

PANEL DISCUSSION

A panel discussion on the update of Military Standard 1541 was chaired by Major Jack Roberts from the U.S. Air Force Space Division (AFSD), the SCATHA program manager and also the Air Force point of contact for the spacecraft charging technology investigation. Panel members included Alan Holman, the program manager for the Science Applications, Inc. (SAI) effort to develop a draft version of the standard for AFSD; James Frankos, from the Aerospace Corporation's Electrical Systems Department; George Brady, a reliability engineer in the Space Systems Division of Lockheed; Paul Robinson, with the Jet Propulsion Laboratory as Group Supervisor of the Engineering Requirements Section; Ronald Schmidt, a materials physicist at General Electric and a member of the survivability group; and John Reddy, from ESTEC, Test Facilities Division.

Major Roberts: The spacecraft charging military standard is a Space Division requirement as outlined in the joint NASA/U.S. Air Force Spacecraft Charging Technology program. Our approach to filling our commitments under that interagency program is to update the current version of Military Standard 1541, which is the electromagnetic compatibility (EMC) requirements for spacecraft with spacecraft charging requirements. Our goal is to have that updated version published by the end of 1982. SAI has been contracted to pull together the detailed technical elements and write a fairly complete draft version of this document. They should have that done by the end of 1981. Then the Aerospace Corporation will take over exclusively, obtain the system program office and industry reviews, incorporate the comments, and have the document ready for publication by the end of 1982. The Air Force places a great deal of emphasis on military standards. As the name implies, they are standardization documents that are very useful, in our opinion, especially in letting requests for proposal. They give the contractor some definite guidance in judging the scope of the work and enable him to submit a better-thought-through bid. By the same token, they help the Government to evaluate better the bids received from the contractors and, once a contractor is selected, to evaluate his performance in the design and test phases. Of course the overlying benefit here is the elimination of gross under- and overdesigns and the costs that can be associated with them. Therefore military standards are a very useful tool for both the system program offices and industry if they are written properly.

The key to a military standard, in particular this one, is its contents. The inputs must be of high quality; that is, we have to have faith in what we put in there; it has to be well thought out and based on a good data base; the utility has to be clear; the credibility has to be there and therefore all these things blend into the acceptability of the document. In other words, for a military standard to be effective the system program offices and the contractors have to accept it.

The major theme of this panel discussion then is how to achieve the acceptability of Military Standard 1541. For instance, if the system program offices do not have faith in a standard, they may not use it, or they may eliminate sections. Therefore all our efforts will reap no benefit. By the same token, industry and the contractors will protest

mainly by increased costs, if they perceive the standard to be unreasonable, too restrictive, or too vague. The military standard, in a way, is really a document that must be accepted by everybody; really it is a group effort wherein everybody has to put their efforts together to accomplish a successful product.

There is an obvious trade-off in the contents of a military standard. Simplistically speaking, there are two approaches that can be taken. One is to try to spell everything out in detail as a requirement, "The equipment shall" sort of thing, but perhaps in some cases this is too restrictive and requires a high degree of confidence. The other approach is to give merely information or guidelines. These guidelines are subject to interpretation in many different ways and by many different people. It can be very vague. So do you use one approach or the other or an approach somewhere in between to develop a military standard with the greatest usefulness? There are many elements to be considered: Analytical models, tools, coupling models, test levels, test requirements - should they be stated as requirements or guidelines? The panel members will discuss the approach to Military Standard 1541, the contents, the test requirements, and the acceptability of the document.

Dr. Holman: To strengthen the point Major Roberts just made, about the importance of making this a salable document acceptable by the system program offices and the contractor community, it must still represent the actual spacecraft charging hazard. Any design analysis or test that is called for must be able to be addressed in a practical way by the contractors.

I want to remind you of the need for an applicability statement within this document. And I would like, when we open this up to the floor, some comments on how that applicability statement should be addressed. Should it be addressed as the definition of a region in space that is important to spacecraft charging concern, or should it be addressed in some other way? There is certainly useful information coming from the P78-2 vehicle, but that information has to be supplemented by all the inputs that are coming from the community. SAI and Aerospace are the focal points for collecting that information and including anything of technical merit that is applicable to the military standard appendix.

It is still vague how we can call out analytical requirements within the format and structure that are currently prescribed for the military standard appendix. That issue should be discussed. Analysis is very important, especially for determining test levels. For example, a spacecraft with multilayer insulation surfaces could be subjected to fairly large discharges, and we would probably come up with some maximum and extreme worst-case level of the discharge and from that define a test level. But as Drew Muhlenberg and Paul Robinson mentioned, the method of puncturing the thermal blankets with pinholes results in many small "earthquakes" instead of one large earthquake. And, if the test level should then be dependent on the smaller discharges that are generated off these kinds of blankets, it will be a less severe environment than the maximum worst-case environment. You really need some analysis of your specific spacecraft design before a representative test level for your design can be determined. I want to remind you of the importance of the high-energy electron charging of dielectrics within the spacecraft. This

might very well drive subsystem design requirements, and I want you to give some more thought to that so that we can discuss these issues later in more detail - always keeping under consideration the salability, acceptability, and practicality of the technical information to be included in the military standard.

Mr. Frankos: I have been one of the "working troops" in the electromagnetic compatibility field, and there has always been a problem between management and the working troops, especially in electromagnetic compatibility. I am concerned that the military standard, when it is updated, really spells things out clearly for management so that the working troops do not have to spend time trying to explain to management what it means and what the company has to do to satisfy the requirement. It has to be practical from the standpoint of the contractor: He has to be able to do whatever it is. As Major Roberts said, it has to be useful - we don't want money going down the drain. My area of responsibility is supporting the program offices and the Air Force and checking the contractors' technical work. If a document is clear and straightforward and spells out the things to be done, it makes my job easier and it makes the contractor's job easier so that everybody benefits.

Mr. Brady: As one of the working troops in reliability I have viewed Military Standard 1541 as it affects testing of spacecraft, space platforms, and subsystems. I am not sure that all these changes should be incorporated into 1541 through an appendix. Although there are some changes that should be incorporated, 1541 actually does cover some discharge space plasma events and perhaps just a beefing up of that area would be appropriate. Some definitions, such as dielectric discharges, should be incorporated as well as - for large space platforms - Debye lengths and plasma sheaths. In addition, there could be a pitfall in trying to design a document around one particular day of one particular space vehicle, in this case for the SCATHA vehicle on day 87. It is only a preliminary analysis, yet this has been called a worst case. However, the ATS vehicles, particularly ATS-6, have experienced some charging activity much greater than that experienced by the SCATHA vehicle. So the environment is yet to be determined.

There seems to be some problem in defining the tests to be incorporated for any system or subsystem. There is a great variety in testing capabilities and procedure, such as using monoenergetic electrons or two electron guns or ions and electrons at the same time - quite a variety. There is also some difference of opinion on the need for incorporating ultraviolet sources. Military Standards 461 and 462 probably should be changed to incorporate additional testing procedures rather than incorporating these procedures in the appendix to 1541.

The analysis is a good idea also, but there could be a problem trying to get NASCAP to agree with what we have seen on the SCATHA vehicle. And NASCAP could be used to analyze test articles in a chamber. For instance, in a test at Lockheed, some charge was inexplicably lost. Perhaps the NASCAP program could tell us where it went.

Regarding the procedures for eliminating differential charging - we know that with conductive paths we get a return current that is much higher than the current from a semiconductor path. And, in fact, 1541 says we should use no materials on the spacecraft surface with a resistivity greater

than 10^9 ohm/cm, and this appears to be adequate from other experiments and from analysis. Perhaps a bleed path with that magnitude would be adequate. In summary, we need a lot more analysis from the SCATHA vehicle for defining the worst case. For instance, the worst case is probably going to come up in 1983, and we need some more test results and some more information on how to combine test results with the analytical approach. All the viewpoints expressed here are my own and not necessarily the viewpoints of Lockheed.

Mr. Robinson: Speaking for myself also, I agree with the general tenor of standard 1541. I think there must be a top level specification that includes spacecraft charging, and as has already been well pointed out it must be realistic, because you do not want to require that the disturbances from spacecraft charging be smaller than the ones from the spacecraft's operating equipment. Also, the standard should allow for as many innovative solutions as it can. For example, the plasma source that Herb Cohen and Chris Olsen and others have suggested as a way to control the spacecraft potential ought to be allowed for because it does provide a nice framework to work in. We need, of course, as Hank Garrett pointed out, to get a clearly defined worst-case environment. We need that modeling effort. We need to provide a procedure for determining material parameters. If you have a novel way of doing your thermal control surfaces, you need a way to verify that and to provide better understanding of the physics involved. This kind of specification should lead to a test program. If you think the spacecraft will not charge up because you have been very clever with the surface or with the materials chosen, you ought to be able to prove it. And if you think your subsystems are good enough that they are immune whether the spacecraft charges or not, you ought to be able to prove that as well. In short, it is a real problem if we ignore it, but otherwise it is well within our capabilities.

This testing may require some upgrading of the ground support equipment as well as the spacecraft itself. The "box" may survive the test fine, but the thing you were monitoring the box with may not. And so you have to look at the whole procedure. We do not know the whole story on how dielectrics charge and discharge. John Stevens, Robb Frederickson, and practically all of us have pointed out details where our models did not seem to hold correctly - they did not predict what we wanted. Perhaps the threshold effect that some people talked about is a real effect. Maybe we do have the right parameters in there and maybe it's a delicate difference between one environment and the next. At this time there is no theory of dielectrics that predicts all the effects that we see.

The same holds for radiation-induced conductivity. We do not as far as I know really come up to that from basic principles. We can put in some coefficients that we think handle it, but we do not have a fundamental understanding of it or of how the arc itself is formed.

Mr. Schmidt: My outlook on the proposed revision is primarily from what has been done on the DSCS-III program. However, I do not speak for General Electric on any of these points, primarily because I joined GE after most of their work on spacecraft charging and design efforts was completed or well under way. Many of the approaches that were used on the DSCS program are very similar to what is spelled out in the proposed revision - the use of

the Faraday cage, conductive materials, and charge modeling with the SCAP program that was presented at the previous charging conference. The program modeled structural currents due to worst-case discharges and used materials testing to determine the needed material properties. These are all very similar and I agree with a lot of the revisions that are proposed, although I do not know why the radiated-fields aspect, which was included in the 1541 treatment of spacecraft charging, has been omitted from the revision. That aspect has a meaningful role in either the analysis or the testing. My biggest concern is the use in the revision of analytical methods primarily in the coupling and discharging areas, which are not really well understood yet. There has been a lot of work in that area, and much needs to be done before it can be used to generate threat level requirements on possible flight-qualified vehicles. This has to be mixed very heavily with an empirical program to give a firm feeling of what is going to happen during the test on a flight-qualified vehicle. SCATHA's primary role in the development of the proposed revisions could be in defining the environment, which is the missing element in the definition of what and how to test. What information SCATHA can bring to the definition of how to develop coupling models is yet to be determined.

Mr. Reddy: I would like to address the approach to including SCATHA data into a standard and the contents of the data. Two types of data are needed: data to support data scientific analysis of the sort that would be done by NASCAP, and more importantly engineering data. Here I agree with most of the panel members. I think it is all well and good talking about electron temperatures and the like, but the technician operating his voltmeter in his laboratory does not relate to electron temperatures very easily. He needs some sort of engineering format. Therefore this document should include two types of test requirements. There are two options when you build a satellite: You can build it to charge and discharge, or you can build it not to charge. Military Standard 1541, if it is going to be revised, should address both of these options. Furthermore the test requirements should be at the system and unit level, rather than at the subsystem level. Subsystem tests have yet to give any meaningful data.

It is a bit peculiar that a strong requirement is given as an appendix to a military standard. And what's more, this appendix quotes 1541 as an applicable document. That's a little bit chicken-and-egg.

On the last point, as to whether or not we should produce a requirement that is acceptable to industry, two years ago at this conference there was a panel session that related to the credibility gap between studies by the SCATHA group and those by the electrostatic charging groups and the difficulty of convincing management that there was in fact a problem. If two years later we still cannot convince management that there is a problem, we might as well throw this thing out the door now. If we believe there is a problem, if we can identify this problem, if we can produce numbers to the problem, then whether industry finds it acceptable or not is by-and-large immaterial - satellites still have to survive in this environment.

Major Roberts: Obviously, our intent when we set up this panel was not to speak with one unified voice because it is early enough in developing this military standard that we need to have some healthy and diverse dialogue

over what we are doing and our approach to it. So I have encouraged that and I encourage it from the audience. Some good points have been brought up by the panel to jog your thought processes and memories.

Question: I have a question for Al Holman. Al, I noticed in the military standard that most of our efforts have been concentrated on the geosynchronous environment. Will we be flying satellites in other environments, and if so, will the standard address these environments or is that something to be added later?

Dr. Holman: Well, you are certainly referring to flying more of your JPL payloads around Jupiter and Saturn. Currently, 1541 is an Air Force military standard meant to address requirements for Air Force programs. Most Air Force programs involve satellites still flying around the Earth, in the general vicinity of synchronous. There has got to be a better definition of where the region of spacecraft charging exists. And that, no doubt, is the way it is going to be called out in the applicability statement within the military standard. Now that does not mean 1541 cannot be picked up by a program office supporting the development of a Jupiter probe, for example, and still called out in their statement of work as an applicable document. But presently we do not have a good enough definition of the region of space that should be of concern. We are looking for a better definition to come out of the Environmental Atlas.

Panel member: To add a little more to what Al has responded, the update of Military Standard 1541 is based on the SCATHA program effort. If there is a concern for the near-Earth environment, or even farther out than geosynchronous, the SCATHA program cannot provide the basic information. If future programs can provide it, there will be another update.

Mr. Garret: Would you feel then that there is a need for a follow-on program to define other regions of the near-Earth environment?

Major Roberts: Yes, there is under assessment right now a program plan to update Military Standard 1541 additionally around 1986 based on information from the Environmental Interactions Technology program.

1. Report No. NASA CP-2182 AFGL-TR-81-0270		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle SPACECRAFT CHARGING TECHNOLOGY 1980				5. Report Date October 1981	
				6. Performing Organization Code	
7. Author(s)				8. Performing Organization Report No.	
9. Performing Organization Name and Address National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135				10. Work Unit No. 76610803	
				11. Contract or Grant No.	
				13. Type of Report and Period Covered Conference Publication	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546 and U.S. Air Force Geophysics Laboratory (PHK) Hanscom Air Force Base, Massachusetts 01731				14. Sponsoring Agency Code	
15. Supplementary Notes Cochairmen: N. John Stevens, NASA Lewis Research Center, Cleveland, Ohio, and Charles P. Pike, U.S. Air Force Geophysics Laboratory (PHK), Hanscom Air Force Base, Massachusetts					
16. Abstract The third Spacecraft Charging Technology Conference, sponsored by the National Aeronautics and Space Administration and the U.S. Air Force, was held at the Air Force Academy from November 12 to 14, 1980. The proceedings contains 66 papers, dealing with the geosynchronous plasma environment, spacecraft modeling, charged-particle environment interactions with spacecraft, spacecraft materials characterization, and satellite design and testing. The proceedings is a compilation of the state of the art of spacecraft charging and environmental interaction phenomena.					
17. Key Words (Suggested by Author(s)) Spacecraft charging; Environmental interactions; Space environment; Satellite modeling; Satellite design; Satellite test; Satellite materials characterization				18. Distribution Statement Unclassified - unlimited STAR Category 18	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 1005	
				22. Price* A99	

* For sale by the National Technical Information Service, Springfield, Virginia 22161