

# 2

## Key Players



**Credit: XCOR**

“This is not optional for me. I believe humanity opening up a frontier in space is important. I think if we want to have a future, we have to do it. As soon as I see other people doing it in a way that I think will work, I can stop. So far, I don’t. So I can’t.”

*Jeff Greason*

*Rotary Rocket*

This was the company that developed the Roton, a reusable single-stage-to-orbit vehicle designed to reduce costs of delivering payloads to orbit by an order of magnitude. Roton's design was as unique and revolutionary as they get. Supported by US\$30 million from venture capitalists and angel investors, the Rotary Rocket team, led by Gary Hudson and Bevin McKinney, planned to create a hybrid helicopter-rocket. The idea was that spinning rotor blades powered by jets at the blade tips would lift the spacecraft to an altitude where air density was too thin for helicopter flight. At this altitude, the spacecraft would switch to rocket power. The cone-shaped rocket (Figure 2.1) was designed to bring down the cost of payload to orbit to around US\$1,000 per kilogram. While the helicopter-inspired design allowed the Roton to land just about anywhere, the early flight testing wasn't without its problems. To test the hover capabilities, Rotary Rocket built the Atmospheric Test Vehicle (ATV) that flew three test flights: the co-pilot for the tests was Brian Binnie incidentally, who went on to fly with Virgin Galactic (the second X-Prize flight) and then XCOR. The limited visibility in the ATV's cockpit was so restricted that pilots nicknamed it the Batcave. While Rotary Rocket claimed they couldn't continue due to lack of funding, some pointed to unproven technology and a flawed design that led to some unstable landings. Rotary Rocket eventually closed its hangar doors in 2001.

In the revolution that is New Space, there are many key players and personalities. Most people have no doubt heard of Elon Musk and his super-successful SpaceX Falcon rockets and Dragon capsules, just as almost everyone has heard of Virgin Galactic and its flamboyant figurehead, Sir Richard Branson. While these leaders receive the lion's share of media coverage, there are others who pursue the same dream of commercial access to space with a little less fanfare. Take Jeff Greason. This highly experienced engineer may be more reserved than Elon Musk or Richard Branson, but he shares many of the attributes of his more visible counterparts. Like Musk and Branson, Greason has a very clear vision of how to evolve space technology and how to realize a long-term business plan – one that was kick-started way back in 1999 with the founding of XCOR. Before XCOR, Greason worked as an electrical engineer for Intel but, in 1997, he decided to recalibrate his career path by joining Rotary Rocket (see sidebar above) in Mojave. When Rotary Rocket folded two years later, Greason, together with his team of four engineers, decided to strike out and found their own rocket company. Inspired by the X-1 and X-15 programs, they decided XCOR was a catchy name for their rocket company.

Rotary Rocket's demise is just one of many in the short history of commercial space-flight and it serves as a reminder to those who are still working in the Mojave in the form of a 20-meter-high prototype located in Legacy Park. Greason advises XCOR interns to look but not to touch, reminding them of the local superstition that everyone who has touched the vehicle has lost money. Following Greason (Figure 2.2) were Dan DeLong, Doug Jones, and Aleta Jackson, whom we'll introduce later in this chapter. Without a steady income, the four kept XCOR alive by working on government propulsion contracts.



2.1 Rotary Rocket Roton ATV on permanent display at the Mojave Spaceport. Credit: Alan Radecki

## JEFF GREASON

I had the very good fortune to meet Jeff at the Next Giant Leap conference in Waikoloa on the Big Island of Hawai'i in November 2014. At the time, my proposal for this book was still taking shape, but I knew it had to feature an interview with the company's Chief Executive Officer, so I asked Jeff if he would mind my asking him a few questions. He graciously gave me 45 minutes of his time and so we sat down in front of the life-sized



2.2 Jeff Greason observing a cold flow test. Credit: XCOR

replica of the Curiosity Rover in the Waikoloa Marriott lobby to discuss XCOR. But, before we get to the interview, here's some background on one of New Space's tech titans.

As a student at the California Institute of Technology, Greason was lucky enough to take a class taught by Richard Feynman. It was Feynman who served on the accident investigation panel following the *Challenger* tragedy, which occurred while Greason was at Caltech. And it was Feynman who garnered most of the media attention with his withering attack on NASA's failure to address critical problems that led to the *Challenger* accident. To Greason, the savaging of NASA by such an esteemed scientist was something of a shock and it got him thinking that perhaps the agency wasn't as untouchable as he had once thought. In fact, Greason reasoned, perhaps government agencies weren't the only ones who could figure out the business of launching rockets into space. It was something he thought about during his career at Intel, where he developed cutting-edge techniques to enable the mass production of new generations of computer chips. His work dramatically reduced the time of development to actually realizing a customer-ready product, which is partly why Intel management awarded him with the prestigious Intel Achievement Award. It was during his time at Intel that Greason attended the Space Access Conference. That was in 1994. After returning from the conference, Greason set about learning everything he could about rockets from assorted rocketry books and engineering journals. Three years later, at the same conference, Gary Hudson, an entrepreneur on the lookout for a technical manager, collared Greason and asked whether he would be interested in building a reusable spacecraft. For Greason, the decision was a slam dunk.

With a promising management career and solid financial security, it must have been tough to walk away into the decidedly hit-or-miss venture that was Rotary Rocket, but Greason had always had his eye on paving the way for civilians to travel in space, so he took the plunge. Fortunately, his wife Carrine (whom he met while at college in Portland) supported him, reasoning it was best to have a happy spouse and viewing the move from

Portland, Oregon, to the Mojave as an adventure (thanks to her freelance job as marketing communications support to high-tech companies, she could work wherever there was an internet connection). It helped that Greason had a supremely talented engineering team working for him at Rotary and the fact he had squirreled away a decent nest egg while working at Intel. After Rotary folded, Greason's income rolled down to almost zero, so he siphoned off funds from his Intel stock while making the commute from Tehachapi to the flight line at Mojave (for the first year, to keep the company going, Greason's engineering team used credit cards to buy parts). With quiet streets, few stores, and the odd signal light, Tehachapi, with a population that hovers around 30,000, is a world away from the big-box towns, as is Waikoloa, which is where the following interview took place.

One of the first questions I had was when test flights would commence.<sup>1</sup> Since the 2004 flight of SpaceShipOne, the commercial spaceflight industry seems to have been in a perpetual holding pattern – one which seemed to have stalled with the SpaceShipTwo tragedy that took place less than two weeks before I interviewed Jeff. The plan was to start the flight-test program in late summer 2015, with the aim to fly as many as 80 test flights of the Mark I. When asked how long he expected this would take, Jeff replied he would be surprised if the test program could be completed in less than six months and doubted it would take longer than 18 months. But, he added, the Lynx would fly when it's ready to fly and XCOR's engineers were working as fast as they could to make that happen. The last thing XCOR wanted to do was to apply extra pressure by announcing a flight date. For those of you who have followed Virgin Galactic, you may remember the seemingly never-ending pronouncements of dates for when revenue flights would start. First it was 2009 and then 2010. Then the absolute latest date for rocketing passengers into suborbital space was 2013. Following the SpaceShipTwo accident, Virgin Galactic has adopted the XCOR mantra. A case in point: when asked by a member of the audience at the 2015 Space Access Society conference in Phoenix when SpaceShipTwo would fly, Will Pomerantz followed the XCOR mantra and replied it would fly when it was ready. And, before flight testing could begin, Jeff reminded me, there were still a few tasks that needed to be completed, the first of which was to piece together all the structural subassemblies (Figure 2.3) and after that they had to begin debugging the propulsion system. And, while he couldn't predict when all these pieces would come together, Jeff was confident that work was progressing as it should.

Next, I asked for Jeff's perspective on the competition in the commercial suborbital and orbital spaceflight arena. Of all the people in the business of New Space, Jeff is recognized as one of the most knowledgeable. He is an expert in the Federal Aviation Administration (FAA)'s office of commercial spaceflight (AST) reusable launch regulations and is a co-founder and vice chairman of the Personal Spaceflight Federation so, when he offers his opinions on the subject of where commercial spaceflight is heading, people sit up and take notice. Jeff is convinced the suborbital and orbital markets will remain very distinct entities for quite some while for the simple reason that there are no overlapping segments. On the subject of the orbital market, he thinks it will be dominated for quite some time by expendable launch vehicles and that it may take some time before reusable vehicles take

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<sup>1</sup> Rather than laying out the typical question-and-answer format, I have condensed Jeff's replies into the following narrative.



2.3 Reaction Engines' Skylon. Credit: Reaction Engines

center stage. But, when reusable vehicles come on stream and can be flown regularly, they may come to dominate the lower end of the market. On the subject of the suborbital market, he is very confident that XCOR will be in a very strong position to compete on price because the company's capital costs are so low and the design of the Lynx means that the company can fly up to four flights per day: that won't be the case with Virgin Galactic, although SpaceShipTwo can carry up to six times as many passengers than the Lynx.

On the subject of point-to-point transportation (Figure 2.4), Jeff recognizes that there is a lot of interest in this mode of high-speed travel, but he doesn't expect it to be realized before the mid-2020s. One of the reasons for this, apart from the tremendous technological challenges, is the competition with regular commercial air travel. The market for those who need to get somewhere very, very fast while paying stratospheric ticket prices is very small. And, despite all the nice pictures in the glossy magazines, this mode of travel isn't exactly practical because any prospective passenger first has to travel to the remote spaceport to catch a flight which will land at another remote spaceport. At the end of the day, this ultra-fast mode of transportation may not end up being that fast at all. And, as far as using the Lynx for point-to-point travel is concerned, the idea is a non-starter because the vehicle can't fly much more than 320 kilometers downrange – a distance that could be extended by subsonic glide, but not enough to make point-to-point travel financially viable.

Another sensitive issue we discussed was the International Traffic on Arms Regulations, or ITAR. Part of XCOR's business plan is to launch the Lynx from other countries, but to do that they need to transport the vehicle outside of the US. The problem, according to Category XV (Spacecraft and Related Articles) of the US Munitions List (USML), is that





2.4 The Starfighter 104 is being used as a test bed to develop point-to-point transport. Credit: Starfighter

the US Government considers tanks, fighter jets, bombs and ... suborbital spacecraft as munitions. That's right: suborbital vehicles are a regulated item, right along with ballistic missiles. In the 2000s, this classification caused more than a little consternation among those in the commercial spaceflight arena and ITAR quickly became a four-letter word. It still is. In May 2014, the State Department revised Category XV and removed some commercial satellites and components used to build those satellites, but the hot-button issue of suborbital vehicles remained. The rationale was cited as follows:

“For example, launching spacecraft to sub-orbit or orbit requires MTCR Category I items, upon which are placed the greatest restraint with regard to export. Spacecraft specially designed for human space flight that have integrated propulsion present another security concern, for such capabilities may be used for the purposes of weapons targeting from space. So, although these technologies and capabilities are used in commercial endeavors, they continue to merit control on the USML.”

The State Department's interim final rule for the revised Category XV of the US Munitions List.

While the satellite manufacturers were reasonably happy with the amendment, the commercial spaceflight industry was less than impressed. There had been some hope that the State Department would have moved suborbital vehicles to the less restrictive Commerce Control List (CCL), but it didn't, which is something that frustrates Jeff because it not only means that XCOR is banned from transporting the Lynx out of the country, but also prevents the company from hiring non-US nationals.

## DAN DELONG

Dan DeLong (Figure 2.5) is XCOR's Vice President and Chief Engineer. His career as an engineer got started while working as an underwater equipment designer for Westinghouse Ocean Research and Engineering, where he developed emergency life-support equipment and worked on closed-circuit breathing gear. From Westinghouse, DeLong moved to Perry Oceanographics, where he worked as the company's Staff Materials Engineer between 1978 and 1983, during which time he helped develop the company's remotely piloted vehicle RECON III. After Perry, DeLong spent five years developing air-launched orbital vehicles while employed by Teledyne Brown Engineering, working alongside famed Dr. Ernst Stuhlinger who had been brought to the US as part of Operation Paperclip along with Wernher von Braun. During his time at Boeing, DeLong also served as an analyst for developing the International Space Station (ISS)'s life-support system. For a couple of years after his stint with Boeing, DeLong was president of Eureka design, which built hardware for Kistler Aerospace, but, in 1997, he moved on and co-founded Rotary Rocket. When that adventure ended in 1999, he followed Jeff and co-founded XCOR. He's stayed there until November 2015 before joining Jeff to found Agile Aero.

To say that DeLong is one of the world's leading rocket propulsion innovators is an understatement. In 2002, *Esquire* magazine featured him in one of *America's "Best and Brightest" 43 People Who Will Revolutionize the World*. Which is exactly what DeLong has been doing in the Mojave for the past 15 years. If you're planning on flying on the Lynx, you'll be taking a ride in a vehicle that has been designed by one of the very best engineers in the business. And that's partly because the Lynx isn't the first reusable launch system DeLong has had a hand in designing. While working for Teledyne, he worked on the Spaceplane and the Frequent Flyer, both air-launched reusable vehicles. The Spaceplane



2.5 Dan DeLong. Credit: XCOR



was designed to be mounted on a converted 747 Carrier aircraft and launch up to three tonnes of payload to 400-kilometer low Earth orbit (LEO). The idea was that it would be built with off-the-shelf components and be powered by one Space Shuttle Main Engine (SSME) and six RL-10s. After delivering its payload to LEO, the winged single-stage-to-orbit (SSTO – with the assistance of the 747) vehicle would glide back for a runway landing. Although the Spaceplane wasn't a thoroughbred SSTO since it benefitted from the air launch from the 747, the mission design was elegant in the way it solved the challenges of a pure SSTO vehicle. To design a ground-launched vehicle capable of horizontal take-off and landing is still a significant challenge, even in the mid-2010s. That's because a ground-launched vehicle needs to be fitted with landing gear that supports the full weight of the vehicle and wings that must be capable of producing lift at the very low take-off speeds. As if that isn't bad enough, the vehicle must have engines that can operate equally well at sea level as in a vacuum. How do you resolve these problems? DeLong decided to use air launch – a decision that made the whole flight much, much easier. For one thing, there are fewer meteorological uncertainties at higher altitudes, which means that fuel reserves can be reduced. And, since the launch occurs at high altitude, this means that not only are aerodynamic drag losses less, but Max Q is less also, which lowers the structural mass of the vehicle. Also, because the vehicle is no longer required to lift the full weight at low take-off speed, the wing area can be reduced, which further reduces structural mass. Finally, the mission flexibility of an air-launched system is much greater than a thoroughbred SSTO because the carrier aircraft can fly up-range if necessary (to optimize the launch point relative to an orbital destination, for example) and this ability also permits a greater return-to-launch-site abort window. In addition to the Spaceplane, DeLong also worked on the Frequent Flyer, an unmanned vehicle that was also designed to be launched from a 747. The Frequent Flyer's job was to deliver 300–450-kilogram satellites to LEO, although there was an option to carry passengers using a special pod. Unfortunately, neither the Spaceplane nor the Frequent Flyer was built, but that isn't the case with DeLong's current project.

## DOUG JONES

As XCOR's Chief Test Engineer, it is Doug's job to deal with the test design and analysis of testing of the Lynx's engine development – a job description that fits his skill-sets like a glove. Born with an unusual ability to pinpoint the most minute of minute propulsion anomalies, his colleagues long since conferred the title of the Rocket Whisperer upon him. Prior to joining XCOR, Doug, like Dan and Jeff, worked for Rotary Rocket, where he was tasked with coordinating the design of the rocket engine and interpreting the reams of test data. As part of his job as flight-test engineer, Doug flew the X-Racer on a number of occasions. Ensnared in the right seat, Doug's job was to keep an eye on the propulsion system as the pilot put the aircraft through its paces. This job was achieved thanks to the strategic positioning of myriad sensing devices in the engine and a mini camera (one of four) attached to the vertical stabilizer that was focused on the engine exhaust. During the 37-flight X-Racer program, Doug worked with Primary Flight Test Engineers Mark Street and Douglas Jones, to troubleshoot the detail and system design choices affecting the performance of the aircraft. This process was a relatively quick one thanks to the rapid turnaround



2.6 Aleta Jackson. Credit: XCOR

between flights. During the flight, the engineer would identify the problems, the issues would be fixed on the ground, and in short order the aircraft would be flown again.

## ALETA JACKSON

A technician, editor, and pilot, Aleta (Figure 2.6) is XCOR's Chief Technician and Office Manager. Like Jeff, Dan, and Doug, her previous employer was Rotary Rocket where she managed technical documentation. Prior to her stint at Rotary Rocket, she worked for McDonnell Douglas and Electron Emissions Systems, although she is perhaps best known as the first woman to fly the X-Racer.

## THE TEST PILOTS (FIGURE 2.7)

### NASA astronaut Rick Searfoss

As momentum has continued to build in the commercial spaceflight industry, it has opened up a second career for some spacefarers leaving the astronaut ranks. For example, in July 2014, Bigelow Aerospace hired former NASA astronauts Ken Ham and George Zamka. Zamka, who had left NASA in 2013 to work at the FAA's Office of Commercial Space Transportation, was an ex-military pilot who flew on Shuttle missions STS-120 and STS-130. Ham, who joined Bigelow from his job as chairman of the US Naval Academy's Aerospace Engineering Department, was a US Navy Captain who flew on STS-124 and STS-132. One of his jobs at Bigelow Aerospace will be to develop astronaut training programs for Bigelow's sovereign customers who will be spending time on the company's orbiting habitats. SpaceX is another New Space company who had hired NASA retirees, counting Garrett Reisman among their employees. Reisman, who is the project lead for the



2.7 Rick Searfoss. Credit: NASA

manned Dragon variant, the V2, flew with Ham on Shuttle flights STS-124 and STS-132 in addition to flying on the *Endeavor* during STS-123, which was the flight that delivered him to the ISS as a member of Expedition 16. While SpaceX and Bigelow Aerospace attract more media attention than XCOR, the trend of employing NASA's retired astronauts was one that was started by the Mojave-based company when it hired Searfoss to fly the X-Racer in 2008.

In Searfoss, XCOR was one of the most accomplished pilots in the US Air Force (USAF) and an astronaut to boot. A Distinguished Graduate of the USAF's Top Gun School and the Naval Test Pilot School, Searfoss has accumulated more than 6,000 hours of flight time in more than 70 types of aircraft, including the X-Racer. It was while he was working as an instructor at the test pilot school that Searfoss was selected by NASA for its astronaut program. After graduating as an astronaut in 1991, Searfoss didn't have to wait long before being assigned to and flying a mission. His first was STS-58 (Figure 2.8), which launched on 18 October 1993 – a flight on which he piloted *Columbia*.

STS-58 was followed in short succession by STS-76 (22–31 March 1996) and STS-90 (17 April 17 to 3 May 1998) – a flight for which Searfoss served as Commander. All told, Searfoss had logged 39 days in space by the time he retired from NASA in 2003. And, for a deposit of just US\$20,000, you can book a seat next to Searfoss on an upcoming Lynx flight.

### Commercial astronaut Brian Binnie

Like Searfoss, Binnie is a supremely experienced pilot with a stellar resume. A graduate of the US Navy's Test Pilot School, Binnie has accumulated more than 5,000 hours of flight time on more than 60 aircraft types and has an Airline Transport Pilot's license to



2.8 Rick Searfoss. Credit: Rick Searfoss

boot. Much of his test-flight experience was logged flying the F/A-18 while expanding the launch envelopes of various weapons systems and testing the transonic performance of the aircraft. In addition to his military experience, Binnie also gained skills in the commercial space sector as a test pilot for the Roton venture (where he worked alongside Greason and DeLong) – a program for which he developed the aircrew checklists and emergency procedures. After Roton folded, Binnie headed for Virgin Galactic, where he found everlasting fame when he piloted SpaceShipOne on the second X-Prize flight (Figure 2.9) – a flight that earned him his commercial astronaut wings.

“I wake up every morning and thank God I live in a country where all of this is possible. Where you have the Yankee ingenuity to roll up your sleeves, get a band of people who believe in something and go for it and make it happen. It doesn’t happen anywhere else.”

*Brian Binnie, after piloting SpaceShipOne on 4 October 2004*



2.9 Brian Binnie. Credit: D. Ramey Logan

On 9 April 2014, almost 10 years after that historic flight, Binnie was in the headlines again when XCOR announced it had hired the distinguished pilot as the company's senior test pilot.

"The combination of Rick Searfoss and Brian Binnie at XCOR is a powerful statement from the professional flight test community about XCOR and the Lynx. The pairing of two people who are decorated military test pilots, rocket-powered aircraft pilots and astronauts is a powerful team that defines XCOR as a leader in the industry."

*Andrew Nelson, commenting on XCOR's hiring Brian Binnie*

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