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955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

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SUBJECT: Summary of NASA's Participation in the Grumman/Piccard PX-15 ("Ben Franklin") Gulf Stream Drift Mission - Case 730

DATE: June 10, 1969

FROM: B. A. Gropper

ABSTRACT

The Grumman/Piccard PX-15 ("Ben Franklin") deep-sea submersible is being prepared for a 4-6 week drift within the Gulf Stream. It is planned to carry a 6-man crew to depths as great as 2000 feet, while drifting submerged from Florida to Nova Scotia. The primary objectives of this mission are to obtain data from a wide variety of marine research, operational, and life science observations.

Grumman is under NASA contract to evaluate the use of such submersibles as space mission analogs. The program will attempt to extend the application of laboratory-quality observational techniques to this undersea field-study in such areas as habitability, maintainability, environmental analysis, microbiology, and physiological and behavioral performance assessments.

This memorandum summarizes the major mission components and events, the characteristics of the primary vehicle and crew, and the anticipated scope of the measures related to NASA interests.

(NASA-CR-103646) SUMMARY OF NASA'S PARTICIPATION IN THE GRUMMAN/PICCARD PX-15 /BEN FRANKLIN/ GULF STREAM DRIFT MISSION (Bellcomm, Inc.) 21 p

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MEMORANDUM FOR FILE

I. INTRODUCTION

The purpose of this memorandum is to describe the proposed Gulf Stream Drift Mission of the Grumman/Piccard PX-15 deep-sea submersible and NASA's participation in it.

The mission is of importance to the nation since it offers potential contributions in the areas of:

a) Significant marine research - biological, geological and oceanographic observations within the Gulf Stream;

b) Long-duration human performance - observations of highly motivated groups of men engaged in meaningful scientific, and operational activities within isolated, confined, and hazardous environments.

This second aspect, and its possible analogies for future space missions, are the bases of NASA's participation. NASA's role in examining this mission as a possible space analog is exploratory since this represents the first use of a mobile submersible for these objectives.

II. BACKGROUND

NASA is now conducting earth-based simulations of space systems and is participating in cooperative undersea missions. NASA's goal in these activities is to gain the knowledge needed to successfully develop space systems within which men can live and perform useful work over long durations. Investigations have recently been conducted within fixed undersea habitats which permit intensive observations of man's operational performance. The present study will use a mobile deep-sea submersible which, although designed primarily for marine science observations, provides an unusual opportunity for the field study of human performance.

The Grumman/Piccard PX-15 ("Ben Franklin"), is the world's largest operational deep-sea submersible. It is now being readied for a 4-6 week mission, planned to start in June. During this mission it will drift submerged within the Gulf Stream from Florida to Nova Scotia to depths as great as 2000 feet. It will carry a crew of 6 men who will obtain data from a wide variety of marine research, operational, and life sciences observations. This initial Gulf Stream Drift Mission represents a cooperative effort on the part of the U.S. Navy, Grumman/Piccard, and NASA. In this effort NASA has made a relatively modest investment through Grumman for the definition and implementation of a program to evaluate the use of such submersibles as space mission analogs. Plans call for the acquisition of data related to evaluations of habitability, maintainability, environmental analysis, microbiology, and physiological and behavioral performance assessments.

This memorandum summarizes the major mission components and events, the characteristics of the primary vehicle and crew, and the anticipated scope of the measures related to NASA interests. It is based upon information obtained from the Grumman Corporation's project teams having primary responsibility for the planning and execution of each phase; from Dr. Jacques Piccard, who originated the concept of the drift mission and the basic design of the vehicle; and C. B. May of NASA/MSFC, who has been the primary force behind the development and implementation of the NASA portion of the program and will be NASA's onboard crew member(1).

III. CHARACTERISTICS OF THE UNDERSEA HABITAT

The Ben Franklin submersible vehicle is primarily a mobile marine science laboratory. Its basic configuration and equipment features are largely dictated by the nature of the undersea environment and the operational requirement to support extended underwater research on an essentially self-sufficient basis. (See Figure 1)

In the establishment of a program for the in-situ assessment of crew status and behavior, it was necessary to balance the demands of the concurrent goals of underwater research, safety, comfort, and crew acceptability.

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(1)References to preliminary documents are not included here. This summary is intended to reflect the scope of the proposed NASA program, rather than its successive stages of evolution. The program's final components and documentation are now being prepared by Grumman.

The vehicle's most relevant physical and operational characteristics are summarized in Tables 1.a and 1.b. For assessing the crew's status and behavior during the mission, these may also be described in terms of the resulting methodological constraints and situational stresses.

METHODOLOGICAL CONSIDERATIONS

a) Power extremely limited - no hard-line or regeneration capability

b) Limited real-time communication - no direct visual access or TV monitor of crew; limited voice contact.

c) Flexible scheduling - minimal constraints on response capabilities to scientific targets of opportunity

d) Use of real mission operations and scientific tasks as performance measures

e) Reliance on crew self-reports, logs, diaries, and other partially intrusive methods for data acquisition; with participant observer and recording device supplements

SITUATIONAL STRESSES

a) Physical hazards, including: reliance on mechanical equipment for survival in deep-sea; closed ecological system; possible microbiological or atmospheric contamination; lack of direct physical contact with any fixed base.

b) Psychosocial factors, including: isolation, confinement, danger; limited privacy and recreational outlets; celibacy and separation from families; high intra-group responsibility; differences in crew roles and responsibilities; required self-reporting; awareness of monitoring of activities and evaluation of behavior by others.

IV. MISSION PROFILE

The Ben Franklin will initially submerge off the eastern coast of Florida near Palm Beach. Remaining submerged, it will drift in a northerly direction following the Gulf Stream, as indicated in Figure 2. It will passively hover within the stream, using its four electrically powered engines only for corrections or contingencies.

In the region between Florida and Cape Hatteras five descents to the bottom will be made. For a part of this path the vehicle will drift along within 30 feet of the bottom. From Cape Hatteras northward the Ben Franklin will operate at nominal depths of 600 and 2000 feet, since the bottom in this region is beyond its operational limits. The mission is planned to take 4 weeks, although the vehicle will be equipped to support the crew safely for up to 6 weeks, and the drift will be completed off the coast of Nova Scotia.

Networks for safety assurance, tracking, mission control and communication have been established to support the Ben Franklin's drift. Major scheduling, consumables budgeting, and planning decisions will be divided into nine blocks of approximately 3 days each. The primary surface support ship will be the M/V Privateer and the secondary support ship will be the USNS John Gilbert Kellar. In addition to their other functions, the surface vehicles will conduct supplementary scientific activities such as acoustic calibrations, bottom reflectivity measurements, plotting of the Deep Scattering Layer, temperature/depth profiles across the drift path, and data storage and processing.

V. CREW COMPOSITION

The primary six-man crew for the Gulf Stream Drift and their mission assignments are given in Table 2. The prior experience of the crew members represents marine science and technological backgrounds consistent with the mission objectives. During the last several months of preparation for this mission they have been familiarized with the operation and care of the onboard equipment, and have contributed to establishing the final configurations and procedures. Throughout these training experiences every effort has been made to establish effective team relationships.

Selection of the crew from a candidate pool on the basis of screening tests was not practicable due to the highly specialized scientific nature of the mission. Prior to the mission, these individuals will have received batteries of medical and psychological tests, and will have had extensive personal interaction. Any significant negative results within these would lead to replacement from the backup crew members, who have undergone parallel evaluations for such contingencies.

Training of the crew for this drift mission has been largely in the areas of onboard procedures and NASA program tasks, rather than their primary marine science observations. The skills necessary for safety within this environment have been practiced and some cross familiarization has been given in vehicle and equipment maintenance, scientific objectives and activities in other crew roles. The crew members may be considered highly motivated by the intrinsic rewards of their specialized scientific and operational objectives within this mission. But they cannot be considered homogeneous in skill levels across their areas of specialization.

NASA will have a crew member onboard for support of its program requirements during the mission. His major objectives are to provide: a) routine monitoring and maintenance of the onboard equipment needed for data acquisition of the NASA measures, and b) backup capabilities for these, and related observations. By his onboard participation both of these objectives may be gained with minimal additional equipment or task-sharing being imposed on the remainder of the crew. The crew will have to be participant-observers for much other information to be obtained in this mission. With regard to the NASA program, the basic distinction between the NASA crew member and the rest of the crew is in evaluating the effects of his dual role as a contributory program planner and a participant within that program. His activities have been reviewed in order to maintain compatibility between these roles. The intent has been to assure that his major onboard role will be that of a non-evaluative equal participant, and that whatever supplementary observations he may make related to others will be only when recording data on objective activity measures.

VI. MAJOR MARINE SCIENCE AND NASA STUDY ACTIVITIES

The planned onboard studies during the drift mission are indicated in the Appendix. Within these studies direct visual and closed-circuit TV observations will be made of the ocean environment. Photographic and instrumented records will be obtained and biological and water samples will be retrieved.

Onboard data will be coordinated with readings of concurrent conditions taken from the supporting surface ships. In addition, the crew will also carry out maintenance activities for themselves and the vehicle. They will make microbiological checks, and will periodically record their activities and reactions in operational and personal logs. Sequence cameras will photograph their movements within the ship, and tapes will be made of communications with the surface support ships.

The scope of the studies immediately within the NASA program are also indicated. They are primarily addressed to the support and evaluation of systems maintainability, habitat environmental conditions and crew performance, although the NASA crew member will participate in some oceanographic data acquisition, equipment monitoring, and vehicle support activities.

VII. THE "BEN FRANKLIN" AS A POTENTIAL SPACE MISSION ANALOG

The potential value of this mission from NASA's viewpoint, lies in the characteristics of the situations and activities within it, and their similarity to those in possible future space missions. The net value of the present study will be in its success in the translation of these inherent possibilities into retrievable and meaningful data. These, in turn, must be interpreted so as to reveal the interactions, causal relations, and correlations among all aspects of interest in the performances of the crew, the equipment, and identifiable antecedent and concurrent conditions.

Reference to the descriptions of the vehicle, the operational environments, the crew composition and activities (Table 1, 2) indicates that the basic characteristics of this mission have similarities to those in anticipated future space missions. They may be reasonably compared in terms of habitat size and accommodations (400 cubic feet per man, with reconstituted food, advanced waste management, sanitation and recreation facilities); crew size and composition (6 men, with scientific and technological backgrounds); mission activities, duration and stresses (real scientific and operational tasks, for 30 days in a moving, remote, confined environment without resupply capability); and many other attributes. Some of these (such as fidelity of stress due to real hazards) would be difficult or impossible to provide in more conventional simulations.

Of course, there are also many obvious dissimilarities between this undersea drift and any reasonably anticipated space mission. Perhaps the most relevant of these are the nature of the gravitational field (zero-g or rotational forces will not be present); the severe methodological limitations imposed upon the monitoring of the crew and onboard systems (no direct bio-telemetry or systems telemetry, and limited real-time information retrieval); and the fact that the specific tasks and hazards encountered will be those of the undersea environment rather than those of space flight. Such factors, of course, must be considered in the evaluation of any technique for the simulation of space missions.

This study represents a cooperative effort to extend laboratory-quality observational and testing methods into a remote field-study environment. Because of the primary marine science objectives of the mission, many operational factors have constrained what could be studied within the NASA portion of the program. The final makeup of the data acquisition, reduction, and interpretation preparations is now underway.

The goals of this exploratory undersea study are to accurately reveal the interplay of man-systems performance within this mission, and help NASA establish an additional source of information for the planning and development of future space missions that may be both scientifically valuable and economically attractive.

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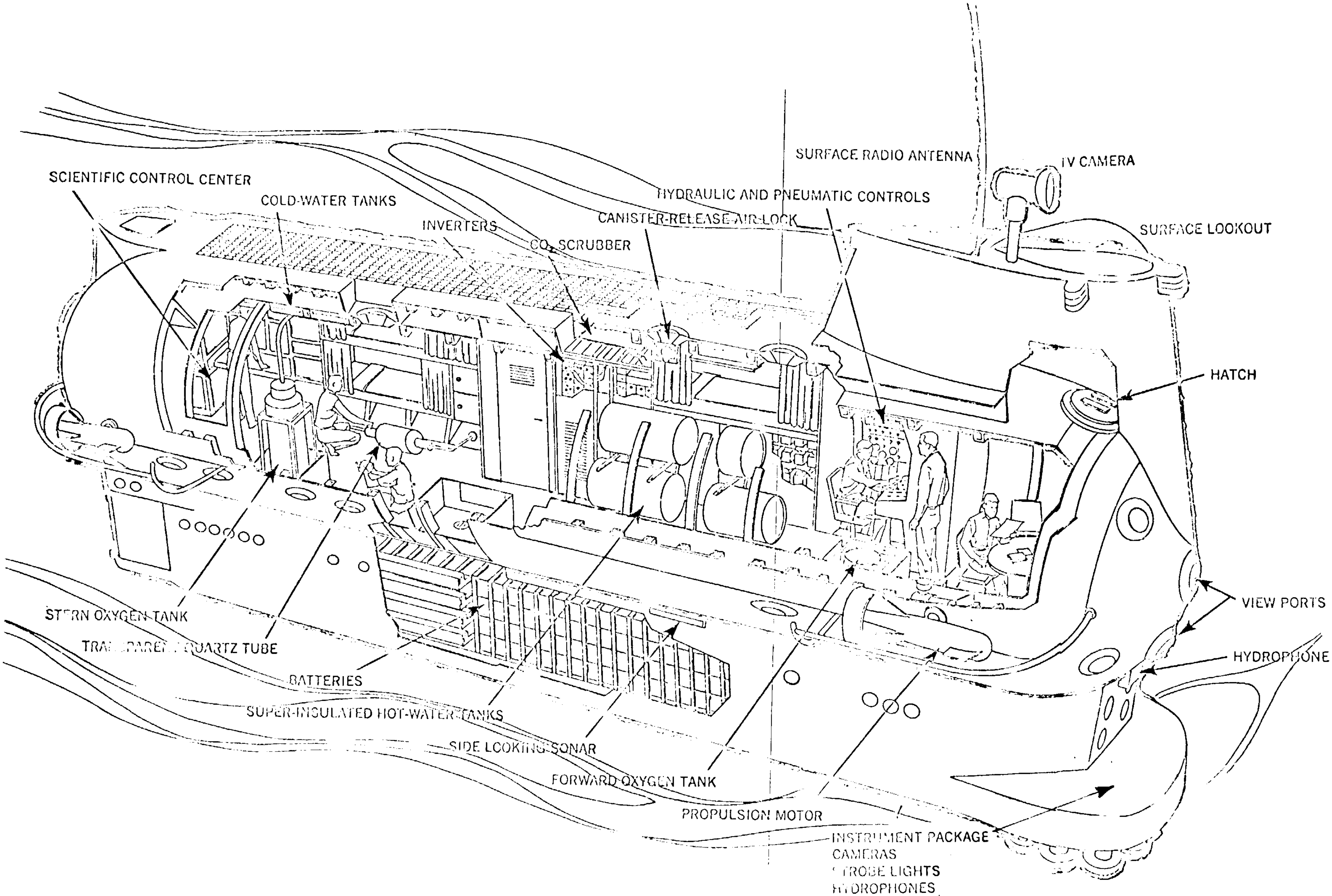
B. A. Gropper

Attachments
- Figures 1 and 2
- Tables 1 and 2
- Appendix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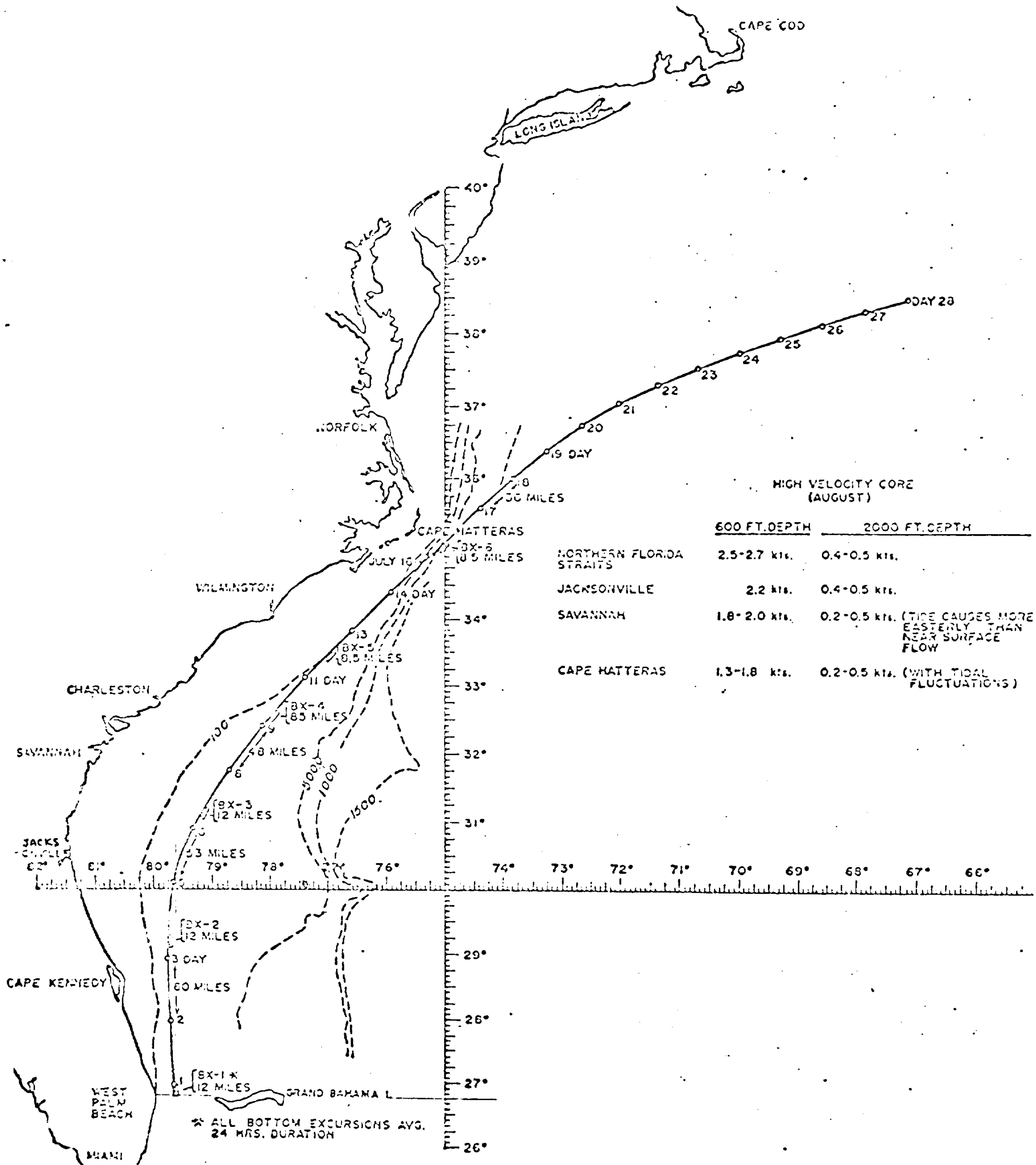
SURFACE LOOKOUT
HATCH
VIEW PORTS
HYDROPHONE
STERN OXYGEN TANK
QUARTZ TUBE
BATTERIES
SUPER-INSULATED HOT-WATER TANKS
SIDE LOOKING SONAR
FORWARD OXYGEN TANK
PROPULSION MOTOR
INSTRUMENT PACKAGE
CAMERAS
HYDROPHONES

FIGURE 1



ANTICIPATED BEN FRANKLIN DRIFT

FIGURE 2

TABLE 1.a

PX-15 ("BEN FRANKLIN") VEHICLE CHARACTERISTICS

Overall Length	48 ft., 9 in.
Overall Height	20 ft., 0 in.
Pressure Hull Interior Diameter	10 ft., 1 in.
Volume per Crew Member	400 cubic feet
Access Hatches	(2) 30 in. diameter each
Submerged Displacement	284,150 lbs.
Maximum Operational Depth	2000 ft., (4000 ft. collapse depth)
Maximum Submerged Speed	4 knots
Battery Capacity (1000 hr. rate)	750 kwh total
Propulsion (Electric)	(4) 25 hp. motors
External Visibility	30 Viewports, 1 remote control TV monitor
External Lighting	70 lamps
Voice Communications	hydrophone
Operating Fluids, Gases, and Solids	7500 lbs.
Emergency Droppable Ballast	5 tons
Life Support Capability	6 men for 4 weeks, 2 week backup; limited medical supplies.

TABLE 1.b

OPERATIONAL AND ENVIRONMENTAL CHARACTERISTICS

Location	Mobile: drifts with Gulf Stream from Florida to Nova Scotia
Mission Duration	4 to 6 weeks
Crew Size and Composition	6 men; Scientific and technological teams; heterogeneous national linguistic and organizational backgrounds
Scientific Activities	Marine biological, geological and oceanographic laboratory; interior and exterior observations; no EVA possible
Information Management	Limited retrieval and analysis during mission; power limited; no hard-line for power or communications; periodic voice communications with surface; dependent upon participant-observers and self-reports.
Operating Depths	Normally 600 and 2000 ft; some bottom-following within these limits.
Atmosphere	Isobaric; normal earth O_2 - N_2 mixture
Temperature	Isothermal with Gulf Stream environment (@ 50 - 75°F)
Operating Conditions	Single cylinder configuration with main center aisle and common areas at each end; variable light, noise, and vibration levels.
Ecology	Closed system; no resupply, and limited sample retrieval
Habitability Features	Conventional bunks, shower, waste management, and reconstituted food; exercise and recreation available (books, cards, games, music); privacy areas available.

TABLE 2

PRIMARY CREW AND DRIFT MISSION ASSIGNMENTS

Function	Personnel	Affiliation	Mission Assignments
Captain	Donald J. Kazimir	Grumman (GAEC)	Responsible for vehicle operations, crew comfort and safety. Also serves as chief pilot.
Pilot	Erwin Aebersold	Bureau Piccard	Second to Captain in piloting and all other vehicle operations.
Mission Leader	Dr. Jacques Piccard	Bureau Piccard	Responsible for coordination of all experiments. Directly responsible for performing the following: a) Plankton Sampling b) Turbulence Research c) Oceanographic Optical Study d) Water Potability Will also relieve and assist pilots and NavOceanO team as needed during the bottom cruise periods.
Chief Oceanographer	Roswell F. Busby	NavOceanO	Responsible for performing the NavOceanO experiments.
Oceanographer	Kenneth Haigh	NavOceanO	(Same as above)
Engineer/ Researcher	Chester B. May	NASA/MSFC	Responsible for performing and onboard data collection on the following: a) Maintainability b) Gaseous Contaminants c) Environmental Sampling d) Physiological and Behavioral e) Power Management Will also assist pilots and NavOceano team.

APPENDIX

MAJOR MARINE SCIENCE AND NASA STUDY ACTIVITIES

Marine science activities are the primary objectives of this mission. They will be incorporated into the planned crew performance assessments, but these activities will not be equally relevant for all crew members.

A. Naval Oceanographic Office Studies

1) Investigate speed, direction, turbulence, and physical/acoustical properties of currents with depth and time.

2) Record DSL (Deep Scattering Layer) characteristics from above, below, and within - over a wide frequency band (3.5 - 32 KHz).

3) Monitor DSL components visually, and obtain written and photographic documentation. Conduct limited sampling and obtain environmental data on DSL (temperature, salinity, nutrients, light levels, chlorophyl) concurrent with observations and samples.

4) Acoustically and photographically map the bottom relief and visually delineate the nature of the bottom at selected locations.

5) Conduct acoustic (5.5 KHz) sub-bottom profiling at selected locations to a depth of 300 feet below the water-sediment interface.

6) Measure acoustic reflectivity (Bottom Loss) at selected locations.

7) Measure gravity and magnetic anomalies periodically throughout the mission.

B. Oceanographic Optical Measurements

Obtain optical measurements of the bio-luminescence, chlorophyl and fluorescent mineral contents of the surrounding ocean environment.

C. Turbulence Experiment

Hot film anemometry measurements will be taken of water velocities, temperatures, natural turbulence. The magnitude, direction, and gradient of natural currents within the Gulf Stream will be recorded.

D. Plankton Sampling

Live marine specimens will be taken for onboard and post-mission analyses.

E. Grumman/NASA Study Activities

The studies within the NASA portion of the overall program have been planned to form a compatible set within the primary marine science objectives and operational conditions. The intent has been to obtain a broad base of interrelated measures with minimum intrusion on crew activities.

During the mission a wide range of environmental, operational, and crew status measures will be taken. These will be related to pre- and post-mission measures, and the resulting data will be analyzed for possible patterns of significance among the crew performance indicants and corresponding conditions.

For purposes of discussion they may be considered under the general categories of: I. Maintainability, II. Atmospheric Environment Analysis, III. Microbiology, IV. Habitability, and V. Physiological and Behavioral Assessments. Those marine science activities (VI) in which the NASA crew member will actively participate are also indicated.

Since they are significantly different in their scope and the operational conditions under which they will be made, the pre- and post-mission measures may be discussed before the onboard measures during the mission.

1) Pre-Mission Measures

a) Physiological measures will include; pulse rate and metabolic costs of exercise (Harvard Step), vital capacity, hand strength, EEG sleep monitoring, baseline psychomotor performance (using SCOW complex coordination device), and a standard physical examination.

b) Behavioral measures will include: personality profiles based on Rorschach, Edwards PPS, NMRI scales, ISQ, PAS, SSS, Firo B, Fitzgerald; interviews and demographic information, personal diaries and indoctrination to the purposes and scope of the planned observations.

2. Post-Mission Measures

a) Comparisons on all physiological measures. In addition, the crew will have been divided into two sub-groups (3 men each) for an onboard exercise program. One group will have participated in an exercise program, and the other will have refrained from systematic exericse. Post-mission comparisons will be made between these groups to evaluate the effects of such an exercise regime.

b) Behavioral measures will include the Edwards PPS, NMRI scales, interviews and debriefings. These will serve to indicate whether intrapersonal and interpersonal characteristics reflect mission stresses and experiences after mission completion. The interviews and debriefings will supplement these and also contribute toward evaluating the data in such areas as the objective behavioral observations and habitability assessments.

3. Onboard Measures During the Mission

The topics of these onboard studies and the corresponding measures of the crew and vehicle are interrelated and overlapping. This preliminary breakdown does not exhaust all the activities of each crew member which will be documented and evaluated - such as sleep, recreation, personal hygiene, intravehicular traffic, etc. The following lists indicate the anticipated NASA crew member tasks related to the major study categories within the NASA program.

I. MAINTAINABILITY

Investigates the effects of operational conditions on the time history of scheduled status monitoring, routine maintenance tasks, and crew maintenance capabilities under related contingencies.

These data may be useful for validation of the applicability of analytic predictive techniques (e.g., Methods 2 and 3 of Series 374 Maintenance Manuals). They may also contribute toward study of the times required to perform maintenance tasks under stressful conditions similar to those in possible future space stations.

A. Ben Franklin Vehicle

1) Scheduled Tasks

- Battery Monitoring
- Penetrator Inspection
- Cycle Sea Valves
- Hydraulic system Inspection
- Pneumatic System Inspection
- Ampere Hour Readings

2) Unscheduled Tasks

- Fuse Replacement
- UQC (Module Replacement)
- Macerator Replacement
- Water Pump Replacement
- Megger Test
- AEG Inverter Test
- O_2 System

B. Experiment Equipment

1) Scheduled Tasks

- Recorder Paper Replacement
- Camera Inspection
- Stop Watch Record for Lights/Equipment on Line
- Tape Recorder Inspection and Cassette Replacement

2) Unscheduled Tasks

- Gas Chromatograph
- NASA Cameras (film replacement; intervalometer or camera maintenance)
- Turbulence Experiment (Modular Replacement)
- Light Experiment (Modular Replacement)
- SCOW Complex Coordinator

II. ATMOSPHERIC ENVIRONMENT ANALYSIS

Investigates the time profiles of atmospheric components by gas chromatogrophy. The objectives of this are assurance of crew safety and investigation of effects of atmospheric composition on crew performance measures.

These data may contribute toward establishing design criteria for similar closed ecological environments (e.g., space stations), and also provide evaluation of a potential technique for inflight atmospheric monitoring.

A. Calibration Check Tests

- Trace Contaminants
- CO Concentration
- CO_2 Concentration
- O_2 Concentration
- H_2 Concentration

B. Syringe Samples for Post-mission Analysis

III. MICROBIOLOGY

Investigates the bacterial history (in terms of water potability, human and environmental flora) of a closed ecological system under operational conditions.

These data may also be used for crew safety and the evaluation of the relations of crew performance measures to microbiological changes. They may also potentially contribute toward design criteria for control of similar closed ecological systems (e.g., space stations).

A. Crew Safety Tests

- Drinking Water in Galley
- Total Cold Water System
- Hot/Cold Water Usage Reading
- Monitor Hot Water System at Galley when temperature is below 150°F
- Decontaminate BF with Detergent
- Urine Analysis
- Anaerobic Throat Cultures

B. Habitat Monitoring and Maintenance

- Potability Tests with Endo Media, Yeast-mold and Total Media
- Iodine Purification of Water System
- Anderson Sampler Cultures of Environmental Bacteria
- Post-readings of Bacteria Colony Counts at 24, 48, and 72 Hours
- Human Flora Samples

IV. HABITABILITY

Investigates the mission history of physical environment variables and correlated patterns of human responses, including: work/sleep cycles, food consumption, traffic patterns, recreation, socialization and area usages.

These data may be used to help evaluate the adequacy of the vehicle design for efficient support of crew activities. The data may also supplement available design information for similar vehicles (e.g., space stations).

A. Environment Measurements (Daily)

- Light Levels
- Noise Levels
- Vibration Levels

B. Photographic Documentation

1) Fixed Cameras for Crew Activity

   - Checking Camera and Intervalometer
   - Winding Camera
   - Removing, Storing, and Replenishing Film

2) Portable Camera for Close-up Task Pictures

   - Checking Camera
   - Winding Camera
   - Removing, Storing and Replacing Film
   - Check Floodlight Sunbeam Unit

C. Traffic Counter Readouts

- Bunk Sensors/Timers
- Shower Counters
- Head Counters
- Water Meters

D. Food and Clothing Usage

- Food Consumption
- Garbage Collection
- Log Food in and out
- Log out Clothing

more efficient gathering of oceanographic data so as to

V. PHYSIOLOGICAL AND BEHAVIORAL ASSESSMENTS

Investigates the mission history of relationships among physiological and psychosocial measures under operational conditions, using objective activity measures and confidential self-reports.

Among the physiological measures, the pulse records will be used as a technique for the indirect assessment of metabolic costs. Supplementary testing on one man will evaluate the use of an EEG sleep monitor device under conditions similar to those in possible future space stations.

The psychosocial measures may be used to evaluate possible changes in other behavioral and operational measures, with possible application to crew monitoring techniques for future missions.

A. Procedures and Logs

- Pulse Meter - Checking, Using, Charging
- Manual Pulse Checks
- SRT - Operating and Collecting Data
- Passageway Counter Recording
- Shower Use Records
- Tape - Removing, Storing and Replacing
- Head Use Record
- Data Timers - Inspection Synchronizing, Record
- Noise Level Meter - Use and Record
- Light Level Meter - Use and Record
- Vibration Meter - Use and Record
- EEG Sleep Monitor - Checking, Using, Storing Readouts

B. Backup for Contingency Records

- Event Recording and Logging
- Task/Time Profiles

VI. OCEANOGRAPHIC EXPERIMENTS

The activities in this area are intended to assist in the integration of the NASA crew member's scientific activities with those of the other crew men.

These activities are intended to reduce intra-group role differences, enhance crew rapport, and also permit more efficient gathering of oceanographic data so as to further ensure overall mission success.

A. <u>Turbulence Experiment</u>

- Calibrate
- Operate
- Alternate Modes

B. <u>Optical Experiment</u>

- Calibrate
- Operate
- Alternate Modes

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