MANNED SPACECRAFT CENTER

MEDICAL RESEARCH AND OPERATIONS DIRECTORATE

POSITION PAPER

EXTENDING THE DURATION OF MANNED SPACE FLIGHT MISSIONS

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THIS PAPER

~~The purposes of this paper are to~~ describes the rationale used by the staff of the Medical Research and Operations Directorate ① TO EVALUATE ~~in evaluating~~ strategies for extending the duration of manned space missions, ② to identify the essential sources of data for evaluation and decision-making, and ③ to state medical constraints governing mission extension for Skylab missions 2 and 3.

~~Medical consideration of extending the duration of~~ C continuous human exposure to the space flight environment must deal with the unresolved question of the overall suitability for long-term human existence of the null-gravity state and the physical environment afforded by a spacecraft ~~inflight~~ HABITAT. Data from U.S. and Russian flights have demonstrated that significant physiological changes occur during the course of manned space missions. ~~Current theories to explain these changes generally agree that~~ IT IS KNOWN THAT the absence of a gravity vector results in alterations in the distribution of blood flowing through the circulatory system. These alterations initiate automatic (reflex) responses in the nervous and endocrine systems, resulting in major readjustments in physical and chemical processes within the body. THERE STILL REMAINS ~~The~~ question ~~of~~ AS TO whether these processes stabilize after a

period of acclimatization, establishing a satisfactory new equilibrium state for the control of fluid and electrolyte transfer, as well as body metabolism, or whether the alteration in the physical environment initiates a continuously unstable situation, leading to the gradual decompensation of regulatory processes and collapse of the individual. ~~is the key point which must be resolved~~.

Progress toward resolution of these problems requires ~~additional facts either in the form~~ ACQUISITION of new ~~fundamental~~ knowledge about human physiology or ~~in the form of empirical~~ NEW knowledge gained ~~through the~~ EMPIRICALLY FROM exposure of people to weightlessness for increasing periods of time. The ~~latter~~ EMPIRICAL approach ~~is the approach~~ HAS BEEN ~~this approach is~~ followed to date in the manned space flight program ~~and is planned for the Skylab program~~.

~~Unfortunately, this simple and straightforward approach to the solution of the problem has one serious drawback.~~ The physiological changes discussed above are not detectable through ordinary inflight subjective or objective methods of observation and health status determination until major system decompensation occurs. The exposed individuals can become abruptly incapacitated and can ~~transition~~ CHANGE in a matter ~~of a few~~ hours from an apparently healthy individual to one approaching a ~~state of normal health to a~~ state of shock and total collapse. Moreover, the major effects of the internal readjustments that

take place within the body to maintain normal functions during orbital flight may not become apparent until reentry and landing. It is entirely possible, therefore, that a crew could perform normally, feel essentially well, and be judged to be in satisfactory condition, based on all operational biomedical parameters available to the ground throughout a Skylab mission, only to find during reentry that they had undergone an insidious process of deterioration and were totally incapable of functioning or even assuming an erect posture in a 1g force field. In this regard, it is noteworthy that the Russians have reported that the cosmonauts aboard Soyuz 9 were physically incapable of moving out of their crew couches upon landing ~~after~~ following approximately 18 days of earth orbital flight. The Soviets have also stated that throughout the course of the flight, there was no indication on the ground, or awareness on the part of the cosmonauts, of any significant alteration in their physical condition. It is, of course, an objective of the Skylab program to have each crewman physically sound and capable of accomplishing any action required for his safety under his own power, throughout all phases of each mission, including recovery.

During the Mercury program, it became apparent that neither ground-based laboratory models nor inflight monitoring of the

available physiological parameters ~~were capable of providing sufficient information~~ COULD BE USED to predict how an astronaut would respond to the return to a 1g environment at the conclusion of a mission. A policy of cautious incremental extension of flight duration was ~~therefore~~ proposed according to which the postflight condition of the crew at the conclusion of each new increment of exposure to weightlessness became the key data point for evaluating the feasibility of embarking on subsequent longer flights. As a rule of thumb, ~~it was proposed that so long as~~ WHEN postflight examination findings ~~from any given mission did not~~ FAILED TO reveal a significant degree of degradation of the functional status of major body systems, the next incremental extension of mission duration could be determined by doubling the length of the longest successfully ~~negotiated~~ flight. This informal policy became so well accepted that early plans for AAP missions were based on doubling the 14 day longest flight of Gemini as an initial increment, followed by doubling the proposed 28-day exposure and planning for subsequent missions of 56-days duration.

Actually, the mission-doubling rule based on postflight data alone has an upper limit of about the two-week flight duration.

In the absence of detailed inflight medical data, it is not possible to extrapolate the long-term space flight effects

on one crew based on the short-term experience of another crew.

~~The~~ Acquisition of inflight physiological data ~~in~~ the Skylab flights permits the missions to extend from 14 to 28 to 56 days. ~~This inflight~~ data will permit the physician to determine in near-real-time trends in physiological systems which would indicate medical problems.

Our analysis of the physiological changes measured inflight to date indicates that ~~if there is~~ progressive deterioration ~~occurring~~, there ~~must be~~ concomitant loss of body mass, a net fluid loss, and a progressive deterioration in the capacity of body systems to respond to demands for increased work or high-energy expenditure.

The measurements being made for Skylab medical experiments will detect some of these changes if they occur during the flight. The repetition of these measurements at ~~the~~ planned intervals will permit both the magnitude and the rate of change to be determined as a function of flight time. The measurements of primary value in this regard include whole body mass; intake of food and liquid (both quantity and type); urine volume; response of heart rate, the vectorcardiogram pattern, blood pressure and lower limb volume to the lower

body negative pressure procedure; and subjective feelings along with the response of heart rate, blood pressure, respiratory rate and volume, oxygen uptake and CO_2 production to the bicycle ergometry procedure. Assuming that these measurements are accomplished essentially according to schedule and that the data from them are received in the Mission Control Center, it will be possible to assess the physical condition of the crew and the feasibility of continuing the mission.

Specifically, it will be possible, ~~given the conditions outlined above, to ascertain~~ during the first two weeks of the Skylab 2 mission, To ascertain whether the condition of the crewmembers is stabilizing ~~in the weightless environment~~ or undergoing a continuous process of deterioration. A limit of allowable "deconditioning" will be established preflight ~~and~~ if crew condition continues to change during the third week, both the magnitude and the rate of change in the measurements ~~previously described~~ will be analyzed, These analyses will provide 3 to 5-day projections of crew condition ~~in order~~ to assure their capability ~~of~~ To perform competently during reentry and landing.

~~One key point that is basic to the foregoing discussion must be clearly understood.~~ It must be understood that the intervals between repetition of individual measurements on each crewman specified in the

Skylab Medical Experiments Plans have been based on the expectation that most of the physiological changes will occur during the first two weeks of flight, and that the planned sequence of repetitive measurements will document stabilizing physiological adjustments characterizing the acclimatization of the crew to weightlessness. If the physiological status of any of the three crewmembers continued to show a steep rate of change from preflight baseline values into the third week of the mission, it may be necessary to alter the frequency with which measurements are made in order to maintain sufficient visibility of the dynamic situation to preclude the undetected transition by any crewman into a dangerously deconditioned state.

Table 1 presents a comparison between the presently scheduled sequence of measurements and the potential maximum useful frequency of performing these same measurements if physiological stabilization is not achieved after 14 days in orbit. The actual scheduling of LBNP and ergometry in the contingency case would be a task for real-time mission planning, but the table identifies boundaries within which this rescheduling would occur.

~~Simply stated,~~ it is the position of the MSC Medical Directorate that Skylab missions 2 and 3, ~~viewed separately,~~ with ~~their~~ proposed extensions of manned flight ~~exposure~~ to 28 and 56 days respectively, constitute major biomedical experiments. ~~by which~~ the capability of man to acclimatize successfully to the null-gravity state ~~will be tested along with the first attempt to record the physiological interactions between man and the space flight environment~~. If the capability of making ~~these~~ measurements is lost, ~~for any reason~~, it will be necessary, ~~in the interest of safety~~, to terminate the mission within three to seven days following the loss of inflight data, ~~depending upon the medical assessment of crew condition at the time of data loss~~. Table 2 identifies ~~minimum~~ essential inflight data requirements necessary for the medical support of continuation of the Skylab 2 mission for more than 21 days, assuming that not even these critical measurements are successfully accomplished during the first 14 days of flight.

Table 2

MANDATORY INFLIGHT MEDICAL MEASUREMENTS FOR CONTINUING SKYLAB MISSIONS BEYOND 21 DAYS

1. All mandatory operational biomedical and environmental parameters		
2. Food and liquid intake plus urine volume output measurements as specified for the M070 experiments	or	Whole body mass accurate to ± 500 gm

3. LBNP and associated measurements as specified for experiment M092	or	LBNP with one lead of ECG and blood pressure
4. Ergometry and associated measurements as specified for experiment M171	or	Ergometry with one lead of ECG, blood pressure, and either CO_2 production or O_2 uptake.

The longer we can fly Skylab 2 with successful retrieval of valid MEDICAL data ~~from the medical experiments,~~ the more confidently we will be able to ~~extrapolate our data to assess~~ Recommend the feasibility of extending mission durations. ~~No physiological breakthroughs are anticipated prior to the scheduled launch of Skylab 2 that might eliminate the necessity for obtaining actual flight data to evaluate the compatibility between human physiology and extended 0g space flight~~. In the event that data returns from the first two to three weeks of the Skylab 2 mission strongly indicate that the crew have acclimatized to the weightless environment and have ~~achieved a stable physiological status, with~~ exhibited adequate ~~compensatory~~ reserve capabilities to function ~~as required~~ during reentry and recovery, then the satisfactory conduct ~~throughout the flight~~ of at least the minimum set of measurements identified in Table 2 would serve ~~as an adequate capability for mission monitoring in the event it is desirable to~~ to guide the extend this mission to as long as 36 days. The ~~actual~~ feasibility of accomplishing a mission of that duration will, ~~of course,~~ be contingent upon evidence that (physiological conditions) the crew ~~condition~~ continues to be stable as the flight progresses. If the data are of

marginal or unsatisfactory quality, or if crew condition fails to stabilize, it will be necessary to terminate the mission and evaluate the status of the crew on the ground before any commitment to a longer duration mission can be made.

The planned Skylab 2 mission stands as a very genuine milestone in the development of this nation's manned space flight capability. The proposed medical studies should provide answers to the question of the fundamental compatibility of man with weightlessness. The feasibility of flying subsequent missions, including Skylab 3 for 56 days ~~as planned~~ or longer, depends primarily on how clearly that answer is obtained from inflight data. If our technology is not up to the challenge, ~~then~~ the only alternative approach for the extension of manned space flight ~~that the medical staff can offer at this time~~ is to conduct a series of progressively longer flights, with each incremental exposure being five to seven days longer than its antecedent, until postflight assessment of crew condition after each flight extension can establish the character and time course of man's physiological responses to the flight environment.

Table 1

PROPOSED USE OF KEY MEASUREMENTS FROM SKYLAB MEDICAL EXPERIMENTS

TO SUPPORT EXTENDED DURATION FLIGHT

MEASUREMENT	REQUIRED PERFORMANCE FREQUENCY PER CREWMAN	
	Expected Situation: Stabilization apparent in 1st 14 days	Contingency Situation: No stabilization apparent in 1st 14 days
Food & liquid intake	All intake measured & recorded. Data collected & evaluated in MCC 1Xper 24 hr.	Same
Urine volume	All urine output measured. Data collected & evaluated in MCC 1Xper 24 hr.	Same
Body mass	Measure & report 1Xper 24 hr. Would assume 4 @ 1875	Same
LBNP & associated measurements (M092)	*approximately 1Xper 72 hr.	1Xper 24 hr.
Ergometry & associated measurements (M171)	*approximately 1Xper 120 hr.	1Xper 72 hr.

*Actual interval between planned repetitions of these procedures varies among individual crewmen due to total mission scheduling constraints.