APOLLO 11: 50TH ANNIVERSARY SPECIAL EDITION

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ONE GIANT LEAP

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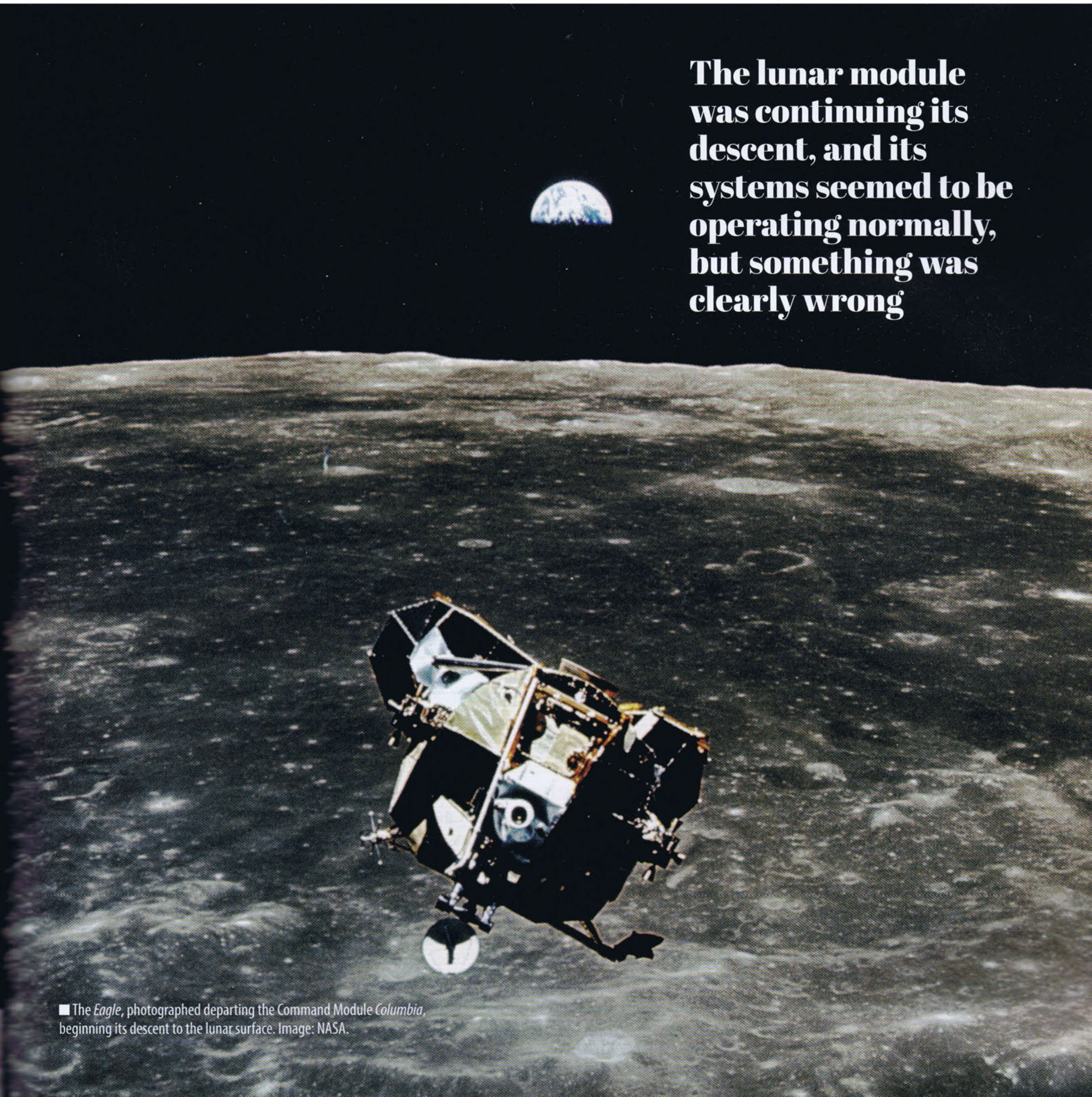
THE STORY APOLLO 11'S DRAMA-FILLED DESCENT

The first steps on the Moon will likely be remembered for all of human history, but the events of the landing that led up to that 'giant leap' will stay long in the memory too, writes **William Harwood.**

> **The lunar module was continuing its descent, and its systems seemed to be operating normally, but something was clearly wrong**



■ The *Eagle*, photographed departing the Command Module *Columbia*, beginning its descent to the lunar surface. Image: NASA.

■ Steve Bales, sitting at his console in mission control about a month before the launch of Apollo 11. Image: Stephen Bales.

The Apollo 11 astronauts were three minutes into their descent to the Moon when 26-year-old Steve Bales, the guidance officer in mission control, suddenly saw a computer alarm code – 1201 – from the lander. He had never seen a code like that during previous training runs and he had no idea what it meant. Neither did the crew aboard the descending lunar module.

Quickly referring to a software glossary for the lander's guidance computer, Bales saw the 1201 alarm indicated 'executive overflow' and 'no vacant areas'. Clearly, something was overloading the computer, preventing it from completing all of its planned computations in a given cycle, but what wasn't getting done, and was it mission critical?

In his book *Failure Is Not An Option*, Apollo 11 descent Flight Director Gene Kranz described the critical moments that followed. After more alarms popped up in quick succession, Bales called Jack Garman, a 24-year-old lunar module software expert in a nearby support room.

"Jack, what the hell is going on with those program alarms? Do you see anything wrong?" Bales asked. Garman replied, "It's a bailout alarm. The computer is busier than hell for some reason, it has run out of time to get all the work done."

Meanwhile, the lunar module was continuing its descent, and its systems seemed to be operating normally, but something was clearly wrong and there were no flight rules defining a procedure to correct the problem. After still more alarms, Bales, seated on the right end of a string of consoles known as 'The Trench', reached a decision.

"Flight, Guidance," he called over his headset to Kranz. "I've got a bunch of computer alarms. Abort the landing... abort!"

Astronaut Charlie Duke, the capsule communicator, or CAPCOM, who was responsible for relaying comments and instructions to the crew, turned to Kranz, asking "[are] we going to call an abort, Flight?" Kranz sharply replied, "Abort, CAPCOM, abort." Duke relayed the instructions and the crew executed an abort, cutting away the descent stage, igniting the ascent stage engine and blasting back into orbit.

So ended the final flight simulation before the launch of Apollo 11. It was 5 July 1969, just 11 days before launch of the first mission to send astronauts to the surface of the Moon.

Kranz was furious. He wanted to end the final simulation with a successful landing, an upbeat note leading into NASA's ultimate flight. "Damnit, we should have finished our training with a landing on the surface," he wrote in his book.

The cheat sheet

It turned out that the aborted landing was a godsend. Richard Koos, the simulation supervisor who added the computer alarms to the final test run, said the alarms in question were not mission critical. In fact, the lunar module was operating smoothly and only lower-priority items were failing to execute from time to time, triggering the alarms. Continuing with the descent was a much safer option than a low-altitude abort.

Bales, now 76 and long retired from NASA, recalls the simulation like it was yesterday.

"After the sim, we all unplugged, [and] Gene asked me come up to 'console'," says Bales in an interview from his home near Philadelphia. "He

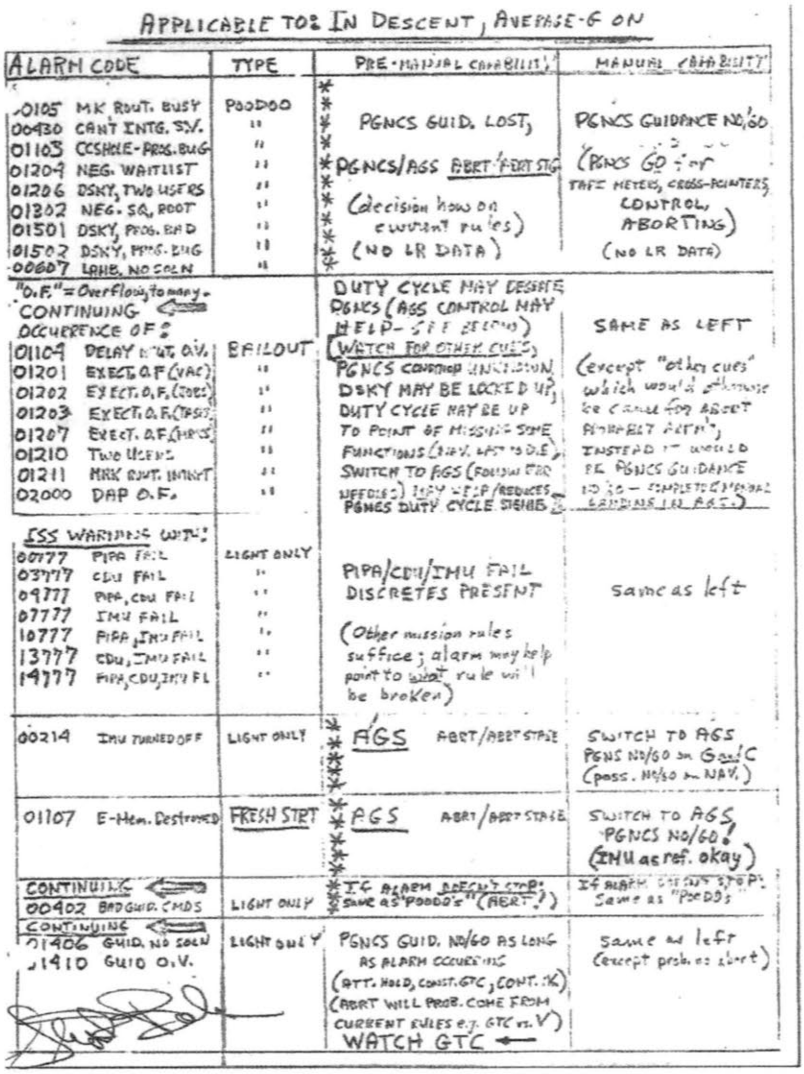
Coming into work that morning, Bales immediately noticed that you could cut the tension in mission control with a knife

said, 'I want you to go and add these [computer alarms] to your rules'. We didn't have any rules about them. I said Gene, I've got a gazillion things to do, I listed off two or three things, and he said 'I don't care what you say, get it done'."

Bales called Garman and asked him to consult with the Massachusetts Institute of Technology (MIT) engineers who developed the lunar module's software and come up with a 'cheat sheet' defining what needed to be done in response to various alarm codes.

A week later, Garman presented a list of codes and responses, written by hand on a single sheet of paper. Bales taped it to his flight console in the mission control centre. He did not think it would ever be needed.

"There were not that many that we could do anything about," he says. "Some of them, if they came up the computer was gonna stop. You're done. But there were several, 1210, 1201, 1202, maybe one of two others, [where] you had to make a choice [on whether to proceed with the landing]. So I said okay, and off we went."



APPLICABLE TO: IN DESCENT, AVERAGE-G ON

ALARM CODE	TYPE	PRE-MANUAL CAPABILITY	MANUAL CAPABILITY
0105 MK ROUT. BUSY 00430 CAN'T INTG. SV. 01103 CCSHOLE-PROG. BUG 01204 NEG. WAITLIST 01206 DSKY, TWO USERS 01302 NEG. SQ. ROOT 01501 DSKY, PROG. BAD 01502 DSKY, PROG. BUG 00607 LAHB. NO SOLN	POODOO	PGNCS GUID. LOST, PGNCS/AGS ABRT/ABRT STG (decision how on current rules) (NO LR DATA)	PGNCS GUIDANCE NO/GO (PGNCS GO for TAPE METERS, CROSS-POINTERS, CONTROL, ABORTING) (NO LR DATA)
"O.F." = Overflow, to many. CONTINUING OCCURRENCE OF: 01109 DELAY ROUT. O.V. 01201 EXEC. O.F. (VAC) 01202 EXECT. O.F. (JOBS) 01203 EXECT. O.F. (TASKS) 01207 EXECT. O.F. [illegible] 01210 TWO USERS 01211 MRK ROUT. INTRPT 02000 DAP O.F.	BAILOUT	DUTY CYCLE MAY DEGRADE PGNCS (AGS CONTROL MAY HELP – SEE BELOW) (WATCH FOR OTHER CUES) PGNCS CONTROL [illegible] DSKY MAY BE LOCKED UP, DUTY CYCLE MAY BE UP TO POINT OF MISSING SOME FUNCTIONS [illegible] SWITCH TO AGS (FOLLOW [illegible]) MAY HELP/REDUCES PGNCS DUTY CYCLE [illegible]	SAME AS LEFT (except "other cues" which would otherwise be cause for ABORT probably [illegible]; INSTEAD IT WOULD BE PGNCS GUIDANCE NO GO – COMPLETE MANUAL LANDING IN AGS.)
ISS WARNING WITH: 00777 PIPA FAIL 03777 CDU FAIL 04777 PIPA, CDU FAIL 07777 IMU FAIL 10777 PIPA, IMU FAIL 13777 CDU, IMU FAIL 14777 PIPA, CDU, IMU FL	LIGHT ONLY	PIPA/CDU/IMU FAIL DISCRETES PRESENT (Other mission rules suffice; alarm may help point to what rule will be broken)	same as left
00214 IMU TURNED OFF	LIGHT ONLY	AGS ABRT/ABRT STAGE	SWITCH TO AGS PGNS NO/GO on G&C (poss. NO/GO on NAV.)
01107 E-Mem. Destroyed	FRESH STRT	AGS ABRT/ABRT STAGE	SWITCH TO AGS PGNCS NO/GO! (IMU as ref. okay)
CONTINUING 00402 BAD GUID. CMDS	LIGHT ONLY	IF ALARM DOESN'T STOP: SAME AS "POODOO's" (ABRT!)	IF ALARM DOESN'T STOP: Same as "POODOO's"
CONTINUING 01406 GUID. NO SOLN 01410 GUID O.V.	LIGHT ONLY	PGNCS GUID. NO/GO AS LONG AS ALARM OCCURRING (ATT. HOLD, CONST. GTC, CONT. OK) (ABRT WILL PROB. COME FROM CURRENT RULES e.g. GTC vs. V) WATCH GTC ←	same as left (except prob. no abort)

▲ The 'cheat sheet' of alarm notes that MIT computer experts and Jack Garman prepared for Steve Bales following the final, aborted, simulation of Apollo 11. Image: Jack Garman.

The descent

Apollo 11 finally got underway at 1.32pm GMT on 16 July 1969.

Strapped into the Apollo command module *Columbia* atop their huge Saturn 5 rocket, mission commander Neil Armstrong, lunar module pilot Buzz Aldrin and command module pilot Mike Collins shot smoothly into Earth orbit. Two hours and 50 minutes later, after checking out the spacecraft's myriad systems, flight controllers at NASA's Manned Spacecraft Center (now the Johnson Space Center) in Houston cleared the crew to restart the third-stage engine and head for the Moon.

Three days later, at 5.21pm GMT on Saturday 19 July, the astronauts braked into orbit around the Moon. The next day, Armstrong and Aldrin bid Collins farewell, entered the lunar lander *Eagle* and undocked during the crew's thirteenth lunar orbit.

Coming into work that Saturday morning, Bales immediately noticed a change in the atmosphere of the mission control center. "You could cut that tension with a knife," he says.

Making one more loop around the far-side of the Moon, Armstrong and Aldrin began their descent towards a target altitude of 15.2 kilometres (50,000 feet) above the lunar surface. At that point, the crew would fire the lunar module's main engine – powered descent initiation, or PDI – to begin the 12-minute plunge to the targeted landing zone in the Sea of Tranquillity.

During that last pass behind the Moon, with the lander out of contact with mission control for about half an hour, flight controllers took a final break. Kranz gave an impromptu, now legendary, speech on an unrecorded audio channel accessible only to his 'White Team' flight controllers.

"I remember this so clearly," Bales recalls. "He said, 'however we walk out of this room, whatever happens, we're walking out as a team. I'm taking responsibility, you may have been part of the mess up, [but] however we get out of here we're going out as a team, we're not pointing fingers at anybody'. And that was an incredible plus. The leader says I'm with you, and it's my responsibility whatever you guys do. That was incredible... I remember that clearer than the landing."

The *Eagle* swung back into contact with Earth at 7:49pm GMT.

During the next 13 minutes – the time it would take the lander to reach 50,000 feet – the flight control team had to verify the spacecraft's trajectory, velocity and general health. Right away, there were problems.

"So we come around the hill, and we don't know anything's going wrong at all, [and] neither does the crew," says Bales. "But the comm(unication) was so bad, if you were listening to that comm you'd have wondered

■ The scene in mission control as Neil Armstrong climbed down the ladder of the *Eagle* to take his first famous steps onto the Moon. Image: NASA.

whether we were going to be able to go on or not. That was Gene's call, and boy, it was dicey."

As it turns out, a shield that was added near the nozzle of a manoeuvring thruster was partially blocking the radio signal. Don Puddy, a flight controller monitoring communications, asked the crew to turn the lander slightly "and comm came back," says Bales. "So Gene tells them, you're 'GO' for powered descent, the crew keys in the program, [and] everything's looking great."

Dropping faster

However, voice communications and telemetry were still intermittent, "and just before we turned that engine on everything dropped out and we had no filter data, we had no telemetry data, we had no voice data, we just had a bunch of noise," says Bales.

Two minutes later, telemetry resumed and Bales quickly saw a guidance issue.

"The vehicle was going toward the Moon 20 feet [six metres] per second faster than it should have been," he says. That mismatch could be have been caused by an external force that had acted on the lander that was not taken into account, or it could have been trouble with the inertial guidance system, or it could have been a problem with the spacecraft's accelerometers.

The powered descent phase of flight was designed so that the crew could carry out an emergency abort at any point during the trip down to the surface, but only if the descent rate was within 35 feet (10.6 metres) per second of the planned velocity. *Eagle* was more than halfway to that limit.

"So I'm sitting there praying," Bales says. "If you listen to the tapes, somewhere I say, 'Gene, that's downrange, we're going to make it, I think'. You're not supposed to say 'I think', but I said it anyway. He knew that we were two-thirds of the way to the abort limit, but [the descent rate] held constant, it held and held and held."

Bales began to relax a bit. Aboard *Eagle*, Armstrong and Aldrin, who had been facing the surface to track landmarks, yawed the lander to help its radar lock onto the ground.

"And we said this is great, because we could see that the radar said they were off about 3,000 feet [~900 metres] in altitude, [which is] exactly what we saw, 20 feet per second in altitude rate," says Bales. Using the radar data, the computer could correct for the higher-than-expected rate of descent, and it did just that.

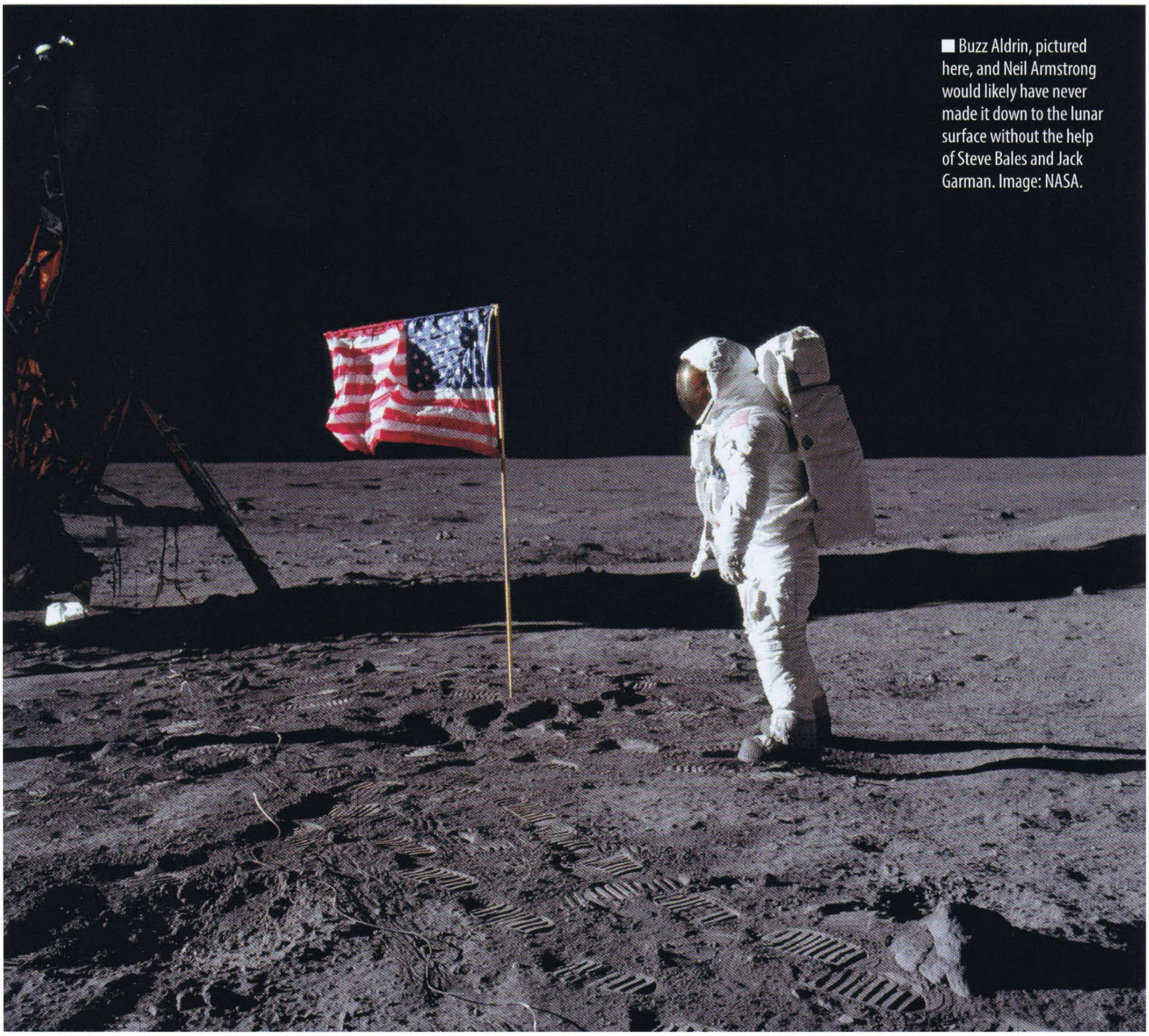
The lander would still miss its planned touchdown target by about 6.5 kilometres (four miles), "but it was going to correct for the altitude rate so that they wouldn't be getting big problems when they got down lower. It was going to fix the altitude and altitude rate, it could not fix the downrange [i.e. the planned touchdown target]."

In other words, so far, so good.

Alarm

Around this time, just over seven minutes to touchdown, Aldrin entered commands for the guidance computer to calculate the difference between the radar readings and the computer's predicted altitude. That was necessary to give the crew situational awareness in case of problems that prevented communications with mission control.

Aldrin entered the command, "and wham, he says we just got an alarm, 1202," Bales says. Because



■ Buzz Aldrin, pictured here, and Neil Armstrong would likely have never made it down to the lunar surface without the help of Steve Bales and Jack Garman. Image: NASA.

it takes telemetry a few seconds to reach Earth, get processed and displayed in mission control, "I think it was about a three- to four-second delay before we even saw it."

Bales and Garman immediately thought of the 5 July landing simulation. So did Kranz and Duke.

The 1202 alarm "tells us the computer is behind in its work," Kranz wrote. "If the alarms continue, the guidance, navigation and crew display updates will become unreliable. If the alarms are sustained, the computer could grind to a halt, possibly aborting the mission. Each alarm must be accounted for. They have the capacity to create doubt and distraction, two of a pilot's deadliest enemies."

An unanswered question was the definition of 'sustained'; that is, how rapidly did the alarms have to recur to trigger an abort? That was a judgement call, and it was up to Bales to make that decision.

A few seconds went by. Suddenly, Armstrong, who was doing the actual flying, came on the audio loop and ratchets up the tension, saying, "give us a reading on that 1202 program alarm." His tone of voice left no doubt he expected a quick response.

It was Bales' responsibility: the fate of the Moon landing was on his shoulders at that moment

"I'm frantically trying to remember where my little cue card is and Jack, thank God, is telling me, 'Steve, Steve, we're 'GO' unless it keeps reoccurring'. I said Jack, I trust you. And I say, Flight, we're go on the alarm. Now, it had been 20 seconds, maybe? Perhaps longer. It was an eternity in the control room."

It was more like 31 seconds and in the world of flight operations, that's as close to eternity as any controller would ever want to get. CAPCOM Charlie Duke knows that as well as Bales.

"When Neil says 'give us a reading', Charlie knew he'd best do something quick," says Bales. "And so the only time in the descent, the only time ever I heard him do so, I said we're 'GO' and he didn't even wait for Gene. If you listen to the audio loops, he's telling the crew before Gene even tells him it's okay, and that's usually a no-no.

"But if he hadn't done that, I think we wouldn't have made it, I think the crew would have bailed out. I really do. We'll never know, but Charlie saved the mission by doing that. I think he saved it right then and there."

But it was Bales' responsibility. The fate of the Moon landing was on his shoulders at that moment – not on Kranz, or Duke or even Garman, who Bales always credits for the guidance and expertise that ultimately helped win the day.

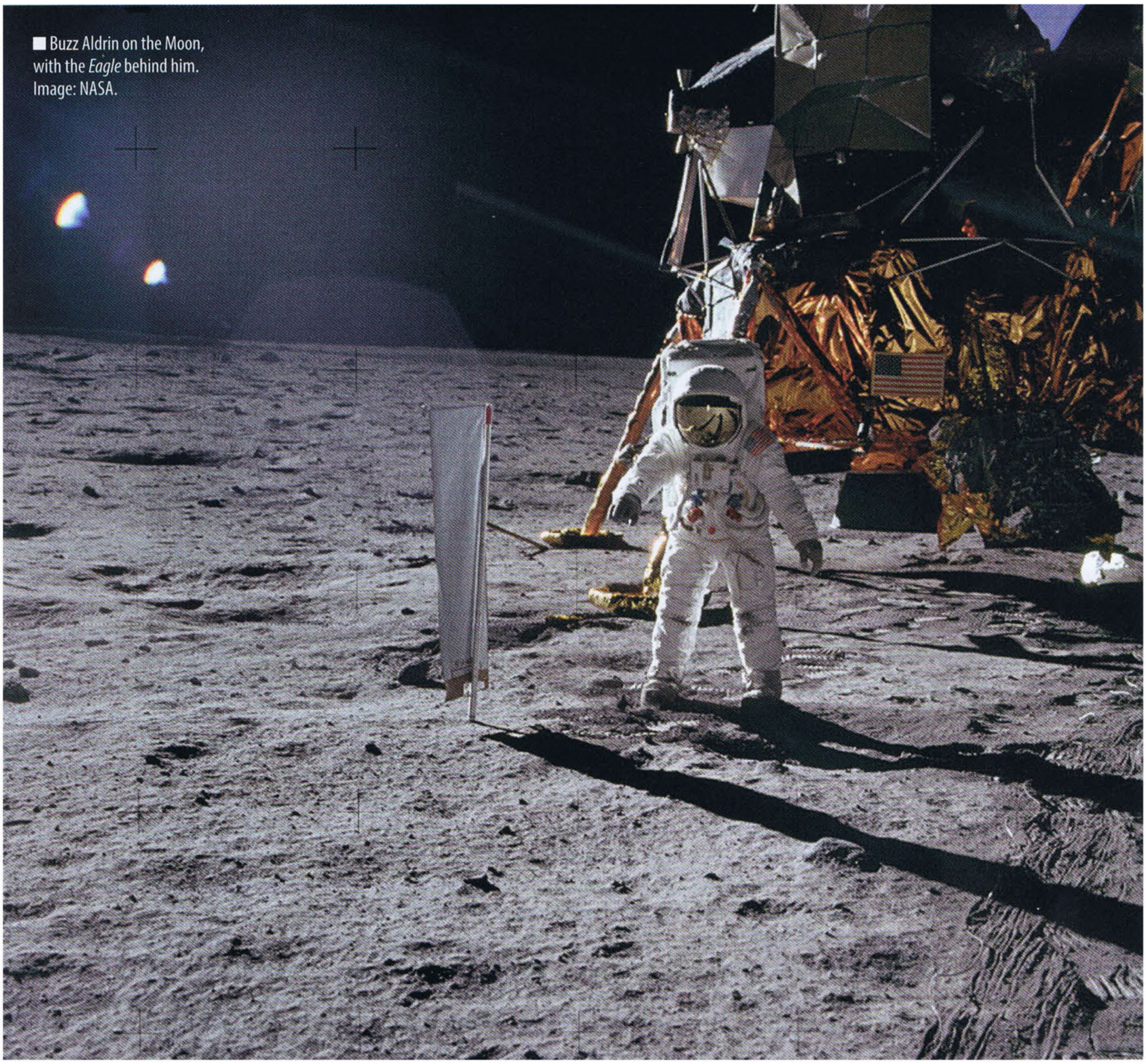
As the MIT computer experts would later explain, the guidance computer normally ran at about 83 per cent capacity during that phase of mission operations. Another 13 to 14 per cent was lost because of interference from a communications circuit between the computer and the lander's rendezvous radar. When Aldrin asked the computer to display the altitude data, "it was just enough to trip it over," says Bales. "And for at least one second, it didn't get everything done. That's when we got the 1202."

The final moments

The descent continued. Aldrin was told not to call up any additional displays and to rely on mission control for trajectory data. More program alarms cropped up, but they did not occur so close together that they violated the somewhat subjective definition of 'recurring'. Bales and Garman were 'GO' almost as soon as each alarm was called out.

"If it happened four or five times, say, in a 20-second period, that might have been enough [to trigger an abort]," says Bales. "The other judgement call is, is the computer managing to do what it's supposed to do? And I had that, because I had [computer data that I could] compare with the landing radar and they were both solid. So it was fine."

Because of the downrange error noted during the initial descent, *Eagle* was taking the crew to a boulder-strewn crater. Armstrong took over manual control. He halted the descent, hovered and then flew sideways in search of a smoother landing area. Nervous flight controllers could only watch their data and listen as Aldrin called down altitude, vertical and horizontal velocity in feet per second.



■ Buzz Aldrin on the Moon, with the *Eagle* behind him. Image: NASA.

After all the drama of the landing, planting a boot into the dirt on the surface of the Moon was the easy part. Image: NASA.

Following the landing, Steve Bales received a NASA Group Achievement Award, on behalf of the Moon landing team, from President Nixon, before becoming Deputy Director of Mission Operations at Johnson Space Center. Image: NASA.

"Houston, Tranquillity Base here. The *Eagle* has landed"

As if the drama could get more intense, sloshing propellant uncovered a low-level fuel sensor indicating the tank would run dry in 60 seconds. And the lander was still well above the surface.

Aldrin: "100 feet, 3 1/2 down, 9 forward. 5 per cent. Okay. 75 feet. Looking good. Down a half, 6 forward.

Mission control: "60 seconds…"

Aldrin: "Lights on. Down 2 1/2. Forward. Forward. Good. 40 feet, down 2 1/2. Kicking up some dust. 30 feet, 2 1/2 down. Faint shadow. 4 forward. 4 forward. Drifting to the right a little. Okay. Down a half."

Mission control: "30 seconds…"

Armstrong: "Forward drift?"

Aldrin: "Yes. Okay. Contact light. Okay. Engine stop. ACA out of detent."

Armstrong: "Out of detent."

Aldrin: "Mode control: both auto. Descent engine command override: off. Engine arm: off. 413 is in."

Duke: "We copy you down, *Eagle*."

Armstrong: "Houston, Tranquillity Base here. The *Eagle* has landed."

Duke: "Roger, Tranquillity. We copy you on the ground. You got a bunch of guys about to turn blue. We're breathing again. Thanks a lot."

History made

Armstrong stepped onto the Moon's surface six hours and 39 minutes after landing, taking a "giant leap for mankind." Aldrin followed suit a few minutes later and they spent two hours and 15 minutes collecting 22 kilograms of rocks and soil, deploying scientific instruments, erecting a US flag and taking a congratulatory phone call from President Richard Nixon.

Armstrong, Aldrin and Collins later received the Medal of Freedom from President Nixon, the highest honour the United States awards civilians. Nixon also gave the mission operations team a NASA group achievement award. The man the agency sent to accept the award? Steve Bales.

Bales would go on to serve as Deputy Director of Mission Operations at the Johnson Space Center before retiring to pursue business interests in the chemical industry.

Reflecting on the landing 50 years later, Bales says that he's "not sure 50 years later [whether] I really quite grasp it. I grasp it in a historical sense, it really gave a boost for the country when it really, really needed it. I don't know, I can't even put it into context now because I don't know how it will all turn out.

It may be a long time before we are able to go to those other places we want to go to. I hope not, but it may be. But when we finally do, it's going to be something that's incredible."

William Harwood is CBS News' Space Correspondent.