SESSION V - ENTRY AERODYNAMICS AND HEATING

Dr. Walter Olstad, Chairman

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MR. VOJVODICH: We are very fortunate in having Dr. Walter Olstad of Langley to chair the entry aerodynamics and heating panel. I am not going to go into Walt's background. He is well published in this area and without further delay, I will turn the proceedings over to Dr. Olstad.

DR. OLSTAD: Yesterday we heard some discussion about technology for the probes being pretty much in hand. Today we have some surprises for you. The technology isn't all that well in hand, and we have some genuine concerns about which you will be hearing today.

Before launching into the talks by the panel, I would like to give a brief overview of some of these problems.

Looking first at the problem of entry aerodynamics and heating, Table 5-1, we ask: What are we supposed to do? The first and obvious answer is to assure survival of a probe, which gets us into the heating problem. But, beyond that, mere survival of a probe isn't sufficient. It doesn't guarantee any data coming back; or if data does come back, it doesn't guarantee that you can interpret that data. So it is very important that we be able to predict performance and that performance be reliable.

Figure 5-1 presents some of the challenges to making predictions for a probe entering a severe environment. We always have the problem of transition from laminar flow to turbulent flow. And, as those of you who know anything about the transition problem are aware, the only way to learn about it is through experimentation. It is not something you can calculate. Unfortunately, our ground facilities don't provide the conditions that will be encountered during entry in the outer planets. And so, we have to extrapolate from experiments and ground facilities.

Furthermore, we must be able to predict the turbulent

ENTRY AERODYNAMICS AND HEATING PROBE REQUIREMENTS

- SURVIVAL
- RELIABILITY OF PERFORMANCE
- PREDICTABILITY OF PERFORMANCE

Table 5-1

TECHNICAL CHALLENGES

- TRANSITION
- TURBULENT HEAT TRANSFER
- RADIATION BLOCKAGE
- CHEMICAL STATE
- AFTERBODY HEAT TRANSFER
- ASYMMETRIC ABLATION
- REAL-GAS AERODYNAMICS

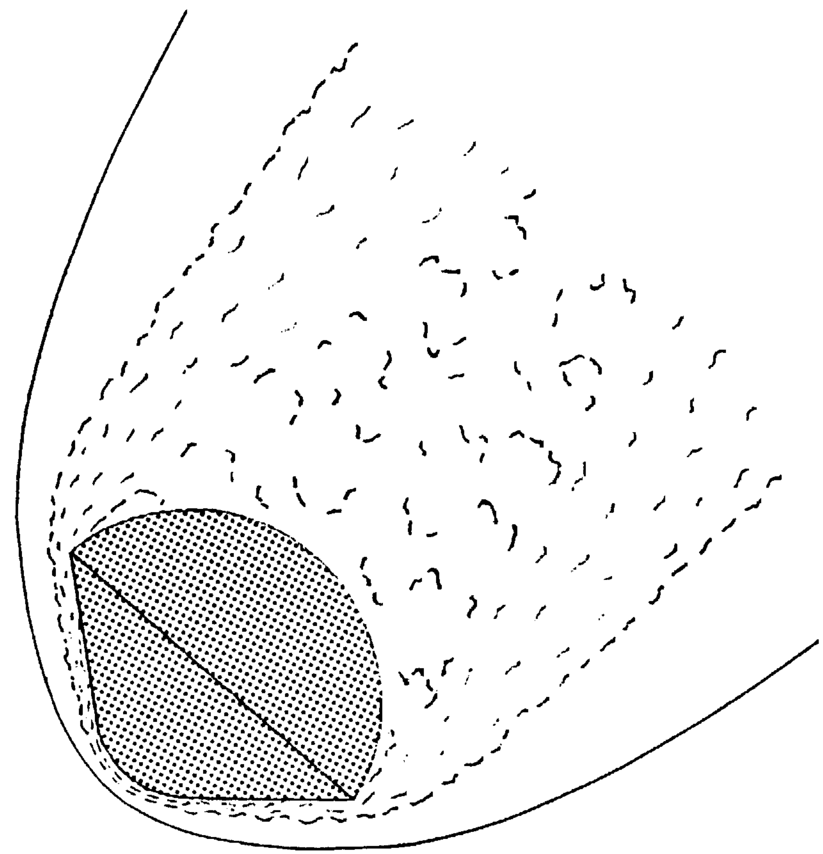


Figure 5-1

heating. Turbulent heating is also an area where empiricism is necessary. Once again, we have to extrapolate from ground facility experience, and that is a long and uncertain extrapolation.

The third area is one that I have labeled radiation blockage. The ablation products which are injected from the vehicle's surface tend to absorb some of the radiant energy from the shock layer. This is generally a beneficial effect which heats up those ablation products which are then swept into the wake. But we have a difficult time predicting how much absorption or blockage we get. One of the big problems is that we don't know the radiative properties of some of the heavy molecules which are constituents of the ablation products. Further, we don't know really what the chemical state of the ablation layer is. We don't know if it is in chemical equilibrium or not. That makes quite a difference in any calculation.

As you will hear a little later in this session, there is some question about the chemical state of the shock layer itself, and this, again, relies on experimentation. Fortunately, we can do a good bit of the necessary experiments in shock tubes.

Another problem area is that of afterbody heat transfer. Generally, it is not large enough to significantly affect the design of a probe but the greater confidence we have in predicting afterbody heating, the less will be the margin of safety we have to put into heat shield design and the more weight can be allotted toward increasing the science payload or enhancing system reliability.

Asymmetric ablation may be something of a problem. It can affect the aerodynamics for the rather blunt vehicles that we are talking about. Our intuition tells us it is not too much of a problem. There is some experience which shows that it can be a rather severe problem for slender vehicles. It is an area that hasn't been looked at very carefully, as yet, for blunt vehicles and requires some attention if we are to have full confidence in our ability to predict the performance of a probe.

The last area is real-gas aerodynamics. We have lots of wind tunnels, lots of ground facilities in which we can study aerodynamics, but generally we don't get real-gas effects which can play an important role during planetary entry.

So these are some of the technical challenges that still remain. They are being worked on, and I am reasonably confident that we will have the right kind of information at the right time. But it is not all in hand right at the moment.

On Table 5-2 I have listed some of the major obstacles that must be overcome to achieve technology readiness. We have to extrapolate our experience from ground facilities to the flight environment, and that extrapolation is very lengthy and uncertain in terms of heating rate experience; it is an order of magnitude or more that we are extrapolating. I am sure you will hear more about this problem in the second session this morning.

There is a lack of flight experience. The flight experience that we have now is in the regime of Apollo entry. With Pioneer Venus we will gain some flight experience at more severe conditions. But when you talk about outer planet entries, even the Saturn and the Uranus entries, we are talking about potential heating rates, an order of magnitude larger than the Venus heating rates. So we will be lacking any real flight experience, and there is bound to be some kind of risk associated with undertaking a mission without it. At the present time, I am not sure we know how to assess that risk. It is important that we be able to assess it and to quantify if as best we can so that the mission planner can then make his decision as to how much of a risk he is willing to accept.

MAJOR OBSTACLES

- MAJOR EXTRAPOLATIONS FROM GROUND TESTS TO FLIGHT
- LACK OF FLIGHT EXPERIENCE
- LACK OF PARAMETRIC DATA
- UNCERTAIN KNOWLEDGE OF ATMOSPHERES

Table 5-2

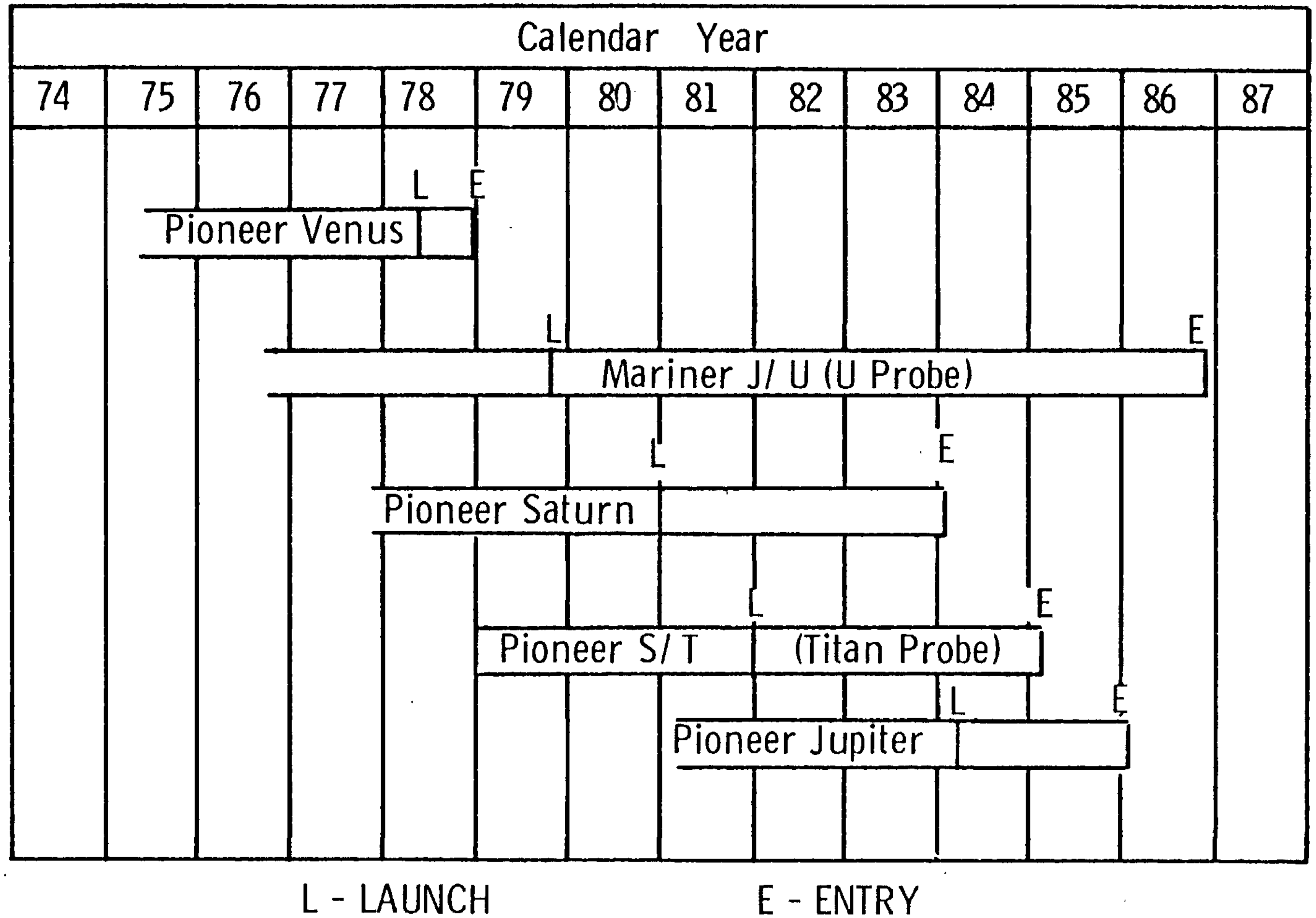
There is a lack of parametric data, as well. If you look at the information available to a probe designer, it is limited to a rather small family of sphere-cone vehicles and a small family of spherical segment vehicles, like an Apollo shape, and that is about it. And as you will hear a little later, even that information leaves a lot to be desired, at least in terms of predictions of heat transfer.

Finally, lets address the area that was talked about yesterday, the uncertain knowledge of the atmospheres. I heard what I thought were two stories that were somewhat conflicting. I heard one story that said the upper and lower bound atmospheres, or the cold and warm atmospheres, were probably too far away from the nominal; that if you applied some statistics and asked about three sigma errors and things like that, you could close in on the nominal atmosphere. But then I heard that the nominal atmosphere wasn't necessarily the most probable atmosphere. We also heard a good bit about the Pioneer 10 results, and the question which has arisen as to how to interpret those results and what they mean in terms of an atmospheric model. Think back to our experience with the Martian atmosphere; what we know as the Martian atmosphere now falls completely outside of the bounds that we had placed on the Martian atmosphere prior to any information gained from Martian orbiters. So I am not all that confident that we can squeeze down on the nominal atmosphere because I am not all that sure the nominal atmosphere is the proper one.

We need some good information on what really are the bounds of the atmosphere. Obviously, the scientists can't tell us precisely what the atmosphere is. That is one of the reasons we are going there. But anything they can tell us about what really are the upper and lower bounds on the atmosphere will be very helpful in probe design.

I wish to elaborate a bit more on the lack of flight experience, and what it really means. This Figure 5-2 is labeled as

CURRENT OSS MISSION MODEL*



*APRIL 1974

Figure 5-2

the current OSS mission model. That is the model which Dan Herman came up with yesterday. Let's look at what kind of flight experience will be generated by the current series of proposed missions. The schedule shows the Pioneer Venus multiprobe mission with launch in May, 1978, two Mariner Jupiter/Uranus spacecraft (possibly with Uranus probes) with launch late in 1979, two Pioneer Saturn probes with launch late in 1980, two Pioneer Saturn/Titan spacecraft (possibly with Titan probes) early in 1982, and two Pioneer Jupiter probes with launch early in 1984. At first glance this may appear to be a reasonable sequence in (roughly) increasing order of difficulty. However, when trip times are considered the sequence becomes rather distorted. The first probes to enter are the Pioneer Venus probes late in 1978, only one year prior to the Mariner Jupiter/Uranus launches. The next probes to enter are at Saturn in early 1984, only a few months before the Pioneer Jupiter launches. All other probes enter the target atmospheres after 1984. As a result, the only real flight experience which can impact outer planet probe design must be gained from the Pioneer Venus multiprobe.

So with this kind of schedule, we face the possibility of committing ourselves to a series of probe experiments without really gaining any flight experience. This may be all right, but we have to assess the risk associated with this kind of operation. I don't think we have as yet. Instead, we rather hopefully claim that the technology is in hand. As I said earlier, I think you will hear this morning that it is not that well in hand.

I'll now introduce our first speaker, Donn Kirk of Ames who will discuss the effect of initial conditions on the deduced atmosphere for Uranus and Jupiter entries. This relates to our ability to reconstruct an atmosphere based upon the data we get from a probe considering the uncertainties in entry conditions and aerodynamics.