USE OF THE BEN FRANKLIN SUBMERSIBLE AS A SPACE STATION ANALOG

Volume II – Psychology and Physiology
OSR-70-5

Prepared for
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Advanced Systems Office

Contract NAS 8-30172

Prepared by
Space Station Analog Study Team

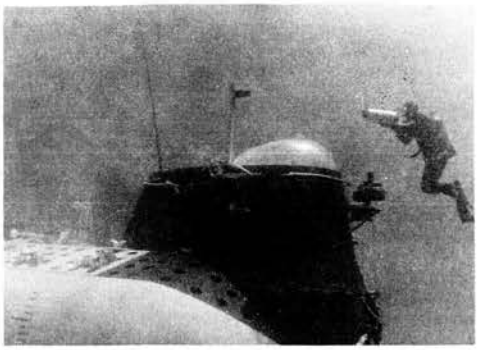
APPROVED BY M. J. Ferguson

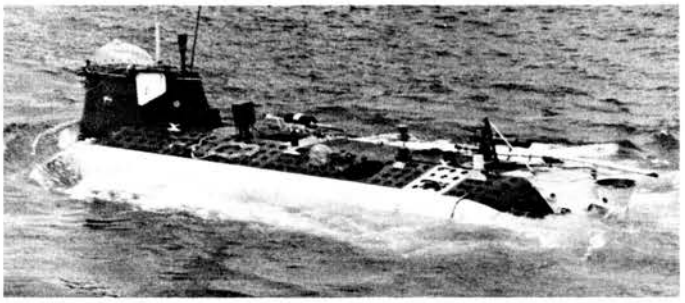
M. J. FERGUSON, *Study Manager*

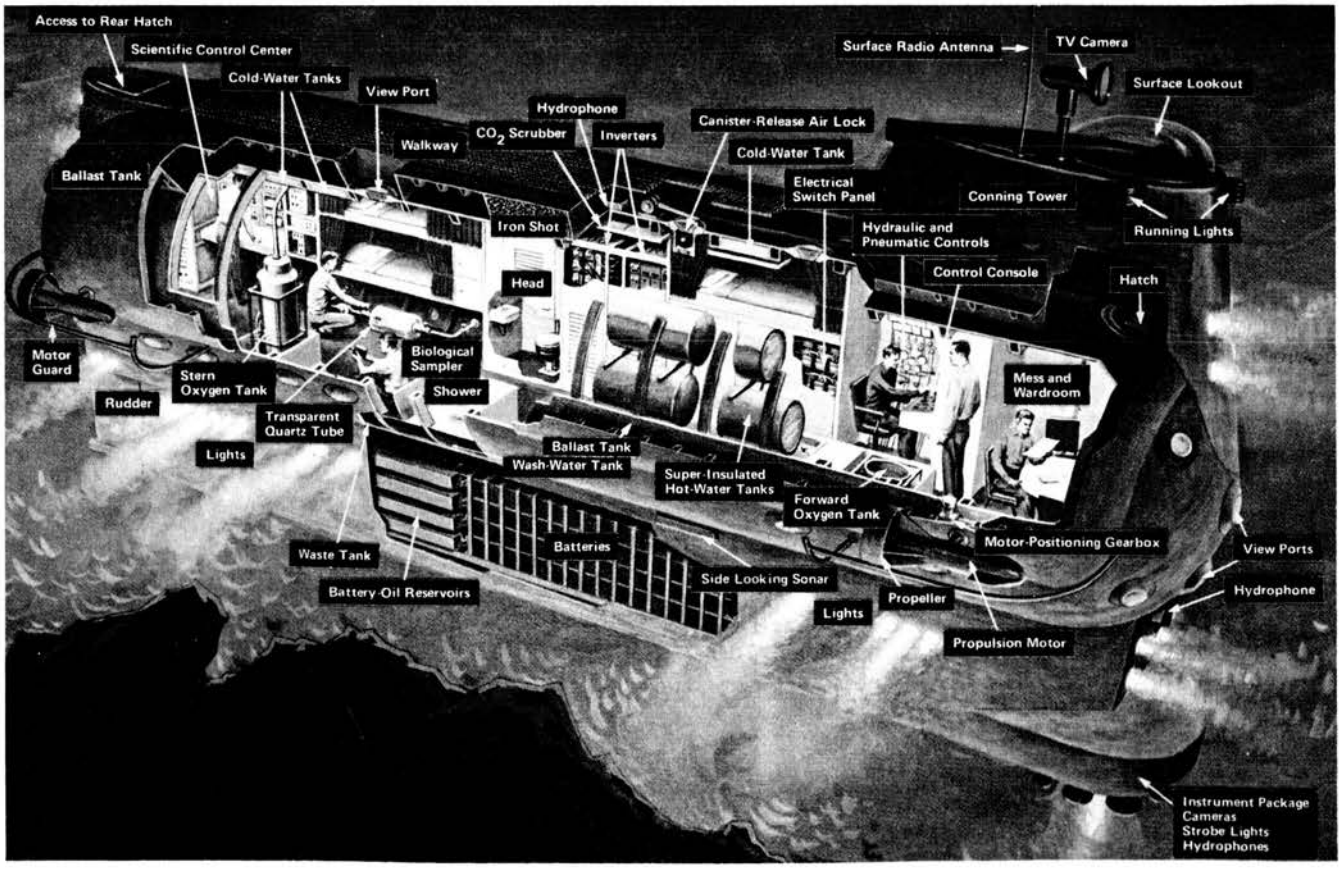
May 1970

GRUMMAN AEROSPACE CORPORATION
BETHPAGE, NEW YORK 11714

THE BEN FRANKLIN DURING THE GULF STREAM DRIFT MISSION







FOREWORD

During 1969, the Ocean Systems Department of Grumman Aerospace Corporation conducted the 30-day Gulf Stream Drift Mission, using the BEN FRANKLIN submersible. As a part of this mission, a NASA study was conducted to investigate man related activities which are analogous to long-duration space station missions. During the mission, a NASA crew member was aboard the BEN FRANKLIN for data collection, observation, and task participation. This work was performed in accordance with the Statement of Work in NASA Contract NAS 8-30172, "Use of BEN FRANKLIN as a Space Station Analog," for the George C. Marshall Space Flight Center, Advanced Systems Office, under the direction of C.B. May. The program was coordinated by Manager M. F. Markey of NASA, Washington Headquarters.

The Final Report consists of the following five volumes:

- OSR-70-4, Volume I, Summary Technical Report
- OSR-70-5, Volume II, Psychology and Physiology
- OSR-70-6, Volume III, Habitability
- OSR-70-7, Volume IV, Microbiology
- OSR-70-8, Volume V, Maintainability

CONTRIBUTORS

Contributors to this study were:

Dr. Milton Delucchi	NASA, Manned Space
Mr. I. Donenfeld	Naval Medical Research
E. Dougherty, Ph.D.	Naval Medical Research
Mr. E. Fisher	NASA, Marshall Space Flight
Dr. J. Frost	Baylor University
Mr. W. Funston	NASA, Marshall Space Flight
B. A. Gropper, Ph.D.	Bellcomm, Consultant for NASA
W. W. Haythorn, Ph.D.	Naval Medical Research
Mr. R. Heckman	NASA, Marshall Space Flight (Backup crew member)
Mr. A. C. Krupnick	NASA, Marshall Space Flight
E. J. McLaughlin, Ph.D.	NASA, Space Medicine
Dr. J. N. Scow	NASA, Langley Research
Dr. S. Smith	Naval Medical Research
W. W. Umbreit, Ph.D.	Rutgers University

ABSTRACT

This report presents the NASA effort using the BEN FRANKLIN submersible as a space station analog during the 30-day Drift Mission in the Gulf Stream, starting July 14 and ending August 14, 1969. The areas of investigation include:

- Psychological and Physiological measurements during the pre-mission, mission, and post-mission phases
- Habitability in a closed ecosystem
- Microbiological evaluation of the water system, human flora, and environmental samples
- Maintainability considerations for scheduled and unscheduled tasks.

AUTHOR CREDIT

The five volumes were prepared by the Space Station Analog Team as follows:

Subject	Author(s)
• Psychology and Physiology	C. P. Seitz, Ph. D.; A. Goldman, Ph. D.; R. J. Del Vecchio, Ph. D.; C. J. Phillips, Ph. D.
• Medical	R. P. Jessup, M. D.; R. Fagin, M. D.
• Habitability	
- Habitability Analysis	M. J. Ferguson
- Environmenta'	F. Abeles, N. Kameno
• Microbiology	D. Valentine, K. Feindler, R. F. Davis
• Maintainability	J. R. Kappler, R. Toussaint
• Oceanographic Experiments	H. Reichel
• Summary	M. J. Ferguson

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SECTION I

INTRODUCTION

In a previous Grumman study (OSR-68-6 11 March 1968, NASA Contract NASW-1965) it was concluded that changes in human psychosocial behavior typical of some of those possibly anticipated in a long space voyage could be observed and studied in crews operating for 60 to 90 days in a submersible. The PX-15 submarine (BEN FRANKLIN) was recommended as an analog of a space vehicle because its operation provided the crewmen many characteristics of travel in the space environment. Among these are:

- Confinement in a closed ecosystem
- Isolation from normal family and social contacts
- Difficulty of escape or return
- Hazardous environment external to the vehicle
- Reduction in variety of stimuli.

Additionally, the BEN FRANKLIN was recommended as a suitable analog for anticipating some human reactions to long-duration space flight because it:

- Provided a normal earth atmosphere in terms of gaseous composition and pressure
- Is the approximate size and provides approximately the same free volume as some concepts now planned for future space missions
- Was to be used in a scientific mission that required the kind of motivation typical of space flight or, in fact, any major scientific effort.

An opportunity to test the utility of a submarine as an analog of a space vehicle arose when Grumman undertook the Gulf Stream Drift Mission (GSDM) in cooperation with the United States Navy (NAVOCEANO). The specific purposes of the psychological and physiological studies in the GSDM were as follows:

- To evaluate the environment, habitability, and human-engineering variables as contributors to behavior of crew members
- To relate the psychological characteristics of the crewmen to predicted and observed behavior
- To find out whether the crewmen experienced physical deconditioning as a result of confinement and limited activity for 30 days
- To determine the suitability of the testing devices and training procedures.

It should be noted that the following conditions and constraints had to be considered in planning the study reported here:

- Power available for collection of data was limited to 5 kilowatts
- Environment, scheduling, human-engineering, and composition of the crew, were predetermined and could not be varied by the investigators.

The NASA study effort was, therefore, not an "experiment", but a systematic observation and description of psychological and physiological aspects of the mission.

1.1 STUDY PLAN

Based on the concepts and constraints noted, it was planned to obtain on the six crewmen the following kinds of data:

1.1.1 Pre-drift Phase

- Psychological profiles to establish characteristics of:
  - dominance - submission
  - social adjustment
  - anxiety
  - need to achieve
  - need to affiliate
  - mood

- A prediction of individual adaptability of each crewman
- A prediction of reactions to human-engineering and environmental limitations of the BEN FRANKLIN

- Baseline data on the Langley Research Center Complex Coordinator (motor skills test)

- Studies of physiological reactions to confinement
  - physical fitness index
  - wrist and forearm strength
  - recovery pulse
  - blood pressure
  - oxygen utilization
  - weight

1.1.2 Drift Phase

- Psychological and physiological data (covering the same characteristics measured during the pre-drift) and human-engineering considerations

- Performance on Langley Research Center Complex Coordinator
- Wrist and forearm strength and pulse rates before and after exercise
- Preferences with respect to food
- Measurements of noise, light, and other environmental conditions
- Use of water and sanitary facilities
- Recreation
- Activity
- Use of bunks
- Measurements of performance of onboard tasks.

1.1.3 Post-drift Phase

- Repeat of psychological tests given in the pre-drift phase
- Repeat of physiological tests given in the pre-drift phase
- Intensive individual interviews.

1.2 THE CREW

Six volunteers, ranging in age from 34 to 46, made up the crew of the BEN FRANKLIN (see Figure 1-1). Although each member had a role that justified his participation, none was selected on the basis of compatibility. Each of the men received thorough medical and psychiatric examinations before and after the mission. A summary of medical and physiological data collected for the drift mission is presented in Figure 1-2 and compared with like data obtained in a McDonnell-Douglas study of confinement in a space cabin simulator. During the mission the crew of the BEN FRANKLIN was aware that medical assistance was available onboard the surface ships.

1.3 THE ENVIRONMENT

The BEN FRANKLIN is a cylindrically-shaped vehicle measuring approximately 48 by 10 feet, with a free volume of slightly more than 3500 cubic feet. Not all of this volume was available for living. Some was lost by the need to include a deck, installation of bunks, storage areas, and equipment bays. The general arrangement of the interior is shown in Figure 1-3. Walking space, allotted areas, and free volume of the BEN FRANKLIN was compared in Figure 1-4 with that of the McDonnell-Douglas Space Cabin Simulator used in a 60-day study.

The BEN FRANKLIN provided normal sea-level atmosphere. Environmental temperature was not under direct control and therefore the product of external ambient temperature. On dives it became cold in the vehicle and the crewmen had to add additional clothing. Humidity and CO_2 concentration were passively controlled. They were maintained within acceptable limits by deployment about the vehicle of silica gel and lithium hydroxide. A more complete discussion, including a description of the hygiene, water, and waste removal systems can be found in Volume III.

1.4 METHODS OF DATA COLLECTION

Data were collected by means of pre-planned logs, time-lapse photography, and tape recordings. Even in those instances where objective data were reported, as in the case of the Langley Research Center Complex Coordinator, the log was the place for recording the data.

Age	Marital Status	Specialty	Submarine Experience	Education/ Training
41	married	engineer	yes	engineering
46	married	scientist	yes	pol. sci. /engineering
34	married	naval officer	yes	NROTC
37	married	engineer	no	engineering
46	married	engineer	yes	naval science
36	married	oceanographer	yes	oceanography

Figure 1-1. Demographic Characteristics of the Crew

Type of Examination	Grumman Applied			McDonnell-Douglas Applied			Grumman	McDonnell-Douglas
	Pre	Dur	Post	Pre	Dur	Post	Gen Results	Gen Results
History & Physical Exam	x		x	x		x	Within Norm Limits	Within Normal Limits
Audiograms	x		x	x		x	Within Norm Limits	Slight temporary decrease in acuity
Visual Test	x						Within Norm Limits	
Electrocardiogram	x			x		x	Within Norm Limits	Within Normal Limits
Vital Capacity	x			x		x	Within Norm Limits	No Change
Physical Fitness Index	x		x	x		x	No significant Change	Decreased in 3 of 4 subjects
Blood Vol. (RBC Mass)	x		x	x		x	Within Norm Limits	No change
Hemoglobin	x		x		wkly		Within Norm Limits	Within Normal Limits
Urinalysis	x		x		wkly		Within Norm Limits	Within Normal Limits
Blood Chemistries	x		x		wkly		Within Norm Limits	Intermittently sugges-tive of mild dehydration
Microbial Culture		x	x		wkly		Shifts in flora	No stable consistent changes. No staph accrues cross infections
Vital Signs	x		x		Dly		Within Norm Limits	No change

Figure 1-2. Comparison of Data Gathered in Grumman Ben Franklin and McDonnell-Douglas Studies

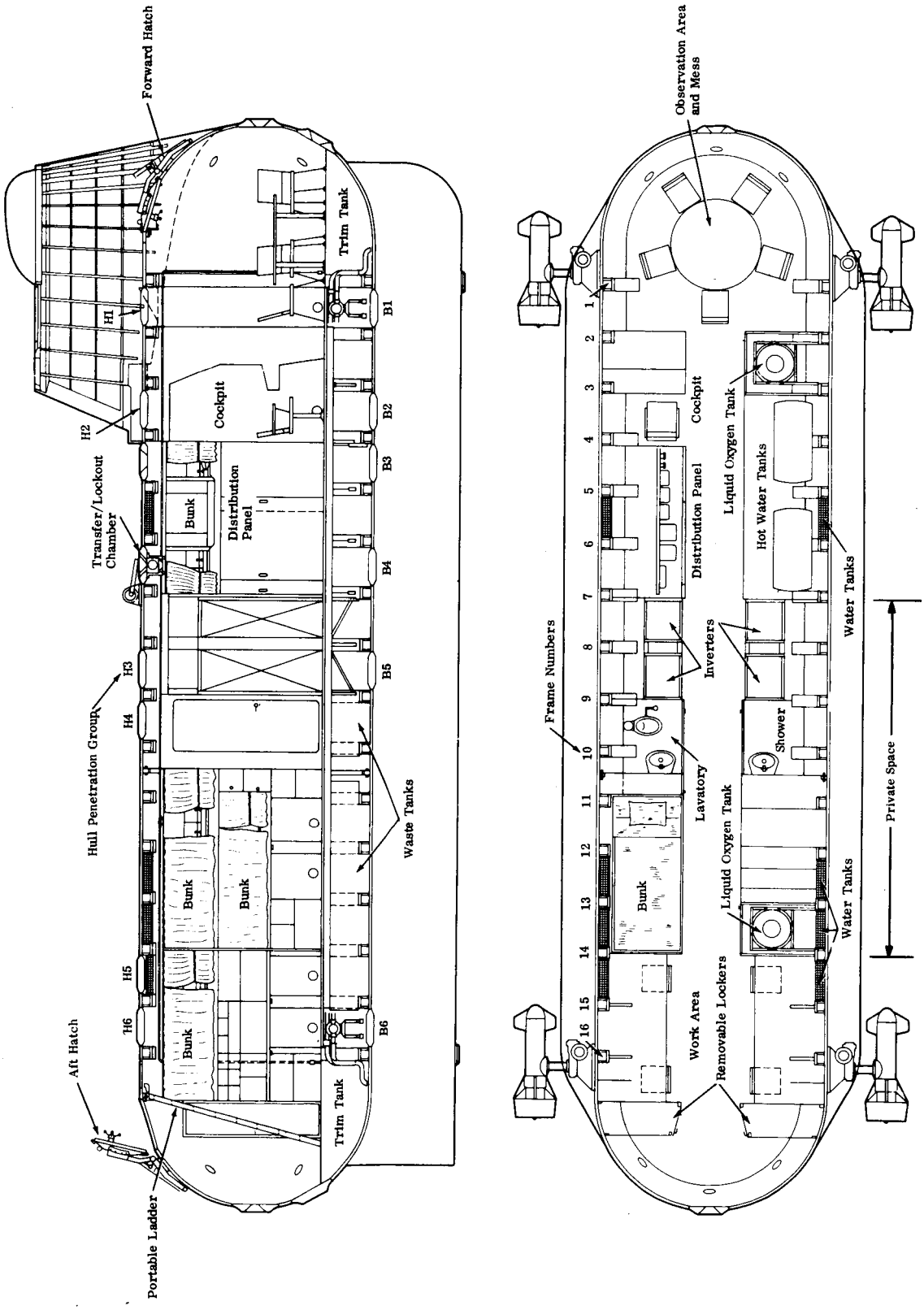


Figure 1-3. Inboard Profile of Ben Franklin

Area	Free Walking Space		Free Volume	
	BF*	SCS**	BF	SCS
Command	10 ft^2	8 ft^2	49 ft^3	459 ft^3
Bunk			236	448
Aisle				
Galley and adj. area	23	38.9	176	284
Recreation	40	59.1	400	433
Hygiene area	13.4	15.1	124	101
Other free space	91.2		387	
Total	117.6	61.1	1372	1725
Total per/man	29.6	40.2	229	431

Total Volume of Ben Franklin - approximately 3500 ft^3

Total Volume of SCS - approximately 3600 ft^3

*6 men

**4 men

Figure 1-4. A Comparison of Areas and Volumes of Ben Franklin (BF) and the McDonnell-Douglas Space Cabin Simulator (SCS)

Because the personal logs were such an important source of data, a considerable amount of time was devoted in the pre-mission phase to organizing the content and format and obtaining cooperation of the crew. The topics that were inquired about and the frequency of their sampling are shown in Figure 1-5. In order to keep the daily logs of manageable length (a matter considered important if the crewmen were to respond), not all items were sampled daily. Appendix C is a sample of the log provided each member of the crew.

Still pictures were taken simultaneously every two (2) minutes from three fixed locations. Hand-wound 16mm Kodak cameras equiped with 160^{o} wide-angle lenses were mounted to cover the forward hemisphere, the area in front of the galley, and the aft section (the scientific equipment bay). An area of privacy was provided on the insistence of the crew. Excluded from the field of view of the cameras was the area delineated on Figure 1-3 as private space.

Figure 2-1 in Vol. III shows the installed positions of the three cameras. They were operated synchronously by a timer. A clock was in the field of view of each camera so that the three frames taken at any given time could later be matched for study. Film with an ASA rating of 4000 was used because of the extremely low ambient illumination (2 to 6 foot-candles). Special processing also was required.

Crew conversation was to be recorded daily at breakfast (15 min.), lunch (15 min.), dinner (30 min.), and 60 minutes at the discretion of the crew member assigned to operate the recorder. One of the crew members agreed to make all of the observations and to record the data. This crewman was instructed in these tasks. Prior to the mission each crewman was made aware of the data to be collected.

1.5 TRAINING

The crewmen were together at the Port of Palm Beach in preparation for the drift for more than two months before the mission. In this time, they became acquainted with one another and with three of the investigators who were preparing the psychological and physiological testing programs. The crewmen learned to do the various tasks to be carried out during this mission, learned to use the logs, and in general became familiar with

Item	Day																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Sleep recall	x							x							x							x							x	
Eating	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Food preference	x							x							x							x							x	
Langley device	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Strength exercise	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Pulse	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Medicinals	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Symptomatology	x			x	x	x				x		x			x					x		x				x		x	x
Housekeeping	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		x	x			x	x	x	x	x		x	x
Free time	x	x	x	x	x	x				x	x	x	x	x	x	x	x		x	x		x	x	x	x	x	x		x	x
Frustration		x		x		x		x		x		x		x		x					x	x				x		x		x
Time at writing	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Where writing	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Mood		x			x								x							x							x			
Need for additional crew			x				x						x			x			x				x			x				x
Adequate time?			x			x						x				x			x				x			x			x	
Time for additional duties			x		x	x		x			x			x				x			x			x			x			x	
Additional tech. skills needed			x				x				x				x				x				x				x				
Important thing of day			x	x	x	x	x	x		x	x	x	x	x	x	x	x					x	x	x	x	x	x		x	x
Scientific tasks accomplished			x				x				x				x				x				x				x				
Ship operation accomplished			x				x				x				x				x				x				x				

Figure 1-5. Frequency of Sampling of Some Log Items (Sheet 1 of 2)

Item	Day																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Subjective feeling				x																									
Better preparation needed				x								x								x								x	
Requirements of Crew						x	x													x							x		

Figure 1-5. Frequency of Sampling of Some Log Items (Sheet 2 of 2)

the purpose of the NASA program. There was resistance to psychological testing and concern with an apparent invasion of privacy but at the time of the mission most of this concern, except on the part of one crewman, had been overcome successfully.

1.6 PRE-DRIFT TESTING

Each of the crewmen was examined prior to the mission in order to establish a personal profile that later could be related to his behavior during the drift. The data assembled to provide the profiles were obtained from the following sources:

- Interviews
- Rorschach test
- Primary Affect Scale (PAS)
- Subjective Stress Scale (SSS)
- Group Confinement Inventory (GCI)
- Edwards Personal Preference Scale (EPPS)
- Continuous Addition
- FIRO-B.
- Minnesota Multiphasic Inventory (MMPI)

Additionally, the crewmen practiced on the Langley Research Center Complex Coordinator with the intent of reaching a plateau of performance. This plateau was achieved by two of the crewmen, and closely approached by three of the others.

SECTION 2

PSYCHOLOGICAL ADAPTABILITY

2.1 INTRODUCTION

Two of the investigators attempted independently to predict crew adaptability. These predictions were made on the basis of psychological profiles and close association with the crew members for more than two months prior to the mission. The two predictors made nearly identical observations; they predicted nearly all of the crew incompatibilities that became evident during the mission. Predictions with respect to negative reactions to human-engineering and environmental variables proved to be the most accurate of those made by the investigators. This indicates that current understanding of people permits prediction of behavior with acceptable reliability. The predictions are summarized in Figure 2-1. The log, which required crew cooperation, was successful in that all crew members completed the items with consistency. They are provided additional, unrequested information.

Time-lapse photographs and voice tapes of onboard activity provided essentially no quantitative data on social adaptability, but was useful for area utilization study, crew activity, and time line analysis as shown in Volume III. Although the film used in the cameras had an extremely high emulsion speed (ASA 4000), interior lighting generally was too dim for the aperture setting used. Unfortunately the apertures could not be adjusted in accordance with changes in the available light. The film, furthermore, was too granular when projected and thus facial expressions as well as details of activity could not be studied. However, examination of considerable footage did provide some substantitive qualitative data. The voice tapes were difficult to analyze because of background noise (usually music) and the difficulty of accurately matching the tapes to time-lapse photographs. The tapes were useful in providing clues to clinical evaluations.

2.2 EVALUATION OF COMPATIBILITY AND INTERACTION

The crew successfully completed the 30-day drift mission without untoward responses to situation-generated stress but incidents and conditions that pointed to this possibility indicate that a longer or more eventful voyage might have precipitated serious responses.

Predicted Behaviors and/or Responses	Correctly Predicted	
	Yes	No
Crew reactions*		
Will defer to topside under pressure	X	
Very conscious of responsibility	X	
Anxious	X	
Asserts authority	X	
Will come in conflict with X	X	
X will control behavior though upset	X	
Great need for recognition	X	
X will collide with Y (he did, but controlled himself)		X
Strongly motivated - will carry on even if unburdened	X	
Least likely to provoke conflict	X	
Will not be a leader in developing group cohesiveness		X
Difficult but will accommodate	X	
No. 1 irritant	X	
No. 2 irritant	X	
Extremely competent	X	
Reveals anxiety but controls it	X	
Crew will close ranks and resist over hostility	X	
Hostility will arise if power resource fails	-	-
X will be annoyed by mess	X	
Housekeeping		
Difficult because of limited space	X	
Insufficient storage area	X	
Lack of training will prevent a clean, orderly, inspectable environment	X	
Untidiness could cause hostility	X	

* Crew codes not given because it would permit identification.

Figure 2-1. Prediction of Crew Behavior and Responses Prior to Drift (Sheet 1 of 3)

Predicted Behaviors and/or Responses	Correctly Predicted	
	Yes	No
Hygiene		
Spaces adequate, difficult to keep clean	X	
Clean up may result in hostilities		X
Ear infections will be present		X
If a cold or other infection occurs will spread	X	
Showers will give way to sponge baths	X	
Water will become contaminated	X	
Cold water for bathing will be unacceptable	X	
Water		
Taste will be unacceptable	X	
Expect cold water will become contaminated	X	
Will run short of hot water	X	
Food		
Will not be liked	X	
Will not affect health	X	
Need hot food, cooked in more conventional manner	X	
Carrying of pantry supplies will result in some hostility based on consumption	X	
Recreation		
Crews will at first be very busy-little time for recreation	X	
Will play group games-cards		X
Conversation will be a major recreation		X
Entertainment will eventually become more individual	X	
Two sets of earphones would help	X	
There will be some complaints about interference of sleep because of music	X	
There will be much general talk	X	
Art Supplies will probably not be used	X	
Eating will be a major source of enjoyment	X	

Figure 2-1. Prediction of Crew Behavior and Responses Prior to Drift (Sheet 2 of 3)

Predicted Behaviors and/or Responses	Correctly Predicted	
	Yes	No
Crew Quarters		
Use as storage area will reduce acceptability	X	
Location will interfere with sleep; privacy	X	
Quarters provide little opportunity to exhibit territorality	X	
2 Crewmen will show some territoriality	X	
Bunks should get favorable comment regarding comfort (Silica gel and Li OH Panels were stored under mattress)		X
Complaints about headroom	X	
Complaints about absence of lights	X	
Curtains will not provide sufficient noise isolation for light sleepers	X	
Temperature & Humidity		
Lack of controlled temp/humidity will result in complaints	X	
If humidity is high will cause skin irritation	X	
Will complain of cold when near bottom	X	
Work Stations		
Command & Control Station not well Human Engineered but well understood by crew-will not result in problems	X	
Lack of Writing & Work Stations will be complained about	X	
NAVOCO cannot monitor equipment & see outside at same time	X	
Crew will have numerous complaints & recommendations	X	

Figure 2-1. Prediction of Crew Behavior and Responses Prior to Drift (Sheet 3 of 3)

On a number of occasions expression of dominance by a crew member which was precipitating reaction by another, was subdued by the dominant crewman's need to achieve. It is our judgment that crews for long-duration space missions should not and probably would not be selected (as was this one) with regard to individual ability and desire to participate. Crew compatibility is an important ingredient of success and although many factors in a mission will and can balance incompatibility, it nonetheless clearly was evident in this short and mild expedition.

Men paired by assignment worked together as a team and hence had the greatest amount of interaction. Because of the small size of the BEN FRANKLIN and over-lapping schedules, there also was abundant opportunity for interaction of all crewmen. Comments in the logs, post-mission interviews, and recorded communications, indicated that more negative interactions occurred between men who were predicted to be incompatible than between individuals expected to be compatible. During the post-mission interview several of the crew indicated that they would not participate in another mission if a particular person were to be part of the crew.

Each of the men underwent psychological tests and was interviewed as his schedule permitted in the three months before the mission. This time was a period for acquaintance and unobstrusive observation for the psychologists to collect data on the crew.

Attributes were selected which were hypothesized to affect compatibility; for example, the degree to which the personalities could:

- Enhance cooperativeness
- Increase subjective sense of well being
- Lead to peer judgements that indicate each man's choice as to his companion(s) and co-worker(s), for another longer mission.

It should be noted, first, that "attributes" are not factor-analysis derived traits and, second, that these "attributes" were not precisely those defined by a single psychological instrument. The instruments, it will be noted (ref. par. 1.6), ranged from projective techniques such as the Rorschach through scaleable items such as the Group Confinement Inventory for which factor analytic outcomes are available but still under development.

Previous work in the area, for example that of Radloff, Helmreich, and Smith, mentions the problem of compatibility but does not contain the basis for a testable hypothesis. The psychological study in the GSDM was a pilot study. Therefore, we proposed to estimate the usefulness of essentially clinical tests to permit prediction of compatibility on a qualitative basis.

The scales on the graphs in this section are used to illustrate the clinical judgements and should not be compared to standards in the literature.

In this framework attributes such as anxiety, need to achieve, introversion-extroversion, dominance, and compulsiveness (the length of the list of needs and drives varied with the man being described) were extracted from the test protocols and scores. All of the available tests were utilized. The clinical process can be described as formulating a tentative hypothesis about an individual's psychodynamics from the analysis of one or two instruments and the implicit testing of that hypothesis against the information from other parts of the psychological test protocol. The method had proven useful for subject selection in a pilot study at Grumman (Grumman Ocean System Report OSR-67-1). This technique is an effort to systematize the process by which the psychiatric screening was accomplished. Indeed, for some of the men the results were made available to the psychiatrist. A three-dimensional volumetric matrix was prepared to show the predicted compatibility on a 3-point descriptive scale for each man with each other man at each of 15 data points. This matrix is not reproduced here because: (1) The names of the data points, like the scale designations of the Minnesota Muliphasic Inventory and Edwards Personnel Preference Scale from which some of them were borrowed, are subject to misinterpretation by seeming to have pathogenic significance; and (2) the public nature of this document might compromise or seem to compromise the right of privacy of six very cooperative subjects. It bears iteration that the purpose of this procedure was to assess the value of the method -- not the compatibility of these men.

Analysis of test scores obtained during and after the mission, analysis of photographs, comments in daily logs, and voice tapes revealed no clear indication of anything that might be considered disruptive in the sense in which incompatibilities appear in laboratory studies. The GSDM differed in being a mission-oriented project, conducted by a mission-oriented crew. It has been indicated earlier that the crew of the BEN FRANKLIN was not selected from among a number of candidates. Each member was chosen to fill a place on the team. However, each man had been qualified on basis of earlier medical and psychiatric examinations.

There were occasions in the mission when some of the crewmen found themselves at odds. These problems were solved primarily by the motivation for mission success. The post-mission interviews made this clear. More importantly, the crewmen did express preferences as to whom they would or would not accompany on another long-duration journey and these choices were reasonably consistent with the data shown in Figure 2-2.

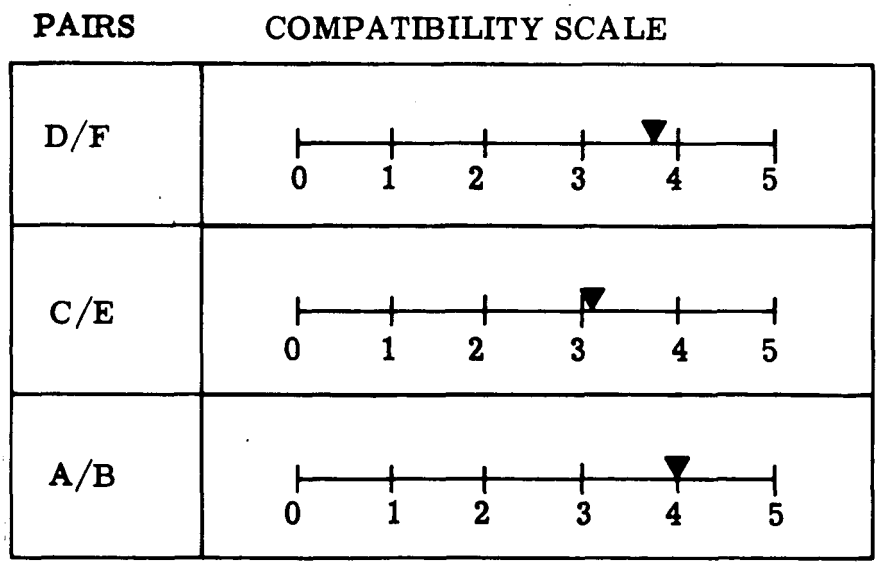


Figure 2-2. Predicted Compatibility of the Six Men in Three Working Pairs

Figure 2-2 considers the men in working pairs. From the psychological test scores a description of each man was prepared. These descriptions, were compared for each of three pairs of men who were scheduled by the task time line to be awake and working at the same time, or who would have to cooperate to perform a set of tasks. Two men might be described in the same terms with regard to one characteristic with the expectation that this becomes a point of potential friction; a very high need for dominance. For another characteristic, say orderliness, the greater the similarity, the more cooperation would be expected.

On the above basis, the compatibility of each of the six men, in specific pairings, was predicted on a 6-point scale. The left side represents "incompatibility"; the mid-point represents ability to complete the mission without the intervention of other crew members with some noticeable friction; number 5 on the scale represents an idealized profile in which every descriptive detail for one man would match or complement, as the case might be, the same descriptive detail for another.

Many of the crewmen individually judged that the vehicle and other crewmen would not be tolerable for periods longer than 30 days. This was said of subjects as divergent as the arrangements for privacy and amount of free space (the vessel's accommodations were said to be tolerable for 30 days but that for longer periods a six-man crew would require more space and, especially, better provision for privacy) and judgments about personality of other crewmen ("I could go with certain individuals just to get a mission accomplished, but if I had to live with a crew for six months, I would insist on having a voice in its selection").

By inspecting the matrices of test scores and evaluating the debriefing interviews, we determined the following: Man A was irritated only by "people noises" (men walking heavily in the passageway and men conversing loudly). He stated, however, that when he called this to the attention of another man (one of the two whose relationship we had marked as negative) the irritation grew much less. Man B remarked in the personal log and in debriefing about his differences with E. Although he denied any incompatibility with Man F, he did remark on Man F's expression of territoriality. Man C remarked on frustrations, most of which he denoted as situational. He also: (1) made a point about other people not appreciating the requirements of his task; and (2) did not seem insistent on avoiding criticism by his

mates. Men D and E responded with only partially concealed rivalry when the anxiety of one or the status needs of the other were challenged. Man E would not choose D, B, or F as companions for another voyage; but carefully and consciously avoided sources of friction during the 30-day period. Man F found reason to assess his relationship to all the other men as compatible.

Additional data relevant to crew compatibility and interactions were obtained from the log as responses to questions asked daily at breakfast, lunch, and dinner. These questions were as follows:

"With whom did you eat?"

"Where?"

"Who prepared the meal?"

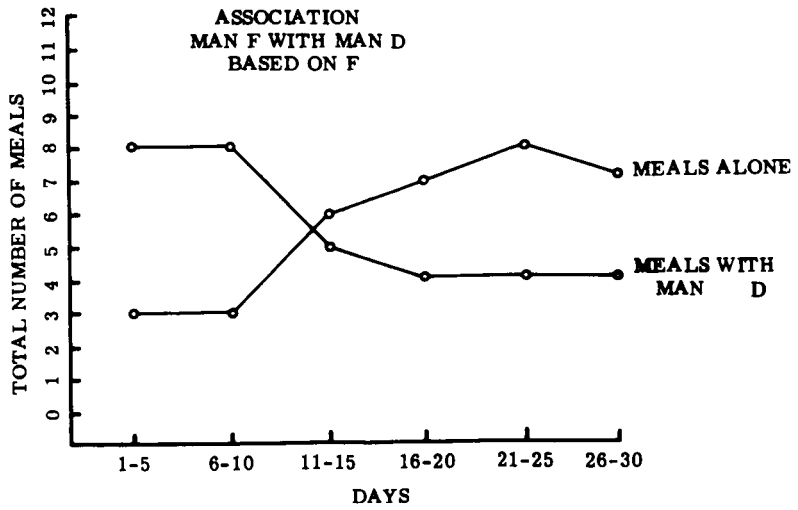
"Who cleaned up?"

The most important information about meal-time associations gleaned from the personal logs resulted from the question "With whom did you eat?" The questions about "Where did you eat," and about "Who cleaned up," and "Who prepared," the food provided little meaningful data. Generally, each man prepared his own food and, by his own account, cleaned up afterwards.

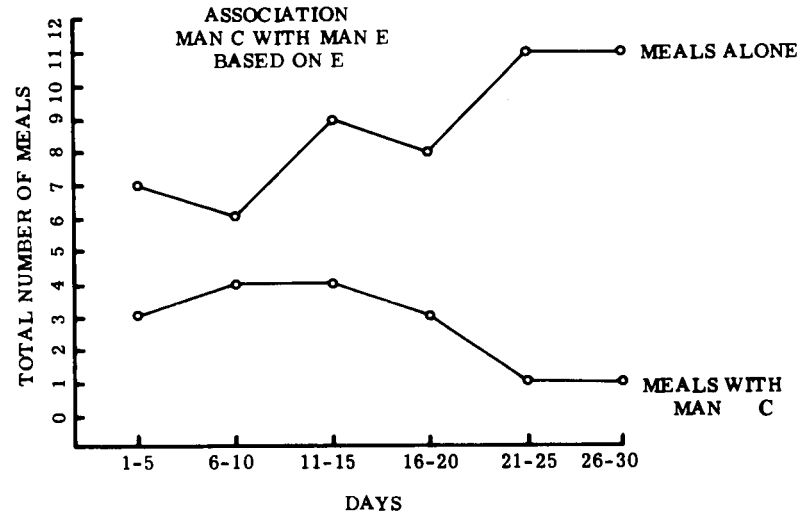
Figure 2-3 shows meal-time associations during the mission; these graphs are based on the personal logs of three of the individuals (men B, E, and F). The six men generally ate in pairs (man F usually ate with man D, man C with man E, and man A with man B) and, therefore, the most noteworthy comparisons are based on the association within each of these pairs.

The number of meals eaten alone and the number eaten with the designated partner do not add to 21 meals a week because some meals were not eaten or a man might eat with several others instead of alone or with his selected partner.

(2-3c)



(2-3b)



(2-3a)

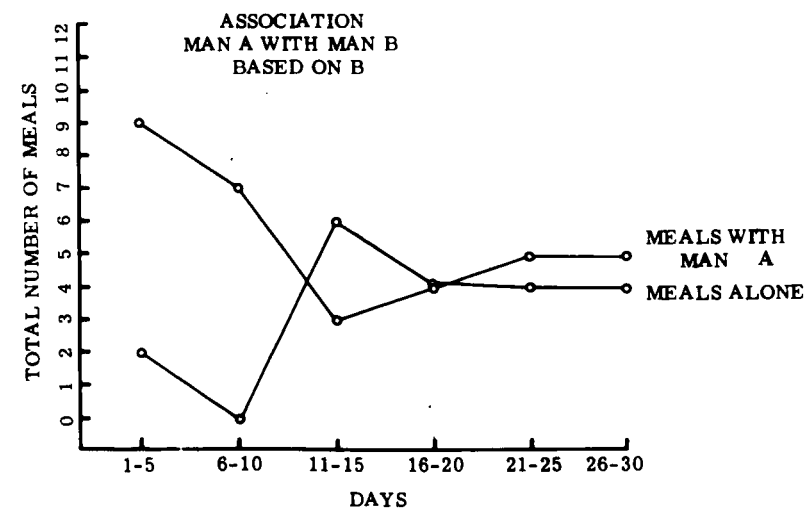


Figure 2-3. Meal-Time Association of Pairs of Crew Members
(Based on Personal Records of 3 Crewmembers)

According to the personal accounts of the three men whose responses were used to prepare Figure 2-3, all were eating more meals alone at the end of the mission than they were at the outset. Indeed, for the first few days, the entire crew (or at least 4 or 5 of the men) ate dinner together. The reason for the change cannot be determined from the available data. As can be seen in Figure 2-3a, man B frequently ate alone during days 11-15; in this time period the subject was under great psychological stress. According to the log report of Man E (Figure 2-3b), he and Man C ate together less and less often as the mission progressed. Man F (Figure 2-3c) by his own account also was eating alone more often at the end of the mission than he was at the beginning. The overall pattern thus was the same for these three crewmen. The original pairings of the men at meal-time were the result of coincidence of task schedules and free time. Although the pairings held throughout the mission, men within the pairs tended to eat alone (at least insofar as they personally were concerned) more frequently as the mission progressed.

Additional insights regarding socialization were obtained from the tapes, the time-lapse photographs, recreational activities, and a log item inquiring about use of free time. Surprisingly enough, very little group activity took place. Poker was played only once and not everyone participated; chess was played twice by the same two men. There is evidence, that need to win was the reason that one of the men sought to play games. Once he had demonstrated his ability to win, the need for more play was over. This same individual showed a strong need to be recognized as an achiever, but his attempts to stimulate other group activity failed. As time went on, the men tended to do more and more things alone unless the operational assignments required them to work together. This tendency to "go it alone" is typical of a confined group and may result, at least in part, from the fact that there is little new to communicate even among those who are compatible.

The Group Confinement Inventory (GCI) was used to measure crew characteristics in relation to adaptability to isolation. The GCI was used in a form adapted from that used by the Naval Medical Research Institute (NMRI). The GCI appeared in the personal log on Days 9, 21, and 28. When the crew members returned to Bethpage, following completion of the mission, they each received a "package" of test material that they were asked to complete and bring with them to the individual debriefing the following morning. The package contained a version of the GCI requesting the respondent to complete the questionnaire in retrospect.

Weighted scores were assigned to the responses and a matrix was prepared. These scores were analyzed by means of a computer program at the Naval Medical Research Institute and 35 factors extracted. The results were compared (by NMRI personnel) to data obtained from laboratory studies of groups in confinement, as well as to control subjects. The GCI measured interpersonal friction by means of a checklist of feelings relating to other members of the crew. Interpersonal compatibility is more important in confined groups than for groups operating in a more enriched environment. The results of the NMRI analysis are described below and in Figure 2-4.

- Negativity toward partners remained at a fairly constant level throughtout the GSDM but increased when the retrospective report was made.

- Negativity about environment increased as the time grew longer.
- General positive feelings were found to be higher in retrospect than at any time during the GSDM.

- Positive feelings toward partners were reported to parallel general positive feeling.
- Annoyance with partners increased steadily throughout the GSDM.
- Annoyance with mannerisms increased gradually throughout the mission and was highest in retrospect. The crew expressed a somewhat higher level of general annoyance than did a comparative group studied by personnel at the Naval Medical Research Institute. The highest level was reported in retrospect.

- General tension increased gradually and was slightly higher in retrospect than on Day 28 of the mission. General tension dropped slightly on debriefing day in the comparison group (NMRI).

- Anger was at a lower level of intensity than was "general tension". Otherwise, the comment of the one applies to the other.

Condition	Pre-Drift	Drift	Post Drift
Negativity to partners		→	↑
Negativity to environment		↑	
Level of annoyance (general)		↑	↑
Annoyance with partners		s ↑	
Annoyance with mannerisms		↑	↑
General tension		g ↑	s ↑
Anger with respect to general tension		↓	
Subject's own anger was remembered		↑	↑
Compatibility 4 wk compared with 3 wk		↓	
Comparison group reported		c ↓	
Conflict between 9-21 day		↑	
Privacy seeking		↑	
Boredom		c ↑	
General positive feelings			↑
Emotional control		c ↑	↑
Compatibility by end of 3rd wk as compared with lst wk		↑	
Cooperation		→	
Consideration		→	
Conflict 21-30 day		↓	
Motivation	↑	→	↑
Morale	↑	→	↑

* c = continuously
g = gradually
s = steady

↑ more or increased
→ same
↓ less or decreased

Figure 2-4. Response of Ben Franklin Crewmembers to Group Confinement Inventory

- Subject's own anger was much like that for the comparison group (NMRI), except that the crewmen of the BEN FRANKLIN in retrospect remembered their anger as greater than they had reported during the mission. The retrospective level of the comparison group was less than they had reported on the 19th day of their study.

- Emotional control increased at each administration of the GCI and was highest in retrospect. For the comparison group, the retrospective score was lowest.

- Compatibility was reported to be greater at the end of the third week than it was at the end of the first week. Crew compatibility was lower by the end of the fourth week than it had been at the end of the first week. The comparison group reported continually declining scores in compatibility.

- Cooperation and consideration remained about constant. This was true also of the comparison group, although their group scores were higher.

- Conflict rose between the ninth and 21st days, and then fell to a level below that of the ninth day.

- Motivation and morale remained high and relatively constant. The crew reported scores slightly higher in retrospect than they did during the drift.

- Motivation reached its lowest level at about the 21st day but increased to early levels during the last quarter of the mission.

- Morale was high throughout the mission. In retrospect, the crew rated their morale higher than they had at the times of the three earlier questionnaires.

- Positive mood was at about the same level as reported for the comparison group.
- Privacy seeking increased with time.
- Boredom with environment increased continuously with time.
- Social penetration was high but dropped slightly with time.

It can be seen in Figure 2-4 that different but not necessarily independent factors were reported as negative or annoying. Nine factors reporting positive feelings remained about the same. Among these were motivation and morale. This indicates that in spite of living under difficult and annoying circumstances, the crew was far from a critical phase. The post-drift reports were as expected in that the crew members remembered the "bad things" as being worse than they were and the "good things" as being better. These data affirm the view that retrospective crew reports may not be valid.

Changes in mood also reflect adaptation to environment. Four times during the mission (on Days 3, 5, 13, and 27) the men were asked to provide a statement of mood. On the days noted, there appeared in the log a page of words that each man was asked to check as applying to himself "not at all," "somewhat or slightly," or "mostly or generally." The first time (on Day 2) he was asked to consider "How you usually feel." From Day 5 on, he was asked "How do you feel." Fifty-five words were selected, by pre-testing, from the Mood Checklist Scales of the Naval Medical Research Institute. Selected words were included from the scales for happiness, fear, depression, psychological well-being, and lethargy.

The data were evaluated by scoring the "negative" words (from anger, fear, depression, lethargy scales) and the "positive" responses (happiness, well being). Values of zero to two were assigned to the level to which a word applied. Zero was assigned to "not at all"; 1 for "somewhat"; and 2 for "mostly." The results shown in Figure 2-5a through 2-5e are the numerical averages for the negative and positive words for five crewmen (one did not provide sufficient data). Positive moods are represented above the neutral line and negative scores are shown below it.

Two of the crewmen were more variable than the other three for whom data are available. Scores for two men (Figs. 2-5b & 2-5d) indicate a mood of depression on Day 13, about halfway through the mission. On this day, the BEN FRANKLIN was under tow and the men generally were uncomfortable because of wave action and an increase in environmental temperature. One man (subject B) clearly was more liable than the other crewman; this subject's sense of psychological well-being decreased considerably between Day 5 and Day 13, in correspondence with an increase in level of depression (Figure 2-5b). By late in the mission (Day 27), however, his sense of depression had greatly decreased, and, additionally,

his sense of overall psychological well-being had increased slightly from the low level of Day 13. When the patterns of self-reported moods of this individual are related to his scores on the Langley device, it is seen that there was a sharp drop-off in his ability to perform this task. Mood scores of the remaining men generally were stable throughout the mission (Figures 2-5a, 2-5c, 2-5e). Three of the five subjects reported a continuous but low level of fear. Level of fear did not increase in conjunction with changes in sense of psychological well-being or depression or both. Level of fear for one crewman (Figure 2-5a) appears to have increased slightly near the end of the mission.

The crew was asked on 14 different days to report the "most frustrating thing" and "the most important thing" that happened. The information from this source overlapped that from others, such as reports on feelings, attitudes, and complaints about environment. Questions about frustration and important events were intended to provide an additional source of information on the one hand and to provide some measure of opinion of importance on the other. Responses are summarized in Figures 2-6 and 2-7. It is notable that each crewman was frustrated by different things. It is equally notable that none of them was a world-shaking matter, but each was the kind of little thing that could cause a major, important operation to run down. It also is relevant that the frustrating things reported were characteristic of the personalities of the crewmen and were directly relatable to their profiles.

The reports on most "important thing that happened" show considerably more overlap (Figure 2-7). References to sighting of fish, an attack by a swordfish, diving to the bottom, all were matters of common concern and reflected the success of the mission. Reference to relief from environmental factors such as the comment "Next bottom dive is only 4 hours" by three people emphasizes the discomfort experienced during dives. This was verified in the debriefings. As in the case of the previous question, these responses also reflect the work assignments and personalities of crew members involved.

The "Sleep Recall Questionnaire" appeared as the first item in the log on Day 1, 8, 15, 22 and 29; thus, each man was asked to complete the questionnaire once a week. Additionally, each man was asked on each of the other days to rate the quality of the previous night's sleep on a 4-point scale of fitfully, poor, well, and extremely well.

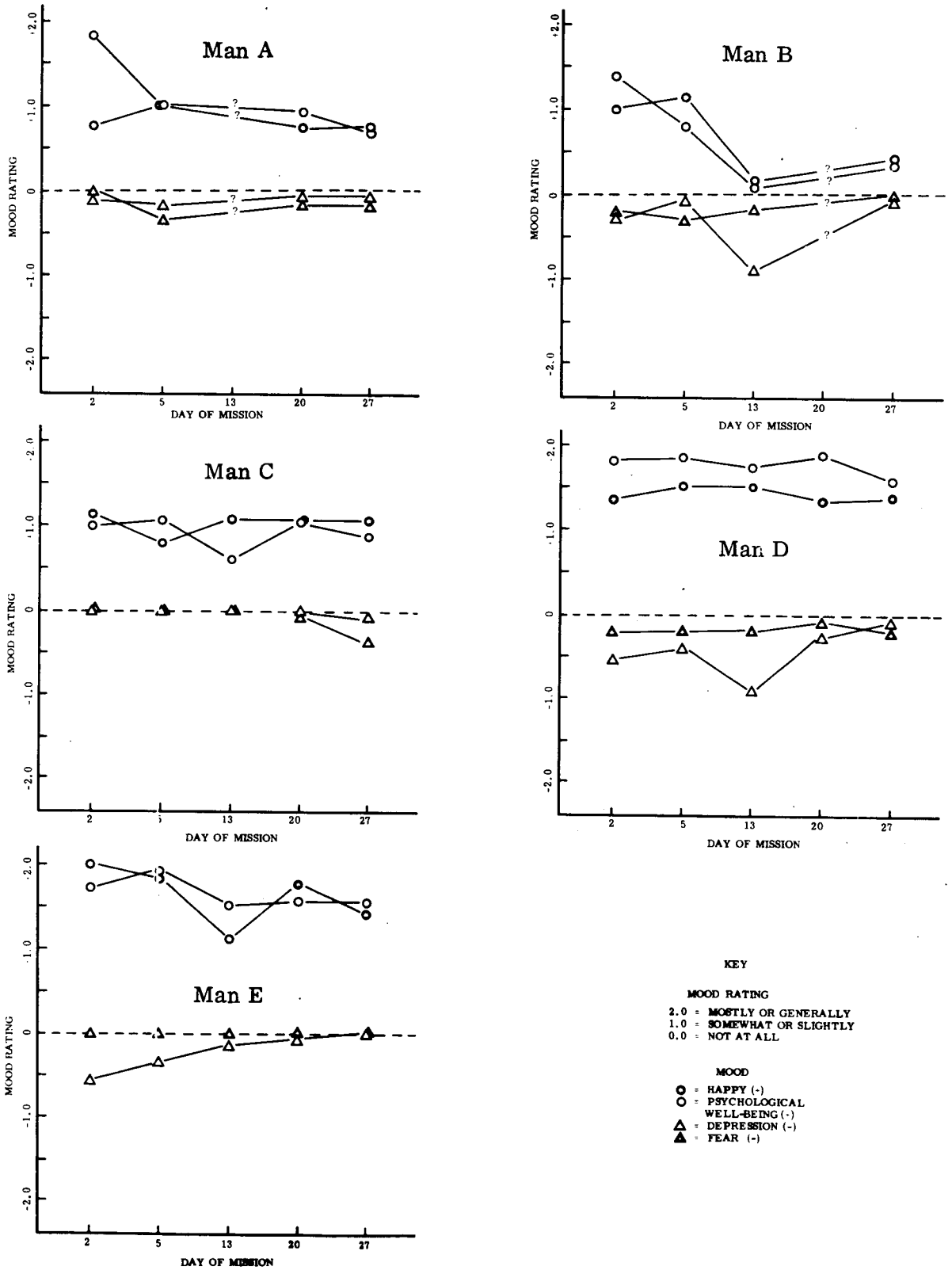


Figure 2-5. Subjective Sense of Well-Being for 5 Crewmen

Response	Crewman					
	A	B	C	D	E	F
Equipment		1	2			
Food			1			
Surface Ship			1			
Navigation			1		1	
Leaving GS				1		
Lack Spare parts			1			
Operation			1			
No free time		1				
Time to get data		3				
Need for tow		1				
Could not celebrate anniversary		1				
Mistake in game		1				
Temperature	1					
Family news	1					
Lack of conversation	1					
No fresh food	1					
Food bad					1	
Shaky table						1
Absence of sea life						1
No time for photos						
Lack coordination with NAVOCO						
Loss of hot H_2O						
Loss communication with PRIVATEER				1		
Macerator out				1		
Bumping obstructions					3	
Cleaning head alone					1	
Difficulty sleeping (noise)				1	4	
Eating utensils					1	
Boat keeps going up				1		
Pressure from top side				1		
Lack of hot H_2O				1		
Dull day				1		
Depth				1		
Log too long				1		
Bad weather in recovery zone				1		

Figure 2-6. Frequency of Crew Responses to the Question: "The Most Frustrating Thing That Happened Today"

Response	Crewman					
	A	B	C	D	E	F
DSL			2			
Fish attack		1	1	1		
Acoustic run			1		1	
Being in eddy		1	1		1	
Surfaced			1	2	1	1
Birthday		1	1			
Halfway	1		1		1	
Sighting tuna	1	1	1	1		
Apparent breach of confidence			1			
News about surfacing			1			
Last day	1	1	1		1	
H_2O lacked iodine		1				
Helped fix macerator		1				
Lunar landing	2	1		2	1	4
Bottom excursion	1	1		3	3	1
Next bottom dive will last only 4 hrs.	1	1				1
Change of course		1				
Finishing dives		1				1
News		2				
No message from home		1				
Discussion of what crew will do topside		1				
Position too far west	1					
Drive with motors	1				1	
Cabin comfortable at 600 ft.	1					
Perfect stability	1				1	1
BF made good way	1					
New position for BF	1					
Watch whales	1					1
Order dinner for surfacing	1					
Descend to 500 ft.	1					
No correction needed for drift						1

Figure 2-7. Frequency of Crew Responses to the Question: "The Most Important Thing That Happened Today." (Sheet 1 of 2)

Response	Crewman					
	A	B	C	D	E	F
Interesting bottom						1
Weather improving						1
Hot water				1		
Sleeping good 7 hrs.				1	1	
Eating					2	
Reading					1	
Inability to sleep					1	
Extension of time by 15 hours					2	
Breakdown of recorder					1	
Out of Gulf Stream				1		
Lost key to locker				1		
High spiral drift				1		
Instability of boat				2		
Passed 1000 mile mark				1		
Bad weather (hurricane)				1		
End of Log				1		
Boat Operating OK				1		
Temperature up to 65° F				1		

Figure 2-7. Frequency of Crew Responses to the Question: "The Most Important Thing That Happened Today." (Sheet 2 of 2)

A method for assessing quality of sleep during the mission was desired because: (1) sleep disturbances frequently are reported during confinement and isolation and difficulty in sleeping or not being refreshed by sleep can increase fatigue and thus reduce proficiency; and (2) complaints about the inability to sleep or to be refreshed by sleep could be an indication of increasing anxiety. The "Sleep Recall Questionnaire" was adapted from that of Maurice Steinberg, M.D. (Naval Medical Research Institute). A scoring scheme developed by the investigators and applied to the Sleep Recall Questionnaire was used to analyze these data. It provides a single numerical value to describe the difficulty in sleeping. The higher the score, the more difficult the crewman's experience in sleeping. This number was derived as follows: The items were numbered from 1 to 11. Items 1, 2, 4, 5 and 10 are 7-point scales. Items 3 and 8 permitted 5 possible answers. These were scored 1 to 5; the shortest time was 1 and the longest time was 5. For item 7 the 7-point scale was used, scoring 8 as zero. The scores for 9 and 10 were reversed so that the meaning of "better/worse" would be scored the same way. Items 6 and 11 were eliminated because they are not scalable. The sleep scores reported in Figure 2-10 are the mean of the scores for each crewman for Days 1, 8, 15, 22, and 29.

Figure 2-8 shows the mean scores for each man for each of the days on which he responded to the questionnaire and Figure 2-9 is a scatter diagram of the same data. It is evident that Man A had considerably more difficulty with all aspects of sleeping during the first half of the mission than did the rest of the crewmen. This may have been due to the location of his bunk (the exact location of the bunk is not revealed in order to avoid identification of the man) and to his task assignment.

Man B reported increasing difficulty in sleeping in conjunction with reported changes in level of psychological well-being. Thus, whereas Man A adjusted by Day 22 to the ambient noise and level of activity that made his bunk an unfavorable location for sleeping and to his disruptive routine as well, Man B's difficulty in sleeping probably increased, at least in part, as a result of psychological stresses.

These data differ slightly from those summarized in the previous paragraph. Thus, a man who had difficulty falling asleep, but then slept well, would report having had a good night of sleep on one questionnaire but would be scored as having a fairly poor quality of sleep on basis of the Sleep Recall Questionnaire.

	MISSION DAY				
MAN	1	8	15	22	29
A	1.5	5.0	5.8	3.7	1.6
B	2.1	2.2	2.2	4.3	4.1
C	2.8	1.6	1.7	3.4	---
D	3.0	.18	1.6	5.0	1.3
E	2.7	2.7	1.4	3.8	2.1
F	1.3	2.7	1.7	---	2.4
$\overline{X}$ =	2.2	2.7	2.4	4.0	2.3

Numbers are qualitative measure of difficulty in sleeping, the higher score representing the greater difficulty in sleeping.

Figure 2-8. Scores from the Sleep Recall Questionnaire

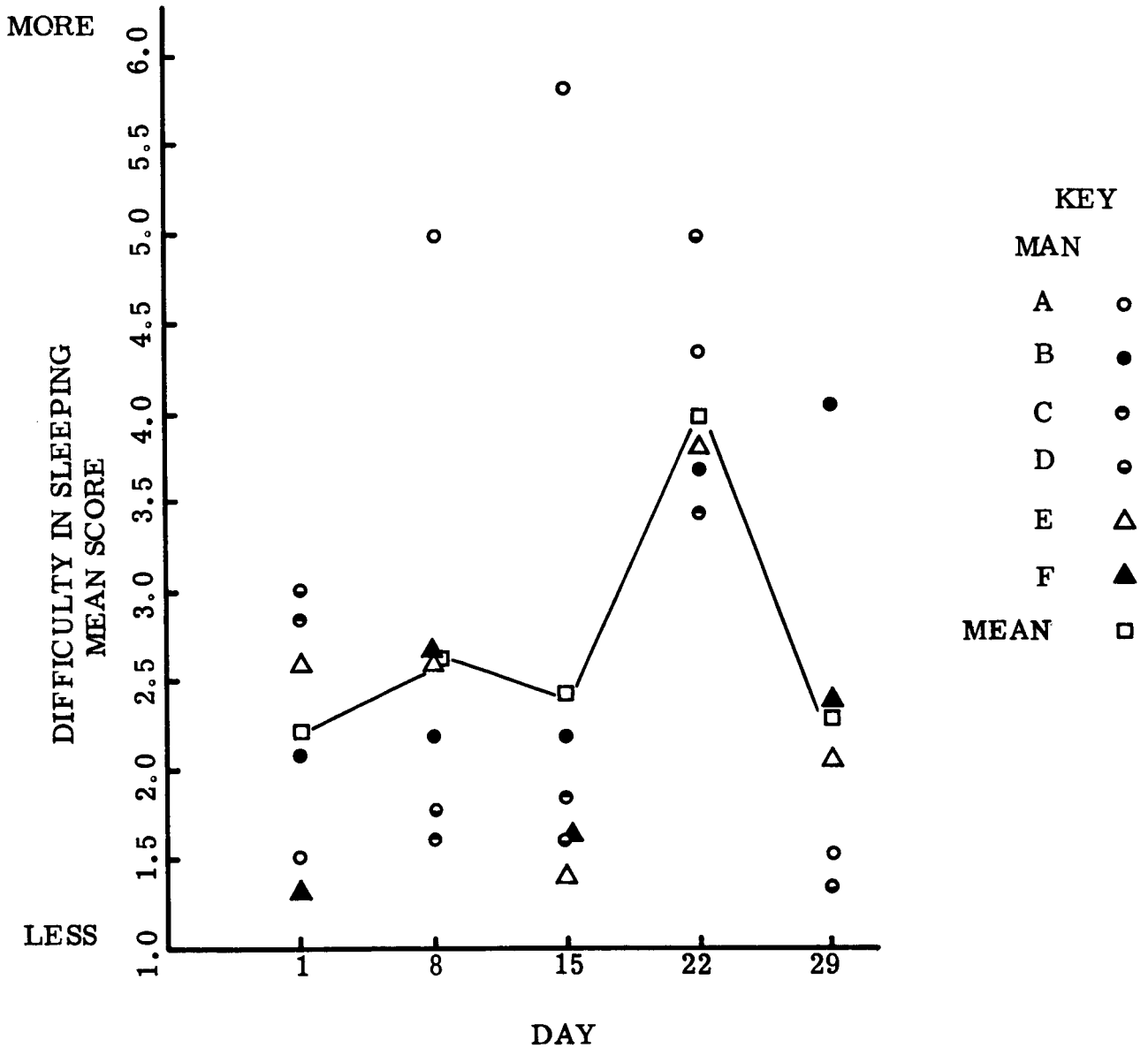


Figure 2-9. Scatter Diagram of Data from Sleep Recall Questionnaire

Because the scoring system applied to the Sleep Questionnaire does not yield a ratio scale, no significance is to be attached to the size of differences. These data are not properly subject to statistical tests of differences or significance.

Responses to the question about how well each crewman slept indicate that overall Man A was the most consistent, having had "poor" sleep only early and late in the mission (Figure 2-12). Man B slept well from Day 3 through Day 10 but thereafter often slept fitfully or poorly. In a total of 17 reports he stated that he had slept poorly or fitfully on 12 occasions and had slept well on only 5 nights. These data correspond well with the data from the Sleep Recall Questionnaire (Figures 2-8 and 2-9). Men C and F slept erratically, ranging from having slept "extremely well" to "fitfully" (Figure 2-10). Man D also reported erratic sleep during the first half of the mission; his pattern in the second half is somewhat cyclic, indicating that he would sleep poorly one day and then sleep well for several days before again having difficulty sleeping. Subsequent to Day 10, Man F slept poorly or fitfully until late in the mission (Day 26). On Days 20 through 23, he simply reported that he slept "so-so" and therefore this portion of the graph of his data has been left blank (Figure 2-10).

Data on quality of sleep were compared to work-rest schedules to detect any possible role of circadian rhythm in change of sleeping habits. It was found that erratic sleep or generally poor sleep did not obviously relate to a break in the normal sequence of day and night. It is possible, of course, that the many other factors (such as psychological stresses and interpersonal problems) masked any effects relatable to alteration in circadian rhythm. The number of hours slept each night was deduced from other data in the logs. Because the work schedules were extremely varied, a matter not fully anticipated, the replies relating to hours slept are ambiguous. Figure 2-11 presents these data for 5 crewmen. With some notable exceptions (that were related to mission objectives) most of the subjects spent approximately 8 hours a day in bed. The time in bed was not, however, directly related to effectiveness of sleep in recovering from the previous day's activity.

Performance and behavior in general are affected by quality of sleep. Improvements in the location of bunks to assure greater privacy, isolation from sudden noises, and shielding from light could improve quality of sleep. Even more important than improvement

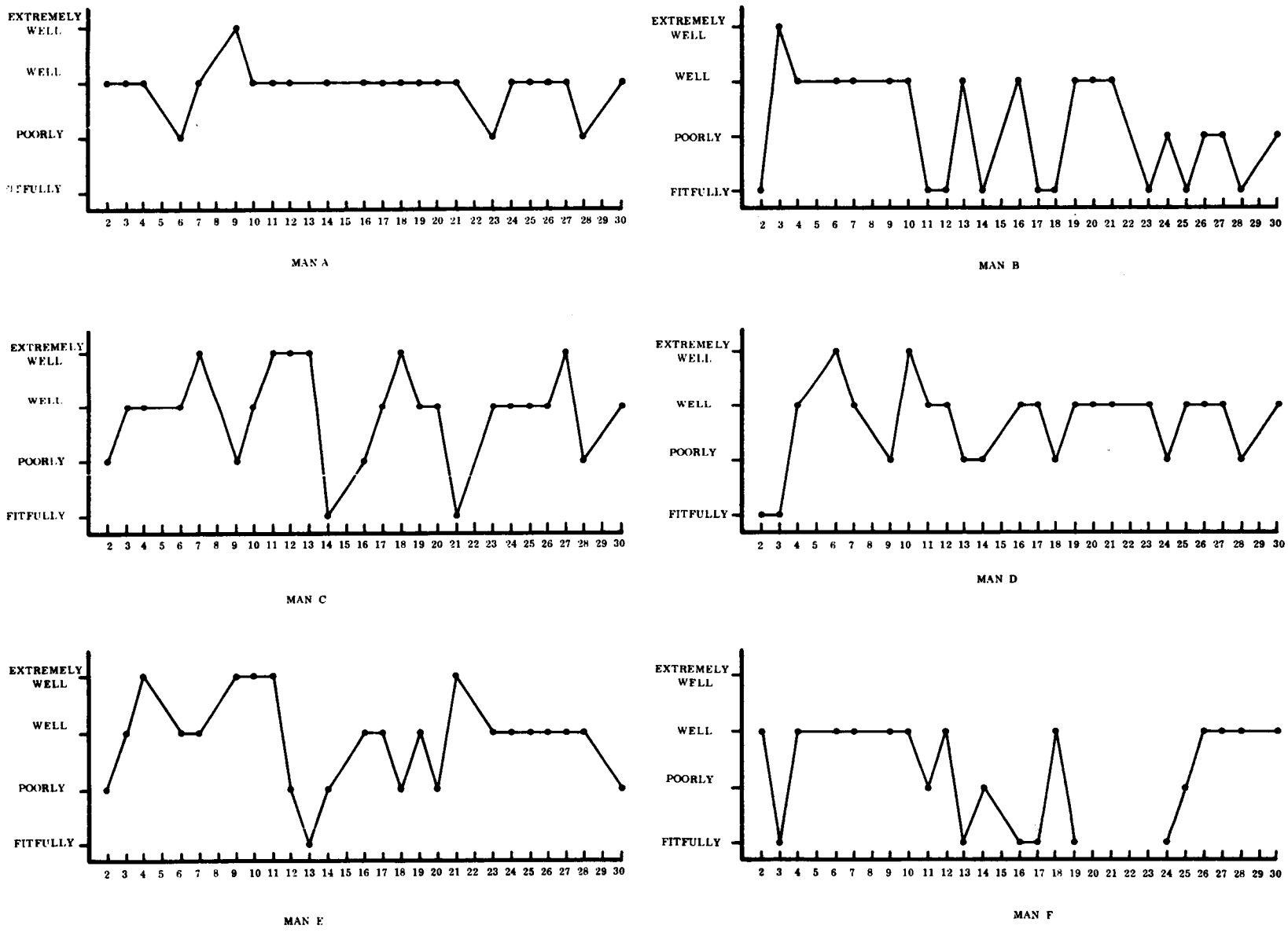


Figure 2-10. Quality of Sleep

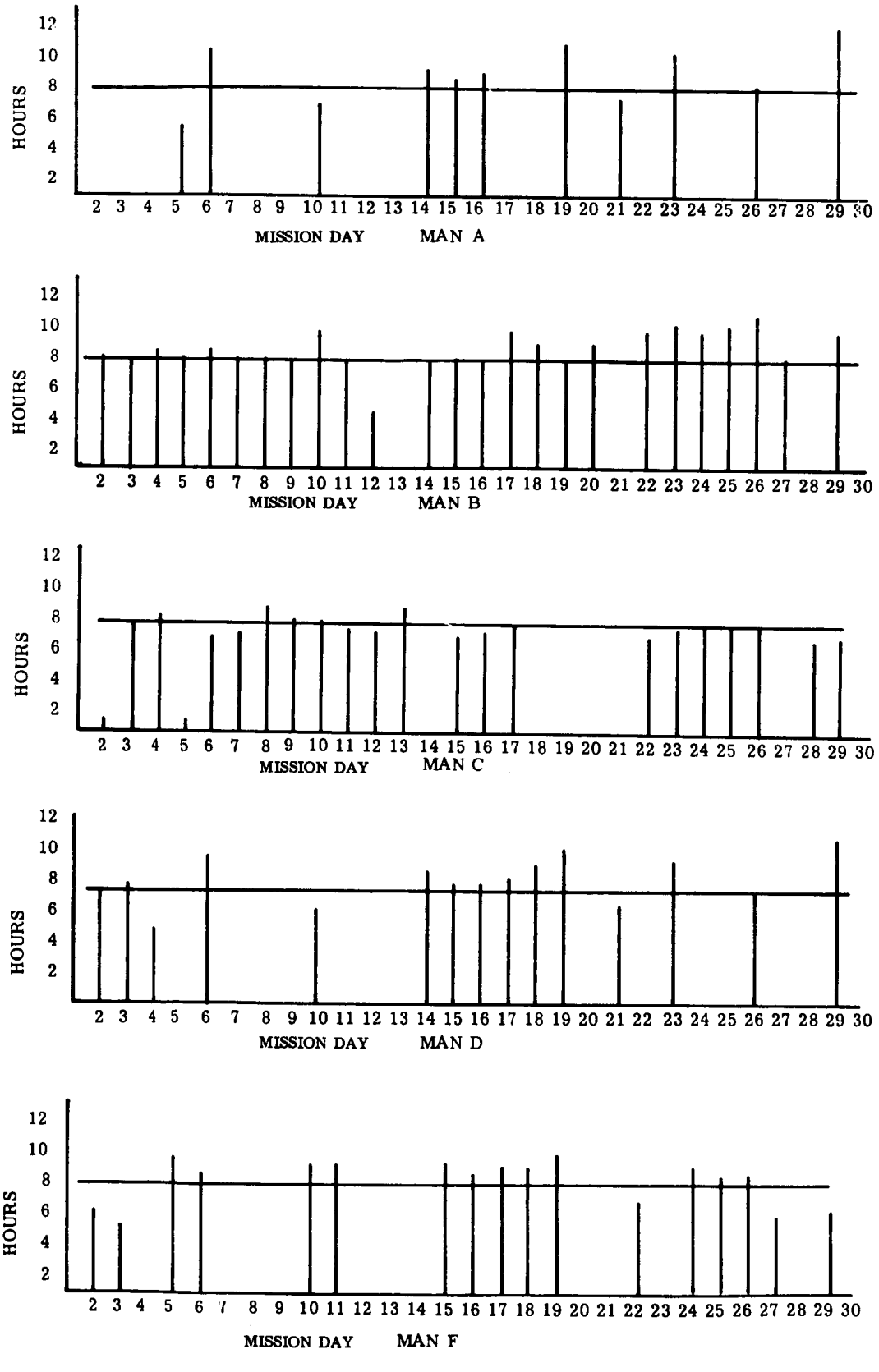


Figure 2-11. Hours in Bunks for 5 Crewmen

of facilities to assure sound sleep is the "management" of the stimuli that affect the individual psychologically. In this regard we have in mind, for example, the manner in which information about family is communicated and contributes to or causes anxiety.

The Subjective Stress Scale (SSS) was completed on 3 occasions (Days 4, 11 and 25), and on the second day after the drift. The results reported in Figure 2-12 show the words selected by each subject to describe "how one feels now" in comparison with how one normally feels.

The crew of the BEN FRANKLIN, as indicated by this scale, exhibited no signs of stress. There are other data that disagree with this. An examination of the list of 15 words from which the crew was able to choose (Figure 2-13), suggests that with the possible exception of "nervous" none of the "negative" words could be used to express anything but extreme reaction. The choices did not provide a range to cover the milder reactions to stress such as what we observed elsewhere. Because of its lack of sensitivity, this test is not recommended for inclusion in future studies.

On Days 6, 7, 20 and 27, each crew member was asked to rate a list of personal attributes of crew members. The attributes to be rated were: physical strength; neatness; quiet; argumentative; religious; talkative; and stubborn. Space was provided for the insertion of other attributes on which the individual was willing to comment. The rating scale read "necessary", "desirable, not important," and "undesirable." The use of the questionnaire permitted men who in many characteristics resemble the population from which space station crews will be chosen, to judge what characteristics should be sought in men to be selected to live together in a closed, isolated environment. Furthermore, because the investigators were acquainted with the individuals who were the respondents, it was hoped that results of this questionnaire would help to validate the pre-mission judgements made by clinical evaluation.

Each of the logs was inspected for each day on which appeared the questionnaire about personal attributes. Additionally, personal characteristics for crew selection was discussed with each of the men in debriefings. The investigators also discussed this privately

DAY	MAN					
	A	B	C	D	E	F
4	comfortable	fine	steady	fine	fine	comfortable
11	comfortable	fine	steady	fine	fine	comfortable
25	comfortable	fine	fine	fine	fine	comfortable
25	comfortable	fine	fine	fine	fine	comfortable
R*	--	fine	fine	fine	fine	comfortable

* Debriefing Day

Figure 2-12. Choices on the Subjective Stress Scale

1. Timid	6. Unsafe	11. Frightened
2. Steady	7. Terrible	12. Unsteady
3. Wonderful	8. Worried	13. Fine
4. Comfortable	9. In agony	14. Nothing bother
5. Nervous	10. Indifferent	15. Scared Stiff

Figure 2-13. List of Response Words in Subjective Stress Scale

with each of the men during the pre-mission interviews. From these sources, it was determined that the crew would seek men who are neat, quiet, cooperative, and who show consideration for others. The crewmen believed that argumentative or stubborn people are incompatible. There was general agreement that the members of a crew should have the opportunity to judge each other.

Additionally, the specialists among the crew believed that their own specialty should be better covered. Therefore, although each man was considered well-qualified in a particular scientific specialty, he recognized the need for help with his task.

During the course of the drift an incident occured that placed one of the crewmen (Man B) under severe psychological stress. This was the only such incident during the entire mission. Overtly, Man B carried on most of his duties although there are evident lapses in the diary. Figure 2-14 is a smoothed-out presentation of information on this crewman and includes data from meals taken alone and mood data. These graphs show that during the middle of the mission there was considerable change in psychological integrity. This change was associated with the stress experienced by this crewman. Examination of the psychological profile of this man indicates that the strength of the response is consistent with the clinical description made prior to the mission.

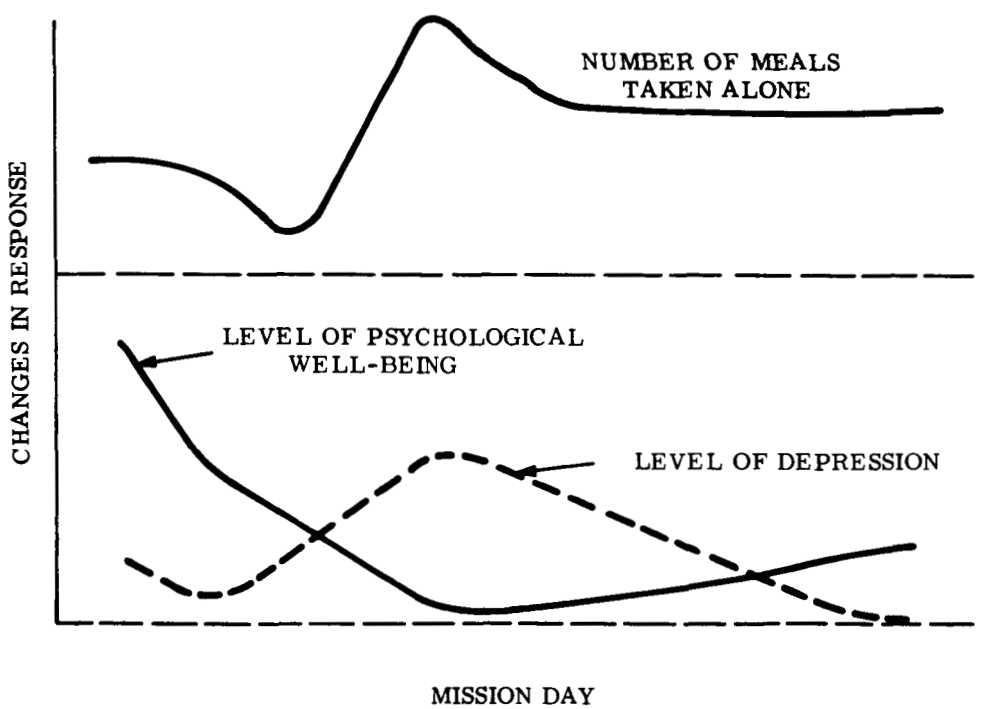


Figure 2-14. Comparison of Results from Two Sources of Information for Man B During the Mission

2.3 Performance

Starting on Day 6 and about once a week thereafter, each man was asked:

- "Do you have enough time to accomplish your assigned duties"?
- "Could you perform additional duties"?

Figure 2-15 shows that with a few minor exceptions the crewmen were able to perform their assigned duties. In the first week or so of the mission, however, the men spent as much as 12-16 hours to accomplish tasks that later were completed in 6-8 hours. In response to the inquiry regarding additional tasks, three of the crew indicated they could have taken on additional duties; three thought that they were fully occupied (Figure 2-16).

Those crewmen who reported availability for additional duties (Figure 2-16), in the opinion of the writers, correctly evaluated the situation. In some instance, it was due to the nature of their specialization and reason for participation in the drift.

The observation that additional planning and training would not have significantly changed the observed pattern of behavior and the inference that personal characteristics determine a "style of behavior" is a subject of importance with respect to the success of long-duration missions and probably deserves more thorough examination in future studies. "Style of behavior" did not in any concrete way change the outcome of the drift mission. There is no doubt, however, from the comments in the logs and particularly from the debriefing that "style" was getting to the men. The observation by several of the crew that under no circumstances would they undertake another expedition with the same crew supports this.

Analysis of responses to log questions about tasks and timelines revealed the following; (1) The men did not attempt rigid adherence to the time-lines. They believed that detailed, rigid time-lines would be "hopelessly inoperative". There was a great deal of improvising. This, in the opinion of the men, was "good". They believed that the time-lines as given to them (the mission profile) were properly conceived because they allowed for that adjustment and served as guides. Improvising was not something they had to do but something that they were able to do; (2) The duty cycle was too long, because it was based on the terrestrial 24-hour day; (3) In the early days of the mission, work used up all the available time.

MAN	Day								Totals		
	3	6	12	16	19	23	26	29	Y	N	-
A	Y	Y	Y	Y	Y	Y	Y	-	7	0	1
B	N	N	Y	N	Y	Y	Y	Y	5	3	0
C	N	N	Y	Y	Y	Y	Y	Y	6	2	0
D	Y	Y	Y	Y	Y	Y	Y	Y	8	0	0
E	Y	Y	Y	Y	Y	Y	Y	Y	8	0	0
F	Y	-	-	Y	Y	Y	Y	Y	6	0	2

Code: Y = yes N = no - = left blank

Figure 2-15. Summary Responses to Question of Whether or not Individual Crewmen Had Time to Accomplish Their Assigned Duties

MAN	Day											Total			
	3	5	6	8	11	14	17	20	23	26	29	N	Y	?	-
A	Y	N	N	N	N	N	N	N	N	N	N	10	1	0	0
B	N	N	N	N	N	N	N	N	?	Y	Y	8	2	1	0
C	N	N	N	N	N	N	N	N	N	N	N	11	0	0	0
D	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	0	11	0	0
E	N	N	Y	N	Y	Y	-	Y	Y	Y	Y	3	7	0	1
F	-	Y	-	-	-	-	-	Y	-	Y	-	0	3	0	8

Code: Y = yes N = no ? = uncertain - = left blank

Figure 2-16. Summary of Responses to Question of Whether or not Individual Crewmen Could Have Handled Additional Duties

(4) The crew was task-oriented. They considered getting the task done important and the timelines as unimportant. (5) Recognized shortcomings in human-engineering were readily compensated for in ship operation. (6) Space per man becomes more important as missions grow in length. The crew thought that another man could not be accommodated for 30 days in the available space.

The Langley Research Center Complex Coordinator was developed at NASA-Langley by Dr. J. Scow. The device illustrated in Figures 2-17 and 2-18 was included in our inventory of tests because NASA personnel thought that performance on the device could be extremely responsive to changes in environmental, psychological, and physiological variables.

As noted previously, the crewmen practiced with the intent of reaching a plateau of performance prior to the mission. This was achieved for men B and E. The others, with the exception of F, came close. Only 1 test, which consisted of a block of 50 sequential reactions, was permitted each day during the drift. It was our judgement that 1 test per day would not add to the skill level and, therefore, changes in score would be relatable to changes occuring during the mission. Alternative schemes involving multiple tests were rejected because the devices used too much electrical power. It was listed as one of the first tests to be dropped if battern problems developed during the drift.

The Langley device was normally set up once each day by the NASA engineer. Each crewman operated the equipment for one test. The subject estimated the total time required to solve 50 problems and estimated how many of the 50 problems would require time in excess of that allowed and set into the device. After the 50-problem test, each man entered in his log the total time and the actual number of problems which required more than the allowed time for completion. The device was set to require that the solution be held for 0.2 seconds before the crewman could continue to the next test. Thus, a uniform level of difficulty was maintained. Scores on the Langley device for the six crewmen are as shown in Figures 2-19, a, b, c, d, and e.

Crewman A apparently improved, even with but one run a day, reaching a plateau on Day 22. The variability in his scores, especially the marked drop on Day 10 cannot be explained on the basis of available data.

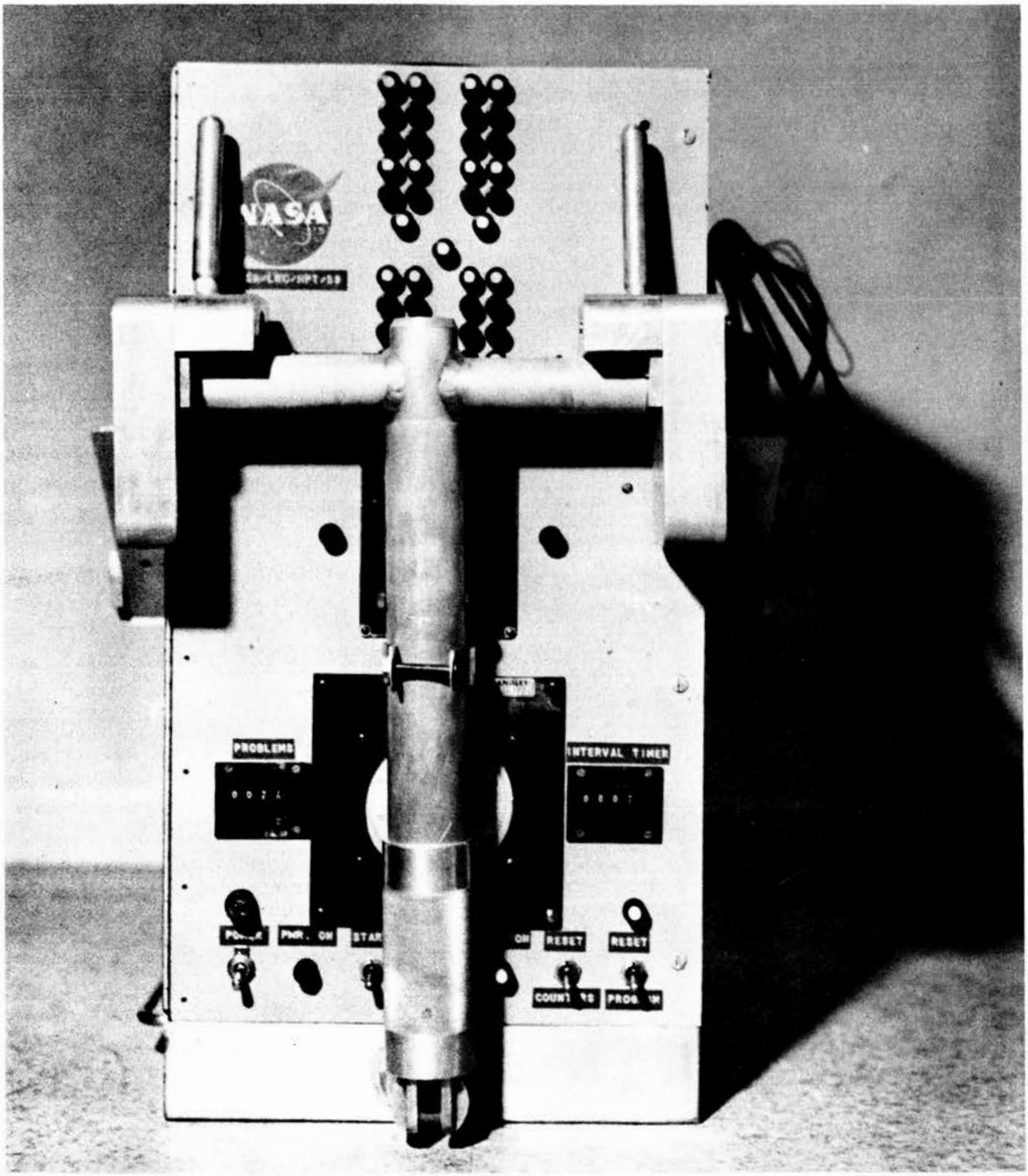


Figure 2-17. Top View of NASA-Langley Research Center Complex Coordinator

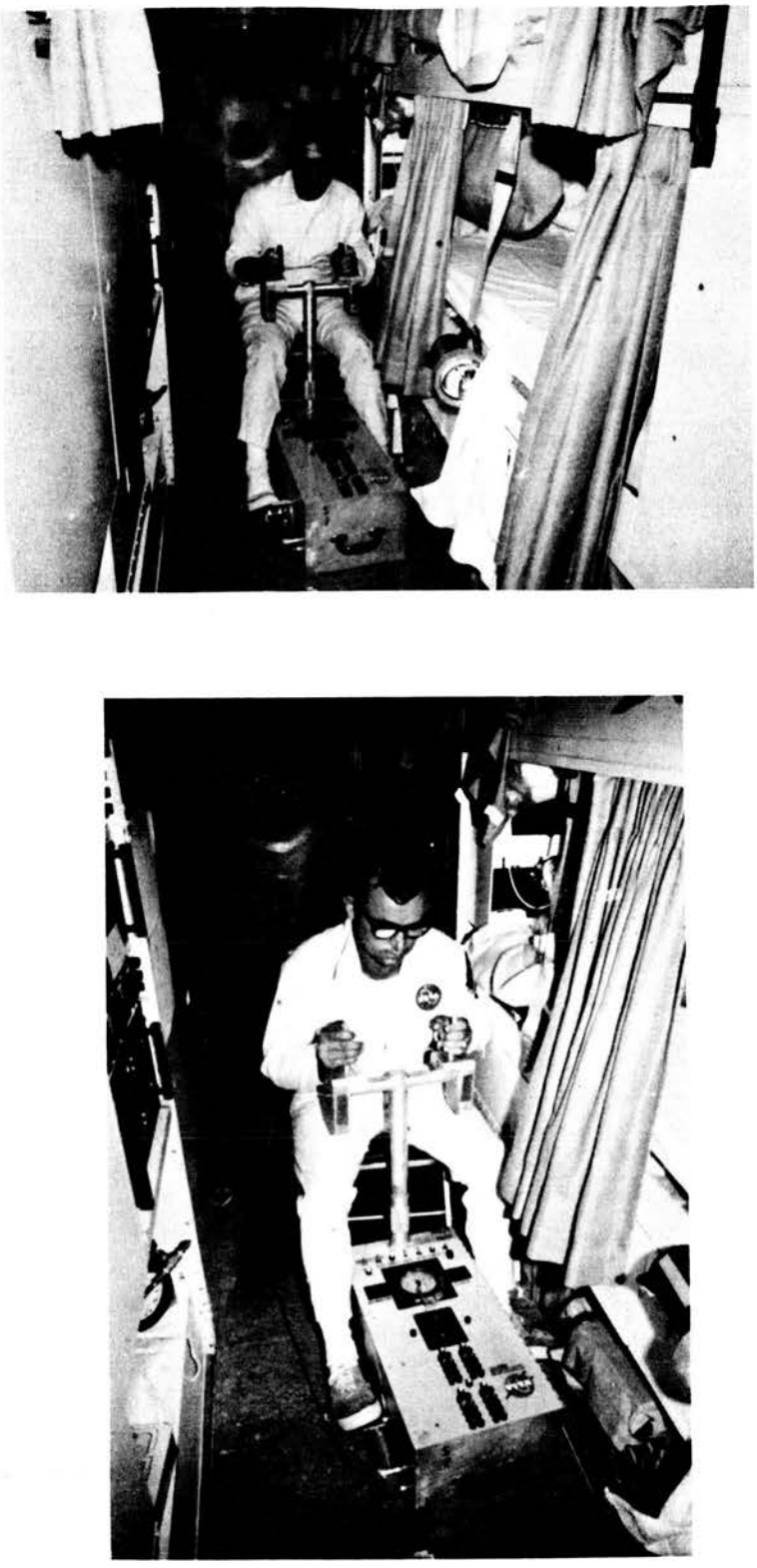


Figure 2-18. Two Crewmen Performing Daily Tests on the Langley Research Center Complex Coordinator (LRC)

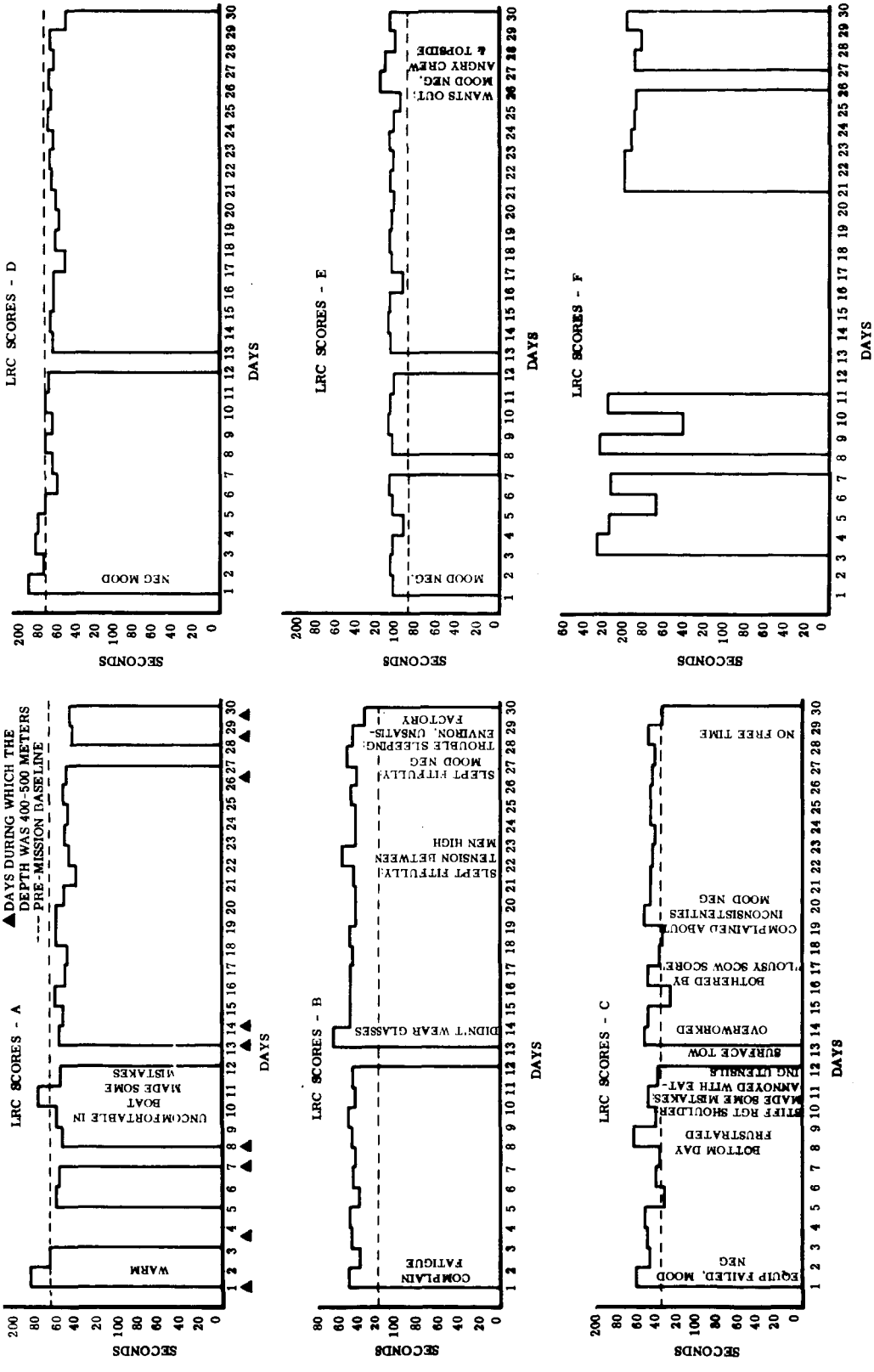


Figure 2-19. Crewmembers' LRC Scores During Mission

Crewman B was well-practiced and made consistently low scores during the pre-mission practice period. The 20 percent increase in his scores during the mission is notable. This crewman was anxious and eager to succeed. His decrease in proficiency may be due to his anxiety. That the coordinator scores reflect changes in psychological state is suggested further by the marked increases in score near the mid-point of the mission. This change in score correspond to an increase in this crewman's reports of stress.

Crewman C, also well-practiced, did not perform as well during the drift as he had during the pre-mission phase. This subject was stressed more during the initial phase of the drift than later, which was to be expected from the nature of his assignment. The gradual decline may show learning or accommodation to the environment. The large increase in scores between Day 8 and Day 30 seems to be related to some of the annoyances or frustration.

Crewman D was well practiced but did not perform as well in the beginning of the drift as he did later. The higher scores may be related to the fact that his psychological profile and behavior showed marked signs of anxiety. The beginning of the drift unquestionably was the most stressful part of the mission for this crewman.

Crewman E was the most practiced and skilled of the crewman but his scores also were consistently higher during the drift (by about 15%) than they were prior to the mission. It maybe reasonable, to say that the higher scores reflect the reaction of this man to "stress." The scores for the last 3 days are slightly higher than for the rest of the mission. The last 3 days were especially tense for this man and tend to confirm that the scores on the coordinator reflect changes in psychology.

Crewman F was the least practiced and it is uncertain as to whether or not he reached a plateau prior to the mission. During the drift, he recorded scores for only 16 of the thirty days. Considering the lack of scores, no attempt was made to evaluate these data.

Generally it can be stated that scores appeared to show the expressed psychological state of the crew. Overall, scores seemed to increase with level of stress and depression of mood. Further investigative work needs to be performed with this device under controlled laboratory conditions in order to establish effective programs for its use and in order to relate changes in scores to intensity of stimuli.

2.3.1 Subjective Reports of Performance

The crewmen were requested on Days 3, 7, 11, 15, 19, 23 and 27 to respond to a questionnaire on their level of proficiency in "performance of scientific tasks." The results are summarized in Figure 2-20. On the same days three of the crewmen responded also to a questionnaire about "ship operation and control". These data are shown in Figure 2-21.

Man A reported lowest proficiency in the middle portion of the drift mission. On Days 11, 15, and 19, he noted that he had made mistakes and that the elimination of certain checkpoints necessitated redoing an operation. On Day 15, at a time when difficulties existed for almost all of the crewmen, Man A wrote that his ability to concentrate decreased and that he became fatigued while carrying out assigned tasks. Although his overall efficiency and interest increased up to and including Day 15, Man A reported that these aspects of his performance leveled off in the remainder of the mission. This crewman was one of three who filled out the questionnaire on ship operation and control. In this area of responsibility, he reported no loss of proficiency. The self-reports of proficiency of Man A could not be related to his sleeping pattern (Figure 2-9).

Man B reported on Day 2 that he sleft fitfully. Day 3 was difficult for this man, who wrote that he made mistakes, missed operations, became fatigued, and failed to collect all of the data as scheduled (Figure 2-20). His analysis was that his overall efficiency had decreased. Days 7 and 11 went somewhat better for this crewman. In conjunction with this he reported elsewhere in the daily logs that he was sleeping well, (Figure 2-10). On Days 15, 19, 23 Man B was bored with his assigned tasks, his level of interest decreased, his level of concentration was poor (Days 19, 23), and he missed operational steps and had to repeat procedures (Days 15, 19). Man B slept poorly or fitfully on nights preceeding days on which the questionnaire was presented (Figure 2-9). Day 27 apparently went smoothly for this crewman.

Crewman C, whose tasks were complex, reported having made minor mistakes on six of the seven days on which the performance questionnaire was presented (Figure 2-20). Even so, he felt that his overall level of efficiency remained the same. Insofar as this

Topic	Responses For Days						
	3	7	11	15	19	23	27
Did you make any mistakes today?	N	N	Y	Y	Y	N	N
Did you skip operations or check points and have to start over?	N	N	Y	Y	Y	N	N
Did you lose any data because you forgot to replace a tape?	N	N	N	N	N	N	N
Did you have any near misses?	N	N	N	Y	N	N	N
Was the procedure sufficiently planned or did you have to extemporize?	N	Y	N/Y	I had to extemporize	N	-	N/Y
Did your concentration wander?	N	N	N	a little	N	N	N
Did your interest increase or decrease?	increase	increase	increase	increase	same	same	same
Did you get tired (fatigued) doing the experiment?	Y	N	N	Y	N	N	N
Did you get bored?	N	N	N	N	N	Y	N
Did the performance of surface facilities cause your difficulty? (includes operators)	N	Y	N	N	N	N	N
Do you think your overall efficiency is up or down?	N	up	up	up	same	same	same
Did you obtain all the data you scheduled for this run?	Y	Y	Y	Y	-	-	Y

CODE: N = No
Y = Yes
- = Blank

Figure 2-20. Responses of Man A to Log Questions Concerning "Performance of Scientific Tasks." (Sheet 1 of 6)

Topic	Responses For Days						
	3	7	11	15	19	23	27
Did you make any mistakes today?	Y	N	N	N	N	N	N
Did you skip operations or check points and have to start over?	Y	Y	N	Y	Y	N	N
Did you lose any data because you forgot to replace a tape?	N	N	N	N	N	N	N
Did you have any near misses?	Y	Y	N	N	N	N	N
Was the procedure sufficiently planned or did you have to extemporize?	Y	Y	Y	I had to extemporize	extemporize	-	OK
Did your concentration wander?	N	Y	Y	N	Y	Y	N
Did your interest increase or decrease?	steady	Y	same	decrease	decrease	decrease	same
Did you get tired (fatigued) doing the experiment?	Y	N	N	Y	N	N	N
Did you get bored?	N	N	N	Y	Y	Y	N
Did the performance of surface facilities cause your difficulty? (includes operators)	N	N	N	-	N	N	N
Do you think your overall efficiency is up or down?	down	same	same	-	same	same	same
Did you obtain all the data you scheduled for this run?	N	Y	Y	-	Y	Y	Y

CODE: N = No
Y = Yes
- = Blank

Figure 2-20. Responses of Man B to Log Questions Concerning "Performance of Scientific Tasks." (Sheet 2 of 6)

Topic	Responses For Days						
	3	7	11	15	19	23	27
Did you make any mistakes today?	N	Y	Y	Y	Y	Y	Y
Did you skip operations or check points and have to start over?	N	N	N	N	N	N	N
Did you lose any data because you forgot to replace a tape?	N	Y	N	N	N	N	N
Did you have any near misses?	N	N	Y	Y	Y	Y	Y
Was the procedure sufficiently planned or did you have to extemporize?	Y	Y	Y	-	-	-	-
Did your concentration wander?	N	N	N	N	N	N	N
Did you interest increase or decrease?	increase	static	static	static	static	N	static
Did you get tired (fatigued) doing the experiment?	Y	N	N	N	N	N	N
Did you get bored?	N	N	N	N	with log	with log	with log
Did the performance of surface facilities cause your difficulty? (includes operators)	N	N	Y	-	Y	Y	N
Do you think your overall efficiency is up or down?	normal	static	static	-	static	static	static
Did you obtain all the data you scheduled for this run?	N	Y	N	-	-	Y	N

CODE: N = No
Y = Yes
- = Blank

Figure 2-20. Responses of Man C to Log Questions Concerning "Performance of Scientific Tasks." (Sheet 3 of 6)

Topic	Responses For Days						
	3	7	11	15	19	23	27
Did you make any mistakes today?	N	N	N	N	N	N	N
Did you skip operations or check points and have to start over?	N	N	N	N	N	N	N
Did you lose any data because you forgot to replace a tape?	N	N	N	N	N	N	N
Did you have any near misses?	N	N	N	N	N	N	N
Was the procedure sufficiently planned or did you have to extemporize?	Y	Y	Y	OK	sufficient	sufficient	N
Did your concentration wander?	N	N	N	N	N	N	N
Did your interest increase or decrease?	N	no change	-	decrease	same	same	N
Did you get tired (fatigued) doing the experiment?	N	N	N	N	N	N	N
Did you get bored?	N	N	N	N	N	N	N
Did the performance of surface facilities cause your difficulty? (includes operators)	N	N	N	N	Y	N	N
Do you think your overall efficiency is up or down?	down	up	up	up	same	up	same
Did you obtain all the data you scheduled for this run?	Y	Y	N	Y	-	Y	Y

CODE: N = No
Y = Yes
- = Blank

Figure 2-20. Responses of Man D to Log Questions Concerning "Performance of Scientific Tasks." (Sheet 4 of 6)

Topic	Responses For Days						
	3	7	11	15	19	23	27
Did you make any mistakes today?	Y	-	N	Y	N	N	N
Did you skip operations or check points and have to start over?	Y	N	N	N	N	N	N
Did you lose any data because you forgot to replace a tape?	Y	N	N	Y	N	N	N
Did you have any near misses?	Y	N	N	Y	N	N	N
Was the procedure sufficiently planned or did you have to extemporize?	N	-	N	Y	Y	Y	Y
Did your concentration wander?	N	Y	N	N	N	N	N
Did your interest increase or decrease?	increase	level	N	N	same	decreased	same
Did you get tired (fatigued) doing the experiment?	N	N	N	N	N	N	N
Did you get bored?	N	N	N	N	Y	Y	N
Did the performance of surface facilities cause your difficulty? (includes operators)	Y	N	N	-	N	Y	Y
Do you think your overall efficiency is up or down?	up	up	up	-	up	down	down
Did you obtain all the data you scheduled for this run?	N	Y	Y	-	N	Y	N

CODE: N = No
Y = Yes
- = Blank

Figure 2-20. Responses of Man E to Log Questions Concerning "Performance of Scientific Tasks." (Sheet 5 of 6)

Topic	Responses For Days						
	3	7	11	15	19	23	27
Did you make any mistakes today?	N	N	N	N	N	N	N
Did you skip operations or check points and have to start over?	N	N	N	-	N	N	N
Did you lose any data because you forgot to replace a tape?	N	N	N	-	N	N	N
Did you have any near misses?	N	N	N	-	N	N	N
Was the procedure sufficiently planned or did you have to extemporize?	-	-	N	-	-	Y	sufficient
Did your concentration wander?	N	N	N	N	N	N	N
Did your interest increase or decrease?	-	same	same	same	same	same	same
Did you get tired (fatigued) doing the experiment?	-	N	N	N	N	N	N
Did you get bored?	N	N	N	N	N	N	N
Did the performance of surface facilities cause your difficulty? (includes operators)	N	Y	N	N	N	N	N
Do you think your overall efficiency is up or down?	-	up	same	same	same	same	same
Did you obtain all the data you scheduled for this run?	-	N	N	Y	-	N	Y

CODE: N = No
Y = Yes
- = Blank

Figure 2-20. Responses of Man F to Log Questions Concerning "Performance of Scientific Tasks." (Sheet 6 of 6)

Topic	Responses For Days						
	3	7	11	15	19	23	27
Did you make any mistakes in ship operation today?	N	N	N	N	N	N	N
Did you skip any operations and have to start over?	N	N	N	N	N	N	N
Did you meet all of the requirements of the scientific plan?	Y	Y	Y	Y	-	-	Y
Did an experiment have to be run again because of ship operation?	N	N	N	N	N	N	N
Did you have any trouble navigational controlling?	Y	N	N	N	N	N	N
Did you almost make an error which you caught in time?	N	N	N	N	N	N	N
Was the procedure sufficiently planned or did you have to develop it as you went along?	N	some	N/Y	N/Y	-	-	N/Y
Did you get tired (fatigued)?	Y	N	N	A little	N	N	N
Was it hard to concentrate?	N	N	N	N	N	N	N
Did you get bored with the repetition?	N	N	N	N	N	N	N
Do you think your overall efficiency is up or down?	N	Up	Up	Up	same	same	same
Did the crew make your job more difficult by changing the mission profile?	?	N	N	N	N	N	N
Are the ship controls and displays well suited for the purpose?	Y	Y	Y	Y	Y	Y	Y
Do you have too many things to do at once?	N	N	N	N	N	N	N
Could top side have made your job easier?	N	N	N	N	N	N	N

CODE: N = No Y = Yes - = Blank

Figure 2-21. Responses of Man A to Log Questions Concerning "Ship Operation and Control." (Sheet 1 of 3)

Topic	Responses For Days						
	3	7	11	15	19	23	27
Did you make any mistakes in ship operation today?	N	N	N	N	-	Y	N
Did you skip any operations and have to start over?	N	N	N	N	-	N	N
Did you meet all of the requirements of the scientific plan?	N	Y	Y	Y	-	Y	N
Did an experiment have to be run again because of ship operation?	N	N	N	N	-	N	N
Did you have any trouble navigational controlling?	N	N	Y	N	-	Y	N
Did you almost make an error which you caught in time?	N	N	N	N	-	N	N
Was the procedure sufficiently planned or did you have to develop it as you went along?	Y	Y	Y	OK	-	sufficient	sufficient
Did you get tired (fatigued)?	Y	N	N	N	-	N	N
Was it hard to concentrate?	Y	N	N	N	-	N	N
Did you get bored with the repetition?	N	N	N	N	N	N	N
Do you think your overall efficiency is up or down?	down	up	up	up	same	up	-
Did the crew make your job more difficult by changing the mission profile?	N	N	N	N	N	N	N
Are the ship controls and displays well suited for the purpose?	N	N	N	N	fair	N	fair
Do you have too many things to do at once?	N	N	N	N	N	N	N
Could top side have made your job easier?	N	N	N	N	N	N	N

CODE: N = No Y = Yes - = Blank

Figure 2-21. Responses of Man D to Log Questions Concerning "Ship Operation and Control." (Sheet 2 of 3)

Topic	Responses For Days						
	3	7	11	15	19	23	27
Did you make any mistakes in ship operation today?	N	-	N	N	N	N	N
Did you skip any operations and have to start over?	-	-	N	N	N	N	N
Did you meet all of the requirements of the scientific plan?	-	N	-	Y	-	-	Y
Did an experiment have to be run again because of ship operation?	-	-	-	N	N	N	N
Did you have any trouble navigational controlling?	N	N	Y	N	N	Y	N
Did you almost make an error which you caught in time?	N	-	N	N	N	N	N
Was the procedure sufficiently planned or did you have to develop it as you went along?	-	-	Y	Y	-	-	Y
Did you get tired (fatigued)?	N	N	N	N	N	Y	N
Was it hard to concentrate?	N	N	N	N	N	N	N
Did you get bored with the repetition?	N	N	N	N	N	N	N
Do you think your overall efficiency is up or down?	-	same	same	same	same	same	same
Did the crew make your job more difficult by changing the mission profile?	N	N	Y	N	N	N	N
Are the ship controls and displays well suited for the purpose?	-	Y	Y	Y	Y	Y	Y
Do you have too many things to do at once?	N	N	-	-	N	N	rarely
Could top side have made your job easier?	N	Y	Y	N	N	N	N

CODE: N = No Y = Yes - = Blank

Figure 2-21. Responses of Man F to Log Questions Concerning "Ship Operation and Control." (Sheet 3 of 3)

individual is concerned, problems with performance did not appear to be related to quality of sleep. Instead, his difficulties stemmed from equipment failures and difficulties with crewmen on the surface ships.

Man D reported few difficulties with performance of scientific tasks and ship operation and control (Figures 2-21). Day 23 was the most troublesome; on that day this crewman noted mistakes in operation and problems with navigation and control.

Days 3 and 19 were the most difficult for Man E in terms of accomplishment of assigned tasks (Figure 2-20). These days were preceded by nights on which quality of sleep was poor (Figure 2-10). Crewman E also reported, on Days 19 and 23, that he was bored with his tasks.

Man F left more questions unanswered than did any of the other crewmen. Overall, this man felt that his efficiency and interest remained stable. He also reported few difficulties in operation of the vehicle and performance of tasks (Figure 2-20). He did, however, note that not all scheduled data was collected.

In summary, subjective reports of performance varied from man to man but most of the crewmen reported difficulties early in the mission, which would be expected because the men were adjusting to a new and difficult environment. Additionally, several of the men noted decreases in performance during the middle portion of the drift, when stresses were greatest. Quality of sleep probably indirectly affected performance.

This attempt to obtain data about performance by having crewmen report about themselves proved to be more productive than expected. It appears that effort directed at generating and recording such information could result in a process even more informative and useful than was the one used in this mission.

2.4 Recreation

The men were asked almost daily how they spent their free time. Additional comments were solicited on a daily basis and the "human-engineering" check lists also contained questions about recreation. The onboard tapes, the post-mission debriefings, and sampling of the time-lapse photographs offered additional evidence of how the men spent their time and how they socialized.

Recreational materials had been chosen on the basis of pre-mission interviews. A cassette tape player, a number of musical tapes, playing cards, a scrabble board, drawing pads, water colors, a chess set, and a dart board were provided. Additionally, all of the men included technical and fiction books in their personal gear.

The items of relevance in the personal log, were "How did you spend your free time today?" and two questions that appeared once a week, "During this week, did you have enough room for recreation?" and "What changes would you like to see?"

When all of the data sources were reviewed, listening to music proved to be the most frequent leisure-time activity of the crew. This included one man who had stated in advance that he thought the music on board would be a disrupting influence. The tape player was in use almost continuously, especially between 1900 and 2300 hours, when all of the men tended to be awake and gathered in the "wardroom" (forward hemisphere). Only one set of stereo earphones was provided and thus there were times when more than one man wanted to listen to music and could not do so without disturbing others. It is recommended that for all future missions enough sets of earphones be provided to accommodate the entire crew. The dart board was a popular, much used game. The equipment for painting and most of the other hobby materials were not used at all. The one man who ordinarily did an appreciable mount of sketching did it in his diary. Chess was played, but not to any great extent, by two of the men. Poker was played only once.

Free time increases during long missions in isolation because the crewmen:

- Learn to accomplish work more efficiently; during the GSDM the work day decreased from 12-16 hours in the beginning to 6-8 hours later
- Eliminate certain tasks as irrelevant - during the drift the planned record keeping regarding the food was ignored;
- Are unable to do certain tasks because of equipment failure - during the drift - certain of the oceanographic equipment failed, thus reducing the work load.

Because free time must be filled, a mission must be planned for such contingencies. A flexible scientific program, innovative scientists among the crew, and a wide range of acceptable recreational facilities are among the possibilities.

In our pre-drift inquiries regarding crew preferences for recreation we found (as have others before us) that many of the preferred activities (swimming, tennis, golf, and basketball were impossible in vehicles of this type. The great interest in the dart game as well as the motivation to operate the "game-like" Langley device suggest that investigation might provide the basis for developing activities that yield equivalent psychological satisfaction to that ordinarily obtained through the preferred outlets.

2.2.5 Training

It appears from the logs, that more training would have been helpful. Responses of the crewmen to questions about preparation are summarized in Figure 2-22. Twelve to sixteen hours were required to complete tasks in the beginning of the mission that were later completed in 6 to 8 hours.

The significant reduction in time to perform planned tasks is almost entirely attributable to the fact that the men were unable to practice their assigned duties on the BEN FRANKLIN in the drift configuration before the mission began. As previously observed, the crew members were together for the first time as an operating team at the start of the drift. The decrease in time to perform duties indicates that there was consolidation of separate tasks and skills into an effective work schedule during the mission. To some degree this also was true of the operation of the BEN FRANKLIN since the Captain never before had operated a submersible under these conditions. He said that he would have to "go slow" at first and find out about the handling characteristics of the BEN FRANKLIN.

Figure 2-23 is a summary of crew responses to an inquiry regarding the need for additional technical skills. It will be observed that all but one crewman felt a need for some additional skills. It would be impossible to relate these skills to the crewmen without disclosing their identity, consequently, it must suffice to note that there were additional requiremments for skill in oceanography, biology, and an particularly strong need for more knowledge in electricity and electronics. It is not unworthy of notice, however, that during any mission some unidentified problems almost surely will arise. The need for individuals of broad background and demonstrated ingenuity as problem solvers is indicated. As previously noted, the successful completion of the GSDM was due in part to having such a crewman aboard.

Day	Man					
	A	B	C	D	E	F
4	No	Yes	No I could have done with more practice time.	No	No	No
12	No	Yes From the standpoint of knowing the system maintenance better.	Yes I could have done with more sea trials instead of being out on two short trips	Yes We learned a few things (minor) that would have helped	Yes	Yes We should have known more about the boat.
20	No	No	Yes too short (sea trials were not enough)	Yes	No	-
28	-	No	No More trial times would have been useful	No	No	-

Figure 2-22. Summary of Responses to the Question: "Could You Have Been Better Prepared for the Mission?"

Man	Day							Totals		
	3	7	11	15	19	23	27	Y[1]	N	-
A	N	N	N	N	-	N	N	0	6	1
B	Y	N	N	Y	Y	Y	N	4	3	0
C	Y	Y	Y	Y	Y	Y	Y	7	0	0
D	Y	Y	Y	Y	Y	Y	Y	7	0	0
E	Y	Y	Y	Y	Y	Y	Y	7	0	0
F	Y	-	Y	-	N	-	N	2	2	3

[1] The combined additional skills included electrical, electronics, oceanography, biology.

Code: Y = yes
N = no
- = left blank

Figure 2-23. Summary of Responses to Question of Whether or not Individual Crewmen Thought That Additional Technical Skills Could Have Been Used

SECTION 3.

PHYSIOLOGICAL ADAPTABILITY

3.1 PHYSICAL CONDITION

Physical condition of the crewmen was measured before, during, and after the mission. Daily readings from the hand dynamometer were plotted for each crewman. Although the dynamometer is not an especially sensitive measure of strength, it is suitable for demonstrating gross changes. On this basis, none of the subjects had any noteworthy loss of strength resulting from the mission (Figure 3-1). One man (subject A) slightly increased his scores with both hands and attained his maximum readings by Day 21. The second crewman (subject B) also showed an increase, especially with his right hand; he reached his maximum readings by Day 16 and remained fairly constant thereafter. Dynamometer readings for Man C increased only slightly (to about Day 10) and then became relatively stable. No decrease in strength was indicated by his score. Man D also showed a slight increase, but varied considerably from day to day, especially with his right hand. Man E was interesting because of the inconsistency of his scores. This individual (who is righthanded) showed an increase with his right hand until Day 15 when his readings decreased only to increase again on Day 22. It is of additional interest that the scores for the left hand decreased slightly; it is unclear as to whether or not the decrease was due to slight loss of strength in the left arm or to some psychological factors, such as disinterest or unwillingness to exert maximum effort. The daily dynamometer readings for Man F were fairly stable and showed no noteworthy increase or decrease throughout the 30-day mission. Judging from these data, none of the six crewmen lost strength in his wrists and forearms as a result of confinement and reduction or change in usual physical activity.

Although our data on cardiac output are limited, two patterns are worthy of discussion. First, for each of the crew members, the differential between pre- and post-exercise pulse rates remained essentially the same throughout the mission. The increase in pulse rate following specific exercise on Day 30 did not differ significantly from that of Day 2. A tendency for an increase over time in differential pulse rates following exercise would have been taken as an indication of deconditioning. Secondly, the pre-exercise pulse rates of several crew members decreased in variability about Day 18 (Figure 3-2). It was noted that although temperature and concentration of oxygen

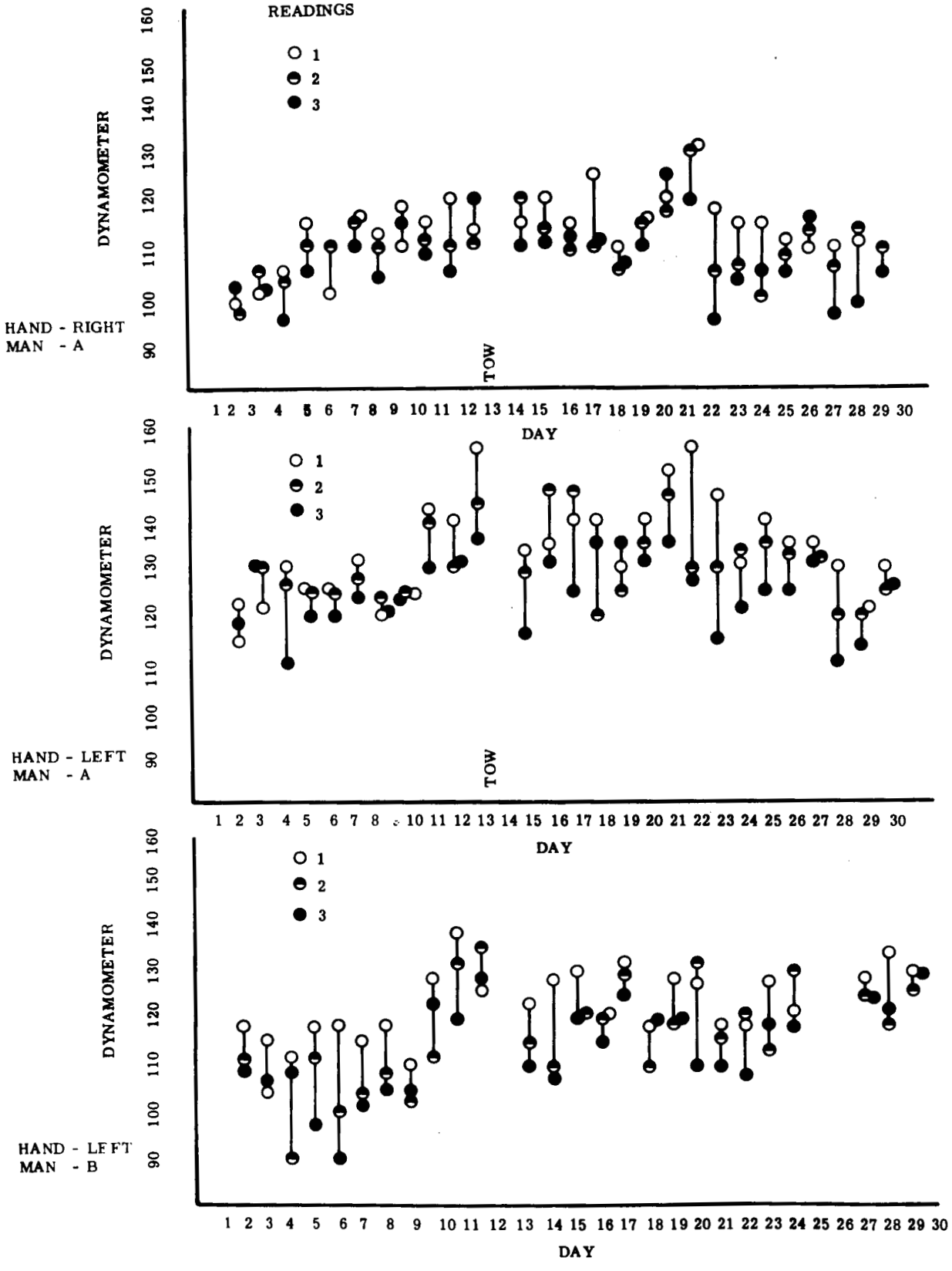


Figure 3-1 Dynameter Reading Sheet 1 of 4

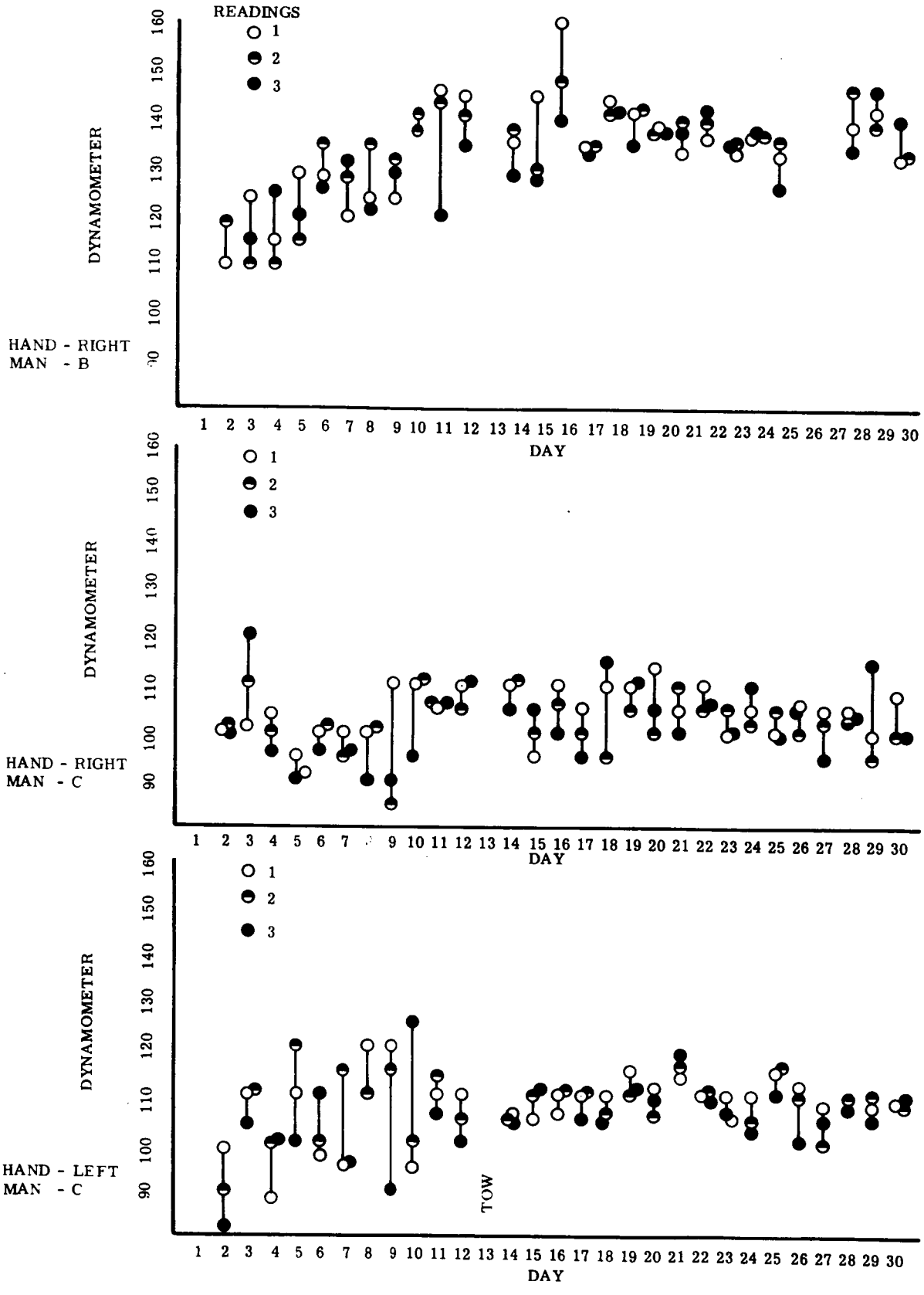


Figure 3-1 Dynameter Reading Sheet 2 of 4

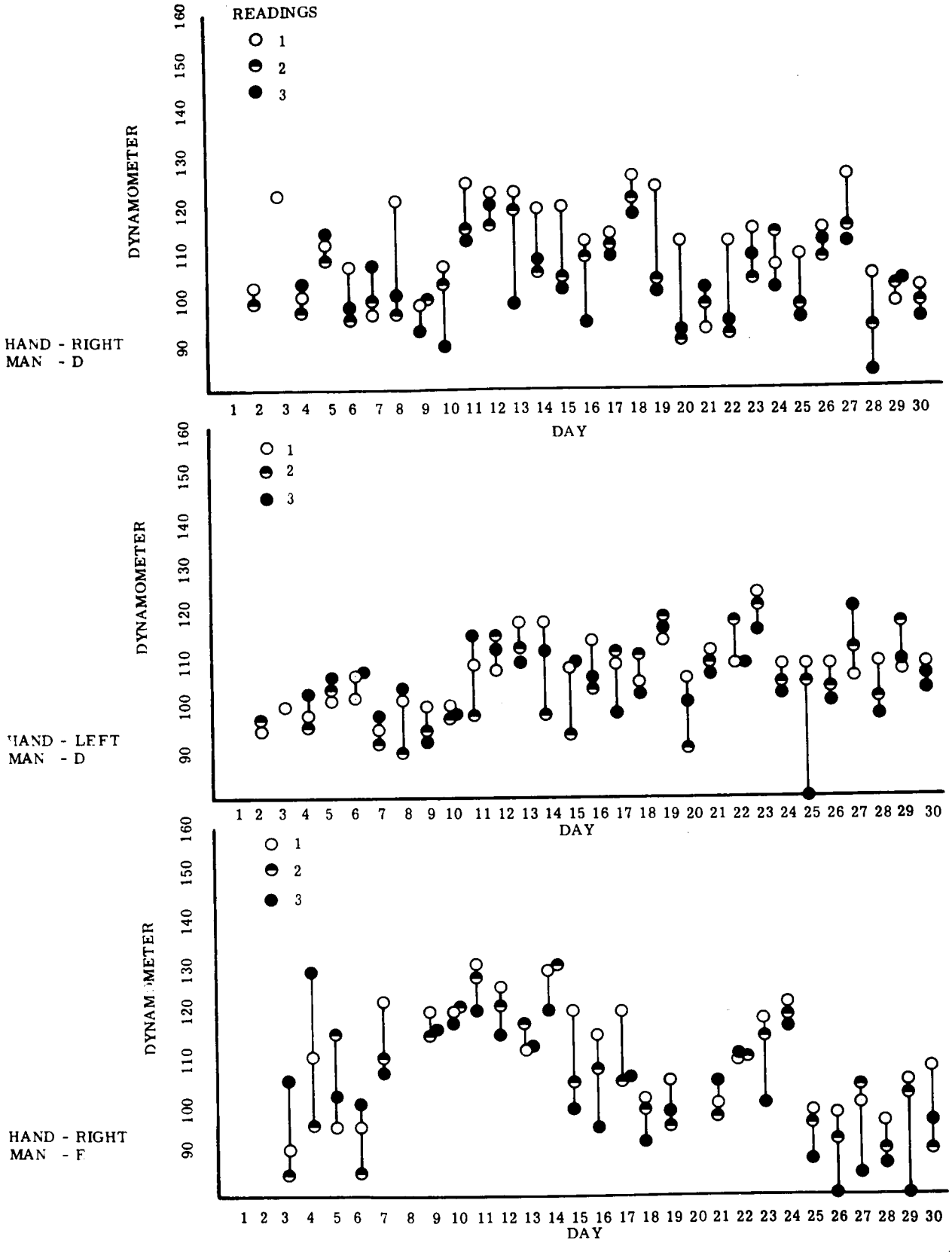


Figure 3-1 Dynameter Reading Sheet 3 of 4

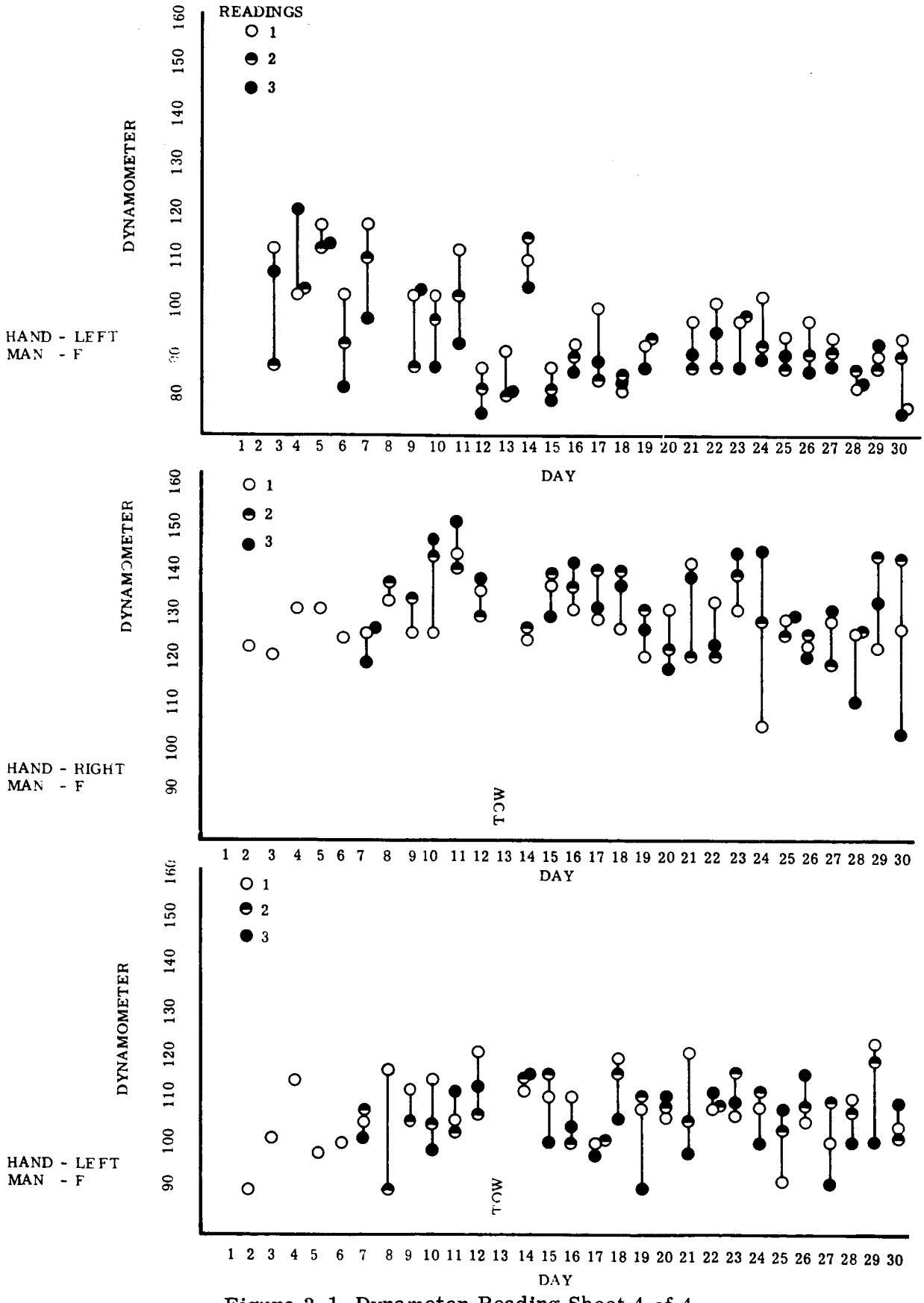


Figure 3-1 Dynameter Reading Sheet 4 of 4

were variable up to this point in time, they too were more stable during the second half of the mission. Two additional factors also must be considered: (1) the first half of the drift included changes in depth, a tow, and bottom excursions, all of which certainly were more stressful than drifting at 600 ft, which characterized the second half of the mission; and (2) it is not unlikely that individual willingness or ability to record pulse rate accurately decreased during the second half of the mission when the on-board pulse meter was inoperative. Changes in daily pulse elevation following exercise are of special interest because of possible influence of psychological factors on intensity of effort. One man apparently exercised more strenuously on days of high stress (Days 13-15) as depicted in Figure 3-2. The role of physical exercise in sublimation of psychological stress clearly is an area deserving additional consideration in planning of long-duration missions.

Pre- and post-mission respirometer data were used to determine pulse rate and consumption of oxygen, which would be converted to work output in BTU's. A physical fitness index was calculated pre- and post-mission in order to detect any physical deconditioning.

Post-mission work output (BTU/hour) and oxygen consumption for each of the crewmen did not differ notably from their pre-mission condition. Because of an error in technique, however, these data must be compared cautiously. In the pre-mission test, ambient air was used by one of the authors to stabilize respiration prior to oxygen consumption, whereas post-mission, a technician stabilized the subjects with oxygen before beginning the respirometer analysis. Three crew members had post-mission readings that essentially were the same as those made prior to the drift. Three others had post-mission data that differed slightly from the pre-mission data. Taking inconsistency of technique into consideration, there were no significant changes in the physical fitness indices (Figure 3-3). This is supported further by the medical examinations of the crewmen (Appendix A). These results differ from those obtained in the 60-day mission in the McDonnell-Douglas Space Cabin Simulator. Three of the crewmen in that study had notably lower physical fitness indices subsequent to their simulated mission. In our study, base-line blood pressure and pulse rates for each of the men showed no indications of deconditioning. Indeed, it is altogether possible that at least one or two of the crewmen were in slightly better physical condition than they were prior to the GSDM.

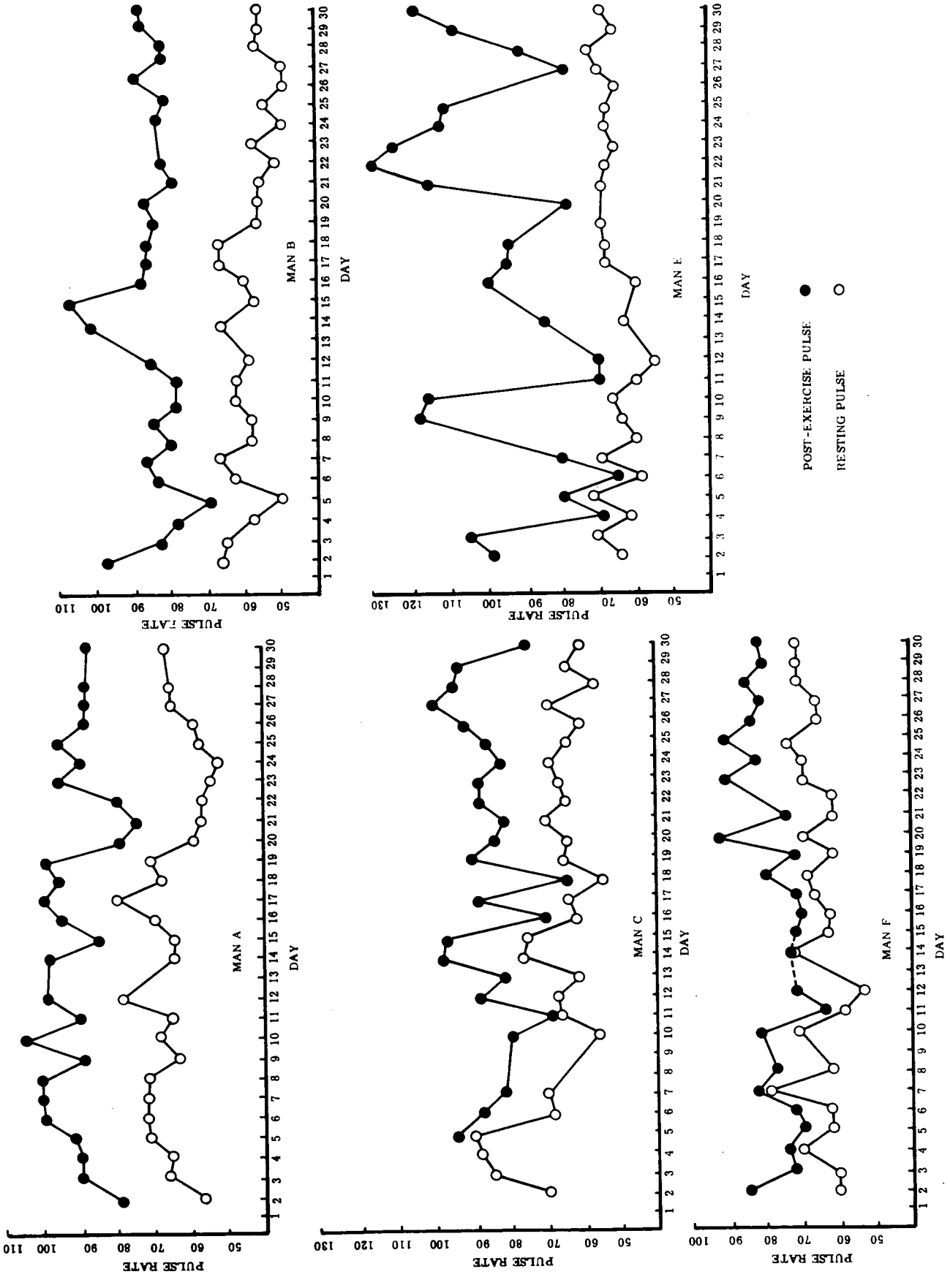


Figure 3-2 Pre and Post Exercise Pulse Rates

Man	Pre-mission	Post-mission
A	1.3	1.4
B	2.1	2.9
C	1.9	1.9
D	2.4	2.4
E	4.0	4.6
F	2.5	2.6

Figure 3-3. Comparison of Pre- and Post-Mission Physical Fitness Indices for Each of the Six Crewmen

Four crewmen lost weight; two remained the same and one lost 19 pounds. Loss of weight was no greater than would be expected as a result of dietary changes, slight dehydration, and alterations in the eating schedules.

All the data indicate that none of the crew members experienced any noteworthy physiological deterioration during or immediately after the drift mission. This conclusion is consistent with the medical record.

Judging from daily recording of pulse rates prior to exercise, the crew had adjusted to their environment by Day 20. Furthermore, most of the crew members were able to improve their dynamometer readings slightly and none showed noteworthy loss of strength in his arms and hands. It is not unlikely that at least some of the crew members actually were in better overall physical condition following the mission than they were before the mission; slight loss of weight probably could be considered beneficial to at least one or two of the men and certainly not harmful to most of the others.

In future studies, it is recommended that weight be recorded daily, so that the actual pattern can be determined. From this it can be determined when weight is lost or gained and when (or if) the pattern becomes stable.

Data obtained by techniques more sensitive than those used in this mission would have been useful in the analysis of impact of confinement and isolation on the crewmen. Records of food intake, water consumption, and output of urine should be kept. Initial plans for the drift included such considerations but they were eliminated because collection of such data was incompatible with the mission time lines.

Collection of useful biological data could be significantly improved, in our judgment, by the presence of a professional physiologist. This conclusion is made because experience has indicated that an operational mission is not so well planned that collection of sensitive data can be assured. The flexibility provided by having a physiologist onboard would greatly increase the amount and quality of the information obtained.

3.2 MEDICATION

The primary check on medication was its issuance by the Captain on the telephoned instructions of a physician onboard the PRIVATEER. The interest of the psychological investigation, however, was in the subjective sense of well-being. Therefore, the men daily were asked what medicine they took and for what "symptom". Additionally, the

Cornell Medical Index (CMI) was administered prior to the GSDM in order to obtain a statement as to each man's criterion for judging his own well-being. The results were compared to his responses to the same inquiry in the debriefing. Items chosen because they reflect psychosomatic or hypochondriac complaints or because they describe symptoms reported in other confinement experiments were inserted in the personal logs beginning on the fifth day.

Figure 3-4 shows that little medication was used by the crew during the GSDM. Five of the men reported that they had "colds" in the first week and that "Coricidin" had been taken to counter the symptoms. Nausea was reported by two men on Day 13, when the BEN FRANKLIN was under tow on the surface. Four of the crewmen reported that they had headaches on one or two occasions; one man took aspirin for his headache late in the mission. One crewman reported that he felt slightly "dizzy" on Day 13 but this was suspected to be associated with seasickness. None of the crewmen reported having trouble with their ears, but all the men reported an occasional rash and an itchy feeling. The latter two symptoms can be attributed, in large measure, to inadequate bathing.

3.3 FOOD AND FOOD PREFERENCES

The food for the GSDM was prepackaged to provide 3 meals and a snack totalling approximately 3000 calories per day. Preparation required mixing some of the foods with hot or cold water. There also were canned foods and ready-to-eat items. In addition, pantry items were taken along by the individual crew members.

The questions in the diary regarding food eaten and food discarded were intended to reveal food preferences. We also expected the crew to keep a log of food taken, returned, or discarded. Because of the work load, and perhaps the "trouble" involved, this book-keeping was not accomplished. Tabulation of the data showed that certain foods were preferred over others. A complete menu, which consisted of 5 different combinations is presented in Volume III. Figure 3-5 lists the foods complained about most frequently. Compared to the available items this is a short list. The rejected food does not, however, tell the whole story. Although the food was eaten it was not really enjoyed. Figure 3-6 shows a wide variety of response with regard to acceptability even at the beginning of the mission. The lowest rating at the start was "fair"; by the end of the mission the average was "fair" with 3 of the crewmen rating the food "fair" to "poor".

Day	A	B	C	D	E	F
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	(Headache) Bufferin	(Cold) Coricidin	0	(Cold) Coricidin	(Cold) Coricidin	0
4	(Headache)	(Cold)	0	Aspirin Coricidin (Cold)	(Cold) Coricidin	0
5	(Cold)	(Cold) Coricidin	0	Aspirin Coricidin (Cold)	(Cold)	(Cold) Coricidin
6	0	(Cold) Coricidin	0	(Cold)	0	(Cold) Coricidin
7	0	(Cold) Coricidin	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	(Stiff Shoulder)	(Headache)	(Itchy)	(Itchy)
12	0	0	0	0	(Sore Arm)	0
13	(Headache)	Skinrash	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	Mycostatin	(Sore Hand)	0
16	(Cold-Headache)	Skinrash	0	(Skinrash) Mycostatin	0	(Skinrash)
17	0	0	0	(Skinrash) Mycostatin	0	0
18	0	0	0	(Skinrash) Mycostatin	0	0
19	0	0	0	(Skinrash) Mycostatin	0	0

Figure 3-4. Record of Medication and Symptomatology (Sheet 1 of 2)

Day	A	B	C	D	E	F
20	0	0	0	(Skinrash) Mycostatin	0	(Itchy)
21	0	0	0	(Skinrash) Mycostatin	0	0
22	(Itchy)	0	0	(Skinrash) Mycostatin	0	(Itchy)
23	0	0	0	(Skinrash) Mycostatin	0	0
24	0	Coricidin (Cold)	0	(Skinrash) Mycostatin	0	0
25	0	0	0	Aspirin (Headache)	0	0
26	0	0	0	Aspirin (Headache)	0	0
27	(Itchy	0	0	0	0	(Itchy)
28	0	0	0	0	0	0
29	(Itchy)	0	(Rash under Arms)	Aspirin (Headache)	0	(Itchy)
30	(Cold, Itchy)	0	(Rash under Arms)	Aspirin (Headache)	0	(Cold, Headache)

Figure 3-4. Record of Medication and Symptomatalogy (Sheet 2 of 2)

Food	Rating		Remarks
	Acceptable	Poor	
Soups		X	few ate these items
Nut Rolls	X		portions too large
Puddings		X	sloppy (clean up problem)
Crackers		X	tasted badly, broken
Chocolate Bars		X	discolored
Beef Jerky		X	poor quality
Familia	X		not eaten at first (too sweet)
Peaches		X	problem in shaking sugar out
Mashed Potatoes		X	

Figure 3-5. A Summary of Foods Most Often Complained About

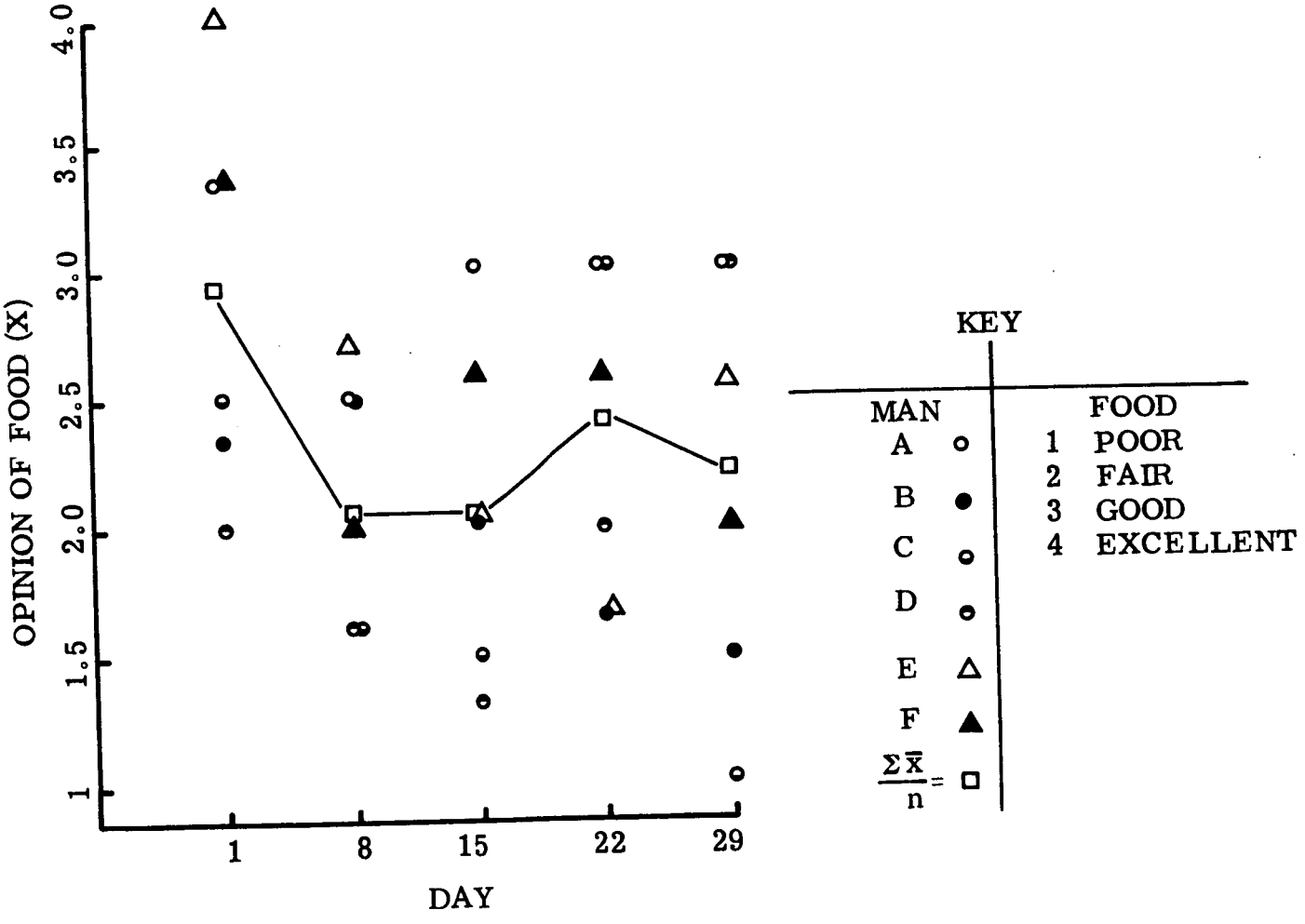


Figure 3-6. Acceptability of Food as Rated on 5 Separate Days

Food was a frequent topic of conversation. However, it was not sufficiently unacceptable to be a source of noteworthy stress. In longer missions this cannot be counted on. The reactions of the crew indicate this likelihood and in post-drift interviews it was quite clear that improvements in this area were very important. Hot and more palatable foods were among the suggestions made by the crew. Trouble in preparing food and problems in cleanup also are items that were overlooked in planning this mission and that deserve appropriate attention.

SECTION 4

LIVING AND WORKING CONDITIONS

Living conditions and working environment are known to affect the mental outlook of individuals as well as their ability to perform work. The crewmen of the BEN FRANKLIN were asked on five separate occasions (Days 8, 15, 22 & 29) to report their opinions of a large number of environmental and human engineering considerations. Additional data on this subject were obtained from the comments in the log as well as during the debriefing. Figure 4-1 summarizes the data reported in the log in response to directed inquiries. It is evident that almost every aspect of the environment caused complaints.

Interactions with the surface crew, bunks, seats, clothing, the table, food accessability of equipment, water and temperature control were the most frequently reported items. They also received the most attention during debriefing.

Figure 4-2 groups these complaints into four categories: things, people, environment, and operations. "Things" and "environment" account for the majority of the complaints, totaling 230 out of 293. The forward table, which was shaky and had to be removed so that the forward view port could be used for observation and bottom navigation, was a frequent source of comment. The seats were disliked because they tilted forward, giving the sensation that one would slide off.

The observation that the jump suits had to be completely removed when a crewman had a bowel movement and that the suits fitted poorly and bound at the seams should be instructive to clothing designers.

Water as well as food is an extremely important element of life support and as such affects psychological adaptability. Figures 4-3 and 4-4 show the amount of water allocated and the amount consumed. Considerably less water was used than was planned. The supply of cold water became contaminated and could no longer be used for drinking and preparation of food. Even before it became contaminated, the cold water was disliked because the iodine used to prevent microbial growth gave it an unacceptable taste. Many of the complaints regarding food, changes in mood, and the reported "itchiness", are correlated with the inadequacy of the water. Hot and cold water in sufficient quantity is essential to a successful mission of considerable duration. The signs pointing to this are clearly evident in the reactions of the crew.

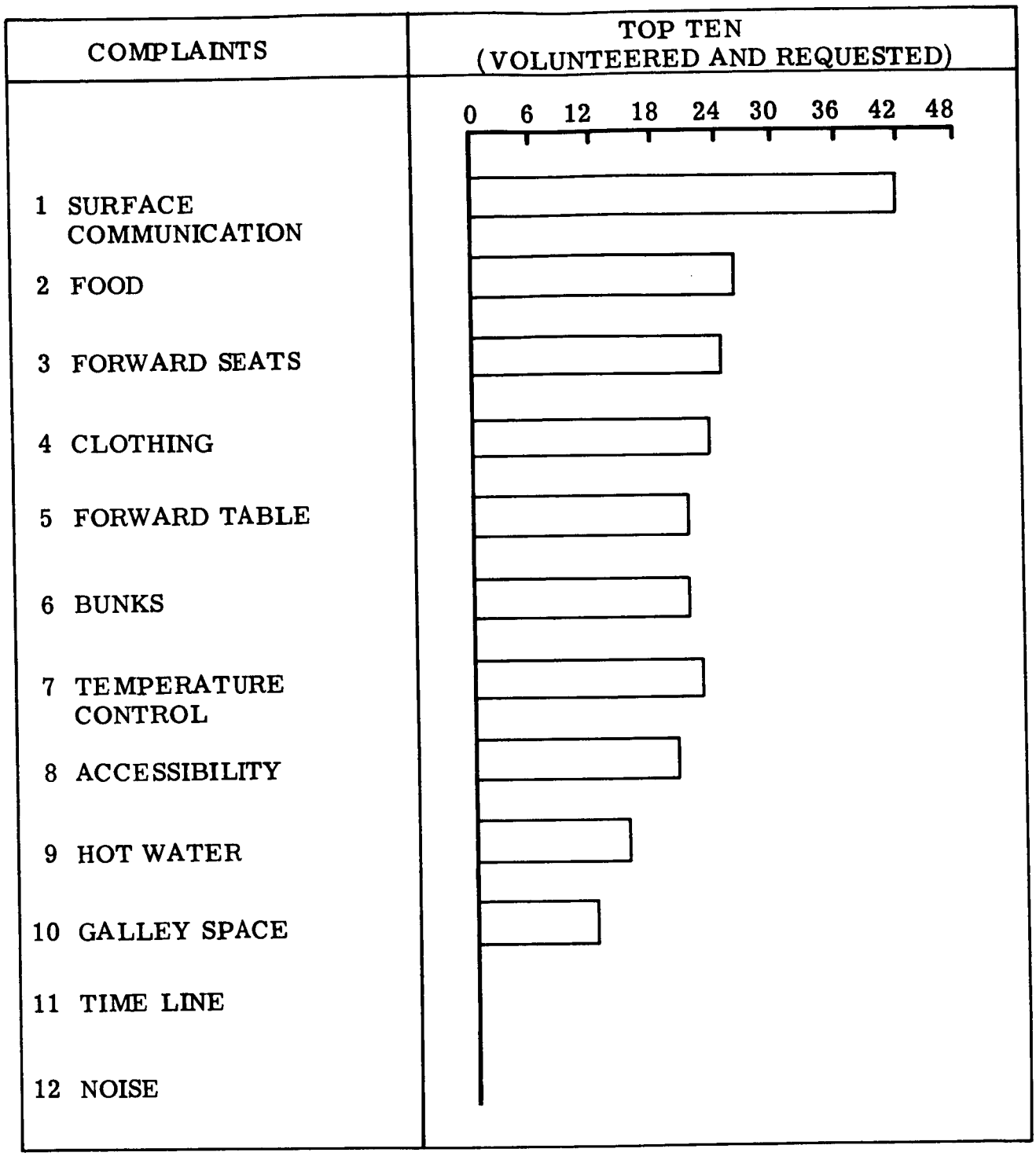


Figure 4-1. Major Complaints

	No. of Items	Day					$\sum$	$\bar{x}$
		8	15	22	24	29		
Things	6	21	25	25	24	26	121	20.1
People	2	4	8	5	5	6	28	14.0
Environment	12	26	29	22	13	19	109	9.0
Operations	3	5	11	6	7	6	35	12.0

Figure 4-2. Summary of Selected Complaints

Item		Allocated Supply	Consumed
HOT	Food Prep.	5.4 lbs./M day	5.5 lbs./M day
	Washing	2.75 lbs./M day	None
	Total	8.15 lbs./M day	5.5 lbs./M day
COLD	Food Prep.	3.75 lbs./M day	None
	Washing	8.75 lbs./M day	11 lbs./M day
	Total	13.83 lbs./M day	11 lbs./M day

Figure 4-3. A Summary of Allocation and Usage of Water

Item	Amount Start	Amount End
Cold Water	352 gals.	112 gals.
Hot Water	177 gals.	57 gals.
Total	529 gals.	169 gals.

Figure 4-4. Summary of Water Supply

Data on illumination, noise, and vibration were gathered during the drift. Illumination was measured on nine separate occasions at 3 different locations. (Figure 4-5). The average illumination was about 2 foot-candles. The variation was extremely narrow. Additionally, there were some lanterns, a portable battery powered table lamp (which was quickly exhausted) and flashlights.

Overall, crew complaints about lighting were not as frequent as one might have expected. This probably is in part due to the fact that they could carry out their duties with the help of auxiliary lighting. A low level of irritation is not to be taken to mean low levels of light are acceptable. The adaptability of the crew is surely evident but it is likely that there was some cost in proficiency.

Initial plans called for objective measurement of vibration, but this was eliminated for engineering reasons. As a substitute, subjective estimates of vibration were obtained on 9 separate occasions, at three different locations. All log entries indicated that level of vibration was low. Comments by the crew indicated that the engines and the macerator were the only important sources of vibration. Since these were on infrequently, the BEN FRANKLIN was relatively free of vibration.

Noise level similarly was sampled on 9 different occasions in each of 3 separate locations. Figure 4-6 shows that the ambient noise level for the 3 frequency ranges sampled ranged from 48 to 78 db. The usual sound level was in the range 55-60 db. This is really a very quiet environment and corresponds to the noise levels recorded in offices in which there is typing.

The requested notations in the logs, unsolicited comments, and comments from the debriefings indicate that noise in the BEN FRANKLIN was mostly made by people. The background noise was low because there were few sources of energy. People noises were superimposed on this low background and, because they were discontinuous, they had a greater effect. There were few complaints about noise, but the debriefings indicated annoyance with the noises made by people (such as pitch of voices, heavy foot steps, and raucous laughter). It is believed that to a considerable extent the crewmen controlled and restrained their reactions to noise. This suggests that is necessary to control generating sources of noise, locate sleeping quarters in noise-free areas, or provide suitable protection from noise.

Day	Date	Time	Foot Candles Location			Sources of Illumination		
			F	G	A	F	G	A
2	July 15	1945	1.0	1.0	2.0	8 Watt Portside	8 Watt Gallet	40 Watt NAVO Area
5	July 18	1925	5.0	1.0	2.0	8 Watt Light	8 Watt Light	20 Watt Light
8	July 21	1730	0	1.0	1.0	-	-	-
11	July 24	2000	1.1	1.0	0.9	20 Watt	8 Watt	20 Watt
14	July 27	1700	1.3	1.0	0.9	40 Watt	8 Watt	20 Watt
17	July 30	1830	1.3	1.0	0.9	40 Watt	8 Watt	20 Watt
20	Aug. 2	1900	1.1	0.9	0.8	40 Watt	8 Watt	20 Watt
23	Aug. 5	1600	1.1	0.9	0.8	40 Watt	8 Watt	20 Watt
26	Aug. 8	2000	1.1	0.9	0.8	40 Watt	8 Watt	20 Watt

F - Forward G - Galley A - Aft

Figure 4-5. Illumination Level Measurements

Day	Date	Time	Location						Sources of Noise			Activity
			Set	F	Set	G	Set	A	F	G	A	
2	July 15	1930	CS BS AS	62 59 57	CS BS AS	58 54 52	CS BS AS	56 55 53		Voices	NAVOCEANO Equip.	
5	July 18	1830	CS BS AS	58 56 58	CS BS AS	62 52 56	CS BS AS	66 56 54	Music & Voices	Voices		
8		1720	CS BS AS	66 64 60	CS BS AS	68 64 56	CS BS AS	66 62 58				This is a bottom day and the noise should be at its max. level
11	July 24	1800	CS BS AS	58 60 64	CS BS AS	60 64 66	CS BS AS	50 52 54	Everyone Forward	Everyone was Fwd. & Talking		
14	July 27	2700	CS BS AS	60 58 54	CS BS AS	55 55 54	CS BS AS	58 57 58				Normal Mode for drift and the recording of Blasting Caps from Top Side.
17	July 30	1830	CS BS AS	54 53 52	CS BS AS	54 56 58	CS BS AS	55 52 54				
20	Aug. 2	1907	CS BS AS	50 54 52	CS BS AS	54 53 50	CS BS AS	55 51 52				
23	Aug. 7	1000	CS BS AS	54 78 76	CS BS AS	54 58 54	CS BS AS	50 50 50	Voices			
26	Aug. 8	2000	CS BS AS	50 52 52	CS BS AS	52 52 50	CS BS AS	50 48 50				

F = Forward G = Galley A = Aft

Figure 4-6. Measurements of Noise Level

It was noted previously that the crew played the taped music many hours each day. It is not improbable that the taped music also provided a background level so that the discrete noises seemed less intense. It is suggested, therefore, that background noise as a means of reducing the impact of discrete additions to environmental noise deserves consideration in the design of small vehicles.

In missions longer than the Gulf Stream Drift it can be expected that the expressed irritation and annoyance from sources like those in the BEN FRANKLIN would be greater. The potential effect on performance and psychological well-being would be undersirable. Many of these complaints can be avoided by recognizing the sources of trouble during initial design. The causes for complaint during the Gulf Stream Drift Mission can serve as a guide so that they may be minimized in future systems.

SECTION 5

CONCLUSIONS

The following conclusions are based on analysis and interpretation of psychological and physiological data from the daily personal logs, pre-and post-mission testing, interviews with the individual crewmen, time-lapse photography, and recordings of conversations made during the mission.

- Pre-mission psychological profiles of each of the six crewmen enabled the investigators to predict certain relationships among the men during the mission. Pairs of men thought to be incompatible in one or more aspects of personality (e.g., "need to achieve") demonstrated their incompatibility through conflict at times of stress. As was predicted, however, all of the men were able to control and sublimate agression in order to achieve a successful mission. Data that can be obtained from existing psychological tests and interviews will enable an experienced psychologist or psychiatrist to predict compatibility. It is the belief of the investigators that the procedure can be abbreviated. One projective test (Rorschach), one inventory (Edwards or MMPI), and Continuous Addition would make, we believe, a statisfactory battery. The GCI requires and deserves further work to provide the base for a systematic determination of compatibility over the long term. The use of peer ratings should be explored further.

- It had been hoped that time-lapse photographs and on-board tapes would be valuable in our analysis of psychological adaptability of the men but due to technical difficulties neither technique proved especially useful.

- As time progressed, all of the crewmen tended to eat more and more meals alone, thus reflecting a need for privacy and avoidance of conflict.

- Analysis of the results of the Group Confinement Inventory revealed pertinent information including the following:
  - The crewmen became more negative about their environment as time progressed
  - Annoyance with partners increased steadily throughout the mission

- Annoyance with mannerisms of others was greatest in retrospect
- General tension increased gradually
- Overall crew compatibility was highest at the end of the third week
- Level of conflict was highest during the middle part of the mission
- The crewmen sought more privacy as the mission progressed
- Boredom with environment increased with time

- Analysis of data from a Mood Scale revealed that several of the men were depressed at the mid-point of the mission as a result of interpersonal conflicts and operational difficulties

- Kinds of frustrations reported by the crewmen were characteristic of clinical interpretations of their personalities and predictions of their responses to environmental stresses

- Individual reports of important events generally reflected work assignments and personalities of the crewmen

- Sleep analysis indicated:
  - Quality of sleep was not cyclic
  - Quality of sleep for most of the men fluctuated and did not improve with time
  - Quality of sleep was affected by noise, especially that made by people
  - Quality of sleep for one man would be clearly related to psychological stress
  - Quality of sleep could not be related to work-rest schedules or circadian rhythm
  - Amount of time spent in the bunk remained remarkably constant for each of the crewmen

- When questioned during the mission the men reported that consideration for others was one of the most important requirements for crewmen

- The Langley device was included because it was stated that the device was more sensitive to stress than would be gross measures of performance. For the only crewmember who was exposed to an evident external stress, performance on the device did in fact deteriorate.

- Subjective reports of performance varied, but for two of the six men, performance apparently was worse on days following fitful or poor sleep than it was on days following a "good" sleep
- Group recreation was rare; the men found that reading and listening to music were excellent forms of relaxation
- The available data indicate that additional training would have been useful; the men often felt that they had inadequate information and this was a source of annoyance
- Although four of the six crewmen lost weight, none suffered detectable physical deconditioning as a result of 30 days in confinement with limited activity
- None of the six crewmen made psychosomatic or hypochondriac complaints even though pre-mission clinical analysis indicated that one of the men had hypochondriac tendencies
- Little medication was used but most of the men had "colds" and occasional rashs or itchy feelings
- The food was disliked and was a frequent topic of conversation; improvements in this area are important
- Certain aspects of the internal environment of the submarine, and provided equipment, were serious sources of annoyance and generalized psychological stress
- Conflicts with the personnel of the surface command were serious enough to underscore the need for selections of crewmen for the command post vehicles to be based on integrated compatibility with the subsurface crew.
- The logs, the psychologists, topside command and the human-engineering limitations of the BEN FRANKLIN were targets for the release of the crews frustrations. People isolated from society should have targets other than their immediate fellowmen against whom they may vent their aggressions. To the extent to which it can be managed these aggressions should be directed to targets that do not affect mission accomplishment.

- Communication with the outside was important for the well-being of the crew of the Ben Franklin; news from "home" should be unscheduled because men respond negatively when news is inexplicably lacking
- Methodology employed by the investigators was adequate but could have been more sophisticated had it not been for constraints on power, space and time
- Pre- and post-mission test and interviews, and daily questionnaires used during the mission were the most productive sources of data.

SECTION 6

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APPENDIX A

MEDICAL

A.1 CREW QUALIFICATION REQUIREMENTS

The crew underwent psychiatric and physical examinations before the GSDM. These examinations consisted of medical history, psychiatric, physical, dental, laboratory tests, and consulations. The results of these examinations were reviewed and it was concluded that the selected crew members were physically and mentally fit for the GSDM. The breakdown of the various examinations is presented in Figure A-1.

A.2 MEDICAL CARE

A.2.1 Onboard Medical Kit

A medical kit was supplied which contained a sufficient number of drugs, bandages, and inflatable splints that would provide the physician on the surface with the necessary flexibility to direct treatment of a wide variety of viral, bacteriological, fungal, and metabolic disorders. The contents of this kit are listed in Figure A-2.

It was the duty of the BEN FRANKLIN's Captain to report any illness to the physician on the M/V PRIVATEER, and upon instructions the Captain was to dispense the appropriate medication. The medical kit was kept under lock and key, and only the Captain and/or his backup was authorized to dispense any drugs, upon the advice of the physician. The Captain was required to keep a log of all drugs dispensed.

A.2.2 Medical Monitoring

Dr. Robert Jessup, Medical Director, Grumman Aerospace Corporation, monitored the GSDM while onboard the M/V PRIVATEER. His duties consisted of:

- Receiving medical briefing from the Captain, via hydrophone, concerning the crew's health status, as well as onboard toxic hazards
- Being immediately available on a 24-hour basis for medical consultation/transfer to the BEN FRANKLIN if necessary to treat an emergency case
- Prescribing medication and treatment instructions via hydrophone to the Captain or his backup

- Keeping a log of any onboard medical problems, toxic hazards, and water potability
- Keeping the Mission Director informed as to the condition of the crew, as well as the impact of crew health on the mission

Dr. R. Fagin and Dr. A. Baldassarri served as additional medical support for the GSDM duration. They were located at Bethpage and were on call 24 hours a day on alternate days.

A.2.3 Medical Evacuation

In the event of a medical emergency requiring evacuation of a crewman from the BEN FRANKLIN, it was planned to have the M/V PRIVATEER request assistance from the U.S. Coast Guard Rescue Control Center, Governors Island. The Mission Alert Facility at West Palm Beach and Grumman Bethpage would also be informed. A Coast Guard helicopter would be dispatched to pick-up the crewman and transport him to the nearest medical facility along the east coast.

A.2.4 Actual Medical Problems

No injuries requiring treatment or medication were reported during the entire mission.

Two crewman had mild colds just prior to the mission. One crewman recovered just as the mission began. The other crewman had cold symptoms which disappeared a few days after the mission started. About 2 days into the mission, the Captain reported that four other crewman were complaining of nasal congestion and stuffiness. Thus, a total of five crewmen had cold symptoms about 2 days into the mission. A decongestant, Coricidin, was prescribed. Within 24 hours, no further symptoms were noted.

No further cold symptoms were reported for the rest of the mission, although there were two crewmen who, for the first 3 weeks of the mission, took an occasional aspirin whenever they felt cold, damp, or tired. Further questioning revealed that it was the habit of these two individuals to use aspirin for any problem that they might have.

On July 27, 2 weeks into the mission, two crewmen complained of pruritic (itchy) rashes. One crewman had a rash in his groin, and the other crewman had a rash in his groin as well as on the inner aspect of the left elbow. Mycostatin was prescribed and used

for 4 days during which time the rashes disappeared. They never recurred. The rashes were probably due to a mild fungal infection.

On August 13, the last day of the mission, one crewman had a sudden, rapid onset of severe epigastric (upper abdominal) pain. The pain was constant and remained localized to one spot in the upper abdomen. There was no vomiting, no diarrhea, and no loss of appetite. Lomotil was prescribed and symptoms disappeared in 2 hours. There was no recurrence of the symptoms or pain. The crewman recovered completely. No definitive diagnosis was made at the time.

A.3 POST-MISSION MEDICAL STATUS AND CREW DEBRIEFING

A.3.1 Post-mission Physical Examination

On August 14, Dr. Robert Jessup examined the crew onboard the Coast Guard Cutter, COOK INLET. The examination was identical to the pre-mission physical. The results of these examinations were as follows:

- The entire crew was extremely pale. This pallor disappeared within 24 hours. The pallor was probably due to 30 days without sun and the mild motion sickness experienced during the rubber raft ride from the submersible to the COOK INLET.
- A mild non-specific dermatitis of the right axilla (armpit) was noted in one crewman. No treatment was given. The dermatitis disappeared within 2 days following the mission
- A definite weight loss was noted in four of the six crewmen. The weight loss ranged from 6 to 19 pounds
- A thorough examination of the crewman, who had suffered the acute abdominal pain just prior to mission termination, did not reveal any abnormalities. He was found to be in excellent condition
- Analysis of pre- and post-mission blood and urine samples using Student's "T" test statistical methods revealed no statistically significant differences between blood and urine samples taken immediately before and after the mission.

A.3.2 Medical Crew Debriefing

The crew felt that it was too cold and damp in the submersible to take showers. As a result, personal hygiene was relatively poor during the last half of the mission. The crew complained about the lack of potable water and its poor taste. The freeze-dried and canned foods were adequate nutritionally; however, the crew was critical of the lack of food variety, the flat bland taste, and the difficulties in reconstituting the food in water. In effect, the significant weight loss noted in four crewmen was due to a greatly reduced food intake resulting from the lack of palatability of the freeze-dried foods. The lack of diversion and recreation created a sense of boredom among the crewmen at various times during the mission.

CREW MEMBER EXAMINATIONS AND QUALIFICATIONS

Examination	Qualifications
History	General and Family history was taken with emphasis on: • Psychiatric Illness • Orthopedic Problems • CNS Problems • Chronic Pulmonary Disease • Heart Disease • Allergic Conditions
Psychiatric	An psychiatric interview and evaluation for undersea duty was performed by a psychiatric specialist experienced in evaluating undersea-work personnel.
Dental & Physical	Prior to GSDM, significant dental problems, found during oral examination, were resolved. Physical examination consisted of: • USAF Class II comprehensive physical examination • Visual examination with Bausch and Lomb Ortho-Rater • Hearing evaluation with an audiometer-Rudmose audiogram • Intra-ocular pressures with Schultz tonometer • Transillumination of sinus • Indirect laryngoscopy • Proctoscopy

Figure A-1 Crew Member Examinations and Qualifications (Sheet 1 of 2)

CREW MEMBER EXAMINATIONS AND QUALIFICATIONS

Examination	Qualifications
Laboratory Test and Procedures	These test and procedures consisted of: • Photograph - front view and profile • Resting EKG • Stress EKG - Masters • Electroencephalogram (EEG) • Spirometer studies • X-rays - Chest PA and lateral - Skull and sinus - Abdominal scan - Dental X-rays • Urinalysis - chemical and microscopic • Blood chemistries - Cholesterol - Uric acid - BUN - Blood sugar (2-hr post-prandial) - Prothrombin time - Thymol Turbidity - VDRL • Hematology - CBC - Hematocrit - Platelet count - Blood type and RH
Consultations	Consultants were referred to for evaluation when any questionable deviation from the norm was found. The criterion was that any condition would be disqualifying if it could cause the mission to be terminated or prevent the crewman from performing his duties.

Figure A-1 Crew Member Examinations and Qualifications (Sheet 2 of 2)

ONBOARD MEDICAL KIT CONTENTS

Item - Quantity	Item - Quantity
Darvon Compound, 65 mg - 50	V-Cillin K - 50
Demerol Syrettes - 10	Bufferin - 100
Fiorinal - 24	Seconal 1-1/2 gr - 24
Donnagel PG	Dexedrine - 12
Nupercainal Ointment 2 tubes	Phisohex Soap - 1
Coricidin - 50	Robaxin - 36
Ornade - 50	Azo Gantrisin - 50
Afrin Nasal Spray - 1	Telfa - 1
Neosynephrine Nasal Spray - 1	Vaseline Gauze
Tuss Ornade - 24	Band Aids - 1 can
Sorboquel - 36	Tape, 1-inch - 2
Lomotil - 50	Combines - 2
Dulcolax - 18	Sterile Bandage, 4 x 4 inch - 24
Compazine Suppository - 6	Kling Bandage, 2-inch - 4
Tigan Suppository - 10	Inflatable Splint - full leg - 1
Marezine - 50	Inflatable Splint - full arm - 1
Chlortrimeton - 36	Thermometer - 2
Benadryl, 25 mg - 18	Applicators - 1 pkg
Mycostatin Ointment - 2	Merthiolate Swabs
Tinactin - 1	Butterflies
Terramycin Ointment - 1	Alcohol Sponges - 18
Neosporin Oph Ointment - 2	Tourniquet - 1
Neodecadron Oph Ointment - 2	Bandage Scissors - 1
Debrox - 1	Tongue Dep. - 12
Lido Sporin - 1	Ace Bandage, 2 inch - 1
Vosol Otic Sol - 1	Cepacol Loz. - 1 box
Tetrex - 50	

Figure A-2 Onboard Medical Kit Contents

APPENDIX B

COMMAND AND CONTROL

B.1 COMMAND FUNCTION

The command and control of the GSDM on M/V PRIVATEER was formulated to be a service function. This concept was developed to provide maximum opportunity for mission success. Maximum mission success was assumed to exist if command and control exercised minimum interference with mission routine which had been thoroughly preplanned insofar as the BEN FRANKLIN activities were concerned. Therefore, the command and control service function was concerned with mission safety, the transitions from stage to stage of the operating plan, and readiness to deal with deviations as they might occur.

The command of the BEN FRANKLIN was the Captain's responsibility. Operations in the BEN FRANKLIN were performed in accordance to the mission plan, and altered by oceanographic sightings of opportunity, bottom obstructions, low temperatures, and the Gulf Stream itself. The command and control activity aboard the BEN FRANKLIN is shown in Figure B-1.

B.2 COMMAND ELEMENTS

Grumman Emergency and Technical Alert Facilities were established to act as shore-based activities which could respond to any emergencies which might arise, act as a filter to prevent extraneous activity ashore from diluting the effective conduct of the mission, and to provide consultation and mission monitoring in critical areas.

These facilities were in daily contact with M/V PRIVATEER by means of single side-band transceivers on the 4-, 6-, 8-, and -2-kHz bands. Communication between M/V PRIVATEER and BEN FRANKLIN was maintained by underwater telephone (with the exception of one incident when the radio telephone was used during the surface tow.)

Emergency response was a responsibility of the U.S. Coast Guard, operating under the authority of the National Search and Rescue Plan for all water evolutions except a submerged rescue. (Submerged rescue is interpreted by the U.S. Coast Guard as a matter for the U. S. Navy Supervisor of Salvage. The National Search and Rescue Plan does not provide for the contingency of a submerged non-military submarine rescue. As a consequence, the U.S. Navy Supervisor of Salvage agreed to respond to requests for assistance from the U.S. Coast Guard during the GSDM.) During the period of supporting response,

the U.S. Navy Supervisor of Salvage maintained a group of ships and diving systems in readiness. In addition to these units, a submersible and support system capable of operating in water depths in excess of 4000 ft (BEN FRANKLIN calculated crash depth) was maintained in a ready response state under a call contract to the U.S. Navy Supervisor of Salvage.

B.3 COMMUNICATIONS

The U.S. Coast Guard maintained two radio stations (Radio Miami and Radio Washington) available for daily mission, safe conduct communications, or single sideband frequencies. On occasions, the U.S. Coast Guard coastal stations were used for routine weather inquiries and safety traffic. Communications for the GSDM is shown in Figure B-2.

The highest order of alert was exercised in the command and control of the surface escort, M/V PRIVATEER, and its position was controlled to assure contact with BEN FRANKLIN at all times. When other surface ships were operating within a 3-mile radius of the BEN FRANKLIN, their position was controlled to prevent any interference with mission activity. In the case of USNS LYNCH, control was only exercised when the vessel was within 3 n mi of the BEN FRANKLIN location. Beyond the immediate operating site, USNS LYNCH operated under the direction of the onboard senior U.S. NAVOCEANO Representative. Off-site communications with USNS LYNCH were poor to non-existent.

On two occasions, when a U.S. Navy aircraft flew over the M/V PRIVATEER's operating site, communications on single sideband frequencies were established and maintained until the aircraft advised of its departure.

During the last day of the mission, the R/V ATLANTIS II and the U.S. Coast Guard Cutter COOK INLET were in the operating area and their position was controlled by mission control to maintain a safe distance from the BEN FRANKLIN. Communications were maintained on 2-kHz marine frequencies. In a case of mistaken identity, an attempt was made to establish control over a lurking USSR factory ship. The master was unresponsive. This vessel finally changed course, when USNS LYNCH started to cross its path.

The Communications link to BEN FRANKLIN was by means of a Straza ATM-503 underwater telephone. This link was exercised every half hour throughout the mission by the M/V PRIVATEER calling BEN FRANKLIN for a communications check and update on drift depth and water temperature.

At approximately 2000 hours each day, the news was transmitted from M/V PRIVATEER to the BEN FRANKLIN. During the day, the BEN FRANKLIN reported mission occurrences. These transmissions were usually short and to the point pertaining to general health, personal communications, and mission activity.

B.4 OPERATION PROCEDURES

Onboard the PRIVATEER, the Mission Director, two Mission Controllers, three Trackers, and six NAVOCEANO personnel continuously tracked and plotted the BEN FRANKLIN position. Closing and opening range to the BEN FRANKLIN proved very useful in maintaining the M/V PRIVATEER's relative position.

The M/V PRIVATEER's geographic position was plotted continuously from fixes obtained by Loran A & C. The USNS LYNCH established the Gulfstream's boundaries. The Gulfstream data were transferred to the M/V PRIVATEER by radio-at-sea.

B.5 ADEQUACY OF COMMAND STRUCTURE

B.5.1 Communications

Effective communications in an effort as widely dispersed and complex as the GSDM is a difficult task. The ship-to-shore or ship-to-ship communications were unsatisfactory because of interference with the tracking operations. Any communications systems utilized in the future must meet the test of not interferring with the basic system between the close-in escort and the submersible. Secondly, the communications system should be removed from the ship control and tracking control stations to avoid aural interference and the confusion associated with voice radio operations. Communications with the BEN FRANKLIN were loud and clear in the Gulfstream.

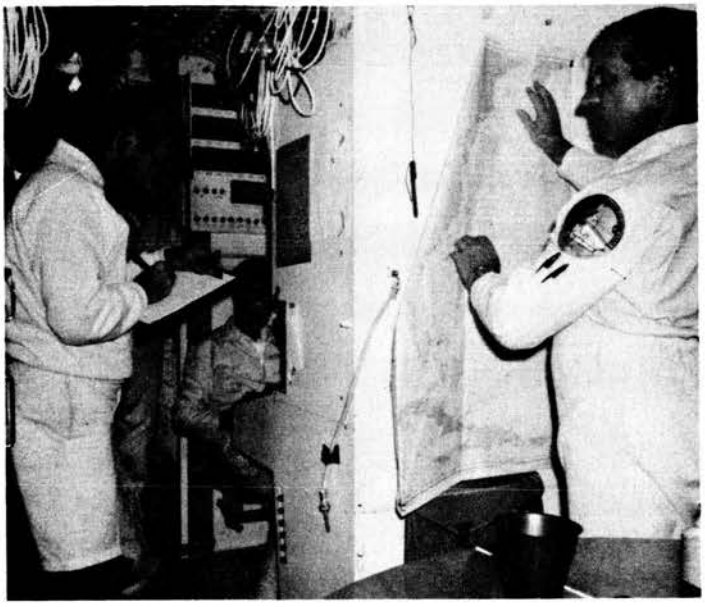
B.5.2 Complaints

During the GSDM, several decisions were made by the surface command on M/V PRIVATEER which elicited complaints from the BEN FRANKLIN crew members because they were not consulted. This created problems between the crew and the surface command which should be avoided in future missions. For example, one crew member felt than an explicit mission definition was not generated with a means for change or contingency planning. Another question was on who should have the final say on ballast shot loading after tow.

Complaints were not because of the underwater telephone system, but rather "people-type communication problems". These complaints with mission control are illustrated in Figure B-3, and it can be seen that they tend to increase with time.

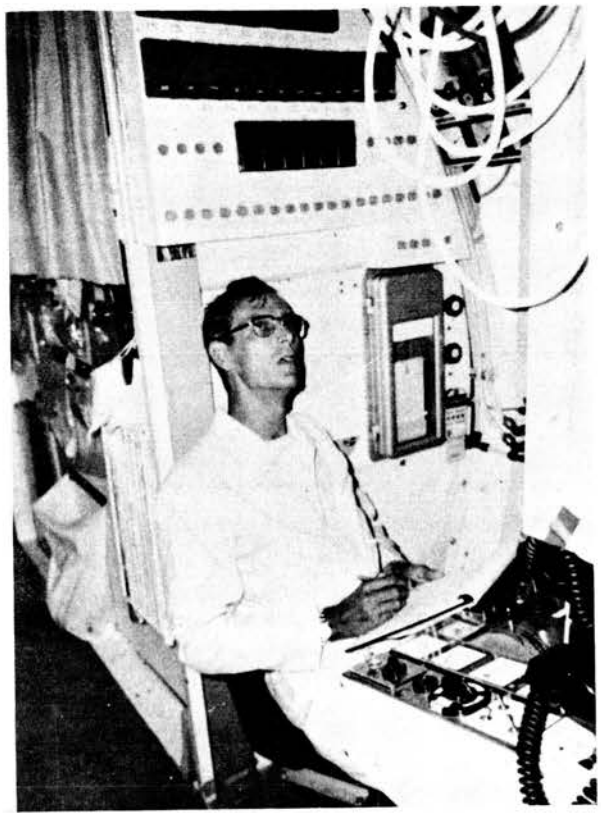
During the program development phase, Drift Mission Direction was defined and reviewed with the NASA/NAVOCEANO/Grumman crew members. The results of the sit-down sessions were incorporated in the NASA and NAVOCEANO contracts (for example, refer to Article X Drift Mission Direction in Contract NAS8-30172 Document). The overall mission planning document for the GSDM Grumman No. OSR-69-14 includes organization and functional organization requirements. Apparently, during the mission, the crew disagreed with being treated like subjects in a confined/isolated environment who were not in a position to exert authority in the decision making process.

For future missions, complaints may be minimized by: improved communications between the support ship and submersible crew members; a means for personal communications with the family; clear limits on operating decisions made by the mission control without submersible crew participation; and a communications manager with the necessary facilities for handling crew personal problems, documentation, and interpretation of conversation for post-mission psychological analysis.

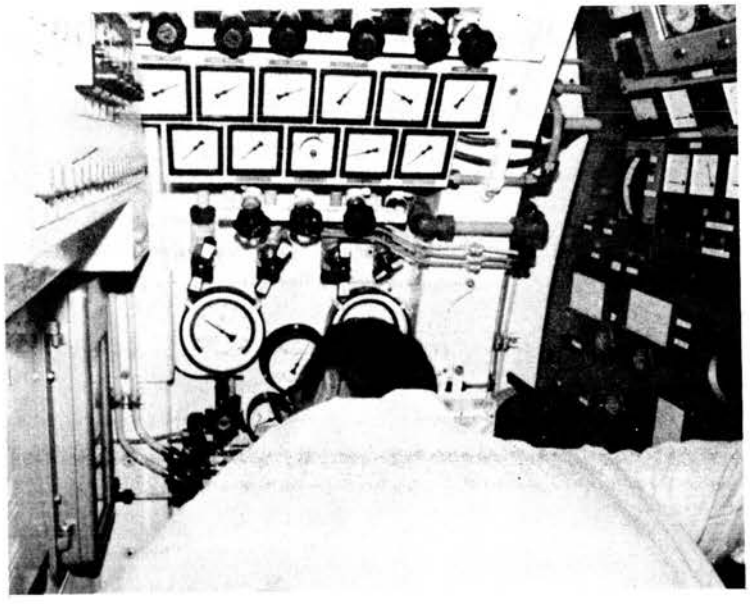


DRIFTING 15 FT ABOVE OCEAN FLOOR

Figure B-1 Command and Control Activity (Sheet 1 of 2)



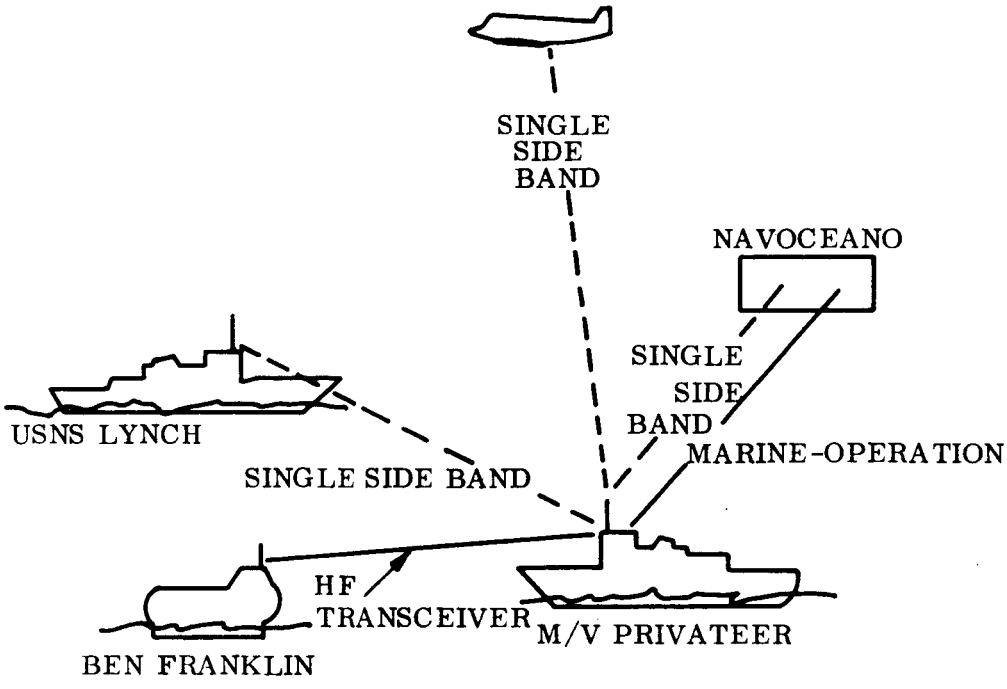
PILOTING



WATCH ROUTINE

Figure B-1 Command and Control Activity (Sheet 2 of 2)

SURFACE



SUB-SURFACE

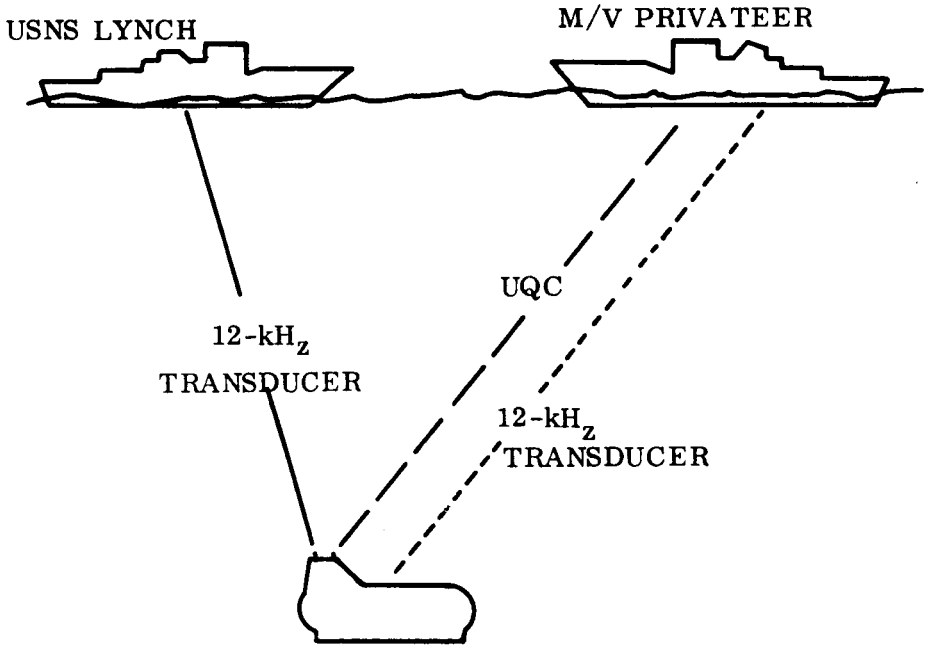


Figure B-2 GSDM Communications

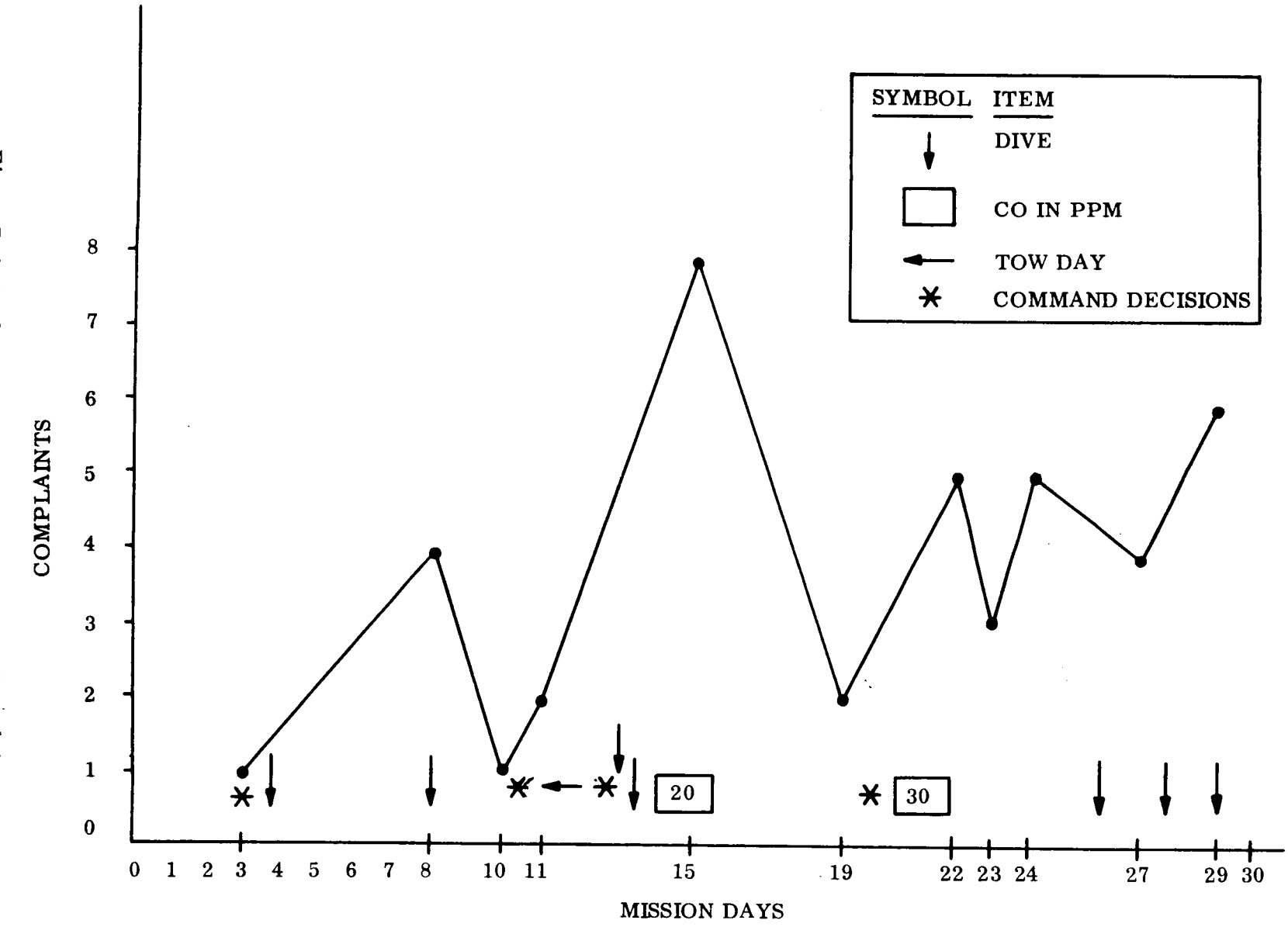


Figure B-3 Surface Command Communication Complaints

APPENDIX C

Appendix C is typical of the formal log which the crewmen filled out each day. All of the matters inquired about were not called for each day. Figure 1-5 shows the schedule of inquiry.

I.D.#_____Day:_____Date:_____Time now:_____

I arose today at _____.

I slept: fitfully ( ); poorly ( ); well ( ); extremely well ( ).

With whom did you eat breakfast? _____Where?_____When? _____

What did you eat? _____

Who prepared breakfast? _____

What did you discard (not eat?) _____

Why? _____

Breakfast was poor ( ); fair ( ); good ( ); excellent ( ).

Who cleaned up after breakfast? _____

Exercise: Time _____Pulse Before _____ Pulse After _____

Dynamometer: Time _____Right hand(1)_____(2)_____(3) Left(1)_____(2)_____(3)____

Space Skills Test: Time at which performed _____, Setting:_____

Before starting, estimate time: _____; Count _____

Actual score: TIME _____ COUNT _____

I ate lunch with _____At(place)_____Time:_____

Lunch consisted of: _____

It was prepared by:_____. I discarded _____

_____, because _____

Lunch was excellent ( ); good ( ); fair ( ); poor ( ).

Who cleaned up after lunch?_____

Time now _____ Place you are writing_____

I ate supper with _____at:(time)_____Place_____

I ate:_____

I did not eat: _____

Because: _____

Supper was: fair ( ); poor( ); excellent ( ); good ( )

Who prepared supper? _____

Today's Log is Continued on the Next Page

Who cleaned up after supper? _____

Of today's meals I most enjoyed breakfast ( ); lunch ( ); supper ( );

Because _____

Time now? _____ Place you are writing _____

Did you personally perform any housekeeping tasks today? YES ( ) NO ( )

Describe: _____

Did you take medicine of ANY KIND today? YES ( ) NO ( ).

If so, What? _____ Why? _____

How did you spend your free time today? _____

_____

The most frustrating thing that happened today was: _____

_____

What time is it now? _____

Where are you writing? _____

NOTES AND COMMENTS: _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Today's Log is Continued on the Next Page

I.D.#_____ Day _____ Date _____ Time Now _____

Below is a list of words describing different kinds of moods and feelings. Indicate the degree to which each word is characteristic of how you usually feel.

	Not at All	Somewhat or Slightly	Mostly or Generally
Raging			
On top of the world			
Terrified			
Grief-stricken			
Energetic			
Leisurely			
Pissed Off			
Wonderful			
Desperate			
Miserable			
Lively			
Lazy			
Angry			
Joyful			
Sorrowful			
Mad			
Fine			
Lonely			
Vigorous			
Weary			
Grouchy			
Good			
Jittery			
Blue			
Alert			
Sluggish			
Apprehensive			
Sad			
Steady			
Inactive			

	Not at All	Somewhat or Slightly	Mostly or Generally
Impatient			
Calm			
Indifferent			
Solemn			
Restless			
Overjoyed			
Scared Stiff			
Hopeless			
Active			
Burned Up			
Cheerful			
Depressed			
Hostile			
Happy			
Afraid			
Despairing			
Mean			
Lighthearted			
Insecure			
Downcast			
Sarcastic			
Contented			
Timid			
Annoyed			
Quiet			

USE THE BACK OF THIS PAGE FOR TODAY'S NOTES AND COMMENTS

Retired at _____(time) PULSE _____

Put this page in the locked box