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FROM DIFFUSION PUMPS TO CRYOPUMPS: THE CONVERSION OF GSFC'S SPACE ENVIRONMENT SIMULATOR

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ABSTRACT

The SES (Space Environment Simulator), largest of the Thermal Vacuum Facilities at The Goddard Space Flight Center, recently was converted from an oil diffusion pumped chamber to a Cryopumped chamber. This modification was driven by requirements of flight projects.

The basic requirement was to retain or enhance the operational parameters of the chamber such as pumping speed, ultimate vacuum, pumpdown time, and thermal system performance. To accomplish this task, seventeen diffusion pumps were removed and replaced with eight 1.2 meter (48 inch) diameter cryopumps and one 0.5 meter (20 inch) turbomolecular pump.

The conversion was accomplished with a combination of subcontracting and in-house efforts to maximize the efficiency of implementation.

INTRODUCTION

The SES (Space Environment Simulator) is a vertical, cylindrical, 8.2 meter (27 foot) diameter by 12.2 meter (40 foot) high working volume thermal vacuum test chamber. It is located in Building 10 at the GSFC (Goddard Space Flight Center) in Greenbelt, Maryland. Constructed in the early 60's the chamber used 17 oil diffusion pumps, without isolation valves, to create the high vacuum environment. The high vacuum system had worked quite well for almost thirty years, but driven by ever increasing cleanliness requirements of flight projects it was decided that the facility must be upgraded. The upgraded facility would allow NASA to support advanced payload development with continued strong in-house capability.

This upgrade was the seventh in a series of upgrades to thermal vacuum facilities at the Goddard Space Flight Center. Using lessons from the previous upgrades, this task was accomplished by a combination of in-house efforts and subcontracting to maximize the efficiency of implementation, meet flight project schedule requirements, and to stay within budget constraints. A three phased approach that spanned four years was used to accomplish this task.

IMPLEMENTATION

Phase 1 - Preliminary Engineering Report

In July of 1987 a PER (Preliminary Engineering Report) was undertaken to determine the scope of modifications necessary to convert the SES into a state of the art Thermal Vacuum Facility on par with the industry. The basic task requirement was to maintain or enhance the operational characteristics of the chamber, while eliminating the possibility of contaminating payloads with oil. These operational characteristics included rough down time, high vacuum pumpdown time, high vacuum pumping speed, and ultimate pressure. Also to avoid disruption to Flight test schedules, the chamber down time must be kept to a minimum. A timeline of the Project is shown in Figure 1.

To meet the task requirements for cleanliness, it was decided that the high vacuum system would have to be replaced. Cryopumps were chosen to replace the oil diffusion pumps because of their "innate cleanliness" and the net decrease in operational and maintenance costs. The 17 oil diffusion pumps and cold wall elbows would be removed and replaced with eight 1.2 meter (48 inch) diameter cryopumps with chamber isolation valves. The eight cryopumps provided a net pumping speed of approximately 238,000 L/S, which was 20% more capacity than the seventeen diffusion pumps. To reduce cost and ease installation, the diffusion pump chamber penetrations were utilized to mount the cryopumps.

Because some of the future payloads would be evolving a large amount of noncondensible gases, a .5 meter (20 inch) diameter Turbomolecular pump was added to assist the cryopumps which have a finite capacity for pumping these gases. Another benefit of this pump is that it would aid in leak checking the chamber. The turbomolecular pump is capable of pumping approximately 5,000 L/S of non-condensible gases. To again reduce cost and ease installation, a diffusion pump chamber penetration was utilized to mount the turbomolecular pump.

To improve roughing system performance, the facility roughing piping would be enlarged and rerouted for better conductance and reduced pumpdown times. Chamber isolation valves and cold traps were added to reduce the possibility of backstreaming roughing pump oil. To increase the reliability of the roughing system, each roughing pump was rebuilt. Rebuilding the system was more cost efficient than an outright replacement.

To increase system reliability, reduce maintenance, and make the system more "user friendly" a new vacuum system control console was developed along with a new PLC (Programmable Logic Controller) based control system. The vacuum console featured a full graphic representation of the vacuum process and a PC (Personal Computer) based color graphic system that will link the operators in near real time to the vacuum process. The specification provided for the selected contractor to be responsible for removing the old diffusion pumps, cutting the diffusion pump elbows, and modifying the roughing system. As well as procuring the new cryopumps, chamber isolation valves, VJ (vacuum jacketed) LN2 piping and installing these components on the chamber. The contractors were asked to bid a firm fixed price for the work. The contractor proposals were evaluated and a contractor was selected and a letter of intent was issued contingent on project funding.

Realizing that the .5 meter (20 inch) turbomolecular pump was a unique and possibly long lead time item, a specification was generated and this pump was also competitively bid during this Phase.

Another aspect considered during this phase was the preparation of demolition plans for the facility. Because the chamber is located in an operational lab area, contamination of the lab with dust, dirt, vapors, and other debris was of a major concern. Another concern was the safety of flight hardware and personnel in the immediate vicinity of the construction work. Working with the mechanical subcontractor, a demolition plan was developed that would minimize contamination to the lab and provide safety for personnel and equipment.

The plan revolved around enclosing the facility in a large fire proof canvas "tent" This tent would contain dust and debris and prevent personnel from entering the construction area. In addition, to keep particle contamination to a minimum all of the small piping would be sheared off rather than sawed. The mechanical subcontractor also devised a method of actually milling the stainless steel diffusion pump elbow off the chamber. This cutting method generated large chips of steel that were easy to clean up. Plasma cutting, which would have generated a large amount of contamination was not necessary.

Phase 3 - Construction

In March of 1990 funding for the project was received and work immediately began on implementing the task. The first step in our plan was to release the prime mechanical subcontractor. It would be about 7 months before the mechanical subcontractor was ready to move on site to install the vacuum system. During this seven month period, the project team concentrated on our in-house efforts and reviewing the efforts of the mechanical subcontractor.

In-house work began on the design of the PLC control system, the Mimic Panel (A large graphic panel), and fabrication of numerous shop drawings. Procurement specifications were developed, RFP's requested, and contracts awarded for the PLC, the color graphics system, the vacuum console, and the mimic panel.

In June of 1990 in-house demolition of the Facility began. Demolition began with the utility systems such as air, water, and nitrogen piping and electrical wiring. Removing these items cleared the way for the mechanical subcontractor to remove the diffusion pumps and elbows.

PLC based control system is covered in an "Application of Programmable Logic Controllers to Space Simulation", 17th Space Simulation Conference NASA CP-_____, 19__. (Paper ____ of this compilation).

Cleanliness of the vacuum was a prime concern. So it was decided the entire interior of the chamber would be cleaned to remove residual traces of diffusion pump oil.

MODIFICATION OF THE SPACE ENVIRONMENT SIMULATOR
PROJECT TIME LINE

7/87
♦ PRELIMINARY ENGINEERING REPORT
10/89
♦ PRELIMINARY ENGINNERING
3/90
♦ PROJECT FUNDED
6/90
♦ FACILITY DEMOLITION
11/90
♦ FACILITY CONSTRUCTION
10/91
♦ FACILITY
VERIFICATION

Figure 1: Project time line for SES showing major milestones.

Phase 2 - Preliminary Engineering

Prior to project funding, preliminary engineering work began in October of 1989. Driven by flight test schedules for the HST (Hubble Space Telescope) project, a 19 month construction schedule was decided. To meet this tight schedule it was decided that a combination of both in-house personnel and subcontractors would be necessary.

Four contractors that expressed an interest in this project were contacted. Each of the contractors visited GSFC to review and comment on the task. To utilize the expertise and construction capabilities of these subcontractors, a performance specification was generated that covered the procurement and installation of the new vacuum system. The

The mechanical subcontractor began on site work in November of 1990 and completed the task of installing the vacuum system in about three months. In March of 1991 the in-house mechanical construction crew took over and began the task of connecting all of the utilities to the new vacuum system (air, water and nitrogen), see Figure 2, and rebuilding the roughing system. The in house electrical construction crew installed the new vacuum console (see Figure 3), mimic, re-built the motor control center, and began point to point wiring of the facility. Construction of the Facility was completed in September of 1991.

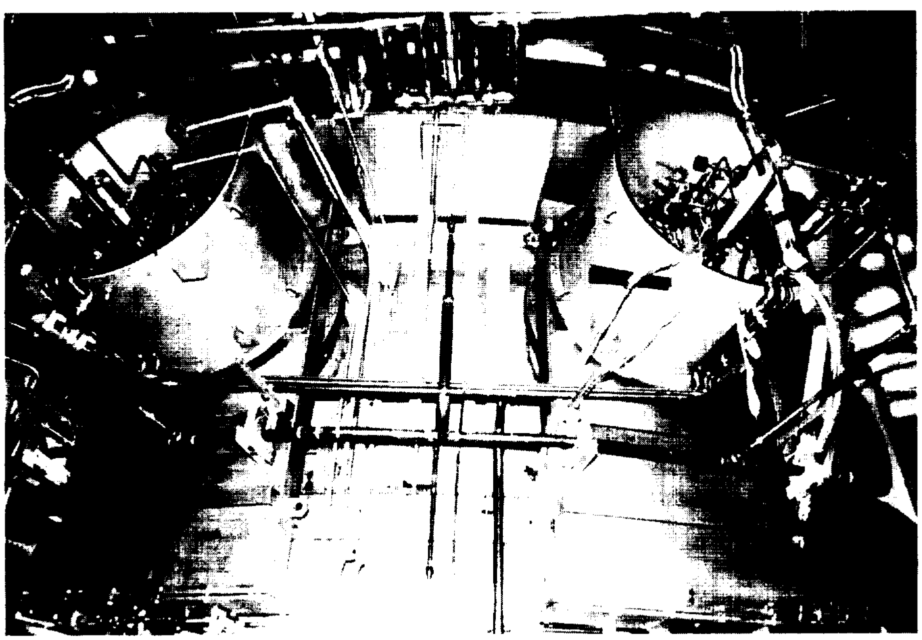

Figure 2: Installation of utility piping to 48 inch diameter cryopumps.

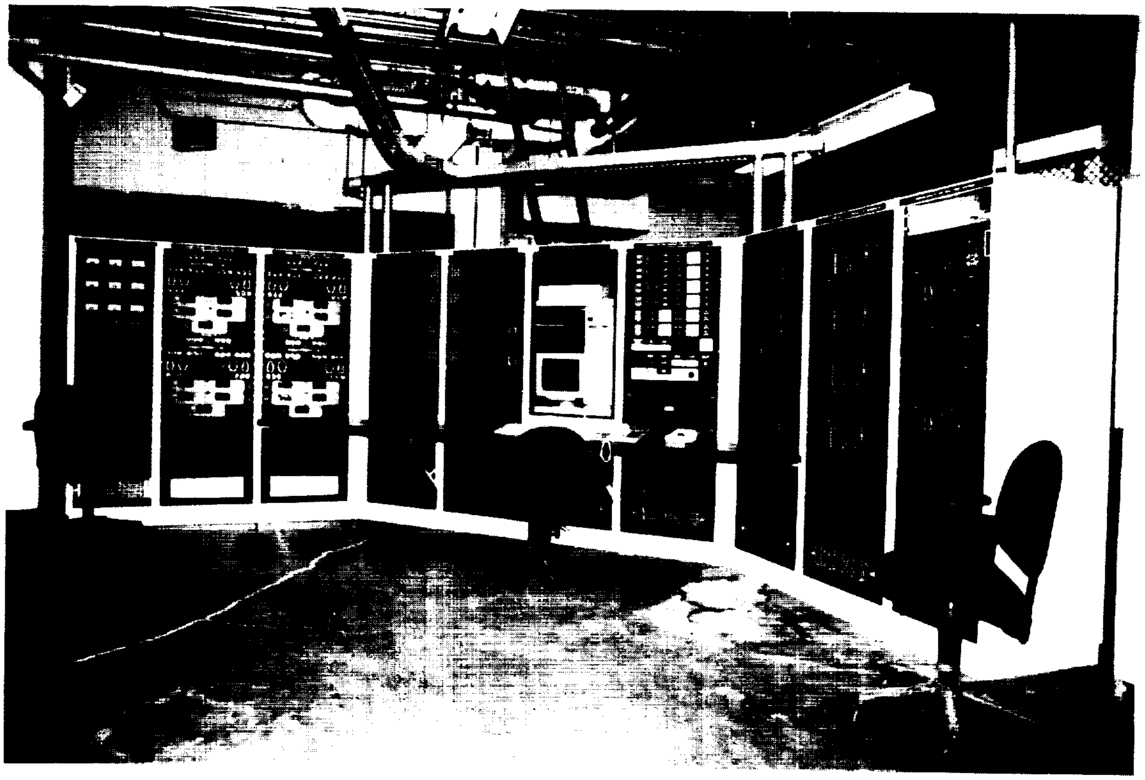

Figure 3: New vacuum control console during construction phase.

Verification And Performance Testing

During the month of September 1991, the chamber shrouds and shell were extensively cleaned to remove traces of diffusion pump oil. This task was subcontracted so that in-house efforts could be channeled at checkout of the facility. Prior to cleaning of the facility, wipe samples were taken at selected areas on the shell and shrouds. The samples were evaluated by the NASA materials branch and a base line cleanliness of the facility determined. The cleaning subcontractor then used a three stage cleaning process. In the first phase the chamber was completely vacuumed from top to bottom using HEPA filtered vacuum cleaners. This removed the large contamination from the chamber, while preventing the generation of more dust. The second stage was to completely wash the chamber shell and shrouds with an emulsifying detergent, followed by a DI (deionized) water rinse. The detergent wash was applied by a combination of high pressure washers and hand scrubbing with sponges. In the final cleaning stage, the chamber shell and shrouds were completely rinsed and wiped down with reagent grade alcohol. Wipe samples were again taken and showed that all surface traces of diffusion pump oil had been removed. A baking of the chamber would provide the final cleaning of the chamber.

During the month of October 1991, the facility was certified and performance verified. The goal of the verification was to prove that each of the new sub-systems, the PLC, and system interlocks operated as designed and that systems not upgraded during the task still functioned as designed. During the facility verification every component of the facility was exercised by procedure. Each electrical circuit was tested and the system tested by simulating failures and observing that alarms were initiated and systems shutdown as designed.

CONCLUSION

System performance met or exceeded all goals established in the PER. The chamber is capable of roughing down to 100 microns, our crossover pressure, in 2.5 hours. With six cryopumps operating the chamber was able to reach a pressure of 2 x 10E-7 Torr in less than 4 hours. Regeneration of the pumps can be accomplished in less than six hours. To complete the cleaning process, the chamber was baked and certified at +75 deg C with two QCM's (Quartz Crystal Microbalances) at -20 deg C with a delta frequency of less than 300 HZ for 3 consecutive hours. The chamber is now qualified for most all NASA projects.

The task however was not completed without learning a few new lessons. The number one lesson learned on this task was to require complete performance testing of key equipment and then to witness the vendor tests. In spite of witnessing many performance tests of equipment, in more than one instance equipment that was not tested and witnessed at the vendors shop failed during facility verification. A second lesson learned concerned the use of prime subcontractors. The use of a prime contractor was a great benefit. Not only were we able to bring to bear additional resources, the task was completed for a fixed cost. This allowed us to coordinate a large amount of work through a single subcontractor.