PAUL B. MACCREADY
(1925 - 2007)

INTERVIEWED BY
SARA LIPPINCOTT

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Abstract
An interview in three sessions with Paul B. MacCready, Caltech graduate (MS physics, 1948; PhD aeronautics, 1952) and inventor and entrepreneur who became internationally known in 1977 as the "father of human-powered flight." Conducted by Sara Lippincott, the oral history covers MacCready's scientific and entrepreneurial career, including biographical details. MacCready discusses his family life, early education and aeronautical interests in New Haven, CT. During his youth he progressed from the construction of model airplanes to the flying of motor-propelled aircraft and gliders. MacCready recounts his soaring competitions along with his education at Yale in the 1940s; he continues by describing his graduate work at Caltech from 1947 to 1952 and his high altitude soaring in the Sierras and Europe; he relates this to his interest in weather modification and his entrepreneurial work in cloud seeding.

In 1971 MacCready founded AeroVironment with his associates Peter Lissaman and Ivar Tombach; he discusses his early clients and research. Beginning in the mid-1970s MacCready began work on the celebrated Gossamer aircraft series; the interview includes discussion concerning the advent of the Gossamer Condor in 1976-1977 and the flight of the Gossamer Albatross across the English Channel in 1979. The interview also includes his continued interest in

human-powered flight and environmental issues, as well as unmanned solar-powered flight.

Administrative information

Access

The interview is unrestricted.

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By the age of 15, Paul MacCready was already winning laurels in gas-powered model airplane competitions. In this photo he poses with his model "Topper," circa 1940, which won trophies in two classes by swapping out two different sized engines on the same plane. Photo from Paul B. MacCready Papers, Caltech Archives.

Paul MacCready flies the Orlik in a soaring contest over Torrey Pines, on the Southern California coast north of San Diego, in the spring of 1948. He was then 22 years old and a graduate student at Caltech. A few months later he won the 15th National Soaring Championship held at Elmira, New York, with the same plane—a Polish-built sailplane with 49.5-foot wing span. About the open cockpit, MacCready wrote on the back of the photo: "It was much more fun without the canopy." Photo from Paul B. MacCready Papers, Caltech Archives.

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ORAL HISTORY PROJECT

INTERVIEW WITH PAUL B. MACCREADY

BY SARA LIPPINCOTT

PASADENA, CALIFORNIA

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Pasadena, California

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LIPPINCOTT: I want to welcome you here, Dr. MacCready. We can start this interview by talking about your childhood and your early education—and maybe your early interest in flight. You were born in New Haven in 1925 and grew up there?

MACCREADY: Yes.

LIPPINCOTT: What did your family do?

MACCREADY: My father was a doctor. My mother had been a nurse, but she wasn't working when I was born.

LIPPINCOTT: Did you have any siblings?

MACCREADY: Yes, two sisters, one five years older than me and the other six years older.

LIPPINCOTT: Were you right in the city of New Haven?

MACCREADY: Yes.

LIPPINCOTT: Was it nicer back then?

MACCREADY: We lived on East Rock Road; we had moved there by the time I was two. I've visited a few times, three years ago and ten years ago, and it was just the same as it always was. It's close to East Rock Park, which has been maintained. There is a fair amount of wildness around there, so this whole area has been preserved.

LIPPINCOTT: Is that near Yale?

MACCREADY: It's probably a mile and a half from Yale.

LIPPINCOTT: You went to public schools there?

MACCREADY: I went to Worthington Hooker School through eighth grade, though I skipped one grade. I then went to Hopkins School, which is a private school, and took an extra year there, so it took me five years to get the four years of high school. Hopkins was a school on the edge of New Haven that a lot of Yale faculty kids went to, so it had fairly high standards.

LIPPINCOTT: Your father wasn't connected with Yale, was he?

MACCREADY: No. When he arrived in New Haven, a bit before I was born, it was with the expectation of being on the Yale faculty and so on, but he found that it was difficult and unrewarding, and he ended up in private practice, with an affiliation with Yale. He rented an office at the corner of Temple and Trumbull Streets. The building is still there, after all these years. He rented the building and rented out space to other doctors.

LIPPINCOTT: And after Hopkins, you went to Yale.

MACCREADY: Yes.

LIPPINCOTT: Which you could probably walk to, is that right?

MACCREADY: No, it was still a ride into town. But I lived at Yale, so I wasn't staying at home. I was at Yale for a year or so; then I got into the V-5 navy training program. When the war was over, I was in the last stage of flight training and could have gotten my wings if I had stayed another three months, but I decided to go back to college. I went back and graduated from Yale in 1947—which is when I would have graduated if there had been no war. War speeded up things, so you were doing stuff in the summer.

LIPPINCOTT: Before we get too far ahead, tell me first why you decided to go to Yale. Was it simply because it was right in the same town? Did you have any longings to get out of New Haven or not? What drew you Yale?

MACCREADY: The high school I went to seemed to be a prep school for Yale; about half the graduating class went to Yale. It was just what you did. It was a good place, and you were there, so I went there. I didn't know much about the quality of it or other places; it just seemed to me that that's what you did. And when I finished Yale, I came to Caltech because by then I was interested in a combination of physics and aeronautics, for which Caltech was the best place, without any question.

LIPPINCOTT: You were already interested in planes when you went to Yale, isn't that right?

MACCREADY: Yes. When I was a youngster, we would spend the summer at Branford, Connecticut, where my parents had built a house at the end of a peninsula. It was very nice, but it was also away from other kids—mostly you learned things yourself rather than going around with other kids. I encountered a little caterpillar of the Swallowtail butterfly, but I had no inkling what it was about—and as I explored it, insects got more interesting. I began really being excited about bugs. I got a couple of books on them, and this was a very receptive time in my life—there weren't other distractions. And bugs were really interesting—butterflies and moths. I just devoured the books and learned the scientific names of various insects that were around. I made collections and learned how to mount the bugs, butterflies, and moths. I was quite active in that field, probably to the age of twelve. I remember being quite devoted to the field, active in it, collecting live caterpillars that would grow, and so on.

LIPPINCOTT: You were what was called a naturalist, in a way.

MACCREADY: Yes, and that was mostly in the summers in Branford. But then I was given some insight into model airplanes, which my father bought a kit for and I started building. This was balsa wood, which was incredibly light. I remember that he thought this kit was really pretty advanced for a young kid; he thought we'd just store the kit and get to it in a year or two. But I remember being so excited about it that we un-stored it quickly and finished it, and then I got another kit, a little plane that would fly around the room.

LIPPINCOTT: Was that remote controlled?

MACCREADY: Oh no, they didn't have any remote control back then. This would be 1937, I guess. I was around twelve.

One thing led to another. I did most of the work on the models in Branford in the summer, but there was still a good bit that went on in New Haven, in the winter. There was a store in New Haven where you could buy the model materials. The store was just a room in some guy's house—that field was just getting going. I got another couple of friends involved in the modeling, but they weren't anywhere near as active as I was. And as I got further along, I made all sorts of experimental things—ornithopters, autogyros, helicopters—

LIPPINCOTT: What is an ornithopter?

MACCREADY: It's a wing-flapping thing. It's like a bird. Instead of a propeller, it uses wing flapping.

LIPPINCOTT: Oh. Is that feasible for a large aircraft, or just a model?

MACCREADY: It's not feasible for a large aircraft. A few people have tried building something that a person would fly in, but it doesn't make any sense. The largest natural flier was the QN

[*Quetzalcoatlus northropi*] pterodactyl, which we built a replica of here [AeroVironment, Inc., in Monrovia].

LIPPINCOTT: What's an autogyro?

MACCREADY: It's a device that, instead of a wing, has a rotating fan on top, which permits you to fly very slowly.

LIPPINCOTT: These were small models, were they?

MACCREADY: I think I made one with a seven-foot wing span. As time went on, I got into all sorts of flying things—gliders, powered planes, rubber-powered indoor fliers, outdoor fliers. I was able to use the basketball court at Yale for indoor flying sometimes, when they had no meet.

LIPPINCOTT: Was this before you were a student at Yale?

MACCREADY: Yes. When I was doing modeling, I gave a couple of talks at Hopkins about the models. I was still doing just a little bit of modeling when I went to Yale, but it had pretty much dropped off by then, because there were other pressures. But the modeling was great training. My skills were not great, but I actually was doing more of a variety, in more fields of modeling, than any other person in the country, or the world, back then.

LIPPINCOTT: Did you have correspondence with other modelers, or were you pretty much on your own?

MACCREADY: Pretty much on my own, but you'd get model airplane magazines and you'd go to contests and you'd find out what others were doing. I would go to various contests that my father would drive me to. I recall going to the national competition in Chicago, which was the longest trip I had yet made. This was in the summer of '41, just before the U.S. went into World War II. I entered indoor-model and outdoor-model competitions—rubber-powered, gasoline, and so on. I think I was the top scoring person in the junior class, which was sixteen and under.

But that was the last period that I was active in modeling.

LIPPINCOTT: When you went to Yale, did you think then about going into aeronautics and physics?

MACCREADY: No. I didn't really know what I was going to go into, and I got started in mechanical engineering. I also had a job at Yale. Most kids who had jobs were waiting on tables; I was the only one who worked in the physics lab, where they were building various things. That was a good education.

LIPPINCOTT: What did you do there?

MACCREADY: Whatever they needed done. I don't remember exactly what I did that helped them, but I remember that what they did taught me some things.

LIPPINCOTT: Were you helping them build instruments?

MACCREADY: Yes, that's what it was. And then after a year or so, I joined the navy and left Yale.

LIPPINCOTT: Was that in your sophomore year?

MACCREADY: Yes. And when I came back, I started as a junior and finished the last two years. But I switched my major to physics—

LIPPINCOTT: After you got back from the navy?

MACCREADY: Yes. And that was awkward, because I had no real background in college physics when I switched to it. My degree was in physics, but I missed various things. It was basically just two years of physics—but it was a good start in physics.

LIPPINCOTT: What did you miss? Were you more on the experimental side, and so you missed some theory?

MACCREADY: I missed some theory. I just didn't have time to get into it and didn't have the right vector analysis, and so on, that others did. I only had what amounted to a year and a half of physics to get the degree.

LIPPINCOTT: That's incredible—that you got the degree anyway.

MACCREADY: Yes. Well, people worked fairly hard at their education when they were back from the war. There was less rambling around and being interested in other things. People worked harder. I think it's eased up a bit since then.

Though I was by then distracted by flying sailplanes. I got a light plane with another student for $400 or $500. We got this little plane fixed up. When his family found out that he was involved in it, they made him sell his part to me for $200. So I owned the plane.

LIPPINCOTT: Were they afraid he'd hurt himself?

MACCREADY: Yes. It was a Buhl Pup.

LIPPINCOTT: What's that?

MACCREADY: It had an aluminum fuselage and a midwing and a Szekley engine up front that was not very strong. In the summer, its service ceiling, which is the height at which you can still climb 100 feet a minute, would be below sea level on a hot day.

LIPPINCOTT: Below sea level? Then how could it get off the ground?

MACCREADY: Yes, there was that problem.

LIPPINCOTT: [Laughter]

MACCREADY: You'd take off from a hill and catch thermals. In winter, it would go up 4,000 or 5,000 feet.

LIPPINCOTT: This was more or less like a hang glider, then?

MACCREADY: No, this was a regular powered plane.

LIPPINCOTT: Oh, it had an engine. But you still had to take off on a hill, so that it would—

MACCREADY: In the summer. It was very weakly powered, and in the warm afternoon of a summer day you could take off but not climb at all. But in the winter, it was cold enough so that the air was more dense and it would fly. I flew it one summer out to Michigan to visit a friend.

LIPPINCOTT: You flew this plane all the way from Connecticut to Michigan?

MACCREADY: Yes. It would fly about sixty or seventy miles an hour. It was not a very good plane for traveling across country.

LIPPINCOTT: You'd have to stop every…what?

MACCREADY: I think I stopped about five times going out there, to get gas. You could take off in the morning, when it was cool. And you'd be in an airport on a hill, anyhow, and the thermals would be enough to get you up to altitude as the day progressed. So it was a pretty marginal flying machine, but a very wonderful one. I was learning sailplane flying, too. I got a war-surplus sailplane from Americus, Georgia. Five people chipped in and bought the plane, but I was the only one who could go down and get it. I believe this was in '46.

LIPPINCOTT: You were still at Yale.

MACCREADY: Yes. And then I got training in it. I remember the early days of soaring, going to

Elmira [NY]. I got a flight in the sailplane, which was a very great experience. It was flown by John Robinson, who was the national soaring champion, and I was taken there by Henry Struck and Parker Leonard.

LIPPINCOTT: Who were they?

MACCREADY: Henry Struck was a national champion in model-airplane building. He lived in Saybrook [CT]. Parker Leonard lived in Essex—he became my father-in-law, eventually. He had built sailplanes, too, but he tended to build things very heavy, and they didn't perform well. But I was there with them, and I got started in soaring, which had seemed very desirable to get into when I was in the navy pilot training. And I did get involved in it as soon as I got out.

LIPPINCOTT: And what was Elmira a center for? Why did you go there?

MACCREADY: It was *the* spot for soaring. It had been chosen by people who were very involved in soaring. It had a hill [Harris Hill] and a place to take off at the top of the hill. It subsequently has become something of a national shrine; they have a building with old sailplanes there.

LIPPINCOTT: Do sailplanes have engines at all, or are they just gliders?

MACCREADY: Back then, they didn't have any engines—they were just gliders. Gliders can be crummy or elegant, but the elegant ones you'd call sailplanes. They were made for long-distance flight.

LIPPINCOTT: How long a distance can a sailplane go?

MACCREADY: Now they've gone 2,000 miles, but back then—well, let's see…. I went to the National Soaring Contest at Elmira in '46, flying a Pratt-Reed sailplane, which Parker Leonard had been one of the designers of—that was the war-surplus plane I mentioned. I got my license just before the contest. We took eleventh place—or something like that—in the contest, but it was a great experience. You could fly in clouds then. You're not permitted to fly in clouds now in sailplanes, but you could back then, and there were thunderstorms and so on.

LIPPINCOTT: Did you go into clouds during a thunderstorm?

MACCREADY: Yes.

LIPPINCOTT: What was that like?

MACCREADY: Fortunately, the first time I tried, it was so bad that I didn't really get into the cloud, but there was intense rain all around me.

LIPPINCOTT: Lightning?

MACCREADY: I don't remember lightning on that flight, but you couldn't see out the window, the rain was so intense. By opening the window at the side, you could lean out a little bit and look down and see where you were, and I was able to guide the plane down to an airport, which was below the place where you took off. This was a two-seater airplane, so I had somebody in the plane with me. Then on other days, which had much gentler weather, there'd be ordinary little cumulus clouds. You'd spiral up in the cloud, but you'd tend to spiral out of it, because your feeling was so different from what the instruments told you. You *felt* that the instrument showing your rate of turn couldn't be right—it must be going bad or something—and you'd operate by feel. But then you'd suddenly spiral down out of the cloud, and you'd see that the instrument had been right all along. People, when they first get started flying with instruments, sometimes feel they're going this way whereas the instrument says they're going that way. It takes some practice to accept the instrument—and by the time the contest was over, I was doing that.

Then I got a new sailplane that looked pretty good. It turns out that it was made by some people here in Pasadena. It was called the Screaming Wiener.

LIPPINCOTT: Wiener, like a hotdog?

MACCREADY: Yes. It really didn't have a very good glide ratio, but it was very small and light. I fixed it up some, made a different canopy for it, and flew it in 1947 in a contest which was then in Texas. I got second place in that contest, which was pretty good, considering that the plane really didn't have much performance. But in that contest I also did a goal-and-return flight that was a record. It was the first international record that anybody had gotten in the U.S. since the thirties. Now, of course, there are lots of U.S. records. And then I got an Orlik sailplane.

LIPPINCOTT: Orlik?

MACCREADY: "Orlik" means "eagle" in Polish. I got that fixed up and entered the contest in '48 and won that.

LIPPINCOTT: These are the National Soaring Championships?

MACCREADY: Yes, and in '48, '49, I won with the Orlik. I won with a borrowed glider in '53, I think. And I went to international contests in '50, '52, '54, and '56.

LIPPINCOTT: Were they in this country?

MACCREADY: No, they were in England, Spain, Sweden, and France. I took second at the one in Sweden in 1950. The one in England I probably took fourth, but I only got three flights, because the weather was so bad—it was just luck whether you got in all your flights—and I got sixth in Spain. But then in France I got a first, because I had a good sailplane. By then the one I flew had a 35:1 glide ratio. Others had been 29 or 27:1.

LIPPINCOTT: What does that ratio mean?

MACCREADY: How far you go forward versus how far you go down. Now they're over 60:1. Planes have gotten better. But that contest I won, and I was so far ahead before the last day that I didn't have to fly, but I did fly, and it was a very extreme day. The other American pilot, Bill Ivans, crashed in the mountains and barely survived. No part of his airplane bigger than about two feet remained.

LIPPINCOTT: But he lived?

MACCREADY: Yes, he lived—until he died a few years ago [July 13, 1999] in a sailplane accident with the head of the Smithsonian's National Air and Space Museum. There was an NTSB [National Transportation Safety Board] investigation as to what caused that accident.

But the competitions, the flights, were extremely tiring.

LIPPINCOTT: On this particular day in France, what kind of weather was there—a lot of wind?

MACCREADY: Yes, a lot of wind, and you had to go through mountains, and the mountain peaks would be in cloud. The wind was, oh, sixty miles an hour or more, and you'd get a down-current behind the slope, maybe 100 feet a second down, mingled with currents of 100 feet per second up. And it was luck as to whether you made it there. It was a very stressful competition. I remember one of the other planes—they couldn't take its wing out when it was finished, because it had been wrenched so much. So many things were overpressured at the contest; some of the competitors really were pushing the rules, doing things that were dangerous, and so on. They were working too hard to try and win. I quit soaring after that contest. I still go around to soaring events, but it was—

LIPPINCOTT: But you didn't do it yourself after that?

MACCREADY: I didn't, really. I did a little bit of recreational flying. And during the soaring, I had done research on a high-altitude wave—

LIPPINCOTT: What is that?

MACCREADY: In the mountains around Bishop, California, is where you'd go. You'd get waves that are on the lee side of slopes, where air would go down and up and down and up, and the up would be big up-currents. I got to 29,500 feet in one.

LIPPINCOTT: In a glider?

MACCREADY: Which would have been a record.

LIPPINCOTT: There's no air up there, is there?

MACCREADY: Well, there's enough, but you have to have oxygen. I had oxygen; I had an extra little bottle as a safety precaution. And I'd gone up in pressure chambers a few times with the oxygen equipment, to do everything that was safe. And also I'd fixed up the sailplane's canopy, which was breaking up at the high altitude, in the cold temperature. It hadn't been made for that. I made one that did handle the high altitudes.

LIPPINCOTT: So you could pressurize your cockpit?

MACCREADY: No, you don't use pressure at those altitudes. I had a regular military-type oxygen system. But that was the last day of, probably, '48, and the next day, '49, I went up with John Robinson, who was very involved in soaring and was getting good altitude, but the weather was overcast then. You had to go up through the clouds, and you wouldn't know where you were or what you were doing, so I wouldn't do that and I came back and landed. But he didn't, and he got to a higher altitude—33,000 feet, I think—so I didn't bother with my record of the previous day. I didn't do much more of the high-altitude soaring after that. I maybe made a dozen flights that involved altitudes where you needed oxygen systems. But it was a good introduction to this new realm of soaring flight, and it preceded by a couple of years the U.S. doing an actual Sierra wave research program. They just had the fiftieth anniversary of that project this last summer, and they had various sailplane people doing flights. One person who was involved got killed when his oxygen system ran out and he wasn't aware of it. And another who was in a Pratt-Reed sailplane—the big, rugged kind that I was in first—hit the severe turbulence you sometimes get, and it just broke the airplane all up. He was barely able to get out. His feet were locked in. He somehow pulled his feet out of his shoes and escaped.

LIPPINCOTT: Barefoot in his parachute?

MACCREADY: Yes, and he's still around to talk about it. They were pretty rough soaring conditions.

LIPPINCOTT: Did you say that the U.S. government was interested in these sailplanes? What would have been the application? Why were they interested?

MACCREADY: These are big up-currents and down-currents, which are things that airplanes can't withstand. I described the huge turbulence that a sailplane broke up under; an airliner would also break up under such circumstances.

LIPPINCOTT: So the FAA [Federal Aviation Administration] was interested in the conditions.

MACCREADY: Yes. There was an airliner that was lost in Japan; it got in a wave condition down-slope. What's the big mountain there?

LIPPINCOTT: Mount Fuji?

MACCREADY: Yes. It's all part of learning in aviation.

LIPPINCOTT: Did you ever ask yourself why you liked doing something that dangerous, or did that just not enter your mind?

MACCREADY: What I was doing was difficult, but I thought I was operating safely. I would have backup equipment… [Tape ends]

Begin Tape 1, Side 2

MACCREADY: I had done parachute jumps before, so if I had to bail out it wouldn't be the first time. I thought I was being pretty safe. And still I would stumble on these odd things. I got around a ten-G gust load, which would break up an ordinary sailplane. And the wings went way up—

LIPPINCOTT: But they stayed on.

MACCREADY: A lot of the gliding of that type was when I was at Caltech. You had to work hard on the courses here—hardly the way my mind works. I tended not to get great benefit from the class. It would be the homework I had to do—reading the books and doing reports, and so on.

LIPPINCOTT: Just to keep the chronology straight—you got your BS from Yale in ’47 and then came out to Caltech for your graduate work.

MACCREADY: Yes. And this is where most of the soaring was, but I would go back East for the contests there. I wouldn’t practice for the contests, because the contests were so intense. You’d be exhausted when it was done, and you couldn’t do practice flights with that intensity.

LIPPINCOTT: Did you ever go up to Mount Wilson and do the hang gliding that I see people do?

MACCREADY: I was involved many years later in hang gliding. The growth of that field began, really, in 1971—

LIPPINCOTT: Oh, so they weren’t doing it when you came out to Caltech?

MACCREADY: No, they weren’t doing any hang gliding. My first flight in a hang glider was, I think, in 1969. The field really started in ’71. My children got fairly involved in it. We all went to the first contest and then built a little hang glider afterward. But by then the field was beginning to mature and somebody provided gliders for them. And around ’75 or ’76, the field became sort of safe, finally. Everybody was just shooting from the hip at first, without being careful. They were killing fifty people a year, in this small sport. And in ’75, the manufacturers got together and set up test techniques and so on. I did a little bit of hang gliding myself, but mostly it was my sons Parker and Tyler. A friend, John Lake—whom we had hired at my first company, Meteorology Research, for a bit—was in hang gliding, and he developed a little tail thing that he put on the wires that go up to the tail, and it gave you positive control. The person who made our gliders didn't like any junk like that on his gliders, and his thirteen-year-old son was flying one and got into a predicament and crashed and died. We had other friends who died in the sport. My sons were then going to school at Thacher.

LIPPINCOTT: Thacher School in Ojai?

MACCREADY: Yes.

LIPPINCOTT: Is that where they did their hang gliding? Or did they do it in the San Gabriel Mountains?

MACCREADY: They did it at different places, but they sort of got out of it in '76. In '76 we went on a vacation trip, which is when the idea for the Gossamer Condor arose. They were doing some hang-gliding flights then, but that was pretty much the end of their hang-gliding career, because there were too many other things going on.

LIPPINCOTT: I want to get back to Caltech, though, in the late forties and early fifties, when you were here. You wanted to get your PhD in physics—or aeronautics—is that right?

MACCREADY: I got my master's degree in physics, which is what I had signed up for. But in doing that, the very first course I took was in aeronautics.

LIPPINCOTT: Who taught that?

MACCREADY: Fred Felberg, who is still around. I see him occasionally. It was a good fundamental course in basic aeronautics. I did well in aeronautics courses but not so well in physics courses, and thought I wouldn't be permitted to get a master's here, but to my surprise the people in physics said O.K. They saw something in me that I didn't see. I had had only two years of physics, with a lot of parts missing, when I came here, so difficulties arose. One thing was [William R.] Smythe's course [on electricity and magnetism], which you might have heard about.

LIPPINCOTT: I have heard about that. Very difficult, wasn't it?

MACCREADY: Yes. But I did get through that. I thought it was awful. I think I got a C at the end, but it turns out that half the people who started it never got through it at all. I do remember that I got good consulting help before the final exam, on how to do things I just hadn't sorted out in my mind. And this was from—what's [Linus] Pauling's daughter's name?

LIPPINCOTT: Linda Kamb?

MACCREADY: Yes. It was her husband, Barclay Kamb [Rawn Professor of Geology and Geophysics, emeritus], who spent a few hours tutoring me on that. His help was very appreciated by me. I got through.

When I went into aeronautics and got my PhD, my thesis, which was under Homer Joe Stewart, was on atmospheric turbulence ["Investigation of Atmospheric Turbulence," 1952].

LIPPINCOTT: Which you knew a lot about first-hand, by that time.

MACCREADY: Yes. It combined fluid mechanics with the real atmosphere and up-currents and so on, so it fitted in with my interests, which were not in transonic planes or other things that would equip me to go into a regular aerospace firm. Though I had enough background and could have, I didn't want to.

LIPPINCOTT: Your real interest was in atmospheric turbulence—weather and so forth?

MACCREADY: Yes. Well, I was interested in many things. In '49, I was very involved in weather modification. I think I really got started in it in '48. Bob [Robert D.] Elliott and Ted [Theodore B.] Smith were in [Irving] Krick's meteorology department here, which left Caltech around '48.

LIPPINCOTT: The whole meteorology department left?

MACCREADY: Yes.

LIPPINCOTT: Where did they go?

MACCREADY: On Colorado Street, just north of here, they set up Krick's weather-consulting company. But as cloud-seeding—weather modification—began to get going, they moved into that very quickly.

LIPPINCOTT: Didn't you start your own weather company, too? I saw in some biography of you that you founded a company called Meteorology Research, in 1951, in Altadena.

MACCREADY: Yes. In '49 and '50, I was doing too many things. I was running a seminar course in aeronautics. I did a cloud-seeding project in Phoenix—or in the central part of Arizona—which was the first one ever to get published results.

LIPPINCOTT: This was to make rain?

MACCREADY: Yes. And I also was involved with Bob Elliott and Eugene Bollay in a company that was in weather modification. And I found that working on all these things at once was just too much. I was beginning to shake, and you could see that I'd collapse in a while. Because running a seeding project in Arizona, which you'd have to go to regularly, back and forth, and so on—

LIPPINCOTT: Who wanted you to do that, the state of Arizona?

MACCREADY: The Salt River Valley Water Users' Association. That was the only commercial project I was on.

I started Meteorology Research, Inc.—MRI—to provide a tool for doing research in weather modification, though our first project was in some atmospheric turbulence stuff that was an outgrowth of the Caltech research.

LIPPINCOTT: Was this with those two people you just mentioned?

MACCREADY: No, I worked with them in North American Weather Consultants. As I say, I was getting too involved in too many things, and so I quit the involvement in that company and quit the cloud seeding in Arizona. I quit doing everything but just getting my PhD degree here, which I did, in 1952. The work was finished around ’51.

LIPPINCOTT: And you in the meantime had founded MRI, your own company.

MACCREADY: Yes.

LIPPINCOTT: Were you the only MRI employee, or did you have a staff?

MACCREADY: The company wasn’t a corporation to make money, it was just an entity to provide a mechanism for doing various projects one wanted to do. It had no employees except myself, and then I hired one and then another and another and another as circumstances permitted.

LIPPINCOTT: Who were your clients?

MACCREADY: Government, Air Force Cambridge Research Labs. And the weather modification studies were—the main one was for a government research group in Washington that gave us a project fairly early to assess weather modification’s reality and do research on it. And this contract permitted us to grow, and we actually had the largest group in the world in weather modification, back in ’53, ’54. I had also done some consulting in weather in ’50, ’51, ’52, ’53 with Vincent Schaefer, who had been one of the people who got the field going.

LIPPINCOTT: Your bio says you were a consultant to the President’s Advisory Committee on

Weather Control, in ’56 and ’57. That would be Eisenhower?

MACCREADY: Yes.

LIPPINCOTT: Why was that committee started up? I mean, there’s not so much interest in that now.

MACCREADY: No. I was involved in weather modification from, let’s say, ’48 to ’58 very actively and still doing some of it up to ’70. I got a unique start in the field, because the people who were leading the field, [Irving] Langmuir and Schaefer and Krick and so on, all tended to hate each other, and were suspicious and wouldn’t communicate with each other, but they would all talk to a nobody graduate student, which I was. I would hitchhike around the country. Non-schedule airlines were flying then, and I was able to hitch a ride on those, or take a bus, and because I was a graduate student they’d all talk to me. I did a lot of research and read papers and so on, and I think I probably had the best total background in the field in 1950 of anybody, because of my ability to talk to all of them.

LIPPINCOTT: You mention, in one article I saw, that Irving Langmuir was your mentor, or that you paid quite a bit of attention to his theories. He was at the GE [General Electric] research lab in Schenectady. Is that where you visited him?

MACCREADY: Yes, I visited him there, but also I met him at the professional events I would go to, where he and others would be giving talks. He and Vince Schaefer were the ones who really got the field going. Schaefer was his assistant and discovered the cloud-seeding potential, but Langmuir got deeply into it. Langmuir had worked on cloud droplets and visibility and such during World War II, which equipped him for this.

LIPPINCOTT: Was the aim of this field to help agriculture?

MACCREADY: Yes. The field of weather modification started with three absolute blockbusters. Vince Schaefer seeded a stratus cloud and showed that just by dropping dry ice out you could cut big holes in it—letters and so on. Then somebody seeded a cloud in Australia on a day when there were loads of cumulus clouds, and they picked one and seeded it, and it grew bigger and bigger and finally it was the dominant thing in the sky and gave a huge amount of rain. And they reported all that. Then Irving Krick went to Prosser, Washington, for a seeding project—this was in the early days—and seeded clouds with silver iodide from the ground, and there was a stupendous effect, if you plotted percentage of normal rain.

LIPPINCOTT: Is that eastern Washington, which is like a desert?

MACCREADY: Yes. The weather was perfect for it, and they were able to induce some additional effect right there.

So here were these three blockbuster projects. They were the first three significant experiments in cloud seeding.

LIPPINCOTT: All in the fifties?

MACCREADY: Well, in the late forties—'46 was Schaefer's and '47, I think, was the cloud-seeding in Australia. The one in Prosser was 1948. Those were the early days, and the results from the seeding were just stupendous, and people got rather enthusiastic about it. But the reality turned out to be much different. People tried to do seeding, and I don't think they got any effects like what had occurred in Australia, because at that time the weather had been set up just perfectly for the seeding to be effective. And the winter storm in Prosser, Washington, was an unusual one, with everything just right for seeding to work. This got the field going with unwarranted exuberance, but as they tried to continue, they weren't getting the effects very much. And as the years went on, the regulatory process got awkward. If you seeded an area because ranchers wanted more rain, you'd get paid for that. But other groups wouldn't want more rain—they'd need dry weather for something or other—and they would sue, and the suit would exceed what you had been paid. So the field began kind of coming apart; it looked as though there wasn't any way to be very successful in it. There are people doing seeding now, but they're all small companies, and mostly small companies that got their start fifty years ago—some of the folks are pretty old. It has not become a big field.

However, in the meantime, the inadvertent seeding of clouds that humans are doing, with all the pollution that goes up, is having much bigger effects on weather patterns than seeders could have. We're doing a lot of inadvertent cloud seeding now, and a great deal of research is going on, trying to figure this all out. It was an exciting field, that was a good time to be in it, but we tended to get out of it in'56, '57, '58. We were still doing stuff, but the field wasn't going to go anyplace, and we moved into other subjects.

LIPPINCOTT: Yes. Also, the weather is so complex. Probably in the flush days, in the late forties and early fifties, there was a feeling that human beings could take over the climate and make it do what human beings wanted it to do. But you became disabused of that idea.

MACCREADY: Yes, that's correct—and now we're having much bigger effects on the weather, but it's still as complex as it was back then.

LIPPINCOTT: Did you, in Meteorology Research, Inc., begin to get interested in environmental issues?

MACCREADY: I was somewhat interested in environmental issues. Cloud seeding is an environmental issue, and turbulence studies, and so on. I looked for business that the company could do. We got into instruments—selling instruments—and we researched all sorts of subjects, getting more and more into environmental work. I left MRI in 1970. It had been bought five years earlier, by Cohu Electronics.

LIPPINCOTT: Was that a Japanese company?

MACCREADY: No, it's a firm in San Diego. The chief engineer was Bill Ivans, whom I've mentioned. We did a good job getting the right board together and having the company move along. We had some difficult years when we first were acquired, but we straightened those out and we were profitable when I left. But I left because it was obvious that we were going to just do the same things we'd been doing in previous years, not getting into new areas. And we had gotten the company up and profitable; in fact, we made more money than the rest of Cohu

Electronics made in one or two years. I left amicably. They replaced me with the person who was the—I don't remember what role he had in the company, but he was the person doing the general management. But he wasn't appropriate for the president of the company.

LIPPINCOTT: You had been the president?

MACCREADY: I had been the president. And while I was president, Dr. Harner Selvidge, the executive vice-president, was really the manager of the company, but he left a couple of years before I left. The company, after neither of us was involved with it, did continue to grow, doing the projects it had been doing, but it wasn't adding anything new. So slowly it toppled off, and finally they just sold it for the price of the equipment that was in it.

LIPPINCOTT: MRI was in Altadena?

MACCREADY: MRI was on North Lake Street and then on West Woodbury Street, where we built a building for it.

LIPPINCOTT: Well, this might be a good place to stop, and then I'd like to resume later, because pretty soon you're going to found AeroVironment, and we want to talk a lot about that. [Tape ends]

PAUL B. MACCREADY

SESSION 2

February 25, 2003

Begin Tape 2, Side 1

MACCREADY: For a year after I resigned from Meteorology Research, Inc., I served as a consultant, and I didn't have my plans worked out for what was coming next, just knew that MRI was not going to be the right challenge for me. Just about a year after I resigned, I decided to start AeroVironment, and I initiated that sometime in the summer of '71.

LIPPINCOTT: On your own?

MACCREADY: Yes. Again, I had no employees; I was the only employee—and then I got some others with me and it slowly grew. The two key starting people were Peter Lissaman, whom I had worked with before—he had been a professor of aeronautics here at Caltech but was doing something else then, I don't remember what—and Ivar Tombach, who was another Caltech PhD who had worked for a large aerospace firm for a year or so. But like me, he did not want to be involved with a large aerospace firm, so he joined me. Those two got on board toward the end of '71, and then there were a few others. We had a peculiar goal for the company: It was to do work in the type of things that appealed to us. But a lot of things appealed to us, so you couldn't set out a direction for the company. We just felt there were enough projects of the type that we would find interesting, and slowly projects arose. We got financial support from a company that was in the cement business.

LIPPINCOTT: That's a funny company to back you, when you were interested in aeronautical things, isn't it?

MACCREADY: Yes, but they had gotten acquainted with me a bit and found that I was trying to put something together that involved, among other things, meteorology, which they felt was very important for what they were doing. Because they had a lot of meteorological problems, they provided the support for AeroVironment, both by investing in it and loaning it some money. I don't remember the amount.

LIPPINCOTT: What would the connection between meteorology and cement be?

MACCREADY: If you're working with cement, you have to deal with meteorological problems as you're creating the cement.

LIPPINCOTT: Do you mean rain?

MACCREADY: Yes. It's a very complicated process to make cement. You grind up big rocks and do a lot of burning, using natural gas. You do the manufacturing in a very long horizontal tube. And there were pollution consequences. This was the outfit that owned that small mountain, or large hill, on the freeway as you go out east.

LIPPINCOTT: Oh, near those big debris basins?

MACCREADY: No, beyond those; probably beyond Pomona. It was a small mountain, south of the freeway, that had the right materials for making cement, and they were grinding it away more and more—and as the years went by, it got smaller and smaller. I think maybe it's disappeared by now. So has the whole company, probably—I don't know the status of it. Anyway, they also had a plant in the hills, southeast of Tehachapi, and they were concerned with the pollution effects on that. They knew we were not especially addicted to their concerns, because we found business in other areas, but still they thought it was worthwhile putting up money. So we did get started with them, but after four or five years it was obvious that our paths were not really going to cross very much, and we bought them out, putting up as much money as they had put in. So they didn't lose anything. They were good sorts. I believe that that company has had a lot of trouble since then, as the cement industry has had setbacks, with cheaper cement coming in from foreign countries and so on.

LIPPINCOTT: But you and Lissaman and Tombach—you were talking about your company's goal. It was primarily aeronautics, wasn't it? Weren't you interested in aircraft, mostly, at that time?

MACCREADY: A PhD in aeronautics equips you for plunging into various subjects, because fluid mechanics involves the flow of liquids and gases. It's fairly general stuff. Most people think of aeronautics just as airplanes, but it really is a pretty broad subject, and we were in broad aspects of it—just whatever interested us, but not getting involved with large airplanes in aerospace firms, because those would get you working on one topic for years, and there was so much of interest that you'd like to be able to finish something in six months, or a year and a half, or two years.

LIPPINCOTT: What were you particularly interested in at that time?

MACCREADY: It was a case of digging up projects that would provide some income for the company. We started an instrument division by studying what instruments were out there that were related to meteorology but not well developed—instruments with good potential. We decided, toward the end of the first year, that acoustic radar would be a subject worth putting effort into, because it was obviously a field of some significance. You could detect what was going on in the atmosphere above 100 meters, or 1,000 meters. As time went on and the devices got more versatile, we began using the Doppler shift of the signal, so that we could detect the movement of echoes. Sodars, they're called, the acoustic radars—

LIPPINCOTT: Sonar?

MACCREADY: Sodar.

LIPPINCOTT: What does that stand for?

MACCREADY: "Sound, distance, and range"—like radar is "radio, distance, and range." Sodar uses sound and doesn't really go very far, but the principle is like radar. You can look at an atmosphere. You have your transmitter on the ground and you can receive with the same thing. *Beep*, the sound goes up, and you listen with this antenna system. You do this every five or ten seconds and you plot what comes back, and you see all these layers in the atmosphere. You can tell the height of the mixing layer and how the mixing layer blows during the day, where things don't mix at night. And then, as the sun shines, there does get to be transport from the surface up, but just to a low height, and then a larger and larger height during the day. Sometimes it would get through the temperature inversion, which might be at 1,000 feet, and go up very high, but you'd only see the bottom parts of it, up to maybe 3,000 feet. The height you would get on a sodar would depend on the frequency you were using. The signals are lost a bit; they're diluted in the air. At high frequencies sound just doesn't travel all that well. At low frequencies there isn't much diminution, but at low frequencies, unless you have a giant antenna system, the sound doesn't go up in a narrow beam. It tends to spread out.

So you have to take all these things into account. And what we made was operating at around 3,000 hertz with a parabolic dish on the ground that was about two meters in diameter. Subsequently we have gone to higher frequencies—so it takes a smaller dish—and dealt much more with the lower heights, of maybe 200 meters, because these are the heights of interest to wind-power people, who want to know what the wind speeds are above the ground.

LIPPINCOTT: You mean people who want to have wind farms to make electric power? Those were your customers?

MACCREADY: Yes. Well, it was a general-purpose tool at the beginning, because wind power wasn't yet a big field. But as our muscles in acoustic radar kept improving, the wind-power field did get moving, and that field is growing rapidly now and it turns out to be the main user of sodar devices. But they're still also used for space launches and landings.

LIPPINCOTT: Like at Edwards Air Force Base? If NASA wants to know whether the shuttle can land there safely, they would use one of your devices?

MACCREADY: Yes. And they're tested at airports. As they've gotten more sophisticated, they send up three beams. One goes straight up, one goes a bit off to the east, and the other goes a bit off to the north. And from the signals you get from all three of those, you can find the whole wind structure, by the Doppler shift that you get back. This simple device, just sitting on the ground, can give you the wind profiles way up. There are some other things you can add that give you temperature sounding. So things in the lower atmosphere that are of most interest to most people, you can get with these devices. We have been in that business sort of forever, after getting it started. We were the first commercial producers of equipment, and we still make them. Of course the ones we make now are much more sophisticated—but it is not a great business. New people come into it every couple of years, with probably good equipment, but they find it's not all that fruitful and they get out—and then others get in. It's a million-dollar-a-year business for us—or three-quarters of a million—but it's just the same, year after year. It's not what you would ordinarily go into business to do, but since we were already doing it, we will stick with it. It doesn't cost us. We don't lose money; we don't make money on it.

So that was the equipment part of what the new company worked on. We also worked on diffusion studies and the wake vortices that airplanes put out. These can upset another airplane that's flying close behind, but after a couple of minutes the vortices break down. And that's a subject that was of concern to airport users and designers. We were involved with that and with the examination of the wakes that planes put out at high altitude—the contrails you see form—and how they break up.

So these were projects that, as they arose, we would do. There were significant projects with regard to the building of freeways. They would have to do a meteorological study first, to see if the pollution this freeway would put out—as you changed the speed of the cars—would improve or get worse. We did a lot of those meteorological investigations—it wasn't really a goal of AeroVironment to get into this much meteorology, but it seemed to offer good possibilities, so we got into it. As time went on, the company got more and more dependent on these projects—there'd be some big ones that came in. We grew to maybe 120 people in twenty years.

LIPPINCOTT: Who were some of your biggest clients at that time?

MACCREADY: The state of California—we'd get contracts from the state to do the meteorological studies. But the meteorological work was not my greatest interest. It *was* the greatest interest of Ivar Tombach. When the company grew to more than twenty or twenty-five people, I didn't want to be running it, and I got a person with much more experience in management, Stan Taylor, to join the company as executive vice-president and general manager. And we had various people on the board.

LIPPINCOTT: Who was on your board?

MACCREADY: Peter Lissaman, Ivar Tombach, myself, Stan Taylor….

LIPPINCOTT: Murray Gell-Mann [physicist and Nobel laureate] is on your board now, right?

MACCREADY: Yes, and we got him on the board at the very beginning.

LIPPINCOTT: Why did you ask Murray Gell-Mann to be on your board?

MACCREADY: He was a good friend. He lived near us on Armada Drive—just a few houses down the street, on the other side. I had been in classes with him at Yale in 1946 and 1947, and I got reacquainted with him. I graduated from Yale in '47 and he graduated in '48. So I'd gotten to know him when he was pretty young, and then it was a delightful surprise to have him move in across the street in the Caltech days. So, yes, he was a director and has been ever since.

We did some investigating with outside advisors, trying to figure out how to make the company more effective. And out of all this, I decided around 1990 to have Tim Conver, our current president, become the president, because it was obvious that we needed a good president. I was not serving in that role, and the person that I had sort of defaulted the role to I didn't feel was quite right. The environmental division of the company was not working quite right and we couldn't control it. We kept hiring new people, but our business was decreasing. There were various things that made it essential to go through a significant change.

LIPPINCOTT: This was in the early nineties?

MACCREADY: Well, I think it was in the mid 1980s that Tim Conver came in. I brought him in as a director when one of the previous directors [Dale Myers] left; he had retired from NASA, but NASA needed him and he went back to NASA as deputy administrator and felt he couldn't be a director of our company because he was no longer living here. I got Tim Conver to acquire his stock interest, and he helped us look for a proper president and then decided he would quit his job and become president himself. He took about a seventy-percent salary cut and came with us.

LIPPINCOTT: What sort of job had he had?

MACCREADY: He ran a division of Whittaker Corporation in Simi Valley that made electronic devices for government work. It was very successful, but not all that appealing to him, and so, to my surprise and somewhat to his surprise, he decided he would like to take over AeroVironment. I had gotten acquainted with him first through a management consulting group, where about a dozen people who run companies get together and meet once a month. Of all of them, Tim Conver was the most effective person, so I got him to be director when Dale Myers went back to NASA.

LIPPINCOTT: I don't want to completely skip over the seventies, because we have to talk about these planes—the Gossamer series of planes. Were they something that AeroVironment built, or was this a sideline that *you* concentrated on?

MACCREADY: The company was having problems as it grew bigger. There really wasn't enough business for its size. In the early to mid-seventies, we had maybe forty or fifty people. I wouldn't be needed full time, so I would spend part of my time on other things and see if I could dig up any consulting business, or work on this project or that project. We got some corporate money from a group in the east that I had known about, and they tried to turn us into a strictly aerospace group, because they were in aerospace and they had the contacts. But it just wasn't the right match, and we eventually bought out their interest for the same amount of money that they had put into it. But they had even insisted on putting another president in my place, which we did, but it was someone who was in only for—oh, six months or so, and just didn't work out. He didn't understand the business, and he couldn't bring in new business, and he couldn't interact with the people. We felt that this wasn't going to be feasible, and he departed. That was in the mid- to late seventies.

And while that was going on, and I had some spare time to think about other things, the Gossamer Condor project arose in my mind, because of a debt I had acquired helping a company that made catamarans and needed $100,000. It was my brother-in-law's company and I had arranged a bank loan—probably the bank loan was $70,000 and loans from friends of mine were $30,000, so the company got $100,000. But it didn't do well in the marketplace. It was when the Hobie Cat sailboat was marketed, and our catamaran competed with it. We thought ours was better, but it was a bit more conventional and it didn't have the marketing jazz. So that company didn't succeed, but the money had gone into it.

LIPPINCOTT: And you had to pay the loans back.

MACCREADY: Yes. I had money from the sale of my stock in Meteorology Research. But my agreement when I left was that if the stock price exceeded ten dollars for a certain period of time, I wouldn't get any more shares. And the shares wandered around, went up and down a bit. But then, in the designated period, they went up over ten dollars for about thirty-two days and that eliminated my chance of being able to get rid of them. I could have sold them right away when they went over ten dollars, but I didn't. They came down to five, so I ended up only with about half the profit from owning most of Meteorology Research. The combination of that and the loaning of $100,000 to the catamaran firm—I didn't have any way of getting rid of that debt. If I had been more careful with my funding, I wouldn't have had any debt; we would have had considerable money.

I had been vaguely aware of the prize offered for a human-powered airplane. In fact I had sat in at a meeting, a technical conference, where it was described.

LIPPINCOTT: Where was that conference?

MACCREADY: This was in Boston, at an MIT-related thing. I don't know the year exactly, but let's say '74. So I was aware of what people had done.

LIPPINCOTT: Who wanted this human-powered airplane?

MACCREADY: Henry Kremer had set up the prize in 1959. He was a British industrialist and he had various companies. He made the plywood wings for the Spitfires in World War II, and so on. And he put up a prize for human-powered flight. At first, the prize was about £5,000, and people tried for it. British teams worked on it, and they'd even get into the air, but they couldn't fly far.

LIPPINCOTT: About how far did they get?

MACCREADY: Oh, maybe 500 feet or so.

LIPPINCOTT: Were they pedaling, as if they were on a bicycle? Was that the usual design?

MACCREADY: Yes, the power was always pedaling, although some people did try slightly different things. There were probably a dozen ships that got built, and these were large teams that were involved. When there was a flight, there would be an accident at the end. They would try and turn or something, and the plane would crash. These were fairly slow-flying, maybe twenty- or twenty-five-mile-an-hour airplanes.

LIPPINCOTT: How high did they get?

MACCREADY: They would fly only ten feet or below, because the prize was to be given for a figure-eight flight around two pylons a half mile apart, with hurdles at the start and the end of the flight that were ten feet high. So you couldn't have a ground-effect machine, which lets you fly on very low power, and you had to turn right and you had to turn left. It was a very good set of rules worked out. It had to be a real plane; you had to climb and turn and so on. But to keep the planes lightweight, they were all flimsy. The British made rather elegant aircraft that met some of the requirements but not all of the requirements, and they drifted away from being active in the field as years went on. Kremer had raised his prize amount up to £50,000, which was around $100,000, when I won it, and he had thrown it open to anybody in the world, not just people in England. When I won, it was eighteen years after the prize was first offered, and not much was going on at the time, because the people in England had more or less given up. There was a group in Japan that made a new plane every year as a college training project for aerodynamics and flight control and so on. They were making some fairly good flights, I think—1,000 feet.

LIPPINCOTT: Not 1,000 feet high?

MACCREADY: No, 1,000 feet horizontally, and when they turned, they'd crash. And the planes would be just as complex to repair as the ones in England, which took six months to repair for a new flight.

LIPPINCOTT: Let's talk about your plane. So you conceived the idea of going for the prize in the middle seventies, and you built the Condor, essentially.

MACCREADY: Yes. I decided I wanted to win the prize because I had this $100,000 debt and the prize was about $100,000. [Tape ends]

Begin Tape 2, Side 2

LIPPINCOTT: Let's talk about how you built the plane, and what you built it out of, and how you conceived of it as different from previous entries.

MACCREADY: I got started with it in the beginning of 1976. I did a bunch of thinking and sketches and so on, and thought I might try it, but it turned out that these designs were similar to what the British had already done, with large teams of people and a lot of money, and they weren't successful. This approach of doing it the conventional way would not win the prize. So I gave up on it in the spring—I didn't waste any more time thinking about it. But then I went off on a month's vacation in the summer of '76, with my wife Judy and our sons, Parker, Tyler, and Marshall, who were probably twelve, ten, and five, or thereabouts.

LIPPINCOTT: Where did you go?

MACCREADY: To the East Coast. We visited various friends and relatives—both Judy and I are from the East Coast. And on that trip I got started with a project to study the flight of hawks. I had found very attractive a study that somebody named [A. H.] Woodcock had done, which I had read about in *Soaring Magazine*. It was published in the 1940s, during World War II, and it had made an impression on me. It was somebody just using his eyes, and a couple of instruments he had, while he was out on a naval ship on the Atlantic Ocean. He was doing serious work, but while he was out there he also made an investigation of how birds soared over the ocean. He found that some soared in circles, some soared in straight lines, and then they didn't soar at all. And he tried to figure out what air motions permitted one kind of soaring, another kind of soaring, or no soaring. When he made the measurements—the wind speed, the temperature of the air versus the water—and plotted the various kinds of soaring against those variables, he found that all the soaring around in thermals, circling, fit into one plot, and the straight lines fit into another plot, and those who couldn't soar at all were in yet a different plot.

And he found that with this plotting, he could infer a bit about the air motions and what drove them. He made an analogy to the study of Bénard cells in the lab, which show up in a thin amount of liquid on a plate, maybe a centimeter-thick layer in a little saucer that's twenty centimeters in diameter. If you heat the bottom of the plate, you can have instability. First nothing happens, but then it gets stronger, and then you get the Bénard cells, which are a regular hexagonal pattern of cells, the up-currents. And if you blow or move the liquid over the plate, you get longitudinal shapes for these up-currents. The study of Bénard cells was rather elegantly done by big-gun aerodynamicists in laboratories and showed how nature works.

LIPPINCOTT: These cells you create in the laboratory are analogous to what's happening in the atmosphere?

MACCREADY: Woodcock was the first person to make the analogy—that the little motions you see, molecular motions, could be translated to giant turbulent motions in the atmosphere on a scale of ten meters or 100 meters. It was a fascinating study to me; it made an impression on me when I first read the article, and when I thought back about it, it made more of an impression. So I wondered whether there was something interesting I could do on a vacation trip with the kids and wife, going in a van across the country. And I realized that you could study the soaring of birds from a car. As the bird does a 360-degree turn, you measure the time it takes to do the turn with your wristwatch, and you estimate the bank angle—which you estimate just by looking up at it. From those two things, you would end up knowing the speed of the bird's flight and the diameter of the circle, which you could infer. And if you look up in a library the wing loading that was typical of that species of bird, you could even find the lift coefficient at which the wing was operating. There's a lot you could do that people had never done with birds just by looking at them. As the trip started, we did this in Arizona, and then going on east, we'd do it with black vultures and turkey vultures and redtail hawks and frigate birds and so on.

LIPPINCOTT: Did Judy help you with this?

MACCREADY: No, but the kids helped. I lured the kids into making some of the measurements. They humored me by making the measurements; they thought it was all silly. But this actually did work, and I got a couple of minor articles out of it, because we were able to find out the lift coefficient at which the wings of the birds were operating and the size of the thermals and so on. After doing that for a couple of weeks on the vacation trip, as we were going east, we stopped at where the Wright brothers had done their—

LIPPINCOTT: Kitty Hawk?

MACCREADY: Kitty Hawk. We went to see that. I began thinking about what I'd been doing and also about the Kremer prize for human-powered flight. And the day after we were at Kitty Hawk, we were up at a niece's barn in Pennsylvania when the ideas began fitting together. As you look at the size and the weight of the plane you're thinking about, you find that if you keep the weight very low but increase the wingspan and wing chord a good bit, the power needed to fly goes down. And I knew from hang-gliding experience that a good hang glider with about a thirty-foot wingspan takes about one-and-a-quarter horsepower to fly. This is just a consideration of the weight and its sinking speed. And starting with those numbers, you realize that if you make the hang glider up to three times as big—say, a ninety-foot wingspan and three times the chord and nine times the wing area—it will fly only a third as fast, but at the same angle, and only use a third as much horsepower. That means you're now down to about .4 horsepower to keep this large plane up, if you keep its weight very low. It didn't matter if the plane was ugly and inefficient, like a hang glider is. The key is that if you kept the weight the same but tripled all the hang glider's dimensions, it would fly on about .4 horsepower, which is about what a really good bicyclist could put out.

So that was the simple idea, which I could have had six months earlier—or anybody in England could have had—but we all tended to think too much in terms of flying sailplanes, which have long, slender, elegant wings. And when you try to adapt a plane and make it a bit larger but still carefully constructed, like a sailplane, then it's much too heavy. This other approach of starting with the absolute simplest form but keeping the weight very light—it was obvious that this could win the prize. So when the vacation trip was over and I talked a bit about this to the Schweizer brothers, who had the only glider manufacturing firm in the U.S.—

LIPPINCOTT: Where were they?

MACCREADY: Elmira, New York, which was the glider capital of the country back then. They helped in my thinking a bit, about turning and so on. They helped make my ideas sound more logical to me. When I got back, toward the end of August of '76, I immediately built a model with about a six-foot wingspan that would have the various features of this plane. And I'd swing it around on its wing tip. Just while you're standing there, you could swing it around your head fast enough to keep it upright, and then you could let go and see whether it glided. I had decided to make a canard detail in the front, because—

LIPPINCOTT: What's a canard?

MACCREADY: It's just an airplane with the tail in front.

LIPPINCOTT: The tail in front?

MACCREADY: Yes.

LIPPINCOTT: It's not a tail, then, is it?

MACCREADY: Well, it's—

LIPPINCOTT: There's no propeller?

MACCREADY: Well, you can have a canard with a propeller or without propellers. We have made many canards and they have found out eventually that the canard is not as efficient as having a wing in front and the tail behind. If you have the tail in front and the wing behind, you can fly, but it's not quite as efficient, because the front surface needs to have a higher lift coefficient than the rear surface, and when you put the tail in front and have it have a high lift coefficient, you can't have the wing have that high a lift coefficient behind; you just don't get as much lift in the wing. But if you have a regular plane, where the wing is in front, it can operate at a high lift coefficient and a lower lift coefficient with a tail in the rear, which is why almost all airplanes have the wing in front.

LIPPINCOTT: Did you decide to put the wing behind?

MACCREADY: I decided to put the wing behind, because it permitted the propeller to be right behind the wing, and this had to be an awkwardly shaped flying device. It needed wires to support the wing, and you had to have a body eight or ten feet high to permit the wires to go up at a steep enough angle to different parts of the wing, to provide the strength. And when you sat in it, you had to be near the center of gravity, because you were the heavy part of the airplane. And because of where it was, the propeller had to be fairly large to be efficient at the low speeds. The propeller was about twelve feet in diameter, so it had to be up on the wing someplace. And this made it difficult to concoct an airplane except with a canard configuration. You had a tube going forward from the wing that had wires going back to hold the wing structurally forward. You had wires comprising the rear of the wing that would keep it tight, but you didn't have any way to keep this far forward, so you had a tube out front. And in the front of that tube there were wires going back to the edge of the wing that would keep it all rigid. Well, if you had this rod out front that was necessary to keep the wing rigid, you could just put the tail there and you wouldn't have any extra weight. And by having the tail only at a lift coefficient of half of the wing, you end up with a plane that is unstable but efficient. If you have the wing at its maximum efficiency, its lift coefficient is not held down by having to be less than the tail. The inefficiency that you usually get with a canard [didn't matter] because this plane had such peculiar dynamics that you didn't even know if it was stable in pitch. You'd control the front surface, and the slightest control would keep you stable, though it wouldn't have been stable by itself.

So we were able to have the benefit of the canard for a configuration, but—

LIPPINCOTT: Without the disadvantages.

MACCREADY: Yes. And also we used the canard as a rudder. It could be tilted left or right, and so its lift would pull the nose around to the left or pull the nose around to the right. If you didn't need that, you'd just keep it horizontal. So it was an airplane without any rudder except when you needed it, and that was another one of its good features.

LIPPINCOTT: You didn't wind up piloting this for the demonstration. It was a man named—

MACCREADY: Bryan Allen. We had different pilots.

LIPPINCOTT: You flew it though, didn't you?

MACCREADY: I flew it, and my sons, the two older boys.

LIPPINCOTT: You let your sons fly it?

MACCREADY: Yes. They were in high school and they were able to spend weekends out with me.

LIPPINCOTT: Where were you doing the test flights?

MACCREADY: Those were all at Shafter Airport, about ten miles northwest of Bakersfield. The first flights of the Gossamer Condor were at the Rose Bowl, where we rented, very cheaply, for a month or so, the facility that's used for the construction of floats for the Rose Parade. This was from September to the beginning of October. I got a friend, Jack Lambie, to do work on the plane. My brother-in-law did a bit of work. I did some work.

LIPPINCOTT: What is your brother-in-law's name?

MACCREADY: Kirk Leonard. We put together a sort of full-size version of the Gossamer Condor, but it was very crude. It didn't have the propeller system in it, but we were able to fly it at the Rose Bowl at night and see that it did fly very crudely but with the kind of power we expected for a plane this size and shape.

LIPPINCOTT: Did this draw a crowd of people?

MACCREADY: No, it was probably ten o'clock at night, and there weren't any other people around. We had to be out of the Rose Bowl in just a day or two, anyhow, and we got the full-size model to the point where—

LIPPINCOTT: What was the wingspan?

MACCREADY: It was ninety-six feet. We had learned from that first six-foot model where all the wires had to be and so on, and then we made the ninety-six-foot model without power. We'd just push it around, and it showed us that we seemed to be on the right track. Then we immediately took that model, or the parts of it, up to Mojave Airport, where we had found a facility—a fairly large hangar—for building the final plane. But we had to cut the wingspan down by a foot, because it couldn't quite get into the hangar. So we did the flights there with a ninety-five-foot span instead of ninety-six, and we got the plane going and made probably 150 flights there during December, January, maybe February.

LIPPINCOTT: Yes, when the Mojave was livable, in those months?

MACCREADY: Well, it wasn't livable. It was fiercely cold. It's 4,000 feet high, and there's snow. The hangar was unheated and would—

LIPPINCOTT: Did you want those cold conditions, for the test flight?

MACCREADY: No.

LIPPINCOTT: Why did you go there, then?

MACCREADY: Because the hangar was available, and it was the only place we knew of that would work. It was a good place to fly, because the wind was very light in the morning, but it was not an ideal place to fly, because it was too close to the mountains in the west, and their drainage flow would create maybe a four-mile-an-hour wind at night. There was just a short period in the morning when the sun would heat up the air at the ground enough to mix it a little bit. There would be enough up-currents from the ground to stop that four-mile-an-hour wind—because this was just a shallow layer of air coming from the mountains. And there would be a half hour or so when there'd be no wind speed but very slight currents, because of the little bit of turbulence. But then the mixing would get a little deeper and the regular daytime winds would begin, from whatever direction they were coming. So this meant that most days you could fly for about a half-hour period, during which you could do your test flights.

All the test flights we flew there showed the capabilities of the plane, but it had difficulties flying when there was much turbulence, and it was very hard to find a time when you could contemplate a whole flight around these pylons a half mile apart. The turning capability of the plane was not well worked out there. It just didn't work. You'd have an aileron on both wings. When you twisted the ailerons, the plane would still just keep flying straight ahead. And when you'd have a big drag on one tip, the plane would still just fly straight ahead. This was quite surprising to us, and that got us to stop—but it still looked promising. Then we found that the flight had to be done farther away from mountains, and we located a spot northwest of Bakersfield.

LIPPINCOTT: Right in the middle of the Central Valley.

MACCREADY: Yes, and that was the idea. If you were in a very flat region, equidistant from hills on the east side and hills on the west side, the hills would not be making these airflows, and you could expect lighter winds to occur early in the morning. And that's what we found at Shafter. So we moved to Shafter, and we had in the meantime conducted an experiment at my home in Pasadena, in the swimming pool, with a model that had just a three-foot wingspan—a piece of balsa wood glued to another piece of balsa wood as the fuselage, and another piece as the tail. The model weighed virtually nothing, but the water it was in had a lot of weight. And we had begun thinking that the apparent mass effects of the airplane's interaction with the atmosphere were what were giving us the peculiar lack of controllability we were seeing. All airplanes have an apparent mass effect, but the airplane is usually heavy and the apparent mass effect is a very minor one percent or tenth of a percent. But in our case, the mass of the air that the plane is coupled to is about four times the mass of the airplane. So we made this device and operated it in the swimming pool, and within five minutes of just pushing it around the pool, we were able to verify the apparent mass effect and pretty much have the idea of how to remedy it, which was to minimize the effect by redesigning the plane with small wingtips. Instead of an eight-foot chord at the tips, we cut the tip chord way down. The plane would fly a little bit faster because it had less area, but the apparent mass effect was less. And you would go along with the remainder of the effect, rather than fighting it.

This eventually worked out. As we rebuilt the plane with all the improvements, it began being fairly straightforward to fly. But now we made the plane with a bottom surface to the wing as well as a top surface; originally we had just had a single-surface wing. We had streamlining on the body so that the person was in the fuselage, which cut down the drag. We made various improvements like that, and the plane began working. As each improvement was made, it would fly farther.

LIPPINCOTT: Was Bryan Allen involved at this point?

MACCREADY: He was probably involved most of the time while we were at the Shafter Airport, but not at first; at first, we relied on the original pilot, who had to leave. We just used him occasionally, but he had to go over to Europe, where he was doing competitive cycling, and we didn't have anybody else, so we searched for a pilot. I wrote down a list of what the ideal qualifications would be—somebody with light weight, good experience in bicycling, a good bike racer who could help build the plane, who had some experience in model airplane construction, and who was unemployed, so that he would be available. I brought that list to Sam Duran, who was helping us on the project out there, and he said his roommate would be good—he was rooming with Bryan Allen.

LIPPINCOTT: Where was this?

MACCREADY: In Bakersfield, close to Shafter. Duran had a job with an oil company there. And Bryan Allen had no job, so we were able to get Bryan.

LIPPINCOTT: He was a bicycle racer?

MACCREADY: He was a bicycle racer. It turned out that he was just phenomenal in all the things that were key to the project, and we were very lucky.

In fact, a number of years after our flight across the English Channel, which Bryan Allen also piloted, the people at MIT who had worked a bit on human-powered airplanes built a plane to do a long-distance flight—seventy-four kilometers, from Crete to Santorini—to symbolize the flight of Icarus. There were no more prizes for strictly human-powered airplanes, but they kept working on their plane just as a research project. And they did succeed in their flight, though the plane broke just before it reached the island.

LIPPINCOTT: Just like Icarus.

MACCREADY: They got five different students from MIT to test to be the pilots. They tested them a lot and they knew exactly how much each pilot could put out. Bryan Allen went over there about two years after their project and when he wasn't on a tight training schedule, and he was able to perform better than any of the other pilots. So he was an outstanding pilot. Their plane—Michelob Lite was the name—

LIPPINCOTT: [Laughter] Named after a beer?

Macready: Yes. That flight was fifteen miles an hour. Our plane, the cleaner version that was left over from our flight in England, could have made their flight. It would have taken a little longer, but they had a bit of tail wind, and ours would fly with as little power as theirs did, just not go quite as fast—twelve miles an hour. But there was no motive for us to try it. Their airplane had no turn control. Ours did.

One last technical aspect of our plane—both the Gossamer Condor and the Gossamer Albatross—was that the turn configuration needed the wing to twist. At first, we thought it wouldn't have to, because the bank angles were very shallow, and we thought we'd get by without that. But when I sat down and calculated, I found that it did need to have the wing twist in order to get it to work right. And we found that as you'd twist the wing in the way that would make an ordinary airplane bank to the right, in our case, when we had enough drag on the left wing, say, the plane would begin pulling to the left instead.

The Albatross and the Condor both had very good stability and controllability. With an ordinary airplane, you have a more complicated control, but if you wanted to go left in our planes, you just pushed the stick—well, basically, to the right. And that would add enough drag to the left wing to turn left, but it would give a higher lift coefficient on that wing and a lower lift coefficient on the other wing, and that would be just right for continuing the turn. It worked very well. [Tape ends]

PAUL B. MACCREADY

SESSION 3

March 14, 2003

Begin Tape 3, Side 1

LIPPINCOTT: When we left off, we were just about in 1979, when the Gossamer Albatross flew across the English Channel. And you embarked on that project partly, I guess, because there was another prize from this British industrialist, Henry Kremer, and it was £100,000 for the first human-powered flight across the English Channel. So you built the Albatross and had Bryan Allen fly that one, too. This was his second flight for you.

MACCREADY: This was a much bigger project than the Gossamer Condor but much less interesting. It didn't really entail a bunch of new ideas, though there were some. So the Gossamer Condor project was more enjoyable to be involved in.

Anyhow, this one worked very well. And when the final flight was made, in June of '79, it basically finished my involvement with human-powered planes. The sponsor, Henry Kremer, thought this channel-crossing project would take another eighteen years, like his first project had. But we realized that if you just cut the power required by, say, twenty percent, a person could put out that smaller amount of power for a much longer period of time, and we could win this prize just by making a very cleaned-up version of the Gossamer Condor.

LIPPINCOTT: Still powered by pedaling?

MACCREADY: Yes.

LIPPINCOTT: But the flight would be a whole lot longer than the flight of the Condor—twenty-two miles or something?

MACCREADY: Yes, which is why Kremer thought it would take so long. He didn't realize that the way human physiology works, if you cut down the amount of power you need to put out by a small amount, you can put it out for a much longer period of time.

The reason for the project was to win the money and pay off the debt that had not been taken care of by the Gossamer Condor project. And of course there was some excitement and glory in winning the prize.

LIPPINCOTT: Was there a lot of press coverage for this event?

MACCREADY: Yes, this time there were probably 100 press people at the take-off spot.

LIPPINCOTT: Which was where?

MACCREADY: At Folkestone, right near Dover. There was a paved surface there that had been built, I think, in anticipation of the channel tunnel, but the channel tunnel never went there. But this site was big enough to put the plane together and take off from, and it was down close to the water.

LIPPINCOTT: What was the wingspan of the Albatross?

MACCREADY: Ninety-six feet.

LIPPINCOTT: And you planned to follow it across the channel in a boat?

MACCREADY: I was preceding it in a boat. I was the guide boat. I stayed a half mile in front of the airplane at all times, adjusting my speed to keep that distance and paying a lot of attention to the other ships in the channel. There were many ships, going both ways, and you couldn't fly the plane closer than a mile in front of one of these large ships, because if you crashed they couldn't have turned quickly enough to miss you. And you couldn't fly within a mile of the downwind part of the ship, because the ship would stir up the air enough to cause a lot of trouble. So each ship constituted a traffic menace. You couldn't start out across and then spot a ship problem and just turn left for a while, because that would make the whole flight longer. So we did this with changes of only ten or fifteen degrees in direction, and we were helped by the French and English traffic-control people—though there was one ship that wouldn't respond to anybody's control and that we had to avoid. But it all worked out.

LIPPINCOTT: What was the landing destination in France?

MACCREADY: Cap Gris-Nez, which was the closest place in France.

LIPPINCOTT: And you landed there with no trouble, I presume.

MACCREADY: It was an extreme case, because Bryan could put out the amount of power required for the plane for only about two hours, and two hours into the flight he decided to give up, because a headwind had come up that meant the plane needed more power to fly and he still had many miles to go. But as he went up higher for just a minute or so, so that our boat could make the pickup—that is, come underneath him and reach up with a fishing pole and snag the line under the front of the glider—he began dodging the pickup. His radio transmitter didn't work, and we couldn't figure out what he was doing, but his receiver worked and we were finally able to get enough communication across to see that he was trying to avoid the hookup, because he had found that the air, when he went up this extra ten feet, was quite smooth and stable, which means that the plane took a little less power to fly, and he thought he'd stick it out another five minutes, and another five minutes, and another five minutes, and so on.

LIPPINCOTT: Was he still over water at this point?

MACCREADY: Yes, he was over water for the entire flight. And he had consumed his—well, if you're asking about water, there's the water he flew over but there's also the water he drank, and he had finished that water in the two hours, because that's what it had been calculated at. So he did the last fifty minutes of flight—or close to an hour—without any additional water, which was an amazing feat. It was amazing that he could stay conscious and pedaling all that time, but he had had very good training. He worked with an exercise physiologist the last two months doing all the required training, and getting his spirit figured out, as well as the physical side of it.

LIPPINCOTT: What do you mean, getting his spirit figured out?

MACCREADY: He pedaled in a way that was way beyond human endurance.

LIPPINCOTT: Is that right?

MACCREADY: His human endurance had been figured out in the tests that we had run with him pedaling on a bicycle every day—we knew that he could put out enough power to stay aloft for two hours—and we were hoping that the wind would be nothing, or that there would even be a slight tail wind. But instead, though it started out with no wind as we took off, it became a headwind. And he got through the ordinary discipline of the two hours of flight but then got to the more transcendent state of being able to put out more power for almost an additional hour without any water to drink. When his left leg would cramp, he'd pedal mostly with his right. When his right leg would cramp, he'd pedal mostly with his left. Both legs cramped toward the end, and he somehow just struggled through. And I know he was thinking that he wanted to get this done with this flight, because he couldn't go through something like that again.

LIPPINCOTT: What shape was he in when he finally landed?

MACCREADY: When he landed and got out of the plane—we had to cut the side open, because it had been taped up when he was put in—he was pretty fatigued, but he could talk. And within a minute or so, he was back to normal.

He now works at JPL [Jet Propulsion Laboratory], writing reports for a private company that's doing a lot of stuff up there. He enjoys the work. I see him every two years or so; we communicate by phone. I don't keep up with him, but I am aware that he looks the same as he did twenty-five years ago. He has the same personality and spirit.

LIPPINCOTT: This was your last experience with human-powered flight, wasn't it, essentially?

MACCREADY: Pretty much. It was not quite Bryan's last experience. We had him fly the backup plane, which was more elegant than the one that did the channel crossing. We used the first plane, the experienced plane with a lot of repairs and so on, as the first try across the channel, and it worked, thank goodness. We had been thinking that it was more likely that the next plane—which was the same but cleaner, a little better ventilation in it, and so on—would be needed, but it wasn't. So he flew that plane at a few other events. He flew it at Oshkosh a year or two later.

LIPPINCOTT: So the first Albatross was—

MACCREADY: Never flown again.

LIPPINCOTT: And it was less good than this second plane?

MACCREADY: Yes. The second Albatross would have been a little bit better. It was a little cleaner.

LIPPINCOTT: Why didn't you use that one for the channel crossing?

MACCREADY: We didn't want to use the more elegant plane. There were twenty or fifty things that could have gone wrong with it and we felt that the prospect of its completing the flight was very unlikely and that it would be better to use it as a test device rather than as the final serious device. The first Albatross went to the Smithsonian National Air and Space Museum.

LIPPINCOTT: And the Condor went to that museum, too?

MACCREADY: The Condor went there, too—there was only the one Condor that we made. The Albatross, the first one that flew the channel, went to the Smithsonian and was not flown anymore, but with the number-two plane, which was a little more elegant, we did some flights. Bryan flew it at the big air show at Oshkosh, and I think it was taken over to South Africa and flown there. Then it went to a museum, too—the Museum of Flight in Seattle—which is where it is now.

And then we had a third plane, a backup that was a three-quarter-size plane—the idea being that it would take a little more power but you could get it across the channel much quicker.

And that plane is the one we then used for solar-powered flight, which we got into later.

LIPPINCOTT: So you used the same plane for human power and solar power?

MACCREADY: Yes.

LIPPINCOTT: The design wasn't any different?

MACCREADY: This smaller plane flew faster and it was a little lighter weight. When we started the solar-airplane flights, we procured solar cells, a small quantity of them, from Bob Boucher, who had tried to make a solar-powered plane—an unmanned solar plane, for a government project. And it had broken up at altitude, because the people he had to work through were demanding various maneuvers, and the whole project sort of collapsed. Well, he was able to find some of the cells that had landed on the ground, and he kept them.

LIPPINCOTT: Why was it so hard to find solar cells? Is it that the solar-cell industry was so—

MACCREADY: These were cells that were made in 1980, 1977, 1975. It was at the infancy of the field, and the cells didn't have good power. I think ours were around twelve-percent efficiency. Now you can fly with twenty-percent efficiency and there are some cells that get up to thirty percent, but they're very expensive.

Anyway, we put a panel with these solar cells above the airplane—not many solar cells, but it was enough. My son Marshall made the first human-piloted solar-powered flight in it, on May 18, 1980.

LIPPINCOTT: Where was this flight?

MACCREADY: At Shafter, at the same airport where we had been doing all the development. He had flown in it while we towed it along and tried to measure how much power it put out and so on. And finally the plane got good enough so that he was actually able to fly it by himself on solar power. I remember that date because my wife said that it had been our wedding anniversary and I should have remembered.

LIPPINCOTT: Was it? [Laughter]

MACCREADY: It was. And it was also the same day that Mount Saint Helens blew up.

LIPPINCOTT: The very same day?

MACCREADY: The very same day. So it's easy to remember May 18, 1980, as the first human-piloted, solar-powered flight. Marshall was probably thirteen at the time and he only weighed eighty pounds. As we got the program further along and moving toward the Solar Challenger, we had to make the flights at NASA's Dryden Flight Research Facility.

LIPPINCOTT: Where is that?

MACCREADY: It's northeast of Palmdale. DuPont was sponsoring the work, and they considered Marshall too young to fly officially, so we got a woman pilot, Janice Brown, who weighed about ninety pounds, and she flew it on one long flight there [August 7, 1980]. That was the flight we did for a public demonstration, but after that flight there was no more action with that plane.

LIPPINCOTT: This was the Gossamer Penguin?

MACCREADY: Yes. The Gossamer Penguin was then shown at the 1982 World's Fair in Knoxville, Tennessee, and then it was given to a museum in Dallas, Texas, though the museum didn't have much space for it. The plane had to be assembled in one room with a wing sticking out into another room. But that's the Gossamer Penguin. And we then immediately plunged into making the Solar Challenger.

LIPPINCOTT: Yes. I want to talk about the concept of solar-powered flight. Isn't the big advantage that a solar-powered airplane can stay aloft as long as it wants to?

MACCREADY: As long as the sun keeps shining.

LIPPINCOTT: Is that why DuPont was interested in it?

MACCREADY: The reason for the solar flights, from our standpoint, was to help the solar-power field, which had experienced some small aggressive growth, getting better photovoltaic cells and putting effort into it. But the government intended to cut down its support of solar power under the new administration.

LIPPINCOTT: This was the Reagan administration?

MACCREADY: The Reagan administration. Reagan was not enthused about a lot of things that we were enthused about.

LIPPINCOTT: He wasn't concerned about the use of fossil fuels, in other words?

MACCREADY: He was in favor of fossil fuels, and doing things the same old way, and so on. And we felt that flying an airplane on solar power would be a bit of a help to the field, because it would bring a lot of publicity. We weren't interested in solar planes per se; we thought of this as just sort of a stunt. The real reason was to help the solar-power field, and I think the publicity about the Solar Challenger did help a bit, so that the funding was not decreased as much as it would have been otherwise. But the surprising thing for us was that the solar-powered flight actually led to other things. We were just doing that one project, trying to make a flight from Paris to England. We wanted the Solar Challenger to land at London, but the air traffic control wouldn't permit that, so we landed in eastern England, at the air force base where we had worked [Manston Royal Air Force Base]. That flight was the purpose of the program. It got a lot of publicity, and we thought that that was going to be the end of solar-powered flight, because it's pretty marginal; we were getting under two horsepower from the solar cells. And this had to be an airplane that would fly like an airplane and be safe structurally—not like the Gossamer planes, which were flown only at an altitude of ten feet, so if they broke it didn't matter. This had to withstand any gust loads that it might experience; it had to be more of an ordinary airplane. But we made it very lightweight.

LIPPINCOTT: It needed to be lightweight because of the low horsepower, is that it?

MACCREADY: Yes. The basic plane weighed 100 pounds, and the motor and solar cells and wiring and propeller added another 100 pounds, so it was about a 200-pound airplane.

LIPPINCOTT: So you felt that it wouldn't be practical as a plane—obviously not for the transportation of people.

MACCREADY: No. Its only purpose was to get publicity for solar cells. Flying an airplane on solar power, we felt, would get more publicity for the solar-power field, and it did.

LIPPINCOTT: With regard to the altitude. It flew, on this flight from Paris to England—this was in 1981, my notes say—

MACCREADY: Yes.

LIPPINCOTT: It reached 11,000 feet.

MACCREADY: The altitude gave it a little more speed; the winds that it had to cope with were a little less troubling at 11,000 feet than they would have been at 6,000 or 4,000.

LIPPINCOTT: What if the sun had gone behind a cloud? Would there have been some residual power in the cells that would get you through something like that?

MACCREADY: No. For this flight, we did not store any energy. We didn't have a battery in the plane. We didn't even use the little gasoline motor we'd used just to have some extra power during some early tests of the plane. The final flight was to be strictly solar-powered. But the plane had flown as high as 14,000 feet on its solar power during some tests.

LIPPINCOTT: And this was a manned flight, with a pilot?

MACCREADY: We had Stephen Ptacek fly it; he was a test pilot, an airline pilot. He weighed about 140 pounds, and we felt that if he could diet down to about 125, he'd be able to fly the plane, and he was just a super pilot. Some people are good at it, some are not good. Janice Brown was a schoolteacher who also flew and had had some flight instruction but didn't have the innate skill that Ptacek had. He was able to fly the plane better—make it climb faster, take off earlier, and so on—than she could, so we opted to have him do the final flight, which was a bit awkward. We had hoped to have Janice Brown do it, but she, in some flights we were doing in Arizona, just didn't have the proper rudder and turn control. It would be slipping and skidding continually, and we felt we just had to go with Ptacek, who, although a little heavier, had excellent skills.

LIPPINCOTT: And more experience.

MACCREADY: Yes, more experience—but the experience wasn't as important as the flight skill. Some people just are instinctive pilots. Our son Tyler, who did much of the flying in the Gossamer Condor, has that innate ability. The first time he gets in an airplane, he flies it smoothly—coordinated, and so on. I can't. Our son Parker couldn't.

LIPPINCOTT: You don't feel you have that skill yourself?

MACCREADY: No, I don't.

LIPPINCOTT: But you won all these flight contests.

MACCREADY: Yes, but I used my brain power in the important part of the flight. Those contests wouldn't be won by somebody who could do turns effortlessly but by somebody who knew where the next thermal was.

LIPPINCOTT: I see. And that's what you were good at.

MACCREADY: I would concentrate very hard. I found that you couldn't practice for the contests, because the flights were so intellectually exhausting you just couldn't do that on a Sunday afternoon. It had to be at the contest. So I just flew in the contests. In spiraling up in a thermal, I might hang my head to one side in the cockpit and lean it against the side and not care whether the plane was slipping or skidding but just try to make sure I stayed in the right part of the thermal. And I would determine when to leave it, and where the next one was, or which way to go looking for the next one. Maybe you'd see a cloud in the distance, or a topographic feature, and by concentrating all your thoughts on the next five minutes or thirty minutes of the flight and ignoring the details, you wouldn't climb quite as well as the perfectly coordinated person, but that difference wouldn't matter much. But when you left the cloud and headed out to where the next up-current should be, that was where the flying skill came in. I'm not the experienced, coordinated person for flying effortlessly, like some people. But certainly anybody can learn to fly; it's just that for some people it's not as quick and easy as it is for others.

LIPPINCOTT: So the Solar Challenger flight from Paris to England was piloted by Ptacek, who dropped down to 125 pounds, presumably?

MACCREADY: Yes.

LIPPINCOTT: Was he was ever in any real danger? Did he carry a parachute, for example?

MACCREADY: Oh, yes. The plane was rugged and wouldn't come apart, but it had only small ailerons, as a concession to the wing structure and where you put the solar panels on the wing, and it would not be safe to fly on any ordinary, turbulent day.

LIPPINCOTT: So the weather had to be almost perfect for that flight?

MACCREADY: Not perfect, but there was a question as to landing if you experienced the turbulence that comes from ten-mile-an hour or twenty-mile-an-hour winds and a lot of sunshine, giving you up-currents and down-currents, and so on. It was a very slow-speed airplane. It flew at around twenty miles an hour.

LIPPINCOTT: While it's in flight, it's only going twenty miles an hour?

MACCREADY: Yes, because it had to not use much power. If you go faster, then you need more power.

LIPPINCOTT: But twenty miles an hour is enough to keep it up?

MACCREADY: It was enough to keep it up with the light weight. If the plane weighed 200 pounds and the pilot was 125, that's only 325 pounds for the whole thing. The wingspan—

LIPPINCOTT: What was the wingspan?

MACCREADY: Forty-six-and-a-half feet. The chord was fairly wide, because you weren't after—

LIPPINCOTT: The chord?

MACCREADY: The fore-and-aft dimension of the wing. It was fairly large, not like a sailplane, and the airfoil bottom was very flat. We needed a lot of area on this wing, to mount the solar cells. We also had a very large tail just for the solar cells. In fact, when we started building the tail, we found some more solar cells in a box we had, so we made the tail bigger.

LIPPINCOTT: What was DuPont's interest in the Solar Challenger? Why were they a sponsor for this?

MACCREADY: They had sponsored the Gossamer Albatross project, which had been very good for them. In fact, when they bought Conoco, I think it was, they had in their quarterly newspaper a piece about the purchase of that company, and it opened with two pages on the Gossamer Albatross program. They felt that this airplane, although not a practical plane, embodied the spirit of their technology, and they used it in their advertising. They got a lot of benefit from it.

LIPPINCOTT: Did they produce any of the materials out of which the plane was made?

MACCREADY: They made a number of the materials. The mylar for the Gossamer Albatross came from DuPont. They had some that was the right thickness—probably a third of a mill thick or something like that. And it was made so that when it was heated it wouldn't shrink much in one direction but it would shrink a good bit in the other direction. We were able to use that so that when we heated it, to smooth it and get it to take the wing shape we wanted, it would not cave down in between the ribs, because it didn't shrink much in the fore-and-aft direction, while it shrank rather a lot in the longitudinal direction. That kind of material, which was some special stuff they had, was very useful for the Gossamer. But we really focused on DuPont material in the Solar Challenger.

Begin Tape 3, Side 2

MACCREADY: DuPont had various materials we used for joints, for pulleys, for mechanisms, and so on—some of these in the Gossamer Albatross but many more in the Solar Challenger.

LIPPINCOTT: When did it occur to you that there might be a practical use for a solar-powered plane, as opposed to just publicity for the solar-cell industry?

MACCREADY: As we were doing the project, we found the flights of the Solar Challenger at altitude were surprisingly good. And as we did calculations on them, we realized that probably the plane would have its best flight at around 30,000 feet, if you didn't have to worry about adding oxygen for a pilot and so on, which is so much weight.

LIPPINCOTT: Why was it so much better at 30,000 feet than at 11,000 feet?

MACCREADY: Although you need more power to fly as the altitude goes up—and the air density goes down and the flight speed goes up—the amount of power you get from the solar cells increases, because there isn't as much air in their way cutting down on the sunlight they get. So they keep giving you a little more power than the power you needed, up to around 30,000 feet. Above 30,000, they give about the same amount of power they'd give in space. So as you climbed up above 30,000, your plane would fly faster but then it would take more power, and they wouldn't have any more power, so you'd lose out then. With the weight of the pilot replaced by a radio-control system, the plane could probably have flown up to about 50,000 feet, or maybe 55,000. This was the calculation we made, and it was conveyed to government people who were interested in high-altitude flights. And we got the first project, which eventually resulted in Helios.

LIPPINCOTT: What government departments are you talking about, Defense?

MACCREADY: The Department of Defense. We did the studies and made a plane that flew around a little bit below 4,000 feet. It was obvious that this plane was not going to do the job required: The solar cells weren't good enough; the plane's design wasn't good enough. The technology was not good enough for achieving the sponsor's goals, and the project was put on hold. And then, when the Star Wars program got going—

LIPPINCOTT: Reagan's Star Wars?

MACCREADY: I think it was; I don't remember the year. But by then a bunch of years had passed and we felt that the technologies had improved enough so that high-altitude solar flight would be feasible. And we started the Pathfinder program during the last two or three years of Star Wars. But Star Wars ended, and by then NASA's Environmental Research Aircraft and Sensor Technology [ERAST] program found the plane to be useful, and they took on the project. So now Helios is a NASA project.

LIPPINCOTT: What would the Star Wars program have used such a plane for?

MACCREADY: They wanted a plane that could fly at an altitude where it wouldn't be shot down—up at 60,000 feet, say. This plane might have some missiles in it, to shoot down an enemy missile while the missile was still going up—as opposed to waiting until we knew where it was going and trying to shoot it on the way down.

LIPPINCOTT: So it was to be part of an early-warning system, perhaps?

MACCREADY: It was more than a warning—it was supposed to shoot down a missile that was going up.

LIPPINCOTT: You'd have to fit the plane out with its own missiles, is that right?

MACCREADY: Yes, but the missiles would be very tiny. Nothing could weigh much.

LIPPINCOTT: Did you get that far with that plane?

MACCREADY: Oh no, we didn't, but that was what was supporting it in the Star Wars program. But then Star Wars was cancelled and NASA picked up the project and has provided support since then, with their presumed uses being for communications and/or gathering data. For example, if there's big hurricane damage someplace and no radio communications, this plane flies overhead and can provide communications, assess damage, and so on.

LIPPINCOTT: Its function would be that of a communications satellite, essentially, is that right?

MACCREADY: Yes. It flies slowly enough so that at 60,000 feet it can stay in virtually the same place. Sometimes it has to head into the wind; other times, when there's no wind, it goes around in circles, and it could stay within 2,000 or 3,000 feet of a point—

LIPPINCOTT: Above the surface of the earth.

MACCREADY: Yes.

LIPPINCOTT: So it's like a geostationary satellite, in some sense.

MACCREADY: It's like a geostationary satellite in locations and seasons where the daily sunlight is adequate for keeping it up and charging its batteries or a fuel system.

LIPPINCOTT: But the geostationary satellites are much, much higher.

MACCREADY: They're 2,000 times farther away. When you consider radio waves, it turns out that you can use this plane to substitute for a very large number of communicators. We could get by with this plane putting out just one watt to cover an area three miles in diameter, and a watt and another antenna covering an adjacent three-mile-diameter spot, and another watt for another adjacent spot. It would take perhaps three or four planes to cover an area like Los Angeles and provide local communications—although in places like Los Angeles, the communications have gotten so good using ground devices that there probably isn't a need for these airplanes. But for other places not that advanced—especially in countries that are just getting into communications systems—this would be a cheaper way of doing it.

LIPPINCOTT: Helios is the solar plane that AeroVironment is working on now?

MACCREADY: Yes.

LIPPINCOTT: Is it deployed and doing this kind of communications work?

MACCREADY: No, it's in the development stage. We're working on having the plane stay up at night at the same altitude as during the day.

LIPPINCOTT: How could it stay up at night?

MACCREADY: You have to store excess energy that you collect during the day. Your solar cells are giving out three times as much power as is needed to keep the plane at 60,000 feet, so you store that excess energy in a fuel-cell system. You get only half the stored energy back, but if you've stored—

LIPPINCOTT: You lose a lot of the energy?

MACCREADY: Yes, you lose a lot, but there's enough to let you fly at the same altitude—60,000 feet—all night long, at least in many locations. The altitude record we set with the airplane, at 96,863 feet, was a little more of a—you could call it a stunt, to see what its ultimate uses might be. But there's no way to have it fly day and night up at that altitude. Flying that high takes a lot more energy, because there just isn't much air up there. But at 60,000 feet, it takes only about three-and-a-half times the energy it takes at a low altitude, so you can get by with the excess energy from the solar cells going into a fuel-cell system. But the way batteries are improving—and it's something we're looking at very carefully at AeroVironment—I think in another year or so, batteries will be able to do the same job we're now doing with a complex fuel-cell system. And batteries are very, very simple. It takes pretty good elegance to get them to work this effectively, but with the latest lithium batteries likely to be feasible, about ninety percent of the energy you put in, you get back out, whereas you get only about fifty percent out of the fuel-cell approach. So we're working on all this now.

LIPPINCOTT: How long can a Helios plane stay up in the air?

MACCREADY: Well, the basic idea is that it can stay up forever, but we don't know enough about what might wear out and what might have to be changed. So we think that flights of about six months would be the standard, after we've gotten the stuff all worked out. Now, there's the problem that if you're flying in the far north, it's great in summer, because the nights are short, but in the winter the nights are long and the sun isn't overhead even in the daytime. How far north or south you could go with this plane and stay up day and night depends on the particular plane and its various features. Much of the civilization you would be serving with this plane is at fairly high latitudes, north and south, and for those places we expect to have a plane with liquid hydrogen as fuel. It would use the oxygen from the atmosphere and it should stay up between nine and twelve days on the fuel you carry up with you. So, for a week or two in the winter, you would use this plane, but then you'd go back to using the ordinary planes that keep going for a long time.

LIPPINCOTT: Well, there are a lot of developing nations on the equator, and they're easier to service with the solar cells, right?

MACCREADY: Yes, but you want to have something that will work everywhere. At present, this isn't going to work up at extreme latitudes.

The Helios that flew to 96,000 feet had fourteen propellers. It was tailored for that task, whereas now that we will not be flying as high, there will be fewer propellers. But we're improving the quality of the motor system. We're making the propellers a little more efficient and making the motors a good bit more efficient. Various improvements are coming from a research program that's being continually upgraded.

LIPPINCOTT: And NASA is still funding this research?

MACCREADY: Yes, and they will for another three years or so. But we're doing experiments for other outfits that will use all these technologies. There's a consortium of government and private companies in Japan that thinks that this kind of airplane could meet a lot of their communications needs.

LIPPINCOTT: That's telephone communications?

MACCREADY: Yes. They've contributed for two years to the research we do over in Kauai, and they'll be over there this summer with more complete equipment.

LIPPINCOTT: AeroVironment has a headquarters in Hawaii where it's working on this?

MACCREADY: We go over to Kauai every year.

LIPPINCOTT: Why there?

MACCREADY: Because there's a navy station there where we can put up a building that's big enough to hold the airplane. It holds the airplane in two parts.

LIPPINCOTT: How big is the airplane?

MACCREADY: It has a 247-foot wingspan, so it's very large. But you pull it apart in the middle and it fits into the building. People are going over next month to get the program going this year. For the basic project, but also for other clients we have contracts with.

LIPPINCOTT: Do you visit over there yourself?

MACCREADY: I've visited each summer for the last couple of summers, and we probably will have a board meeting there again this summer and try and have it coincide with one of the flights, but I don't get involved with having to be over there and having to be part of the flights. We have a very good team of people who seem happy to go there.

LIPPINCOTT: I just want to touch one more time on NASA's involvement. Were they thinking of using planes like this as substitutes for, say, their Goldstone antennas for tracking their spacecraft?

MACCREADY: I don't think so.

LIPPINCOTT: Why were they interested in it?

MACCREADY: They're interested in airplanes. NACA [National Advisory Committee for Aeronautics] became NASA—and their missions still fly in the atmosphere as well as in space.

LIPPINCOTT: Oh, right, for looking down at the earth.

MACCREADY: Well, NACA was the aviation research part of the government and worked on airfoils, on engines, on everything on airplanes. And now that it's called NASA because space has been added to it, that doesn't mean the rest has been taken away. They're still working on all aspects of airplane flight, as well as on rockets and satellites.

LIPPINCOTT: Yes, well, I know at JPL part of what they do has to do with Earth-observing satellites and nothing at all to do with going up into space.

This may be getting way off the topic, but when you read futuristic authors, they talk about using solar power for interplanetary flight. Is this anything you're interested in or have thought about?

MACCREADY: Solar power can be used for all sorts of things. We are *not* interested in man in space, because—

LIPPINCOTT: No, but how about robot spacecraft?

MACCREADY: The robot spacecraft do make good sense. We keep up with projects at JPL, but we don't have any work with them at the moment. We have done a Mars spacecraft that would fly in Mars' atmosphere, dropped from a larger craft. It's a very tiny plane, maybe a six-foot wingspan—you don't send a big plane up there. And this would glide flat enough and far enough. You have only about eighteen minutes of easy communications with the orbiter overhead, and during that time the plane would go along the walls of the big canyons and valleys and monitor details. You could power the plane, but powering the plane requires so much stuff that you would have only a tiny bit of room and weight left for the research instrument. And for communications, it has to be a very different setup. If you have a powered plane that flies longer, you have to rely on a different way of getting the information back out.

LIPPINCOTT: Did one of these small planes actually fly on Mars?

MACCREADY: No, it was just a study; we made the planes and worked on them. There's a program now to continue these studies, but we and JPL were not one of the winners. We think that's because it was a NASA group in the east that needed the business.

LIPPINCOTT: And the Helios telecommunications hasn't been deployed? It hasn't actually provided a telephone network yet?

MACCREADY: No, we're in the design stages. It's a very expensive project, requiring a lot of people and a lot of test flying and so on. You can't just build it and fly it.

LIPPINCOTT: Do you have any idea how far in the future such a system might be deployed?

MACCREADY: It will be two years from now when it will actually be permitted to be employed for practical purposes.

LIPPINCOTT: And what area would it be serving at that time?

MACCREADY: That depends on who wants it. If Japan is using it, it would be in Japan.

LIPPINCOTT: OK. Shall we talk some more about solar power, because you were also involved in solar cars, weren't you?

MACCREADY: Yes.

LIPPINCOTT: Is that something that's still going on, solar-powered cars?

MACCREADY: The use of solar power does meet some needs, but it costs about twenty cents a kilowatt hour, and wind power now costs about four cents a kilowatt hour. Wind power is cheap and fits in with our electric-power systems, which are mostly coal and natural gas and regular fuel.

LIPPINCOTT: But you can't use wind power in a car, so what about transportation?

MACCREADY: Well, you can now make a battery-powered car that would have a range of, say, 250 miles with lithium batteries.

LIPPINCOTT: Without recharging?

MACCREADY: Without recharging. They have rocketed into practical application in the last two years. These batteries now used in cellular phones and microcomputers have very high energy per pound. They're used in the model-airplane field. Three years ago, a model airplane might fly just a minute or two on the battery you could put in it; they now fly over half an hour on a battery. The batteries have gotten so cheap and standard that a lot of people are using them for model airplanes. One of my sons, Tyler, is working for Hasbro Toys as their model-airplane developer. He does half-time work on that and goes over to Hong Kong maybe three times a year, which is where they build the things. He has a biplane with a wingspan of perhaps two-and-a-half feet; you can buy it, radio controlled, with a transmitter and the receiver and the radio and the battery, for just $50. They don't use the most expensive batteries in that little plane, but if you do use those, you can fly the plane for a much longer period of time.

LIPPINCOTT: Do you envision the automobile of tomorrow as being battery-run or solar-cell-run?

MACCREADY: The automobile of tomorrow, I think, will be battery-run. And the surprising thing is that no car company is now admitting to any interest in battery-run cars. And the RAV4 electric vehicle—

LIPPINCOTT: What's a RAV4?

MACCREADY: It's the Toyota battery-powered car. I have one, which they just loaned me for a couple of years. Toyota sold them for a while last year, but now they don't sell them anymore. And the other is the General Motors Impact. GM turned it into the EV1, and they sold those.

LIPPINCOTT: Were you involved in that?

MACCREADY: Not in the sale, but we were the people who developed the Impact, which got the mandate going in California and got General Motors to say they would commercialize it. That was what we did in '88 and '89, after the solar-car competition, which was just a competition—not for any practical vehicle. And then when we proposed to GM to do the Impact car in '88, they bought the idea and let us do it. We collaborated with various people at GM, but it was basically our car design. We did all the building, but the building we did was just using a carbon exterior, not metal.

LIPPINCOTT: The chassis was carbon?

MACCREADY: It was the size and weight of a commercial vehicle but we used simple materials appropriate to developmental work. When they took over the car, we were no longer involved with it, and they manufactured it using the more standard techniques. The EV1 is the first car that any car company has put out in which every part is new and different. When you buy an ordinary car, about ninety percent of it is last year's model. So this was a big change for the industry, and General Motors probably got a lot of benefit from working on it. They had a special team that worked on all the parts, all the materials, and so on, after our work was done, and they put close to half a billion dollars into these developments. But then they decided they really didn't want the car out commercially.

LIPPINCOTT: Why did they decide that?

MACCREADY: It cost them a bunch. They didn't make many of them, they cost a lot, and GM didn't know where the field was going.

LIPPINCOTT: And consumers were nervous about driving an electric car?

MACCREADY: No, anybody who got one is a wild enthusiast. GM wouldn't sell it to just anybody and wouldn't sell many of them. GM would much rather build sport utility vehicles, which they make a lot of money on right now. This is perhaps a reasonable stance for the industry, but while they've been fighting with the California Air Resources Board about regulations and so on, companies in Japan have made hybrid vehicles.

LIPPINCOTT: Those are half gas and half electric?

MacCready: Maybe not half and half, but they are gasoline vehicles with batteries used for part of their operation—particularly at the lower speeds, where it may be all on batteries. At the higher speeds and during acceleration, they will add the gasoline power. They have very nice two-person, four-person, five-person hybrid cars in Japan that have been sold there and in the U.S. They cost about $20,000, and enough of them have been sold so that the price does pay for the car. I don't think there's a big profit on them, but all the cost is covered. And these are cars that did not fit any of the regulations the Air Resources Board wanted. They didn't conform to the U.S. rules.

Lippincott: Why? They were polluting?

MacCready: Yes, they give out some pollution, because they are not exclusively battery-powered. They didn't fit our rules, and the Japanese companies didn't worry about fitting our rules; they just concerned themselves with making cars that were an improvement over ordinary cars. There's much less pollution from hybrids, and they get forty or sixty miles to the gallon.

Lippincott: Why would the Air Resources Board object to a hybrid vehicle?

MacCready: It didn't object to them, it's just that hybrids weren't covered in any of their regulations. But hybrids make sense, and people find them very comfortable, and the Japanese have sold a bunch and they're selling more. And now the American car companies have become aware that this is an important field, and they intend to come out with their own hybrid vehicles, maybe as early as this year or next year. Development in Japan costs about a fourth as much as in the U.S., and the Japanese can make money selling smaller cars. They don't have to make all their money selling sport utility vehicles.

Lippincott: Is AeroVironment involved in making or designing battery-powered cars?

MacCready: We are doing various projects that involve special cars for the government or other groups, and special power systems. But this gets into a lot of projects that sponsors don't want people to know about. They aren't really classified projects, but what we're doing with them we don't talk about.

However, cars that are just battery-powered suddenly make huge sense, if you use the new batteries that have been developed—the lithium batteries that are used elsewhere now, for cell phones and microcomputers and model airplanes. If you were to use those for cars, that makes huge sense, whereas the big efforts now in this country deal with hydrogen power, and that makes very little sense. You would use only about a quarter of the hydrogen power for moving your car; three-quarters of it would go into all the processing of the stuff to get the energy to the car. And the car would only go about fifty or 100 miles with the amount of hydrogen you could store in the vehicle.

LIPPINCOTT: These are hydrogen fuel cells you're talking about?

MACCREADY: The fuel is hydrogen, and you have to have enough of it to power your system. It does go through a hydrogen fuel cell, as the mechanism to get the power out. But I'm saying that the technology is rather tangled. They say that maybe it's our children who are going to use these cars. About the time a newborn goes to college—say, fifteen to twenty years from now—it may be that long before those cars become practical, if they ever do.

LIPPINCOTT: And you have to use power to make hydrogen in the first place, right?

MACCREADY: Yes. But with regard to the battery-powered cars, there are improvements from other fields that could be applied that would make them quite satisfactory. And this fits in with AeroVironment's overall goal, which is to work on the technologies and sell products in those areas that make a significant difference, so that humans can get by and not run out of power. We are very interested in energy that does not come from burning coal or burning oil or natural gas, because they all have…. [Tape ends]

Begin Tape 4, Side 1

LIPPINCOTT: Well, we've brought you pretty much up to date now with AeroVironment. I'm interested in what you have to say about the future of transportation and energy use in the United States, and you just started to get into that. That was AeroVironment's real reason for being.

MACCREADY: The overall subject of what we do and why is fairly important. It gets back to the company's dedications, which really were a result of my giving a talk on the subject when I got the Lindbergh award in 1982, after the Gossamer Condor and Gossamer Albatross projects.

LIPPINCOTT: Who gives the Lindbergh award?

MACCREADY: The Lindbergh Foundation. They give the award to somebody each year, usually somebody who has advanced the field a good bit.

LIPPINCOTT: I have here the citation. They gave it to you for your "significant contribution toward creating a better balance between technology and the environment."

MACCREADY: Yes.

LIPPINCOTT: So that's what their concern is, too.

MACCREADY: They're interested in preserving Charles Lindbergh's activities—his airplane flight, but also what he devoted the last fifteen or twenty years of his life to, which is the environment. He had a unique understanding of it. As I think back, he was a real pioneer. And the woman who wrote the book in 1962 about the environment—

LIPPINCOTT: Rachel Carson?

MACCREADY: Rachel Carson's *Silent Spring.* She was another of the real thinkers on the environment. When you look at the policies of this country and the rest of the world since then, you realize that very little of their thinking has been applied—though some has. Their work was very important. When I had to give a talk in getting the award in 1982, it forced me to take a look at all the various things I had been up to and really think about what my interests were. And I decided to talk about what I would see if I visited Earth as a space traveler every 5,000 or 10,000 years. For several thousand of such visits, I would have found Earth, and all its animals and plants, and so on, to be pretty much the same. But on the visit in this era, in 1982, things would have been very different.

LIPPINCOTT: Different because of human—

MACCREADY: Because of humans. One group—humans—is now taking over. One thing I've done is to put together a plot of vertebrate mass on land and in the air, which is roughly proportional to what vertebrates eat. Humans and their livestock and pets now make up ninety-eight percent of the vertebrate mass on land and in the air, and two percent is wild nature. That's a horrifying number I show the audience when I give talks.

LIPPINCOTT: Why is that horrifying, necessarily?

MACCREADY: That *we* now are controlling the world? We are no longer living in a big world that we're just a part of and a lot of other things are a part of, too. We are now in charge.

LIPPINCOTT: But is that a bad thing? I don't want to get—well, I do, I guess, want to get into this, maybe. There's two ways to look at it. There is the stewardship idea, that the human beings are the stewards of the environment.

MACCREADY: That would be nice.

LIPPINCOTT: Well, the only way we can be the stewards of the environment…. That suggests that we are also the masters of the environment.

MACCREADY: We like being the masters, but we don't particularly care about being the stewards. As you look at this number, you begin asking what humans are, what populations there should be. It turns out that a human population of about two billion—now, fifty years from now, 100 years from now, 150 years from now—would be a sustainable population on Earth. But that's not what we have now. We have six billion, and we are on the way to eight billion, and who knows, ten or twelve billion.

LIPPINCOTT: Do you feel that that's not sustainable?

MACCREADY: I don't think anybody who thinks about it agrees that's it's sustainable. But that's the population we have, while we're busy using the energy we get from inside the earth—the coal and the oil and the gas.

LIPPINCOTT: The so-called nonrenewable resources.

MACCREADY: Yes.

LIPPINCOTT: But if we could make a shift to renewable resources, would a ten-billion population be sustainable then?

MACCREADY: What's renewable in the way of food for these people? I don't think it would be.

LIPPINCOTT: So you'd have a food problem but not necessarily a fuel problem?

MACCREADY: Yes. You can get by on solar energy for your fuel—except for airplanes. We don't know how to do airplanes. As far as airplanes are concerned, I think—one of my dismal thoughts here—that the likelihood that our big airliners will continue in the future is not too good, because terrorists could knock out three 747s at about the same time—in Hong Kong and LAX and Heathrow, England, say—and make it very obvious to people that an airplane can easily be shot down on takeoff or landing with a surplus missile that's cheap and doesn't even have to be manned. You just have one sitting in an attic someplace, ready to go at the right time.

LIPPINCOTT: And that would put an end to the airline industry?

MACCREADY: Oh, yes. Well, I think as fuel prices go up, which is inevitable, in another five or seven years, you wonder what the airline industry can do—whether it can survive even that.

LIPPINCOTT: In *any* case, terrorists or not.

MACCREADY: But the terrorists, surprisingly, did a different sort of thing on September 11, 2001. I had thought that the first thing they would do would be to shoot down airliners instead.

LIPPINCOTT: Not fly into a building.

MACCREADY: Yes. And now we have greatly changed the airline industry, screening the passengers and so on, to make it fairly unlikely that they'll be flying into buildings in the future. That solves one of the problems, but I think there are other, bigger problems. When you really try and take a look at what we humans are going to be doing in twenty years or fifty years, you have to think through a lot of these big subjects. And just the one statistic—that ninety-eight percent of the vertebrate mass on land and in air is now humans and their livestock and pets—I find it a disquieting number. It's not going to get much bigger, I'm pretty sure.

LIPPINCOTT: Well, it can't.

MACCREADY: Yes, it can't. But we can make it to ninety-nine or ninety-nine and a half. Birds will still be flying around, but fewer of them. But elephants and so on won't be around. This is something we humans can do, and a lot of humans are delighted to do it.

LIPPINCOTT: To do what?

MACCREADY: To just take over. We're everything, and to heck with nature.

LIPPINCOTT: But we *are* nature.

MACCREADY: Well, we are one part of nature, yes. Look, the population was 1.7 billion when I was born, and it's gone up by almost a factor of four since then.

LIPPINCOTT: Have you completely lost hope in the future of the human race, then?

MACCREADY: Oh, yes. But I figure that being born in 1925 and being around until 2025 or some time like that—that will be pretty good. That will be the best time for the human population. And what you'll see after that, I have no idea—but it doesn't sound especially good.

LIPPINCOTT: But in your work, you're still soldiering on, trying to make things better at AeroVironment, or you wouldn't be doing it.

MACCREADY: The dedication of the company, and we don't follow it exactly, but it is still to do things efficiently—not just get any business you can, but work on the things that can be effective. For instance, you can make a ceiling fan that moves the same amount of air in a room and makes people comfortable by making the blades proper aerodynamically—which gives you a factor of two less energy needed. When you look at the mechanism for the electricity that spins the blades around, you find that it's horribly inefficient—about twenty-percent efficiency. You can make it sixty-percent efficient, so you can get a factor of three out of that. For a device that costs just about the same as a ceiling fan, you can move the same amount of air with one-sixth the amount of energy. Now, that's not a big important thing, but it sure shows what can be done when you start being efficient about things.

LIPPINCOTT: So you're still into ameliorating this dismal situation.

MACCREADY: Yes. And your cars can be made very efficient. You can improve their mileage a lot by having an electrical system as part of, or all of, the parts of the car. Instead of using up energy in braking, you generate electricity. You don't throw it away in the brake lining; you put it back and use it again. Cars will do that in the future. In ten or twenty years, all cars will generate electricity in braking, and that will make them better. The aerodynamics of cars—well, the tires do create some of the energy loss, but the aerodynamics of cars is a huge problem, especially as we travel faster on freeways. And there are ways of cutting that down that are being explored now, where you decrease the drag of a van that has a big flat rear. There are ways of cutting down the drag of that to maybe half its ordinary drag.

We have to worry about travel, because as we get into bigger cities, travel just gets impossible. Travel in Los Angeles—lots of people go thirty or forty miles to work every day and you have traffic jams.

LIPPINCOTT: But in the meantime we're getting into telecommuting and Internet commuting, so that's a trend that's on the rise.

MACCREADY: Yes, which we thought would take the place of having to drive. And it does do some good, but not as much good as it should. The commuting distance gets a little greater every year, and the commuting tie-ups get a little worse, and if you look at—

LIPPINCOTT: Yes, and the carbon dioxide output goes up.

MACCREADY: Yes. If you look ahead ten years from now, there just isn't enough space. I saw an estimate of the travel component in Los Angeles some years ago, and something like seventy percent of the land was devoted to transportation, if you included the roads, the sidewalks, the garages, the gas stations—

LIPPINCOTT: Parking lots.

MACCREADY: The parking lots, and everything. They have double-decked some of the freeways, but I don't think that's especially good. You can't do double-decking on all the streets. So there are too many people—

LIPPINCOTT: But we have to cope with the situation as it is now. I mean, we can't get rid of the human population of the earth. We have to deal with it.

MACCREADY: Some of us think wars are a good way of dealing with it.

LIPPINCOTT: Yes, but… [Laughter]

MACCREADY: And there are some groups who think they should have ten or fifteen kids.

LIPPINCOTT: Yes, well, people should be disabused of that idea, sure.

The people at AeroVironment besides yourself—I'm thinking of the board members and the company as a personality—are they all this pessimistic about the—

MACCREADY: No.

LIPPINCOTT: They're not? Would you say you're the—

MACCREADY: I'm probably the most pessimistic. The businesses we get into are good businesses for the company, but they tend to be businesses that fit with the realities of the world. Instead of working on another car that uses gasoline, we work on a car that uses a battery.

LIPPINCOTT: Well, I'm glad you're there, then! I think we can wrap it up now. I just want to thank you for coming in and talking to us. It's a good interview. [Tape ends]