"BEN FRANKLIN"

Vehicle Description

Grumman Aircraft Engineering Corporation
Ocean Systems Department
1969

"Ben Franklin"

General Specifications

The basic design features of the "Ben Franklin" are as follows:

Displacement	295,000 pounds
Length	48 feet, 9 inches
Beam	18 feet, 6 inches
Height	20 feet
Operational Depth (maximum)	2,000 feet
Collapse Depth	4,000 feet
Submerged Speed (maximum)	4 knots
Life Support	6 men for 6 weeks
Payload (nominal)	5 tons (mission dependent)
Total Power	756 KWH

"BEN FRANKLIN"

VEHICLE DESCRIPTION

I PRESSURE HULL

The structural arrangement of the pressure hull consists of a ring-stiffened cylinder with hemispherical end closures. The internal dimensions are approximately 10 ft 1 in. by 48 ft 6 in. Two 30-inch diameter hatches with viewports are provided, one at the upper portion of each hemisphere. A small lockout/transfer chamber with viewport is located on the vertical centerline amidships. In addition to these, 12 viewports in the hemispherical ends, and 15 viewports along the cylindrical section are provided, 29 in all. Twelve multipenetration reinforcements are available, six along the upper centerline and six along the lower. A substantial number of hull penetrations are reserved for future utilization. These can be used for cable, pipe and coaxial lines.

The hull is fabricated of 1-3/8 inch thick steel plate having a yield strength of 78,500 psi. Structural rings spaced uniformly along and inside the hull provide sufficient support to the shell to permit safe operation to depths of 2,000 feet while maintaining a margin of safety of two on hull collapse. The box ring frames are 6.3 in. by 5.7 in. deep and are spaced 27.5 in. apart. The combination of hull plating and reinforcement provides a hull bulk modulus in excess of 400,000 psi.

The basic structure is completely welded with the exception of a hull mechanical joint located in the amidships area. After fabrication, the two hull sections were stress relieved. To preserve this stress relief, no future weldings may take place on the pressure hull. For future use, additional attachment clips have been provided on the hemispherical ends.

2 INTERIOR ARRANGEMENT

Basically, the vehicle is divided into three areas as follows:

- Observation, mess, vehicle control area (forward)
- Life support, electrical conversion and distribution equipment, and sanitary facilities area (amidships)
- Scientific equipment and crew berthing area (aft)

2.1 Life Support

(1) Provisioning Allowances

Design of the various life support elements is based, in part, on the metabolic requirements of the crew which are summarized in Table A. In addition to these requirements, a supply of water is required for washing and toilet facilities.

The provisioning allowances used for the drift mission are:

° Food	1.75 lb/man day
° Water - potable	6.00 lb/man day
- sanitary	12.00 lb/man day
° Oxygen	2.00 lb/man day

(2) Tank Capabilities

Half of the potable water is stored in tanks which are in good thermal contact with the hull plating, thus providing cool drinking water. The remaining potable water is stored in superinsulated tanks at approximately 210°F. This water is used in the reconstitution of freeze dried food. Stored hot water was chosen in preference to electrically heating cold water primarily on the basis of minimum weight and electrical energy.

° Cool water	3000 lb
° Hot water	1600 lb

Oxygen is stored in cryogenic tanks in liquid form.

° Oxygen (two at 496 lbs ea)	922 lb

Table A

Life Support Requirements

Item		Pounds/Man Day		6 Men/42 Days Pounds Total	Remarks
INTAKE:					
Food		1.23		311	Freeze dried and heated for use. 2800K cal/day. 12-40-48 diet. Food does not include water.
Water (total)		6.00		1512	Potable stored.
Oxygen		2.00		504	Moderate activity levels.
Total:		9.23		2327	
OUTGO:					
CO_2		2.25		567	Gaseous
Water (A)	3.10		781		Urine
Water (B)	2.68		676		Respiratory
Water (C)	0.85		215		Perspiratory
Water (D)	0.22		55		Feces (Water only)
		6.85		1727	Total Water
		0.13		33	Feces (Solid only)
Total:		9.23		2327	

(3) Waste Management

The waste management system chemically treats and stores metabolic wastes on board. In this manner, minimum power is required and there are no hull penetrations. The system requires no power except for the odor removal unit and a macerator, both of which are operated for very short intervals. All pumping and flushing is accomplished by manually-powered mechanisms. Wastes are stored in tanks located below the floor between ring sections. The six tanks have a capacity in excess of 6,000 pounds.

(4) Air Purification

Purification of air requires control of CO_2, odor and contaminant level, the latter being generated by man's metabolic process and by the equipment and materials within the hull. Lithium hydroxide (LIOH) is used for CO_2 absorption. In order to conserve electrical power, the LIOH is used in panel configurations located throughout the vehicle to permit the natural convective currents within the cabin to circulate through them. These panels also contain activated charcoal for odor and certain contaminant removal.

Required LIOH panel weight is calculated at 4 lb/man day. Contaminants which are not processed by the charcoal will be neutralized by a portable, active odor removal unit which consists of a blower, a chemical absorbing section and a chemical oxidizing section. This unit will be activated periodically whenever the contaminants reach significant levels.

Contaminant levels will be determined with "Drager" gas detector tubes. Approximately 40 different detector tubes will be available to monitor the range of anticipated gas contaminants. Since many can be toxic, even on small concentrations, careful control of all equipment used in the cabin will be exercised in order to minimize the source of potentially dangerous contaminants.

This system requires no power. Measurements are made by inserting the tube into a hand pump, breaking the tip off the tube and pumping a specified quantity of cabin atmosphere into the tube. The chemical in the calibrated tube will discolor, lengthwise, proportionally to the specific contaminant. Each measurement will take about one minute.

(5) Temperature and Humidity

Temperature and humidity control of the cabin atmosphere is controlled by purely passive means. For the Gulf Stream Drift Mission, preliminary analysis indicate that the vessel's interior will operate between 10-15°F above sea water temperature. This is based on a sedentary crew activity level of 400 btu/hr/man and an average heat generated by cabin equipment of 680 btu/hr. The vehicle temperature should remain between 63°F and 81°F for the expected range of sea water temperature in the Gulf Stream without the need for wall insulation. The uninsulated walls will condense atmosphere moisture and maintain a relative humidity between 40 and 70 percent during the drift.

For missions in colder water, active heating and dehumidification may be required, depending on crew size and equipment heat load.

(6) Emergency Equipment

In addition to first aid equipment, an emergency O_2 supply and fire-fighting equipment are provided. The emergency O_2 supply is provided in the event smoke or any other irritant enters the vehicle atmosphere. Though only minutes are required to surface and open the hatch, provision has been made for at least four hour's emergency oxygen supply. Six masks will be provided, each weighing approximately 14 pounds. The masks are fueled with super oxide which will simultaneously remove CO_2 and generate O_2.

Chemical type fire-fighting equipment is provided. These are standard commercial type wall-mounted units.

(7) Mission Utilization

With the possible exception of temperature, humidity control and oxygen masks, the life support systems, as presently configured, are adequate for a complement of up to 12 persons over shorter periods.

Very careful analysis will be made by Grumman of the life support requirements of each Ben Franklin mission to ensure that the safety of vessel and its complement is not compromised.

2.2 Trim System

The pitch trim system enables the pilot to cope with changes in pitch by transferring water between two tanks located at the extreme ends of the hull. The system holds enough water (about 50 cu ft) to fill either of the tanks completely, and can correct pitch conditions as large as 10° above or below horizontal. This is equivalent to placing five crewmen at one end of the boat (as at meal time in the forward compartment). The two tanks, transfer pipe, and transfer pumps are all located beneath the floor, and the two tanks are also connected by a vent line which passes overhead within the hull.

The two transfer pumps operate at about 80 gallons per minute and can offset the effect of two men walking from one end of the boat to the other. The pumps are electric, and operated by the pilot as required.

In future utilization, careful attention will be placed on the distribution of payload to ensure that full payload allowance is available for equipment and stores. There is no system designated primarily for static list control. Control can be achieved by asymmetric loading on the shot (emergency ballast) tanks.

2.3 Hydraulics System

A manually actuated hydraulic system pressurizes accumulators to operate the emergency ballast system and the lockout/transfer chamber hatch. The manual pump, reservoir, accumulators, shutoff and selector valves are located within the submersible. Hull tube penetrations connect the actuators to the system.

The emergency ballast steel shot is contained in a hopper in each side of the vehicle, between the main ballast tanks. In an emergency, doors at the bottom of the emergency ballast hopper can be released. A manual selector valve ports the pump to either the emergency ballast system or to the release hatch. A reversible rotary actuator outside the hull is used to open and close the transfer chamber hatch.

2.4 Lockout/Transfer System

A transfer system capable of passing parcels up to 5.5 inches in diameter enables the crew to send exposed film or other objects of interest to the surface for pickup by support vessels. The system is comprised of the following:

- A hydraulically-operated hatch, flush with the top of the hull, opening outward.
- A hull-strength pressure chamber bolted beneath it to the inside of the hull.
- Pipes and fittings for blowing and flooding the chamber.
- A supply of hollow two-piece aluminum spheres.

To use the lockout system, the sphere is loaded with the film, taped together with rubber tape, and put into the chamber through the bottom hatch, which is then dogged tight. The chamber is then flooded and the top hatch is opened. A window in the bottom hatch enables an observer to see that the sphere floats clear. The top hatch is then closed and the entrapped water is then blown out through a pipe to the sea by compressed air pressure.

The normal container for use in the system is a 5.5-inch aluminum shpere with an inside diameter of 5.25 inches. Its payload (the difference between its weight and the volume of water it displaces) is about 2.25 pounds, but the lighter its cargo, the faster it will float to the surface. Because of its spherical shape and construction, the sphere will not collapse even at a depth of 6,000 feet.

On its way to the surface, the sea pressure will keep the two halves of the sphere tight to protect its contents and its bright orange paint will make it easier for retrieval from support vessels.

3 EXTERIOR SYSTEMS

3.1 Rudder

The rudders are located at the aft end of the keel. They are conventional, flat spade rudders and operated electrically. The rudders will normally only be operated while the boat is surfaced, but their position while submerged may be adjusted to act as a trim tab to compensate for current and drift.

3.2 Ballast Systems

Two systems of ballast control are provided; the main ballast (MB) system for maintaining freeboard on the surface and the variable ballast (VB) system for ascent/descent and precise depth control.

To arrive at a predetermined depth, sea water will be taken into the variable ballast tanks. The actual amount of water ballast required to effect a change in depth is a function of pressure and salinity, as well as the ambient sea temperature and heat generated within the vehicle.

MB compressed air is vented to the sea after use. VB air is normally vented to the sea, but alternatively may be vented into the hull interior. An on-board compressor can then recompress it and return it to the circuit.

In addition to these systems, an emergency ballast (EB) system containing in excess of five tons of droppable iron shot provides emergency ascent capability in the event of power failure, when "stuck" on the bottom, or in the event of complete exhaustion of the compressed air supply.

Major external elements of the ballast systems can be removed from the hull to facilitate overland transportation.

(1) Main Ballast System

Four "soft" fiberglass main ballast tanks are mechanically attached to the hull, two on each side, and provide additional buoyancy to the vehicle when it is surfaced. The additional buoyancy provides adequate freeboard for ingress/egress through either of the vehicle's two hatches. These main ballast tank assemblies are normally completely flooded during submerged operations. Diving from the surface is accomplished by permitting water to enter these tanks from the bottom while air is vented off at the top.

When surfacing, the top vents are closed and compressed air used to blow the tanks. The compressed air is carried in high pressure tanks located in the deck section.

(2) Variable Ballast System

The limited compressibility of the hull and the use of compressed air and water in the VB system permits the crew to operate the vehicle at any desired depth without expending any electric power and with a minimum of subsequent ballast adjustments.

Variable buoyancy control is provided by pressure-resistant (hard) tanks located beneath the hull in the lower keel section. The vehicle is neutrally buoyant near the surface when these tanks are half full of water; allowing water to enter, or blowing water out by compressed air gives vertical maneuvering capability for the vehicle within its operational depth limits.

To reduce the boat's displacement, compressed air is let into one or more of the tanks, and water is driven out. To increase the displacement, this procedure is reversed and ambient sea water enters the tanks; the air thus displaced is normally vented overboard.

BEN. F.

(3) Pneumatic System

The pneumatic system utilizes high-pressure air, stored external to the hull, in six 3000-psi flasks totaling 76 cu ft. This system is used to control the variable ballast tanks, to blow the main ballast tanks, and in addition, to blow the lockout/transfer chamber. An electrically-driven air compressor is provided inside the hull for added system flexibility. It is not normally used because of the large electrical energy requirements to compress a large quantity of air. Except for the solenoid vent valves on the main ballast tanks, all the valves controlling the pneumatic system are manual and are located within the pressure hull, with tubes penetrating through the pressure hull.

(4) Emergency Ballast

The emergency ballast (EB) system provides for the quick release, in excess of five tons, of iron shot to provide great positive buoyancy in the event of difficulty in surfacing by normal procedures. The shot is stored in bins between the forward and aft main ballast tanks and the release of shot ballast can be controlled either electrically or manually. The electromagnetic shot valves are divided into two sections. The upper section is made of steel having high magnetic retentivity. This section becomes magnetized when the field coils are briefly energized with 110V current. It retains its magnetic property for extended periods of time (like a permanent magnet), thus restricting the flow of shot without expending electrical energy. The lower section of the valve is a control coil which prevents the dropping of shot only when current flows through the coil. Shot ballast can be dropped at a constant rate by the electrical demagnetization of the upper section or in a small quantity by the demagnetization of the upper section and the intermittant activation of the control coil. In either case, shot drop is stopped by the remagnetization of the upper section.

In addition to the shot valve, a door is located at the bottom of each shot bin. This door is held closed by a hydraulically controlled system. Manual release of trapped oil on one side of each cylinder and/or oil pressure ported to the other side of each of two cylinders in the system will open the doors and all of the shot will be dropped. This system is totally independent of electrical power.

3.3 Electrical Systems

(1) Primary Batteries

Electrical power is supplied by lead acid batteries housed in the keel section. The system is pressure compensated to sea ambient. The battery consists of 378 two volt cells which may be connected in series/parallel combinations and are subdivided into four basic groups. The total battery capacity is 756 KWH.

Group A - Consists of six 56 volt strings connected inside the pressure hull to provide ±168 volts (336 volts total).

Group B - Consists of two 56 volt strings and four 28 volt strings connected inside the pressure hull to provide 112 VDC power and either 28 VDC power or 224 volts, in series with Group C, for propulsion power.

Group C - Consists of four 28 volt strings connected inside the pressure hull to provide either 28 VDC power or 112 volts, in series with Group B, for propulsion power.

Group D - Consists of three 28 volt strings connected in parallel within the pressure hull to supply 28 VDC power.

(2) Emergency Battery

A separate battery system is installed inside the pressure hull to supply 28 volt power to the 28 volt DC bus in the event of loss of power from the external batteries. This power source consists of fourteen (14), 2 volt cells with lead calcium grids, having a capacity of 192 ampere hours at 12 hour rate to 1.75 volts. Activation of this system is manual and disconnects all other sources of power from the bus prior to connecting the emergency battery.

(3) Distribution

The master mode switch, a six-position manual switch, controls the primary selection and combinations of battery elements and then directs these outputs to the boat's inverters and other equipment. Secondary selection capability is provided through the B battery switch.

The primary load for DC power is the pair of variable-frequency, solid-state inverters which supply the main motors with AC power. The next heaviest load is the two fixed-frequency, solid-state inverters which power the pod positioning motors. The DC system also includes a 112 volt supply for the exterior lights and a 28 volt supply for on-board equipment, including general lighting.

The five basic loads are:

- Port, 60 kva propulsion inverter (Inverter I)
- Starboard, 60 kva propulsion inverter (Inverter II)
- Propulsion motor positioning system inverters (Inverters III & IV)
- 112V DC lighting (external) and auxillary equipment
- 28V DC lighting and internal equipment. Internal equipment includes two 28V DC to 115V, 60 Hz inverters for limited use.

(4) Inverters

Two solid-state static inverters, operating on 336 volts DC, power the four main motors. Two static inverters convert 168 volts DC to 115 V AC for the pod positioning motors. The inverters are located amidships, but are controlled from the pilots station.

The main inverters are three phase and permit the reversing of the main motors. The output of the main inverters can be varied from 5 Hz at 70 volts AC to 50 Hz at 220 volts AC.

The secondary inverter's output is 115 volts AC at 60 Hz.

4 PROPULSION AND CONTROL SYSTEM

Propulsion is accomplished with four 25-hp motors. These motors are 220V, 3 phase, 50 Hz units manufactured by Pleuger. They are fresh water filled, pressure compensated, and operated by the two main solid-state inverters.

This configuration provides vehicle speed control and sufficient power or propulsion to a maximum speed of approximately four knots. In addition, the propulsion motors can be fully reversed and rotated in the vertical plane, thus providing up, down and reverse thrust capability. By applying forward thrust with the motors on one side of the vehicle and reverse thrust with the motors on the other side of the vehicle, the Ben Franklin can make still-water turns within its own length.

5 NAVIGATION, GUIDANCE AND COMMUNICATION EQUIPMENT

5.1 Submersible Equipments

The following instrumentation and equipment will be provided on the Ben Franklin:

(1) Pressure Gages - Three pressure recording devices will be installed at the control station as follows:

- 0-80 meter gage with 1% full scale accuracy
- 0-1000 meter gage with 1% full scale accuracy
- 0-800 meter continuous depth recorder (ink pen and paper strip type)

(2) Attitude Indicator - One pendulous pitch attitude indicator will be located conveniently to the pilot. Accuracy better than 0.5 degrees.

(3) Heading Indicator - The following instruments are being integrated into the control console:

- Master Compass - Consists of flux-gate pickup mounted outside the hull and with servo drive for an indicator at the pilot station.
- Secondary Compass - Consists of an aircraft magnetic compass located inside the hull and magnetically compensated.
- Directional Gyro - Used as heading reference.
- Rate of Turn Indicator - Similar to aircraft turn and bank indicator.

(4) Tachometers - Four tachometers, one for each main motor, are located on the pilot's console and indicate the shaft speed of each motor regardless of the direction of rotation.

(5) Pod Positioning Indicators - Four pod position indicators, one for each motor pod, are located on the pilot's console and indicate the angle of the pods with respect to the centerline of the boat.

(6) Voltmeters - Four voltmeters, one for each main motor, indicate the voltage applied to each.

(7) Ammeters - Each main motor has a separate ammeter which indicates the amount of current it is using at any time.

(8) Fathometer - A Simrad Model EP Fathometer will be installed having the following characteristics:

- Operating frequency: 38.4 K Hz
- PRF: 30 pulses per minute
- Pulse length: 2.7 milliseconds
- Maximum range: 600 fathoms

(9) Television - An Eastman underwater TV system will be installed.

(10) HF Transceiver - Simpson Model No. 150A, 150 watt, 8 channels, 28 volts.

(11) Intercom

(12) Underwater Telephone - Straza Model ATM 503, compatible with AN/UQC telephone and the AN/PQC (diver held) underwater sound communications.

- Range: 7500 + yards
- Acoustic output: 2.5 watts
- Carrier frequency: 8.087 K Hz

(13) Underwater Acoustic Tracking and Ranging System (Ocean Enterprises) - Consisting of the following units: (See Section 5.2 for associated surface equipments)

- Transponder Model TR-02
- Acoustic output: 20 watts
- Frequency: 27 K Hz
- Range: 15,000 ft in moderate sea

(14) Hydro Products TV - Mounted on a pan and tilt mechanism with a 250W thallium iodide light.

This unit is located at the bottom forward fairing of the boat for forward and bottom surveillance.

(15) CTFM - Obstacle avoidance sonar system, Straza Model 500

- Range: 10 to 1500 yards
- Sonar operation: 87 to 72 KC/S
- Sweep angle: ±150 degrees
- Scan rate: 25 degrees/second

5.2 <u>Surface Support Ship Equipments</u>

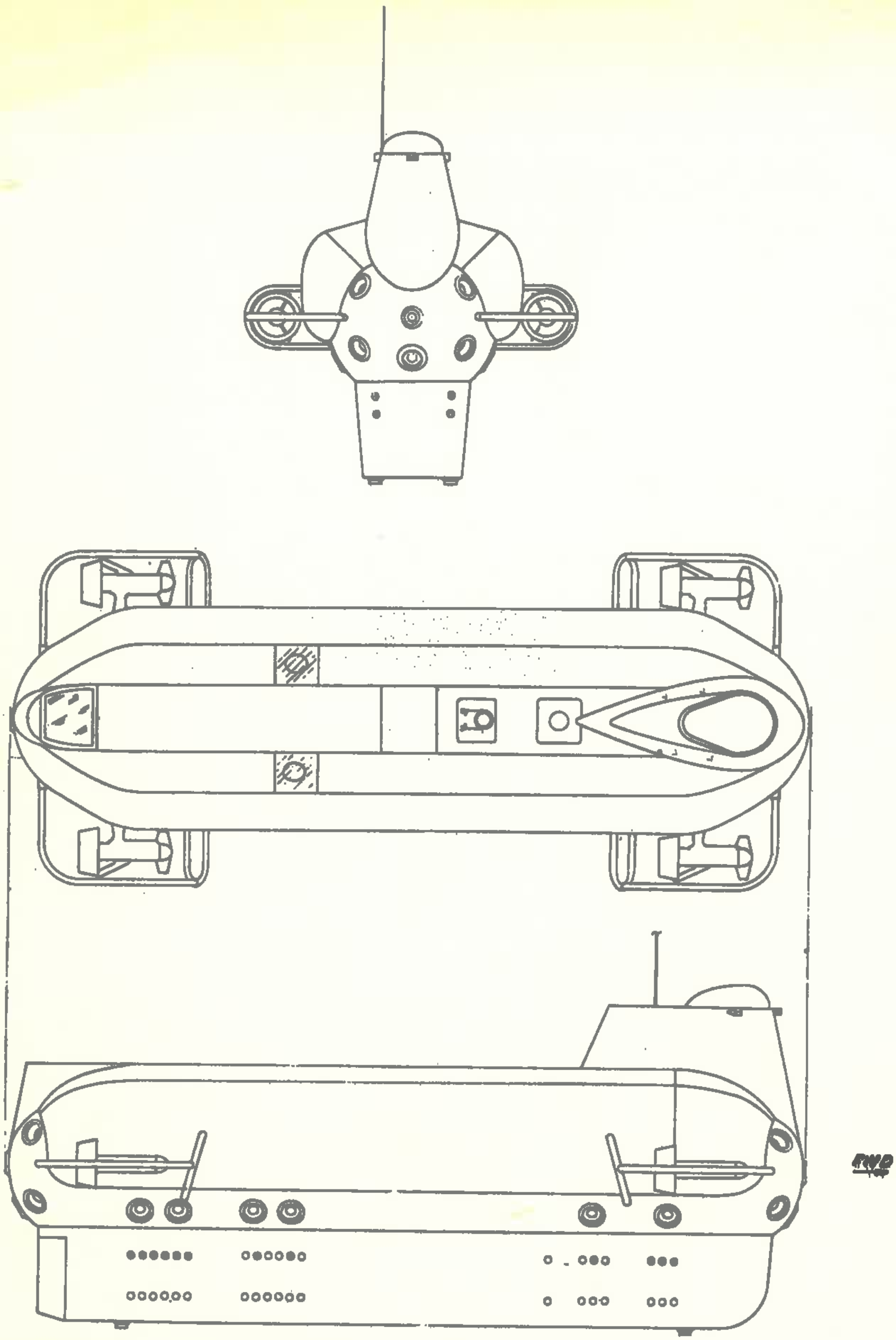
(1) Receiver Antenna Model PA-02

- Beam pattern: parabolic reflector with 10° cone

(2) Readout Module Model TTR-02

- Tracking Section:
  - Gain: 125 db
  - Bandwidth: 26.5 - 27.5 K Hz ± 1 db in the bandpass and 70 db down K Hz outside of bandpass
  - Power supply: standard 12 volt lantern battery, average battery life 100 hours

- Ranging Section:
  - Acoustic output: 20 watts
  - Meter scale: 0-1000 and 0-10,000 ft
  - Operating frequency: 25 and 27 K Hz



General Arrangement -
Ben Franklin