flat plane of cotton. The sky directly above was the deepest, richest color of blue imaginable.

This unreal blue-black hue to the sky and this pure, penetrating, white sunlight now streaming down into the elevator car were previously known only to mountain climbers and aircraft pilots. Bruce felt his sagging spirits begin to lift.

* * *

In no time the pair sat in their launch vehicle, poised and ready to take off. For Bruce, there was razor-sharp alertness, but no tension this time. Just a fierce determination to prove that his child had the potential he had always claimed for it.

For the third time, Bruce recited the count-down.

"...five...four...three...two...one...ENGAGE!"

Reggie grinned, but the grin soon became the grimace of rapid acceleration as the weights of the two men were immediately multiplied by ten. There was a building rush of rarefied air flowing around them. Sky Bridge began its soft, high-pitched singing. Balloons were passing by too fast to perceive.

Suddenly, they were out of the launcher. There was a slight sensation of slowing, much softer than on their first disastrous attempt. This was merely the deceleration of punching a tunnel through the thin gases of the upper atmosphere. The landscape far below passed beneath the nose of the craft with impressive speed. The already-dark sky ahead grew darker still as they rapidly left the remaining atmosphere behind. Like a cinematic lapse-dissolve, the azure sky transformed to star-lit blackness.

They were in space.

The experience of zero gravity was both strange and delightful. A small nut which had lain unnoticed on the floor was now slowly tumbling past Bruce's face. It was difficult for either man to keep from playing around with the PC's now floating freely over their laps.

They now had a half-orbit ahead of them before the rendezvous maneuver which would circularize their orbit and send them to space station Alpha. This meant forty five minutes of coasting freely. Time enough for a little sight-seeing.

Bruce had heard one of the Space Shuttle astronauts describe orbiting the Earth as like a ride in the gondola of a hot-air balloon. The comparison was a good one. They drifted in serene silence while the landscape of the Earth slid by.

Clouds layered the atmosphere. In the seemingly tiny gap beneath each cloud, the shadows which they cast on the surface of the Earth could be seen. It looked as though the clouds had been painted on the topside of a sheet of glass which had been laid atop the land.

It was interesting to compare the outlines of the continents with the familiar traces learned in geography school. Some lands were tan or gold with desert. Others were green with forest. Mountain peaks stood out vividly with the white of snows.

The most staggering sight was that of the sun disappearing behind the edge of the Earth. The sun moved closer and closer to the limb of the planet, which was outlined with a thin, blue arc of haze. When the sun touched this haze, it seemed to set it afire. Gorgeous yellows, oranges, and reds shone through the atmosphere. It was a sunset in the shape of a rainbow. The light soon dimmed, and blackness was all around.

But the Earth was not completely dark. Here and there one could see the glow of major cities. Oil field flares dotted the Middle East. One could occasionally spot flickers from lightning in thunderstorms.

Both men seemed overawed by the beauty of the Earth and of space. For Bruce, this was the culmination of a childhood dream. He was in space at last. Even Reggie, who usually had a smart remark for every situation, was reverently silent.

Shortly after crossing back into daylight, the four small rocket engines at the tail of the passenger bullet fired. The aimlessly drifting nut was drawn to the back of the cabin and stayed there. The small, hydrogen-oxygen engines gave a smooth, gentle ride. This burn brought the perigee, or low point of their still-lopsided orbit, up out of the atmosphere. On the screen of Reggie's PC they could see their orbital plot as a thin line which still dipped back down into the atmosphere at approximately the same area as the launcher. As the orbit circularization engines fired, the low point of the orbit slowly raised above the atmosphere. They continued their modest acceleration until the orbit plot became a perfect circle, and then the thrust ceased. Their indicator was now very close to that of space station Alpha.

There was one more brief engine fire to bring them in on the approach path to the station. Alpha could now be seen as a multi-branching collection of cylinders, solar panels, and heat radiators. It had grown enormously in the years since Sky Bridge became operational.

Automated systems maneuvered their small craft into a cylindrical hanger bay about twice as big in diameter as the bullet. The bullet slid into a cradle and locked down. A large door on the entrance to the hangar swung down and sealed in place. A hissing noise gradually became noticeable as the hangar was pressurized, and sound was restored.

The canopy raised. The two men cautiously swam up out of their craft, and pushed off to the hatch at the station end of the hanger. The hatch was already opening to reveal several enthusiastically smiling faces all oriented at different angles. The crewmen of Alpha reached through the open hatch to grab the hands of the engineers and pump them vigorously. For a moment, Bruce couldn't understand why this was creating a sense of *deja vu*. Then he realized this event echoed the Apollo-Soyuz linkup, with the American and Russian astronauts shaking hands and smiling to each other through the open hatchway joining their two craft. That event had been broadcast live on television, and was recorded for posterity. This event also was being broadcast to millions, and would be replayed down through history for as long as humans existed.

* * *

Bruce and Reggie both took to zero-G eagerly. Reggie soon discovered even his own natural exuberance could not begin to compete with Bruce's enthusiasm for joyful frolic in the weightlessness.

They stayed on Alpha for almost a week, being interviewed from Earth, playing tourist, and even visiting the materials processing engineers working at the station. The Alpha engineers eagerly showed off the new class of zero-G processed materials they were creating in space. The Sky Bridge designers discussed with them potential uses for the super-materials in construction. Among the possibilities were even bigger and better space launchers.

* * *

All too soon their visit had drawn to a close. Now it was time to prove the last promise made for their system: that a safe return to Earth was possible. After the hanger bay depressurized, the outer door opened, and the cradle gently pushed the passenger bullet out. A tether which was mounted on the top of their space craft connected them to a giant take-up reel in the hanger. Line was reeled out, and the bullet drifted towards the Earth. They dropped to altitudes where orbital velocity was somewhat higher than at Alpha. But the tether kept them at the same orbital speed as the station. As a result, a very tiny fraction of the Earth's gravity pull could be felt, and the cable came under tension.

They were lowered until they had reached the end of the line. They hung there momentarily, waiting for the precise moment. Then the tether attachment on the bullet released, and the line snapped away upward. The bullet was now on a slightly altered trajectory, one which would graze the upper atmosphere. This would be enough to kill their orbit and bring them back to the surface.

Half an orbit later, they began to re-enter Earth's atmosphere, and radio contact with Belo Horizonte was lost. This loss of signal was expected, and was caused by the buildup of plasma around the speeding passenger bullet. It was true what the Shuttle astronauts said: re-entry was like flying through a neon tube. They were surrounded by a diffuse, pinkish-red glow. Although Bruce and Reggie couldn't see it, they knew the belly of their craft was also glowing. The pair were pressed down in their seats as tiny collisions with millions of air molecules decelerated the vehicle. The speed of the bullet dropped tremendously, and the crimson light faded.

"Belo, this is Bullet Three," Reggie stated. "Come in."

"Bullet Three, this is Control," said Casandra. "We read you loud and clear". The joy in her voice was evident.

The steerable parachute deployed without problems. The automatic guidance systems steered them towards the landing field north of the starting end of Sky Bridge. One of the radial landing strips was automatically selected based on wind direction, and they began to line up with it.

"Touchdown," Reggie reported.

The parachute and the brakes in the landing gear combined their efforts, bringing the bullet to a halt. A tow car approached the tiny craft. Under normal circumstances, this car would have pulled the passenger bullet to the terminal with the passengers still inside. But neither Bruce nor Reggie could be restrained. They popped the canopy, leapt out, threw their helmets to the tarmac, and embraced each other joyfully.

All restraint was lost in the Launcher Control Room as well. Technicians let out triumphant yells and threw sheaves of paper up into the air in the grand style of the old NASA. Casandra was literally jumping up and down with joy. She was also enthusiastically pumping back and forth on the back of the seat in front of her.

Simon rode the wildly bucking chair with a good-natured grin on his face. But at the same time, the technician was inspired to conceive a new design feature for the Launcher Control Room: a circular railing surrounding the seldom-sat-in Head Controller's chair. Something sturdy; suitable for gripping, tapping, pounding, and general abuse. Simon resolved to discuss it with Bruce at the next opportunity.

Epilogue

2031: A hopeful present

Bruce tied up his bathrobe, and groggily padded from the bedroom hallway into the kitchen. The windows were still open (nights were never very chilly here), and both sunlight and bird song were streaming though. He approached the coffee maker, ordering it to dispense his morning cup. He remembered a time in his life when he was a young man, and could launch up from his bed and into his day without the fuel of caffeine. He blamed the habit on all of those years he had spent in Brazil. Life there seemed to revolve around coffee. Oh well, he reflected, there were probably worse vices he could

have picked up in Brazil.

He approached the living room, and called out, "TV on. Channel ISNN". The wall-sized television sprang to life. Christmas was approaching, and American Spacelines was back to showing the commercial about the space colonist preparing to head down to his parents on Earth for the holidays. The background music was "I'll Be Home For Christmas". The young man boarded a Spacelines aerospace plane which then undocked from the habitat, flew to the blue and white globe of the Earth, re-entered the atmosphere, and glided down to a landing. All the while, the colonist looked out the window, and smiled at nostalgic thoughts of his parent's home. Mushy stuff, but Bruce looked at it anyway.

Then an attractive anchorlady appeared, looking into the camera.

"Hello, I'm Emily Rockwell, and this is the Inner-System News Network."

"Our feature story today comes to us from outside the Inner-System. The inter-planetary space craft Discoverer I is nearing Jupiter. We will be having reports from the Discoverer shortly, but we thought it might be interesting to first look at how well science fiction has done at predicting this momentous event: the manned exploration of the Jovian system."

"The first serious science fiction movie to deal with a voyage to Jupiter (or indeed the first movie to deal with any kind of space travel in a serious way) was Stanley Kubrick's '2001: A Space Odyssey' released by MGM in 1968. Although this was a landmark movie, and remains a classic still popular today, it is nonetheless a twentieth century view of how future space travel would be accomplished."

The report began showing documentary footage illustrating each of her points. "Although the launch of 2001's Discovery is not shown, it is assumed that even if the craft was assembled in orbit, it was certainly launched from the Earth system. But in reality, the first Jupiter expedition was mounted in the asteroid belt by people who had already been living and working there for over a decade."

"And what about that rebellious computer, HAL? No science fiction writer of the last century could have predicted that the first crew to voyage to Jupiter would have not just one talking computer, but one for each member of the crew. In fact, we all now carry computers with us which, though philosophers may debate their ability to think, can certainly understand our spoken commands, and respond with a voice of their own. The crew of Discoverer report they have not yet noted any unusually independent attitudes in their PCs, but assure us they're keeping a very close eye out."

Emily smiled at her audience mischievously. The documentary footage resumed.

"But the biggest miss 2001 makes is on the scale of the project. Kubrick's Discovery craft was smaller than an aircraft carrier, and had a crew of five. But the real-life Discoverer space ship is a community in space. It is a modified Model One Bernal Sphere one kilometer in diameter. It boasts schools, libraries, cinemas, malls, sports stadiums, and parks. It is also a setting which the inhabitants are already well used to. With very few exceptions, the crew consists of people who have already made a home in space, and have lived in habitats which are very similar."

It was true that Discoverer's main rotating sphere was enormous next to 2001's modest spinning centrifuge. But the traveling habitat being shown on the TV still looked small compared to Bruce's current surroundings. He left the couch, and walked over to a window to pull back a curtain and view the Model Three Bernal Sphere which was his home. It was four kilometers in diameter, a vast inside-out world. Sometimes natural clouds would form in a cylindrical area encircling the spin axis. Even on a clear day like today, the villages and fields on the far side of the sphere were hazy in the sky and indistinct with distance.

Bruce noticed there were a number of hang gliders already practicing their sport in the skies above. One was diving down lower. It was a dare-devil game. The closer to the axis hang gliders flew, the lower the gravity. As they moved away from the center line, the air began to push them around with the rotation of the colony, and they grew heavier. It was a contest among them to see how low one could go and still recover.

A smile came to his lips as he recalled a story on last week's news. A hang glider pilot had come down right in the middle of an out-door restaurant. Fortunately, there were no injuries involved. The pilot turned out to be well into his sixties. Too old, one would think, to indulge in such foolishness. Bruce was intrigued to hear that the errant pilot was a retired balloon repairman for Sky Bridge One, and had been associated with the project from its very earliest days. Bruce had probably passed the man in the hallways of the Launcher Control building more than once. It was a small Solar System.

During his reverie, Emily Rockwell had looked at two or three other science fiction movies which dated back to the twenty-tens and twenty-twenties and also dealt with the exploration of Jupiter. Now she was moving on to the next story.

"Today marks the twenty-fifth anniversary of the first successful manned launch from Sky Bridge One. This event, more than any other in the history of humanity's move outward into the Inner-System, is credited with beginning the process which led to space as a frontier for the average man."

There followed historical footage which brought back to Bruce a rush of memories from those bygone years. Once again he watched a youthful Reggie and himself shake the hands of the Alpha crewmen. The archival footage was interspersed with clips from an interview ISNN had recorded in his home just last week. He had a live interview scheduled with them for this afternoon.

There were two reasons for this day to make him think of that part of his life. It was also the day his old partner Reggie Deitrich was coming to join him for that interview.

The doorbell rang. Bruce headed to the door with an eager smile. When the door was thrown open, a look of dismay immediately covered his face.

His old friend was encased in a horrid-looking, very complicated set of leg braces. He was bent over a walker, and looked as though the effort of traversing the short distance from his rental car to Bruce's front step had drained the last bit of strength he had in the world.

Reggie began to scowl. "Quit looking at me like that! I'm not old and feeble. Not yet, anyway. It's just that you guys keep the gravity turned up way too high in this crazy ball."

Reggie started to fitfully push on his walker, and lumbered into Bruce's home. Bruce shut the door behind him. Reggie kept up the complaining every laborious inch of the way.

"Smart habitat engineers design for a rotation rate producing an artificial gravity of one-sixth G. That way their dear old lunar friends can come to visit them in comfort and ease."

"You're on the moon now?" Bruce asked.

Reggie turned around to look at him. "Well of course I'm on the moon now. Don't you keep up with what your old friends are up to? Oh, by the way, here."

Reggie reached into a tote bag hooked onto the front of the walker, and pulled out a T-shirt which he handed to Bruce. Bruce held it up. There was the famous picture of Buzz Aldrin on the moon saluting the American flag. Above this were the words "My friend went to Tranquility Base Memorial Park, and

all I got was a lousy T-shirt".

Reggie had finished his slow journey across the living room, and without invitation collapsed into an over-stuffed couch. He sprawled there like limp spaghetti.

"What are you doing on the moon?" Bruce inquired.

"Dr. Bruce Franklin, my dearest and oldest friend. Don't you remember the life's ambition I once shared with you in our youth?"

Bruce's eyes darted to one side and then returned. "You own the first bar on the moon?"

"Well, it's really more of a night club, actually. The name of the place is 'Tycho's Nose'. I called it that partly because it's in the crater Tycho, but also because the guy really knew how to party."

"It's a great place," the old man enthused. "On the sign outside there's a picture of Tycho Brahe, you know. And there's this little yellow light near the tip of his nose, you see? And it winks on and off...wink...wink...wink. It's glinting, you get it?"

"Tycho's nose may have been made of gold, but it was painted flesh color," Bruce stated.

"Oh, hell," Reggie waved a hand in front of him dismissively, and then immediately let it collapse back down onto his chest. "I'll take historical color over historical facts any day. So anyway, I now provide drink and comfort to the poor working stiffs who mine the ore which you use to build these pleasure palaces in the sky. I believe we also have the distinction of being the only off-world bar to serve guaraná."

"To serve what?"

"Guaraná. You remember! The Brazilian answer to Coca-Cola?"

"Oh, that's right. I recall you were having crates of it shipped to you after we returned to the states."

"Oh, by the way," Reggie suddenly remembered, "Casandra says to send her love. She was going to come with me to see you, but when I told her New Brazil was an Earth-gravity habitat, she just smiled at me and said 'Bon Voyage'".

"Say, you really are suffering aren't you?" Bruce said with concern. "Hey, we've got a park that's fairly high up on the sphere. It's just below the south windows. Gravity there won't be one-sixth, but it's a lot less than here. Let me put something on, and then I'll take you there."

"Oh by all means," Reggie drawled, "let's go to your park". The emphasis was on the word 'your'. Bruce seemed somewhat embarrassed before he turned and left.

When Bruce returned he helped Reggie out to the car, and then placed his walker in the back seat. He got in, touched his thumb to a sensor, and said "Destination: Franklin Park."

The vehicle started out of the driveway, and turned off onto a road which headed toward one of the two rings of windows which encircled both "poles" of the habitat. As they traveled further up the sphere, the grade of the road became steeper. At the same time, however, both the car and its contents became lighter, and the electric motors had no trouble keeping the car moving. The road began to snake back and forth a bit, and then ended at a small parking lot in front of a glassed-in elevator.

The reduction in gravity had resulted in a visible improvement in Reggie's condition. He no longer seemed quite so old and infirm. He slipped out of the leg braces, and left the walker behind in the car, although he did still carry a cane which he had brought along.

The pair boarded an elevator, and it slowly rose. It deposited them at the entrance to Franklin Park. The park was a level, shelf-like projection which jutted out from the wall of the sphere just below the curving ring of windows at this end. Above the tree tops, concentrated sunlight which had been gathered by vast mirrors on the outside of the habitat streamed past to illuminate the other side of the sphere.

Children were cavorting here and there through the park lands, enjoying the low gravity. Some turned graceful back-flips. Others swung through the trees like slow-motion monkeys.

The two men began walking in the direction of a row of statues. The row was straight, but could be seen to arc upward slightly in the distance. At this higher level in the sphere, the curving of the ground was more apparent.

They neared the first statue. It was Johanne Kepler. He held an orrery in his outstretched hand.

"Kepler," Reggie harrumphed. "Wouldn't have amounted to anything if not for the observational data of Tycho Brahe."

"Tycho's data would have had no meaning without Kepler's equations to explain them," Bruce countered.

Changing subjects, Reggie asked him, "Have you been keeping up with all of the new space launcher development these days?"

"Yeah, I'm pretty familiar with the newer designs..." Bruce started.

Reggie continued undeterred. "They expanded Sky Bridge One again. Six hundred and twenty kilometers now. Only takes five G's to leave Earth. And the newest launcher they just finished in Africa is not only longer, it's bigger in diameter, too. The passenger craft they're launching from it are comparable to the fuselage of a Boeing 777. You remember the 777, right?"

"And of course our lunar launchers are even more impressive," Reggie added with pride. "We use them for deceleration too, you know. One offers direct non-stop flight from the surface of the moon to re-entry into Earth's atmosphere."

In the course of this conversation they had passed the statues of Galileo, Newton, and Einstein. Each figure held an object identified with the life of the individual.

Reggie was tapping the pedestal of the next statue with his cane. "This must be where you come to pray every Sunday."

Bruce gazed up at the figure of Gerard K. O'Neill. He had always felt it was a particularly good likeness. The Beatles hair-cut, the ubiquitous turtle-neck sweater, the lop-sided smile, all were there. He held a small model of an O'Neill Cylinder space habitat.

The eyes of every statue in the park were slightly elevated, as though each genius were looking at some vision above the heads of ordinary mortals. One would certainly expect this in the O'Neill figure. But Bruce felt that more than any other statue in the park, the eyes of this one seemed to be taking in the surroundings. Bruce liked to think Gerry was enjoying his excellent view of the vast expanse of land which curved away all around, and that the crooked grin came from a sense of vindication.

Reggie had continued on to the next statue. Bruce reluctantly joined him.

"Ugh," Reggie said while pointing upward with his cane. "Definitely the ugliest of the lot."

This was, of course, the statue of Bruce Franklin. The figure held a mass-driver coil in its hand.

"And I'm not even dead yet," Bruce complained. "At least they could have waited, and spared me the embarrassment."

"Oh, sure. Your modesty was always one of your strong points. Hey, lookie here." Reggie was fishing around in his pants pocket, and now withdrew a short length of red crayon, sans paper, with a finely sharpened point. Bruce immediately began to chuckle. He recognized it as one of the "bullets" from the model of Sky Bridge Reggie had built all those years ago.

"Do you know why I brought this out now?" Reggie asked him.

"I suppose to remind me of a time long ago when we were both young men and space launchers were nothing but a gleam in our youthful eyes."

"Wrong. I'm going to go back, climb up on Gerry, and give him a red mustache."

"Yeah, right," Bruce snorted derisively. "Like you had the strength, you feeble old bastard."

"Senile old coot," Reggie countered.

The pair turned and started back towards the entrance of the park. They needed to start thinking about getting ready for that ISNN interview.

"I could probably find you a nice, zero-gravity hotel we could put you up in while you stay," Bruce offered.

"Are you kidding? Like I want to sleep in a room that's surrounded by Earther newlyweds bouncing off the walls all night long. No thanks. Don't you worry about me. I'll get along. I'm not old and feeble yet, you know."

As the pair headed back along the pathway to the elevator, it occurred to Bruce that he was supremely happy. He had survived the man-rating of Sky Bridge: his greatest single creation. He was exactly where he had always wanted to be. His oldest and dearest friend was still around to abuse him.

And best of all, the future was back on track.

The End

AFTER WORD

I cannot claim originality for the concept behind Sky Bridge. Gerard O'Neill described such a

structure in the "Wild Cards" chapter of his book 2081: A Hopeful View of the Human Future. He considered it as the ultimate space transportation system for a very distant future, and allowed that, "Some of that system may in operation by 2081, but not, I would guess, very much of it". So all I have done is merely perform a radical acceleration on his time-table.

The notion of a mile-wide solar-powered hot-air balloon permanently supporting both itself and a load high in the upper atmosphere may at first seem almost beyond belief, but the concept has been thoroughly studied by researchers at the Franklin Institute. They were interested in developing a manned research platform for study of the upper atmosphere. The project was called STARS: Solar Thermal Aerostat Research Station. Buckminster Fuller was also reported to have promoted the idea. Unfortunately, I have not yet gotten hold of the original paper, so any gross errors concerning the design of the balloons are entirely mine. The point is that their calculations indicated such a balloon would work. I merely repeat it endlessly for Sky Bridge.

Ad Astra!
Mike Combs

December, 1994

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