AEROSPACE
AMERICA

THE SUSTAINABILITY QUESTION

X-59 will test community tolerance for the noise of supersonic travel, but what about possible atmospheric damage? Here's the science. PAGE 22

FEBRUARY 2024 | A publication of the American Institute of Aeronautics and Astronautics | aerospaceamerica.aiaa.org

AIAA
SHAPING THE FUTURE OF AEROSPACE

Tom Jones during a 2001 spacewalk outside the International Space Station. NASA

Lessons from the space shuttle

It's been 13 years since the last space shuttle orbiter flew, but in some ways it feels like a lifetime ago: Commercial companies are ferrying non-astronauts to the fringes of space and into orbit; NASA has taken the first steps in a 21st century moon program intended to put astronauts on the lunar surface for weeks, not days as in Apollo; and the International Space Station is slated to be decommissioned to make way for a crop of privately operated stations. To former NASA astronaut Tom Jones, there is one program to thank for these leaps forward. "Everything we know how to do well in space today, we learned on the space shuttle," he told me. To chronicle those lessons, he spent the last few years interviewing a member of each shuttle crew (and consulting public statements and personal emails from those who died in the Challenger and Columbia accidents) for his latest book, "Space Shuttle Stories." I reached Jones by phone to discuss his book and the new era of space exploration. Our conversation has been condensed and lightly edited. — *Cat Hofacker*

TOM JONES

POSITIONS: Since 2001, speaker and consultant on topics including human spaceflight for NASA, Florida-based Institute for Human and Machine Cognition and various aerospace companies. 2003-2019, columnist for Aerospace America. Author and co-author of eight books, including last year's "Space Shuttle Stories." 1990-2001, NASA astronaut; on four space shuttle flights, logged 53 days in orbit and three spacewalks. 1973-1983, trainee and then pilot for the U.S. Air Force; resigned with rank of captain.

NOTABLE: Flew B-52D Stratofortresses on strategic deterrence missions. Member of the STS-80 Columbia mission that in 1996 set a record for longest time in space by a shuttle crew (17.7 days). In 2001, conducted spacewalks outside International Space Station with fellow crew members to complete hook up of U.S. Destiny Laboratory delivered by shuttle Atlantis during their STS-98 mission. With a planetary science education, he's advocated for increased government funding for technologies to detect and deflect near-Earth asteroids as a member of the Association of Space Explorers.

AGE: 69

RESIDES: Vienna, Virginia

EDUCATION: Bachelor of Science, U.S. Air Force Academy, 1977; Ph.D. in planetary science, University of Arizona, 1988.

Q: What was missing from the public accounts of the shuttle era that you wanted to provide with your latest book?

A: NASA had put out some of its own histories compiling its research achievements and operational experience, and there have been some really good technical histories written by Dennis Jenkins, called "The History of the American Space Shuttle." Those were all focused on the technical aspects of the shuttle, and what was missing was the human component of the space shuttle's 30-year career. Many lessons about how humans operate in space and what unexplained problems cropped up and how you dealt with those challenges, those were not recorded anywhere. Even though NASA has an oral history program, it was incomplete in terms of getting anything like a good sampling of the shuttle astronauts. So I thought what I could contribute was to get down on paper one story from each of the shuttle missions. Three hundred and fifty individuals flew on the space shuttle; I said, "I can't talk to 355 people, but I think I could talk to 135 and ask them for their most memorable experiences and how they felt about their space trips and what they accomplished and what the shuttle taught them."

Q: I was struck by how few of the astronauts described feeling fear or trepidation. Is that really the case, or do you push those emotions to the background to focus on the mission?

A: They didn't really talk about fear. I think what they confronted is the sense of anxiety that you get when you're taking on a new challenge, and you're just not sure whether you've prepared for every last aspect of it. "Will I do a good job? Will I let my friends down? Will I embarrass myself in front of mission control?" Those are the kinds of fears you have. It's not the physical fear of the risk of going to space. You've already made peace with that when you signed up to do the job. On orbit, I felt a great appreciation about the fact that I was traveling 5 miles per second, and my machine and I and my crewmates all have to slow down somehow to get back on Earth and in one piece. After we lost the Columbia in 2003, I told myself that I should have worried about reentry more than I actually did, because it really demands the utmost of the technology that we put together to take people to space and get them back. It all has to work perfectly for you to get home in one piece. In the current day, we're looking at the Artemis II mission, and there are some questions now about whether the Orion heat shield has the right capacity to reliably bring the crew back.

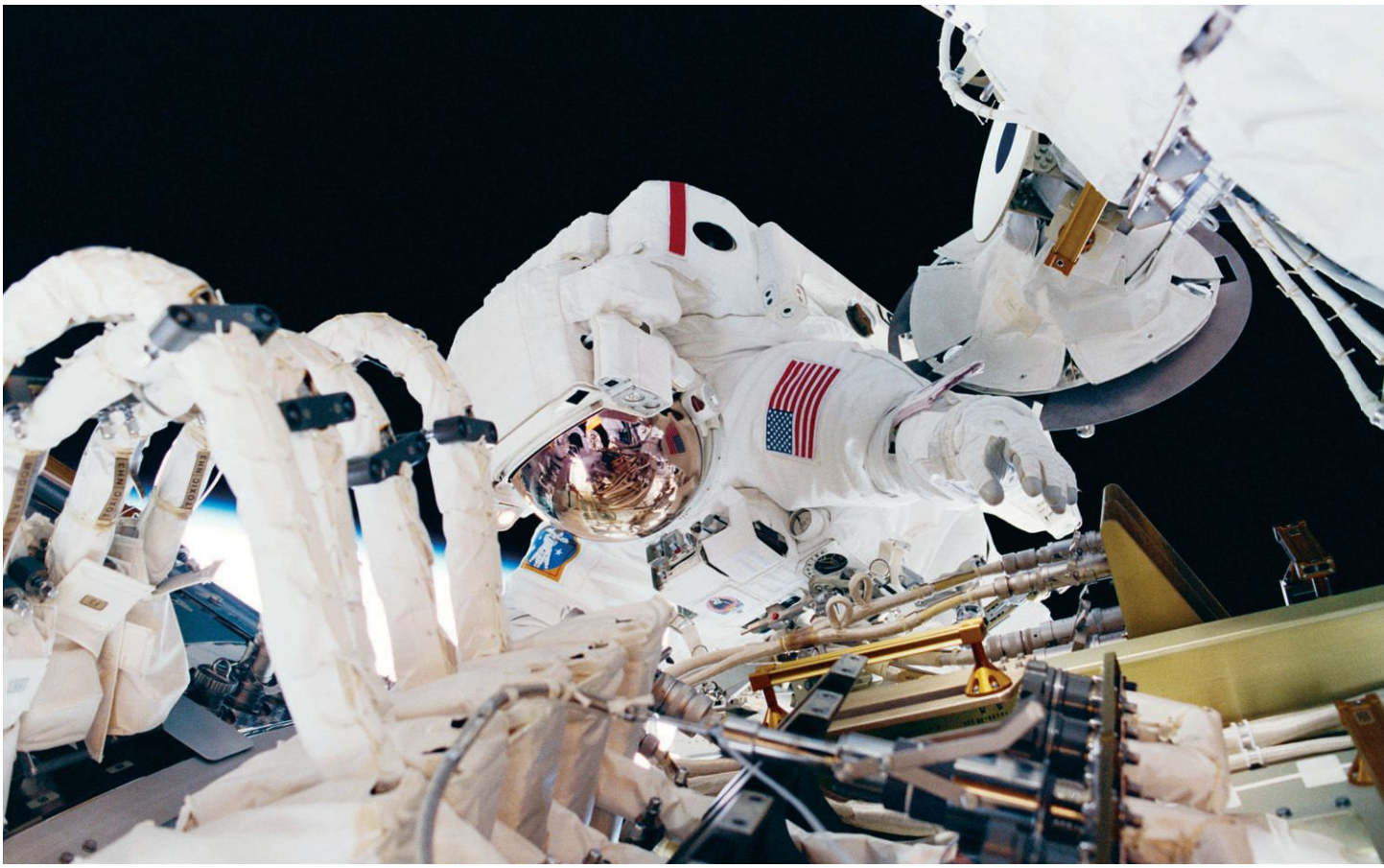
In January, NASA announced it would push the crewed Artemis II mission from December 2024 to September 2025, in part to conduct extra analysis on the Orion heat shield from the Artemis I uncrewed test flight. Portions of the heat material ablated more than expected based on computer models and ground testing. — CH

My advice is pay really good attention to that heat shield and make sure it's going to work for you before you put those people out there going 7 miles a second.

Q: Did writing this book while the Artemis program was underway give you a new perspective on the space shuttle's place in U.S. history and the history of human spaceflight in general?

A: I had my parochial view of the value of the space shuttle from my 11 years as an astronaut, and I knew how versatile and marvelous a machine it was. And yes, it was fragile, and yes, it was expensive to operate, and so it fell down on some of its goals that were set out for it in the 1970s. But over 30 years, the space shuttle really delivered a vastly important base of experience to the country in terms of how we can operate in space and take on really complex challenges there. Everything we know how to do well in space today, we learned on the space shuttle.

"Now we're putting people at a much higher level of risk because of radiation, because of the distance from the Earth, because of new technology. And so we as a society have to realize there are going to be failures."

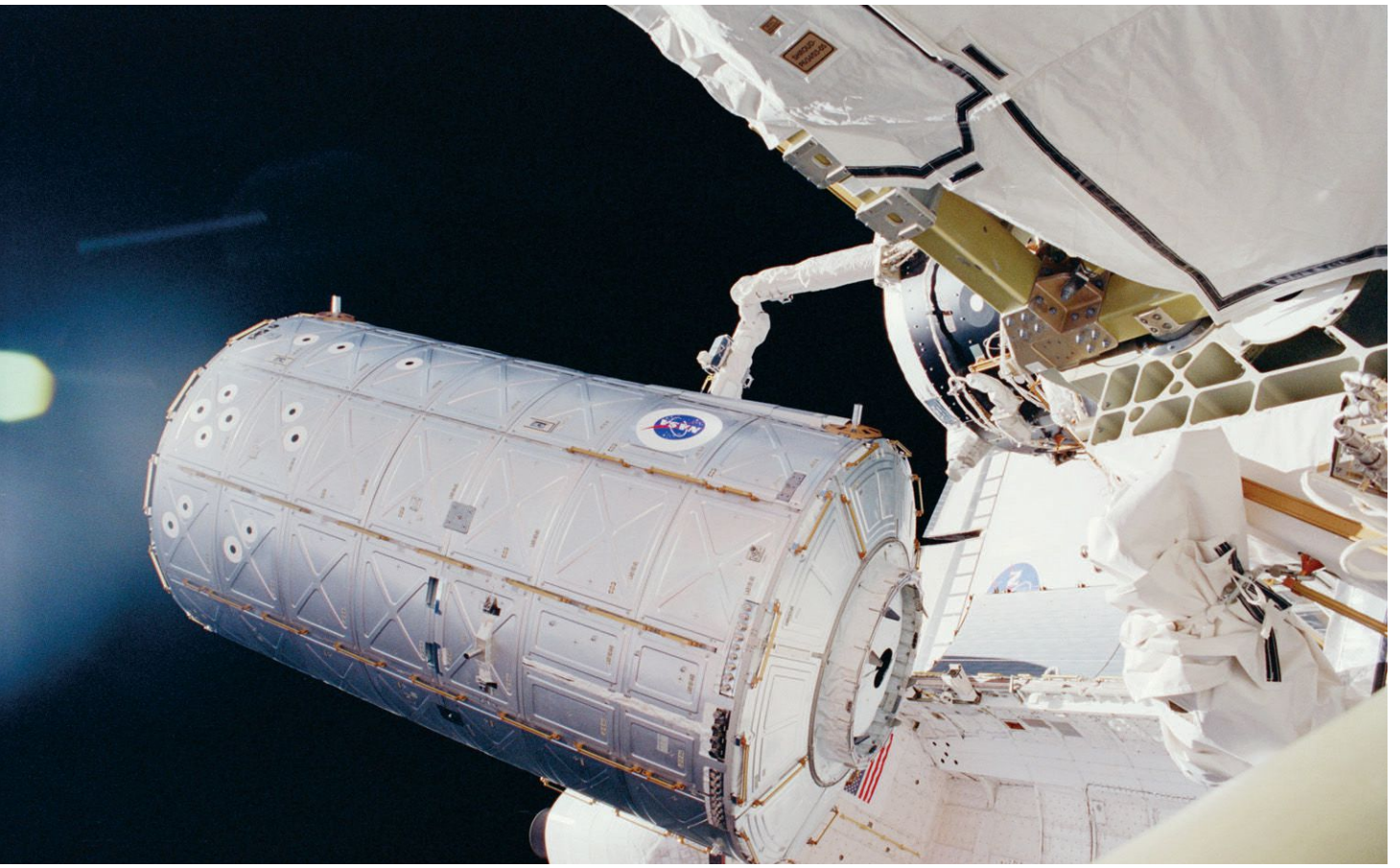


Now, you know, the shuttle couldn't go to the moon so we need to build a new different spacecraft and capability to go back to the moon. But what I got out of my research for the book was how many challenges were overcome that I never even heard. These personal stories from my colleagues were ones that had escaped me because I was so busy focusing on my own missions and preparations for them. The book taught me how versatile we actually were on the shuttle in terms of meeting and overcoming challenges, and how valuable the capabilities of the shuttle were and where we made mistakes with the shuttle: losing Challenger and Columbia. These lessons need to be remembered a generation later as we confront the higher risk levels of going into deep space, to the moon, to asteroids and Mars — and if you forget about those, we're going to have other tragedies in the future that can be avoided.

Q: One of the biggest lessons from Challenger and Columbia were the dangers of schedule pressure. But many of the leaders in commercial space, like Elon Musk, believe that deadlines are not only healthy but essential to achieving these lofty goals. What's your perspective?

A: My experience is that you do need to have a deadline to shoot for so that you can manage the program in terms of technical milestones and the cost. If you just have an open-ended program, that's just going to grow in cost and constantly slip, and your workforce isn't motivated if you don't have a good firm deadline to shoot for. So it should be challenging to your team, and a deadline will help challenge them to do their best to meet the goal. However, you can't let the goal override safety concerns that people legitimately surface, so while applying schedule pressures in a good way, you've got to have the communication channels open so that anybody can stand up and surface a safety concern that they have. You have to be able to stop, and you've got to have the willpower as an institution to say, "Stop, we have to fix this risk before we go." In the case of the shuttle, it should have been grounded when we started losing chunks of insulating foam off external tanks that were damaging the heat shields.

Foam striking space shuttle orbiters was a frequent occurrence long before the same phenomena caused the Columbia orbiter to break apart as it entered Earth's atmosphere. "Photographic evidence of foam shedding exists for 65 of the 79 missions for which imagery is available," the Columbia Accident Investigation Board wrote in its report. — CH



▲ For his last spaceflight, then astronaut Tom Jones helped deliver and install the Destiny Laboratory, the primary research facility in the U.S. segment of the International Space Station. The robotic arm on space shuttle Atlantis removed the laboratory from the orbiter's cargo bay (above), then Jones (left) and astronaut Bob Curbeam latched and bolted Destiny to the front of ISS, meaning the side facing Earth.

NASA

We should have realized the catastrophic potential of that; nobody did, and so they didn't say, "Halt until we fix this design flaw." And you can draw parallels with Challenger as well, where the hardware was speaking to the engineering community and saying, "The boosters are flawed. They're not performing as they were designed, so stop until we fix that." In the Artemis era, we have to be able to stand up and say, "We have to accept an 18-month delay to a trip around the moon because we've got to fix concerns with the heat shield or the life support system or what have you." On the other hand, in the real world, schedule and budget are always going to be factors; you can't escape from them. You just have to have the right balance of being able to know when to audit your team and focus on risks that should be eliminated and accept the schedule if you can. Now, Apollo was very different. It was a Cold War crash program, and people had to accept the schedule pressure or else we weren't going to beat the Soviets to the moon. But you know, we're not in a space race today, and we should realize that we do have the time. Even though we want to get back to the moon before the Chinese, we need to do it in a safe way. And if the schedule has to slip, so be it.

Q: I found it interesting that you and a few other astronauts in the book referred to shuttle as forever "experimental." Will SLS and Orion also fall in that category, since they're targeted to fly once a year at most?

A: When you're on the frontier of what the technology can do — and that's certainly the case in the deep space arena right now — yeah, these are going to be experimental spaceships that are carrying people out to the fringes of what we know how to do, technologically. So we should treat each flight as an experimental test in a sequence that builds our capabilities slowly, and then maybe someday we'll get to the point where we have a taxi that can go between the Earth and the moon without too much worry. But for right now, these are definitely experimental vehicles. They're not in the same vein as a Crew Dragon to the space station. And we as a society have to understand that higher level of risk. Artemis is not going to be a space shuttle program; it's not going to be a space station program where you have long missions filled up for research programs, but the crew is in a pretty safe spot on the space station on a day-to-day basis. Now we're putting people at a much higher level of risk because of radiation, because of the distance from the Earth, because of new technology. And so we as a society have to realize there are going to be failures. I hope they're not fatal ones, but we have to build the system to give the best chance of crew survival and

▲ NASA now plans to conduct the Artemis II crewed lunar flyby in September 2025, almost three years after this unoccupied Orion capsule looped around the moon in late 2022 and returned to Earth for a splashdown in the Pacific Ocean. During post-flight analysis, NASA discovered that more of Orion's heat shield eroded during its entry through Earth's atmosphere than anticipated, prompting the agency to conduct further tests.

NASA

then realize that we're going to occasionally stumble. So we have to wake up to that. It's not going to be a perfect program, and it won't be for some time.

Q: Are frequent flights the only way to build up confidence, or are there other ways today given that the modeling tools and artificial intelligence are much more sophisticated?

A: We have much more capable ways of simulating flight and analyzing the loads and the environmental impact on the spacecraft and building the spacecraft so that it can easily handle that environment and the loads that it will experience. For the Earth orbit transport mission that Crew Dragon and soon Starliner and Dream Chaser will do, that's pretty well understood in terms of the accelerations and the forces and the temperatures that you'll experience. They're small enough that they're not going to become overwhelmingly heavy as a result of those designs, so you can make them very robust and give the crew a very good chance of surviving any mishap. But because weight is at a premium on these deep space missions, the spacecraft are going to be designed to just do the job and be no more robust than necessary — otherwise it gets too heavy and too expensive. That's the designer's challenge: to know what the environment is well enough to make sure that the spacecraft can withstand it all with an extra margin of safety. I'm confident that we can model the way you build the spacecraft. What you don't know is the interaction of all the systems and the hidden design flaws that don't surface for another 10 years after you start operating the system. So pay attention to the spacecraft when it comes back, see what kinds of shortfalls it's had or any compromised systems, and then modify your systems accordingly so they can take care of them. Be careful and make sure that you listen to the hardware.

Q: Another big difference today is the increased automation, so astronauts don't have the same opportunities for manual flying as they did with the space shuttles.

A: I don't have any doubts that the crew members will be able to meet the demands of carrying out the mission. There's still very high-quality people that are flying these Crew Dragon spacecraft or will fly the Starliners. Even though they're not called upon to do a manual return to Earth, I think they can monitor and make intelligent decisions about going to a redundant system or going to plan B in terms of accomplishing their mission. That's the human mind and its flexibility and adaptability at work. When you go out to the moon and are landing a billion-dollar vehicle on the surface, I would vote for having a human in the loop even though the autopilot is probably capable of guiding you to a descent to the lunar surface. There's no doubt that we can land robots on the moon. We've done it with automated spacecraft — and the Chinese and Indians have done it recently — but for a pilot and craft with all the human value aboard all that's riding on the national prestige, I would put the landing in the hands of a capable pilot.

A few days after our conversation, Japan's SLIM lander touched down on the moon, making Japan the fifth nation to land a robotic spacecraft on the lunar surface. Shortly after the landing, JAXA, the Japan Aerospace Exploration Agency, reported that the lander's "solar cells are currently not generating power." — CH

Q: On a topic closer to home, what thoughts do the upcoming retirement of the International Space Station stir up for you?

A: I don't have a problem with decommissioning the parts that have worn out or have exceeded their useful lifetimes or that pose an extra risk for the crew, but I can't believe that we have to throw the entire thing away in 2030 and dump it into the ocean. I would like to see a really concerted effort to take off the modules that still have some life left in them and be built into parts of these commercial stations. And maybe one way to do that is to park part of the space station in graveyard orbit. That would give us 10 or 20 or 30 years to figure out ways to recycle elements. Eventually we're going to be able to smelt scrap metal in space and manufacture things with the space junk that's up there, and the space station perhaps could be a way to test those techniques of salvaging and repurposing material. You know, we threw away 135 space shuttle external tanks, 65,000 pounds [29,500 kilograms] of aluminum each.

In 1998, NASA began flying a variant of the external tanks that weighed 26,500 kg when empty. — CH

We could have done a lot of good things with repurposing that metal, and with just a little squirt of rocket fuel, we could have gotten them up into orbit to use as a resource.

Q: Are you optimistic that these commercial space stations will help establish a low-Earth orbit economy?

A: We should let the commercial sector let their imaginations run wild for what they can use orbital space for, whether it's filming the next "Mission Impossible" movie with Tom Cruise up there or building a pharmaceutical materials or manufacturing facility. They should explore hotels, they should explore every commercial option that can make a profit and try to make those facilities self-supporting, and then just let NASA be a tenant. Let the government go and explore with its partners the edges of deep space rather than be stuck operating a facility that's perhaps after 30 years run its course.

Q: Are you interested in visiting one of these stations someday?

A: Of course, yes! Tourism is going to be an element of what we do in low-Earth orbit, and these private companies with the transports that they have now have the means of getting tourists to a venue. I think we're going to very soon see very modest but capable space stations that can host people for a couple of weeks at a time, getting the chance to explore the weightless environment. That'll be a start in one direction, and then other low-Earth orbit facilities will be used for research or for manufacturing. I hope that's going to raise enough money in the private sector that we just keep our economic activity and space growing and growing. It's a very bright future, and the more people that can go and experience a space environment and do useful work up there, the greater the support will be for the frontier and pioneering activities out by the moon and the asteroids and eventually leading to human visits to Mars. We need that wider exposure and access to space to enable humans to become the multiplanet species that we ultimately have to become.

Q: You mentioned that the public has to accept there will be failures with Artemis. When there are failures in LEO, do you think the commercial world will prove as resilient as the government world has been?

A: I think so. Take commercial airlines. When there's a fatal accident in the commercial aviation sector, you don't stop flying people around the country. You just see a shakeout in the way the industry is structured. And so you might see space companies go out of business if they can't maintain a safety record, or the fact that the accident occurred throws a bad light on the company and they may not be able to compete anymore. But the basic mission and ambition of the industry is going to continue. I think we'll cope with fatal accidents, but certainly any company knows that they've got to protect their customers and their guests that are flying on their spacecraft if they hope to have a long-term future.

Q: Do you believe this is a pivotal moment in the history of U.S. spaceflight?

A: I think this decade is very key. It's time to commit to returning humans to the moon and to have them in deep space in general; it's time to get out of low-Earth orbit and start pioneering again. It's in the national interest that we have an international partnership that attempts to take our model for the space station and moves it out to a lunar outpost and taps the resources of the moon, and then the nearby asteroids after that, to expand our economy into space. If we give up on that now, I think you're going to see the U.S. and the West drop back into a subsidiary role, while other countries set a higher and more ambitious agenda for themselves and thus control the economic model that we use in space. I would like to see us be the leaders in that process rather than just follow somebody else by virtue of our not having that ambition anymore. ★