QUEST

THE HISTORY OF SPACEFLIGHT

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Controlling Hexagon

John Denver and NASA

Space Elevator Architectures

An Interview with
Dr. George R. Carruthers,
Apollo Astrophysicist

Birth of the Test Ranges
Part III: The Air Force
Western Test Range

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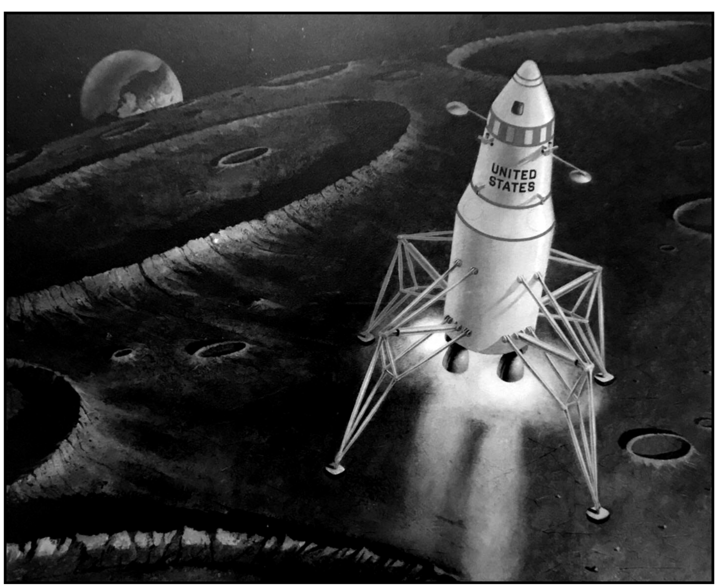

An image from The SPACE 3.0 Foundation Archives, a Lockheed design concept for a lunar landing module design. Credit: Lockheed Martin

Front Cover Caption

A February 1995 artist concept of a possible exploration program: After manufacturing its own propellants using Mars' thin, carbon-dioxide atmosphere as feed stock, a small ascent vehicle lifts off from the surface to begin its journey home. This spacecraft is returning rock and soil samples that were collected and stored inside by two micro-rovers during a 500-day surface stay (S94-44357).
Credit: Artwork done for NASA by Pat Rawlings, SAIC

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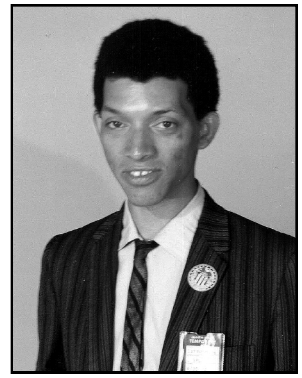
AN INTERVIEW WITH DR. GEORGE R. CARRUTHERS, APOLLO ASTROPHYSICIST

Interview by Glen E. Swanson

The 30th anniversary of *Apollo 11* was approaching as I began work in the fall of 1998 as a historian at the NASA Johnson Space Center. Any time a significant anniversary ends in a "5" or "0," especially for the lunar landing missions, the media gives them more attention. There was an expectation that something would be done by NASA to recognize the first Apollo lunar landing by the agency that helped achieve it.

NASA had funds and I had ideas. What emerged were several projects that included a book titled: *'Before This Decade Is Out' Personal Reflections on the Apollo Program*. The book contains a collection of interviews mainly from those who worked behind the scenes to help make Apollo a success. As the book's editor, I did not want to include interviews with the Apollo astronauts because I felt then, as I do today, that



Dr. George Carruthers, Naval Research Laboratory. 1972.
Credit: NASA

Dr. George R. Carruthers

Born: 1 October 1938
Cincinnati, Ohio

Died: 26 December 2020
Washington, DC

EDUCATION

- BS, Aeronautical Engineering, University of Illinois, 1961
- MS, Nuclear Engineering, University of Illinois, 1962
- PhD, Aeronautical and Astronautical Engineering, minor in Physics and Astronomy), University of Illinois, 1964

CAREER

University of Illinois (1961-1964)

- Research and Teaching Assistant, Department of Aeronautical and Astronautical Engineering

Naval Research Laboratory (Washington, DC)

- Astrophysicist, Space Science Division, 1964-2002

Principal investigator for the following orbital or lunar space flight investigations

- *Apollo 16*, Far UV Camera/Spectrograph, 1972
- STS-39, Far UV Cameras Experiment, 1991
- High Resolution Shuttle Glow Spectrographs (HRSGS-A flown on STS-51, 1993)
- Far Ultraviolet Imaging Spectrograph/Spartan-204 (STS-63), 1995
- Global Imaging Monitor of the Ionosphere/P91-1 (ARGOS) Satellite, 1998

AWARDS & CITATIONS

- Arthur S. Flemming Award, Washington Jaycees, 1970
- *Apollo 16* Exceptional Scientific Achievement Medal, NASA, 1972
- E. O. Hulburt Annual Science Award, NRL, 1972
- Warner Prize, American Astronomical Society, 1973
- National Civil Service League Exceptional Achievement Award, 1973
- Honorary Degree (Doctor of Engineering), Michigan Technological University, 1973
- Outstanding Young Alumnus Award, Department of Aeronautical and Astronautical Engineering, University of Illinois, 1974
- Alumni Honor Award for Distinguished Service in Engineering, College of Engineering, University of Illinois, 1974
- Samuel R. Cheevers Award, National Technical Association, 1976
- NRL Commanding Officer's Equal Employment Opportunity Award, 1986
- Black Engineer of the Year Award—Technical Contribution, 1987
- Honored Guest, Los Angeles Council of Black Professional Engineers Seventh Annual Educational Banquet, 1990
- Inducted into National Inventors Hall of Fame, 2003
- National Medal of Technology and Innovation, 2011

their stories have been told so many times that very little new remains to be told. I felt that readers want to know more about the half-a-million other people who helped the astronauts get into space and back.

But I was told that such a book issued on the 30th anniversary of *Apollo 11* had to include at least one astronaut interview, along with interviews from former NASA administrators, high-profile managers, and engineers. In spite of these necessary "celebrity" inclusions I was able to still capture several interviews from individuals who rarely if ever had been interviewed about their role in helping land us on the Moon. Among these folks was Geneva Barnes who served as the administrative secretary to Neil Armstrong during the year after his return from *Apollo 11* and who accompanied the crew on a 45-day Presidential Goodwill Tour. Geneva was absolutely thrilled about sharing her story. In addition to Barnes, I interviewed Dr. George Carruthers, a quiet and brilliant astrophysicist and engineer who led the building of the world's first observatory to be placed on the surface of another world.

George R. Carruthers was the principal designer of the Far Ultraviolet Camera / Spectrograph that was placed on the Moon as part of the *Apollo 16* mission in 1972. The device returned several hundred images in the far ultraviolet part of the spectrum that revealed new information about the composition of the Earth's atmosphere and interstellar space.

Carruthers grew up on Chicago's South Side in a Black ghetto. Though the environment in which he spent his formative years was not conducive to learning, it could not suppress his interest in science, specifically space science. Dr. Carruthers built his first telescope at the age of 10 and taught himself astronomy before he went to college.

He joined the Naval Research Laboratory (NRL) as an astrophysicist in 1964 after completing his PhD in Aeronautical and Astronautical Engineering at the University of Illinois. From 1966 to 1982, Dr. Carruthers had responsibility for an average of one sounding rocket experiment a year, which led to numerous scientific findings including the discovery of molecular hydrogen around Xi Persei that helped confirm theories of star formation.

In addition to serving as the Principal Investigator of the *Apollo 16* Far UV Camera/Spectrograph, Dr. Carruthers also designed a similar camera that was used aboard Skylab and the Space Shuttle as well as for various satellites.

Although he was painfully shy, Dr. Carruthers served on numerous committees and panels but also set aside time to work with inner city schools and those with large numbers of Black students to encourage them to pursue careers in science. He developed an apprentice program for high school students at the NRL and taught courses in the summers to help science teachers in the DC-area public schools.

After nearly 40 years with the NRL, Dr. Carruthers retired in 2002 but continued teaching Earth and space science classes at Howard University. Dr. Carruthers received the NASA Exceptional Scientific Achievement Medal and was named to the National Inventors Hall of Fame. In 2011 he received the National Medal of Technology and Innovation from President Barack Obama during a White House ceremony.

On 25 March 1999 I interviewed Dr. Carruthers. I had just purchased a new digital tape recorder and was not that familiar with it. Halfway through the interview I discovered that it had not recorded. But Dr. Carruthers remained calm and patiently went through the lost material a second time.

Unfortunately, my interview with Dr. Carruthers did not make it into my book. Instead, a two-page callout was included in the chapter containing an interview with *Apollo 16* astronaut Charlie Duke showing Dr. Carruthers and the *Apollo 16* telescope that he created.

Dr. Carruthers died on 26 December 2020 due to complications from dementia and other ailments.

* * *

Swanson: Dr. Carruthers, I'd like to begin by again addressing your background, particularly what led to your interest in science, and, specifically, in the work you've done in astronomy and cosmology.

Carruthers: Well, my interest in space science and astronomy came about by reading science fiction comic books when I was about nine years old, and then after that I became interested in astronomy because I came across some books on the subject. Of course, that was long before there was a space program, so people weren't really overly enthusiastic, including my relatives, about my interest in astronomy. They thought I should pursue something more practical, such as engineering, because my father was an engineer, but he also gave me an interest in technology as well.

So once I moved to Chicago—I was actually living in a rural area near Cincinnati, Ohio, called

Dr. George Carruthers, center, principal investigator for the lunar surface ultraviolet camera, discusses the instrument with *Apollo 16* Commander John Young, right. The photo was taken on 22 December 1971. From left are Lunar Module Pilot Charles Duke and Rocco Petrone, Apollo Program Director. This photograph was taken during an Apollo lunar surface experiments review in the Manned Spacecraft Operations Building at Kennedy Space Center [108-KSC-71P-544]. Credit: NASA

Milford, Ohio—when the family moved to Chicago, I had access to a much broader range of resources, like public libraries and so forth. And also I came into contact with the Adler Planetarium and spoke with some of the astronomers there.

Just prior to that, the famous issues of *Collier's* magazine, featuring Dr. Wernher von Braun and others who were proposing spaceflight for the first time, human spaceflight like space stations, and Fred Whipple had proposed using space as a base for astronomy. But when I talked to the astronomers at the Adler Planetarium, they said, "Well, you know, that's fantasy. That's science fiction. Ground-based astronomy is really the thing that we do, and we think that there's no advantage in going out into space."

But I was really interested in space from the engineering point of view as well, because of having read about it in Wernher von Braun's publications. So I went to the University of Illinois and obtained, basically, the equivalent of a dual background in aerospace engineering, with minors in physics and astronomy, so that I could cover both aspects of the subject.

When I was in graduate school, I read about postdoctoral appointments at the Naval Research Laboratory, which I had read about quite a bit already, because they had developed the Viking rocket and the Vanguard rocket and several other space astronomy-related projects. So I applied for a postdoc to come to Naval Research, and I've been here ever since.

Swanson: You mentioned that your father was an engineer. How much of an influence were your parents in nurturing your interest in astronomy and your eventual career path?

Carruthers: Well, they weren't so much of an influence in the astronomy and spaceflight part, but my father, being a civil engineer, instilled in me the importance of learning about math and science in general.

Swanson: Did you have any heroes at the time when you were growing up? You mentioned you enjoyed science fiction. Were there particular writers that you enjoyed reading more than others, and then also real-life individuals? You mentioned Dr. Wernher von Braun.

Carruthers: Well, actually, the only real motivator person that I'd actually had the opportunity to contact directly was Dr. von Braun, because after reading his articles in *Collier's* and other places, I sent him a letter saying I was interested in space and all that sort of thing, and he sent me an autographed photograph, which was totally unexpected. That was while he was still part of the Army at the Redstone Arsenal, before the creation of NASA.

Swanson: During your college career, obviously it was during the [19]60s, [there was] a lot of civil unrest and so forth. Did you find, because of your race, any obstacles in your education career?

Carruthers: I don't think that I really had any overt obstacles in my college education. Of course, African Americans were like one percent of the engineering students there, so we were relatively rare, but I never saw any instances of discrimination that prevented me from doing whatever I wanted to do there, on the part of either professors or other students.

Swanson: You mentioned your coming to the Naval Research Laboratory. You received a scholarship or you worked as a co-op student or an intern?

Carruthers: It was a postdoctoral appointment when I came to NRL, which was funded by the National Science Foundation at the time, and that was my first real chance to have hands-on participation in space science, because NRL was one of the few organizations that was directly involved in the space program.

Swanson: What were some of the early experiments work that you did relating to the space program prior to Apollo?

Carruthers: Most of our work was done with sounding rockets in those days. Sounding rockets have the advantage that you can build something on a relatively short time scale, a relatively small expense, and get results from it quickly. So one of the projects that I came to do as part of my postdoctoral appointment was what was then a hot topic, look[ing] for molecular hydrogen in interstellar space, which could be detected only by the use of ultraviolet spectroscopy, and therefore required rocket flights above the atmosphere.

Swanson: On these sounding rockets, can you relate any interesting incidents with failures, either during the launches themselves or recovery of the payloads?

Carruthers: Well, actually, as was also true of the film *The Right Stuff*, where the astronauts were shown examples of the rockets they were supposed to ride blowing up on a launch pad or early in flight, there were quite a few mishaps even in the sounding rockets—either the rocket not getting to sufficiently high altitude, or the parachute not working, or the attitude-control system that needs to point the instrument at the target of interest not working properly. So usually it took two or three tries to get one fully successful result.

Swanson: Leading up to the work on Apollo, can you basically describe how you came into working on the camera that was used on *Apollo 16*?

Carruthers: Well, shortly after the first Apollo lunar landing in July 1969, NASA put out an announcement of opportunity for scientific experiments on the follow-on Apollo missions, and I put in a proposal to use an instrument similar to our sounding rocket experiment on the Moon to look back at the Earth, specifically to study the Earth's upper atmosphere. [This] is difficult to study, even from low Earth orbit because of the fact that the hydrogen atmosphere in particular extends out a very large distance away from the Earth, and also we proposed to use the camera for astronomy as well, which would take advantage of a lower sky background on the Moon than would be available in low Earth orbit.

At the time, there was also another proposal put in by Dr. Thornton [L.] Page, who at the time was on a sabbatical at Johnson Space Center in Houston, to do a very similar kind of experiment, more focused on astronomy. He proposed a number of alternative instruments, including one of the type that we had developed here at the Naval Research Laboratory. So NASA looked at these two competing proposals and suggested that we join forces. So we did that, and the program was then set up with Dr. Page and myself as co-principal investigators. I would be in charge of developing the instrument and he would be in charge of the further development of the observing program and the data analysis.

Swanson: The program was pretty intense timewise from when you received the go-ahead approval with your proposal to the time of the actual instrument. Can you describe a little bit of those days working on the instrument and some of the highlights and problems and pleasures that you encountered during that project?

Carruthers: Yes. It was a very intense time scale, because the schedule was determined by the launch schedule. The time from start to finish was only two years, so we got approval in 1970 to go ahead with it, and the launch was in April of 1972. The advantage, though, was that money was no object in those days, unlike now, and there was plenty of funding so that we could have a much larger staff of people to work on a project than would have been typical of a sounding rocket. We had [the] Engineering Services Division here at the Naval Research Laboratory to support us and many other people in specialized roles to support it, so that, to some extent, compensated for the very compressed time scale; in contrast to missions nowadays which have been much longer from start to finish, but funding is a lot harder to get these days.

Swanson: When you were developing the camera itself, did you meet with the astronauts frequently during the development of the camera?

Carruthers: Not very frequently, but we did have a lot of meetings down at the Johnson Space Center with the other engineers, mostly on engineering details and mission-planning details. We did talk to the astronauts on a few occasions and we also did some training sessions with the astronauts in the final stages down at the Cape to show them how we operate the instrument; [to] make sure that they knew what to do once it was deployed.

Swanson: Can you describe a little bit about the deployment of the camera? You were there at JSC at the time of deployment during the mission?

Carruthers: Yes, I was there actually before the Apollo landed, and there was some delay because of an engine problem that they had on the Service Module, which is the device that has to bring them back to the Earth. We were almost afraid that they weren't going to land but then at the last minute, they decided to proceed with the landing. We were very much relieved at that. I believe that the actual deployment of our instrument was almost a day after they landed, certainly not immediately after they landed. But I was there for that part of the mission operations, and we could—as is true, even now, the scientists did not have the chance to talk directly with the astronauts, but we were able to hear what the astronauts were saying and give some input to the mission controllers about what the astronauts should be doing.

We could actually hear them talking about our instrument. Like, for example, John Young was using a sight on the side of the camera to point it at the Earth in order to set the reference for all of the other targets that we were going to be using, and he verified that he had sighted the Earth and it was in the center of his field of view.

Swanson: Please describe the camera, actually how it works. It's not a typical point-and-shoot film camera.

Carruthers: It's really an electronic camera. It's a type of camera we call electrographic, which uses film, but is also an electronic imaging device. We call it electrographic because the imaging device produces electrons, just like in a video camera. But instead of being recorded by CCD [charged coupling device] or other electronic imaging device, it actually hits the film and is recorded directly as darkening of the film. It's more quantitative and also a lot more sensitive than direct photography. And unlike the electronic imaging devices, the film does have to be recovered and brought back in order to get the data.

Swanson: Was that a little frustrating for you, knowing that, unlike some of the instruments where they could actually monitor the data that they were gathering immediately, you had to pretty much wait until they came back before you knew if your instrument worked or not?

Carruthers: To some extent, but we knew that ahead of time, and that had always been true in other flights, including sounding rocket flights, that we wouldn't know for sure what we got until we processed the film.

Swanson: Was this a considerable time after the mission completed before you could pretty much bring closure to this point in your life—knowing that the results came through, the film was processed, and you could start analyzing the data?

Carruthers: Yes, it was sort of an apprehensive time,

Mission Commander John W. Young practices on 12 November 1971 with the Far Ultraviolet Camera/ Spectrograph that would be carried to the Moon by the crew of *Apollo 16*. The crew was training at the Kennedy Space Center Flight Crew Training Building and on an adjacent field that simulated the lunar surface. [NASA 108KSC-71P-628]. Credit: NASA

Apollo 16 Lunar Module Pilot Charles M. Duke Jr., left, and Mission Commander John W. Young examining the Far Ultraviolet Camera/ Spectrograph are shown on November 1971 at the Kennedy Space Center Flight Crew Training Building. This camera was carried to the surface of the Moon during their *Apollo 16* mission [NASA 108KSC-71PC-731]. Credit: NASA

because it was like a couple of weeks between the time that they returned and the time that the film was actually processed by the people at Johnson Space Center, so I wasn't there at the time and would not have been able to participate in it even if I was there. But once we found out that the images were good, we were certainly quite relieved.

Swanson: What were some of the results? In layman's terms for some of our readers of these interviews, what were some of the results from the camera, the highlights, that you found?

Carruthers: Well, the most immediately obvious and spectacular results were really for the Earth observations, because this was the first time that the Earth had been photographed from a distance in ultraviolet light, so that you could see the full extent of the hydrogen atmosphere, the polar auroras, and what we call the tropical airglow belt. All of these were revealed in pictorial form for the first time, so that's something you don't have to wait for data analysis to show people.

We also obtained UV images of stars, including the Large Magellanic Cloud, the nearest nearby galaxy, but these were less immediately different from things that were done from sounding rockets and from low Earth orbit, at least in terms for the general public.

Swanson: Were any of the results used from the *Apollo 16* instrument later dusted off and compared to some of the subsequent missions where this instrument was flown? Is there a similar instrument aboard the *Hubble* [*Space Telescope*]?

Carruthers: No, there's not one on the *Hubble*, because the *Hubble* is a much more specialized, high-powered telescope with a very narrow field of view, whereas our cameras are really more survey instruments with wide fields of view, so you can actually map a large area of the sky, or take a picture of the whole Earth, or whatever. So it's really a different kind of science than most of the other NASA missions have been, including our own missions in low Earth orbit, like on the Space Shuttle in 1991 and the *ARGOS* [*Advanced Research and Global Observation Satellite*] satellite, which we just launched this year [1999].

Swanson: You mentioned that it was also flown on a later Skylab mission. How did the instrument differ on the Skylab flight, as opposed to that used during *Apollo 16*?

Carruthers: On the Skylab flight, the primary objective was to observe Comet Kohoutek, which was prominent during the time of the mission. Since it was in the Skylab space station, all we really needed was the basic camera. We didn't need the stand, the tripod, and the pointing system that we had on the Apollo mission, where it was pretty much a stand-alone instrument. So the backup camera from the Apollo mission was used for Skylab, but not the whole tripod assembly.

Swanson: Why wasn't this camera flown on subsequent Apollo missions? Why was it just on *Apollo 16*?

Carruthers: Well, actually, we would consider ourselves lucky to have had even one opportunity because of the fact that the highest priority of the Apollo missions was on lunar science specifically. Many of the lunar scientists felt that something looking at the Earth or looking at the stars is a lower priority, in terms of the uniqueness of it, compared to lunar science. But we justified it because of the unique perspective of the Moon for doing astronomy, in comparison to low Earth orbit. But we did not have a second chance, that's true.

Swanson: And going into the development of the camera for that mission, you knew that ahead of time?

Carruthers: Yes.

Swanson: Did that in any way influence the design of it, what you wanted to accomplish at that point?

Carruthers: No, because even if we had a reflight, it would have been basically the same.

Swanson: Going back to *Apollo 16* and the instrument flown on Skylab, you had the same or similar instruments flown on several Shuttle missions. How did those differ from the previous missions, particularly the Shuttle missions?

Carruthers: The Shuttle mission, being in low Earth orbit, had somewhat different objectives than the Apollo mission. Also, on the Shuttle flight, which was on STS-39 in the spring of 1991, we had two cameras mounted on a pointing system so that we could obtain pictures in two different colors of ultraviolet light at the same time. But aside from that, it was basically the same instrument technology as used on the Apollo and in the sounding rocket flights.

Swanson: Did you use some of the data from the earlier missions in your science for the Shuttle missions as well, and was that useful?

Carruthers: Yes, because it gave us a baseline of what to expect in terms of instrument calibrations. We could look at some stars that were the same in the two missions, and use those to compare the sensitivities of the two instruments, what we call inflight calibration. And also the fact that we had done something similar gave us a better idea of what to expect in the later flights.

Swanson: You mentioned that on the Shuttle flights, starting with the first one, STS-39, that they no longer used film, but these CCDs. Can you expand a little bit more on the differences between the film versus CCD, the advantages, and the disadvantages?

Carruthers: Well, the Shuttle flights did use film, just like the Apollo mission, but what has changed recently was the long-duration, unmanned satellite mission called *ARGOS*, which stands for *Advanced Research and Global Observation Satellite*, which was launched by the Air Force in February of this year [1999], for a minimum of one-year mission duration.

Now, for that kind of mission, we definitely need an electronic readout device to send data down remotely to the ground because of the fact that you don't have astronauts there to bring it back...You have to radio the data down, just like the *Hubble Space Telescope* [*HST*] does. The basic distinction is that the charge couple device takes the place of the film to record the electrons, so that you get a signal that can be processed by telemetry and sent down to the ground as an image, just like in the *HST*.

Swanson: I suppose one of the advantages of that is that you have instantaneous results, you don't have to worry about retrieving the film and then processing it, and so forth.

Carruthers: Right. And also it's more quantitative, because with the advances in computer technology, we can convert CCD images to light intensity much more readily than we could convert film images into light intensity.

Swanson: The instrument, as it's deployed on the Moon, is basically housed in the descent stage on the Lunar Module, and then hauled up by the astronauts?

Carruthers: That's correct. It had to be in a protective bag to keep the inside of it dry, because one of the problems we had in all of these cameras is that since they are designed to be open to the vacuum of space, we have to protect them from being contaminated when they're on the ground. In particular, water vapor is a big problem, so we have to put them in dry bags, make sure they're purged with dry nitrogen and that sort of thing.

Swanson: Earlier this week, we were at the [National] Air and Space Museum attending a conference, and we noticed one of these instruments on display there; they had a sign next to it, describing it as a backup instrument. How did that come about, bringing it out to display? Because I don't remember seeing that a while back. I don't know if that was relatively recent or not.

Carruthers: Well, actually, Dr. David DeVorkin at the Air and Space Museum had requested the backup of the Apollo camera as a possible display item. The backup unit was used for the actual display on the Lunar Module exhibit at the Air and Space Museum. It turns out that the film transport, the actual film transport that's on that display model, is the actual flight one from *Apollo 16*, which was brought back there by the astronauts. We don't advertise that to the public, because we don't want somebody to steal it and try to sell it for a million dollars, just because it had been to the Moon and back.

Swanson: So they had this in storage, the backup, for a number of years here?

Carruthers: Yes, right. The actual camera from the backup module was used in Skylab, so we had to remake a model of the camera for the display at the Air and Space Museum.

Swanson: The only difference then was that instead of the tripod when it was on Skylab, it was attached to—

Carruthers: To an airlock.

Swanson: You attended this conference yesterday at American University, and we were talking about your feelings of manned or robotic versus unmanned, human spaceflight. I was wondering if you could share what your feelings are and the differences between them; what one can accomplish versus the other. and if you have a preference of one over the other.

Carruthers: Well, that's one of the things that's changed a lot over the years with the advances in technology, because one of the justifications for the Space Shuttle back in the [19]70s was that it would provide human presence for carrying out experiments in low Earth orbit that would not be practical to do robotically with unmanned satellites.

However, with the advances of computer technology, we've seen a shift over the years in that many of the experiments that originally would have only been practical with human presence are now practical to do remotely with robotics. For example, the *Mars Pathfinder* was a good example of how miniaturized electronics can do almost as much in a hundred-million-dollar mission as a billion-dollar *Viking* mission of 1976.

There are still some things that really require the human presence, but in the area of astronomy, the shift has been largely toward the robotic techniques. That's also evident in our changing over from film to the CCD recorder, so we can have it in an unmanned satellite, long-duration mission, as opposed to short-duration missions like the Space Shuttle and Apollo.

Swanson: When you were working on the Apollo Program, were you aware at all of the significance of the work that you were doing, beyond just its scientific return, but more because you were being a participant in the race to the Moon and just being involved with the Apollo Program?

Carruthers: Yes, I think that, as was mentioned by several people at the Space Symposium at American University, Apollo was sort of unique, in that it was driven by the race between the United States and the Soviet Union to be first. Once that race was won, and also, again, once the Cold War was over, the competitive urge decreased and, therefore, there was less pressure on getting things done quickly and more pressure on getting them done cheaply. That's the reason for the better, faster, cheaper approach nowadays, in that faster is faster simply because it's smaller and cheaper, not because there's more time available or less time available to do it.

The advances in technology, particularly computer technology, have made it possible to do things better, faster, and cheaper. It's not really just because somebody said that this is what we want to do. It's just that it's been more practical to do it nowadays better, faster, and cheaper, as opposed to the old approach of having a billon-dollar spacecraft with twenty instruments on it because you only get one chance to go to Jupiter, for example.

Now, the drawback of all of this, in comparison to the Apollo Program, from our point of view, is that, as I mentioned, we had a tight time scale for the Apollo Program, but also there was adequate funding to carry it out. Nowadays, it's much harder to find funding for these things. The time scale is determined by the funding, to a large extent. So even though in principle you might be able to do something fast in practice, things tend to drag on because of the fact that the time that it takes increases when funding is tight. So I guess it really amounts to the Apollo Program being a unique thing in the space program over the years.

Swanson: Yes, money wasn't really too much of an option. It was more of whatever it takes to get it done, and done quickly.

Did you ever feel that during your work with Apollo and your subsequent work with NRL, that you had any additional obstacles because of your race?

Carruthers: No, I don't think I had encountered any particular obstacles from that point of view at NRL, or even when I was in graduate school at the University of Illinois. One of the things that's different nowadays is that there is more of an incentive for professionals to participate in community outreach activities to try to get students, particularly those of underrepresented minorities, interested in science, because now the general public knows that there is a shortage of technically trained scientists and engineers, especially among the underrepresented minorities. The best people to serve as role models for those are ones who have already been successful in that area.

When I was their age, I had no role models because nobody ever publicized them, not that they didn't exist. George Washington Carver and Percy Julian and others had preceded me in science, but nobody ever publicized their accomplishments, and, therefore, many of the minority students didn't know that they had a future in science because they figured it was something that was not for them. So one of the things that I try to do is to help students get involved in science and engineering by showing them that it's really fun if you get the right background in school.

Swanson: Tell us a little bit more about some of the current outreach that you're involved with. I understand from the display at the Air and Space Museum, plus reading some of your background material here, that you are quite active in mentoring and working with other students.

Carruthers: Yes. Well, actually, the video that's on display at the Air and Space Museum in connection with our exhibit there involves one of our

Dr. George Carruthers standing next to the Far Ultraviolet Camera/Spectrograph. Standing to his left is William Conway, project manager at the Naval Research Institute.
Credit: Naval Research Laboratory

students who came to us through the Science and Engineering Apprentice Program, which is an eight-week summer program which is free of charge to the mentors, and allows students to come in and work for eight weeks in a laboratory such as ours, in either engineering or science.

We've had several students over the years. In fact, the most advanced one, which we had as a high school student in 1985, I believe, went to the Air Force Academy and is now a captain in the Air Force. We've also had a student who was in the program at American University last night, Marja Matthews, who's a senior at Anacostia High School. She has not only been a participant in the Science and Engineering Apprentice Program, but also in several of our other education and outreach activities, including the Moonlink program, which is sponsored by Space Explorers, Incorporated.

As a member of the DC Space Grant Consortium, I was tasked with getting the DC public schools involved in the Moonlink program, and we established a program involving Ballou High School and Anacostia High School during the fall of [19]97 and the spring of [19]98, when the *Lunar Prospector* was launched and first came into operation...

We also do teacher training. For example, I taught a course in Earth and space science the last two summers for DC public school teachers, and also we're planning to do a physics course for them, because there's a special shortage of teachers in the DC public school system who are qualified to teach physics.

Swanson: You mentioned some role models that you had while you were going through your early career in school. Have you found that some of the students that you've worked with through these community outreach programs, have recognized you as a role model, especially some of the individuals that have established themselves with careers, in large part due to the influence that you had in working with them?

Carruthers: Yes. So far, the only one who has actually established as a career is the one who is the captain in the Air Force. The others are either in graduate school or still in college. But I think they all acknowledge the help that I might have given them in the process.

Swanson: Looking back over your long career with the NRL and the work that you've been doing in the fields of astronomy and space science, what do you feel has been your most significant accomplishment?

Carruthers: Well, I guess the Apollo camera on the Moon, in terms of its overall results, would be one, and also we had a sounding rocket flight in 1970, which was before Apollo, which made the first detection of molecular hydrogen in interstellar space. So those two, I would say, would be the most significant single events.

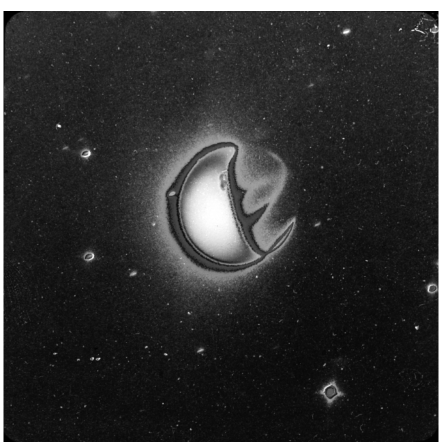
Of course, we've had a lot of other projects in the interim. We've had many sounding rocket flights. We've looked at comets Halley, Kohoutek, and West, and we have the current *ARGOS* satellite, which has the potential for more data return than everything else we've done altogether, assuming everything works properly for the three-year mission. But I would say those two probably would be the ones that, to me, stand out.

Swanson: What, personally and professionally, made those more important than others?

Carruthers: Well, I guess simply because they were first of a kind in both cases. Not that they were necessarily more significant in terms of the overall field of science, but just that they were a first of a kind. Of course, everything is superseded by more advanced technology, because certainly nothing that I have done would compare with *Hubble Space Telescope* or anything like that.

Swanson: You mentioned molecular hydrogen earlier. For those such as me that aren't really informed on the significance of that find, can you explain a little bit more about what that means and why it's significant?

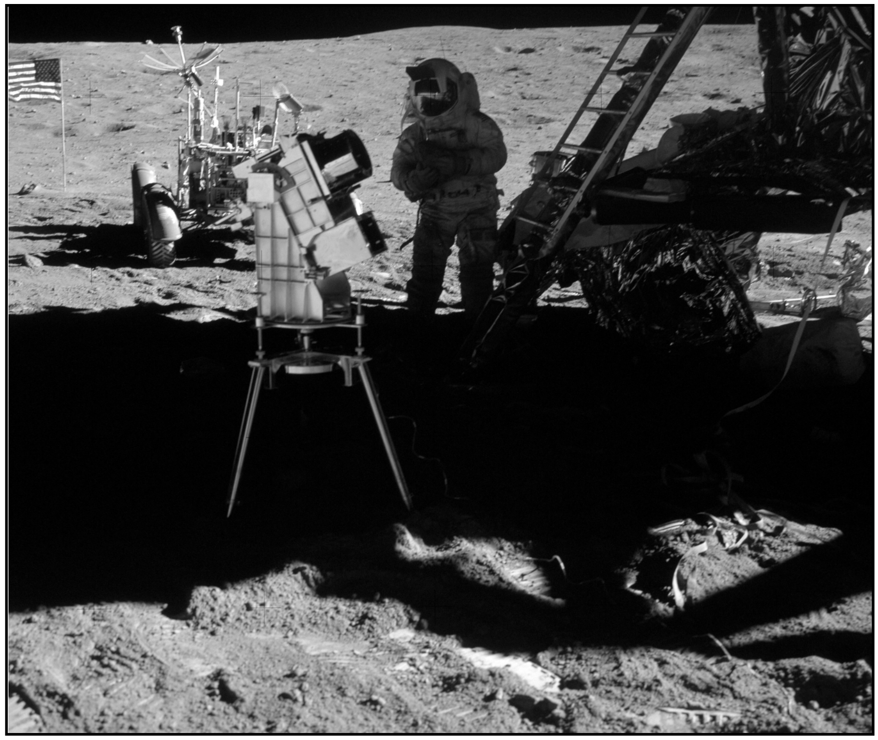
Carruthers: Well, molecular hydrogen, which is two atoms, is the form of hydrogen that we're most familiar with here on the Earth. Whenever you use hydrogen in a laboratory, it's in the form of molecules, but in interstellar space in the early 1960s, the only hydrogen that could be directly detected was atomic hydrogen because of its radio wave emission and absorption.



A ten-minute far-ultraviolet exposure of Earth, taken with a filter that blocks the glow caused by atomic hydrogen but which transmits the glow caused by atomic oxygen and molecular nitrogen. Note that airglow emission bands are visible on the night side of Earth, one roughly centered between the two polar auroral zones and one at an angle to this extending northward toward the sunlit side of Earth. The photographic number of the original black and white UV camera photograph is AS16-123-19657 [S72-40821].
Credit: NASA

But astronomers had hypothesized that molecular hydrogen must exist because of the fact that there were these dense clouds of gas and dust which did not show any atomic hydrogen, even though they had every reason to expect a lot more hydrogen in these dense clouds than in the more clear regions of space.

But back in those days, they had no way of detecting it directly, except in the far ultraviolet, and we just happened to be the first to do that. So that's the reason why it was significant. Later experiments, of course, expounded on that in much greater detail than we could possibly do. The *Copernicus* satellite launched by Princeton in 1972 was really the one that did the most work in that area.



Astronaut Charles Duke Jr., Lunar Module Pilot, stands in the shadow of the lunar module behind the Far Ultraviolet Camera/Spectrograph. This photograph was taken by John Young, Commander, during the second *Apollo 16* lunar surface EVA. The camera's gold surface is designed to maintain the correct temperature. The astronauts set the prescribed angles of azimuth and elevation (here 14 degrees for photography of the Large Magellanic Cloud) and pointed the camera. Over 180 photographs and spectra in far-ultraviolet light were obtained showing clouds of hydrogen and other gases and several thousand stars [AS16-114-19439]. Credit: NASA

Swanson: What did you find as being the biggest challenge over your career?

Carruthers: Well, the biggest challenge is finding money to do things. Nowadays, most of the funding for space astronomy and things like that comes from NASA, and they do that in response to proposals. For example, if you send in a proposal for a space mission, like *Hubble Space Telescope* or a planetary mission or a small Explorer satellite, there are usually thirty or forty proposals for each one that they accept and fund, so it's very difficult to break in to get money for that.

At the Naval Research Laboratory, since we are part of the Department of Defense, we are supposed to be doing things that are in some degree relevant to the military, and it's hard to come up with experiments that are both high-priority basic science, from the viewpoint of NASA, and also important from the military relevance point of view within DoD. So in that respect, we have advantages by being a DoD installation, but we also are somewhat disadvantaged in comparison to, say, a university, in proposing to NASA.

Swanson: Your educational background is kind of an interesting combination, being aerospace engineering as well as astronomy. Did you find advantages and disadvantages to that combination in your career?

Carruthers: Well, when I first came to NRL as a postdoc, it was definitely an advantage because most of the other postdocs who came in with pure science backgrounds didn't have any expertise in building spaceflight instrumentation or hardware; so they had to get engineers to help them in designing and building the hardware before they could actually do a spaceflight experiment. Whereas since I had backgrounds in both engineering and science, it helped me to know both what the scientific objective was and how to go about it with design of an instrument.

One of the things that has changed over the years is that now there's more emphasis on larger projects with larger groups and the demands that are made on the projects are such that you really need to have people who are specialized in structural analysis or thermal analysis or some other very limited field of expertise in order to get the instrument or the satellite built. And if you are both a scientist and an engineer, it makes it hard for you to fulfill that role. If you do too much work in the engineering area, then you don't have time to analyze the data from the experiment once it flies. To some extent that's been a problem for me, because when I write proposals, people say, "Well, what have you published in the last five years?" and the only response I can give is, "Well, we were very busy developing this instrument to fly on the Shuttle," or on the *ARGOS* satellite, or whatever it was we were working on. But they don't really consider that to be an excuse, so that's really the good and the bad of it.

Swanson: Would you recommend that path of education for someone that wanted to work their way up to a position such as yours?

Carruthers: Well, I would still say that it's good to get a broad background when you're at the early college level and the high school level, because you don't want to specialize too soon and cut off your opportunities to change to different areas of interest. So I always advise students to get a broad background in both math and science when they're in high school, and also in their early years of college. That is, not to overly restrict their outlook to, say, one specific field of science or one specific field of engineering, but try to obtain some expertise in all areas. Like you would take some mechanical engineering courses, some electrical engineering courses, some physics courses, that sort of thing.

Swanson: Others have moved from one area to the next, maybe ten years of NASA and then they move on to a university or some other area, but for you it's been pretty much NRL all your career. Is there a reason for that?

Carruthers: Well, actually, I have not seen any reason to go anywhere else, because, for the most part, NRL has been supportive of my activities, allows me to do a lot of things that I might not be able to do in a private industry kind of situation, and also we have better resources available here than would be possible in most university institutions. So I think that it gives the best mix of resources and handicaps of various alternatives.

Swanson: Going a little bit, I guess, philosophical, how do you feel about the direction that the space program is going? What are your feelings about the future of space exploration?

Carruthers: Well, I think the trend toward a lot of small missions, as opposed to a few large ones is a good one. Simply because when you have a lot of small missions, you can get a wider variety of people involved in them, and there's less lost if there is a launch failure. The time from start to finish on these individual missions would be much shorter, so you can carry out a wider variety, over a shorter time scale, of scientific investigations. Of course, there are some things that you can't do small, like the *Hubble Space Telescope.* It has to be big in order to get the image resolution that's required. So there will always be a mix between large and small missions. But here again, the real issue is funding, because the funding is really what limits what you can do. And although I don't really have any gripes against the *International Space Station*, I know that a lot of other scientists do, because they say that the money that's being used for that could be used better on robotic missions, but I think that you really need both kinds. And if there is an *International Space Station*, I'm sure that people will propose to do their experiments on it, even those who are against it right now.

Swanson: Focusing on Mars, which seems to be popular now, what do you envision, say, within the next ten, fifteen, twenty years?

Carruthers: Well, the focus for the near term will be on the unmanned missions, even including sample returns. The disadvantage of that, in the longer term, is that there are a lot of situations that really require human presence as opposed to telepresence—because of the fact that it takes half an hour for radio waves to travel back and forth between the Earth and Mars most of the time, and...computers are still not to the point where they perform autonomously and exercise judgment about what to explore.

So it's really the exploration of Mars that really requires the human presence to really go out there and dig around and sightsee and find a crashed UFO amongst all the boulders and that sort of thing, which a robotic mission would not be able to do very efficiently. So I think in the longer term, there will be return of—well, the first trips of humans to Mars, similar to the Apollo missions in 1969 and 1970s.

Swanson: Looking back at your career, what would you single out as being the most significant discovery or find in the field of space science astronomy?

Carruthers: Well, it would be kind of hard to come up with any one thing that would be most significant. Certainly, a lot of the discoveries being made with the *Hubble Space Telescope* are extending our reach of the universe by a very large amount. There is even more still beyond the horizon, like the next-generation space telescope and things like that, which will give us a much broader view and deeper view of the universe.

I may be biased toward optical and UV astronomy, but I'm also interested in infrared astronomy and things like that. Even though I don't directly participate in it, I can see the benefits of all of these missions. For example, I was asked to participate, by an old friend of ours, Martin Harwit, who used to be head of the Air and Space Museum, and who actually worked here at NRL when I first came here as a postdoc. I was on a team that was reviewing the NICMOS [Near Infrared Camera and Multi-Object Spectrometer] instrument on *HST*, which ran out of coolant, and they were planning to replace that with a mechanical cooling system. So I found that very interesting, as well as an opportunity to broaden my education about astronomy.

Swanson: What projects are you currently involved with?

Carruthers: The main activity right now is the *ARG*OS satellite, which was launched on 23 February [1999], and that's going to be a long-duration mission with a one- to three-year lifetime. Just the mission operations and data analysis for that will keep us very busy for quite a while. Now, of course, we will still be on the outlook for opportunities to propose missions beyond that. But unlike in the past where we were almost always trying to build something new while we were still looking at data from something old, I think the next few years will be sort of distinct, in that we won't really have any new flight projects in the works for a while. That doesn't mean that there aren't opportunities for student participation, because we do have actually a community outreach activity similar to the Moonlink program, in which the students will actually look at our data and work with it as well.

Swanson: Were you involved at all with the *Clementine* and the *Lunar Prospector* mission?

Carruthers: Not directly, in terms of actually participating in the science. The *Clementine* was actually built here at the Naval Research Laboratory, but it was done by the Naval Center for Space Technology as a contractor to the Ballistic Missile Defense Organization, so we did not have any chance here in the Space Science Division to participate in that.

The *Lunar Prospector* mission was strictly in the area of community outreach activities and education. One of our students did a highly rated project in the DC City Science Fair, which was last weekend, in which he demonstrated a method of extracting water from frozen soil at the lunar north and south poles, which was something he did in a vacuum chamber here in our laboratory.

Swanson: How did that work, the process?

Carruthers: The idea was to put heaters in the frozen soil, which has ice in it. As the vapor comes out, it condenses on a black plate, which is shaded from the sun, so that it radiates the space and stays very cold. The water vapor comes out and condenses as ice on the underside of this plate. After enough ice has been collected, astronauts can come and scrape it off.

Swanson: Basically harvesting ice from the Moon.

Carruthers: Right.

Swanson: Does it take considerable amounts of energy to heat the soil?

Carruthers: Yes, but energy is not really a problem on the Moon, because the Sun is out all the time, and near the north and south poles, one could set up a solar panel in an area where the sun shines, and transmit that electricity to the area where you need to heat the soil that's in shadow. So really, the problem on the Moon is there's no readily accessible water or oxygen or hydrogen, which are really the most important things that you need to bring from Earth...And that's, of course, very expensive. But sunlight is free on the Moon. You just need to bring solar panels.

Swanson: A while back I did a paper in which we had proposed an ultraviolet spectrograph on the poles of the Moon, the far side, particularly in one of the craters, so that there wouldn't be sunlight exposed at all. Do you know if there were any plans at one time to actually do that?

Carruthers: There have been a lot of proposals. In fact, I even participated in a workshop on that at University of New Mexico in Albuquerque about five years ago. There have been many studies along those lines, but so far no funding to build the hardware, simply because there really was no plan to return to the Moon until the *Lunar Prospector* mission this last year.

Swanson: Looking back again to Apollo, what were your feelings on...the fact that the later missions were canceled? They had plans of landing in Copernicus, I think, one of the craters on the far side of the Moon, as well. Then all that went to the wayside. What are your feelings on why the Apollo Program stopped and why there wasn't a more aggressive post follow-up manned missions to the Moon?

Carruthers: Well, I guess it had to do with the reason that it was done in the first place, which was to beat the Russians. Once the Russians were beaten, then the general public didn't see any reason to continue it, so that's really the reason why it was so abrupt. There was a very high level of activity until that objective was completed, but then once that objective was completed, it sort of passed away. Lunar science was never really the primary objective of the Apollo Program, although a lot was done during that mission.

Now that we have renewed scientific interest in the Moon, there might be justification for returning to the Moon with human beings to further explore it. In particular, as in the case of Mars, there are some things you can't do with robots. But the only problem is that right now it's a pretty low priority, because the Moon rates behind Mars in scientific priority right now, I would guess.

Swanson: Looking back at the overall science return from the Apollo Program, what are your feelings on the quality and the amount that was returned?

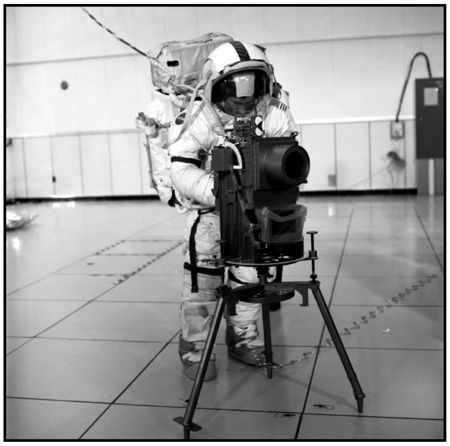
Carruthers: It certainly returned unique data, which could not have been obtained any other way. The fact that we have had so much time to analyze the data since then at the lunar science conference they have each year in Houston, now people have a much better idea of what they really should do next. The *Lunar Prospector* was just the first of those things that they felt that we needed to do next. Now the *Lunar Prospector* has returned data, it gives even more incentive to get back to doing some more lunar science. But just how it's going to rate in the overall mix of things, I don't know. I don't even know if Dan Goldin [then the administrator of NASA] has that answer.

Swanson: Many people refer to the [19]60s as kind of the Golden Age of unmanned exploration. Do you feel that's a fair assessment?

Carruthers: Well, I think that actually things have improved a lot since the [19]60s, in terms of the unmanned missions, simply because of the advances in technology. For example, if you compare the results from the current *Mars Global Surveyor* with the first Mariner missions, there's absolutely no comparison. One of the things that was remarkable was how quickly the *Mars Global Surveyor* debunked the face on Mars, because most scientists knew already that it was not a human artifact, but it was hard to convince people who were less knowledgeable. But the picture that was taken by the *Mars Global Surveyor* was so much sharper than the previous *Viking* images, there was absolutely no way that someone could imagine that to be a face on Mars. And that hasn't been in the tabloids yet. Of course, they don't want to publish that, because that makes their previous news look bad.

Swanson: Going back to some of the work that you've been doing with others in the outreach program, as a student entering the field of astronomy and space science, or wanting to pursue a career, what advice would you give him or her?

Carruthers: Well, the primary advice would be to get a complete but broad background in math and science. Nowadays, everything has become multidisciplinary. For example, there are no sharp divisions between chemistry and physics, or between chemistry and biology. For example, in space science, in particular, we have what we call astrobiology. So far, no one has any proof and evidence of life elsewhere, but the study of the origins of life on the Earth is one example of a multidisciplinary subject which requires physics, chemistry, and biology to understand. And there are a lot of other examples as well that require a broad range of expertise. So one really should get a broad education, but the computer aspects of it also need to be included. That was something that didn't even exist when I was in school. Because almost everything requires ability to use computers, not necessarily to program them or to design them, but just to be able to use them.



On 22 December 1971 Astronaut John W. Young, Commander of the *Apollo 16* lunar landing mission, participates in lunar surface extravehicular activity (EVA) training in the Flight Crew Training Building at the Kennedy Space Center. Young adjusts a training model of a Far Ultraviolet Camera/Spectrograph, an instrument that was emplaced on the Moon during the *Apollo 16* EVA. Deep-space sources of hydrogen in interplanetary, interstellar, and intergalactic regions will be mapped by this instrument which gathers both photographic images and spectroscope data in the far ultraviolet spectrum. This experiment will be the first such astronomical observation emplaced on the lunar surface [S72-19739].

The film holding assembly brought back from the Moon is now part of the Smithsonian collection [NASM T20150081000-PS01].
Courtesy: NASA

Apollo 16 astronaut John Young, center with left hand in suit glove pointing to the instrument, practices on the Far Ultraviolet Camera/Spectrograph during training at the Flight Crew Training Building at Kennedy Space Center on 12 November 1971. Dr. Carruthers is standing at far right. [108-KSC-371C-468-04] Credit: NASA

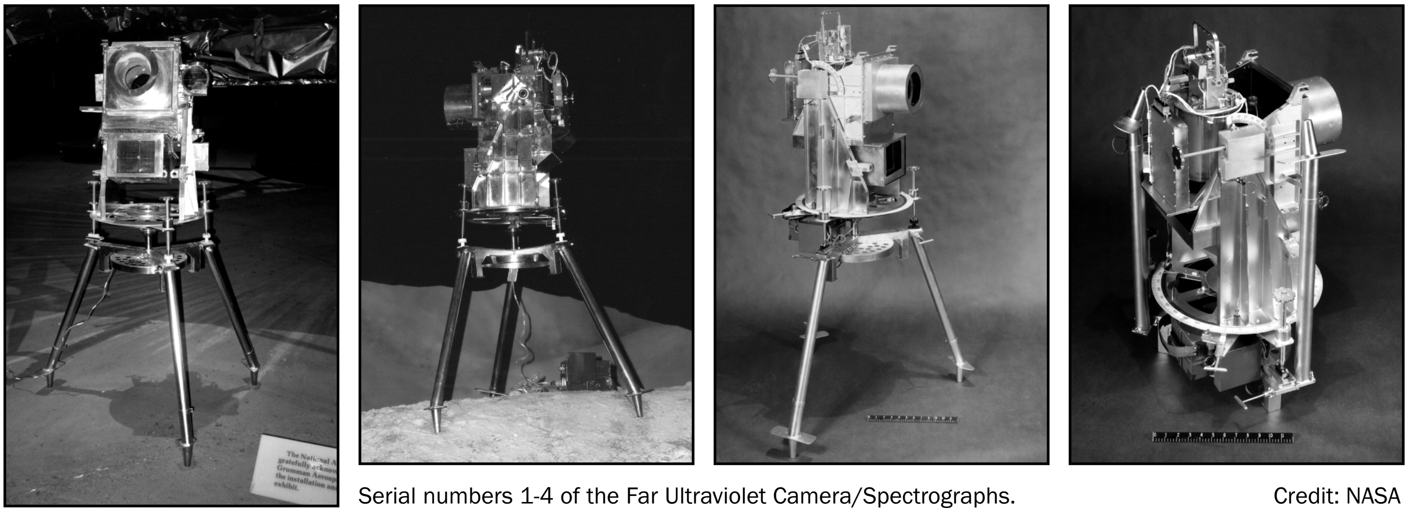
Swanson: Going back to Apollo and the program at the time, did you find that you had to justify at all some of the work that you were doing, in light of the civil unrest that was going on at the time; that this money should be used for food and housing and other programs, rather than the Apollo Program?

Carruthers: No, actually, I never had any direct involvement in that. Of course, I read about it in the newspapers, but one of the things that we always point out about the space program is that it's less than one percent of the federal budget. Even in the Apollo days, it was only like two percent of the federal budget, and a much larger percentage is spent on welfare and housing and that sort of thing. So canceling the space program altogether would only add a small percentage to the funding available for welfare and housing.

I never had to defend it myself, specifically, but I know that that was something that people were concerned about. Nowadays, of course, it's even a much smaller percentage of the federal budget, the space program. In fact, Dan Goldin actually has made a point that he's been able to do things with a reducing budget at NASA, as opposed to an increasing budget at NASA, relative to the gross national product.

Swanson: As far as science goes, the actual process used in research and development, what has changed the most from when you first started?

Carruthers: Well, the process in general has not really changed all that much, but the advances in technology have made a lot of things easier and faster. For example, with word processing and the ability to store images in electronic form, and even do electronic publishing, have made start to finish a lot faster. You don't have to—I still remember when we used to write proposals for the Apollo mission, if you made a mistake on one page, the secretary would have to type the whole page



Serial numbers 1-4 of the Far Ultraviolet Camera/Spectrographs. Credit: NASA

The *Apollo 16* Far Ultraviolet Camera/Spectrograph

by Glen E. Swanson

Four Far-Ultraviolet Camera/Spectrographs were supposedly built for the Apollo Program. These cameras were identified by their serial numbers 1 through 4.

Serial number 1 was used for training and is currently located at the Naval Research Laboratory. The instrument on display at Space Center Houston is serial number 2. This camera belonged to Dr. Thornton L. Page at NASA's Johnson Space Center who was the co-investigator with Dr. George Carruthers on the *Apollo 16* project. Among other uses, the engineering unit would have been the instrument subject to testing and may have been tested in the thermal vacuum chamber at JSC to make sure it qualified for use in the harsh conditions of space.

Camera with serial number 3 was flown to the Moon on *Apollo 16* where it remains today. A flight backup camera, serial number 4, is on display at the National Air and Space Museum.

In 1992, the Smithsonian's camera was loaned to the NRL so that Carruthers and his students could restore it prior to putting it on display next to the Lunar Module in 1993 at the National Air and Space Museum. In a recent e-mail exchange, David DeVorkin, senior curator, history of astronomy and the space sciences at the Smithsonian who worked on the restoration project of the camera with Carruthers, acknowledged that in the past there was some question about how many versions existed of S201, the model camera used in Apollo. He confirmed the whereabouts of the fourth camera, noting that in 1981 they acquired a second "back-up" camera, a less detailed version, that they de-accessioned it to the Naval Research Laboratory, where it remains on exhibit. DeVorkin notes that they refer to the camera on display at the Smithsonian as a "reconstructed back-up engineering model." When they restored the camera in the early 1990s Carruthers detailed what was added or removed to it in a letter dated 6 March 1993:

1. Items which were manufactured as replicas of the missing originals were the camera mounting plate, corrector plate motor drive motor enclosures and control electronics box (simulated by solid blocks of aluminum), and miscellaneous small parts.

2. Items which were replaced by similar, but not identical, hardware on hand as *Apollo 16* prototypes or hardware for other flight experiments, include the camera assembly (including magnet) and high voltage power supply.

3. The film transport assembly on the display unit is the actual flight unit which went to the Moon and back on *Apollo 16.*

The following items are not included in the display model because they would be internal components not visible from the outside, and/or because replacement items would be difficult to obtain or manufacture:

1. Camera internal optics (primary mirror and photocathode).
2. Corrector plates, holders, and drive mechanisms.
3. Motor input power filters (would attach to motor drive enclosures) and power input cables.
4. Electrical wiring and mechanical parts for which sufficiently detailed first-edition documentation was not available.

In his 25 March 1999 interview, Carruthers noted that, "The actual camera from the backup module was used in Skylab, so we had to remake a model of the camera for the display at the Air and Space Museum." So what camera was used in Skylab? DeVorkin notes that the Skylab observations were imaging only so the astronauts during that program may have used only the camera component of the Apollo camera not the entire instrument.

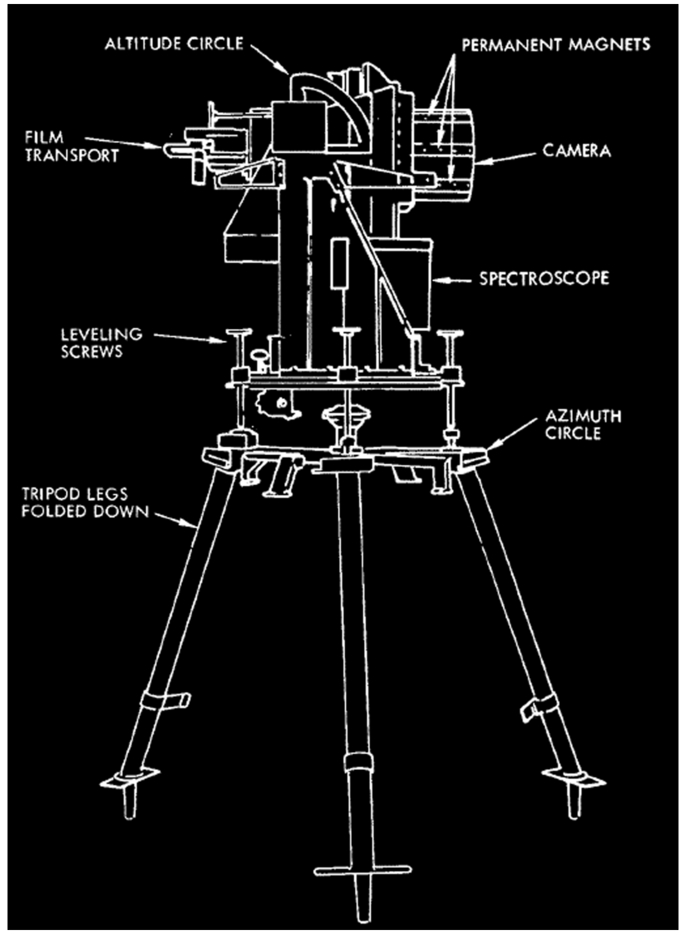
over again, that sort of thing, and it was really a very slow and laborious process.

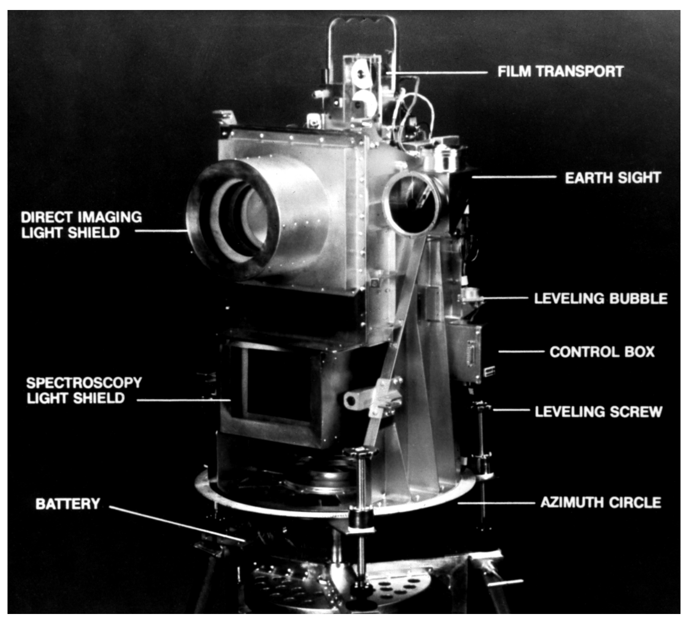
Nowadays, with word processors, not only is it faster, but, actually, the quality of it is a lot better too...

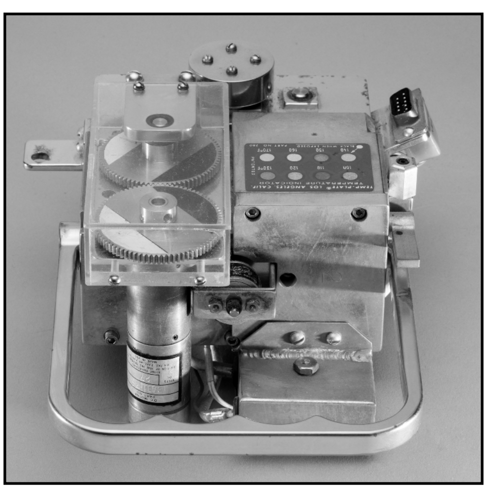
Now, as far as the process of doing science, that also has had a major impact from the computer side of the house, in both the acquisition of data and in the processing of data. One of the things that became apparent to me in the late [19]70s was that the kids were ahead of me in terms of their expertise in these things, because they were using AutoCAD and I was still using the T-square to draw things. So I had to learn from them about using AutoCAD and word processing and things like that, because they learn it in school, whereas I didn't have anything like that when I was in school.

Swanson: I've often found in circles where they speak of the internet and computers in general, that the speed at which information is being distributed is much more rapid now. So there's a lot greater pressure for scientists to more rapidly publish their results and get their information out, because of the "publish or perish" syndrome—the competition for dollars and sharing the limelight, basically, to get your information out there first. Do you find that that is an advantage or a disadvantage?

Carruthers: Well, it's an advantage in some respects, but one of the drawbacks, which a lot of people have noticed, is that sometimes people aren't very careful with what they put on the web or in e-mail messages. When you publish in a regular journal, everything has to be peer-reviewed and an editor goes over it and there's a minimum number of mistakes in a published hard-copy version. Whereas some of the stuff that you get as e-mail messages or websites has blatant errors. Where it's obvious that whoever wrote it didn't take the time to proof-







Above and Left. Details of the Far Ultraviolet Camera/Spectrograph. Credit: NASA read it before they put it out. So the fact that there is no censorship of the internet makes it a disadvantage. In some cases, it may not be a problem, but in other cases, it might be.

Swanson: Maybe this is out of your area of expertise, but one question that I've touched upon in the work that we're doing right now for the thirtieth anniversary of *Apollo 11* is, what have we learned directly from Apollo about the Moon. In subsequent missions, particularly *Clementine*, *Lunar Prospector*, and others, can you summarize more directly what we learned about the Moon from Apollo?

Carruthers: Well, I think we learned quite a bit about the Moon from Apollo, that we didn't know before, because of the fact that they were able to return samples, not just one kilogram worth of material, like a robotic mission could have done, but 400 pounds or even more, which had a much broader variety. Also the fact that the human being can select which rocks are different from others, and comment on them over the microphone if they can't write it down. So that the accuracy of location on the Moon of these samples is a lot better.

They also had the opportunity to explore different regions of the Moon, like in the mountains and in the plains, to compare the different soil types. As I mentioned before, even now, they're still trying to make sense out of all of this data, but the big advantage of that time lapse is now they have a much better focus on what they need to do next. So that by analyzing the Apollo to the greatest extent possible, now they know that the polar orbit kinds of missions like *Lunar Prospector* are really the next step, as opposed to those Apollo missions, which really sampled only the equatorial regions of the Moon.

Certainly we're a lot further ahead understanding the Moon than in understanding Mars, for example, where the data has been much more limited, even though we have more advanced technology. But...after these next few missions get their results on Mars, it may be getting closer.

Swanson: During Apollo, the science missions basically occurred on the later flights, mostly in response to the scientists themselves who were objecting to the fact that they knew that there was a limited number of missions and we need to gather more science. Other than the *Apollo 16* proposal, were you concerned that we weren't getting the science that we should?

Carruthers: No, simply because back in those days I really didn't know that much about lunar science in general. The astronomy that we were doing was really quite separate from what most of the scientific mission was about, which was the Moon itself. See, we weren't involved in studying the Moon, so I really could not really judge that. In fact, the only reason that I have somewhat broader knowledge of lunar science now than then was not because of any experiment I did, but because of the community outreach, where we have to educate students about a much broader range of topics than what we do specifically.

Swanson: The instrument itself was basically designed separate, to be assembled by the astronauts. Was there any consideration given to building that into the side of the lunar module or having it fixed, rather than as a separate instrument?

Carruthers: No, simply because it would have been impossible to do that and still get the kind of sky colors we needed. Actually, we designed it so that the astronauts did not have to do any assembly. All they had to do was offload it and set it up on the tripod and do some alignment. We were warned well in advance to make it simple for the astronauts to do because they had so many other things they had to do during the mission. And they didn't really have time to learn in great detail how our instrument worked.

Swanson: So it was basically pointing it in the direction and then shooting it. Then they returned after a period of time and would point and shoot according to a schedule?

Carruthers: Yes. So it really was a more complicated version of their Hasselblads, in that they were just there to use it, not to really do any science of their own.

Swanson: And then the retrieval of the film itself, that happened last?

Carruthers: Yes, that was last. And also, they didn't have to bring the rest of the instrument back, so they could just leave it there. All they had to do was take out the film transport and put it in their bag and leave.

Swanson: Make sure they didn't forget that film. [Laughter]

Carruthers: Right.

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