# INSTRUMENTAL STUDY FOR AN ENVIRONMENTAL SPACE SIMULATION FACILITY

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## Introduction

As space simulation facilities become larger and more complex to meet the rapidly expanding requirements of today's space age, the associated instrumentation becomes increasingly complicated. Frequently, the testing objectives change, and a flexible data and control system is mandatory to reduce excessive delays and high costs of instrumentation modifications or replacements.

This article presents the basic conclusions of a study which was undertaken to determine a minimum basic instrumentation and control system required for the operation of an environmental space simulation chamber and the instrumentation necessary for monitoring the environmental effects on the test vehicles. The space simulation facility criteria include:

1. Capability of storing rocket propellants under simulated orbital conditions and the effects upon ignition;
2. Ignition of the rockets when subjected to the combined simulated environments of pressure and temperature;
3. Maintenance of a reduced pressure during motor firing periods; and
4. Man-rated to enable repairs to be performed on the test vehicle and studies conducted related to the degree of performance of personnel when subjected to the simulated environmental conditions.

It has been assumed that the chamber conforms to the following general description (See Figure 1):

1. Chamber top-loading, right circular cylinder with domed ends.
2. Solar simulation on one side of the vehicle using carbon arc lamps for radiation source.
3. Earth radiation and albedo simulation using infra-red lamps with reflectors completely around the vehicle.
4. Cold of outer space simulated with cryogenic cold walls -319° F (liquid nitrogen).
5. Vacuum system capable of simulated 300-mile altitude with adequate secondary system to evacuate the products of combustion of the propulsion rocket ignition and of simulated ascent pressure profile.
6. Interlocks for enabling personnel access to the test vehicle while under test.
7. Adequate repressurization capabilities to assure personnel safety.

Because of the extensive scope of such a study, only the basic subsystems will be considered here. The instrumentation and control of each subsystem will be presented in block diagram form with a brief aescription of each principle constituent, its function, and the reason for its selection. The material in this paper does not include any information relative to the instrumentation required to monitor the operational parameters of the test vehicle. Additional information may be obtained on request.

The instrumentation and control systems are divided into eight major subsystems:

1. Master programming and control system,
2. Vacuum pumping-system,
3. Diffuser system,
4. Cryogenic system,
5. Interlock and repressurization system,
6. Solar and heat flux simulation system,
7. Vehicle environmental parameter monitoring system, and
8. Preventative maintenance survey system.

The complexity of these subsystems indicates an expensive initial investment, but the flexibility and versatility of this facility would result in considerable cost savings in test preparation and conduct. For example: an average of ten dollars per hour, including overhead and fringe benefits is typical for testing personnel. A teat program in operation forty percent of the time, or 142 days per year, would cost $11,360 (plus premium pay for weekend coverage) for each testing person. By the system proposed herein it should be possible to reduce the operational personnel from approximately 87 men to 36, thus saving $612,000 annually. Further, use of the Preventative Maintenance program would result in a corresponding reduction of maintenance personnel and fewer, if any, equipment failures.

## Master Programming and Control System

The principle objective of the master programming and control system is to provide the controls and stimuli for the operation of all subsystems and to insure that all operations are executed in the correct sequence and at the required time. The system (Figure 2) would consist of:

1. Master clock,
2. Program tape readers,
3. Serial code generators,
4. Time and orbit displays, and
5. Programming relay matrix.

All operations would be controlled by the master clock. A series of DC shift codes would be provided for all test information for accurate chronographic control. This code would appear on all analog strip charts, magnetic tapes and printed data. This system would create a pattern of circuit closures at pre-set times during the testing program. The unit would correlate the operation of all the subsystems.

The system has the capability of obtaining instructions from and/or combinations of the following modes of operations:

1. Manual override control of subsystem operations,
2. Digital timing clock and tape functions, and
3. Safety override control system.

Test real time would be continually available with visual output for the convenience of testing personnel. In addition, count down signals prior to important events would be shown, and if desired, given audibly.

Deviations from operational norms would be continuously monitored and vigilance maintained for those situations which might create unsafe operational conditions. Then appropriate counteractions would be automatically executed. Of particular concern would be the control of the repressurization system for manned activities and the prevention of erroneous operation.

Vacuum Pumping Control and Instrumental System

The vacuum pumping system (Figure 3) would be used to perform three primary functions:

1. To establish low pressure environment for the testing of test vehicles;
2. To maintain adequate vacuum during firing of small altitude control jets or rockets; and
3. To provide rapid recovery of low pressure conditions subsequent to firing of larger rocket motors.

The control system would activate the various pumping systems: roughing, ejector, diffusion, and cryogenic. Each must be turned on to standby prior to actual operation to permit proper warm up. Adequate pressure, temperature and liquid monitoring capabilities would have to be installed so that all pumping groups would always be within correct operational parameters.

Commands from the Master Programmer would normally initiate and terminate operations. Specific instrumentation to be obtained in addition to actual pressure measurements would include temperatures of pump oil, traps and baffles, oil levels, valve operation, and so on.

Calibrated leaks would be periodically used to determine the actual pumping rates and ensure maintenance of acceptable pumping speeds. Special controls would provide absorbsion pumping during and immediately after the firing of the altitude rockets.

Diffuser Instrumentation and Control System

The diffuser instrumentation and control system includes the burst diaphragm, liquid nitrogen flow regulation, temperatures of shroud for cooling propulsion gases, and the operation of the steam ejectors (Figure 4). The exhaust gases would be monitored by temperature sensors so that the flow of liquid nitrogen is sufficient to maintain proper cooling of the propulsion gases.

The accurate timing of the burst diaphragm, which is pyrotechnically controlled, is critical in order that the rocket engine be subjected to a minimum pressure at ignition and that all burning bi-products would be immediately exhausted.

Cryogenic System Control and Instrumentation Requirements

Included in the cryogenic system are the controls of the liquid nitrogen heat sink (-100° K), the 20° K cryopump, and liquid nitrogen storage and transfer system. In addition to temperatures, flow rates and pressures must be monitored. The accurate monitoring of cryogenic fluids is difficult because existing flow meters have been somewhat nonlinear.

The cryogenic system (Figure 5) would require adequate visual displays to provide operational information for necessary maintenance. All pumping systems would have sufficient redundancy to ensure adequate reliability during long periods of testing. Instrumentation should maintain a constant vigilance to insure timely warning and, when desirable, switch to standby systems.

Interlock and Repressurization System

Because of the obvious necessity for reliable controls for the repressurization and interlock operation, there should be dual controls for repressurization: one would provide stimuli for the burst diaphragm and the other stimuli for the back-up high pressure valves. Two "dive" systems would be included: a dive at *any* particular rate and an emergency rapid dive.

The instrumentation that monitors the pressure in the interlocks would also keep the doors sealed unless acceptable pressure were present. Manual overrides and completely fail safe instrumentation and control would be mandatory insuring both accuracy when diving be required and safety from accidental operation. This would include an array of gauges to monitor the pressure from 14.7 psi to $10^{-9}$ torr such as thermocouple, Perani, Alphatron, ion, Baird-Albert and Redhead gauges.

The interlock doors would be held in place entirely by the pressure differential. Spring-loaded pins would permit the chamber doors to be moved in emergency Conditions.

Solar and Heat Flux Simulation Control and Instrumentation

The control of the solar simulator (carbon arc lamps) would consist of the regulation of the aperature opening thereby changing the intensity of the simulated solar radiation. The infra-red heat lamps would be controlled by either regulating the number of lamps turned on or the power applied. (The power regulation is less desirable because the radiation wave length changes with voltage changes.) Radiometers would provide information of the intensity and, by using filters, the approximate spectrum density for both the solar simulation and the earth radiation and albedo simulation. In addition to the radiometers, special calorimeters (Figures 6 and 7) would be used to determine the incident heat that is being programmed. Coincident with the monitoring of the radiant energy, continual monitoring of the power to both simulation sources would be required to determine the possibility of subnormal performance.

Vehicle Environmental Parameter Instrumentation System

The test vehicle instrumentation and control system is composed of the necessary programmed stimuli voltages for the control of specific functions such as target controls for horizon or star sensors and planet simulation. Because of the required reliability and longevity of tests, hard-line instrumentation is recommended instead of multiplex or R.F. methods. For temperature measurements standard thermocouple methods would be used. The reference junction would be placed inside the chamber thereby permitting all copper leads to be used through the chamber walls to the analog input section and to the digital data recording section. The digital section converts analog data into digital form, and it is then displayed visually, stored on punched cards, and recorded numerically for immediate comparison. Suitable maximum and minimum temperature limits would be established prior to testing and those data which are out of specification would be so indicated.

The thermocouples are best mounted on small copper plates by either welding or brazing. The plate can then be attached to the required item using a standard heat transfer epoxy or adhesive.

In addition to the temperature, the pressures within and adjacent to the test sample must be monitored. The block diagram includes sufficient analog recorders to provide monitoring capabilities within the chamber.

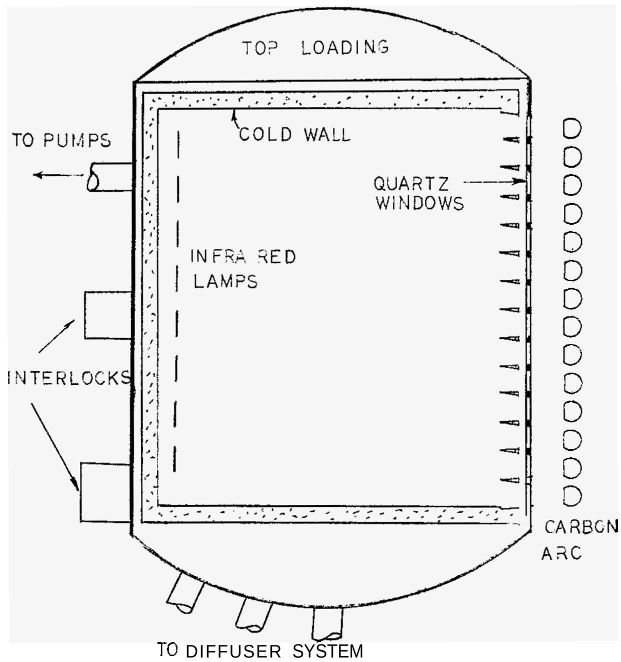


*FIG 1 CHAMBER DESCRIPTION*

## Preventative Maintenance Survey System

Substantial assistance in the assurance of a reliable test facility operation can be obtained through the use of an automatic data gathering system. A typical system (Figure 8) would consist of a high speed recorder and associated electronic equipment, a signal conditioning unit, an alarm panel, and the necessary transducers, wiring and accesory equipment. For example: one data acquisition unit would include an FM tape playback, a digitizer and compressor, and a multiple-channel oscillographic recorder which could transform the magnetic tape records to a suitable form for analysis by maintenance technicians. Each separate equipment system or subsystem would require a detailed study to establish the total number and type of sensors and the range of maintenance parameters to be recorded.

This system would be capable of monitoring many parameters normally read on experimental test equipment and frequently manually reduced. The data gathered would provide early warning of incipient equipment failures and would also improve operational economics by reducing arbitrary overhaul of equipment as part of a general service program as well as the reduction of operational failures with the associated costly delays.

It would be highly desirable to augment this system with the capability of determining the accuracy of the operation of the various instrumentation subsystems. This function could be accomplished by the injection of given signals into the various subsystems periodically which would check the validity of test measurements being taken.

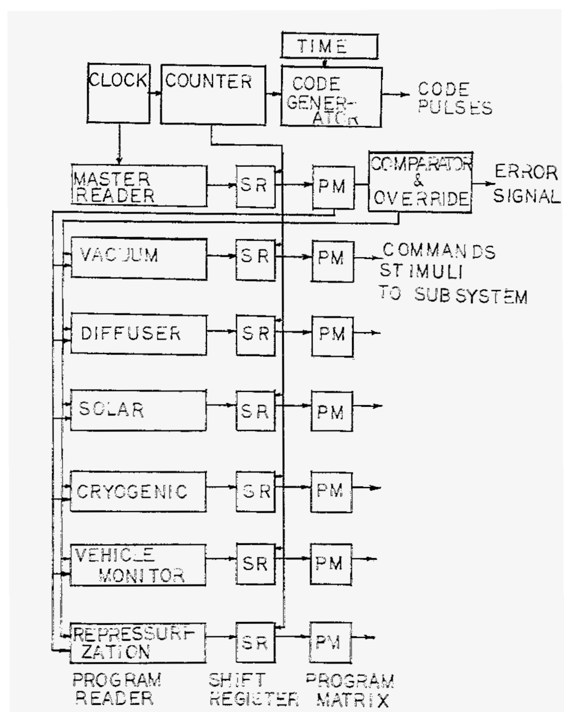


*FIG 2 MASTER PROGRAMMING AND CONTROL SYSTEM*

## Conclusion

The methods of instrumentation and control outlined in this article are not new; similar approaches have been used in the checkout of missiles and at launch sites. In the opinion of the author the need for such a system in any major environmental testing facility is germain to its effectiveness and is more than justified when considered in terms of the time and monies saved as well as the increased accuracy and reliability of the testing results. The application of these principles for the operation of a space simulator could easily be applied to any large testing facility such as a vibration or acoustics testing chamber, accelerometer or launch motion simulator.

## Acknowledgments

Appreciation is due H. W. Bruce and J. J. Kelaher, both of Lockheed Missile ana Space Company, for their assistance in the gathering of information for this survey.

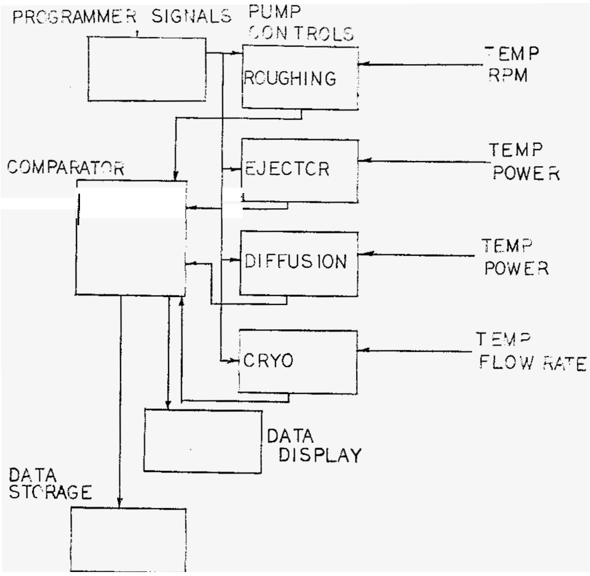


*FIG 3 VACUUM PUMPING SYSTEM INSTRUMENTATICN AND CONTROLS*

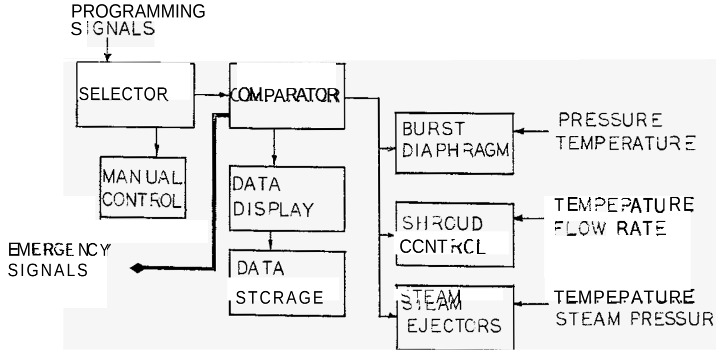


*FIG 4 DIFFUSER INSTUMENTATIONAND CONTROLS*

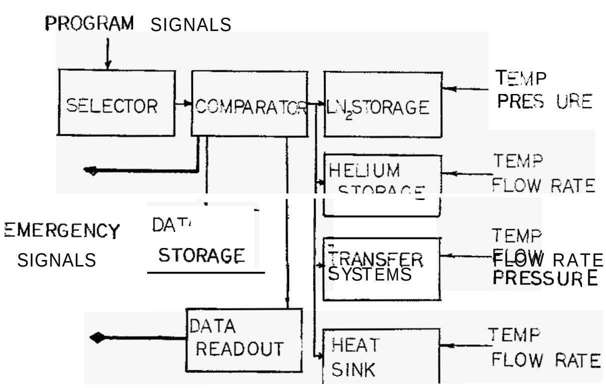


*FIG 5 CRYOGENIC CONTROL AND INSTRUMENTATION*

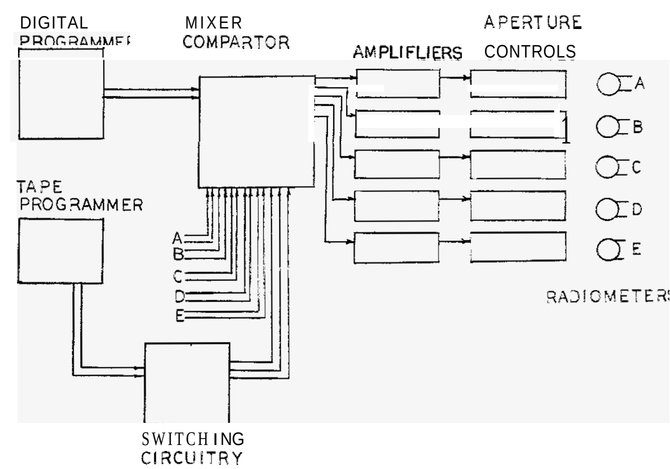


*FIG 6 SOLAR SIMULATION PROGRAMMING AND MONITORING SYSTEM*

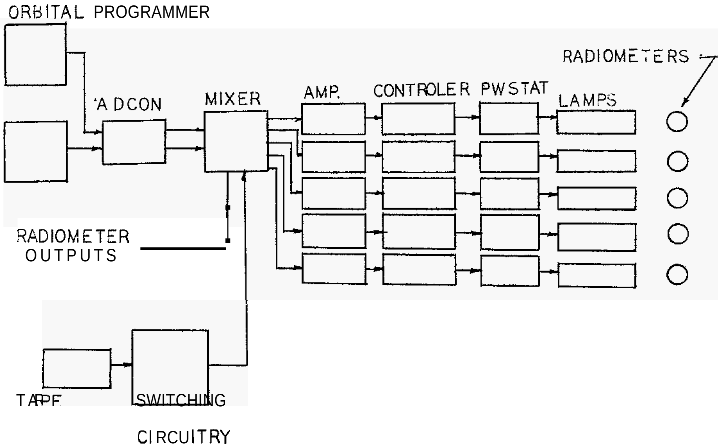


*FIG 7 HEAT FLUX* ***PROGRAMMING AND MONITORING SYSTEM***

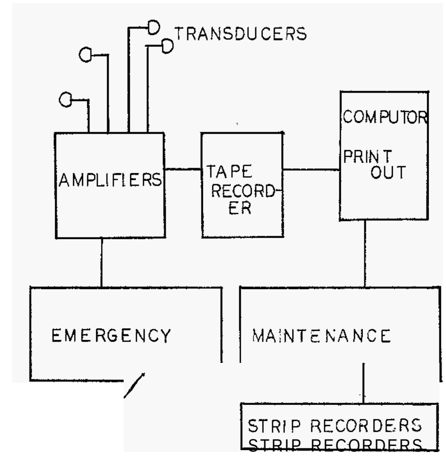


***FIG 8 PREVENTATIVE MAINTENANCE MONITORING AND READOUT SYSTEM***

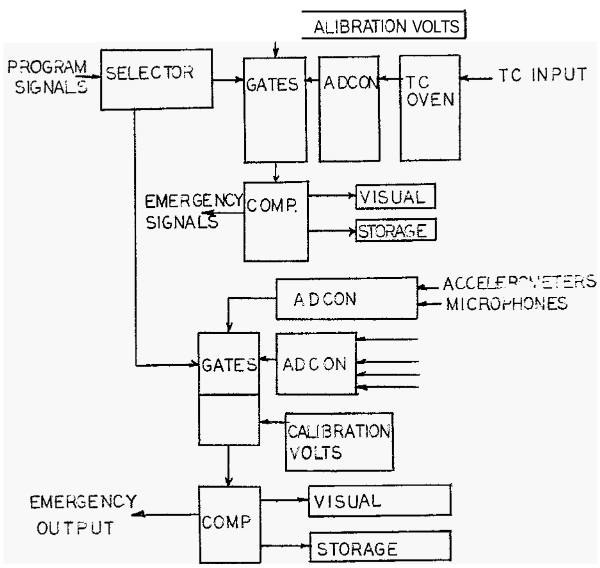


***FIG 9 VEHICLE ENVIRONMENTAL SYSTEM***

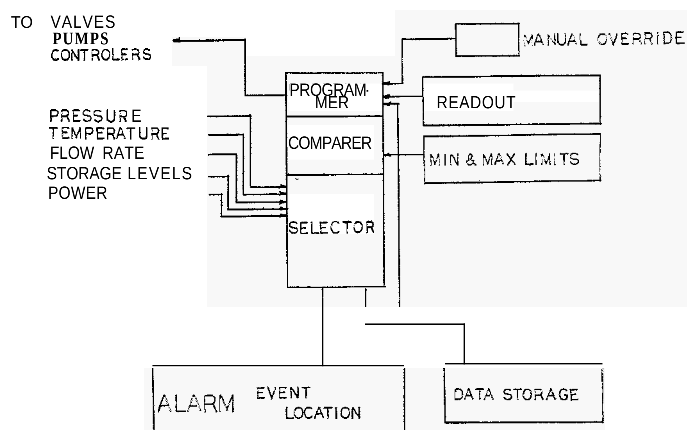


***FIG 10 VACUUM AND CRYOGENIC INSTRUMENTATION***