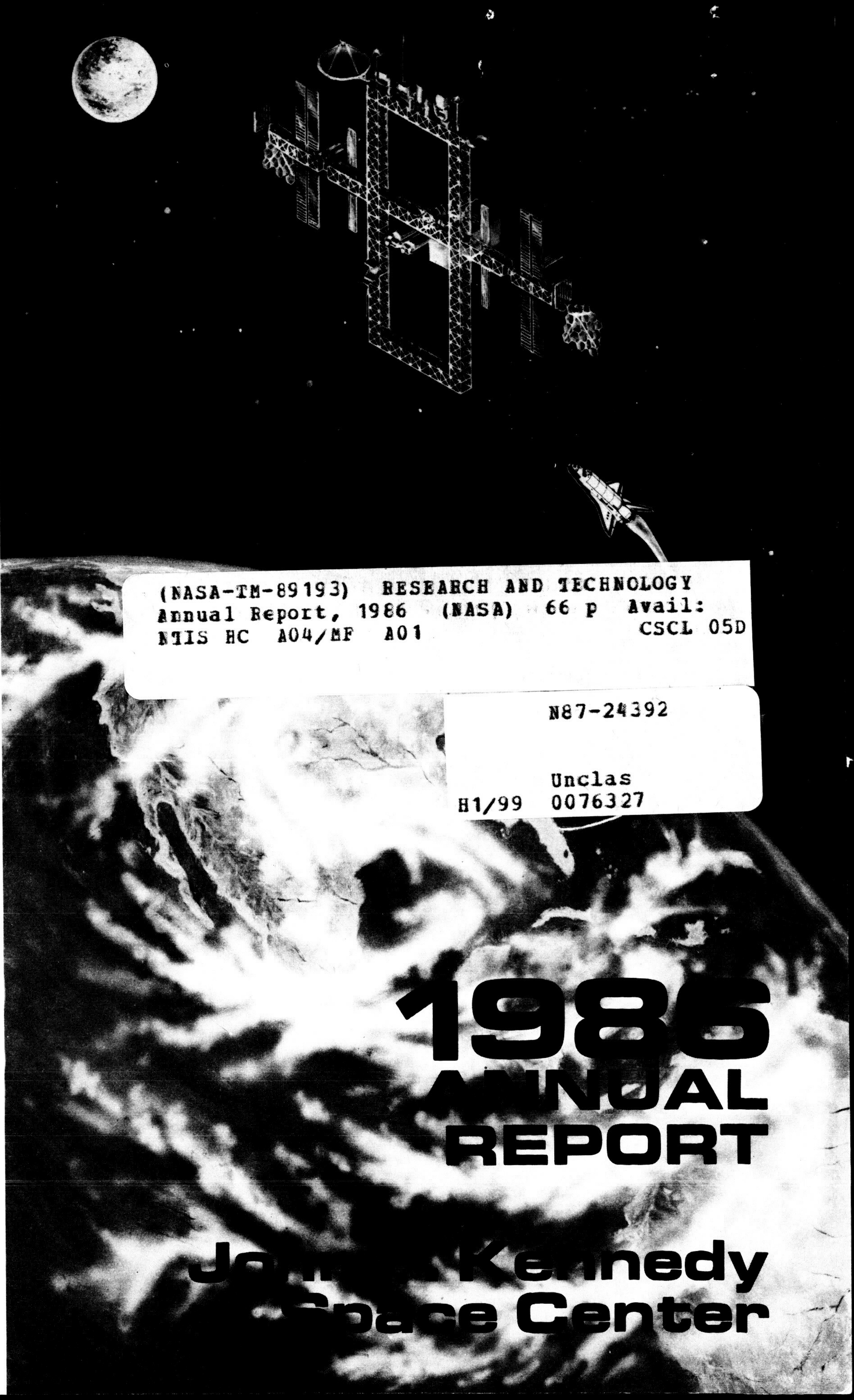
NASA Technical Memorandum 89193

RESEARCH AND TECHNOLOGY



1986 ANNUAL REPORT

John F. Kennedy Space Center

NASA Technical Memorandum 89193

Research and Technology 1986 Annual Report of the John F. Kennedy Space Center

FOREWORD

As the NASA Center responsible for assembly, checkout, servicing, launch, recovery, and operational support of Space Transportation System elements and payloads, Kennedy Space Center is placing increasing emphasis on the Center's research and technology program. In addition to strengthening those areas of engineering and operations technology that contribute to safer, more efficient, and more economical execution of our current mission, we are developing the technological tools needed to execute the Center's mission relative to future programs. The Engineering Development Directorate encompasses most of the laboratories and other Center resources that are key elements of research and technology program implementation, and is responsible for implementation of the majority of the projects in this Kennedy Space Center 1986 Annual Report.

For further technical information about the projects, contact David A. Springer, Project Engineering Office, DF-PEO, (305) 867-3035. James M. Spears, Chief, Technology Projects Office, PT-TPO, (305) 867-7705, is responsible for publication of this report and should be contacted for any desired information regarding the Center-wide research and technology program.

Forrest S. McCartney
Forrest S. McCartney
Lt. General, USAF
Director

AVAILABILITY INFORMATION

For additional information on any summary, contact the individual identified with the highlight. Commercial telephone users may dial the listed extension preceded by area code 305. Telephone users with access to the Federal Telecommunications System may dial the extension preceded by 823.

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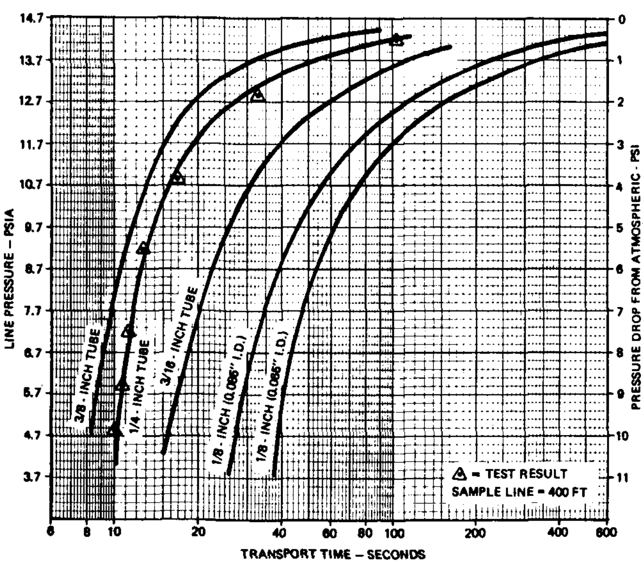
Hazardous Gas Detection System Sample Line Transport Time Study

The use of large quantities of explosive and toxic propellants at Shuttle launch and landing sites necessitates the use of a number of gas detection sensors and systems. These draw samples through lines that range from a few to several hundred feet in length. While NASA has expended considerable effort to collect and publish a handbook for the designer of high-pressure gas systems, the designer of gas sampling systems is forced to calculate from first principles for each new problem.

In this study, an analytical model of sample lines has been developed which uses coefficients obtained from laboratory tests of short lengths of various size tubing, ranging in diameter from 1/8 to 3/8 in. From this work it was determined that 1/4-in tubing was the optimum size for KSC applications.

Tests of 200- and 400-ft lengths of 1/4-in sample line were conducted to verify the analytical model. The test results correlated closely with the analytical data. The study has resulted in a chart showing sample line transport time for 1/4-in tubing ranging from 50 to 1,000 ft in length. The figure "Sample Line Transport Times for 1/4-Inch Tubing" shows the close correlation between model data and test results (indicated by triangles) obtained with a 400-ft sample line.



Sample Line Transport Times for 1/4-Inch Tubing

Peter J. Welch, 867-4614 DE-MAO-2

Hazardous Gas Detection System

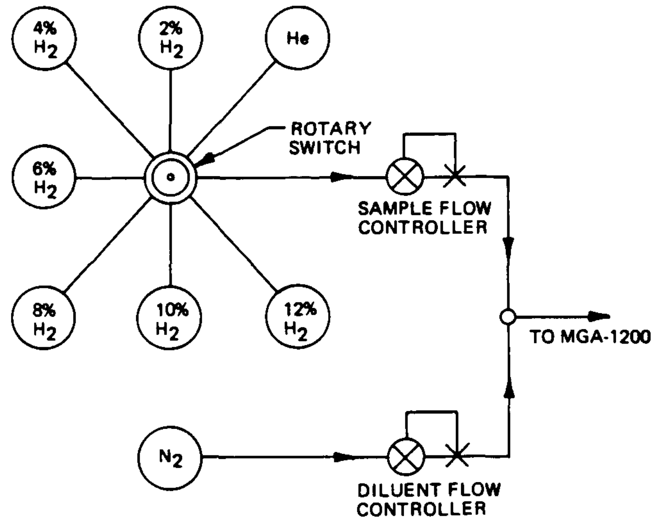
Objective: Develop a prototype detector for gaseous propellants used aboard the Space Shuttle. The prototype will be based on the proven Navy Central Atmosphere Monitoring (CAMS) hardware. It is not the intent of this portion of the project to produce a complete system to replace the current Hazardous Gas Detection System (HGDS), but to prove that the CAMS analyzer will meet and exceed the performance and reliability specifications required for the HGDS.

Background: Prior to launch, various compartments of the Space Shuttle are monitored for hydrogen, oxygen, and helium leaks. The current monitoring system does not have the desired reliability, serviceability, or any guaranteed long-term manufacturer support. NRL was tasked by NASA to adapt the CAMS for the above monitoring task. CAMS is used aboard all nuclear submarines and has a MTBF greater than 3,000 hours when operated continuously in a submarine environment. It does not require recalibration during its 20,000 hours of average use between refurbishments. The expertise to refurbish the unit, spare parts, etc. are being maintained and will continue to be maintained by Navy far into the future.

Approach: The mass spectrometer module of the CAMS will be modified to detect helium and argon in addition to water, nitrogen, and oxygen. Where possible, the CAMS mechanical and electrical hardware will be used. For testing and evaluation the analyzer will be interfaced to a commercial microcomputer system.

Results: The CAMS-HGDS prototype analyzer is a reliable system capable of performing the analysis requirements of a HGDS system. The only "failure" of the system in over one year of continuous testing has been spiking of the ion pump. The spiking would not cause the system to fail but could add some noise to the signal. Control of the leak valve using the nitrogen signals works well and gives very stable readings. Manual coarse adjustment of the leak valve should only be required a few times a year. The relative sensitivity of the unit is very stable, typically varying a few percent per month. Except for helium, the absolute detection limits are more than adequate for HGDS requirements. The system appears to be linear from the lowest detection limit of 20 ppm to high percentage levels for all gases. An upper limit occurs only when the amount of nitrogen in the gas stream decreases sufficiently to affect the leak valve control circuit.

J. D. Collins and W. R. Helms, 867-4438
DL-NED-32



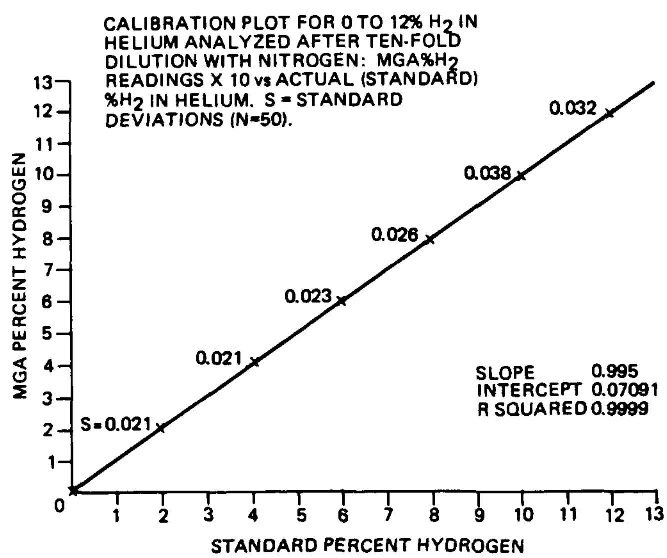
Gas Dilution Apparatus

Feasibility of a Gas Dilution System for Analysis of Hydrogen in Helium Atmosphere Using an Ion-Pumped Mass Spectrometer

The objective of this study was to design and test a gas dilution system which can be used to dilute helium purge from various umbilical cavities associated with liquid hydrogen (LH_2) lines of the Shuttle. The dilution of helium purge with nitrogen was necessary to allow detection of hydrogen leaks in the LH_2 umbilicals using the existing Back-Up Hazardous Gas Detection System (BUHGDS). The BUHGDS includes a Perkin-Elmer Multiple Gas Analyzer Model MGA-1200, which is a magnetic-sector-type mass spectrometer with diode ion-pump. The mass spectrometer is range-optimized for the detection of H_2 (0 to 2 percent), He (0 to 20 percent), O_2 (0 to 2 percent), and Ar (0 to 1 percent) in nitrogen atmosphere.

The helium purge cannot be directly analyzed by the MGA-1200 since the mass spectrometer cannot handle more than 20 percent helium in a sample. Any higher concentration of helium interferes with the efficiency of the spectrometer's ion-pump. However, a helium purge sample on dilution with nitrogen could be analyzed with the MGA-1200 if helium concentration is reduced below 20 percent.

The gas dilution system used in this study included two MKS Model 1258-B mass flow controllers calibrated for helium and nitrogen flows, respectively. The figure "Gas Dilution Apparatus" illustrates the experimental system. The testing of the dilution system included dilution of standard hydrogen-helium mixtures with known amounts of nitrogen and subsequent analysis with an MGA-1200 similar to the BUHGDS. The percent hydrogen in the H_2/He sample was determined by applying the dilution factor to the MGA's percent H_2 reading. The testing was carried out for five-fold, ten-fold, and twenty-fold dilution of hydrogen-helium samples with nitrogen. The figure "Ten-



Ten-Fold Dilution Test

Fold Dilution Test" illustrates the results for the ten-fold dilution experiment. The relative error in all the tests was less than 4 percent, indicating the feasibility of the analytical method.

The dilution factor can be calculated from the flow rate of H_2/He samples and the flow rate of nitrogen diluent. However, this requires that the H_2/He sample should not be contaminated with any other gas, as contamination of a sample alters its flow rate. Calculation of the dilution factor using an algorithm and the MGA's percent N_2 and percent O_2 readings is possible. The algorithm does not require the knowledge of the sample and diluent flow rates. Use of the algorithm to calculate the dilution factor is recommended since it yields accurate results for the uncontaminated H_2/He samples as well as for the samples which may be contaminated with either nitrogen or with air. The algorithm can be programmed into a computer interfaced with the MGA's internal computer (PMSC), so as to directly provide calculated percent hydrogen leak in a helium purge sample.

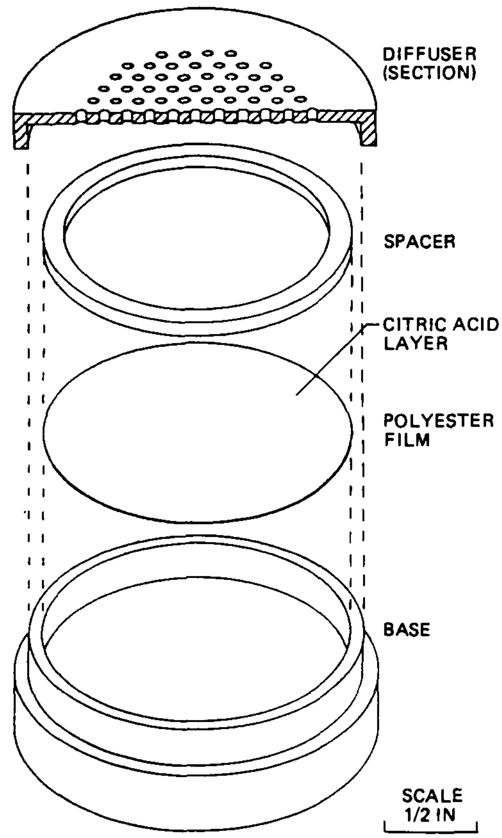
J. D. Collins and W. R. Helms, 867-4438
DL-NED-32

Personal Dosimetry for Toxic Rocket Propellants

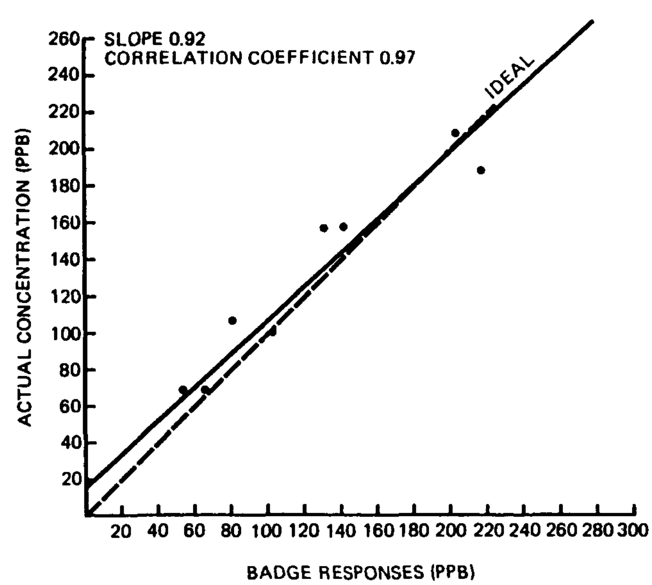
Objective: Develop a dosimeter system capable of measuring hydrazine and monomethylhydrazine at a dose rate of 100 parts per billion (ppb)-hour. In particular, passive systems that could be worn by individuals will be investigated.

Background: Space Shuttle operations often require that a large number of personnel work in areas in which the possibility of hydrazine leaks and spills exist. In the event of a hydrazine release, no suitable quantitative dosimeter exists to determine personnel exposure.

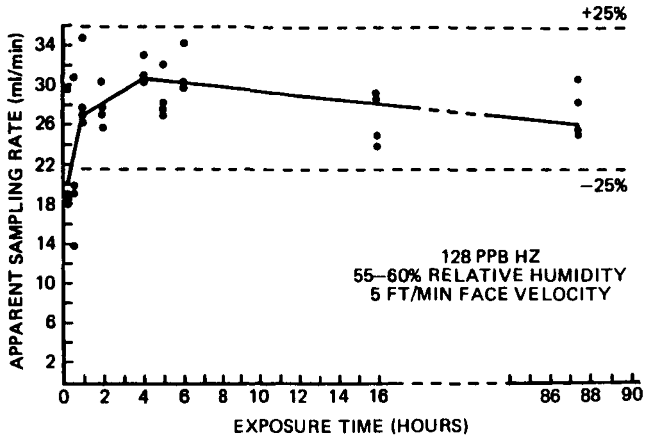
Approach and Results: Available commercial and experimental dosimeter badges were investigated. Studies of experimental liquid sorbent badges manufactured by GMD Systems, Inc. and Dupont did not have the precision or accuracy required. A solid substrate consisting of citric acid-methanol solution on a matted polyester disk was invented as a collection medium and tested. The collection medium is housed in a molded plastic badge with 140 1-mm machined holes on the top. The holes provide the diffusion control and collection is reproducible down to 2 ft/min face velocities. The badge design is shown in the figure "Dosimeter." The badges were tested with hydrazine and MMH from 50 to 500 ppb. They demonstrated good linearity as shown in the figure "Linearity of Badge Response." The detection limit of the badge



Dosimeter



Linearity of Badge Response



Hz Adsorption on Badge

is about 15 minutes at the TLV. The badges have been shown to be linear and stable for 91 hours of exposure at the TLV. (See the figure "Hz Adsorption on Badge.") The badges can also be stored for 1 week before analysis. Field testing will begin as soon as badges with a molded diffusion barrier arrive.

J. C. Travis and W. Helms, 867-4438
DL-NED-32

Comparative Evaluation of Toxic Vapor Sensors

Objective: To test and evaluate technologies suitable for monitoring hydrazine at the parts-per-billion (ppb) level. The three promising technologies are: 1) chemically-doped paper tape, 2) chemical derivatization followed by chemiluminescent detection, and 3) photoionization.

Background: The results of Sniff-Off I demonstrated that none of the existing technologies for hydrazine detection meets NASA objectives for reliability, stability, and selectivity. Therefore, new, yet unproven, technologies will be investigated to determine if a suitable instrument based upon them can be developed.

Approach and Results: The following technologies are being investigated.

1. Chemically-Doped Paper Tape. The results of Sniff-Off I showed that paper tapes were capable of selectively determining hydrazine at the ppb level. The performance of the associated instrumentation was inadequate. New instrumentation utilizing an improved tape transport mechanism has been studied to determine its potential. The instrument was much better than the previous design.

2. A method of sampling hydrazine by first reacting it with acetaldehyde then detecting the reaction product has been developed by Thermo Electron Corporation (TECO), now known as Thermedics. Preliminary studies with hydrazine have shown that the breadboard instrument possesses excellent linearity and accuracy and has adequate sensitivity. The TECO instrument has been evaluated to determine its limit of detection, accuracy, precision, and long-term reliability for MMH. The performance of the system is limited by the reliability of the derivatization method. An improved prototype is to be received soon that should correct the reliability problems.

3. Photoionization appears to be a selective method for hydrazine detection due to the low ionization potential of hydrazine. Preliminary work with hydrazine and MMH has shown that the technique possesses the necessary sensitivity and dynamic range. In addition, this method appears particularly attractive for use in space operations. A portable photoionization detector has been modified and evaluated for use as a hydrazine detector. At the ppm levels the instrument is fast, reliable, and has few interferences. For ppb level analysis, much work is needed to reduce the interference effects from other commonly found amines.

J. C. Travis and W. Helms, 867-4438
DL-NED-32

Ultra-Violet Flame Detector Evaluation

Objective: Determine which type (or types) of commercially available flame sensor permits optimum sensitivity and reliability for the detection of a hydrogen flame.

Background: It is necessary to monitor areas in which hydrogen is stored and/or handled in order to protect as well as alert personnel of an impending hazard. Prior studies have proven that it is desired to monitor the storage/handling areas with an ultraviolet (UV) flame sensor. Additionally, it is desirable that the flame sensor not be sensitive to sunlight or for that matter any other source of background UV radiation so as to cause a false alarm. Hydrogen is a highly flammable gas, and when ignited the plume is invisible to the human eye, infra-red detectors, and standard video equipment. It is, therefore, advantageous to monitor an event from the furthest possible distance while still maintaining reliable detection.

The Model SC-2B incorporates a logic circuit that enables it to discriminate between background and the UV radiation emanating from an actual hydrogen flame. It works on a time domain basis, with a fixed sensitivity. The characteristics of the SC-2B are adjusted by a statistical evaluation of the input data. This makes for simple setup of the detector for almost any flame condition.

Approach: Subject UV flame detectors were selected on the basis of known or suspected sensitivity, cost, reliability, and compatibility. Each subject detector was evaluated using procedure DE-022065 and compared to the existing UV detectors (79K08421)/(S70-1222) used at KSC.

The table below presents comparative data using the existing UV detectors (79K08421)/(S70-1222), Detronics U7602, the Armtec 630, and the Sci-Tronx SC-2B in a side-by-side test. This test was conducted under the conditions stated above.

Manufacturer	Distance in Feet (note 1)
Sci-Tronx SC-2B	24
Detronics U7602	12
Edison (79K08421)/(S70-1222)	10
Armtec 630 (note 2)	5

Note 1: Distance in feet (from standard flame - 5 liters/min)

Note 2: One unit submitted for evaluation, all others evaluated with minimum sample of 5 units.

Conclusions: Of the subject UV flame detectors evaluated, the Sci-Tronx Model SC-2B proved to be highly sensitive and did not exhibit any false alarms. The SC-2B is also 100 percent compatible with the existing flame monitoring system at KSC. No modifications were required.

Note: Sci-Tronx is presently developing for NASA a bench-top UV flame calibrator that will ease the evaluation/calibration of future flame detectors. Additionally, this will allow NASA to standardize the calibrations of existing flame detectors, traceable to NHS standards. Sci-Tronx is also developing for NASA a flame sensor capable of detecting a standard hydrogen flame, as outlined in DE-022065, from a distance of over 100 feet.

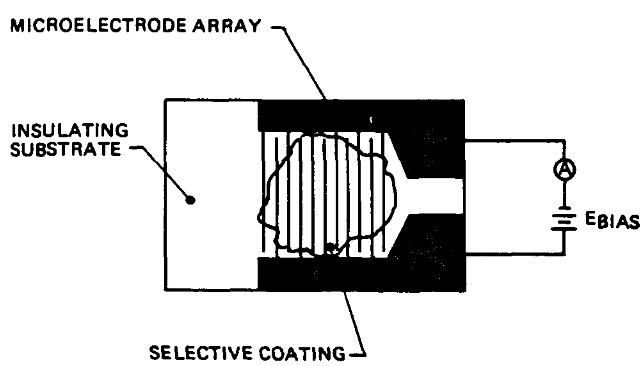
R. Howard, 867-3366 DL-DED-31

Pattern Recognition Methods for Toxic Vapor Detection Using Microsensors

Objective: To develop a microsensor array capable of measuring hydrazine at the parts-per-billion (ppb) level.

Background: Personnel safety requires hydrazine vapor detection at ppb levels. The commercially available instruments cannot reliably detect hydrazine, monomethylhydrazine, and unsymmetrical dimethylhydrazine at the National Institute of Occupational Safety and Health (NIOSH) recommended values of 30, 40, and 60 ppb.

Major advances have been made in microsensor technology and pattern recognition techniques that could improve hydrazine detection. Novel chemical microsensors (chemiresistors) shown in the figure "Microsensor Components" are being developed for the detection of chemical vapors. Chemiresistors change resistance when exposed to different compounds and the magnitude of the change depends on the interaction of the gas vapor with the coating on the microsensor.

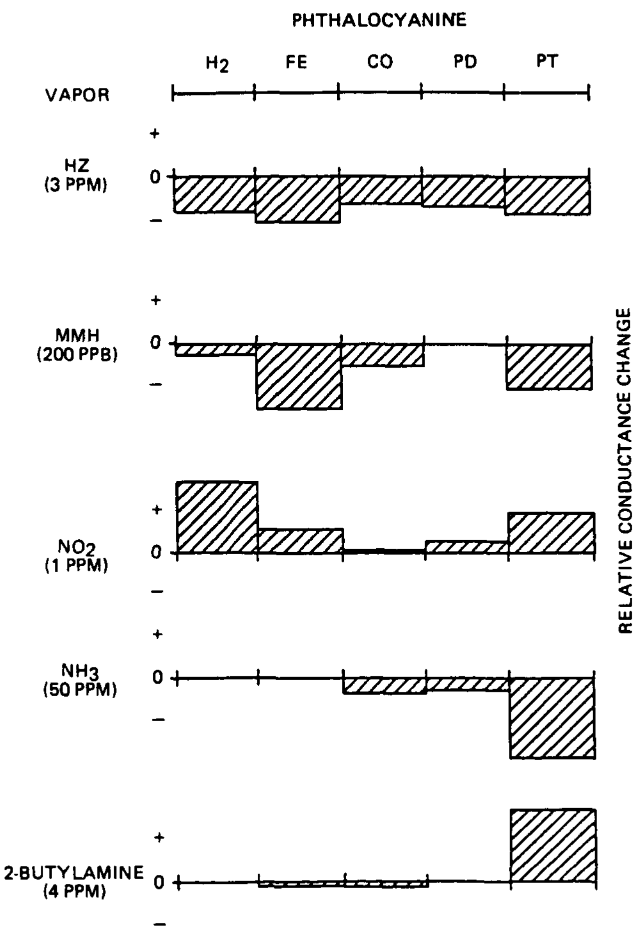


Microsensor Components

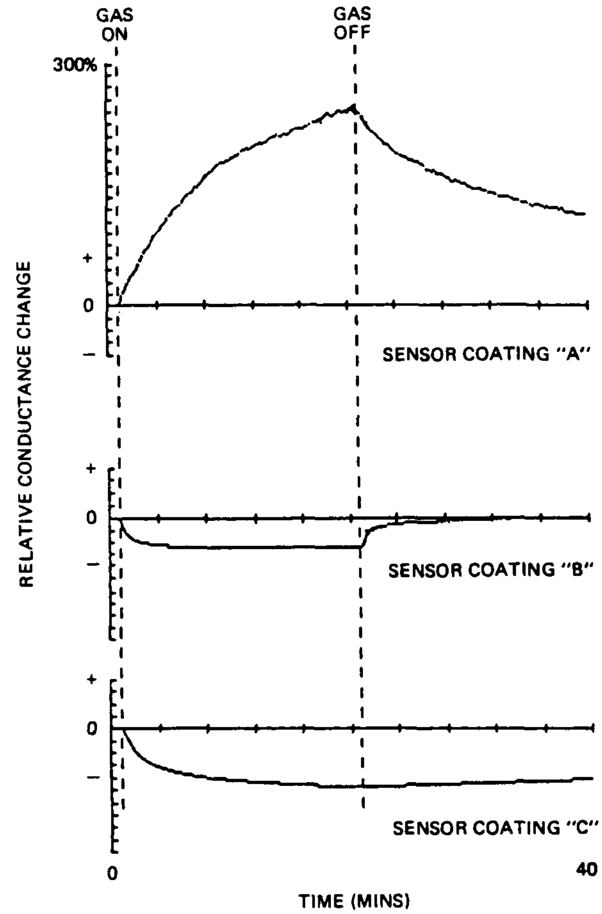
Approach: Coatings are being developed to make microsensors that will respond to different chemical classes of compounds in a complex air mixture. An array of these sensors has given unique patterns, or fingerprints, describing the substances present.

Interpretation of the fingerprint produced by an array of sensors will be done using pattern recognition methodology. These methods use modern mathematical techniques of multivariate statistics and numerical analysis to improve the measurement process as well as extract more chemical information. One of the keys to successful data analysis through these techniques is the development of coating. The coating provides the chemistry which allows a means of encoding chemical information in a numerical form. Each compound can be thought of as a point whose position in space is defined by the values of each sensor response. Similar objects will tend to cluster in a space defined by the descriptors. Pattern recognition is a set of methods for investigating the clusters in space.

The classification of the compounds into the appropriate classes will be achieved by selecting the proper microsensor coating to form the individual clusters. Through the use of computers and mathematical and statistical methods, the data of interest



Relative Reactions of Microsensors



Response and Recovery Times of Microsensors

will be extracted from a complex background. The goal is to quantitate this information and to make progress towards the design of a "smart" detector.

Results: Eight coatings were screened; then five were assembled into an array. The array has been exposed to a large number of vapors near their threshold limit value. The sensors gave no response to many of the common interferences found at KSC. Unique patterns were obtained for the vapors in which the sensors gave response as shown in the figure "Relative Reactions of Microsensors." Pattern recognition methods applied to a data set of single components in air had no difficulty correctly separating the hydrazine vapors from other possible interferences. Mixtures of hydrazine with other components were more difficult to identify, but 81 percent of the mixtures were correctly identified. A new coating is being investigated that is extremely sensitive to hydrazine and is fairly selective. Recovery times are slow, as shown in the figure "Response and Recovery Times of Microsensors," but modifications are currently under way to improve the recovery speed.

J. D. Collins and W. R. Helms, 867-4438
DL-NED-32

Evaluation of Materials for MMH Gas Sampling Systems

Objective: To test and evaluate various sample lines for monitoring part-per-billion (ppb) levels of hydrazines in ambient air.

Background: The toxicity and large quantities of hydrazine used in the Space Shuttle program require special precautions be taken to ensure personnel safety. These precautions include routine hydrazine monitoring at the ppb levels. It would be desirable to have a centrally located detector monitoring many locations simultaneously. This approach would be possible if a material, inert with respect to hydrazines, could be found and implemented as sample lines.

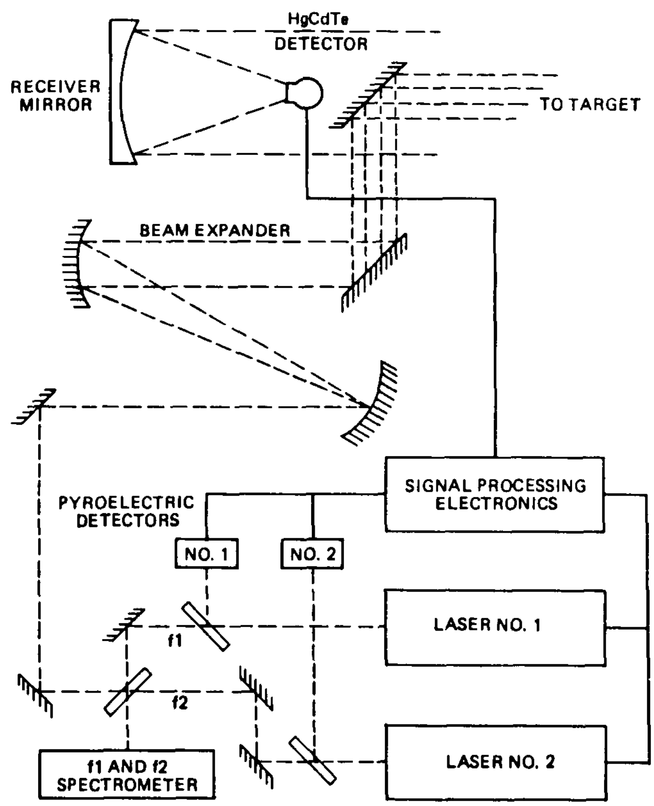
Approach: A chemiluminescence detector was selected to follow the monomethylhydrazine (MMH) concentration eluting from the sample line. The rate of transport and the maximum percent of MMH through a given sample line was recorded. The rate is expressed by time required to reach 50, 75, and 90 percent (if applicable), of full scale deflection. The atmospheric variables of temperature and humidity were investigated, as well as the physical aspects of tubing length, internal diameter, and teflon jointing of tubing segments. Results of pushing versus pulling of the contaminated air stream were also explored.

Summary of Results: The order of ranking tubing performance showed insignificant change due to the atmospheric variables. Similar results were noted from the physical variables. However with increased length, the differences in transport percent and rate were accentuated. At shorter lengths (8 feet) there were few mentionable differences between many of the teflon and plastic tubings, but as length increased the differences developed and became more apparent. At 75 feet Bev-a-line, teflon, high density polyethylene (HDPE), and polypropylene (PP) gave the best results. In addition, polyethylene and teflon (FEP) were tested at approximately 200-foot lengths, 1/4 inch internal diameter. The transport times for both lines were slow, about 8 minutes to 50 percent of the TLV. FEP transported 92 percent of the MMH after about 8 hours while the PE transported 82 percent after 10 hours. Both lines were washed with methanol before the exposure. When the inside of the tubing is "dirty" from sampling air outside (due to dust, etc.), its ability to transport MMH is much worse.

J. C. Travis and W. Helms, 867-4438
DL-NED-32

Remote Sensing of Hydrazine

A laser remote sensing instrument has been fabricated and delivered to the Kennedy Space Center (KSC) by the Jet Propulsion Laboratory (JPL). JPL performed the research that determined the instrument design as the initial phase of this project. In the next phase, JPL fabricated and tested the instrument to verify the concept. This prototype system is designed for the detection of hydrazine, monomethylhydrazine, unsymmetrical dimethylhydrazine, and ammonia remotely to a distance of 250 m. The key elements of the system, shown in the figure "Laser Remote Sensing System," are a pair of rf-excited, grating-tuned waveguide CO_2 lasers, a beam expander, an f/1 receiver mirror, a mercury-cadmium-tellurium (HgCdTe) detector, and signal processing electronics.

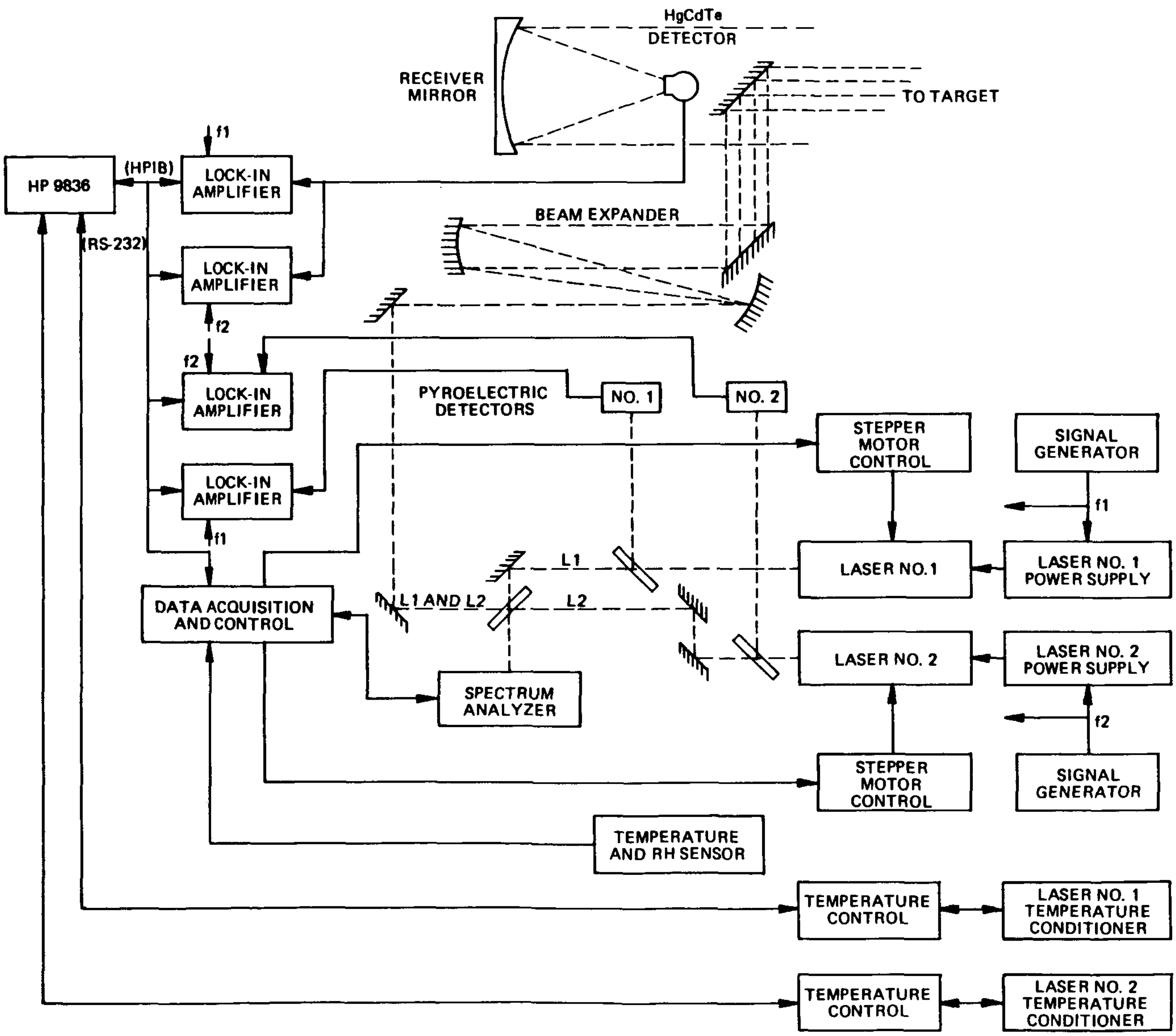


Laser Remote Sensing System

The instrument uses the differential absorbtion lidar (DIAL) technique for detecting the above vapors. Each laser is tuned to the appropriate set of wavelengths, one to the wavelength that the vapor of interest absorbs the infrared (IR) energy, and the other one to a wavelength that is close to the first but will be absorbed less by the vapor. These sets of wavelengths were determined by JPL during the research phase of this effort. The two laser beams are then combined into a single beam, which is expanded and transmitted to a target that will reflect the IR energy (asphalt, trees, etc.). The reflected beam received back is focused onto an HgCdTe detector, which produces an electrical signal that is amplified and processed by the electronics for display. The electronics determine the concentration of the vapor by separating the received signal into the original laser signals and taking the ratio of the two signals, which gives a concentration-pathlength result.

KSC has taken the basic elements of the JPL-delivered system and added an HP 9836 desktop computer and data acquisition and control hardware, which allows the system to operate under computer control as shown in the figure "Computer Controlled System." The computer will use predetermined settings or calculate values to set up and control the temperature controllers for the lasers, set up and control the lock-in amplifiers, and tune the lasers to the proper wavelengths for the vapor selected. The computer will read the output of the lock-in amplifiers and calculate the concentration-pathlength of the vapor detected, output the results to the CRT, and continuously update the CRT. This instrumentation system will be used in field tests and the laboratory to find ways to improve the hardware and its use, and to develop operational requirements to improve the system design.

M.M. Scott, Jr., and P.M. Rogers, 867-3086
DL-DED-32



Computer Controlled System

Rocket Engine Leak Detection Mass Spectrometer (RELDMS)

Prelaunch monitoring of potential hydrogen and oxygen leaks in the Space Shuttle is presently limited to ground-based Hazardous Gas Detection Systems (HGDS). These units are located within the mobile launch platform and are interfaced to the Shuttle via long sample lines. HGDS systems are turned off prior to main engine (SSME) ignition. Approximately 75 percent of the fuel lines are not wet until immediately before ignition; thus, many potential leak sources are not monitored.

The RELDMS would be a flight system mounted on or near each SSME. This system will be optimized for propellant leakage during prelaunch operations, main engine ignition, lift-off, and powered flight. RELDMS operation during powered ascent will permit identification and area localization of low-level leakage. These data will be used to guide post-flight corrective maintenance.

The first year study efforts by Perkin-Elmer focused on hardware optimization trades to define the RELDMS configuration. Prototype development will be initiated during the second year of this project. A fully operational flight prototype will be developed and tested by employing ground-based static engine tests. Positive test results will enhance the probability that RELDMS may become operational instrumentation on Shuttle.

J. D. Collins and W. R. Helms, 867-4438
DL-NED-32

Comparative Evaluation of Optical Particle Counters

A comparison study of three commercial optical particle counters used in aerosol monitoring systems within cleanroom environments is carried out in order to characterize instrument-to-instrument variability and factors which influence this variability. Instruments manufactured by Climet, Hiac/Royco, and TSI, Inc. were used in the study. Model aerosols of polystyrene latex spheres and monodisperse liquid oil droplets were used to measure counting efficiency in the 0.5- to 10.0-μm particle size range. In all cases the TSI particle counting system recorded higher numbers of particles than the other two instruments.

Results indicate that instrument-to-instrument variability can be as large as X4 for 3/8-inch sample tubing and X6 for 1/4-inch tubing. Further, variability is consistently less with the larger diameter tubing and is also reduced for the larger particles by operating at lower volume sampling rate. Preliminary evidence is presented which indicates the response of the TSI counter does not increase in monotonic steps as particle diameter increases in the 4.0- to 6.0-μm range.

J. C. Travis and W. Helms, 867-4438
DL-NED-32

Shuttle Tile Moisture Measurement Sensor Development

The purpose of this study is to develop a method of determining the moisture content in the Space Shuttle tiles after exposure to rain or other environmental conditions that would cause moisture to accumulate in the tiles. This method must be a "non-contact" method. The testing shall be performed on actual tile samples to verify the validity of the tests performed. The tile samples will be provided by the Government.

A study has been performed to determine the best "non-contact" method to measure the moisture in the Shuttle tiles. The most promising method seems to be the use of microwaves for the detection of water in tiles. Initial testing was done using Shuttle tile samples that were wet with tap water. There was a concern that tap water, which contains traces of chlorine and fluorine additives, would affect the experimental data.

Further testing showed that the interaction with the water molecules is primarily associated with polarity effects and not with trace Cl and F ions. A tile sample was wetted with distilled water in one case and with water and liquid bleach in the other. The test results indicate that the absence or abundance of Cl ions in the tile moisture has a negligible effect upon the detection of the presence of water.

A Shuttle tile test panel was fabricated by NASA and delivered to the University of Florida. Preliminary results indicate that the magnitude of the microwave return signal using the new, larger test panel is approximately the same as for the previous smaller tile test samples.

An attachment for positioning the new tile test panel will be designed and installed and further testing will be accomplished in an environmentally controlled area to validate the moisture detection methods in different humidity environments. Field testing will be done at KSC to obtain baseline data on the Shuttle tiles.

R. Howard, 867-3366 DL-DED-31

Contaminant Gas Monitor (CGM) for Space Station

Kennedy Space Center has undertaken a cooperative effort with Marshall Space Flight Center to develop instrumentation that can identify and quantitate trace level contaminants in Space Station modules. Fiscal year 1986 support was provided for Perkin-Elmer to repair and evaluate performance of their prototype Trace Gas Analyzer (TGA) which was designed for Shuttle Spacelab missions. The TGA is a gas chromatograph (GC)/ scanning mass spectrometer instrument. The analyzer was developed during the Viking program, where it functioned for over a year as part of the Viking Lander experiment.

Although Space Station operational requirements for trace analysis have not been finalized, several changes in the TGA will be required. Minimum 90-day mission durations will press instrument sensitivity to its limits, wider ranges of compounds must be identified, multipoint sampling will be necessary and data analysis must be performed on board the station.

The TGA was designed to record mass spectral and GC data on digital tape and then downlink this information to ground based laboratories for data reduction. Data analysis is an area requiring significant improvements and automation to obtain a CGM suitable for Space Station.

Activities for fiscal year 1987 will focus on implementing a data reduction concept which utilizes a personal computer and commercially available compound identification software. Completion of this task will be a significant step toward a stand alone flight prototype CGM. Vastly increased capabilities of microprocessors and their mass memory efficiencies will permit this prototype system to be upgraded into flight hardware.

The prototype system will be furnished to NASA-MSFC and evaluated as part of their Space Station ECLSS Test Bed. The same instrumentation may subsequently be employed at NASA-KSC to monitor Life Sciences Closed Ecological Life Support (CELS) tests.

J. D. Collins and W. R. Helms, 867-4438
DL-NED-32

Flow Metering Using Vortex-Shedding Instrumentation

The objective of this investigation was to develop a 1/2 in. flowmeter for cryogenic or other fluids which uses the vortex-shedding principle. The final prototype had to be compatable with existing KSC GSE.

Phase A: The literature review and patent search revealed a great number of shedder bar flowmeters of varied designs, each having certain characteristics. Many different shapes and combinations of shedder bars have been used. A number of such flowmeters were found unuseable under cryogenic temperature conditions.

The best design seemed to be an edged shedder bar with piezoelectric crystal pick-up located at the end of pressure ports. At this point, it was decided to go to experimental studies of the optimum shedder bar shape and best pressure tap location and size.

A water table was constructed and set up to visualize the vortex motion around different shedder bar shapes and the travel of these vortexes toward the walls. Also, an air wind tunnel was set up to make similar investigations, but by using anemometer probes to determine the action of the vortexes and the best positions of measuring the pressure pulses.

A water loop also was constructed where actual measurements for flow rate and total flow measurement were taken and the best designs of the flowmeters evaluated. A similar flow system was set up using LN_2 as the cryogenic fluid to measure flow rates and total flow under those environmental conditions.

From the experimental studies, guided by the theoretical work, it was found that:

1. The square-or diamond-shaped shedder bar facing the fluid edgewize gave the strongest and cleanest signals. This shape does not appear to be patented.

2. The pressure tap-hole was 1/16 in. and located at the pipe wall at the centerline position of the shedder bar.

3. The pressure tap-pulses were, for example, at 1.7 gpm, 70 counts per second and 0.06 psi peak-to-peak. At 3.58 gpm, the corresponding values were 215 counts per second and 0.6 psi.

4. The counts (pressure pulses) per second varied linearly with the flow rate.

5. The total flow was proportional to the total count or number of pressure pulses.

6. Only the frequency of pulses, and not the wavelength of the vortexes, changed with the change in flow rate. Thus, once the optimum pressure tap position was found, it remained the same for the total flow range.

7. The flowmeter measured flow rates to within +/-1.5 percent.

8. The flowmeter could also be used as a two-phase flow sensor since it has worked nicely in liquid cryogenics, but has stopped oscillating or vortex shedding in two-phase flows.

9. A reliable vortex shedding flowmeter could be developed that would operate at Reynolds numbers less than 1000.

Phase B: The final flowmeter prototype has been constructed and evaluated at the University of Florida as a complete flowmetering system consisting of the flowmeter and signal conditioner. This is required to make the prototype directly compatable with KSC and VAFB Launch Processing System (LPS) Ground Support Equipment (GSE).

The flowmeter system was calibrated throughout the entire range using standard flow rates. The flow rate, output pulses, and signal conditioner voltage output was recorded.

The maximum deviation from a straight line projected through the maximum flow point and the origin was 1.32 percent of full scale output. The maximum deviation using the best fit line method was 0.88 percent of full scale.

The prototype unit will be further evaluated at KSC and the design is under review by the Government and University of Florida for a possible patent.

Full design and manufacturing drawings will be available to industry for possible marketing.

R. Howard, 867-3366 DL-DED-31

Liquid Characteristics Under Micro-Gravity Conditions

In space, under micro- or zero-gravity conditions, liquids will behave differently. Top and bottom of tank notation will lose their meaning, and there will be no guarantee that the outlets of tanks will be covered by liquid, which is so necessary for liquid-transfer operations. Ingestion of vapor into pumping systems is a very likely occurrence during liquid transfer under such environmental conditions.

Dynamic effects, in conjunction with liquid surface curvature produced by surface tension, can be exaggerated in low-gravity fields. Very little information could be found in the literature, especially after 1970. Many questions on the behavior of liquids under the above-mentioned environmental conditions do not seem to have been answered thus far.

Theoretical investigations give some information about behavioral trends. Experimental investigations, mostly done by NASA in drop tower tests, support the fact that surface tension is an important parameter, if not the most important one, in controlling the behavior of liquids in low-gravity fields. Drop tower tests are expensive, short in duration, and need to be done in a facility.

The investigation team working on this project thought it might be possible to simulate the behavior of liquids in low-gravity fields by immiscible liquids having a clearly defined interface, but otherwise equal specific gravity. Some preliminary experimentation was done.

An even more promising approach, using soap films or bubbles to simulate the interface between two liquids, was developed using air in the cases investigated here. By pulling a vacuum on one side of the soap film, the soap film seems to take on the configuration of the liquid vapor interface similar to actual conditions. The last statement is based upon preliminary tests and comparisons with the drop tower results reported by NASA.

The simple and inexpensive laboratory simulation techniques developed here and preliminary test results seem to indicate that this powerful method can be used in investigating the behavior of liquids in low-gravity environments, especially during liquid transfer, and can be used in designing proper or optimum configurations, as well as defining proper transfer procedures of liquids under those conditions.

A computer model has been developed to solve the Poiseuille Flow problem. This allows simulation of zero-g flow during drainage of a cylindrical tank. The overall program for flow prediction involves alternate iteration between the velocity field and the pressure field. A test of the velocity was made by decoupling the pressure field by the application of a fixed pressure gradient to the flow system. The program was then checked by comparing the predictions to an available exact solution.

Further improvements were made to the microgravity flow simulation test fixture and a series of test runs have been plotted and compared to the computer simulation model. Further data will be taken using high speed photography and compared with the computer model.

R. Howard, 867-3366 DL-DED-31

Gamma Ray Densitometer Liquid Level Instrumentation

The gamma ray densitometer essentially consists of a radioactive source (very weak for the application under consideration here) and a detector system measuring the radiation intensity at desired locations. The radiation beam is weakened by the intervening material. From the absorption characteristics of the materials, the quantity of matter and liquids in this particular investigation can be determined.

In this investigation, a suppressor tube was developed so that in turbulent systems, even when mixing vapors with liquids, the true liquid level can be determined.

A small, radioactive source encapsulated and attached to a float can be put inside a tank, restrained by the collapser tube, and will float, indicating the surface of the liquid in the tank. Radiation detectors mounted on the outside of the tank then can be placed at the top, bottom, or side of the tank. The weakened count will give the position of the floating source and, thus, the liquid level in the tank.

In a cylindrical tank, a straight suppressor tube can be used in the middle or on the side of the tank;

in a spherical or other-shaped tank, the collapser tube can be attached to the wall, having the same contour as the wall.

The detector can be fixed in position or can be of the scanning type, depending upon convenience in a particular application. Even several different sources and detectors can be used to give easily interpretable information in three dimensions.

The information obtained this way can be fed into a computer, which can display a simulated tank and show the position of the float and liquid level at all times. This method was demonstrated to the NASA personnel during one of their visits.

A number of different detector configurations are discussed below, and the results and accuracy given. The liquid levels could certainly be fixed within 1 cm (or better, as shown below) of actual position, using the gamma ray densitometer instrumentation. Lengthening the counting time or increasing the source strength for the same counting time would naturally improve the accuracy. For this investigation, very weak radiation sources were used which could easily and safely be carried in one's pocket.

Theoretically predicted results were closely verified by the experimental work. The configurations used in the present investigation included cylindrical tanks with the axis both vertical and horizontal, and a spherical tank. The detectors were located, in some cases, on top of the tank, on the bottom, or both. For other experiments, the detectors were located on the side of the tank, either fixed or in a scanning mode.

If it should be desirable not to have any sources inside the tanks, a collimated source could be located on one side (top or bottom) of the tank, and the detector could be placed on the opposite side of the tank, again measuring the weakening of the beam as it traverses the contents of the tank.

As an example, the 1-second counts with an AM241, 300-mC source, and a water liquid level of 5 cm varied for the bottom detector at a count rate of 140,766, about 3,000 counts for each millimeter of liquid level change.

The reproducibility of experiments with a 1.1-C Cs-137 source fell well within 2 percent of each other. The increase in counting time, if quick response and instantaneous readings are not required as mentioned above, will increase the accuracy of determination and can reduce the required strength of the source needed.

Another approach, using the gamma ray densitometer not investigated under the present contract, would be to make the liquid level and liquid inventory determination by relying upon the information from back-scattered gamma rays.

R. Howard, 867-3366 DL-DED-31

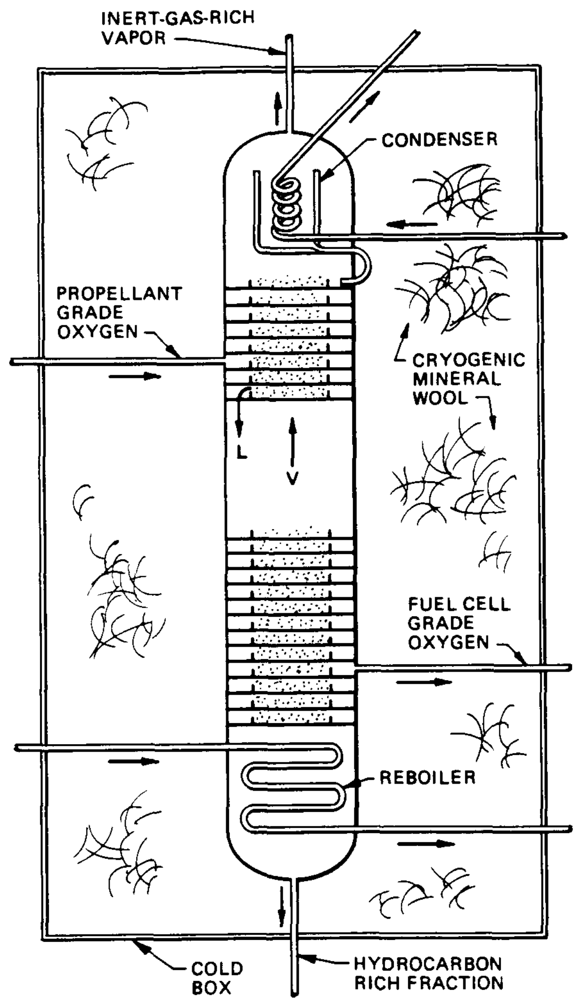
Distillation of High Purity Oxygen

The Kennedy Space Center (KSC) uses high purity oxygen (HPO) 99.99 percent pure, in the Space Shuttle's fuel cell system to make breathing air. HPO is stored at its critical temperature and pressure on the Space Shuttle for use as a reactant in the Shuttle fuel cell system, which provides power for the Shuttle and water for the crew. Currently, HPO is purchased from Liquid Air Corporation in Savannah, Georgia, for $264/ton. The average consumption of HPO per launch from STS-20 through STS-32 is 26.9 tons with a corresponding cost of approximately $7,100 per launch. To save money and become independent of industry, a way of producing HPO at KSC is desired. Electrolysis and a turnkey distillation column are capital cost prohibitive. Building a distillation column at KSC with existing manpower and materials appears economically feasible.

KSC recommends that HPO be produced at KSC using a distillation column built on base. The distillation column uses propellant grade oxygen (PGO), 99.6 percent pure, as a reactant. The impurities to be separated are the inert gases, nitrogen and argon, as well as hydrocarbons. Inert gas buildup will require that the cathode be purged more frequently, losing valuable reactants. Hydrocarbon will oxidize at the cathode, forming carbonates which poision the cathode and electrolyte.

The column has been modeled with the computer program Advanced Simulation Process Engineering (ASPEN). The computer model was run to determine the optimum column configuration. The initial column design has 29 distillation trays with a reboiler and condenser. The column is put in a cold box insulated with compatible mineral wool to minize the heat leak into the column.

The figure "Oxygen Distillation Column" shows the flow pattern of the liquid and vapor in the column at steady state. Liquid PGO reactant enters the column at the sixth tray from the top, and the liquid HPO product is removed at the fourth tray from the bottom of the column. The inert-gas-rich oxygen vapor exits the column at the top of the column, while the hydrocarbon-rich liquid oxygen exits the column at the bottom.



Oxygen Distillation Column

Liquid oxygen flows over the sieve trays with an 8 percent void area. The liquid oxygen flows over one tray then down to the next tray. At the bottom of the column, some of the liquid oxygen is evaporated in the reboiler to form vapor which travels upward through the column. At the top of the column, the condenser condenses some of the inert-gas-rich vapor, which then travels as liquid over the trays and down the column. As the liquid oxygen flows over the sieve trays, the vapor travels through the sieve holes and forms an equilibrium with the liquid. This equilibrium at each tray allows the inerts and hydrocarbons to be separated from the oxygen. Fabrication and testing of the column will be performed at the KSC Prototype Laboratory.

K. Buehler, 867-3313 DD-MED-43

with a temperature range of 70 to 500°F. Values are given for temperature, compressibility factor, molecular mass, and chemical composition.

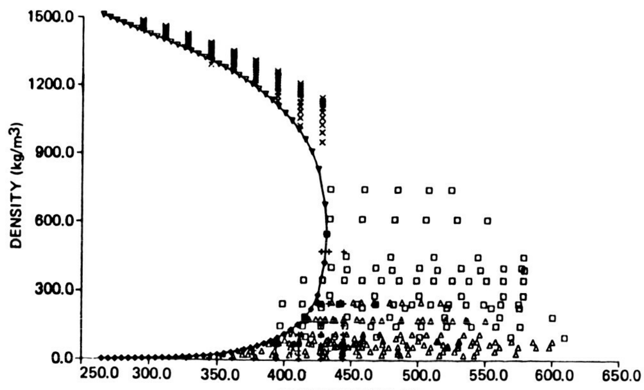
F.S. Howard, 867-3201 DD-MED-4

Nitrogen Tetroxide (N2O4) Thermodynamic Properties Tables

Thermodynamic properties tables were completed and published in National Bureau of Standards document "The Thermodynamic Properties of Nitrogen Tetroxide" by Robert D. McCarty, Hans-Urich Steurer, and C.M. Daily, IR 86-3054, July 1986.

The development of the equation of state proved difficult because the nitrogen tetroxide (N_2O_4) does not remain nitrogen tetroxide. It may convert to a mixture of nitrogen tetroxide, nitrogen dioxide, nitrogen monoxide, and oxygen. The extent of these reactions depend on both pressure and temperature, and the equilibrium concentration of the various components changes from state point to state point. This made the determination of the equation of state more difficult than with pure gases such as oxygen, nitrogen, and hydrogen.

A plot of the equation of state is shown in the figure "Pressure-Temperature Plot of Equation of State Against Existing Data." The tables are presented in isobars from 14.969 psia to 5000 psia

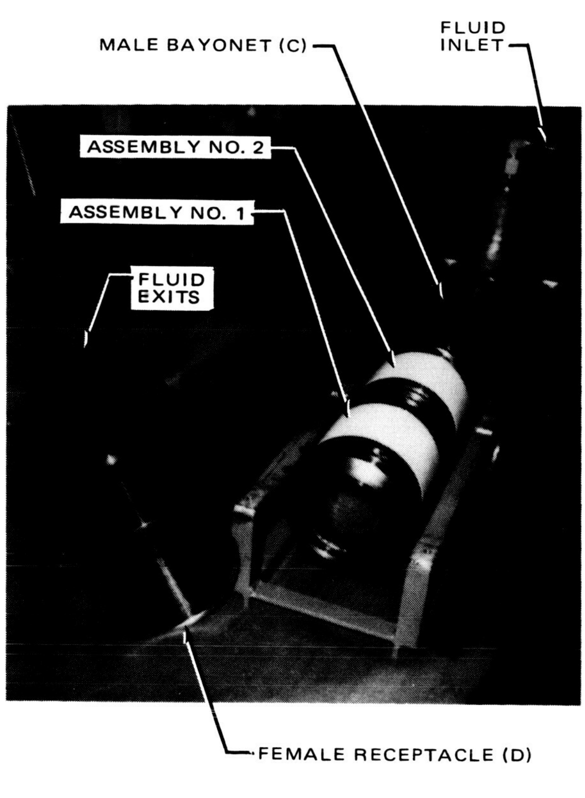


Pressure-Temperature Plot of Equation of State Against Existing Data

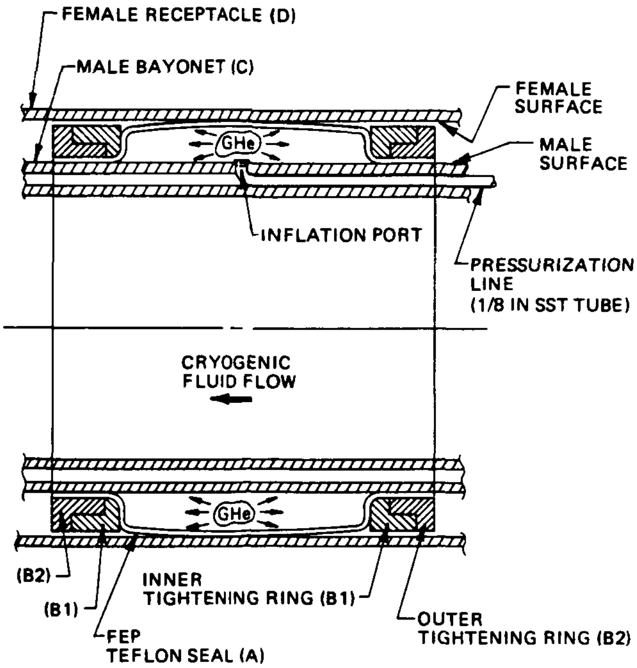
Cryogenic Bayonet Inflatable Seal Quick Disconnect

A prototype design of a cryogenic inflatable seal quick disconnect (QD) has been fabricated and tested at the KSC Prototype Laboratory. The quick disconnect tested successfully without leakage past the inflatable seals.

The bayonet consists of male and female components, fabricated from CRES 304 stainless steel, with inflatable seals surrounding the male and forming a sealing surface with the inner surface of the female. (See the figure "Inflatable Seal Bayonet Quick Disconnect.") The figure "Seal Inflation" shows a longitudinal cross section of the mated QD seal area. The helium travels to the seals through tubing fabricated into the male component. The FEP Teflon seals are secured and tightened with metallic rings to maintain sealing pressure in the



Inflatable Seal Bayonet Quick Disconnect



Seal Inflation

seal. FEP Teflon was choosen as the sealing material because of its processing versatility and relative impermeability to gaseous helium, which is required for liquid hydrogen service. Each inflatable seal has a set of tightening rings that prevent the helium from leaking out of the seal and secures the seal in place. The rings have acme screw threads for applying the required force on the seal ends during the tightening process.

The inflatable seal assembly is compatible with all cryogenic fluids. The disconnect could not be used for liquid helium service because the gas inflating the seals would condense. For liquid hydrogen and liquid oxygen, the pressurizing gas will be helium and nitrogen, respectively.

Successful testing performed with liquid nitrogen demonstrated the feasibility of the design. There were no leaks past the seals, which were pressurized to 85 psia. The advantage of using the bayonet disconnect with cryogenics is the potential insulating properties of the QD. The quick disconnect has worked, and development is continuing in the design of the tightening ring and reducing the weight of the QD.

K. Buehler, 867-3313 DD–MED–43

Simulation of Steady, Liquid-Vapor Flow Under Zero-Gravity By Using Immiscible, Neutrally Buoyant Droplets in Water

Objective: To establish an earth-based facility to study the dynamics and heat transfer behavior of turbulent liquid-vapor flows of oxygen and hydrogen (fuel transfer lines) and ammonia and freon (heat rejection system) in pipelines under 0-g environment..

Accomplishments in First Year (February 21, 1985 to February 20, 1986)--Isothermal System:

1. Establishment of similarity criteria for modeling liquid-vapor flows based on recently published time- and volume-averaged conservation equations

2. Completion of an experimental flow loop for the determination of flow regime and pressure drop in steady, fully developed two-phase flow in ducts of constant cross section under 0-g. Vapor-liquid flow is simulated by using neutrally buoyant n-butyl benzoate droplets in purified water.

3. Completion of preliminary test runs using n-butyl benzoate droplets of diameters ranging from 2.1 mm to 5.1 mm, suspended in water flowing at Reynolds numbers of 12,700 and 19,700 in a square duct, where the flow is fully developed. Velocity slip was found insignificant in both vertical and horizontal flows for volume fractions up to 0.28%. Photographs, obtained with successive stroboscopic exposures, revealed no measurable oscillation of droplets.

Second Year Effort (Started June 9, 1986)--Isothermal System, Continued: In view of the initial success and experience gained from the operation of the flow loop simulating liquid-vapor flows under 0-g, it was decided to upgrade the system to accomplish the following five tasks:

1. To increase the flow rate in the test section--Reynolds number up to 170,000 has been achieved.

2. To increase the droplet volume fraction from 0.28% to 1.11%. Further increase is planned.

3. To obtain a better match between densities of the discrete phase (n-butyl benzoate) and

the continuous phase (purified water) by fine tuning with temperature control (significant in horizontal flows only).

4. To incorporate solid-liquid flow capabilities into the system. Pellets of thermoplastic polyethylene compound having a density of 1.01 g/cc have been tested, and some results obtained.

5. To semiautomate system operation.

All five tasks were completed on August 28, 1986. In addition, two electrical conductance probes for flow regime study have been designed and fabricated. However, they are yet to be tested. An IBM PC/AT will be used for data acquisiton and processing.

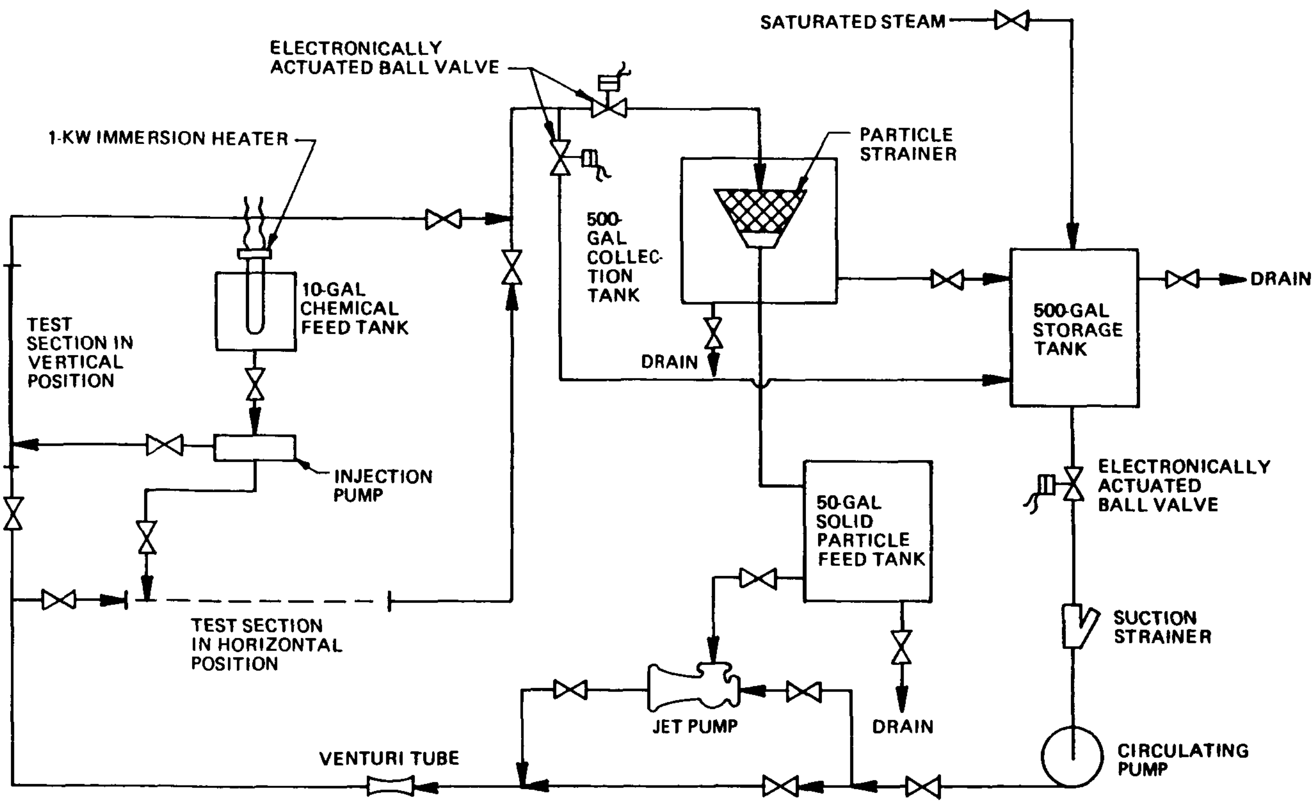
Plans for Immediate Future:

1. Obtain extensive two-phase pressure drop data covering a wide range of particle sizes, flow Reynolds number, and volume fractions using both n-butyl benzoate droplets and polyethylene pellets. Attention will be given to the onset of droplet oscillation and break-up at high Reynolds numbers, if they occur. Preliminary pressure drop data obtained for neutrally buoyant droplets and solid particles of approximately 3 mm in diameter, flow Reynolds numbers of 77,000 and 107,000, and volume fractions up to 1.1% revealed no significant differences.

2. Collect data using electrical conductance probes to establish quantitative relationships between the wave form of the voltage signal (a measure of the two-phase flow structure) and flow regime. Two-phase pressure drop data obtained in item (1) will be categorized in accordance with flow regime, followed by development of correlations.

3. Attempt to establish flow regime map for liquid-vapor flow under 0-g. This information will also be useful for future heat transfer studies involving vaporization and condensation.

F.N. Lin, 867-4156 DD-MED-1



Two-Phase Flow Loop for Simulating Liquid-Vapor Flow Under Zero-G Environment

MATERIALS SCIENCE

Metals Ignition in High Pressure Oxygen

During the past several years the White Sands Test Facility (WSTF) of the Johnson Space Center has developed several test methods to determine the flammability and ignition properties of metals in high pressure oxygen. Currently, KSC is having WSTF evaluate the metals in the KSC operating systems using several of these test methods. Also, several metals being considered for new KSC oxygen systems are being evaluated to provide a broader data base for the selection of metals in these systems.

The test methods selected are rubbing friction, particle impact, and flame propagation rate. The metals being evaluated include several stainless steels, a carbon steel typically used in vacuum storage vessels, nickel, and several nickel alloys.

The particle impact test, using iron oxide and sand as the particles, was selected as the first test. At the present time, the test matrix is approximately 50 percent completed. Variables in this test include oxygen pressure and flow rate while keeping the particle size essentially constant.

C. J. Bryan, 867-4614 DE-MAO-2

Permeability of Polymers to Organic Liquids and Condensable Gases

Workers involved in the production, use and transportation of hazardous chemicals can be exposed to numerous compounds capable of causing harm upon contact with the human body. The deleterious effects of these chemicals can range from acute trauma such as skin irritation and burns to chronic degenerative diseases such as cancer. Since engineering controls may not eliminate all possible exposure, attention should be given to reducing the potential for direct skin contact through the use of protective clothing that resists permeation, penetration, and degradation.

Permeation tests are being performed by Tuskegee University to evaluate the effect of decontamination on the breakthrough time and steady-state permeation rate of chemicals through protective polymeric based materials. Work currently in progress is in one-inch and two-inch ASTM cells to investigate the hazardous chemicals, hexane, toluene, dimethyl formamide, hydrazine, and nitrogen dioxide and their effect on polyvinyl alcohol, Neoprene, and butyl-coated Nomex. Work involves the evaluation of different decontamination procedures for the polymeric base clothing (washing with detergent, Freon, etc.). The permeation results (breakthrough times and permeation rates) for the decontaminated samples are then compared with the ones for fresh (new) clothing samples.

C. J. Bryan, 867-4614 DE-MAO-2

Evaluation of Sealants for Dissimilar Metal Corrosion Prevention

A study has been initiated to determine the effectiveness of a number of commercial sealants or corrosion inhibitors in controlling the corrosion of threads in aluminum alloy, when used with stainless steel screws.

Aluminum nuts and stainless steel screws were assembled with a uniform torque on aluminum panels, using the various sealants. All of the sealants were represented on each panel. The panels are exposed at the Kennedy Space Center (KSC) Beach Corrosion Test Site. A schedule has been established whereby exposed panels are returned to the laboratory periodically for examination. The break-loose torque is determined, and the nuts, bolts, and panels are examined for evidence of corrosion.

Examination of specimens after exposure periods of up to a year has been completed.

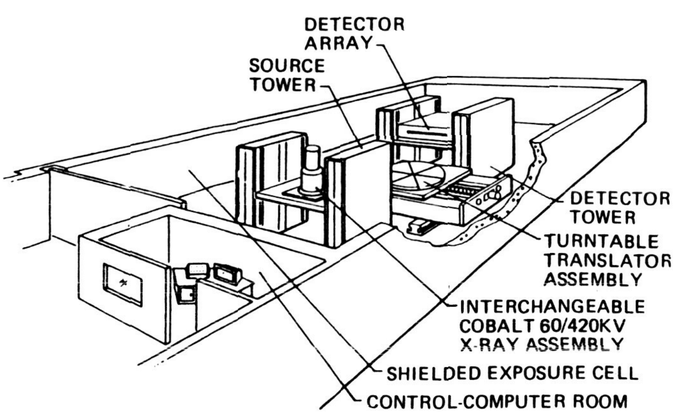
Other specimens are still at the test site and will be examined after exposure periods of 2, 3, 4 and 5 years.

C. V. Moyers, 867-4614 DE-MAO-2

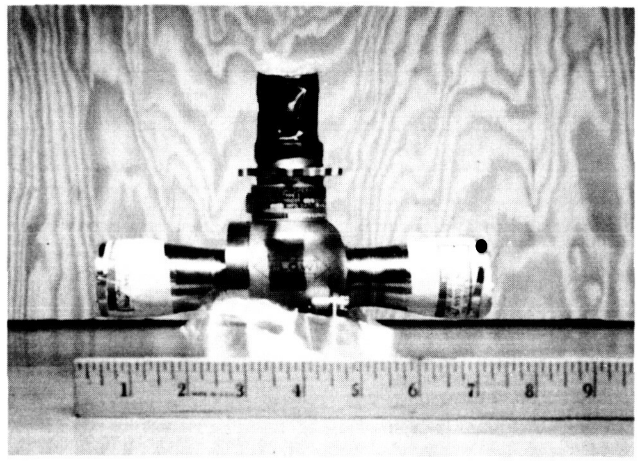
Computer Tomography

An industrial computer tomography system is now online at the Kennedy Space Center. Industrial computer tomography, a take-off from medical CAT scan techniques, is a unique nondestructive evaluation technique providing data acquisition not available with conventional radiographic methods. The current capability of the KSC system provides both a digital radiograph and a cross sectional slice of the item under investigation. The KSC system has been designed to be highly versatile, thus maximizing its potential use on a variety of components supporting launch activities. An object weighing up to 2,000 lb and measuring up to 6 ft in height and 5 ft in width can be examined. The system utilizes interchangeable (variable 420 kV x-ray/20 curie cobolt) sources which require approximately 15 min for change-out. This provides penetration capabilities from thin, low density materials up to a steel equivalent thickness of approximately 8 to 10 in. Examinations currently include evaluation of critical components for presence of packing material, weld integrity, component location-dimensional measurements, and changes in material density. In addition to supporting KSC operational and research and development activities, plans are in progress to participate in interagency study activities investigating computer tomography applications to specific problem areas.

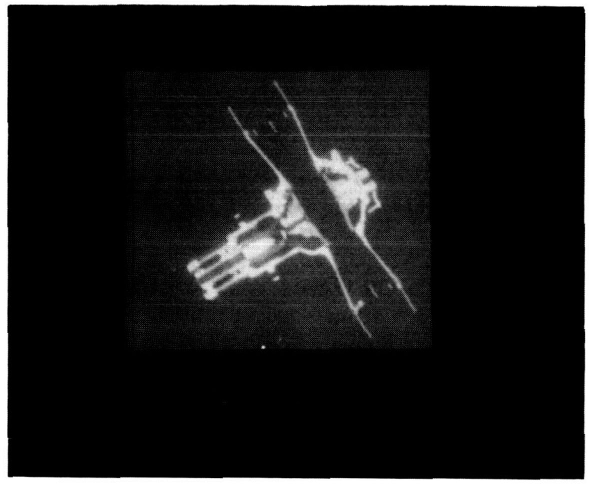
J. W. Larson, 867-3423 or -2997 SI-PEI-3A



Kennedy Space Center Computer Tomography Facility



Shuttle Fluid Control Valve



Computer Tomography Cross Section of Control Valve

Conductive Organic Polymers as Corrosion Control Coatings

The objective of this study is to develop coatings from conductive organic polymers that will provide galvanic protection similar to the inorganic zinc-rich coatings currently being used at Kennedy Space Center (KSC). These organic coatings should be formulated to provide easy application, repair, and long-term resistance to the KSC launch environment. Three basic polymer systems are of interest: polyaniline, being developed by researchers at the University of Pennsylvania, and polpyronne and polyphenylquinoxaline, being developed at Los Alamos National Laboratory

(LANL).

Formulations of polyaniline have been developed that permit brush or dip coatings to be applied to iron, steel, and stainless steel substrates. Good protection of stainless steel has been demonstrated in laboratory tests with this polymer system.

Work on the development of coatings for brush or dip application is underway at LANL. Studies on accelerated testing procedures are also under review.

Studies will continue to focus on formulation, application, and evaluation. Final evaluation will be performed by exposure testing at the KSC beach corrosion test site.

C. J. Bryan, 867-4614 DE-MAO-2

Study of Coatings That Require Minimal Surface Preparation for Potential Application to LC-39 Structures

With the evolution of the Shuttle program, the coating systems used to protect the structures at Launch Complex (LC)-39 have experienced localized failures. These coatings were developed during the Apollo program to protect the structures from Kennedy Space Center's (KSC's) marine environment and the byproducts of the rocket exhausts from the launch vehicles of that era.

The Shuttle launches have changed the LC-39 environment. The exhaust products from the Shuttle Solid Rocket Boosters (SRB's) contain hydrochloric acid, aluminum particulate, and other elements. The heat and exhaust products have, in some cases, destroyed the protective coatings on the launch pad structures and caused their corrosion.

It would be desirable to have a simple, inexpensive repair coating system which requires minimal surface preparation for the LC-39 structures.

In conducting the study, coatings were applied to the structures over corroded areas which had only been prepared by wire brushing.

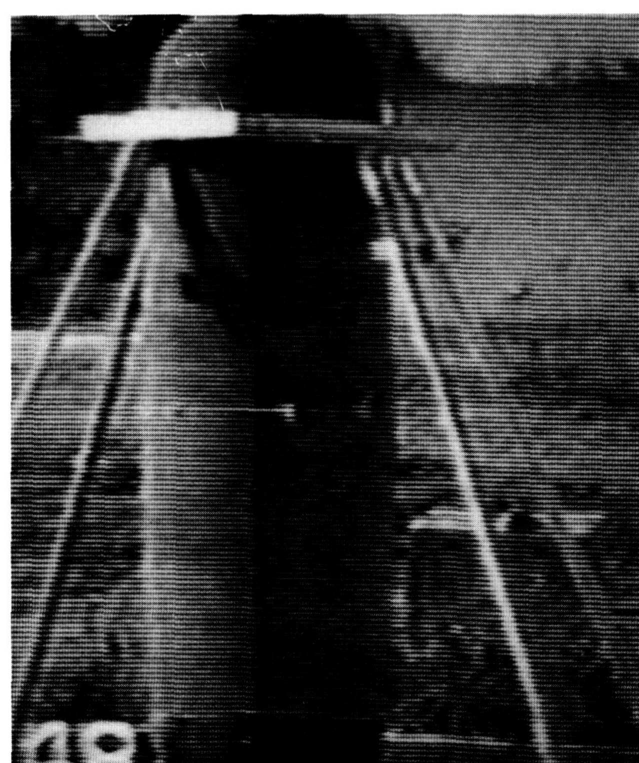
The results of the study indicated that typical maintenance coatings (epoxy, polyurethanes, inorganic zincs, etc.) cannot be expected to survive on the pad structures when subjected to the reflected blast from the SRB's.

This study has helped to more clearly define the severity of the launch environment and underline the need to develop a protective coating system for the structures subjected to the launch environment.

P. J. Welch, 867-4614 DE-MAO-2

Applicability of Acoustic Emission Monitoring to Pressure Vessel Testing

An acoustic emission (AE) event is defined as a localized material change giving rise to an acoustic wave. This can result from crack propagation or other phenomena which causes elastic or plastic deformation of the material. Specialized instrumentation is used to detect and locate the origin of the acoustic waves.



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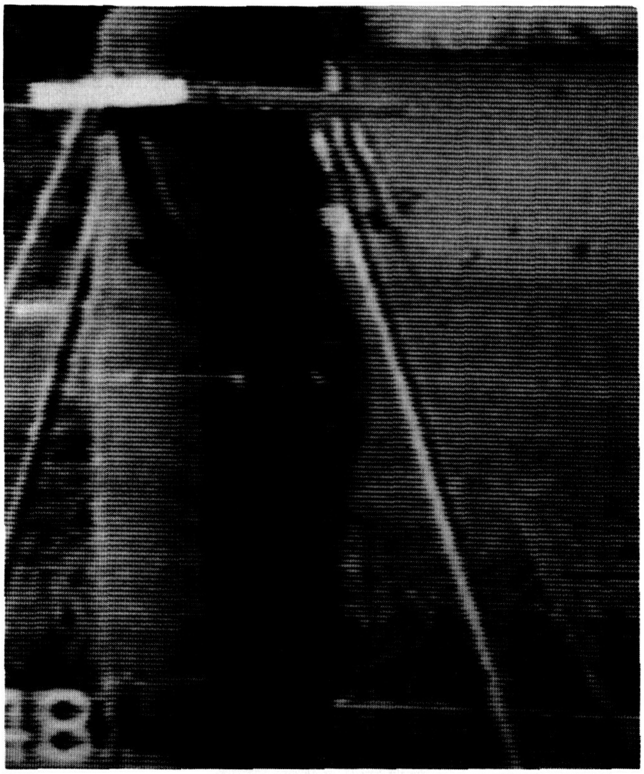


Sequence of Views Showing AE Test Vessel Rupturing During Hydrostatic Test

AE is becoming an accepted nondestructive test method for tanks and vessels in the petrochemical industry. At Kennedy Space Center (KSC) as at other NASA centers, work is being performed to apply AE testing to high-pressure vessels. To date, work has been performed to evaluate the AE event source location capability of commercially available AE testing equipment.

AE work is presently being conducted at the Development Testing Branch. Low pressure (250 psig) vessels are being monitored with AE equipment during hydrostatic test.

P. J. Welch, 867-4614 DE-MAO-2

Study of Thermal Sprayed Metallic Coatings for Potential Application on LC-39 Structures

Past experience and previous studies have revealed significant factors about the Zone 1 areas of the structures at Launch Complex 39 during Shuttle launches:

1. A significant amount of the area on the structures adjacent to the Mobile Launch Platform (MLP) reaches temperatures in excess of 750°F. This is indicated by the gross failure of the inorganic zinc coatings.

2. Surface temperatures on the MLP deck exceed 2000°F with the water deluge flowing.

3. Structures adjacent to the MLP are impinged by the reflected SRB exhaust blast containing molten aluminum oxide (AL_2O_3) in the range of 2000°F to 3000°F.

These observations indicated that thermal sprayed metallic coatings presented a potential method of providing a protective coating for the Zone 1 strucures.

The objective of this study is to evaluate candidate thermal sprayed metallic coatings for potential application on the Zone 1 structures at LC-39. Tests will be performed to determine if the candidate coatings will protect the structure from the abrasive blast, heat, and acid rich environment associated with the Shuttle launches.

P. J. Welch, 867-4614 DE-MAO-2

Protective Coating Systems for the STS Launch Environment

Zinc-rich coating systems for exposure to the STS launch environment have been suffering premature failure due to the highly acidic residue produced by the Solid Rocket Boosters. Early attempts at topcoating these zinc-rich coatings with thin film topcoats to increase their chemical resistance have produced only marginal results.

Currently, other topcoat systems are being tested to improve coating performance for exposure to this harsh environment. The present study focuses on using thicker film topcoats over the zinc-rich primers to improve the chemical resistance to both a marine atmosphere and the highly acidic residues.

Presently, some 119 materials producing 67 coating systems are being exposed to atmospheric contaminants at the KSC beach corrosion site with concurrent application of an acid slurry made of hydrochloric acid and alumina (Al_2O_3). The slurry is applied to the KTA (Tator) panels with no subsequent washdown to simulate the worst-case scenario experienced at the launch sites.

The current test will be conducted for 5 years to determine the suitability of the topcoat systems. The panels will be judged for performance at 6, 12, 18, 36, and 60 months. During this 5-year period, there will be approximately 130 applications of the acid slurry.

L. G. MacDowell, 867-4614 DE-MAO-2

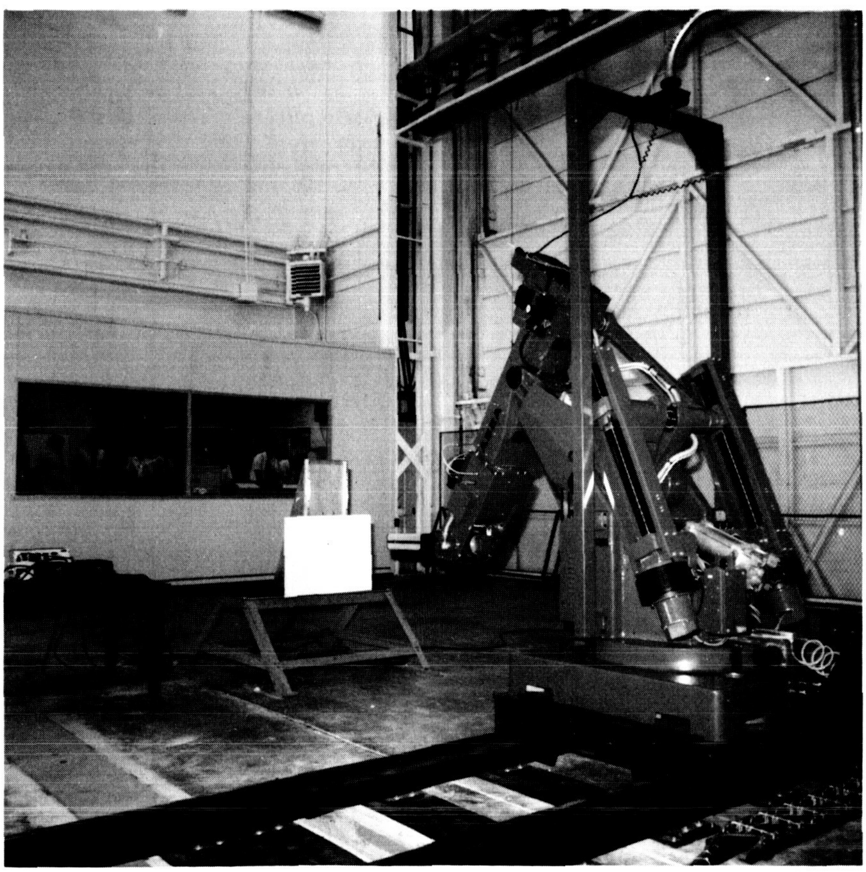
KTA Test Panels at Beach Front Corrosion Site

Robotics Applications for Remote Umbilicals

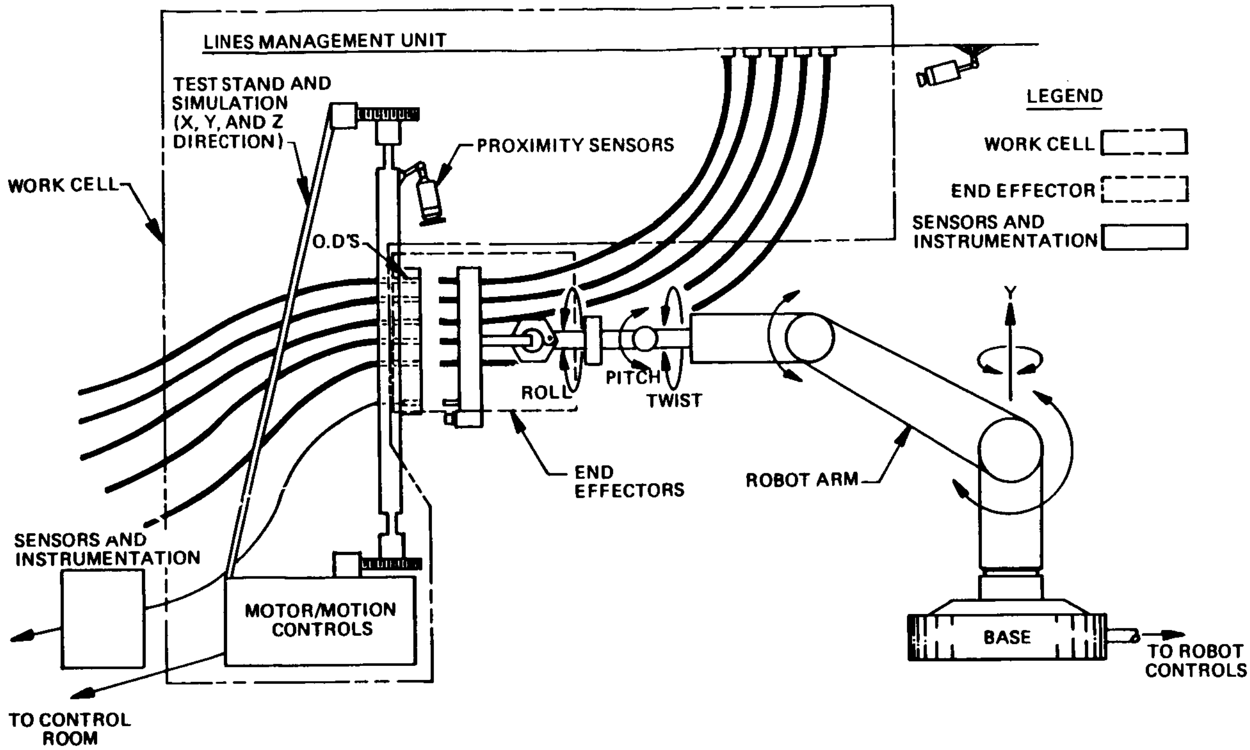
At KSC, the Space Shuttle Vehicle (SSV) requires umbilical connections for fuel; communications; heating, ventilating, and air conditioning (HVAC); hydraulic power; electrical power, etc. Most of the connections are hazardous to worker safety (mainly the hypergolics and cryogenics), repetitive, and heavy/cumbersome to handle. The largest umbilical, the Tail Service Mast (TSM), weighs approximately 1,500 lb.

NASA/KSC is currently working on the system definition and hardware requirements in three areas utilizing robotics applications to address the SSV umbilical connections. The areas are: (1) an auto-, mated soft connect/disconnect function for the T-0 (lift-off) umbilicals, (2) static weight counterbalance techniques, and (3) design concepts for a heavy umbilical robot.

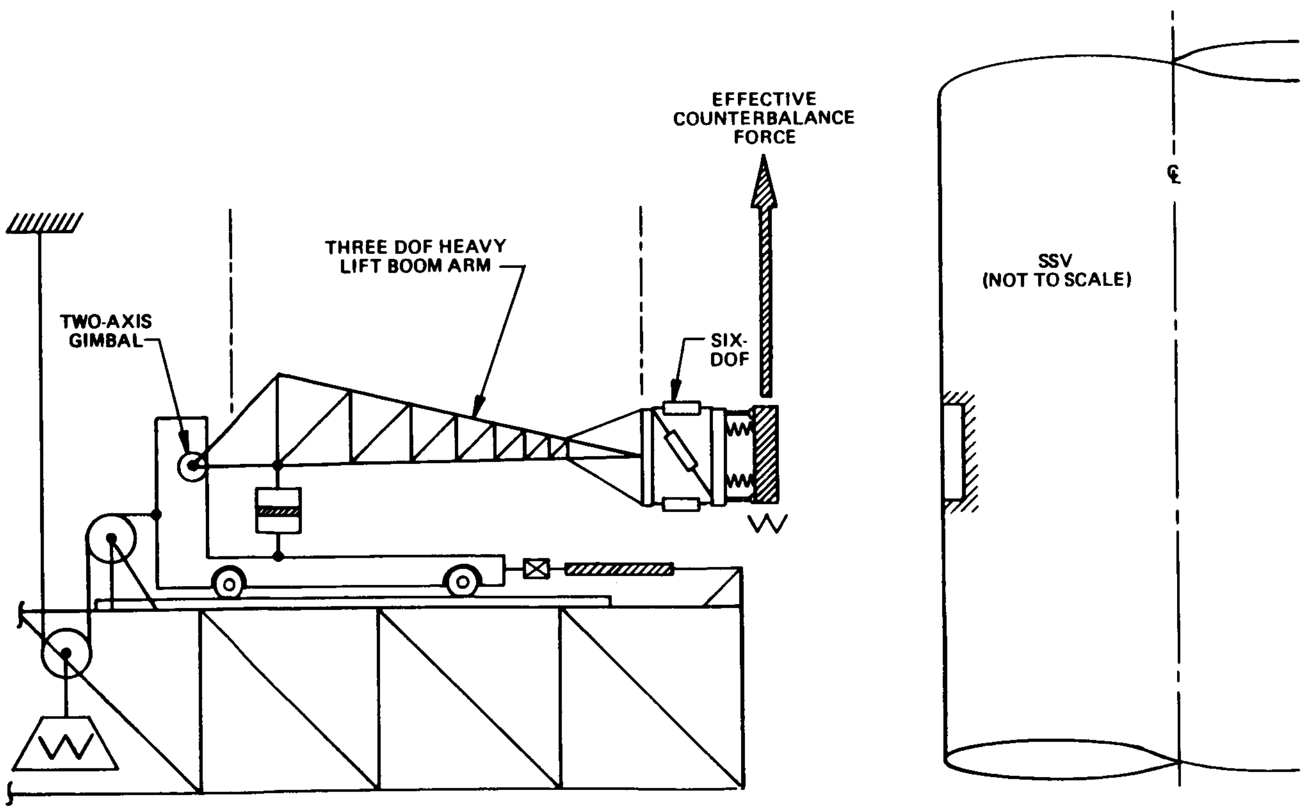
For the final 300 seconds before launch of an SSV, all systems are retracted except for the T-0 umbilicals. They are connected until the time of launch because manual reconnect currently takes technicians 24 to 32 hours, and an aborted launch attempt would require that LOX and LH2 be off-loaded promptly. NASA/KSC is currently working on a robotic automated umbilical system for the T-0 umbilical that would allow a soft disconnect at several minutes before projected launch time, with the capability to reconnect promptly in case of delay. NASA's Robotics Applications Development Laboratory (RADL), as shown in the figure "NASA's RADL," will be utilized for researching special quick disconnects, electrical connectors, and umbilical plates to perform this operation, as shown in the figure "RADL Work Cell, Prototype System for Handling T-O Umbilicals."



NASA's RADL



RADL Work Cell, Prototype System for Handling T-O Umbilicals



Heavy Umbilical Robot Concept

For heavy umbilicals, the static weight will cause elastic deflections of the robot structural elements, resulting in an accuracy loss of the robot by slowing its dynamic response and ability to track a moving target. Therefore, static weight counterbalance techniques are currently under study. Counterbalance research and mechanisms will be performed in the RADL.

Design concepts are currently under study at KSC for a robot required to handle heavy umbilical plates. One concept is a heavy-lift, three-degrees-of-freedom, actuator-driven boom arm for coarse positioning, with a six-degrees-of-freedom robot manipulator for the dynamic motions of tracking and homing connection to the SSV, as shown in the figure, "Heavy Umbilical Robot Concept."

L. Shawaga, 867-3402 or -9788 DL-NED-22

Pulse C-Band Radar Detection of Clear Air Phenomenon

As the NASA Center responsible for the checkout, launch, and recovery of Space Transportation System elements and payloads, the Kennedy Space Center is placing increased interest on local area weather forecasting. Of particular interest is the prediction of thunderstorms with a lead time of at least two hours. A possible key to thunderstorm prediction is a knowledge of surface to 3,000 ft wind flows in the vicinity of the KSC. One way of measuring wind flows is with a doppler radar that can detect the inhomogeneity of visually clear air. The ability of radars to detect these inhomogeneities has been demonstrated by several weather research organizations. It is the goal of this project to demonstrate that the tracking radars used by the Eastern Space and Missile Center can be converted to doppler radars and used to detect clear air phenomenon. Data from the C-band radars will then be used to determine the usefulness of clear air doppler data in predicting thunderstorms at KSC. This approach avoids the large expenditure of funds for the procurement of a dedicated radar facility.

Accomplishments to Date:

1. A high speed radar data acquisition system has been built and checked.

2. Radar reflectivity (ground clutter) data have been obtained using the 19.14 radar.

3. Simple plots of the radar reflectivity levels have been made.

4. Reformatting of data tapes is in progress. Reformatted tapes will be used with existing software for more extensive analysis and plotting.

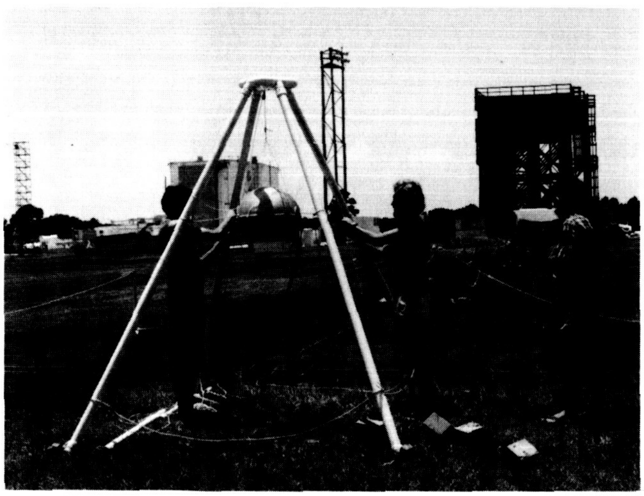
5. Hardware has been ordered to convert the 19.14 radar for operation as a doppler radar.

C. L. Lennon, 867-4068 GI-INS-1

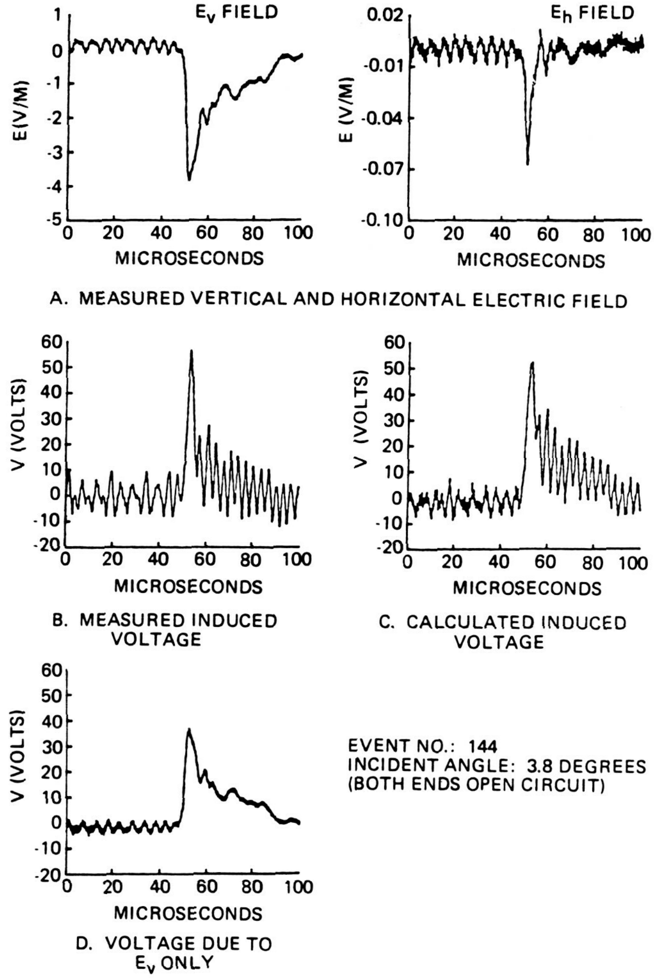
Pulse C-Band Radar Installation

Lightning Induced Effects on Power and Communication/ Telephone Distribution Lines

In the 1986 Atmospheric Sciences Field Laboratory/Rocket-Triggered Lightning Program (ASFL/ RTLP), simultaneous measurements of the induced voltages at both ends and middle of a 500-meter, 3-phase power distributed power line, correlated closely with vertical and horizontal electrical field (see the figure "Vertical and Electric Field Sensor") from natural lightning as well as triggered lightning at a distance of about 10 meters from the end of the test line. Previously written programs were tested to assure that they could predict voltages. Horizontal electric field is partly determined by the local ground conductivity. That parameter was measured as a function of depth.



Vertical and Horizontal Electric Field Sensor



Lightning Induced Voltage Measurements

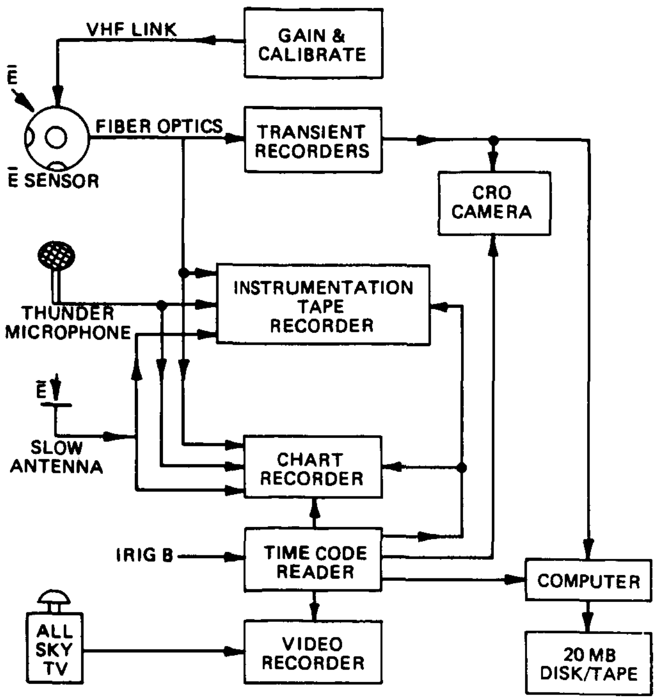
The validated programs were then used to model effects of nearby lightning on realistic power distribution lines. It should be noted that employing electromagnetic field sources other than lightning, such as an electromagnetic pulse (EMP) from a nuclear weapon burst, can also be compared.

Detailed results of the 1985 experiment were reported by Tseng of the University of Florida as shown in the figure "Lightning Induced Voltage Measurements." The primary significance of this work is:

1. Data was obtained on actual induced voltages due to lightning at close ranges
2. Validation of computer programs that can be used to calculate induced voltages on power distribution lines on any configuration, given the present knowledge of lightning electric fields as a function of distance

During the 1986 ASFL/RTLP, the experimental fiber optics measurement process was automated as shown in the figure "Block Diagram of Experimental System," collected over a number of triggered lightning events as well as natural lightning.

Similar measurements on vertical and horizontal communications/telephone lines 30 meters north alongside the power lines were made in 1986. The goal of this experiment was to determine if close lightning may provide an environment similar to that produced by nuclear EMP. Further, the coupling mechanism – if the two cases have elements in common – may possibly be used to assess the EMP hazard to a distributed system in



Block Diagram of Experimental System

terms of its response to triggered lightning, which provides a somewhat controlled close lightning environment.

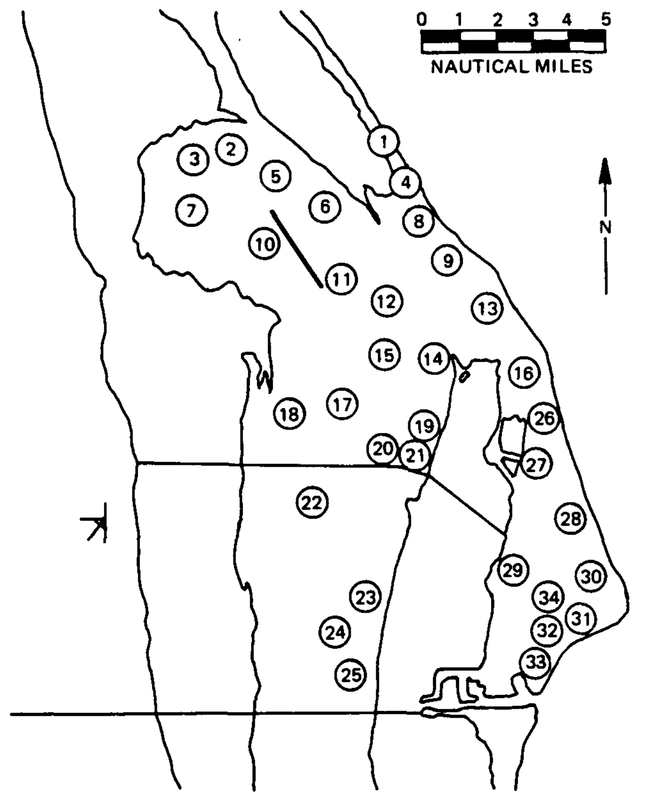
W. Jafferis, 867-0605 GO-MGT

Electromagnetic Versus Electrostatic Field Lightning--Detection Interferometer

KSC has an ongoing program with the Eastern Space Missile Center (ESMC) weather group to improve the forecasting of thunderstorms and adverse weather warnings and other weather phenomena. This relationship has resulted in one of the world's most advanced weather forecasting facilities, consisting of the Meteorological Interactive Data Display System (MIDDS), which provides access to the world's meteorological data and weather satellites as well as local radar, sounding system, and expanded mesonetwork (50 stations). A five-year weather forecasting enhancement program is ongoing and will add additional systems such as clear air doppler radar, volumetric scanning radar techniques, acoustical sounding systems, improved lightning locating systems, etc. The full utilization of this unique set of meteorological systems is being applied to improvements in weather forecasting techniques.

This involvement with semitropical severe weather at KSC has created two situations:

1. Recognition of KSC as a center of knowledge and experience with lightning and other severe weather, with frequent requests for information and assistance
2. The potential problems posed by the increased frequency of future Shuttle launch and landing operations



1 – CAMERA SITE 10
2 – CAMERA SITE 11
3 – WEATHER TOWER 816 (OLD)
4 – CAMERA SITE 9
5 – WEATHER TOWER 415
6 – CAMERA SITE 5
7 – WEATHER TOWER 714
8 – CAMERA SITE 4
9 – CAMERA SITE 7
10 – SHUTTLE RUNWAY
11 – WEATHER TOWER 412
12 – WEATHER TOWER 311
13 – CAMERA SITE 12
14 – CAMERA SITE 15
15 – MARGO (INST BLDG)
16 – CAMERA SITE 3
17 – WEATHER TOWER 509
18 – FREQUENCY CONTROL SITE
19 – FIRE TRAINING AREA
20 – CIF ANTENNA SITE
21 – CAMERA SITE 2
22 – USB SITE (TEL IV)
23 – CAMERA SITE 1
24 – WEATHER TOWER 803
25 – 19.14 RADAR SITE
26 – INACTIVE
27 – LC 37
28 – LC 13
29 – RECLAMATION FACILITY
30 – METEOROLOGICAL LABORATORY
31 – INACTIVE
32 – LC 25
33 – PORT CANAVERAL
34 – LC 18
35 – INACTIVE (AT PATRICK AFB)

Launch Pad Lightning Warning System Mill Locations

Thunderstorm-producing lightning is a frequent operational problem for processing, launch, and landing of the Shuttle Vehicle. The existing electric field mill network of 25 electric field mills, shown in the figure "Launch Pad Lightning Warning System Mill Locations," needs to be expanded consistent with our expanded mesonetwork because of high cost of electric field sensors and associated maintenance. Other types of systems are being studied with thoughts of augmenting or replacing these sensors.

This summer's Atmospheric Sciences Field Laboratory/Rocket-Triggered Lightning Program (ASFL/RTLP) hosted a French-designed interferometer system which can be used to characterize thunderstorm activity using electromagnetic radiation. The present KSC field mill network senses electrostatic fields.

The French group of researchers from the Office of Aerospace Research deployed three antennae 20 km apart. The three antennae sites were located at Ti-Co Airport, Playlinda beach, and Cape Canaveral (Hangar "AO"). The base station was located at Hangar "AO" and consisted of communication modems, receiving/digital interface electronics, and PC-type computer/color video display system. Each antennae site consisted of a microprocessor, communication modems, and electronic interface equipment. The antennae incorporated three elements located approximately one meter apart, consistent with the system's operating frequency of 140 megahertz.

Lightning Activity at KSC VAB

The system was assembled, tested, and calibrated, and operated in two months during three thunderstorms on successive rocket-triggered lightning days. One 5-minute plot of the lightning activity (intercloud and cloud-to-ground) centered on the Vehicle Assembly Building (VAB) is shown in the figure "Lightning Activity at KSC VAB." These data will be correlated with weather radar, cloud-to-ground lightning, Air Force and KSC electric field mill network, and wind convergences.

W. Jafferis, GO-MGT 867-0605

Lightning Protection System Adequacy--A Verification Technique

The Kennedy Space Center is located in an area having the highest frequency of thunderstorm and lightning activity in the United States. Outdoor operations at KSC involve space vehicles, servicing towers, explosives, toxic substances, fuel storage, distribution facilities, aerial and buried cabling systems that connect widely distributed sensitive electronic and mechanical equipment; all subject to exacting and critical schedules. This condition makes lightning a serious hazard to successful operations. For this reason, KSC has for many years conducted extensive studies of lightning phenomena, its characteristics and effects, and methods of protection against it, as well as methods to locate and forecast thunderstorms and lightning.

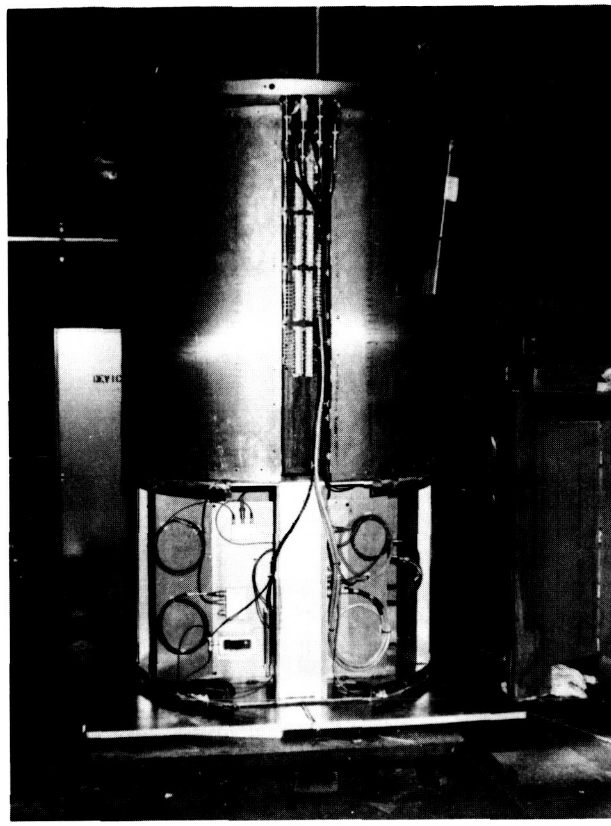
In past years KSC has hosted a number of scientists during summer months for extensive studies of lightning and thunderstorm phenomena. These efforts resulted in improved Lightning Protection and Measurement System and Lightning Detection and Hazard Warning Systems. The Space Transportation System (STS) landing requirements at KSC create the need for further improvements in severe weather forecasting and lightning detection and protection systems to provide more cost effective and safer operational capability under marginal weather conditions.

Since 1983, KSC has participated in a Federal Aviation Administration/Air Force Wright Aeronautical Laboratory (FAA/AFWAL)-French rocket triggered lightning program designed to improve the understanding of the lightning electromagnetic field and direct current effects on aerospace and ground systems. The analysis of data from these events (see table 1) has affected the design of lightning simulators, aircraft and ground lightning protection systems, lightning locators, and the development of standards. As part of the NASA Technology Utilization Program at KSC, Atmospheric Sciences Field Laboratory (ASFL)/Rocket-Triggered Lightning Program (RTLP), Lawrence Livermore National Laboratories/Sandia National Laboratories (LLNL/SNAL) participated in the KSC 1986 RTLP and provided a prototype Lightning Invulnerable Device System (LIDS). This represents an appropriate follow-on to simulated lightning tests performed by Lightning Transients Research Institute (LTRI) at their Miami Beach facility.

The ASFL/RTLP involves many participants including the Eastern Space and Missile Center (ESMC), NASA, AFWAL, Naval Research Laboratory, French aerospace and nuclear scientists, and U. S. university research scientists, as well as private (U. S.) sector scientists from ATT Bell Laboratories, Colorado Research Corporation, Communication and Weather Research Foundation, and Low Latitude Dynamics, Inc., who share ideas, equipment, and data. This permits a more cost effective research program (i.e., KSC is interested in LLNL plans to demonstrate that suitable protected bridgewires and squib devices will not be fired within the LIDS as a result of a direct strike to the LIDS cables. In conjunction with the LIDS experiment, KSC Electric Field Mill Network data is being correlated with LLNL-furnished electric field mill data to permit a better understanding of their performance in the presence of distant and local thunderstorms for future use at the Nevada Test Site.

Table 1. Lightning Events (Flashes) Versus Ground Lightning Strike Object (LSO)

Aircraft	Ground LSO	Lightning Events
C130 (French)	---	2
C160 (Transall French)	---	18
F106B (LRC)	---	670
(CV580 (FAA/AFWAL)	(LRC)	2
	(KSC)	57
	AFWAL 40-ft Cylinder	14
	LLNL/SNAL (LIDS)	29
	KSC ALPS	63



Lightning Invulnerable Device System

The figure "Lightning Invulnerable Device System" shows the equipment used in a simulated lightning test at Miami in which short (12-inch) lengths of cable were mated to a feed-through connector to the LIDS for making lightning voltage measurements at high peak amplitudes and high rate-of-rise current pulses. The KSC RTLP permitted use of a 28-foot cable that was subjected to the high voltages, high peak current, high rate-of-current rise and a significant follow-on current which included multiple restrikes. (See figures "Rocket Triggering Site" and "Rocket Triggered Lightning.") It should be pointed out that although triggered lightning has, in the past, produced typical currents in the range of 40 kA, this value will subject the LIDS to the equivalent of a "worst-case" 200-kA strike because of division of current through multiple cables.

During the 1986 RTLP, one MC-17 and two RF-14 cables were subjected to lightning strokes (table 2), one cable at a time, and there were no perceptible internal currents or voltages from a 40-kA return stroke. In the second RF-14 configuration using a TC-185 isobox, protected by a coaxial transient limiter (CTL) with a 500-V spark gap, a total of eight lightning flashes, 35 return strokes, and one flash containing 8 return strokes with a

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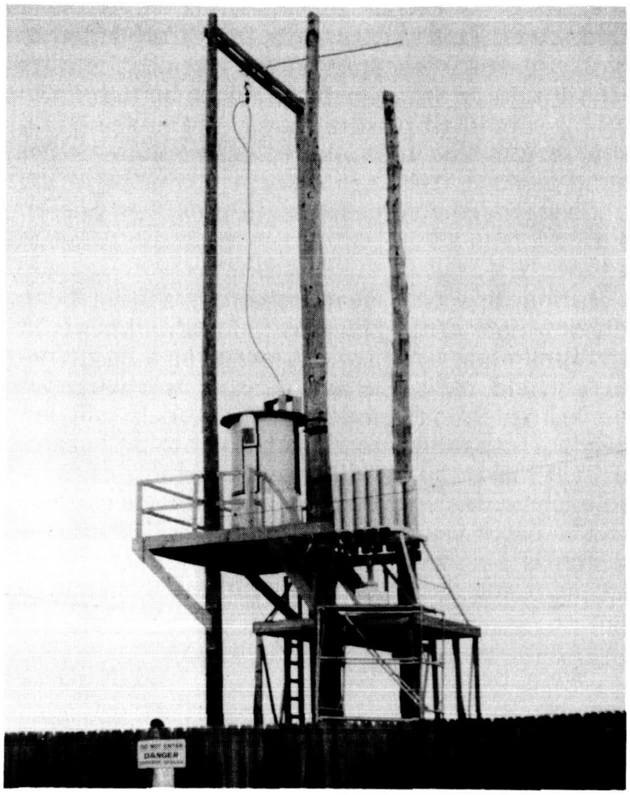
maximum peak of 15 kA did not produce any perceptible corresponding load ring current. All Arm and Fire (A&F) systems checked following exposure to lightning were working normally.

Table 2. Lightning Flash Summary

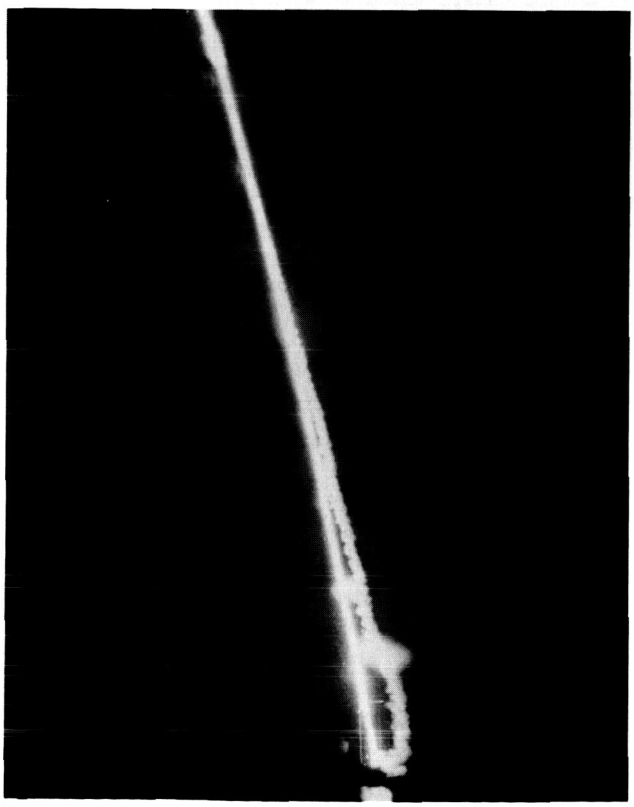
Storms	5
Launches	38
Triggered flashes	22
Return strokes	80
Peak current - max	52 kA
Peak current - min	4 kA
Peak current - mean	14 kA (std dev 9 kA)
E-field at launch - max	-6.3 kV/m
E-field at launch - min	-3.7 kV/m
E-field at launch - mean	-5.1 kV/m (std dev 0.7 kV/m)



Rocket Triggering Site

One of the long-term goals of the ASFL/RTLP is to demonstrate the adequacy of lightning protection systems design techniques up to the full thrust of lightning. Progress toward this goal is shown by data from four different types of aircraft flying through thunderstorms and withstanding 750 lightning strikes, with attachments from LLNL/SNAL LIDS exposure to over 100 lightning events, and KSC Launch Complexes 39A and 39B exposure to 32 lightning events over the Apollo, Skylab, ASTP, and STS programs without significant effects to personnel and electric/electronic equipment.

W. Jafferis, GO-MGT 867-0605



Rocket Triggered Lightning

Clear Air-Wind Sensing Doppler Radar

A reliable 90-minute thunderstorm forecasting capability would minimize Shuttle launch and landing delays and enhance flight safety. Discussions at KSC meteorology workshops with many weather research people suggest that clear-air wind-sensing using a doppler radar may provide such a capability.

Preliminary planning studies to test a clear-air wind-sensing doppler radar at KSC have been completed. This year's efforts include initial tests of an existing range radar for possible modification to a clear-air doppler radar and the initial development of doppler display software. Next year, a clear-air doppler radar should be operating. Also, display, editing, and Universal Format data exchange software should be completed. If so, the testing and development of algorithms for the detection of thunderstorms can begin. These algorithms may include volume-velocity processing techniques, divergence analysis, or Planetary Boundary Layer numerical modeling techniques.

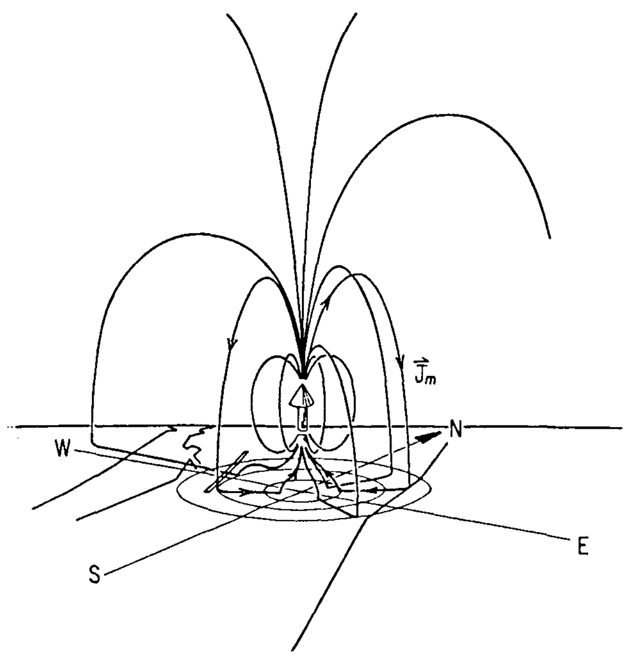
R. P. Wesenberg, 867-4438 DL-NED-32

Thunderstorm Currents

Lightning can make the handling of propellant and ordnance materials at KSC a very hazardous occupation. A system that detects the potential for lightning is in operation at KSC; however, the system cannot predict whether the lightning hazard is increasing or decreasing. To do that, the state of the thunderstorm generator itself must be determined.

Some recent developments suggest that this may be possible. Recent research in atmospheric electricity conducted by the University of Arizona Institute of Atmospheric Physics suggests that an electric-current sensor network may be able to track the state of the thunderstorm generator that produces the electricity that results in lightning.

In the figure below, the large arrow in the center represents the thunderstorm generator, while the contours represent current density streamlines.



Theoretical Description of Typical Thunderstorm Generator's Structure in Terms of Current Density (Jm)

Since charge is conserved, the streamlines make closed loops. This fact suggests that, from an array of current sensors located on the ground, the state of the thunderstorm generator might be determined. This simplified picture may be complicated by many factors; the best way to determine whether ground-based current sensors can characterize the thunderstorm current generator is by a field experiment.

During this past year, researchers have been analyzing data from previous field experiments at KSC. Preliminary indications are that a combination of field mills, current sensors and what we have learned about cloud charge models will improve our capability to detect a lightning hazard. This will make the handling and transport of flammable chemicals, propellants and explosives safer at KSC. Next year, an independent review of this research is planned. If the review is favorable, development and design of an operational system will begin.

R. P. Wesenberg, 867-4438 DL-NED-32

Thunderstorm Weather Forecasting Expert System

At Kennedy Space Center the Shuttle operational weather forecasting is provided by the U.S. Air Force from the Cape Canaveral Forecast Facility. Shuttle operational forecasting is very difficult because of the location, on the coast and on the Florida peninsula. The forecasters have tours-of-duty ranging typically from two to four years. The expertise that they develop leaves with them at the end of their tours-of-duty. Shuttle operational forecasting is further compounded by the wealth of information available from conventional weather data sources and from a multitude of specialized instrumentation systems. In the process of making a short term forecast, it is difficult to know which data sources are appropriate, much less assimilate the data.

In this context, the Thunderstorm Weather Forecasting Expert System (TWFES) Project is developing a weather forecasting aid which captures the corporate and individual expertise developed by the forecasters and also focuses their attention to anticipated events and to the appropriate data sources. An additional goal of this project is to develop inhouse NASA expertise in applying expert system technology.

Arthur D. Little, Inc. was selected for the feasibility study and for the follow-on phases. During the feasibility study they identified summer thunderstorm forecasting as the best choice in terms of benefits and in terms of appropriateness to expert system technology. Shuttle operations are strongly affected by lightning near the operational areas.

During the proof-of-concept phase, knowledge engineering has been performed, the initial knowledge representation has been chosen, and the initial knowledge acquisition has been accomplished. The knowledge representation is a scenario. The proof-of-concept system has a scenario editor which has speeded the knowledge acquisition. Twelve scenarios have been elaborated. The run time portion reasons temporally. Spatial reasoning is implicit in the scenarios. The user interface utilizes a mouse and modest graphics in addition to the keyboard. The system runs on a Symbolics 3640 and has a hybrid architecture utilizing both Zetalisp and Automated Reasoning Tool (ART).

The prototype phase will identify and elaborate more scenarios, the user interface will be improved, data interfaces will be hardened, and the prototype will undergo testing during the next summer season. At this point, further development will be solely in-house with the goal of moving TWFES into the operational setting of the Cape Canaveral Forecast Facility in 1988.

A.E. Beller, and P. McVeagh, 867-3223 NE-AIN

Project KATE--Knowledge-Based Automatic Test Equipment

In order to further the state-of-the-art in process control, monitoring, and diagnosis, NASA's Artificial Intelligence applications Office at KSC is continuing the development of project KATE (Knowledge-based Automatic Test Equipment). This system, written entirely in Common Lisp, utilizes a knowledge base which describes every component in the system and how all components are interconnected. This knowledge base is central to the KATE system; it is used to control components, monitor all measurements to determine the "health" of the system, diagnose discrepant readings to determine failed components, and create mouse-sensitive schematic diagrams as part of the user interface.

With this sort of approach none of the "component" programs used at the Space Center are necessary. Component programs are a series of command-level language statements. For example, the statements might say: "To get valve V1 ON, first turn to commands C1 and C2; then wait 10 seconds and check that measurements M1 and M2 are ON. If not, then go to safing sequence . . . .". These explicit programs (a new one for each component) are laborious and very expensive to create, maintain, and modify. With KATE the control, monitor, diagnosis, and schematic generation code is generic. When applying it to a new or modified

Project KATE Development System

hardware system, only the knowledge base needs to be changed.

The major features of the KATE system are:

1. High Level Control. The test engineer can specify any object and a value as a goal to be obtained and the machine will automatically determine which commands need to be set to what values to achieve the desired goal. Any level of component or frame can be used, such as (goal purge-pressure 20.0). Since most systems at KSC are highly redundant, a number of options usually exist to accomplish a goal. KATE finds all valid options and uses the simplest one.

2. Detection of Anomalous Conditions. The system constantly monitors all measurements and checks each one for correctness within the current context of the commands given to the hardware under test. Any inconsistent measurements are given to the diagnoser for it to determine the faulty component(s).

3. Diagnosis of Failed Components. Any discrepant measurement is diagnosed by getting a list of all objects which affect the measurement and systematically eliminating as many as possible, using the current readings of related measurements. All objects determined to be failed are marked as such so that they will not be used during further testing. This means that the machine can differentiate between a sensor failure and a major component failure.

4. Maintenance of a State (Recovery from Failures). When a failure is detected and diagnosed, the system knows if it will effect a maintained component. If so, redundant paths are invoked automatically to return the component to the correct state. If no redundancy is available, the user is notified of the failure to maintain the condition.

5. Automatic Drawing. The system generates "live" schematic diagrams, which show all objects and their present states, exclusively from the knowledge base. Objects are mouse-sensitive and easily controlled by clicking the mouse on any component and specifying a desired value.

6. Simulation/Training. Because the knowledge base can be used to predict the results of any command or action, the system can act as an effective, high-fidelity simulation tool for training new operators.

At present, a bread-board model with 13 components and 13 commands and measurements is set up to check out the KATE system on real hardware. PC AT class machines (with a voice board for giving verbal notices) are used to run the Lisp code and control the hardware. Development continues on both the PC's and large, fast Lisp machines in order to expand the complexity of testable systems and the capability of the KATE system.

Possible applications of this approach include launch vehicle control systems, power plants, space stations, ships/planes, and other large process-related systems.

M. Cornell and E. E. New, 867-3224
NE-AIN

Generic Model-Based Diagnostic System

General: An initiative to apply artificial intelligence techniques to the real-time control, monitor, and diagnostic aspects of the Kennedy Space Center (KSC) Launch Processing System (LPS) Pad B Environmental Control System is underway with the development of the Generic Model-Based Diagnostic System (GMODS). It is a joint NASA and Mitre Corporation effort. A system will be developed which will reside in a general purpose workstation receiving information concerning the ECS operation from a computer-based data acquisition system: the Local Processor Controlled Hardware Interface Module (LPCHIM). Its goal will be to develop techniques for process monitoring, control, and diagnostics; develop man-machine operation concepts relevant to the operation of such a system; and test and control the Pad B ECS, and other LPS subsystems. As data is received, it will be checked for consistency against expected values for measurements derived from an expert system model of the ECS components. Inconsistencies will be referred to a diagnostic facility, which will isolate possible causes, provide an explanation for the diagnosis, and display schematics relevant to the system elements in question. The component models will be generic for systems at KSC and thus expandable to other implementations.

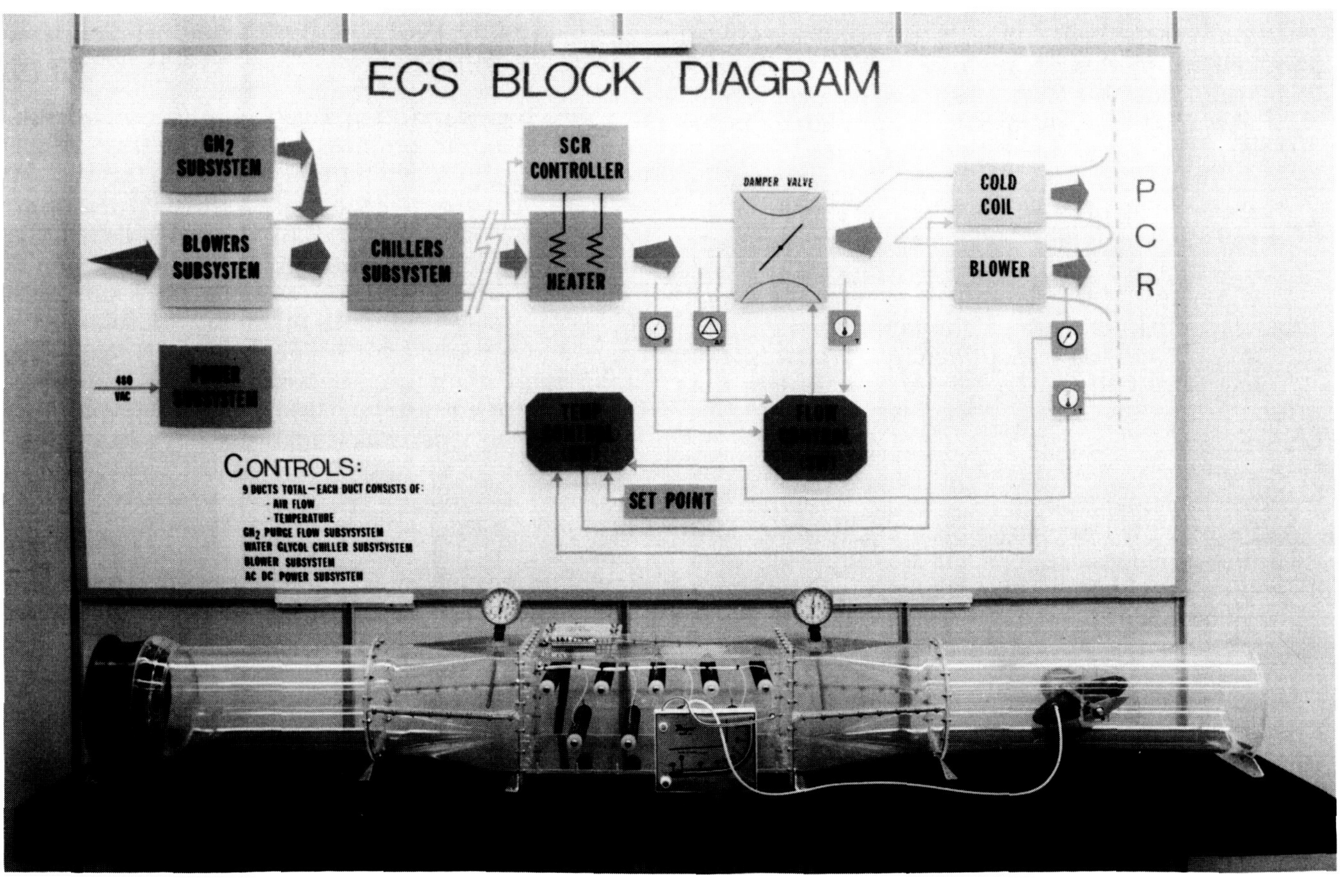
Architecture: The architecture chosen to implement GMODS is not the standard dedicated LISP machine, but rather a 68000-based general purpose workstation. Common LISP code generation will be accomplished in a Unix environment. The Graphics Kernel Standard will be used for the generation of graphics to maximize portability. Standard implementations of other languages will be used as required. It is felt that this approach will allow more widespread use of any product developed. It will also allow use in the second generation Launch Processing System at KSC. Several difficulties with this approach must be overcome:

1. The speed of operation with a non-LISP-specific machine may be slower and affect system performance.

2. General purpose implementations of Common LISP do not allow concurrent LISP processes.

3. Garbage Collection, the process of recovering no-longer-used memory space, must be carefully managed. Resolution of these concerns will affect technical decisions throughout the design.

GMODS: The GMODS program is an attempt to extend the concepts developed in other expert systems to handle more complex components and processes. A scheme is being developed for the representation of system elements in the ECS that shows how the component functions, relates component terminals to inputs and outputs, and provides system connections. This object representation must be generic so that it will apply to all KSC areas. The entry of knowledge base information must be straight-forward so that future systems development cost and time is minimized. In order to handle ECS components and subsystems, the representation must deal with feedback loop analysis. Time must be explicitly modeled and performance of the elements must account for data history in modeling integral relationships and trends. Component descriptions will incorporate knowledge defining the states that a component can achieve, the behavior of that component when in that state, the path of propagation through the component, and the transition circumstances required to attain another state. Components with clearly defined states and characteristics will be modeled quantitatively. Those with less definable relationships will use a qualitative description technique. Using a single-pole-single-throw relay as an example, states are "energized" and "de-energized", signals present on the common terminal propagate to the normally closed terminal when de-energized; and to achieve the "energized" state, a positive voltage in some specific range must be applied across the coil. A similar representation will be developed for components such as valves, heaters, transducers, and other components within the ECS. Terminals will be defined for the components to name inputs and their relationships.



Hardware Duct Simulator for GMODS Validation

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Levels of Abstraction: The terminal definition will be broadened to define ports that will act as a translation medium between different detail levels. The final product will be able to display and act on the system at varying levels of abstraction. A complete subsystem can be handled at one level as a sum of many components interconnected at a detailed level, each with its own terminals, behaviors, etc., and requiring propogation of signals and states in a very detailed manner to determine proper operating conditions. Or a series of components performing a common function could be grouped together with a single function and treated with higher-level, less-detailed analysis. Instead of handling a temperature control loop as a mass of relays, temperature transducers, heaters, etc., it could be treated as a single high level component with a set point input and temperature output whose behavior can be determined by a relatively simple relationship. Representing the system at different levels of abstraction and being able to switch between these levels provides a means of dynamically reallocating computer resources to monitor subsystems. A critical process requiring great machine power, such as diagnosis, might force moving other less critical processes to a higher abstraction level to free up machine time.

Enhancements: Additional goals set for this project include an attempt to handle multiple failures occurring simultaneously, components which have multiple outputs, troubleshooting within a feedback loop, addressing conduit failures in the diagnosis, and representing components with memory or whose performance must be measured over time. The ECS has components which fit in these categories and will provide an excellent testbed for development of these techniques.

Next Phase: During the initial phase these concepts will be developed in a monitor mode only. The first effort will involve modeling a single ECS duct control system in the Payload Changeout Room. The system will be tested against a laboratory simulator, and development of a checkout scheme will attempt to solve the problems involved in verifying a system of this complexity in an automated fashion prior to installation in the field. This phase is expected to take 1-1/2 years. The second phase is hoped to include introduction of control and the verification of this technique. Additionally at that time, the GMODS should be ready to be applied to the LPS II prototype.

R. Hurt, 867-3367 DL-DED-31
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Expert Planning and Scheduling Systems

At the Kennedy Space Center (KSC), science, applications, and commercial payloads are processed through a number of steps before they fly as part of an integrated Space Shuttle payload. Following inspection and preparation in support areas, payload elements begin an assembly-line-like process that brings them together to form a compatible, functioning payload unit. Each phase of integration results in a progressively more complete, functional flight payload. As can be imagined, planning and scheduling is an important part of this process. As a result, two expert systems are being developed to enhance existing capabilities. Both are advanced versions of earlier developments. One is Expert Mission Planning and Replanning Scheduling System (EMPRESS II), the order is Multiple Architecture for Reactive Scheduling (MARS). In time, both systems will become integrated.

EMPRESS II is an Artificial Intelligence (AI) expert system being developed jointly by NASA-KSC and the MITRE Corporation of Bedford, MA. The main objective of EMPRESS II is to provide a system which utilizes the tools and problem-solving heuristics (rules) employed by a planning and scheduling expert at NASA-KSC in constructing and maintaining mission schedules for Spacelabs, partial payloads, and Space Station. EMPRESS II supports the KSC planner in defining schedule activities by specifying the time, resource, and task requirements associated with payload processing.

Since mission requirements change frequently, and since payload processing can vary greatly from payload to payload, the environment in which payloads are processed is a dynamic one. To monitor and control this environment and to ensure a capability to process multiple payloads simultaneously, KSC generates and maintains a hierarchy of schedules. When one of these schedules change, dependent schedules must be updated. In an effort to maintain consistency among related schedules, EMPRESS II identifies task and resource violations which are introduced as a result of schedule change. Through its interface, EMPRESS II supports a mixed-initiative interaction with the user in resolving resource conflicts and in refining schedules. EMPRESS II also incorporates problem-solving strategies that can be used to automatically plan and replan payload processing activities. In an effort to support multiple users, EMPRESS II stores schedules in a relational data base.

The principle objective of MARS (being developed by McDonnell Douglas Astronautics-KSC) is to demonstrate the feasibility and application of expert system technology to the problem of daily 72-hour/ 11-day planning and scheduling activities, including facility/resource utilization. The project effort resulted in creating and documenting a prototype of this application called PLANNET. The results of the PLANNET prototype indicated that a more powerful system was needed to accomplish the desired project objectives for the eventual support of an operational system. This expanded system is called MARS. The ultimate objective is to support overall operational planning and scheduling. The initial demonstration requirements addressed only a subset of the planning and scheduling capabilities; work will continue to expand the prototype system to make it more realistic than speculative.

In addition to ascertaining the existence of constraints between newly manifested mission payloads and supporting short-term payload-processing activities, EMPRESS II and MARS will be used to assess the impact of possible changes or hypothetical situations. In this role, these systems will serve as a method for identifying constraints and exploring alternative paths for resolution. One of the prime objectives of this technological application is to provide this function, along with sophisticated capabilities to detect conflicts, which usually necessitate the replanning of activities.

J. M. Ragusa, 867-7882 CS-SED

Remote Maintenance Monitoring System

The Launch Processing System (LPS) at the Kennedy Space Center has over 200 Modcomp computers. The task of maintaining and repairing these computers is manpower and time intensive. The Remote Maintenance Monitoring System (RMMS) project is developing a prototype RMMS to facilitate maintenance of the Modcomp computers. RMMS is composed of a Diagnostic Expert System (DES) and sensor implant into the Modcomp computer.

The sensor implant will monitor and store digital and analog measurements for the DES. Since the sensor implant is constantly monitoring Modcomp performance, it is capable of capturing failure data from intermittent failures. Intermittent failures are one of the most difficult and time consuming maintenance tasks in LPS. The sensor implant for the Modcomp has been designed and fabrication has begun.

The DES for RMMS will use failure data gathered by the sensor implant to determine the cause of failure. The initial prototype will diagnose power supply and parity error anamolies in a single Modcomp computer. NASA has developed a forward-chaining inference engine with conflict resolution to fire rules for the initial DES.

Future development will extend RMMS to diagnose more types of failures and monitor a distributed network of multiple Modcomp computers. With assistance from MITRE Corporation, NASA plans to develop a hybrid model-based/rule-based DES for diagnosing failures of Modcomp computers. The RMMS project will continue to explore ways of improving diagnostic capability for maintaining the computers that compose LPS using expert systems.

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BIOMEDICAL

Controlled Animal Nutrients Delivery System (CANDS)

Nutritional inadequacies, whether due to diet composition or animal intake, are capable of influencing the reliability of data from most experiments using animal subjects. Every nutrient in the diet, including water, should be readily available, nutritionally balanced, and in an acceptable form. Nutritional recommendations are expressed as average requirements for "normal" animals maintained in "conventional" environments. Within the non-conventional environment of space for prolonged periods, minimum nutrient requirements may be altered as adaptation occurs. The additional influence of diet, housing, and delivery methods, and the interaction of these variables, must be known for adequate interpretation of data. In an attempt to provide a mechanism for determining nutrient intake and facilitate the research of the pathophysiological mechanisms of weightlessness in laboratory rats, a series of ground-based studies were undertaken at KSC to investigate a diet form and a delivery system enabling:

1. A reproducible formulation with purified ingredients to allow possible single-nutrient level alteration
2. Accurate data collection regarding consumption and feeding activity with minimal dietary waste
3. Diet stability, sterility, and easy storage
4. "Normal" animal performance to support various research objectives on the ground and in microgravity

A purified diet formulation (AIN-76A with modified starches and extra vitamins) in powder form was selected for incorporation into a 65 percent moisture diet for laboratory rats. The diet form was evaluated for consistency, nutrient content, sterility, shelf life, ease of delivery, animal performance, and suitability for flight. Weanling male, Sprague-Dawley, specific pathegon-free rats (n=75) were fed an irradiation-sterilized (3.5 to 4.9 Mrad), high moisture diet with and without water ad libitum over a 28-day period and compared to rats fed the same diet in powder form (irridated at 3.7 to 4.7 Mrad) with water ad libitum. Control rats were fed either non-irradiated powder diet (AIN-76A) or autoclaved pellet diet (NIH-31), both with water ad libitum. Results from these trials suggest that this paste diet formula may be a usable dietary form for selected experiments conducted with animals during spaceflight.

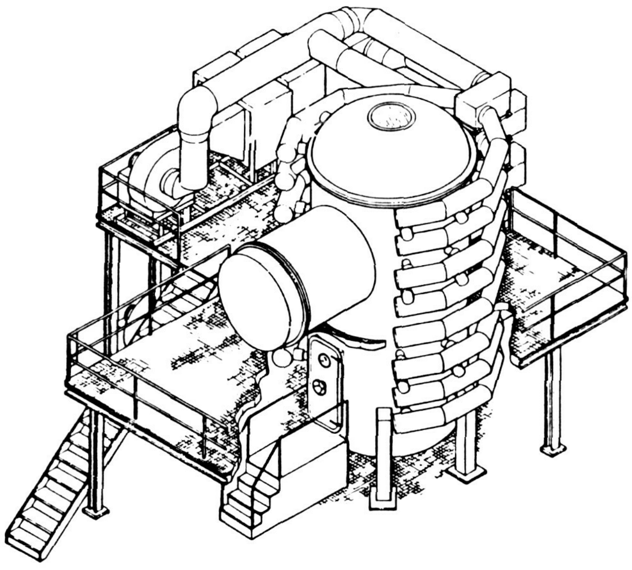
Further diet development will include pre-processing techniques prior to irradiation as well as various disposable packages, which are lightweight and easily delivered and replaced. Techniques for packaging powder diet and water separately will be investigated for potential use on long-duration flights in space. Design of the delivery system hardware to interface with existing middeck equipment (Animal Enclosure Module) will be based on a commercially available powder/liquid diet feeder. Ground-based prototype testing for biocompatibility and biocontainment are planned with subsequent flight hardware testing and eventual controlled delivery of high moisture diets in microgravity.

W. M. Knott, 853-5142 MD-RES

Controlled Ecological Life Support System(CELSS) Breadboard Project

A major project was initiated at Kennedy Space Center in 1985 with a goal of integrating elements of a biological regenerative life support system within, or in association with, a large atmospherically sealed plant growth chamber. This project will scale up laboratory bench level methods and equipment to a level adequate to test their performance for use in sustaining humans during long duration spaceflight.

During the past year, the major activity has been to modify a large steel chamber (24 ft x 12 ft) so that it can grow plants under controlled environmental conditions. The construction is nearly complete and initial performance testing of the chamber is scheduled for the last two months of this year. Once this sealed chamber facility, the Biomass Production Chamber (BPC), is operational, it will be



Biomass Production Chamber

the only one of its size and type in this country.

The first crop to be grown in the BPC will be wheat. Several studies have been conducted in plant growth chambers at KSC during the past year to develop a hydroponic system and nutrient solution maintenance techniques to be used during the initial wheat growouts in the BPC. A plastic tray approximately 0.25 m^2 in area has been developed to grow the wheat in a nutrient film technique manner. Tops to the trays are plastic with flexible wings to hold the wheat plants in place. Each tray will grow approximately 300 wheat plants and the chamber will hold 64 trays when fully operational. The nutrient delivery system consists of plastic pipes and tanks with each of 16 trays supplied a modified nutrient solution from one of four tanks. Each tray has manual valves for shutoff and flow control.

The nutrient solution to be used for wheat growth is a modified Hoagland's solution. During the wheat growout studies this year, the recycling solutions used have been characterized as to chemical and microbial make-up, change over time, and daily water evaporated by the system. These data are being used to develop a simple model that should be useful in maintaining an acceptable nutrient supply to plants being grown in the BPC.

Next year's effort will concentrate on quantifying mass and energy fluxes through the BPC during wheat growout studies. A trace contaminate gas control system will be constructed and tested as will a system to recycle condensate water for make-up of the nutrient solution. Other crops will be tested in the plant growth chamber for future incorporation in the BPC.

W. M. Knott and R. P. Prince, 853-5142 MD-RES

Three Hydroponic Growing Trays With Young Wheat Plants

Long-Term Environmental Monitoring and Research Program

At the John F. Kennedy Space Center (KSC), the Long-Term Environmental Monitoring and Research Program continues to utilize the state-of-the-art technology and analytical tools to ensure the space programs continued mutual coexistence with the unique environment within the Merritt Island National Wildlife Refuge. The uniqueness of the area and its diversity of habitats is exemplified by the presence of more Federal and State listed threatened and endangered plant and animal species than can be found on any other refuge in the United States. Examples of these unique species include the bald eagle, wood stork, Florida scrub jay, least tern, Florida manatee, gopher tortoise, indigo snake, loggerhead turtle, black mangrove, red mangrove, sea lavender, and many others. The presence and abundance of these organisms are a direct function of the amount of high quality habitat that exists at KSC. The Environmental Monitoring and Research Program has as its basic objective the development of a working understanding of the ecological factors that control the complex interactions between organisms and habitat, ultimately improving management's decision-making capabilities regarding environmental impact predictions and mitigation strategies.

To achieve this objective, the Biomedical Operations and Research Office has implemented the acquistion and development of an automated Geographic Information System (GIS). Utilizing color infrared aerial imagery and ground truthing, a comprehensive set of vegetation and land use maps, detailing 42 different categories, have been developed and digitized for manipulation on a microcomputer. These maps have been printed at a scale equal to the KSC Master Planning Maps, making them extremely useful for environmental assessments and facility siting decisions. Since all data are computerized, any area within the KSC boundaries, including the open water and seagrass habitats, can be defined and evaluated.

The Long-Term Monitoring staff, working with other organizations such as the U.S. Fish and Wildlife Service, the Florida Department of Natural Resources, and Brevard County have begun to define the relationships between organisms and their habitats with the ultimate goal of incorporating the information into the GIS.

One recent investigation involved the use of a compact video camera system to determine the relationship between the number and density of gopher tortoise as related to the number of burrows found in different habitat types. A backpack size portable waterproof camera system with lights, a black and white television monitor, a power supply, and a video recorder was designed and field tested. This system allowed investigators to census the 10- to 20-foot long burrows from the inside, giving accurate information on burrow occupancy and the use of burrows by other species such as the indigo snake. An important finding of the study, that was somewhat unexpected, indicated that the gopher tortoise utilized low-lying moist habitats to a greater extent than previously recorded, and that tortoises were observed living in burrows that were completely flooded during the winter portion of the study. Other ongoing long-term investigations, often involving numerous other organizations, are examining relationships between birds and fish and their use of the many unique habitats at KSC.

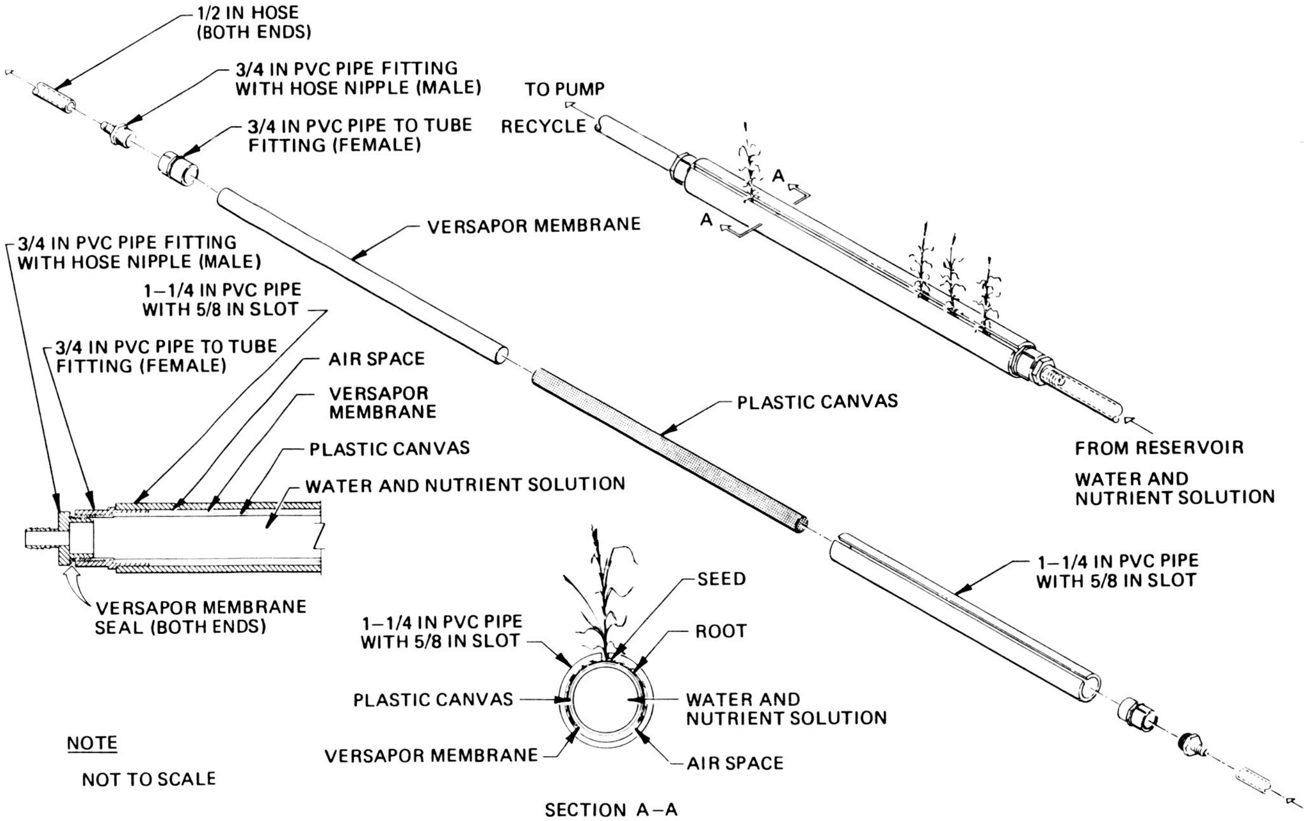
In the area of environmental impact analysis, several investigations regarding the effects of Space Shuttle launches on the environment at KSC have recently been completed. In the relatively small 20 to 30 acre area north of the launch pad, several acute effects resulting from the deposition of HCl and particulates have been documented.

Future activities will include refinement of the GIS and continuation of selected environmental and biological investigations that will assess environmental problems or develop relative baseline data.

W.M. Knott, 853-5142 MD-RES

Tubular Membrane Plant Growth System

A Tubular Membrane Plant Growth System was developed as a possible hydroponic method for growing plants in microgravity. It consists of a hollow tube of plastic screen, covered by a microporous membrane, through which an aqueous solution of plant nutrients are drawn using a positive-displacement pump. The membrane core is encased in PVC pipe with a slit down one side for placing the seed on the membrane surface. Capillary attraction allows the seed, and eventually the root, to draw nutrient solution through the membrane; while the surface tension, and a slight negative internal pressure, prevents the solution from freely flowing through the membrane, and prevents air from entering the system.



Tubular Membrane Plant Growth Unit

A Tubular Membrane Plant Growth System
With Young Grain Crop

Two crops of wheat were germinated, grown in, and harvested from this system (under one gravity) with production similar to other hydroponic methods. Beans have also been germinated and grown in this system and bean sprouts produced. The initial trial with rice has not been completed. but germination and growth appear to be normal.

Additional tests will be conducted during the next year. A prototype of the flight system will be built and tested. Flight testing will be scheduled for the future, given a successful completion of these tests.

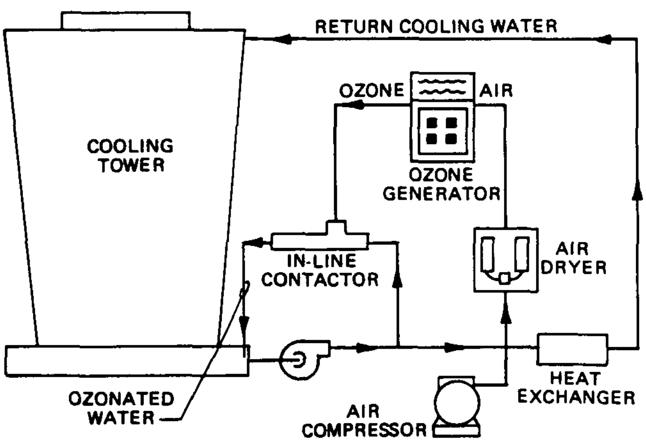
W.M. Knott, 853-5142 MD-RES

The Investigation and Application of Ozone for Cooling Water Treatment

Kennedy Space Center is currently investigating the use of ozone for cooling water treatment. Traditionally, air conditioning cooling water systems required chemical treatment for microbiological growth and corrosion inhibition. However, because of the increasing cost of this and the high maintenance involved, an alternate method of treatment was needed. Ozone, being an extremely effective oxidizer and disinfectant, was chosen for study in July 1984.

Ozone has been used extensively in European countries for water purification but has never been utilized to any great degree in the United States. Although ozone was known to be effective in combating microbiological growth, its effect on scale buildup and system corrosion in areas of high humidity and temperatures was not known. This study allowed for the application of ozone to a 600-ton cooling system with special observation of scaling and corrosion on the system. The process schematic for the study is shown in the figure "Ozone System."

During use of the ozone treatment, the automatic cooling tower blow-down was not required.



Ozone System

This increased the cycling of the tower, resulting in potential scaling tendencies of the water. During the study, cycles on this tower went from the established 4 cycles up to 15 cycles. However, visual inspections of the condenser water boxes showed no signs of scale buildup. Corrosion rates were examined weekly, using a corrosometer, and monthly, using conventional corrosion coupons. Corrosion rate data for this tower show no difference from that measured at other KSC cooling towers using chemical treatment.

Other parameters measured were also encouraging. Biological growth in the tower was reduced in the order of 10^4 population units. Also, turbidity of the water went from approximately 40 to an average of 4 turbidity units.

The cost comparison between ozone and conventional chemical treatment was greatly in favor of the ozone application. The following is a breakdown of costs involved for teatment of the cooling tower chosen:

Item	Chemical Treatment	Ozone System
I. Chemicals:		
Corrosion Inhibitor	$1,800.00	0
Microbiocide A	810.00	0
Microbiocide B	250.00	0
II. Water Consumption:		
Blowdown (1,260,000 gallons)	1,260.00	0
III. Electrical Costs:		
kWh	0	$265.00
IV. Labor		
Maintenance	1,680.00	675.00
Field monitoring	2,860.00	1,050.00
Lab monitoring	525.00	1,575.00
Chemical addition	2,860.00	0
Yearly Total	12,045.00	3,565.00
Cost of Ozone System (Equipment + installation)		16,057.00

Conclusions:

1. Ozone is effective in controlling microbiological growth in the cooling tower and recirculating water system at concentrations of 0.05 to 0.2 ppm in the cooling tower basin.

2. Ozone has satisfactorily demonstrated the ability to inhibit or prevent any scale deposition in the heat exchanger tubes or water boxes.

3. Corrosion rates determined by the coupon method were comparable to other cooling tower systems at KSC. The corrosion rates are acceptable by industry standards and were in in the range of 3 to 5 mils per year.

4. The ozone system meets or exceeds the effectiveness of chemical method it replaced, and no detrimental effects are introduced into the environment.

5. Operating and maintenance costs using the ozone treatment are about 30 percent of the costs using chemical treatment.

The ozone system is still in use with tower cycles approaching 15. A project to employ ozone in a larger cooling tower than the study tower has been identified. This project is planned for the next year as part of the continuing investigation.

R. Blackwelder, 867-0539 GO-FOD-B

Mishap Reporting and Corrective Action System

KSC has developed a prototype Mishap Reporting and Corrective Action System (MR/CAS) for mishap data collection, analysis, and reporting. This system allows mishap data to be electronically transmitted from NASA Centers to NASA Headquarters, and provides a bulletin board system for near real-time exchange of hotline information and lessons learned data among all NASA Centers.

This System runs on IBM PC-compatible microcomputers and was developed using a commercially available data base management system called dBase III, from Ashton Tate. The System presents the user with data entry screens selected from very simple menus. These screens look exactly like the Mishap Report Form used throughout NASA for recording mishap data. Standard reports are generated automatically by the System software, including quarterly reports required by NASA Headquarters. Ad hoc query and analysis capability is provided through the dBase III assist function, which helps the user perform queries through a menu selection scheme.

The MR/CAS System will be expanded in fiscal year 1987 to include other NASA Centers and NASA Headquarters.

L. W. Chamberlain, 867-4493 SF-ENG

Quality, Reliability, and Safety Data Base Development

A prototype system has been developed for analysis of quality, reliability, and safety data extracted from various heterogeneous data bases at KSC. The objective of this effort is to provide a single workstation to assist quality, reliability, and safety engineers in performing analytical studies.

Methods have been developed for collecting subsets of data bases which reside in various mainframe computers and downloading this data to a microcomputer. The data is then reformatted to the structure of commercially available data base management systems for microcomputers.

The effort to date has concentrated on data from the Problem Reporting and Corrective Action System (PRACA) and the Configuration Management Data System (CMDS). PRACA contains failure data and CMDS contains design data for all systems at KSC associated with launch processing of Space flight hardware. PRACA resides on a Honeywell DPS-8 mainframe computer in an IDS data base, while CMDS resides on an IBM 4341 mainframe computer in an ADABASE data base. The microcomputer used is an IBM PC-XT, compatible with dBase III and RBASE 5000 data base management systems.

Once the data has been restructured on the PC, analysis is performed via three available methods. RBASE 5000 can be used directly to perform ad hoc queries, CLOUT (a natural language processor that works with RBASE 5000) can be used to perform queries using English-like requests, and special analyses can be developed using an expert systems development shell called INSIGHT 2.

The prototype system is currently being expanded to include hazards data and mishap data, and the microcomputer is being upgraded to an IBM PC-AT compatible machine to enhance system performance.

L. W. Chamberlain, 867-4493 SF-ENG

Documentation Management System

The management of documentation in support of advanced space systems has been, and will continue to be, an expensive and difficult task. This is especially true when Space Station on-orbit considerations are integrated with ground processing documentation requirements. An ongoing effort has been underway to identify an automated baseline system that will be cost-effective and efficient, as well as being responsive to the individual needs of the user community and providing effective management overview. Tasks to date have been in the following areas:

1. Document number assignment/accounting
2. Hazardous/non-hazardous documentation control
3. Status of assigned documentation
4. Documentation traceability
5. Documentation utilization
6. Documentation storage and distribution
7. Revision control
8. Data base report generation

A requirements specification has been developed and implementation is planned to be accomplished in three phases as follows:

Phase I.

- System interfaces
- Data base elements
- Menu/screen identification
- Data base development

Phase II.

- Milestone definition
- Document profiles
- Mission assignments

Phase III.

- Report generation

A standard HP3000 computer information system that integrates data from various sources will be utilized. The plan is to use the basic architecture of this standard software package and develop major software subsystems that will integrate the defined data elements and provide a number of sort routines for report generation.

T. R. Mariani, 867-4861 CS-CSO-1

Bar Code Equipment Tracking and Utilization System (BETUS)

Kennedy Space Center's Launch Processing System (LPS) uses more than 2,200 items of test equipment to maintain its operation. These items of test equipment range from oscilloscopes and logic analyzers to voltmeters, crimpers, and other hand tools. An accurate and efficient method was needed to track and account for these items. The manual method that was being used showed only how many items were currently in supply, not the number of items checked out, nor the locations of the checked out equipment or the equipment utilization. Using the latest techniques of bar code technology, a system was developed to replace the manual tracking system. This state-of-the-art system utilizes bar codes to identify the test equipment, the equipment users, and the location at which the equipment is used.

This automatic system is called the Bar Code Equipment Tracking and Utilization System (BETUS). BETUS has the capability to determine equipment activity, utilization, location, user, and calibration status, in addition to status of benchstock assets. The KSC system has been operating effectively since September 1984, and has been accepted by the Shuttle Processing Contractor (SPC) as a required tool in its operation.

BETUS produces various reports, such as average turnaround in the Calibration Laboratory, listed items due for calibration, and average length of time a particular kind of item is checked. Utilization and activity reports have been among BETUS' most beneficial features. Activity information is gathered as equipment is checked in and out of a supply area. This information includes the number of times the equipment is checked out to technicians or to the Calibration Laboratory, and the total time in either category since the item was entered on the data base.

Utilization is determined by conducting a monthly survey of various locations with a portable bar code reader. The host computer prepares a list of locations to be surveyed and a list of items currently at each location. The person conducting the survey is expected to locate and survey at least half of the items at each location. During this process, the portable reader program checks for valid location and status.

In addition to providing important statistical data regarding the percentage of time items are actually in use, surveying also provides a means of finding "lost" equipment. Activity and utilization reports allow management to monitor the usage of each item of test equipment, to make more judicious decisions regarding the purchase or nonpurchase of test equipment, and to dynamically allocate test equipment resources to meet LPS maintenance demand. This is of great importance since the savings brought about by the non-purchase of just a few pieces of test equipment, such as oscilloscopes and logic analyzers, has easily paid for BETUS.

Additional savings have been realized due to elimination of ongoing manpower costs of approximately three man-years per year required for manual tracking.

The use of BETUS at KSC has cut manual test equipment check-in/out processing time by 90 percent. BETUS has been so successful in tracking test equipment and cutting processing costs that a similar bar code system, Production Tracking System (PTS), is being developed to track LPS line replaceable units through the Intermediate Level Maintenance Facility. Both BETUS and PTS are also in-work to become operational tools at Vandenberg Air Force Base, California.

The development and implementation of BETUS has provided numerous benefits over a manual or paper-driven system. The use of bar codes has eliminated the element of human error when making data entries into the BETUS data base. BETUS' data base cross-referencing capability allows the test equipment to be tracked in real time and to be more efficiently managed. Since the system has been installed, the problem of lost equipment and lack of accountability has been virtually eliminated. The attributes of BETUS could easily be applied in such other fields as logistics management, tool crib applications and asset management, and configuration control.

R. A. Perry and J. R. Rogers, 867-7690
GI-LPS-13

Rapid Prototyping--A User Friendly Approach to Space Station Concept Development

Kennedy Space Center (KSC), as a member of a tri-center team, has been formulating requirements and concept specifications for a User Support Environment (USE) to be implemented by the Space Station (SS) program. The USE is intended to support user interface to SS systems, both on the ground as well as on orbit. KSC's role has been the definition of requirements and a conceptual design for that part of the USE which supports the Integration and Test (I&T) environment.The Space Station Operations Language (SSOL) System, callable by the USE, will provide support for members of the I&T community, which includes: scientists, engineers, manufacturers of SS systems and payloads, systems integrators, and SS crews. It will be used in the development and execution of integration and test procedures, starting with the initial development of components and systems through the ground integration process to I&T on board the SS.

In the process of defining requirements, it was determined that better methods of interfacing with the user community to collect, validate, and verify requirements were mandatory. KSC's approach to develop valid requirements utilizes an interactive, rapid prototyping methodology to support the traditional requirements analysis, which is based on user interviews, documentation review, and revision.

Rapid prototyping is a method of developing software products whereby the user is allowed to view and actually try out individual components of a system during its development phase. This method allows the user to visualize future operating procedures and to make modifications early in the development effort.

The standard life-cycle approach rarely provides the user with hands-on experience of the system until it is delivered as a final product. Frequently, what appears adequate on paper becomes impractical when put into operation. What inevitably follows is a stream of requirements changes to modify the software product to reflect revised user's needs.

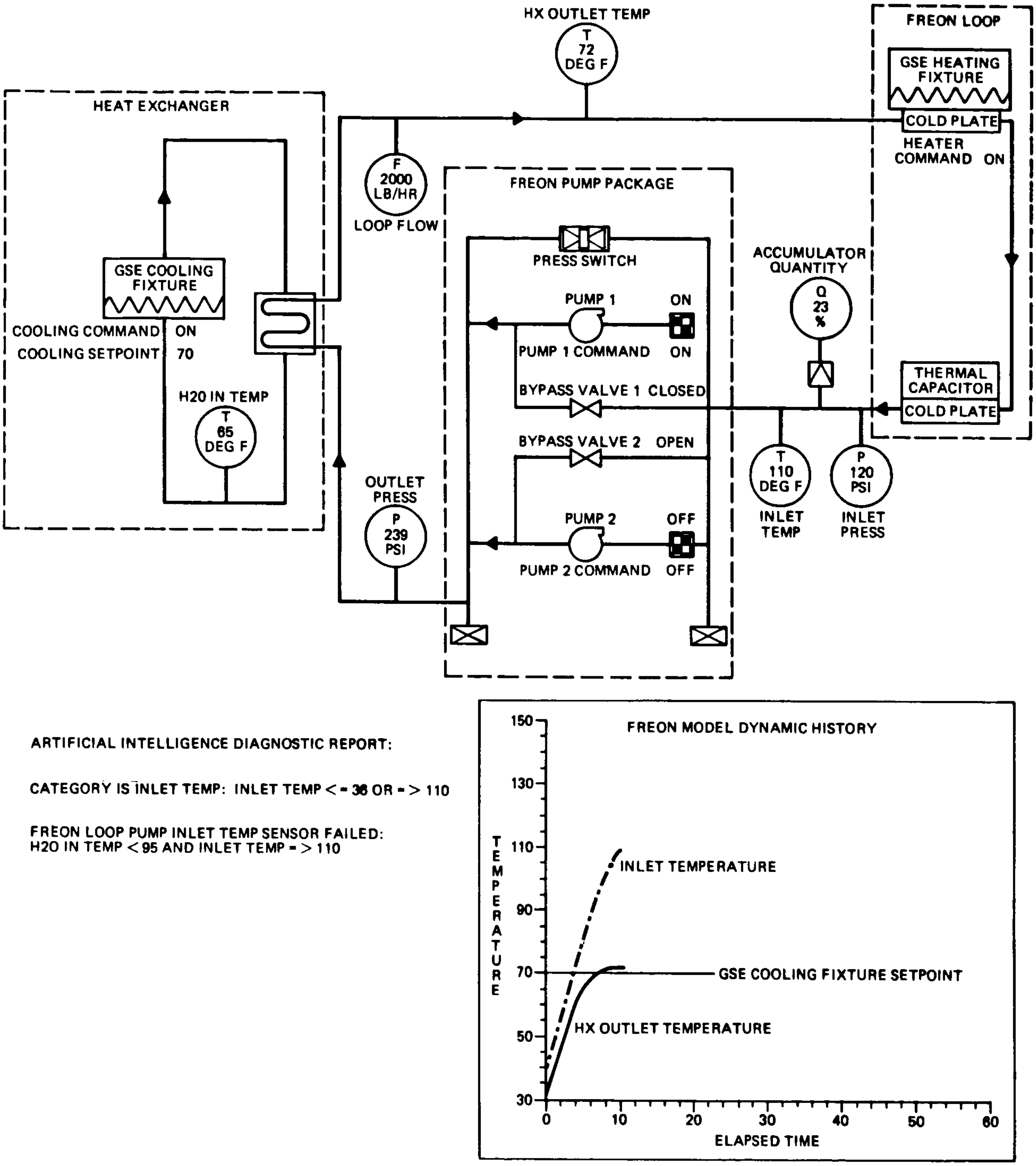
Rapid prototyping provides an alternative approach to the generation and validation of written requirements specifications, and is a method of ensuring that a software product will be responsive to the user's needs.

In brief, rapid prototyping is a structured method of breaking down a system into integral components which can be exercised independently by the user as development proceeds from requirements definition through design and implementation. As software components are developed, selected components are implemented as prototypes for user trial interactions. Revision is accomplished by incorporating the user's changes. Also, any second order impacts, such as revisions to the user's mode of operation, can be evaluated and responded to during this process.

In order to support the process of prototyping user SSOL requirements, an interactive demonstration facility was developed and equipped with terminals, graphic display units, large screen projectors, a sound system, and a VAX 11/780 computer. This capability provides an environment for direct interaction between users and developers. The figure "SSOL Demonstration Area, EDL Room 104", shows some of the equipment in the demonstration facility.

SSOL Demonstration Area, EDL Room 104

Prototypes are used to portray various features and characteristics of the SSOL software concept.



Space Station Active Thermal Control Loop
Simulation Viewport Into the Model

An important benefit of the rapid prototyping approach is the capability of quickly implementing several alternative methods of performing a system operation. As an example, an SSOL control function is implemented for two operating environments: a text based environment, where the user interacts with the system through standard character based display terminals, and a graphically oriented environment, where the system is represented by graphic symbols (icons). This allows the user to express preferences and concerns over an implementation concept, and usually results in greater user feedback than a single implementation can provide.

As requirements evolve, they are incorporated into the prototype for user interaction. Users are encouraged to comment on the desirability of an approach, as well as the validity of the underlying concept, and to suggest improvements that should be made to the demonstrated prototype. User comments are entered into a database and evaluated. When appropriate, the comments are incorporated into the next prototype revision.

The initial prototypes were demonstrations of proposed concepts. These demonstrations were intended to provide the user with a view of the functions available in the SSOL and how the user would interact with them. These demonstrations were valuable in identifying broad user requirements and concerns. This user feedback also aided in assessing the validity and relative importance of various SSOL concepts. An analysis of the user response to the demonstration identified several major areas of interest to the I&T community: test article definition, man-machine interfaces, automatic display generation, SSOL compiler/interpreter, artificial intelligence, and voice technology. These areas of interest were used as the basis for developing the next phase, which was an interactive prototype system.

In developing the interactive prototype, an analysis was performed to identify the set of functions and capabilities that would substantially represent the areas of interest. Following the analysis, the software modules were developed and integrated into a system that demonstrates the capabilities of the SSOL system concept. The figure, "Space Station Active Thermal Control Freon Loop Simulation Viewport into the Model," represents a typical display screen in which a test procedure is controlled directly from the graphical display using a light pen or other graphic input device. This figure also shows a report from an artificial intelligence/expert system module, providing a continuous check on the health of the test system. In addition to implementing the above areas of interest, the interactive prototype demonstrates a number of technology concepts that will improve the efficiency of the I&T life-cycle. Notably, these concepts are test system independence, integration of commercial software packages, software reusability, and portability of graphic displays.

Throughout this project, a great deal was learned about the benefits and cost of utilizing a rapid prototyping approach. Among the benefits, the most important is an improved user/designer relationship. The communication between the user and the designer is much more open and less adversarial than in the traditional design process. This allows the designer to become knowledgeable about the user's requirements early in the design process, reducing or eliminating revisions when the system is delivered. Other benefits of rapid prototyping include: a test bed to prove the feasibility of a concept, an 'idea factory', and a medium of information dissemination and management communication. However, rapid prototyping is not without its costs. Effective use of this approach in early design requires the filtering and weighing of a voluminous and complete range of user comments and criticisms. The prototype system must be flexible and expandable, with dedicated personnel to support and maintain the prototype. Finally, it may be difficult to conclude the prototype activity and move on to development of the 'production' system.

To summarize, rapid prototyping provides a more realistic validation of user requirements than the traditional review of specifications and manuals. Prototypes make it possible to quickly generate alternative systems and approaches, and provide quick response to user concerns.

W. R. Sloan, 867-4430 DL-DED-21

FY86 Digital Voice Record and Playback Project Status

A survey was made to determine if magnetic and optical recording equipment were available for recording the 512 voice channels in the KSC Digital Operational Intercommunication System (OIS-D).

According to the survey, the "read-write" optical recorders have the best performance characteristics but will not be available until CY 87.

Voice processing techniques which reduce data storage requirements were investigated; however, the electronic components needed for implementing these techniques are too complex and not fast enough for processing voice data in real time. Semiconductor manufacturers are currently developing components suitable for real time speech processing.

Since suitable recording and voice processing equipment will not be available until FY 87, no funding was needed in FY 86. Funding of $75,000 in FY 87 and $50,000 in FY 88 will be needed to purchase recording and signal processing equipment for the development effort.

FY 87 Digital Voice Record & Playback Development Plans:

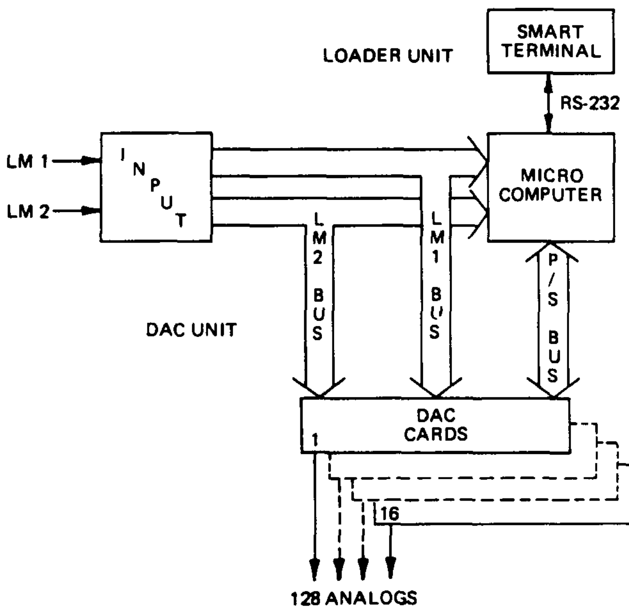
1. Design (in-house) and fabricate prototype voice processing equipment to record only "active" voice channels in the OIS-D. Since very few of the 512 voice channels are active at the same time, this technique will significantly reduce storage requirements.
2. Purchase recording equipment and interface to prototype voice processing equipment.
3. Purchase computer hardware (PC type) for initialization and loading of prototype equipment and for analysis during system testing.

G. D. Matthews, 867-4684 GI-INS-3

Dump DAC System

A state-of-the-art electronic system, which accommodates the recording of telemetry data on strip chart recorders, was recently introduced at the Kennedy Space Center. The system is installed in the Telemetry Station at Hangar AE. The system provides 128 independent analog channels, thereby accommodating 128 distinct telemetry measurements or signals. System initialization is fully automatic, or, if desired, can be placed under user control at any time. The latter is possible by employing a smart terminal for control purposes.

The system, shown schematically in the figure "Dump DAC System," is comprised of two 10-1/4 inch high chassis units which are mounted in a 19-inch wide rack. The Loader Unit is a smart terminal. It is micro-computer based and contains three peripherals; a 9-inch CRT, a keyboard, and a floppy disk drive. This unit serves as the control for the system and provides user intervention through its keyboard interface by sending commands to the DAC Unit to activate its programmed functions. These commands are eight bit coded characters, and are transmitted to the DAC Unit via an RS-232 interface. Presently there are three command types, which are designated as: parameter, program, and status. The number of commands within each type is 1, 9, and 3, respectively. Status information sent from the DAC Unit is displayed on the CRT on an eight-channel basis defined as a group. This feature allows a user to view the program aspects of every channel.

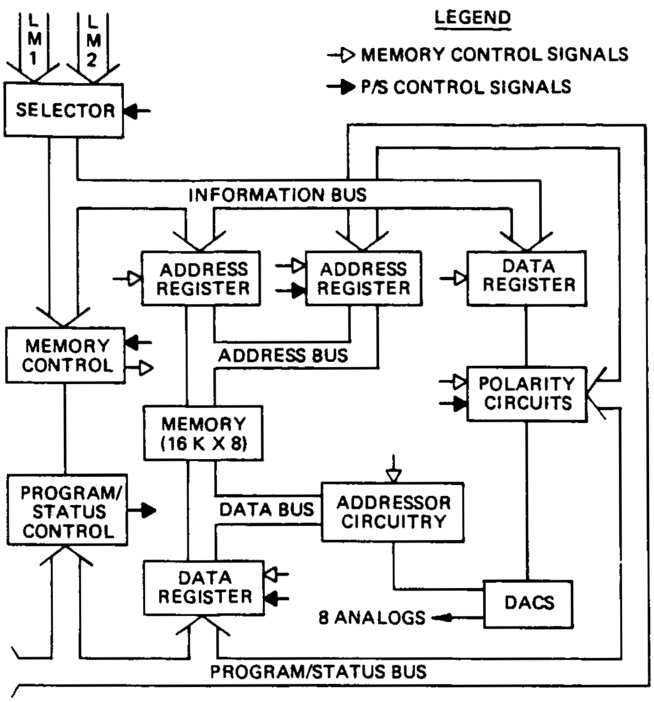


Dump DAC System

The DAC Unit is comprised of 18 printed circuit boards. The input board terminates and level shifts the two inputs and distributes them on a thru-put basis to the other 17 boards. Both inputs are link multiplexer outputs which contain telemetry and other data which have been digitized and identified into 22 binary bits, which are called a word. The word structure is 8 bits for data and 14 bits for address. These bits are provided in parallel with a maximum word rate of 250 kilowords per second. These 22 bits, along with three timing signals, are bused to the other boards using a rear chassis back plane.

The micro-computer board employs a Motorola 6809 micro-processor. Its input/output (I/O) structure is configured to accommodate 25 signals, 16 of which are bilateral. These signals are bused to the 16 DAC boards and are used to program and obtain status from these boards. Additional I/O interfaces to both the link mux buses allows, under interrupt control, the inputting of selected link mux data. The CPU is programmed to dispatch the 13 functions related to the previously mentioned commands. It is also programmed to accommodate an automatic function. This function allows a channel for which a source has been assigned to switch between valid source data and a prescribed calibration signal at loss of data. This is accomplished by monitoring the source decommutator lock status over the appropriate link mux bus input.

The 16 DAC boards are all identical. They are set up by address through a four bit mini-digiswitch. Each board is referred to as a group and provides eight analog output signals. The output signals are bipolar, having a ±5-volt swing, and interface directly to strip chart recorders. The figure, "DAC Block Diagram," shows the DAC board logic. The nucleus of the logic is a 16 K x 8 non-volatile static RAM chip. The RAM's eight data bits are related (program-wise) to the eight analog channels. This memory is programmed, then used as an instruction look-up device to route incoming data to the appropriate DAC channel. Each board is programmed to accept data from only one of the link mux inputs.



DAC Block Diagram

For channel programming, 14 address bits, along with the appropriate data bit(s) and polarity bit (s) (if inverted data is desired), are sent from the CPU via the program/status bus and stored in the appropriate registers. In the case of channel status, only the address bits are sent. Upon completion of transmission, the program/status control orders a program or status cycle of the Memory Control. At the next available cycle (no data), the requested function is executed. For both functions, and at the proper time, the memory is addressed with the stored address. For a program function, a write operation is performed, which places the contents of the Data Register into the memory. For a status function, a read operation is performed, which places the contents of memory into the Data Register. For status, the CPU then inputs from the board: the link mux selected, memory data, and polarity. The CPU, through further status inputs, can determine when a requested Program (P) or Status (S) cycle has been completed.

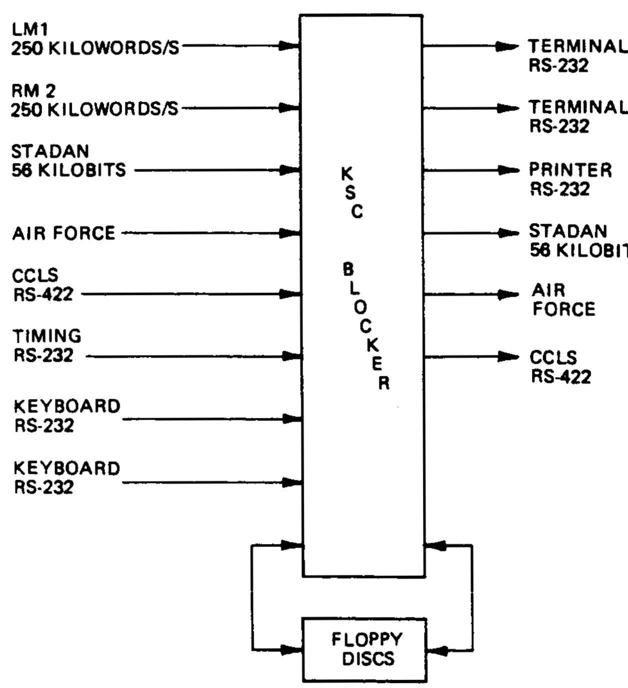
The actual routing of incoming data to the DAC channels occurs at data cycle time. This is accomplished in the following manner: Upon receipt of a data-available pulse on the Information Bus, the Memory Control stores the incoming 14 address bits in the Address Register, and the 8 data bits in the Data Register. Upon completion, a memory read, using the stored address, is performed. The data contents of the memory location are then available to the DAC Addresser Circuits over the Data Bus. Within these circuits, the data bits are serially strobed, two bits at a time , and the proper data is stored in corresponding DAC channel whenever a data "one" bit is encountered. Serial addressing was required because only two quad DAC chips were employed. The serial strobe operates at four times the rate of the information bus. This circuitry was designed to operate at a serial speed of up to 2 megahertz.

The system was employed in the checkout and launch of the Delta 180 vehicle.

A. J. Ordonez, 853-2769 CV-DSD-1A

KSC Blocker System

Often, the need for passing on of telemetry and tracking data, along with other raw and processed information on Launch Vehicles and payloads is met with the incorporation of additional facilities. At Kennedy Space Center (KSC) a need existed on the Shuttle/Centaur project to send several items of information to a number of locations. This need was met through the KSC Blocker System. The KSC Blocker is a computer-based system which receives inputs from available data systems and sends information to various required locations.

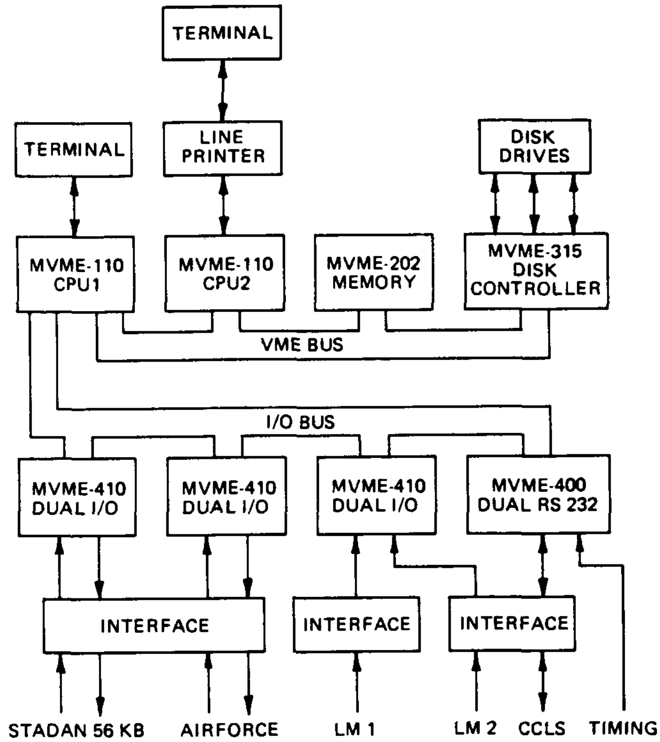


KSC Blocker Inputs/Outputs

The System inputs and outputs are shown in the figure, "KSC Blocker Inputs/Outputs." The two Link Multiplexer inputs are provided from the Telemetry Ground Station located at Cape Canaveral Air Force Station (CCAFS) Hangar AE. Each input provides a word of information comprised of 25 parallel digital bits and operates at 250-kiloword per second rate. Through these inputs, selected blocks of data are extracted and input to the system. The STDN input comes from the Goddard Space Flight Center in Maryland. Goddard is the Control Center for the NASA Space Tracking and Data Acquisition Network, which is world wide with many stations. The input labeled "Air Force" is a PCM type input supplied locally. An RS-422 input is available from the Computer Control Launch Set (CCLS) located at the CCAFS Complex 36. Two additional inputs are reserved for RS-232 asynchronous transmissions. Floppy discs are employed primarily for program loading and the recording of pertinent data. Of the five outputs, two are RS-232 types presently connected to a CRT and a line printer. One output provides data to the Goddard NASA Communications (NASCOM) Network at the required 56-kilobit per second rate. A PCM wave train is available to the Air Force, and data is sent to the Complex 36 CCLS via RS-422.

The system was designed on a modular basis. The acceptance and wide use of the VME microprocessor bus at KSC influenced the selection of this bus for the card cage and cards. A split chassis was employed using ten input/output (I/O) slots and eight VME slots. The system is comprised of eight standard Motorola VME modules, four of which are I/O types and four are VME types. Four in-house designs were required to accommodate the I/O interfaces. These designs were incorporated on three cards which are accommodated in two I/O slots and one VME slot. The chassis is mounted in a standard 19-inch rack.

The figure, "KSC Blocker Block Diagram," shows the system operation. All inputs on the I/O bus are interrupt assigned. Of the two system computers, one handles all the I/O Bus activity. This computer stores input data in table form in the global memory, on a double buffered basis. The same computer takes data from output tables stored in global memory and channels it to the appropriate output via the I/O Bus. The second computer is reserved for all data processing required, output (I/O Bus) table formatting, and the remaining peripheral control. Unit control can be exercised through the terminal connected to this computer.



KSC Blocker Block Diagram

The KSC Blocker has three categories of firmware: utilities, diagnostics, and applications. Both computers employ programs of the first two types. The third type is confined to the second computer and is customized to system requirements. This item is a desired system feature in that it provides flexibility to accommodate data format changes within the output interfaces.

The unit is presently installed at the CCAFS Hangar AE Telemetry Station. Checkout of the unit was completed with all inputs but one (Air Force). Data was successfully routed, nearly simultaneously, to three separate locations in Maryland and California.

A. J. Ordonez, 853-2769 CV-DSD—1A

PROJECT REFERENCE DATA

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Hazardous Gas Detection System Sample Line Transport Time Study	P. J. Welch 867-4614 DE-MAO-2	
Hazardous Gas Detection System	J. D. Collins, W. R. Helms 867-4438 DL-NED-32	Naval Research Laboratory (J. Wyatt)
Feasibility of a Gas Dilution System for Analysis of Hydrogen in Helium Atmosphere Using an Ion-Pumped Mass Spectrometer	J. D. Collins, W. R. Helms 867-4438 DL-NED-32	Monmouth College (Dr. D. V. Naik)
Personal Dosimetry for Toxic Rocket Propellants	J. C. Travis, W. R. Helms 867-4438 DL-NED-32	Naval Research Laboratory (S. Rose)
Comparative Evaluation of Toxic Vapor Sensors	J. C. Travis, W. R. Helms 867-4438 DL-NED-32	Naval Research Laboratory (S. Rose, J. Wyatt)
Ultra-Violet Flame Detector Evaluation	R. Howard 867-3366 DL-DED-31	Sci-TronX, Inc. (S. Cusumano)
Pattern Recognition Methods for Toxic Vapor Detection Using Microsensors	J. D. Collins, W. R. Helms 867-4438 DL-NED-32	Naval Research Laboratory (S. Rose, J. Wyatt)
Evaluation of Materials for MMH Gas Sampling Systems	J. C. Travis, W. R. Helms 867-4438 DL-NED-32	Naval Research Laboratory (S. Rose)
Remote Sensing of Hydrazine	M. M. Scott, Jr., P. M. Rogers 867-3086 DL-DED-32	Jet Propulsion Laboratory
Rocket Engine Leak Detection Mass Spectrometer (RELDMS)	J. D. Collins, W. R. Helms 867-4438 DL-NED-32	Perkin-Elmer Applied Science Division (M. Koslin, C. Sawin)
Comparative Evaluation of Optical Particle Counters	J. C. Travis, W. R. Helms 867-4438 DL-NED-32	University of Arkansas (A. J. Adams)
Shuttle Tile Moisture Measurement Sensor Development	R. Howard 867-3366 DL-DED-31	University of Florida (Dr. E. Farber)

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Contaminant Gas Monitor (CGM) for Space Space Station	J. D. Collins, W. R. Helms 867-4438 DL-NED-32	Perkin-Elmer Applied Science Division (M. Rotherman, N. Carl, C. Sawin)
Flow Metering Using Vortex-Shedding Instrumentation	R. Howard 867-3366 DL-DED-31	University of Florida (Dr. E. Farber)
Liquid Characteristics Under Micro-Gravity Conditions	R. Howard 867-3366 DL-DED-31	University of Florida (Dr. E. Farber)
Gamma Ray Densitometer Liquid Level Instrumentation	R. Howard 867-3366 DL-DED-31	University of Florida (Dr. E. Farber)
Distillation of High Purity Oxygen	K. Buehler 867-3313 DE-MED-43	
Nitrogen Tetroxide (N_2O_4) Thermodynamic Properties Table	F. S. Howard 867-3201 DD-MED-4	National Bureau of Standards (R. D. McCarty, H. U. Steurer, C. M. Daily)
Cryogenic Bayonet Inflatable Seal Quick Disconnect	K. Buehler 867-3313 DE-MED-43	
Simulation of Steady, Liquid-Vapor Flow Under Zero Gravity By Using Immiscible, Neutrally Buoyant Droplets in Water	F. N. Lin 867-4156 DD-MED-1	University of Illinois
Metals Ignition in High Pressure Oxygen	C. J. Bryan 867-4614 DE-MAO-2	
Permeability of Polymers to Organic Liquids and Condensable Gases	C. J. Bryan 867-4614 DE-MAO-2	Tuskegee University
Evaluation of Sealants for Dissimilar Metal Corrosion Prevention	C. V. Moyers 867-4614 DE-MAO-2	
Computer Tomography	J. W. Larson 867-3423/2997 SI-PEI-3A	EG&G Florida, Inc. (H. P. Engel)
Conductive Organic Polymers as Corrosion Control Coatings	C. J. Bryan 867-4614 DE-MAO-2	University of Pennsylvania Los Alamos National Laboratory
Study of Coatings That Require Minimal Surface Preparation for Potential Application to LC-39 Structures	P. J. Welch 867-4614 DE-MAO-2	

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Applicability of Acoustic Emission Monitoring to Pressure Vessel Testing	P. J. Welch 867-4614 DE-MAO-2	
Study of Thermal Sprayed Metallic Coatings for Potential Application on LC-39 Structures	P. J. Welch 867-4614 DE-MAO-2	
Protective Coating Systems for the STS Launch Environment	L. G. MacDowell 867-4614 DE-MAO-2	
Robotics Applications for Remote Umbilicals	L. Shawaga 867-3402/2997 DL-NED-22	
Pulse C-Band Radar Detection of Clear Air Phenomenon	C. L. Lennon 867-4068 GI-INS-1	
Lightning Induced Effects on Power and Communication/Telephone Distribution Lines	W. Jafferis 867-0605 GO-MGT	University of Florida (A. Tseng, E. Thompson)
Electromagnetic Versus Electrostatic Field Lightning-Detection Interferometer	W. Jafferis 867-0605 GO-MGT	Eastern Space and Missile Center
Lightning Protection Adequacy--A Verification Technique	W. Jafferis 867-0605 GO-MGT	Air Force Wright Aeronautical Laboratories Center for Nuclear Studies at Grenoble, France Eastern Space and Missile Center Federal Aviation Administration Office of Aerospace Research, France Aerospace Research, France Naval Research Laboratory State University of New York University of Arizona University of Florida
Clear Air-Wind Sensing Doppler Radar	R. P. Wesenberg 867-4438 DL-NED-32	Air Force Geophysics Laboratory University of Wisconsin, Stout
Thunderstorm Currents	R. P. Wesenberg 867-4438 DL-NED-32	University of Arizona (Dr. P. Krider)
Thunderstorm Weather Forecasting Expert System	A. E. Beller, P. McVeagh 867-3224 NE-AIN	Air Force Arthur D. Little, Inc.

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Project KATE--Knowledge-Based Automatic Test Equipment	M. Cornell, E. E. New NE-AIN	
Generic Model-Based Diagnostic System	R. Hurt 867-3367 DL-DED-31 L. Rostosky 867-4430 DL-DED-22	MITRE Corporation
Expert Planning and Scheduling Systems	J. M. Ragusa 867-7882 CS-SED	MITRE Corporation (Dr. J. Katz)
Remote Maintenance Monitoring System	J. R. Rogers 867-7690 GI-LPS-13A L. G. Simpkins 867-3926 GI-LPS-13 R. C. Owens 867-7690 GI-LPS-13A	
Controlled Animal Nutrients Delivery System (CANDS)	W. M. Knott 853-5142 MD-RES	The Bionetics Corporation (L. Kalla)
Controlled Ecological Life Support System (CELSS) Breadboard Project	W. M. Knott R. P. Prince 853-5142 MD-RES	
Long-Term Environmental Monitoring and Research Program	W. M. Knott 853-5142 MD-RES	The Bionetics Corporation (Dr. R. Hinkle)
Tubular Membrane Plant Growth System	W. M. Knott 853-5142 MD-RES	The Bionetics Corporation (T. W. Dreschel)
The Investigation and Application of Ozone for Cooling Water Treatment	R. Blackwelder 867-0539 GO-FOD-B	EG&G Florida, Inc. (E. S. Feeney, L. V. Baldwin)
Mishap Reporting and Corrective Action System	L. W. Chamberlain 867-4493 SF-ENG	
Quality, Reliability, and Safety Data Base Development	L. W. Chamberlain 867-4493 SF-ENG	
Documentation Management System	T. R. Mariani 867-4861 CS-CSO-1	

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Bar Code Equipment Tracking and Utilization System (BETUS)	R. A. Perry J. R. Rogers 867-7690 GI-LPS-13	
Rapid Prototyping--A User Friendly Approach to Space Station Concept Development	867-4430 DL-DED-21	
FY 86 Digital Voice Record and Playback Project Status	G. D. Matthews 867-4684 GI-INS-3	
Dump DAC System	A. J. Ordonez 853-2769 CV-DSD-1A	
KSC Blocker System	A. J. Ordonez 853-2769 CV-DSD-1A	

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15. Abstract

As the NASA Center responsible for assembly, checkout, servicing, launch, recovery, and operational support of Space Transportation System elements and payloads, Kennedy Space Center is placing increasing emphasis on the Center's research and technology program. In addition to strengthening those areas of engineering and operations technology that contribute to safer, more efficient, and more economical execution of our current mission, we are developing the technological tools needed to execute the Center's mission relative to future programs. The Engineering Development Directorate encompasses most of the laboratories and other Center resources that are key elements of research and technology program implementation, and is responsible for implementation of the majority of the projects in this Kennedy Space Center 1986 Annual Report.

For further technical information about the projects, contact David A. Springer, Project Engineering Office, DF-PEO, (305) 867-3035. James M. Spears, Chief, Technology Projects Office, PT-TPO, (305) 867-7705, is responsible for publication of this report and should be contacted for any desired information regarding the Center-wide research and technology program.

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