Tape #1, Side 1
Interview with Roy Godfrey:

RB - Why don't you go back a little bit and mention how you came on board out here at Marshall and where you did your work, what your professional background is.

RG - Well, I came on board here in early '53 when the Redstone was first underway--one of the first Redstone's assembled and joined the Quality Assurance and Reliability Lab at that time in testing and was in charge of the mechanical checkout of the first Redstone; pressure checks, alignment, all of the things required before the vehicle was sent for test or launching. I stayed there until I first got into project work, eventually became the deputy to the director of the Quality Assurance Laboratory, ______________. Then went over into project work. Let me refer here to my notes and get my dates straight.

RG - I went into the S-IVB stage in January of '64 as project manager. At that time the S-IVB was just under way as a Saturn I-B version of the S-IVB ______________ on both the first Saturn IB and then Saturn V. That was a unique stage in that it responded to two different programs at the same time. It was a different version, a non-restartable version for the Saturn I and then for the Saturn V it was adapted with a different inner stage. Clearly the most technically demanding problem in the S-IVB was the coast and the restart. In that regard the Saturn V program manager, at that time Art Rudolph, and the Saturn IB program manager, Lee James, both had a vested interest in the S-IVB. I was brought in to try to answer to those two people.

RB - Could we stop this for just a minute? Since I have also been working on the S-IVB could you explain a little bit more about the problems in the coast and the restart?

RG - Sure, at that time no liquid stage to my knowledge, no cryogenic stage of any size had ever been restarted. Centaur had not made it yet at the time the S-IVB was first put under development. Now Centaur tried it, I believe it was after the S-IVB first flew and had difficulty--naturally. When you go to zero G and all your propellants spread over the tanks, float around in the tanks and get mixed up with gas one of your greatest difficulties is settling it adequately so that you get no bubbles in the inlet of the pumps and cavitate the pumps. Now it takes energy to ____________ and it takes time even at a low G and low energy it takes quite a bit of time.

RG - The original idea on the S-IVB was to use a brute force approach and use some solid rockets and four ullage motors to settle the ullage sufficiently to start. But that was quite a performance penalty.

RB - They finally did use the APS modules on this for that reason.

RG - APS modules were the next choice that came along with large, because of the penalties of the solid ____________________ the S-IVB system carried ullage rockets in its APS module in addition to attitude control. That was the preferred choice after the solids were rejected because of the high performance penalty. But it was again a relatively high thrust and burned quite a bit of propellant, and even there the performance penalty was pretty high.

RB - Excuse me, what do you mean by the performance penalty of the solids--what was the problem?

RG - Well, just take the performance the ____________________ specific of the solid compared to the storables that you used in the APS module. They really weren't that much different, to be honest. Storables were a little better, OK.?

RB - O.K., so then that was enough...

RG - But you see the problem is that it was 1500 pounds of thrust in each of the ullage motors that were in the early Saturn V configuration. You had to have many seconds because that would only give you, I believe, less than a tenth of a G. And at less than a tenth of a G it takes quite a while to settle the propellants to be sure that no liquid is down at the bottom of the ____________ line and would cavitate the pump.

RB - Do you remember how long it would take to...

RG - I believe it was 20 or 30 seconds to be safe. It takes quite a bit of propellant so eventually, before we flew, the solution was adopted to use hydrogen gas and vent it with very little thrust over a long period of time. In fact, you had a continuous vent system, venting the hydrogen continuously and never letting the propellant get completely unsettled. Now to prove that, we flew an S-IVB stage configured so as to try that. In other words, after we completed the S-IVB two-stage mission and had the S-IVB in coast we had sufficient hydrogen, we had an early shut-off, you see we had sufficient hydrogen left to settle it with a very low G _____________ of -4, I believe, or something like that.

RB - Now was this on a Saturn I?

RG - That was on a Saturn IB and it was SA203. It was the restart mission for the Saturn V vehicle to prove that approach. Now we believe that the Centaur problem was they didn't have sufficient time to completely settle and they started with an essentially free-falling stage with an O-G stage. So this continuous very low thrust just from venting hydrogen gas as the hydrogen boil-off developed because of the heat input in the tank and orbital coast, continually vented and ____________________ into the -4G positive thrust. That 203 had a television camera to look at the hydrogen and be sure the configuration was ______________________. So that proved to our satisfaction that it would work and that was ultimately adopted. We were still sweating out that restart because not only did you have to have propellants, both hydrogen and LOX settled, you had to have the engine temperature right in all of the systems, you had to have the chill-down sequence. Generally, I would say that the biggest sweat on the S-IVB ___________________ was reasonable but it was really an S-IV stage, a blown up S-IV. I'm sure you've heard this before. So there was no new state of the art there. The J-2 was new and of course we learned how to use that in the early IB flights. But it was a raw engine. It took some shaking down in flight. But again the Saturn V _____________ configuration and restart was our biggest sweat.

RG - We fired the engine at Arnold under vacuum conditions. We still encountered a problem with it of course. You heard of the ASI line?

RB - I just now jotted that down to ask you about it. Could you explain that a little bit for me, please?

RG - ASI line was a problem which was not caught because of the testing sequence on the ground. Ithad occurred only in flight conditions. Very simple, we had a flexible hose in the ignition circuit of the S-IVB engine going to the ASI automatic spark igniter carrying hydrogen or LOX, I've forgotten which--one or the other. So in any event, this flexible hose on the ground was cold. It was chilled. It was a cryogenic hose. Now it was a bellows hose with a stainless steel ________________ over the top of the hose. You've seen that type of hose.

RB - Right.

RG - On the ground ice developed due to the moisture from the atomosphere condensing, of course, between the ________________ and the bellows and stiffened that hose. In all the ground testing it worked beautifully in the stiffened condition, however after we got it up out of the atmosphere, and even on the ground at the launch site we had a nitrogen purge, it probably didn't have as much moisture anyway and up in the vacuum condition the ice was gone and that darn bellows ______________ and broke under a few seconds of flow. It was a flow resonance problem. It was undetected on the engine because the engine was always fired at sea level. And even at Arnold we didn't have sufficient vacuum long enough in the testing up there to cause the hose to fail. The hoses we qualified were not qualified under vacuum cryogenic conditions. That would be a systems test,in a sense even though we had a tremendous qualification program the hoses were not qualified that way. We didn't expect that icing to be a factor, frankly. So, we missed until we actually flew and found it.

RG - And of course there was quite a story with how we ran down the nature of the problem.

RB - Who did most of the running down, was it Marshall or...

RG - A tremendous joint venture. You see the thing happened on two different stages, S-II had it. It knocked tow engines out. It knocked one engine out on the S-II and then the S-IVB failed to start. As luck would have it, all on one vehicle. So all of the North American people on the S-II were busy--the Douglas people, of course, were busy, and all of the Marshall propulsion people. We traced down--on the S-II we had a temperature profile because of the large amount of instrumentation around the engine, and for example, I was with S-II at that time, I know that story. We began to pinpoint the source of the leak, the direction of the gas flow because of the temperature response all around the engine. We began to suspect the area where the problem started, and then it was simply a matter of suspecting that particular hose and reproducing the conditions that had caused the failure. We had two or three candidates that could have caused a failure the way it failed. We knew the engine started o.k. on the first start, you see, and in S-II as it got up in altitude far enough the ice ____________ quickly away and it failed. And then the S-IVB failed on the start. It ran through its first burn successfully. It was a marginal condition, you see. And then it failed in its second burn.

RG - so we pinned down the possibilities and knew there were only a few components that could have caused a failure in such a manner. A few seconds after start we suspected a start problem so then we started testing the hoses; and somebody had the bright idea, "Hey, this hose has never been tested ______________________ and it failed to vacuum." And as soon as it vacuumed it popped ___________________________.

RB - Do you remember who....?

RG - A Marshall guy, no wait was it a Marshall or a contractor, I can't remember which propulsion ________ finally thought of that. We were all working so hard at the same time. But as soon as.....I believe it was a Marshall man over in Fuhrmann's Shop. Herbert Fuhrmann was the mechanical man over....I believe it was one of his people who said, "Hey, let's try that hose under vacuum conditions, but I'm not sure, I wouldn't want to give credit to the wrong guy. In any event, it was typical of how we chased several serious problems, everybody's entire resources, we had a communication net, you might say, exchanged information each day, certain people did one type of testing and others did other things. We suspected an actuator. Some people chased all the actuator problems down. We simply narrowed it down finally, when we tried that one test that was a clear answer. And then we reproduced that...

RB - And what was...

RG - Very simple, just put a heavy hose on it that wouldn't fail in ____________ heavier bellows hose. That's all it took. Of course, we re-qualified every hose that had not been vacuum tested in the entire vehicle, of course that had cryogenics in it. Naturally when you miss one you miss several others. So that was the most serious problem ever encountered on the S-IVB I guess in flight and one of the second most serious in the S-II. In the S-II the engine was knocked out by the ASI failure and it shut itself down, fortunately in a ____________ manner. That shutdown uncovered another problem--some crossed wires which shut down another engine because these crossed wires occurred during modification and were not found in the systems reverification test because they didn't run an engine-by-engine shutdown sequence, you see, didn't run all the failure _________ and missed that particular wiring problem. So that caught two engines on the S-II and it was touch and go. The guidance was not designed for that failure, but it just made it. We had successful guidance with two engines out on the S-II.

RB - It wasn't designed for two engines--it was designed for one engine.

RG - It was designed for one engine now, but the guidance did accommodate both engine failures. We didn't have a disturbance sufficiently large to cause us to lose control.

RB - I hadn't thought about that aspect of it.

RG - In fact, the mission rules were to abort the mission with a two-engine failure on the S-II. The Mission Control saw we had lost two engines. After we thoroughly confirmed we had lost thrust on two engines, and to our satisfaction, we made the decision to continue to fly because we were maintaining control and we had nothing to lose. That one was unmanned. But then, that was 502, I believe. That was the S-IC POGO.

RB - So in order to get ready for 503 you had to solve....

RG - We had two problems. We had the ASI which was a narrow problem, but once it was clearly identified no problem to prove it. The POGO was a little different. Incidentally, the problem probably would never have resulted in a vehicle problem.

RB - POGO you mean...

RG - POGO. The POGO level in the S-IC was an extremely low level POGO. Now there was a coupling up in the spacecraft with lateral G's, but the lateral G's that did develop were well below the structural limits. However, POGO was a strange thing. You never know when it is going to get worse. Its unlikely that it would have gotten rose, but we decided to fix it. Now there the solution was fairly straightforward. It was similar to that which had been used on the Titan--it is an accumulator fix. You simply tune out the resonance between the propulsion system and the engine and the structure in a pre-flight condition which....of course none of the POGO, by the way, on S-IC or S-II either, was ever detected on the ground or could be reproduced on the ground after we detected it in flight. You didn't know that? Well, the reason being is that when you fired the stage on the test stand the stage is more restrained and it has the entire vehicle freedom, you see. Its a free-flying article with the total vehicle hooked up and a free mode and all of its structural and aerodynamic thrust interractions giving it a certain resonance. So neither the S-IC nor the S-II POGO could be verified, except what we did. We verified that we changed the coupling frequency, of course, of the S-IC and the S-II. We knew what we changed. And of course you have to calculate what your POGO margins would be with that new propulsion fix against the known system characteristics--low frequency vibration characteristics in flight that you measured.

RB - Now I have two questions. One is, since POGO was a known phenomenon and was part of the problem, I think, earlier in Titan and Gemini, there must have been studies or why did the studies ____.
How was the POGO missed on AS-501?

RG - On the S-IC?

RB - Yeah.

RG - How was it missed?

RB - Was there any POGO on the S-IC?

RG - I believe if there was it was such a low level that it was not considered a concern. I think we had a structural reaction on 501.

RB - So, can you say that at some times there is just that much differentiation from one burn to the next one?

RG - Yes, definitely. In fact, the same on S-II. We had violent POGO on I-SII and we had zero on others, within the noise level you might say of the system.

RB - And in spite of the fact that Gemini triggered the preliminary test, it didn't indicate you would have a POGO problem?

RG - That's right. In fact, we had a POGO team consisting of Titan people--in fact all of the best people in the country who went over the entire vehicle. But, in all honesty, the entire structural dynamics of the Saturn V was still under study at the time we were flying the first Saturn __________. And indeed, I wouldn't expect you to complete your knowledge of such a system until you had flown it a couple of three time and saw the variations because each flight is different. You fly under different trajectories, you fly different ___Q___ levels, different G levels, propellant loads are different, and ______________________________ because of the nature of the mission. So it takes you a little while to complete your homework and get enough data to fully understand the systems, and understand the variations that normally happen in that system as it flies from mission to mission.

RG - So as we went back, of course, we saw some evidence in the earlier flights after we had seen ______________________ in a later flight like the 503 we saw the S-IC coupling. We could dig back into 501 too, I'm sorry, in 502 we saw. We dug back into 501 and saw a very, very low level POGO but it would never have concerned us if we had not developed the structural resonance in 502. The level of the POGO was a very low level. So it was a total vehicle problem and the solution was simply to remove all signs of any low level pulse frequency in the S-ICV ________________ it in the accumulators. And I do believe they may have done something in the spacecraft to remove that extreme sensitivity to the lateral frequencies. I'm not sure about that.

RB - There is something else you mentioned I really don't remember getting into. Do I understand you correctly to say there was also a POGO situation in the S-II stage?

RG - A completely different type, though. In fact some people wouldn't call it a POGO.

RB - O.K., maybe that's why I've missed it. Can you explain that a little bit for me?

RG - Yes. In my judgment it was the single most serious problem we encountered in flight in the entire Saturn V history. It came the closest to a disaster.

RB - Which flight was this?

RG - About 506, I believe, something like that. It was not 506. It happened on-- I can't be sure. I'll have to look it up. It has been so long. In any event, let me tell you the problem. The POGO resonance, and of course any propulsion system has some low level resonance which changes during its entire burn time. It has an exciting frequency, in other words, many exciting at very low levels. In the S-II there is no overall structural resonance between the launch vehicle spacecraft or anything else. It was a localized problem. The center engine sat on a crossbeam. Now this particular POGO happened when that crossbeam deflection developed at around ______________________ against the center engine resonance, in other words _________ engine started oscillating up and down working together in a local POGO resonance you might call it. That occurred rather late in flight. On most flights we saw just enough evidence to want to do something about it. While working on an accumulator fix we saw it on an earlier flight. We couldn't calculate the probability. We had to more or less base our decision to fly the flight where it occurred--again I would have to look back to be sure exactly which one it was on. It was on one of those where I was in charge at the Cape at that time as Saturn program manager. I remember it very well. We had a fix develop which is an accumulator fix just like we'd used on the S-IC. However, we had not had sufficient testing of that to prove it wouldn't make the problem worse. You see, we had to test it propulsion-wise at MTF Testing and we didn't have sufficient data to run through our calculations and confirm that that fix was really in the right direction.

RG - So when we flew that mission and had the failure it was a failure that resulted in the engine shutting down just before the engine would have broken the structure. The shutdown occurred because the pressure variations in the thrust chamber were sufficiently high that the Pressure OK switch--in other words, when the pressure in the engine thrust chamber goes to a certain level it automatically shuts down--an engine shutdown safety sequence that goes into effect. The engine propulsion or pressure chamber pressure reached a sufficiently low level during its 18 ____________ variations that it shut itself down before the center beam's oscillations reached the point that they would have failed the beam and turned an engine loose.

RB - That would have wiped out a lot.

RG - That's why I said it was potentially the most serious problem we ever encountered. So then we simply put that fix on we'd been developing and testing. It made it quite clear there was no choice. We had to fix it. But I guess the science, you might say, of predicting such ~~propulsion~~ structural ~~interaction~~ propulsion interactions is probably one of the toughest things that ___________ liquid people ever faced. In fact, I'd say it was <u>the</u> toughest, because you've got to have a complete knowledge of how that entire vehicle structure acts in all of its modes in flight, and you have to have a complete knowledge of the propulsion system. And then you have to predict how they'll couple in all the many, many modes. And the computer models do that and it is just amazing.

RB - Well, now this POGO showed up towards the end of the flight because of the changes in the vehicle's resonancy because of ______________________?

RG - Right.

RB - It set up a different dynamic situation for the ___________vehicle.

RG - The S-II burned about 8 minutes and I guess this occurred _________about 6 minutes into flight or something.....

RB - That's ~~anotherxthingxaboutxthisxtoo~~ what's interesting about the S-II is the duration of that burn--its a long haul up there.

RG - Yes. The S-IVB is a long haul too. They are both on the order of 6 - 8 min. at least, but once you turn those things on they seem to go quite well.

RB - Somebody told me once...I was asking how long a rocket engine runs. And they said especially when you get into regenerative engines as long as they've got fuel they just keep going.

RG - In fact, after they're in a stable condition temperature-wise after only a few seconds and if nothing is deteriorating because of a leak, bearing problems, or anything of that nature it will run.....Now that is the hydrogen engines in particular. The _____, the F-1 engines and the H-1 did eventually tend to accumulate carbon and they ___________. They wouldn't run quite as long as favorable, but they would still run plenty long to carry out the mission.

RG - So those, I would say, were the toughest problems, the S-II center beam problem and the ASI on the launch vehicle side of things. Of course, we sweat many other things. We sweat _______________ mechanics. We sweat the...on the S-II tank. I don't know whether you ever heard of that one or not.

RB - I'm glad you brought that up because I... Let me backtrack. How long were you on the S-IVB and when did you get on the S-II.

RG - I was on the S-IVB from January '64 - December '67. And then I was the Project Manager of the S-II stage from December '67 - January '69.

RB - Were you the assistant.... (end of tape side 1)

RG - We had a crisis in the S-II.

RB - That's one of the things I want to talk about. But now if you came on the S-II in January of '67

RG - December of '67

RB - December of '67 some of the crisis had already occurred.

RG - The stage was well under way and we were trying to get the first structures developed. The big problems were in putting that structure together. In fact, the technical problem on the S-II was the very high mass fraction, light weight construction, the external insulation which used the cryogenic properties of aluminum.

RB - I don't know what you mean by mass fraction.

RG - Mass fraction is the ratio of the empty weight of the stage to its fully fueled weight. And that simply says how heavy is this stage as an __________ weight compared to its fully fueled weight.

RB - So when it was fully fueled it was almost heavier than it could ___________.....

RG - No, what mass fraction really means is a structural likeness efficiency ratio. If it was .9 that meant that only 1/10 of the total loaded weight was structure and the rest was propellant. The S-II was probably, and it was in the Saturn V, the most structure-efficient stage of all three. The S-IC was the heaviest, heavier piece. Of course first stages normally have to be. They have to hold down the base of the vehicle and all that. The second stage was the hydrogen stage here and a big stage and it needed ________________________________ in order to have a high performance for the total vehicle. The S-IVB was a very small stage and its mass fraction was not as good as the S-II. Normally a bigger stage will carry a little higher mass fraction or higher efficiency than a smaller one will--made the same way.

RB - Actually, in terms of introduction the S-IVB was an "older" technology than the S-II.

RG - Right, we used the S-IV technology on the S-IVB as far as the insulation, the common bulkhead, the tanks and the structure. Of course the engine was new.

RB - Well, how would you summarize then the problems of the S-II. Was it fraction?

RG - Yes, I think I could categorize the S-II problems as primarily structure because looking back, of course, you're always smarter, but we probably drove that thing too hard down the lighter structure road. In other words, we tried to reduce the weight too much. We reduced the safety factor from 1.4 down to 1.3. It was the only stage in the stack in which that was done. At the time these decisions were made we were very concerned about the total launch vehicle performance. The spacecraft was growing every day, or every month we would see the weight of the spacecraft go up and continued to have to make modifications there. We were afraid of not having enough performance to carry out the mission. So there was an early decision made to go in and take more weight out of the S-II in certain critical areas.

RB - Do you know about what time this decision would have occurred?

RG - Early in the development history of the S-II. I would say effort was under way a couple of years--something like that.

RB - O.K., the S-II contract was let in September of '61--we're talking about '63 period.

RG - Probably somewhere in that time frame. And all they did was simply reduce the skin thicknesses here and there. They didn't change the designs drastically. They changed some materials and milled out the skins a little thinner and generally just lightened it up. And then, of course, we had such a lightweight structure and it was further light. I believe there were two heavy stages. I'm just thinking now as we talk. Two heavy stages were already under way and it was too late to be effected by modifications. And the third one was a light weight stage.

RB - Was that the S-II-1 or the....

RG - S-II-3. I believe that was the first light weight stage or something like that, and then we had about three of those. And then after we had so many problems putting it together, getting good quality welds between the extremely thin skin and the big bulkheads, for example, holding those in alignment, keeping the stress down, getting adequate quality of the welds to take the stress in that very highly stressed structure. That's when I came ____________ in the middle of those very serious problems. The S-II was the furthest behind, development-wise, of all three. It paced the Saturn V schedule-wise.

RB - The date that I jotted down in terms of your earlier troubles was a little bit different than what you are talking about. In '64 in the S-II-S they had the failure of the aft bulkhead in the hydrostatic tests. And then Sept. '65 when the S-II-D ________ rupture failed on attempt ____________________. And then in '66 when the S-II-T went. But then those stages then, if I understand it, were actually using heavier gauge...

RG - Those were the heavier gauges and those problems were not related to the later problems that almost stalled the project out. The troubles that I'm talking about that paced us schedule-wise--well, there are many problems in a new stage, components, you know we had trouble with components, big hydrogen valves. Everything was a problem typically as in the first early years. But the thing that slowed down the schedule and put us into such a critical schedule pacing problem in the launch vehicle--we had to use a dummy piece to assemble the first flight vehicle ________ waiting for the S-II to come down and be exchanged.

RB - You took the S-II-T ~~ax~~ down there or something, didn't you.

RG - Yes, we took something down there to use as a spacer we called it. So the first flight stage was late because of the many problems. But again the most critical problem of all was simply learning how to tool up, weld, and prove that structure to our satisfaction.

RB - OK let me get some _____________ here and get on these light weight structures. You say the S-II-3 was the first lightweight structure.

RG - I'm guessing somewhere in that category. They were all built the same way. The only difference really was in the safety factor. The stages were almost identical.

RB - And about what time you say you finally went back to heavier gauge.

RG - Oh, after about 3 vehicles or so. We got into troubles with the vehicle. We saw how difficult it was to build it and maintain adequate structural assurance. And about that time a big question was also raised by a fracture mechanic specialist named Mr. Bill Brown, who was at Louis Research Laboratory. He was concerned about the fracture characteristics of the 24ST aluminum used to build the stage under cryogenic conditions. Now, that's another difference between the S-II and the S-IV-B. The S-II used external insulation which put the aluminum inside. Now aluminum is stronger at cryogenic temperatures than it is at room temperature and the S-II was designed to take its maximum pressures, you see, under the cryogenic conditions. Therefore it could be lighter and was lighter--one of the reasons it had better mass fraction than the S-IVB which had internal insulation and warmer skin. But a problem arose in that there was a technical challenge, if you had the tiniest little flaw or crack in any weld under cryogenic conditions it could be more sensitive to stress and cause a fracture to occur which would burst the entire structure.

RG - Now how do you prove that? Well, of course you hydrostatic test all the structure to a high stress to begin with, all the pieces, but that's at room temperature.

RB - That's not cryogenic.

RG - No, and his point was, and of course we disagreed, the Marshall people, we ran tests and so did North American. But how do you prove conclusively? Well, a tough decision was made. The only conclusive proof was to subject the stage at MTE to the same internal pressures and loads as you would incur during flight where you can cryogenically ___________it, you see. Now, normally when you fire this stage you don't take it up to the full pressure it ___________during flight, because during flight you have the gravity head, you might say, on the propellants acting on the tank too. Do you understand what I mean? So, not only tank pressure but the gravity head, so at MTF we had to run a special test, a proof test, under cryogenic conditions on each flight stage including the 501. I believe, if I remember, we had to hold 501 schedulewise to run that test. Or even had to ship it back, I believe.

RG - So there was a cycle there to meet that demanding requirement. It _____________ proved ____ ____ We had to cryogenic proof test the early flight stages. The decision was made by Gen. Phillips to do that, and we did do it. Each one was individually pumped up to full load, structural load, under the cryogenic condition on the ground and tested as a complete stage. So, again, that's an indication of the nature of the stage with regard to the structural integrity, the concern with stress level, the loads, etc. That's why I continue to tell you that the most demanding problems on the S-II were structural in nature.

RB - That answers one question I had, I guess, I had on the welding on the S-IC, although they had trouble, same diameter, but a "different breed of cat". And the other thing is, now, and I get confused on this. On the S-IC were they using _______ welding on that? Marshall had a favorite mode as I recall and they got into a hassle with ___________________....

RG - Marshall favored _________ I believe, for awhile and Douglas _______, but that was not a serious problem. After all, the S-IVB--the S-IV ~~xxx~~ welding was developed by Douglas and it was really a matter of tooling and inexperience and control of all the parameters. And there was a big debate about, "Would you be better off welding-quality-wise to convert over to what Marshall had had experience with on the 24SD or not. As I recall, they did not convert over, they stayed with what they had.

RB - 20-24?

RG - 20-24. 20-24 was used on both the S-IV and S-IVB--S-II and SIVB, I'm sorry, as well as the earlier S-IV.

RB - On the S-II that 20-24 was ~~xxxxxxxx~~ milled to finer thicknesses.

RG - It was a bigger diameter stage and, relatively speaking, yes, to finer thicknesses. Considering the fact that the diameter was bigger, of course it had to be bigger.

RB - What did they use on the S-IC?

RG - That was 60-61, I believe. It's the same we're using on the external tank in shuttle. It's fracture characteristics are more forgiving, much more forgiving, and it's easier to weld. That 20-24 is. It's harder to weld, but it has a higher strength.

RB - 20-24 does?

RG - Yes.

RB - So the problem I still don't...I want to make sure I get this correct here. The problem in welding on the S-II was the size...and although the size was the same as the S-IC the gauges __________ there. Quite a bit more distortion and everything else.

RG - Prone to distortion and also, well, as we said the material was harder to weld. And we had ____________________ on our welds because of the higher stresses. And we had the question of...

RB - common bulkhead

RG - There was a big concern about that. It turned out that so much attention was given to it that it was never much of a problem. It was one of those that responded to the concern. No problem occurred in the common bulkhead. It was a tricky thing to put together, but it worked quite well.

RB - Could you say there was a good deal of experience extrapolated out of the S-IV and S-IVB--program on that?

RG - Oh, yes, definitely. But the two were built differently. They had different insulation in between.

RB - I was going to ask, now given the fact that Douglas had been so successful with internal insulation, why did North American go to external--I guess you have already answered that. They get higher strength cryogenically by using external.

RG - That was one of the major reasons.

RB - And so why did Douglas go to internal then, maybe that's how I should ask the question?

RG - Well, Douglas, you know there were pros and cons. There was a list of 15 plus and minuses on that choice. Douglas maintained that the insulation is a fragile thing, which it is, and it's protected inside. However, that skin is exposed then. So the proponents of external insulation argued that the skin is protected. External insulation can be repaired externally ______________________ as it was many times on S-II. If you damage it internally.... of course you don't get inside the S-IVB very often. But if you did damage it you may not know it and it's a little more difficult to repair. I think the S-II insulation was lighter--certainly the spray foam insulation that was later used was lighter than the S-II--than the S-IVB, for example. S-IVB used balsa, you know for the early S-IV. Then they went to the polyurethane with a honeycomb core. And they retained some balsa in some parts, critical parts of the structure, there too, if I remember.

RB - I'm glad you mentioned that--up in the corners--is that where they had a lot of convex, concave, curved, etc., they used the balsa wood?

RG - Right.

RB - As I remember too, one of the early stories when they were going to try to find suitable ______________ for the internal insulation they were going to use balsa wood all over. And they made a study and came to the conclusion that the production of balsa wood wasn't sufficient. Is that right?

RG - Yes, there was some concern expressed.

RB - For some reason, I have always found that amusing....

RG - Certainly if the S-II had gone that way.....

RB - Because they were talking about a lot of stages at that time.

RG - ~~Pretty~~ Very high-grade balsa, too.

RB - Not just run down to the model shop and get some balsa wood.

RG - It was very specially selected. In their time both systems worked quite well. The S-II was more of a long range problem. It started out with a layer-type insulation and ________________, external ___________.

RB - Could you go into detail on the S-II insulation because that's a problem I have never been able to...

RG - I was not in the S-II at the time the decision was made to select the layer-type insulation. It was layer insulation that was purged by helium, O.K.? And it worked beautifully except you always had a concern about leaking, helium leaking out and air leaking in while pumping. In other words, cryogenics. The skin was cold and had a barrier out here with a very light density strip in between purged with helium. And as long as no air could get in and get moisture started and build up an ice dam you would be fine. But the vulnerability of that insulation system was of the cryo pumping. We had one whale of a problem getting those first stages, I believe there were three or four, like in the S-II, like in the heavier-lighter structures that were built with the first type of insulation, layered insulation helium purged. And then North American was running studies and they found an externally applied foam-- Nopco was the name of the foam, which would withstand the cryogenic temperatures. The bond would be adequate and would withstand the external stresses during flight--the higher temperatures during flight.

RB - So this helium purge thing meant you had to have a constant...

RG - Continuously ..... well you put a bunch of two's....The material was put together in layers and had cross members like polyurethane, like a honeycomb, and then an external shell--again of polyurethane or fiberglass you might say. And then you purge longitudinally all the way up and down..

RB - the honeycomb

RG - with helium. In other words, you put helium in the bottom and it came out the top. And you had to maintain a positive internal pressure. And you monitored the pressure at the bottom and at the top to be sure that you didn't have a leak sufficiently great to allow air to find itself way in and start cryo pumping.

RB - That sounds like a plumber's nightmare.

RG - That was indeed a plumber's nighmare and that's why the decision was made to go the...one of the driving forces in going to the foam type, which was a dense--well, I mean it was a uniform, continuous structure of foam. It had its problems too, of course.

RB - When they started out they figured that the technology for the solid "foam" wasn't dense enough that they could use it.

RG - Right. It had not been developed to that stage yet. They did fly with a phenolic material. ______________________ , if you could have talked to him was in the middle of that decision.

RB - I'm trying to get ahold of him yet while I'm down here.

RG - He was in the middle of that particular decision. He gave you all the pros and cons.

RB - They sprayed the phenolic foam on. They actually had phenolic cutters then. They went around and...

RG - You're talking now of this spray foam. You spray the foam on and it rises to so thick and then you use phenolic cutters to trim it to an even 1 inch, 1½ inch thickness. And then you put a bonding seal coat on the outside.

RB - And the problem I would guess was getting that initial bonding between the skin surface and where the phenolic....

RG - You had to have a good bond and there could be no little voids because, again, the problem would occur and it would pop off little pieces. Now it turned out that you could stand some small voids. Let's say a little plug would pop out of the foam. And it didn't hurt anything. You didn't lose enough insulation to cause boil-off of hydrogen. As long as the foam adhered all around it and would not fall off during flight until you got high enough so you got out of the atmosphere. So it had to maintain its integrity. It could have a few little divots that would pop out, and they did do that each time you tanked______. So the problem with that stuff was looking at it to be sure all physically intact and no big pieces fell off. And after you de-tanked, then you lost some pieces and had to go up and repair it ready for the ______ flight. So at the test site and at the launch site after it was ________________....

RB - or even the ________________ you'd have to do that too wouldn't you?

RG - Oh, yes, at the test site you'd have to do that. You had to repair it and eventually, as we learned more about it and fixed some of the minor problems, the repairs were down to a level that they were far less of a problem than in the earlier helium-purged installations. We were happy with it after it was developed and we got the bugs out. of S-II But insulation, and I call that a part of the general structure,/was a continuous problem until down around 506 or 8, something like that. Then it began to be something we could live with.

RB - OK, I'm glad to hear that explanation because the insulation problem has always bothered me. I could never exactly figure out how that worked.

RG - Both of those, of course, were really new developments. Both types of insulation on a stage of that size had never been ______________________.

RB - I have some other questions maybe you can help with too? One of them actually goes back before you came on board of the S-II--Program or Project Manager?

RG - Project. A stage of the project and the Saturn vehicle was the Program.

RB - Why does the Government go out and build all those facilities at Seal Beach?

RG - Well, it was the same reason theybuilt all the facilities throughout the rest of the U.S. It was the Government policy at that time to erect the major ____________ facilities or peculair only to the Saturn V stages, the big assembly pieces in other words on Government property and built by the Government. And you say, "Why would they do a thing like that?" First of all, to my knowledge only one contractor elected to provide the facilities. That was Douglas and they had done it as an offshoot of the Thor development and they already had the facilities, simply modified them up at Sacramento. So nobody would bid to do that because the investment was rather enormous for the large aseembly and test facilities, you might say. Now there is another reason. And I'm not an expert here. You might want to talk to Bob Wessells or somebody who is in the facility business to understand all the policy reasons. But I'll give you one which is very striking which I encountered in my tour in the shuttle. If the Government owns the major construction and assembly and test facilities as well as launch facilities, of course, a contractor who doesn't perform over a long period of time can be replaced. You simply say, "This is a Government facility. We are now opening bids on the production of this stage." You cannot do that on a contractor facility. You do not have the option. In the unlikely event that a contractor's performance would be that poor, if the Government really wanted to reopen and get a better contractor or a lower price--of course we always had concern about...You know, Saturn was supposed to be flown 24 per year, I believe. You have run into that before?

RB - Yes, there was a very high launch rate.

RG - Well, that's why the facilities were so large, of course, or envisioned to be so large. Some of them were never completely developed, naturally.

RB - And the reason for all that land down at MTF

RG - MTF and the Cape, the VAB, everything was headed towards the, I guess, 12 per year was required production launch rate that we had during Apollo. The production flight was on into several years--was envisioned was a high possibility. Therefore, the desirability of the Government owning the major facilities was very clear.

RB - But Douglas went in and that new facility that was put up at Seal Beach--that was their money.

RG - Yes, that new facility, by the way had--it was Huntington Beach. Let me tell you about that. There was only one facility in that entire area which was really peculiar, I would say--a production ____________. Any other facility they built could be used for a variety of things. You see, S-IVB wasn't really that big of a stage, not much bigger than some of the spacecraft of today, in fact, I guess ______________ would go in there. They were working on that eventually. The Government did build the two firing stands at Sacramento, although on S-IV, I believe Douglas used Douglas facilities for testing. They adapted the S-IV facilities, I believe. But the S-IVB, for sure, I recall the Government built all on a little piece of Government land _________________________ But all that stuff at Huntington Beach, the laboratories, the assembly shop could be used for other things. One assembly tower which the Government did finance as a major tooling item in that one contractor _______________________________. That was all.

RB - Getting back to the Seal Beach facilities at North American, was that built on part of the Navy's dock?

RG - Yes, the Seal Beach assembly area was on the Seal Beach Naval property. Now across the street from that North American had its own facilities where it housed its engineering force. It had a division there. They built their own facilities and they remained there after we shut down the S-II.

RB - OK, I'm really glad to find that out because it was one of those questions that just bothered me.

RG - And I have not given you a complete answer, mind you, I'm just telling you that there were a couple of major....

(Beginning of Tape #2, Side 1)

RB - Is there any use that the Government plans to make of the Seal Beach facilities, those production facilities, that you know of?

RG - I don't have that much knowledge. I know there was quite a bit of activity to convert over. I was on the shuttle at the time that final decision was made to turn that back, to open that back up to bids to dispose of the ___________________ and I know it was the shuttle, for example, that went in and picked up quite a few of the items, autoclaves, a lot of the equipment that was recently used. The land would revert back, the ____________________ will be salvaged, generally all the equipment will be salvaged. So it's my understanding, I guess you would have to check with somebody who was in closing down the period of the Saturn to find out about that--what the intentions________________

RB - Now could you tell me a little bit about _________ forming of the gore segments? Apparently they started doing that and then decided--no they kep doing that. That was one of the things they kept doing.

RG - That was in the early development days. No one knew the best way to form a large bulkhead--either explosive forming or ______________________________________. There were about three or four different ways of forming bulkhead ___________________________.

RB - Did Boeing use that for the FIC? I should have asked Matt Erlock that? I'll have to call him back.

RG - I don't believe any contractor wound up explosive forming. I believe they were all bulge formed, if I remember correctly.

RB - You did a lot of experimenting with __________________

RG - Oh, yes, yes.

RB - But you're not sure if they actually used those in production ______________

RG - No, I'm not. I'm not sure either way. I just can't remember well enough to give you.......

RB - ____
Well, that brings us to another question I had and that is......

RG - _________________ may remember. You might try that on him.

RB - Another question related to that was after they formed the, well it was actually the production core segments themselves, sometimes they apparently explosive formed them and then they ____________ milled them.

RG - Oh, yes.

RB - And then they, and I'm not sure about this but I'm trying to find out, apparently they decided that wasn't going to do and so they machine milled them in the flat and then they ______________ and formed them.

RG - Yes, they did it both ways. I think that was a matter of almost individual choice, either ____________ mill after or before. Again, my memory is not good enough.

RB - Well, on the S-IVB, as I recall, they really, they milled them in the flat and then formed them. I think that's right.

RG - I think that's right.

RB - I can check that. I've got some Douglas papers.....

RG - You can confirm how each one was done. And each one was done as a result of long experiment ____
Each one used different tooling. Some people used a sub-contractor or another element of the country _________ inter department. The North American people used Long Beach. Douglas has a another group that did their bulge forming for all projects .....

RB - up in Santa Monica. O.K., here is something you can help me out with. What is the significance of the dual plane separation treatment from the ST?

Interview with Roy Godfrey:

RG - O.K., we'll keep it fairly simple. And again I would suggest that you check it again with Willie ____________. Willie was in the middle of that. But the basic reason for the dual plane separation was the concern for clearance of the S-II engines. Let's look at the alternatives. If the innerstage were left attached to the first stage of the S-IC the S-II would have to fly out, you might say, coast out.

hole?

RB - Was that called "fire in the hold?"

RG - That was called "fire in the hold", or you could use ullage motors and fire after it was out of the hold, but then you've got an attitude control problem.

RB - ____

RG - Well ____ was just one way to get out. _______________________________________ and coast out or you can fire in the hold. Either way you come out of the hold with engines and you know the S-II engines are spread out. And so you've got that lateral clearance concern. And the problem with the S-II is that it separated while there was a positive atmospheric pressure Q-level, Q-pressure we called it, that was sufficiently high to give you that ________________ disturbance during separation. Now all these are calculations, of course, many calculations of different disturbance factors, tipping of the S-IC because you just shut it down, and how many propellants are going to boil out of the chambers, you know, and will it continue to cough and puff. And will it kick, and as the S-II starts up, you know, will you have a disturbance factor because of one of the ullage motors not firing, or what. These many concerns lead to the desire to separate with the skirt down at the S-IC and leave it intact with the S-II and fly for awhile with it until you got out of the Q, out of the atmosphere, out of the _______________________ pressure, and then kick it off.

RG - So that's the basic reason for carrying it with you. And, of course, you have a performance degradation if you carried it all the way. And you also have a temperature problem because if you radiate to it and back in _________________________________

RB - But you still have to get rid of it. And even so, I don't remember the dimensions, but the fairly narrow clearance _______________________ you can get rid of the rest of that skirt ______________________.

RG - Right, there was a sweaty thing there we had to worry about a little bit. We photographed it, of course, the separation ____

RB - I remember seeing photographs of that.

RG - Very dramatic, and you get to see the Earth...... and that completely clear hydrogen_________________. You don't see the hydrogen _______________. YOu see through it. You probably didn't think about it. You're looking at the Earth, you see no disturbance no heat waves or anything ....

RB - That thing that falls away that looks as though chunks of ice are falling around it too. That's a beautiful, dramatic shot, very, very effective

RG - Its a favorite shot for people to use

RB - Oh God, yes, I've shown lots of Apollo, Saturn films. I teach a course in the history of technology ____

RG - Did you see the films of the separation of the S-IVB pulling away with the engine ________.

RB - No.

RG - The cameras in front of the S-II and they look on the S-IVB and it ________ away, beautiful and ________ and there is the chill-down, you know you see the puff com- out of the engine and then you see a light. You look right ________________________

RB - OK, that raises another question, how in the dickens does the S-IVB separate?

RG - It's out of the atmosphere. The skirt stays attached to the S-II, the separ- ation plane, it flies out of the hose. You've got center engines. In fact the skirt has to taper inward to reach it, and you've got an enormous area down there to fly out of. So there is no concern there for, at least the concern was certainly not sufficient there to warrant ________.

RB - And also on the separation plane for the S-IC and the S-II I was wondering how much that top bulkhead of the S-IC comes up there and creates additional bulge, if there is any more than the S-II bulge__________________. Maybe not, those were both semi- electrical bulkheads. _________________

RG - Yes, I've been ____

____

RB - Well, anyway that should help ____

____

RG - It's complex. You wouldn't do it unless you felt you had to. And there were arguments that you didn't have to, that it wouldn't collide, naturally. There are always differing views on all these technical issues. Some of them are hard to call. It depends on your assumptions, how much of a safety factor do you allow for this factor. What are the maximum windshears that you expect to encounter in any one flight? That would contribute toward tipoff. There must be a dozen things that you have to treat or sometimes 15 or 20 major factors to treat, and the assumptions you make ~~make~~ on each one tend to add up to an answer. And of course people make different assumptions and get different answers. So, second plane seaparation was one of the chewed-upon technical issues during the Saturn ______________ . And it was one of the major technical decisions that was well known.

RB - One of the other questions I had was "old" and "new" technology, because it did have so many problems. And I guess we have already kind of answered that. It wasn't that the S-II had all kindsof new technology ______________________________________

____

RG - Well, the new thing on the S-II, of course, was the extremely lightweight structure with an insulation, but it was a clustered hydrogen stage. That was new.

RB - What problems did that...Well, the SIV had had clustered ______pins on it.

RG - Yes, it had ___________ pins indeed.

RB - Six of them?

RG - I believe it was six of them. The RL RO-10 performed very dependably and without wide excursions from one flight to another. I'd say the J-2 was lead time between, even though we flew the J-2 first on the 201, 2 and 3 before we flew it on 501. Even though we had those earlier flights the first clustering of those 5 J-2s was somewhat of a problem. The battleship/did uncover a few cluster problems, temperature problems, high temperatures.. firings

RB - Would this be ____________ electrical harnesses and stuff that were down around the engines? Where was the temperature problem?

RG - I don't recall. I believe most of them, in fact I came on after the battleship firings were complete. This was the second ______________________________________ There weren't too many serious problems uncovered, they did not uncover, unfortunately, center beam resonance ....________________________________ because that was a structural problem as well as propulsion problem. I think the problems were that any of the propulsions, the stage devices, the valves were still being developed, were still being shaken down. They were somewhat larger than some we had used on the S-IVB. And

and we had a combination of many, many component and a few system problems. The job of firing the cluster stage, of getting everything all ready, five engines and the start pumps... Start boxes were very demanding. Do you know what a start box is?

RB - No, before you do that let me ask another question. One thing that has interested me about the program is that you start theoretically with test and hardware like in each one. What was the problem then with making a bigger engine out of an F-1? But you can't extrapolate from a known, from a used piece of hardware to a larger one without inducing other problems.

RG - Oh, yes.

RB - Because all of the geometric progression of flow rates of gas, of propellants, of whatever create new stresses and unknown problems. You end up having generalizations..

RG - That is certainly true. You usually can't scale up. You usually have to change the way the system operates in some critical fashion. Scaling usually introduces enough problems that you change the way the pumps operate. For example, H-1 and the F-1 were quite different in use in many respects.

RB - O.K., now what was a start box?

RG - Start boxes are the temperature pressure limits. In other words you have a box consisting of a lower and upper pressure range and temperature, lower and upper temperatures. The engine has two pump inlets which must be within certain conditions so that you guarantee the propellants are sufficient quality to give you a reliable start. Starting is always a sweat. When you've got five in a cluster, to get those propellants right you have to have well insulated suction lines between the tank and the engine. You can't have heat leaks. For example, the S-2 used a vacuum insulated suction line and heaven help you. They were in several pieces, you know, they were wrapped all around and you said a plumber's nightmare awhile ago--those were big suction lines, each vacuum insulated. Now the S-IVB only had two lines. You only had two to watch. It had ten. So there were just a multiplicity of things that you had to watch and get all sorted out right and get all the components working. We had some problems that would make your hair turn grey just building those S-II suction lines. The vacuum insulated lines were, again, lightweight, couldn't have vacuum leaks, again under cryogenic conditions.

RB - Did the successful construction of those things sometimes depend upon new advances in metallurgy?

RG - I'd say not so much metallurgy, but rather the tooling, manufacturing process quality control process, all end to end. You had to have an extremely high quality in everything. You take the skin thickness down to 13 thousandths in a stainless steel bellows in a suction line it has to be perfect. There can be no flaws, not even a flaw too small to be seen by the human eye, let alone, as you say, X-ray demanding. The demand on each weld, each inch of any weld was X-rayed and re-X-rayed again and again. Sometimes after operation different crews of experts would come in and think they would see something. Gee, did they or didn't they? Well, we'd have to play it safe. So under a stage like the S-II, where the tolerances are tight, stress levels are high, you just tighten yourself up where you worry more about less, therefore the perfection you have to achieve in manufacturing and quality control is just unheard of. And I'd say will never happen again. I think the technology the people now have learned--not to push themselves in any one area too far. I think that is one of the things you learned in the Saturn stack.

RG - We did push a little too hard in certain areas of the S-II and we paid for it by having to try awfully hard and watch yourself very carefully. Good grief, the thing performed beautifully. The Saturn V payload went what, 7,000 lbs., I've forgotten....... It started out at 95,000 and went up to 107 I believe as far as the total weight to the Moon, something on that order. So after we sorted it all out and found out what its capabilities and reserve were under operating conditions it did perform well, so it did pay off. We ~~didn't~~ wouldn't have been able to carry that Lunar Rover up there if we hadn't gone to the light weight construction of the S-II, for example. It saved several thousand pounds of payload. We were able to do more than we originally set out to do. Even though the spacecraft weight did grow we were able to accommodate it and give it a little margin to carry more experiments. So it pay off, and I'm sure, I know in shuttle, for example, that in these structural areas they will be a little more conservative, use a little higher margins so that they don't get themselves in the tight spots, particularly in the tanks.

RB - What about the management problems at North American, some of the stuff I've been reading there's a hell of a lot about management problems--O'Connor and Phillips, in particular ____

____
In December of '66, again just before you came on board the _______ program there. Yarkin was out there with Phillips

RG - He was the manager at the time Phillips ...

RB - But now I've forgotten, it was not until after you came on board then that North American really shuffled people out and put Greer in.

RG - No, Greer came in just prior to my coming on. He was assigned at that time. You see there, the fundamental management problem out there is that North American took on two very demanding jobs. I told you the S-II was demanding, naturally the spacecraft was equally demanding. So the total drain on their resources was far more than any other major contractor. I'm sure that that is true in Apollo. Each other contractor had one big piece, but not two big pieces. So they really ran lean on management capability to do the total job and were really desperately struggling to get the best people in and solve their problems and continue to upgrade themselves. And Bob Greer was certainly a very successful move on their part in terms of the kind of management it took to bring out the S-II.

RB - Why do you think Greer was so successful?

RG - As an individual, he was very successful in that he was a brilliant engineer and had enough management know-how to develop his team, pick the best people and get them in the right positions and proceed to get the job done. In other words, he had to have both a good over-all engineering, systems engineering knowledge, and he had to be knowledgeable of people and project management on that scale. He was. He had had prior experience. He was well educated in engineering fields. He just had the combination that it took to bring up into being. He had some good people working for him too, excellent people, engineering and lower level people.

RB - That reorganization ______________ was kind of strange because Greer came in and the man who ______________ Parker became his deputy. Did they have a good relationship?

RG - Yes, they did.

RB - How did that work? What was the balance there? Did they complement each other?

RG - They did, very well, because Greer at that time was totally immersed, I would say, in many, many technical management, engineering and manufacturing problems to get some of the stages developed and qualified and ready to fly. I'd say, without Bill Parker's assistance in terms of keeping the shop running, that is administrative and technical management back of Bob, Bob wouldn't have made it. He came into a project already deep in troubles, without much knowledge and he needed very much backup and support of Bill Parker. I would say that Bill did not have that combination, that exact combination of technical and people know-how that Bob Greer had as an individual. Bob had more horsepower and Bill had to support him with project knowledge. They knew what mistakes they had made. He knew what they could and couldn't do, but I don't believe he could have handled all the tough decisions with the same forcefulness and resources that Bob Greer finally brought to it as he got settled in his job. I'm just trying to give you my opinion of the two people.

RB - Would you say that Greer was stronger in the technical areas or in people areas?

RG - People areas and the project background knowledge in depth.

RB - As I recall, too, about that time they called it the Space & Information Systems

Division. And at about that time they took,theysplit the Information Systems out of it and made it Space Division, so it made it easier then for Greer to concentrate on one thing instead of having to worry about...

RG - Greer was totally dedicated in the S-II. They also had another guy in there if I can remember his name, Ralph Rue ____ who was, had a lot to do with the success of the project. All of the manufacturing problems________________________________ Without him I don't think they would have made it either. Our experts here, the experts in the various technical fields also worked independently with Ralph on many, many problems. We would find something stalled out down in the shop where they were having trouble. Ralph would get on it and help expedite. And he had company contacts all throughout the company, high and low and wide to help him trouble-shoot, you might say, key, problem areas....

RB - What about Arthur Rudolph's role? How did he cope with the S-II?

RG - Well, you see Arthur hadn't had the entire Saturn V to cope with. He knew that the S-II was a show stopper as far as he was concerned. He knows Sam Phillips and kept communications going. He sat in all the major reviews as well as the key center people ________________________________ the major technical decisions that had to be made. I'd say Arthur's handling of the thing was more helping the project manager work with all the tough exterior elements he had to work with to get the job done here at the center, at headquarters, at the Cape.

RB - That's kind of the feeling I had. He...

RG - The project manager had to solve his problems. I can assure you that that was the case because I worked for him on two different stages. And, of course, the communications were very intense between him and the project manager. He demanded to know all of the problems and all of the proposed solutions, and he had me cross check on his staff of experts to be sure they were good. And he would then present them to Sam Phillips in the major reviews and to other people to check and double check. So, he was a focal point for the entire Saturn and spent more than the S-II spare share of time on that problem.

RB - What about the Tiger Team? I'm not quite sure how the Tiger Team functioned.

RG - The S-II Tiger Team?

RB - They had some at MTF and they had some out at Seal Beach.

RG - The Seal Beach was the big operation. At that time the S-II was several months behind in pacing ____ as I said earlier the entire launch vehicle. So it was clear that the process of technical decision-making in some of these problem areas were, for example, a man out there on the West Coast, a contractor or Government man out at Seal Beach would see a problem developing in tooling. Now the process of coming back and talking to all the experts here and getting communication back to the company was pretty slow. And there were so many things going on that we simply could not afford to handle the total flow of communication to be sure we were doing the best we could with any one problem. To the Tiger Team consisted of picking a bunch of technical experts, very carefully, from here and sending them out with Sam Yarkin on the West Coast to live out there directly with the problems and have first hand, quick reaction capability, technical management-wise on the spot. That's when I was brought in to be the anchor-man here because we still had to keep all our support reacting to the people out there to be sure it would work. And also I had to work with Rudolph to keep him aware of what was going on on the West Coast.

RG - So we shifted the focus of the S-II management, technical and management, in every way to the Tiger Team for a period of two or three months until they began to get on their feet. Then, about that time Yarkin left the Government went with McDonnell-Douglas and the Tiger Team was gradually phased out. We always had more people there to continue to watch, but the numbers went down and we went back into the normal project.....

(end of Tape #2, Side 1)

RB - Now, how come Genglebach ? had a, what seems to me, a very unusual position at North American. He always showed up on the organization charts, whereas the other resident managers of the S-IV ____, the F-IC and the IU never showed up on the organization charts.

RG - Never showed up on the organization charts?

RB - No, but there was always a little gizmo out there with Genglebach name in it. Was there some reason for giving him such visibility even early in the program at North American?

RG - It was probably an administrative grade-level thing more than anything else. The relationship worked the same. There really was no difference.

RB - When the Tiger Teams went out there they were still working more or less under the project manager and not Genglebach .

RG - Right. But naturally with the project management now being moved out there, in effect, there was a new relationship. It was more of a parallel relationship with the ______________ rather than a series. If you have to act through the resident office to work a problem of course there is a man ____________ geographically separating. You have a communication line to the contractor through him. With the project manager out there, there was a direct communication. But the office continued to function and continued to do all the many things, the administrative functions without change. Pacing items, you might say, pacing technical management problems with the Tiger Team never worked. The rest of it ____

RB - O.K., looking at my list of questions here.

RG - The only one I've had to bomb out on, I guess, is that one that ________________ ________________________.

RB - Whatever happened to Harrison Storms? He was eased out. He was named one of the corporate vice presidents or something.

RG - I don't know where he is now.

RB - He was still with the company?

RG - Oh yes, still is__________ I'm not sure about that.

RB - Well, do you have any other anecdotes or comments you'd like to make for the historical record?

RG - No, I wanted to get the feeling across to you from my viewpoint about what the Douglas problems were in the three stages. The S-IC was a monster, 7½ million pounds of thrust. Its early development was joint in nature, I'm sure you've found out. We started the thing out parallel with Boeing ......

RB - One of the things that I have wanted to get with Erwell about.....

RG - Tremendous resources applied to it and no major problems occurred. Because of the performance and mass fraction characteristics of the S-IC we could afford to put more beef in it and did than we did in the S-II or the S-IVB.

RB - Is that the same as fractional mechanics?

RG - No, mass fraction is the ratio of the weight of the stage to the amount of repellant it carries, and therefore it's a function of how light is the structure, how beefy is it in relation to the job it has to do. S-IC was a high horsepower machine and handled tremendous thrust levels and loads, but it was designed to do the job. And it had, I would say, more adequate safety margins than some of the others. So it worked quite well. It was very successful and I'd say was the easiest of the three projects. The S-IVB was easy in that it leaned on the S-IV, but it had that nasty restart concern that I told you about and also had to function as a space vehicle in coast. It had to maintain attitude control ____________ and all that good stuff. So it had some new things to do. The S-II was probably the toughest problem ______________________________

____
Those were the three characteristics of the three stages. The IU I haven't talked about at all. I think you ought to talk to somebody who is familiar with it. It performed quite well, flawlessly in all of the problem areas where it was called on to do something. It came through every time. Now, I haven't mentioned the software. You know the launch vehicle had its own independent guidance and control. It put the spacecraft into its trans-lunar trajectory-- TLI -- using its own guidance. People argued that we could use the spacecraft for guidance to do that to save all that IU, to have each stage __________ ____. And that's true, it could be done. However, Apollo typically had redundancy wherever we could afford it. You know, the stress in Apollo was to get to the Moon by the end of the decade. The name of the game was to foresee all possible problems, find a solution, and where you could not have a high confidence of a solution put in a redundancy.

RG - Therefore, we had redundance guidance between the launch vehicle _________________ ____ and the spacecraft. Now, on one occasion where I was at the Cape ____________________________________ we had lightning strike and it knocked the spacecraft out. It ____________________ off its computer off its circuit. They were dead. And we had one orbit to let them recover themselves and get reconfigured while we depended on the launch vehicle for guidance. The launch vehicle guidance was uninterrupted by the lightning strike. It went in the bottom of the S-IC. It hit the vehicle about 60 feet off the ground or so. It went in the bottom of the S-IC and out the top of the spacecraft. It went from the ground, through the vehicle, and out the top. It carried some tremendous loads through the entire structure. The launch vehicle was designed to withstand lightning or high energy fields. It was carefully grounded. We had specifications built in and safety features built into the system which let it withstand the loads. The spacecraft was not so fortunate, and I guess the place where the lightning lit was closer to some of its critical elements. Its guidance was knocked out, but not permanently, but they had to reconfigure and bring themselves back up to speed again. So on that particular case we saved that mission, by having the redundancy in the guidance between the launch vehicle and the spacecraft.

RG - On the contrary, the astronauts were trained to fly the launch vehicle if the launch vehicle guidance dropped out. They could take command. It was very tough for them to do and there were few places during the flight where if they lost the launch vehicle guidance they probably couln't have controlled it, but at least we had redundancy both ways. we weren't sure

RB - What kind of control would they have been able to take over ______________

RG - They would have been able to steer it. Using the spacecraft guidance they could tell whether they were on the right trajectory or they wouldn't have been able to steer it--literally steer it into the right yaw and pitch maneuvers, to control it, using the auto-pilot in the spacecraft and its computer. They tracked continuously, you see, to be sure everything was going. So you had just that one major example of redundancy that was built into the total system. Each stage, of course, had redundancy wherever it could. I say could because obviously... Well, the S-II had redundancy in engines. We could lose one engine and complete the mission and did do so. We lost two.... The S-IVB didn't have redundancy. If we lost that one engine we had it. But there were many components like vent valves and other things were, and certainly in the IU many places.... __________ these circuits were triple redundancy ______________________________. So you had to do over a triple redundancy wherever we could put it in logically. Where we couldn't, of course, we were very careful to qualify with high margins.

RG - The name of the game was to, was not the concern for the money to do the job, we had to be concerned with money and stay within our budget figures; otherwise we would go over on the entire program, which we __ but we did indeed have to have the assurance built into the entire _____________ launch vehicle that it would do the job and that it could fly to make it on schedule. And I'd say that operational mission, that 503 was the turning point. You knew of the problems we had on 502. Our conservative approach would have been to fly 503 unmanned rather than ____ but that would have put us out of the decade probably. So we did compress actual missions on top of early emerging flight development problems that occurred in flight. The ground test program was tremendous. We solved many hundreds or even thousands of problems in component system testing on the ground. Without a question. And only of those that, only a very, very few component problems occurred during flight that should have been found on the ground. Most of them occurred during that long sequence of testing and retesting. __________

RB - Something has occurred now that we talked about the S-IVB. What was the difference between the S-IVB to the Saturn V and the SIVB to the Saturn I-B--not a whole lot I would guess. Is that correct or...

RG - No, the stage propulsion-wise they were quite different in that the S-IVB Saturn V had the restart provisions, the IB did not. You had pressurization bottles that would re-pressurize the tanks, repress bottles they called them.

RB - Those were ________________ from the hydrogen tanks as I recall, right? The start tanks were helium for the first burn, something I recall

RG - Yes, you had helium, actually you had the pressurization tanks inside the helium tanks to keep them cold and get more efficiency for the first burn. But you had to re-pressurize the second burn. And that came from ambient bottles in the aft skirt. We had that big tapered aft skirt that fit the S-II, you know, ________ circle the bottles. By the way, one of those bottles blew to cause that stage blowup.

RB - That was on the ________________. And that was a problem the titanium, ________ ___________ a weld problem.

RG - The titanium restart bottles blew up. Tracing that one down ________________ was a problem too, what caused the failure, bang, the stage blew. Tracing it down, not only to a titanium bottle, but why it failed was a very interesting story.

RB - It was a weld problem, wasn't it?

RG - It was a weld problem because the welder ~~chose the welder chose~~ chose the wrong welding wire. The story about how this happened ____ ____ There are so many hundreds of valves and some steps that are taken in manufacture that have to be watched very carefully. This coil of wire looked identical, it was all certified. It looked right and had the right pedigree, but somewhere somebody had failed to take the proper steps and the wrong alloy had crept into the manufacturing of the welding wire.

RB - Good grief, so the guy actually picked up the right wire directly.

RG - As far as he knew it was right. It was identified and all, but someone back behind him in the burnishing of the wires was where the problem occurred. And the guy that tested the wire didn't find it. He should have taken a sample of the wire to confirm. Can you imagine the terrific job of testing all of the basic materials that go into the launch vehicle? It's a wonder it worked as well as it did.

RB - That was another thing that got me about the vendor quality-control program that McDonnell, for example, had. Another question I wanted to ask you was during the orbital phase of the Saturn V ____

____ then who makes the decision to go TLI. Is it the ground?

RG - Both have to, yes the ground makes the decision.

RB - Is it made here or down at the Cape?

RG - Oh, no, the command of the launch vehicle reverts to Houston right after liftoff. After it clears the tower then the decision to Go is by launch vehicle and spacecraft ____ And the launch vehicle was represented by the Mission Control Center here tied in with Houston. In other words, we have telemetry readouts of all the S-IVBs features as well as the people in Houston have monitors, but we monitor more in depth here. We look at every aspect of the S-IVB to be sure it was ready to restart, that all of its parameters were in Go condition. And the spacecraft, of course, did the same thing. They had to confirm that they were ready to go before the restart command was given.

RB - So that was really monitored in both places, but the final decision was made in Houston.

RG - At Houston, right. In other words, Mission Control for the total Apollo was concentrated at Houston but they took inputs from out there at the spacecraft site as well as here at the launch vehicle site before the burn ______________________________

____ And, of course, during the burn there was relatively little the ground could do to override. There was relatively little they could safely do, they could shut it down, and abort, or in some rare cases the astronauts, like I told you earlier, could possibly take over and try to guide the final phases of the flight. I've heard that they could not guide during the ______________ unless they were lucky. So, it was simply a matter of setting up the abort conditions, and if a problem began to develop that looked like you should call an abort then it would be called up by Houston and they would execute an abort. If the escape system was still on they could pull the crew off. If it was not on then the S-IVB would separate from the S-II and fly away. And if the S-II goes, S-IVB goes then of course that's it. They lost the escape tower, of course, they jettison that ______________________.

RG - So it was certainly an interesting big, big program, big management __________

______________________________ just I'd say...I would credit Sam Phillips as the individual who made itall happen. George __________ sorted it out and got it started right. But he was more of an introverted individual, brilliant, but I think Sam helped go out and get the people of the Cape, the launch site, the Marshall people, the Houston people and all the contractors on the same frequency. You know we had a lot of independents. The launch vehicle was relatively independent of the spacecraft and vice versa. Sam had to be sure that somebody made that whole thing fit together and get the proper overall analysis, and so did George.

RB - Did General Electric have an overall contract for the whole vehicle, or was it just for the propulsion stages?

RG - Boeing had a... Bell was the total/mission/guidance contract to Headquarters, looking over the whole thing. They were important in the early days to set up the mission profile ________________________. Later Boeing had a system contract that looked across the entire thing. Sam Phillips more or less ____ That was Headquarters oriented, pieces of it were to be sure it all played.

RB - Did that create some friction?

RG - Oh, yes, because each piece, like they had a piece at Marshall. We'd find the problem, we would go solve it, we'd report it, and then Boeing would look into it and say "I agree with this, not that." So, you know, when you've got to check and double check, naturally there's going to be some.....

RB - But it worked

RG - Yes, it worked. It was assurance, assurance, triple, double, triple assurance in both management and technical.

RB - I remember coming across some memorandum once when von Braun first heard about the

____

____

RG - Well, you see everybody wants his own integral control of his part of the problem. Ideally, you want nobody telling you what to do except one man. But that's the point I was trying to __________, The earmarks of Apollo were very, very high assurance that the job would be done as committed to by ____________ in every way that you could think of. And a lot of things that were done were controversial because someone believed that we should have that xxxxxxxxx additional assurance that everything would work. They did uncover enough usually to justify themselves. Sometimes no, but they usually did.

RB - Let me ask you another question about the gem boxes, which always seemed to me a very unusual managerial arrangement ______________________ the gem boxes, so called, the mirror image concept between Miller's office and Washington where you, in some respects, really jumped several layers of administration to get right down to the project manager's level between Miller's office directly and the project manager. You almost ____ bypassed the program manger. Did that really work out pretty well?

RG - That worked alright because those offices were not big enough or strong enough to short circuit...

RB - Primarily informational?

RG - It was informational. I think it was beneficial. Take for example, the guy that was in charge of the S-IVB, named Wendy Weathern ______________________ ______________ We kept him fully aware, he was the one who attended all the briefings, he was fully aware of all the problems. And what you hate to have happen, is a rumor of a problem which is just emerging. It hits Sam Phillips before it gets sorted out and we even know what we're talking about. The first thing you know here comes a big conference call. We hear you have a problem. Well, we've heard, too, but we haven't talked about it. But we just heard it last night ourselves. Well, tell me what you're going to do about it. This is disrupting, you see, problem is the same of the game in a thing like that. You've got to be sure that your management doesn't stall people out before they have enough answers themselves. You have to let them work at it a little bit. And therefore, I think the mirror boxes said, "Here is the status of that problem. There is a problem, they're working at it. I think they're working it alright."

RG - But if he says "I don't think they're giving it enough attention," then we might get a call and he would say, "Why aren't you giving this problem attention?"

RB - Miller should have called you up ____

____

RG - Yes, he saved a lot of disorientation in terms of jumping back and forth before

____

RB - That really put a heavy premium on making sure that the man in each box ____ Washington down here are completely candid with each other. You've got to be particularly candid ____________________

RG - If you're standoffish he'll be suspicious and as soon as he hears something then you'll get a call from somewhere else. And those things can be disrupting because management hears the same way. The center management wants to be informed. The contractor has to be informed. But pretty soon you're just spending your time telling people about what the problem is before you know what the hell it is yourself or what you're going to do about it. I'm talking as a project manager, of course.

RB - Did you ever have the feeling that North American tried to cover up a few things? Do you think they were completely candid with Marshall about the problems they were having?

RG - No, I think that was one of the misjudgments that occurred earlier. They felt that Marshall was too deep in the technical management issues and that they should be left alone to work the thing out. Marshall was very worried about the S-II. It knew from the very beginning where the risks were, the launch vehicle. Some of the people, I think, maybe Storms and Rees, for example, were at each other's throats. This feeling of get the hell out of my hair and let me work it, and one day I'll tell you what my problems are or I'll bring you a vehicle or something. And we were, of course, violently opposed to that. Naturally, all Apollo was because of the thing that I just discussed. So that did occur.

RG - I didn't intend to mention it to you, maybe this is privileged, if you'd like to consider it. It is sort of a personal relation that I developed with Bob Greer. Bob had picked up a little bit of that feeling in his previous orientations out there and still had it when I came on board the S-II. I had a little trouble convincing him that we had to keep the technical and management people back at Marshall on board early enough so that they could satisfy themselves in parallel with his people that a problem was being worked and solved properly.

RG - And when we did that and when Bob realized it and agreed with me to work that way we had a fine relationship. That's all it took. We had all the capability __________ ____________________ after he had done his necessary shaping up to make that team work, but we did not have adequate communications ____________________________________. And, of course, the Tiger Team tended to work against that. They tended to make decisions without having to worry about this. They were presumably represented by all the people, but not really. So, I think that one sorted itself out quite well. Now, the Douglas people, on the contrary, were different. They had grown up over this ____________________, you see in their relationships. They knew when they had to talk to each other and how well they had to talk. They always argued about it. Nevertheless, they had matured that much. And it had to happen in the early part of the S-II and that was one of the struggles that caused people problems and sparks to fly.

RG - Boeing, naturally grew up in ____ so that one built up in the right direction. And, of course, the same problem occurred with Douglas. They were very independent on the S-IV. Hell, they built the Thor in competition with us on the Jupiter and knew more about it than we did, and what the hell!

RG - But over a period of time the project managers get together and decide that both sides have to be satisfied. Ted Smith and I did this. He's a great guy. I really like him. We've had many fine years together.

RB - ____ Douglas talked to a lot of people ____

RG - Did you ever meet Hal _________ at North American, their chief engineer?

RB - John __________ interviewed Hal ___________ and I've got the interviews ______________________________

RG - Hal was their best man under Bob Greer.

RB - How would you summarize how the S-II got back on track again? You've talked about a lot of things. I wonder if you could kind of tie it up for me.

RG - I think I could summarize it by saying that the S-II team grew up and matured solving problems. After awhile the Marshall people got to working well with them and helping them rather than interrupting them, you might say at the wrong time. Some of that was bound to occur in the early days before we could get sorted out. And so there was a joint teamwork of technical and management relationships which were adequate to quickly react and wrap up those remaining problems and search out those that were still in the system, and solve. It was just a maturing of people and capabilities and the focusing so that they were ready to react quickly and methodically, and to find the right solution, give the consent of both parties, yes that's the right way to go. All bets placed and let's go solve the problem.

RG - In doing that with about 16 - 20 problems on the board at any one point in time is a pretty demanding thing. For a Government contractor team to successfully, to its own satisfaction, jointly, work that many major problems _____________________ ____ is a challenge, but it was done. I guess, in retrospect, the S-II people impressed me most because I think they had further to go and they had to try harder. And they kepttrying. They really came around and those guys were so on top of it. I thought it was the best team, probably. No, of course, the S-IVB gang was more mature at the top. But they didn't have to work so hard, and therefore down lower I felt they weren't as alert to problems and had to be watched more carefully by us and their own management.

(end of Tape 2, Side 2)

Interview with Roy Godfrey:

RB - One of the things that's always intrigued me about this is that you hear so much said about the Government's industry team, and I'm beginning to see more and more I'm going to have to say something fairly strong about it, I think, in the history. And I always took it as a phrase, but it really does seem to be a very different and unique relationship. And to your knowledge, does anything like it exist anywhere else in Government?

RG - No, not to my knowledge.

RB - Is this one of the unique things about the Nasa style?

RG - I believe so. There may be some examples elsewhere in Government industry where no developments are emerging, but I imagine they are on a smaller scale. It's easier to do that on a smaller scale, project you might say--15 Government people and a hundred contract people. It probably happens more often there. But in our case, many of the problems--you couldn't predict where the solution would come from. As I told you, on the ASI I couldn't quite recall who first had the idea. We divided the problem up and worked it in parallel. And you couldn't tell where the breakthrough would occur and you wouldn't care where it occurred. You just wanted it to happen as quickly as possible so you could make that next mission.

RG - And so we exercised to the utmost all of the facilities here and at every contractor's place and all the engineering teams here and at every contractor's place.

RB - It really got to be an unselfish and selfless kind of...

RG - Not completely, naturally. There were people involved and feelings involved. But I would say that everybody was fully turned on, without any question. Now, we may have argued results. Naturally, when you're emerging and problems being worked out, and its got branches and you don't know which one to take you'll fuss and argue about it among engineers. But it didn't take too long to trace it down. So that if a guy said this is the right way to go, we'd say, you work it if you've got the capabilities and somebody else will work that one. And pretty soon we'd get to the end of the string and find out which way was right and we'd go ahead then.

RG - But I'd say that in that particular case the teamwork was using the full resources both the contractor and the Government had. And another thing that's unique is that it's pretty rare that you have the resources as strong on the Government side that you can actually work in parallel and, in some cases, even ahead of the contractor. That's pretty rare. And I'm sure the same thing happened in Houston to a certain degree. You know, they had Mission Control soft ware capabilities out there that were in advance of what the contractors were doing in terms of software, programming and a few things that were unique, where they would work either in parallel or ahead or joints or behind or whatever you want to call it. But I think a lot of that occurred in Apollo. I would say if

RG - Apollo had an earmark at all it was that fine functioning of both sides of the whole team, mutual coupling and working of problems that we never saw before to that degree or that scale. But I guess it was necessary to get the job done. That's tough to make happen though, management-wise.

RB - Is that still going on in the shuttle program? /RG - I think some of the Apollo has spilled over on it, but it will probably never happen in the same magnitude because the schedule is not that demanding. The schedule is being stretched by funding problems. Gee, you know, if the contractor can sort it out, and you can concur without doing it in parallel, double or triple, working the problem three times at once it's simpler and cheaper. The resources that we have on shuttle are so far less by a third or so to do the same kind of job. There isn't enough resources, I mean people and facilities and duplication to work it like we did. So there has to be less by the nature of the two programs.

RB - Do you feel that there might be a slight problem compromising maybe the workability of the shuttle compared to the input that Marshall was able to make earlier on Saturn, for example?

RG - Compromising capabilities?

RB - Yes

RG - In what respect?

RB - Safety or reliability. When you look back you had all these labs and everything else ready to ________________ the contractor and say, "Hey you're off on the wrong...

RG - Well, let me tell you what Marshall is doing in shuttle. Have you talked to any shuttle people here? Well, I'm an ex-shuttle guy so I'll tell you about that. It's not that bad. What Marshall is doing on the shuttle it did on the Apollo is developing the engine, the restartable engine for the shuttle. Rocketdyne, the same people here know Rocketdyne, they were using Rocketdyne _______________ facilities that they were familiar with. We're doing no testing here, but we're testing down in TF and we have some people down there who've been there before. In fact, Jerry Wilson, who was in charge of S-II testing, is in charge of the shuttle testing, the cluster firing of the shuttle __________.

RG - So we have some people carryover. We know engines, engine development. We did it in Apollo and therefore that experience is carrying over. We won't fire shuttle engines here like we did Apollo engines. And that's the difference, you see. We've got less backup and parallels, but we've still got some carryover in doing the same kind of a job. Now in the tank, Martin got a different contractr. Martin's building the tank. We're building it out of that S-IC type of material which is easy to weld. And we're using the shoe where we have already established ourselves with tooling and all that.

RB - Is that where... these are the solid...

RG - Now, that's the tank, the external tank. So we have people who know who are using the S-II external type of insulation. We know the problems. Martin is learning them fast. We're using the external tank manager, Jim Odum, who was an S-II man. He was my chief engineer at S-II. So, we've got carryover in tank and engine. And in the booster, we brought in Bill Rice, an air force Colonel who managed the solid motor part of the thing. We're using our own booster people back here to put the booster elements into the solids, recovery, the actuators, the structural elements to tie the vehicle down to the ground.

RG - So we're using S-IC booster type experience and some recovery type experience on the boosters. And we do have quite a number of people who have had experience in solid motors too. So, I'd say that the thing we're doing which is the least carryover is probably in the solid motors, but they're well within the state of the art. They are a scaled-up 156 type. They are 120 scaled up to the right size. And, of course, they are somewhat smaller than has been fired before and are using the Titan propellant, nozzle construction. Type of nozzles have been fired before. So. the technology demands, we're staying well within, below the state of the art. So, I think shuttle, in some respects, while it doesn't have the parallel capabilities here and there, like we had in some respects, we sure have a lot of experience to pour into it. And we're trying to take more conservative, lower cost, lower risk approach wherever at all possible. The engines are one area where it is not possible. It's a stage combustion, I'm sure you've talked to some engine people haven't you? Well, we don't have to talk about the shuttle, but that's the only thing that's really new to us, the stage combustion, high pressure engine ____________________________. So I won't get into that, but I'm saying to you

Bostwick.
RB - I talked to XXXXXXX Bosworth, I think it was Bosworth ________________________

RG - So I think, although we can afford less muscle on shuttle to solve each problem we have very expereinced people into it. And if we have to, and it comes to a show stopper and it becomes cheaper to fix it with a double approach we could proba bly crank back up and do some of that on call basis, not a pre-organized basis like Apollo was. There we tried to foresee every problem and had two teams ready for every one or two solutions. So that was the name of the game. Make the thing happen.

RB - Well, it's interesting, if I read you correctly then, Apollo really was different in a lot of ways. You were on the cutting edge of space technology. And a lot of those problems, at least ____________________, have been taken care of.

RG - Well, it was just a tremendous engineering.. Hell, we didn't invent anything new, you know really when you get right down to it in Apollo except to make a great big complex machine work very early in its development cycle with a high confidence level. And, can you imagine, each one, even though we had failures, and things that make your hair turn white, each mission succeeded. That to me is really remarkable. It shows what can be done if you're determined enough and you put enough horsepower on it to get the job done. But I guess the country will never be able to afford that again, although I suspect in the AEC business and a few other things they had similar massive efforts to get breakthroughs on call, you might say.

RB - So, it seems to me one of the big forcing functions of the Apollo-Saturn program was the race with the Russians. I find a certain irony, not negative irony, but just kind of an irony ______________________________ Saturn IB, which is very close to the Saturn I ______________________________

RG - And we flew our last Saturn V, at least the first two stages, to put ______________________________ Well, I don't believe I can tell you much more. I've tried to give you my viewpoint and my comments about a few people I would rather not...They were obviously personal opinions, but, I think, since we had a brief discussion I won't feel bad about talking about it.

RB - Well all these things help. They help give a feel for the thing that it's hard to pick up a document and read a report. There have to be personalities behind these things. It helps to get a better feel for it ______________________________.
Well, I sure thank you.

(End of Tape 3, Side 1)