Dr. Thornton

M74-M167

MEMORANDUM

ACTION DA

INFO AA CA CB DF TA TE LA MA EA EB FA

TO: MH/Director, Space Shuttle Programs

FROM: MM/NASA Director for Life Sciences

SUBJECT: Proposed Shuttle "White Paper"

For the past several months, members of my staff and I have discussed the activities relating to Shuttle development and as my concern increased with each meeting, I asked that we document many of these concerns in a Life Sciences status paper on the Shuttle.

I am deeply concerned that in the agency and program office zeal to reduce Shuttle spending to imposed ceilings, not only are other necessary SR&T programs suffering but compromises are being made in the Shuttle design which will impact the use for which it is being touted to the scientific (user) community. In Life Sciences, we are a user and NASA must fund this use adequately.

In particular the crew quarters area of the orbiter I feel is being compromised, and we are not taking advantage of our previous flight experience. To go backwards in feeding, water and waste handling, biological sampling, and in sleep arrangements appears ridiculous for a "next generation" spacecraft. An additional issue that needs further address by Shuttle and Spacelab is the provision for access to the biological payloads during the vertical phase of the prelaunch period down to T-2 hours.

There has also been inadequate Life Sciences input at the JSC and HQ program levels and the true situation in needs and use of the Shuttle for my Life Sciences data and experiment activity must be squarely faced. Crews and experimenter must live in the orbiter and it is now inadequate for the job.

Info cy: MM/Jones MM/White MM/C MM/R MM/V MM/E MM/S

Original signed by
Charles A. Berry, M. D.

cc: M/Schneider

Charles A. Berry, M. D.

MM/CABerry:bw:3/25/74:x52347
Retyped 3/26/74

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Enclosure

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CONCURRENCES

SYMBOL	MM							
SURNAME								
DATE	3/26							

NASA FORM 1287 OCT. 69 PREVIOUS EDITIONS MAY BE USED.

LIFE SCIENCES

OPERATIONAL SUPPORT/HABITABILITY REQUIREMENTS

1. Flight Crew Monitoring Requirements

Physiological monitoring and data gathering on the flight crew will continue to be essential to crew medical support and safety. With the considerable additional data base that is being obtained from the Skylab experience and the questions arising therefrom, it is apparent that man's response to the space flight environment is not well enough described to do otherwise.

The additional consideration of introducing "non-astronaut" crew members on Spacelab flights makes the requirement for establishing more definitive crew selection and assessment data critical. It is important to establish the relationship between the current data base gained on astronauts with non-astronaut scientists. We need to collect data on both groups, i.e., all crew members, early in the flight program and selectively thereafter.

These requirements, described below, relate to the capability to obtain essential data, as needed, on all flight crew members and passengers on Shuttle missions, whether or not related or identified with the Life Sciences Research Program. Some of the data serve a dual requirement in that they may contribute to Life Sciences experiments in addition to being essential methods of monitoring the health and well-being of the crew and scientist passengers.

These requirements impact directly on Orbiter design as the crew will live, eat and sleep in the Orbiter and be supported at all times by the Orbiter environmental and life support systems. The capability to meet these requirements, even if not used on all flights, thus must be incorporated into Orbiter design.

The flight crew operational support monitoring capability requirements which will impact the Orbiter are:

a. A feeding system which will permit accurate determination of food and fluid intake. This was addressed by RID #MM-4, August 6, 1973.

b. Body mass measurement capability. This was addressed by RID #MM-4, August 6, 1973.

c. A waste management system that will measure urine volume and provide the capability to obtain urine samples. The Life

Sciences SR&T Program has under development a retrofit commode and istrumentation which can meet the fecal and urine identification, sapling, volume and mass measurement requirements. This was stated i RID #HM-3, August 6, 1973.

d. A waste management system which can determine the wet o dry mass of feces and provides the capability to obtain fecal siples. The Life Sciences SR&T Program has a retrofit commode which ci meet the fecal and urine sampling and volume requirements. This w addressed by RID #HM-3, August 6, 1973.

e. Sample preservation and storage capability for forty- t man-days within the Orbiter.

The minutes of the August 16, 1973 SRR Board contain the following cments on the applicable RID (#HM-3): "BOARD DISPOSITION: Submit t NASA Headquarters, Space Shuttle Program Office, for evaluation by t OMSF/Life Sciences Office." Life Sciences has not yet received a correspondence in this regard.

2. Rescue

The capability to conduct personnel rescue from both the Oiter and the Spacelab remains a firm operational support requirement, rardless of the scope and requirements of the Life Sciences Research Pgram, crew size, or Orbiter-Spacelab configuration. Rescue aumptions should include provisions for the inter-vehicular tnsfer of incapacitated crew members. For rescue missions when hd docking/docking module methods are not used or available, the tnsfer method will require use of a pressurized container or con- tners for crewmen being rescued. The capability exists to develop aimple, economical universal pressurized container for this EVA rcue; the specific technology to develop this "garment" and devise mns of transfer between spacecraft awaits definition. The equip- mt should be as simple as operationally feasible.

The EVA rescue method and equipment should not constrain cw (scientist) selection or impose extensive training require- mts; rescue methods for non-astronaut crewmembers should thus be bed on the premise they cannot provide assistance. Prime crew tining for EVA rescue is not expected to be lengthy or complex, bi is a requirement. This training will vary according to the wst case mission-specific emergency for which rescue would be atmpted.

3. EVA

Life Sciences fully supports the Level I decision making "operational" EVA a program requirement. Beyond the greatly increased potential for assisting experiment operations, for conducting maintenance and repair, and for handling contingencies, so well validated on Skylab, EVA as an operational mode can be expected to simplify manipulator and payload design (by permitting inspection, assembly, extend cargo handling and the like). The currently baselined Orbiter airlock is a necessary component for EVA. Extravehicular access capability should be available for all missions, with or without a docking module or Spacelab. The EVA procedure should not involve depressurization of the Spacelab when it is onboard.

4. Life Support/Habitability Requirements

a. Acceleration Profiles. The Orbiter End Item Specification, July 30, 1973, submitted for SRR review, presented maximum acceleration levels which are excessive (Page 263). They are:

G-Vector	Crew	Time	Passengers	Time
Transverse (±Gx)	8g	120 sec	8g	120
Positive (+Gz)	4g	120	TBD	TBD
Negative (-Gz)	2g	120	TBD	TBD
Lateral (±Gy)	6g	120	6g	120

These limits probably exceed the tolerance levels of a large segment of the general population. Life Sciences has received reentry load factor profiles on baseline reference mission simulations showing peak loads of 1.2+Gz; also, MH has stated that the "Shuttle is being designed to accommodate loads during reentry from symmetric flight maneuvering load factors of 2.5g positive and 1.0g negative, and symmetric and unsymmetric maneuvers and gust levels consistent with transport category airworthiness requirements, specified in MIL-A-8861."

We realize that the OEI Specification acceleration statement is a limit on design and does not reflect nominal mission

guidelines. That differentiation should be clearly stated to preclude any assumption that these equipment design limits are physiologically acceptable for nominal mission profiles.

We are aware of the approved RID to change the OEI Specification to conform with the acceptable launch and reentry G force restrictions of Section 3.2.1.1.11, Volume X, Flight and Ground System Specification (Level II). When this is accomplished, there still remains the need to define and establish acceptable acceleration loads (in terms of peak G, duration, time course and axis) for alternative, contingency or emergency modes. If G loads on the order presented in the July 30 OEI Specification are anticipated in any of these modes, special acceleration protective devices or seat configurations should be considered.

b. Carbon Dioxide Limits. In consideration of the stated engineering difficulties and penalties involved in achieving a pCO_2 of 0.23 mm Hg (Earth atmosphere), Life Sciences will accept a nominal CO_2 level of 3 mm Hg with 5 mm Hg maximum for the Orbiter crew, as a crew safety and habitability requirement. This is not intended to imply that 5 mm pCO_2 is acceptable as a nominal design level. Additionally, crewmen may have dual roles as experimental subjects and thus, must have carefully controlled atmospheres in all habitable areas for certain experiments. Provisions for lower CO_2 levels than stated above can appropriately be charged to payloads. The JSC report of Space Shuttle and Spacelab discussions, October 11-12, 1973, JSC 08500, Volume B, Page 10, shows the planned range of CO_2 pressures to be 0 to 7.6 mm Hg, with an implied average of 3.5 mm Hg (Page 16). The upper limit of 7.6 mm Hg is excessive and should be lowered to 5.0 mm Hg.

c. Trace Contaminant Monitoring and Control. As with carbon dioxide levels, the capability to monitor and control trace contaminants is an operational crew safety requirement. Several RIDs expressing these requirements were submitted to the August 1973 Systems Requirements Review. All were rejected or shelved for various reasons. The October 11-12, 1973 Space Shuttle and Spacelab Discussions documentation (JSC 08500, Volume B, Pages 22-24 and 106-107) indicates that trace gas contamination is to be controlled through appropriate materials selection, ECLSS design and avionics isolation. There is no mention of monitoring or active control capability, without which the Shuttle will be deficient from a crew safety and habitability standpoint.

Shuttle is an entirely new spacecraft design and the vehicles will be reused over a several year period. Ground based validation studies and careful materials selection alone will not provide absolute assurance that toxic materials will not be present

with some configurations and payloads on-orbit. The payloads will be of multiple origins and will be recycled; trace contaminant gas monitoring and control will be necessary to assure and validate the success of the 'materials selection' preventive approach. The planned cabin purge rate of three pounds/day through the avionics bay and approximately one pound/day from waste management represents a percentage turnover on the order of a few percent, quite insufficient to provide trace contaminant control by dilution.

These considerations are separate from and additive to experimental ones, which in themselves, require trace contaminant control in all habitable areas for the reasons stated in b. above. The contaminants of prime concern to the scientific community and to experiments proposed are carbon monoxide, ethylene, hydrocarbons and hydrogen. A hybrid sensor for this purpose is virtually developed, having successfully completed two previous iterations. It would be able to detect cabin levels of the hazardous fluids aboard the Orbiter - hydrogen, hydrazine and monomethylhydrazine.

d. Two Gas Atmospheric Sensor/Controller. The atmospheric control subsystem for Space Shuttle must permit unattended operation, provide sufficient oxygen and nitrogen stores, and insure, by positive control, the correct oxygen and nitrogen ratios. These requirements can be met efficiently by a system developed for Life Sciences. This system combines a flight qualified mass spectrometer with a recently developed pulse-rate modulated controller. It has proven most satisfactory in Skylab as medical experiment hardware. In fact, it is currently supplying Skylab with its carbon dioxide data since its prime carbon dioxide sensors were unreliable. We strongly recommend its use in Space Shuttle.

e. Feeding System. As presented in the October 11-12, 1973 Shuttle and Spacelab Discussions (JSC 08500, Volume B, Page 66), the food is to be rehydratable; JSC Crew Systems Division personnel have advised Life Sciences that this is to be Apollo-type food. This would represent a considerable regression from use of today's state-of-the-art Skylab food, failing to implement the many lessons in metabolism, nutrition and crew acceptability taught by our past flight experience. Life Sciences requests information and data from background studies relevant to the decision to use Apollo-type food for the Shuttle Program.

f. Waste Management System. The currently proposed commode for the Shuttle can accommodate only one person at a time. Past space flight experience has demonstrated that there are periods of over-demand on a single commode by only three crewmen. It can be assumed that discomfort and inconvenience will result, as crew size increases to seven; even with a two shift schedule, unless additional provisions are made. Life Sciences requests reconsideration of this potentially serious habitability problem to include time line studies and the like, with the data being made available for further study.

g. Habitability, Crew Duty Cycles and Sleeping Accommodations. The current Orbiter design provides sleeping accommodations for a total of four persons simultaneously. For flights with larger crews, a two shift operation, with sharing of sleep accommodations, thus becomes mandatory, by design fiat, as well as prior management decision. There are serious drawbacks to a two shift cycle, outweighing its advantages so much as to restrict its indications to contingency situations. This is especially true in the employment of spacecraft with marginal habitable volume as will be the case with the Orbiter as presently designed. Circadian rhythm problems, noise masking/elimination, light diminution requirements and formidable mission/flight plan coordination problems have all been well established in past flights with two shift operations and are clearly to be avoided.

Life Sciences questions a spacecraft design which commits the program to a two shift operation at this time. We further question the general adequacy of the total habitable volume for a crew of more than four. The dimensions of the habitable portion of the pressurized module approximates a volume of 8 X 11 X 12 feet. Inside this are to be all seats and work stations, the galley, sleep stations, airlock, passageways, many provisions and up to seven functioning, productive individuals for 42 man-days (obviously 30-day missions magnify the problem even more). This entire subject needs thorough study and review prior to the PDR in early 1974 to preclude excessive design changes at a later date.

ORBITER-PAYLOAD ACCOMMODATIONS AND INTERFACE REQUIREMENTS

Many of the design requirements discussed below are of concern because Orbiter design has not been fully described in certain areas, or because current design appears to be of questionable compatibility with Life Sciences Spacelab requirements. In this category are payload bay interior acoustic levels, vibration spectra, computer services and communications, vis-a-vis weight/volume constraints. If Life Sciences requirements in these areas cannot be met by basic Spacelab design, they can then be satisfied only through Shuttle design, thus becoming Orbiter-payload accommodations considerations.

1. Life Sciences Spacelab Dimensions

Life Sciences has reevaluated its Shuttle Lab equipment requirements seeking to preserve research capability in the smallest acceptable volume whose need was identified by ESRO studies. We have done this by: (1) deleting some research capability entirely; (2) breaking down the single complete Life Sciences laboratory concept into multiple Life Sciences laboratory concepts of different discipline mixes; and (3) reducing the number of experiment unique equipment items that will fly on a given mission. In Step 2, we have identified the minimum integrated laboratory, supporting the most important Life Sciences research requirement and have used this to define our dimensions. This most important research requirement is medical research on man supported by parallel animal surrogates and a cells and tissue capability. This has been demonstrated by our Skylab and USSR flight findings which indicate a strong need to define mechanisms and cellular changes which can only result from identical exposure of man and animals.

This approach has reduced our required experiment equipment volume from the old value of 20.6m^3 to a new value of 12.3m^3. This value assumes no Tracking and Data Relay Satellite (TDRS) capability and thus, onboard tape volume for data and picture storage. With TDRS capability, the new Life Sciences Volume requirements are 11.9m^3. To this must be added, the new NAS specified animal centrifuge volume of 9.7m^3 for a total of 22.0m^3 without the TDRS capability and 21.6m^3 with the TDRS capability.

The minimum length for the medical research laboratory is dictated by the man research station requirements needed to perform supporting inflight surgery on animals. This requires two scientists operating as a surgical team supported at an equipment station by the third scientist. The result is a working laboratory 15 feet long, down from the old length of 16 feet, plus four feet for the new centrifuge requirement giving a pressurized volume length of 19 feet.

The minimum diameter for Life Sciences results from the new animal centrifuge requirement. The NAS/SSB review panel at Woods Hole concluded that the minimum radius to the animal c.g. which would preclude coriolis effects was on the order of five feet. When engineering detail of cage structure, waste disposal, centrifuge clearance and wall thickness are added, a laboratory of OD of 14 feet is required.

The equipment weight of the medical laboratory is 6,283 pounds down from the old value of 12,661 pounds. The centrifuge weight of 722 pounds when added to this value gives a Life Sciences medical lab weight of 7,005 pounds. If TDRS is available, this will drop to 6,055 pounds.

2. Life Sciences Spacelab Power

Average power for the Life Sciences Medical Lab is 2.1kw and for the centrifuge 0.5kw. This total of 2.6kw is well below the proposed ESRO value of 4.7Ckw.

3. Crew Size

The largest crew size requirement is the need for inflight animal surgery to support Life Sciences experiments in the Spacelab. As described earlier, it requires an operating team of two men assisted by a third at an equipment station. Even without surgery, however, the work load to operate the medical laboratory dictates three men. This Life Sciences crew size was determined by using a "facility approach" to the design of the laboratory. This approach was developed based upon the frequency of occurrence of the functions to be performed and results in a model of the activities within the laboratory, how often they occur, and for how long. This gives a basis for estimating the operations - dependent quantities.

The model was used as the basis for estimating total crew time requirements (work load). The work load was divided by the time available per crewman to determine the crew size required. Available crew time was constrained by the assumed duty cycle for each laboratory.

The selection of a simultaneous duty cycle was based on the Life Sciences laboratory experiment requirements. No experiment requirements for round-the-clock (RTC) operations have been assumed for these laboratories. The all-on, all-off operation was selected in order to increase the availability of crew skills during the duty cycle, minimize noise during sleep periods and maintain ground biorhythms.

For the 30-day mission, six out of every seven days are devoted to experimental activities after initial orbit and set up have been achieved. A highly flexible seventh day is provided with no scheduled activity from the functions inventory. This day is scheduled as an experiment evaluation and review time between the onboard experimenter and ground based Principal Investigators to take full advantage of the research flexibility allowed by manned laboratories in space. The basic duty cycle assumed for Life Sciences Spacelab personnel was 12 hours on-duty and 12 hours off-duty, seven days a week. The 12 hours of on-duty time is divided into ten hours of experimentation with a two hour allotment for contingency time. The 12 hours of off-duty time for each crewman are divided into: (1) eight hours of sleep; (2) 2.5 hours of food preparation, meals and cleanup, or about 45 minutes for each of two meal periods and an hour for the third; and (3) 90 minutes of exercise and personal hygiene activities. Periodic housekeeping of the living quarters is assumed to be completed during this latter time period as required.

The results of this operations analysis indicated a need for three men. The allocation of the work load between the payload specialist station and the Spacelab will be mainly dependent on the location of the experiment controls. For many experiments (but not inflight surgery), it appears feasible to utilize the payload specialist station.

To broaden the statistical base of medical data, all Shuttle flight personnel should be available as possible subjects for routine medical and performance monitoring inflight.

4. On-Orbit Stability and Acceleration Control

Since many of the Life Sciences experiments will investigate the influence of weightlessness on organisms, it is imperative that the G-forces experienced by the payloads during launch, orbit and reentry be recorded. During orbit, many experiments will require essentially 0-G, i.e., 10^{-3} for prolonged periods of time. Sudden or rapid angular or translational accelerations during orbit will be quite harmful to Life Sciences experiments.

RID #HM-6 stated this requirement; it was accepted in principle as being less stringent than RID #335A, which requires 10^{-4}G maxima. The present concern regards the duration of these constraints; the Life Sciences requirement for 10^{-3}G applies to the entire orbital flight period.

5. Life Sciences Payload Heat Rejection Requirements

The Life Sciences heat production level will be 2.6kw plus an estimated 0.1kw more for metabolic heat load when animals are aboard. The Life Sciences heat load is barely above the worst case Shuttle 2.5kw hot orbit value and thus does not appear to be a problem. Particular thermal requirements such as the need for cabin temperatures of 68-72°F or equipment cold plate temperatures will be dependent on acceptable inlet temperatures to the laboratory. The latter has been satisfied by Paragraph 3.2.3.1., Payload Shuttle Interface Data Book, Revision A, July 27, 1973, which provides for heat exchanger inlet temperatures of 45 + 5°F. SRR activities resulted in acceptance for study of RID #M156A, having the same ATCS inlet temperature requirement and a heat rejection capability of 30,000 BTU. The Life Sciences requirement should not be disregarded if the study of RID #M156A demonstrates the latter's infeasibility.

6. Payload Bay Thermal Environment

Thermal protection of Spacelab personnel and experiments requires that payload wall temperatures shall not exceed 120°F or 100°F average, nor should normal direct contact temperatures exceed 113°F. The experiments cannot be met with pre-SRR payload bay allowable temperatures without excessive insulation/ecolant systems chargeable to payload. We have been notified informally that various RIDs have satisfied these Life Sciences program requirements; they should now appear in documentation.

7. Communications

Life Sciences requirements are derived without using the Tracking and Data Relay Satellite (TDRS). Thus, our requirements provide for onboard storage of data. An estimate has been made of the "Dimensions" savings available if only 24 hours of onboard data storage is required. Equipment volume would decrease by 0.4m^3 and weight would be reduced by 950 pounds.

8. Computer Services

The Life Sciences requirements for handling experiment data were obtained assuming the Spacelab had the data management subsystem (DMS) described in the 1972 MSFC Phase B Sortie Lab Study. This DMS contained a mini-computer for experiment control and data processing, a display control console, remote acquisition stations around the lab and standard tape recorders. The capacity of the study DMS is 100 Kbs. The current Life Sciences data estimate is 33 Kbs and thus well within the DMS capacity. If the DMS is not available, then Life Sciences must add volume, weight and power.

9. Free Flying Teleoperator Controls

Experiments are being developed to validate remote servicing and retrieval of operational Shuttle payloads using free flying teleoperators. Man-machine systems need verification of remote manual control system procedures, techniques and integration of automatic control system, manipulator and end effector performance. Life Sciences recommends incorporation of a plug-in control console unit into the Payload Specialist Station to provide manual control mechanisms (hand controller, push button, etc.), visual displays, etc. required by the operator.

10. EVA Technology Experiments

The Life Sciences Space Flight Research Program has a requirement for EVA technology experiments, for two purposes: to measure the performance of man in the EVA system; and to evaluate and validate the design principles of the system and man-machine interface. Experiments will be required to cover a wide range of potential EVA applications.

GROUND OPERATIONS AND SUPPORT REQUIREMENTS

1. Pre-Launch Payload Access

Many of the Life Sciences experiments are living systems and often need either to be placed into the payload late in the countdown or may need to be examined at a late stage. This establishes the requirement for manned access to the payload up to two hours pre-launch. During pre-SRR activities, RID #HM-7, stating this requirement, was approved and incorporated in RID #D35A. At the completion of the SRR, the launch access time specified in this DCD RID read "TBD." Life Sciences reiterates the requirement to have easy physical access via crew hatches and existing apertures, to the Spacelab, up to two hours pre-launch, for the purpose of installation/replacement of experimental organisms and modules.

2. Post-Landing Payload Access

Differences between space biological research constraints and other functional program areas, even within the biomedical research area, include the need for extensive inflight and ground based controls in biological research; the need for extensive experiment-flight compatibility verification; and the need for biological specimens to be controlled and stabilized. These Life Sciences requirements for the Spacelab will necessitate immediate post-landing access to the Spacelab with capability to remove experimental organisms/modules without delay, or else provision of ATCS and ECLSS conditions identical to those provided by the Shuttle ATCS/ECLSS on-orbit. Deviations from these conditions can be expected to degrade the validity of scientific data obtained to the point of rejection by the scientific community.

3. Central Integration Facilities

Life Sciences favors the use of central integration and checkout facilities located at the launch sites, or elsewhere, as the most efficient and feasible method of providing the experimental support and access requirements cited above.

LONG DURATION MISSION CONSIDERATIONS

For full realization of the potentials for Life Sciences research, which are time dependent functions, long duration flights will be required as early in the program as possible. There are also many valid investigations of early changes in Life Sciences experiments which are achievable in seven day flights, especially the early adaptive body system changes in cardiovascular, fluid and electrolyte, etc., and those utilizing organisms with short life cycles or involving short term phenomena (e.g., embryonic development). Longer duration flights are necessary for many experiments and observations essential to preparation for future longer and complex flights. In many cases, flight experience is the only reliable way of collecting such data.

Longer duration flights are relatively less expensive per unit of orbital flight time, would take fuller advantage of the first real opportunity to undertake a broad based specialized, man-tended basic and applied research in the space environment, and would more fully exercise the laboratory. Life Sciences recognizes and accepts smaller laboratory/experiment payloads forced by the necessity for increased amounts of consumables on longer duration flights in order to participate in the latter.

As a means of extending mission duration beyond 30 days, it is recommended that the feasibility of resupply or Spacelab transfer between Shuttles be seriously studied as representative methods of increasing Spacelab time in orbit.