# ORAL HISTORY TRANSCRIPT

RICHARD H. BATTIN
INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: Today is April 18, 2000. This oral history is being conducted with Dr. Richard Battin in Lexington, Massachusetts, for the Johnson Space Center Oral History Project. Interviewer is Rebecca Wright.

Thank you again for letting us into your home. You were so vital in the success of the systems for the Apollo spacecraft, but tell us, how did your interest first begin?

BATTIN: Okay. I've done all of my work at MIT [Massachusetts Institute of Technology, Cambridge, Massachusetts]. Started there as a freshman in 1942 and never left, except for a couple of years. I did my undergraduate work in electrical engineering and my graduate work in applied mathematics. I graduated with my doctorate in 1951. It was not a good time to look for jobs. I interviewed at various places and never really was very excited about anything that was available.

Then a friend, who lived in the same little graduate housing complex, knew I was looking for a job, he said, "Why don't you interview at the MIT Instrumentation Laboratory."

I said, "What's that? Never heard of it."

So I did, because it would have meant if I worked there, that I wouldn't have to move. [Laughter] I didn't want to have to move or leave the area.

So I was interviewed there and they hired me. If Lenny King had not lived in that same little complex, and if I hadn't been talking to him, I don't know where I would have gone. I was not going to apply to a laboratory that I'd never even heard of. So that was, I think, the luckiest day of my life. [Laughter]

The person…who was [to be] my boss, was on vacation, so I spent two weeks at the lab just sort of sitting there in his office waiting for him to come back from his vacation so that he could get me started on something. That person was [J. Halcombe] Hal Laning. He was my mentor and we worked together for many, many years. We wrote papers together, we wrote a book together, and even today we still play tennis together. [Laughter] So I've known him essentially forever.

In the early days when I was at the laboratory, we were working on classified guidance systems. The big one was to provide a backup system for the Atlas intercontinental ballistic missile, which was a 5,000-mile range. The job that the laboratory had was to provide a self-contained, that is, had no communication with the ground or received no commands from the ground, just navigated itself while the engine was on. [At the proper time]…the engine [thrust] terminated, and the missile [would] just coast to the target. So our job was to guide this missile and to calculate when to turn off the engine and what direction to point [it]. So that was really [our] first major guidance activity which had anything to do with space.

…We couldn't look in any textbook to find out how to guide a missile. I mean, no one had ever really thought about doing it, especially how to guide a missile in an onboard system. So we just had to create a…method. It actually became very famous… It was known as the Q-guidance system. Q didn't mean anything, except it was [a] particular symbol we happened to use for a fundamental matrix that appeared in the system.

It was classified secret, and it actually was never used for the purpose for which it was intended. It didn't fly on the Atlas, but it was used on the Thor, which was an intermediate-range booster missile. It was also used [for] Polaris, the sea-launched ballistic missile for the Navy program, and it really formed the basis of our understanding about guidance, at least how and what kinds of computations that you would have to make on board.

…[This] was in the 1954-'55 era. Then I made the big mistake of thinking that other pastures should be explored, they might be greener. I like to tell people that the worst mistake I ever made was to leave MIT. I went to work for [the] Arthur D. Little [Corporation], which is a consulting company. I was in the operations research group. I thoroughly disliked the whole thing, primarily because none of the jobs that I was assigned to do were very interesting to me, [but] I should be interested in them…because the customers were willing to pay for [the work].

There was an awful lot of travel, which I hated. When I looked at the people who were farther advanced than [I] in the company, they traveled more. So the only thing I had to look forward to was more travel and working on projects that I really didn't enjoy, [like] inventory control, nothing that I really had been doing at the Instrumentation Lab.

Fortunately, the Russians launched their Sputnik in October of 1957. I remember standing out in [my] driveway, getting up early in the morning, and it was cold, and straining my eyes. I did see the Sputnik fly overhead a few times.

…[I had] been staying in contact with Hal Laning, of course. He was, as I said, my mentor, and Hal was telling me that he was flying round trips to the planet Mars on the MIT computer. …That really made me…homesick. I wound up [my] affairs as quickly as I could to go back to the laboratory. So the best decision I ever made was to go back to MIT. [Laughter]

The [project] that was inspired by Sputnik [at our lab]…became known as the Mars Probe. There were a few of us who were trying to…[design] a spacecraft…and the guidance system…[for a] round trip flight to Mars, take a picture of the surface, and bring that picture back. We suspected that if we were [ever] going to get into the space business, we ought to do it [now]. Rather than sitting there waiting for somebody to ask us to do something, we'd…make a dramatic proposal…ourselves.

We had an Air Force contract to work on ballistic missile [guidance] systems… Fortunately, there was a little clause…that said we could…[devote some time on] any…thing that might be interesting to us that was relevant to guidance. …We couldn't make a big project, but there were about three or four of us that [could be] funded under this [contract]. Today they [would] call it IR&D…

We actually built a model of the spacecraft and did all of the preliminary work… Hal and I were calculating the trajectories to Mars and…testing guidance [techniques] that could be [used] on board the spacecraft, because this spacecraft was certainly not going to be controlled from the ground. All of the abilities we have today to track [objects] didn't exist then. We couldn't even get cooperation from the astronomers. We…talked to people at the Smithsonian Astrophysics Observatory in Cambridge, and they thought we were crazy. They [asked], "How [are] you going to go to Mars? You don't even know where Mars is."

And they were right. At that time with ground-based telescopes, the uncertainty as to [the location of] Mars was about 20,000 miles. You knew that Mars was somewhere in a circle of…[20,000 miles] diameter. They never did understand that we were not going to rely on…ground-based measurements, that we were going to make those measurements on board the spacecraft. …I don't [need] to know the latitude and longitude of New York City to get there. I can just drive there, as long as I can see where I'm going. I don't need somebody in Boston to tell me where I am and how fast I should be going and where I should be pointing. I just look for New York and [steer for] it.

…As a matter of fact, the year before Sputnik was launched, the Astronomer Royal in Great Britain made the mistake of saying, "Space travel is utter bilge. Don't even think about it." …[Laughter] Yes, I'm sure he probably regrets, if he's still alive…having ever said that.

We worked on this [project], and…wanted to present [our findings] to the Air Force. …We'd done all the preliminary design, and we wanted to go ahead and build the spacecraft. The Air Force said, "We're not in this business anymore. There's [a] new government agency called NASA that you've got to go talk to, because they're in the business of flying spacecraft…[not us]"

So we went [to Washington] to talk to Hugh [L.] Dryden…[the deputy Administrator of NASA]. [Telephone interruption.]

…We happened to arrive on the same day [as] Nikita [Sergeyevich] Khrushchev…so all the…top NASA people were…doing the things that were necessary for satisfying the protocol of a visiting official, especially a Russian one.

But the people we did talk to thought we had done a nice piece of work. They did not…give us a blank check…but they did offer us some…study money to…refine some of the things that we had talked about.

So we came home with…mixed emotions. We were really disappointed. We were young and naive and expected that they would say, "Hey, this is great. How much do you need? Go ahead and do it." But, of course, that didn't happen.

The wooden model of the spacecraft is part of the archives of the laboratory, the Draper Laboratory, which is the name that the MIT Instrumentation Laboratory became when it was spun off from MIT. That model [is] hanging from the rafters in…the museum area of the lab. …It was the most famous spacecraft that never flew. [Laughter]

But [of] all of the things that we needed to guide that spacecraft, the onboard computer was the most important. …MIT's Whilrwind computer was housed in an enormous building, and it had very little capability. It had 1,024 16-bit words of memory. When they turned [the computer] on, they had to first notify the Cambridge powerplant, because it put such a [strain] on their system that they had to be prepared for this. So you have a very primitive computer that's using enough power [for] the city…[to be concerned]. That was the state of the art in computers, and for us to even be talking…[of a computer to be carried in a small spacecraft seemed quite far-fetched. Therefore,] some of the study money…[from

NASA] was used…to perfect [an] on-board flight computer. It actually was the grandfather of the Apollo guidance computer.

The…study money that we were given…sounds pitifully small…[today]. They gave us a six-month contract funded for $50,000. [Laughter] Which was enough to keep a handful of us occupied, but it never really amounted to anything until the Space Task [Group] was…[organized] by NASA. They [were] expected…to make [a] proposal to the President about what the country ought to do. We attended, by invitation, some of those Space Task Group meetings and told them some of our ideas.

Bob [Robert G.] Chilton, who was at Langley [Research Center, Hampton, Virginia] at the time and had a title like flight control chief, was really very interested in what we were doing. He wrote a letter, which he gave me a copy of a few years ago…recommending that we…[be included in the Apollo project]. (They were…using the word "Apollo" even before [President John F.] Kennedy announced it.) He said that the kind of work that MIT was doing was really exactly what was needed for the Apollo Program, because Apollo was not going to [depend on] communication with the ground. The Russians might interfere with the communication link, and so we would have to…navigate to the Moon and back, self-contained, autonomous…[and not] endanger the lives of [our] astronauts.

We always thought that…was the…[reason for our selection for] Apollo, but everybody who was involved has their version of the story. Doc [Charles S.] Draper had his [story]. He [personally knew] Jim [James E.] Webb. Jim Webb was the NASA Administrator at the time. Jim Webb was not a technical person; he was a lawyer. He was, I think, one of the top NASA Administrators, primarily because he said to us, "Don't expect me to make any technical decisions." He said, "Hugh Dryden is my man. He'll make all the technical decisions." He said, "The thing I'm going to do for you is get money out of Congress. You need that, and I know how to do that, and that's what I'm going to do." [Laughter]

So anyhow, as I said, Draper and the new administrator were friends, so he got a call from…[Mr. Webb]. He said, "Dr. Draper, you know we have to build a spacecraft to go to the Moon."

"Yes."

He said, "I think that the guidance system…[is] one of our hardest problems." Do you think that you could help us with that?"

And Draper said, "Yes, of course."

He said, "Well, when…would the system be ready?"

Doc said, "It would be ready when you need it."

Webb didn't know what else to ask. He said, "So how [will] I know [if it will] work?"

Doc said, "I'll volunteer to go [along] and fly it for you to the Moon." So that's Draper's story. If anybody would ask him, "How did you get into Apollo [program]?" he'd always tell that story.

But the truth of the matter is that exactly eleven weeks after Kennedy announced that we were going to go to the Moon in this decade, the first…[NASA prime contract was] signed with the MIT Instrumentation Laboratory to build the guidance and navigation system. That was in August of 1961… First you have to realize that the MIT Instrumentation Laboratory could not bid on jobs. It was nonprofit, and they…couldn't compete. They could only be asked to do a job. If it were a matter of competing with…other companies, write a proposal, we couldn't do that. All the work that the laboratory had ever had was by…the government…saying, "We want you to do such and so."

So there was no competition for the job…for the guidance and navigation system for Apollo. It was by fiat given to the MIT Instrumentation Laboratory. We had demonstrated—I mean, they had lots of ammunition to defend that decision, because we had done a lot of work on self-contained guidance systems, and even though it seems unbelievable today, the Apollo system was going to be totally self-contained in its original design.

…We had a contract, [but] there was no work statement. In fact, the whole thing, I think, was eleven pages. We had to give them a proposal for what we were going to do, and I think it was eleven pages. Today, you know, [they would require] volumes of preliminary designs. We had no idea how we were going to do this job, other than to try model it after our Mars probe. As it turned out, all of elements of the Mars probe were replicated in the Apollo spacecraft, with the exception of the attitude control system. The attitude system in the Mars probe was angular momentum wheels… By transferring momentum from those wheels to the spacecraft, you could roll the spacecraft and point it. But in Apollo, they used little attitude thrust jets that would do the same thing.

In the Mars probe, we had a telescope…to measure angles between stars and planets. We had the little computer, which would process all the measurements and give instructions to the attitude system…to orient the spacecraft, and then we had a small rocket…that would make course corrections. All these things were part of the Apollo guidance system.

…At the time we signed the contract, the guidance computer, which we'd been working on with the study money, had 4,000 words of 16-bit memory, which was read-only, and 250 words of volatile memory, or RAM, random access memory… That's very small, by any standards. It was small even then. So we found ourselves…[on the defensive]. How in the world can you possibly do this job with such a small computer?

Well, our [reply] was, "We don't know what the job is, but this is the computer we have, and we'll work on it, we'll try to expand it, we'll…do all that we can. But it's the only computer that anybody has in the country that could possibly do this job…whatever this job might be."

We were in the process of…[defining] what the guidance and navigation system requirements were. We didn't get…requirements from the government. We had to…convince the customer that we were doing the right thing. They would…visit us, and we'd…visit them, and we'd tell them what we were doing. It was really a relationship which was unique and I don't think will ever happen again.

WRIGHT: Was there a lot of trust from the NASA side that—

BATTIN: Certainly. We were all in this boat together. Kennedy had told us what we were going to do, that was the goal…[but] the lunar orbit rendezvous [scheme had not been proposed]. That wasn't even thought [of] at the time we started work. We didn't know whether we were going to be on a spacecraft that was going to be launched from Earth to the Moon, landing the whole [spacecraft], and then flying the whole [spacecraft] back…

People started talking about…rendezvous. We were thinking [that] we'd have to do Earth orbital rendezvous, that is, put the spacecraft together in Earth orbit if it was going to fly to the Moon. It was only later, a year or so later, that the idea of taking only a part of the spacecraft and landing it on the moon while the rest of it was in orbit, in other words, the [concept of the] command module [CM] and the lunar module [LM] was born after we'd been working on the job for well over a year.

So when that came about, then the question was…[do we] need a whole new different guidance system for the lunar module than we have for the command module. What are we going to do about that? We convinced [NASA to]…use the same system in both spacecraft. They have different missions, but we could put a duplicate system in the lunar module… So that's what they did.

One of the big worries…[was the reliability of the computer]. The computer was the brains of the system. What if it failed? We [would] need a backup computer. …[But] the spacecraft designer, North American Aviation, it was called then, had already designed the command module. They asked us how big the guidance computer was. We told them, well, about a cubic foot. How much does it weigh? A hundred points? We were just guessing.

By the time they started worrying about whether we should have two of these systems, they had asked North American, "We want to double the space for the guidance computer, because we want to put two of them in there." And North American said, "What do you mean? You can't do that. The spacecraft's designed… We have weight budgets. We can't put an extra hundred pounds of stuff in there. There's no space for it. What are you talking about?"

…Well, maybe we could do in-flight repair. Astronauts are going to be able to replace modules if their [computer] fails. …[Others] who were more realistic, said, ["How are astronauts going] to repair a computer [in their clumsy suits]? …[And] you'd have to have spare parts. You [would] need a lot of training to do this. That's not acceptable."

The decision was made that we'll just have one computer and there will be no redundancy. We're just going to make this computer reliable. Today…you'd be thrown out of the program if you [said] you're going to build it so that it doesn't fail. But that's what we did. …The computer was…[designed using a single] circuit…called the Norgate. Actually, the Apollo guidance computer was the first computer to ever use integrated circuits.

When the Draper Prize was first announced ten years ago, it went to the two gentlemen who developed the first integrated circuits. They were not members of our laboratory. But [the] first flight computer that ever used integrated circuits, was in the Apollo guidance system. So the idea was to use just a single circuit, because then your supplier [c]ould learn how to make [just] that element… We'll make the whole system very simple from the manufacturer's point of view.

So we screened these little elements, and the computer was [assembled] by Raytheon. We did the design, but Raytheon did the manufacturing. They were close enough [to MIT], they would come work with us, we'd send some people out there. The whole idea was to make a computer that would not fail, and it never did fail. We never had a computer failure [in] any of the flights.

Neil Armstrong, after his flight, he never flew again, I suppose for the same reason they didn't want John [H.] Glenn [Jr.] to fly again, because he was an icon. You don't want to risk his life. [Laughter] So they gave him a desk job in Washington [D.C]. He was in charge of the—I forget the title, but he was in charge of new systems and aircraft systems, primarily.

One of his projects was called the F-8 fly-by-wire system. The F-8 aircraft was going to be an experimental plane so that a digital computer would fly the airplane. …[When the pilot] moved the stick he wasn't controlling any of the flight control systems directly, he was merely sending digital signals through a wire, that's the fly-by wire, to control the ailerons and elevators and what have you. But he had no direct control, so if the computer failed, the plane crashed.

The computer was going to be a computer developed by IBM, and it was going to be a triplex system, three computers. Actually…the idea was to test [these computers] in this F-8 system, because they would be part of the shuttle. But the IBM computers were late. They wanted to fly the F-8, and so they asked Neil, "What shall we do?"

Neil said, "Well, the most reliable computer I know is the computer that took me to the Moon." And he said, "Couldn't we use one of those computers to fly the F-8?"

Well, everybody thought he was crazy. They said, "How are you going to do that?"

He said, "Well, get a hold of MIT and see if they can do that."

So we actually did exactly that. We took—and it wasn't even a new computer. We took a computer out of a spacecraft that had already flown a command module, and we sent a team out to the West Coast, installed this computer, programmed it. They had only one computer, just [as] in the Apollo system, and they flew the F-8 for quite a while, till the IBM computers were [ready]. Then they took the Apollo computer out and put in three IBM computers, because they didn't have the reliability that this machine had.

The bad thing about it, at least the allegedly bad thing about the Apollo guidance computer, was the memory. Four thousand words was clearly not enough. But the memory was a unique system called a core-rope memory. The nice thing about it was that it was a mechanical memory, it was electromechanical, which really meant that you could not lose your memory. That is, if you had an electrical failure, you would not lose your memory. …[The memory consisted of] little magnetic cores, and one core could represent an entire word, and you'd have sixteen sense wires. Now, if one of those sense wires threaded the core, it would be a one, and if it didn't thread the core, it would represent a zero. So you could store a 16-bit word in this configuration, a single core [with] sixteen wires. Then when you wanted to read the word out, you'd just switch the core, and those sense wires that [threaded] it would read out ones and the rest of them would read out zero. …The only way you could lose your memory is if you destroyed it physically.

We learned also how to go even further and get more sense wires through these cores, and wound up with a single core holding several words, not just one. [With] little breakthroughs like that and learning how to…make the core smaller, we were able to get more memory. So instead of 4,000 words, we wound up with about 36,000 words. If you use the nomenclature of today, the Apollo guidance computer had 72 kilobytes of memory. …[Today we have] megabytes and gigabytes. [But] this was 72 kilobytes. …Several copies of the Apollo guidance memory…[would fit in a modern floppy disk]. That's how little [memory] we had.

The thing that NASA didn't like about it is the fact that although the memory was reliable, you had to very early on decide what the computer program was going to be, because…[it took time to] manufacture these ropes. I mean, somebody had to put the wires through all these little cores, and it was literally done using the LOL method—Little Old

Ladies—who sat there with something that looked like a weaving machine. They would…push a probe through, and they had to, in essence, thread those cores by hand.

One of the clever engineers [had] adapted a weaving machine to do this job, but even so, it took several weeks to manufacture [the memory], and then [it] took [several] more weeks to test it. If there were any errors, then, of course, you'd throw it away and…start over. So it took about six weeks to manufacture and test a memory system.

[NASA asked] "What if we had a…last-minute change?" We said, "Well, [we] can't have last-minute changes." Anytime you want to change that memory, you built in a six-week slippage, minimum. Well, this is intolerable. We can't [have] that. Well, that's the way this computer is. What do you want to do about it? There isn't any other computer you can…[use]. They were furious. [Laughter] "We can't operate like this."

Well, actually, we did learn to do that, and what it meant was that we had to do an awful lot of testing of the Apollo computer… We had the entire Apollo computer simulated on a big computer, so that every cycle, every step, was an exact simulation of the Apollo computer.

So we could design the memory and test it by…simulation. …[We would] use that simulat[or] to prepare the wiring instructions for making these cores at Raytheon. They would make them and then we would…essentially plug this core memory into the big computer to make sure it works. …[To make] absolutely certain that the simulator was simulating the exact situation was a big effort.

Then when they finally manufactured it and…put the memory into the real computer, you could be 100 percent sure that everything was okay, that the computer memory actually was what had been tested on these large, big room-size [simulators]. So that was the scheme. NASA never really liked it, but it did put a certain amount of discipline into [the process].

You [would] not…release a design for manufacturing unless you were absolutely sure that you had done all the testing that was required, because you knew that you couldn't make any last-minute changes. As I say, NASA never really liked that, but, in fact, if we had had any other kind of memory with only one computer and…you had an electrical problem which [could] erase the memory…there was no way of uploading that memory from the ground.

When changes were made to the erasable portion of the memory, they were not sent up; they were voiced up. The astronauts would…key these changes into the erasable memory. There would have been no way they could have loaded 36,000 words of memory by hand or any other way. There was no mass storage capability on the spacecraft…

Apollo 12, [Charles] Pete Conrad's flight, was struck by lightning, and it did cause us to lose a lot of the erasable memory, which had to be reloaded. It caused the inertial system to tumble. It [c]ould have been a disaster. [NASA was] so worried about this, that it was a very tough decision: "Are we going to go to the Moon with this system?" …We know is it's been struck by lightning. We didn't know what happened to it. But the fact that they could get the computer up, and they did this in just a very short time, and it was running fine. The mechanical memory wasn't harmed by this electrical surge, but everything worked. So I guess Pete convinced them that, "Let's do it. Let's go. We haven't got any problems." Any other kind of memory, it could have been a disaster. We might not even have been able to [bring] them [back to earth] if we'd lost the memory.

WRIGHT: As you were constructing this, as you mentioned, you didn't have requirements, never had been done before, now you were working with a new agency. Would you share with us the communication level? How are you able to find what the priorities were? Because all of this that you were doing, you were doing in a time constraint, as well.

BATTIN: …Aaron Cohen was a junior engineer at NASA. He was assigned to monitor what the MIT Instrumentation Lab was doing with their navigation system. So that's how I got to know him. He would come to MIT, and we would show him what we were doing. Then he would ask questions, and we'd discuss things, and he became an expert on the Apollo navigation system. Then he would go back to reassure the NASA folks that was all under control, don't worry about that.

…For every system, every piece of the software, major component of the software, there was some NASA expert who became an expert…by worrying about the same problem we were worrying about. They'd come up and we'd talk to them. So we became great friends and confident in each other. He had to relay a confidence to his bosses at NASA, and he could do that because he understood the system and came up and helped us. The fact that we had to convince other people was good for us, too, so we weren't just talking to ourselves. We had to convince the customer that what we were doing made sense.

So that was the first contact I ever had with Aaron Cohen, and the rest is history, as they say. Aaron had a unique…[career at NASA]. It's like starting out in the mail…room and becoming the chairman of the board. Well, that's Aaron. He started out as a young junior engineer and then wound up as the center director. [Laughter]

WRIGHT: Well, because everything was new, everyone did start on the same level.

BATTIN: Nobody really knew what to do, and it was sort of invented in real time. If the system had been done as we would do it today, that is, someone from NASA was going to write out the requirements, detailed requirements, they wouldn't have been able to do that. We had one requirement: take man to the Moon and bring him home safely. That was our requirement. Detailed requirements had to come as we better understood [the problems].

We were able to make decisions without consulting a lot of people. I remember when Ray Alonzo was responsible for the core-rope memory. He and Hal Laning were the two key people who developed that core-rope memory. I remember Ray stopping me in the hall one time and he said, "Hey, I've got a great idea of how to communicate with this computer."

The noun-verb communication, the design of the display panel and the keyboard, he just showed me this. He said, "What do you think of this?"

And I looked at it and said, "Well, it sounds good."

Today you'd have to have a big committee, and they would have to go through every [decision]…"Have we considered this way of doing it versus that way?" [To] get forty people in the room and try to get them all to agree on some design. It never would have happened.

WRIGHT: You mentioned, or used the term "handful," there were a handful of you [working on the Mars probe]…at MIT [before Apollo]. How many?

BATTIN: No more than five. Less than five.

WRIGHT: And your communication was continuous.

BATTIN: We were working in the same building, in the same space, so we didn't have to keep elaborate records or memos. Everybody knew what everybody else was doing. We just did what was necessary.

WRIGHT: A lot of long hours. Were there a lot of long days or did you try to stay on—

BATTIN: As a matter of fact, in those days I was very discouraged, because it didn't look [as if] we were [n]ever going to be doing anything except little studies that nobody was going to really fund us to do something real, so it was sort of hard to keep your interests up. We didn't really have much of a schedule. We'd get an idea, we'd work on it. It was kind of depressing, until all of a sudden, wow, we're going to…[the moon]. Then that became even more depressing, because here we were given this enormous job and we didn't know how to do it. [Laughter] And certainly nobody thought that we could do it in the time schedule that [President John F.] Kennedy was talking about.

WRIGHT: When you heard the announcement from him, what were your thoughts when you first heard this, before you found out you were going to be—

BATTIN: Well, as a matter of fact, I was over at the MIT Faculty Club, either for lunch or dinner or whenever, and somebody had the TV on, and Kennedy was on the TV, so we all crowded around. That's when I heard that we were going to go to the Moon. Everybody went, "Hey, that's great. He's made a decision, but are we going to have a part in this?" [Laughter] We didn't know. We thought, "Will we even be working on it, and if so, who will we be working for, and who will be responsible?" All of those things.

Then all of a sudden we find out eleven weeks later that the person responsible is us, and nobody's going to tell us what to do, because nobody knows what to do. [Laughter] As I said, it's a set of circumstances which was, in a way, very wonderful, but it'll never happen again. Never happen again.

WRIGHT: In the course of these events, did you have individuals or other organizations telling you what you should be doing when you were creating the requirements and the system, as well? Did you have critics or times where it was—

BATTIN: Let me take time out for a moment. [Tape recorder turned off.]

There was an important milestone that happened. NASA Headquarters, the top people at NASA, for a long time were concerned with the Mercury Program and the Gemini

Program. The next flight is the most important piece of business, and those people were not thinking about Apollo, they were flying Mercury, they were flying Gemini.

George [E.] Mueller, who at that time I guess his title was Associate Administrator for [Manned] Space Flight, asked one day—at least this is the apocryphal story. IBM was doing the flight control system for the Gemini Program, and they needed to make a program change in the descent program for Gemini. IBM…did a little calculation and said, "It'll cost you one million dollars." One million dollars in those days was a lot of money. And George Mueller was upset, "A million? This is a software change."

"Yes, [but] we have to do this."

Then George said, "Well, if it costs a million dollars for IBM to make a change in this software, what kind of a problem are we going to have with the Apollo system, the Apollo computer?" He says, "That's…a much bigger job…" He says, "By the way, who's doing the Apollo guidance computer work anyhow?" He didn't know. [Laughter]

So that was the first time that a top person in NASA said, "What's going on with Apollo?" Well, then all of a sudden now the floodlights are on us. George Mueller came up to visit, and he was sending people up from Headquarters. "What is this system?" Then…he found out that we had this funny computer and funny programming system… He hadn't really been following the development. So all of sudden the interest in Apollo software became paramount.

Now, he was particularly concerned, because [once] he had a flight software problem that destroyed—I think it was the Mariner mission. In essence, it was a missing piece of code. Somebody had left a hyphen out of the code, and the missing hyphen caused the Mariner to be aborted and the system lost. And this made George Mueller particularly interested in flight software. In fact, he had a hyphen framed, hanging…behind his desk, to remind people that it just takes one little thing like that to ruin a program and to abort a mission.

So he wanted to find out how we were doing the Apollo software system, so he formulated a task force. I think it was the Apollo Guidance Software Task Force. He had members from NASA and industry, and I was the one for the Instrumentation Laboratory. We would meet periodically all over the country to visit this part of the program and that part of the program, and always we would…have to be defending ourselves. "Are we doing the job properly?" and so on.

I remember one time [when] George…[realized] we didn't have enough memory. No matter how much memory we had, it was never enough. So the issue came up, well, maybe what we really need to do is to be more disciplined… They asked me…"Do you think you could program this system using only half the memory, just so we'd have something to expand into?" So I said I thought this was a dumb question. [Laughter] "We're doing everything…as best as we know how, [so] how [could] we possibly…use just half? We're using the full computer. How are we going to use just half?" "Well," they said, "maybe somebody else could do that."

So he…told all the people on the committee that they [sh]ould go back to their companies and see if they could do this job with using half the memory. And just as I was afraid of…there were people who said, "Yes, we can do it for half the memory."

So we met [later]. …I forget where it was, but we all got together, and we were going to hear the proposals of people, how they were going to do this [job] using half the memory. The first presenters were Bell Com, Gordon Heffron was his name. He had been asked to look at this, too, so he was going to give his presentation of how he could do it using half the memory. He stood up and he said, "We have made a very careful study of what MIT is doing, and we are convinced that we couldn't possibly do it using half the memory. What they're doing is really topnotch, and no one could possibly do it using half of the memory."

Well, that ended the discussion. I mean, none of the other people who were there, who were going to talk about how they were doing to do it—they just passed. [Laughter] So we had a vote of confidence from Gordon Heffron. And that was the last time that George Mueller…look[ed] for somebody else to do our job.

As a matter of fact, even though the Apollo guidance systems were built elsewhere, we did all of the design and prototypes… Raytheon was building…all the guidance computers. AC Sparkplug, which was part of General Motors, was building the inertial system, and Kollsman Instruments [Company] were building the telescopes that were used in the system. But we didn't farm out the software. All of the software for all the flights, we did right up through the Skylab missions, the Apollo-Soyuz… The computer didn't change, even though by…[the early seventies], there were much better computers, much faster computers, memory, but you wouldn't want to go in there and change something that worked. If it ain't broke, don't fix it. [Laughter] So it was never an option to upgrade that Apollo guidance computer.

WRIGHT: Did you have in your mind a basic formula when you started creating something from nothing? Were there certain things that you did?

BATTIN: Well, you see…it would have been much harder if we hadn't had the experience with the Mars probe.

WRIGHT: Right.

BATTIN: Because whatever breakthroughs that were needed, we had spent several years hammering them out for that. …There was only about eight and a half years to the end of the decade when we got started. I don't think any of us believed that we'd ever make that deadline. I mean, it was nice to have a President say we were going to do this, and we thought, well, we weren't even sure we could do it, and nobody was sure that we'd ever be able to do it on time, especially when we started to realize that we didn't have enough people working on the software. It had to be so carefully crafted. It was not like sitting down and writing a program today where you don't even have to worry about the memory you have; you have essentially all you need. But everything had to be very carefully done to try to keep [within] the memory [size], and also it was not a fast computer, so things had to be done [carefully]—these were real-time computations that had to be done… If you had one second to do some calculations and if it took two seconds, that's not acceptable, because the clock is running and you've got to keep up with it.

So we initially resisted trying to get more people. We kept telling them, you know. There was a standard joke…Aaron always likes to tell that story about my saying that it's like the Pope being unhappy with Michelangelo because he's not working fast enough, and want[ing] to give him a bunch of house painters to help him out. [Laughter] You can't do that. Or to use another analogy, how many people do you have to squeeze into a phone booth in order to make a phone call? I mean, it's a one-man job.

…The customer was telling us, "You guys don't have enough people," which is kind of interesting. Usually the customer is trying to cut expenses, [but] we weren't spending the money fast enough. We didn't have enough people on the job.

The thing that worried me was that…suppose we did suddenly double our work force. What are they going to do? The ones who are working will have to stop working and try to teach them what the problem is, get them up to speed. So initially we always felt we were behind, and that bringing in more people would put us even farther behind.

But eventually—and this happened when [Howard W.] Bill Tindall [Jr.] came to the lab and sort of took over—he was going to whip us into shape about the software, the fact that we didn't have enough people and the fact that we seemed to be behind all the time. He really did apply good discipline to our shop, and we did learn how to get people, but we didn't hire them. We brought in subcontractors, and we would give a subcontractor a specific job to do. There would be one person that we would have to talk to, to show him what the job was, and then he'd go away, or generally he'd bring his people, we'd have to house them at the lab, to take responsibility for different aspects of the program.

It was…a management technique, which I, frankly, was not equipped to handle. I was really a person who liked to do things, and generally liked to do them myself, and I wasn't really up to trying to direct the whole orchestra when I wanted to concentrate on a piece of it. So it didn't take me too long to realize that we couldn't really keep doing things the way we were doing it, because we had some very good people, but no matter how hard they worked, we could never have made the schedule.

So we wound up—it's hard to believe—we wound up with 350 people writing programs for the Apollo computer, for this little dinky computer. Well, they weren't all writing programs. There were a lot of people who were writing test programs, and there were people who were performing the tests and analyzing the tests. But we peaked out at 350 people. I certainly couldn't possibly have even known who they all were or even meet them all. [Laughter] It became a big monster.

WRIGHT: Do you recall about when your handful started to grow? Was there a certain time period?

BATTIN: Yes. The handful that I was referring to was when we were just working on the Mars probe. Then all of a sudden when we got the job, I remember telling—Ralph Reagan was the one I thought would probably be the head of the program for MIT, and I remember saying…"Ralph, I'm going to need some more people."

He looked at me and said, "What for?"

I said, "Well, you know, this guidance job is a big job.

He said, "Well, you got the Q system," the one I told you about. He said, "That's pretty simple. What else do you need?"

I said, "Well, that's only a small piece of the job."

Then he said, "Well, how many people you think you need?"

I said, "I might need twenty or thirty people."

"Twenty or thirty people? What would you do with [them]?" [Laughter]

So that was the original point of view. If I had told him we needed 350 people, I think he would have said, "You're not the person to do this job. We'll find somebody else." So it was a whole change in point of view, that this project was not really a few of us working on the Mars probe; it was a much bigger job, and we had to have lots of people whose only function seemed to be to keep everybody happy, not just NASA, but the spacecraft builders and the people at Grumman. I mean, we had to have customer relations people who were more than customer relations; they had to know the system. They also had to make sure that they were satisfied. If Grumman didn't think they were getting what they needed from us, they would complain to NASA, and then NASA would say, "What's going on here?" So we always had to have fire fighters to put out the fires.

WRIGHT: Now, were you directly involved in smoothing out those issues, as well?

BATTIN: There were people who were doing that who were much better at it than I was. …We had one concept which was rather interesting…for each flight there will be a person responsible for the core-rope for that job. In fact, we called [him] the "rope mother." The rope mother was responsible for everything that had to do with the success of that flight. He would decide how many people were needed to do it, and he had sort of free rein to…pick out who he needed. That worked very well, until we found that we had to be doing all these things in parallel… We couldn't just do this, and do the next one and do the next one. And we really didn't have enough people to spread out over all the different jobs that we [had]. So we got lieutenants who would take major responsibilities for things and worry about every aspect of that job. It was not something that any person could do.

I mean, I recognized that I could no longer function the way I liked, which was to understand everything that was going on in every aspect of the job. I just couldn't do that. But we really did have an organization in which there were probably a dozen people who you didn't have to direct. They had major aspects of this job, and you knew that if they were in charge, you didn't have to worry about that. And it worked fine…

WRIGHT: Before we get more specific about the missions and you can share with us your excitement and your, I guess, satisfaction of knowing that your instrumentation and your systems worked, I want to take a brief break and we're going to change the tapes out.

BATTIN: Sure. [Tape changed.]

I hate to think that the thing that really saved us was the Apollo fire. It was January of 1967, I think, when [Virgil I. "Gus"] Grissom and [Edward H.] White [II] and [Roger B.] Chafee died. We all felt that that's the end of the program, it's over. But it wasn't, of course, and Aaron Cohen was given the responsibility of redesigning the command module, to get rid of all these failures—you know, fire hazards. That's how he began [down] the road to being [Johnson Space] Center Director. He was in charge of the redesign of the command module.

But it was about a year and a half before anything flew again, and that was the time that we needed to get our software act together and to get things moving along…without that…year and a half, we would have been always the late ones. They'd be ready to go and they'd say, "MIT, where's the software?" "Well, we're not ready yet." And we never wanted to be in that position. Turns out we never were. Even when the first rope—the first rope mother took twice as long to do it as we had expected, and needed more people…even so, when they finally delivered [the core rope], it wasn't used for several months. So even though we were very, very late, everybody else was later. So we got away with it then, but we knew that unless something happened to give us a block of time to catch up, that we were in trouble.

Then we got that time, but I would just as soon have gotten it some other way. I mean, there were people who were talking about the end of the decade. "Heck, we can do it. We can be on the Moon in two years less than that." I don't know what these people were smoking. [Laughter] But it didn't make a whole lot of sense to us, that you could do that. But then when they finally did get started, when [Walter M.] Schirra [Jr.] flew the first manned Apollo flight, Earth orbital flight, in Apollo 7, then NASA started making decisions which I thought were absolutely dangerous. I mean, you fly Apollo 7 and then the next thing you say, "Oh, we're going to go to the Moon on the next flight." Well, what are you going to do at the Moon? You don't have the lunar module. "Well, we'll figure out something to do. We'll go in orbit around [the moon]."

…Then after we flew Apollo 8, then what are we going to do next? Well, we've got to get that lunar module operating. So Apollo 9, let's fly the lunar module. Only time the lunar module ever flew in Earth orbit was Apollo 9.

Apollo 10, let's go to the Moon, only we won't really do it. This will be a dress rehearsal. We're going to separate the lunar module, we're going to fly down to 20,000 feet, abort, come back up, re-dock. All of those were new things. We had never done anything [like that]. All we had done [with] the lunar module was fly it around in Earth orbit and practice docking with it. Now next time we're going to do it, we're going to do it at the Moon, and if we make a mistake, we're going to leave some people, maybe nobody will come home. That'll sure end the program. But it all worked.

Then Apollo 11. These flights were happening every two months. Was it two months or was it three months? I guess it was three months. Every three months there would be a new flight. This was George Mueller's idea primarily. He would say—you wouldn't have to try to convince him that we didn't have to do this over again. Generally when you're making major steps, you'd say, "Well, let's see if we can do that again before we go abandon it and do something dramatically different." But George Mueller's attitude was, "If you can't convince me—George—if you can't convince me that there's a need to do it over, then we're not going to do it over. And merely saying you'd like to get more data or you think you'd feel more comfortable if we could prove we could do it again, that's not good enough. You've got to prove to me that you must repeat it." So nobody could do that, so they just kept going and going and going.

If they had had a failure, a major failure, any of those flights up to Apollo 11, we would never have gone. We never would have gone [to the moon].

WRIGHT: Share with us how the decision for Apollo 8 changed what you were doing.

BATTIN: Well, it didn't. We were ready to go. The thing that was different is that we had been counting on that flight involving the lunar module, but Grumman [Aerospace Corporation]—I mean, they were behind schedule, and rather than just repeating Apollo 9—excuse me, repeating Apollo 7, which was just flying the command module in Earth orbit, but there was a major step which should have caused somebody to say, "Hey, we're going too fast," because the next flight was going to be the first flight of the Saturn V. So Saturn V was going to put the command module in Earth orbit. George Mueller says, "We've done that. We don't have to do that again. We'll do the next flight. We're going to go to the Moon." That's a big adventure by itself, but before you do that, you're going to be doing it with a rocket system that has never flown a human being. So you're going to use the Saturn

V, put this thing up into orbit, and then that's one thing brand-new, and then brand-new you're going to send these people off to orbit the moon.

The thing that I remember most [about] Apollo 8,…my favorite mission, was because we actually did navigate to the Moon. I mentioned the reason we got the job was because everything had to be self-contained, but as time went by, that requirement got less and less [important], and the ground people, the control center in Houston, they were in charge, "And you don't have to navigate to the Moon on board because we're going to navigate. We'll tell you where you are." [Telephone interruption.]

As time went by, the requirements for doing everything on board lessened. We were no longer concerned that the Russians were going to interfere with the flight, and the ground capability was improving, so the decision was more the ground, Houston [Mission Control], would be in charge and we would be only backup, in a sense.

When memory was getting tight, people would say, "We don't need all that on-board stuff. We don't need to navigate on board." And so then I kept raising the question, "Well, all right, if everything goes well, you don't need it, but what if you do lose communication with the spacecraft, and even for non-sinister reasons, the Russians had nothing to do with it, you just lost communications? Then the astronauts will not get home. They need to have the capability on board to get themselves back home, even if you can't talk to them."

"Oh." [Laughter] "Okay. You're right."

So what they did on Apollo 8 was to try, for the first time, to see if astronauts actually could navigate to the Moon without ground help, and the Apollo navigator was going to be Jim [James A.] Lovell. I like to tell my kids this story. They say, "Jim Lovell?" Yes, the same Jim Lovell who was commander of Apollo 13. But on Apollo 8, his job was to do all the navigation. So he came to MIT to train to do this. We were the only ones that had an horizon simulator that could be used [by] him to make star elevation measurements above the Earth's horizon. The navigation scheme required making those kind of measurements when you're near the Earth, and when you're near the Moon, you make star elevation measurements of stars above the Moon. And this data would be processed in the computer and all.

We found out that when Lovell was practicing, that he was identifying what he called the horizon was really about twenty miles different than the actual horizon, so that was okay, as long as he was consistent. So you put the twenty-mile bias number into the computer, so every time he made a measurement, we would adjust it for the twenty miles.

So they were going to do this navigation on Apollo 8, and during the first few measurements that he made, the ground was checking, and it was discovered that really the bias…should have been…ten miles instead of twenty. So this bias number was in the erasable portion of the memory, so they just changed the bias number. From that time on, there were no changes, and Lovell and the guidance computer did all the calculations of position and velocity all the way to the Moon, and there was no need for a velocity correction until…just before arrival at the Moon, never had to make a velocity correction.

[Christopher C.] Chris Kraft [Jr.] said there was essentially no difference between the onboard system's position and velocity compared to the ground system. He said, "So why don't you just go ahead and make the velocity correction without getting an update." The mission rules were that if you're going to make a velocity change, then you have to get an update from the ground. Well, Kraft said, "Go ahead and do it," but then some [space] lawyer said, "There's no reason to." I mean, just no reason to violate the mission rules. So we did get the update, but we didn't need it. Kraft knew we didn't need it. So Jim Lovell did actually navigate himself to the Moon without any help from the ground, and did it all the way back, too, navigated from the Moon back to the Earth. And the navigation system worked fine. Sadly, they never did that again. They had proven that the thing worked, and in emergency, they would be able to navigate home without ground help, but they never did lose the communication.

There was another exciting thing on Apollo 8. When they disappeared behind the Moon, they were going to have to make a major velocity change to get into lunar orbit, and that took place when nobody could see them. A lot of nervousness there. Our system had to work. If it didn't, we might never see the astronauts again. It could be that they would make a correction which would send them crashing into the Moon, or the whole thing might blow up when they turn the engine on, and you'd never know it. So there was a lot of anxious moments there till they appeared coming out from the other side.

When they came out, they announced their position and velocity, and the ground people said, "What are they talking about? We haven't even had a chance to track them yet. How do they know what their speed is and where they are?" They forgot they had an onboard system that was telling them all that stuff. [Laughter] So it took a while for the ground folks to realize that there was all this capability they had on board and it really worked. [Laughter]

WRIGHT: It must have been very satisfying and rewarding to all of you.

BATTIN: Sure.

WRIGHT: Were you together with the rest of your group?

BATTIN: Oh, yes, we were all sitting there. Well, when they were in orbit around the Moon on Christmas Eve, it was late in the evening, and I sat in my den [at home], I was on the radio, sort of a talk show, people calling up and asking about—I can't remember a single question they asked, but I do remember that I was on the radio trying to explain what was going on with these guys in lunar orbit. It was Christmas Eve and it was probably midnight, one o'clock in the morning, I was still on the radio. Everybody at the house was asleep.

WRIGHT: I guess what a present to you and your whole team to know that—

BATTIN: That it worked.

WRIGHT: —everything was exactly how you wanted it to be.

BATTIN: But then we had the big worry about when it's time to come home, we've got to burn that rocket behind the Moon. We hope it works, because all the anxieties again, if it doesn't, we'll never see them again, or the whole thing could blow up. But, of course, it didn't.

WRIGHT: More smiles for everybody.

BATTIN: As I say, that was really the most exciting mission for a lot of us, primarily because nobody had ever been that far away from the Earth before. …[We]'d sent people into Earth orbit, but you'd never sent them out to where they could have a very reasonable probability of becoming a solar satellite and never coming home, ever.

WRIGHT: When you started your project, so many unknowns was the only thing that was known. Everybody was still making decisions.

BATTIN: As a matter of fact, one of the things we didn't know was whether you could land on the Moon without sinking into the dust. There was a great concern. We had someone from NASA explaining to us that the Moon probably had ten feet of dust and you try to land on it, you'd sink in there and you'd never get out. Well, that's a pretty serious thing to worry about. But they were able to—actually, I think they were able to track some of the unmanned landers and actually see them on the Moon, and they weren't buried.

WRIGHT: Of course, 8 moved into 9, and more decisions were being made. Tell us how those decisions were affecting what you were doing at the laboratory.

BATTIN: At that time they really weren't. Because of the manufacturing time of the core ropes, we were not making major changes. [For] every one of those flights, we were exercising a portion of the whole mission that we had already…put together. …At one time we were even naive enough to think that we could do this once and for all. We would have a universal memory, and the only thing that would change would be things that would go into the erasable memory, and…we'd just manufacture that once. Well, of course, it didn't work that way, but theoretically it could have, that we just had put all of the mission elements together in the memory…[that] the astronauts called up for what[ever] mission they wanted.

Well, that was partially true. The major parts weren't going to change. When they said, "We're going to not take the lunar module; we're just going to take the command module of Apollo 8," that was interesting, but it wasn't anything that we had particularly to cope with. We were prepared for navigating the command module to the Moon, whether or not it had the LM with it, and it had to go into orbit around the Moon… The thing that made a difference was if you don't have the LM, the mass is different, and so the burn times are different, and all those things had to be checked…[with] the simulator. The…spacecraft is lighter if you don't have the LM, so you've got to check those things out. But they're not cause for major program changes unless you find it doesn't work. [Laughter] Then you have to worry. …I don't recall any changes that we had to make because things had not been carefully planned.

WRIGHT: Information from other contractors you might have needed, was it readily available to you?

BATTIN: Sometimes. I mean, generally it was flowing the other direction. What we needed from the contractors was mass properties of the vehicles and moments of inertia of the vehicles. We always wanted to make sure that we had the latest of that kind of information, but generally we had to ship our programs to Grumman, to North American, to NASA, because [by] this time they all had simulators running and they could help us.

In fact…[often] they would think they had uncovered a problem and it turned out it was a lack of understanding of how…thing[s] worked. …[It] was good to have other people exercising our software in their simulators. It gave everybody a warm feeling when everybody agreed that nobody had discovered any bugs. Sometimes, of course…they did find problems, and we were glad that they did. We'd fix them. But it was certainly, I think, much better that we were not the only ones that had a simulator, the only ones who were testing the flight software. It was important to have as many other people do it as possible, and there were at least, at that time, at least four different…[organizations]. That's why we needed so many people…[for] back and forth and talking to the people who…[think they have] found problems. It took a lot of people to do that.

WRIGHT: Did you find yourself in residence at the laboratory most of the time during these eight years, or were you on the road a lot?

BATTIN: …We had a lot of trips to Houston, to explain what we were doing… There were software control meetings…if a requirement changed, how can we cope with that, and if we have to add something to the computer, you can't do it, there's no room, you have to take something else out. Well, it's just as serious taking something else out as it is adding something, because if you take something out, you may screw up the rest of the program. So these decisions were [made by]…a Change Control Board for the software, and no one could touch the software, make any chances unless they got a legitimate change control authority…we felt handicapped by these things, but we began to realize that we couldn't operate any other way. We didn't like to have all of these people telling us things we couldn't do or things we had to do, since we were sort of a free-spirit outfit. [Laughter]

WRIGHT: I'm sure sometimes they even contradicted each other, so that must have really put you in a position—

BATTIN: That's right. We learned to operate in a big system, and…this was a new experience for the laboratory. They'd never had to do that before. In fact, there were people at MIT who didn't think we ought to be doing that either. We're a research outfit. Why are we involved with all these picayune daily little problems? Fortunately, their voices were not listened to. [Laughter]

WRIGHT: Were your offices right in the midst of MIT complex?

BATTIN: Actually, we had a special building. We didn't have enough room in the regular laboratory. We had to find a place, and they found a building on Memorial Drive, right on the river, which was actually a warehouse for underwear. [Laughter] And we took over that building and refurbished it, nothing dramatic, we just partitioned it off into useable space and we all lived there. The building is gone now. It's been replaced by expensive condos, highrise condos, that no one could afford to buy anymore. But our building…is gone and the space doesn't exist anymore.

WRIGHT: You mentioned that on Apollo 8 you were here in your home.

BATTIN: Well, I was that night, yes…

I did go to a couple of the launches. Went to the Apollo 11 launch. I think that was the first one I saw. And then I went to Houston for the landing, so I was there.

WRIGHT: Can you tell us about that experience?

BATTIN: Which one, the launch?

WRIGHT: Both, you know, because it was kind of the beginning and the middle of that, so—

BATTIN: Well, I'd never been to a launch before, and so the whole atmosphere was strange. There were lots of people there, and the best place to be was just standing on the ground, where I took up a spot. I remember when it was all over, the grandstands, there were a bunch of people congregated around one particular person who was in the grandstand. I didn't know who that was, but it was—Carson.

WRIGHT: Johnny Carson?

BATTIN: Johnny Carson. [Laughter] So the people were more interested in him than they were in the mission. [Laughter] The Vice President was there, Spiro [T.] Agnew, and [it] turned out that Spiro Agnew and I had one thing in common, we both went to the same high school.

WRIGHT: Oh!

BATTIN: But we didn't overlap. He was there and gone by the time I arrived, and, of course, Spiro Agnew left [office] in humiliation. But he made a little speech right after Apollo 11 that NASA was now going to start planning a manned mission to Mars, and I thought, "Wow! Great." And, of course, we didn't.

WRIGHT: Were you there a few days before you came to Houston, or did you come—

BATTIN: I don't remember whether I—I don't think I stayed down there. I may have gone home and then gone on down to Houston. …But it was very—the landing was exciting because the computer kept [giving] alarms. And even today George Mueller—George Mueller and I are great friends—even today George Mueller thinks that was a computer error, and the last time I saw him, I said, "George, look. It was not a computer error." I explained to him in great detail exactly what it was, and he said, "Yes, yes, yes, but we did get the alarm, right?" Yes. "So that was an error, right?" "No, George!" [Laughter] "The alarm was merely telling you that the computer was doing things, shutting down activities, there wasn't too much time, and restarting those activities which were absolutely essential. There was a mistake, and the mistake was that somebody had left a switch in the wrong position." The computer had to [count]…a whole [unnecessary] string of pulses… And it takes time to do that. As long as it's doing that, it's not doing…[the computer's] job…

Fortunately, we had a bunch of people who anticipated that that might happen, and so they designed some software…so that…wouldn't [be a] problem. But I don't know if I ever convinced him. "It was an error." No, it was not an error, because if we hadn't had the program in there to fix it, that would have been a bad error.

Fortunately, they had actually experienced this problem…in Houston several weeks before the flight, and they had [experienced] one of these alarms, and [Chris] Kraft was very upset. He told the software people, he said…"I want you to make sure that you understand every alarm that [the] guidance computer has and what causes it, because I don't want anybody to ever have a surprise and an alarm come on and they not know what it was."

…When the alarm came, everybody asked [the flight controller], "Okay, what is it?" And…because he'd had this recent experience, recognized what it was and said, "It's go. It's all right." It happened twice. But if this hadn't [occurred] before, it's almost a sure thing they would have aborted. To get an alarm the last few minutes, you don't know what it is, the safest thing would be to abort, but if you've been studying alarms and you know what that means, it just means that the computer is doing a restart, it's got too much to do, [but] does not cause for abort. But every time I tell people that the Apollo computer never made a mistake, never made an error, they always bring [this] up, "Yes, it did."

WRIGHT: George Mueller said so. [Laughter]

BATTIN: No, it didn't. It did exactly what it was supposed to do.

WRIGHT: Several missions occurred after the Apollo 11 landing on the Moon…

BATTIN: [Apollo] 17 was the last one. That was a mistake, because they had all the rockets…everything for three more flights. The best excuse I ever heard for canceling them was, "Let's quit when we're ahead. We've done enough, and every time we go, there's a danger of error, losing [the crew]." [Tape recorder turned off.]

—Skylab, and it was one of those things that I remember where I was, I remember where [Bob Chilton] was standing and explained to me that Skylab—they were just going to take an S-IVB and hollow it out and make a laboratory. I said, "Why didn't I think of that?" [Laughter] That's a good idea. You have almost a free spacecraft. Of course, it wasn't

[free]. [NASA] did a lot of [work on] it. But I think it was a very good idea, rather than build something completely from scratch. You have it, and it worked. The Apollo guidance computer had to do its thing, it had to put the bird in orbit…[Interruption.]

[And] it had to bring the [crew] home after it was over. We kept doing the software because it didn't make any sense to try to train somebody else to take this job over, so we did that…[right through] Apollo-Soyuz [Test Project, ASTP]. Then when it finally ended, of course, it was sad. We knew, for one thing, that when the shuttle was born, Bill Tindall told us…"I think you guys are absolutely great, and you're the best ones to do the same job for the shuttle, but we couldn't possibly give it to you, because that's what we'd have to do, we'd have to give it to you, and there are enough people and enough companies in this business today, they would have their senators on the phone in an instant. They'd say, 'We can do that job,' and they probably could do the job. 'We can do that job. What do you mean, you're going to give that to MIT.'"

So he said, "That just can't happen. Now, hopefully you'll get some responsibilities for the shuttle, but it's not going to be like you had in Apollo, where you were in total charge." And it was hard for us to appreciate that, to know that if we could compete, we would win just on the basis of the fact that we were farther along than anybody else, but the inability to compete or to bid on jobs, we just couldn't do that.

WRIGHT: When you were working with the Apollo-Soyuz Test Project, because you were going to dock with a different type of vehicle, did that propose challenges?

BATTIN: That was not our problem. We knew how to [use] the software…[for] a docking program. The thing that [NASA] had to worry about was the two vehicles and building a coupling unit… But that wasn't any problem that we could contribute to. We didn't have anything to say about it or worry about it. Whatever they chose, our docking program would be the one you would use, and we've been doing docking for many years. It was not a major problem for us; it was just a general overall sadness that, well, that's it. End of a big era.

WRIGHT: As it was announced that Apollo 17 would be the last and then, of course, you had Skylab and ASTP, did you find your responsibilities starting to move to a different direction with MIT?

BATTIN: Well, you mean my particular ones?

WRIGHT: Yes.

BATTIN: Actually, you know…we started to reorganize, and instead of an Apollo group, they talked about a NASA group and somebody to run the NASA group. There was a brief instant there whe[n] I thought, gee, I'd like to have that job. Then I thought, no, I really don't want [to do] that job. I think Bill Tindall said, "Battin shouldn't do that." And I felt very unhappy. Why not? I mean, that looked like a nice promotion. But then Al Hill said—I don't mean to be boastful, but he said, "You are a great technical contributor. You get ideas. You do things. It would be a waste to have you running a big NASA segment of the laboratory." So they made me the associate head of the NASA [programs]… When it happened, I felt disappointed. Then I realized that the last thing I really wanted to do was to be the head of that group, so I was the associate NASA head, and that was [fine].

WRIGHT: How did teaching enter into your career with MIT? When did that begin?

BATTIN: I started teaching at MIT the year after I got my bachelor's degree. In fact, that was really one of the reasons why I went to the math department. When I came back for graduate work, I told my…advisor…[that] I would really like not to just be a full-time student, I would like to do some teaching. He said, "Well, we could make you a lab assistant."

I said, "I don't really want to be a lab assistant." I said, "I'd like to teach a course. I'd like to stand in front of a class, with chalk, and teach a class."

He says, "Well, we don't let people do that in EE [electrical engineering]. Guys like you are lab assistants." He said, "If you really want to teach a class, let's go down [the hall] and talk to the math department."

So [he] introduced me to the head of the math department and I said, "I'd like to teach part time."

They said, "Well, if you want to do that, you've got to be in our department."

I said, "Okay. I'll be in the math department."

So I started teaching two sections of freshman calculus in 1946. And except for two years when I was away at Arthur D. Little, I taught a course at MIT ever since, and I'm still teaching, and I'm still teaching my astrodynamics course, which started really…[as] a preliminary course, sort of a trial balloon in 1960, and then a real course in 1961, and the first student in the class was [Edwin E.] Buzz Aldrin [Jr.]. Of course, he was not an astronaut at the time, so I couldn't say, "Gee, here's an astronaut in my class." [Laughter] He was just Buzz Aldrin.

The next year I had Dave [David R.] Scott, who was commander of Apollo 15. Then…[the following year it was] Ed [Edgar D.] Mitchell. Ed Mitchell was my third student. I think he got his doctorate also. And, of course, he flew with Alan [B.] Shepard [Jr.] on Apollo 14. As a matter of fact, I used to tell my students that 25 percent of the men who walked on the Moon took my course, but now I can say that…a third…of the men who walked on the Moon took my course, because three of them are dead.

WRIGHT: Well, certainly you must have influenced them somehow. Did you end up serving as partially their mentor through these years? Did they come back?

BATTIN: Not really. I mean, they all left before they were astronauts.

WRIGHT: Did their roles as astronauts bring them back to MIT at any time during the program?

BATTIN: Oh, sure…they all came back. We kept training astronauts throughout [Apollo]—from the very beginning. We didn't do any of the Mercury or Gemini. We didn't have those people [for] training. I do remember we had all of the Mercury 7 astronauts [come] to visit the laboratory on the same day, and that was a circus. [Laughter] Somehow or other they divided everybody who was in the Apollo Program…into seven groups. …Each group would go out to lunch with a particular astronaut, and one of the astronauts didn't finish his sandwich, and so somebody in the group grabbed the sandwich and had it encased in plastic. [Laughter] This is the uneaten sandwich that—I forget who it was. Maybe it was John Glenn's sandwich. But, as I say, it was really a circus.

After that, when the Apollo astronauts came, it was pretty routine. Nobody paid much attention.

WRIGHT: I guess in the case of Scott, Aldrin, and Mitchell, they were never far from your class if they were coming back to MIT for training and you were there.

BATTIN: Yes.

WRIGHT: And you mentioned you continue to teach today. In the same class, or have you added more to your schedule?

BATTIN: …When I first started to teach the course, I was creating class notes and papers that I had written back in the Mars probe days, put out about four papers, and then at that time, even before the first class, I thought [that] what I should really do is to write a book. So the book I wrote was called *Astronautical Guidance*, which was the name of the course at the time, and it was published by McGraw-Hill. Another title for it would have been *Everything I Know About Celestial Mechanics and Guidance [and Navigation]*, because it really was putting in [the] detail all of the mission elements that we needed for Apollo. Since I had very large classes, everybody was interested in this stuff. I felt it was a useful thing to do, even though some people would say, "You've got to put man on the Moon. Why are you writing a book?" Well, the book took a few months, and I worked pretty hard on it, but the people who took the course wound up being some of our key people. It was a good training exercise. It was good for me to try to get all these things down on paper and in a manner that you could say, "Here. Read the book." So to some it looked like a boondoggle. …[But] it was really a good training ground for a lot of people who wound up working for us and [who] became vital members of the MIT Instrumentation Lab.

WRIGHT: At some point, the lab changed its name and then eventually moved apart from MIT. Could you share with us that evolution?

BATTIN: That was a thing that shouldn't have happened. It all came about [with] the unrest of the sixties—I mean, there were demonstrators at MIT. It was just a very unpleasant time. I remember Howard Johnson [President of MIT] came to one of our meetings and said, "I'm glad I'm here today, because I can't get in my office."

I said, "What do you mean, you can't get in your office?"

He said, "Well, the students are occupying my office."

I knew Howard Johnson well enough, I said, "Howard, why do you let them do that? Why don't you just have them removed?"

You know what he said? He said, "You clearly don't understand the problem, do you?"

I said, "I guess not." [Laughter] I said, "What if I came over and threw you out of your office and wouldn't let you in and I sat in your office? What would you do about that?"

He says, "Well, I would fire you, of course."

I said, "Well?"

He said, "It's not the same thing." I could never convince him.

So Howard Johnson made a promise that he would, before his administration ended, that he would divest the laboratory from MIT, and he said, "It's the only way that the laboratory is going to survive, because you want to do classified work and the students think you're building atomic weapons or guiding atomic weapons, they're not going to tolerate that, so we're going to move toward divestment."

When the time came to divest, I think it was 1972, nobody was making any noises anymore, so I said to Howard Johnson…"Well, you know, we don't have to do this now."

He [said], "But I made a promise…"

So we were divested, and it cost—the immediate effect was it cost MIT five million dollars a year, which they had to scramble around to try to replace. Now, in those days, five million dollars is…a [really] big pot of money. …The laboratory contributed five million dollars to the overhead at MIT. The fact that we were no longer there didn't mean the overhead could go down by that much; it just meant that they'd have five million dollars less money to play with. And we had to…duplicate all the functions that MIT had [provided] for us.

So it…[turned out] really…he was right that during the] last stages of our relation with MIT, [there was]…a committee that had to decide…[for] every contract that came to the laboratory, whether it was a [job] that we should do. It was hard enough to get jobs, but for them to tell [us] that [we] can't work on this because it might have some bad military application, we kept saying, "Well, you know, defending the country is not a bad thing to do." Well, yes, it is. And on this committee they had two students…and they would pick students who had that point of view, challenging whether the lab should be working on that stuff. We couldn't have survived if we had to stay there under those circumstances. It's when you let the inmates run the asylum, then all these crazy things can happen.

WRIGHT: So you actually moved lock, stock, and barrel at that point in time?

BATTIN: Well, actually, they built a new building, which is 555 Technology Square, where the lab is now. It expanded beyond that, and they acquired another building which is across the street. It's now called the Hill Building. But it still was a short walk to MIT. My relation didn't change. I mean, I continued teaching my course. They wanted to maintain the contact with students. There were always MIT students working at the Draper Laboratory and doing theses at the laboratory, and they wanted that to continue. I was always teaching my course. They wanted that to continue. It was just the administration and removing MIT from any control [over] what the laboratory was going to work on.

WRIGHT: Do you still do work for the laboratory or did you—

BATTIN: Now?

WRIGHT: —end that relationship?

BATTIN: No, I retired from the lab in 1987. I told the [MIT] department head, I said, "Instead of paying [the lab] for my time to teach my course, why don't I just continue teaching…and you pay me instead of them?" They said, "Fine." [Laughter] So that's the relation I've had ever since. They pay me for roughly 20 percent of a full-time [professor] and I teach [my course in astrodynamics].

WRIGHT: Do you still travel and do seminars and symposiums as well?

BATTIN: Only under rare circumstances. I did "A Funny Thing Happened on the Way to the Moon" …but that was paid for by [the AIAA]. But I don't have any travel funds. If I go on a trip, if I go to an international congress, I pay my own way. I don't do any consulting. I don't want to do any consulting. All I want to do is teach my course and the rest of the time do what I want to do.

WRIGHT: A good plan. Good plan. You were recently in Texas for an event at Texas A&M University. Tell us about that.

BATTIN: Well, last year I received an honorary degree, doctor of science, from Texas A&M, and they told me that one of the things they like to do is to have some interaction with students and faculty, and may not be able to do it at the graduation time, but they'd like to have me do something later on. So the "something later on" turned out to be this symposium named after me, the Richard H. Battin [Astrodynamics] Symposium… It was a two-day event with a lot of people, many of whom had been my students and some colleagues and other people who just knew me and came. It was very, very [wonderful]—my wife was with me, and she kept saying, "It's like going to your own funeral." You go to a funeral, everybody says all these wonderful things about you that you can't hear. So to hear people talking, extolling your virtues when you're alive and listening to it, it's very—it was hard to climb back down to Earth after that.

WRIGHT: I'm glad you got to enjoy that. [Laughter]

BATTIN: One of the people—I must tell you—John Kechichian, he gave a paper, and before he gave the paper…he gave a little history of himself. He said, "I'm from Belgium, did all my education in Belgium, and I remember as a student I went into a bookstore and I saw your book on the bookshelf, *Astronautical Guid[ance]*." And he said, "I was curious. It was a good title. I picked it up and I thumbed through it, and I bought the book. I used money that I didn't have. I probably should have been buying food. I was a poor student. But I wanted that book." And he said, "It changed my life, because I decided that that's what I want to do." So he went to Stanford [University] and studied under John Brakewell, who was also a great astrodynamicist. So I really felt, "Wow! My book changed this guy's life, so it must have been a worthwhile effort to write it, [afterall]."

WRIGHT: Looking back, and especially just recently you heard other people tell you about your accomplishments, but what do you consider your most significant accomplishment, or even your contribution to the space industry?

BATTIN: Well, I think the body of work that I made contributions toward were navigation, space navigation, and guidance, and orbit determination, which were all various papers that I presented, which were published in journals, and which became the nucleus for my last book, which is called *An Introduction to the Mathematics and Methods of Astrodynamics*, and it's a big thick tome, about 800 pages. Contains all of those contributions and everything at the time that I knew about the subject. People say, "What did you do?" I say, "Well, it's all in that book." Everything that I did that I was pleased. with and…[made] a contribution to a program, it's all in that book. [Laughter] So it's nice to have done that. I still use it to each my course, and I keep finding out other people around the country who teach the same stuff use the book, too. So I think that's what I feel is what I can look back on with pride.

WRIGHT: As you do that, in order to get to where you are, could you pick one time that it was the most challenging milestone for you, something that maybe almost altered your career, that you said, "Hey, maybe this is not going to work" or, "I don't want to do this anymore"?

BATTIN: I'll tell you a thing that did happen, which was kind of a—it's one of the funny things that happened on the way to the Moon. In 1961, when we got the job, we had been working on spacecraft navigation, and in the fall of '61 we had a visiting professor. The Hunsacker professor, is the title. We still have somebody who does the Hunsacker professor chair for a year. It was Sam Herrick. Sam Herrick [was] well known. In fact, he invented the term "astrodynamics." Very well known. He was an astronomer who recognized that space applications were important, not like the Astronomer Royal. And he became *the* expert. So he was going to be the Hunsacker professor, and what an opportunity I would have to benefit from him to help us with the Apollo system.

I had this report on navigation, which…was based on what we had done for the Mars probe and what we were proposing to do for Apollo. I gave him a copy of the report. I said, "Would you read this over and let me know what you think about it?" So I gave it to him and I didn't hear from him for a few weeks. Finally, I got hold of him. I said, "Sam, did you get a chance to read that report?"

…[He] rummaged around through his briefcase, handed it back to me. He said, "Do you really believe this?"

My jaw dropped. "Well, yeah." I don't even remember the rest of the conversation. I was just—here is the absolute world expert in astrodynamics, he not only didn't like it, he asked me whether I even believed that it would work or believed it was true.

[Sam]…gave the Hunsacker Lecture on space navigation just about two months later, and it wasn't [about] space navigation at all; it was orbit determination done the old classical astronomy…way. There was nothing that he saw any different [about] space navigation than the astronomer's job of orbit determination, which is fine, except that you don't have to do [that] in real time and you don't have to do it in a small computer. You're going to have lots of data and you're going to have lots of opportunity to play with your hand calculators and [determine] these orbits, going to do all these standard techniques that astronomers do, but you're not going to do that in a spacecraft…

So his criticism of me was that I did not understand what astronomers do, and he called people like me "Johnny come latelys." I mean, "You have never had any training in celestial mechanics, so you don't even know what you're talking about" was the implication. Well, no, I had no official training in celestial mechanics, but what he was talking about was not possible in our Apollo computer, not possible. But my system was…used. [Laughter] But it was a big shock to have—it's sort of like having Einstein saying your discovery in physics is, "Do you really believe what you just said?" [Laughter] Well, it's kind of a shock.

Well, funny thing is that Sam and I turned out to be very good friends, and [I] visited in his [home] on Mulholland Drive, beautiful home on top of the mountain, knew his wife well, and we exchanged lots of conversation. But he was just of the old school. I don't think I ever became more than a Johnny come lately. [Laughter]

WRIGHT: Well, history has shown that you have been more than that.

BATTIN: Yes. [Laughter]

WRIGHT: As a researcher and a teacher, inventor, creator of all sorts that have impacted history. Did you ever in your wildest ideas as a young boy—

BATTIN: No.

WRIGHT: —think that you would be—

BATTIN: No, no… The only thing I [knew about space] was the *Buck Rogers* comic strip. *Buck Rogers in the 25th Century*, I enjoyed that. But I had no idea that we would ever actually do what we did, landing on the Moon. The last thing I would have thought is that I would have had anything to do with it. [Laughter] …But no one, no one planned for that. No one in my generation grew up saying, "I want to work on space flight," because the only thing you could reasonably have said, "I want to grow up and be an astronomer." You would not have been thinking about flying anything. That was just not possible, or if it was possible, you'd have to wait five centuries before you'd ever see it.

WRIGHT: All the systems that you designed, did you have any desire to see how well they worked in the spacecraft? Did you want to be part of the crew?

BATTIN: Did I ever want to do it? You mean be on the crew?

WRIGHT: Yes.

BATTIN: No. I don't even like to ride in roller coasters, much less do that. No, I have never had any ambition at all to ride in the space vehicles. I wouldn't like it even if they could guarantee me a safe return.

WRIGHT: Well, you certainly have made such an impact on making sure others have had a safe return, and as we come to a close today, are there other areas, is there any other things that you would like to add here at the end that we haven't had a chance to talk about?

BATTIN: Don't think so. I think I'm all talked out. [Laughter]

WRIGHT: I certainly appreciate your time, and I look forward to sending your package to you for your review, and then hearing from you again.

BATTIN: I wonder what it's going to look like when I see it in print. [Laughter]

WRIGHT: Just as wonderful as I heard it. [Laughter]

BATTIN: It's funny, the other time I was interviewed, I think I did get a written copy of it, and I started to make some corrections, to at least make what I said into sentences, and I said, "Oh, I can't. There's nothing I can do to this." [Laughter]

WRIGHT: It truly is the charm of oral history. Your experiences have meant so much to many, so I'm looking forward to sending it to you and have you review it, and please feel free to add.

[End of Interview]