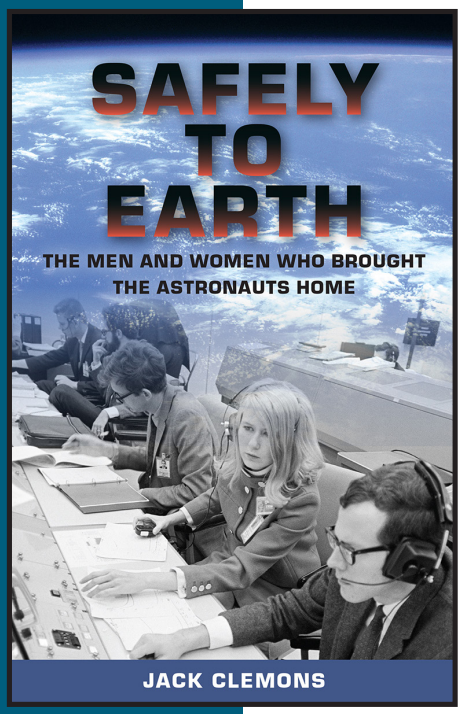
WHAT PEOPLE ARE SAYING



"The details Clemons provides are what make the book so memorable.... The main story is economically and briskly told, bolstered by a thoughtful, helpful appendix, as well as a collection of direct questions ('Did Apollo 10 Almost Crash into the Moon?') and frank answers."

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WHAT PEOPLE ARE SAYING

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—John Aaron, former flight controller and project manager, Apollo and Space Shuttle programs

SAFELY TO EARTH

The Men and Women Who Brought the Astronauts Home

JACK CLEMONS

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Credit: Angie Moon

JACK CLEMONS

is a professional writer and consultant as well as a speaker and presenter on NASA's space programs. Earlier in his career he was an engineering team leader on NASA's Apollo Program and senior engineering software manager on the Space Shuttle Program in Houston, Texas. He has also held the role of Senior Vice President of Engineering for Lockheed Martin. He has bachelor's and master's degrees in aerospace engineering from the University of Florida. His works of fiction have earned him an Established Artist Fellowship Grant for Literary Fiction by the Delaware Division of the Arts and membership in the Science Fiction and Fantasy Writers of America.

Jack Clemons

is available for interviews and appearances

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Q&A

with

JACK CLEMONS

author of

Safely to Earth

What first made you interested in space exploration?

I have been stirred by science fiction stories of humans traveling to the stars since my early teens. My brother-in-law was a skilled amateur astronomer who pointed out the constellations and the Milky Way. He shared his telescope so I could discover the wonders of the Moon and planets closer up. Still, traveling into space seemed like science fiction until 1957 when the Russians launched Sputnik, the first satellite to orbit the Earth. That's when I realized it might happen.

What is the biggest misconception people have about your job as an aerospace engineer?

People often ask me if I was a science nerd growing up. Not really; I never set off small rockets in my backyard or played with chemistry kits. It wasn't until my sophomore year in college, when John F. Kennedy gave his "We choose to go to the Moon" speech, that I turned my studies, and later my career, to join the team who made human space flight possible.

What were some of the biggest technological advances you witnessed over the course of your career?

The biggest single technical advance I witnessed was the change within a

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dozen years from considering space travel a science fiction dream, to being a member of the team who supported Neil Armstrong's one small step onto the Moon. Beyond that, it was the incredible speed at which computing technology evolved—from using slide rules on Apollo to building highly advanced flight software programs for Space Shuttle.

You left the field after working on procedures and software for the Apollo and Space Shuttle programs for 16 years. Were you ever tempted to return?

I was honored to have the chance to be part of both the Apollo and Space Shuttle programs, and extremely proud to have had a role in making them successful. But by 1984, with the Apollo Program over and the twelfth launch of the Space Shuttle completed, I felt it was time to move on. I'm not by nature one to live in the past; I always feel the urge to try something new. I loved those programs and that challenging work, but I haven't wanted to return.

What was the proudest moment of your career?

I've played a role in supporting both Apollo 11 and Apollo 13, and I was part of the team that made the Space Shuttle fly. It was not one individual, but a team of dedicated and resourceful people who made those programs a success. I am proudest of getting to work beside the most outstanding men and women professionals I've encountered in my career.

You are the author of several science fiction stories and novels. Did your work for the Apollo or Space Shuttle programs inform any of these works?

For the most part, my later science fiction wasn't informed by either my Apollo or Space Shuttle experiences. I went back to my passion for writing in 1984 when my days on the space program had ended, and as I said, I felt it was time to move on. My first published story was about a time traveler who returns to the Lincoln assassination. A later story was about a blue-collar space crew mining an asteroid, for which I called on my collegiate studies of orbital science, so there was some connection. It wasn't until my agent convinced me to recount my experiences on Apollo and Space Shuttle that I returned to those programs with this book. Fortunately, I had kept profuse and detailed notes during my time working on them.

Do you have any advice for those considering careers in aerospace engineering or other space-related fields?

Although NASA's human space flight program is suffering from uneven Congressional funding at the moment, NASA's unmanned robotic exploratory space programs are alive and well, and planning exciting things—from exploring the Moon and outer planets, to launching deep space telescopes, to rendezvousing with asteroids that pass close to Earth. And private industries such as SpaceX, Virgin Galactic, Boeing, Lockheed Martin, and Orbital ATK are filling the void in near-Earth orbit travel that NASA has moved beyond. There are many opportunities in the U.S. and abroad requiring the skills and credentials of aerospace professionals, and fewer people available with the qualifications to fill them. If aerospace is your passion, embrace it—we are on the threshold of a new and exciting era of space flight.

Are you in favor of the private space companies you mention, such as SpaceX?

I'm very much in favor of SpaceX and other companies traveling into space. NASA's role was to develop the new and untested technologies required to put humans into orbit around the Earth. This is what government-funded exploration is about, and must be. No private enterprise would have had the expertise, the financial resources, or the business motivation to undertake the task. Now that NASA has made that investment of resources and people, and the technology has been thoroughly tested and proven, the future of near-Earth human space flight is, as it should be, in the hands of private industry. NASA should focus on the next great challenges: returning to the Moon, putting humans on Mars, and detecting and deflecting asteroids that threaten Earth.

Do you think NASA can ever recapture the glory days of the Apollo program?

I hope so. NASA has ambitious plans to send humans back to the Moon and on to Mars. The biggest drawback to success is a severe lack of adequate funding, and lukewarm support from Congress, the President, and the general public. One would hope that, in time, common sense and sound engineering will prevail. I believe such a plan successfully carried out with international cooperation and involvement could rally public interest and support to the levels of Apollo's "Golden Age."

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What, in your opinion, was the most positive impact that "Golden Age" had on the world as a whole?

The Space Race of the sixties was justified by pointing to our ongoing Cold War threat from the Soviet Union, but in the larger view it enabled the first human beings in history to leave our planet and set foot on another world. Since that time we've been to the Moon and back nine times and walked and drove on its surface. We've launched a fleet of winged spaceships and used them to build an orbiting multinational space station. We've turned over the business of near-Earth travel to private industry. The space program has often broken through political divisiveness to unite us in common cause and pride. And perhaps most important of all, the space program has given the human race an option for long term survival. As President Kennedy said at the outset about the challenge of going to the Moon, "That goal will serve to organize and measure the best of our energies and skills." I believe it did.

What can readers who may already be familiar with the Apollo and Space Shuttle stories hope to discover in *Safely to Earth*?

There have been a number of books written about, and by, Apollo and Space Shuttle astronauts and the specialists in NASA Mission Control who supported them. *Safely to Earth* is unique in its coverage of both the Apollo and Space Shuttle Programs; it discusses the corresponding transition of technologies and human skills required to move from one program to the other successfully. Readers are taken even further behind the scenes than in other books, by someone who was there and who worked side by side with amazing yet unsung professionals. I recount the stories of some of the many unheralded men and women who supported NASA's heroes—of the inventive and resourceful work they did to ensure the missions were successful and to return the astronauts safely.

What are you working on next?

I'm writing on a non-fiction book for the University Press of Florida about the potential threat of an asteroid impact on Earth and what we can do about it. I'm also finishing up two novels; one science fiction and the other historical fiction.

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4

LIFTOFF MISSION ONE

CATCHING APOLLO

Clear Lake City: The Cow Pasture Space Center

The division of the TRW Systems Group that hired me was located about twenty-five miles southeast of Houston, Texas. TRW's offices were literally across the street from NASA's Manned Spacecraft Center in Clear Lake City, a newly built community that encircled NASA's property. TRW Corporation has long since divested itself of aerospace interests, but in those days its Systems Group headquarters located in Redondo Beach, California, was a major player. The Houston location that hired me had won a contract with NASA's Mission Planning and Analysis Division to provide support for all phases of the Apollo flights. In practice we were to do a lot of the engineering grunt work preparing NASA for each mission, and also support the NASA staff during the flights.

I started work on October 14, 1968, three days after the first launch of an Apollo spacecraft with humans on board. I was introduced to my new manager, Bob Manders, an aerospace engineer who'd been working there since 1966; was assigned a desk and shown where the restrooms and cafeteria were located; and met my coworkers, while Wally

Apollo 7 Crew (*left to right*): Donn Eisele, Wally Schirra, and Walter Cunningham, 1968. NASA Image.

Schirra, Donn Eisele, and Walt Cunningham orbited overhead. The mission was designated Apollo 7, the first manned space flight of the Apollo Program, a chance for NASA to demonstrate all they'd learned from the Apollo 1 fire and to restart the manned program to meet their end-of-the-decade mission to the Moon.

Bob Manders was, in his words, an Iowa farm boy who ended up sending men to the Moon and getting them back safely. He'd graduated from Iowa State University and was hired by Douglas Aircraft Company's Missile and Space Systems Division in California to do launch and reentry studies of U.S. Air Force missiles. He also started working on a Master of Science degree in aerospace engineering from the University of Southern California. While he was still working on his degree, one of his USC professors, who also worked at the Space Technology Laboratories in Redondo Beach, offered Bob a job. The company, which would later become TRW Systems Group, had won a contract with NASA in

Houston to support the Apollo Program, and they needed engineers. Bob took the job, and his new boss asked him to go to Houston for three months to help define the Apollo reentry corridors. By the time I got there Bob's "temporary assignment" had turned into a much longer one. It would be many years before Bob got back to USC and finished his masters.

I also soon realized just how well my new assignment fit my dreams. At one point I was telling Bob about my interest in science fiction and he revealed that he was a member of the Science Fiction Book Club, which was, and still is, a monthly subscription for SF books. Bob said if I joined on a trial basis through him, he could get a free book. Later I did, and that marked the beginning of my rediscovery of science fiction as an adult.

When Barbara and I arrived in Clear Lake City, it was far from the bustling, hi-tech, fashionable suburb it later became. It was a hot, humid, godforsaken place. When she and I drove around during our first week, exploring neighborhoods searching for someplace affordable to rent, the temperature soared into the nineties every day and the humidity was right up there with it. It was mid-October!

A well-worn bromide passed around by Texas locals, as in several other southern states, assures newcomers that they'll get used to that sort of weather as soon as their blood "thins," whatever that means. If so, my blood must be especially thick. In the sixteen years that I lived in that sweltering crock pot, I never got used to having my glasses fog up when I stepped out of my car in the morning, or having my shirt sweat-pasted to my back by the time I'd crossed the parking lot. There may be advantages to living in that southeast Texas climate, but thinning your blood isn't one of them. Yet, in spite of the stifling heat and humidity, I stayed in Houston for sixteen years for one reason, because that's where NASA was.

The Manned Spacecraft Center had been built four years earlier on a thousand acres of undeveloped pasture located about twenty-five miles southeast of downtown Houston, in the middle of nowhere. That cattle grazing ground was not on the original short list of nine locations chosen by NASA's site selection team to meet a detailed set of criteria established by Congress (access to water transport, a major airport nearby,

moderate climate, etc.). Tampa and Jacksonville, Florida, were, as were San Diego and San Francisco, California. Sigh.

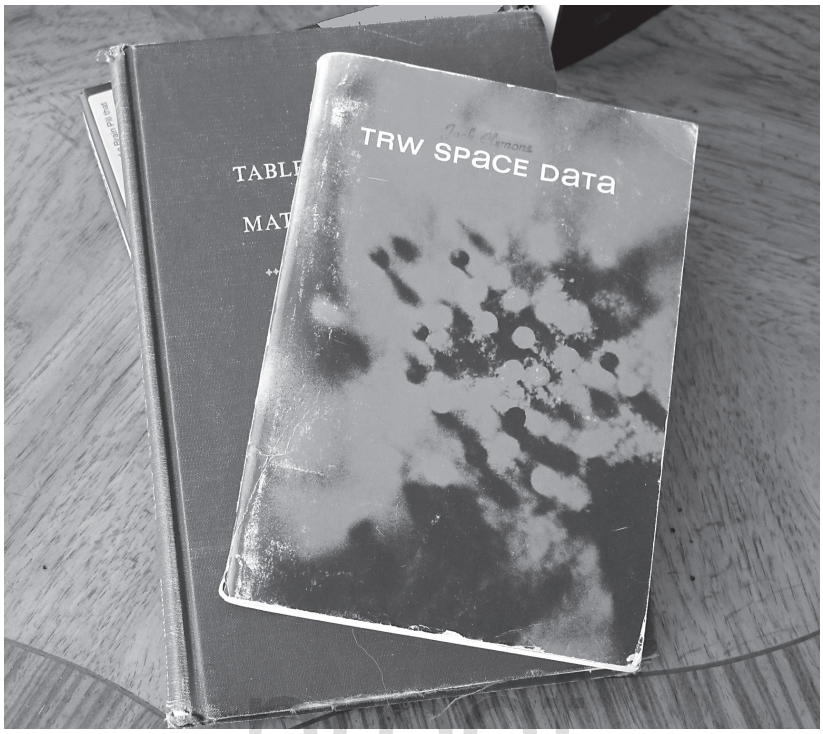
For some reason the selection committee reconsidered its list, and this time the Clear Lake cow pasture was added. Possibly the reason was that a Texan, Vice President Lyndon Johnson, was head of President Kennedy's Space Council, and Texas' Congressman Sam Rayburn was Speaker of the House, and three other Texas congressmen directly controlled NASA funding, and Rice University had agreed to donate the land (which had been donated to them by Humble Oil Company of Houston). But "moderate climate"? Seriously?

NASA referred to the Manned Spacecraft Center as the Houston Space Center throughout the Apollo Program, though the area wasn't swept up into the city limits until 1980. I suppose the name Cow Pasture Space Center wouldn't have sounded very "space age." In 1973 the NASA facility was renamed the Johnson Space Center.

The 1,600-Mile Roller Coaster

And what, exactly, was my new job? I mentioned earlier, my education and GE work experiences were about using mathematics to predict how high-speed spacecraft, or Air Force missiles, would behave when they came roaring back from outer space and plunged into the Earth's atmosphere. That's what Apollo did when it came back from the Moon, except that the Apollo Command Module (the only part of the Apollo spacecraft that actually made it back to Earth), was shaped like an oversized Hershey's Kiss, with the astronauts cramped three abreast into a workspace smaller than the inside of a car and chockablock with equipment. Not quite the sleek, needle-nosed spaceships from my college courses. Another complication was that the Command Module entered Earth's atmosphere fat side first, giving it all the "flight aerodynamics" of a Stonehenge pillar.

My job was to work on a plan for the so-called reentry phase of the mission—the part that starts when the Command Module first reaches the topmost edge of Earth's air and ends when it drops into the ocean—but what was there to plan? Couldn't it belly flop into the atmosphere, which would certainly slow it down, and then descend on

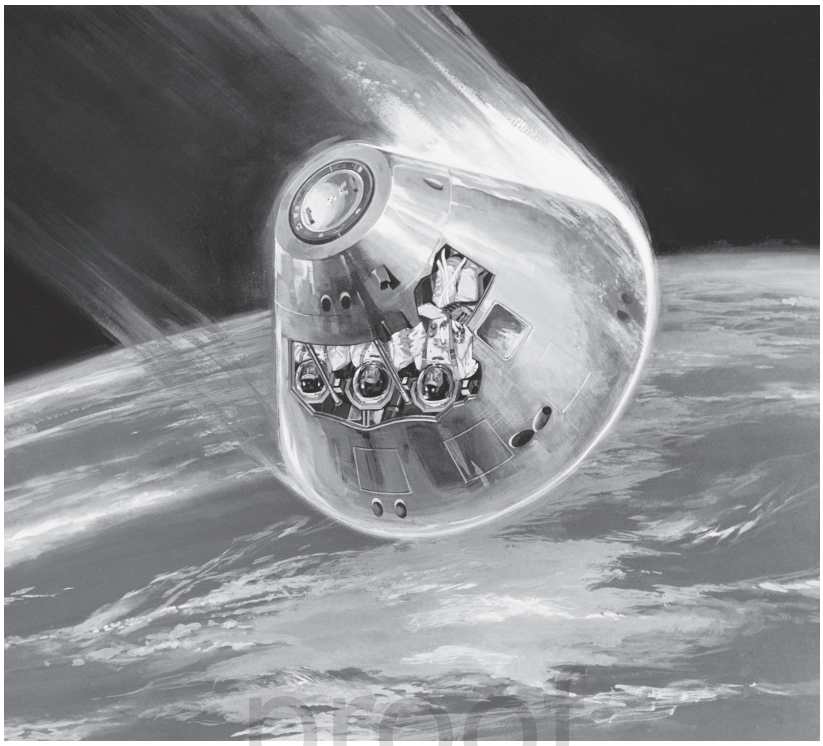


The reference manuals I used to calculate the Apollo reentry paths.

its parachutes until it splashed into the ocean? The short answer is: it wasn't that simple.

First of all, Apollo couldn't splash down just anywhere; it had to make its way across the Pacific Ocean to the U.S. Navy aircraft carrier waiting to pick up the crew. The 12,000-pound flat-bottomed teardrop had to learn how to "fly" to its destination. After leaving the Moon, the Apollo spacecraft fell home "downhill," covering a quarter of a million miles in three days, gaining speed the whole way. By the time it entered the Earth's atmosphere it was traveling at about 25,000 miles per hour, ten times as fast as a modern rifle bullet. At that speed even a boulder can fly.

Let me give you an example. The next time you're cruising in your car at, say, 40 mph, try this experiment, from the passenger seat, of course. Lower the window and put out your hand, palm flat, fingers together, and pointed at the sky but tilted forward a little. The wind's



Atmospheric heat buildup during an Apollo Command Module reentry. NASA Illustration.

force will jerk your arm upward. Rotate your hand 90 degrees and it'll kick to the side. (Watch out for drivers in the oncoming lane who may not be as interested in science.) Rotate your palm down and your arm will dive toward the road. You get the idea. That's how the Command Module flew. It was designed with its weight a bit off-center, so that when it came back into the atmosphere the flat side would tilt about 20 degrees into the direction of the wind, if that's the right word for the air coming at you at 30 times the speed of sound (a velocity that aerodynamics folks call a Mach number of 30).

Evenly spaced around the tilted wide end of the spacecraft was a set of small rockets that faced crosswind. Short bursts from these jets caused the Command Module to roll on its long axis, much as your arm might twist if you rotated your palm outside the window. If the spacecraft isn't slowing down quickly enough, the jets fire to rotate the

tilt downward and push the Command Module deeper into the atmosphere. Slowing down too quickly? Rotate up again and loft like a stone skipping over a pond. Need to get centered on a path to the recovery ship? Rotate partway to the left or right and move sideways. An Apollo reentry was a fifteen-minute, 1,600-mile, high g-force, gyrating roller coaster ride: not for the faint of heart. Part of my job was to help teach the astronauts to fly the Command Module, which takes me back to the bigger picture.

The complete Apollo spacecraft system was a complicated and many-faceted machine. Its Command Module (CM) housed the astronauts and served as their command center during a mission. The Service Module (SM) was unmanned and provided power, water, and oxygen to the Command Module and also contained a rocket-based propulsion system. The Lunar Module (LM) was a fully autonomous powered spacecraft designed solely to ferry two astronauts to the Moon's surface and return them to lunar orbit for rendezvous with the Command Module once the surface exploration phase was complete.

At liftoff, these three modules rested atop a massive Saturn V rocket capable of generating 7.6 million pounds of thrust. No element of that Apollo system was intended to be reused. As a mission progressed, its components were sequentially discarded into the ocean, or into space, or abandoned on the lunar surface. The total launch weight of the assembly was more than six million pounds, but only the 12,000-pound Command Module returned to Earth. It splashed down in the ocean and was recovered, but it was not reused.

The Command Module had a small computer onboard to perform a variety of tasks, including automatically controlling the reentry flight. It was an autopilot designed to guide the craft on a sinuous, high-speed trajectory to a safe ocean splashdown. Both the computer itself and the programs that ran on it were newly developed for the Apollo Program. No previous craft of any description had been called upon to make such a "flight." With an excess of caution that characterized the NASA culture after the Apollo 1 fire, each phase of an Apollo mission required a backup plan—an alternative means for the astronauts to complete that segment using only redundant instruments and manual controls; in other words, independent of the autopilot.