Table 3 Analysis for ozone and sulfuric acid[a]

Contaminant	Voltage, v	Found,[b] ppm	90-day limit,[c] ppm
Ozone	2.15	0.02–0.05	0.02
	2.20	1	
Sulfuric acid	2.15	0.22	0.1[d]
	2.20	0.28	

[a] Inlet air temperature 75 ± 5°F and inlet relative humidity 50 ± 2%.
[b] Parts per million by volume based on the O_2 plus N_2 mixture at a ratio of 1:4 and at 1 atm pressure and 25°C.
[c] ppm by volume of gas at 1 atm and 25°C (Space Science Board, 1968).
[d] See text.

posure limit is concerned, a value of 0.1 ppm by volume will be assumed.[8] Although the concentrations of acid and ozone are higher than the acceptable limits for these materials, a standard glass filter (Flanders Filter Inc., Riverhead, N.Y., 6C-33G size A) was able to reduce the acid spray to a level less than 2×10^{-6} ppm, which is acceptable. Also, a standard charcoal filter (Barneby Cheney Model PAB Type Filter, Type AC charcoal, 6-10 Tyler mesh size) reduced the ozone concentration to an undetectable level (<0.0025 ppm). The lower limit of detection for ozone is also acceptable for continuous exposure for 90 days.

Visual inspection of the electrodes after disassembling the unit upon completion of the 3268 hr of total test time failed to reveal a significant loss of platinum black from the cathode. Discoloration of the gel matrix, however, indicated some loss of platinum black apparently from the cathode. (Since the platinum catalyst used on the anode was not flaky, platinum black, but instead an adherent platinum catalyst, it is doubtful the discoloration was due to platinum from the anode.) The appearance of the anode was unchanged.

After over 3268 hr of operation this unit gave no indication of physical or operational degradation. Cell resistances measured with a General Radio Impedance Bridge at 1000 cps before start-up and at the end of the 2500-hr test showed little change. The average resistance for each cell was 0.102 ± 0.008 Ω initially and 0.100 ± 0.005 Ω after testing.

The unit used in this extended evaluation was designed to operate nominally as a $\frac{1}{4}$-man capacity unit ($\frac{1}{2}$ lb O_2/day). In practice the unit operated at an O_2 production rate as high as 0.756 lb/day and as low as 0.142 lb/day (at 2.2 v) depending on the inlet relative humidity. The 0.756-lb/day rate was achieved at 60% relative humidity and 76°F and the 0.142 lb/day rate at 30% relative humidity and 72°F.

Conclusion

Reliable operation of a $\frac{1}{4}$-man capacity water-vapor electrolysis unit for an extended period of time has been demonstrated. The range of relative humidity and temperature that the unit could tolerate without impaired performance was much greater than the nominal ranges anticipated in manned closed environments. The range of inlet relative humidities over which the prototype unit was operated without drying out or flooding was 30% to 70% at an average temperature of 72.8° ± 1°F.

Gas analysis for trace contaminants indicated the presence of H_2SO_4 aerosol and ozone. Although the ozone and acid aerosol concentrations were higher than permitted for continuous human exposure, standard filters reduced the concentrations well below the toxic level.

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Minimizing Launch Cost by Institutionalization of Launch Facilities

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THE national space program has required a very significant investment in launch facilities and equipment. It may require an additional investment to support: a) the development of space transportation systems; b) the establishment of permanent manned space stations/bases; c) the advent of nuclear propulsion systems; d) expanded lunar exploration; and e) planetary exploration. The operational costs at the launch site constitute a significant portion of the cost picture, particularly for extended programs. Institutionalization of our launch facilities and support equipment would lead to more economical multiprogram support of a variety of space vehicles, compared to further extension of the current program-oriented, dedicated launch facilities.

Development of support equipment for the most part starts at a later date than that of the flight article, as indicated in Fig. 1. Special support equipment requirements usually cannot be defined until flight hardware concepts have been formulated and preliminary design specifications have been prepared; therefore, less time is available in which to develop such equipment, even though its development will determine the efficiency of the operational process. Still, it must be ready for operation at the same time as the flight hardware. Therefore, from an over-all management standpoint, it is advantageous to utilize to the maximum extent possible institutional facilities for supporting services and apply resources only for the development of special support equipment. This management approach will reduce program risks by introducing the minimum number of developmental items into a new program.

Prior to entering into a major effort to institutionalize launch facilities, the following requirements need to be established: a) a multiprogram environment, b) a high degree of program independence in the launch site configuration, and c) a high degree of program independence of the launch site management structure.

Ground support and launch operations for major space vehicles require support of the following types: power, environmental control, propellant loading, communications,

Presented as Paper 70-244 at the AIAA Launch Operations Meeting, Cocoa Beach, Fla., February 2–4, 1970; submitted February 27, 1970; revision received May 11, 1970.

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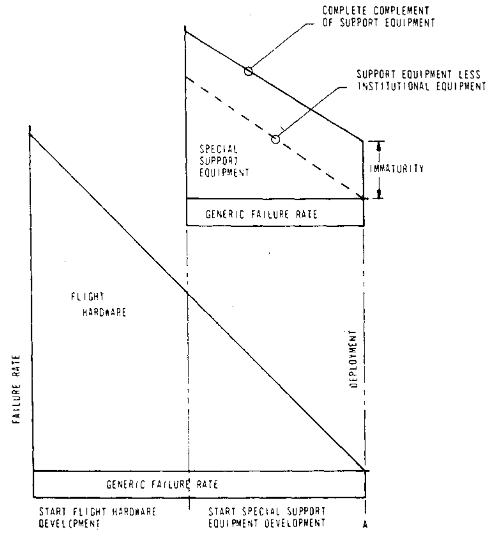

Fig. 1 Development diagram for support equipment.

monitor and control, automated testing sequences, safety, and tracking and recovery.

The system design must satisfy existing and future programs requirements without compromising the institutional aspects. Some of the design concepts and goals should be: 1) providing simultaneous multi-vehicle test capability, 2) accommodating various vehicles with minimum change, 3) providing cost effective operation through the application of only the hardware and software systems required, 4) establishing a software library of proven test and checkout subroutines, 5) providing user-oriented conversational capability between computer and test personnel, 6) providing ample automation capability, 7) providing independent subsystem test capability, 8) providing high reliability through selectable operational redundancies, 9) providing data interfaces with other Centers, and 10) utilizing commercial equipment to maximum extent possible. A concept for providing checkout and launch control within the foregoing framework is shown in Fig. 2.

Institutional support systems will require a new technique for specifying performance which, in many instances, will be appreciably different from previous techniques. National standards for space vehicle control and monitoring data formats, frequency allocations, propellant loading rates and pressures, etc., need be established to enhance standardization, to simplify vehicle to ground interfaces, and to reduce the design effort for program variations.

Admittedly, fulfilling all these goals in a single step is ambitious; it is nevertheless desirable to maintain these goals as a guide in the continuing process of system development. Some of the advantages which will accrue from an institutional approach are as follows.

Table 1 Nominal space shuttle traffic model (flights per year)

Program	Time in years								
Space station[a]									
12 men	7	7	7	7					
Space base									
50 men						23	23	23	23
Unmanned planetary	7	1	8	3	4	6	5	2	7
Unmanned satellites	2	2	2	2	2	2	2	2	2
Lunar program									
6 man orbital station				48	48	34	34	34	34
6 man lunar base									
Total	16	10	17	60	61	65	64	61	66

[a] A twelve-man station will require 12,000 lbs of cargo each quarter of which 2700 lbs is food.

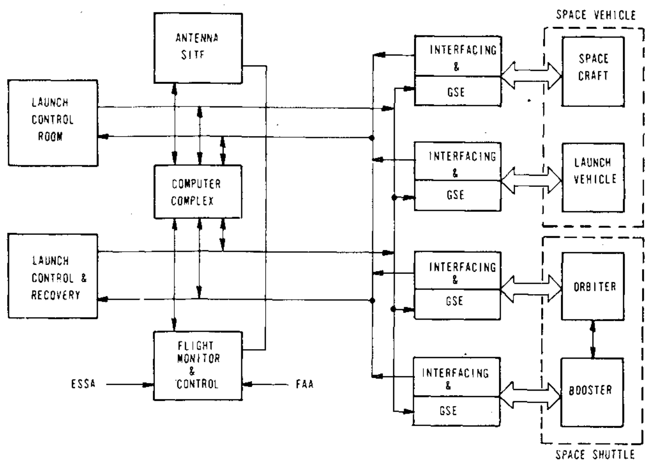

Fig. 2 Ground institutional system.

1) Cost effectiveness, because duplication of efforts and creation of unique test equipment for each program will be reduced, support requirements will be met at reduced costs, special talents and equipment will be utilized more efficiently on multiple programs, and manageability will improve. Continuous utilization of the developed expertise and the supporting documentation and operational procedures will insure high proficiency from program to program with a minimum of retraining.

2) Reduction in support, due to improved efficiencies in maintenance, logistics, and configuration control. A dedicated equipment approach requires the establishment of these equipment support functions for each on-going program, whereas an adaptable system would require only minor variations in these existing support functions.

3) Manageability, because of clearer divisions of responsibility for planning, implementation, and costs. Studies have shown that institutionization of launch facilities can be implemented by increments in an orderly manner, so that compatibility with existing and future programs is maintained with minimum disruption of launch site operations.

New Program Requirements

If recommendations made by the Presidential Space Task Group are adopted, future ground checkout and launch systems will be required to check out and launch the Saturn vehicles, the command service module (CSM) and lunar

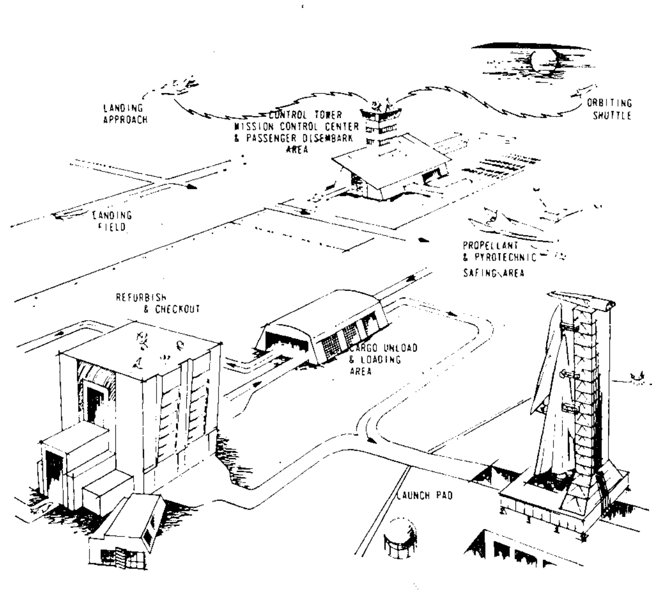

Fig. 3 Possible future shuttle facilities at Kennedy Space Center.

module (LM), the AAP dry workshop, the space shuttle, and the space station and its attendant experiments. The space shuttle will feature short turn-around capability, advanced maintenance concepts, and airline handling techniques. The launch site will resemble an airport of the future (Fig. 3). The space shuttle will support many programs (Table 1), each having characteristics and requirements which must be satisfied by the launch facility's capability. Reduced operational costs will be vital to the success of such future programs; continued high costs would reduce the scope of future programs by limiting the funds available for flight hardware, experiments, and research.

Summary

The fulfillment of NASA's space role will depend on the establishment of an efficient operational concept for processsing vehicles such as the space shuttle. The facilities, floor space, equipment, and manpower commitment can be minimized through implementation of the institutional approach, which would provide a high degree of standardization, adaptability, and flexibility in facilities and equipment.

A Tube Wind-Tunnel Technique for Rocket Propulsion Testing

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A TUBE wind tunnel for providing supersonic flows has been developed at the Cornell Aeronautical Laboratory (CAL) for rocket propulsion testing and has been in use for a number of years, primarily under the NASA/MSFC base-heating program.[1,2] The original motivation for the development of this short-duration wind tunnel was to provide an inexpensive means of producing an appropriate external flow environment (including a wide variation in freestream Reynolds number) for base-heating tests with models of Saturn-type boosters which avoided the complexity, cost, and frequent scheduling problems associated with testing rocket models in existing continuous flow or blowdown wind tunnels. The operation of the CAL tunnel and its use in base-flow investigations are discussed in this Note.

Short-Duration Tube Wind Tunnel

The main components of the tunnel are shown in Fig. 1. It is a modification of the type of blowdown tube wind tunnel conceived by Ludwig,[3,4] and it operates according to the nonsteady wave principles discussed in Ref. 5. A Ludwieg type of tube tunnel is presently undergoing check-out at NASA/MSFC for application in aerodynamic testing at high Reynolds number conditions.[7] In the tube tunnel at CAL the test gas is initially contained in a 42-in. i.d., high-pressure supply tube by a plastic diaphragm located upstream of the nozzle. Upon the mechanical cutting of this diaphragm, a centered expansion wave propagates upstream in the supply tube and accelerates the test gas from rest to a steady velocity. The gas then expands through the nozzle and into an evacuated 8-ft-diam, 30-ft-long dump tank. The expansion wave in the supply tube propagates upstream at acoustic velocity, and until the wave reflects from the far end of the supply tube and returns to the nozzle inlet, the nozzle supply conditions remain constant and the flow is steady. For the 30-ft-long supply tube currently in use, a steady nozzle supply is maintained for nearly 40 msec when using room temperature air as the test gas. This time is more than adequate to establish the nozzle and model flowfields and make the desired measurements. The nozzle starting time is on the order of 10 msec for this configuration with the diaphragm upstream of the nozzle. Various gases can readily be used as the test medium in this tunnel since the operation of the facility simply involves loading the desired gases into the closed supply tube prior to the test.

Since the volume of the supply tube is relatively small, a reasonably sized evacuated dump tank can be used. The latter allows higher altitudes to be simulated without concern for flow separation within the nozzle, and enables the tunnel to be operated in the laboratory environment by completing a closed system within which any test gas and rocket exhaust products are confined upon completion of a test, and overpressure and acoustic effects are contained. The evacuated dump tank also acts as a convenient "pumping" source for the choked-wall perforated nozzle developed for use with this tunnel.[6] The reduced pressure in the test section prior to the opening of the diaphragm also has the beneficial effect of reducing the starting load on the models to a level below the steady-state operating load. High starting loads on the models can be a significant problem in the Ludwieg form of the tube wind tunnel.[5]

The majority of tests performed in this tunnel have been concerned with base flow effects on scale-model rocket vehicles and basic investigations of rocket plumes. To avoid possible tunnel blockage and the effects of shock reflection and strut wake in base-flow investigations, the models are installed in a nacelle which is cantilevered from struts located in the supply tube and extends through the length of the nozzle to the test region (Fig. 2). The techniques developed by CAL for duplicating the liquid and solid-propellant rocket exhausts in such short-duration rocket testing are described in detail in Ref. 8 and will only be discussed briefly here.

Because test periods are short, uncooled combustor hardware of straightforward design and flexible operating capabilities can be used to provide the desired rocket exhausts relatively simply and economically. Liquid rocket-propellant combustion is simulated by burning gaseous fuels and oxidizers. Thermochemical duplication of most liquid propellant combinations can be achieved by the use of appropriate multicomponent combustible gaseous mixtures[9]; in some cases a less exact, but adequate and more convenient simulation achieved by the use of a single component gas. The use of gaseous propellants greatly simplifies the injector, combustor, and propellant supply system. The gaseous propellant supply system developed for these tests capitalizes on the same nonsteady gas-dynamic wave processes as used in the tube wind tunnel, and is simplified to a pair of pressurized gas storage tubes containing the oxidizer and fuel gases. To operate the rocket engine, supply tube valves are opened, allowing the gaseous propellants to flow out of the tubes through sonic metering venturis, through the injector, and into the combustion chamber where they mix and burn. As in the tunnel itself, coincidently with the start of flow from the tubes, nonsteady expansion waves propagate upstream in the supply tubes at acoustic velocity. Until these waves reflect from the far end of the tubes and return to the metering station, propellant supply conditions remain constant and steady combustor flow is achieved.

Actual full-scale propellant is burned in model rocket combustion chambers to provide solid-propellant rocket exhaust plumes. A thin web thickness of the propellant is

Presented as Paper 69-335 at the AIAA 4th Aerodynamic Testing Conference, April 28–30, 1969, Cincinnati, Ohio; submitted March 30, 1970; revision received April 24, 1970. The NASA/MSFC work described herein was performed under Contracts NAS 8-20027 and NAS 8-21097, with H. B. Wilson, Jr. as technical monitor.

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