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ARGO/JASON

Imaging System Upgrade

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Final Report
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16. Abstract (Limit: 200 words)

The contractor was tasked to conduct research on the ARGO/JASON Support Systems. The work was intended to enhance the imaging capabilities of the JASON vehicle to meet full deep ocean requirements, to provide a means of transferring bottom samples to the surface from a deep sea operation, and to upgrade the precise navigation system to allow operation at depths of 20,000 feet for recovery of bottom samples.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

Remotely Operated Vehicle (ROV)
Precision Underwater Navigation
Tethered Underwater Vehicles
Underwater Tools
Recovery Systems
Sampling Systems
Collection Systems

c. COSATI Field/Group

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Report Documentation Page

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I. Executive Summary

A modification program for the ARGO/JASON survey system was instituted in order to upgrade (1) the imaging suite, (2) develop a sampler system, sample storage unit, an elevator system to recovery the samples, and (3) develop a wireless precision navigation and vehicle control system for the JASON Remotely Operated Vehicle (ROV). Section IV, Description of Tasks, contains a detailed description of each task.

The purpose of this report is to provide the results of this modification program.

II. Introduction

There were three tasks to be undertaken under this contract. They were:

A. **Imaging System Upgrade** - The JASON vehicle had limited video imaging capability. To meet the requirements for a deep sea imaging suite, a new technology high resolution intensified CCD TV camera system and high resolution Electronic Still Camera (snapshot video) system were required. To extend the coverage of the Electronic Still Camera system, strobe lights were to be provided to JASON. Integration of these systems into the ARGO/JASON system were also a requirement.

B. **Wireless SHARPS Navigation Modifications** - The JASON ROV is controlled and tracked precisely by an integrated SHARPS acoustic positioning and control system located on ARGO and JASON. JASON is controlled and tracked in relation to the ARGO sled. The SHARPS system was limited to 1,000 foot water depths. The transceivers also had to be redesigned for operation at 20,000 feet.

   Another requirement for JASON was to acquire samples from precise bottom locations. This precise location of JASON relative to the bottom required a modification to the SHARPS transceivers so that they could operate in a wireless mode. Software changes to the basic SHARPS control board were required to accommodate changes in timing sequences.

C. **JASON Sampling/Recovery Modifications** - The JASON ROV is designed with manipulator control. A requirement of deep sea operations is to utilize the manipulator to acquire bottom samples and place them in an elevator for transport to the surface. JASON then does not need to make the transit to the surface each time samples are collected. A sampling system was to be designed and built with a limited number of sampling storage units mounted in the elevator.

The contract refers to an ARGO sled as the mother vehicle for the JASON ROV. In actuality, there are several ARGO type sleds that can be, and are, used in place of ARGO by the Navy. The use of ARGO in this and other reports refers to these ARGO type vehicles that are used interchangeably to support JASON operations. In the case of this development, the actual vehicle chosen and used was MEDEA, a fiber optic ARGO type sled.

SHARPS is a registered trademark of Applied Sonics, Inc. and is manufactured under exclusive license by Marquest Group, Inc.

III. Proprietary Information

Identification of Restricted Rights for Marquest Computer Software

The Contractor, Marquest Group, Inc. has identified to the Government that the software, [TOOLKIT for Real Time Image Processing (TRIP), and the SHARPS operating software] contained in the Electronic Still Camera (ESC) and in the SHARPS systems that were modified and delivered under this contract were developed at private expense, are "Commercial Computer Software" as that term is defined in DFARS Clause 252.227-7013, and have been supplied to the Government Subject to restrictions on the Government's use and disclosure of the same as set forth below.

Pursuant to DFARS Clause 252.227-7013 the Contractor is supplying to the Government such software and all modifications made thereto pursuant to this contract only with "Restricted Rights", as that term is defined in DFARS Clause 252.227-7013, and the Government agrees that it shall have only "Restricted Rights" in such software modifications.

IV. <u>Description of Tasks</u>

A. JASON Imaging System Upgrade

Summary of Task

Prior to modification, the JASON vehicle had electronic imaging capability suitable primarily for close up viewing and inspection. These cameras provided high resolution color video for viewing forward and in the work area of the manipulator. The camera suite was not designed or intended for large area viewing or high altitude survey.

In order to meet requirements for wider area coverage, bottom survey and image mosaic, the JASON imaging system was upgraded with the addition of an Intensified CCD (ICCD) TV camera and a high resolution Electronic Still Camera (ESC). These cameras were mounted on the vehicle in a down-looking configuration to provide the desired view. In addition, the ICCD camera was augmented with additional down-looking, incandescent lighting and two strobe lights were added to provide illumination for the ESC.

Background

JASON is a remotely operated vehicle built for deep ocean applications. The nature of working in water depths to 20,000 feet demands flexibility and multiple function capabilities because of the complexity and expense of deploying mission specific vehicles to these depths. For applications requiring large area viewing, search or survey, the JASON imaging system needed upgrading. In addition, because of the fine control and stability of JASON, it makes an excellent platform for creating image mosaics.

Typically these requirements are addressed with low-light-level video cameras used in conjunction with film cameras. The low-light TV cameras provide real-time imagery and are used as view finders for the film cameras. Film provides high resolution images of the bottom which are often "pasted" together in mosaics. This approach provides high resolution from relatively low altitudes.

Deep ocean water (greater than 6,000 feet) is generally clear enough to afford good viewing to higher altitudes. To accomplish this the imaging system must address the problems this environment presents. Underwater images are characterized by inherently low contrast scenes and scattered light which further degrades the apparent contrast. Further, high altitude imaging, because of the strong attenuation of light caused by the seawater, introduces a need for low-light-level cameras and is plagued by highly varying light levels.

These constraints imposed by the underwater environment can be translated into meaningful requirements for camera parameters as follows.

Low Contrast Scenes: Natural objects on the seafloor are typically low reflectance. Man-made objects which end up on the seafloor quickly become dull, low reflectance targets. Resolving the subtle contrasts of these scenes requires an imager with high contrast resolution, i.e. for a monochrome camera this means it can resolve many (thousands) shades of gray and exhibit low sensor noise so the steps between shades is very small.

Scattered Light: The water illuminated by the light source creates scattered light that enters the camera. It fogs the film. It is an additive component which can be very large, depending on water clarity, and it can overwhelm the light reflected from the target scene. The net result is a large signal, backscattered light, added to a relatively small amount of information, i.e. the seafloor scene. To extract these small signals requires an imager with large intra-scene dynamic range. The camera must resolve small levels of signal while at the same time not saturate with signals that are several thousand times larger.

Low-Light-Levels: Seawater exponentially attenuates light due to both absorption and scattering processes. As a function of range, water absorbs nearly all wavelengths in the red end of the visible spectrum, such that blue-green light is preferentially transmitted, although still attenuated. As range to the target is increased, the attenuation increases dramatically, and the camera receives only low levels of light reflected from the target. For cameras, the limit to low-light-level detection is sensor noise and quantum effects. The best imager for underwater applications will exhibit maximum responsivity to blue-green light and minimum sensor noise.

Non-Uniform Illumination: The conventional underwater imaging system will consist of cameras and lights configured into a geometry of camera pointing angles, field of view, light angles and beam patterns. It is difficult to provide uniform illumination to the entire field of view at all ranges. The effects are exaggerated by the large differences in attenuation between near field and far field. Again to overcome this problem, the camera must have wide dynamic range.

Target Resolution: A universal problem for any imaging system is providing enough spatial resolution in a camera to adequately see detail in the target scene to detect or recognize an object. Underwater, resolution is ultimately limited by the scattering of light as it travels from target scene to camera. This forward angle scattering introduces blur in the image. Fortunately in the deep ocean this has not been a limiting factor, and camera resolution is governed more by mission requirements and the state of technology.

Introduced in 1987, the Underwater Electronic Still Camera demonstrates a unique solution to the foregoing problems by providing low noise, wide dynamic range, excellent blue-green response and high resolution. The ESC accomplishes this by using high quality, scientific grade CCDs as its imaging sensor and through signal processing of the CCD output. Operated in a snapshot mode, the ESC constrains the bandwidth of the signal chain by reading out the CCD in slow scan mode (less than 1 Mpixel per second). This, and other processing techniques such as active cooling, provides low noise light detection that is practically limited only by the quantum nature of light itself. Due to this process, image repetition rate is limited to 0.2 to 1 Hz.

The ESC is a digital imager. Pixel data is digitized in the camera head to 12 or 14 bit precision providing the wide dynamic range and high contrast resolution that is desired. Data is easily manipulated for enhancement and analysis, and data is never lost or degraded by reproduction or post processing.

The ESC is an obvious replacement for underwater film cameras since it provides orders of magnitude, more sensitivity and dynamic range. Since the ESC is strictly a snapshot imager, it is complemented in an operational sense by the Intensified TV Camera. Earlier generations of this camera genre, such as the SIT Camera, have recently seen competition by a solid state alternative, the Intensified CCD TV Camera or ICCD. These cameras provide low-light performance by using high-gain, light amplifying Image Intensifiers. Used in conjunction with the ESC, the ICCD is a low resolution viewfinder which provides continuous viewing rather than snapshots. The ESC and ICCD are well matched in terms of overall sensitivity, and the ESC delivers the high quality images needed for post processing and analysis.

Description of Work

As designed, the Electronic Still Camera can be installed in a number of mechanical and electrical configurations depending on interface requirements. Since JASON is a moderately sized vehicle, we partitioned the subsea camera into two subassemblies: (shown in Dwg. 800186) 1) the Sensor Housing Assembly and 2) Subsea Electronics Assembly.

The Sensor Housing contains the CCD imager, thermoelectric cooler, analog signal processing electronics and the digitizer. Physically, the Sensor Housing is small enough to mount in the forward instrument bay of JASON. For our testing, this housing was mounted in a down-looking configuration. The lens chosen has a 16 mm focal length providing a field of view of 45^{o} (H) x 31^{o} (V). This model of the ESC uses a CCD with a format of 576 (H) x 384 (V) pixels.

To save on weight and volume, the Subsea Electronic Assembly was designed to fit into an existing pressure vessel on JASON. This assembly included a small computer system (VME Chassis on Dwg. 800186) which provided the interface to JASON's fiber optic telemetry. All image data and control signals are transmitted in digital form to maintain signal integrity. With this interface we were able to sustain data rates up to 614 Kbits per second and provide the capability for data packet retransmission when errors were detected. Additional work involved modifying the ESC power supply to interface to JASON's power bus (100 VDC) and also supply power to the strobe lights.

Image data is transmitted via JASON's telemetry system to the ESC Display and Recording Unit (DRU) in the surface control van. The DRU is shown in Dwg. 800214. It provides an operator interface, shown on the front panel, to control image parameters, repetition rate, data recording, display processing and image enhancement. Image data is recorded in raw digital form on magnetic tape cartridges. The DRU was also networked with the JASON data management system so vehicle data such as altitude and time is recorded with each image file. Supplied with vehicle parameters such as altitude, pitch and roll, the DRU has built-in capabilities for measuring object size in the image field of view.

Implementing the ESC on JASON represented the major portion of design and interface work. The ICCD TV (see brochure in attachments) was also installed on JASON to provide a viewfinder for the ESC. The electrical interface involved routing power and video signals to the JASON telemetry system. Since the ICCD interface "looks" like a standard video camera, this was readily accomplished. As is typical for analog interfaces, electrical noise was a problem, but this was solved by some modifications inside the ICCD camera itself.

Lastly, some modifications were made to JASON's lighting system. Two strobe lights (rated at 100 Watt-Sec each) were mounted to provide illumination for the ESC. Incandescent lamps were moved to optimize lighting for the down-looking ICCD TV. This work took advantage of our experience in designing underwater lighting geometry to minimize backscatter light.

Status

Prior to at-sea testing, all equipment was delivered to the Deep Submergence Laboratory for integration and testing on JASON. The at-sea operation included both test and operational phases. The Imaging System Upgrade performed as expected. Excellent images were obtained with both the ESC and ICCD TV. The only major problem occurred with the ESC telemetry interface. At depths greater than approximately 3,000 meters, we observed increased signal attenuation in the fiber optic telemetry system which lowered the overall optical power margin. This made the telemetry system more susceptible to mechanically induced optical transients. The net result was that images were lost due to telemetry drop-outs and image repetition rate was lowered due to retransmission time. This is a problem that would be corrected with additional time for design and testing, and could be addressed as either a telemetry problem or an ESC problem.

After the at-sea operation, all equipment was refurbished, manuals were updated and everything packed in transit cases for shipping. Appendix A lists all equipment and destination for shipping.

B. JASON Wireless SHARPS Navigation System

Summary of Task

The JASON ROV is controlled and tracked precisely by an integrated SHARPS acoustic positioning and control system located on the ARGO sled and on the JASON ROV. JASON is controlled and tracked by SHARPS in relation to the ARGO sled.

The SHARPS system is limited to 1,000 feet water depth, therefore, in order to take full advantage of the ARGO/JASON system, the SHARPS transceivers had to be redesigned for operation at 20,000 feet.

The SHARPS system is fully cabled. In order to support operations at the required depth, a "wireless" version of the SHARPS transceivers had to be developed. Software changes and modifications to the basic SHARPS control board were required to accommodate the resulting changes in measurement algorithms, and calibration procedures for the modified wireless SHARPS transceivers.

Description of Work

Modifications to the SHARPS Navigation System required for wireless operation at 20,000 feet were completed on schedule and the system was delivered for integration with the Argo/JASON system in time to support the test cruise. As part of the development, numerous shallow water tests were performed, however, the JASON vehicle itself was not available as a platform for testing the SHARPS modifications. JASON was not deployed during the test cruise due to difficulties experienced with the support ship's dynamic positioning system, therefore even though a Marquest SHARPS Senior Engineer was on board to support SHARPS tests, none were performed. As a result, the extensive modifications made on SHARPS had never been tested on JASON when the system went to sea in support of the main at-sea operation.

Status of Work

Testing required to quantify and qualify the success of the modifications to the SHARPS system, was delayed until the main at-sea operation. During the operational at-sea period, three partial tests of SHARPS were performed as follows:

1. At a test site a wireless transponder was lowered on the elevator while JASON was deployed. Due to an electrical noise problem caused by an IC chip

in the interface between SHARPS and JASON, JASON was unable to acquire the SHARPS signal. This is the type of problem which would have been detected during the test cruise had the JASON/SHARPS interface been able to be tested.

2. The interface problem was corrected at sea, and a transponder was installed on Medea with the intention of tracking JASON from Medea. However, Medea was unable to acquire the SHARPS signal from JASON, because of the wild thrashing Medea was suffering at the end of the tow cable due to severe weather being experienced at the operational site. An attempt was also made to track Medea from JASON, but a fiber optic penetrator failed on Medea, eliminating the capability to ping the transmitter on Medea.

3. At the main operation site a transponder was lowered on the elevator in preparation for another test, but JASON was never deployed again due to bad weather.

Although valuable testing was performed leading to the correction of the JASON interface IC problem, and confirming the satisfactory performance of the new deep water SHARPS enclosures, no performance data on SHARPS navigation was obtained. Marquest and Woods Hole therefore requested that the system remain on JASON during JASON operations in Bangor, Washington.

Additional tests were performed in Bangor, but these tests were also plagued by problems in the vehicle interface. Woods Hole is convinced that these problems can be worked out given sufficient opportunity and time, and that the SHARPS system and its modifications operated properly.

After the at-sea operation, the equipment was refurbished and packed for shipment. Appendix A lists the equipment and destination for shipping.

C. JASON Sampling/Recovery Modifications

Summary of Task

The JASON ROV is designed with manipulator control. A requirement of deep sea operations is to utilize the manipulator to acquire bottom samples and place them in an elevator for transport to the surface. JASON then does not need to make the transit to the surface each time samples are collected. A sampling system was to be designed and built with a limited number of sample storage units mounted in the elevator.

Status

a. The sampler system was designed and 115 samplers fabricated to be operated by JASON's manipulator. An intermediate storage facility was developed. The samplers were configured to be used with the recovery elevator.

b. Two Recovery Elevators were designed and fabricated. An acoustically commanded recovery elevator system was designed and the components built for assembly at-sea. The elevators utilize a transponder / acoustic release system similar to that used in other parts of the ARGO/JASON system.

   The sampling/recovery systems have been delivered per Attachment A.

APPENDIX A

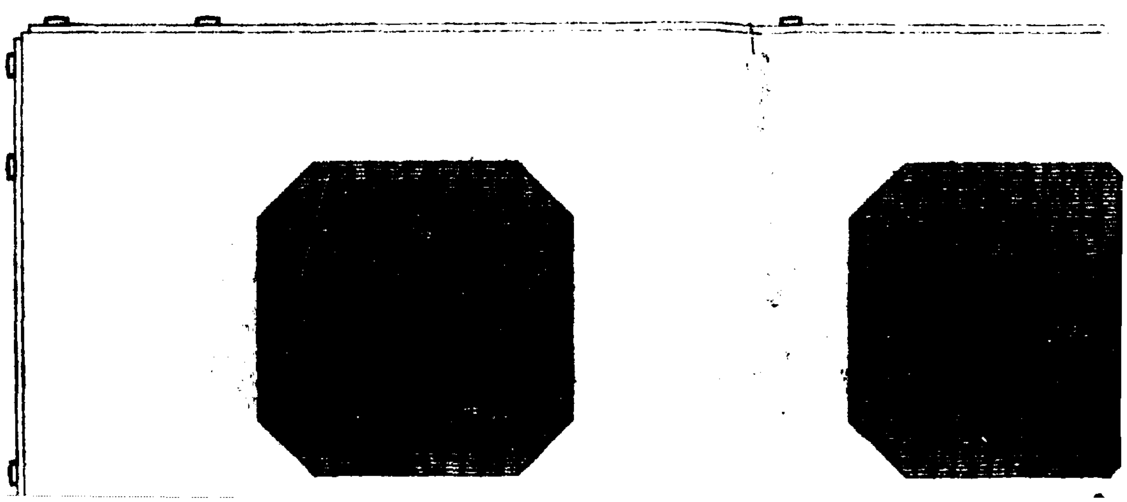
Equipment List

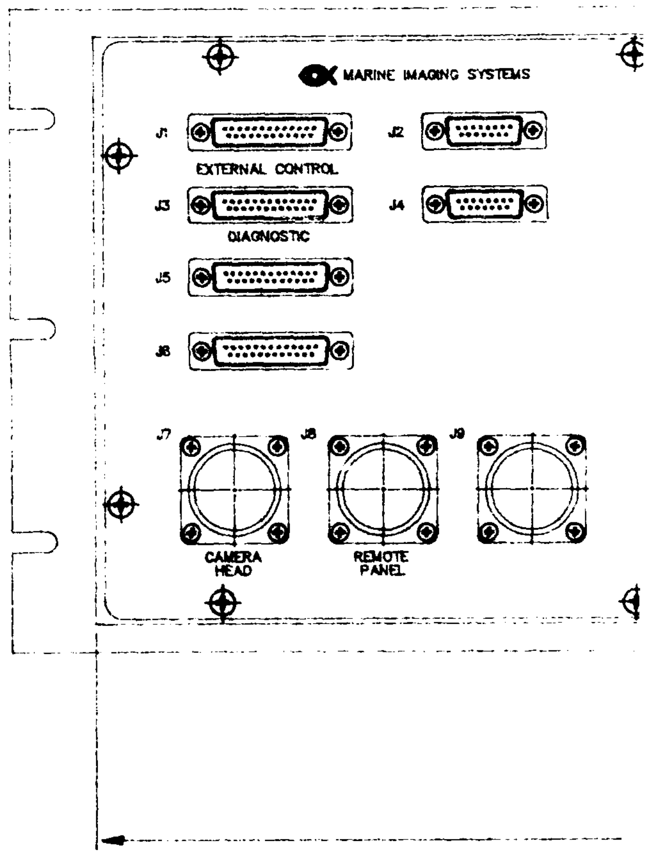
APPENDIX B

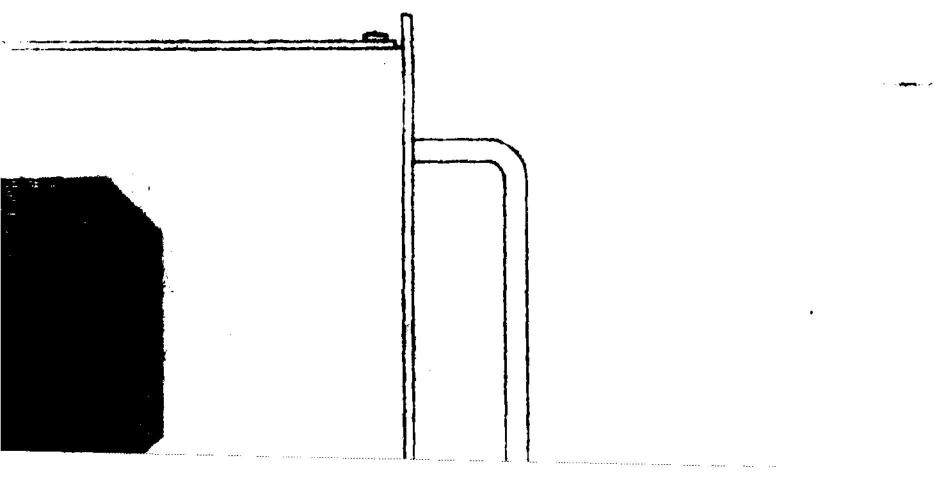
Equipment Drawings

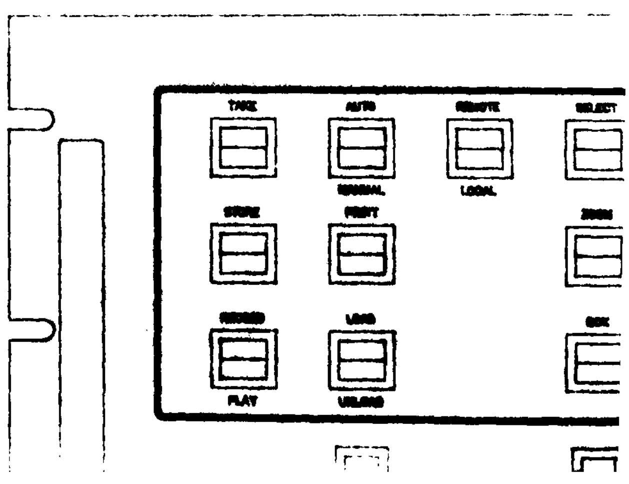
1. 800214 - DRU

2. 800186 - Subsea Camera Subassemblies




MARINE IMAGING SYSTEMS
J1
J2
EXTERNAL CONTROL
J3
J4
DIAGNOSTIC
J5
J6
J7
J8
J9
CAMERA HEAD
REMOTE PANEL

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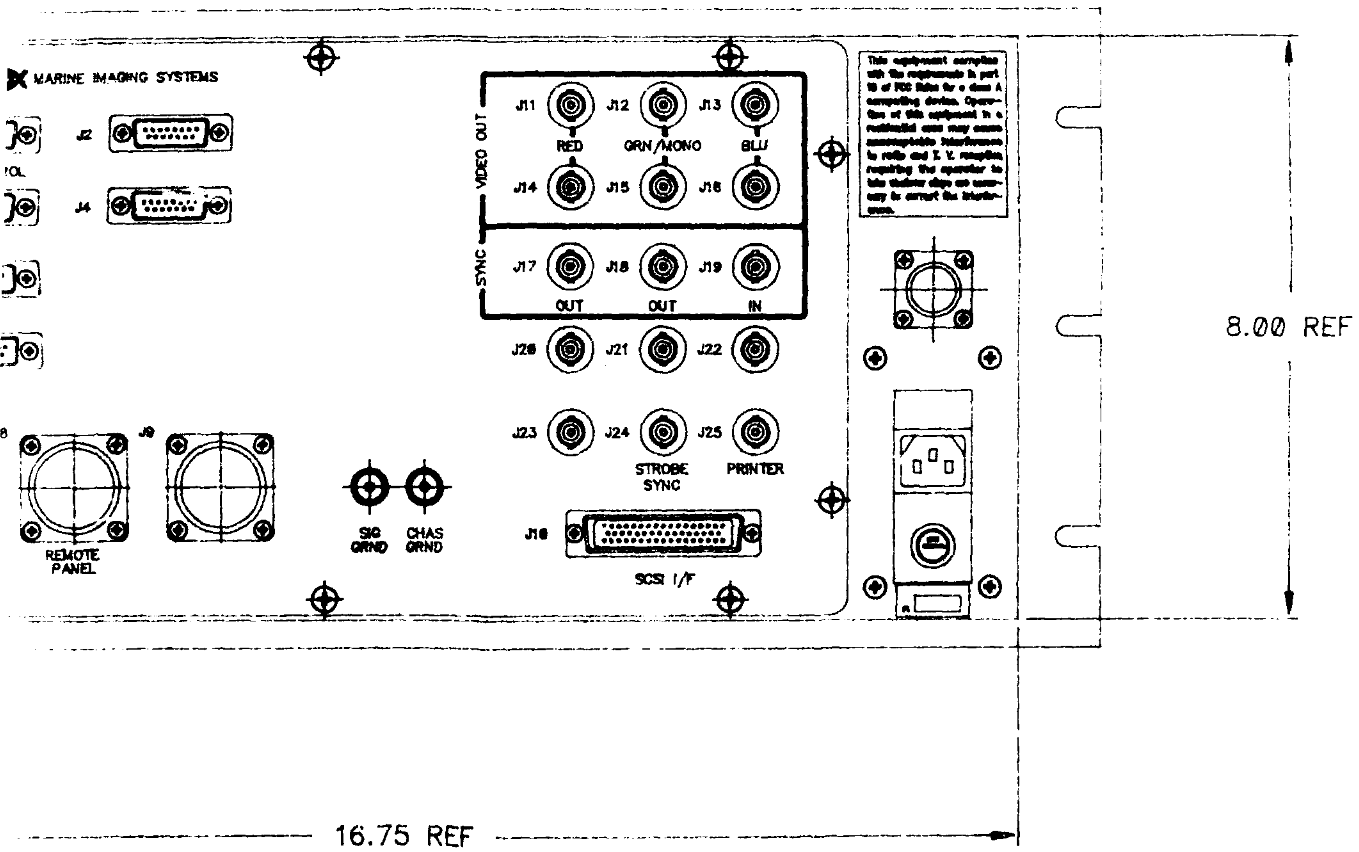

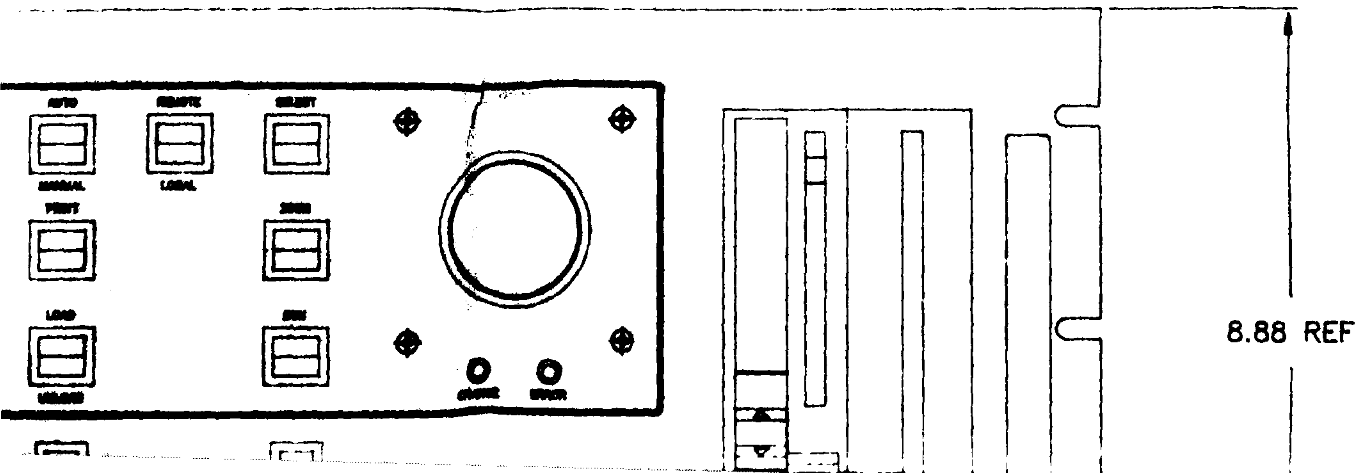

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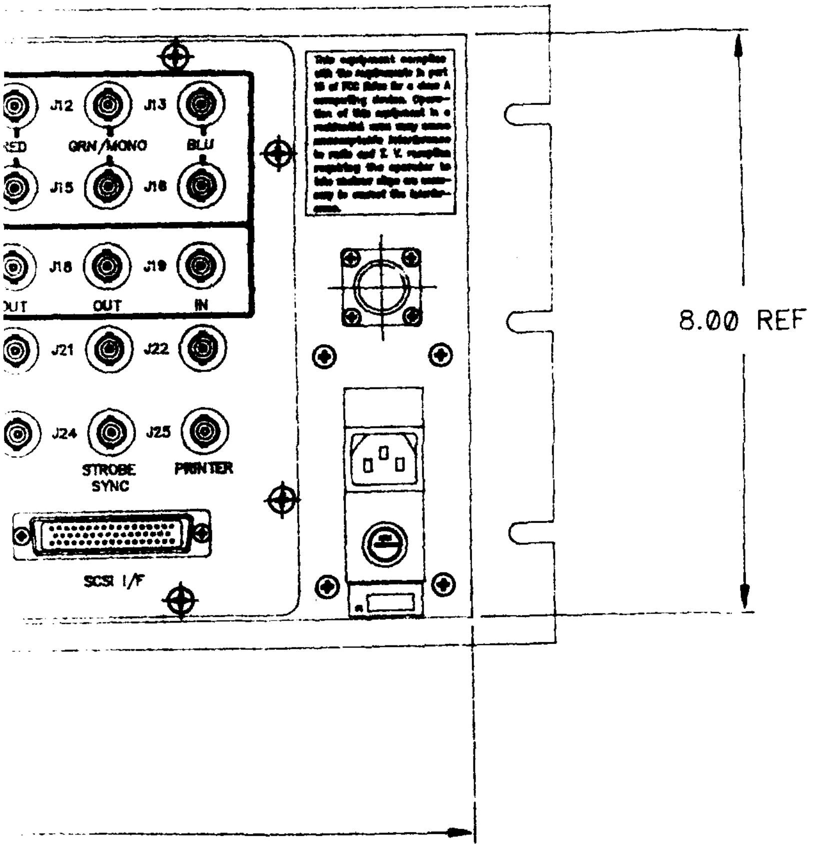

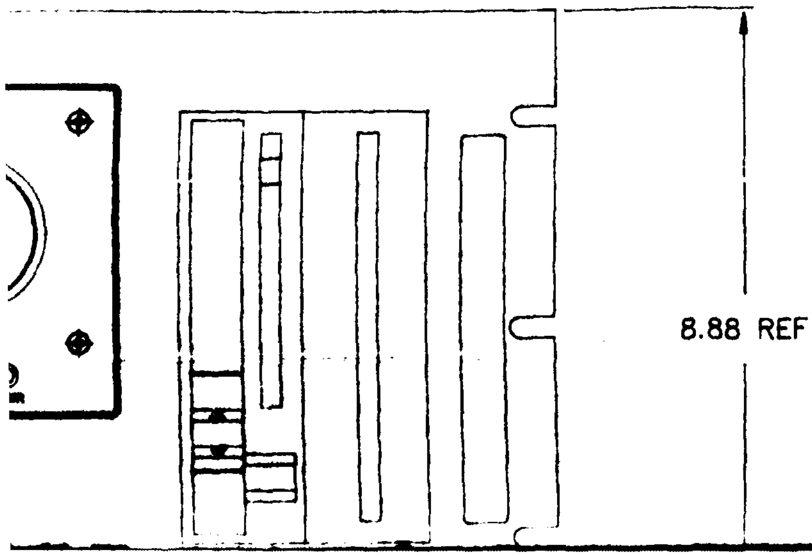

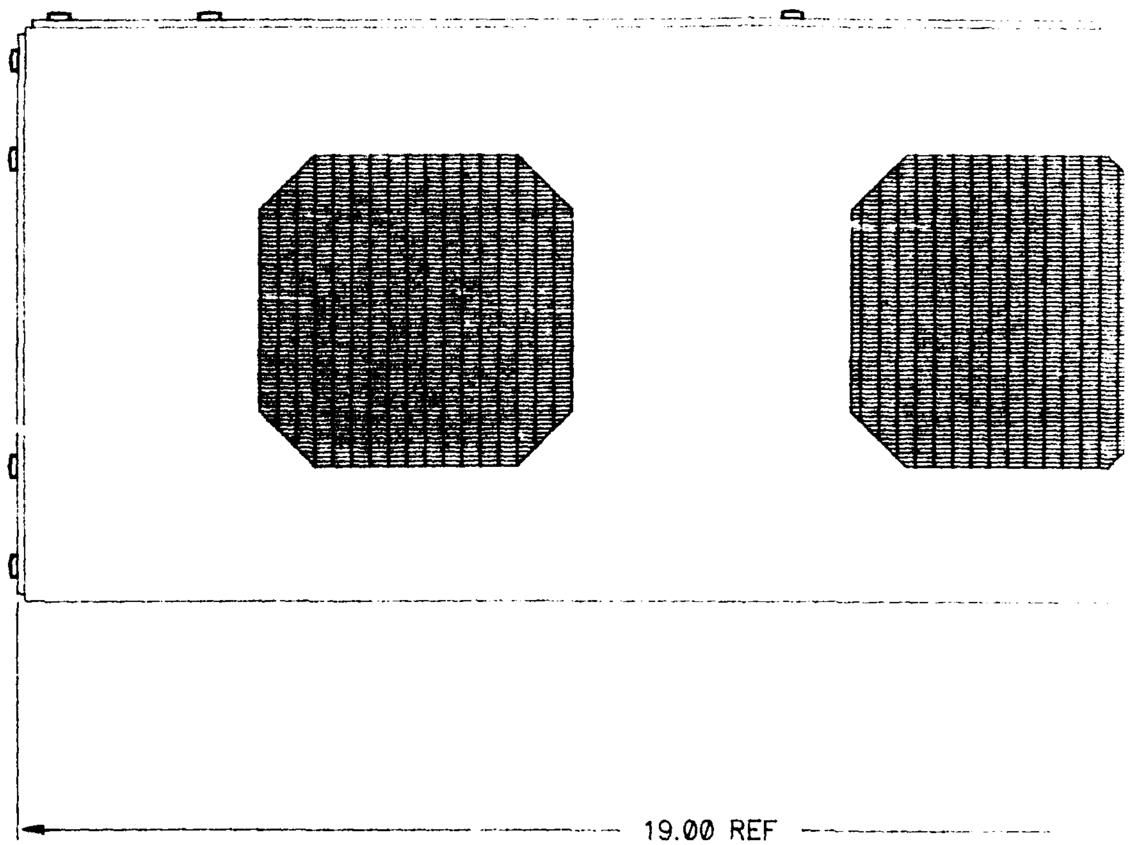

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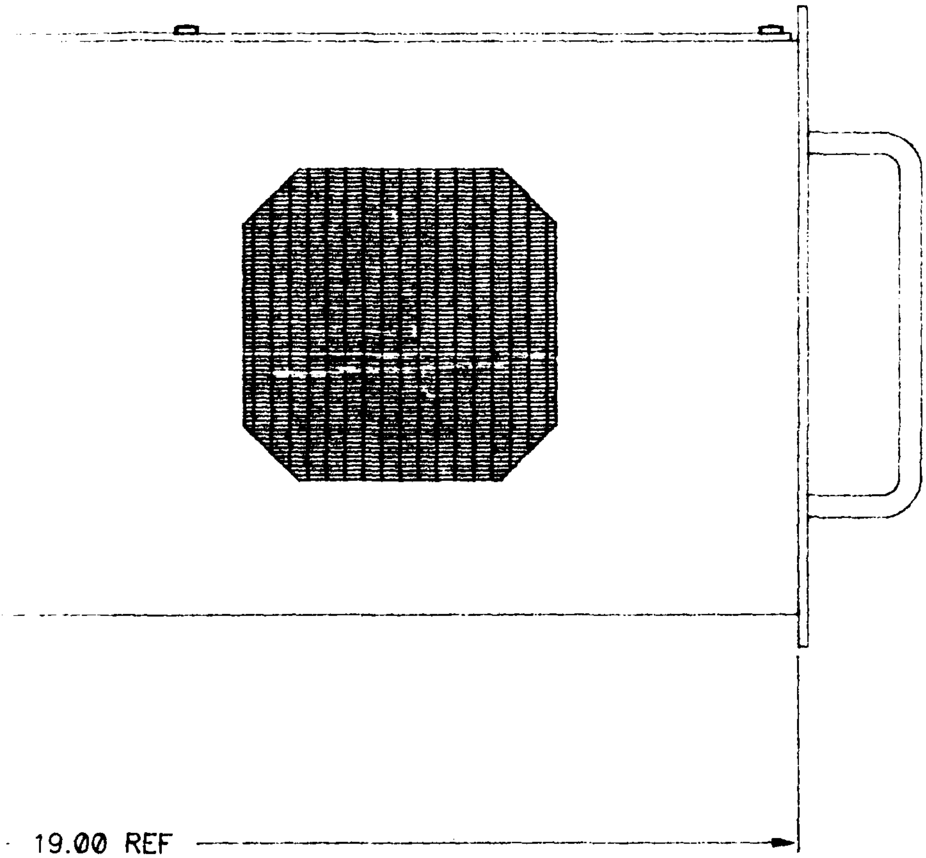

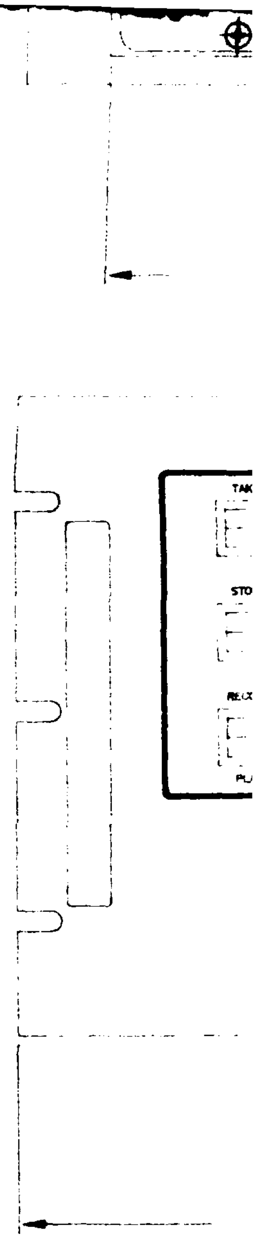

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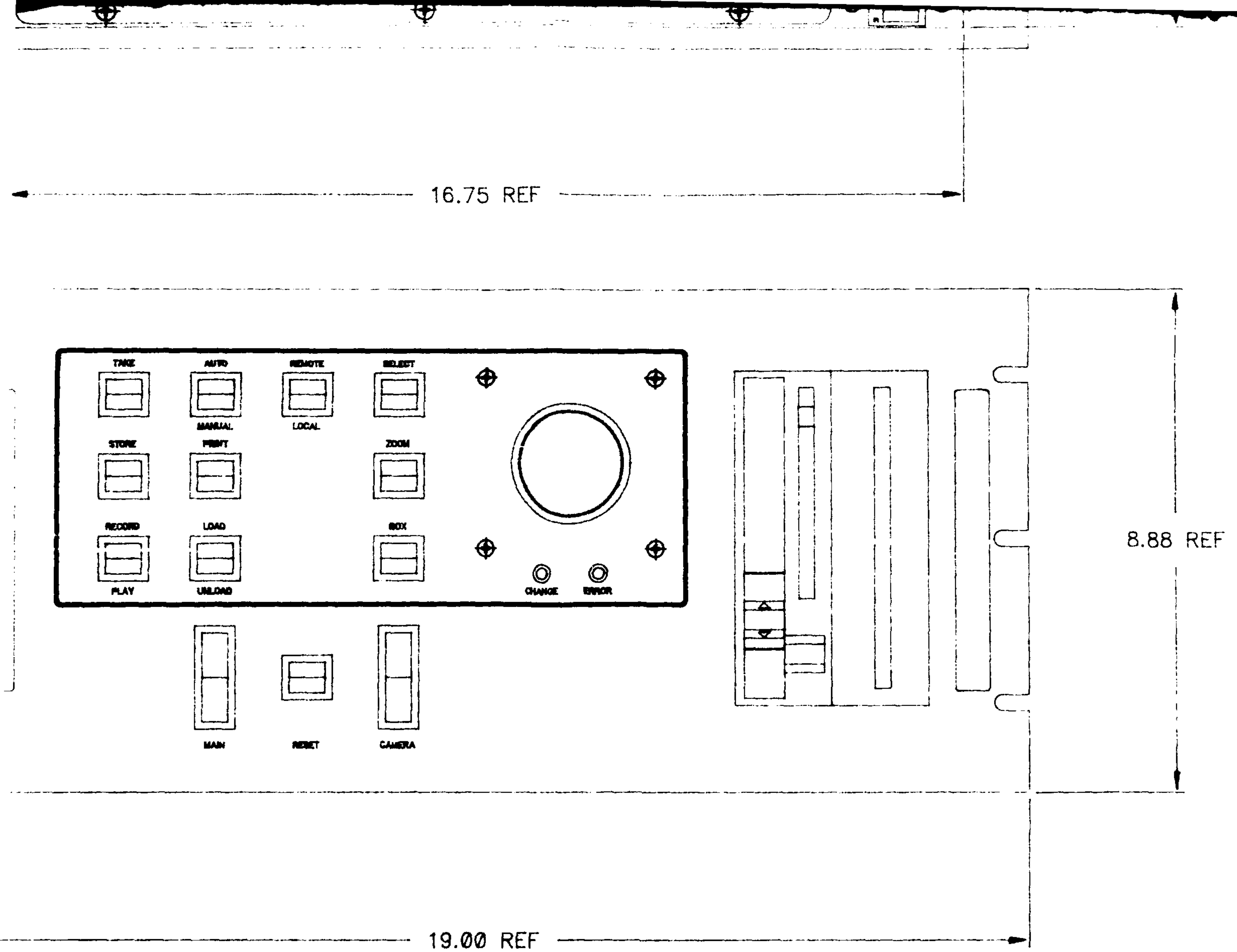

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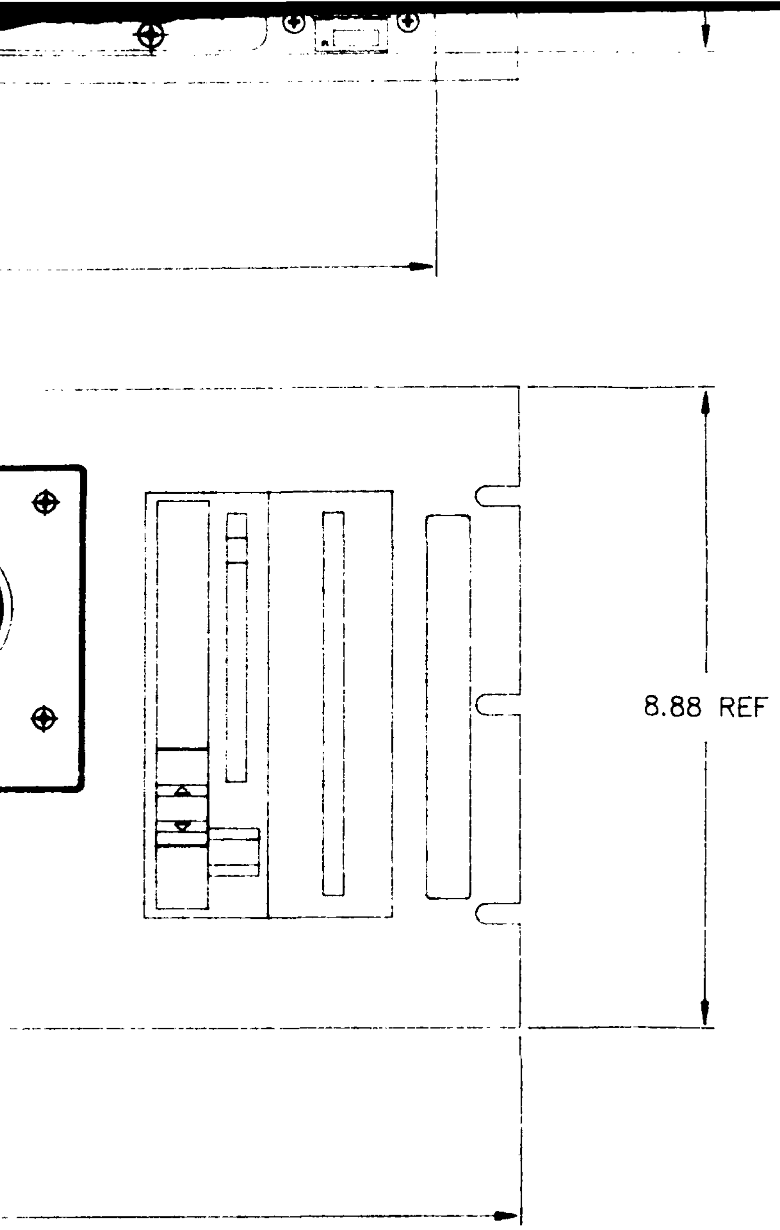

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MARINE IMAGING SYSTEMS
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TITLE DISPLAY RECORDING UNIT
TOP LEVEL ASSY

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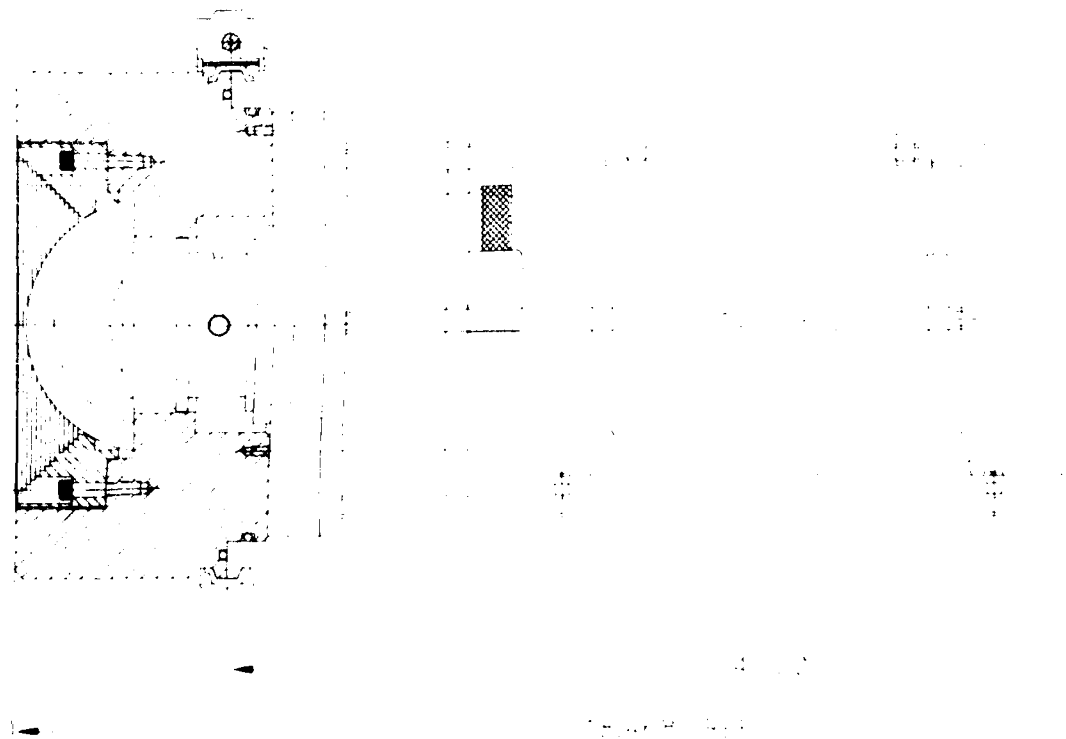

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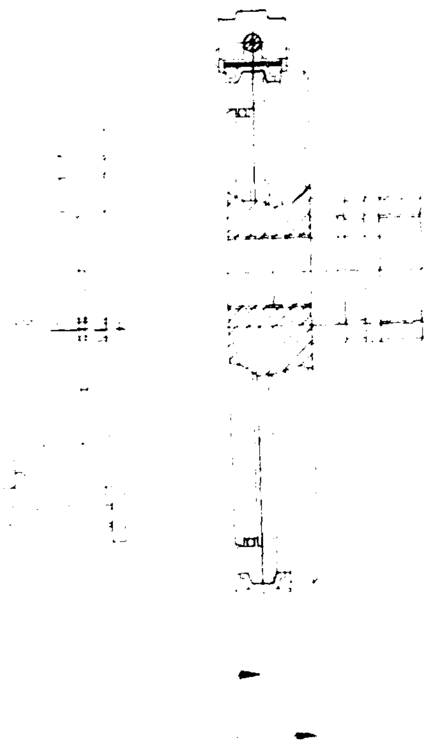
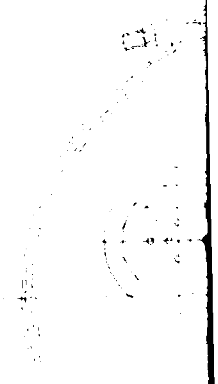
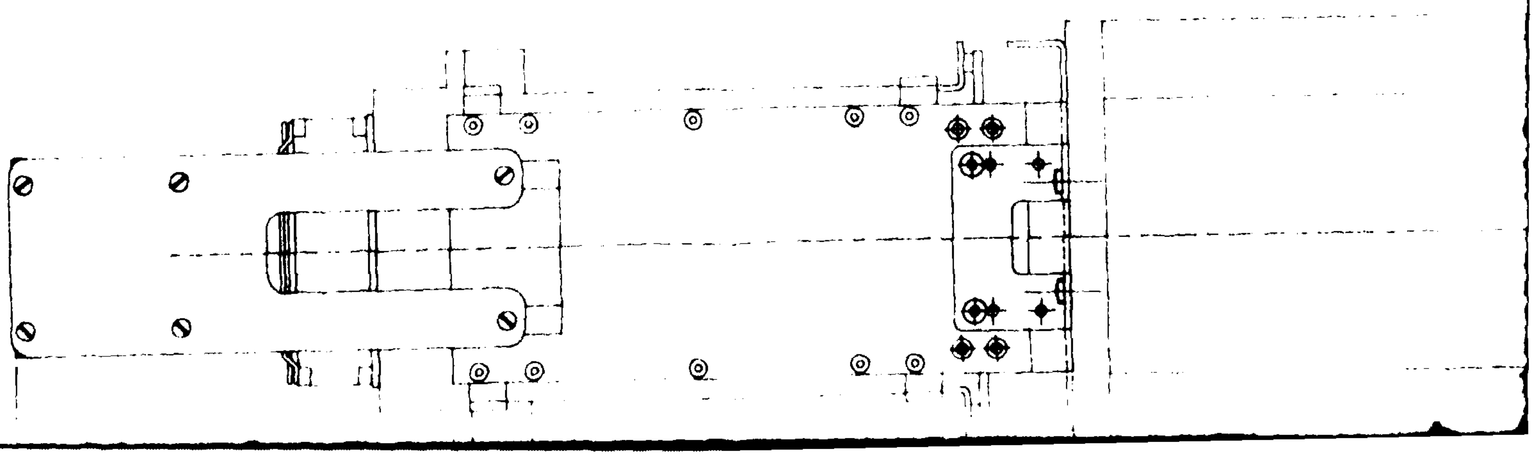




Subsea Electronics Assembly



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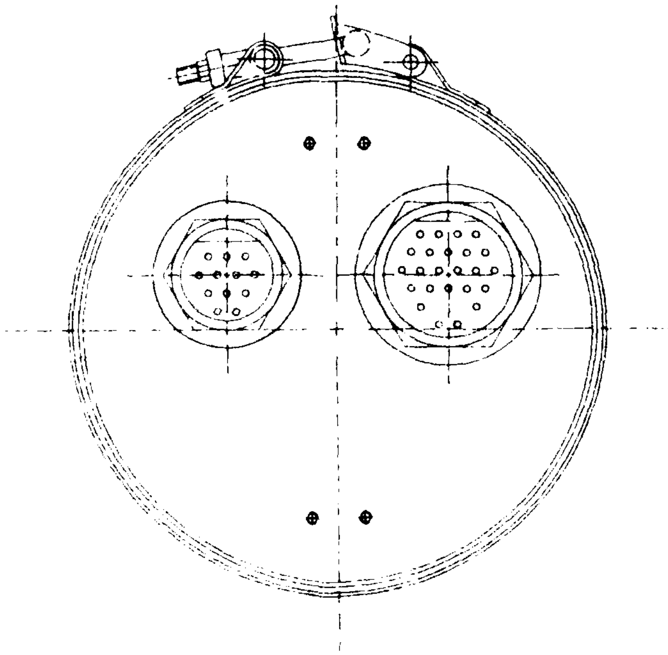

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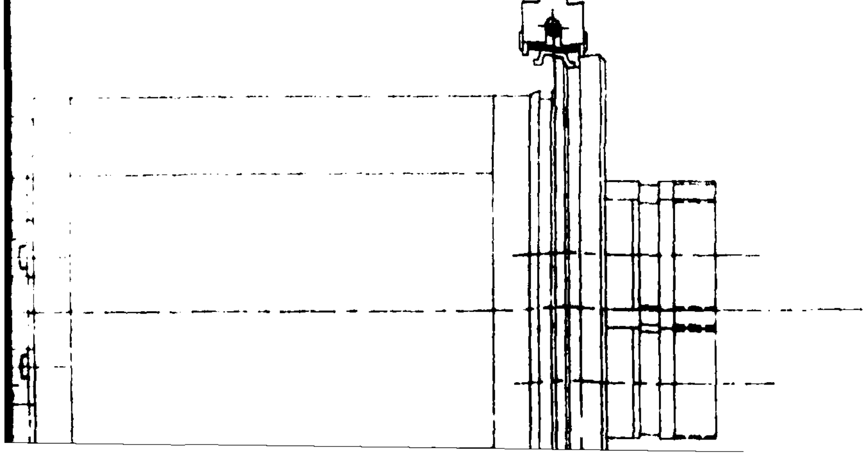

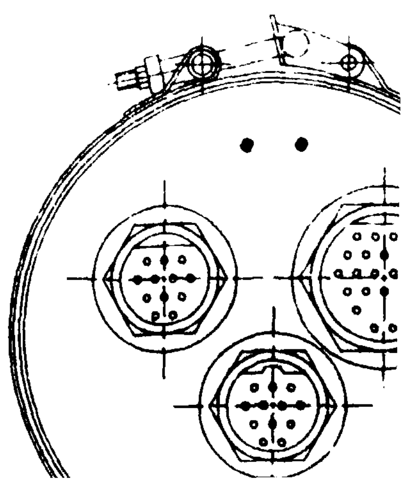

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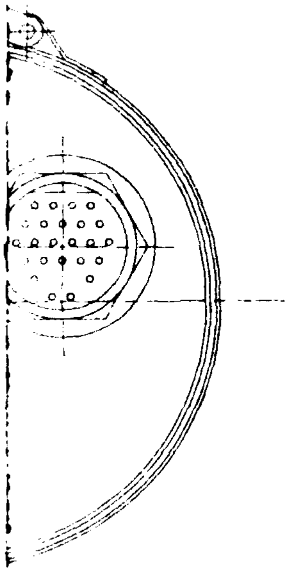

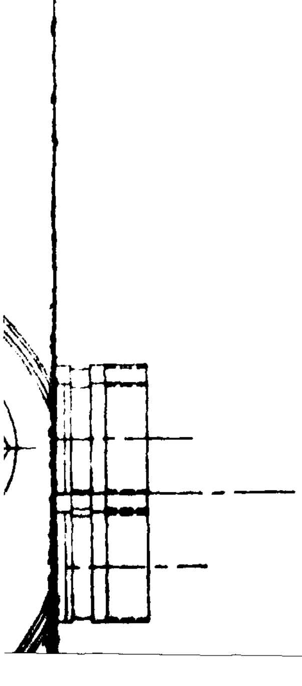

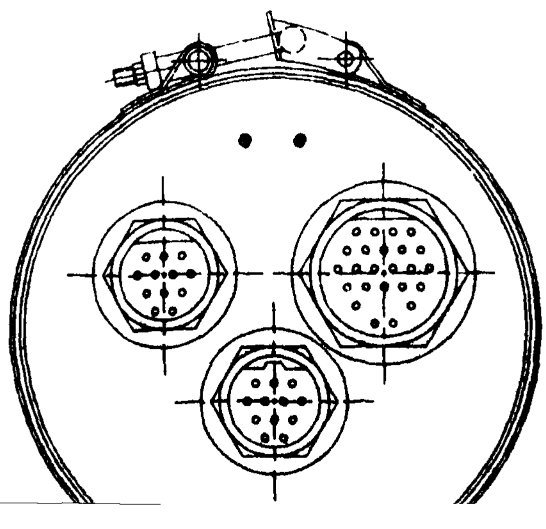

8.468 (REF)

NOTES:

1. CONNECTORS: BURTON SERIES 5500, 12 AND 32 PIN.
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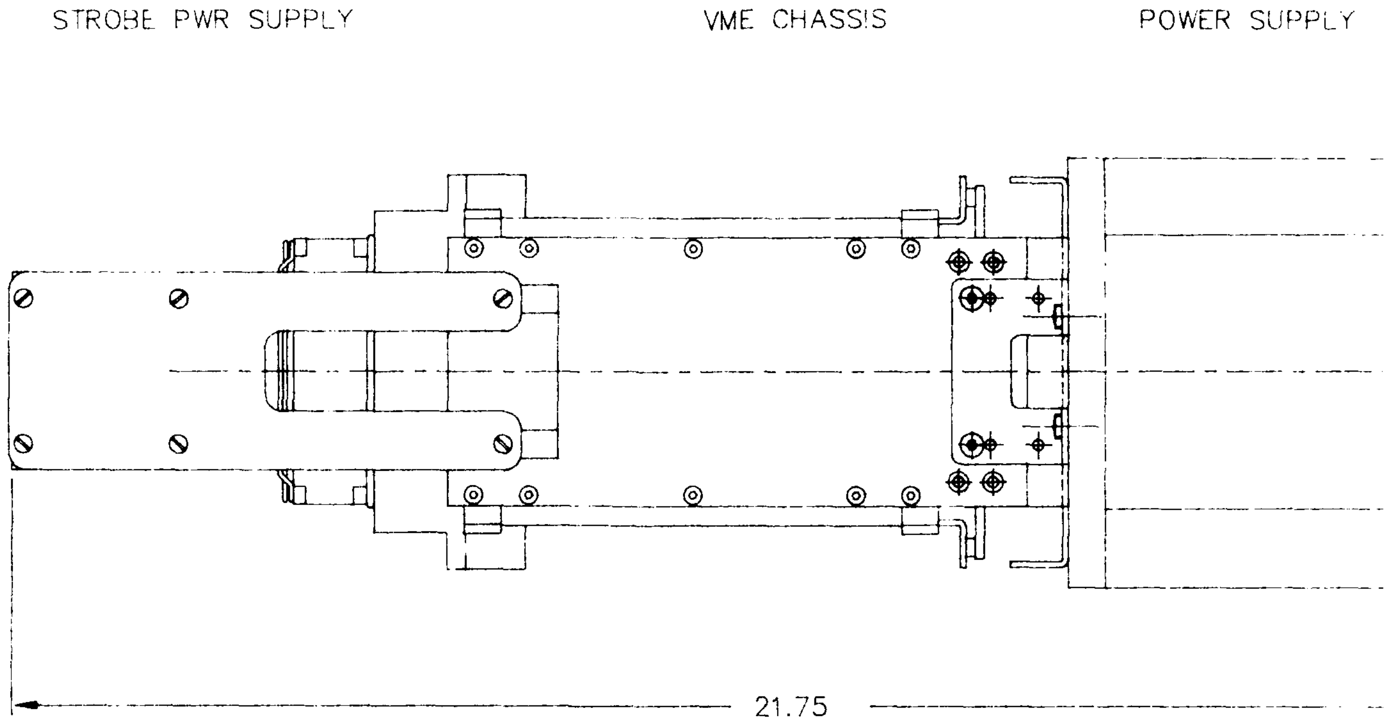
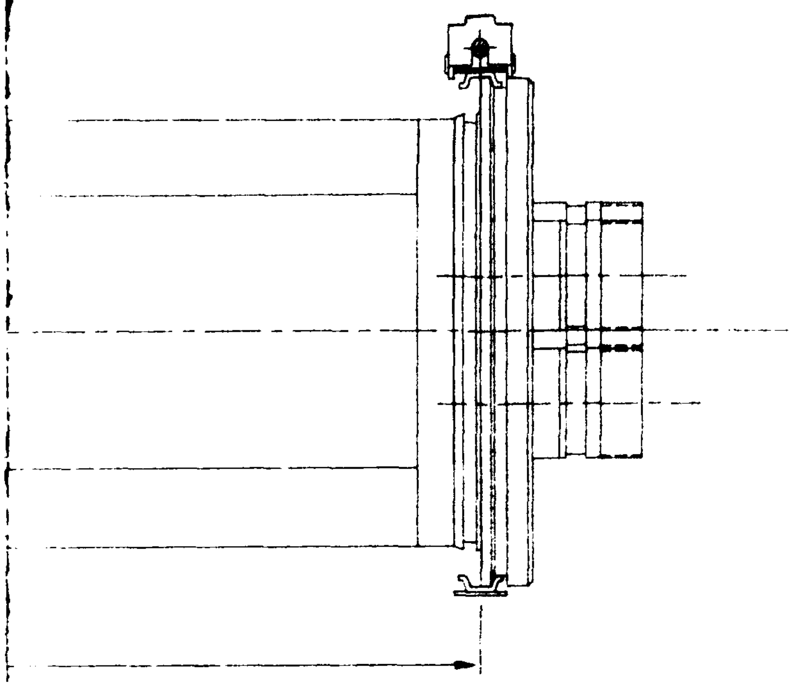
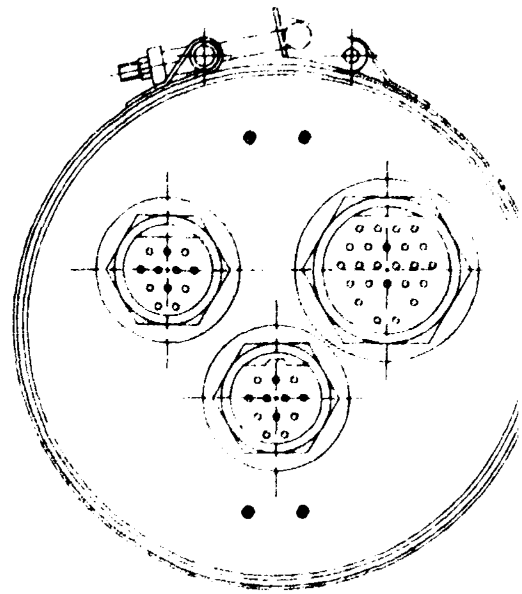
Subsea Electronics Assemb



ics Assembly

POWER SUPPLY





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	All dimensions are in inches. Remove all burrs and break sharp edges 0.010R. Tolerances: Decimals .XX = ±.02 .XXX = ±.005 Angles ±1° Surface Roughness 63	DRAWN TJG DATE 09-19-89	TITLE ELECT... JASON...
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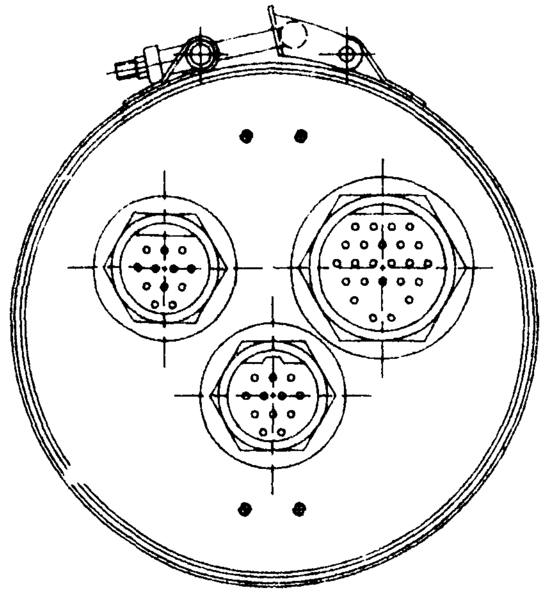

NSION AND ANCING Y 14.5M	UNLESS OTHERWISE SPECIFIED	CONTRACT NO. —	MARINE IMAGING SYSTEMS POCASSET, MASSACHUSETTS 02559 USA (508) 564-5122 FAX (508) 564-8134
	All dimensions are in inches. Remove all burrs and break sharp edges 0.010R. Tolerances Decimals Angles ±1° .XX = ±.02 .XXX = ±.005 Surface Roughness 63	DRAWN TJG DATE 09-19-89	TITLE ELECTRONIC STILL CAMERA JASON CAMERA ASSEMBLY
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CONTRACT DATA REQUIREMENTS LIST
INSTRUCTIONS FOR DISTRIBUTION

DISTRIBUTION OF TECHNICAL REPORTS AND FINAL REPORT

The minimum distribution of technical reports and the final report submitted in connection with this contract is as follows:

ADDRESSEE	DODAAD CODE	NUMBER OF COPIES: UNCLASSIFIED UNLIMITED	NUMBER OF COPIES: UNCLASSIFIED/LIMITED AND CLASSIFIED
Scientific Officer	N00014	1	1
Administrative Contracting Officer	S2206A	1	1
Director, Naval Research Laboratory, ATTN: Code 2627 Washington, D. C. 20375	N00173	1	1
Defense Technical Information Center Bldg. 5, Cameron Station Alexandria, Virginia 22314	S47031	12	2

If the Scientific Officer directs, the Contractor shall make additional distribution of technical reports in accordance with a supplemental distribution list provided by the Scientific Officer.

Distribution of Reports which are NOT Technical Reports

The minimum distribution for reports which are not technical reports is as follows:

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Administrative Contracting Officer	S2206A	1	1

CONTRACT NUMBER: N00014-89-C-0139