PANEL DISCUSSION: BRIDGING THE GAP TECHNOLOGY DEVELOPING FLIGHT HARDWARE

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I would like to welcome each and every one of you to Goddard Space Flight Center. I think this is the 11th year that we have had a meeting here on batteries and the 10th year officially where it was called a workshop.

I would like to know how many are here this morning for the first time. Would you just raise your hands. Well, that is quite a large percentage of the group. I hope you enjoy the workshop. We try to vary the format from year to year, and this year for reasons stated earlier, we have a panel discussion.

Lou Slifer has given you the background on the OSTA workshop that was held this summer. There were four different disciplines discussed at this workshop. They were power which Lou has covered, electromechanical, attitude control, and radiometric instruments.

It so happened that the initial call for the workshop was on radiometers or radiometric instruments, but because of ongoing flight spacecraft, different problems with different missions, it was decided to expand the workshop into the other areas. As with the design of the satellite, the last thing thought about was the power system workshops. So, we somewhat got into the tail end of it.

Having been a participant in that workshop, it was very worthwhile. We found out that we are not flawless, we do make errors in design and we make errors in judgement. But, the proof of how good a technical group we are is to learn from these past mistakes, and that is what the workshop was all about.

To further that discussion, I have requested people from private industry and government labs to sit in and to assist me in establishing a dialogue with the people in the battery community, particularly defining the problem, trying to come up with some recommendations, and bridging the technology gap. Out of these four workshops, there was one very common theme: that is technology gap. Or, better said, the lack of engineering data base. Where is the line drawn between R&D laboratories saying, yes, this is developed technology, and the project manager saying, yes, we are ready to fly?

What is very real is that there is a large gap in that area. We find that, and I am sure most of you have been in this situation, you have something that looks good, you follow it from development for 4, 5, maybe even 10 years, and you sit down with a project manager and say, "We think this is what you need for your mission. It has the peculiarities necessary to solve your problems."

The project manager asks that question, "Where has it flown before?" Well, it probably has not. But yet he has a need, and you would like to see him use the technology. So you both have a vested interest. The real problem comes when the project manager then says, "Yes, I would like to fly it, but let's see some data on it. Let's see that engineering data base which I can make a decision on."

So you go back to the literature, you make a few frantic phone calls, and you find out, yes, there is a data base; it is rather fragmented, there is no real, solid core from which you can make up your story and provide a convincing argument that this is where we got to go and this is what we have to substantiate our claim.

With the emphasis on cost-effectiveness programs, low risk and long life, there has got to be a better solution than the piecemeal effort I think we have had in the past. The question is, what constitutes flight readiness?

Certainly, our project manager is very reluctant to take on a development program and a piece of spacecraft hardware. I distinguish that between a flight instrument, because use of flight instruments is just that they are pushing the state of the art. Very few project managers are willing to push the state of the art in the spacecraft design.

So, the question is, where is this engineering development going to come from? Who should do it? Should private industry, government labs, or who? That is what the topic this morning is.

I would like at this time to introduce the panel members. I think you know most of these people, the ones that have been here before.

On my left is Dr. Steve Paddack. Dr. Paddack has been with Goddard for a number of years. He is like myself, he does not talk about how many years any more. He is the deputy for technical on the COBE project, and he is here to represent the project viewpoint on the question that I have raised.

We also have Jim Masson from Martin Marietta. Jim has been working in NiCad for a number of years, and I am sure he has experienced some of the problems I have already mentioned.

We have Dr. Badcock, Aerospace Corporation. Chuck and I have sat across the table a few times with unresolved problems that we wished to resolve before the launch.

We have Fred Betz, Naval Research Lab. Fred is one of the few who have been able to sell his project on flying the state of the art, since Fred was one of the first, or the first to get a nickel-hydrogen battery on a satellite and still working successfully.

We have Bill Naglie, Lewis Research Center. Bill is more or less to represent the research end of the discussion.

Then, I have Gert Van Ommering, Ford-Philco, Ford-Aerospace almost at Comsat. Gert comes to us with kind of a mixed background, so I think he can speak from either side of the subject.

Ed Kipp, TRW. Ed's background is in aerospace batteries. He has been in it for a number of years. He works off in the manufacturing and applications end.

And, of course, Dr. Dave Pickett, TRW. I am sorry, I knew I was going to miss one this morning–Hughes.

With that I have asked each panel member to be prepared to give us a 2- to 5-minute discussion of his viewpoint on the issue.

After the panel members give their viewpoints, we will then open the discussion for questions and general dialogue from the floor. I encourage and will seek your participation. Steve, I would like for you to initiate the discussion, if you would.

DISCUSSION

PADDACK: I have the uncomfortable feeling that I am the only member of the user community group. I use your batteries, and a lot of the things that Floyd was saying really rings true. We find ourselves in very awkward situations. I have dealt primarily with missions that are made here at Goddard, so I am more familiar with in-house projects than I am with the projects that are made out.

We find ourselves in a situation in which we want to fly a real good spacecraft for nothing. Like, reduce the cost to practically minimum. You would like to develop new technology, but they say, "Take high risks. But, if you fail, you are in trouble." That is the vice. They want success, they want to keep the manpower costs down and the hours cost down, and it is a very difficult situation.

Everybody gives a lot of lip service to new things, where we often find ourselves in situations in which we would like to fly things and try new things. The remarks that Ford was making about the engineering development phase, the data base and the information, we find ourselves in a situation often in which a new technology, a new thing, a new device we would like to be used in a spacecraft, and the project officer says, "Has it flown before?"

And the answer may come back, "Well, not really. You know, we have changed it a little bit, we have got this new thing called a lithium battery, and it is great." Or, "silver hydrogen," or whatever.

We say, "Well, good, we will talk about it and maybe develop some kind of a phase." Then we say, "We would like to test it" and the manufacturer that produces the battery wants to test it and will say, "Here is our environmental test program."

We will say, "We would like to test it like we fly it." But, we find for a variety of reasons we cannot do that, and we cannot test it like we fly it, so we go off with a pretty substantial risk. It makes us very nervous to fly new technology from that point of view.

I don't know what the solution to this kind of problem is. I have been involved with cases where we fly new technology, and I guess a case in point is related to solar cells. We had to have a new spacecraft, the whole surface of which was conductive. Well, that is kind of a bizarre thought to start with. How do you handle a totally conductive surface of a spacecraft?

Well, they get the solar cells and the antennas; the whole thing starts developing. In particular, with the solar cells—and I see Dr. Gaddy smiling up there—he was put into it up to here, and we did not know whether it was going to work. But, we had to put the cover on these solar cells to transmit charge from one place to another. We were not talking about much charge.

But, we were finding that the stuff that we coated the cells with changed its characteristic. It was not always the same resistance. Then, we had to tie each solar cell to the next, and we would run into such simple problems, the kind that you would run into at home with your kid at dinner time.

You would give Mark his glass of milk and you say, "Don't spill it. You spilled it last night." He reaches over and his coat sleeve knocks over his glass of milk. You say, "Spilled your milk again." And you get angry.

Well, this happens with the spacecraft. We have technicians who wear lab coats, and we say, "Look, delicate stuff, don't touch." Lab coat drags across the solar cells and breaks the little conductive wires that connect.

These are the kinds of things that rather get you. You cannot test something. You want it to be a success, and when you are all done, you look through your development program, you say, "What do we have?" You say, "Well, I have got a battery I think is going to work, and I have a system that looks good."

Readiness Review Committee says, "Let me see your test program." You know it always comes back to that thing. And you say, "If we had a few more dollars." You don't get a few more dollars. "If I had some more time." You don't get more time.

It is really a tough problem. It reduces to the thing where we would like to, from a conservative point of view, go down to Sears and buy a Diehard. Look, we got a 5-year guarantee. It is kind of like the conservative person.

But, on the other hand, the big panacea comes, shuttle. We have got his wonderful shuttle that is going to solve all our problems. Weight is no problem. All of a sudden, weight is a problem. So, we are pressed back into weight. They keep nibbling away at us. We feel very uncomfortable with it.

Would we like to find new technology? Yes. I would like to do it here at Goddard. I would like to see new technology flown on the spacecraft here at Goddard. I was encouraged to see that Fred Betz has got nickel hydrogen into orbit. I hope it works.

BETZ: I cannot do it alone.

PADDACK: However, that is the kind of thing that we are into. It is a trap. It is a dilemma situation.

BETZ: It is funny. I think I missed only one of these workshops and that was the first one, so I have been here a long time.

This is not a new problem. It was a problem when I was working with batteries 10, 11, and 12 years ago, getting new technology on. And the problems have been the same: It is developing the data base.

We, at NRL, together with Comsat Labs, did get nickel hydrogen flying without a data base, without a voluminous data base that is required for most programs. We did it with a backup system with nickel cadmium to back up the nickel-hydrogen system. So, that made it relatively easy.

Also, I represented the project officer at the same time I represented the people responsible for the power system, so we could do pretty much what we wanted to do. We had that kind of flexibility in our organization.

Comsat Laboratories had developed the technological element, and we, together with Comsat, aggressively said, "Hey, we want to fly this stuff." It was not a case of the project office saying, "We don't want to fly it." Or, "We are afraid of it." We went after it aggressively, and that is the difference.

However, when we proposed NTS-3, we said, "Let's leave the nickel cadmium battery off. If we are going to fly just nickel hydrogen, we are going to make it failure-proof. We will put bypasses on the cells." And our management said, "Wait a minute. The last one worked so well, we are not going to change it." NTS-3 got cancelled.

But it is amazing how the inertia of the system developed through one program. "You flew nickel hydrogen, fly it again, but fly it the same way, don't change anything." And money came into the picture. We did not have the money to run a new development program for bypass.

I think that new technology will come in where it is mandatory. The Galileo program, perhaps, will force the lithium system into spaceflight. Where the needs are mandatory, yes, you will get it; where the needs are not mandatory, alternative approaches today seem to be the way to go.

Now, the only way around this that I see is for the organizations that do technology development sponsor it. The organizations that launch spacecraft which are the same organization, primarily the Department of Defense and the Air Force—pardon me, the Air Force and the Department of

Defense—and NASA, who do the technology development and end up primarily responsible for flying spacecraft to force the issue in technology development. I will propose that those people target these new developments directly into their future programs and force them along.

You are saying that there is a cost benefit in the future for these programs, for this new technology. The cost benefit is in the future. The corporate payoff is in the future for NASA and for the Air Force. But, you guys don't want to invest the dollars for the program manager to bring it along into his program. He says it costs too much and it is a risk.

Take the risk out by funding the development from the technology right through the flight, to the flight on a given program. Then you have bridged the gap.

KIPP: When Floyd asked me to sit on this panel, I somewhat got to reminiscing, because I can go back to about 27 years into the mid to late 1950s when we started in the early ballistic missiles programs at the General Electric Company. When I started thinking about this and thinking about the change in atmosphere and the climate that has taken place between those days and what we are looking at today when it comes to flying hardware.

I am sure that anything that any one of us will say here today will be an oversimplification of what the problem really is. When each of us in his own way and in his own shop tries and finds ways of convincing program managers to fly different kinds of hardware, it seems as if we had lost some of the spirit of adventure.

Back in those early days, it was not a matter of having to develop so much of a data base. It was finding something to fly. Finding someone who could make something that you thought might work.

Well, we did. Earlier our goal was, "If I can get something to fly for 3 months, that would really be neat." We found something that would fly for 3 months. Then, we flew 3 months, it lasted 6 months, it lasted 3 years, and we were very elated.

Also, in those days, there was lots of money available. Program managers at that time were not so profit-oriented as they are today. They were success-oriented, as far as getting something that would fly, and fly and last for 3 months or 6 months.

Today, the climate is totally different. Speaking from the commercial end of the world if you will, at TRW, where we are in the business to make a profit and to have successful programs, the climate has truly changed. Today, you have to be a darned good salesman to convince a program manager that what you are proposing will work and that it will work successfully.

We have gone through this stage where we have been flying nickel-cadmium batteries for the most part in supporting low-Earth orbit and geosynchronous kind of orbit missions, and we have got them working for 5 years, 6 years, and in the area of 7 and 8, even though there have been a lot of problems come along when we get to the 6-year and 7-year point.

As Fred said, it has been working, you face a program manager with a silver hydrogen, nickel hydrogen, or something else, and he says, "Prove it to me fellows. You know I got something that works; I know it worked for 7 years or 6 years." You have got to be a darned good salesman in today's climate. You have got to start your selling very early. You have got to sell. If you are working with a government agency, try and sell them on the idea that it is a feasible idea; if you develop the necessary data base, it will work. You carry your selling right along.

You sell in-house people; you sell your own functional management to get the money to start something, to develop the data base, to buy the hardware; and then you start working on the program manager end of it.

Right from the beginning to the end it is a matter of convincing someone that it is a good idea, that it will work, and that the payoff is there.

PICKETT: Along the same lines, I would like to mention that in selling the technology sometimes you get so enthusiastic about it, sometimes it is oversold a little bit, and it is sometimes hard to live up to the expectation once you get some real test data on the article.

It is very difficult to develop a data base for new technology. Most program managers want to see real time, live testing on the component or cell that you are trying to introduce into their program. This is not always possible. By the time you get the real-time test data on the thing, the technology is almost obsolete to satisfy some people anyway.

Really what is needed—the Air Force and NASA have recognized this for quite some time—is accelerated testing, so one doesn't have to go through the arduous process of going through the real-time test every time you want to put a new battery, cell, or whatever it is on the spacecraft.

We, at Hughes, are still continuing in this line. We have got some accelerated testing going in our R&D, and we continued to watch with interest the research that goes on with the NASA program.

Accelerated testing has got a bad name in the Air Force to some extent. When I was with Wright Patterson, it was very difficult, if not impossible, to sell anybody on an accelerated test program for nickel-cadmium batteries. It was only with NASA's cooperation that any kind of a sizable program was developed and proceeded with.

Generally, everybody uses accelerated tests. But trying to get government agencies to fund them, because of all the money that has gone into it, is sometimes difficult.

Changing the subject just a little bit, my experience, mainly with new technology, is trying to introduce electrochemically impregnated plates into nickel-cadmium batteries. That's where I started out.

If the nickel-hydrogen system had not come along, we might still be struggling with it. But, it was found out that this type of electrode was ideal for the system. The point I am trying to make here is there has to be a definite need. We have to have some kind of driving force to get the new technology into a system. Just because it is an improvement, it will not happen. There has to be some type of driving force or basic need to get it done.

MASSON: I guess I would like to make a couple of the same points that Fred did.

When you are trying to make a transition from the new technology, any kind of new technology toward flight hardware, there are a couple of different paths you can take, ranging anywhere from government or industry-funded R&D efforts, to direct funding by the user program.

Of course, the path you take depends on awful lot on the technology that you are looking at. Technology has to be evaluated in terms of the potential benefits, development costs, and the risk. If the potential benefit of a given technology becomes essential to meet the basic requirements of a particular program, then, in a lot of cases, you can expect the program to pick up the responsibility and the cost of funding that technology development up to flight status.

A good example of that kind of development effort was the development of the battery in the Viking program. By international agreement, there was a requirement that the Viking spacecraft had to undergo heat sterilization at 135°C before launch to prevent contaminating the Martian environment. The Viking program undertook the development of a nickel-cadmium cell that was heat sterilizable and was successful, I might add. Those cells are still operating after 3½ years on Mars.

The same kind of technology development that is funded by our program organization might be applicable, as Fred mentioned, to some of the new lithium systems in which the stand life, or the extremely high energy densities that are potentially available, might really become essential to meet some of the new requirements.

Other kinds of technology development, such as improvements in nickel-cadmium systems or the development of metal-hydrogen systems, face a little bit different problem. In a lot of cases, their application is not essential to a given program, so the program will tend to evaluate those in terms of potential benefit versus risk. And, in a lot of cases, what they are doing is competing with existing "flight-proven" hardware designs. That becomes another kind of a problem.

I guess the point of all this is that there are a couple of different ways to get from a new technology system to flight hardware, and you really have to look at the individual technology to determine what the right path is for that development. In some cases it is easier than others, and again it depends a lot on how necessary or how much a given program hinges on that technology.

VAN OMMERING: I would like to use my few minutes to illustrate this whole question with an actual example that I am involved in at Ford Aerospace that has to do with bridging the nickel-hydrogen gap.

They have taken a system here that has been proven in the lab quite a few years. As we heard earlier, Fred Betz had the guts to put it on NTS-2, and it is working there really well. So, we are looking at a situation in which we have a reasonable data base that allows us to seriously consider doing something like that on an actual working commercial spacecraft.

Fortunately, Intelsat decided this was the time to do it, Intelsat 5, for some late problems and other improvements that we would like to see, particularly in the lifetime of the spacecraft. It was decided in the middle of the Intelsat 5 program that we were going to try to introduce nickel hydrogen as a sole energy storage system on the spacecraft.

Now, Intelsat took the approach of making essentially a near-zero risk situation. We are now involved in a program of developing nickel-hydrogen batteries for Intelsat 5, but at the same time we are committed to building nickel-cadmium batteries right alongside it for the same spacecraft that they are going to put nickel hydrogen on.

That's rather an interesting situation because it takes a bit of the pressure off the schedule requirements. If nickel hydrogen has some technical problems that you still need to solve, we have the option of slipping it on the spacecraft and using nickel cadmium.

It also takes the pressure off entirely in the area of technical success. If a real snag develops, you have the backup system there and you can put it on the spacecraft at a fairly late stage, a few weeks before launch.

So this is really an ideal way to bridge that gap. All that it takes is a lot of money and a lot of confidence on the part of the eventual spacecraft user. I think, in the case of synchronous spacecraft, the payoff appears to be large enough in terms of added years of operation and added general reliability, as well as the weight advantage that we have in nickel hydrogen, that it is worth the $5 to 6 million that Intelsat has pumped into this program or is going to pump into this program and bring it on line.

When you consider the payoffs once you get into Intelsat 6, 7, and on stage, I think a general approach to this new technology is to look at those benefits very simply in cost terms. If we can lay some money on the line right now in the development of a usable spacecraft stage, there are tremendous payoffs in the long run.

In some cases that may not be true, and I think that has got to be based entirely on that sort of an argument.

BADCOCK: My comments are really from the end user. You have something that has been developed, and you have to find someone that has the need. Having done that, you have a sponsor. I am going to address some of the questions that sponsors are going to ask and expect to h ve answered. All of these are, again, motherhood statements. They do have a lot of bearing on how happy he is going to be with whatever your new development is, and he is willing to pay for it.

I guess the first thing is, you know he needs it, that is why it is there. He should understand that he is going to buy the pain that is involved in bringing this new development on line. It is not the same as the last one, it is new. There are going to be a lot of little things around that are going to give you at least intermittent grief.

So, what does he expect to see? Well, we have talked about the demonstration base. That is very important. But included in that you need to be able to demonstrate what it is going to play with the rest of the system, whatever it is. If you have a battery that works well, why you should also be able to demonstrate that it is going to interface with this system properly. So, between the system and the batteries, they are not going to kill one another, either immediately or several years downstream.

The sponsors also should ask for the failure mechanisms, and you should be able to tell them. You cannot say, "Oh, it doesn't fail." You should be smarter than that. So, you should define these failure mechanisms. You know how it is going to fail, but still it is a better product.

I guess the two final things, early in development you want to start talking about are aerospace quality specifications. It is your development, you built this, you built that, and so on. But, as you come along, you really should start considering aerospace or flight quality specifications to be written in the program and things to be built to that, and not let it come after the fact. This adds costs. All these things add costs, but they are really important if you want to demonstrate to the end user that he should buy your product.

Along the same line, you want to get a manufacturer into this. If you are the manufacturer, great. But you want to get the manufacturer into this at an early stage, so you can demonstrate you can make a lot of them, or as many as are needed.

Other than that, I think those are the kinds of things that you wish to get from the standpoint of the guy who is going to use it in the end. These are the things he wants to see to demonstrate that this is a better mousetrap, or whatever.

NAGLIE: Let me go way back. I represent the technology end. Our workhorse system, the nickel-cadmium system, has not yet been characterized from the inside to the point at which you can design a battery for a particular mission.

In the beginning, they flew many NiCad cells for 20,000 cycles at very shallow depth in low-Earth orbit. There comes a time they put it in synchronous orbit, and they got into trouble. Why? There is no actual data base system from the standpoint of how the electrodes are impregnated, whether they are impregnated fully or shallow, or what kind of current densities any particular electrode will stand.

The batteries themselves are not designed for the mission. Even in the workhorse system, the nickel-cadmium system, we do not have that data base.

The technology end of it has not developed it, and it is not that hard a thing to do. It has been rejected back in the 1960s several times, and I am mad about it, of course. But, let us go on to future systems.

I still think we need the NiCad data base, and we should develop it for any given method of impregnation in the electrodes and any given method of making the electrodes. It is only a matter of doing the work and building a character box. All right, we are going to fly this mission; therefore, we need this nickel electrode, this cadmium electrode, and this separator.

Probably it is as extensive as the accelerated testing program, but it still is not available and it should be if we are going to fly NiCads.

Now, going back to getting the program manager to accept new technology, in the NASA organization, we failed several times with new technology. We failed the silver zinc getting on the Viking. That was a little problem with economics. We do have a silver zinc cell. Some of them are still alive now after 11 years being sealed and sterilized. It is a new separator development that we worked out at Lewis.

The thing that has to happen for new technology to get on a mission is at the time, even before the mission is approved, when it is conceived with mission analysis people, the technology people have to be informed of it and develop a parallel technology program so that they have the data base. When it is approved, now they have the data, and they can convince the program manager that this is the electrical storage system that should go on a spacecraft. It takes a lot of data to convince the program manager. Not just the NASA program manager but the industry program manager has to be convinced.

KILLIAN: As technologists, we work on new technology for a long time to try to get it into spacecraft. As has been pointed out, the program managers are reluctant to receive it. So, we think, my God, something is wrong and we should be doing something else. I would like to inject the thought that perhaps nothing is wrong at all and that we are perhaps more enthusiastic than we should be. It is just nature taking its course. It is difficult to get these things into the spacecraft.

I would like to quote a famous saying by Lou Gomberg at RCA. He had an Air Force DMSP program. He says, "Better is the enemy of good." Whether he is correct or not is based on a lot of experience. So, I would just like to inject that thought. Perhaps I don't think it is wrong at all.

GROSS: I would like to say amen to the remarks of Bill Naglie, and perhaps restate some of the things he said and build on what he said a little bit.

Certainly, making the transition from old technology to new technology has its own set of problems. But, in general, they are usually able to get this work properly funded. Possibly not at the rate we would like, but we are usually able to get new technology aboard. The problem is to avoid making the same mistakes in new technology that have been make in the past.

The nickel-cadmium system, for example, has been in space for 20 years, and we know very little about it. We do not at this time have any formal methods to characterize electrodes for this system; we cannot tell good from bad; and we cannot find any way to determine if electrodes made from one batch are the same as another batch. But we have many problems with this system continually failing prematurely. And, year after year, the government research decisions take the view that the nickel-cadmium technology is a developed technology, it is established, and there is no need to spend more money in this area. So, very little research gets done.

The Air Force, for example, sponsored Dave Pickett's work. But, right at the point when he got to start learning a lot about it, they cut off the basic research.

NASA Lewis people have always said that more basic work is required in the nickel-cadmium area, but they have never been able to sell it to get it sponsored. It has not been recognized as an important area.

I am pleased to see Lou Slifer's summary today, pointing out the great need to get more basic understanding of this old system. With regard to the data base, the data that is needed is not simply cycle life data, but it is also basic understanding of the old system.

OTZINGER: With regard to the data base, a lot of companies have, I think, their own data bases that they consider to be somewhat proprietary. I think there is a data base. Unfortunately, it is not generally available.

One thing that maybe would pay off in a workshop much like this one is that we could identify some of the kind of characteristics we are looking for in R&D. You could have people present papers pretty much one area, and the data base becomes generally available.

I think, my comment there again, there is data around but it is not accumulated by any particular source. What is needed is someplace where everybody can go to say, "This is our data base, an agreed-upon data base."

No one wants to believe anyone else either. We do our forecasting in our lab and say, "Well, it means something over there, but you know we don't believe everything they do."

So I think, if we could bring up data here in a particular area, say nickel hydrogen, for example, cycle life, each year we would have four or five companies all testing. Like the Air Force, they have Applied Physics Lab (APL) WPAFB, and made cells available to a lot of different companies to test. Now, if each one of those companies were to test somewhat the same area and then present the data, we could sift through it and say, "Okay, this is what we agreed is the acceptable data base."

Another comment is that with regard to flying things and saying, "Well, we have flight history." I think we have an opportunity in the near future of putting experiments on the shuttle and actually conducting tests, going up there and having a dedicated test that would demonstrate the feasibility, demonstrate that you have a workable system.

I suggest this now to the NASA and to the Air Force, to people that present the money for this kind of R&D work.

Now, as I say, that is a suggestion and that would be one way that you could get on lithium. You would get some of the more controversial systems up there, you could get some data, and everybody could see where you are.

KIPP: I think Burt has got a good comment when he talks about the fact that we all do our own thing.

I have been coming to these workshops for a long time, and I propose we have another gap: the gap I see is the gap between people and all the different government areas and industry doing their own thing, but having a reluctance to sharing that information with everyone else.

I think we need more different kinds of meetings where we can share that information and find out how we get people to break down the reluctance to share that information with everyone else. We all do have a common purpose, but we seem to have a reluctance to share that information.

BARNARD: When you take these high risks, who carries the can? Where does the warranty come in? Is it the responsibility of the company if something goes wrong with it, or does the user pay?

BETZ: The user pays.

FORD: I think the answer to that could be twofold. But, yes, ultimately, the user does pay and the user, meaning a satellite program that has invested its resources and is willing to take a certain amount of risk. Then, once the satellite is up there, you have found out the emphasis of resources and risk was somewhat out of perspective apparently, because the risk somewhat overshadowed all the spending you did to get a successful satellite.

I might point out that I think a point we made earlier about the changes in environment, that in the early part of the program we were looking for something that worked, and today we are dealing with, primarily, two classes of satellites; those that are operational satellites that are put up there for scientific purpose. The ones most familiar to you in the audience are the weather satellites that are put up there and they are operational. They want low risk, they want cheap satellites, but they want a 10-year mission.

Now, talking about the other satellites which are scientific in nature, they are very much research oriented as the Viking program and some of the astronomy programs. And these program managers recognize there are risks that can be taken, but they usually are willing to take the risk in the instrument field, not in the spacecraft field, not in the design of components for the spacecraft.

SEITZ: Fred Betz, you mentioned the Galileo program with forced lifting into spacecraft. I am wondering what were the requirements in the Galileo program to do this, and what sort of lifting systems do you see?

BETZ: I would like to pass that one since I am not personally involved in the Galileo program. Dave Pickett is probably familiar with that, and I will pass the ball to him and let him tell you.

PICKETT: I think the reason is simply that the state of the art in batteries just would not suffice to complete the mission.

Now, as far as the batteries themselves and that type of thing are concerned, we have a gentleman here from Honeywell who is going to talk about the cells and that type of thing later on in the program.

That is the best answer I can give you in a nutshell. Stan Krause has been running the Galileo program at Hughes. I have not been involved with it. When I took over as head of the section, that program was split out with Stan paying personal attention to it. So I haven't had the opportunity to spend the detail with it that I would like to give you a more specific answer to your question. But, you can talk to Stan, and he can fill you in on the details.

LEAR: I would like to voice a couple of comments that the panel had brought up about the low risk in the NiCad system, and also the low cost of flying a NiCad system on board the spacecraft.

You have to be a very good salesman nowadays when you are working proposals for spacecraft applications. You go to your program manager and say, "I would like to run an on-line test for a peculiar situation we are in," or the test that is required to substantiate flying a spacecraft in that particular orbit that you are working on.

Because of the data base that we are supposed to have with the 20 years of background testing and all that we have done on NiCads, the program managers are not willing to support our cases now, and they say, "Well, new technology is coming along. Nickel hydrogen has got a zero data base. But we have got NiCads that have got 20 years. So, we don't need to run a test."

Therefore, the cost is out. No more testing. You have got a data base. So, we have to educate the program managers as well as the customers because he is also trying to cut down when you are substantiating a data base.

HALPERT: When the technologist attempts to sell his product to management, he has to speak from a position of strength. I will have to allude to another gap that we have, and that is between the scientist and the technologist.

There are 100 papers on the nickel-hydroxide electrode, and yet we don't go back into the basic data to understand how the nickel electrode is working. All we want to do is keep testing the batteries, keep testing the cells.

It is understandable how some of the project managers can look at that and say, "My God, another test program. What are we going to get out of it the next time we buy it as something new?"

So, I think we need some interpretation of people from the basic sciences, the guy who is working at the microelectrode level on up to the hardware item, to extend that technology or to extend that science to the technologist so that he can then speak from a position of strength.

NAPOLI: Among the users and manufacturers of various agency representatives that we have here, there is a wide data base of nickel-cadmium cells that exist, and there is also a wide variety of types of cells that have flown. So, you have a big choice of cells in the data base to look back on in history. I think you will find if you look at the various programs, Air Force and NASA commercial programs, you will find that some cells are performing better than others.

What I haven't seen come out, except at a last SAMSO workshop, is that there was a general agreement as to what should be done to improve the longevity and reliability of cells. I don't see coming out of this, particularly the Goddard battery workshop, people getting together and saying "Look, that company, that group, or that agency did something right. What did they do that is different?"

Okay. "Why don't you try to investigate that, and if they are doing something that is right, how come we cannot do that?"

I think the problem why that does not come out is the old "NIH Syndrome" that seems to prevail throughout the industry. Not only is it an "NIH Syndrome," but there is also a feeling of pride and sensitivities in some of the programs that exist. One company does not want to exchange data with another company. There are many users here who just don't want to show their data until maybe 8 or 9 years after the program is past and gone.

So, I think the problem you have to overcome is the "NIH Syndrome," for one thing. If GE has a power system, TRW has a power system, and Hughes has a power system, some way you will see some of those power systems – when I say "systems," it is ultimately a system problem – are working better than other spacecraft or other programs. And yet, someone does not go back and say, "What are they doing different?" "How come we don't do that?"

Again, it is the old NIH problem. So, I think we should all take a little bit, sort of an in-depth look at what we can do to change that. Unfortunately, it is beyond us on the working level. It is more on the corporate level that you have these resolutions come to a head.

GASTON: I heard the comment made by several gentlemen this morning of use of accelerated testing to build up a data base relatively quickly.

I am all for that. I would like to caution people. You have to be able to correlate it with real-time factors, degradation rates, and so on, because there have been some real wrong conclusions drawn based on accelerated testing. We have to understand the mechanisms which occur and possibly correlate them with the component degradation inside, or compare very carefully with real tests, because that is a dangerous road.

SCHULMAN: I would like to propose a question to the panel. You know we hear quite a bit about battery anomalies. Unfortunately, the only channel most of us hear about these is through the channel of industrial gossip.

With all these battery anomalies that seem to exist, I would like the panel's opinion as to whether they are caused by an inherent fault within the nickel-cadmium battery itself, or an inherent fault with the system engineer who has applied his experience to the utilization of this battery.

FORD: That is a big task. Which of the panel members would like to field that?

BETZ: I will take that. Irwin, you have really got a good question there. But let me say this: Somebody mentioned very early in the sesion, I think it was Sid Gross, who said that years ago we flew batteries and they got 20,000 cycles on them. And a lot of batteries got 20,000 cycles. They only expected 6 months and they got 18 years, this kind of thing.

What is different between then and now? The batteries have improved; the power systems have improved. The difference is that management thinks we can use the batteries more and more. They are forcing the engineers to 80-percent to 90-percent depth of discharge. They are forcing more cycles at higher depths of discharge, and the battery engineer really has his back to the wall.

That is the way I feel. The battery fails because you push it too far. You have to understand the limitations of the battery because you cannot change the battery. You have to understand its limitations and to work within its limitations. If management pushes too far, it is going to fail. So, we have an anomaly.

KIPP: One thing about Irwin Schulman is that he knows how to ask the right questions. There are many paths for the answer to that question. If you are looking at the military that has a requirement for a spacecraft, one of their requirements is that your exposure to it, your availability to look at that spacecraft and to look at what it is doing is extremely limited.

They want a spacecraft that will fly virtually hands off, so you design systems that will do that job. You work with all the power system people, and you come up with systems that will do that job. Maybe 5, 6, of even 4 years later you will find, "Gee, there is something we didn't look at because we are not all instantly superintelligent. We designed systems 5, 6, and 7 years ago that we thought would do that job. We are finding today. . .," and here are specific references to anomalies. "We are finding we didn't know all the things that we should have known or would have liked to have known about how to use those systems in that kind of mode."

Now, you look at the other side of the coin where you have scientific kinds of satellites, a lot of them are operated by NASA where you can look at them constantly, 24 hours a day. You have on-line programs to look at the data; you have off-line programs to massage the data. In many cases you will not have the same problems with the spacecraft you can look at 24 hours a day, that you have with those you cannot look at.

So, we have more than one kind of problem here that we have to address.

FORD: Yes. In response to your question, Irv, I might point out that at the workshop there was a broad cross section of reasons for the problem. There was no one area that we pointed out that we don't understand the technology as a specific cause. When you look at it, there are many reasons that we have problems in orbit.

One of the things that was mentioned early, and I believe Chuck mentioned this, I believe it should be looked at. This is in light of the data base that we have. We are comparing what we are doing today, what we have done in the last 3, 4, and 5 years, with what we did 10 or 15 years ago.

Sure, there is a whole wealth of information or data based in the NiCad field. But, the question you always have to ask yourself is, "How relevant is that to what I am doing now?"

And that is where the real clincher comes, because you find out that, by and large, there have been changes in the manufacturing process; maybe a manufacturer has totally relocated his plant; and we have people who get involved which also affect the builder's ability to produce the product.

Getting to the economy, Chuck, I believe it was you who said something to the effect that perhaps early in the program, "to establish the confidence, you need to start even a development program or research program" – more specifically research – to start doing those in the area of quality, make sure you have got someone to manufacture the technology you are looking at. Don't wait until the project manager says, all right we are ready to buy, and then say, "My God, who have we got to make this thing now."

I think there is an area there we have really got to be sensitive to. In other words, you can do a lot in the R&D labs, but bring along the capability of a manufacturer to transfer or to infuse in that manufacturer the technology and development you need later.

BADCOCK: May I comment? First I would like to answer Irv's question. Yes. One of the things we have talked about here that needs to be pointed out, there needs to be a trade-off between fundamental understanding and testing. I bite my tongue here because I like the fundamental understanding. But, you can only trade that so far. People talk about, you know, if we understood everything, we would not have to test. I don't think that is true. Nobody is going to buy that.

So you have a region in the middle here with testing on one side and fundamental understanding and research on the other. You have a region in the middle where you can move these back and forth. So, I think, with NiCads, we are pretty much to the testing side at this point because we keep changing these things.

BLAGDON: The Galileo program is using a modular concept in its battery design power environments. That has already offered some system flexibility to the systems people, design flexibility that would not have been there had we selected or chosen a singular battery package for the thing.

I like the comments of the panel relative to the modular concept to power systems design. With respect to establishing a common data base industrywide, I think it has some definite advantages and has some system flexibility.

One other comment I would like to make is that the current Galileo program has been stretched out. That stretch-out gives us the opportunity to establish some real-time data that we did not have in the original program which, we believe, is going to lower the risk on the overall program.

So my comment basically is that time and sponsorship are also very, very critical in establishing this data base that we are looking for. You can accelerate test programs, but absolute confidence from an end user who does not necessarily fundamentally understand the system is only going to come with some real-time data.

But I would like to comment relative to the modular design concept, relative to establishing a common data base.

FORD: I would like to summarize. I think we have heard a large variety of inputs, all of which have to be taken collectively. And it may well be that we, in the technical field, have the same problem that you find in management by the mall distribution principle. That is, basically, you only have 20 percent of the information you need to make 80 percent of the decisions you have to make.