Transcription details:

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Transcribed From:	The Apollo Guidance Computer, Part Two: David Scott Computer History Museum Catalog Number: 102651598
Description:	Recorded: June 10, 1982 This is a two-part talk that chronicles the design of the Apollo Guidance Computer (AGC), the custom-made space borne navigation system that first guided men to the Moon in July of 1969. Part I covers the design of the AGC and features Apollo Guidance Computer lead designer Eldon Hall. Part II tells the AGC story from the astronaut's point of view, with Apollo 9 and 15 pilot commander David Scott. Part Two Astronaut David Scott recounts his time at MIT, the Naval test pilot school, and early experiences with the AGC as a part of the Apollo training program. He discusses the reliability of the system, the training and development process, as well as his time flying in the Gemini program with Neil Armstrong. Scott describes the use of the DSKY interface and its language. With two character 'words' acting as commands, the DSKY language used a verb-noun format, and Scott covers some of the specific two-digit words, as well as how they were used in-flight. He describes the methods for control and guidance, including decisions made to allow for astronaut control over 'fly-by-wire'. He outlines some of the early limitations of both the ACG and the landing module itself, as well as detailing the process of using the ACG to touch down on the lunar surface.
Notes:	Transcribed by Mark Omo

Transcription:

DAVID SCOTT: 00:11

I thought I would relate to you a little bit today, at Eldon's suggestion, some of the things that we did as users back in the old days and some of the problems we had, some of the challenges, and some of the fun that we had. I got my start in this business here at MIT as matter of fact or at MIT. I was a young pilot in the Air Force and always wanted to be a test pilot. And they told me the best way to do that was to get a graduate degree. So I looked around, and I'd heard about this school in Massachusetts and applied for it and was fortunate enough to be selected and started my matriculation under the team guided by Doc Draper. And I remember early on, there was a lecture one night given by a fellow from Germany named Wernher von Braun. And so a friend of mine and I went to listen to this, and he was talking about rocket ships. Now, I was an airplane driver, and I remember when they announced the first Mercury astronaut, so I thought, "Monkeys." [laughter] But anyway, we went to this lecture by Wernher von Braun. He had these pictures of these big rocket ships. And he said, "We're going to send men to the moon in these things." And I hit my buddy and said, "[laughter] This guy is really wild." But by gosh, sooner or later, I realized that Wernher's philosophy was correct. And by golly, we did all that. Matter of fact, he used to have another saying that he used, which I think is good philosophy and applies to about everybody, especially up here. He used to say, "If you want to be successful, you must early to bed, early to rise, work like hell, and advertise." [laughter]

DAVID SCOTT: 02:03

But I enjoyed my days at MIT. I think the hardest I ever had to work in my life, but it was interesting. And there's a story-- I live in California now. And in California, they think Caltech is the place to be. And there's a story about two students talking about the contributions of the two schools to exploration of space. And of course, at MIT and the lab, etc., they designed and developed the Apollo computer. And the MIT student was saying, "We helped get to the Moon and did all this work on the Apollo Guidance and Navigation System." And Caltech student says, "Well, yeah. But we're going to do better out here in California. We're going to design a system to go to the Sun." Of course, the MIT kid says, "You can't do that. It's too hot." And the Caltech student, not being outdone, says, "Yes, we can. We're going to go at night." [laughter] But you can't put one over on an MIT student. I'll guarantee you. The MIT student looked him right in the eye and says, "You can't do it in one night."

DAVID SCOTT: 03:20

And it brings us to the question, now that we've been to the Moon, which is more important, the Sun or the Moon? And we found out that, indeed, the Moon is more important because at night, the Moon shines and gives us a little light, whereas the Sun only shines in the daytime, and it's light anyway. [laughter] You've got to think about that. And then there's the one about the new president who takes office and doesn't have much experience with space exploration. And having realized that he has many, many problems upon initially taking an office such as that, one day the secretary of state, who's also new, walks in and says, "Mr. President, we have some dramatic news about space." The president says, "Oh, really?" The secretary says, "Yes, sir," he says, "But some of it's good, and some of it's bad." And the president says, "Oh, my goodness. Well, why don't you give me the bad news first. I'm used to it." And the secretary says, "Mr. President, we just learned that the Chinese have landed on the moon." The president says, "Oh, my goodness. What can be good about that?" The secretary looks at him and says, "All of them." [laughter]

DAVID SCOTT: 04:35

Anyway. One of the reasons we're able to do all that is because we had a terrific computer. And after I left MIT, I went out to the test pilot school and spent a couple of years there doing what I thought I really wanted to do until I realized that I got pretty interested while I was here in school in space as opposed to aeronautics. And about 1963, NASA advertised the selection of the third group of astronauts, and I thought, "Well, I really did enjoy the inertial guidance, other things I learned at MIT." And I thought I'd give that a crack. And I was selected in October of '63. And I went to NASA as a young captain at the time, fresh out of test pilot school and fresh out of MIT. And there were a total of 30 of us. And they looked around to see who could represent the astronaut office in various disciplines with some background. And of course, I was fortunate enough to have spent a couple of years up here working with people who ultimately built the Apollo Guidance System. And matter of fact, Dick Batten was my thesis advisor, and I think the first course I ever had at-- I even knew what inertial guidance was, Walt Wrigley taught. And Doc Draper was running the instrumentation lab where I did my thesis. So when I was offered the opportunity to follow for the crews guidance and navigation, I really jumped at that. And I started coming back up here to monitor that for NASA in Houston relative to the user.

DAVID SCOTT: 06:24 And being an astronaut, we helped in the design configuration from the user's viewpoint. It was quite an educational process because you have to understand what goes on inside to be able to assist in the design outside. And I spent many nights up on a roof in Cambridge looking at the stars and working with a sextant and a telescope and a computer. And it all looks pretty simple and straightforward now, and as a matter of fact, as I reflect back on the crudeness, really, in those early days and how little we really knew about what we wanted to do, a lot of people knew, the people who invented it, but to try and configure that and make it as useful as it ultimately became I think was a remarkable achievement. Some of the things that we did in those early days-- as a matter of fact, when I first came up here, I remember the lab Jim Nevins was there at the time, and he had two pictures on the wall. And one picture had this Apollo spaceship and its sort of conical configuration, and there were three guys inside lounging around having dinner or something, nothing else, totally clean on the inside, one button, two buttons that said go and come home. [laughter] And that was one side of the coin. The other side of the coin was that you can picture a little spacecraft full of computers and tapes and all those sorts of things where it was totally complicated, and nobody could really figure out what was going on. Fortunately, we got somewhere in between.

DAVID SCOTT: 07:57 Also in those days, this was about '64 and '65, there was a concept we called in-flight maintenance throughout the whole spacecraft, and the idea was, if something fails, well, you replace it in flight, and I remember they'd established a course, a curriculum up here, for six months to help teach people how to change components in flight. Well, we never did that because, gosh, it was tough enough to learn how to operate the first-line systems much less how to change them. But, late in the program, I remember when other people joined the program, we did have some things left over from the early design in the spacecraft itself which reflected in-flight maintenance, and people used to say, "Gee. I wonder why that connector's there and that connector's there? Nobody uses it." Well, you just never got around to a change order to take them out. But it was quite different from what we ultimately ended up with.

DAVID SCOTT: 08:49 Another interesting discussion was what kind of clock do you have? Well, in those days, everybody had analog clocks, watches. Nobody really heard of a digital clock. And a computer naturally expressed its time digitally. And it was quite a design - what should I say? - consideration, competition, discussion, whatever, on what kind of clocks to have. And I think the influence of the digital computer ultimately showed the advantages, especially in our business, of traveling in space, if you will, the advantages of a digital clock. And the initial Apollo design, as a matter of fact, had three analog clocks on a panel and ultimately ended up with digital clocks. And, as a matter of fact, the whole control center in Houston ended up with digital clocks. And everybody wears one in their watch now. So I thought that's a pretty interesting evolution.

DAVID SCOTT: 09:45 We also had some challenges in terms of capability and capacity of the computer. And this was really in the days before anybody flew one. How many words you could get into it and what was the configuration. A core rope memory was something that precluded changes late or close to launch, late in its development time. And at first, everybody said, "Oh, my goodness. We won't be able to change the day before launch." But I remember, in the end, everybody said, "Thank goodness we can't change anything the day before launch," [laughter] because every time you change one little routine, everything else had to be verified. Probably one of the best decisions, in my opinion, that was ever made was to freeze it early so even we got in the erasable later on, but that was a pretty good decision, and people had to settle down and decide what they wanted to do.

DAVID SCOTT: 10:38 We also had some interesting limitations. As I recall, we had, in the beginning-- I wish I had heard Eldon's complete discussion because I might know more about what I'm talking about then, digging back into my memory. Matter of fact, it was sort of fun to sit down and think about this. I hadn't thought about the Apollo Guidance Computer for, gosh, six or seven years. It was sort of fun going back and reflecting on some of the things that we got to do. But as I compare what's available today with what we had then-- as I remember we had 24,000 words and stretched it to 36,000 words, and that was just a major, major effort. And I've got a little Apple II in my house, and I get 48,000. And it's easy. I mean, it costs hardly anything if I want to get another card, I stick another card in it. It's incredible how far we've come.

DAVID SCOTT: 11:25 We also had this panel that we operated, the crew, and great debates occurred relative to what it should look like. And how do you talk to a computer? Everybody was right-- when I went to graduate school, why, we had a language called MAC, which I guess was a predecessor to FORTRAN, and a lot of people did machine language. But how do you take a pilot and put him in a spaceship and have him talk to a computer? That's not easy in real time. And I think somebody, and I don't even remember who came up with the verb-noun concept, but I'm surprised that's not utilized in other computers today because it was very simple for us to operate with a series of two-digit numbers representing verbs and another series of two-digit numbers representing nouns. And it's so straightforward and simple that even pilots could learn how to use it. [laughter] And we had some interesting words. Our initialization program was 00, and we abbreviated the identification of programs, of course, with a P. If you wanted to do a major engine burn, you use P36 or P45 or some identifiable program with a combination of P and the number. If you ever had a problem, you went back to 00 which we ultimately called poo. So if you ever had a problem, you went to poo and reinitialized. [laughter]

DAVID SCOTT: 12:52 And a lot of the words like that-- we also had, you developed the digital autopilot which was the DAP, and a lot of guys had trouble punching all these keys. I liked it. I thought it was sort of fun, get in there and see how fast you could go. Some guys could never really get a hold of this key punching bit, and they wanted to reduce the number of keystrokes to get information. And we, at one point, tried to design a sort of semi-automatic program or a minimum keystroke program and that became known as minkey, minimum keys. And some people liked minkey, and some people didn't like minkey. It sort of limited your capability, but it was a lot easier to work.

DAVID SCOTT: 13:38 But anyways, as we went through the development or the end of the development process and got the computer actually into operation, we had it in simulators and quite a few places, and it was really, I think, from a computational capability, it was a joy to operate. I mean, that was just a tremendous machine, and you could do a lot with it. As a matter of fact, it was so reliable that we never had a backup, and we never had a failure. I think that's a remarkable achievement. We had some glitches here and there, but to my knowledge, at least in flight with the 10 years I spent with it, there was never a real computer failure.

DAVID SCOTT: 14:20 We practice a lot of computer failures, and a simulator simulate a lot of computer failures, but we never really saw one. As I went through my career, I spent a couple of years up here in the early design development phases, and then I went off and flew Gemini VIII with Neil Armstrong, and we had an interesting computational exercise ourselves. I heard that another company had a computer on here. I don't remember its name, but it wasn't DEC. It was somebody-- but we had, for the first time, no re-entry program on that particular Gemini flight, and you had to read a tape in to program it. Well, Neil and I had this little problem and had to come down early. And in those days in Gemini, there was great competition on who could land closest to the carrier with a computational capability on board. And they were getting down 12 miles, 9 miles, 6 miles, 3 miles. Boy, it was really great competition among the crews. Well, Neil and I still hold the record for landing furthest from the carrier. [laughter] We only missed it by 6,000 miles. [laughter]

DAVID SCOTT: 15:34

Some people say it was the tape. Some people say it were the parameters we loaded in it. Actually, it was some other problems. Another capability that we had in the Apollo computer, and now I sort of move past Gemini into my second flight, which is Apollo 9, and that's where we really got into the digital autopilot utilization and development of procedures and the capability. Apollo 9 was an Earth orbital check out of the entire Apollo configuration, all the spacecraft, all the computers. And it was a 10-day flight. First 5 days were just jampacked with operational activities. And we did such things as the lifeboat exercise with the lunar module which was subsequently used on Apollo 13. It was a demonstration of having the lunar module, which was a lander, and the command and service module, which was the orbital vehicle, together and utilized the engine on the lander to actually get back from the Moon which Apollo 13 had to do. And the program was written prior to Apollo 9, and we demonstrated it in flight. And it was an interesting exercise.

DAVID SCOTT: 16:45

I was the command module pilot or I was in a spacecraft that kept one person while the other two guys would go down to the Moon. Although on Apollo 9, we didn't go to the Moon, but the exercises were carried out. And as my cohorts, Jim McDivitt and Rusty Schweickart performed the exercise in a lunar module of lighting the engine, why, I figured out a little program in a command module, with the help of my MIT buddies, to monitor their burn in a reverse direction so that I could tell with my computer how their burn was going. Of course, I had the platform and accelerometers and everything, but it's just a matter of reversing a couple of signs. And I could tell them, as matter of fact, had they lost their LEM Guidance Computer, I could have given him the cutoff instructions and everything else on board. It's not a big thing, but for a user, it's a big thing to be able to have flexibility to do something like that because nobody had ever planned that. And I found it alone in the command module, it was nice to have something to do. [laughter]

DAVID SCOTT: 17:47

But in this particular flight, another thing we did was to burn the big engine on the service module which is a large rocket engine and a combination to actually light it and guide it through a manually controlled trajectory change. And by that, I mean that we actually programmed the computer to give us the parameters in a display format such that during a period of fixed time with the engine on, we would steer, if you would, the vehicle by hand. And this is one of the fun things I got to do on the flight. I actually got to hold a hand controller, and with the needles on the display panel being driven by the computer, fly the spaceship in space with the engine running for, I don't know, must have been something like three or four minutes, which is a long time. And that's a pretty exciting thing. All through a digital autopilot. One of the early, you might call fly by wire. Airplanes do it now all the time, but that was, I think, a pretty important demonstration of a new capability. Matter of fact, I remember when we were having a meeting in Houston one time and all the people from the instrumentation lab came and presented for the first time the idea of a digital autopilot, everybody said, "Oh, you can't build a digital autopilot. Come on.

Why don't you guys quit wasting time? Go back to MIT and think." But by golly it worked, and, gosh, now everybody has digital autopilots.

DAVID SCOTT: 19:20

Another thing we developed in those days was a rendezvous capability. When I was going to school here, why, the question, and this was in '61, '62, it was a question about could we rendezvous or not in space? Is it even possible? Can you develop the mathematics to bring two vehicles together at a precise point in space and time? A lot of people did a lot of work. Slowly, that evolved to the fact that we could do it. And not only that, we put it in the computers in the spacecraft. And on Apollo 9, we did the first Apollo rendezvous wherein Rusty and Jim got in the lunar module and separated from myself and the command module and went out about 60 miles and then came back on a rendezvous. Well, today, after all the Apollo work and everything, nobody thinks that's a big deal because we've done it so much, but I'll guarantee you, at that time, it was very interesting because they didn't have a heat shield and had they not returned in a rendezvous, there was no way home. Well, there was a way home, but it wasn't a very good way. [laughter] They could come down, but even that little exercise was exciting.

DAVID SCOTT: 20:29

We didn't have everything we wanted in the Apollo days. People used to think we did, but, for instance, the command and service module, where I was, did not have a radar. There was no way you could actually measure range or range rate. And that's essential - well, we used to think it was essential - for a rendezvous. The lunar module had the radar. The command module did, however, have a computational capability to perform the rendezvous, but without what we thought at the time was adequate information. In other words, we believed at the time that without range information, direct measured range information, the computation wouldn't really converge. And so we still had a program onboard. I'll tell you a little bit about the other part of that, but Rusty and Jim separated, went out, and part of their rendezvous was at night. And lo and behold, the light on a LEM, which I was supposed to watch through the sextant to monitor them, failed. And they went into the dark side, and that's the last I saw of them for about 20 minutes. And that gets to be rather exciting [laughter] especially when you're never really sure that the engine burned right, that the attitude was right, did it burn long enough, and all those sorts of things. And I remember, boy, it was really an exciting thing when they came in the sunlight, and I had them right dead center in the sextant automatically. And it was a combination of the two computers in which the computer on the lunar module calculated the burn, read out the residuals, and Rusty and Jim read the residuals to me, and I entered the burn parameters into my computer, and I told my computer to point the sextant where they would be when they came into sunlight. And all that got done absolutely perfectly. I mean, boy, it was an amazing thing that they popped into the sunlight, and they were right dead center where they were supposed to be. After all the uncertainties of attitude control and main engine burns and drift and all that sort of thing, pretty amazing operation.

DAVID SCOTT: 22:33

Another thing we had on that flight, which really wasn't associated with the computer, that only went on one flight that I know of, was a little device we called the diastimeter, a diameter measuring optical device through which you would look in specific increments of time. You would measure the size of the object and you could calculate range. The golfers used that to see how far the pin is. Some of them do. And I carried that on Apollo 9, which was rather interesting. A lot of people used to call it the disastermeter. [laughter] But I was able to put-- I would have been able to put range in and actually get some directly measured information. But a lot of that ultimately evolved into an optical type rendezvous. And to take the story on through evolution, our worries in the early days about not having directly measured radar sort of disappeared. As a matter of fact, I then got to fly Apollo 15. And to stay on the rendezvous subject, we did it so many times that, at the end of the program, my last flight, you could actually use your watch and a rate of angle change and a piece of paper and do a rendezvous. I mean, it becomes, after you repeat it so many times, so straightforward as long as you don't have too many uncertainties or a failure of some sort. And it took me back to the days in the early '60s when people said, "Can we do one?" And then 12 years later, sure, you can do it in the back of the envelope, which is that's pretty good progress. I think all of that though was because we had a good computational capability in between which developed the techniques. All the manual techniques really evolved from the computational capability of the computer. We followed the computer, and by doing that, we learned what the computer already knew in a trajectory analysis in a physical sense. So it was quite a lesson.

DAVID SCOTT: 24:39 I think another thing that happened in those days, back in the Apollo 9 days, as I remember, was an event up here called Black Friday when everybody converged upon the instrumentation lab and started taking programs out of the computer because there just wasn't enough memory. There wasn't enough room. And they took out some programs that were absolutely not supposed to be violated, return to Earth programs from the Moon and everything. [laughter] But lo and behold, the judgments were right, and people would work around it, and we'd figure out some other way to do it. But at that time, some of these in the historical evolution of the ultimate capability, sometimes you just don't think you're going to get there. I mean, well I can remember times we thought a computer won't work, not enough memory, memory cycle time isn't fast enough, we can't do this, can't do that, doom and gloom. And all of it worked out so well, it's just the-- almost unbelievable that we were able to do what we did with that old stuff. I mean, I could see it today. I mean, DEC could build a great computer, and we could go to the moon real easy. But when you look at the old things that we were dealing with, quite an accomplishment.

DAVID SCOTT: 25:53 I think after I got through with Apollo 9, I went on and spent some time as a backup crew member on Apollo 12, and then I got into Apollo 15, which was the fourth lunar landing, in 1971. And by that time, the capability had really matured. People understood it. We were able to do a lot more than even conceived in the beginning. The lunar landing itself could have been done automatically, and a lot of times people have asked me about that. It could have been accomplished automatically through the LEM Guidance Computer, but nobody ever did it. We all felt, and I was one of them, that you just, when you get to that point, and you're going to land on the moon, you got to have your hands on a stick. [laughter] I mean, I like computers. I believe in computers, but it ain't going to land me on the moon. [laughter] I'm going to do that because if something gets screwed up, it's going to be me. It ain't going to be the computer. But actually, my thinking, at the time, to be honest about it, was that if a problem did occur, it was so time critical that you wouldn't have time to take corrective action. So you stay ahead of that problem by flying it manually. Now, you're probably fooling yourself because you're still going through the computer. I mean, the stick that you move goes through the computer to fire the thrusters, which is not a lot different from the computer doing it itself. But you feel different. [laughter] I got it.

DAVID SCOTT: 27:24 Matter of fact, it sort of takes me back to one of our events on Gemini VIII, Neil and I got in this tumble up there. We had a thruster stuck on. And in the Gemini spacecraft, you had only one hand controller. It was in the center console between the two crew members. And the guy on the left would fly it with his right hand, and the guy on the right would fly on his left hand, same hand controller. And we got in this spin up there, this tumble, and Neily was the boss, and he was trying to get everything situated and organized and get us stopped. And he had tried everything, and we'd been talking back and forth and, "Try this, and try that." Every switch we could think of, every combination we could think of, and in a period of frustration like that, you dig really, really deep and to try something else. So Neil's doing all this with the stick, and he looks over at me and says, "You try it." And I grabbed it, and I went like this. I said, "I can't stop it either." Well, it's only one stick. [laughter] And it ain't going to make any difference who's hanging onto it. [laughter] But you get in a situation, and we both agreed at the time it would be better for somebody else to hold onto the stick. [laughter] And we didn't figure that one out for about three months. [laughter]

DAVID SCOTT: 28:36

But anyway, back to 15, the LEM Guidance Computer had the capability to automatically land on the Moon, which says that we could a send a tremendous payload up there if you could get rid of the guys and send it automatically. But once it got there, what would it do? But it had, as we did our landing, and as this system evolved, we got more and more capability. We had a little switch that we put in. And instead of trying to descend to the lunar surface by some visual display and a coordination of a throttle, we put a switch in a computer, and every time you flicked the switch, it was spring-loaded, you'd get one foot per second change, which was a really nice way to land. You're coming down at 10, you go click, click, click, click. You're coming down at 7, 6, 5, and you would probably hear on the ground, on Earth, the lunar module pilot, the guy on the right side calling out these descent rates, altitude and altitude rate. And it sounded like the guy flying it was really precise with that throttle. Well, he was. He had a computer there doing it for him. So you'd hear this neat, crisp, "10 feet per second, 8 feet per second." Really smooth. Click, click, click. And you think, well, that guy is really flying it. Well, he just hit the switch there [laughter]. The computer doing the whole thing.

DAVID SCOTT: 30:00

But we also had some of these human factors, considerations in the computer and the whole spaceship, and I remember one that got a lot of attention up here, a lot of attention in Houston, too, was how to simplify the command of the computer to do the next step. And we had, finally, we developed a button called a proceed button, Pro. And I think probably everybody takes that for granted now. But boy, if you could go through the iterations that we went through to get this proceed button, which was a one-button push to have something happen, and a lot of people were afraid of having no confirmation button, push proceed, and things happen, but we worked through that, although I remember everybody in the lunar module during a landing had to think very carefully about which buttons they pushed because there were three buttons that you could push and had to push, as a matter of fact, in sequence. There was a proceed button on the computer. There was an engine shutdown button, which turned off the engine, and there was an abort button, which separated the ascent stage from the descent stage and aborted it. And all three buttons were in the same proximity [laughter]. And one of them was a black background with a little Pro written on it. Another one was blue, and the other one was red, but they were all sort of the same size, and you really had to think about that coming down to the landing because when you got down, you had to hit the proceed button to put the computer to sleep for a while. When the probes on the bottom of the landing gear touched the lunar surface, you got a signal in the cockpit, and they were about, I don't know, 12 feet, 10 feet from the ground, and you had to shut the engine down then because, on our flight, in particular, we had an extended engine bell, and if you settled on the lunar surface with the rocket engine running, you'd blow the bell out because of the compression. So as soon as you had the signal, you had to push the button to shut the engine down. But you didn't want to push the abort button because then you would never land [laughter]. So it was a really tricky situation, and the human factors things came in. But as I look back on it, I say we probably got away with one there [laughter] because nobody ever hit the wrong buttons that I know of [laughter].

DAVID SCOTT: 32:17 Anyway, I think that maybe, as sort of a background, perhaps I could answer questions if anybody has any questions relating to the user's approach to this sort of device. I think maybe in summary, the Apollo Guidance Computer, the lunar module guidance computer, we had a lot of names for the device. It was the same basic machine. It was really a terrific system. It had a lot of capability, a lot of user input. And I don't know what the people who actually built the computers thought about we users, but we thought it was pretty remarkable that all this could be done, and we kept coming up-- I keep thinking these stories. One thing that I thought was terrific, on Apollo 9, about two weeks before flight, we had this big rack of four cameras that we wanted to point directly to the Earth and take pictures, the first real IR pictures anybody took, a different film in each of the four cameras. So you had to point directly at the Earth, and as you were going over the Earth, you had to track the vertical very precisely. And in simulators, we found out we could do fair but not really as good as the principal investigator wanted. And as I remember, something like two weeks before the flight, we called up the folks up here, and I forget who it was, but I remember working with the guy. He said, "Hey, can we do a little orb rate with a computer driving a spacecraft?" He said, "Of course. Which way do you want to go and how fast?" And in a matter of, I think, a couple of days, we had a program in a simulator that automatically drove the spacecraft at orbit rate, perfect orb rate, and we got in the flight with very little chance to practice or verify it and put it on the cameras, and it was remarkable. It was perfect. You could not manually fly it that well. And it did a good job getting pictures. Well, does anybody have any questions that I might answer? Right in the front.

S2: 34:17 Did you have [inaudible] what sort of commands [inaudible]--

DAVID SCOTT: 34:23 The question was what sort of commands could we issue and what sort of functions? Well, the language that was developed for the user was a verb-noun language, and two digits would be a verb, for instance, display the coordinates of, and two more digits would be a noun, velocity. So you'd say verb 26, noun 34, and you'd get a display of three components of velocity, or you could say position the spacecraft at some orientation or attitude, and you'd load that in, you'd do a verb, then do a noun, load your coordinates or your position, your attitude, push proceed, and it would automatically move the spacecraft to that orientation. So it was a combination of verbs and nouns. We could display. We could maneuver. We could turn the engine on and off. We could navigate anything. Gee, I'd have to go back and look at the list. But I think, at the end, we were using something like, what, 50 or 60 verbs.

S2: 35:25 [inaudible]--

DAVID SCOTT: 35:26 Yeah, pretty close to maximum. And I'm sure we could have-- each flight, people thought of more things to do.

S2: 35:33 [inaudible].