DR. SIMON RAMO
NASA ORAL HISTORY

INTERVIEWED BY CAROL BUTLER
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BUTLER: Today is April 6, 1999. This oral history is with Dr. Simon Ramo. This interview is being conducted at the TRW Space Park offices in Redondo Beach, California, by Carol Butler.

Thank you for joining us today.

RAMO: Happy to be here.

BUTLER: To start with, let's talk briefly about the initial beginnings of the ICBM [Intercontinental Ballistic Missile] program and when you first realized the seriousness of the program and the Russian program, what was going on with that, and how that sparked the U.S. program.

RAMO: Well, it was startling and sudden, out of the blue, you might say. We had just founded the Ramo-Wooldridge Corporation. This was following a period in which we—"we" meaning Dean Wooldridge and I—had led the buildup at Hughes Aircraft Company. We were heavily involved in guided missiles and a considerable amount of other electronic high-technology efforts, all of which had been concentrated on what was then the highest priority weapon systems project for the United States.

This was to put ourselves in the position to defend the nation against what was considered to be an important number-one possibility of enemy action, and that is if the Russians came over with manned bombers to drop H-bombs on the United States. This involved a complex system of ground radar and then manned interceptors that would rise to destroy those Russian bombers before they could drop any bombs. That was, not surprisingly, the number-one project effort of the United States.

Now, imagine our surprise then during the very first week from the founding of the Ramo-Wooldridge Corporation, where our intention had been to go into, in a much bigger way, commercial semiconductors and commercial computers—instead we were called back within that same first week by the Secretary of the Air Force to sit down and listen to what had just come in from intelligence sources, namely that the Soviet Union was not building a fleet of manned bombers the equivalent of our SAC, our Strategic Air Command. Maybe they had decided they couldn't do it, really, realistically. But at any rate, they had gone to what for them was the next phase; they'd gone to an intercontinental ballistic missile, and they were well along on the creation of an ICBM system.

If, indeed, they did that well before us, and threatened us with a knockout blow on the United States, we had no defense whatsoever for that. The multi-billion-dollar, huge program of defense against Russian bombers by interceptor manned airplanes carrying guided missiles and radars, all of which we were building at Hughes—we had a sort of monopoly on that—they could destroy us in twenty minutes and the retaliation would be very likely not of great interest to them.

Now, the intelligence information that was made available to us looked highly credible, and that meant there was no question the Defense Department had to mount immediately an effort to evaluate all of this. So they put together a group of top scientific personnel with the highest priority for their backup, and they asked the Ramo-Wooldridge Corporation to drop any of our plans, any and all plans, and aid in that effort.

The assessment that was made—it took a few months to make it—was that the ICBM was a doable weapon system, and therefore we had to take seriously that the Russians had started on that years before. It would not be surprising that they would be well ahead of where we might otherwise be.

We all knew—those of us in the guided missile game—all knew that there was a little study contract at Convair [Consolidated Vultee] Aircraft Company to examine the possibilities of an ICBM. It was mainly on what you might call the aircraft structural aspects—what kind of thrust would you need, how big a rocket engine or engines would you have to have, what kind of accuracy could you expect. You take the weight of an H-bomb as the load that you're going to carry, and you're going to take that five or six thousand miles. There was a listing of the problems, but it was not taken very seriously. There was no hardware work. It was just a little study.

The Air Force was totally dominated by the idea that the only way we would expect to drop H-bombs on the Russians, and the only way they would expect to be able to drop them on us, would be to have men in the airplanes, and so everything was built around that.

BUTLER: When you began to then realize that the ICBM was going to be the direction to go, what did you think of the possibilities of doing it, whether it was feasible and whether the right equipment could be built to build it and the right materials and the guidance?

RAMO: Dominating the thinking of the Defense Department—and, I think, all the way up above the Defense Department to General [President Dwight D.] Eisenhower very quickly—was not the technical aspects, important as they were. It was, rather…could we organize to do it and to do it at so fast a pace that we could beat the Russians? Or at least come in very close to them so they would have essentially no substantial period in which they would have a threat of the size of importance that it would be to us if they were well ahead of us and we had no chance of being [even] with them.

The reason I say that is I remember that during that period—we're talking about the middle fifties—if you look back at the ten years from the end of the war to the middle fifties, that decade, it was taking us, to make a 10 percent improvement of anything, it was taking us something like ten years. The procedure was so slow, so bureaucratic, and the time it took to go through every stage of approval on contracts, the system of judging what to do, the system for simply making a decision as to what you want to do, what are the requirements, what will be the military situation that you want to apply advanced technology to, to solve—that procedure was cumbersome. It took endless committee action.

Now, look at the ICBM for a moment. In the ICBM it was clear that you would need rocket engines at least ten times bigger than any rocket that we'd ever designed and constructed. You would have to have instruments that would be ten times more accurate to sense the acceleration and, hence, the velocity that you reach, and, hence, know that you are directing the missile somewhere near the target, able to go 5,000 miles.

An ICBM to first approximation is a big container of fuel, rocket engines on the bottom to bring you up to such velocity that when you leave the atmosphere and sail off towards the target, you have such velocity that before gravity can pull you down, you've gone 5,000 miles. In fact, when you talk about 5, 6, 7,000 miles, considering that the Earth is round, or at least that's what we have recently been led to believe, if you go 10 percent faster than you intended to, you could miss the Earth entirely; you overshoot the target. You can go into orbit. We knew that the same equipment that would land several thousand pounds at a distant target a quarter to halfway around the Earth would enable you to put just slightly less weight into orbit.

Now, to do that you have to have a structure that would hold the fuel and all the instruments and, of course, the warhead that you're going to deposit on the target, hold that all together. The structure would have to be lighter by a factor of ten times than anything done with airplanes. In other words, if you take the ratio of the weight that you must carry, the fuel and everything else, to the structure that's holding it all together, it was a ten-to-one improvement that you'd have to have. So the question is, can you put the structure together and make that ten-to-one improvement?

I mentioned accuracy. I should say accuracy not only of the ultimately terminal guidance, but accuracy in control. Unlike an airplane where you depend upon surfaces to pick up the pressures of the air and give you forces that you can use for controlling the direction and the stability in flight, so you don't have it turning over and going through crazy oscillations. In the case of the ICBM, you start out with so little velocity. You've seen movies—everybody's seen television shots of a missile, a big rocket taking off—and you see it first moving up very, very slowly, a big blast of air underneath. Well, there you have no air forces coming from your motion. You have to swivel or control the thrust of the engines, the direction of the thrust. It's almost like balancing a pail of water on the end of your finger, taking it off, moving it up, keeping it balanced. Then you go through air. You're going faster and faster into the air that has great thickness. In that period it's a little bit like an airplane, but you go through the speed of sound. It becomes supersonic, and that's a different aspect of control in relationship to force that you can generate to control the angles, the stability of the whole craft as against the velocity.

Then you go into space, that is to say, into a region where you have very little air, for all practical purposes, almost the same as if you had a vacuum, and now to control that whole operation presents a set of problems, each of which is, again, ten times or more worse than any problem you've ever had.

Then ultimately there's the terminal accuracy. If you are going to have the H-bomb really effective in the target, you can't miss it terribly. You can miss it a lot more than with an ordinary small bomb, of course, but when you're going 5,000 miles—and that's a long distance—you have to compare the amount of miss that you can tolerate on the target against the distance that you've traveled. And this involves a factor, again, of the order of ten times. I use ten times because that's an order of magnitude and it just gives you an idea compared to 10 percent changes, little tiny changes taking so long.

And then comes the matter of reentry. You're out of the air, up into space, and you come back down. You're going at a high supersonic speed several times the speed of sound, so you're generating a great deal of heat. The heat would be enough to so raise the temperature of the bomb that it would make it ineffective. You have to protect it. How do you protect it? You can put a cover over it. Maybe it has to be thick because you're likely to lose a good deal of that cover in the process of the effect of the heat.

You have a problem of what you might call—I think we did call—highly interdisciplinary physics, aerothermal chemistry, because you've got heat, you've got the air forces, and you have the matter that makes up the air and the material in the nose cone coming together, abrasion, melting off, and, in general, losing material whose atoms and molecules mix with the air. Some of the heat gets carried away, some of it gets absorbed and will cause melting and, of course, ruination of the structure. That was more than a factor of ten times anything being generated before.

So we knew we had to do things like the following. First of all, we had to create an industry that could make the devices, the rockets, the accelerometers, the gyroscopes that could stand enormous acceleration, high Gs. You had to figure out how to handle a structure, maybe do it with new exotic materials. You had to solve basic physics problems.

Somehow you had to simulate the amount of heat that would be generated into the nose cone. You could take some air, put it into high speed in a tunnel of some kind, have an explosion that would create that high-speed air, cause that to impinge on a target, measure the heat being generated. You could fire a rocket—maybe three or four stages to get up to high speed, up into the sky—and then design it so that as it falls back down it would turn over, and then fire some rockets on the way down so when you get into thick air you generate even more heat…than the ICBM would, [and] measure that.

You could take some of the top theoretical physicists in the United States and put them to work theorizing about how much heat is generated and what might be done to remove that heat, and people that know a good deal about fundamentals of matter to speculate on how you might choose such materials to cover the nose cone, that it would absorb a lot of heat as it gets heated up by the forces being generated during reentry.

In other words, this was quite a project of tremendous dimensions. I mentioned very briefly the need for a manufacturing industry that would manufacture these things. It's not only that you needed a system that would include just one missile or ten, but maybe hundreds, thousands of them. But before you could get there, you would have to be manufacturing a good many more parts on the way to refining the design so that all the parts would work and have a reliability such that when put together, the missile, upon takeoff, has a very good chance of getting to its target—which means you have to do a lot of tests of the components. You have to shake them. You have to put them through stresses. You have to set up simulations. So you take the pieces and you cause them to think that in the actual missile you subject them to all the high vibrations that you will have. For example, you put signals in and out. You put electrical communication into action. You create a big chamber that you evacuate so it will have the conditions of vacuum in space, and you cause the materials to be subjected to what they will be subjected to under those circumstances.

So you need ten, fifteen times as much equipment. You need a production line of some things that you haven't designed yet. You'd better start working on a production line even though you don't know exactly the details of what it will produce. Insofar as you have a pretty good idea what kind of thing you will need, you'd better start getting those factories ready. You need to instrument Florida and the islands east of Florida, because you're going to have to test, and you want to go in that direction away from the United States because it gives you the advantage of the speed of the Earth as it turns in that direction, and you don't want to have the missiles come back on the United States, some parts falling back. You want to do it out into the ocean, and you have islands out there. So we had to make a part of

Florida a high-technology test region, and that means you have to design apparatus that would do the measuring. So you needed big teams, and they all had to be coordinated.

Now, you can see why I say the technology clearly, of course, basically was the dominant characteristic, but it soon presented itself in such a way that you knew organizing to get the effort done was going to be a bigger problem than the technology that you're trying to create. This was made clear by the people that understood this kind of thing, this group that had been put together. Wooldridge and I had been asked to serve on it. The great John von Neumann, one of the great geniuses of the century, was asked to be the chairman of that advisory committee. [It reached]…the conclusion it could be done, provided you organized it in an exceptional way. This went, again, right up to the top of the government.

It required, on the part of President Eisenhower, that he recognize that the Congress would have to be brought along, but not in a way that has become the pattern, in a way that could be done, then, and especially, I guess you could say, with Eisenhower as President, because unlike the typical President, he had a position as an expert in the military side of things, as well as a confidence in his objectivity. He could go to two or three leading senators, the most important one of which who was more or less the chairman of this small group, was [Henry Martin "Scoop"] Jackson from Washington. Jackson, because he was from the state of Washington, was often called "the senator from Boeing," because the biggest thing in the state of Washington having to do with the military was the Boeing Aircraft Company.

Boeing was one of those heavily involved in manned bombers. The leaders of the then Air Force were man-in-the-cockpit generals. It was not natural for them to think in terms of an ICBM being a way in which you're going to persuade the Soviet Union not to start a nuclear war, and we did have SAC as a result, and Boeing was the principal contractor of the airplanes making up our manned bomber force. Yet despite this, "Scoop" Jackson, as he was called, saw right away that this was something of unusual, unprecedented importance.

This program had to go, and it had to go in such a way as to make it successful. He was very helpful to the President in creating a program of such secrecy that it was understood that the rest of the Congress did not have to know and be in on what was going on. A few members of Congress—and they were something on the order of five—in effect, were able to say, on a nonpartisan basis, to the rest of the Congress that this was an important thing that had to be done and had to be kept secret. You couldn't do that now, I don't think, politically. I'm not, of course, an expert in this field, but I think most leaders of the newspapers or watching the television news could be forgiven for assuming that it would be very, very difficult to have something like that occur today.

This program was created, then, as a really super crash program, and General [Bernard A.] Schriever was selected as the military executive who would be given the task of overall responsibility insofar as the Defense Department had responsibility. He was given unprecedented authority, and the part of the Defense Department that handles contracts assigned a general to him, who would be able to produce the contracts. The Secretary of the Air Force, of course, was in on it, and there was a chain, in other words, of just a few people who could bypass the rest of the organization. That took a bit of doing and, again, if that had not been the case, if that organization could not have been put together, the ICBM program would not have been a success.

Eventually, with our method of doing it, we would have had an ICBM capability. But it would have been far later than the Soviet Union, and the consequences of their being considered ahead in most vital aspects of the Cold War situation, namely the ability to knock out the other nation with an H-bomb attack without any defense against it, would have caused them to have a prestige, a confidence, a bravado, a position with the rest of the world that would have given us, shall we say, great difficulty, and anything that the Soviet Union was interested in pressing would have gone better.

Any doubt that what I'm saying is true, I'd say, was dispelled by the reaction of the world to the Sputnik. The fact that the Russians were the first to put something into orbit caused them to be regarded as superior in technology all around the world, and gave them a position that caused the United States to have to react to that, having already reacted to the far more important thing of their possibility of ICBM superiority.

BUTLER: You mentioned Sputnik. When did you learn of Sputnik and what was your initial reaction? At the time, did you realize how much impact that did have on the public and the world?

RAMO: Well, first of all, I personally had a problem or a challenge having to do with organizing the scientific and technical team to do the job of overall design, development of the ICBM system, to serve as the central integrating team to make the decisions on a technical basis and to utilize the top technical industry and the talent of those in academe and in government laboratories, to get the top talent of the country.

Naturally, it was obvious to me, and it is no great indication of ingenuity or great vision on my part, that I had to consider what would happen next. I knew the ICBM situation would go on indefinitely for decades with improvements, 10 percent improvements and so on, additions, and we were in a permanent contest with the Soviet Union in that regard. But I meant what do the top unusually outstanding scientists and engineers do next? It was very plain that what had been talked about as evident for many years, of putting equipment into orbit, was going to be a next step, because it would be so easy to do. All you had to do was take out, as I said, a little of the weight of the warhead and you could put the equipment into orbit.

If what you wanted to do was to have, in effect, a relay up in space for communications so that you could communicate with it from a point on the ground, then have that communication relayed back down to some other point on Earth, you could put any two points on Earth in contact with each other [as] if you had a high mountain out there, a high point for relaying it. You could use that position to observe the Earth and to observe the universe beyond the Earth in a different and, in many ways, superior way. You could do a better job of airline navigation and traffic control. You could study the weather. You could even conceivably influence the weather in time, by putting nuclear energy in the right places at the right time. You could observe the Earth resources. You could know when situations were developing that might cause severe floods or impact on agriculture. You could bring television between points on Earth. Instead of the shortwave communication where you send your signals up to the sky and hope that they'll bounce around against the ionized layers that exist around the Earth and come down to Earth [and] you get high static.

Some people are alive today that remember when we used to use short waves for the purpose of getting communication from observers in other countries. The signal would go in and out. You'd sometimes hear it and sometimes not. Telephony, voice communication, would not have to be done necessarily by cables. Cables at that time appeared particularly impractical for television.

So whether it be entertainment or research or airline navigation and traffic control, computer-to-computer data, running the operations of the physical world, it was clear at some time there [were] going to be numerous systems of satellites in the sky affecting the society on Earth here. Of course, for the military, observation of what was happening—intelligence, reconnaissance, and communications for the military—was going to be important, so this was going to be an important dimension.

So I had actually incorporated the name Space Technology Laboratories [STL] and gotten approval from the board of directors of TRW [Thompson Ramo Wooldridge, Inc.] to acquire land and start building some facilities for the manufacture of spacecraft before there was a Sputnik. So it didn't come as a great shock when the Russians put up something in space, although I was surprised that they had chosen to do that.

There was something that was going on at that same time called the International Geophysical Year. The scientists concerned with pure physics, physics related to the Earth, were planning what was called the IGY. The International Geophysical Year, I think, is where it came from, and one of the plans was to put up a small satellite on some small rockets. It was a small project. The question had arisen—from some scientists that were cleared and were working on the ICBM program, if only in a consulting capacity, and who had a great interest in the IGY—they would naturally bring up, in classified circles, "Hey, this would be an easy thing for the ICBM, big ICBM project. You've got the rockets. You've got all the stuff. You've got the setup in Florida." [With two] tiny little side efforts, and we [could] put up a bigger thing with more stuff on it, get a lot more done.

This was international. I, not being primarily associated with International Geophysical Year people, was loosely aware not only of the project itself, but of the fact that the Soviet Union was regarded as a pretty minor possible contributor. If I had been truly visionary and smarter and, more especially, if others had been in the United States, they could have reasoned as follows: The Soviet Union, working on an ICBM and ahead of us, at least initially until we got really rolling, must have asked themselves, "What can we do in the IGY year?" And they possibly could have been insulted to have the rest of the world, particularly the United States, really the leader of the IGY program, assuming that they would have practically nothing to contribute. It would have occurred to them that one of the things they could do is put up something in orbit ahead of us and with substantial weight.

I need to bring up in this connection one thing that we also knew by then from intelligence. The Soviet Union was well behind us in the development of nuclear bombs, so that for the same kind of yield, for the same effectiveness of a bomb, they had to assume it was going to be heavier. If you have a heavier payload, all the way down, the missile down to the rocket engine[s] has to be bigger. So they were working on an ICBM that was bigger than ours and, therefore, able to put more weight into orbit. If you take a bigger bomb out, you could put even more weight in it. Surely we should have figured out it would occur to them that one thing they could do was go ahead and put something into orbit ahead of our IGY program and show, by gosh, that they were not inferior, they were superior.

Now, even if we had figured that out and counted on it, it is reasonable now, looking back, to assume that our leadership, though I'm sure did not think about this, would have assumed that the Soviet Union putting up something into orbit—"So what? What if they put a dog up in orbit as well on the second one? All we have to do is say, 'Well, that's not a great feat. All you do is have sloppy guidance accuracy and overshoot a little bit and you go into orbit.' What's the big deal?"

In fact—a more direct answer to your question, when did I learn about it—every Saturday morning General Schriever and I—we called it Black Saturday—used to gather in a special room that was loaded with charts, and we'd spend three hours, nine to twelve, reviewing every aspect of the program each Saturday. That was the Saturday mission, what had happened during that week, what was supposed to happen during that week, and then a lot of numbers that were generated.

We knew, for example, how many engineers were on the payroll of each of our major contractors, and so we could look at those curves and why would the curves show, for example, a sudden rise in the number of people working at Company X on the program? We knew that meant that they had just had something canceled somewhere else and they moved those people over to the program. What were they doing with those people? Why did they do that? What I'm saying is, we had not only progress on tests and on flights, on difficulties that we may have run into, technical difficulties, we had a lot of numbers showing progress that gave us clues as to what everyone was doing and where it was going on. That was Black

Saturday. We were interrupted. I remember a colonel coming in and giving us the information that, "The Soviet Union has put something in orbit."

On Monday morning when I came into work, I changed the name of the part of Ramo-Wooldridge that was doing this work, which had a nice general title—it was called Guided Missile Research Division [GMRD]. There were a number of companies involved in guided missiles. It didn't give away anything about what we were doing. I changed the name of that entity, announced a new name: Space Technology Laboratories, a name that I had incorporated in order to save the name, as I have mentioned earlier, some years before in anticipation of space becoming the follow-on to ICBMs.

On Wednesday, I received a call from the Deputy Secretary of Defense, Don [Donald A.] Quarles. Charles [E.] "Engine" Wilson, the former chairman of General Motors, was the Secretary. Don Quarles, who was a top man from A&T, was the Deputy Secretary of Defense. He said, "Si, I've just learned that you changed the name of the part of TRW that is running the nation's most urgent, highest priority, biggest program, to Space Technology Laboratories. Now, you're a private company. I can't tell you what to do. But may I suggest that you consider removing that new name, going back to the name that you had? The Secretary and I have discussed this, and we have decided that this little thing that the Russians have done, putting this little basketball up into space, will be forgotten in two or three weeks. It doesn't amount to anything. But you will be in the position of appearing to have gone off and with an exaggerated impression of the importance of this. In other words, you're off in space, and this will hurt your position of realistic, sound management of the program."

So I said to him, "I will do just what you said. I will consider changing the name back." I didn't say I would; I said I'd consider it. Because the moment he said it would be forgotten in two or three weeks, I said, "That's a big question, and I don't think that's going to happen. But I have two or three weeks. I'll wait two or three weeks and see if it's forgotten."

The buildup was enormous—in the world. I felt there were only two other occasions I had experienced: [Charles A.] Lindbergh's landing in Paris when I was a teenager, I guess, about that time, FDR's [Franklin Delano Roosevelt's] death, and the Sputnik, in terms of the nation being aroused and feeling something very fundamental, something earth-shaking, something that's going to change things in a major way, affecting all of us, is going to take place. This was an enormous reaction.

I never heard from the Secretary—and I saw a good deal of him and talked to him a lot—about changing the name back. It remained Space Technology Laboratories. [Laughter] And because we had started and were preparing for it, we did win in the competition the first spacecraft when NASA [National Aeronautics and Space Administration] got put together, and decided it was time for them to put out contracts. They chose to create an unmanned space program, and that was the Pioneer series. That was the reaction to Sputnik that I felt.

BUTLER: Wonderful. You mentioned NASA. In response to Sputnik, of course, the U.S. did put up Explorer eventually, then moved in to creating NASA. As the U.S. was trying to respond to Sputnik, at the time what were your thoughts, your involvement, and then as NASA was being created, what were your thoughts on that agency?

RAMO: Naturally, when I mentioned that we had created Space Technology Laboratories as an entity, then moved that name over, it was a subject of considerable discussion among those very active in the ICBM program, that what we had was 90 percent of what you needed to put equipment up in space. So there was a great deal of discussion as to what would happen, how would this program go. My favorite—naturally I remember my own thoughts somewhat more than I remember other people's—my own favorite prediction was that we would do, the United States, with space something similar to what we did with regard to nuclear energy.

When World War II was over, it was clear that nuclear bombs were going to be here to stay and were going to be an enormous factor in determining national security policies and the development of weapon systems, and that would be true not only of us, but other parts of the world, notably the Soviet Union. But we didn't assign to the Defense Department everything involving nuclear energy. In fact, with the war over, with the idea that practical commercial applications for the good of society that were not involved with weapons should be the dominant thing in the minds of all of those in the public and in the Congress, who would decide such things as budgets, the Atomic Energy Commission [AEC] was created as an independent entity reporting to the President, and it provided the weapons for the Defense Department, but it was seen, you see, as a civil organization. It had high clearances because it included the weapon system, but much was made of the peaceful civilian applications of nuclear energy, rather than further development of bombs, which remained highly classified. The Atomic Energy Commission, five commissioners, one of them to be a noted scientist in nuclear matters, there were various committees advising the AEC.

Now, looking at the ICBM program, a bit of an analogy there. The ICBM was the application that went up into space and back down to bomb a potential enemy, but space should be looked at by the public and by the Congress as the nonmilitary aspects that deserved independent government funding. So there would be a new agency.

I remember joining in some discussions, having fun with the “hole-in-the-ground agency.” I would make my point by saying, "Suppose the Soviet Union had dug a hole deeper than any of our drilling for oil wells, a big hole at that, and had gone deeper than anyone has ever gone." There would be those who say, "You know, if you do that, you will learn a lot about physics of the Earth, really find out what goes on down there. Now you'd have something big enough that you could put a man in a capsule down this hole, not just six inches for oil wells."

Some would argue that they can mine us from underneath. It will be a military advantage to them. The Air Force will say that the moment you dig a big fat hole like that, air goes down in it, and it's the Air Force's project. The Navy will say, if you go down, chances are you're going to find water. And, of course, the Army will say, if there's anything, that's ground-to-ground warfare. Some noted scientists will point out that you should really do research to find out how to dig bigger holes.

For example, some of us were inventing words like "terrajet." You use a nuclear bomb that's controlled. By that time there was discussion about what happens if there's a runaway effect of a nuclear reactor. Remember the movie or two that was made based on that. You'd get down to China. You can't stop it. It gets hotter and hotter and keeps eating the Earth away. Well, use that phenomena to dig a big hole and find out what really is at the center of the Earth. Great, important scientific project!

So you see this was a subject of great discussion, and I argued that we ought to have a new agency for space, and if the Russians had gone down in the Earth instead of up in the sky, we'd have a new hole-in-the-ground agency. So we must have a space agency, because you can't let the Air Force and the Army and the Navy [in] interservice rivalry over space. Well, of course, the Air Force would be given the military applications of space, but there's a lot more to it than the military. So, NASA should be created, and so we fully expected NASA to be created.

When NASA was created, we said, "Well, you see, we analyze this and we're ahead of everybody. We understood it. Look what great predictors we are." The secret, of course, of being a great predictor is to have the knack of being able to forget any predictions that you made that were wrong and be able to remember with great accuracy, as I'm doing now, the predictions that you made that are right.

BUTLER: Absolutely. That's the way of the great predictor. As NASA was being formed and as Sputnik and Explorer were happening, what discussions or investigations or studies were you involved with for the manned aspect of space?

RAMO: My own personal involvement tended to be in what you might say "goals in the large." By this time I was getting to be, I guess, in the semi, at least, elder statesman class. I'd been heading a big program and I was moving along in years. I knew the leaders, whether they were in industry or in government. I was part of the fraternity.

I was frequently invited into discussions of what we should be doing. There were some that were extremely interested in having man in space, sending a man to the moon, sending a man to Mars and so on. The military never saw putting a human being in space as any real advantage. There would be discussions of the following kind, oftentimes with people from the media involved when it was unclassified discussions and when it was at some large meeting of scientists and engineers with people from the press present. Some military, some civilian, people in the government, here and there a senator, congressman who was especially interested, and there would be statements like the following made: “Whoever possesses the moon controls the Earth, because it's the high ground.” Of course, if you're on the moon, the Earth is the high ground. In other words, it's nonsense to talk about high ground when you deal with that kind of an assumption in the first place, about using the heavenly bodies. Whoever controls the moon would be able to use, say, the back of it to store ICBMs, and if you're not up to the technology, you won't be able to do anything about those ICBMs. You could also, of course, put the ICBMs at the bottom of the ocean or the North Pole if you want to take places where it's difficult to get to and handle the stuff, and requires [an] enormous project to place them there. You could think of things almost as silly as the moon, without including the moon.

So there were a lot of things that didn't, shall we say, last very much once they were analyzed a little bit. The Air Force was the dominant of the three, four major services, depending on whether you count the Marines or the Coast Guard along with the others, but there was never any real interest in a practical way, because anything that a human being could do in space for the military could be done with apparatus far better.

If you want to look at the Earth, you don't want to depend on a human being's eyes and have the problem of getting him up and down and keeping him healthy. You want to put instruments that will be far superior to eyes, whether it be radar [or] infrared, covering the range of sensing of effects from a distance, not just the optical range suitable for human beings. If it's a matter of listening to signals coming from the Earth, so you know what's going on down below, again you want to be able to pick up radio, television, radar, other signals that the human being can't pick up anyway. Well, of course, a human being can sit up in a space capsule and look at a screen that has all the apparatus, but why not send the same information that goes to the screen from the sensing instrument down to Earth? If you can put a man up and back and stay in contact with him, of course you can send those signals back down and let people look at a much bigger screen together, analyze it, and make prints and do all the things you want to do. So, to this day, to my knowledge, the Air Force has no interest in man in space.

In a similar fashion, the scientists of the world had two barriers to an interest in man in space. First of all, was the question of interest in space. If you have a certain amount of funds only, a certain amount of effort you can fund in pure research, you should put it into those areas that deserve the highest priority. And to scientists in general, space was just [one] field of interest. Nothing signaled that it was especially blessed from up above with a priority that required it to be put over, let's say, microbiology, where you might get a cure for cancer. So to scientists at large, space was not a special priority, and with most scientists it was not regarded as equal priority to many other things that they could mention in other fields of endeavor.

To the commercial world, it's very difficult to compare the possibility that maybe you could manufacture something in space better than you can on Earth, and if you took return on investment, investment placed at risk to advance technology to do things for the peacetime commercial pursuit of civilization here on Earth, th[en] information technology—computers, communications—would have to rank much higher. And insofar as space could be a factor, as with communication satellites, fine. But man in space? No.

If your interest is in research in space, what you can learn by equipment in space, what you can learn about the formation of the universe, particularly of the solar system, the cost of having human beings involved, such as placing human beings on Mars, protecting those human beings, and even putting human beings on the moon—to the scientists' world that couldn't compare with all that you could do with instruments and communication.

Some may recall that we actually did put a microminiaturized laboratory about one cubic foot in size, a cube of about one foot on each side, of apparatus to search for life on Mars. It was landed there automatically, scooped up earth automatically, analyzed the earth. It poured stuff on to a little bit of earth there, made observations of various kinds to chemical reactions and so on, and sent signals back. That was a substantial program, like 100 million dollars. It would have taken not 100 million, but 100 billion dollars to put a man up on Mars and bring him back alive, and he would not be able to do all the things that this instrument did, unless you accompanied him with this same package. And you wouldn't want him to wait and come back and tell what he learned. Send the information back by radio!

So how come we did the lunar project? How come that was so important? That, of course, was psychological. We would not have had a lunar project, at least not at that time, if the Soviet Union hadn't put man in space first and appeared to be ahead in the ability to place men on the moon.

Now, at about that time, I chaired for the CIA [Central Intelligence Agency], a committee that met once a month. This was in the sixties, after we had the goal to land men on the moon and bring them back alive before the end of that decade of the sixties, and succeeded. The principal reason for this advisory committee was to enable the CIA to have greater confidence that their staff was doing the right things, and analyzing from everything the kind of information we could get, how the Russians were doing in landing men on the moon. Another race. We must land men on the moon before the Russians.

We began to realize, as the information came in, that they had no intention of putting a man on the moon. They had done what appeared to many in the United States involved in these activities, the right thing to do, and that is to put instruments on the moon, put instruments in orbit, put instruments in the lunar landing and do various things, sense various things, bring back information in that way.

The Soviet Union that had this spectacular, sensational set of successful results with their initial Sputniks, including putting an astronaut into orbit, began to run into difficulties, and they never did get their lunar program to work. They made a number of efforts. Things just didn't work for them. They went the way probability analysis would suggest you might expect they would.

We, on the other hand, had spectacular results in a favorable way after we lost three astronauts on the ground [Apollo 1 (AS-204)], where I personally thought this was going to be typical, and we had one spacecraft to the moon, it was Apollo 13, where we had an explosion. We couldn't separate away the two astronauts to make their landing. We had to use equipment that we had on board in ways that hadn't been planned for as a possibility to bring three astronauts back alive. But it wouldn't have been surprising to some of us had we had the program delayed by years and stopped it a number of times because it seemed to be dependent upon equipment whose reliability could not be expected to serve the purposes in a way acceptable to the American public. And as you know, as we all recall, who were involved in any way, the three astronauts who were killed on the ground before a takeoff—when we were using pure oxygen rather than a mixture of oxygen and nitrogen for the gas to be breathed, and had the fire—we delayed the program for a year or two to be sure that we had solved that particular problem. And even more recent flights in which we did lose a number of people in—what was the number?

BUTLER: The [STS] 51-L, *Challenger*.

RAMO: The *Challenger*. That caused a substantial disturbance and delay, and yet it was the only one. Those craft, with several people aboard, have gone up now many times. So they had good luck, if you can use the word "luck" there. They [the Russians] had a good record of reliability and success at first that was very impressive to those of us in the game, that made us fear it would take us some time to attain that degree of reliability.

Then they began to catch up with themselves, you might say. What they were trying to do was a little bit beyond what they were prepared to do. They were also handicapped by racing and hurrying, and we caught up with and improved our reliability to the extent that we did it exceedingly well.

BUTLER: You mentioned the problems with the Apollo [1] fire and with *Challenger* and so forth, yet the first discussions about putting man in space, from the American program, were on the Atlas, which was intended to be a missile, which was intended to destroy and to kill people. What were your thoughts when the discussions were arising about putting people on top of this and the problems in developing it and making just the rocket as a whole? Of course, it experienced difficulties along the way.

RAMO: Regardless of what each of us might have thought we would do if we were the benevolent dictator for the United States, we could see that what the Soviet Union had accomplished psychologically around the world, and the repercussions of that, very negative for the United States, required that we have a man-in-space program.

Goodness, a South American or Central American country on the verge of going Communist, the respect for the Soviet Union increasing as it did, could and did make oftentimes a difference between whether they were going to go in the direction of being in the United States' camp, relying heavily on relationship with the United States, or in the Soviet Union camp, and whether the world would go Communist or not was, in part, going to depend upon whether we had a man-in-space program and could outdo the Russians in that. So we knew it was necessary.

Now, what did we have? We had equipment coming off our production lines. The Atlas was an example. It's not the only one. There was the Titan missile, there was the Thor missile. We had a certain amount of weight we could put into orbit. That could include, especially if you did a little additional boosting, a little modifications to cater to that particular mission. It was the most reliable thing we had, because we'd been doing a lot of testing to try to get the reliability we needed for the ICBM program. To start from scratch and say, "This isn't optimum," if we had it to do from scratch, we would build a somewhat bigger missile. The Titan was somewhat bigger. It would take a larger payload a little farther than the Atlas would. But either one of those was a good starting point, so we took it for granted that's what you would do, since those of us that were directing, doing the ICBM program, were most knowledgeable about that apparatus we were involved in, in providing everything about that flight, the control of the hardware from beginning fabrication to the launch pad, and various things about the launching in Florida.

BUTLER: If the ICBM program hadn't gotten the approval and hadn't gotten the boost when it did, and yet the Russians had gone ahead and put up Sputnik and had their ICBM and put a man in space, what impact do you think that would have had on America?

RAMO: Of course, now, I'm perfectly willing to give you my thoughts. It should be understood that I don't presume that I have the expertise. …I could be forgiven for assuming at least I have or had access to in the case of the military application, the ICBM program But again I say it would not be surprising if anyone of some reasonable intelligence, who was in discussion with people that were anxious to write about these things, whose background might have been history or psychology, but I think that what happened, as we know now, is that as years changed to decades, the Soviet Union lost its prestige. The negatives of what they were doing and how they were doing it in the running of their world became more evident than the positives.

They were looked upon as being wrong about the way you organize a nation and the way you handle the relationships between a government and its people. But they would have done better, they would have gone further. This could have led to all kinds of difficulties. We might have had Vietnam, Korean, Central American situations going much further in their direction, so it would not have been possible for us to change it without a much bigger effort, which we might not have taken on. We might have felt that we couldn't do it.

Just as today, for example, no one assumes that we could go into China with a military operation and tell the Chinese how to run their world. We would have had to give up some of those marginal things. But more importantly, you may recall that Italy, for example, was on the verge of going Communist, a reason for the Marshall Plan, what we did in Greece. The Soviet Union, moving from the east [to] west, might have succeeded… They took over Czechoslovakia and, of course, there was the uprising in Hungary. A good part of Europe, in other words, might have gone much more strongly into the Soviet Union camp, making it exceedingly difficult. NATO [North Atlantic Treaty Organization] might have been less successful in organizing relations between the leading nations of Western Europe and the United States to have a credible defense against the Russians, should the Russians have decided that they wanted to take over all of Western Europe, as [Adolf] Hitler did.

So one way to say it is, who knows what would have happened? But at least it is reasonable to assume that what would have happened would have been less desirable from our standpoint than what did happen. And either we would have been caught up into situations that would have required much greater expenditures with poor results in order to hold our own, or else we would have moved back, become more isolationist, and let these things happen, even as Western Europe let Hitler take over [as] Britain and France did, for example, and that led them into a situation far worse than what might have happened had they acted earlier. We would have been prevented from taking some of the actions that we took.

BUTLER: Thank you for your thoughts on that. Luckily, it has worked out well and America has still got a strong stand.

RAMO: Well, it's worked out better than it might have, had the space program not gone the way it did, which wouldn't have happened, as you said, as you suggested, without the ICBM program.

BUTLER: Very key element. Looking on that and the involvement, then, with the Mercury Program and applying the Atlas to the Mercury Program, what was then your interaction with NASA, as well as the military at that time? How did that relationship evolve and what did it entail?

RAMO: As near as I can recall, the relationship of NASA and the Air Force was a good one. There was a clarity that in some respects might have been surprising, between the NASA mission on the one hand and the Air Force's mission on the other. It was far superior to the typical interservice rivalry situations that exist today, that have always existed as long as there's been the three services. The role, for example, of aircraft carriers versus long-range bombers has always been, and always going to be probably, a good example of gray areas, difficulties in trying to define the areas, the missions of each of the services. But NASA was nonmilitary and the Air Force is military, and that worked out well. [Brief interruption.]

BUTLER: Looking at the involvement, as we were just recently talking, with NASA and the Air Force on the Atlas Program, to bring the Atlas up to manned specifications and to work NASA into it and using it and launching it, what roles did you have there? Were you involved with any training aspects for them or the launch site, developing that?

RAMO: Well, the large teams that we had on the apparatus itself, on being sure that everything was in proper condition, checking everything out, and the teams in Florida to make sure that the launch would go well, they were placed totally at the disposal of NASA. Except for making sure that that would happen, I personally was not on the site and not standing there directing anything. So I had very little to do with such details.

BUTLER: Were you able to be on hand to watch a launch of the Atlas, a manned launch?

RAMO: I watched a couple of launches. I watched the first night shot, for example.

BUTLER: Was it very satisfying to be able to see what you'd been spending so much time on come to fruition?

RAMO: Well, of course, before that I had seen ICBM launches and I'd seen a lot of pictures that we had taken of ICBM launches, and I'd seen pictures, of course, of the launches of the Apollo Programs. I have to say that what I saw with my own eyes was what I expected to see. It was not all that surprising, different, thrilling, really.

BUTLER: I guess that's good.

RAMO: Well, if this is what you do for a living, it can't be quite the same as it is if you're on the outside. The mystery was not very high.

BUTLER: And you like it to go as you expect, because that means everything's going well.

RAMO: Yes. Naturally, you're always a little nervous, a little concerned. But if you're in this kind of endeavor, you have to be prepared for disappointments and not let it get you down. In fact, you've been improperly selected for the task if you're the kind of a person that's going to allow disappointment if things don't go well to dominate your decisions and the enthusiasm of the effort.

You know, once on the Thor missile, the first missile that had a launching to try out the launching apparatus, I had to make a decision as to whether we would attempt to launch it. The Thor was…the intermediate-size missile…in some respects using the same rocket engines, but less of them, with less fuel, smaller distance to be traversed if all went well.

We had assembled the various pieces, important pieces of apparatus, had shaken them, had vibrated them, had put signals on and off of them, and subjected them to various mechanical and temperature stresses. These things were, what should we say, worn out, they were no longer reliable pieces of apparatus. You wouldn't expect them to work the first time without further adjustments perhaps here and there, a change of a little part, if all you were doing was putting them on a table and putting them through some paces, some aspect of what they were up to.

I thought it was important to assemble the whole shebang, hold it down on the test bed, and fire the rocket engines and see what we could learn, even if things would be falling apart in front of us. And then having done that and done some tightening up and replacing and beefing up, readjusting, reassembling, I decided we should take the risk of letting it go. The worst that would happen would be, it would go up for a few inches and fall back down, or it might go out a short distance before things would come apart one way or another. And not only that. I wanted us to subject it to additional forces beyond what would be the ordinary ones, by which I mean give it a direction, an order to turn severely, more than it would in the ordinary flight. If, of course, it came down prematurely, we would have to blow it up and be sure we were off on a trajectory where there would be nothing underneath that might harm individuals or something of importance in the way of apparatus underneath.

Sure enough, this missile came up and came down pretty quickly. Everyone was disappointed, of course, even though we knew that that's what it was very likely going to do. [Laughter] And there we were in this specially prepared bunker with extra-thick glass, little windows to look out, at a proper distance away and so on, and the buttons were pushed and it fired up, which in some respects was great. Instead of failing to fire up and finding out what had gone wrong, the rocket engines lit up and began to exert their force. And then something went wrong and it came back down. And coming back down, the fuel, of course, was burned in a hurry. You could call it a semi-controlled explosion. But it had left the pad, and there was this lull. No one said anything for a moment. So I said, "Now we've proven it can fly. We simply have to improve the guidance accuracy." Because, you see, the Thor missile was supposed to go 1,500 miles. We had a 1,500-mile miss of the target! We now see what the next step is: improve the accuracy of the guidance. [Laughter] And everybody had to laugh, if only to be polite, I suppose.

But this is what I mean when I say that if you've lived with the apparatus and you've been observing enough flights and enough film of flights, and as with going to the doctor's office and getting a check on your heart and you see all the wiggly lines on paper, if this is what you do, even if you get some unusual lines that indicates that you've maybe become the discoverer of a new heart disease that never was there before, a very experienced physician is not going to jump up and down either from negatives or positives he observes.

BUTLER: Just doing the job and seeing it gets done.

RAMO: Yes.

BUTLER: A few weeks after Alan [B.] Shepard's [Jr.] flight, which was actually on a Redstone, President [John F.] Kennedy made the announcement that we should go to the moon by the end of the decade and bring a man safely back to Earth. Were you involved in the buildup to that, the discussions on that? And what was your response?

RAMO: Yes. Well, my contact at that time on that subject was Jerry [Jerome B.] Wiesner, who was the President's Science Advisor, Jerry Wiesner, who, after that, became president of MIT [Massachusetts Institute of Technology] and was one of MIT's leading professors. He was head of their big electronics research and development laboratories that had a lot of government contracts. He had also been, from the beginning, a member of that committee I referred to earlier that helped make the decisions about whether we could do the ICBM, and, if so, how to do it, and the decision to do it.

He and those advising him—members of what was called the PSAC, the President's Science Advisory Committee—they were very much against the psychological PR [public relations] program, what they called it. They correctly predicted that we would land some astronauts on the moon and we would put the Russians to shame, and once we had done that, there would be lack of interest and the moon program would be stopped and never go anywhere, and that was what happened.

Now, I felt that, while I understood that reasoning, that they were overlooking the very PR thing that they'd labeled it with. It was necessary. I had no doubt that if I were the President, I would be influenced more by the need to show that we were superior to the Russians, not the other way around. But that had to be done, and it would be worth the tremendous effort and expense, and I would feel this so essential that I wouldn't make comparisons between how many additional hospitals you could build and how many poor people you could bring up above the poverty level with that same money, as being the right thing to do against the moon program. I felt it had to be done, and you might as well accept it and get on with doing it.

I had to appear before the congressional committee that was presumably deciding whether to fund the program that President Kennedy said he wanted. The Congress, in the end, [would] have to decide to foot the bill and, hence, to make the decision to do it. Couldn't be done by the President by edict alone. It had to be something that Congress had passed a bill to do and provided the funds for. And I decided I would, in my testimony, try to state what I saw as the pluses and minuses of doing this, and I did that, and I thought I did it reasonably well.

I was not amazed when the chairman said, "Dr. Ramo, I can't tell whether you're for it or against it." [Laughter] What he would have preferred would have been just a simple "yes" or "no." Do you think we should spend this money to send a man to the moon? I had no intention of doing that. For one thing, I felt, not with any false modesty, but in total awareness of what I could consider myself knowledgeable about and not, I didn't think I was an expert to decide on the political, psychological, social importance of proving superiority in this arena.

There were many other ways in which we were clearly superior to the Soviet Union, and including in high technology and in science, and that this was not necessary totally But I didn't think the public would see it that way. And I could understand that the political leadership of the nation should have been, at least, regarded by me as expert in political, psychological, public relations aspects as in the space and missile business. So I didn't want to simply say, "I can see a lot of negatives about putting so much in the way of resources in that direction," but on the other hand, that's overridden by the importance of the impact on the general public of the world. Who am I to talk about that comparison when I'm only knowledgeable in one part of the two? So I thought I would just list the pluses and minuses as I saw them and not try to arrive at a final decision. I didn't attempt to explain that to the chairman. I think I must have, as I recall, said something like, "Well, you have just the [right] impression of what I said." [Laughter] At least I was clear on that subject.

BUTLER: That's good. Very clear.

We've talked now a little bit about various aspects of the program and some of the ins and outs. Can we talk about some of the relationships and some of the people you worked with? Like General Schriever, for instance, or some of the people at NASA. Can you tell us about them and how that all worked with the ICBM and then the transition over to manned program?

RAMO: Well, we were, in the United States, extremely fortunate in, I'd say, the accident of Jim [James E.] Webb, in particular, at NASA and Bennie Schriever, General Schriever, in the Air Force being in the positions that they were in.

Let me comment on General Schriever first, because he was in the job of the ICBM before the NASA was created. There were perhaps in the Air Force, in the category of generals from one [star] on up, something of the other of six or seven generals that I would say could seriously have been considered to head this largest program that we've ever had in the United States, a high-technology program, but with much more than technology involved. These were people that, of course, you'd have to first say had leadership qualities—presumably a general has. They would have to be people that had an unusual feel for, if not a substantial degree of expertise in, high technology. They would have to be accepted because of their personal involvement with scientists on one project or another over a period of time, with engineering projects, their education and their contacts and the people that they lived with over a substantial period.

Then, of course, because of the pressure of a program of this kind, a race that has to be won, watched by all of those above you from the President down to the other generals, and then the industry that has to respect you, and I already mentioned the good relations and good feel for the work of scientists and engineers. Now, of that group I'd say the best one was General Schriever, and he was available and he was selected.

General Schriever was a cool guy. No matter what the pressure was, no matter how intensely he might feel that something has to be done that minute because of what he's hearing and seeing, he expressed himself always with clarity. He didn't fall off his chair, he didn't shout, and the effect on everyone around him was that he was a guy in charge. Of course, I wouldn't be able to say it if I hadn't gotten on exceedingly well with him, so we were a good pair. We respected each other, and we saw each other virtually every day. We had our offices set up so that we were frequently in control, and we did many things together. We had to go on trips to meetings. We had to sit in the same room looking at the situation, deciding what to do about it.

And he understood the importance of the technical aspects for the decision. When I say technical, I mean not just a pure engineering, scientific subject like what is the best of three alternatives for handling the reentry problem. Engineering is much more than the science that underlies it, and you're not a successful engineer in the large, and especially that is conspicuous in a big project involving many people and many industrial companies, many specialists, many aspects going from the conception right to the incorporation and the putting in place of a complete operational capability.

It's highly interdisciplinary, not only in the sense that there are many different aspects of science and engineering that interact with each other, but it's interdisciplinary in the sense that the requirements, military in this instance, requirements of a society as to what you do, the timing, the economics, the money that would be required, the comparing of alternatives, the relating of the overall to the pieces, the systems engineering, the need to understand that you've got a complex of people and machinery, human beings and apparatus, and their interconnections, sometimes with big geographical spans, with signals and energy and moving vehicles over substantial distances, constituting numerous overlapping loops in which what happens in one part of the complete system has an influence on another part, and what you must do is succeed in making a compatible ensemble of these various pieces that must work together.

The scheduling itself, the decisions as to how far do you go in perfection before you go to the next step—I'd mentioned earlier that it made sense, I thought, even to begin to learn how to launch and check out your launching procedures and equipment facilities even before you were ready to launch by taking whatever you could pull together, even if it was going to fall apart on you.

So Bennie Schriever understood that kind of thing. It was inherent in his makeup that he understood this. One could imagine a general who said, "I'm the general, so I'm in charge. It is a military project." One could imagine a scientist engineer type who said, "You're in charge of little administrative details. I'm really running this." I've heard about and I've seen that on projects many times over my long lifetime career.

Now, Jim Webb had been a director of the budget. He was a lawyer originally. He'd gone in the government as a budget director. He knew money and government funding. He had been, I think, a Deputy Secretary of State, but more than that, he happened to be an exceedingly broad individual. He came into NASA as a second head of NASA, but he came in at the time when NASA was changing to a really important operating organization with the lunar landing being the big issue. And he was exceptionally strong and just what the government needed.

We've had some good and some less than good heads of NASA. We've got a very good one now in Mr. Dan [Daniel S.] Goldin. Some were maybe individuals who might have been good at a different time, when there was a different aspect, a dominance in what was required for NASA. People have to be right for the time, as well as—I mean for the situation they're put in. You can't just talk about an individual in the abstract. It is a matter of matching to the task. Some individuals who were heads of NASA were not well matched to the task at that particular time. I think that sums up at least some of my feelings about NASA and Air Force leadership, ICBM military leadership.

BUTLER: A couple of examples of some of the people that had the strengths and talents to get the program where it needed to be. Great.

RAMO: Sometimes that happens. It happened here or we would have been very much delayed in both instances, whether it be the lunar landing on the one hand, or the ICBM program, but especially these people were capable immediately of coming together. As a matter of fact…the deputy head of NASA, George [E.] Mueller, [then] in charge of manned space flight—everything had to do with manned space flight—was one of our [Ramo-

Wooldridge] principals—for several years. I recruited him into Ramo-Wooldridge for the ICBM program. He was in charge of the electronics guidance, that aspect of the ICBM program. And he was recruited by NASA as a result of conversations between Jim Webb and me. The general who headed the Minuteman program [General Samuel C. Phillips] became the head of the Apollo Program. That was the case of General Schriever and Jim Webb coming together. There was no question that the ICBM project team, so large and so outstanding, put together, should have been used and was used in many places. A good many of the top executives in the space industry came out of that original ICBM team at Ramo-Wooldridge.

BUTLER: So not only was the ICBM program instrumental in the technological side, it was on the management side as well.

RAMO: And that's as it should be. I mean, you have a very big program and its principal people should move on to other things as you pass a certain peak of requirement for all of them.

BUTLER: The buildup, at least on the manned space program side, was to the [Apollo 11] lunar landing, as you mentioned. Do you remember where you were and what you were doing when they actually landed on the moon for the first time?

RAMO: Well, I was home and watching TV.

BUTLER: Looking back over your career, focusing on the ICBM program and NASA involvement, what was the biggest challenge that you faced?

RAMO: I guess I never thought of a single piece as being bigger than another piece. It was especially easy for me to think in that regard, because I guess if I have to answer the question, to answer it, it was the integration of the whole. Everything connected to everything else, if you couldn't constantly see everything in the context of its relationship to the rest of it.

For example, I'm sure some who are particularly concerned with the rocket engine would say: [get] the smallest weight, most thrust for the weight of the fuel, without the rocket engine developing instability, blowing up because of unusual strains. You had to do such things as introduce the fuel that was being burned in what amounted to a controlled explosion going for like 100 seconds. Such power in it, you had to have strong control of this change from liquid to gas at such high pressure that when allowed to escape through a nozzle, especially shaped to accelerate that, it would come out with such high speed that the momentum of that gas would be enough to drive, by Newton's Law, the momentum in the other direction, to accelerate that. And you'd have to introduce the fuel through little holes that would cool the very metal that would otherwise get so hot it would be caused to fall apart under the excessive strains.

Now, they say that was such a challenge and finding ways to test it so that we knew what was going on, and designing everything, the pumps to pump the fuel in so that it would be as light as possible, and rugged, able to stand the acceleration, the high Gs during the buildup of velocity. But in my case, I had to worry about the relationship of that part of the effort to the rest of it. For one thing, you needed to bring them along together. There would be no point in having your rocket engines all ready to go but have the guidance delayed. Somehow you had to have it all come together, and that required that the timing and the pacing be chosen correctly.

For example, if you had to handicap the rocket engines by having them swivel, they had to be so held together that you could change their direction so you could use this for control of velocity and counter to instabilities if the missile, for one reason or another, began to yaw or pitch or roll. And yet if you insisted on too much action from the rockets, the rockets would be delayed. You'd never get them at the time when you need them. So maybe you should do something else to ensure that you don't have big oscillations during the flight, which would handicap the design of the rest of the structure and some of the control equipment.

So you had to not only see that these were compatible, each doing its part, and ending up with a sensible, in the end, combination of weight, distance to be traveled, and small miss distance. If you increase the requirement for the miss distances, decide you don't want to miss quite so badly, which presumably would require you have a bigger warhead, which would change the weight of everything. Then if you're too severe on that, then you put such restraints, such conditions on the control system that it's harder to get it designed and working well within the time allocated.

We didn't have a problem of expense, not that money was no object. Money sometimes is an indicator of whether you can really do it at all. If you need all the money in the world to do it, there's something wrong and it's not going to happen because it implies too many people doing too many things all in a short time, and you won't get it assembled so that it's all harmoniously compatible.

BUTLER: That certainly is a challenge, to bring all those aspects together and for a program that was brand new.

RAMO: Well, we began to call that the systems approach. Now, the word "systems" [is] in the vocabulary of the layman. We speak of a transportation system. We speak of the telephone system, electric power distribution system, and the word "system" in that sense already implies that it's a combination of many things and people. It's a complex arrangement, an interconnected group of components. But systems engineering was hardly at all properly considered as an intellectual discipline until we began, and especially in the United States, to design systems of such complexity and on such time schedules and with such newness about various aspects of technology, so that you had to extend the art greatly. You couldn't do it by kind of hit-or-miss, "Let's connect these things together, they seem to do the job. You ought to be able to do it." And then you find one piece doesn't work right in compatibility with the others or, as I say, you don't have a piece when you need it because you put conditions on it that can't readily be met within the time scale that you've set for yourself.

So what you have to do by way of analysis and modeling, the way you have to extend even the mathematical techniques you use, take, for example, probability and statistic[s]. Almost everything that you wanted to specify and say what it is that you need was some [probability] numbers. You'd have to put a range on it. It has to be within a certain range. Well, even if you speak of the ultimate guidance, actually, a simple number, you want one mile. Well, that means on the average. If you launch a number of missiles, some will come within a half a mile of the target, some will come one and a half miles from the target. If it averages a mile, that's satisfactory.

Well, now, you take that band of interest to you, and you [ask] what determines it. One of the things that determines it, for example, is the fact that the Earth is not a sphere, and gravity is working on the missile all the time. You think you understand gravity enough to put down what that does to your trajectory, but as you pass over parts of the Earth that are bumpy, it's not a perfect sphere. Parts of the Earth vary in density. You get variations of density. How well do we know the variations of density of the Earth? What's the probability? What's the variation? What's the band of what you're going to work? You do that for every part that affects accuracy, and pretty soon you come out with the possibilities of being anywhere from the mile you'd like to 100 miles. What fraction will fall within the mile? If only 1 percent does, you haven't got it.

You can see the analysis takes big computers because you've got so many things…where everything's depending on everything else—so every equation you write, every mathematical equation that says "Here is the accuracy for this piece," it depends on the result of the other equations. If you've got simultaneous—hundreds of simultaneous equations to solve at the same time, each in which you put approximate probabilities—you do need a computer to do it. You need to simulate the entire operation, for example. And the moment you have a lot of loops of interactions, you can get some very strange effects.

I can illustrate something that those of you who are accustomed to hearing people talk in front of a microphone—you know every once in a while you get this ring and squeal and terrible noise, because you get a feedback from the speakers back into the microphone. That goes into the amplifier and goes back out louder, which makes the microphone feel an even bigger signal until it gets as loud as the speakers are able to get before you blow a fuse or something.

Now imagine, if you have hundreds of loops making up an ICBM system, what you'll have in that regard. It's not just the missile itself. We have to design the whole rest of the system, like the silos and the system for command and control, and the system for ensuring that you're keeping this missile safe in the silos. You don't want to have a system that shoots down someone who tries to trespass. It might be a deer, and you don't want to stop a launch because there's been the possibility of a trespass.

So we had to consider a wider range of things, all of which needed to be simulated because so very often you couldn't just write equations for it. One of the things you couldn't do readily is write equations for the actions of human beings in a system. So you have to set up experimental simulated conditions and observe how the combinations seem to work.

BUTLER: Quite a challenge. What, then, was your greatest achievement or biggest success, in your opinion?

RAMO: Well, we did beat the Russians. We were able to know where they stood, because, you see, when you're actually moving towards success, towards the final proving out of the system, you're launching into space. So now we each could observe what the others were doing. Our first launchings from Cape Canaveral [Florida], for example, there was no question that there were Russian ships out there watching what we were up to and trying to record any signals that came off of our missiles to tell us what was going on inside, to try to interpret them. Of course, we did a great deal of coding.

We could see that we were ahead of them as they were approaching their really good test flights. We had had higher accuracy in particular and more longer flights with success. And remember, they had a bigger missile. They were handicapped by not being able to design a warhead with as high a yield per pound as we could, and that is a handicap, because there's so many things that have to do with weight when you're handling apparatus. Not to mention the fact that some things don't scale, and you can't assume that a rocket engine of twice the diameter, and that means four times the thrust, is a matter of merely scaling. It will [not] be just as reliable, because some aspects of stability in cooling may not scale. [It] may be much easier to build a smaller device.

As you scale up, to get the strength required—well, I'll give you a simple example. If you have twice as thick a wall as you've got twice the pressure in a bigger rocket, you can't necessarily put holes through it for the fuel to enter and provide cooling on the inner surface, because the holes may tend to stop up as a result of the high pressure upon burning of the fuel pushing back out of the hole, bucking the pump for a longer distance. So that doesn't scale. So in a same sense, the difficulty of designing a 100-story building is not just twice a fifty-story building. It may be four times. So they had some handicaps as they moved towards testing, and we had missiles ready to fire with H-bombs as an operational capability before they did. It took them quite a little while to catch up.

The program's secrecy was so successful, relatively speaking, even when you include the test program, that when President Kennedy ran for office and Bob [Robert S.] McNamara was his choice for Secretary of Defense, there was discussion, you remember, of a missile gap of the Russians. What Senator Kennedy knew, and he was not thoroughly briefed until after he became the President, or President-elect, I should say, he came with McNamara. I gave a briefing on the ICBM in Los Angeles [California]. McNamara, after listening to what we had to say with our charts and so on—we went into considerable detail—he said, "There is a missile gap, but it's in the opposite direction of what we thought."

See, they were aware of the fact that the Russians had done the beginning of the ICBM first, that we had a wrong conclusion that the ICBM was…many, many years away, it was much too unlikely to be created in the next several years, that the way to do it was with manned bombers. The intelligence reports that we'd gotten that caused the setup of the whole program was, by that time, known to President-elect Kennedy. Bob McNamara was president of Ford Motor Company. He was not in the fraternity at all. So when they found out about it, that was the end of the missile gap. The missile gap was in our favor.

So I'd say beating the Russians to operational capability stood out as the most satisfying thing.

BUTLER: And that's definitely on the aspects of national security and for the future of the space program, too, because it did give us that foundation.

Looking at the future and reflecting on the past, what do you see as the relative roles between the industry, between the government, civil, military, and how that's going to evolve?

RAMO: Well, one part I think is very easy, and it relates the past to the future, I think, very well. I mean by that that what we've done in the past seems to have been pretty much the right thing to do. As we see the future, NASA's role is research—I'll get back to that in a moment—research that isn't primarily tied to either commercial or a military application, but to understand best what you can do with apparatus in space and see that insofar as it's worthwhile doing for new things that will be important to the society, you need to develop apparatus and techniques and get on with doing that development.

The military has the military applications, clearly. The military applications can sometimes be such that the inherent technology can be used by NASA for its research purposes that may have to do with understanding the universe and the Earth, and has little to do with the military application per se. But the military application may give rise to technology that can be used. And the same thing goes in the other direction. NASA, with work going on at JPL [Jet Propulsion Laboratory], will extend our ability to sense, to get information out in space, and to bring it back, and that is important also to what the military is after, using space for apparatus that will get information.

I believe there will be, in the foreseeable future—I was going to say in the near future—in the foreseeable future, no applications for man in space either for commercial purposes or to the military. Man in space, if it has a purpose in research, then I think it has to be pitted for what we learn, for the amount of money spent, against other research projects. There is nothing today special about man in space in research as compared with unmanned spacecraft, for example. You simply ask yourself what it is you're trying to understand.

There's one thing you can only understand, and it has to do with science and research, by putting man in space: that is, how man reacts to space. But as to why you are interested in that, you're interested in it because you're interested in everything about man and you're interested in everything about the universe. It's always conceivable, if you understand man better because of putting him in the unusual environment of space, then you can compare what you hope to learn, useful to society there against doing other things with the same amount of money. And in that regard, I think there's a question as to what will happen to the man-in-space program versus time because of the competition of other ways to use money to learn things.

The idea that ultimately, because it's there, Mars is there, we must have a colony on Mars—well, we've had human beings get to the North Pole, we've never created a colony there as a result. Once we had human beings at the North Pole, that was it. One can imagine some projects of research that will require man in space that don't have to do with understanding man, understanding human beings.

If we want to explore the universe to an extent beyond what we can do with today's apparatus, then well beyond such things as the Hubble Telescope, where you put apparatus in space to look out at the universe, and what you can do from a mountaintop in Hawaii, as with the Keck larger, much larger telescopes. If you could put apparatus to observe the universe on the other side of the moon, you have a very, very stable platform there. You could build bigger telescopes or telescopes with bigger distances between them, coordinating them so you have the advantage of the base, of looking at the universe from two points, separated, and deduce some of what you would learn if you had a telescope that was as big as the distance between them.

Earth is not a very good place to go much beyond, if at all, the two Keck telescopes, because you have the air, the turbulence, in the way. You can do some things to cut down the effect of turbulence. Putting a telescope in space, a still bigger one, you have a great handicap in what you can do in a platform that you keep in space, rotating around the world, having it turning to lock onto a target and stay on it for a matter of many minutes, in fact, even hours.

If you're going to assemble apparatus on the moon, you're going to have to have men to do it. You can do a great deal of robotry in the process, but you've got to have men to do it. That is an example of a research project, but comparing that with other research projects here on Earth—we're entering a period not only of understanding the subtle distinctions between animate, living, and inanimate molecules, understanding the genes, the human race, understanding DNA and RNA, with the potential of curing most diseases and even affecting aging, those promises are so overwhelmingly attractive, and some of them appear imminent, if only properly supported—and that means it's more important to have Ph.D.'s in microbiology than Ph.D.'s in manned space flight and its basic science. So the competition's going to be enormous.

Then what's happening on the computer-synthetic intelligence front—the ability to extend man's intellect by artificially created intelligence—what can be accomplished by the combination of human beings and electronic apparatus is moving so rapidly and has such an effect on a society, that again the consequences of that are bound to usurp a good deal of the resources of the country.

Now, the commercial applications of space as a result of this—and I've already mentioned half a dozen—dozens of reasons why apparatus in space will pay off in improving the operations of our society, transportation and communications and the effect of everything—doing research, physicians being able to consult files and get information from around the world with the touch of fingers on buttons—the effect on every activity of man is so great in the expanded utilization of information technology that already we have or are moving towards a trillion dollars of gross world product that comes from that area of endeavor. Now, that commercial work, which doesn't belong in the government—we're not talking about the military part, which does, we're not talking about the long-term research about the universe, which belongs in NASA, in the government.

But when industry is that big, is moving so fast, and is out into the border between what is known and what is not known, it puts pressure on the government to put its research and development behind that. Among other things, there's always national competition, even though we're moving towards a one-world affair. The one-world influence of corporations being international, so they're not best thought of alone as being evidence of national and parochial interests, that international impression will be felt on all countries to spend their research budgets on things that will cause those programs to move along, because there will be more people and interest in jobs depending on those—so that's where the political pressure will come.

So I'm suggesting that while you can find reasons for man-in-space programs as being part of the research of NASA, and it will be NASA and not either military or commercial, industrial, private enterprise, it will be suffering always in the amount of funding available for it against the competition for the same resources.

BUTLER: I think you were good at predicting things back in the past for what would happen, so it'll be interesting to see if everything follows through for the future.

RAMO: Well, now that I'm moving into the last part of the century and my life has started fairly early in the century, and it seems to be moving towards the very end of this century, during this period I have seen and felt, because at a very early age I began to sense the impact of scientific advance and technology. That's why I went into the field. But we had electricity—we began to create the electrification of the nation—before th[is] century. We had automobiles before the century occurred, but in this century, think of it: We've learned how to put human beings, within a few hours, almost anywhere on Earth that we want to, people and things. We can communicate between any two points on Earth. We have added three-dimensional activities—space, airplanes, air transportation—to the two-dimensional society we previously were limited to on Earth.

And it would appear that the next century, if you look at it—this is the technological society century. This is the technological century. We had technology before, but, after all, we had fire and the invention of the wheel in the centuries before. But 99 percent of all the significant influences on society, right down to the negative ones—I mean, we've learned how to destroy the entire civilization in twenty minutes if we don't learn how to live together. We've got a real challenge.

So in the next century we can already predict what's happening in understanding everything from the body at large to the brain, and relating the manmade brains to the artificial brains, which can really affect the life process. The changes, of course, will be enormous, and so I don't hesitate to predict these enormous changes, because it will take another ten, twenty years. If someone comes up to me and says, "Si Ramo," twenty years from now, "boy, were you wrong in your predictions," I'll be perfectly happy about it—as long as I can still understand the question or the claim.

BUTLER: I think it's an exciting future to look forward to, and I thank you for sharing your exciting past with us.

RAMO: Very good.

[End of Interview]