By Andrea Gini

Engineering and Craftmanship
Interview with Art Thompson

On October 14, 2012, Felix Baumgartner broke three skydiving records within a single mission: highest jump, longest free fall, and highest velocity in free fall. It was the pinnacle of Project Stratos, an ambitious flight test program sponsored by energy drink producer Red Bull that resulted in a media event followed live by three billion people worldwide.

The idea of a parachute jump from the stratosphere may seem deceptively simple, until one realizes that the stratosphere is not so different from deep space in terms of the hazards it poses to human life. When Joe Kittinger established the highest jump record in 1960, he climbed up to 31.33km in an open gondola lifted by a helium balloon, and he was protected only by his pressure suit. This flight profile, probably justified back then by the military nature of the program, exposed the pilot to an incredible array of hazards, like extreme temperature, risk of ebullism, decompression sickness, loss of consciousness during free fall, and ultimately, death.

But when Red Bull approached Art Thompson to take the role of Technical Director, he make one thing clear: the only way to make Project Stratos happen was to establish it as a flight test program that would involve the development and incremental test of a pressurized capsule, a pressurized suit, a totally new parachute rig, as well as the development of mission specific procedures. The mission would have clear scientific and technological objectives, in particular developing the next generation pressure suit, documenting the effect of the free fall process on the human body, and expanding the survivability envelope of humans bailing out from a vehicle in distress.

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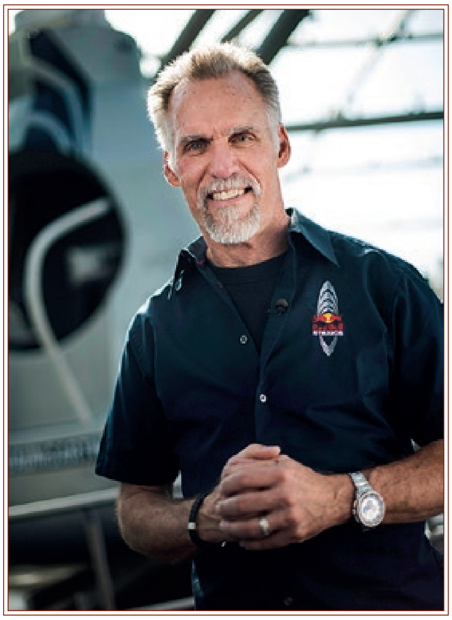
The resulting breakthroughs in space safety have been recognized by the International Association for Advancement of Space Safety (IAASS), which awarded Thompson and the Red Bull Stratos team the Jerome Lederer Space Safety Pioneer Award in May 2013. We had a chance to sit down with Thompson during the 6th IAASS conference to get some insight about the development of the hardware and safety procedures of Red Bull Stratos.



Art Thompson in Hangar 7 in Salzburg, Austria on October 13, 2013. – Credits: Jörg Mitter/Red Bull Content Pool

Red Bull Stratos capsule modular components: from left to right, the crush pad fairing, upper capsule and upper load frame, lower capsule section floor and load frame, and pressure sphere with bezel and hingeless door. – Credits: Sage Cheshire

A Space Capsule without a Rocket

Thompson is an eclectic designer with 30 years of experience in aerospace design marked by accomplishments such as his contribution to the development of the B-2 "Stealth" aircraft. He is co-founder and vice president of Sage Cheshire Aerospace, a company he named after a character from *Alice in Wonderland*, where he works with his wife and his mother, because "if you can't trust your mum, who can you trust?" He treats his company as a family operation because "if you can inspire people to believe in a program from their heart, they always give you 150%."

As with any other project at Sage Cheshire, Thompson did not limit ▸▸

Jon Wells, Sage Cheshire Aerospace mechanical engineer and crew chief for the Stratos capsule, works to review the electrical system and instrument panel in the capsule before testing. – Credits: Sage Cheshire

> "He went home, made a rig, jumped out from an airplane, then called me: 'Artie it works!'"

himself to sitting at the drawing board: he and his team literally hand built the Stratos capsule piece by piece around Baumgartner with tools like saws, hammers, and welding machines, as documented by videos available on the Red Bull Stratos website. This combination of engineering and craftsmanship, driven by a vision, was a key factor behind the success of Red Bull Stratos.

According to Thompson, safety and redundancy were the number one factors in the design of all the equipment for Red Bull Stratos. As an example, the capsule stored ten hours of liquid oxygen onboard even though the flight was two and a half hours, and it used a nitrogen/oxygen atmosphere to reduce flammability. "The operating pressure was 8psi, but we pressure tested the capsules to 24psi, a three times safety factor. The capsule was designed to take up to 50psi, quite a bit more," he adds.

The pressure was set to 4.9km equivalent to reduce the risk of decompression sickness. Just before the jump, the capsule is decompressed in nine seconds. "When [the pilot] opens the door up, he's actually exposed to altitude for less than ten minutes, the time it takes to step out, disconnect and step off, and then free fall," Thompson explains. "When you look at that amount of time, his risk [of decompression sickness] is very low."

The pressure differential allowed Thompson to implement a great innovation: a rolling door with no hinges. "When you're in a vacuum the internal pressure in that door is over 4500kg of pressure," Thompson explains. "Hinges are just extra weight; they are not doing anything for the spacecraft."

Every system on the capsule is controlled by circuit breakers that could be operated either onboard or from mission control. One problem that arose was that NASA didn't have space-qualified solid state circuit breakers because the Shuttle, thanks to its airlock, never exposed electronics to space. "In our condition, when you open that door, all the electronics would have been exposed," Thompson explains. "In order to assure that you wouldn't have a thermal trip from heat or because of lack of atmosphere, we went in and designed and built the first solid state circuit breakers onboard the capsule."

With 19 high definition cameras running on 80 amps of electrical power for over five hours, power supply needed extra care. "We had two separate space rated battery systems: one for the camera system and one for the science and life support, so that the camera systems could never take down the life support or science equipment."

Space qualification was performed in-house: "At Sage Cheshire we built a high altitude chamber, so everything that went on the capsule we would test first in our altitude chamber at 670 meters and -79 degrees Celsius," Thompson says. "That way we knew what the qualifications were before we actually put [a component] on the capsule itself."

The result was nothing short of a real space capsule: "At 29km you're less than 0.2% atmosphere," Thompson explains. "The conditions that it's exposed to in space are pretty much the same, with the exception of, maybe, radiation or micro-particles." The capsule was actually designed to NASA standards, so "the only difference between our capsule and a space capsule would be that it didn't have a rocket at the bottom."

Landing Gear

A big engineering challenge was to develop structures light enough to facilitate the ascent and strong enough to absorb the shock of the landing and be reused. "The pressure sphere, the capsule itself, was about 2mm

Art Thompson communicating with Felix Baumgartner in the first Red Bull Stratos prototype pressure suit at the David Clark Company. – Credits: Sage Cheshire

The Red Bull Stratos capsule with the temporary top cover before being loaded into the Brooks altitude chamber. Note the two 10 liter dewars of LOX and one 25 liter dewar of LN2 that are part of the capsule life support system. – Credits: Sage Cheshire

thick in the thinnest areas and 9mm in the thickest," Thompson explains. "The pressure sphere is mounted inside an aircraft-certified welded Chromoly steel frame with foam supports for absorption between the pressure sphere and the frame. The frame is mounted to an aluminum base floor, where all the equipment is, and that floor is encapsulated with high density EPS foam for insulation with fiber glass, and the crash pad on the base."

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The loads are carried through the floor up around the pressure sphere, and then up into the upper framework, to the attachment with the flight train for the recovery parachute. The 30m diameter recovery parachute brings speed down to about 5.5m/s. With such a speed it would take up to an hour and a half to bring the capsule down from an altitude of 36km, an excessive time in case of medical emergency. "In the event something happens [at that altitude], if you don't bring [the pilot] down quickly enough, then, from decompression they would go comatose," Thompson explains. "Exposure to vacuum those kind of times would cause physical damage that you couldn't survive."

The solution? "We put a reefing line on the parachute, so our 30m diameter parachute was reefed down to 17m. When it is released from an altitude of 36km it falls at a very high rate of speed – up to 179m/s in free fall – so we were able to cut down the descent time down to about 20 minutes." This strategy also allowed the team to reduce the landing area from 40km down to 1.5km, greatly simplifying the work of the recovery crew.

A crash pad area below the capsule was designed to get the shock loads on landing below 12g to ensure survivability of the pilot and reuse of the capsule. "Every time we were flying we replaced the crash pad area so the actual g-load was between 6 and 8g on spike." They never made a crash test with the pilot inside, but "we did do crash pad tests using a 55 gallon drum of sand with accelerometers, measuring what the shock loads are."

Bailing Out from Space

While the capsule made the ascent safe and relatively comfortable, the actual jump exposed Baumgartner to an incredible number of hazards. Besides the environmental hazards

Felix Baumgartner in the Red Bull Stratos capsule in preparation for testing and training in the Brooks altitude chamber. – Credits: Sage Cheshire

> "We need to not be pushed by marketing, but by safety and protecting people's lives"

(see "Falling Free from the Edge of Space" published in the 5th issue of Space Safety Magazine), the biggest risk Baumgartner faced during his descent was to enter into an uncontrollable flat spin, becoming unconscious, and suffering conditions such as ocular hemorrhages. To mitigate these risks, Thompson's team moved the heavy chest pack containing batteries, accelerometers, and radios, up high on Baumgartner's chest in order to change the center of rotation, reducing the head pressure in the event of a flat spin.

An emergency drogue chute, triggered by accelerometers, was added to the rig in order to deal with the event of loss of consciousness. Thompson's team studied a new way to position the gear. "If you change the position of the parachute high on the shoulder, you actually create an asymmetrical position that would stop the rotation," says Thompson. "Our parachute tester used to think 'that won't work,' but he immediately went home, made a rig, jumped out from an airplane, and then called me and said: 'Artie it works!'"

The Red Bull Stratos jump happened at an altitude very close to that at which the Space Shuttle Columbia broke apart in 2003, so proving the reliability of these safety systems has real life significance that could save lives in the next-generation vehicles. "The next step for us is proving the safety equipment we designed to save his life in the event something went wrong," Thompson says, adding that Sage Cheshire is still working on demonstrating that the gear would work even if the pilot lost consciousness. During the Stratos jump, Baumgartner managed to go transonic without the need to activate the drogue chute. "He actually had some control, once he developed enough dynamic pressure, he had some ability to position himself," Thompson explains (see "To the Stratos and Beyond, Interview with Felix Baumgartner" in the 6th issue of Space Safety Magazine). "But even with that, still he went into a flat spin."

"What we're looking to do is more additional altitude flights, with balloons and probably higher next time, dropping dummies with the same safety equipment that we had for Felix and let that [go] into a spin, let the g-load kick off, let the drogue open up, and show that we can stop that rotational spin and control the issue at the end." By embedding safety provisions into the gear, Thompson explains, "we assure that even though somebody doesn't have three thousand parachutes jumps, when the parachute automatically opens up, with an automatic opener designed to operate at near vacuum conditions, we have a weight and balance system, so that we reduce down the flat spin."

Although Stratos has unquestionably produced valuable lessons learned, how those lessons will be applied in future vehicles is up to their operators. "With private space tourism it is really up to the organizations that are developing private tourism to take it upon themselves to really look at what the proper procedures are for space safety, because the first time somebody dies as a space tourist, is gonna affect everybody in the room," Thompson says. "We all need to really be looking at what it takes to be as safe as we possibly can, and not be pushed by schedule, not be pushed by marketing, but be pushed by safety and protecting people's lives. If we have the proper equipment for getting people down, we can assure that in the event of hazard, we've done everything within our power to make sure we can bring these people back alive."

Reaching out to New Generations

In concluding our conversation, Thompson speaks of the impact that project Stratos has had on the public. "It's a little overwhelming to see exactly how big it is and how many people it has touched," he says. "I get letters from children all over the world that tell me that they want to get into science and into space because they have seen Red Bull Stratos. That touches me because one of my big things is we have to figure out how to inspire the next generation to get into science and math and aerospace and carry the torch."

To the next generations of space designers, Thompson makes a final recommendation. "Remember that anything is possible and do not be deterred by failures. Use those as lessons to do better in the future, because it is a learning process. We are all here learning together and we need to look at how we take it to the next step."

Felix Baumgartner and Art Thompson celebrate after successfully completing the final manned flight for Red Bull Stratos in Roswell, New Mexico, USA on October 14, 2012.
Credits: Jörg Mitter/Red Bull Content Pool