Dale F. Bachman, IBM, Owego, New York, April 25, 1968.

Lenz: You were instrumental in the MVS? (Mission Verification Simulation)

Bachman: You could say that.

Lenz: There's the one area I've been trying to nail somebody all day long.

Bachman: I was an opponent of the MVS, actually. But once it got going I guess I got involved in it.

Lenz: We're trying to get more kind of a deal on it. We know that MVS means Mission Verification Simulation, that it was tied into a 94 and the astronauts came in here and flew a reentry--

Bachman: You're mixing a few things together. Actually, what we did is we developed a hybrid simulation capability and this was a situation where the environment and the simulation of all the inputs took place on the 7094. It was brought out of the 7094 into some digital to analogue convertors and some other special gear and converted into inputs. And as far as the computer was concerned it looked like it was flying. So the computer was turned on and it proceeded to operate in a fairly normal fashion, and its outputs, which would normally go to telemetry, were returned, along with things like guidance commands and any other commands it would normally generate, and they were all fed back across another interface line into the computer--the 7094 computer--and these things were then used to modify the flight path, or do whatever was necessary to properly simulate the environment. The principal reason for this was to verify, without a doubt, that the guidance equations and the navigation equations would perform properly in the dynamic situation which approximated a real dynamic situation. And it turned out pretty well. At that point, somebody made the observation that "well, we could just as well put a man in the loop here, in addition to the computer." This was a step that we never got to, however. We did have a man-in-the-loop simulation, but in this case the 7094 simulated the guidance computer as well as the other, so what the man saw was all of the outputs--not all--most of the outputs that he would normally see and all of these being driven by an environment and control program in the 7094. As I recall, the attitude ball was driven; the IVI's were driven; a few lights were driven where it would control; and the hand-controller was operative. So that he could provide inputs to control the effective vehicle adequately, which was fed back into the 94, and the results were fed back out of the 94 and back onto

his attitude ball, and other status lights. This was just a setup to show how well the guy could control the thing, or how hard it was to do it, and what things would look like. We did have some astronauts--do you remember who they were? Gus Grissom was one of them--I'm not sure who else.

Lenz: Oh, Grissom, McDivitt, and White.

Bachman: They came up here for a program review and we let them fly that thing. They put in a few flights with it.

Lenz: As a matter of fact, not to interrupt you, but this little--Grissom gave a little talk while he was up here and he gave things--quality and reliability--he worked with us--we sort of made a poster out of that. He made a little talk and at the end of it he said, "Because of you people I won't be up in space with my fingers crossed." So we made a little poster out of that for our quality awareness program, that type of thing. As a direct offshoot of that little speech he gave here over our public address.

Ertel: They were serious about that. They wanted everybody to do good work.

Bachman: I don't understand that because--Well, that was the man-in-the-loop simulation. That was mainly the tool to see how the system would respond. Kind of tied into that was a situation where we had simulated on a digital computer the full dynamics of the situation, where we had as a result of earlier needs created a six-degree-of-freedom simulation of the vehicle dynamics, with both three-translation degrees of freedom and three-rotational degrees of freedom. With that as a base, then, we went on to these other things like the MVS, which included all this attitude control stuff in the 7094, all being simulated, so that as far as the interface with the computer looked, it was sending in a real vehicle. Really the same environment programs, then, that were used in the man-in-the-loop simulation, things which allowed, again, the indication of how many Gs,for example, the thing was drawing, related to the real trajectory the guy was flying, and how stable the aircraft was aerodynamically was related to exactly he did. The simulated environment was the same and completely under the control of the operator. We never did get this to the point where we had the computer and the operator--what I mean is the Gemini computer and the operator and the 7094 all tied together. But that would have been possible. There was no real motivation to do it.

Ertel: What was the point of the MVS to start with?

Bachman: The principal reason was that it was a very complex device for simulation, with a lot of special purpose interface gear that had to be built, and, in its final form, it turned out to be pretty good, after rebuilding all the interface here. The original problems were really that it looked to me that it wouldn't really demonstrate what it was trying to demonstrate, unless the results were interpreted very carefully. With very crude inputs, you would not expect the computer to fly exactly the path that you might have predicted for it to fly. So it would take very careful interpretation of the results to demonstrate that it did the right thing. The other problem was that it was going to be a very extensive project, involving lots of people, lots of time, and a lot of tie-up of the computer facility. I think that turned out to be about right. The initial MVS had a lot of funny things in it that were hard to explain, most of which were tracked out to anomalies in the simulation, somewhere, although I think there were a few things that were found that probably made it worth while. Ultimately, once the whole facility was checked out and we had good interface here, I think it turned out to be a very valuable device. There was much wear and strain that went into getting it into being that valuable device. Basically, it's a matter of where do you want to spend your money. A big chunk went into that.

Lenz: You had a lot of opposition to that MVS lab in the first place from the money standpoint.

Bachman: I think it ultimately turned out to be a really nice thing to have. That's what I was just saying. Initially, I didn't--as it was initially configured, I didn't see too much hope for it. But after they got the interface straightened out, got that decon gear out of there, and got some good convertors in, it turned out to be pretty good. The decon was a homemade A to D and D to A convertor that they made in our laboratory out of some old gear--I'm trying to remember what it was from--it was from some GD/A project that had been going here--and it was getting kind of old and misshapen. It had seen better days. So once they got some good gear on the interface, and got some--got most of the drivers of the accelerometer simulators and the gimbal simulators refined for good accuracy, it turned out to be pretty good. It still had the fundamental problem. And that is that you had the computer cycle time, which usually was about, on reentry, something like a second, and that meant that the whole thing could shift one second out of phase fairly well; in other words, the guidance commands coming out were quantized, and this worked out real well in the

continuous real world. What we were creating was a situation which had one set of quantitation in the Gemini computer and another set of quantitation, of necessity and smaller, in the 7094 computer. As I recall that was about a tenth of a second steps that the accelerometers and gimbals were updated. So we still had this problem. They weren't locked together. You had the matter of interpretation as the computed path wandered around the real path. But, in the end, the tolerances were such that they were very, very satisfactory. To go back to the other statement, originally the tolerances were such that the wandering would be such that you wouldn't really know whether the wandering was due to the computer, or due to the program, or due to a bad interface, or what. Once it was properly refined, it worked out real well. I don't know what else to say about that.

Lenz (?): Tell us how your experience in Gemini has made you a big honcho in VSF (?).

Bachman: Yeah, right. Or I could expound on how I used to be able to walk into the Gemini lab and the error light would come on. I'm not sure why that was. They were having some troubles with the--I don't recall what the problem was any more--I guess it was the static pickup--but, for some reason, everytime I walked in the error light would come on. It happened a couple of times and then they didn't want me down there any more.

Lenz: What else did you get your fingers into on Gemini?

Bachman: Actually, I started out working in the reentry area, trying to come up with the reentry guidance program, and I wound up, finally, with the auxiliary tape program. Although Marv was more concerned with the tape control itself. I was, at that time, supposedly overlooking the rest of the program, once we started confining these things into modules. When we got the tape, we had five or six modules, each one loaded as a section on the ATM, and it took a little bit of watching to make sure they all were compatible.

Lenz: Everybody was talking today about taking the laurel wreath credits for Gemini VIII flight and loading of the ATM in a spinning situation in space and having such a fine touchdown. Gemini VIII's the one that aborted and splashed down--

Bachman: Yes, I know it was. I'm trying to remember whether that's the case or not. It wasn't loaded while it was spinning.

Lenz: That's what Hutch said.

Bachman: No, that's not true. It was after--the spinning part was all over before he tried to load the thing--but it was subjected to that stress of the spin while they were docked, but that--they were not about to turn the ATM on while they were going around--

Lenz: I thought he disengaged and backed off and said, "All right, what do I do, chief?"

Bachman: Oh, yes, but after it stopped.

Lenz: It was after that that they let him go around one more time then they said, "You'd better come on in." At which time he wouldn't have loaded.

Bachman: No, he did load it during that time.

Ertel: After they used the RCS to get stable, they had about an hour and a half to get ready.

Bachman: They did ------

Ertel: No, I don't think they did. They were on the verge of blacking out, they both admit.

Lenz: I guess they got too scared.

Ertel: They didn't have time to do it.

Bachman: That fast, you think you can bear anything.

Ertel: And that's not time to do it.

Bachman: And your stomach doesn't really know what's happening to it. But after they got stabilized, one of the first commands they got was to load the module,whatever it was, that had reentry in it. I meant to have brought that along, just in case somebody asked. I used to know that call, though --it must be module 4, wasn't it? Which they did and I think they still played around for another orbit before they had to use it--I don't know what the time was-- This was a remarkable accomplishment--everything worked so smoothly.

Lenz: On the maiden flight of the ATM.

Bachman: That was the first flight of the ATM. It was also the first flight of that particular program--the program that was in that vehicle was the adapted mode--it's a slightly different reentry program that hadn't been used before. There was a spinning reentry program that was used up to spacecraft 4 and they switched to the side-by-side then. On this other one we went back to something that was similar to the one that was used on spacecraft 2, 3, and 4, but it had a lot of changes in it. It also had to be broken in pieces so it could be--well, the reentry part had to be broken out so it could loaded as a module to go with the module 1, which was the module that stayed in the memory all the time. Of course, that's when MVS became fairly valuable. When you just have one resident program in the memory, it's a matter of it either worked or it didn't work. When you started having the capability to change what was in the memory, you needed a fairly extensive checkout facility; in that case, it was there. The whole thing has to be checked out, and we were pretty sure it would work. A few people had moments of trepidation that it wouldn't work in the southern hemisphere. It worked out real well. But that was--Gemini VIII and Gemini IX carried the same program; then from X through XII, we got a whole bunch of other modules quotable from the tape included. It's a fairly tricky job to keep track of how all these things were fitted together. The way we chose to do it, we put all the MDIU control, which happened to be part of module 1, so this thing turned out to be a giant control situation, and it had to be able to handle all the other modules. That got to be this job of just making sure that everything's going together. That entertained me for the last year or so of the program. I don't know--to me, it seems like a long time ago.

Lenz: Anybody else using the mission verification simulation approach?

Bachman: It's very interesting. I don't know if anybody's ever using it, but there's a fundamental problem, and worthy-of-note problem. And that is that our Gemini computer was kind of the last of a dying breed. It was an airborne computer, ruggedized, special purpose, and slow. You call add times, 140 microsecond add times, and we happened to have in our laboratory this 7094, with something like two microsecond add times, so what we could do was we could sit in our MVS part of the computer and calculate like mad and stay ahead of the guidance computer. And now that the computers are getting faster, like our 4 Pi--Jack, you should know some of those numbers--add times in 4 Pis must be

running around five microseconds, so they are now so close to the flight computers add time that it's very difficult for them to keep ahead. They can't complete the required computations in order to have the stuff ready when the guidance computer needs it. MVS-like activities are now very, very difficult--the whole aspect of checking out flight computers has got to be done a little bit differently, simply because the ground computers can't keep up. Of course, one way to--a related item is the fact that we had, in Gemini, a Gemini simulator that ran on the 7094 and it could run somewhat slower than real time--I don't recall what the ratio was--but it was maybe ten times--I take it back--you run ten minutes worth in about 30 or 40 minutes, so it's three or four times slower than real time. If you try to do that--and of course this is complete with diagnostics and various printouts along the way, so you could see what was going on--if you try to do that with something like the A7 program, you run a ten-minute flight and it'll probably take you half a day or a whole day, because of the fact that the guidance computer is now running so much faster. I presume that somewhere somebody's still running MVS-like activity. The Apollo people have got something akin to it. You ought to know that, by now, better than I do.

Lenz: We're trying to run it on the B programs out of Washington. We've got a spec out. I don't know--

Bachman: Well, the B program is probably okay--as long as it's using the same computer--adequate to do the job, and there happens to be some nice standard, commercial computer that can keep ahead of it without being overloaded. Trying to do it with a real fast computer and still keep ahead means you have to compromise somewhat. The first thing you do is take out the six degrees of freedom and go back to canned profiles, which I'm sure is done. I guess the thing that you would have done, if you didn't do the whole thing, you would still have canned an acceleration time history and fed that to the computer and see what it would have done. I'm sure that's being done somewhere in some program. Problems are different between aircraft programs and spacecraft programs, naturally, where a considerably more emphasis in the spacecraft guidance area at making it work. The airplane can always come back and land and fix up the program or find out what kind of dynamic problems might exist and then build it and fly it again. So you have a very--

Ertel: Unless it's the 111--they don't build any that can fly.

Bachman: Well, that's true. You kind of hope that guidance program bugs wouldn't destroy the airplane, assuming that there's a pilot in there. It sounds a little bit like maybe one of them did. But this is exactly the kind of thing that NASA was not willing to tolerate in the spacecraft, space environment. The program had to be checked out in essentially all reasonable configurations that it might have to operate in. That's probably a reasonable thing to ask.

Ertel: There's no calling them back for a second launch.

Bachman: You're right--and the fact that if something goes wrong in the middle of reentry, it's a very, very serious problem because you can't stop coming down. If you somehow induce a situation causing the thing to tumble, or something, you create a very serious situation.

Ertel: Were you surprised at how apparently easy rendezvous was?

Bachman: I didn't work too much at setting the rendezvous itself up. I think the thing that surprised me about that was how easy it was, if you follow the game right; and how difficult apparently it is if you don't follow the game--the orbital mechanics game. And I refer to some flight--I don't know which one it was--

Ertel: John Young, when he burned up most of the fuel getting to the original rendezvous--is that the one you're thinking of?

Bachman: No, it was one of the earlier ones, I think, where they did sort of the same thing. The guy used brute force to get there and used up a lot of fuel and didn't quite make it. But I can't remember who it was or what flight it was. But I was part of the postflight group of that particular flight, I'm pretty sure it wasn't X, and we plotted these orbits---

Lenz: That was that three separate rendezvous--Gemini IX?

Bachman: I don't think it was. I think it was before VI, because Schirra made it look so easy on VI. I think it was V, and you can plot the orbits with the help of some NASA people whose names I don't recall. I ran this program--what would this trajectory look like if he didn't do a thing? And it's got a very peculiar shape.

Ertel: Of course, they were in trouble with the fuel cell on that one and powered down for the biggest part of the time.

Bachman: I think it was right after they took off, though. They were trying to do something--a direct rendezvous or something like that.

Ertel: They had a rendezvous pod.

Bachman: Yes, and they were trying to chase the thing--it was remarkable that if you didn't make use of the rules of orbital mechanics, I guess it's pretty clear that you wouldn't make it. That is, if you tried to thrust right at the thing it wouldn't help. You've got to wait till the propitious time--

Lenz: What is that?

Bachman: I know a lot of people down there were working on schemes to find out what the propitious time was and I don't know how they made out with that.

Lenz: Well, in the first orbit rendezvous, though, you shot right up at it.

Bachman: The direct ascent rendezvous was what? IX?

Lenz: XI.

Bachman: XI. Yes, that worked out real well.

Lenz: Of course, you're aimed right at it.

Bachman: Right. Once you get the situation--once you get on the right course, what it amounted to was that there were two regimes that you have to worry about. One of them is the orbital mechanics regime that says, if you thrust toward it, what that does is get you going faster and pretty soon you're up on top of them, which is very tricky. If you weren't real careful how you played that, you were wasting your thrust. Then there's the other regime where you're within sight and you're real close. And it works out pretty well that you're and you can push yourself toward the guy and you're close enough that you really go that way. You've got to tweak your way in. But the far-off problem is very tough. For example, the rendezvous equations, where they were working, they put out some thrust which--again I haven't worked with that too much--but it picks some angle and says, "Thrust that way and you'll get there." Of course, if you plot the thing out right, you

do get there. I haven't seen any rhetorical results yet that says, that when you look at the picture or you look at the target sitting out there somewhere--I don't know of any case where it's clear what you ought to do. Again, I guess the properly experienced guy might be able to figure that out. It's not immediately obvious how this thing ought to go. I guess I took up more time than I thought.

Lenz: Well, there's a lot of good dope on the program to filter out. I'm not sure where it is.

Bachman: If you ever want to put up another Gemini, let us know.

End of interview.