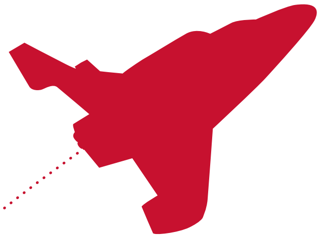

ALONG FOR THE RIDE

Reusable commercial rockets will soon be able to take scientists — and tourists — on suborbital spaceflights. Are these vehicles vital research tools, or an expensive dead end?

BY LEE BILLINGS

As NASA's space shuttle *Discovery* roared into the sky on 24 February 2011, the bass rumble of its main engines and the staccato crackle of its solid-rocket boosters rolled out across the central Florida countryside, growing fainter and fainter with distance. Viewed from a hotel patio some 65 kilometres away in Orlando, the pillar of flame seemed to rise soundlessly, a silent apparition from a bygone era. *Discovery* was on its final mission; only two shuttle flights were left before the programme ended for good. In the United States, the classical era of the nation's human spaceflight was drawing to a close, 50 years after it began with the 15-minute flight of astronaut Alan Shepard on 5 May 1961.

Three days after *Discovery*'s launch, in the bar of the Orlando hotel, two planetary scientists are talking with a group of fellow researchers about what should come next. Sipping his drink, Daniel Durda laments that after half a century, only about 500 people have flown in space. Access to humanity's final frontier is still restricted to people employed by a handful of powerful governments and corporations, plus the occasional joyriding mega-millionaire. "I'd prefer for anyone to be able to go, for any reason they choose," says Durda, of the Boulder, Colorado, branch of the Southwest Research Institute (SwRI).

"EVERYONE WHO CAN AFFORD A TICKET WILL GO. THIS IS GOING TO BE LIKE THE WILD WEST."

His companion, Catherine Olkin, also of the SwRI, agrees. "What we're doing is the next step," she says. "There are huge opportunities up there, not just for science, but for everyone."

That next step is the subject of the meeting that has brought them all here. The second annual Next-Generation Suborbital Researchers Conference (NSRC) is inspired by the growth in recent years of a plethora of commercial companies making rockets designed to carry instruments and paying passengers more than 100 kilometres above Earth — past the edge of the atmosphere and into space. 'Suborbital' denotes vehicles that will come down again without entering orbit, but will still offer researchers precious minutes to make astronomical observations unblurred by the atmosphere, or to study physical processes in the absence of gravity.

Indeed, conference attendees are already buzzing with the news that the SwRI has budgeted US$1.3 million for a four-year suborbital science programme, a portion of which will be used to book passenger seats on spacecraft for Durda, Olkin and their colleague Alan Stern, the SwRI's associate vice-president of research and development. If all goes as planned, the three researchers will be flying into space as fully fledged astronauts by mid-2013.

The SwRI is so far the only research institution to have made such a deal, and everyone here knows the arguments for caution. None of the leading suborbital companies has yet flown its vehicles into space and back. And seats on future flights are going for some $100,000–200,000, yet will give researchers no more than five minutes of weightless 'hang time' above the atmosphere. For most data-collecting needs, it is just as effective to launch automated equipment on an unmanned rocket. Many space scientists, therefore, remain dubious about the usefulness of commercial suborbital spaceflights, particularly those on which researchers accompany their equipment.

But few of those sceptics have made the trip to the Orlando conference, where the prevailing mood is enthusiasm. No one embodies that feeling better than Stern. He hasn't made it to the hotel bar this evening, but that is only because he is busy conferring with launch-industry executives — not to mention preparing to chair panel sessions, deliver a plenary talk and give press conferences.

As the principal investigator for NASA's New Horizons mission to Pluto and former head of the agency's Science Mission Directorate, Stern has a reputation for making big things happen — including the NSRC itself, which he and Durda helped to organize. He frequently compares the state of the nascent suborbital industry to the early days of commercial aviation and personal computing. Eventually, he explains when *Nature* catches up with him the next day, "we'll no longer have one centrally planned space programme where only NASA has the keys to the space shuttle, and everyone has to funnel through that system. Everyone who can afford a ticket will go, and that will generate a lot of innovation, a lot of variety. This is going to be like the Wild West."

Ironically, this 'centrally controlled' programme

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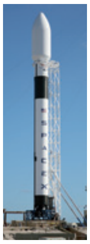
SPACE FOR EVERYONE

A multitude of private companies have joined the competition to provide launch services.



1 FALCON 9

Company: SpaceX
Max altitude: Low Earth orbit
Microgravity: Indefinite
Passengers/Pilots: Seven people in capsule
Status: 2010: Rocket and Dragon cargo capsule achieve orbit. 2011: NASA funds Dragon upgrade for humans.

2 SPACESHIPTWO

Company: Virgin Galactic
Max altitude: 110 km
Microgravity: Four minutes
Passengers/Pilots: Six/two
Status: 2010–11: eight tests, four as a free-flying glider. 2012: commercial passenger flights expected.

3 LYNX

Company: XCOR Aerospace
Max altitude: 110 km
Microgravity: Three minutes
Passengers/Pilots: One/one
Status: 2012: expected test of mark I prototype. 2013–14: expected flight of mark II production model.

4 NEW SHEPARD

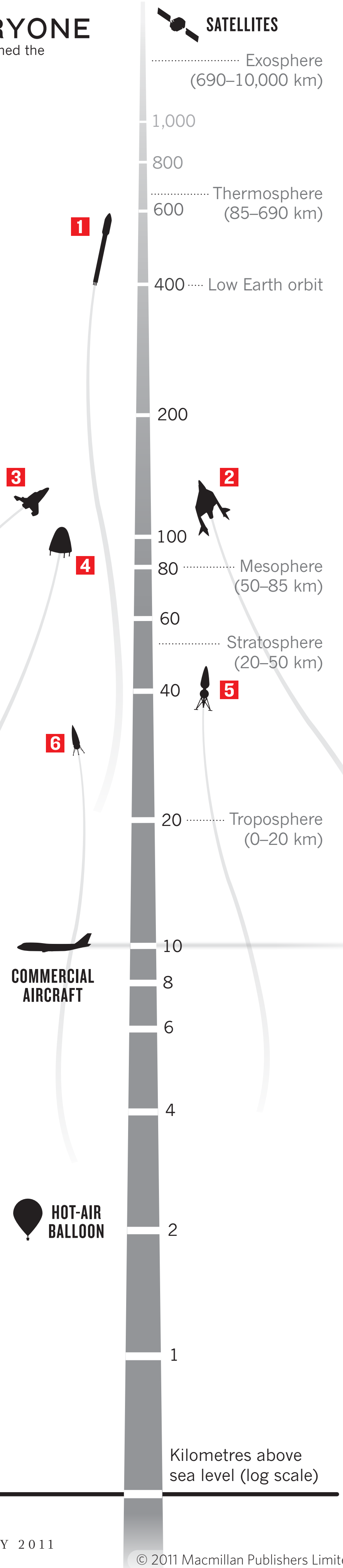
Company: Blue Origin
Max altitude: 100 km
Microgravity: Three minutes
Passengers/Pilots: Three/none
Status: 2006–11: at least three test flights. 2011: NASA funds crew-capsule development.

5 SUPER MOD

Company: Armadillo Aerospace
Max altitude: 40 km (initial flights)
Microgravity: Three minutes
Passengers/Pilots: Unmanned
Status: 2010–11: many test flights. 2011–12: expected flight of new commercial vehicle to 40–100 km.

6 XAERO

Company: Masten Space Systems
Max altitude: 30 km (initial flights)
Microgravity: Three minutes
Passengers/Pilots: Unmanned
Status: 2011: expected test flight to 30 kilometres. 2012: expected flight of larger Xogdor to 100 km.



has relied on private rockets for decades. Most communications satellites and even classified military payloads are sent into orbit atop commercial launchers. Similarly, unmanned private sub-orbital flights are routine, with various companies marketing 'sounding rockets' that take measurements and perform experiments in space.

The problem is that these launchers are so expensive that only the government and large telecommunications corporations can afford them. One reason for their cost is that they are expendable, discarded after a single use. In the 1970s, NASA tried to eliminate much of that waste by developing the fleet of space shuttles, which were partially reusable. But in practice, the advantage of reusability was more than offset by the difficulty of engineering a vehicle that could withstand the stresses of launch and re-entry, and be ready to fly again; the shuttles proved to be hideously pricey.

Now, with the shuttles nearing retirement, NASA has been trying again to get the launch costs down — this time by encouraging the private sector to develop cheaper rockets and crew capsules to reach low Earth orbit. Last month, for example, the agency awarded $269 million in development money to four companies, one of which — the SpaceX Corporation of Hawthorne, California — has already had a successful launch with the Falcon 9 rocket, which first reached orbit in June 2010.

COMMERCIAL ENTERPRISE

For the time being, however, more entrepreneurial energy is focused on the suborbital regime, in which the costs are lower and potential customers are more plentiful. The suborbital race began in 2004, when test pilot Mike Melvill repeatedly flew a privately developed reusable spacecraft, *SpaceShipOne*, to altitudes of more than 100 kilometres in the skies over Mojave, California. Shortly afterwards, Burt Rutan, the craft's designer, partnered with entrepreneur Richard Branson to form Virgin Galactic, a venture to fly tourists on $200,000-per-seat, 110-kilometre-high suborbital jaunts using a fleet of 6-passenger '*SpaceShipTwo*' spaceplanes, which are currently in development.

A number of other start-up firms followed — many with roots in the computer and Internet industries, a testament to the symbiosis between space dreams and lucrative high-tech careers. The companies include Armadillo Aerospace, organized and funded in Heath, Texas, by John Carmack, the computer-graphics wizard behind the hit videogames *Doom* and *Quake*. There is also Blue Origin of Kent, Washington, founded by Jeff Bezos using a fraction of the fortune he earned creating Amazon.com; Masten Space Systems of Mojave, established by David Masten, a former information-technology networking guru; and XCOR Aerospace, also of Mojave, headed by Jeff Greason, an engineer who helped to develop the technology used in Intel's Pentium line of computer chips (see 'Space for everyone').

These entrepreneurs expect one of the most lucrative applications for suborbital spaceflight to be space tourism, but tourist flights won't begin for at least a year, and probably two. In the meantime, to flesh out launch manifests and help to subsidize unmanned test flights, companies have begun courting research institutions, government agencies and independently wealthy investigators who want to run scientific experiments in suborbital space. All five companies sent representatives to the NSRC this year, hoping to court more clients like the SwRI, which has bought a total of eight seats, and options for nine more, on suborbital flights, split between Virgin Galactic's *SpaceShipTwo* and XCOR's *Lynx*.

Few of the attendees in Orlando needed much convincing; just about everyone there seemed eager to climb on board. Astronomers talked about raising telescopes above the atmosphere to perform mid-infrared searches for water on the Moon and to observe planets, comets and asteroids. Planetary scientists detailed microgravity experiments to investigate the collisions of dust and sand that

SPACEX
M. GREENBERG/VIRGIN GALACTIC
XCOR AEROSPACE
BLUE ORIGIN

NASA

Daniel Durda (left) and Alan Stern (floating) train for zero-gravity on an aircraft.

form the building blocks of planets. Atmospheric scientists discussed *in situ* sampling of the 'ignorosphere', the largely unexplored stratum of the upper atmosphere that lies above the altitudes attainable by weather balloons, but below those of satellites. Materials scientists were eager to study how microgravity affects processes such as combustion.

But the enthusiasm of individual researchers is one thing. Getting the institutions they work for to pay for tickets is something else. NASA, for example, has signed contracts with Armadillo and Masten, paying nearly $500,000 for seven flights carrying engineering equipment. But the agency does not yet have approval to buy seats for suborbital passengers — both Armadillo and Masten are currently focusing more on unmanned flight — and none of the flights it has purchased will actually reach space. The highest planned altitude is about 40 kilometres.

To sell those passenger seats, the launch companies will have to convince decision-makers that their reusable vehicles offer significant advantages over existing ways to access the weightless space environment. For only a few tens of thousands of dollars per trip, researchers can book custom-modified aeroplanes that fly in a series of parabolic trajectories, providing microgravity in 30-second bursts for a total of 5–10 minutes per flight. Or, for an admittedly steep $1 million to $2 million, researchers can put automated equipment on a sounding rocket that provides up to 20 minutes of microgravity far above Earth's atmosphere.

The new commercial vehicles vary in their capabilities, but generally fall between the two existing options: they can reach between 30 and about 100 kilometres in altitude and offer 3–5 minutes of weightlessness.

Stern and other proponents believe that the reusable space vehicles' short times in space are counterbalanced by their high frequency of flights. "As a principal investigator, it took me nearly a decade to get seven flights on NASA's sounding rockets, but [the SwRI is] going to be flying these eight missions in the space of about a year," says Stern. "Virgin Galactic alone will be flying daily with six vehicles; XCOR is going to fly four times per day; Blue Origin says it'll fly once a week. This will give us unprecedented access to space."

THE HUMAN ELEMENT

But do humans really need to ride along on such experiments, with all the risks and complexity that entails? "The advantage is twofold," says Stern, making much the same argument that human-spaceflight proponents have been making since NASA's Apollo programme of the 1960s. "First, you don't have to pay to automate your experiment any more. And second, that means you can easily react to your data collection in real time and make changes in your experiment to get better results."

To demonstrate those advantages, the SwRI researchers are planning three showcase experiments. One, 'Box of Rocks', is a transparent case of stone fragments and ceramic bricks meant to simulate how loose material settles on asteroids with low surface gravity. Another uses a refurbished ultraviolet telescope, which flew on a space shuttle in 1997, to observe astronomical objects and upper-atmosphere phenomena through a cabin window. The last uses a 'bioharness' to monitor and record how the blood pressure, heart rate and other physiological parameters of passengers vary under the flight profiles of different vehicles.

Paul Hertz, the chief scientist in NASA's Science Mission Directorate, remains sceptical. He is broadly optimistic about the science potential of reusable suborbital vehicles, but less convinced that involving humans in experiments requiring astronomical observations will be useful. "Because these flights are relatively short, it's really not that constraining to pre-program your observing plan," he says.

The weight of seats and life-support exacts a huge performance penalty, agrees Stephan McCandliss, an astronomer at Johns Hopkins University in Baltimore, Maryland. McCandliss has flown ultraviolet astronomy experiments using sounding rockets for more than two decades, and what the new reusables can do "pales in comparison", he says.

"Sounding rockets are extremely valuable," Stern concedes. "They go higher, have more sophisticated pointing systems, and can carry payloads commercial reusables just can't. But reusables can fly far more frequently, they are 10–20 times lower in cost, and they can bring scientists along with their instruments. This is a debate about having a fork or a spoon at the table — they are for different purposes."

John Grunsfeld, a former shuttle astronaut and current deputy director of the Space Telescope Science Institute in Baltimore, is also doubtful that the new vehicles will be better than sounding rockets, but admits that reusables could offer fresh opportunities for science.

"The real potential to benefit science is not necessarily in this first wave of vehicles, but in their prospect for a future in which crewed commercial vehicles will routinely and frequently access longer periods of weightlessness, or better yet, reach Earth orbit," says Grunsfeld. That ready availability, in turn, could facilitate imaginative science that might not make it through the peer-review processes of government agencies and major academic institutions. Of course, cautions Grunsfeld, "the value of that science remains to be seen".

For Stern, the value of routine suborbital spaceflight shouldn't be measured only in grants awarded and peer-reviewed papers published. Speaking at one NSRC session, he told the audience that they should feel no shame if their interest in suborbital science stemmed mainly from their yearning to fly in space.

"I don't think most scientists appreciate very well how motivational human spaceflight can be," Stern said. "Going into science is hard — there are easier careers where you can make more money. But when everyday educators and working researchers can visit classrooms and speak to schoolchildren about personally going into space, that has real effects. We can contribute to the future by giving birth to this new industry and the opportunities it brings."

That message seemed to resonate at the NSRC. Between and after the sessions, discussions about suborbital science frequently segued into conversations about inspiring the next generation of researchers to do great things — to beam energy to Earth from vast solar panels on satellites, to visit asteroids, to colonize the Moon or to travel to Mars. Indeed, for most of the scientists gathered in the conference rooms and hotel bars, the prospect of democratized suborbital flight seemed to be a blank screen on which they could project their current plans and future dreams of humanity's expansion into, at minimum, the rest of the Solar System.

"A lot of people are reluctant to talk about the big picture, and they may not be able to always clearly articulate why they want to take these trips, but what many of them want is to take part in making the future happen," says Greason, XCOR's chief executive. He is no exception. "The reason why I'm in this business is because I think it has the potential to be the beginning of something that will last for a very, very long time." ■

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