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Ehricke, March 11, Seal Beach

So much has happen^{ed} and a so many ^{CROSS-CURRENTS} but, Let me ask you this
Is there ^{anyway} anybody to review this? ^{In other words} You know as we go on in questions and ~~and~~
answers two things can happen. One can be just a misplacement in time ^{or} ~~of~~ in
connection that one might want to correct me on. What the memory stood by the
question one think. The other ^{is} ~~is~~ ^{one} simple forgot something and say O, god
I should have mentioned that. [Well you could get a hold of me through Ralph.
He'll know where I am. I'm at the University of Ala.ⁱⁿ Huntsville. O.K. Dates
aren't very important and when I teach I do a lot of teaching and when I teach
students I'm not interested in the dates that things happen. I'm interested in
some kind of order. Because its a sequence of events. But I don't care
w^hether they say it was 61 or 64. Because I'm figuring that out in overall ^h ~~h~~ [^] chronology.
So I'm more interested in your impressions and interpretations and I'm interested
in you opening things to me. Which I can then go to the documentation and
check. ^{As} ~~cause~~ you know Marshall saved enough stuff to sink this building into
the sand so far as documentation is concerned.] I can't imagine, ^{must be} unbelievable. I
^{can't} ~~can~~ read all that. So I've got to start at the top with. ^{ever} ~~Can~~ anybody ~~read~~ ^{read} all
that? Will ever anybody? I can't imagine unbelievable. It's one of the paradoxes
in 20th century history. There's so its and embarrassment of ^{riches?} ~~riches~~ you
have so much to do. How do you select what you're ^{going} ~~going~~ to look at? And to
this it won't be typed out and used verbatim at all. But the material if you are
quoted at all you will have a chance to see it later. Our PR people will me or
somebody will get a chance to read the whole thing and comment on it and we'll
send copies to everybody that is involved in it. So you will have a chance to...

O.K. So feel a little free now any time you want I'll turn it off. O.K. Fine.

So give a little more freedom there. O. K. Well, do you have any particular question? Work in the square. Oh. you got to use an hour you an hour you just

sit and look at it. Well, let me say that I personally have always taken the

proudest possible approach to space flight. Space flight has always been two things to me; large vehicle and spacecraft. They really have never completely

separated ^{them} and it has always meant to me exploration and application. I never

separated these two things. My first book back in 59 I made that point very

strongly, and I pleaded for more emphasis on practical applications along with

the exploration or ^{one day} we'll be stopped in the exploration unfortunately some of this

has happened now. We're turning around but it is so some of my thoughts will

be dictated a little bit by the kind of frame of reference. In other works I

always have tried to think in very large indicative blocks rather than individual

^{things;} ~~things~~ so when you see the trend I just want point that out. Now, as you know

really we got our feet wet for the first time in modern history with a real cross-

eyed space [?]craft. If you prec[?]isively speaking in the sense that it had the kind

of reliability that you need ^{it} for repeated launchings rather than the earlier test,

however ingenious they were they had at best a 50-50 chance. This one for the

first time was one which in a very rapid sequence was supposed to become a

system that at any time could be launched ^{by a company} but not excessively trained ^{crew} ~~people~~

by people All human beings are not Nobel prize winners.

or special inventors. Number one number two for the first time an extensive

amount of automatic of kinds of control equipment was involved which was one

almost completely absent in the earlier things

00 anything like that

which was almost completely absent in all the earlier things. The earlier things
 were essentially flying propulsion systems. That was about it. By and large
 which may be a little bit of a generalization they had very premative direction
 devices, but for the first this ^{one} had a full [?] flesh kind of automatic guidance control
 system even though part of it was on the ground, but it was accurately corrected.
 It's designed very interestingly enough the early design of the E-2 attempted
 light weight design. But it was always a self-supporting structure. I do remember
 that in early 42 when we fueled one we two as you know it had ^{V-2} fends. There is
 one of them, the ^{fins} fends were backwards. Actually, so that looked awfully
 dangerous ^{in those days} especially we really not a very good idea how far we could go. You
 know but today we do things we would not have dared to do 30 years ago, 40
 years ago. And so the statue was a little bit reinforced. And fundamentally
 the ^{V-2} E-2 emerged as lightweight by the then existing standards. As a very massive
 eagle by some of todays standards ~~standards~~ not all. Now this line of safe
 design, safe and relatively massive design, is perhaps the ^{principal} ~~principle~~ trademark
 of the quote, unquote "the German team," I'm an exception because I did not
 do that on center. That had certain _____ and discuss it with ^{Werner} ~~Wunor~~
^{Von Braun} ~~Von Braun~~ _____. But you look at ^{the} Jupiter, look at the Saturn, serious
 its very ^{sturdily} ~~sturdily~~ built. An the American wine if you want to call it that even
 though some of us were in on this one too. Started off a little bit differently
 Already Prof. Overt in his book and its really difficult to do something that
 Overt hasn't _____. Overt in his book suggested that because he
 was very much aware Overt was a German _____. He was very much

structure

lightweight

Von Braun

Werner

sturdy

aware of the problems of the mass ratio. And ~~Physics Professors~~ and other people in those days gave him a heck of a time in the 20's late 20's and early 30's that you could never build something light enough to come up the _____

that would be sufficient to send something in orbit. And he felt it could be done, ~~de~~ if we improve our steel ^{sufficiently} so that we could make it so thin that the pressure stabi-

said one way that it could be done that

lizer he called it balloon construction and the American word is more in technological ~~Pressure Stabilizer~~. Now independent of Overt this thought was dev-

veloped by Dr. Bosserk, at Convia. When he worked on the MX774 the Atlas ^{vehicle}

The Atlas ^{vehicle} was indeed based on this kind of ^{structure}. I talked to Dr. Bosserk

with whom I worked very closely my good friend it bothered and killed him a

little bit but he honestly did not know this. This was strictly his own genius

that came up with this idea and ^{when I} saw that as a giant ^{conveyor} ~~conveyor~~ I liked it very much

I thought it was a good way to go. But for the very large eagles it was not

found to be too acceptable, there were just too many forms involved. ~~e~~ And

fierce apprehensions of a very difficult structural situation. Especially if you

have one of the state's vehicles although I was completely ^{convinced} ~~convinced~~ that it

could be done on a two stage vehicle of modest demensions and that's what became

~~Centile~~ ^{Centaur} ~~Centile~~ ^{Centaur}. Now ~~Centile~~ you see what I wanted there at least why I actually devia-

ted from the heavier design ^{infact} actually was even a little bit bolder still

than the Atlas was. Was not really because I like that kind of frame and ship

to much as more due to the fact that the smaller you become the lighter must

you build to maintain a certain mass ratio. Now the oxygen-hydrogen propellant

is terrific because of its high specific impulse. But its very it can be very

mass - ratio range

easily degraded. If your mass ratio isn't good. And that means therefore especially in smaller type vehicles the oxygen hydrogen can practically be wiped out. ^{attitude?} If you are not very careful, therefore very small rockets are just not suitable for the use of oxygen, hydrogen. I was convinced to the point ^{journe} that it became really almost a crusade that we had to move rather quickly to hike specific impulse high energy propellents because that would be the only way in which we could make a real breakthrough toward space flight. With our vehicles, and while the st airforce investigated a large number of advancements including florine and hydrocene ^{and} other things along these lines. I remember these things very vividly in the late 50's. People were surrounded by alternatives. As usual there was no concensus ^u to be achieved, what to do. I personally did continue to push for oxygen-hydrogen for a very simple reason.

No. 1

Oxygen technology we had. We had it from the V-2 meantime on the Atlas we had it on Jupiter and we had it on the ^{Thor} ~~four~~ it was well developed technology.

LH2-on

Now, so therefore only one new fuel had to be gotten. The more we went to florine in the new fuel we had to develop also florine ^{technology} also for all the poisons and the messey thing that goes with it. And it wasn't really necessary because when you ^{were?} ~~were~~ an oxygen _____ [?] or if you want, and went to oxygen-hydrogen you make already 92 to 93 percent of the junk that you ^{could} possibly make even if you would go to flurine-hydrogen. So for the last five or seven percent to go through a completely new oxidizer regardless of what its advantages of density and all this were seemed to ^{make} ~~make~~ very little sense. To go to a new fuel to a new oxidizer but keep the same fuel didn't give you much of a performance

increase. The second reason, why I went to hydrogen rather than hydrocene
 are anything like this was simply because I was convinced from my rocket
? that the time of the nuclear propelled spacecraft would not be
 far away. Perhaps a nuclear propelled launch vehicle ?
 in terms of that and the only rocket fuel that made sense with a nuclear heat
 exchanger rockets is hydrogen. Your special impluse deteriorates very rapidly
 the moment you go away from hydrogen go to hydrozene or anything like that or
 ammonia. So it wasn't very worthwhile to try anything else but hydrogen. So
 it seemed to me it was so logical to use the hydrogen that I could never really
 be never interested in any other solution. On top of it there were obvious advantages
 at every link and while these things were held very classified one couldn't talk
 much about it. Those of us familiar with jet propulsion could very easily de-
 duce that if we were to replace gasoline by hydrogen that we could build air-
 crafts of fantastic performance compar^datively speaking. Everything seemed
 to me in space craft or air craft ultimately to go to hydrogen. But hydrogen is
 a nasty stuff, a difficult stuff to handle very cold, very illusive, very evaporated
 and in small rockets it had that problem. I didn't believe that we could justify the deve-
 lopment of a completely new large rocket vehicle. Based totally on oxygen-
 hydrogen, people who are not quite conv^enced that hydrogen would work and the
 best way to break the door down to begin to at least try to open it anyway. Was
 to select a vehicle that would not be too big a development process like the Atlas
 or even something bigger into multi-billion dollar program. But something
 smaller and at the same time one that would fit on the existing booster and so I

that the centaur even today as it strives works virtually the same as my department and my people and I had another design on the drawing board back in '59.

When we proposed very little change the Saturn vehicle had a different instrument.

Initially, Marshall worked at very large booster vehicles. Completely new

boosters then I think it was a suggestion of our part if I remember correctly

that alpha say well look you have all those pretty nice sized _____?

_____ cluster those together. They had also looked at clusters but dif-

ferent types of clusters but most of them that I saw at that were almost more

like Saturn ~~five~~ type boosters although they weren't in that size. They were

more in the Saturn IB size range but they were S-IC type stages - new stages

and so forth. That caught on at Marshall and they really went into this and said

yes that looks really terrific we can actually build a very nice and dafty booster

out of these out of such and arrangement of Jupiter and ~~Redstones~~ Redstones around it.

But then there was the question of what do we do for an ~~on-core~~ ENCORE now in the upper

stages and oh we had all wild things I use to tell Von Braun that this whatever you're

doing its not going to work its not going to give very good performance unless

its ~~Centaur~~ tipped. And so we had that kidding with Von Braun ~~Centaur~~ tipped

Saturn family he said I'm not sure wheather that flimsey little thing up there is

going to work. You see you need an Oxygen-hydrogen stage you should really

construct an oxygen-hydrogen stage up there but I don't mean we have such a

big development program we really shouldn't yet. Was he worried about hand-

ing hydrogen? Yah, somewhat. Somewhat but not too much I remember that he

asked me it was in 47 or so that somebody had published an article I remember

somebody had published an article at that time I think in the Journal of American Rocket Society I forgot at the moment the name. Anyway in which he proved that Oxygen-hydrogen was an excellent propellant and I know that ~~Werner~~^{Werner} was unhappy about it and he says I don't think this is right. I want you to investigate and work out a comparative ~~manathedility~~^{methodology} for comparative analysis of rocket propellents. Now the point was we weren't always necessarily that accurate in those stages. When these articles or when these arguments came up somebody might have meant for a spacecraft and talked also about the logic _____ somebody else _____ well I don't agree with you. And so different _____ as possibly if so so I set down and wrote this out it was later on published in the Journal of American Rocket Society and the results basically really was _____ the results really was indeed for certain conditions heavier propellents were better and other lighter propellents were better. O.K. on that we were kind of settled. Well I used to say ~~Werner~~^{Wernher} is and this in friendship but he is fundamentally almost more a conservative, the ~~innovator~~^{innovator}. And for the long time for him to really accept the thought of nuclear powered hydrogen spacecraft. Remember in his master he made a point. Using dense propellant. I remember that I was a little bit hesitant I worked the propulsion system of on his staff at that time for this ^{mass?} ~~March~~ Project that he had and he wanted so very much to have dense ~~propellents~~^{propellants}. He kept on saying that its probably safer and if we get a hole puncture in the way ⁱⁿ mars in the hydrogen tank then everything is down the tube and so on and so forth. And so we settled at that time if I remember correctly on wet fuming nitric acid and hydrocane something like that. And I gave the engines

dense propellants

high pressure and I went to hydrocane to get some decent ^especific impulse
 out of this and the thing got completely out of hand, because the desire for
~~this propellant use is~~ [?] so much. In any case it was in those days
 that the situation started and ^{Werner} ~~Wuerner~~ he was fully aware of the higher perfor-
 mance and he liked it but he felt that maybe the time wasn't come yet. So his
~~original, all his original~~ [?] were all based ^{on} dense and
 propellents. Very reluctantly he once looked at Atlas as a second stage [?]
[?] as a second stage which seemed to be ^usturdier and met more his condi-
 tions of non pressurized ^{structure} ~~statue~~ and so far I kept on at it we had many meetings
 in those ^{days} and our friendship kept on all the same he needed a needed a centaur
 tipped Saturn. O. K. now low and behold along came this I still have some I
 remember this [?] of an unbelievable variety of the history and you know [?] -
 even better than I do and probably have a document ^{of it}. The initial C-1
 and C-2 and C-3's is just ^gmurderously different from the final ones, so they
 went through tremendous changes, at that time and it wasn't really settled.

Until a committee was established. I think it was a joint NASA DOD Committee
 which as a result of our relatively good progress that was still before the first
 flight ^{on Centaur} but the way we went ahead and designed it and the ^{way the ed} engine work begin to
 impress people. My god, maybe it isn't so bad after all. It wasn't a donment
^{Silverstein?} The ~~silver stand~~ committee. No. not ^{Silverstein} silver stand. It was Caveno somebody
 like that and it was a joint DOD NASA committee. Have a [?] committee

I don't its possible that ^{Silverstein} ~~silver stand~~ was on but he was not the name carrying chairman.
 Their recommendation was forget about anything other oxygen hydrogen [?] And

? verified what basically was not so difficult ? . My God,
 if you go through ^{that} trouble to build such big a vehicle ^{you are} practically defeating your
 purpose if you don't come up with oxygen-hydrogen ? O.K. that deciding
 that then to really the first Saturn ^{the} where they well look you have now already
 you have the ? engines and the ^{stage} ~~search~~ Why not take the Centaur. So then you
 have a makeshift second stage with was it 8 or 10 or so that with the engines on
 it or 12, six, six ? ^{It was designed for four but} report they couldn't get ? uprated so they
 went back to the six. With the ^{use of} six and which was kind of a super ^{Centaur} centile rating
 very much design ^{ad} after that and then the ^{Centaur} centile on top. Douglas build that did
 they get information from ? . Yes they got information from us. ^{They visited us thereafter} How
 much would you could you guess at I think practically everything they want to
 know they could get, there was not that kind of a competition. It wasn't we
 developed it from government money so we felt it was government property.
 and NASA should profit from it. Anyway in the meantime ^{Centaur} centile which had
 a terrible history of top level ^{management} was kicked around between ^{Army}
 Airforce and NASA and ? . And NASA ^{Headquarters} was taking this over while
 NASA headquarters was in its formative stages ^{everybody} has their own idea
 about what should be done which is unbelievable. And you couldn't get any answer
 when you tried to get a decision, about fundings. Well, ^{Centaur} Von Braun was manag-
 ing ~~Sentor~~ for awhile. Not until very later. Then it went up to Louise? Yeah.
 ? started out with Alpha and they couldn't
 ? - and they couldn't ? and then it went to the air-
 force and then the airforce lost interest or they had other problems and then it

kicked over to NASA headquarters. And at the headquarters _____
 through the _____ into this. And that deducted because that was his pet
 project. He came out of the hagen vangots stable there and he had different
 ideas and he wanted to have the big answer that's another new upper stage for
 Atlas and instead of _____ one so we had _____. And the money for the bigger
 engine came largely ~~largely~~ out of the budget for the centour engine, we suffered
 severely because of these private its ~~private~~ ^{really?} already _____ because
 people had their personal projects. In other words they could not withstand
 the total ~~criticise~~ ^{criticism} they just were imposed by vertue of the high level of certain
 people they ~~said~~ ^{said} well this is what I want to do _____?
 _____ oh that's what he wants to do. Lets go and do it. I don't
 really believe it but lets go. You know. There is everything that came from
 further down had to really be argued through and it had to be really be ~~proved~~ ^{proved}
 and it had to stand up before it could go. So that was super imposed. ~~Now~~
 over it and as a result of their income and the centour was severely disturbed
 _____ we had to drop test _____ later on in the hearing before congress we
 were blamed of not doing enough test here and here. and yet in one year we
 lost what was it? Something in the order of ten or fifteen million dollars on
 testing along ~~which~~ ^{which} which we couldn't do because the money wasn't converted off to
 get _____. But anyway and so _____ wasn't very much interested.
 By the time it got to Marshall ~~Von~~ ^{Von} Braun wasn't interested _____
 _____. Von Braun basically I think couldn't care less. He was
 busy with Saturn. So, _____ -Haunze you want that plane. I knew Haunze
 of course from the days when we were _____ we lit the candle under the

tree so I got along famously with Haunze and it was a really good time. But
 still the proper management structure was not there and it wasn't Marshalls'
 baby and Marshall is too great of a team to be able to absorb somebody elses
 creation I was very difficult. Marshall is not a processor, Marshall is a creative
 team. You see and creative people have difficulties ^{just} processing other peoples
 material. There is always a conflict. In the you see that why for example
 Marshall got along so famously on the first stage of Saturn the S-1 with Boeing
 because Boeing which was desperate in those days for business went all out *and said*
 we are here to please you and my dear girlfriend Rojeck just absolutely loved
 that whereas he got from us often ?. Yeah ? there
 was one famous statement which I was not was in the room when it was made
 I better don't say that even on the was felt it was very knowledgeable and there
 was of couse ? we have our opinion and you have your opinion and thats
 always very difficult you should have creative teams. But don't force them on
 each other. Your technilogical development of a nation is big and as active [?] as
 the United States has enough room to let an independent dealer, now Boeing in
 those days took a different [?] ~~took~~ at the whole thing. Now we want their business
 and we know how to get it. We go to ^{Werner} ~~Werner~~ we go to ? and say how
 do you want us to do it? ? I give you all the drawings
 and before I understand before they change crew they went back and have [?] said
 ?

it worked famously and it is probably good that it worked this way. Because if
 the Saturn would have been build between teams that were conflict with each

they had their own creative outlets and different approaches they are always several ways to skin a cat. They may be practically equivalent but you can't ultimately have only one way. Somebody has to make the decision and Marshall team supremely capable of making the decision and was good _____?

that said well you set the [?]tole and we'll do it. That worked fine. So the in the case of the Douglas situation when Douglas was learning from us maybe they wouldn't like for me to put it this way but they get all the experience obviously and so did Marshall [?]incidentally they came and we gave them anything we had and once again here of ^{course} Marshall is not the team to say this is the way they did let us do it this way. They ^{checked} independently there was some feeling _____?

_____ there was some feeling for example that at least on the larger size Saturn stage it might be more resolved to have the insullation on the inside rather than outside. They didn't like to much _____? insullation not that I was very happy with it. I had introduced at that time for the very simple reason that I had desperately ^{defied} ~~defide~~ it. For every edge I could get on the mass ratio and I wouldn't have made it and there was no need for in those days specified ^{air}force and NASA missions there was no long storage time in it. To keep the insulation on _____?. So we through it out. It didn't seem to be that terrable a problem and _____? initial problems we solved them and it flies off every time which is rather well . That's not one of the critical areas of the Saturn. Ha y look, they had it inside and these sort of changes now the moment you put it inside and you put it against the wall you wouldn't have to fight with the helium layers that we had to have between the

steel wall the pressurized structure and the insulation it ^{facilitated} ~~facilitated~~ things on the one hand on the other hand it made it more difficult because the huge big structure was breathing it was expanding and contracting and to make sure that this insulation wouldn't crack under those conditions and thereby opened up heat leaks _____ [?] pretty ^{formidable} ~~formidable~~ ones. So they exchanged one problem for another and solved it beautiful. ^{by} They were in other words they were different. In other words what I'm saying is that they gained from our experience they could avoid a number of mistakes that we have made and from there they went on to optimize the situation for their own purposes. In the engine field initially nothing was made. To say a word about the engine in the second half of the 50's I worked rather closely with rocket ~~line~~ ^{by} I worked with _____ [?] nuclear engines I worked nuclear and various other large booster engines. I worked with a daring also on a design _____ [?]

Here was to mount on top of this an a reuseable upper stage when people were carried up and a non-reusable ^{freight} ~~freight~~ stage which would be launched automatically. ^{And} sent to a space station. I published an article about that at that time In the Journal of American Rocket Society, and for the first time I think tried to get to put economy in this whole thing. We have a standard [?] which either serves ^{manned} ~~manned~~ for possible reusable flight or unmanned for cargo flights. and that assisted very simple cheap cargo ^{it} ~~it~~ that maybe doesn't have be returned and so we get more payload into this one. _____ ^{2.} and in all these respects I kept on ^{urging} ~~urging~~ rocket ~~line~~ ^{by} to really look seriously in oxygen hydrogen engines. Rocket ~~line~~ ^{by} was very strongly on airforce engines

they were in competition with Lockheed on the ^{Agency} ~~agency~~ and they wanted to come up
 with something that the ~~airforce~~ might like and the ~~airforce~~ was not too interested
 initially enough in hydrogen they were more interested in fluorine-hydrogen
 _____ and 204 _____ hydrogen in which they were to have chosen
 for an ~~mkd~~ _____
 and so ~~yeah~~ we couldn't get them I couldn't really interest them too much and
 then when ~~centaur~~ all of a sudden sold to _____ that really stung rocket-
 dine they really went into the act and started looking at engines and looking at
 larger engines and with the intent of knocking _____ Whitney if at all possible
 out of the satellite they were the ~~saturn five~~ and offer the Marshall team a better
 engine than _____ six which wasn't the nicest thing in the world but it was already
 a big forward improvement over any of them. And they were successful with
 this and they elected a J-2. ^{Reshetdyne ?} That is the next biggest engine that the way that the
 engine was alternately changed and then the ~~saturn one~~ B arrived. And the upper
~~Centaur~~ S last stage I think it was a C-5 stage or something like that yeah never
 came about because Saturn ~~one~~ went ~~saturn I-B~~ became Saturn ~~I~~ and then of
 course we had Saturn-~~5~~ _____. ^{and nobody ?} That changes the mission they said it was
 for deep space probe and then they changed their minds and then they wanted to go
 to the moon. That's right. And the mission of course in Saturn-~~5~~ became that
 principle in which we but what had happened was that the road was indeed open
 to oxygen hydrogen and it is now firmly in our arsenal and it would be unthink-
 able if we really continued to develop another engine to do that if we didn't have
 that kind of oxygen hydrogen experience that we now have through the Saturn

vehicles and through the centour. ^{vehicles} That how this came about and that's how
 we often went different paths in the basic approach to the vehicle design but it
 was based not out of ? convictions but simply because we ^I had no alterna-
 tive with the small like that. I would not have made that design if I had been
 allowed to build it. ? spacious like the S-~~2~~ and the ~~S14~~ ^{S-IVB} not at all. So
 after that one was settled we looked in later on at still ^{larger} larger systems Marshall
 got interested and wanted to know could we build larger systems and of course,
 one thing that comes ^{immediately} to mind is if you do still larger systems ^{it} you better be
 totally reuseable and that led to I got on a contract that led to the ? vehicle
 which was the first of the one [?] body-type booster vehicles so it was basically
 blunt and designed for blunt reentry and we had really what looked like a second
 or third artillery but really just huge payloads. Which gave it then a somewhat
 more ? form but once the payload stages were taken off there was a blunt body
 that came back into the atmosphere. Dr. Sladon pick that one up fill ? turn
 it around came in engine ^{first} I came in head first that lead to their robust design
 which followed. But ? and idea of the ? body have become great I know it
 came out of our stable and ^{presume} ~~persue~~ something like like a blunt vehicle will come
 about once we get over the shadows and get back right now you can talk to any-
 body if everybody is ? a large ^{freighter} ~~frater~~ which gives us to the odd of
 \$10.00 a pound which the next Columbus design can do. And I think in the 90's
 we'll return to that thing. And that will be in a way a continuation of the history
 from the V-2 to the Atlas and the centour ^{new} and the Saturn. This one You said a
 space shuttle is kind of a devience from that program? And that program is a

deviance in the sense that the space shuttle is for small payloads. Small by standards of these large boosters and its a perfectly appropriate payload for the present time 40 thousand pounds or thereabouts is a fine payload - I don't care if it's 30 or 60 or 50, but you see when we get to build larger structures and I could hardly begin to tell you why you should build ^{them} and I think why we will build them by the year 2000 2010 structure like these of 2000; 3000-man stopover station and you could not possibly do that with a 40,000 - pound launch vehicle. You need launch vehicles that have upwards of a million ^{between a million and} pounds or four million pounds. And that are reusable and that is possible in a way I am sorry that I'll be long retired by the time by which this swings back. Because we did a lot of [?] and I respect that if I'm still alive to see some of these ideas re-emerge but there is no question that the first step is the shuttle. ^{it} should be done but then maybe after we've [?] by the late 80's perhaps we'll be allowed to go into a big ^{freighter} frater. So now the as I pointed out I always look at where else can I use it is this a dead end street and does this have a growth potential in its development. To me it was not a dead end street. Everthing like hydrocene [?] and long development you have a [?] and then you find out what the next step [?]

And so the hydrogen was not only good as a booster but its also a very interesting propellent for interplanetary flight until perhaps until we get to the point where we are using pulsed nuclear detonation in which case you would not ^{necessarily} that anymore [?] meadows. And use meadow gas instead for those purposes but thats a totally different situation. And so therefore I also look

very intensely at large vehicle ^{wide} ~~wise~~ interplanetary use. And those
 have been in study for NASA can be lead to what is somewhat today known as
 the typical [?] ~~nerva~~ type interplanetary vehicle [?] slone tanks and so on and so forth.
 Is there a very active nerve program now? The nerve program is not to active
 at the present. I have testified ^{back} before congress in 59 I was asked to testify and
 I supported the never program all out there in fact Harry Finger, Stan Ulum,
 from Los Alomos, Harry Finger from NASA, and some other people were there
 and also Dale Zish from Eljet in these hearings and my support was based on
 the assumption which I published back in '59 or '60 somewhere around there that
 if we do have a nuclear powered vehicle rather than all this chemical stuff
 wheather heavy or lighter propellent but a nuclear powered vehicle that gives
 us at least seven or light [?] then we can conduct fast ? to Mars
 and to Venus and pointed out the fast flight profiles which would make a quick
 flight out, stay for a little while and then come a longer flight, and then go inside
 the earth orbit and so on and so forth. I stumbled on that kind of profile originally
 when I worked for a Science Fiction Novel where I introduced a mishap at the
 planet and had to return they said would they return? They can't return on the
? route they have wait 500 days at Mars you see and they're looking
 at this ? all of a sudden there was a whole family of life paths opening
 itself up that could eventually be used. And from there I went into the utilization
 solar energy from a nubust near the ? where I not bearing solar
 distance, solar height solar heat intensity and used a collector and heater in view
line of the reactor to heat my hydrogen and dump it out at ^{or} 758 hundred per seconds

specific impulse which now was a limit branch and this turned out to be very effective. Although not quite as effective as a ~~Luna~~ flyby. Which because that's purely gravitation but very much better than striking the earth without a conventional category ^{propulsion} ~~compulsion~~ system. I almost cut the departure weight of this _____ 60 percent apart by this ^e ~~manu~~ver alone. Can you tell us what the science fiction ^{novel} was that you worked on this? It was never published it was called Expedition Airrace. It was unfortunately never published because I spent more time but I would be glad to give you a copy of it. I still have that thing. I would love to see a copy. O.K. that's absolutely. I send you a copy I have it in my file at home. I'll write you note. Please do, I'll mail it to you its all typed out it has a fiction part and it has a technical appendix. But I spent more working on the technical appendix than the fiction part and then I sent it to some science fiction journalist today I consider I would consider I was crazy to try to publish it. It was really well it had strong emphasis on the technology part. But it was then it was in the early 60's that I thought my God we have a whole family of fast _____ and nobody ^{at} all. Von Braun still used very nicely the good old flight rules and everybody used it I used it too. _____ . Yeah, but only in my case I wanted to have something going wrong. I ~~dealed~~ conflicts of course in my story and all that and the girl and everything was involved naturally I thought that's necessary to get the science fiction. But anyone would have a mishap and I watched most of my oxygen. In other words what happened was there was a very bad ^e ~~manu~~ver that had to be conducted because they almost collided with an unknown little marsman. I

introduced that. That hadn't been seen from earth _____ they
 made a very rapid ^emanu₁ver as a result of this they lost most of the oxygen and
 their food and it was perfectly clear that if they had to wait 500 days ^{for return flight} they would
 all die. And so they started figuring out what can we do how can we go back. In
 other words it was the first time [?] anybody thought of an interplanetary mis-
 sion aboard what do you do with it? In a mission like that. And so I looked at
 an officer and I saw a number of orbits ⁴ as so I started calculating. So I was so
 absorbed in developing more these families of orbits and then published this in
 the [?] _____. Incidentally it wasn't '59 the original novel was written some-
 where around '51 or '52 but then over the years I developed more classes and then
 I published the whole thing in the ASME Journal. In two parts [?] _____
 _____ [?] to Venus and Mars introduced a concept that we should have
 probes with us which should stay in orbit if possible and just land the probes
 down there and so on and so forth. It how did I need to try to find my way back
 here. Oh, yeah the idea was that this might be worthwhile if we can do it by
 '72 ^{or} '74 somewhere around that time. In '59, '60 that looked like a long time a-
 way, it looked like we might be able to do it. And I had actually I sent you a copy
 of this ASME thing too I was primarily thinking about either '73 or the '75 mission.
 I wasn't trying to be too optimistic although I couldn't help myself feeling that
 maybe we might even make '71. How ridiculous that sounds today. ^{But anyway} About '59
 that didn't seem to be so but I was still cautious but I said maybe '75 but I thought
 I was pretty darned concervative. Well anyway so I supported this, so the years
 went by in the same dragged on and dragged on. And then they sold President

Kennedy on it. And President Kennedy gave it a boost and it became apparent to me that my God this thing is getting completely out of hand. If you plan a certain thing and see I wanted to started development A here because I wanted to fly Mission A Prime here. Because I wanted to be able to fly mission B over here now all of a sudden A slips down that much so that A-prime _____ to B then I got to re-examine the situation and say do I still want to do this? Should I not wind up in a Block A now and better go to what I really need for B. So I started to look at the gas ~~carrier~~ [?] and then I looked at the pulse the nuclear pulse; and I looked at the fusion. I worked with a number of people in this field including IAC people. And I became convinced that the pulse is the answer. And the pulse was at that time [?] [?] [?] [?] brought on at atomics general, general atomics. And general atomics was a sister division of ours so I worked with them _____ and their design is wonderful but I was seeking a bigger design because I'm think ^{ing} of that we do need deffinatly to eventually mine another _____ and the only propulsions system that becomes cheaper and of increasing performance the _____. Is the pulse system so that was for me the argument answer I published for years all sorts of things about the pulse system. Anyway by 1966 my thoughts had ^{coagulated} ~~coaculated~~ to what I thought was hallucinary I seen this thing dragging along. I talked to Harry Finger and Harry says Oh, what is it? I said I'm gonna stop talking about other propulsions, _____

if the rover program is being cancelled and won't be replaced later on we won't have nothing so lets at least have that. I says but Harry this thing is turning

from a driver into a brake. It just holds up everything else. I can no longer
believing that even those fast ~~reconnaissance~~ ^{reconnaissance} missions are really sensible. The
reason why I'm saying this is it can be very critical I was in the early years
very much deeply out on the probe. And tried to push the probe we got to get
some of these programs but primarily I guess initially I really only thought of
fly by probes and maybe orbiters and so forth. It became very quickly apparent
you know with all the ingenious work that was being done that these probes were
capable of a heck of a lot more. And now when you start them sitting down and
think about what these folks can do you find very quickly that you are beginning
to ~~out-compet~~ ^{reconnaissance} compete yourself out of the fast manned ~~reconnaissance~~ mission.
And in one of the last studies for Marshall and NASA where I made some of the
advanced studies section at ~~convia~~ ^{convia} back in '63, '64 alright, my conclusion was
that number one fly by mission a totally out which we had originally for ment.
Totally out because they could be by that time already obviously done so much
better by unmanned probes that it made no sense. Fly by mission I figured that
to about 21 billion dollars and even something like a voyager was no more than
3 or 4 or 5 billion dollars so in bids per dollar or in useful bids per dollar
whatever all that fancy stuff you want to put in on this it became perfectly clear
that this is not competitive. But many people especially of the younger [?]
group members a little bit like Harry Roper for example they were very ^{capable of flyby}
[?] to [?] they thought that would be the thing to do and they felt that was
the only thing could be done. I think [?] North American which felt
that if you soup up the Apollo a little bit then you can indeed make a manned fly -

by to Mars swing up into the _____ and then come back. Well, how you can seriously assume that you can do this and penetrate into the totally unknown environment of the Astroid Belt with its possible meteoroid dangers is actually beyond me. Now that was pushed in those days in fact I began to doubt whether brief capture periods of still use in themselves the basic idea of being that now we may have orbiters long before we know that's right. So what's left is really a type of mission that is really superior to the young man and the kind of mission that one may begin to have serious doubts whether another can do it. And there I went through a dual evolution evolution about '66 I reached the conclusion that I felt that the nerva wasn't very much worthwhile. We should maybe drop it and directly go to something much better. Preferably the pulse on the fusion or at least the gas coriator and have first a big time period of unmanned probes. In other words let's put the 70's and the 80's in the unmanned probes and then maybe perhaps in the late 80's or middle 80's middle 80's of course that was '66 so it sounded like we then went and everybody _____ which we make by '77 we can run the fly by mission. So when you said '82, '84 it sounded like _____ power. _____ today that's no longer of conservative but you know everything changes so fast. But in '66 and then in the 90's have at least the gas _____ not the pulse ready. And then we'll go all out really make the _____. In the meantime I have studied further and have come up with a mission profile which is very exciting ^{which} could be used by any propulsion system but it does the nerva _____ the most good. I just presented that not too long ago to Marshall. There is some interest there on the side of the advanced lunar

and ~~planetary~~ ^{planetary} propulsion _____. And that simply in principle is you take the nerva propelled spacecraft, send the crew out and do nothing to the return capabilities just do _____ the return capabilities and then from but but then actually what amounts to practically a space station over there a very very ^{sumptuous} sumuous propulsion because your payload is almost increased by a factor of 3 so you have plenty of payload. Then start rotating quotes keep that stuff down with a minimum mission module start making some of the fast flights. That will reduce your stay time to just a few days. I don't want go necessarily to a fly by sort of thing but only reduce it to days which already cuts down the difficulties in the return flight very much compared to the original concept where you want it to stay as long as possible. Maybe six weeks or eight weeks and then finally _____ fly by got closer and closer to the sun and then the window was closing you took the last bus after six weeks stay time was where you really had a ~~hack~~ of a fix you had to rush home as fast as you could. Now you wouldn't do that you would stay only a few days _____ the return flights become lot easier. So thats and interesting thing to make maximum use of espeically of the shuttle and of the _____. But its still only a preliminary answer. The main line should really be the pulse or something of that sort. But anyway the ^{re} are still some possibilities open and we may see some of the hydrogen activities derived basically from what originally we all thought I think was a booster possibility. The rover program especially here at North American Rocketdyne they were looking strongly at having a nuclear booster. I worked ^d with them at that time so I know about their plans. And because I worked

on the structure

for their booster and they have gotten into the engine the nuclear engine. So the nerva program drags on and drags on and drags on. It still is not without redeeming features. ~~By~~ God if we don't have it at least by the early 80's then I think we should really take the knife to it and but replace it by something else thats good. What is a different story I think we should try everything possible to replace it by a nuclear pulse. So I don't it depends a little bit on what you want wheather you should keep the nerva alive or not. There are alternatives in the _____ where you don't necessarily have to have a nuclear ~~ferry~~ ^e ferry. A nuclear ~~ferry~~ ^e ferry has ^d big advantage that its booster which boost^d away from earth _____

back to earth and that has to be slowed down has to be well _____ for a ~~rendezvous~~ ^{rendezvous} rendezvous at the target and then has to be slowed down and returned before if can be used. You see, if you had a duel fly³ by where you have an elipical orbit and put a space station in elipical orbit and here is the inner terminal ^{is} and this is the outer terminal ^{inal}. That elipitcal will osolate between inner and outer terminal you would have a duel fly² by situation right? And now you use small fighter-type transports _____ ITD's into orbital interstation transfer league between that elipitcal space station, shuttle station, and the terminal space station here and here and a minimum of dead weight you make an ~~approach~~ [?] approach transition out to the terminal or from the terminal back into the elipitcal and it goes through the ~~approach~~ [?] approach you see. And the same thing on the other end and if you do that then you can with ^{chemical} ~~propellants~~ ^{ants} propellants come down to a crash factor with which is as good as the classical ~~ferry~~ ^e ferry with nuclear. Then you are about 67 pounds of

propellent per pound per payload transported _____[?] trip. From lower to _____[?]
or lower to lunar orbit this is rather similar. So there are various alternatives
and if we zeroed in on some of these alternatives then the nerva is going to be
in real serious trouble. Am I deviating too much? _____[?]

Put me back on the track. I really interested in what you are talking about
unfortunately _____[?] Saturn ... I know are getting off the Saturn thing a little
bit but so ... you've so much bowled me over with this presentation I just have
some minor questions to ask you on Saturn. I'd just as soon have you do what-
ever you like to do. You've really been wonderful. Now let me just ^{say} (that because
our developing because we were I hate to use that word but if you take it judiciously
as I mean it we're are the principleⁱ antagonist of the other line to Marshall I
mean the low weight pressure stabilizer under the influence primarily of the
genious^g of Charlie Barset[?] and the successes that we had and the pride of our
management even as such as when we broke the centaur^{centaur} ice and so forth that our
proposals^{as} were of course taken looked at most judiciously by our friends at Marshall
and we bid^{bid} for the second stage, we bid for the third stage, we even bid for the first
stage of course we couldn't swing it. We didn't make it I guess some of our
in ^{regrained} ~~grained~~ _____[?] I was not directly involved in the making beacuse I was

busy with centaur^{centaur} at that time but then advanced _____[?] made some
of the proposals and they were largely relying on pressurized structure. They
had some good points but you know nothing is totally and absolutely rational. People
have certain ^{innate} ~~innate~~ preferences and Marshall just didn't feel comfortable with
a huge pressurized structure. I can't say wheather^t rightly or wrongly but I

convinced
bid

MSFC
pressurized
structure

certainly can't blame them. I would approach huge big rockets approach the thought of making them a pressurized structure; with much more care that smaller ones this. Maybe it was a beautiful solution for Atlas and maybe it was really not a good solution for Saturn 5 in any case Marshall thought that way and certainly if the other solution was any good we may never know. Certainly the solution they chose was a good one and it works so that's the situation but that got us pretty much out of _____?. We didn't win one single contract .

}?

Back in 61, 62 we didn't make many proposals but I guess we didn't really do what they thought might be the best thing and then they finally did decide that we better design most of it ourselves and _____?. I want ^{somebody that} not out invents me I want somebody who is doing what I tell them. Boeing seemed to be the one.

Boeing MSFC

Yeah but that was the relationship between Marshall and Boeing but didn't the S-2/B come up with their own design? In North America? Well, Did the Structures at Marshall have very much to say about the structure design? Well, they guided it rather strongly. Now I am not the best guy to talk about details and the origin of the S-2/B because I wasn't with this company at that time. I talked to Bill Parker about it and he seemed to think that it was mostly North American's design and they weren't willing to say that Marshall had very many influences except for the management point of view, visibility and coming out and checking on it but I that's not what I've heard from others. Well I intuitively knowing the frame of mind of Marshall not just Marshall and not just the first stage of those days I would be amazed that this is really totally factual I think they had something to say. I must however say that the German team especially those who stayed ^{on the job}

NAA - ASD Boeing

WAFEC
with
availability
Lox H2

?
 for the Germans had no until 62 or thereabouts nothing at all but oxygen ~~gas~~ [?] ~~gas~~ [?]
 that was it. Well, _____ [?] that was about it. Of course
 when I say _____ [?] no question about it. The oxygen-hydrogen
 rocket just wasn't born at Marshall. And you know industry is perhaps a little
 bit because of business pressure is on them little bit more versatile ^{the} once we
 begin to be successful you know rocket ^{line} made that turnabout you know I told
 you about it ~~that~~ ^{isn't} that much of a tradition _____ [?]
 So I think it is true that probably both Dr's in North America had ^{psychological} ~~psychological~~
 and somewhat creative freedom. Because the main pride of rocket esteme was
~~definitely~~ ^{definitely} connected with the first stage, With which they were most familiar.
 had probably a little bit more freedom than Boeing had comparatively speaking.
 But the mode Marshall in those days was we better won the show. It means that
 we don't want to get anything that think was wrong _____ [?]
 _____ [?]. So they keep a tight range on all
 stage manufacturers but I wasn't here and I cannot say _____ [?]
 I only do it by influence. Of course, all of a sudden Marshall was swamped with ^{3 new} ^{stages}
 the responsibility of three new stages, ^{I will} One stage capturing the ⁱⁿ attention
 tremendously the first one. It is possible that they simply couldn't handle it all
 also by ^{default} ~~default~~ like a number of decisions go but probably they reviewed them
 very very carefully. Just one minor point the _____ [?] insulation used on
 the first stage is exactly what North American did before they _____ [?]
 Yeah, that's right. And this is a I can't ^{prove} ~~prove~~ it but I am quite sure because
 we there was no design ^{that used it} ~~that used it~~ before that whatever there was no design period.

There was absolutely the _____ work on an engine with the work of the pump] ?
 and initially I didn't even know anything about the pump. Because when they finally
 did decide in the Airforce to at least move in the direction of being serious
 with an hydrogen powered bomb which was _____ they were most afraid
 of pump. Frankly, I was more afraid of the tanks than of the pumps. _____
 because I was awol. But the Airforce was afraid of the pump so they said this
 is maybe the pacesetter so they added _____ and that pump
 was laid out for feeding the engines of a large bumper but even a huge bumper
 _____ like there is a small rocket. But low and behold
 I came along with my little centour those people in the know at _____ knew that
 this