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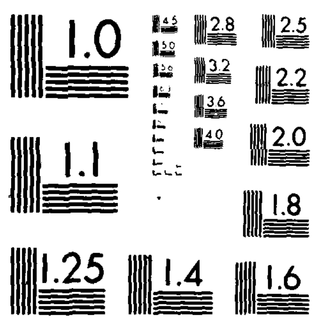

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FREE RUNNING RADIO CONTROLLED SURFACE SHIP MODEL EXPERIMENTS.
PART I: MULTIPLEX AND TELEMETRY EQUIPMENT

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

FREE RUNNING RADIO CONTROLLED SURFACE SHIP MODEL EXPERIMENTS. PART I: MULTIPLEX AND TELEMETRY EQUIPMENT

by

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and

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APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

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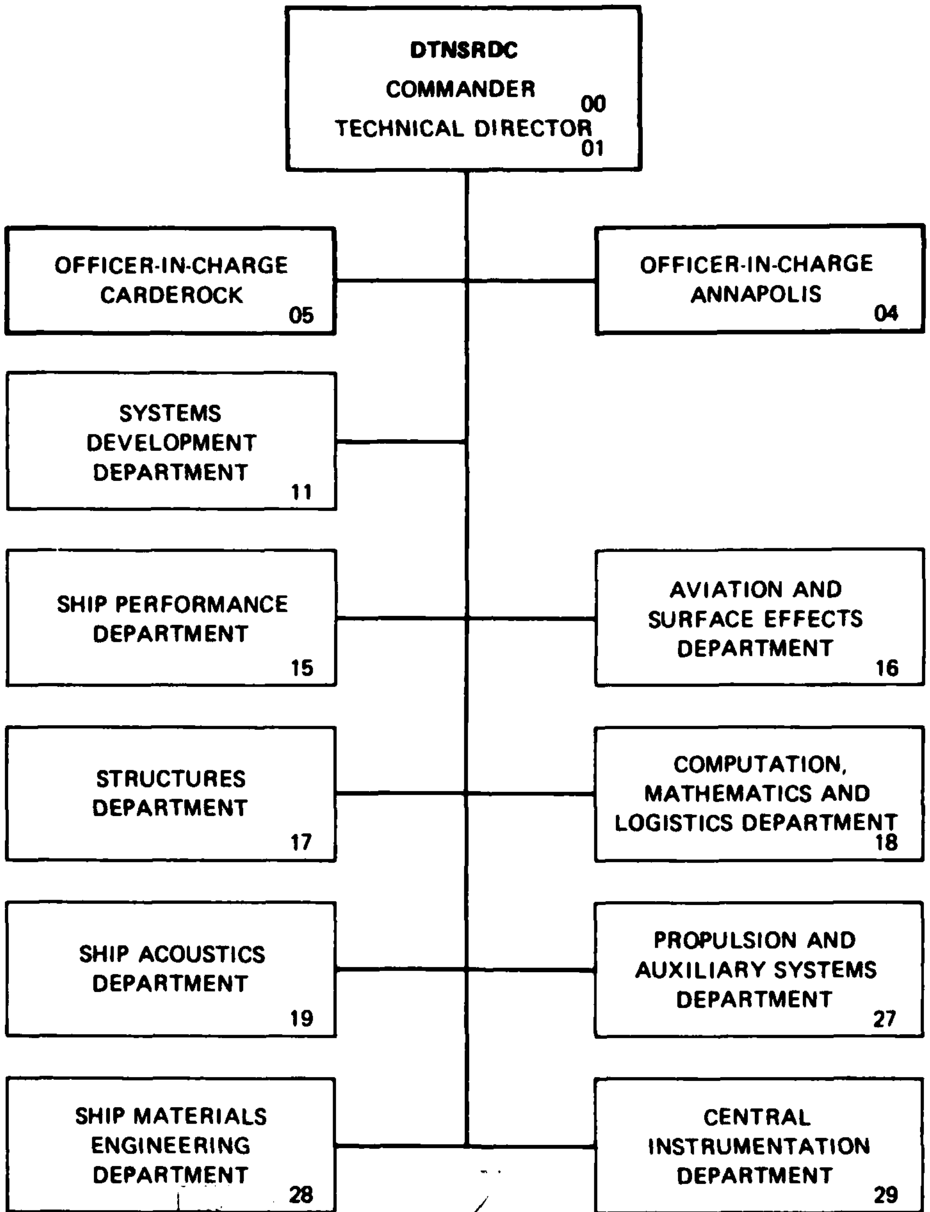

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An FM data multiplexing system and an FM telemetry system have been incorporated into a large surface ship model. Specifications of the system and details of the equipment operation and use for radio-controlled model experiments are discussed. In general, the system can accommodate identical transducers to those commonly used in routine carriage experiments. While a small additional error may result from use of the telemetry process, the new system

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ABSTRACT

An FM data multiplexing system and an FM telemetry system have been incorporated into a large surface ship model. Specifications of the system and details of the equipment operation and use for radio-controlled model experiments are discussed. In general, the system can accommodate identical transducers to those commonly used in routine carriage experiments. While a small additional error may result from use of the telemetry process, the new system provides a capability to perform routine maneuvering experiments in waves at a comparable cost to those for other routine experiments.

ADMINISTRATIVE INFORMATION

The work reported herein was funded under the joint sponsorship of the General Hydromechanics Research Program Element 61153N, Task Area Number SR-023-0101, and the Ships, Submarines and Boats Program Element 062543N; Ship Performance and Hydromechanics Program, Task Area Number SF-43-400-001. It is identified by Work Unit Numbers 1568-100 and 1507-101 at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC).

INTRODUCTION

It became obvious during the early 1960's that the Center could benefit from the use of free-running, radio-controlled models for several types of experiments. Consequently when the maneuvering and seakeeping facility was constructed it was equipped with an overhead photographic tracking system for this purpose. An attempt was made to develop a surface ship radio-controlled model; however, it was only partially successful. Electronic equipment tended to be large, heavy and unreliable, and as a result, radio control was never adopted for use in routine model experiments.

In recent years, the Center has assembled a team of specialists who have developed a very high quality radio control system for use with submarine models. For example, they have successfully overcome problems associated with underwater signal transmission, waterproofing, and overheating. Because of very stringent requirements for the submarine system identification work, they have developed an accuracy that is far superior to that normally required for most carriage experiments. As a consequence, such a sophisticated system is costly to procure and operate for normal surface ship maneuvering experiments (excluding system identification).

While inexpensive radio control systems are readily available from the hobby, craft and toy industry, they suffer from a lack of accuracy, and do not have the capability to collect data or to handle the power requirements of large models.

This document reports on the development of a new capability to conduct routine free-running, radio-controlled surface ship maneuvering experiments of comparable cost and accuracy to present carriage experiments. In addition to the ability to perform calm water maneuvering experiments, a radio-controlled ship model permits the performance of maneuvering experiments in waves. This is the subject of Part II of this report. A thorough investigation of available remote control systems has been conducted and components of a system have been purchased, assembled and tested. Details of the capabilities and use of the system are presented as Part I of this report.

Although the individual components of the telemetry and multiplex system were purchased as working units and identical transducers to those used in routine carriage experiments were used, considerable effort was necessary to assemble the total package into a satisfactory experimental system. The operational power requirements of each transducer were considered and appropriate power supplies were incorporated into the system. Special attention was given to avoiding ground loop problems between components of the system. Data signal conditioning, purchased with the new system, was matched with appropriate transducers, checked, and in some cases modified for ease of operation. Each multiplex channel of data was checked and adjusted to avoid signal over-scale problems and band-edge interference problems between multiplex channels. Antennas, necessary to transmit and receive data between the model and shore, were fabricated and located in the tank to minimize interference effects between data signals, the MASK facility and associated equipment.

INSTRUMENTATION

MULTIPLEX AND TELEMETRY

After considering the three major types of data multiplexing systems, a commercially available FM data multiplexing system with an FM telemetry link between the model and shore was chosen for implementation. This system is similar to one used in early work with the radio controlled submarine model. The modelborne portion of the system is compact and lightweight. The signal conditioning for 16 data channels and the encoding for six control channels is incorporated into one housing weighing only 26 lbs (12 kg).

A diagram of telemetry encoding and decoding equipment in the model is shown in Figure 1. Each channel of data, after passing through an appropriate signal conditioning card, goes through a voltage controlled oscillation, VCO, which converts the input voltage to a frequency modulated signal centered around one of the standard telemetry channel center frequencies. The modulated signals from up to 16 channels are multiplexed on a single channel which is telemetered to shore station receivers shown in Figure 2. Figure 2 is a diagram of the shore encoding and decoding equipment. The multiplexed signal from the shore station receiver is input to a series of discriminators which separate the multiplexed signal into the original individual data channels and recover the original model data. These analog data signals are available for observation, recording, and/or digitizing.

Specifications for the various components of the telemetry and multiplexing equipment are shown in Table 1. According to the specifications for the metraplex multiplexing system and excluding the telemetry link, the output signal will agree with the input signal to within 0.1 percent. Each channel has the same 4 kHz bandwidth and therefore is capable of processing data with a maximum frequency of 2 kHz. This is more than sufficient for all maneuvering measurements and most seakeeping measurements. Impact pressures generally have very fast rise times and can require a frequency response close to 2 kHz. It is recommended that the constant bandwidth system not be used to measure impact pressures without carefully evaluating the signal amplitude attenuation that may result.

The conic transmitters are quite accurate; however, the receivers and RF signal interference are known to have as much as a three percent error. There has been no attempt to measure this error but it is believed to be small (under one percent) for the proposed applications because of the controlled environment of the model experiment.

TRANSDUCERS

Most transducers presently used for seakeeping and maneuvering experiments can be used with the radio controlled model. A partial list is given in Table 2. The types of transducers available for use with the multiplex systems are limited by the availability of signal conditioning modules and power requirements.

Plug-in signal conditioning modules are available for all types of transducers in routine use at the Center. However, it is necessary to confirm the immediate availability of signal conditioning modules in planning an experiment.

Power for all modelborne equipment must be supplied through batteries. It is advisable to keep power requirements for the model propulsion, electronics, and instrumentation to a minimum. The number and size of batteries has a direct impact on many other problem areas including model ballasting flexibility, length of running time between down times for battery recharge, and battery maintenance.

The power distribution for a typical model experiment is shown in Figure 3. Power for the model propulsion and the electronics is supplied from separate battery packs to avoid interference effects. Power converters have been used to generate 15 Vdc for the motor control and 115 V at 400 Hz for the gyro transducer and the tracking system timer. However, the use of power converters is avoided because power losses are incurred.

MOTOR AND CONTROLLER

Direct current motors and efficient motor controllers suitable for large surface ship models are not readily available from commercial sources. For this experiment, an electronic motor controller rated at 100 Vdc and 70 amp maximum continuous operation was used with a 4 horsepower, 1800 rpm, 60 Vdc motor. The individual specifications of both the motor and the controller exceed the requirements for powering the 20 foot (6.1 m) model used in the maneuvering in waves experiment. However, the motor was generally operated at 1/3 to 1/2 of the optimum design rpm, and the controller was restricted to the supplied power at 48.0 Vdc. As a result, the controller was frequently trying to operate over the rated current limit. Following the experiment, it was discovered that the controller did not meet the 70 amp current limit specification and the actual limit was close to 60 amps. This, together with other manufacturing defects discovered in the controller, was the greatest source of trouble with the project. It is recommended that special consideration be given to the selection of the propulsion system for future experiments. This problem could be reduced by using an appropriate combination of motor and power supply.

BATTERIES

As indicated in the Transducers and Motor and Controller sections, the selections of batteries depends on the transducers and propulsion system. A number of battery types were considered, including lead-acid carbon zinc, silver oxide, zinc-chloride, and nickel-cadmium. Nickel-cadmium (nicad) batteries were used because they maintain a rather constant 1.25 Volts/cell voltage throughout the discharge cycle, can deliver high current, and can be recharged frequently. Individual 1.25 Volt nicad cells are commercially available in a number of power ratings which allows for considerable flexibility in designing an appropriate power source and making the necessary tradeoff between battery weight and run time between charges.

Standard MA-5 aircraft batteries were used for the initial experiments. These batteries are readily available and the cells are prepackaged in 24-Volt units with appropriate connectors between cells and on the case. Each 24-Volt unit weighs approximately 74.0 lbs (34 kg), including the case. The three units used for the experiment, see Part II, were positioned during ballasting to obtain the necessary ship characteristics. By using two MA-5 batteries for propulsion and one for the electronics, running time between charges was about two to three hours. All batteries could be charged simultaneously in less than 1.5 hours without serious damage to the cells.

TRACKING SYSTEM

The path of the ship is recorded by two overhead cameras in the maneuvering and seakeeping (MASK) facility. Lights in the bow and stern of the model flash once a second and are recorded on the film. This tracking system was installed in the MASK when it was built but has seen little use. The filmed record for a typical run is shown in Figure 4. The model speed, drift angle and heading angle can be obtained for each one second time interval since the scale ratio between the film and the tank is known.

A camera at each end of the tank is used to view that portion of the tank not blocked by the bridge and subcarriage. Some overlapping coverage in the center of the tank was originally included in the system design. Figure 5 shows a scaled drawing of the MASK tank surface, including the silhouette of a 20-foot model, and the coverage of the cameras. The solid line circle indicates the extent of the camera's view; however, the model lights can only be distinguished within the area bordered by the dashed lines. As a result, continuous tracking is only possible while the model remains in the effective view of a single camera. This is a relatively small area for maneuvering a large model and consequently many runs exceed the boundaries and cannot be fully analyzed.

Film for the cameras is no longer commercially available as a standard product and must be special ordered in large quantities well in advance of the experiment.

MODEL ARRANGEMENT

A list and approximate weight of the major components of the multiplex system, the telemetry system, and the power supplies are shown in Table 3. In general, each component on the list is a separate item and can be located on the model where space is available. It will be necessary in most applications to use the batteries to obtain the proper weight distribution for the ship. It is estimated that the total weight of the instrumentation system, propulsion system, associated power supplies, and interface cables amount to approximately 425 pounds for the configuration shown in Figure 3.

Figure 6 shows the fully instrumented and ballasted ship model and Figure 7 shows components of the major instrumentation in greater detail. Most of the instruments are located to facilitate the ballasting. One exception is the bow and stern lights shown in Figure 7 which were equidistant from the longitudinal center of gravity and near the same height as the vertical center of gravity. Care must also be taken so that the lights are never obstructed from the camera view during maneuvers.

SUMMARY

A data multiplex system and telemetry package have been assembled from commercially available modular components for use with large radio controlled surface ship models. Based on experience with initial experiments with a 20-foot fiberglass model, it appears that the system is applicable for most maneuvering experiments in both calm water and waves. However, a tracking system with better tank coverage than the present photographic system is required if maneuvering experiments are to be conducted in the MASK facility. The system is applicable for experiments where high frequency response is not required. The exact electronic equipment configuration should be developed for each experiment considering the special requirements of the experiment as is routinely done for any seakeeping carriage experiment.

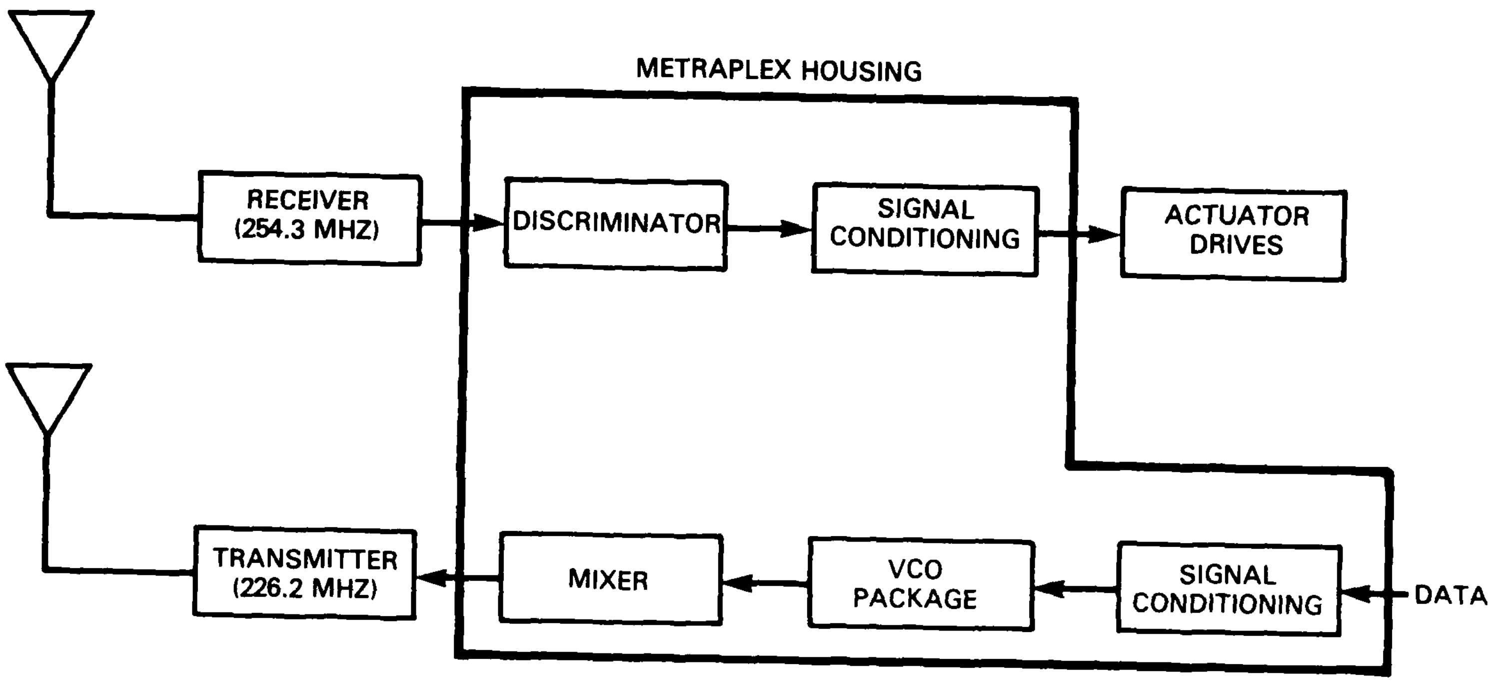

Figure 1 - Modelborne Multiplex and Telemetry Electronics

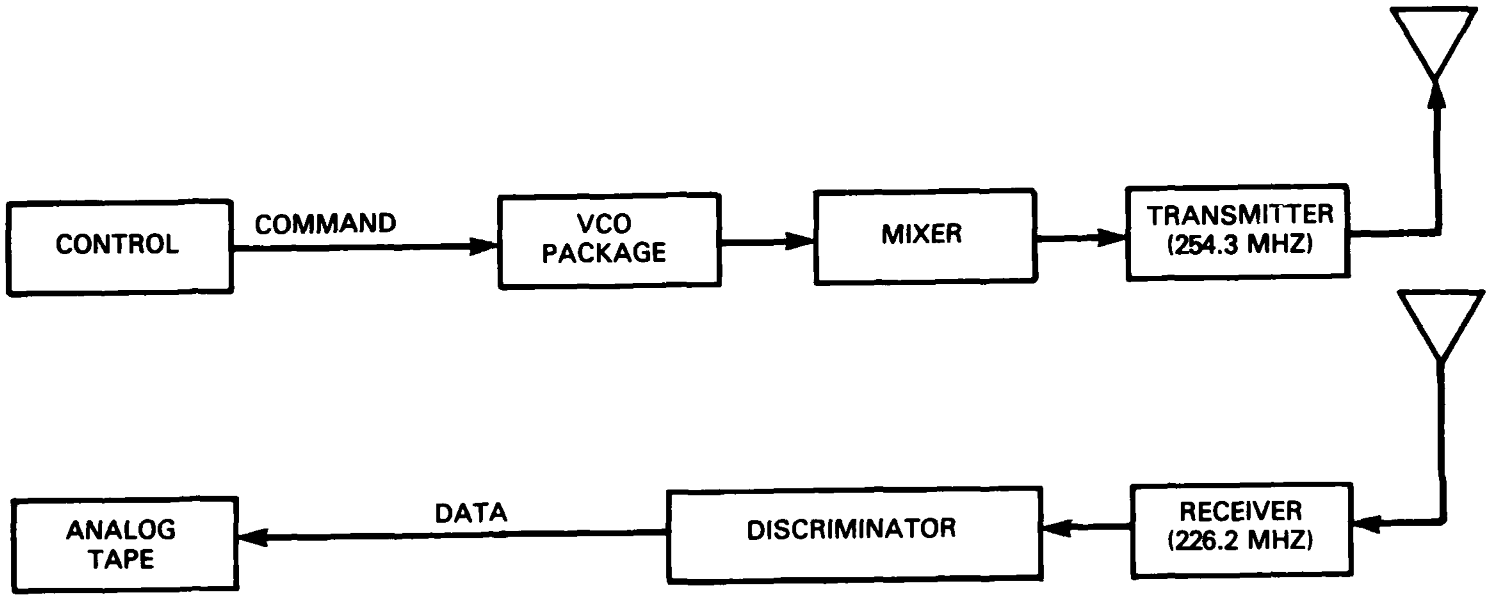

Figure 2 - Shore Station Multiplex and Telemetry Electronics

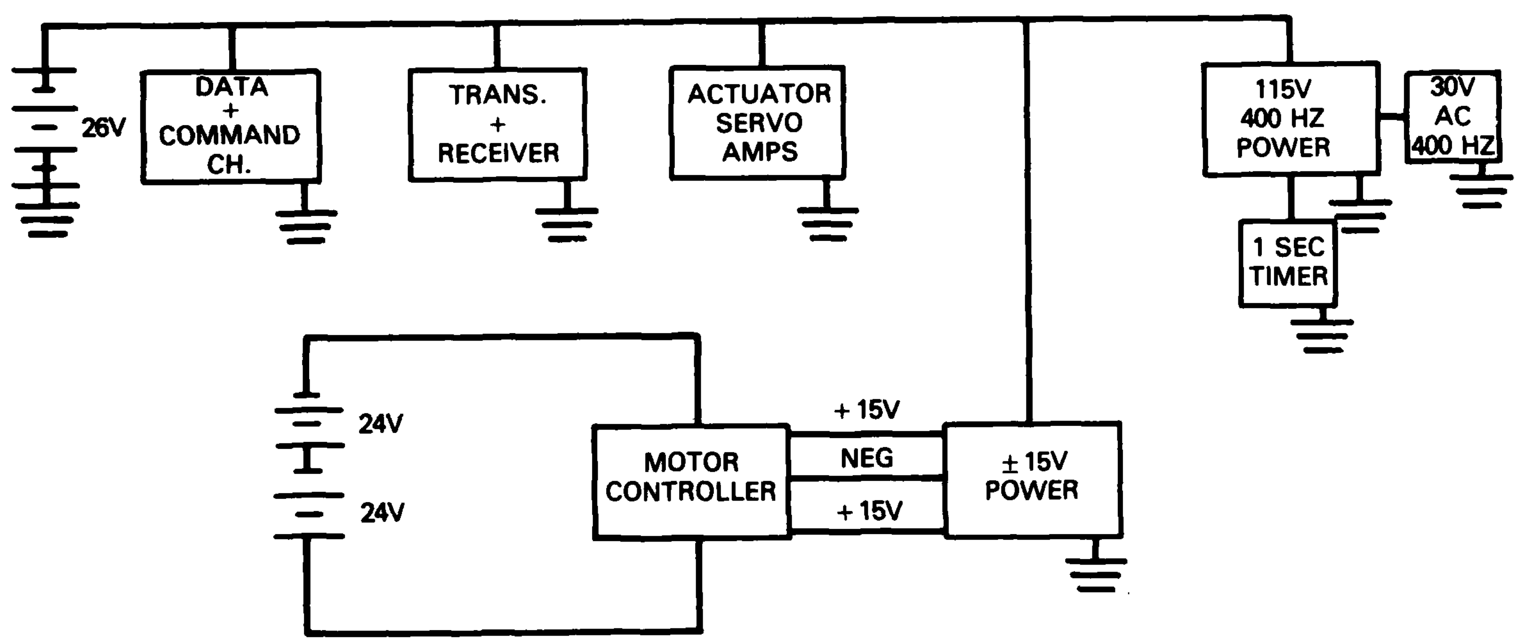

Figure 3 - Power Distribution for a Typical Radio Controlled Model

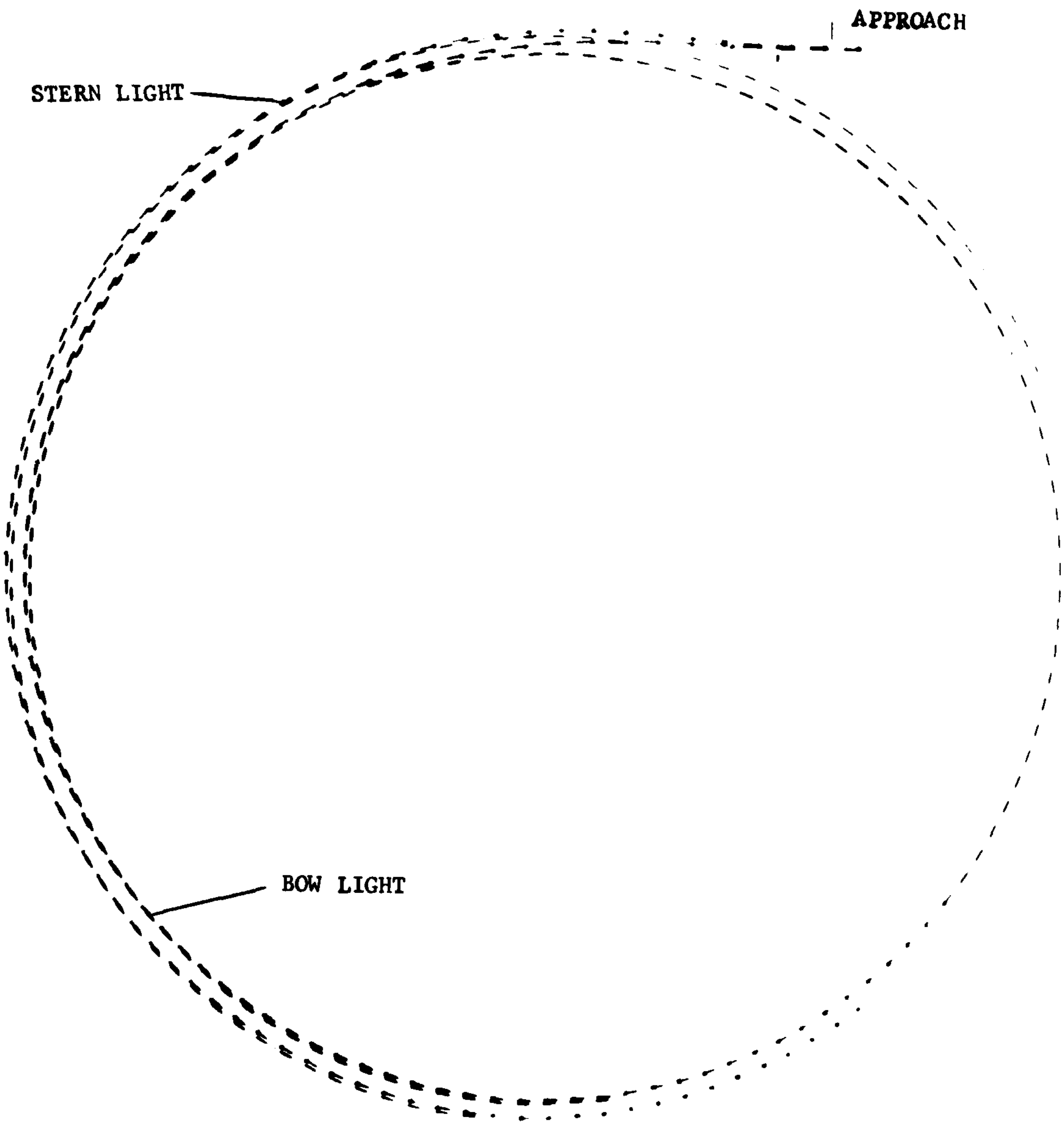

Figure 4 - Typical Tracking System Film Record

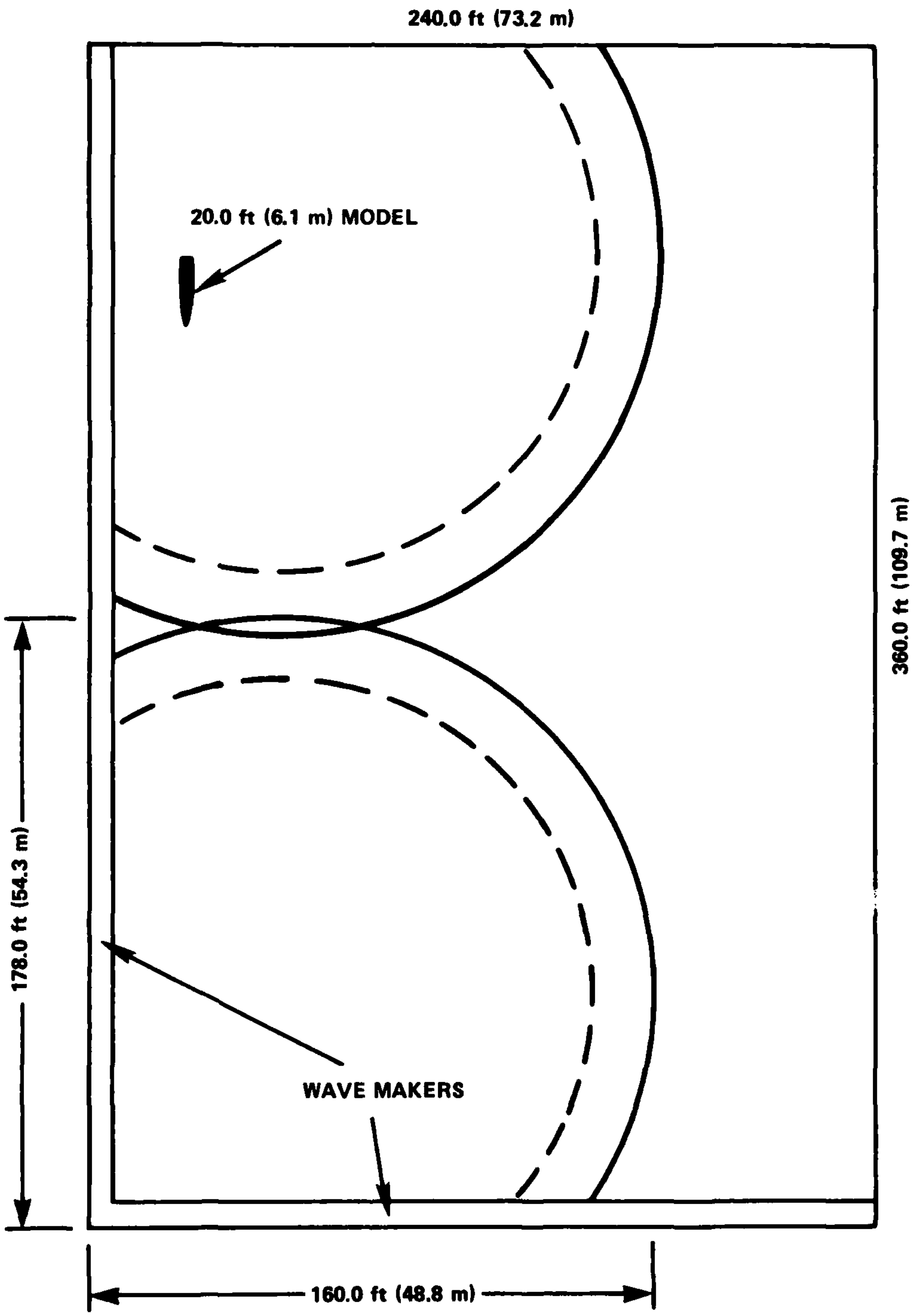

Figure 5 - Scale Model of Maneuvering Basin Water Surface

Figure 6 - Fully Instrumented and Ballasted Model

Figure 7 - Model Instrumentation

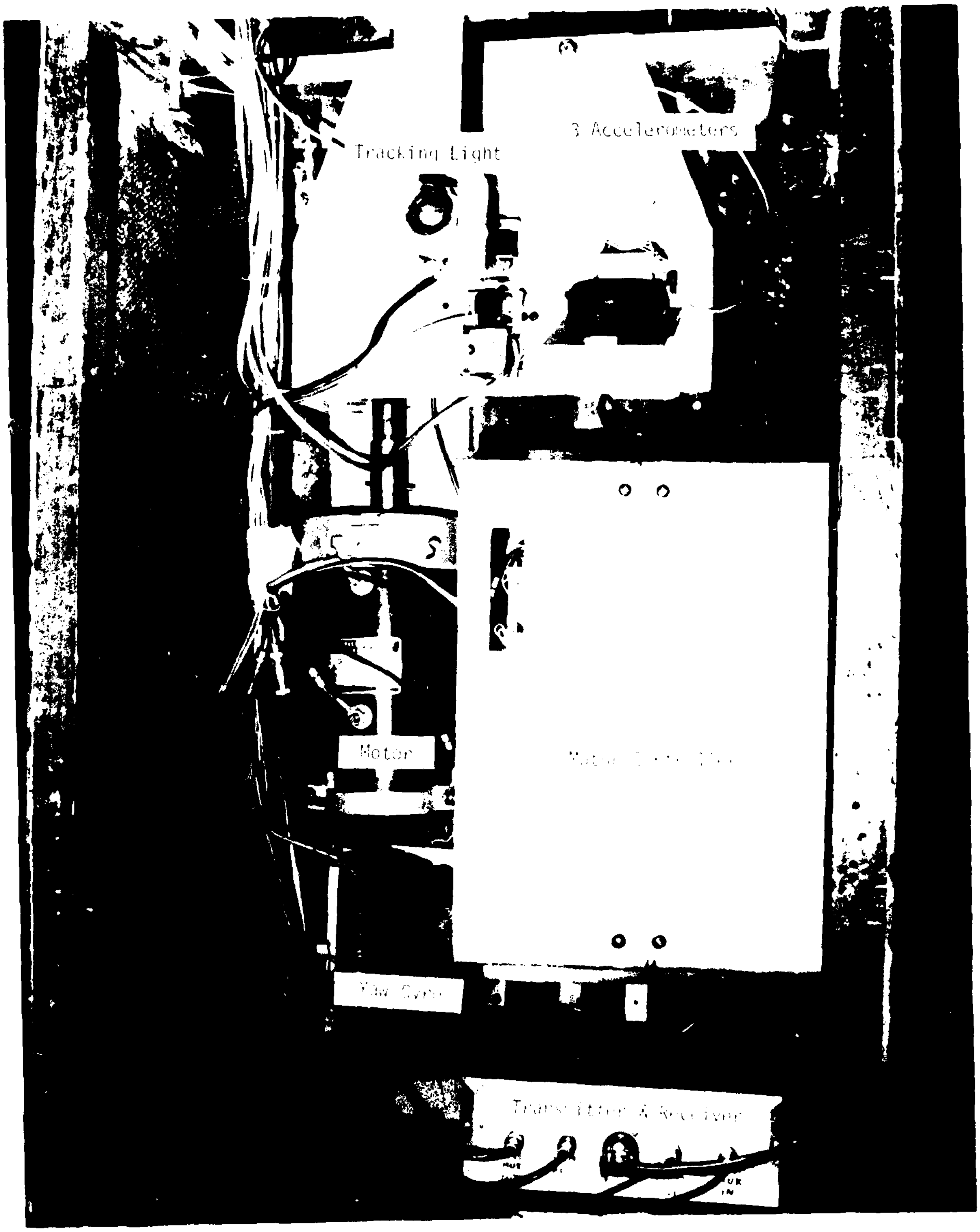

Figure 7a - Motor Controller, Motor, Yaw Gyro, Transmitter and Receiver, etc.

Figure 7 - Continued

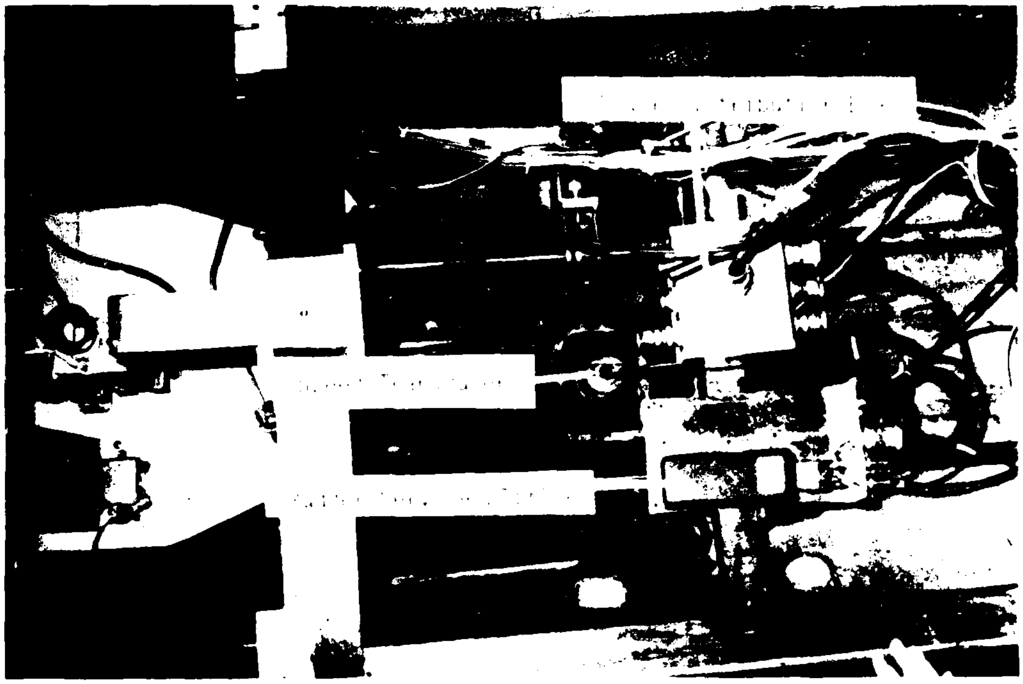

Figure 7c - MA-5 Battery, Stern Tracking Light and Multiplexing Equipment

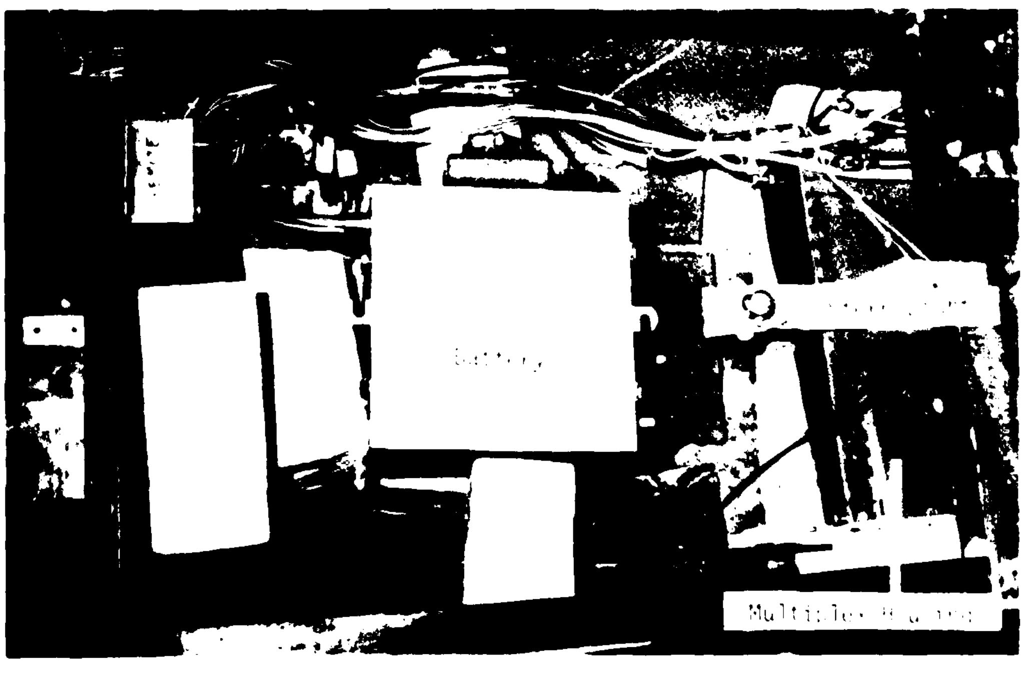

Figure 7b - Power Distribution Box, Speed Transducer and Amplifier

TABLE 1 - MULTIPLEX AND TELEMETRY EQUIPMENT SPECIFICATIONS

Voltage Controlled Oscillator Specifications

Metraplex Model 304A (on model)
114-01 (on shore)
Center Frequency: IRIG Constant Bandwidth
Channels 1A to 16A for data and
Channels 1A to 6A for control
Deviation Limits: ±2 kHz
Nominal Frequency Response: 0.4 kHz
Maximum Frequency Response: 2 kHz
Center Frequency Temperature Drift: 0.005 %/deg
Operating Temperature Range: 0°C to 50°C
Power Input: 14 ma @ 28 Vdc

Discriminator Specifications (Metraplex Model 120-01)

Frequency: IRIG Constant Bandwidth
Channels 1A to 16A
Output Noise level: Less than 10 mV rms for deviation
ratio of 2 or less
Output Zero Stability: 0.005% of Center Frequency per
degree C
Bandwidth: 2 kHz
Power Requirement: 300 ma @ 28 Vdc

Transmitter Specifications (Conic Model CTP-402)

Frequency: 254.3 MHz (Command)
226.2 MHz (Data)
Deviation: ±125 kHz
Temperature Range: -20° to 70°C
Power Output: 2 watts
Carrier Frequency Stability: 0.01% max.
Power Input: 450 ma @ 28 Vdc

Receiver Specifications (Conic Model CAR-200)

IF Bandwidth: 400 kHz
Audio Distortion: 5%
Image Rejection: 60 dB minimum
Power Input: 20 ma @ 28 Vdc

TABLE 2 - TYPES OF INSTRUMENTATION COMPATIBLE WITH AVAILABLE MULTIPLEX SIGNAL CONDITIONING MODULES

Ultrasonic

Accelerometer (Piezoelectric or Piezoresistive)

Gyroscope Stabilized Angle (Potentiometer)

Magnetic Pick-up

Potentiometer

Pressure Gauge (Strain or Piezoelectric)

Rate Gyroscope (Potentiometer)

Speed Paddle Wheel (Magnetic Pick-up)

Strain Gauge

TABLE 3 - SIZE AND WEIGHT OF MAJOR RADIO CONTROL EQUIPMENT

Instrument	Size L x W x H inches (L x W x H) cm	Approximate Weight lb (kg)
Metraplex Housing w/16 Data Channels and 6 Control Channels	17.0 x 10.5 x 5.3 (43.2 x 26.7 x 13.5)	26 (12)
Motor Controller Package	16.0 x 9.0 x 7.5 (40.6 x 22.9 x 19.0)	80 (36)
MA-5 24 Vdc Battery (19 - 1.25 Vdc Cells)	10.0 x 9.8 x 10.0 (25.4 x 24.9 x 25.4)	74 (34)
4 hp DC Motor	12.5 x 7.2 x 7.2 (31.8 x 18.3 x 18.3)	54 (24)
Motor - Battery Cable		13 (6)
Roll or Pitch Gyro	10.0 x 6.0 x 6.0 (25.4 x 15.2 x 15.2)	7 (3)
400 Hz Transformer	10.5 x 8.0 x 5.0 (26.4 x 20.3 x 12.7)	13 (6)

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