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# COMPUTER AIDED PROCESSING USING LASER MEASUREMENTS

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## ABSTRACT

We now have the challenge of processing the STS and its cargo through KSC facilities in the most timely and cost effective manner possible. To do this we have established a 3-D computer graphics data base into which we have entered the STS, payloads and KSC facilities. The facility drawing data are enhanced by laser theodolite measurements into an "as-built" configuration. We have combined elements of the data base to study orbiter/facility interfaces' payload/facility access problems and design/arrangement of various GSE to support processing requirements. With timely analysis/design utilizing the 3-D computer graphics system, costly delays can be avoided. Better methodology can be analyzed to determine procedures for cost avoidance. Some day we hope to have not only a KSC, but an inter-center data exchange network.

## CHALLENGE

The challenge before us today is to process the Space Transportation System and its total complement of payloads (cargo) through the various facilities at the Kennedy Space Center in the most timely and cost effective manner possible.

One of our more pressing problems is the interaction of three primary elements: Space Shuttle, Cargo, and Facilities.

First, the Orbiter must be processed in the Orbiter Processing Facility (OPF) without interference from the many platforms necessary to gain access for post-flight inspection, maintenance, and premate checkout prior to payload installation.

Next, Shuttle elements - the Orbiter, the External Tank (ET) and the Solid Rocket Boosters (SRB's) must be successfully integrated and stacked on a Mobile Launch Platform (MLP) inside the Vehicle Assembly Building (VAB) midst its assorted platforms and levels of access.

Numerous experiments and payload elements must be integrated into cargos for each mission. This integration and checkout is accomplished in the Horizontal Processing Facility (HPF), various hangars, and the Vertical Processing Facility (VPF). Each facility/MMSE (Multi-Mission Support Equipment) must be able to accept and not interfere with the myriad of payload elements.

Finally, the cargo must be entered into the Orbiter. This may be done either in the OPF or at the launch pad in the Payload Changeout Room (PCR). Here all three, the Shuttle, the cargo, and the facility, must interface precisely to accomplish a successful mission.

## METHODOLOGY

Our methodology is common throughout for these challenges and their solutions; let us introduce our procedure.

We have established a computer graphics data base utilizing a three-dimensional color graphic system. The Shuttle configuration, the various cargos, and all the facilities utilized for buildup and processing are inserted into this data base utilizing dimensioned drawings and various input techniques. Single operator input time can vary from hours or a few days for a simple subject, to a month or more for a detailed facility.

Once the data base is built, it is relatively easy to produce the interrelationships between the three elements of Shuttle-Cargo-Facilities. Through the use of the computer graphics system, various components can be manipulated, shrunk, stretched, moved, modified, etc., at will. This is especially useful when arranging or modifying Ground Support Equipment (GSE), or moving an experiment from one payload to another, or arranging different payloads according to the ever changing cargo manifests. Our zoom ability is very useful when a detail must be examined closely, plus, a measurement capability is available to determine clearances, interferences, line lengths, etc. Real-time working documentation can be obtained by a CRT copy machine. Final drawings are procured on a large 36" x 54" plotter on milar or vellum. This procedure, prior to the computer age, was accomplished by using basic drawing with overlays and cutouts.

A major uncertainty in facility definition is the difference between the design drawings and the final as-built configuration. To account for this variation, we at KSC have attempted to survey as much of each of the facilities as possible.

Our survey instrument is a laser theodolite, which is self-powered and field-transportable. It utilizes micropressor calculation with digital display of the data. Data presented is horizontal distance, slant range, height, cross range, azimuth angle, and elevation angle. It does all this with an instrumentation accuracy of $\pm 5$ mm in 5 km (0.0001%). The laser target is an optical prism, which is placed at the point to be measured. In its raw form, the transit data is not compatible with the format utilized by our computer; therefore, we have produced a special program that converts the theodolite data into our Orbiter X, Y, Z coordinate system.

Once we have the survey data entered into the computer graphics data base, we apply the selected points to the model constructed from the design drawings. Here is where you find the interesting discrepancies: doors are misaligned; walls are not plumb; platforms at odd levels; columns moved; and especially outlets for power, fluids, and gases seem to show up on the survey data as "as-built" locations. We have a very high level of confidence that our as-built computer models truly represent the actual facility.

The facilities we now have in our data base include the Vertical Processing Facility (VPF); Orbiter Processing Facility (OPF); Vehicle Assembly Building (VAB); Payload Changeout Room (PCR); and the Horizontal Processing Facility (HPF), including the N&S Level IV workstands, Spacelab workstands 2 and 3, Cargo Integration Test Equipment (CITE) workstand 4, Apollo Telescope Mount (ATM) cleanroom, and various Spacelab handling and access. We have recently completed the Launch Equipment Test Facility (LETF) where we check out the various umbilical and access arms utilized in Space Transportation System (STS) servicing at the launch pad. We can now analyze Orbiter/umbilical motion in three dimensions simultaneously. We do not necessarily have all of each facility surveyed at this time, but we are working on it.

The Orbiter contractor provided us with the Columbia's exterior mold lines, which we input into our data base. We also have Challenger's payload bay in the data base. While we have the Remote Manipulator System in the data base, we have input small details, such as the handrails and antenna, only when we were requested to work a specific problem. Results from various studies show that our Orbiter model is very accurate.

Starting with OSTA-1 which flew on STS-2, we began entering payload information into the data base to assure integrability with the various facilities. Some of our payload models were created from highly detailed drawings; others were created from drawings with very few dimensions that were digitized with our computer equipment.

Any payload in our data base can be positioned into any facility we identify as having a requirement for analysis. We can determine access problems in the various processing facilities. What may be easy access from a workstand in the horizontal position may present a difficult problem when inserted in the Orbiter in a vertical position with only limited levels from which to work. We have an overall high confidence level in our data facility/cargo base and feel comfortable with any challenge presented for solution.

## ACHIEVEMENTS

We are utilizing our computer graphics capability to help simplify and expedite the STS and cargo processing at KSC. The survey enhanced data base has enabled us to analyze difficult three-dimensional problems quickly and with a very high level of confidence in the answers. We have studied a rather broad spectrum of problems from orbiter stacking and payload access to facility/GSE layout.

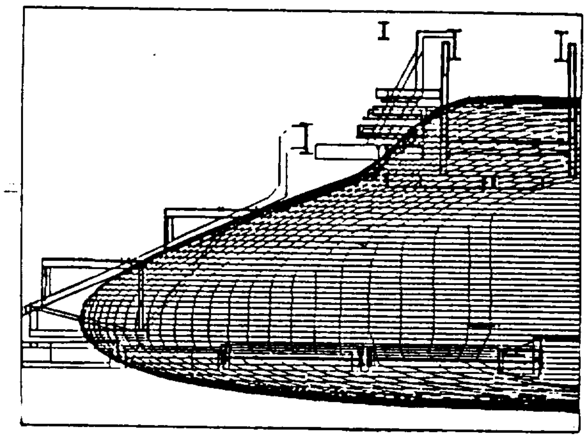
## EXAMPLES

The following is a sampling of how our system is being utilized with examples taken from studies that have been performed at KSC.

### Assure Orbiter/OPF Compatibility

Prior to the arrival of Columbia at KSC, there was concern if any of the access and service platforms in the OPF would interfere or damage the Orbiter when placed in position.

The Orbiter was moved into the OPF; the OPF workstands were positioned around the Orbiter--all done with the computer graphics system! At those points where interferences were identified on the computer simulation, platforms were physically modified to give adequate clearance. The simulation was verified when the Columbia was actually towed into the OPF; the platforms were moved into position--and no interference! Note Figures 1 and 2 which also indicate our zoom capability.



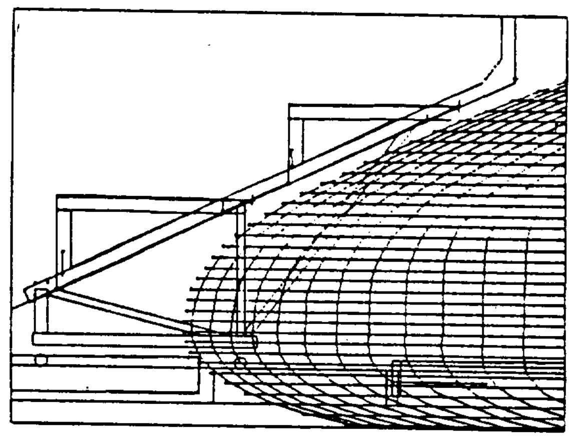


Figure 1. ORBITER/OPF MOVEABLE ACCESS PLATFORMS Figure 2.

### Orbiter/ET/SRB Stacking Enhancement

On STS-6, the MLP was placed 1.5 inches off the predetermined set point. The stacked configuration of the Orbiter/ET/SRB on the off-center MLP was constructed in the data base. Then the VAB extendable platforms were moved into position around the off center stacked configuration. No excessively close tolerances were observed at any of the work levels; therefore, the MLP was allowed to remain off center, and the stacking effort continued without having to move the MLP. But more importantly, time was not wasted, personnel were not endangered and STS equipment was not damaged.

A similar condition occurred when we were asked if the Orbiter could be lowered through the platforms in the VAB with the forward bipod already attached to the ET (Figure 3). Previously, the bipod was attached after the Orbiter was lowered and soft mated to the rear struts -- a difficult and time-consuming operation. Again the model was constructed in the data base, and the operation proved that the Orbiter could be successfully lowered through the platforms, past the bipod, without interference.

Another exercise was run to see if the body flap in a $20^{0}$ below the null location could be passed by the bipod. Again, the simulation indicated that we could lower the Orbiter with the body flap in the designated configuration. This exercise eradicated the need to power up the Orbiter after transfer from OPF to VAB to allow hydraulics to zero the control surfaces before stacking in the VAB.

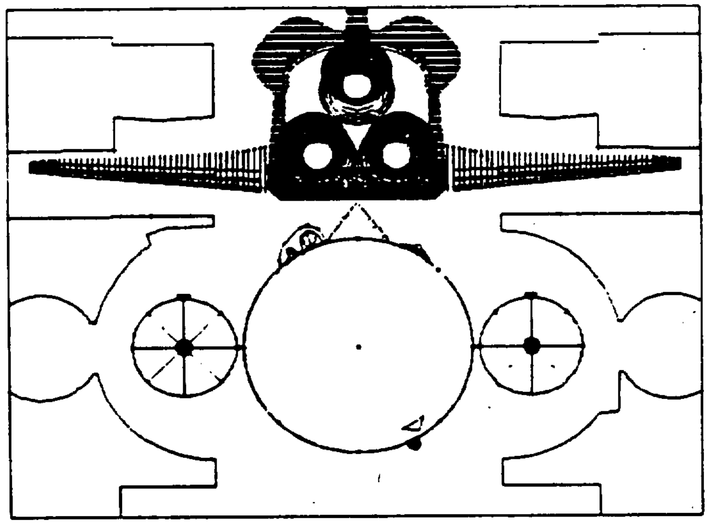


Figure 3. ORBITER/BIPOD CLEARANCE DURING MATING

### Filament Wound SRB Study

The proposed filament wound SRB will have more flexibility than the present steel cases. This will result in greater Orbiter/ET umbilical connection motion. The Tail Service Mast (TSM), which contains the T-0 umbilical and linkage was modeled to study the motion in three dimensions to determine maximum travel limits and element fatigue levels. Various T-0 excursions were analyzed to determine what facility modifications would be necessary (Figure 4). In addition, the entire Launch Equipment Test Facility (LETF) was input into the data base to determine what modifications were required on the LETF to test these new excursions. This facility consists of five major test structures/systems.

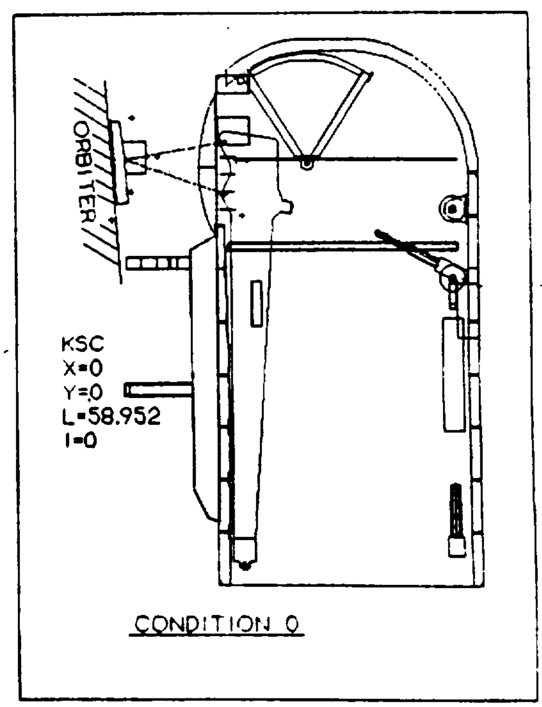



Figure 4. FILAMENT WOUND SRB EXCURSION STUDY
TSM MOD ANALYSIS

## Parallel Processing of Cargo in the HPF

In order to study the impact of increased traffic in the out years, all cargo processing equipment and facilities are being entered into the data base. We have already taken a look at the problem of having SL-2, SL-3, and three elements of mixed cargo in the Level IV workstands at the same time. Various elements of access GSE were modeled to determine optimum use with minimum modification, or hindrance to other elements. It is very easy to cut and try with this system. We plan to model all the handling equipment and GSE necessary to identify all cargo placement in each workstand, at a given time slice, per month and year. This will provide maximum GSE utilization (Figures 5 and 6).

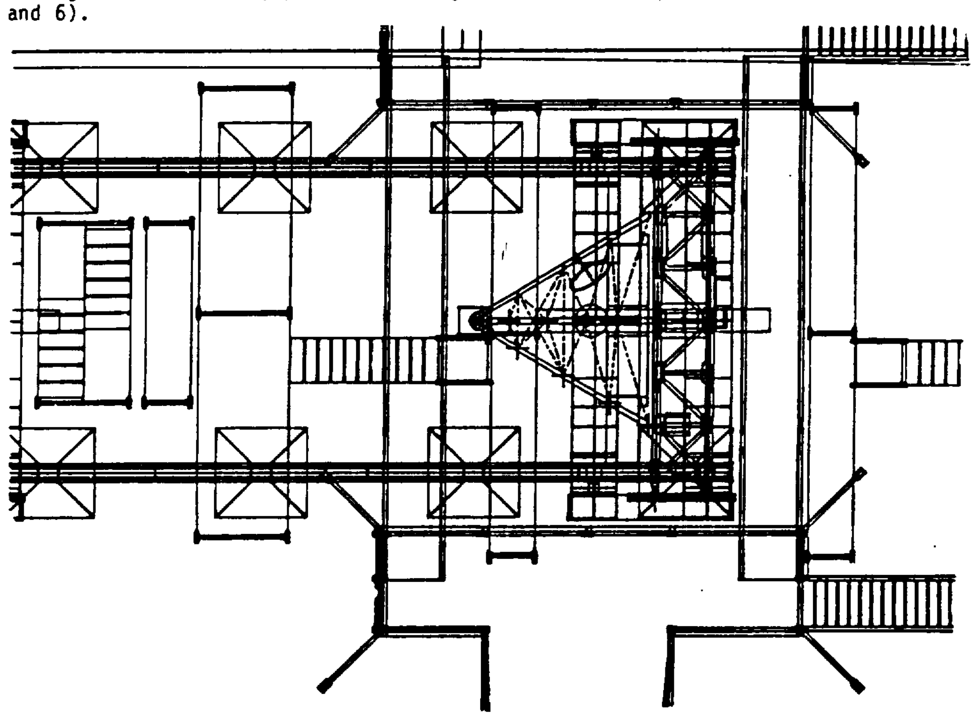


Figure 5. OAST-1 ACCESS STANDS -- O&C LEVEL IV INTEGRATION AREA (PLAN VIEW)

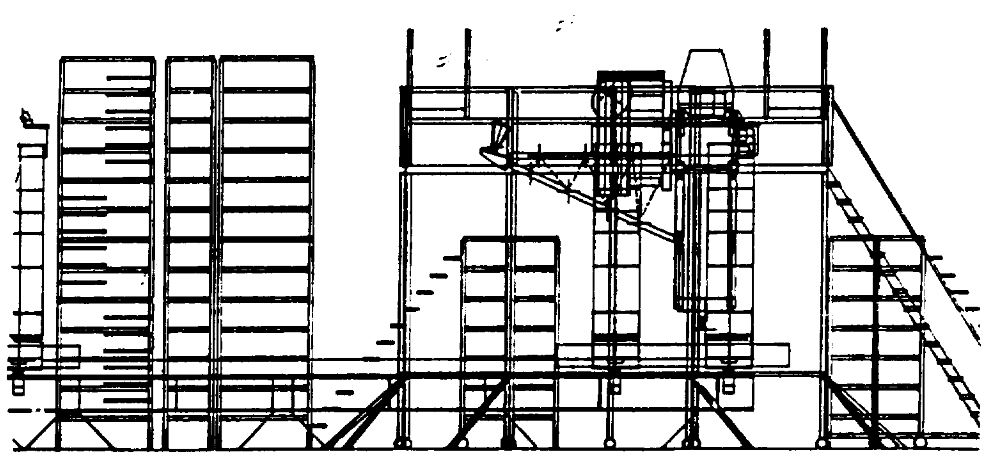


Figure 6. OAST-1 ACCESS STANDS -- O&C LEVEL IV INTEGRATION AREA (ELEVATION VIEW)

## Accessibility of Cargo in Facilities

Accessibility is always a critical element at KSC, and when the cargo is placed into the Orbiter, things get even more difficult.

One of the first challenges we met was determining placement of a Dewar on the platforms in the OPF and PCR. This placement is necessary for servicing two experiments utilizing cryogenics, and line length is critical.



To service experiments on SL-1, it was determined that the present extendable bucket originally designed for access in the payload bay was too large for the limited space available. A smaller 16" x 20" platform was designed on the computer graphics system. An orthopormorphic man was designed to test positioning, movement, and reach from the platform. Engineering and cargo operations conducted the CDR on the computer. This was a first for us, but we believe it is the beginning of many more to follow (Figure 7).

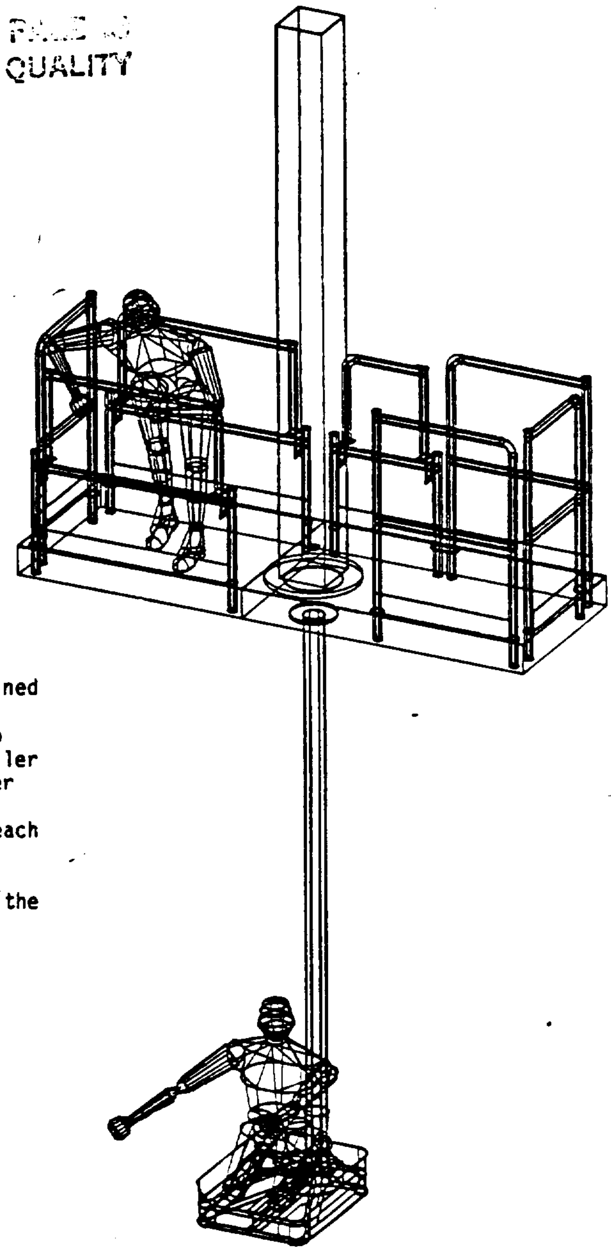


Figure 7. ACCESS PLATFORMS/ORTHOPORMORPHIC MEN

We have simulated several different cargo elements in the VPF to determine access from its work platforms. One of our more famous elements is the space telescope, which requires considerable access to several different panels and compartments on board (Figure 8).

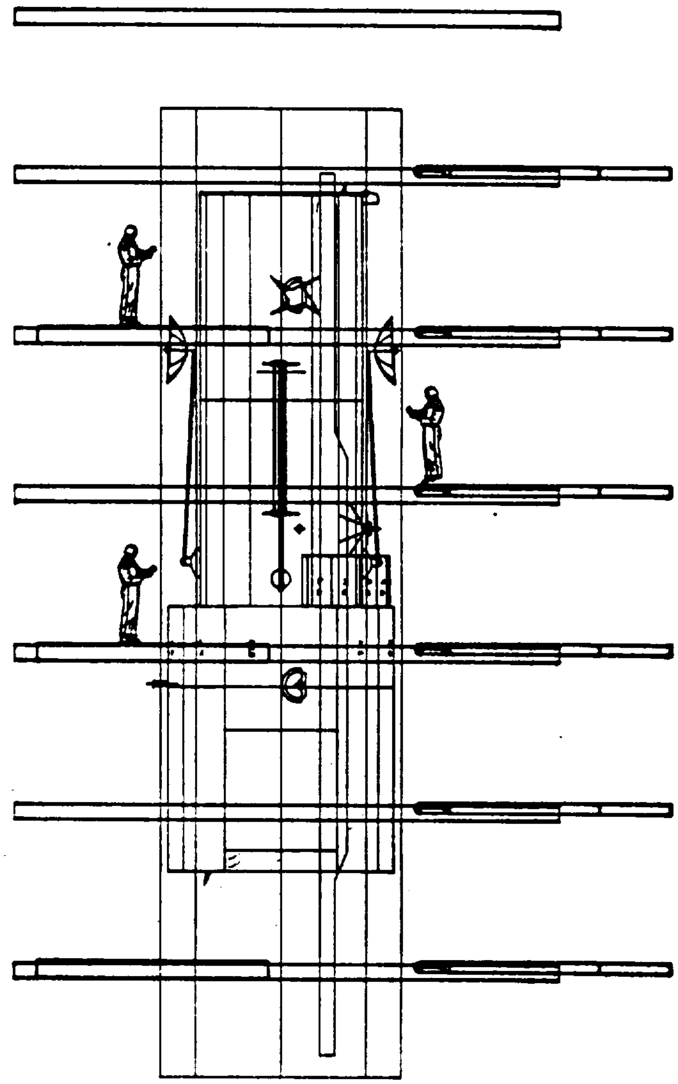


Figure 8. SPACE TELESCOPE IN VPF

The PCR at the Pad provides many challenges for our computer graphics system. Here in the PCR, is where all elements of the mission finalize. Often experiments have late access requirements, which are sometimes quite difficult to achieve in an environment that has rotated 90 degrees, and are now confined by the envelope of the payload bay. OSTA-1 battery access was our first exercise in the PCR. SL-2 cryogenic servicing is a persistent problem we are still modeling (Figure 9).

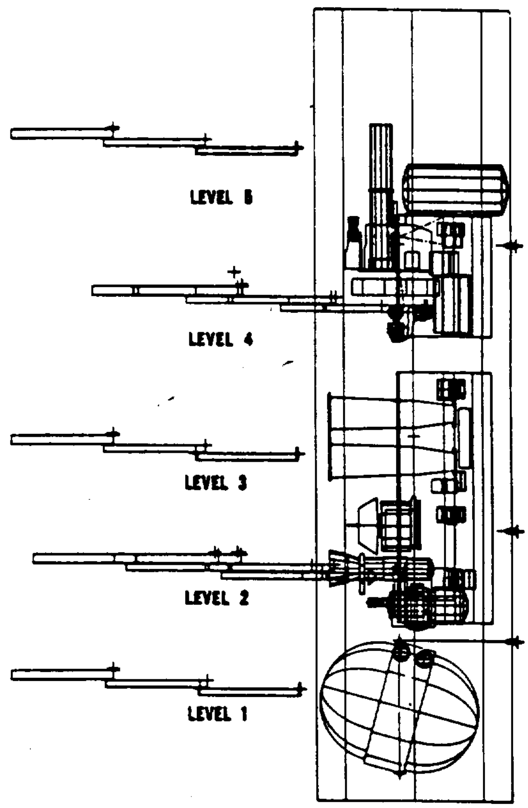



Figure 9. SL-2 IN PCR -- PGHM LEVELS 1-5

We have recently started constructing the data base to model the GSE necessary for a contingency landing site. Here, we must have maximum utilization from a minimum amount of equipment.

Sometimes, when a problem is identified to us, we can point to a solution that saves a great deal of time and money, such as the stacking exercises mentioned earlier, which can be equated in time and dollars saved. Sadly, we sometimes also prove that a clever idea just won't work.

We also must realize that there is a cost saving in preventing problems. These are very hard to quantify. A lot of the things done in the cargo processing world could be done on a drafting board or just by going out and measuring something (sometimes a brave or foolhardy thing to do at the VPF or PCR). As an example, we didn't have to service the OSTA-1 battery at the pad, but we knew that if we had to, we could not extend the center platform past the antenna. So, an alternate method had to be worked out in advance in the event servicing was necessary. How much do you save by putting the access stand up once, right, the first time?

We feel that one of the most valuable things we save is analysis time; time we don't have as the traffic increases.

## PROPOSED RESPONSE TO MEET FUTURE CHALLENGES

At this time, KSC Engineering Development is making an in-depth study to determine our next generation computer system. We have asked our friends in the cargo and vehicle processing world to coordinate their efforts with us to provide an optimum system capable of meeting all our needs. Design engineering requires a large scientific computational capability while, in addition, Operations requires considerable graphics capability. Our intentions are that, in the future, we will design, coordinate, review, and sign off on the computer.

We intend to strive toward a controlled data base. With the new generation of engineers who are accustomed to working with computers we believe an entire engineering effort can be accomplished within the computer data base system.

Once a facility, cargo or flight vehicle, has been defined, it can be baselined and controlled within the system. Engineers can draw this information out of the controlled memory data base and perform operations or modifications at a remote terminal. However, the system would require appropriate sign-off/releases for the mods to be incorporated into the controlled data base. We believe this would also reduce/eliminate the huge volume of paper required and time consuming release boards. We have made the first steps towards these goals and when our new generation system comes on line, we hope to attain all of our goals.

Another important step we would like to propose is to have inter-center coordination for all of our common information requirements. At the present time, our computers and their great store of information in their data bases cannot communicate with each other. KSC has very detailed launch and cargo processing information and other centers such as MSFC, JSC and GSFC have payload information in their computers. Currently, KSC cannot transfer this information from one system to another.

We would like to propose a NASA-wide common data base where we all could exchange information. Perhaps we all do not require the same type of computer, but we should coordinate the effort so that the data bases are compatible, thereby releasing a great amount of transferable detailed information.

We believe that by utilizing such state-of-the-art technology to its fullest, we can minimize unknowns and process Shuttles and their cargo in a timely and cost effective manner. That is the ever present challenge.