WILL SUBORBITAL SPACE TOURISM TAKE A SUBORBITAL TRAJECTORY?

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MOON SUITS WON’T BE READY IN TIME FOR 2024 LANDING

The latest obstacle to NASA’s plans to return humans to the moon in 2024 is the spacesuit the astronauts would wear. NASA’s inspector general concluded in a report released Aug. 10 that the new spacesuit NASA is developing for lunar missions, called the xEMU, won’t be ready until at least April 2025. The report blamed funding shortfalls, technical problems and the pandemic for delays that wiped out the program’s 12-month schedule reserve. NASA has spent $420 million on spacesuit development dating back to the Constellation program, and foresees spending $625 million more to complete the xEMU. A change in acquisition strategy where NASA will procure spacesuit services, rather than the suits themselves, could result in suits that don’t make use of NASA’s xEMU investment.

QUICK TAKES

SIGNIFICANT DIGITS

$45M

The size of the insurance claim Measat is expected to file for its drifting Measat-3 satellite. The Malaysian operator said it was unable to rescue the aging GEO satellite despite maintaining continuous telemetry and command control since an anomaly first appeared in June.

$46M

The amount Japanese lunar lander company ispace raised the Series C round from several Japanese investors, led by venture capital firm Incubate Fund. The company will use the funding for its second and third robotic lunar lander missions, scheduled for launch in 2023 and 2024. The company’s first lander, already fully funded, is currently being assembled in Germany for launch in the second half of next year.

$46M

Coincidentally, also the amount raised by a Chinese company that plans to develop hypersonic spaceplanes. Beijing Lingkong Tianxing Technology Co., Ltd., also known as Space Transportation, said the funds will be used for development of commercial suborbital and hypersonic vehicles. It aims for a first flight of a suborbital space tourism vehicle prototype in 2023 followed by a first crewed test in 2025, with a “global” hypersonic vehicle to follow by 2030. The company performed a flight of a 5.7-metric ton demonstrator named Jiaogeng-1 in 2019.

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CONSTELLATION INFATUATION

The Canadian government will invest more than $1 billion into Telesat’s Lightspeed low Earth orbit (LEO) constellation. Telesat said Aug. 12 the Canadian government will provide $1.15 billion for the 300-satellite system in exchange for Telesat investing in Canadian infrastructure to build out Lightspeed, including hundreds of jobs and scholarships. Telesat has now secured commitments for about two-thirds of the $5 billion cost of the system, with the rest of the funding to primarily come from debt financing from export-credit agencies.

South Korean company Hanwha is investing $300 million in LEO broadband provider OneWeb. Hanwha, which plans to build and deploy its own megaconstellation by 2030, is taking an 8.8% stake in OneWeb in a transaction expected to close in the first half of 2022. Hanwha has built its space portfolio by investing in South Korean satellite manufacturer Satrec Initiative and acquiring British antenna developer Phasor Solutions. OneWeb, which has said its first generation satellite system is fully funded, hasn’t said how it would use the new investment.

Inmarsat, meanwhile, plans to add at least 150 LEO satellites to its global fleet, stepping up competition against OneWeb, Telesat and others developing megaconstellations for enterprise markets. The British satellite operator is investing $100 million over the next five years to lay the groundwork for deploying 150-175 LEO spacecraft, which will join the satellites in its GEO and HEO fleet from 2026 in a constellation it calls Orchestra.
HEAVY LIFTING

The first complete Starship/Super Heavy vehicle briefly took shape in Texas. SpaceX stacked a Starship vehicle known as Ship 20 atop a Super Heavy first stage called Booster 4 at its Boca Chica, Texas, test site Aug. 6. Starship was installed on top of the booster for fit checks, and lowered several hours later. Both Starship and Super Heavy have at least several weeks of testing, including static-fire tests, ahead of them before the completed vehicle would be ready for its first orbital launch, a milestone that requires an FAA license yet to be issued.

SPACEX x SWARM

SpaceX is acquiring satellite constellation company Swarm Technologies. In FCC filings Aug. 6, Swarm disclosed it reached a deal in July to be acquired by SpaceX for an undisclosed sum. Swarm would continue to operate as a wholly owned subsidiary of SpaceX once the deal closes. Swarm operates 120 smallsats that provide internet-of-things services, and says the acquisition would give it access to SpaceX resources as well as synergies from SpaceX’s launch and satellite manufacturing capabilities. SpaceX appears interested in Swarm’s technology and personnel.

ROCKET LAB x VARDA

Rocket Lab won a contract for three missions of its Photon satellite bus from space manufacturing startup Varda Space Industries. Rocket Lab will perform three Electron launches of Photon spacecraft from 2023 through 2024, each carrying a “space factory” developed by Varda, which raised $42 million last month in a Series A round. Varda intends to use the missions to demonstrate production of fiber optic cables, pharmaceuticals and semiconductors, but has disclosed few other details. Rocket Lab has launched two Photon on test flights in the last year, and will use Photon to support the launch of NASA’s CAPSTONE lunar cubesat late this year.

LOCKHEED MARTIN EYES SATELLITE SERVICING

Lockheed Martin will demonstrate tasks associated with satellite servicing with two cubesats built by Tyvak Nano-Satellite Systems. The pair of 12-unit cubesats slated to travel to geosynchronous orbit later this year are part of the Lockheed Martin In-space Upgrade Satellite System (LINUSS) program. One of the company’s goals for LINUSS is servicing the next generation of Global Positioning System satellites built on Lockheed Martin’s LM 2100 bus.

ROCKET ROUNDUP

An Ariane 5 launched on its first mission in nearly a year July 30, successfully placing the Star One D2 and Eutelsat Quantum communications satellites into geostationary transfer orbits. The launch was the first for the Ariane 5 since August 2020 because of problems with the payload fairing separation system seen on that earlier launch as well as one in February 2020. The launch is the first of two before the Ariane 5 launches NASA’s James Webb Space Telescope late this year.

The Aug. 11 launch of an Earth imaging satellite on an India’s Geosynchronous Satellite Launch Vehicle (GSLV) Mark 2 failed when the rocket’s upper stage engine did not ignite. The failure is the first for the GSLV Mark 2 since its inaugural flight in 2010 that also suffered an upper stage malfunction. EOS-03 was to provide images of India and the surrounding region from geostationary orbit.

Rocket Lab will launch three satellites this fall for Earth-observation company BlackSky. The Rocket Lab Electron launches are part of a multi-launch agreement announced earlier this year. Each launch will carry two Gen-2 BlackSky imaging satellites. Two BlackSky satellites were lost in May in a Rocket Lab launch failure.

Planet has designated SpaceX as its “go-to launch provider” through 2025. Planet announced Aug. 5 a multi-launch contract with SpaceX that will start with the launch of 44 SuperDove imaging cubesats in December on SpaceX’s Transporter-3 rideshare mission. Planet did not reveal the number of satellites or launches covered by the agreement.

Intuitive Machines will launch a third lunar lander in 2024 on a SpaceX Falcon 9 rocket. The commercial lunar lander company has space available on the flight, dubbed IM-3, for commercial and civil payloads with a combined mass of 130 kilograms. Intuitive Machines also is set to fly two lunar missions on Falcon 9 rockets in 2022 to carry out task orders for NASA.

ABL Space Systems, Astra Space and Relativity Space will be eligible to compete for missions awarded under the U.S. Space Force Orbital Services Program-4. OSP-4 is an indefinite-delivery, indefinite-quantity contract for rapid acquisition of launch services. Companies previously selected were: Aevum, Firefly, Northrop Grumman, Rocket Lab, SpaceX, United Launch Alliance, VOX Space, and X-Bow Launch. All 11 vendors will compete for 20 missions over nine years.
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AB360 seeks to speed up interplanetary travel

Propulsion company AB360 Space is coming to the United States. The startup established by Ali Baghchehsara, a former Airbus director and cybersecurity firm founder, aims to combine elements of electric and chemical engines to improve engine thrust and efficiency for interplanetary journeys.

With existing technology, a trip from Earth to Mars would take about six months. AB360 seeks to speed up interplanetary travel

ABOVE: AB360 rendering of a hybrid chemical and electric propulsion engine designed to shorten interplanetary journeys. Below, right: Ali Baghchehsara, founder of AB360 Space.

AB360 plans to move the company to Colorado and begin looking for investors. "We are using this infrastructure to get the concept proven," Baghchehsara said. "Once I know the concept works, I will be moving to the United States and launching the company."

Although Baghchehsara is only 28, this would not be his first startup. After building a jet engine as a teenager in Iran, Baghchehsara moved to Germany where he earned a master's degree in aeronautical engineering and is pursuing a Ph.D. in cognitive systems and artificial intelligence. He was named an Airbus director at 25. When he left Airbus, Baghchehsara founded LISA Group, a government cybersecurity contractor.

As a young man growing up in Iran, Baghchehsara saw little opportunity to pursue his passion for propulsion. Since recently becoming a German citizen, he is eager to return to the technology he first explored in his 2014 book, "Electric Space: Space-based Solar Power Technologies & Applications."

Baghchehsara is providing initial financing for AB360 Space. "My intention is to prove that the concept works," Baghchehsara said. "I hate going to investor meetings where they ask if I'm sure it's going to work. I want to show them proof."

AB360 Space plans to begin testing of CLePS in September, followed by Hot Fire testing of electrical and chemical systems in November. Once that testing is completed, Baghchehsara plans to move the company to Colorado and begin looking for investors. "So much capital is available in the market today," Baghchehsara said. "It's a great time to be alive."
WILL SUBORBITAL SPACE TOURISM TAKE A SUBORBITAL TRAJECTORY?

After an extended launch delay, suborbital space tourism is finally ready for liftoff. Many in the industry thought that was the case nearly 17 years ago, when SpaceShipOne, built by Scaled Composites and funded by billionaire Paul Allen, won the $10 million Ansari XPRIZE. Around the same time, Virgin Galactic announced a deal to license the technology, proposing to start flying people in 2007 or 2008.

A few years turned into more than a decade, as Virgin Galactic suffered technical setbacks, including a test stand accident that killed three Scaled employees in 2007 and the crash of the first SpaceShipTwo in 2014 that killed the vehicle’s co-pilot. Even after reaching space in December 2018, the company encountered more technical delays.

The company, though, had little competition. Companies like Armadillo Aerospace, Rocketplane Global, and XCOR
Like a person who waited for ages at a bus stop, only to have two buses show up at once, *suborbital space tourism’s* moment may have finally arrived thanks to both Blue Origin and Virgin Galactic.

Aerospace went out of business long before they were ready to start flying people. Other XPRIZE competitors also faded away (remember The Da Vinci Project?) All that was left was Blue Origin, which had the financial wherewithal to continue development but which worked at a pace that was more gradatim than ferocious.

But like a person who waited for ages at a bus stop, only to have two buses show up at once, suborbital space tourism’s moment may have finally arrived thanks to both Blue Origin and Virgin Galactic. On July 11, it was Virgin Galactic that flew SpaceShipTwo with six people, including founder Richard Branson, on board, demonstrating what a commercial flight might be like.

Nine days later, it was Blue Origin’s turn. For the first time, the autonomously controlled New Shepard would have people on board for this mission, formally designated NS-16. Blue Origin founder Jeff Bezos was joined by his brother Mark, Wally Funk of “Mercury 13” fame, and Oliver Daemen, an 18-year-old Dutch person taking a year off before starting college. It also marked the first time that the company opened up its Launch Site One in the West Texas desert north of the small town of Van Horn to the media.

The flight itself looked a lot like the previous, uncrewed New Shepard flights. Taking off at about 9:12 a.m. EDT, the booster’s BE-3 engine performed as expected, sending the capsule called “RSS First Step” on a suborbital trajectory with an apogee of 107 kilometers. Ten minutes and 10 seconds after liftoff, that capsule landed under parachutes, nearly three minutes after the booster made a powered landing on a nearby pad.

Bezos and the others on board appeared to enjoy every minute of the flight. Video released afterward showed them floating around the cabin, enjoying the view, and even tossing Skittles candies during the few minutes of microgravity. (Skittles, either aware of this in advance or acting with remarkable speed afterward, announced two days later plans to offer limited-edition “Zero-G Skittles” in special packaging.)

“My expectations were high, and they were dramatically exceeded,” Jeff Bezos said in a ceremony a couple hours after the flight at Launch Site One. (The event was billed to the media in attendance as a press conference lasting an hour, but ended after about 45 minutes, having taken only three questions from reporters.) Viewing the Earth from suborbital altitudes, he added, was “very profound.”

Mark Bezos and Daemen offered similar praise for the experience. Only Funk sounded a little disappointed, noting at that ceremony that the view out the window wasn’t as expansive as she expected, and suggesting the cabin was a little cramped. “There was not quite enough room for all four of us,” she said, notable since New Shepard is designed to carry six people.

She wasn’t complaining about the flight that much, though. “It was great. I loved it. I can hardly wait to go again.”

**BUILDING THE SUBORBITAL BUSINESS**

Of the four people on New Shepard, Daemen was the least well known. Blue Origin announced he would fly just five days before the launch, as something of a last-minute replacement. The seat was to go to the winner of an auction that concluded June 12, with an unidentified individual making a winning bid of $28 million. That person, though, had a “scheduling conflict,” Blue Origin explained, but didn’t identify the person or the nature of the conflict. The company announced the July 20 date of the flight when it started the auction in early May.

The soft-spoken Daemen wasn’t a big presence both in preflight interviews the four did with major television networks before the launch or at the post-flight ceremony. “It felt way cooler than it looked,” he said at the ceremony.

He was noteworthy, though, for two things. At 18, he is now the youngest person to fly in space, breaking the record set by Gherman Titov in 1961 when he flew on the second Vostok mission a month before his 26th birthday.

Second, and arguably more importantly, he is the first commercial suborbital space traveler. Everyone who has flown on SpaceShipTwo have been company employees (or, in the case of Branson, the founder.) Jeff Bezos flew his brother and Funk as guests. Daemen, however, paid an unspecified amount for the flight — or, rather, his father, a private equity executive, paid for the ticket.
Blue Origin has taken a different approach to selling seats than Virgin Galactic, which started selling tickets 15 years ago at $200,000, later increasing it to $250,000. Blue Origin hasn’t announced a ticket price or publicly started sales, instead taking the approach of private sales, starting with bidders from the auction.

“Since the auction that we held on June 12, I have had the pleasure of chatting with many of our future customers that have already signed up for the subsequent flights,” said Ariane Cornell, director of astronaut sales at Blue Origin, at a prelaunch media briefing July 18. “We have already built a robust pipeline of customers that are interested.”

The company hasn’t disclosed how many customers it has signed up, or what prices they paid. “Willingness to pay continues to be quite high. Our early flights are going for a very good price,” said Bob Smith, CEO of Blue Origin, at that briefing. “I think we’re seeing very strong interest.”

At the post-flight ceremony, Bezos didn’t disclose how many people had signed up, but did reveal how much the company has raked in. “We’re approaching $100 million in private sales already, and the demand is very, very high,” he said.

Company officials said privately that they’re not trying to build a big backlog of customers because it would take time to fly them. Blue Origin expects to perform two more crewed suborbital flights this year, including at least one with six people on board. It will increase that flight rate next year, but by how much isn’t clear. “What we do in the following year I’m not sure yet. We’ll figure that out, and what the cadence will eventually be,” Bezos said.

Virgin Galactic has about 600 customers who have paid anywhere from a small deposit to the full value of their ticket. Those customers won’t start flying until next fall, as Virgin Galactic plans just one more test flight of its current SpaceShipTwo, VSS Unity, before going into a maintenance period. That late September flight will be for the Italian Air Force, producing about $2 million in revenue for the company. That customer backlog will take more than 100 flights to work through; while future SpaceshipIII vehicles will carry six in the cabin, Unity can accommodate only four. That’s a couple years even at the optimistic flight rate of one per week.

Virgin Galactic waited until its quarterly earnings call Aug. 5 to announce it was reopening ticket sales, starting at $450,000 per person. Michael Colglazier, CEO of Virgin Galactic, suggested on the call that ticket sales will be open for a limited time as the company attempts to control
the demand for seats versus the supply of flights, but didn’t give an estimate of how many the company will sell.

**SURVIVING A BACKLASH**

When SpaceShipOne won the XPRIZE in 2004, there wasn’t much criticism of the role of the wealthy in backing the project. If one billionaire — Allen — wanted to bankroll a suborbital spaceplane and another — Branson — wanted to commercialize it, so be it.

Billionaires, though, have gotten even wealthier and, given growing discussion of income inequality, bigger targets. None is bigger than Bezos, whose net worth is now more than $200 billion, according to Forbes. How billionaires like Bezos accumulate and spend their wealth, or even that they have that wealth in the first place, became a theme of criticism throughout the coverage of the New Shepard flight.

Bezos didn’t help matters much at the post-flight ceremony, at least at first. After thanking the employees of Blue Origin for building New Shepard, he said, “I want to thank every Amazon employee and every Amazon customer, because you guys paid for all this.” While true — Bezos bankrolled Blue Origin thanks to his stake in Amazon — it came off as tone-deaf to many, and factored into the criticism of Bezos, Blue Origin, and commercial spaceflight that followed.

Perhaps anticipating that criticism, Bezos used part of the ceremony for something unrelated to Blue Origin. He announced a new “Courage and Civility Award” he was funding, giving the first two to activist and political commentator Van Jones and to chef and humanitarian José Andrés. Each received $100 million.

**Virgin Galactic has about 600 customers who have paid anywhere from a small deposit to the full value of their ticket. That customer backlog will take more than 100 flights to work through. That’s a couple years even at the optimistic flight rate of one per week.**
SUBORBITAL SPACE TOURISM

Even before Bezos took the stage, though, one member of Congress was weighing in on suborbital space tourism. Moments after New Shepard safely landed, Rep. Earl Blumenauer (D-OR), a member of the House Ways and Means Committee, announced he would introduce legislation to tax suborbital or orbital spaceflights.

“Space exploration isn’t a tax-free holiday for the wealthy. Just as normal Americans pay taxes when they buy airline tickets, billionaires who fly into space to produce nothing of scientific value should do the same, and then some,” he said in a statement.

His Securing Protections Against Carbon Emissions (SPACE) Tax Act — yet to be introduced — would levy per-person taxes on commercial flights with no scientific purpose. (He didn’t disclose what would constitute scientific research.) One tax rate would go toward suborbital flights while a second, “significantly higher” rate would be applied to orbital flights.

“I’m not opposed to this type of space innovation,” he said of commercial spaceflight. “However, things that are done purely for tourism or entertainment, and that don’t have a scientific purpose, should in turn support the public good.”

CLIPPED WINGS

The same day that New Shepard carried people for the first time, the FAA weighed in on who would be eligible for commercial astronaut wings that the agency awards.

The FAA started awarding those wings in 2004, when SpaceShipOne pilots Mike Melvill and Brian Binnie received them for their suborbital flights. It wasn’t until 2019, though, when the agency awarded the next wings: Mark Stucky and CJ Sturckow received them for the first SpaceShipTwo flight beyond 80 kilometers (Sturckow, a former NASA astronaut, had NASA wings from his four shuttle missions), while David Mackay, Mike Masucci, and Beth Moses received them for being on the second flight. All were pilots except for Moses, who conducted tests of the SpaceShipTwo cabin interior.

All appeared to fit the original criteria the FAA established for those wings: be considered part of the crew of the vehicle as defined in federal regulations and go to an altitude of at least 50 miles (about 80 kilometers). In the July 20 update, though, the FAA added a third: “Demonstrated activities during flight that were essential to public safety, or contributed to human space flight safety.”

“When the program was first created in 2004, its focus was to recognize flight crew members who furthered the FAA’s mission to promote the safety of vehicles designed to carry humans,” the FAA
said in a statement. “The FAA has now changed the focus to recognize flight crew who demonstrate activities during flight that were essential to public safety, or contributed to human space flight safety, among other criteria.”

That appeared to exclude some of the people on the recent flights. Was Branson, who flew on SpaceShipTwo to evaluate the “experience” of the flight, performing work related to public safety or human space flight safety? And what about those on New Shepard?

Some, concluding that neither Bezos nor Branson would qualify under the new rules, declared in news reports that they would not become astronauts; coverage tinged with a degree of schadenfreude, perhaps. Reality is a little more complex.

First, even under the old rules, it’s not clear anyone who flew on New Shepard would qualify as crew under FAA regulations. None of them were flying the vehicle, which was controlled from the ground. “This is an autonomous vehicle. There’s really nothing for a crew member to go do,” Blue Origin’s Smith said at the prelaunch briefing.

Second, the FAA order doesn’t define the term “astronaut” at all. It instead lays out the conditions for which it awards “astronaut wings,” and the term “astronaut” is not defined in the law. (“Government astronaut” is, as part of a 2015 fix to federal law to address issues about government employees flying on commercial vehicles.) Some members of NASA’s astronaut corps, for example, don’t have NASA astronaut wings since they have not yet flown in space, but few would not consider them astronauts.

Most importantly, though, the revised rules make it more likely people like Bezos and Branson get astronaut wings. The revised rules give the FAA the ability to award “honorary” commercial astronaut wings to “individuals who demonstrated extraordinary contribution or beneficial service to the commercial human space flight industry” but don’t meet the official criteria.

That would allow the FAA, if it so desired, to give wings to everyone on both the SpaceShipTwo and New Shepard flights, given their historic nature. And it would avoid the outrage that might erupt if the FAA concluded that, under the old rules, Wally Funk wouldn’t be eligible for astronaut wings 60 years after being denied the chance to become a NASA astronaut. Crisis averted.

DIVERGING PATHS
Blue Origin and Virgin Galactic reached the starting line of commercial suborbital human spaceflight at about the same time but took very different paths to get there. Moreover, they’re heading in very different directions.

Virgin Galactic is betting its future on growing demand for suborbital human spaceflight. Its financial projections foresee a rapidly increasing flight rate, supported by development of new vehicles and new spaceports. The company has talked about leveraging that technology for high-speed point-to-point transportation, but that is likely many years in the future, and not achievable at all unless suborbital tourism proves to be as profitable as it foresees.

For Blue Origin, though, suborbital is only a step. The company has talked about how it has used the experience developing New Shepard for its New Glenn orbital vehicle and other projects. (Bezos, at the post-flight ceremony, even mentioned New Armstrong, the even larger orbital vehicle the company has mentioned in the past but about which it has disclosed no details.)

“You would never choose liquid hydrogen for a suborbital tourism vehicle,” Bezos said of the fuel that powers the BE-3 engine on New Shepard. He then pointed to a New Shepard propulsion module, towering over the audience. “What you see behind me is basically the second stage of New Glenn. So, every time we fly this tourism mission, we’re practicing flying the second stage of New Glenn.”

And while that tourism mission may initially be lucrative, one can see a future where, if demand drops off to the point where it’s not profitable, or simply too much trouble, Blue Origin may pull the plug on New Shepard. Presumably they’ll have enough experience flying it to support New Glenn (whose current issues, like delays in development of the BE-4 engine, have little relationship to New Shepard.)

Suborbital space tourism was once touted, back in the days of the Ansari XPRIZE, as the key to unlocking low-cost reusable space transportation by tapping the one market big enough to support the development of such vehicles. The combination of smallsats and SpaceX offered an alternative path that most of the industry has largely followed.

The era of commercial suborbital human spaceflight may finally be here, but whether it lasts isn’t certain, and neither is its importance. SN
**IN-SPACE PROPULSION**

**SMALL SATELLITE PROPULSION BEGINS TO PROVE ITSELF**

*Luis Gomes was fed up with propulsion promises.*

As chief technology officer for Surrey Satellite Technology Ltd. in 2018, Gomes told his assistant to halt all meetings with spacecraft propulsion companies.

“Two companies a week were coming in with the same designs and talking to me about the same things,” said Gomes, now CEO of Sweden’s AAI Clyde Space. “They were just trying to get potential customers so they could go back to their investors and get money to develop it. I told them, ‘I will wait until prove your technology and then you can come back to me.’”

Three years later, Gomes along with the rest of the small satellite community is starting to see that proof.

“There are advancements being made across the waterfront,” Bruce Yost, director of the NASA Small Spacecraft Systems Virtual Institute, said Aug. 10 at the virtual Small Satellite Conference.

Five years ago, cubesats and microsatellites had few inexpensive propulsion options. In the last couple of years, more than a dozen companies have reported successful firing of new satellites thrusters, among them: Enpulsion of Austria; Germany’s Morpheus Space; French firms Exotrai and ThrustMe; Denmark’s GomSpace; D-Orbit and T4i of Italy; Dawn Aerospace of the Netherlands; NanoAvionics of Lithuania; and U.S. companies Apollo Fusion, Bradford Space, Momentus, Phase Four, Rocket Lab, Stellar Exploration and Tethers Unlimited. (Momentus thruster performance claims were later questioned by the U.S. Securities and Exchange Commission.)

Still, it’s too soon to say much about the performance of many of the new cubesat and small satellite thrusters. “There are a lot of missions that recently launched or are known to be coming in the next year or so,” said Gabriel Benavides, a researcher and engineer in the NASA Glenn Research Center’s Electric Propulsion Systems branch. “At the moment, we still have fairly limited flight data on these systems.”

**MORE TESTING COMING**

The first thrusters from Accion Systems and Benchmark Space Systems reached orbit June 30 on satellites launched as rideshares on the SpaceX Transporter-2 flight. The two companies do not yet have flight data to share.

“These are paying customers with operational missions,” said Benchmark CEO Ryan McDevitt. “They are going to use it when they need it over the next weeks and months.”

Even when customers begin firing thrusters, it can take years to observe the full range of propulsive capabilities including initial orbit maneuvers,
long-term stationkeeping and deorbit at the conclusion of missions.

How important are flight tests for thrusters? Experts offer a range of opinions.

Extensive ground-based testing can verify 80 to 85 percent of thruster performance and behavior, said Natalya Bailey, Accion Systems co-founder and CTO. In-orbit demonstrations verify that last 15 to 20 percent and show that thrusters work as designed, she added.

Umair Siddiqui, Phase Four CTO, saw that firsthand. Despite his conviction that Phase Four’s Maxwell engine would work in orbit exactly as it had in extensive testing on the ground, he felt intense relief when he saw proof earlier this year.

“I had the most unexpected visceral reaction,” Siddiqui said. “In five years, we went from a figment of imagination to a unit that’s serving mission needs for customers in space. That all was realized in a feeling.”

NASA considers propulsion systems with space flight heritage to be lower risk than systems tested exclusively on the ground, making the technology with flight heritage more likely to win space agency funding and to be included in missions, Yost said.

Certain technologies, though, can be adequately tested on the ground.

For some chemical propulsion and heritage electric propulsion systems, “we’ve developed a lot of good ground test facilities and methodologies,” Benavides said. In those cases, “it’s logical to do as much testing as you can feasibly within your budget on the ground to reduce the cost,” he added.

JUST OPEN A VALVE

When companies report thruster firings in orbit, it’s important to understand exactly what they have shown.

“If you open a valve with a liquid to outgas, it will provide some thrust,” said Tomas Svitek, Stellar Exploration president. “That does not automatically imply that this is a useful propulsion system.”

Even if a thruster produces a specific change in velocity for one cubesat or small satellite in low Earth orbit, it may mean that the physics involved is sound but it does not necessarily mean future thrusters produced by the company will work equally well.

“Propulsion systems need to be considered in the context of the anticipated mission,” Benavides said. “A lot of missions get into trouble when they assume substantial similarity between their mission and other missions, which may or may not exist. Then, late in their mission development they find that there are issues with propulsion that they didn’t perceive.”

“I strongly encourage any mission considering one or more propulsion technologies to do a deep dive and understand the technology readiness level of any propulsion system within the context of your mission and your mission’s requirements,” Benavides said. “Do that early and it’ll save a lot of costs and headaches in the long run.”

TECHNICAL READINESS

Propulsion is often a spacecraft’s most expensive and complex system.
"If you want to buy low-power processors, you can get them from huge terrestrial markets," said Brad King, Orbion Space Technology CEO and founder. "If you want to buy GPS receivers, you can get them from terrestrial markets. But the iPhone doesn’t yet have a thruster," he said, making propulsion systems “one of the last remaining purely space technologies.”

Since propulsion can claim a large share of a satellite budget, some companies are eager to find inexpensive options.

“Everyone wants fast, cheap and risky until something happens,” said Alexander Reissner, Enpulsion CEO and founder.

To evaluate risk, customers often ask propulsion suppliers about the technical readiness level (TRL) of thrusters.

Some companies fire thrusters in space for the first time and begin “shouting around from the rooftops ‘I’m TRL 9 because I’m working in space,’” Reissner said.

Technology does not earn the moniker TRL 9, however, until it completes a full mission. If it’s a thruster-demonstration mission, that’s far easier to complete than a multiyear Earth-observation or communications mission.

“Putting your product in orbit and turning it on for an hour does nothing to prove that you can meet a 5,000-hour lifetime,” King said. SN

Enpulsion’s Nano R3 is roughly the size of a Rubik’s Cube, weighs about a kilogram, and produces 350 micronewtons of nominal thrust.

Small satellite propulsion has a critical role to play in keeping space sustainable.

While in-orbit debris cleaners and other emerging capabilities capture imaginations, thrusters underpin a healthy operating environment in space.

Onboard thrusters can help ensure a satellite safely reaches its assigned orbit, moves out of harm’s way, relocates as market and mission requirements warrant, and dispose of itself when the time comes.

It is partly why the rise of smallsat constellations has spawned dozens of propulsion startups promising more efficient thruster as concerns over congested orbits grow.

Ensuring space sustainability means giving satellite operators more propulsion capabilities for managing their constellations, according to István Lőrincz, co-founder and president of propulsion startup Morpheus Space.

“You cannot talk about space sustainability without talking about propulsion,” Lőrincz said.

As more satellites are added to low Earth orbit, he believes it will be increasingly crucial for smaller spacecraft to have the means to maneuver within their constellations.

Smallsats might need to dodge malfunctioning spacecraft and debris, or shift their position to heal an issue somewhere else on the network.

Lőrincz believes operators will be increasingly incentivised to deorbit spent satellites faster as constellations grow, enabling them to be replaced more efficiently and maintain or even improve service levels.

Constellations relying on intersatellite links, in particular, will want to minimize costs by limiting the number of satellites they send to space, he said, but risk “serious outages” if a spacecraft is lost and the network cannot be adjusted to compensate.

“You would have to remove it first, and obviously you want to perform that as fast and as coordinated as possible,” he said.

But for now, and in the absence of globally accepted orbital stewardship rules and incentives, he said spending resources to speed up a retired satellite’s atmospheric reentry is more about burnishing an operator’s corporate image than its bottom line.

Still, there are growing calls for international cooperation to enforce standardized rules for space operations. The World Economic Forum is developing a Space Sustainability Rating system, which scores companies based on factors including post-mission deorbit plans and collision-avoidance measures. Missions that voluntarily participate in the system would earn a certification and rating based on how they contribute to space sustainability.

NEW OPERATING ENVIRONMENT

While onboard propulsion is typical for large satellites that have provided vital services for decades, it is not as
commonplace among smallsats that have relatively only recently graduated from experimental to commercial roles.

The satellites AAC Clyde Space is building for Eutelsat will use onboard propulsion for phasing, stationkeeping and collision avoidance.

“I think we’ll start seeing that more and more,” said Luis Gomes, AAC Clyde Space CEO.

“I suspect collision avoidance will become a mandatory requirement from licensing countries.”

Rules for avoiding collisions may apply, for example, to satellites operating at altitudes above 400 kilometers. Similarly, satellites operating at 600 kilometers or higher may be required to have some way to deorbit, or at least to move below the International Space Station’s altitude before deorbiting passively.

Increasingly, nanosatellites programs backed by U.S. or European government agencies require some propulsion.

“They want to see how we are going to mitigate the risk of collision with space junk,” said Vytenis Buzas, NanoAvionics CEO and co-founder.

“People are starting to talk about that and about ways to reduce the orbital altitude after the satellite is no longer operational, including propulsion, tethers and other deorbiting devices.”

If agencies mandate collision avoidance capabilities, they will need to offer clear explanations of the scenarios they envision, noted Brad King, Orbion Space Technology CEO and founder.

“If I’m trying to avoid a collision that might happen next month, that maneuver is very different than if I’m trying to avoid a collision that might happen in the next hour or so,” King said.

Orbion is developing a thruster uniquely designed for collision avoidance. While electric propulsion is extremely fuel-efficient — and thus a popular option for especially volume-constrained satellites — it is unlikely to provide enough on-demand thrust to avoid a collision without substantial lead time.

“Most electric propulsion technologies just can’t get out of the way in time even if you stomp on the accelerator,” he said. “We have a feature we added to our system that resolves that issue.”

Five years ago when Austria’s Enpulsion began developing nanosatellite thrusters, cubesats had few propulsion options. Now, companies are beginning to flight test a wide variety of chemical and electric propulsion systems sized for a growing population of relatively tiny satellites.

At the same time, regulators are beginning to insist satellites actively deorbit at the end of missions.

**OIL SPILLS ARE BAD FOR BUSINESS**

Companies concerned about their reputations don’t want to be seen as bad for the environment.

A satellite that crashes into something during deorbit because it does not have sufficient propulsion to control its descent would be a business-hurting PR disaster, to say the least. Oil spills on Earth, after all, tend to be bad for business.

But adding more propulsion capabilities means additional costs for a satellite operator.

A satellite devoting more of its power budget to thrusters has less available for running cameras, transponders, or other payloads central to generating revenue or meeting its mission.

Propulsion startups targeting the smallsat market aim to introduce affordable, efficient thrusters that provide plenty of boost without overtaxing a satellite operator’s finite resources — namely money, mass, onboard power and fuel.

Morphus co-founder Lőrincz said propulsion companies like his “should be obligated to make their offering so enticing that sustainable operations have no significant impact on the bottom line. Or even better, that adopting propulsion is helping the business and this is what we set out to do.”

Morpheus was the only space mobility propulsion venture to win LEO constellation operator OneWeb’s innovation challenge in July.

Lőrincz said it is in a co-engineering phase with OneWeb to support the operator’s second-generation constellation.

**AVOIDING SPACE EXPLOSIONS**

More power-efficient thrusters could mean a satellite can move while imaging or communicating without putting undue strain on its batteries or solar cells.

That opens up new applications for different types of satellites, according to space propulsion startup Accion Systems, which recently sold a majority stake of the venture to private equity for $42 million.

The type of propulsion is also an important factor in space sustainability, noted Accion Chief Technology Officer Natalya Bailey.

Using a combination of liquid and electric propulsion for thrusters enables Accion’s system to be unpressurized, unlike some others that have to manage pressurized gas containment technology.

Bailey said the ability of its Tiled Ionic Liquid Electrospay (TILE) thrusters to eliminate the need for pressurized fuel tanks and high energy systems will become increasingly important as satellite population grows.

“We’re not needing to launch little bombs into orbit that have the potential to not only destroy a customer’s own constellation, if there’s a chain reaction of explosions, but they could also really muck up LEO for everybody else as well,” she said. **SN**

**DEBRA WERNER CONTRIBUTED TO THIS STORY FROM SAN FRANCISCO.**
SMALL LAUNCH VEHICLES GROW UP

For years after Boeing and Lockheed Martin combined their launch vehicle businesses into a joint venture, United Launch Alliance had a lock on the medium- to heavy-lift launch market in the United States. SpaceX would eventually challenge that, but it would take years of effort, including a lawsuit, for that company to win national security launch business. That created a SpaceX/ULA duopoly that survived competition from Blue Origin and Northrop Grumman to win National Security Space Launch Phase 2 contracts last year.

The next time around, SpaceX and ULA may face even more competition. Besides the prospect of Blue Origin and perhaps Northrop Grumman bidding on future contracts, startups that originally focused on small launch vehicles are looking to move into larger markets. In recent months, both Relativity Space and Rocket Lab have unveiled plans for rockets that can serve medium-class payloads for commercial and government customers. The two companies, while sharing similar ambitions, are taking different approaches to developing larger vehicles.

BUILDING A MEDIUM-CLASS WORKHORSE

For most of the company’s history, Rocket Lab and its founder, Peter Beck, showed no interest in rockets larger than its Electron, which can place up to 300 kilograms into low Earth orbit. The closest Beck came to discussing a larger rocket was when he tweeted a photo of himself standing next to a version of Electron with three first stages: Electron Heavy, analogous to the Delta 4 Heavy and Falcon Heavy. It was an April Fool’s joke.
That changed in March. At the same time Rocket Lab announced it was going public through a merger with a special-purpose acquisition corporation (SPAC), it also unveiled Neutron. That rocket will be far more powerful than Electron, capable of placing up to 8,000 kilograms into orbit.

Illustrations of Neutron show a relatively nondescript vehicle with a conical payload fairing 4.5 meters in diameter. The only features that stand out are what appear to be landing legs folded up at the base of the first stage, like those on the Falcon 9 (Rocket Lab plans to land the first stage on a ship and reuse it.)

However, those public images don’t represent the true shape of Neutron. “The image you see of Neutron there is a bit of a ruse. Neutron looks nothing like that,” Rocket Lab CEO Peter Beck said in a webinar by the Space Generation Advisory Council in early August. “Basically, we’re sick of people copying us all the time.” He said the company would reveal the actual design of Neutron “in time.”

With that unwillingness to show what Neutron looks like, it’s not surprising that Rocket Lab has shared few technical details about the rocket, including its engines. The company says that Neutron will use the same propellant combination as Electron, liquid oxygen and kerosene, but hasn’t discussed the performance or even the number of engines on each stage of the rocket.

In an interview shortly after the announcement of Neutron, Beck said the company would leverage the technology it developed for the Rutherford engines on Electron. Those engines make extensive use of 3D printing as well as battery-powered pumps, and produce up to 56,000 pounds-force.
ROCKET RELATIVITY

of thrust.

“Engines are always the long pole” in launch vehicle development, he said, but emphasized the experience the company has from flying more than 200 Rutherford engines. “We know how to build engines. We know how to scale up manufacturing."

Beck said he expects Rocket Lab to incorporate at least some aspects of the Rutherford engine design for the engine that will power Neutron. “We did a lot of work around combustion stability and injectors, so a lot of that will scale nicely,” he said. That new engine will also likely make use of 3D printing.

One challenge, he acknowledged, may be the turbomachinery of the larger engine. Rocket Lab, though, isn’t seeking to optimize the performance of the engine but instead build a “workhorse” for frequent launches. “For us, extracting the last second of specific impulse out of an engine is probably not the right way to go,” he said. “What we’re looking for is maximum reusability and maximum reliability.”

Work on Neutron will likely shift into high gear once Rocket Lab’s SPAC merger is completed, which is scheduled for late August. Beck said the company wanted to wait until it secured financing before starting Neutron, with a goal of a first launch as soon as 2024.

Rocket Lab believes that, with Electron and Neutron, it can launch as much as 98% of commercial and government satellites forecast to launch through the end of the decade, with Neutron focused on deploying constellations. The U.S. government is already a major customer of Electron, with NASA, the Space Force, NRO and DARPA all launching payloads on it.

The company will also human-rate Neutron, even though it has no current plans to launch people on it. “I’m covering our bases,” Beck said. “There’s no point building a launch vehicle of that class that isn’t rated for human spaceflight.”

A 3D-PRINTED REUSABLE DISRUPTER
Relativity Space also started small, with its Terran 1 rocket designed to place up to 1,250 kilograms into orbit for $12 million. Although the company has yet to fly Terran 1 — the first launch is scheduled for late this year — Relativity has won contracts from satellite operators like Iridium and Telesat, who plan to use the rocket to replenish their LEO constellations.

In June, Relativity announced its largest funding round to date, $650 million, a little more than six months after raising $500 million. That funding will go toward development of a much larger rocket, the Terran R. That rocket is designed to place more than 20,000 kilograms into LEO, a capacity comparable to the Falcon 9.

Terran R, while similar in performance to the Falcon 9, looks more like SpaceX’s Starship vehicle, from its metallic finish to the aerodynamic design of the upper stage. And, like Starship, both stages of Terran R are intended to be reusable.

“That architecture really opens up a lot of long-term possibilities for Terran R,” Tim Ellis, co-founder and chief executive of Relativity, said in an interview. “It serves where we see the commercial market demand is today and over the next decade.”

Terran R will be powered by Aeon R engines, upgraded versions of the Aeon 1 engine it developed for Terran 1 that use liquid oxygen and methane propellants. The first stage of Terran R will have seven Aeon R engines, each producing 302,000 pounds-force of thrust, while the upper stage will have a single vacuum-optimized version of that engine. The company expects to begin testing a prototype version of that engine as soon as the end of this year, a schedule that
supports a first launch of Terran R as early as 2024.

Both Terran R and its Aeon R engines will make extensive use of 3D printing, which has become a hallmark of Relativity. “3D printing actually will help us make a far better reusable rocket that couldn’t really exist with traditional manufacturing,” Ellis said. That technology can allow the company to produce “algorithmically generated and optimized structures” that can’t be made with traditional techniques, along with the use of exotic alloys that have a higher temperature resistance but are lightweight.

Ellis said he sees NASA and the Defense Department as major customers for Terran R, positioning Relativity as a disrupter of the status quo, much like SpaceX. “There’s overall interest there in having a second truly disruptive, fast-paced and innovative launch company.”

**ANTARES ANGST**

Other small launch vehicle companies are looking at developing medium-class and larger rockets. Firefly Aerospace, whose Alpha small launch vehicle is nearing its first launch, has plans for a larger vehicle called Beta, but the company is only now starting design work on the vehicle.

“The long pole will be the engines,” Tom Markusic, chief executive of Firefly, said after the company raised $75 million in May. “Propulsion will be the big focus in the next few months, which is great, because I love rocket engines.”

The experience of another company, though, offers a cautionary note. Fifteen years ago, Orbital Sciences Corp. started work on a medium-class rocket originally called Taurus 2 that it envisioned as a successor to ULA’s Delta 2. It found an anchor customer in NASA through its commercial cargo program, allowing it to proceed with development of the rocket, now called Antares.

While Antares now regularly launches Cygnus cargo spacecraft to the space station, the rocket has not found any customers beyond NASA’s Commercial Resupply Services (CRS) program.

“We are continuing to pursue sales of Antares for non-CRS missions,” said Kurt Eberly, director of space launch programs at Northrop Grumman, at a press conference the day before the most recent Antares launch Aug. 10. Antares is on the NASA Launch Services 2 contract vehicle, allowing it to compete for other agency launches. “We’re talking to some other customers as well.”

That sales job, already difficult given current competition like SpaceX, will presumably become even harder with the introduction of Neutron and Terran R around the middle of the decade that will offer similar or higher performance for lower prices. But Eberly noted there’s often a difference between what a company plans to do and what it actually delivers.

“Everything looks very rosy on paper,” he said. “By the time the new entrants get to launch, we’ll see where they end up. It’s a difficult business.”

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**NATIONAL SECURITY LAUNCH IN TRANSITION AS SPACE FORCE WAITS FOR VULCAN**

It came as no surprise that the U.S. Air Force a year ago decided to retain United Launch Alliance and SpaceX as its two primary providers of launch services.

The selection of two companies for the National Security Space Launch Phase 2 contract was a pivotal moment for the military’s launch program that had long been dependent on a single provider, ULA.

The decision also was significant because it marked the beginning of the end of the U.S. military’s reliance on the Russian-made RD-180 rocket engine. Congress passed a law in 2016 that prohibits the U.S. military after 2022 from procuring launch services on vehicles that use the RD-180 engine.

That requirement did not affect DoD’s procurement of launch services from SpaceX, whose rockets Falcon 9 and Falcon Heavy use domestically produced engines. But it had a huge impact on ULA as the RD-180 is the main engine of its workhorse rocket, the Atlas 5.

To compete for the Phase 2 national security launch contract, ULA developed a two-stage heavy-lift expendable rocket, Vulcan Centaur. Vulcan’s booster propulsion will be provided by a pair of BE-4 engines manufactured in the United States by Blue Origin.

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**SANDRA ERWIN**

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ULA’s engine choice dates back to 2014 when it inked a deal with Jeff Bezos’ Blue Origin to jointly fund the development of a liquid rocket engine. ULA in 2015 announced it would build Vulcan as its next-generation rocket and in 2018 awarded Blue Origin a contract to supply BE-4 engines.

When the Air Force in August 2020 selected ULA as one of its Phase 2 providers, Vulcan was projected to start flying in 2021. But the vehicle’s first flight has slipped to 2022 due to engine delays and customer payloads taking longer to complete than previously estimated.

Vulcan’s main engine is years behind schedule. Blue Origin proclaimed in 2015 that the BE-4 would be ready by 2017 but the company has yet to deliver flight-ready engines needed for Vulcan’s inaugural flight.

Vulcan also needs to complete two successful orbital missions before it can be certified by the U.S. Space Force to fly national security payloads.

ULA’s game plan is to complete Vulcan’s first two commercial launches in 2022 so the vehicle is cleared to fly its first national security mission in 2023. To make this work, not only does ULA need the BE-4 engines but also its customer payloads which are also running behind. One is a robotic lunar lander being developed by Astrobotic. The other is Sierra Space’s Dream Chaser orbital spaceplane that has a NASA contract to fly cargo missions to the International Space Station.

On the one-year anniversary of the Pentagon’s NSSL Phase 2 selections, ULA expects delivery of BE-4 engines by the end of 2021. Astrobotic and Sierra Space are still targeting 2022 launches.

**ATLAS 5 TO FLY ULA’S FIRST PHASE 2 MISSION**

Vulcan’s schedule setbacks already have caused ripple effects in the Phase 2 contract. The first mission awarded to ULA that would have been flown by Vulcan — USSF-51, projected to launch in early 2022 — will fly on Atlas 5.

ULA CEO Tory Bruno said the substitution is allowed under the terms of the Phase 2 contract as long as the price does not go up. “An Atlas costs more than a Vulcan but we offered it at the same price,” he said in a recent interview.

Bruno nevertheless remains confident that ULA’s second Phase 2 mission, USSF-106, will fly on Vulcan in 2023.

“Development is never over until it’s over,” he said. The BE-4 engine so far has performed well in tests and the manufacturing of Vulcan’s first two engines is underway, Bruno said. He said Blue Origin in the coming months will start qualification tests and complete the production of ULA’s two flight engines by year’s end.

Assuming no major technical issues emerge, he said, Vulcan will be ready to fly its first two missions in 2022 so it can be certified in time to launch USSF-106 in 2023.

Once Vulcan is ready to fly, ULA has to contend with the possibility that its customers Astrobotic and Sierra Space might not be, Bruno said. If these payloads experience further delays, ULA would seek other customers so Vulcan can get certified, he said. “There would be a point in time where Vulcan would fly with something else. But we don’t expect that to be the case.”

Switching more NSSL missions to Atlas 5 would be an option of last resort.

“That would be way down the list of backup plans,” Bruno said. ULA has an undisclosed number of RD-180 engines in storage, which the company estimates will be enough to continue to fly Atlas 5 until Vulcan can take over. The congressional ban only applies to Defense Department missions so ULA could continue to offer Atlas 5 for civil and commercial launches.

“We have purchased our last RD-180s,” said Bruno “I’m not even planning to buy any more, and I don’t think I’ll have to.”

ULA meanwhile is working with Aerojet Rocketdyne on a modification to the RL10 engine for Vulcan’s upper stage. The engine has a new 33-inch
nozzle extension that was observed vibrating when it flew a military satellite on an Atlas 5 mission in May.

Concerns about the vibrations led ULA to sideline the enhanced RL10 while it studied the issue. Bruno said Aerojet will modify the engine “so it won’t exhibit that behavior in the future. So yes it will definitely be available for Vulcan missions.”

Space industry analyst Andrew Penn, of the consulting firm Avascent, said the challenges experienced thus far with Vulcan are not unusual with a new launch vehicle. “None of these appear to be systemic issues that they won’t be able to overcome,” he said. “I’m sure there is mutual disappointment with the schedule” for the BE-4 engine but they will push forward.

Under a worst-case scenario — if Vulcan delays persist — the Defense Department could either swap Vulcan and Falcon 9 missions, or request a waiver from Congress to continue using the RD-180-powered Atlas 5, said Penn.

He noted that one of the staunchest advocates of the RD-180 ban was the late senator John McCain, so there may be less resistance if this discussion comes up again.

**SPACE FORCE OPTIMISTIC ABOUT PHASE 2**

Despite early hiccups with Vulcan, the head of the U.S. Space Force launch program, Col. Robert Bongiovi, expressed confidence in the Space Force’s launch providers and the Phase 2 procurement strategy.

“The United States space launch industry is the envy of the world, and we’re proud to continue our industry partnerships and investments,” he said at a Washington Space Business Roundtable event in May.

“There’s a lot ahead of us on Phase 2 in transitioning to new vehicles,” Bongiovi said. “The hard part of Phase 2 is just beginning.”

DoD is investing nearly $1 billion in the development of Vulcan. Bongiovi said ULA’s planned transition from its two legacy vehicles, Atlas 5 and Delta 4 Heavy, to the Vulcan Centaur is expected to reduce the cost of launch services.

With regard to SpaceX, Bongiovi praised the Space Force’s recent adoption of reused Falcon 9 boosters for national security missions. “This allows us an increased launch tempo,” he said.

Another priority is completing the integration of SpaceX’s three-core Falcon Heavy into the national security fleet. The vehicle this fall is scheduled to fly its first NSSL mission, USSF 44, which is almost a year behind schedule. Falcon Heavy flew a military rideshare mission in 2019 that deployed experimental satellites, but will be performing more challenging missions under the Phase 2 contract. For USSF 44, Falcon Heavy must deploy two payloads directly into geosynchronous orbit.

The Space Force has so far awarded seven Phase 2 missions: four to ULA and three to SpaceX. ULA won 60 percent and SpaceX 40 percent of the estimated 34 or so missions projected to be flown between 2022 and 2027.

**LOOKING AHEAD TO PHASE 3**

As the Space Force works through Phase 2 growing pains, officials are meeting with industry executives this month in Los Angeles to start discussions on Phase 3 of the NSSL program.

An industry day was scheduled for Aug. 17 to discuss “innovative acquisition strategies” for national security space launch and “facilitate the development of the Phase 3 Launch Service Procurement acquisition strategy for awards starting in fiscal year 2025,” said the Space and Missile Systems Center (SMC).

Bongiovi said lessons learned during Phase 2 will influence the Space Force’s future strategy to procure launch services.

“There is a way to go in Phase 2 before the program provides all the information we need before we develop our next strategy to partner with industry,” he said. “We have to see how Phase 2 performs before we determine it’s the right model.”

A potential twist in Phase 3 is that the Space Force might consider buying not only traditional launch services from Earth to orbit but also in-space transportation services, according to
NATIONAL SECURITY SPACE LAUNCH

> a request for information issued by SMC in November.

Bongiovi said the Space Force plans to spend some time conducting market research before it makes any decisions about Phase 3.

“The SMC launch enterprise is considering a number of different options for the acquisition strategy for procuring Phase 3 launch services,” he said.

“There have been no decisions, including the number of providers,” Bongiovi added. “The launch enterprise intends to leverage U.S. launch industry innovation and competition to provide the launch capability needed for national security launches starting in 2027.”

With regard to in-space transportation, “We are beginning to explore the space access, mobility and logistics capabilities the U.S. Space Force may need in the future,” Bongiovi said. “We are tracking U.S. industry advances in these areas.”

Another looming question is whether new players in the launch market will be capable of challenging ULA and SpaceX for national security contracts.

Of the competitors that didn’t make the cut in Phase 2 — Northrop Grumman and Blue Origin — only Blue Origin is expected to compete again with its New Glenn rocket. Northrop Grumman terminated its OmegA rocket development program after losing out in Phase 2.

A spokeswoman for Blue Origin declined to comment for this article about its plans to compete for a Phase 3 contract.

Northrop Grumman’s director of launch and missile defense Jo Cangianelli said the company will attend the Space Force industry day to better understand the Phase 3 strategy before it decides whether to invest in another launch vehicle for NSSL.

There are also two well-funded emerging players in the small launch market — Rocket Lab and Relativity Space — that earlier this year revealed they are developing medium rockets aimed at the commercial market but also perhaps with Phase 3 of NSSL in mind.

Rocket Lab announced plans to build the Neutron launch vehicle with a reusable first stage that would compete with SpaceX’s Falcon 9.

Morgan Bailey, a spokeswoman for Rocket Lab, said Neutron will be “ideal for launching national security payloads, including many of those payloads competed for launch in the National Security Space Launch program.”

Relativity Space, meanwhile, unveiled plans for Terran R, a fully reusable, 3D-printed launch vehicle for orbital and interplanetary missions. A company spokesman declined to comment about the company’s future rocket or whether it would compete in NSSL Phase 3.

Penn, the industry analyst, said the prospect of additional players coming into the market would give the Space Force enormous flexibility to decide how it wants to procure launch services after ULA’s and SpaceX’s contracts are up for recompete in 2024.

“There will be more vehicles,” he said. “So why commit to a strategy of just two providers? You could have an open competition with no cap on the number of awards.”

Penn said the Space Force should consider “all paths to space” not just for conventional launch vehicles but also so-called space tugs that provide “last-mile” delivery services after a satellite is released from a rocket.

Several companies, including Momentus, Exolaunch and Spaceflight, are working on orbital transfer vehicles. These are propulsive spacecraft designed to ferry satellites to their intended destinations in space after separation from a launch vehicle. If the economics work — and schedules align — these vehicles would allow the Space Force to utilize excess capacity in large rockets instead of procuring dedicated small launches, Penn said.

Philip Bracken, vice president of engineering at Spaceflight, said the company developed an orbital transfer vehicle called Sherpa “with an eye not just on commercial industry but also on U.S. government needs.” He said the U.S. military is “actively seeking and looking for architectures that can deliver smaller satellites to different orbits and do different persistent missions.”

Bracken said companies in the commercial space transportation industry view the Space Force as a key customer and would welcome government investment in technologies that would help commercial systems meet military-unique needs.

NEW COMMAND FOR ACQUISITIONS

Discussions about the next phase of the national security launch program are starting amid broader changes taking place in the military space acquisition business.

The Space Force is establishing a new Space Systems Command to replace the historic Space and Missile Systems Center in Los Angeles. Officials said the change is not just a renaming but an attempt to build a different culture and adopt more commercial-like ways of doing business.

The first commander of Space Systems Command is Lt. Gen. Michael Guentlein, a former deputy director of the National Reconnaissance Office, a defense and intelligence agency responsible for building and operating U.S. spy satellites.

“This is something to watch: a culture change as a former NRO official takes over the former SMC,” noted Penn.

The military procurement red tape won’t go away overnight, he said, “but I do expect there will be a continued emphasis on getting things done faster.”

NSSL Phase 3 gives the Space Force a clean sheet of paper to begin drawing up a new acquisition game plan for launch and other capabilities, Penn added. “At the very least, I would expect there to be strong consideration of new alternatives before going down a similar path.” SN
The world watched with excitement as former Amazon CEO Jeff Bezos and three others lifted off July 20 toward the farthest edge of Earth’s atmosphere aboard the Blue Origin New Shepard. This mission took place only nine days after Virgin Group founder Richard Branson boarded the Virgin Galactic VSS Unity, embarking on the first fully crewed commercial voyage to space.

More than space tourists, Bezos and Branson are leading the way to commercial and public utilization of space previously only imagined in science fiction. These pioneers of both high-tech business and new space are now blazing trails into an emerging commercial landscape of untold opportunity and promise.

While some may debate the scientific and societal benefits of these flights as well as their cost, the symbolic and technical impact of the past several days cannot be ignored. On the heels of the 2019 commemoration

“What we need to do is always lean into the future.”
– Jeff Bezos
of Apollo 11 and its monumental legacy for crewed spaceflight, we are now witness to another profound first step for humankind. These two flights represent the start of a thrilling new space race as well as a time to celebrate a key milestone of our civilization. After all, our overall advancement and progress have always been measured by transportation and exploration. While reflecting that the real competitors in this arena are the U.S and Chinese governments, NASA Administrator Bill Nelson remarked that Branson’s flight is a “great” milestone.

We believe that the launches of the wealthiest man in the entire world and another billionaire businessman surpass the perception of “rich boys and their toys” to serve as compelling demonstrations of boldness, calculated risk, and the endless possibilities of technical innovation and excellence. Just as the achievements of the United States space program heralded by NASA have delivered countless spinoff technologies that have improved every aspect of life on this planet, the resulting inspiration of a generation and nation-building drive have cemented our preeminence across the world and our destiny to do even greater things.

Although Virgin Galactic aims to “fill the world with astronauts,” Branson offers a universal lesson that success in any venture occurs “when preparation meets opportunity.” Bezos’ thoughts on the disruptive nature of invention are similarly inspired: “If you want to be
understood at all times, then don’t do anything new.” We sincerely agree and have said this before: what an incredibly exciting time to be in the business of space and other disruptive technological fields. As if this wasn’t already one for the record books, Bezos was accompanied by female aviator Wally Funk, one of the original so-called Mercury 13 or First Lady Astronaut Trainees who never went to space, becoming the oldest astronaut in history.

The months ahead should prove to be just as exciting as billionaire Elon Musk and SpaceX will soon launch civilian astronauts aboard Crew Dragon, along with efforts from other companies like Axiom. This unprecedented moment calls for congratulating Bezos and Branson — as well as Blue Origin and Virgin Galactic — for the courageous firsts of many catalysts for an extraordinary future.

MICHAEL LENCIONI is CEO of STELLAR SOLUTIONS, a global aerospace engineering services provider to commercial, defense, intelligence, civil and international sectors.

“Whatever your goal is, you will never succeed unless you let go of your fears and fly.”
– Richard Branson

Space tourism’s environmental price tag

There’s no such thing as a free launch — especially when it comes to suborbital joy rides

Whether or not you agree with Elon Musk that we need higher volume and lower cost access to space so that a small portion of humanity can flee our imperiled planet and become planetary refugees, at least he has a plausible justification (albeit one that deserves scrutiny and debate) for undertaking major industrial activities and launch operations that inject thousands of tons of carbon and other greenhouse gases (GHG) into the atmosphere.

The backdrop, though, is that we are reeling from multiple and recurring extreme weather events caused at least in part by climate change wrought by human activities. So, how do Richard Branson, Jeff Bezos, and to some extent, Elon Musk, justify their extensive, carbon-generating activities? Space Tourism!

I spent a long and interesting professional life in the space industry in a variety of roles, from selling satellites and launch services, to promoting companies that launched constellations of LEO and GEO communications satellites, to opening the new market for satcom services on aircraft. I was always confident that the mission of the civilian satellite industry — to increase knowledge, awareness, and communications among people everywhere — was worthy, and that this mission justified the known environmental costs of civilian space activities.

Now, based on evolving awareness about the environmental impact, I’m not at all sure. The perilous state of our atmosphere is front page news, and it seems increasingly challenging to change human behavior significantly enough, and quickly enough, to avert major disaster caused by global climate change. We are already living in a period with a far higher incidence of extreme weather events — storms, floods, heat waves, fires, etc. — and the link to climate change is clearer by the day.

The carbon footprint and other GHG contributions from the development, construction and operation of space launch systems is massive. As with many human activities, we are only beginning to quantify the total impact of this industry, but it is not impossible to do so; recall the Total Cost of Ownership (TCO) analyses frequently conducted by companies to justify their investments. For launch services, TCO includes the environmental impact of extraction and refining of all the materials, and for developing and producing the vehicles, their support components, and their chemical fuels, plus the very visible large burning event of the launch itself. Whatever the specific analysis eventually reveals, we are talking about tons and tons and tons of atmospheric carbon. It is truly a massive footprint. I challenge the
COMMENTARY Leo Mondale

Above: Jeff Bezos and brother Mark celebrate following their July 20 flight. Right: Virgin Galactic’s VSS Unity performs a burn during July 11 flight.

launch services providers to demonstrate otherwise.

We are long past the days when spaceflight was an indomitable challenge, so climbing the space mountain because it is there is simply not a sufficient justification for doing so in light of the known harm to those of us planning to remain on the planet.

The new human launch systems and their private company management teams offer technical and operational improvements and efficiencies, to be sure, but the underlying technologies and activities still carry huge environmental costs, which are currently passed to the public. With government historically running the show, at least we had the party ultimately responsible for addressing the environmental cost making the key decisions. Those have not always been good decisions, but government is now waking up to the issues of climate change, and while this may shift over time, government is clearly the most important mechanism we have today for structurally addressing the climate crisis.

The economic rationale for the new systems, and their pricing, are based in large part on projected larger volumes. While the start-up costs for these systems are backed by massive private fortunes that can distort the economic rationale, it is clear that current pricing is not supported by demonstrable underlying demand for launch services. In fact, the “business plans” for these larger volumes are supported by optimistic revenue projections for launching constellations of communications satellites that, despite their own optimistic projections, cannot hope to compete with terrestrial services in the medium or long term, outside of the niches where satellite technologies excel: namely, broadcast, low user density two-way connectivity (remote and mobile) and Earth observation.

While other aspects of their plans may be shaky, the worst kind of “business plan” backfilling for this new generation of launch services is space tourism, a “service” for the ultra wealthy, that serves no higher purpose whatsoever, and carries very substantial environmental costs at a time of climate peril for the planet. It is very hard to see how flying billionaires, or even multimillionaires into space is filling a need that is so important that we should be adding tons of carbon and other GHG to the atmosphere so they can realize their childhood dreams, or effect their escape from a planet they are doing much to imperil.

Surely within the space industry we don’t need to discuss whether we believe in science or not, so we should accept the scientific consensus that the environmental impacts of atmospheric carbon and other GHG are real and getting worse. Ideologically, we can probably also agree that protecting personal freedoms that do not cause harm to others is central to our society, and arguably, to its survival. But in the case of space tourism, there is clear and present harm to others. Indeed, if there is a poster child for where to apply a steep carbon tax, or other climate change mitigation policies, it is surely space tourism. I urge legislators and policymakers to do so at once, before this toothpaste is out of its tube. SN

LEO MONDALE SPENT 35 YEARS IN THE SPACE INDUSTRY, HOLDING EXECUTIVE POSITIONS AT MATRA (NOW AIRBUS), FAIRCHILD SPACE AND DEFENSE, MOTOROLA, IRIDIUM, AND ARIANESPACE. HE MOST RECENTLY SERVED AS PRESIDENT OF INMARSAT’S AVIATION BUSINESS UNIT, BEFORE RETIRING IN 2018. HE LIVES IN PORTLAND, MAINE.
Achieving sustainable space

The visibility and attention space missions often get work to the industry’s advantage, from helping to attract top engineering talent to top investment dollars.

But it also comes with heightened scrutiny that risks tripping up young space companies rushing to the commercial market.

The industry is “highly dependent on customer sentiment and regulatory potential impacts,” noted Joe Schloesser, senior director at supply chain manager ISN.

Having a responsible corporate posture is also increasingly important for all companies as more investors — and potential business partners — are rating them based on their environmental, social and governance (ESG) standings.

ISN provides a platform for hiring contractors and managing supply chains for industries including aerospace, and Schloesser highlighted how ESG is one of its biggest growth areas.

He pointed to a growing number of space companies using its score cards to determine where potential contractors and suppliers rank.

It used to be that only performance and cost mattered when it came to building and launching spacecraft.

Now, even large and established space companies are adapting their operations to align themselves with the growing importance of sustainability in society and business.

Boeing released the first comprehensive review of its sustainability efforts in its 105-year history July 26.

It made a number of commitments as part of its sustainability report, including 2030 environmental performance goals to reduce emissions, waste, water use and energy consumption.

“We know there’s still work to do and are committed to communicating our progress and holding ourselves accountable to ensure the aerospace industry is safe and sustainable for generations to come,” Boeing chief sustainability officer Chris Raymonds said.

THE COST OF LAUNCH

The journey won’t be an easy one. The space industry will be tough to decarbonize as the number of satellite launches grows exponentially to serve a new era of megaconstellations.

Billionaires Jeff Bezos and Richard Branson also hope their recent suborbital flights will kick off a space tourism boom that calls for even more launches.

The carbon emissions from a single commercial space launch is equivalent to one car making 74 trips around the Earth at the equator, according to research S&P Global Sustainable1 released July 20.

The financial analytics provider used the Federal Aviation Administration’s environmental assessment report for SpaceX launches in its analysis, showing that a Falcon 9 rocket launch produces the equivalent of 518 tons of carbon dioxide.

S&P Global Sustainable1’s analysis only covered direct emissions, known as Scope 1 in ESG lingo.

Still, it said those emissions are also about the same as a full passenger round trip flight in commercial aircraft from London to New York.

It comes as large airlines are pushing ahead with sustainable aviation fuels, turbine changes and other routes to reduce their emissions.

Space companies could look to them for pointers on the flight path ahead. SN
The pace of technological innovation in the space business has long been dictated by government-funded programs of record. But as the private sector increasingly drives innovation, government buyers are trying to figure out their role in the new space era.

The implications of this shift are significant, particularly for the Defense Department. What’s happening in space today is similar to the transition that took place in the semiconductor industry where the U.S. government invested twice that of private industry 40 years ago but is now outspent by a factor of 23 to 1, says a report from the market research firm Quilty Analytics.

“While government spending still dominates the industry narrative today, private sector spending will inevitably become the industry’s driving force,” the study says.

Critical technologies for space systems such as optical crosslinks, electronically steered antennas and on-orbit satellite servicing, says Quilty Analytics, languished for decades as government-funded R&D projects but are on the cusp of entering mainstream adoption due to private investments.

DoD space buyers are responding to this changing environment with enthusiasm and are increasingly talking about acquiring satellite imagery, weather data and broadband from low-Earth-orbit constellations as services, rather than as traditional acquisitions.

“We need to leverage this kind of innovation,” says Shawn Barnes, deputy assistant secretary of the Air Force for space acquisition and integration. The “entrepreneurial spirit” in the space industry is a strategic advantage the United States has over adversaries, Barnes says.

Change won’t happen overnight but there is momentum in the U.S. Space Force to pivot to new procurement approaches, Barnes said during a panel discussion at the Navy League’s Sea-Air-Space conference earlier this month. “In general the Defense Department has not done a great job with that, but we’re moving in that direction, I think fairly rapidly.”

A marker to watch will be the organization of the new Space Systems Command that will oversee Space Force acquisitions. An existing office within the command is responsible for the acquisition of satellite communications services and there are plans underway to expand that office so it can acquire other types of space services.

The standup of a commercial services procurement office would be an important step, says Col. Eric Felt, who runs the Air Force Research Laboratory’s Space Vehicles Directorate.

“Money is flowing to companies with good ideas,” he told the National Security Space Association during a recent webinar.

Felt’s message to the space industry is that the Space Force is serious about buying commercial services but he suggests that companies should not become overly dependent on government contracts because that can dampen entrepreneurship.

“We need industry to keep innovating and keep pursuing commercial opportunities, not just government dollars,” Felt says. “That’s the model we need to evolve to in the future.”

A thriving space industry is good for national security, says Felt. “We want companies to be successful and stay in the U.S.” He would advise companies to pursue commercial customers, and if the product meets government needs and it’s priced competitively, the government will buy it.

“I would predict that a lot of our future dollars in the lab and in the Space Force are going to be going that route,” says Felt. For that reason, “the most important are not the opportunities we publish in [federal procurement website] sam.gov but commercial opportunities.”

Quilty Analytics, in its report, cautions that the commercial paradigm shift represents both an opportunity and a risk for DoD decision makers. The opportunity lies in the commercial sector’s ability to provide important capabilities for national security faster and cheaper than the government could.

But profit-seeking commercial efforts will not always align with DoD needs and priorities. So the calculus for government buyers is that if commercial products can meet 80% or more of requirements, it’s a deal that can’t be ignored.
## ON THE HORIZON

### AUGUST

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<td>16-18</td>
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## WOMEN IN AEROSPACE

**The 36th WIA Annual Awards Dinner & Ceremony**

**Thursday, October 14, 2021**

Ritz Carlton Pentagon City  
1250 S Hayes St, Arlington, VA 22202  
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A schedule better suited for Artemis

In early August, Russian media reported that the country’s space agency, Roscosmos, had yet to order new spacesuits for its cosmonauts to replace the aging suits required for space station spacewalks. Dmitry Rogozin, head of Roscosmos, turned to Twitter to refute the claims, saying that cosmonauts “will not have to perform spacewalks in their underwear.”

American astronauts have similar concerns. The same day Rogozin was tweeting about spacesuits, NASA’s inspector general issued a report on the agency’s program to develop new spacesuits for both ISS spacewalks and Artemis lunar missions. The usual one-two punch of technical problems and funding shortfalls led the inspector general to conclude that the suits won’t be ready for the Artemis 3 lunar landing mission until at least April 2025, missing the 2024 goal for the mission.

That produced a spate of headlines that NASA’s lunar return will be delayed by spacesuits. But the inspector general noted that’s not the only problem, citing long-running issues with the Space Launch System and Orion. “Moreover, delays related to lunar lander development and the recently decided lander contract award bid protests will also preclude a 2024 landing,” the report stated.

The conclusion of the bid protest July 30, when the Government Accountability Office upheld NASA’s decision to award a single lander contract to SpaceX, provides an opportunity for NASA to move ahead with plans to overhaul, or at least tweak, the Artemis program. NASA for months used the protest as an excuse not to talk in detail about Artemis, saying its hands were tied by the rules regarding such protests. The GAO has now untied those hands.

In a statement the day the GAO rejected the protests, NASA announced it will provide an update “as soon as possible” on its plans for the Artemis program. “Importantly,” the agency said, “the GAO’s decision will allow NASA and SpaceX to establish a timeline for the first crewed landing on the moon in more than 50 years.”

That suggests NASA is reconsidering the 2024 goal, which makes sense. While moving up the date of a human lunar landing from 2028 to 2024 may have been well intentioned, providing the urgency needed to make decisions and more forward, budgets that have not kept pace with projections and inevitable future technical problems make it unlikely NASA can make up for lost time and get everything in place to land humans on the moon in 2024.

Asked about schedules at a July 29 press conference, NASA Administrator Bill Nelson again brought up the GAO protest that he claimed limited what he could say on the matter, but also acknowledged that “we’ve lost some time” because of that protest.

He then fell back on one his most frequent phrases. “Space is hard,” he said. “There’s always things that happen, especially when you’re developing new technology and going further and further.” He declined to either affirm or reject the 2024 date, saying only, “We’re going when it’s safe.”

The only question now, it seems, is by how much to stretch out the schedule for Artemis. Too little and you run the risk of having to delay it again; too much and you risk losing the urgency and momentum built up over the last couple of years. Those may be the calculations the agency’s leadership is making now.

There may be bigger changes in the works, such as selecting a second company to develop a lunar lander, something NASA has supported but currently lacks the funding to pursue. An extended schedule could provide more time to get a second lander funded and in development or adjust when and how the lunar Gateway is developed.

That revised schedule would also ensure that NASA gets all the elements needed for Artemis back in sync. There’s no use to rush to develop a lunar lander, or landers, if the spacesuits the astronauts on board would wear won’t be ready in time. Astronauts would be well advised not to attempt to walk on the moon in their underwear. SN
Dr. Mike's fascination with space meets up with one of the few people on earth whose work extends from Antarctica to the International Space Station. His experiments with astronauts in space may one day affect how we eat on terra firma. Buckle up and meet Scott M. Smith, PhD, NASA’s head of space nutrition – it’s not what you think.

Friday, September 3, 2021
10:00 am PDT / 7:00 pm CEST
6:00 pm BST / 10:30 pm IST
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