

VIKING PLANETARY QUARANTINE PROCEDURES AND IMPLEMENTATION

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DR. HOWELL: As the previous two speakers have mentioned, there has been a great deal of activity in planetary quarantine for a number of years, and there is still a great deal of interest in the subject for the outer-planet probes. Many of the implementation techniques and methodology that was discussed by Mr. Hoffman from JPL has been used on the Mariner programs and applied to the Viking Project.

I would like to share with you some of the techniques and methodology that have been used on Viking at the Martin Company to implement the planetary quarantine requirements. As you well know, Viking is the first U.S. project required to satisfy the full intent of the international agreement, both from a sterile-lander concept and planetary quarantine requirements on the orbiter.

Implementation starts with requirements that are imposed by NASA Headquarters and the Viking Project Office (Figures 9-12 and 9-13). These requirements establish the necessity to sterilize in an inert gaseous environment; that the affluent gas coming from the vehicle during the terminal-sterilization cycle be equal to or less than twenty-five percent relative humidity at zero degrees centigrade, 760 millimeters of mercury, and that lethality may not be counted until the humidity requirement is achieved, and the minimum lethal temperature is one hundred degrees centigrade.

As Mr. DeFrees from McDonnell Douglas indicated, additional information is provided on the accepted standard test organism, D values and Z values the probability of growth, probability of release, lethality of ultraviolet radiation, the microbial density in non-metallic materials, and probably most important, the allocation for the mission in question, all of which are needed to determine the implementation approach for building and sterilizing a vehicle.

PROJECT REQUIREMENTS AND CONSTRAINTS

DEFINITION

NASA Headquarters

NHB8020. 12 (April 1969)	"Planetary Quarantine Provisions for Unmanned Planetary Missions"
NHB5340. 1A (October 1968)	"NASA Standard Procedures for the Microbiological Examination of Space Hardware"

Project

M75-127 (March 1970) Statement of Work	"Viking 75 Project Planetary Quarantine Provisions"
M75-123	"Viking Mission Definition"

Figure 9-12

REQUIREMENTS AND CONSTRAINTS

Sterilization Environment

Inert Gaseous Environment

Humidity \leq 25% at 0°C and 760 mm

Minimum Lethal Temperature (100°C)

Standard Test Organism

"D" and "Z" Values

Logarithmic Death Model

Allocation

Planetary Quarantine and/or Biology

Other Parameters

Probability of Growth, Release, Ultraviolet, etc.

Microbial Density of Nonmetallic Materials

Figure 9-13

In addition to Planetary Quarantine, there may be a requirement or an allocation for biology. In the case of Viking there is such a requirement and we must satisfy a probability of contamination of the biology instrument on-board by terrestrial organisms.

The basic approach for implementing Planetary Quarantine is the same for any vehicle, Figure 9-14. You must start out with the mission allocation and determine the potential contaminating events associated with that mission. For Viking we must consider sterilization, recontamination prior to launch, and recontamination after launch, from the launch vehicle or orbiter. Some of the contaminating events prior to launch include propellant loading of the vehicle, bioshield pressurant gas, propellant pressurization, and the RTG cooling water which is used to cool the thermoelectric generators.

I will discuss only one of these events with you today - the techniques and approaches we have implemented on Viking for sterilization.

There are three types of burden which must be considered when sterilizing the lander: the organisms which are on the exterior surfaces of the hardware, the organisms which are between mated surfaces, and organisms within the materials that the components in the system are constructed of. The latter is called "encapsulated burden." Each of these different burden types have different thermal death characteristics. The encapsulated burden is the most resistant to dry-heat sterilization and requires the longest period of time for reduction. Our approach is to achieve the required encapsulated burden reduction at the component level and to track the reintroduction of this burden type during the assembly and buildup of components and the system. We have integrated the planetary quarantine heat requirements with engineering requirements for heat-compatibility testing on components to achieve this reduction. (Figure 9-15 and 9-16)

There is information which is required before one can determine or specify the appropriate heat cycle for the hardware

DERIVED REQUIREMENTS AND CONSTRAINTS

PROBABILITY OF CONTAMINATION - LANDER SOURCES

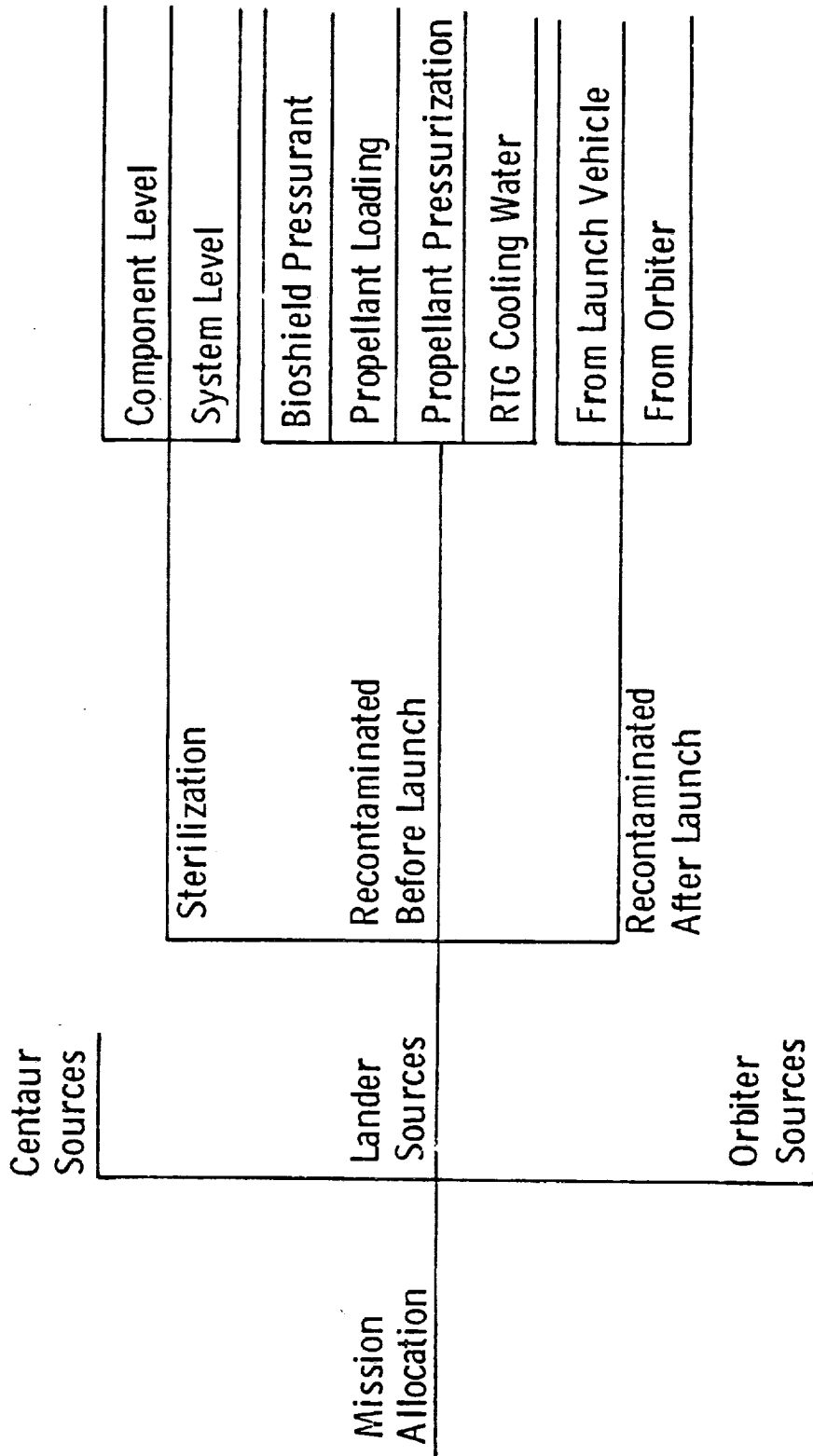


Figure 9-14

DERIVED REQUIREMENTS AND CONSTRAINTS

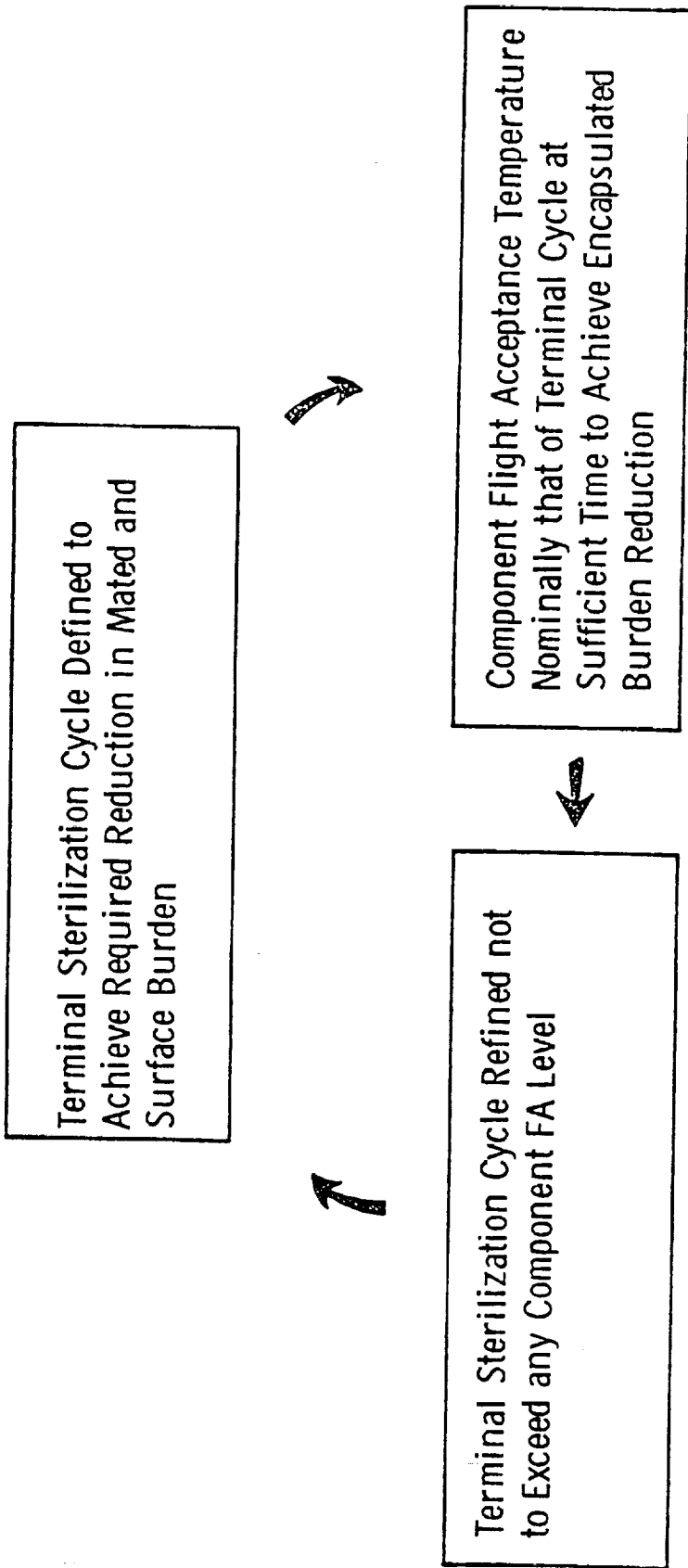


Figure 9-15

DERIVED REQUIREMENTS AND CONSTRAINTS

COMPONENT REQUIREMENTS

Flight Acceptance

Designed to Kill Encapsulated Burden
Temperature Based on Terminal

Qualification

Designed to Qualify Hardware
Temperatures and Time Increased for Margin

Development

Same Temperatures and Time as Qualification

Thermal Analysis Verification

System Requirements

Total Cycle Time Limitation
Time at Temperature Limitation
Temperature Level

(Figure 9-17). To gather this information, thermal analyses are performed to determine the slowest-responding point within that component, the time lag between this point and the exterior of the case, and the instrumentation required to verify the thermal analyses during development testing. This information is used to establish the component flight acceptance heating time required to achieve the required encapsulated burden of reduction.

As shown on Figure 9-16, the development times and temperatures are the same as those for qualification and are elevated both in time and temperature over that which we expect flight hardware to experience.

We use the terminal sterilization process to achieve the necessary reduction of the surface and mated burden. Flight components experience approximately the same cycle as they saw during their flight-acceptance component heat-compatibility. System level constraints of time and temperature have been established to ensure this is the case.

This process is shown schematically in Figure 9-18. A thermal analysis is performed which establishes the requirements for component testing. The component-development test results are used to verify the thermal analysis and make corrections as necessary. And then we perform the component flight acceptance heat-compatibility test on flight hardware to kill the encapsulated burden.

We use the component thermal analysis information and test data to feed back into our system analysis to predict the response of these components at the system level. We then built and tested a Thermal Effects Test Model which is a simulated Viking lander with non-functional components to verify that the system thermal analysis and the component analysis which were performed previously are in fact correct.

Finally, we test our qualification vehicle which is called the Proof Test Capsule, refine our thermal test data and, qualify

VERIFICATION

COMPONENT ANALYSIS

Identification of "Coldest" Contaminated Point

Identification of Instrumentation

Establishes Lag Time

SYSTEM ANALYSIS

Identification of Component Response

Identification of Instrumentation

Identification of Design Changes

First Level Verification of Component Requirements

Identifies Terminal Cycle Operational Constraints

Figure 9-17

VIKING THERMAL ANALYSES & HEAT REQUIREMENTS

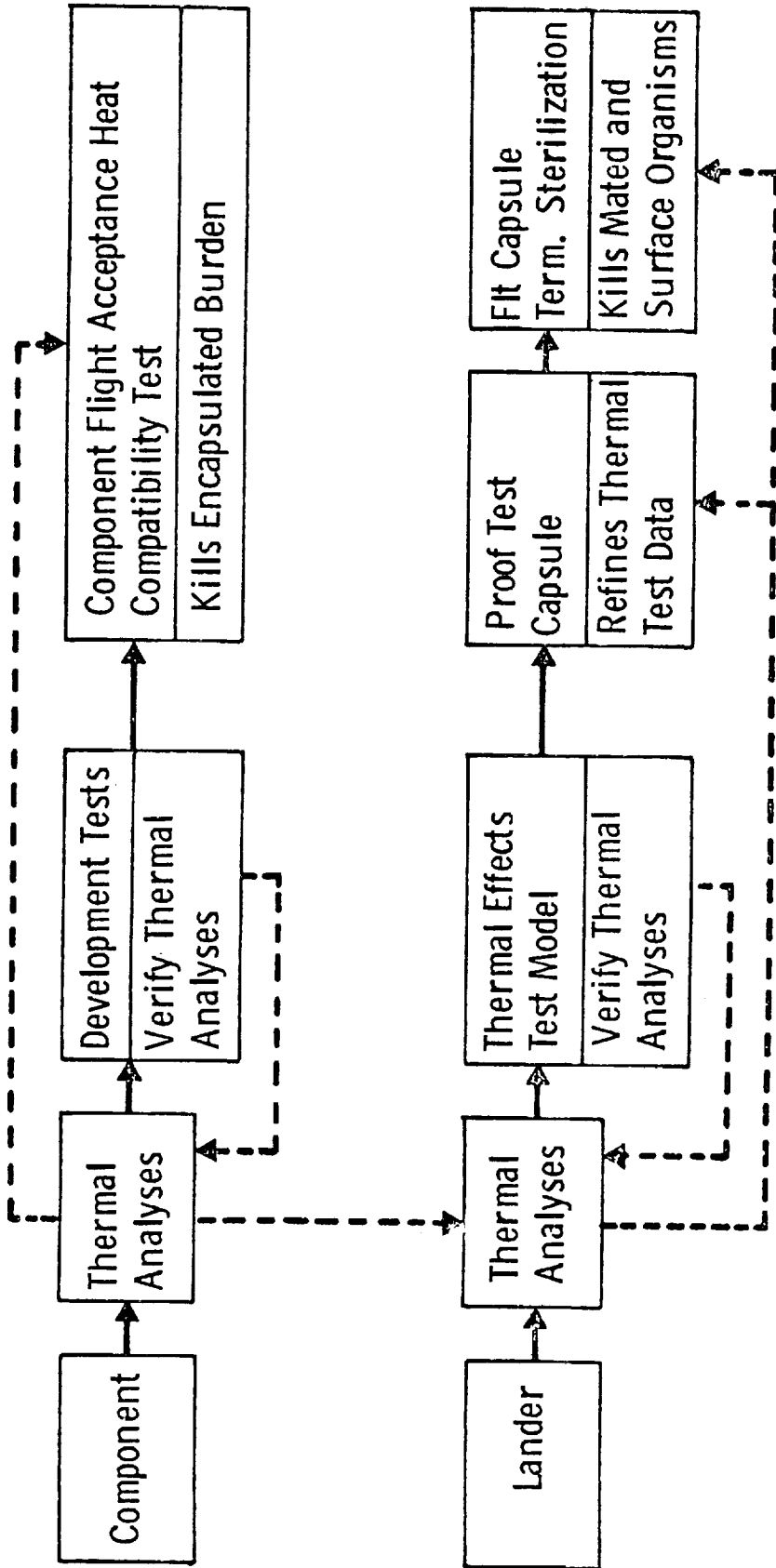


Figure 9-18

the cycle to be used during the terminal sterilization process for the flight landers.

We have completed the Thermal Effects Test Model testing. The results gathered during that test are shown in Figure 9-19. There is an engineering constraint of forty-hour time-at-temperature maximum after the first component reaches its lower flight acceptance level temperature. The camera was the component which reached its lower flight acceptance level temperature first. There are many components which reached 110° to 113° before the camera did, however, their flight acceptance level temperature requirements are higher and did not constitute start of the cycle.

The slowest responding component during this test was the biology mechanical subsystem, and it achieved the terminal sterilization temperature at approximately twenty-four to twenty-five hours after start of ramp-up. There is a 2.4 hour internal lag in the biology instrument between the exterior of the case and the coldest point in the instrument. Since our approach is to place the burden at the coldest responding point in the vehicle and sterilize to that response we must incorporate this 2.4-hour lag time before we can start counting lethality.

As I stated earlier, lethality can't be counted until the humidity requirement is met. On the first cycle this time was approximately twenty-nine hours into the cycle. Therefore, any integration of lethality earlier had to be excluded. The purge rate on the first cycle was 2.75 scfm. Analyses were performed to determine if an increased purge rate would shorten this time. During the second cycle on the Thermal Effects Test Model we increased the purge rate to 4.75 scfm. The humidity requirement was achieved in approximately ten hours. However, there was some question as to whether this shortening of time was actually due to the increased purge rate or that we had heated the vehicle for a second time. We postulated that if we maintained a purge rate of 4.75 scfm, we could probably expect a worst-case situation of approximately

THERMAL EFFECTS TEST MODEL TEST RESULTS

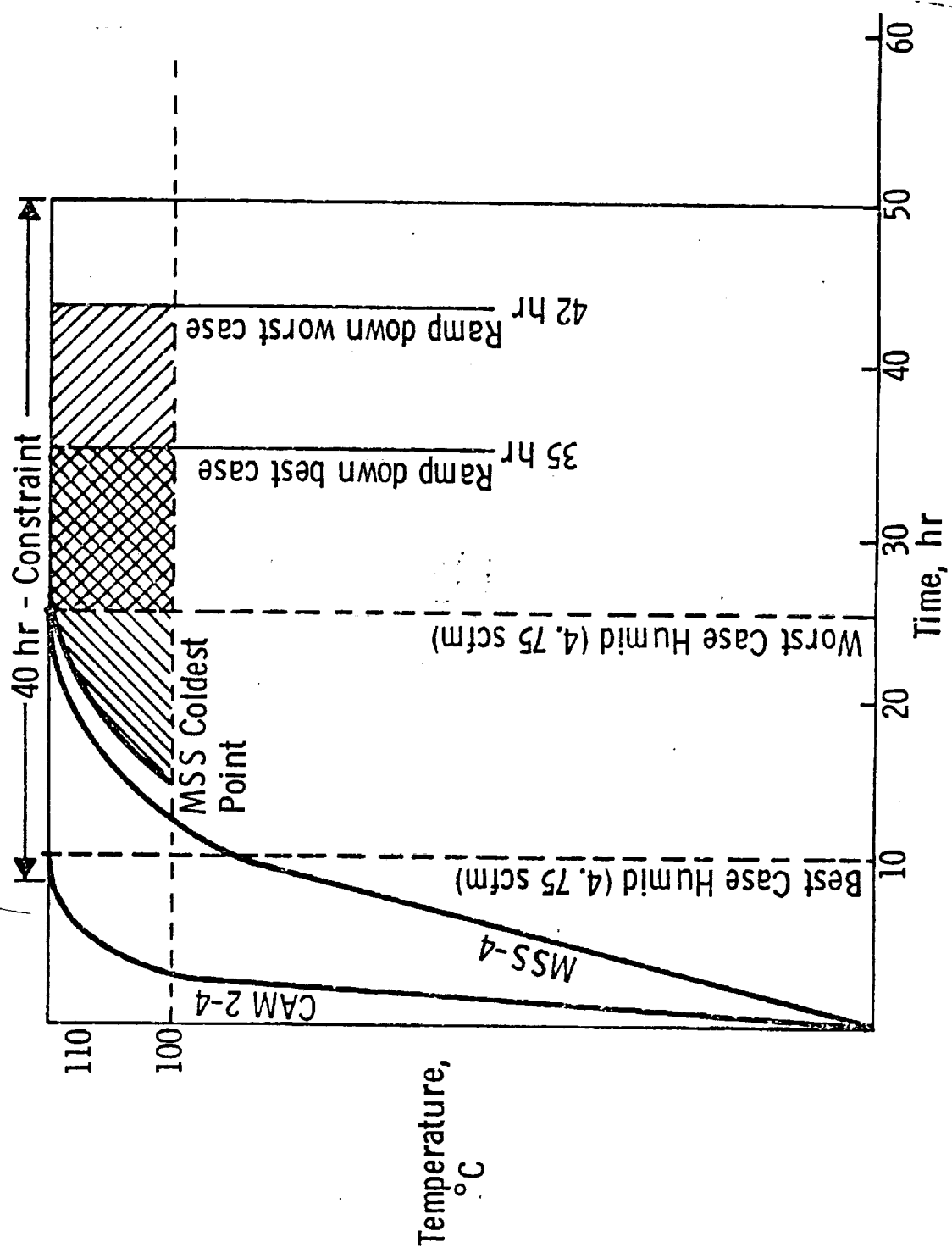


Figure 9-19

twenty-five hours, therefore, to achieve the required kill to meet the planetary quarantine and biology requirements would require forty-two hours heating time from the start of heat-up to the start of ramp-down.

The next view graph* will show you a picture of the Thermal Effects Test Model used during this testing. The TETM's very similar in nature to a flight-type Viking Lander, however, it had thermal simulator instead of functional components. As you will see later, the information we gathered from this vehicle was quite similar to that gathered on the Proof Test Capsule.

Here is another picture* of the TETM inside the sterilization chamber with the bioshield inflated. The vehicle that you just saw in the previous view graph now is enclosed in the aeroshell base cover and bioshield. The bioshield is inflated to a minimum of five inches of water pressure during terminal sterilization, and this picture was taken through the window of the oven during the actual sterilization process.

The next vehicle we have sterilization testing on is the Proof Test Capsule. The objectives of this testing are shown in Figure 9-20 and were completed earlier this year. Results are plotted on Figure 9-21.

The radar altimeter electronics was the first component to reach temperature. Camera number two got up to its lower flight acceptance temperature first, however, it was only the exterior of the insulation and thermal concluded that the interior of the camera, or the electronics had not reached temperature yet, so therefore, we were able to extend the cycle start time by approximately an hour. The radar altimeter electronics reached its lower flight acceptance level temperature in approximately eleven hours. Again, as with TETM, the biology mechanical subsystem was the slowest responding component in the vehicle.

* Not available for inclusion in these proceedings

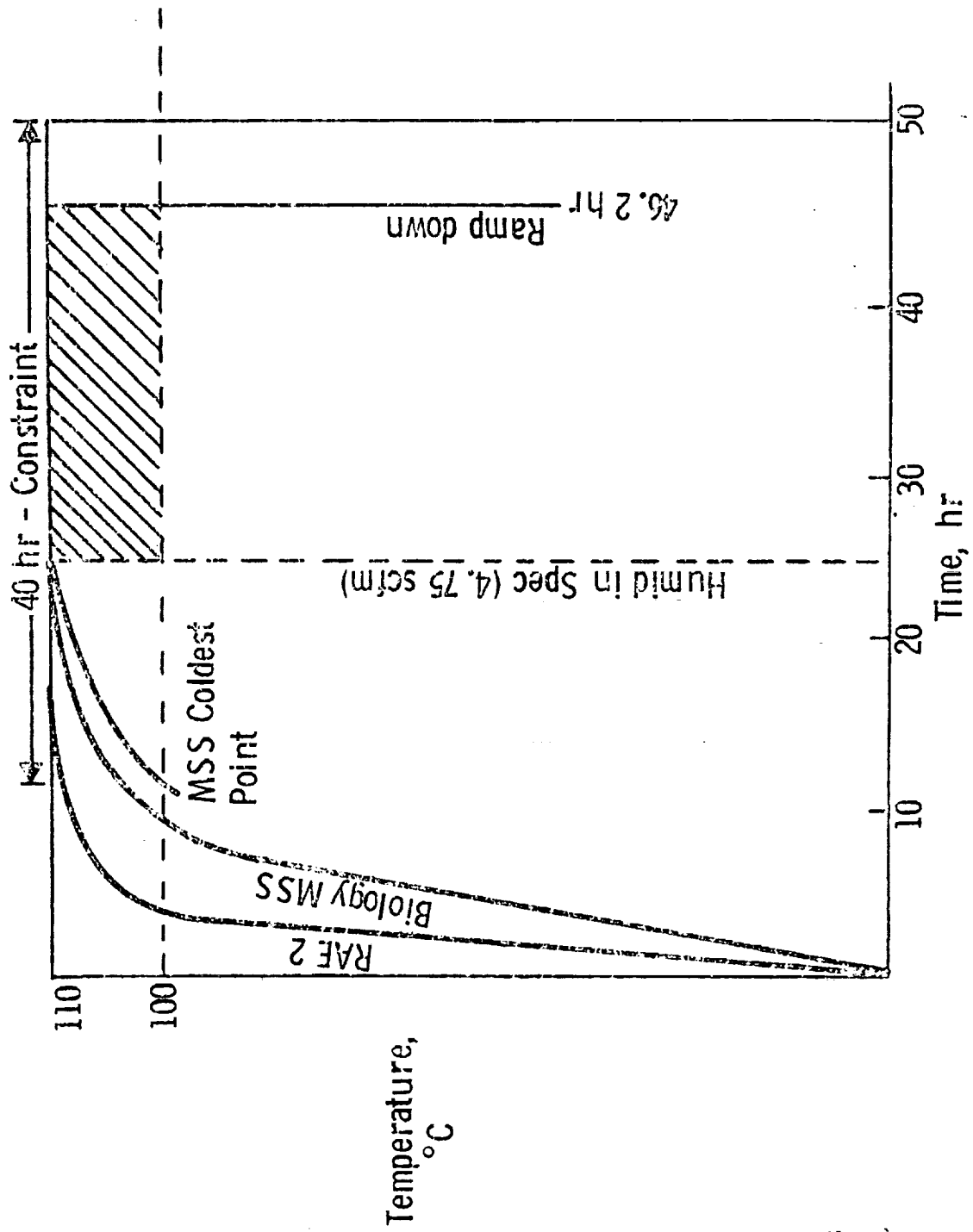
PROOF TEST CAPSULE (PTC) STERILIZATION

Objectives:

1. To Provide Verification That the Sterilization Requirements Can Be Met
On a Functional Flight Type Vehicle
2. To Qualify the Processes Used to Accomplish Number 1. Above

Figure 9-20

PROOF TEST CAPSULE TEST RESULTS



ORIGINAL PAGE IS
OF POOR QUALITY

Figure 9-21

We had a great deal more information when we conducted this test than we did on TETM. We had microbiological sampling data gathered during the assembly of the vehicle. We had the TETM experience and had gained a great deal of knowledge from the time that we had heated the TETM until we heated the Proof Test Capsule.

We calculated the lethality required to satisfy both planetary quarantine and biology requirements, and based on these calculations, vehicle was ramped down at 46.2 hours after the start of heating. The humidity requirement was achieved at 25.17 hours.

Here is an earlier picture* of the Proof Test Capsule. As you can see, many of the components do look different from those you saw on the Thermal Effects Test Model. These are functional components. There were some simulators but very few.

In summary, Figure 9-22, we have taken the requirements which have been imposed on us by the Viking Project Office and by NASA Headquarters, and converted these into engineering requirements. We have imposed these requirements and constraints on ourselves and our suppliers, and have been able to produce hardware which will satisfy these constraints. The hardware has been designed and developed. Our thermal data base has been established, both from the component and system thermal analysis work, from the Thermal Effects Test Model data and now from the Proof Test Capsule data. We have designed, built, and tested a sterilizable vehicle which satisfies planetary quarantine.

(Mr. Toms opened the session to questions to any of the three prior speakers.)

MR. T. C. HENDRICKS: I have a question, I guess for Dr. Howell, and that is: Previously we saw estimates of the cost impact of getting this planetary quarantine requirement on the probe. I was wondering if, in the earlier days of Viking, you made these

*Not available for inclusion in these proceedings

SUMMARY

Requirements and Constraints Established and Imposed
Hardware Designed and Developed
Thermal Data Base Established
Component Verification of Thermal Data Base Completed
System Verification of Thermal Data Base Complete on TETM
Qualification with PTC Completed

Figure 9-22. Summary

cost estimates and now that you are almost done with your program, how close were you able to make these estimates, how good were the cost estimates?

DR. HOWELL: Well that is very difficult to say because from Viking we have not really sat down and separated out all of the costs that have been associated with planetary quarantine. There was a decision early in the project not to do this. The costs associated with some of these things are very easy to obtain, like the cost of developing the bioshield, et cetera. Some of the costs associated with the selection of hardware and so forth become very difficult, become very program dependent and there was a conscious decision made early in the Viking project not to track the specific costs associated with planetary quarantine. So it's

very difficult, if not impossible, to answer your question because I don't know what the actual costs were or have been associated with planetary quarantine on the Viking Project.

MR. TOMS: Dan Herman made a comment in the introductory session that for the outer-planet program, for the outer-planet probes, we would not include planetary quarantine in our present thinking. And I asked him the other day if he could give me more justification than just a whim on that. He says that there is a letter in existence - many of you may know of this - letter that was written to the Space Science Board (in fact it was more in the form of a paper by Dick Goody and Leibowitz and Others) that, in fact, made such a recommendation, and I think that was done more than a year ago. Until that is acted upon by the Space Science Board, it does at least give us a reason for working on the assumption that perhaps planetary quarantine for the outer-planet probes and for the outer-planet spacecraft wouldn't be necessary.

Of course, it is not only the probes themselves but the overall mission design, including such things as the economics of using a bus deflection maneuver and then not sterilizing the bus. They are all part of the same quarantine problem.

MR. DEFREES: What class clean rooms do you use for assembly and test operations?

DR. HOWELL: I'll let Al Hoffman from JPL talk about the orbiter.

For the lander we use a class one hundred thousand clean room environment for the assembly and testing of the Viking lander.

MR. DEFREES: Bob, do you use anything more stringent than that for components?

DR. HOWELL: No, Sir.

MR. DEFREES: You use the one hundred thousand throughout?

DR. HOWELL: In some cases the component assembly areas are equal to or less than a hundred thousand. In some cases we don't even require a hundred thousand environment for the assembly of the components. The basic requirement, for component assembly, is dictated by the functional requirements of that component. If, in fact, there are functional reasons why it should be assembled in a very clean environment, then it will be. So the component assembly spans a range from not fitting into one of the federal standards, 209(a) or (b), categories, to a flat one hundred.

MR. TOMS: Fine, well, I think we'll close that subject. Some of the authors have brought copies of papers with them. There are not enough to make a general distribution of them, but you can ask the authors themselves for copies, if you are interested.

MR. HYDE: Yes, I have a question. Al, would you sum up for me in one sentence your posture about the outer planets, on just the quarantine?

MR. HOFFMAN: On the Quarantine? I think there are considerable unknowns. As far as long-term planning, the picture is cloudy, as to the degree of stringency of the planetary quarantine and sterilization requirements. I feel that as long as there are biologists that are interested in exobiology for the outer planets, there will be some sort of quarantine constraint. The degree of that is unclear at this point. I think we would be amiss at this early stage in our planning to completely neglect it. We should factor it into some of our thinking. And, we have a good basis to start from, our Pioneer, Mariner and Viking experience.

MR. HYDE: I want to expand my question just to say outer planets and all their satellites?

MR. HOFFMAN: Yes, as you are well aware, Titan is of considerably more interest than some of the primaries. And the problem that I was addressing earlier, the reduction in the stringency of the sterilization requirements because of entry heating, may be going for us at Titan. Titan may be, indeed, the one that will dominate our sterilization and quarantine.

MR. KANE CASANI (JPL): The thing I was going to say that I think is important is that your point is well taken, that we ought to assume that there is going to be some quarantine requirements and whether or not those requirements have to be satisfied by actually heat sterilizing the probe is the uncertainty. In other words, it is on these that we can satisfy the requirements without having to heat sterilize the probe and in some cases we may have to heat sterilize. That is the thing that I think is of general interest here. I think we are certainly going to have the requirements.

MR. HOFFMAN: Yes, that point is well made.

J. HYDE: I would only add to that the question of the bus deflection maneuver versus the probe deflection maneuver. It is a crucial issue in this whole thing. If we have to turn around and make the probes, intelligent probes, capable of doing their own deflection, we are not talking about the same kind of probes we have been talking about the last couple of days. We are not talking about the same kind of money. So I think maybe you should start looking at the numbers game on this whole thing. Pay attention to the implications of putting a requirement on the probe to do the deflection maneuver. If you do that, I think we may be out of business.

MR. HOFFMAN: Let me make a comment relative to that first, Jim. I think, as you are well aware, up until 1971 there was an unwritten policy in the United States that bus deflection was not a mode that would be used for planetary missions. Then, after that time, if we can demonstrate that the planetary quarantine

requirements can be satisfied using a bus deflection, that mode is an option that's available to us. And that is NASA policy. One concern relative to that is to demonstrate four or five nines reliability. Many of us get a little uneasy when we must demonstrate reliability greater than two or three nines with that type of operation. But I think it's a problem that can be addressed and worked.

MR. SEIFF: This will agree a little bit with what you said about the gravity of the change in the probe if the probe has to be deflected. Earlier studies have been performed based on that presumption that this was the way that it was to be done and it doesn't have as major an impact on the probe design as you are suggesting.

MR. HYDE: I don't agree with that at all, because I don't think that we are talking about probes in the price category that we have been discussing. If we have to talk about the intelligence required to perform the attitude stabilization maneuver and the deflection maneuver on the probe, I don't think we are talking about the same kind of numbers.

MR. SEIFF: I think the system that you are envisioning is more complex than what is needed to do the job.

MR. HYDE: Well, the issue is going to be bucks. And that is what we've got to address here. What I am trying to poke at is the money that is going to be associated with the impact on the design activity related to incorporating that capability into the probe, and I don't think we want to do that.

MR. TOMS: Let's hear from Bob DeFrees.

MR. DEFREES: I was going to make the same comment that Al just made to Jim relative to the NASA policy that is written into one of the specifications that the bus deflection is an acceptable, in fact, the preferred method of entry. The only thing you have to do is guarantee the probability or reliability of those things

are at least as good, and that means, essentially, a reliability of 10^{-4} , that it will not contaminate the planet with the bus. With redundancy, that is fairly easy to accomplish. But I just wanted to interject that.

MR. SEIFF: The only thing I would like to emphasize in closing the discussion is there are studies on the record in which probe deflection maneuvers have been incorporated as part of the study. And I was just looking around the room to try to find some of the older characters who might have been involved in this; Steve Georgiev, for one. He did a study on a Mars probe that dates back about eight years, by now, I guess, in which that was considered to be the standard approach and it doesn't throw the kind of major monkey wrench into the works that has been suggested here.

MR. HYDE: We might want to take this up outside of this room. I think I need a parting comment too. We are not talking about studies, we are talking about MJU '79 with a probe. We have got to look at the problem of the bus-deflection maneuver, the reliability of that relative to the quarantine, very specifically. I think the cost...

MR. SEIFF: I don't disagree with that, that is fine.

MR. TOMS: Dan Herman wants both JPL and Ames to look more closely at the quarantine problem during the coming months and, of course, we are trying to get Larry Hall and his group back at Headquarters to bring the whole issue to a head, get a ruling on it we can live with, and go ahead from there. It's going to be quite a change of pace.

Now to the other design problems we want to talk about. We have two papers that include discussion of radiation effects. The speaker I want to bring up now is going to talk about not only radiation effects but also long-life batteries. These are two of the problem areas that he has been looking at. Lloyd Thayne from Martin Marietta Corporation.