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P78-2 (SCATHA) SATELLITE THERMAL BALANCE TEST
A LABORATORY TEST

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ABSTRACT

Systems tests in Martin Marietta's Space Simulation Laboratory at Denver are now conducted with greater confidence. Planning and early systems checkout tend to preclude unpleasant surprises. Safety is part of the design and operation; examples are over-temperature kills, gimbal stops, and proven procedures and personnel. However, full-up thermal balance tests using the solar simulator, temperature control of infrared sources, the gimbal, a large number of thermocouples, and other requirements for a high fidelity thermal balance are still a challenge.

Add to this such things as several new members in the operating crew, combining development, qualification and acceptance testing in one test, exceeding the maximum design intensity of the solar simulator, an extremely tight test schedule impacting interface control and definition, a unique gimbal control requirement, and the test really becomes a challenge. This was the P78-2 (SCATHA) Satellite thermal balance test.

The lessons we learned in meeting this challenge is the subject of this paper.

The test was successfully conducted with minimal delays, and the P78-2 (SCATHA) Satellite was launched successfully.

INTRODUCTION

Surely another typical spacecraft thermal vacuum test report is repetitious! Yet, if it involves something new and different or is significant in some other way, the story should be told. No one thing about this test was new or particularly outstanding. However, so many things seemed to be working against a troublefree, successful test that weaknesses in our state of readiness and approach to the test became highly visible. Many tests have been conducted before and after this one. These involved few problems which were readily resolved. The high degree of success in conducting the subsequent tests has led us to believe that although problems will always be with us and accidents are not always prevented, their probability has been greatly reduced by the lessons learned in testing the P78-2 satellite. The satellite in the Space Simulation Laboratory (SSL) 29'x65' thermal vacuum chamber is shown in Figure 1.

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THE LABORATORY'S STATE-OF-READINESS

About two years had elapsed since the last major systems thermal vacuum test had been conducted. A skeleton staff had maintained the facility during this period, but not adequately since most of their time had been spent running component and subsystem tests. Enough of the remaining members of the staff were retained by being placed on other assignments to keep the capability of conducting a systems test. However, we all became rusty, and although we went through a retraining and recertification program, we still lacked the confidence that only several recent tests could provide.

The other aspect of readiness was the facility. It too did not have the advantage of recent use. To get it ready, a refurbish plan was developed and implemented. In fact, refurbishment of the solar simulator, which was known to be critical regarding maintenance and reliability, was started over a year before the first test requiring its use and about a year and a half before this test. It is shown in Figure 2 with some of its capabilities. The original performance characteristics of the system were attained, measured, and documented. Thirty-two kilowatt Xenon arc lamps were then obtained to replace the center seven twenty kilowatt lamps to reach the required intensity of 1.4 solar constants with a nominal fifteen percent margin. We ran a thermal vacuum test on an antenna and two brief development tests using the solar simulator and the chamber, and felt we were ready for the upcoming P78-2 tests, except for one item. This item was the programmable control system for the two-axis gimbal depicted in Figure 3. We started checking out the control system about a year before it was needed on this test. Our mistake here was in not fully recognizing the difficulty in repairing old one-of-a-kind digital control systems. With the suppliers' support, we started troubleshooting and continued on our own once he was not able to maintain his support due to other commitments.

By this time we were to the point where other requirements pertaining to the gimbal began competing with the repair of the control system for use of the gimbal. These requirements were a take-up reel, a partial gimbal shroud, and a safety stop for the gimbal. Limited access to the gimbal caused the these requirements and the controller repair to be delayed to the extent that their verification was not adequate due to schedule constraints. However, lack of good interface to establish its long-term reliability control was even more of a problem.

INTERFACE PROBLEMS

Though we had employed the established methods of interface control with a test plan, test procedures, fixture drawings, detailed schedules and other interface documents and meetings, we still fell far short of the needed interface control.

One interface problem that caused an overnight delay was an interference between the spacecraft and the partial shroud installed on the gimbal that precluded installation of the spacecraft on the gimbal. A design error caused in part by changing designers was not detected. Almost unbelievably, the identical dimensional error was made when dimensional checks were made to verify proper clearances. Once the problem was detected when installing the spacecraft, the error was still difficult to find but could have been uncovered earlier had the interface dimensions been checked specifically by both the laboratory and the project as part of the design check

Reflections of the solar beam from flat surfaces of multilayer insulation (MLI) back up to the collimating mirror and back down to the spacecraft and monitoring radiometers were of much higher intensity than had been anticipated. See Figure 2 . This caused the electrical power to the solar simulator to be significantly less than normal for the intensities indicated by the radiometers. In spite of the fact that temperatures and other parameters from the spacecraft also indicated the solar intensity was slightly low, the correct decision to go with the radiometers was made. Flight data indicate the thermal environment simulation was quite close.

These are just two of the several interface problems encountered during this space simulation test program. They are, however, representative of two types of interface problems, one mechanical and the other environmental. One of the other interfaces we did not establish and work was the project to laboratory interface, especially before the test. No one laboratory engineer nor one program engineer was assigned as the primary one responsible for keeping both parties completely informed and making sure all interfaces were addressed and worked. The laboratory did have one person assigned but much was worked around him which made his task extremely difficult. Had the program and the laboratory provided primary points of contact, problems would have been resolved earlier.

The three aforementioned interface problems were those that were most significant for the laboratory. Others that the laboratory was sensitive to were:

- o Contamination monitoring
- o Instrumentation interfaces
- o Acceleration of satellite by gimbal
- o Quality Control involvement in laboratory operations & configuration
- o Safety responsibility - satellite and SSL
- o Access control
- o Lab schedule
- o Customer/Lab interface
- o Building humidity and temperature control requirements

This list is an example of considerations a laboratory must address.

Up to this point in time, we had not had a formal interface control document (ICD) for test programs. However, previous tests were either much more simple or like Viking, had much more extensive preparation including development and thermal models in which the interfaces could be developed and verified. A formal ICD will not eliminate all interface problems, but it will certainly focus attention on the interfaces.

LESSONS LEARNED

The length of time and intensity of training to retrain or train an experienced technician or engineer to be a competent member of the operating crew who can fill the positions for which he is certified with confidence has been underestimated. While no specific problems were attributed to lack of personnel capabilities, an overwhelming stress was placed on the few experienced members of the SSL staff to meet the needs of the test. A training program has been prepared and is being implemented to augment the on-the-job-training normally employed.

Perhaps even more difficult than the maintenance of skills is the maintenance of the facility. Keeping a facility of this type up to meeting the demands of today's test requirements with the available skills, time, and budget is indeed a challenge. Here again we felt we were refurbishing the facility to a like-new condition. However, a few months and tests later, a whole new set of failure modes began to appear requiring the utmost from the operating crews to keep the facility on-line and meeting the test parameters. A lot of statistical data is not available for these one- or few-of-a-kind system which makes needed maintenance budget and replacement frequency hard to estimate. The state-of-readiness of the laboratory must be maintained so programs come to a safe, reliable facility for space simulation tests. Redundancy, reliability, a good spare parts inventory, and a well maintained system are necessary to assure minimum risk to the item being tested and to the test program.

Given the space simulation facility and its staff are capable of preparing for and conducting successful tests, poor interface control can still lead to trouble. Even with the several problems of our crew and facility, we could have eliminated several problems in the P78-2 thermal balance test with better interface control. We certainly learned the need for a comprehensive ICD for all major systems test. We feel this is the most significant lesson learned from the P78-2 test.

A good communication interface both before and during the test is also critical. We found that the interface during the test has been more than sufficient but when the test requirements are being developed and transmitted to the laboratory, the interface can be quite inadequate. Subsequent test programs have gone very well due primarily to a strong communication link.

CONCLUSION

Space simulation test programs can be carried out with a high probability of being troublefree with a competent staff, a well-maintained test facility and attention to interfaces. The P78-2 (Scatha) satellite was successfully tested with one interruption and a four-day abbreviated retest to verify a modification. This was accomplished in spite of the new test crew, a facility beset with several operational problems, and marginal interface control. These problems have been addressed with very good results. Subsequent tests have been highly successful.

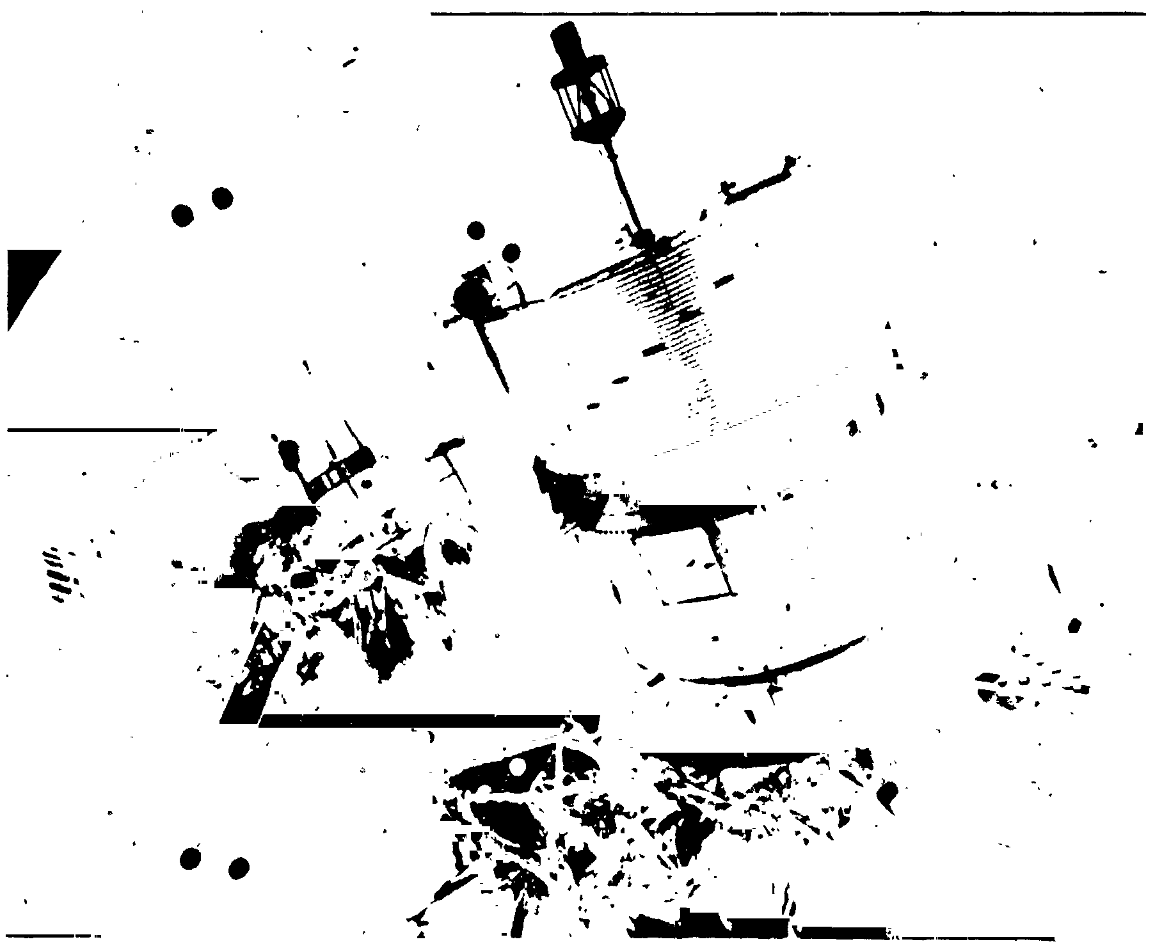

Figure 1. P78-2 Satellite In Chamber

Thermal Environment Simulation

Maximum Test Specimen Size
- Vacuum 20 x 46 ft, Solar Vacuum 16 x 16 ft

Working Vacuum
- 1 x $10^{-[illegible]}$ torr with Gas Load
- 7 x $10^{-[illegible]}$ torr No Load

Cold Wall -300°F, LN_2 Cooled; Solar Collimating Mirror, -60°F Cooled
- Simulates Uniform Free Space Background

Solar Simulation
- 0.35 to 1.25 Solar Constants
- Close Spectral Match to NBS Curve

Infrared Simulation
- 21 Separately Controlled IR Zones
- 1,700,000 Btu/hr
- Simulates Heat from Sun & Planets

Pumping
- 4 Mech. Pumps for Roughing Down to $10^{-[illegible]}$ torr & Diffusion Pumps [illegible]
- (20°K: 3 x $10^{[illegible]}$ liters/sec N_2)

Data
- 1000 Channels Central Logging
- 150 Auxiliary Channels
- 80 Real-Time Display Channels
- 10 Digital Display Channels

Figure 2. Basic Space Simulation Facility

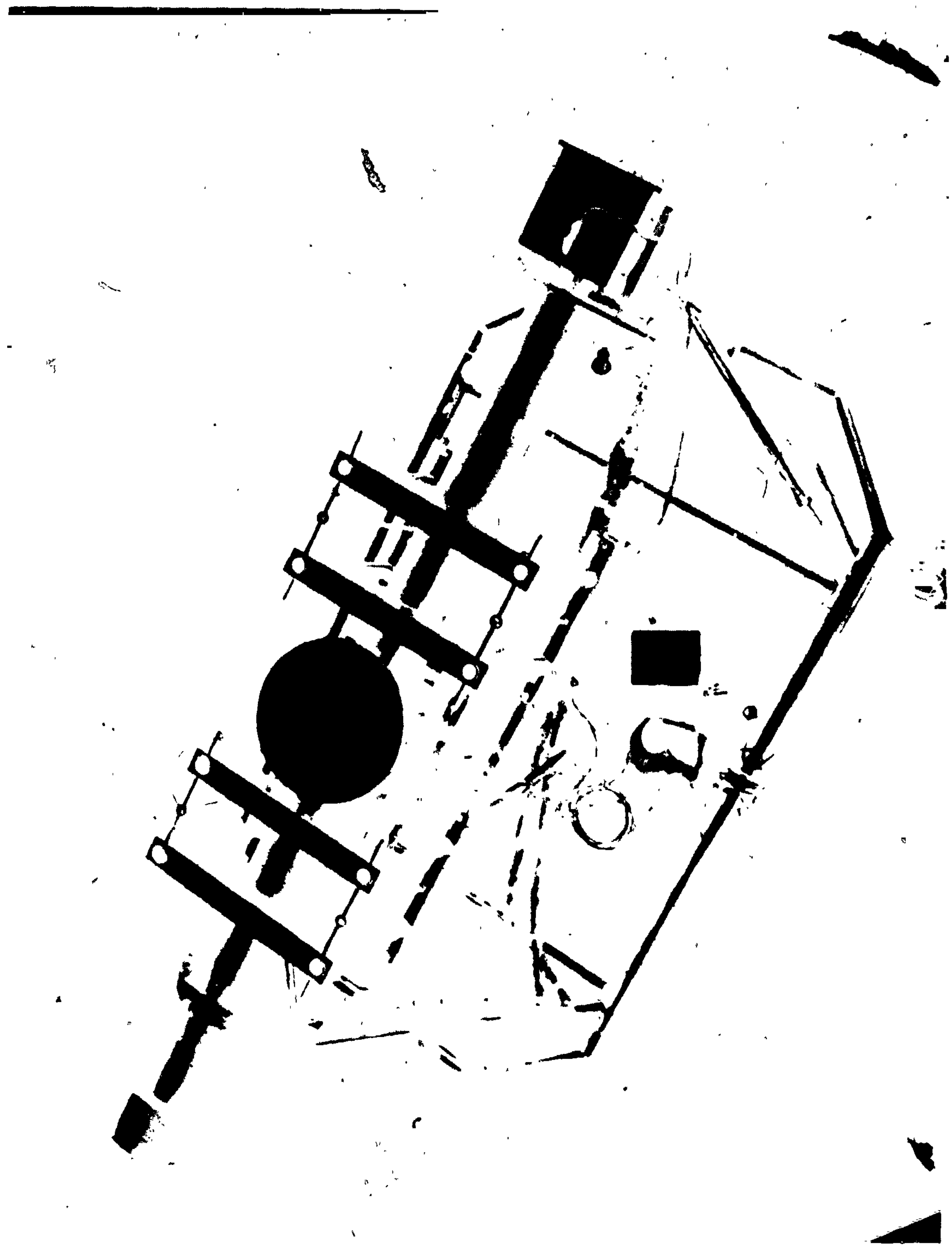

Figure 3. Two Axis Gimbal