PANEL DISCUSSION

Panel Discussion

Panel Chairman: A. Rosen - TRW
Panel Members:
E. C. Whipple, Jr. - University of California San Diego
S. E. DeForest - University of California San Diego
S. P. Bower - Aerospace Corp.
R. R. Lovell - NASA Lewis Research Center
N. J. Stevens - NASA Lewis Research Center
M. L. Minges - Air Force Materials Lab.
W. L. Lehn - Air Force Materials Lab.
M. H. Bunn - SAMSO
J. M. Sellen, Jr. - TRW
C. P. Pike - Air Force Geophysics Lab.

THEME

In view of the data generated on spacecraft charging, hbw should program and project managers Proceed with the design of synchronous spacecraft add verify thetr design?

TOPICS

What analysts tools, standardized design criteria end requtrements, standardized environmental specifications are required?

Spacecraft Testing

What, if any, specific tests should be instituted to assure the integrity of the design and immunity from environmental effects?

Housekeeping Monitors

When should an operational system carry housekeeping monitors and what kind?

Laboratory and Space Data—

What additional material and environmental data is required for Spacecraft design development?

Panel Member	Discussion
A. Rosen	The theme of this discussion is that in view of the data generated at this conference, and prior to this conference, hbw should program managers ahd project managers proceed with the design of synchronous spacecraft and verify their design? Progress in this field has been significant; in the area of spacecraft design and fabrication, in the area of spacecraft testing, in the area of housekeeping monitors, in the area of laboratory data, and in the area of space data. But are we really doing enough? Are there gaps in our coverage? We have been exposed to conflicting bits of data at this conferehce. How should we proceed in the future? The first person to reply to our theme questions is Sherman Depot-est who is going to tali; about the environment.
S. DeForest	Okay, I have approximately five minutes, I guess. I have three paints that I think are rather important. One is that just at this meeting, I got my first look at data we took this Spring with the ATS-6 heutralizer. In other words, we are still getting new data and scratching our heads. The data base is incomplete. GEOS going up with our European colleagues, arid SCATHA going up; I think that will really help. The main point is that the data base is incomplete. The second thing is that even wtth the data base that we have, two days ago I had put out my ideas of what an acceptable model or environmental specification should be. I

have been trying to talk to everyone I could out here to get some feedback on what they thought. The readings I am getting, loud and clear', is that there are a lot bf engineers whb do not want a good model, rather they need some numbers right now. So on the tape here I am going down on record as saying I will switch my efforts €orthe present time to getting out a short term, better grade interim model which will be relatively simple, of limited use, but. will have some numbers to work tb. I think this is one message I Have gotten back from you people. The third point is one that I feel was missed, and it has to do with the theme here; that is, future directions on where to go. There is only one paper whith really mentions it and that is the spacecraft have changed state. I am going to make a weather analogy. We know how to build houses that would survive tornados or earthquakes. It is not cost effective tu build these kind of houses. You can't put all military bases under Cheyenne mountain. I think the same thing should be true bf spacecraft. We need a prediction capability, and I don't think anyone here has considered that. I deliberately avbided that, myself, to hear What other people thought. But I think we should get some ideas toward using the advances that we Have in magnetospheric dynamics, our understanding of it, to set up a method of predicting. I think with the state-of-the-art, right now, if we want to do it, we could get twenty minute warnings, without too much trouble. If you had this soft of system on line, theri you cotild have ybur spacecraft send up a com- - mand to it and say a storm is coming, shut yourself down. This might be a lot cheaper in the long run then having the spacecraft itself sense that something is happening. You mtght want to do that for a military spacecraft but for communications spacecraft, I think it might be too expensive. So on9 thing that I would like to see in the future, in going along with the theme, is the idea to set up a predictive or line capability arid. then designing spacecraft that might be able to change their state and in some way be more hard, for short periods.

A. Rosen

The next speaker is Elden Whipple on Modeling.

E. Whipple

Okay, I just have three points too. I have been very encouraged by the results that have been presented here, at this conference, on the modeling. I am talking here about modeling the sheath, modeling the currents from the environment to the spacecraft that Cause a charging problem. I think that we really are making progress, and there is a t' .e-dimensional program in the works and more than one group is involved in this kind of effort. I think in the next year we shall start seeing some real good results, in this area. I realized oae thing in talking to people, the Systems Science and Software, Inc. effort is taking a first crack by neglecting space charge, and I thirik that is a very good approach. It may be a very realistic approximation. The Debye lengths are very big out in this area. It may be that when we understand the problem, that we cari neglect space charge completely. And this could be a help iri our modeling of the currents. It will make it much easier for engineers and people involved in designing spacecraft. So I think that possibility is really very encouraging and we should certainly look at that approxihiation first and see how good it is. I think eventually we ought to be able to get analytic or algebraic expressions for the currents. Now Lee Parker and I were able to do this some years ago. We were worried about a two-electrode system and we were able to approximate our computer calculations. After we had done the computer calculations, we saw a way of approximating them such that we could get algebraic expressions for the charging currehts. It is a lot easier if you have something like that to work with, to calculate what the charges are eventually going to be. I think that should be kept in mind. The computer, the exact calculations, have to be done to give us a bench mark. But once you have them ycu ought to be able to find out where to make your approximations, so you get tractable expressions that anybody car, work with to do their design with. Finally, I would like to emphasize ..... No, one more point connected with the modellng. Nobody has started working yet on a specific three-dimensional model for the SCATHA spacecraft. Now I think that is being talked about, but I

haven't heard it talked about publicly and I would ltke to go on the record as saying that should be started. It is not going to be an easy thing, I don't think. It should be started soon, so that when SCATHA does go up, we have a working Model we can go to and start using to compare the data. Okay, my final point is to emphasize again what I said in my talk, the usefulness of lab work. Again, I think this is an area that has been relatively neglected. There was mbre here at the conference than I anticipated, and especially the wbrk that is going on at Lewis Research Center is very encouraging. That way they are able to generate fluxes of energetic particles in their vacuum systems and see the effect on materials. But I think we should go beyond just looking at the effects on specific materials and put together a composite miniature spacecraft that truly represehts real spacecraft configuration, materials; and see what happens. We need to have some kind of a model to use to predict What will happen and go in and see what does happen and begin to get some confidence in the calculations.

A. Rosen — Mike Sellen on Laboratory Research and Simulation. .

M. Ssllen — I would like to address three points and one of these is the question of simillitude. This gets to be fairly fascinating when once you get into laboratory experiments and try to duplicate space. It would be a healthy viewpoint to say simillitude yes, but always in moderation. There has been one experience in combined environmental test facilities which I think is consistent; that is, that they continue to insist oh more and more simillitude, the usefulness of the facilities tends to go down, You can always ask if the cosmic rays should be there or whether the extremely hard EUVL shouid be there or a variety of things. On the other hand, it is rather clear that there are certain openers as far as this testing goes, and the spacecraft is going to operate in vacuum and it is going to operate with some kind of electron environment arid some kind of photons. I thlnk it gets to be a hard and fast rule that basically is where the test results will come. You simply will not test spacecraft In ambient air under any circumstances unless that is the

medium you intend to Fly It in. The second thing is to try and talk about what I think might be the overall purpose of a great deal nf the lob research, and I say that there is one outstanding thing that comes out of it that *gives* you a sense of perspective. If there is a single physical parameter that has a greater variation than conductivity, I am not sure right off what it is. It goes from 10^{18} ohms centimeters down to microhm centimeters. It has a variation of 10^{24} in it from one material to another and particularly when you get into weakly conducting materials, it is just a function of just about anything you can think of, particularly in what we will call weak field conduction, less than 10^{5} volts per centimeter. .And so one thing that can come out of it is the possible perception that you are dealing with a *12* parameter problem that includes all of the history, including that of the manufacturer on the night that he made the sample you are looking at. And if that is the case, then maybe one think that the laboratory experiments will try tu do is not *to* try and solve the whole problem, it may simply have too many parameters in there, but it will tend to direct the effort off into what I'll say is just reducing the problem. We will talk about tl.at in this third point. The other possibility of using the laboratory again for perspective is that I am sure there is goirig to be an increased analytic effort and already the computers are, I guess, going to be brought to bear. I think the laboratory will serve as a very necessary antedote to this. I always discovered even when I am doing it myself, that there is a subtle narcotic effect toward having the computer begin to ruh things out and, about once a day, have an experiment keep some of the perspective because the initial. assumptions of the computer program are forgotten I think within a few hours. And these are very sparingly based most of the time. The third point that I would like to discuss is the use of the laboratory to reduce the problem. I think the majority of the program offices would rather see a quick solution to a small problem than an elegant solution and a prolonged solutlon to a very complicated one, and there are all these questions about using these methods to either bring the man to the niountain and vice versa and the only

question is whether you can use the laboratory to keep this thing from being a mountain. Most of the charge up problems, the gross ones, I think the ones that could do damage to spacecraft will go away if you make the material conductive. We will always be troubled with problems of the scientific spacecraft. The major thing is to use the laboratory to very rapidly simplify the problem that one is looking at, because most of the applications here, I think, would really rathef get on to mahy other things that spaeecraft have on their agenda. Thank you.

A. Rosen — John Stevens on Laboratory Spacecrait Investigations.

J. Stevens — I would like to talk about three different items as well. What can project managers do to help their design? You've heard a couple of papers today talking about the use of sparkers and looking into the harness response. I think this type of test should be amplified; it should bé done early in. the design phases arid get away from using the flight spacecraft which imposes severe limitations. You can couple a sparker into a typical spacecraft engineering model (or something similar) and look at what goes into the harnesses. I believe this will improve the transient specifications. Anbther point is that actual spacecraft response to the environment is needed. For that you have to scale. You can't simply go ftom small sample responses to a full size spacbcraft. I believe you are goirig to have to get into testing complicated, large spacecraft models in a simulated envirbnment. Combine this with Elden's comment on developing a model to predict your performance. Then, you might be able to handle how to design the whole system without having anomalies. The last point is that operational satellites, hopefully, will be carrying monitors in one form or another. We need space data. We deed something to tell what Is going on in the spacecraft in response to the environment. With these things together, hopefully, you can build yourself a spacecraft that would survive, without anomalies, in the space environment in which it must operate.

A. Rosen — Bill Lehn on Material Research.

W. Lehn

As you have heard in the presentations in the Materials Development session, materials research and development is underway add new and modified matertals are being developed under these programs for consideration and application by the spatecraft community in the design and construction of spacecraft. There is available right now the new fabric thermal control coating type material which your have heard discussed. I feel that the application of this material offers an excellent opportunity to alleviate, at least in part, the problems of designing around some of the major spacecraft arcing problems resulting ffom dielectric multilayer blankets add solar array substrates. The other materials being developed, the modified poly-. merics, aird others are a little lodger range befo-e successful application will be realized. So, at least for the immediate future, the designers are going *io* have to use the materials that are currehtly available and design, build and test the various spacecraft systems with these materials. Hopefully, the other materials solutions to reduced surface potentials in addition to reduced arcing will be forthcoming. These materials solutions, though, will require the combined coordinated technical efforts and inputs of not only the engineering simulation and characterization group but all of the results of the classical or materials properties group being inputted to the materials program. Hopefully, by this combination of efforts, materials solutions will be forthcoming. Some of these are longer range but will lead to useful materials. Reducing the overall surface potential of a spatecraft to low values, Cy not a shbrt term but rather a longer range problem. It is not quite as simple ad modeling as some of the other problem areas.

A. Rosen

Stu Bower on Spacecraft Testing

S. Bower

Both John Stevens and Mike Sellon have made some comments on the subject. I guess a little dissension is a good thing at a meeting like this, so I think I'll furnish a little. I agree w · on testing by small discharges along cables com· ·ic· with analysis to evaluate what your deeds are and how to use this as a design tool in the early stages

of the satellite design. On the other hand, I back off a little from Mike's thought where he wnnts to tent in the ambient environment. Perhaps testing a full satellite in a vacuum chamber wtth a plasma source is a highly desirable thing from a research standpoint and to determine how this corresponds to what you can do with less expcnsivc, less time consuming test such as simulated discharges, I sort of Peel in the long run that it may not be necessary to use such ah elaborate test on 811 spacecraft as a validation test. You can learn from this and ultimately we should be able to apply this knowledge and cut the test down to something less expensive and less time consuming. Regarding the thought that you can never get an adequate test unless you test in the actual environment, I would like to make mention of the fact that this is very rarely done in any kind of system, aerospace or otherwise. You depend on simulation test, for example, in survivability of a satellite, We do not test them in underground tests nor do we test them In space. We do this entirely wtth simulation. It takes a certain amount of research and thought before you are satisfied that you have an adequate way of doing this and you usually incorporate some safety factor to give you confidence. Just one more comment along this line. Earlier this morning, one of the RCA people was talking to me and pointing out that they have two synchronous satellites up: one has been up for almost a year and the other has been up for a dumber oi months. These satellites were designed with no provisions for spacecraft charging, Nothing was done about that. They simply designed them, on what they thought were *gbod* design practices for those satellites. They have no evidence of any upset from spacecraft charging In their electronics at thts point in time, and the evidence of discharges occurring in the solar arrays, coming down through the boom, are very minimal. Those that they have had, amount to just a few amperes, perhaps 5 amperes, whic.. is certainly very small dtscharges coming down through there. The principal reason I bring thts up is I guess lhat I want to make sure that we don't go for an overkill here. Maybe they just plain lucked out on this thing. But in questioning them a little bit, they had a

three-axis stabilized satellite with the spacecraft body a fairly good Faraday cage, and I suspect also their signal lines normally were coax cables. They were getting rf protection from two sources. And the point is, if you can without any effort and research end all the other fine things, design spacecraft that wtll operate In this environment wtthout discharges, I thtnk we will have to be a little practical about it. Along this same Hnc, of course, ATS 6 is relattvely fret?of anomalies of this source. Granted, they went to some rather extensive steps for rf shielding.

A. Rosen

I am glad that someone came up with something that represents some degree of controversy, especially here in the area of overkilling the problem. We have on the panel, members who are a little bit closer to the management of spacecraft systems. I want to ask these members of the panel to comment and also ask questions of other panel members. The question, as I see it is what is the correct response to the point that Stu Bower raised. Now do we achieve any degree of standardization so that we can address the problem in a sensible way. I would like the persons who are closer to management to comment on this. Do we need Committees? Should the managers themselves participate id the program, To open this thing up, I will ask Bob Lovell, Maury Bunn, Charlie Pike, and Meryl Minges to comment on these points, Let's start with Maury Bunn.

M. Bunn

Having just come out of a program office, I think it is quite important that we include the managers of program systems, I spent two years on the DSCS program trying to get them to fly monitors and I was not successful. I think if they had been at this symposium, it might have been easier to cohvince them that these thin,? do exist and we have got to design the systems to withstand or be insensitive, or not to respond to these effects. I guess I would like to say that we should definitely tnclude the management from the Program offices, the Alr Force, in particular and I would assume that in the civilian COMSAT community, it would hold also.

C. Pike — Along tho line of what Mnury has just said, I hnvc actually been working wlth Mnury Pur a number of years in thi- area. In general, there certainly is n great reluctance to fly monitors and the prevailing philosophy has been the quick fix. Ultimately what will result from our work nnd I Peel what we really turn into the operational community has to be something rather boiled down. If our results nrc in a very complex fashion, by the time they get into the working community, our results could be lost. Unless our results are in a very handy form, we really would have missed a lot of our goal. So along the lide of quick fixes, recommendations should be to the point, but of course hased on a lot of good engineering and scientific research.

A. Rosen — Bob Lovell for comments. Do you have nny questions9

R. Lovell — I guess I am answering the question or commenting on the question or: how do we coordinate our activtties. Is that right? okay. I don't know how mahy of you know about the joint programs that the Air Force and NASA have. There is a piece of paper out that was published in the open literature. This basically describes what several of us here worked on and together it is what we call a rosd map. It lays out our plan of attack oh this problem. Part of the road map calla for a sort of a Steering Group. Again dome of the sanie people or most of us here are on that Steering Group. It was described at the AGU meeting last June 18 and its title "Spacecraft Charging Investigations. A Joint Research and Technology Program." It's a piece of paper like that.

A. Rosen — By the way I ought to mention that it's also published in AIAA as Progress in Astronautics and Aeronautics Series Publication, Vol. 47 "Spacecraft Charging by Magnetospheric Plasmas."

R. Lovell — My point is that we are trying to coordtnate this wlth every- one, The users, the people who need thts information, and so we have a Steering Croup. The Steering Group has set up working groups. These working groups are identified. I guess we are the only ones who know thelr names right now; but basically they are tho people you have heard talk

and they fit into the five elements that we have broken up the problem into. The definition of the environment, is chaired by Lt. Hank Garrett. Modeling which is cochaired by Al Rubin, ana Carolyn Purvis. And so on, So we have these groups of people. What I encourage you to do is get better acquainted with the working groups. Now we have asked them to go out and consult, not odly with the Air Force and NASA peaple, but the university people and industry that is working on this problem arid making the contributions and also the European communities. I would encourage you to contact them. If you have some thoughts and if you think that this effort is nbt going the way it should be or should receive different emphasis, contact those people, because we are looking to them to give us planning direction arid we are trying to get the resources and try to make sure this whole thing keeps going. We on the Steering Group all keep talking to each other, but we are really looking toward the working groups So I guess my answer is that we are trying to coordinate it that way and maybe now I have told you that the groups exists, you can contact them and get your inputs in.

A. Rosen — Merrill Minges oh Materials Development.

M. Minges — From the material development view, I am both encouraged and discouraged by what I have heard the last three days. Encouraged in the sense that we are learnihg a lot of new things about materials, but like the planetary probe work, for each question we answer in the process of testing we raise two new questions. This situation develops from what Mike Sellen was saying about the multiplicity of parameters that must be at least considered if not actually introduced in experimentally evaluating and characterizing the Materials for spacecraft use. Thus, I would ask the question of either the people who develop the materials and run the tests on them, the characterization tests, or the spacecraft designers: "Can we come up with an agreed upon list of parameters and evaluations that we ought to be conducting on materials to assure dependable system design?" Can we standardize on the tests that we should be performing so that they will be reasonably complete in

a physical principal sense, but not get into overkill In terms of time and resources required? Another issue relates to the level of materials development funding, because I feel we are somewhat out on a limb in developing electrically conductive matertals for spaceeraft systems. The funding is very marginal in my view relative to the risk associated With the developments. I think that conductive paints is one typical example. I don't feel in the near term that we arb gbing to get a conductive satellite paint that has anywhere near the desirable thermal control characteristics that we would like. We can always find a conductive black paint or a green one but you pay for that in terms of the heat load you pbt into the satellite because these are not optimized in thermal control terms for example. In bur Air Farce interagency deliberations with NASA over the past number of years, the net result is that NASA-is looking toward the Air Force to put most of the funds into materials development. Well, we have responded positively, but it is a modest sum, overall. Further, in assessing what is gbiag oh in Europe it is my opinion that there is very little materials development.worh there, although we are looking more closely. So again, I feel that we have only a modest amount of funding considering the magnitude of the problem, and I hope that this funding in materials develbpment isn't swamped by the complexities of the testing data that is required.

A. Rosen — I would like to open the discussion so that panel members could ask other panel members questions first before opening it up to the audience. Charlie! Pike had a question that was directed to Eldon Whipple.

C. Pike — In your comments with regard to requirements for a model for SCATHA, to what level of geometrical detail do you feel we should go intb to accurately model the spacecraft configuration. What level of mathematical detail is required, in your opinion, for this modeling.

E. Whipple — Well, I haven't really thought about that. I guess my intuitive feeling is that, as you know, SCATHA is e very complicated satellite. It has lots of booms, a very long antenna for measuring electric fields, several shorter

booms for measuring sheath arid spacecraft related electric fields, and a magnetometer boom. I think that we should-have something that is realistic enough, that the rough surface features are represented. It should have booms in Some crude sense, the antenna, the magnetometer boom and It should also simulate the surface, the gross surhce properties. You know where there are insulators and shbuld represent with an insulating mbdel and, where it id conducting, with a conducting niodel. Nut in the centimeter scale perhaps, but certainly on the ten centimeter scale.

A. Rosen

I have a question appropriate to this topic. During this conference we heard models described that ran the whole gamut from simple circuits, lumped circuits, to very elegant three-dtmedsibnal, dynamical computer codes that simulate the trajectories of particles coming in. Are the simple Models at all valuable? They are much easier tb operate at this time and very easy tb discuss and analyze and know what you are getting. Are they worthless? What is your feeling abbut simple models at this time?

E. Whipple

Well, I think simple models are very valuable. They serve tb illustrate the basic physical processes that are going on. They serve to eliminate processes that are not there and help you to get at the right ones and in the wbrk that I have done in the past where I have had to worry abbut low energy particle measurements, it has always surprised me how well a very crude model can describe the data. For example, I showed a slide in my talk where I had electrbn ctirrent as a function of voltage. Well, I used the Debye potential to mbdel the potential distribution around the sphere. We know that is not an accurate solution, but it fit the data extremely well. And looking bhck on it after we did it, I think we Can explain why. But certainly the very siniple representations, I think, can be very useful and surprisingly good in those cases.

M. Bunn

Elden, in considering the SCATHA vehicle, in particular, to get a first order effect approximation, let's say, what effects do you think we could assume away? I see; that we Have to run the simple models to try to get to the internal

response of the system. And I also think that we have to do some extensive in depth modeling so that the experimenters will know what is going on in that sheath region. The problem is that it is going to happen in reverse. If you have the all-up modeling to show you which were 2nd and 3rd order effects, then you could go into the simple modeling and db it right. Is there a way of coming up with the 2nd or 3rd order effect without the all-up modeling so that the simple modelihg can be conducted now when you need it? And then have the all-up sheath modeling, what you call 3-D modelling, continue in the future.

E. Whipple

I am not sure I understand completely what you are asking, but I think what I have in mind is, first of all, when SCATHA goes up, Joe Fennel for example, is going to have his booms out there to measure the sheath fields. Well, I think the zero order thing we need is the geometry. That sort of determines the gross features of the electric field pattern. Now we need the geometry arid we would deed the surface properties, I think that kind of a 3-D model, you know have 3-dimensions with real geometry but neglect spaee charge and don't worry abbut effects of photoemission oh the sheath or even effects of the plasma, the environmental plasma, on the sheath. I think that will probably give a pretty good representation of gross electric field configuration. Now, we are not, I don't think, even at that point yet. We may be close to it because if you neglect space charge it reduces to just solving Poisson's prbblem for complicated geometry and that shouldn't be too hard to do. Arid the next step would be to put in the particles and merely see where they go, to track them from their source through the system and then back out again or to wherever they go. And that will give you a feeling for the look angles for the instruments. You know, what are they seeing when they look into a certain direction. And that is the first question that experimenters wtll start asking; when they see particles, they Want to know what it is that they are seeing. Are they photoelectrons, are they environmental electrons, where have they been accelerated? And that kind of question you should be able to answer with this kind

of a simple, simple in the sense that it is not self consistent, but complicated in the sense that it really represents the geometry. But we knob how to solve that sort of problem. Does that answer your question?

M. Bunn — Yes. I have just been trying to get a handle an how we go about this whole mbdblihg technique, and the way that I see it is probably about what you described where we take a relatively simple model to find out how the vehicle is going to respond, as soon as possible, Some ground tests should then be performed in brder to understand it more when it gets into orbit and to verify this model, and then to continue in the more complicated modeling for the experimenters.

E. Whipple — Yes, I guess one thing that I should add here. My viewpoint, I thihk, probably represents pretty much those of the experimenters where we are more interested in the science of what is going on around the vehicle and nbt ta first order in anomalies in the spacecraft. Although if sbmething happens, we are going to be very interested. But the kind of modeling that I described may not suffice for getting at when discharges wbuld occur. So that may not be sufficient for what you want eventually, brit I think that id what the experimenters want to analyze their data.

A. Rosen — I'll recognize Bob Lovell at this point. Did you want ta ask a question?

R. Lovell — I would just like to say something and get everyone's response here. When we ask a question about how much is enough in anyone of these areas, whether it is modeling, materials development or whatever, I would like to thihk of the spacecraft charging problem in terms of how it manifested itself. There are four-levels that I see. The first thing that we see is EMI. And thdt is an immediate problem and I thihk one that is on the top of the pile. That is the first thtng that we have to handle, The next is material degradation. You might recall from some of the talks that some of the material does get destroyed and for some mission we would see some thermal problems and I think that is the next level. The third level is what I would call contamination. After you solve the other two, you might

be worried about what comes back to the satellite and fouls up your optical surfaces or that sort of thing. Finally, the science. The people who want to dd science missions m5y require very sophisticated models and precise control. When we are working on this problem, that is the priority that I perceive and I hope we Have agreed on the priority here. I Would like sbme feedback on it. We have tc start at the top of that and go dbwn. Now when we introduced the SCATHA in bur program, which is a big investment and a necessary step, that may require that you get very sophisticated to get everything out of SCATHA that you need so that-you ban come back around and have those answers.

E. Whipple ..... It bothers me a little that you gut science at the bottom of those four levels. I think maybe that your point is that spacecraft has to survive before we can do the science, and that is fair enough.

R. Lovell — I think that our customers out there in the world are mostly operational people these days, arid they're the ones having the problems.

S. Sower — One might put it a different way and I think we must be a little bit careful. Among the contractors and the people who design these things, there is a heck of a lot more manpower there than there is here. That is, a lot rhore concentrated manpower who are clbser to the problem. They are going to come up with some fairly clever solutions once they see what the basic situation is. They'll ccme up with some rather simple fixes for some of .these things that won't require a lot of science and we'll cbme along later with a lbt of science and by the time we do, there will be fixes that people will be using in geheral. Along the same line I would like to make the comment that regardless of what any group such as this does id coming out with specifications or requirements, the individual program offices wtll make the decisions. We wtll not dictate to them. Their life is totally one of making decisions add tradeoffs. The first question that they're going to ask on any of this stuff is what does it weigh, what is the cost, arid what is the scheduling impact? The next question they are going to ask is what are my alternatives, and they are gotng to

insist on alternatives. The next question is going to be what if I don't do anything, what do I lose? And oh the basis of that they may tell us to drop dead, they are not going to do anything. In Pact, this has happened in the past. I hate to be so brutal and so practical, but this is the way programs run.

C. Pike I want to amplify a little bit on my initial comment id regards to what is ultimately turned over to the program offices and the contractof community. The result should be in a simple and boiled down form; but riot at the expense of some very fine scientific research which is something that we really don't want to lose sight of. The problem is, from a physics and engineering point-of-view, extremely complex. The community that is working this problem must keep in their mind that the ultimate product must be something in a useful form. It'd a comment I made earlier and I make again.

A. Rosen I would like to put in perspective some of the comments that have been made. We are operating on a variety of levels aiid I feel With Elden that science should not be at the bottom of the pile. On the other hand, in many cases we are talking abbut spacecraft that have objectives that are nonscientific, yet we are looking *to* these spacecraft to carry environmental monitors, to do scientific analysis. There is no question that a Lot of wotk has to be done in the scientific areas; hawever, programs 3ith nonsctentific objectives are not interested in the science per se. They are interested in design fixes accomplished in the simplest possible way with the least expenditure of money. The thing that we can do as scientists is come up with methods of doing lhese things economically, artd efficiently. From their point of view, our greatest service would be to find methods of giving them the necessary assurance of the integrity of their design and have them do nothing. I like to open this discussion up to the floor.

A. Vampola Obviously, the purpose thls conference is to design or come up with some sort of specification to design spacecraft to. The modeling, the materials development, all these

things are means to an end as far as the spacecraft community is concerned, although the scientific community may consider it an end in itself. We have been gtven some data by Dr. Gore Which shows that paying attention to details of signal conditioning on a spacecraft whtch is otherwise qutte dtrty frbm a charging point of view can, in fact, alleviate most of the problems and I would like to ask Stu Bower what is his opinion after seeing all the material presented the last three days. What is the possibility of sitting down right now and writihg a specification that would have a high probability of producing a spacecraft that would not go bump in the night?

S. Bower I think there is a pretty gobd probability with one exception, which I mentioned this mortling when I was taking; namely, the concern that I Have for haw large an area will discharge at once. Although there are some reasons for believing that it is not going to be the whole surface, there is no rigorous proof available obviously. This causes some concern. We have a handle on abbut how large area; if we had a better handle oh the size of the pulse, I think the probability id pretty good and it is based on two things. We can basically identify the characteristics of the discharges that take place and where they would take place. Secbndly, the coritractors who are designing the satellite have access, in general, to the kinds of information generated from the work that NASA Lewis has done and the design handbook which they are working on. So they have a clue and a starting point and then beyohd that it is based on the fact that the designers themselves are fairly sharp people who know their systems, and given the bask circumstance are quite capable of designing around these problems. They have been doing it for years.

E. Whtpple May I ask a questton? I guess this should be addressed to Gob Lovell br John Stevens. Thts represents a discussion in that hall, I think yesterday, commenting the fact that it appears, for example, in ATS 5 and 6; as far as we know, we have had nc anomalies. And I thihk the NASA spacecraft have not experienced as many anomaltes ih this environment as some of the other ones, and I know that

Bob and John began to look into that. I think ,.. well let speak for themselves, I am just interested if they have any comments as to why that might be so.

R, Lovell — Let me just say something and let John finish it up, About a year and one-haif ago, John, Stu Bower and myself, travelled around to industry and we asked some questions. do you build your satellite? And we picked out selectively some companies that we knew who had satellites up that were not having problems and some that did. We did not, systematically, put that information together and follow through on it. We are delinquent in that. That is, it is our intent to rectify that, to do that and get that information out. I think, in terms of conclusions, at that time, the ones I remember are the same things I heard today, If you pay attention to grounding and shielding, and you do a good job, whatever that really means, then you are not going to have trouble. .I am not sure that we see that. The biggest doubt in my mind is associated with CTS. When we were working on CTS, we concluded that if we did all those good things it would be heavy like a brick house, CTS was a very light weight, relatively open spacecraft. I don't know what Vic has to say about it, I think he said a couple of anomalies, but I really don't think we have spacecraft charging anomalies on CTS.

J. Stevens — As a result of the tour that we took through the aerospace industry, it became evident to us, that the satellites that were experiencing anomalies were the ones that used computer level logic and stored commands. .Those satellites that building in the possible source of anomalies, because the satellite is configured such that any upset would start a whole series of commands. The NASA satellites, the ATS 5 and 6 and the SMS satellites were basically controlled from the ground, There was really very little that could them into trohble. The SMS used latching relays. The ATS 6 depressed the logic levels so that it took something like a 15 volt spike to get the logic to change state. This is in addition, of course, to SMS and ATS 6's Faraday cege, and the shielded wire. Stu Bower's comment et the time was that operational satellites didn't hnvc

large weight margins and you probably couldn't do everything that Was done for the NASA satellites. Exactly how much was really required we were never able to figure out.

A. Bower — In regard your to my remark, We could not afford the weight of rf shielding whlch was done on ATS 6. Now of course that was done because the body of the satelliti?, all the sit right in the main antenna beam and the concern was with the upsets from the thnin antenna beam. The fixes that handled by logic design add no weight to the program as I mentioned this morning. We did go back and redesign a satellite which is a very undesirable thing to do, We want to do it in first place.

A. Rosen — Coldstein had a question. Do you still have it? It was answered. Okay.

M. Sellen — One sort of thing when I'm sittihg around where anomalies are being discussed is the sort of frustratidg feeling you have with very little amount of data on what actually goes on in the You have a few terminals that give you numbers and at that stage you finally can defihe whether you have an anomaly or not just on the basis of the information you get off of that. And keeping the bird on thb air and havihg it do its appointed thing, which is transmitting messages or something like that, it is the primary function of the mission, thed you very well say, hey we might already be there. The only other thing, of course, is saying that we don't really know what is happening on the surface of the spacecraft except those things that happen at the you have the circuits on. And if you look into the science, you can say, was your science anomalous? Well if you happen to know what the ambient particles in space were at that moment, and know that your instruments were turning out a result, theh yes you have got an anomaiy. But there is no way of knowing directly in that circumstance whether it was anomalous or not, You have cnly the data from your terminals. And I think this forms one of the bases. I would like to come back to something We talked about later. This is one of the places where you get perspective. Arid a laboratory allows you to have some

command over the parameters that you are imposing on this And thing, its limited diagnostics that exist on the spacecraft or a model of spacecraft, doesn't tell you the things, then you know you have got an anomaly. Add most of the time you just simply don't have that It is very easy to take a small model of the spacecrak and put it in and have a sensor give you the for 15 different conditions, but it gives only one of reading, and you cafi twist it around all over the place. And that is valuable id terms of what we really know about what's happening on the spacecraft. We know a very limited amount. My is true in the other way. I thtnk half the loading you charge to partikle data is wrong and the other half is questionable. What is very difficult for some poor devil Who spent years on the instrument, you know, is to say that. It shows the JGR.

J. Laframbdise

I have three to make. First of all think that the entire situation that we been discussing this week is classic result of basic science. think that is something that ought tb be obvious to everyone who is Here, but I think there are still lot of people who don't ltke to hear that kind of thing. About ten years it became very difficult for people to talk anybody into hanging particle and field oh satellites. Arid I think the total *cost* of what has happened may very well be greater than the money that was saved at the time. That is my first comment. My second comment is in regard to models. AS the proposer of either the only two-dimensional numerical Model that has been discussed, or one of the bnly two (I am not sure whether Lee Parker would refer to his model "two-dimensional"), I want to talk about the importance of models.

have been e lot of models and there is a very impressive model that has been described. A model is the simplest model that you cad thtnk of, Which is going to gtve you the bask feature of thts ahd that is the between and shaded areas. models can't do it, and models are more elaborate then

you need, to do that. So I think that two-dimensional models will aut to extremely important in getting at a lot the basic physics that is involved in this problem. Finally, I would make an analogy to a situation in aircraft design. Now, when someone rolls a new airplane out of the hangar, you already it is going tu fly, furthermore you know exactly how it is going to fly. You probably have got a simulator built and trained pilots already. That's because there are computet codes for simulating the performance that at all levels There are many, they overlap. There are some simple ones that illustrate bask phenomena and there are some complicated ones that give you three nificant digits or more. I thtnk that or twenty years now, hopefully that will be the situation in the design of spacecraft. There will be codes available that wlll give you that kind of confidence.

A. Rosen — Lee,. do you want to comment

L. Parker — Well, the model that I showed an R-Z geometry. It could be called you add up all the velocity acid dimensions, or 2-dimensional if you plotted in R-Z space.

S. DeForest — I would ltke to comment just a little bit on the very first sentence you made. I don't think that basic physics has been neglected. knew these things were charged up in 1967. The people at Lockheed I wrote a letter to the ATS project office and quoted things all the way back to 1924 which showed that they would charge up. And they do charge up. We have th author up here, Rejean Crard, who sponsored a similar I think back in 1971, who a book, this one very book, The stuff has beeh around a long time. I don't think it's neglected basic physics. I tnink neglected anthropology. That kind of problem,

J. Laframboise — Okay, but I think you'll probably agree that cases where anomaltes occur, there are hardly any cases where there is instr nentation on the same spacecraft to see what the envtronment wa

I think everyone is a friend to tho computer and there is no doubt but what it's going, you know, to increase productivity add do a variety of things. What I think might important to keep in mind though about designed airplane as the computer designed spacecraft, that as far as ,,, if we Into avalation history there those occasional brushes wtth reality and I can thtnk of three, but I am sure there are more; whtch was the retrofit of Electra wing, the landing speed and angle of attack of 727 and the DC-10 baggage door. of which, I am sure, you know, were not picked up in the computer. I thtnk we going to find quite a bit more as we go through there. Clearly, people will make use of analysis. what I was trying to argue for was some kind of check on open loop analysis, It, literally, fascinated with, you know, the complexity and brilliance its codes and sort of goes open loop without an experiment.

Stadler, you want to make a comment and possibly some charts?

Let ask a question in the light of the previous comments, hopefully not to produce any emotionalism. Let us put on the satellite program manager's hat and ask what can be gained by knowing the what advantage is there to him in putting sensors on the spacecraft? can we motivate program managers to add sensors?

J. Laframboise — Do you want me to answer that?

A. Rosen — No, anybody in the room?

J. Laframboise — I guess it is a matter of what ode thinks is going to money. And I Have a feeling that knowing what is going on, is the best way to save money in the loflg run.

P. Stadler — Lobk, I know that something upset-inducing was going on.

J. — Yes, you don't know what the environment was. And if a problem occurred and you don't know what the environment was, it is very difficult to design a spacecraft in the future that isn't going to have that problem.

P. Stadler Let's reduce it to something reasonable, Tho ktnd of that talking nbout are those which you cnr possibly convince somebody to fly an operational communications Are you nbout a of 5 volts In a of less than half cubic ? Whnb can you really tell about the environment with those small sensors

J. Laframboise Well, obviously there are going to be different kinds of spacecraft with or less elaborate sensors.

S. DeForest Can I address this, just a minute? Let's: assume your spacecraft doesn't exist in a vacuum. Let's assume that have got this little thing that you've put on there, a noise sensor, maybe a simple Faraday cup, and then suppose you have a continuing program of monitoring the environment. Then I would say, you've got it. If you've just your simple, you khow, half a kilogram, 10 bits per second something or other and don't know anything else about the maybe you're tryidg to correlate with a ground base or something. Then, I agree, you're going to get very little information. Eternal vigilence is the price of liberty. That is what we have got to have. We've got to khow what is going up there. I am saying the million and one-hall dollar type piasma analyzer, you don't need oh everything. Okay? But you should have one somewhere. Doing something, And maybe cheaper. I don't know. But you should have something up there all the time. And if you have very, very simple noise monitors, plasma type things, on the vehicle itself, which is betng effected. And then I think we can apply physics. SCATHA and both have good instruments.

R. Lovell I would give you the answer to that question. If you put a simple sensor on, like the ones that were discussed here today, and if you are project manager, then I would tell the reason you should put it on if you don't care at all about helping the science communtty is tha' when you have an anomaly on your spacecraft, you'll slave vourself some money in your failure activities, A very point because we have seen it. Dr. Gore mentioned It, maybe you didn't catch it today. Whenever there is a

problem on CTS, very ftrst place they is the transtent effect counter and say "What Happened?" So, it'll you money and it's useful to help explain to boss why something fouled up.

A. Rosen — I would like to support thls.

E. Smith — Is it worth half a million dollars?

R. Lovell — No, I don't think it is worth a dollars. What question am

.... — How much money are going tb save against the cost of the machine?

R. Lbmll — Well, the instrument is simple, which I thought His question was. He is shaking his head, yes, and no. …

E. Smith — When you have to make changes to an existing system, including the changes in software, telemetry, all the other stuff, it is-about a change on a military system, before you start. Now you add $5K instrument on tbp of it. It costs you Now hot you going to save money?

J. Napoli — I would like to answer that questiofi. I think I can answer that question by trying to explain the commercial environment for satellites. I guess there are abbut ten commercial satellites in the altitude and these companies plan to be there. These missions were all seven to eight years. If you could put a means of detecting or trying to correlate an anomalous onboard catastrophic failure, okay, against something that is induced by the environment or something else that is related to the spacecraft charging, which the failure which gives you only a three year bird; have lost six years, or you have lost four years of at two million dollars a channel, twenty-four channels. That is a lot of money. Versus a 205 thousand dollar saving. This is from a commercial

Audtence — The answer you need to give and what you care about In these systems is the fact that you have bird there operating, if you convince people that by putting on a sensor, you are going to be able to solve these problems faster, so thet you have longer life satellites,

they will those sensors. Just to get data, won't them.

5. Well, I think that another problem. I thihk a problem here, too, is if you look at these there is a budget, a very competitive atmosphere, if you lbok at the people in the COMSAT, Western Union, RCA, the well I guess the Canadians really don't much but their type programs, two these heavy insentives on contractor to deliver in two years. We don't have this luxury of running all these test programs we would like to and then again you do go up and you are maybe lucky, like RCA is, in not having anomalies at try to go back and convince management to fly on the third, on F-3 and F-4, fly a monitor on there. It is a difficult thing to do this point.

E. Whipple It to that we are putting the cart befbre the horse . . a little bit. have been talking about flying sensors to find out why we anomalies. And really What we want to do is be able to avoid anomalies in the place. Now, if you have a sensor that just tells you that you had anomalies, afld maybe correlates it with something in the that is fine for ahalyzing what has happened, but your spacecraft is dead by then. hopefully by flying some of these sensors can find something out in the environment that is a precursor for what causes the problem. Sherman DeForest has shown that these injection events Correlate a high charging states of the spacecraft. It think it is very likely that these injectlbh events! that happen in the are prefigured by some kind wave. And if we could identify such a thing and use that as a warning signal, that would really be valuable. Thed could shut dawn the satellite, wait the event is over, and then go back again.

C. Pike I would to amplify on that aiid say that if there is o signature - I see a representative from Air Weather Service here, Capt. Halcrow - if there is a firm monitoring, and if there is, indeed, an

which one could mon-
then that something that really falls Within the Air
Weather of responsibility.

M. Bunn — I think I would like ti, offer another answer to Ed Smith's question to how you justify that $205K. On the **DSCS** prbgram **durirg** a **2** period, we spent about studying anomalies that we were And that doesn't account for the cost of the fixes after we decided what we were going to **fix.**

A. Rosen — Capt. Bunn, with due respect, I want to say that the amount that **was** spent **wad** well in excess of $200K.

M. Bunn — Thank That just reinforces my ...

A. Rosen — It does? Because the amount that actually spent involves a team of over fifty people who traced various aspects of the anomalies. I would guess that in terms of the four **or** five anomalies studies that I was able to observe, the amount spent was much closer tb two tb eight million dollars. The amount that spent in our grbup alone, that is just the analysis to study the environment to try to pili down the phenomena **and** try to get DeForest and anybody else involved in this, well in excess

M. Bunn — I **guess** I **would** still like to monitor:: on those! birds right now I have been trying, but it is difficult, as Pete knows.

P. Stadler — Wouldn't it be for this to consolidate these arguments and try to present, **as** one of the results of this **e** with arguments, that we should **fly** on each military satellite and/or commercial satellite. Wouldn't that be helpful **at** this

R. Lovell — I think that is **a** **idea** and I think we should take it an action item for the! Group, think that is **a** good idea.

J. Napoli — I **go** along **with** that

R. — **We: will that.**

A. Rosen You have my also.

A. The concept is that millions of dollar's are being programmed insuring a couple of spacecraft from failure. It seems ridiculous not to put a couple hundred thousand dollars into on board monitoring, which has practically the same probability of failure these days. The other thing is that looking at some of the massive data, you can see the onslought of these substorms in time to warn people to get on the stick, something is to happen. Is it ping to happen or is it not, even if you have ten minute warning. If you know what to look for, you can prepare for it most of the time. You can take care of it. It is simple insurance.

Audience. It is a bit of a change in topic but earlier on the first day talked about active control, eleetron emitters on ATS 5, 6 and there will some on SCATHA.. How do the program people feel about putting active control on their satellite?

M. Bunn I guess from my standpoint I really can't answer that find out what happens on the SCATHA bird with the active controls on that.

A. Rosen Bob, would you to try that alsb frbm the NASA point of view?

R. Lovell Well, NASA's satellites are more in the science category. I think there is not any doubt that there is a desire to reduce the potential to very low levels and that will probably take an active control device. I am not sure what kind that will be. In our program that I talked about earlier, we had layed out a fairly clear path to get there where the development of passive (mainly materials) and active control devices (things shinning light bulbs, squirting out electrons and whatever) will be investigated. It is down stream because need the kind of that the modelers and the envirodmental people are doing before you can begin to really evaluate.

M. Bunn Let add something here. If you can't get the operational systems to put a monitor on, you're not going to get them to put on an active electron gun or whatever. I think It has to be flown experimentally which is being done on SCATHA, although probably not all the possible active devices, but it will give us a handle.

C. Pike — I would like tu add that the Air Force; Lab is putting the electron and ion system on the SCATHA satellite, and the objective of the experiment is technique for vehicle charge control and to come up with, essentially, how to do it in effective fashion. program will be complimented with the AT3 5 and 6 results.

M. Minges — I would like to present an analogy with active thermal control. From the Air Force point of view, one of the principal design objectives long life satellites, in range from five to ten years. If can provide an active spacecraft charge cohtrol system with moving if doesn't weigh much, and you can assure a level of reliability for the to ten year period, then you would get a responsive audience. If you can't demonstrate that, then I think acceptance of any active system would be difficult to achieve.

A. Rosen — Ray Gbldstein, would you like to comment this question'

R. Goldstein — I think I wbuld have tb between two kinds of The service type satellite is basically up there, runs, and is passive. The other type is the that NASA is primarily involved in, the science type of satellite. My feeling is that it is possible with passive methods, that is, materials, circuitry and whatnot, to have a spacecraft in a charging environment without any upset. That was previously mentioned, for example, for ATS 6. Bob Lovell and John Stevens talked about the differences between those spacecraft which don't and other spacecraft which do see anomalies. There is a difference in the philosophy of how you build a spacecraft. So I think it is possible to build a at least with a protective so that even exposed to the charging environment it will survive. The cost trade-off between putting fifty pounds of shielding twenty for ail active cbntrol device must done. But from the of a scientific satellite, there is no that in order to get good low etiergy you need some sort active as well as inactive type of control. I agree with Mike Sellen that most of the low energy particle data are questionable. The case of Pioneer 10 11, which was briefly mentioned the other day, is a good example.

M. Sellen

There is one other thing that you might want to realize Here, and that is it was you know, a nice piece of fortune that Rad a spacecraft that was arld that could go into eclipse come out and that had a particle counter on it add could suddenly watch the spectra shift rip arid by about ten kilovolts, and had enough passes at that sort of thing to clearly identify the effect. And yet, you know, a Jovian encounter is a Jovian encounter and there isn't the possibility of doing somethpeatedly there. And so specifically, if you try divide the interests along here into spacecraft that have very limited encounters with an invironment, it may be a better thing to put kinds of insurance on there and then include the active device. For that simple reason, you have sueh a limited time and you have such an unknown environment which you ate going. to have to operate anyway. I don't think anyone really has an idea what the Jovian situation can be certain passes.

Audience

I would like to address question tc Sherman. With a predictive on-line capability, don't you feel that the Lab at NOAA could a starting poidt for that? the data.

S. DeForest

It is a starting point. But as I said before we have a lot of sales problems. Williams has been working for years, as you know I'm sure, to plasma instruments on board, There are no plasma instruments oh board GOES. The lowest energy on any of those is a solid state detector which catches the upper end of the injections. They are very useful spacecraft: useful are the magnetometers on board which I have studied with Joe Barfield, beautiful data, but it would worth much more, if there were even a simple piasma device on board. At the present time, I don't think there are any plans for any plasma devices on ariy of NOAA spacecraft, thing is a proper function and should be pursued.

Audience

Why

I think because nobody has asked for them to do it.

S. DeForest — No, no. Don has been trying for years to get oh: at least that's what he tells me and the people who work for him ... I've got to believe that. Is there anyone from NOAA here that you know of to defend yourself, I'll withdraw that.

M. Bunn. — Sherman.
Could I interject a quick question? do you about the correlation between ground based data activity at for erample?

S. DeForest — Okay,. that is a very good question. Actually, I had slides set aside earlier in this area, in case someone asked. In terms of injection, when there is injection of particles at altitude, there is a one to one,. never fail, substorm on the &round. The classical definitions of auroral substarm, the southern most arc brightens, the whble thing. There are features on the ground, particularly along towards dawn in the "dangerous region, called the patchy aurora, rayed structures, and stuff like this. There is no analog in the plasma for those features. Okay. Contrarily, there are things that happen in the zones are mirrored on the ground. For gross things thefe is a one to one correlation and if you count the detailed effect, it is there. Now let's look at something else. Now when there is injection, there are currents flowing between the spacecraft and the ground. The currents change the field. Yau are the ground looking and an accuracy of where you can locate an arc, you miss by half a degree, you're pretty close but you have got a half of a error. That translates into over 1 earth radius. You're going to miss by 1 earth radius in the equatorial zone. addition to that, you have got these currents in between. So you don't know how to map, if had it absolutely accurate on the ground,. you don't know how to map. I think you know this, but I spent a lot of time doing this, trying to correlate between ground base arid equatorial I think the answer is that we improve our ground based measurements. DMSP pictures are very very useful. I don't think we even get detailed one to orie correlation.

J. Laframboise — I would like to make another on I think clearly tile ideal situation is a few ments and a lot of little ones, preferably if you think again of aircraft, you see that aircraft all carry crash recorders. If you had that arrangement with a few elaborate instruments and a lot of simple ones,. elaborate ones could calibrate the simple ones. think of a situation if you had the same instrument on a lot synchrotious spacecraft at different longitudes. If a substorm comes along it is goihg to hit one before the others, have a little time to react, and you can do something with the others if you have that kind of arrangement.

C. Pike — I want to add a comment on the very localized nature of the disturbances which are seen on the ground as mapped down from altitudes. that is that one needs a very dense chain of magnetometers in the auroral region to accurately identify that there is, indeed, a disturbance going on. And there are chains of magnetometers along magnetic and the Air Weather Service has data from one of these chains in real time. The unambiguous identification of these events is a very difficult thing to infer from data.

R. Lovell — I would like to ask Sherman if he would care to give us a ten year weather forecast Are there storms ahead?

S. DeForest — Well, if you have been following the there is a thing known as the Maunder minimum. I expect that is what you might bc referring to. a very long time, essentially for a lifetime of active there no sunspots and there were no ... there was no aurora and there no disturbances arid if we had been around at time Galileo, none of these anomalies would occur, Is that going to happen This is current research. It did not come on immediately. It sort of petered out for a period of time, but I think the answer is yes, we will have another cycle and yes have more substorms and according to one that I rend in" are going to have of And

there will be a big ih California. Charlie points we are having these anomalies now, nnd this la solar minimum. Aroutid it will gel

Audience — I am somewhat about this question of prediction. I prepared grant you that you car. predict thcsb injec- tions. But what are you going to do about it? Because no commercial operator is going to turn his spacecraft off, unless e really believes he is going to lose it. I think in the las three days we have heard enough evidence, he really isn't likely to it. He may have interference, he may have buinped telemetry, but he goihg to bc on air. These are commercial contracts and you can't afford to tucn the darn things off. That is what you're being paid for. Continuity of service.

A. Rosen — A very good pbint. The other point is that monitors don't prevent anomalies, they merely record them and I think the predictive capability is not one that the operational projects, spacecraft project managers want to have. There is only one area where they may want to have some pre- dictive capability, and that is in planning their iaunches and possibly finding a place to store satellites at synchronous altitudes. Would you like to comment that also?

J. Napoli — don't quite follow that last remark planning their launches?

A. Rosen — Yes, is a question as to whether there is a longitud- inal position at which the environment is less adverse than at other longitudes.. Now, the thing that you want to do when you use operational spacecraft is that you don't want any down time at all. So of the schemes that has beeri pro- poaed is to have a passive satellite that is ready to go on momentarily and take its position in order to not have any id service. And the question is, where do you store it tt is passive, in what region? Possibly there research that could be done in this area.

J. Napoli — Prom a commercial standpoint that is very difficult thing to try end accomplish because if you look at the spectrum there, between 90 and 135 degrees, is like the Long island Expressway durtng rush hour. And you want to have

immediate continuity restoration of service, You would to be at just about the same location or a degree, and many and if your intent fixed on a which most of the are, I don't know if that is applicable to the commercial space- which are the equatorial plane right now,

R. Lovell

I would like to address your point a little bit. I think it would be to project that spacecraft communica-. tions, or operational maybe in the next ten years, will carry an operational station keeping device, ltke an electrical thruster, an ion engine. And would you nbt be willing, if you had a warning, to turn that thing on, if it also turns out to be effective as a Yo I think there is great merit id having this capability.

Audience

I think there is merit in having the warning, even after the fact, because something happens, then you are suddenly Faced with something gone wrong and what is it, and look and you say gee, I had a warning Five minutes ago that this was going tb happen, it does pbint you in the direction you have to lobk.

A.

It is getting close ti, are a couple items that I wanted to cover, of them was a request Pete Stadler and Paul to address the question of testing. In this ai-ea, there has been many approaches, and methods that have been used and Paul wants to say a Words. Afterwards, I also wanted Rejean Grard, to comment on what the European, are dbing materlai research arid spacecraft charging. So we start with

P.-Stadler

Note: reader is referred to the paper by and Stadler,

A. Rosen

take one question on Pete Stadler's comments.

E. Smith

We did current injection by capacitors over the various parts a model satellite that was left over from a program that was latinched otherwise. We got quite a surprise. It not radtated EMI that was causing our upsets. It coupllng In structural terms, example. I just thought I would pass that on to you.

P. Stadler — Well, we wtll certainly looking for thnt very thing here. One of the prime ....

A. Rosen — A procedural note: we have to terminate formal of this panel All of you can stay and continue on. will be to answer questions and make comments. I wanted Dr. Crard to mnke the final comment and after that I thtnk of us will be available and we cati continue. The parts are over, but before terminate, br. Crard. .

R. Grard — I feel that we are really shying away from the straight approach to spacecraft testing. We are presently trying to stimulate anomalous spacecraft behavior with coils and spark generators. It would indeed much more realistic and efficient to place the spacecraft in a vacuuni chamber asd to subject it to electron bombardment. I cannot see where the difficulties are. . ....

R. Lovell — is something that we at NASA think is a good idea. But it is an expensive proposition. For the commercial users, I don't think they can afford it.

Grard — Today it is customary to submit spacecraft to vibrations and to expose them to simulated solar and vacuum environments before launch. I believe that testing their susceptibility tb surface charging will become in the future routine procedure which all spacecraft will undergo. do riot have to design new vacuum chambers; we only need an electron gun and a battery of ultraviolet lamps.

R. Lovell — It is not expense of the chamber. Expense of handling a of flight hardware, the associated ground support equipment, staff. It is just expensive.

A. Rosen — I am sorry. I will have to make a closing comment. There is joint NASA/Air Force committee in existence right now and they are open to suggestions and comments from anybody in the audience and anybody interested in field,

M. Bunn — Bob Lovell arid myself are contact points on that Steering Committee.

A. Rosen — I would like to thank thls whole group and state formally that the panel discussion closed.