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EVALUATION OF INFRARED SENSORS FOR OIL SPILL RESPONSE OPERATIONS

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FINAL REPORT

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This report is the third R&D Center report evaluating the utility of commercially available infrared sensors for detecting oil on water at night. This research was conducted as part of the USCG R&D Center's Comprehensive Marine Environmental Protection Project.

16. Abstract

During November 1994, the USCG conducted a field evaluation of several commercially available portable infrared (IR) sensors for their ability to detect oil on water at night. The evaluation was conducted over the natural oil seeps off the coast of Santa Barbara, CA.

The portable sensors were operated from the open door of a Coast Guard HH-60J helicopter. Sensors evaluated included the Agema Thermovision 1000 and Texas Instruments LOCUSP operating in the long wave IR (LWIR) and the Cincinnati Electronics IRC-160ST and IRRIS-256ST operating in the medium wave IR (MWIR). The installed FLIR 2000 LWIR system provided a baseline reference of current CG IR capabilities. The LOCUSP was the only uncooled sensor evaluated.

Surface truth data were collected during daytime helicopter sorties and from a chartered work boat during nighttime imaging. Both daytime surface truth image data and nighttime IR image data were recorded to S-VHS tape for post exercise review and processing.

Analysis of the image data confirmed that all of the sensors were capable of detecting oil slicks at night under favorable environmental conditions. Atmospheric moisture (low clouds and rain) adversely affected the performance of the IR sensors to varying degrees. This and other aspects of oil slick observation are discussed.

Recommendations concerning the design and operation of portable IR sensors are provided for oil pollution monitoring and response applications.

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UNCLASSIFIED	UNCLASSIFIED		

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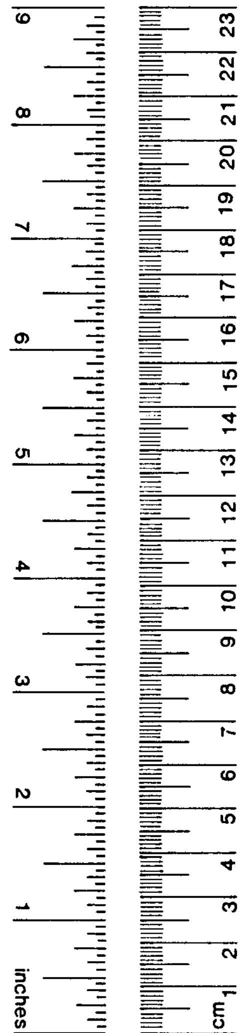
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

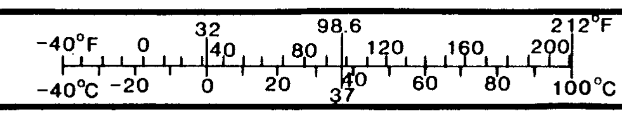
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

INTRODUCTION

1. Background

This report documents a United States Coast Guard (USCG) Research and Development (R&D) Center evaluation of an assortment of commercially available infrared (IR) sensors for their utility in supporting nighttime oil spill response operations in the marine environment. This evaluation was conducted as part of ongoing oil spill surveillance research being performed in support of the USCG Marine Environmental Protection (MEP) program.

During November 1994, the Coast Guard R&D Center conducted a field test off the coast of Santa Barbara, CA, to evaluate the ability of several types of IR sensors to provide a first-response oil spill surveillance capability to USCG marine pollution control units. The results of that evaluation are documented here.

Data from this evaluation will be used to:

1. Further document the oil slick imaging performance of the FLIR 2000 sensor installed onboard USCG HH-60J helicopters.

2. Compare the relative detection performance of several portable IR detector technologies against oil-on-water targets at night.

3. Document several factors affecting the IR detection of oil on water, including distance and orientation of slick features, sources of false positives, and environmental conditions.

4. Determine if current technology can provide USCG oil spill response personnel with an effective, light weight IR sensor that can be used from USCG HH-65A helicopters and other aircraft of opportunity.

5. Identify operability and training issues that should be addressed as the Coast Guard assimilates portable IR technology into its MEP operations.

2. Sensor Descriptions

Table 1 provides a brief description of the sensors tested, their modes of operation and the spectral bands in which they operate. The hand-held units were operated from the open door of an HH-60J helicopter, while the installed FLIR 2000 was operated concurrently from the aircrew avionics position.

The Agema 1000 is typically used in a gimbaled mount and was adapted to lap-top use for the purpose of this experiment. As such , it was the heaviest and most complex of the portable systems evaluated.

The Texas Instruments Low Cost Uncooled Sensor Prototype (LOCUSP) is designed for use as a weapons sight and was adapted to hand-held use by adding a standard pistol grip used with photography equipment. The rubber eyepiece was removed to ease eyestrain during the imaging runs. An uncooled focal plane array (FPA) detector made this the lightest sensor used during the evaluation. The LOCUSP is powered by a lightweight internal battery.

The IRC-160ST and IRRIS-256ST are both about the same size as a standard VHS camera and were operated from a shouldered position. Both incorporate cooled FPA detectors and require an external power supply. No modifications were made to these systems expressly for this evaluation.

The FLIR 2000 was installed and operated by the aircrew in accordance with standard operating procedures. This sensor represents the Coast Guard's current baseline capability for IR oil spill detection and monitoring.

Table 1. Sensors Evaluated by the USCG

SENSOR	MODE OF OPERATION	INFRARED BAND (μ)
AGEMA 1000	Hand-Held IR Camera (Cooled)	8 to 12
LOCUSP	Hand-Held IR Camera (Uncooled)	8 to 12
IRC-160ST	Hand-Held IR Camera (Cooled)	3 to 5
IRRIS-256ST	Hand-Held IR Camera (Cooled)	3 to 5
FLIR 2000	Installed IR System (Cooled)	8 to 12

3. <u>Experiment Description</u>

The experiment was conducted from 14 to 19 November, 1994, off the coast of Santa Barbara, CA. The test area was located between 119° 45'W and 120° 10'W and extended out to 10 nautical miles (nmi) from the coast. This area was chosen because it contains multiple sources of naturally occurring petroleum and biogenic oil slicks.

Three regions containing oil slick features of particular interest were selected from within the test area. These regions are described below.

Area 1: The first region consisted of an oil slick approximately one mile southeast of an oil pumping platform (Holly Platform). This slick consisted of a large patch of oil sheen with thicker streamers that could be seen within the oil slick at various times (particularly in the thermal images). Along the northern boundary of the slick, an oil and natural gas source was visible on the surface. Although the particular location where natural gas and oil break the surface does not directly represent typical oil spill scenarios, it does demonstrate important aspects of thermal imaging.

Area 2: The second region was centered around Coal Oil Point and consisted of several kelp beds and petroleum oil seeps. These sources produced both biogenic and petroleum oil slicks in the near shore areas. This region provided an opportunity to compare petroleum and "false positive" slicks directly.

Area 3: The third region consisted of multiple petroleum oil seeps that created a wide area slick centered approximately 3 nmi offshore near Goleta Point. The slick was several miles long, oriented in a downwind direction. The slick had a silvery sheen appearance during daylight helicopter sorties. Its trailing (upwind) edge contained several point sources of petroleum oil, while the leading edge (downwind) contained several bands of rainbow-colored oil streamers within the larger sheen patches.

Daytime (late afternoon into evening) survey sorties were flown at an altitude of 2500 feet to identify specific slick regions and features to image during nighttime data collection sorties. Nighttime data collection sorties were flown at an altitudes of 500 and 800 feet and were designed to obtain image data in both white = hot and black = hot video polarity. Daytime video and nighttime IR image data were annotated with time and position and recorded on S-VHS tape for post experiment analysis.

A chartered Marine Spill Response Corporation (MSRC) oil spill response vessel (R/V CALIFORNIA RESPONDER) and an embarked Texas A&M Geochemical and Environmental Research Group (GERG) field team provided on-scene surface truth data.

4. Data Analysis

Recorded data were brought to the CG R&D Center for post experiment analysis. The recorded video was reviewed and compared to written logs to select the best of representative recorded footage. An effort was made to select sequences of the same feature from similar look directions and in the same time frame from each of the sensors. A video capture board was used to digitize video frames from within the selected video segments and store them as 8-bit gray-scale image files. Image manipulation and analysis was performed on an 486-compatible workstation.

RESULTS

1. Oil Slick Detection

All of the sensors evaluated during the field test were able to depict oil/water contrast within several miles of the sensor position. The image quality achieved with the hand-held IR sensors was less consistent than that achieved with the installed FLIR 2000 system. The amount and surface age of the oil, orientation and distance of the slick feature relative to the sensor position, and the prevailing environmental conditions all exerted significant influence on the quality of the oil slick images.

2. Factors Influencing the Physical Appearance of Oil Slicks

The appearance of the oil slicks varied depending on the view angle relative to wind or surface current direction and range to the sensor from the target. Viewing a slick at close range (less than 1000 feet slant range) resulted in a shorter path length for the thermal radiation and provided good separation of linear features as well as depicting the more subtle thickness differences through greyscale variations. When viewing an oil slick at longer ranges, the view angle relative to the wind or surface current direction became more important. Viewing a slick in an upwind or down wind direction provided very obvious separation of oil streamers while the same slick viewed at similar distances, but perpendicular to the wind direction, often appeared as a homogenous region of oil.

3. False Alarms and Their Origins

Several sources of false (non-petroleum) slicks were seen during the nighttime IR image data collection. Biogenic oils (from large kelp beds), boat wakes, effluent plumes, and other phenomena presented thermal contrast in the infrared scene at various times during the data collection. Experience with these phenomena during the test included the following.

- Observations made during the daytime sorties were instrumental in efficiently identifying river outflows and likely locations of kelp beds during the nighttime IR imaging operations.
- Boats wakes created distinctive thermal contrast paths on the water's surface that, when investigated, led to the underway boat. Data collected during this evaluation was not designed to determine if overboard discharge contributed to these thermal wakes.
- The natural gas seep, with it's associated surface disturbance presented very changable IR signatures as daily variations in environmental conditions occured.

4. Influence of High Atmospheric Moisture Levels

Atmospheric moisture had a detrimental effect on the ability of the IR sensors to depict spatial and thermal details within a scene. All of the sensors tested exhibited decreased imaging performance against the low-contrast oil slicks when rain showers and low clouds were present in the test area. Only targets with high thermal signatures (i.e., vessel exhaust stacks) were visible through low clouds. In rain showers, steep look-down angles were required to maintain even marginal oil/water contrast levels.

5. Ergonomics/Human Factors

Video Presentation

In their standard configuration, all of the sensors provided clear video presentation of the IR scene. A dual field of view capability was very useful for evaluating scene detail. Uncompensated helicopter vibrations and/or operator induced motion adversely affected image quality.

Image interpretation was made easier by sensors that provided an on-screen video polarity indication. This was particularly true when flying over open water in the absence of easily-identified heat sources such as vessels or shoreline.

On-screen mission data overlays including date/time, position, altitude, and aircraft heading added substantial value to the IR image data. During post-experiment data analysis, this information made it easier to interpret the image detail and provided a sense of scale for oil slick features.

Sensor Controls

Operator comments suggested that changes to the controls on all of the portable sensors were needed to improve their operability in the airborne environment. Suggestions ranged from relocating control(s) to changing their type, spacing and response time. In general, the more complex the system, the more difficult it was to operate in the airborne environment. Sensors that most resembled a commercial video camera were easiest to operate.

CONCLUSIONS

1. All of the sensors evaluated during the field test were able to depict oil/water contrast at night within several miles of the sensor position. The image quality achieved with the hand-held IR sensors was less consistent than that achieved with the installed FLIR 2000 system. Although the amount and type of oil, orientation and distance of the slick feature relative to sensor position, and the prevailing environmental conditions can all exert significant influence on the quality of the oil slick images, ultimately, imaging performance depended on the target versus background contrast and the path length from the target to the sensor.

2. While all of the sensors evaluated demonstrated the ability to detect oil slicks at night, the following sensor-specific qualifications apply:

• The LOCUSP sensor appeared to be most susceptible to the adverse effects of camera motion, high humidity, low clouds and precipitation. Nonetheless, based on projected mass production costs this compact sensor offers potential as a simple, inexpensive oil spill surveillance tool for use at night under favorable environmental conditions.

• The two MWIR sensors appeared to provide sufficient nighttime oil imaging capability and ease of use to support Coast Guard oil spill surveillance operations, even in high humidity and perhaps light precipitation. This endorsement must be qualified with the caution that some oil types may present very low thermal contrast in the MWIR band. This limitation was not encountered during the Santa Barbara field test.

• The auto-brightness control available on the IRRIS-256ST provided a significant improvement in the operability of the camera in all but high atmospheric moisture conditions.

• The Agema 1000 provided very good image detail, expanded functionality (e.g., dual fields of view), and sufficient ease of use to warrant investigation for use as a gimbal-mounted sensor, especially in weight-critical applications such as on the USCG HH-65A helicopters. The sensor's bulk and complexity of cabling are not conducive to hand-held operation at this time. Portable gimbal mounting for use on selected aircraft-of-opportunity types may also warrant consideration.

3. Imaging a potential oil slick from more than one look direction helps resolve spatial details that can assist the responder in reducing false alarms and in determining slick movement due to wind and surface currents. Imaging a slick at close range can provide greyscale information in the IR image that can assist with identifying areas of relatively thick oil. These tactics may facilitate more effective clean-up equipment deployment during night spill response operations.

4. Although IR sensors can image oil slicks under favorable environmental conditions, it must be understood that they do so by detecting a thermal contrast between two adjacent surfaces. At times, local knowledge of the region where the oil is present will be necessary to discriminate oil slicks from other phenomena within the thermal scene. For instance, thermal contrast caused by vessel wakes, river outflows, or biogenic oils can present a confused IR scene.

5. Both the white = hot and the black = hot video polarity provided similar contrast, clear image detail, and equivalent resolution.

6. The availability of a video polarity indication and mission data overlays can help the operator to quickly interpret scene detail and can assist with post-flight image analysis. Within an open-water IR image, these data can provide cues to indicate which areas within the scene are cool or warm, what area is being viewed, what non-petroleum features may be present, and how large oil slick features are.

7. In the open door of an airborne helicopter, sensors with the simplest controls were the easiest to aim and tune. Operator familiarity with the sensor controls directly impacted the effectiveness with which a sensor could be used. A means of controlling unwanted camera motion and vibration would substantially improve image quality.

8. Atmospheric moisture such as low clouds, rain, and fog can be expected to degrade or obscure oil/water contrast. Oil slick detection should be expected only at close range or not at all when imaging in high atmospheric moisture conditions.

RECOMMENDATIONS

Infrared Sensor Operation

1. Oil slicks should be viewed with IR imagers from several look-angles and ranges in order to obtain a complete tactical picture in support of oil spill response operations. Slick limits and orientation can be imaged at altitudes up to 1000 feet and up to a few kilometers from the imaging platform, and should incorporate information from several look-angles. Relative thickness and concentrations of oil within slick regions are best estimated at altitudes of 500 feet or less, and at steep depression-angles, imaging within a few hundred meters of the aircraft.

2. Portable gyrostabilizers may significantly improve image quality by reducing motion-induced smearing. These devices are commercially-available and should be investigated for use with light-weight hand-held IR sensors in the airborne environment.

3. Biogenic oils (concentrated fish or plant oils), upwellings, effluent plumes, and other phenomena can present slick-like thermal contrast in an infrared view. When viewing an infrared image, knowledge of the local area and on-scene environmental conditions must be used to interpret scene details. When possible, following a slick from an established datum (e.g. a known oil source) is the best method of determining slick extent and movement.

4. Daytime use of infrared sensors should be investigated as a complement to visual and video methods for airborne surveillance of areas with intense shipping or petroleum-related activity. This could enhance the capability to locate vessels and fixed facilities that are illegally dumping or pumping waste and provide the opportunity to more effectively focus CG response units.

Procurement and Integration of Infrared Technology

1. The Coast Guard should consider providing portable IR imagers and mission-specific training to many or all of its marine environmental response units. The IR imagers should be incorporated into routine operations of these response units, particularly at night. Mechanisms for documenting lessons learned and incorporating them into future sensor procurements and training programs should be established.

2. As mass production drives down the cost of uncooled, portable LWIR imagers, they should be considered for use by smaller Coast Guard pollution response units that do not require the sophisticated capabilities of the cooled MWIR imagers evaluated during this test.

3. Training should be conducted to educate Coast Guard users in the principles of IR imaging. The training should relate these principals to mission-specific tactics for employing IR sensors in the marine environment. These tactics should be illustrated with actual videotape of IR oil slick image data obtained in a variety of marine environments.

4. A low-cost , simple means of mission data annotation should be identified and incorporated into video recorders used with portable IR sensors.

5. Recommended specifications for hand-held IR sensors suited to the Coast Guard's oil spill detection and monitoring missions have been provided to the project sponsor under separate cover.

6. As part of any sizable purchase of portable infrared imagers, the Coast Guard should require both independent laboratory performance tests to ensure advertised specifications are met and field demonstrations to ensure operability requirements are met.

ACKNOWLEDGMENTS

This evaluation would not have been possible without the contributions of many individuals and organizations. The authors wish to acknowledge the generous support of Ms. Robin Jamail of the Texas General Lands Office (TGLO) in funding the surface truth operations off Santa Barbara. Many thanks also to Dr. Roger Fay and Ms. Tamara Davis of Texas A&M University, Mr. Jeff Howe of A&T, Inc. and the crew of the OSRV CALIFORNIA RESPONDER for their good work in gathering the surface truth data. Special thanks to Dr. Martha Hendrick of the U.S. Coast Guard Marine Safety Laboratories for her assistance in interpreting the Fluorescence and Chromatograms of oil samples provided by TGLO/Texas A&M.

For providing the hand-held IR sensors used during the data collection, the assistance of Mr. Christopher Royal of the U.S. Army Night Vision Directorate; Mr. Don Heller of Agema Infrared Systems; Mr. Fred Hahn of Cincinnati Electronics, Inc.; and Mr. Bruce Robidou and Mr. Chuck Daz of Texas Instruments, Inc. is greatly appreciated.

CWO4 Robert Melia of the Eighth Coast Guard District (m) once again lent his experience as an IR sensor operator to the R&D Center evaluation program. His skill, patience and operational perspectives are very much appreciated.

CWO4 Zeb Mosley of the Coast Guard Aircraft Repair and Supply Center provided essential engineering support in designing and fabricating an HH-60J GPS antenna modification for the R&D Center's data recording equipment.

Finally, many thanks are due to the innumerable people at Coast Guard Air Station San Francisco who made the data collection flights and GPS installation both safe and successful.

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

This report documents a United States Coast Guard (USCG) Research and Development (R&D) Center evaluation of an assortment of commercially available infrared (IR) sensors for their utility in detecting oil slicks in the marine environment at night. This project was performed in support of the USCG marine environmental protection (MEP) program. The primary objective of this project is to identify new technologies that support quick-response investigation of reported spills and that offer a capability to provide close support to night containment, tracking, and cleanup operations.

As part of this project, the USCG R&D Center conducted several field tests to evaluate commercially available technologies for their ability to remotely detect oil on water. In the spring of 1992, the R&D Center evaluated resolution requirements of a synthetic aperture radar and the Coast Guard's Side-Looking Airborne Radar over the natural oil seeps off the coast of Santa Barbara, CA. Results of this evaluation are reported in reference 1. In the spring of 1993, the R&D Center participated in an Environment Canada field test in Ontario, Canada. The USCG portion of this field test was to evaluate IR sensors for their ability to detect oil on water in a specially constructed test tank. References 2 and 3 review the theory behind infrared detection of oil on water, summarize the 1993 field test, and document the results of data analyses conducted on video data recorded during that field test.

During the fall of 1994, the Coast Guard R&D Center conducted a field test off the coast of Santa Barbara, CA, to evaluate the ability of commercially-available portable IR sensors to provide a first-response oil spill sensing capability to USCG marine pollution control units. The results of that evaluation are documented here.

Data from this evaluation will be used to:

1. Further document the performance of the FLIR 2000 installed onboard USCG HH-60J helicopters for detecting oil on water at night.

2. Compare the relative detection performance of several portable IR detector technologies against oil-on-water targets at night.

3. Document several factors affecting the IR detection of oil on water, including physical aspects and environmental conditions.

4. Determine if current IR technology can provide USCG MEP oil spill response personnel with a light weight IR sensor that can be used from small USCG helicopters and other aircraft of opportunity.

1.2 INFRARED PHENOMENOLOGY OVERVIEW

Reference 2 presents a detailed review of infrared phenomenology. A summary is presented in this section.

For an object to be detected by a sensor, the difference, or contrast, in radiation reaching the sensor from the object and its immediate vicinity (background) must be greater than the sensitivity of the sensor. It does not matter whether the radiation from the object or its background is reflected (originating from some other source) or radiation emitted from the object or background itself.

While reflected radiation (from the sun or other light sources) dominates the visible spectrum, naturally emitted radiation dominates in the infrared spectrum. Remote sensing at thermal or IR wavelengths is usually confined to spectral regions, called atmospheric windows, where the atmosphere is sufficiently transparent to allow radiation to travel over significant path lengths with little absorption. These atmospheric windows exist principally in the 3.1- to 4.1-micrometer (μ) and 4.5- to 5.5μ wavelength bands known as medium wave infrared (MWIR), and the 8- to 12μ wavelength band known as long wave infrared (LWIR). Strong absorption bands, resulting principally from atmospheric water vapor and carbon dioxide, effectively eliminate thermal remote sensing outside these regions.

At night, when the main source of differential heating (the sun) is removed, oil and water cool to the same physical temperature and the relatively small differences in emissivity (the ratio of the radiance of a given body to that of a perfect emitter) become the major source of thermal contrast. Generally, oils are less emissive than water, and at night, will appear cooler than water once they reach the same physical temperature.

For most oils, the difference in emissivity is more pronounced in the LWIR spectral band than in the MWIR spectral band, so under ideal conditions, an LWIR sensor is likely to provide images with better oil/water contrast than MWIR sensors. Atmospheric moisture, however, absorbs thermal radiation more in the LWIR spectral band and the contrast level available at the sensor becomes a combination of factors, especially as distance to the target increases.

Reference 4 states that a water surface greater than 0.03 centimeters thick is essentially opaque in the infrared spectrum. This means that bottom features, even in shallow water, that are visible to the naked eye will not be visible to an infrared sensor. It also means that an infrared sensor's ability to detect an object will be degraded as the atmospheric moisture content increases in the path from the object to the sensor.

1.3 SENSOR SYSTEM DESCRIPTIONS

To support this field test, the R&D Center obtained four portable IR sensors for nighttime imaging of oil slicks, an S-VHS-C camcorder to obtain daytime surface truth images, and an HH-60J helicopter with an installed FLIR 2000. Previous analyses have documented the capabilities of the FLIR 2000, and this IR system is used here to represent the USCG's baseline nighttime oil spill surveillance capability.

1.3.1 LWIR Sensors

LWIR sensors obtained for the field test were: the installed FLIR Systems, Inc. Model 2000; an Agema Infrared Systems Agema Thermovision 1000 (typically used in an installed, gimbal-mounted forward-looking IR (FLIR) configuration, but modified to permit laptop use for this experiment); and a hand-held Texas Instruments Low Cost Uncooled Sensor Prototype (LOCUSP) sensor. Specific sensor characteristics are as follows.

FLIR 2000

The FLIR 2000 uses a cooled, 8-element Mercury Cadmium Telluride (HgCdTe) scanning detector array (350 by 343 pixels) to provide a wide field of view (FOV) of 28 by 15 degrees and a narrow FOV of 7.0 by 3.25 degrees. The advertised wide FOV thermal sensitivity is 0.16°C minimum resolvable temperature difference (MRTD) at 0.36 cycles/mrad spatial frequency. Advertised narrow FOV thermal resolution is 0.18°C MRTD at 1.3 cycles/mrad spatial frequency.

The sensor is mounted to the airframe in a gimbaled turret that is controlled remotely by the air crew. FLIR 2000 data can be displayed at the air crew position and in the cockpit. The weight of this system precludes it from installation on the Coast Guard's lighter HH-65A helicopter airframe. Figure 1-1 depicts an HH-60J helicopter with the installed FLIR 2000 system.

Agema 1000

The Agema 1000 uses a cooled, 5-element HgCdTe scanning array (798 by 400 pixels) to provide a wide FOV of 20 by 13.3 degrees and a narrow FOV of 5 by 3.3 degrees. The advertised wide FOV thermal sensitivity is 0.16°C MRTD at 0.4 cycles/mrad and 1.0°C MRTD at 0.8 cycles/mrad. Advertised narrow FOV thermal resolution is 0.16°C MRTD at 1.6 cycles/mrad and 1.0°C MRTD at 3.2 cycles/mrad.

The Agema 1000 is typically used in an installed, gimbal-mounted FLIR configuration. Although compact and lightweight compared to most other gimbal-mounted FLIRs, it is not specifically designed for hand-held use. It was adapted by the manufacturer for lap-held use during this field test, and is considerably larger and heavier than the other portable sensors evaluated. A 28V external battery powered the sensor and remote control unit, and a separate 12V power supply was required for the external monitor. A separate, hand-held remote control unit provided the operator with all required sensor adjustments and settings. Figure 1-2 depicts the Agema 1000 portable IR sensor with associated cables and required accessories.

LOCUSP

The LOCUSP is an uncooled LWIR sensor with a Barium Strontium Titanate (BaSrTi) focal plane array detector and optics that provide a 7- by 9.3-degree FOV. The advertised sensitivity is approximately 0.1°C noise-equivalent temperature difference (NETD). MRTD data were not available.

The LOCUSP configuration tested is currently used by the U.S. Army as a gun sight for various weapons. For this field test, a standard pistol grip accessory was attached to the bottom of the sensor as a handhold. Figure 1-3 depicts the LOCUSP. All controls are integrated into the upper body of the sensor with video polarity and focus forward and brightness and gain aft. Automatic gain control is activated at the far range of the gain control barrel switch.

Figure 1-1. HH-60J with FLIR 2000 Installed

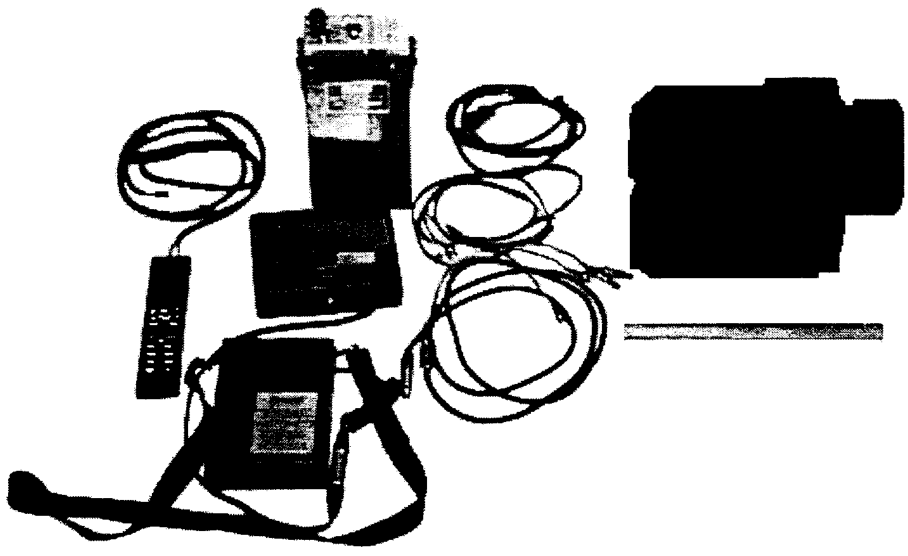

Figure 1-2. Agema 1000 Portable IR Sensor

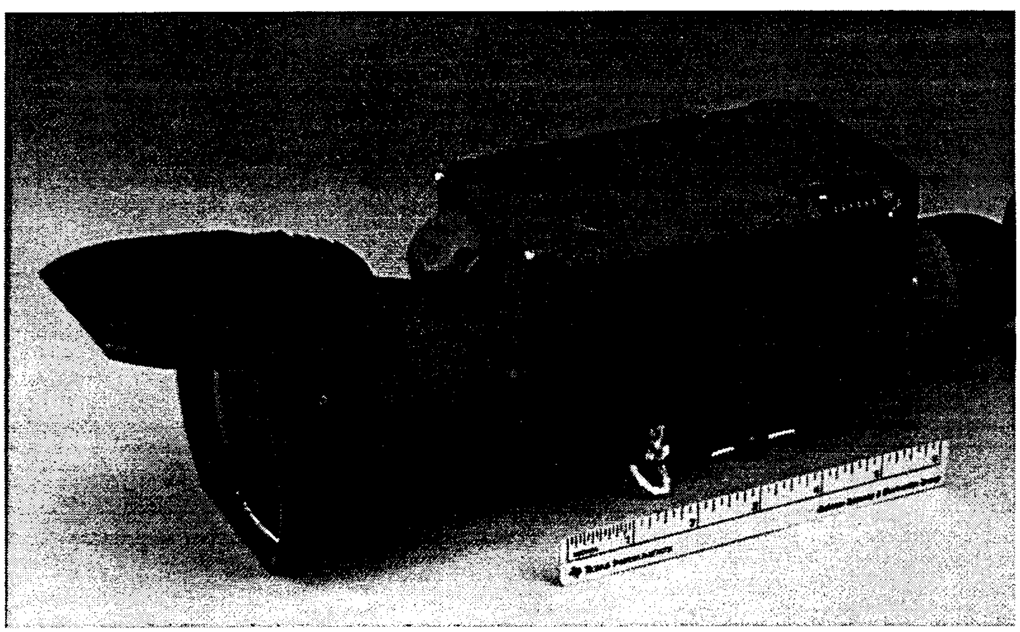

Figure 1-3. LOCUSP IR Sensor

1.3.2 MWIR Sensors

Both MWIR sensors obtained for the field test were manufactured by Cincinnati Electronics Corporation. They are the IRC-160ST and the IRRIS-256ST. Sensor descriptions are provided below.

IRC-160ST

The IRC-160ST uses a cooled, 160- by 120-element Indium Antimonide (InSb) focal plane array that provides a 9.1- by 6.8-degree FOV with the 50 mm lens used during this test. The advertised thermal sensitivity is 0.025°K at 300°K NETD.

The Coast Guard presently owns several IRC-160ST cameras. This sensor is approximately the same physical size as a standard VHS camcorder, incorporating a handstrap along with brightness and contrast controls that can easily be adjusted with a single hand. Focus is controlled by a lens ring and is adjusted with the other hand. Video polarity is controlled by a rocker switch in the rear of the sensor. Figure 1-4 depicts the IRC-160ST sensor.

IRRIS-256ST

The IRRIS-256ST uses a cooled, 256-element square InSb focal plane array that provides an 8.7- by 8.7-degree FOV. The advertised thermal sensitivity is 0.025°K at 300°K NETD.

The IRRIS-256ST uses the same sensor technology as the IRC-160ST, but provides a higher resolution focal plane array and a different user interface. The sensor controls have been moved to the left side of the sensor, on the lower portion of the sensor housing. This configuration requires the use of both hands to aim, focus, and control brightness and contrast. IRRIS-256ST controls are smaller and less like those of a typical camcorder. Figure 1-5 depicts the IRRIS-256ST sensor.

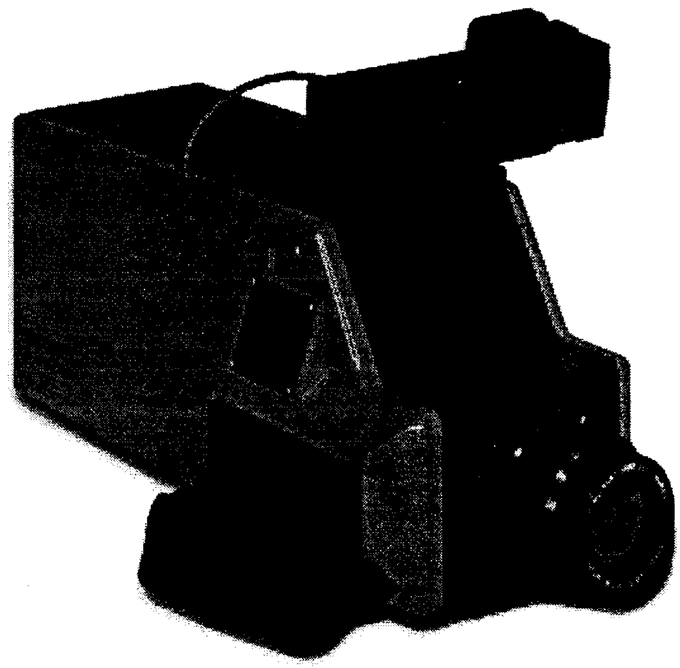

Figure 1-4. IRC-160ST IR Sensor

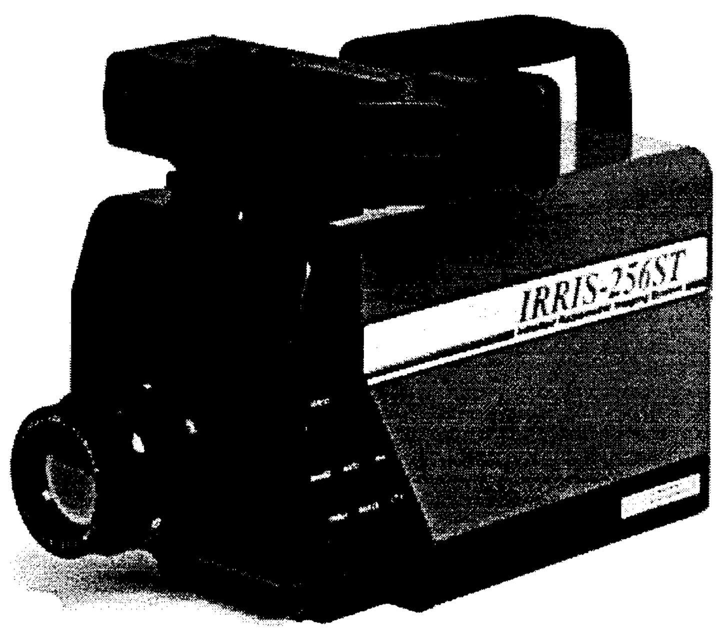

Figure 1-5. IRRIS-256ST IR Sensor

1.3.3 Video Capture System

Image data from all portable sensors were recorded on S-VHS video tape in an R&D Center-developed video annotation and capture system. Figure 1-6 depicts the video capture hardware. Sensor video data were passed through a video titler that received time and position information from a portable Global Positioning System (GPS) unit. The annotated video signal from the video titler was then recorded on an S-VHS recorder. A video monitor that received a video signal from the recorder's video pass through provided confirmation that the video image was being sent to the recorder.

All components of figure 1-6 were integrated into a customized case (3 feet by 2 feet by 8 inches) to minimize loose cables and fittings. A single external 12V battery supplied power to the components within the customized case. Each sensor was powered by its respective battery system. The GPS signal was provided from the aircraft in accordance with USCG Aircraft Repair Supply Center Elizabeth City engineering specification H60710100.01, dated 19 October, 1994 (see appendix B).

Concurrent FLIR 2000 images were recorded to VHS tape on a recorder integrated into the FLIR 2000 pallet.

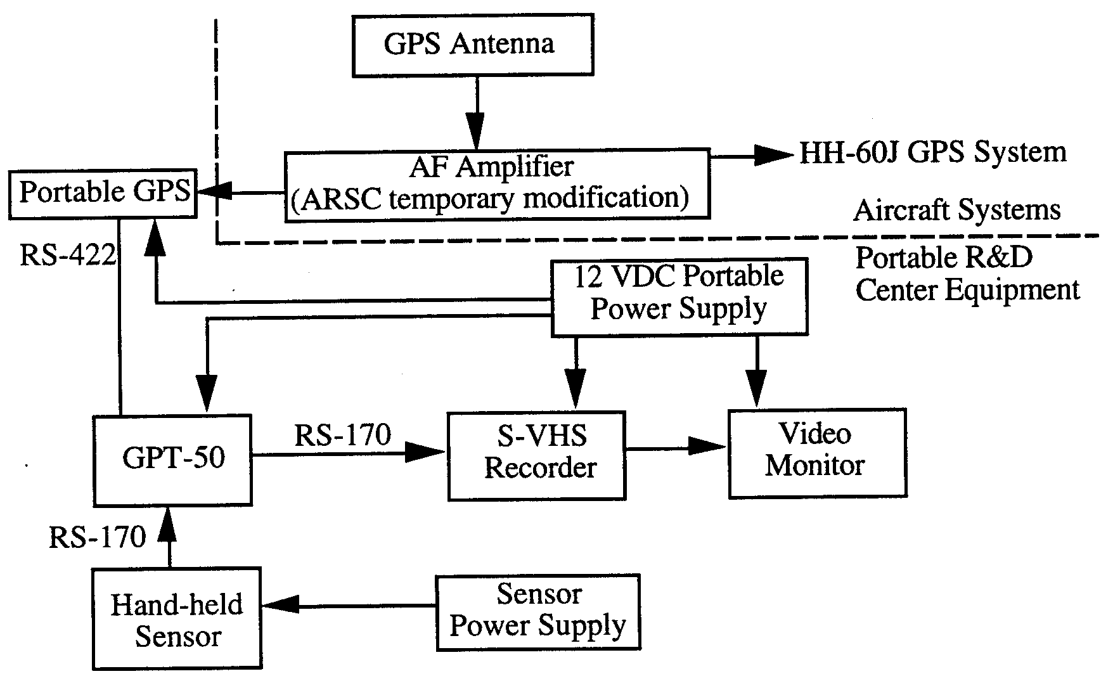

Figure 1-6. Video Capture System

1.4 EXPERIMENT DESCRIPTION

The Coast Guard planned and coordinated the field test, obtained the use of the hand-held IR sensors, provided the FLIR-equipped HH-60J helicopter, and provided all airborne data collection equipment and personnel. The Texas General Lands Office agreed to sponsor a Texas A&M Geochemical and Environmental Research Group (GERG) field team to assist with surface truth data collection. A Marine Spill Response Corporation (MSRC) oil spill response vessel (R/V CALIFORNIA RESPONDER) was chartered by GERG to provide an on-scene surface truth data collection platform.

The experiment was conducted from 14 to 19 November 1994 off the coast of Santa Barbara, CA. This area was chosen because it contains multiple sources of naturally occurring petroleum and biogenic oil slicks.

1.4.1 Test Site Description

The test site was located off the coast of Santa Barbara, CA, within a box bounded by 119° 45'W to 120° 10'W and extending out to 10 nautical miles (nmi) from the coast. During daylight survey sorties, three regions containing oil slick features of particular interest were selected. The location of these regions is shown in figure 1-7. The oil slick regions are described below.

Area 1: The first slick area consisted of an oil slick region approximately one mile southeast of an oil pumping platform (Holly Platform). This slick consisted of a large patch of oil sheen with thicker streamers that could be seen within the oil slick at various times (particularly in the thermal images). Along the northern boundary of the slick, an oil and natural gas source was visible on the surface. Although the particular location where natural gas and oil break the surface does not directly represent typical oil spill scenarios, it does demonstrate important aspects of thermal imaging.

Area 2: The region around and between Coal Oil Point and Goleta Point contains several kelp beds and petroleum oil sources. Both types of oil source produced slicks in the near shore areas. This provided an opportunity to compare petroleum and "false positive" slicks directly.

Area 3: The third oil slick region consisted of multiple petroleum oil seeps that created a wide area slick centered approximately 3 nmi offshore near Goleta Point. The slick was several miles long, oriented in a downwind direction. The slick had a silvery sheen appearance during daylight helicopter sorties. Its trailing upwind edge contained several point sources of petroleum oil, while the leading edge (downwind) contained several bands of oil streamers within the larger sheen patches.

Oil samples collected from within the regions of interest were analyzed by Texas A&M/GERG and the results are reported in reference 5. The report indicates that in each oil slick area small quantities of oil were collected from within thin sheens. Analysis of these samples indicated that within some sheens, heavily weathered tar balls and small quantities of entrained organic matter were present. None of the samples contained light components and most appeared heavily biodegraded and weathered when compared to oil from typical crude oil spills. The level of biodegradation and weathering was severe even in samples that were collected near locations where oil first reached the water's surface. Because the oil reached the surface without these light components, evaporative cooling normally associated with fresh oil slicks was not a significant contributor to the thermal contrast between oil and water.

1.4.2 Experiment Design and Conduct

The experiment was scheduled for a five-day period in mid November. Data were collected on three nights during the test period. During daylight hours on each data collection day, the HH-60J helicopter conducted a late afternoon/early evening sortie to identify and document slick regions of interest for the nighttime IR imaging sorties. The documenting sorties were flown primarily at an altitude of 2500 feet, with brief descents to an altitude of 800 feet to provide more detailed viewing of particular features. The R/V CALIFORNIA RESPONDER coordinated efforts with the HH-60J to document surface data in selected regions of interest.

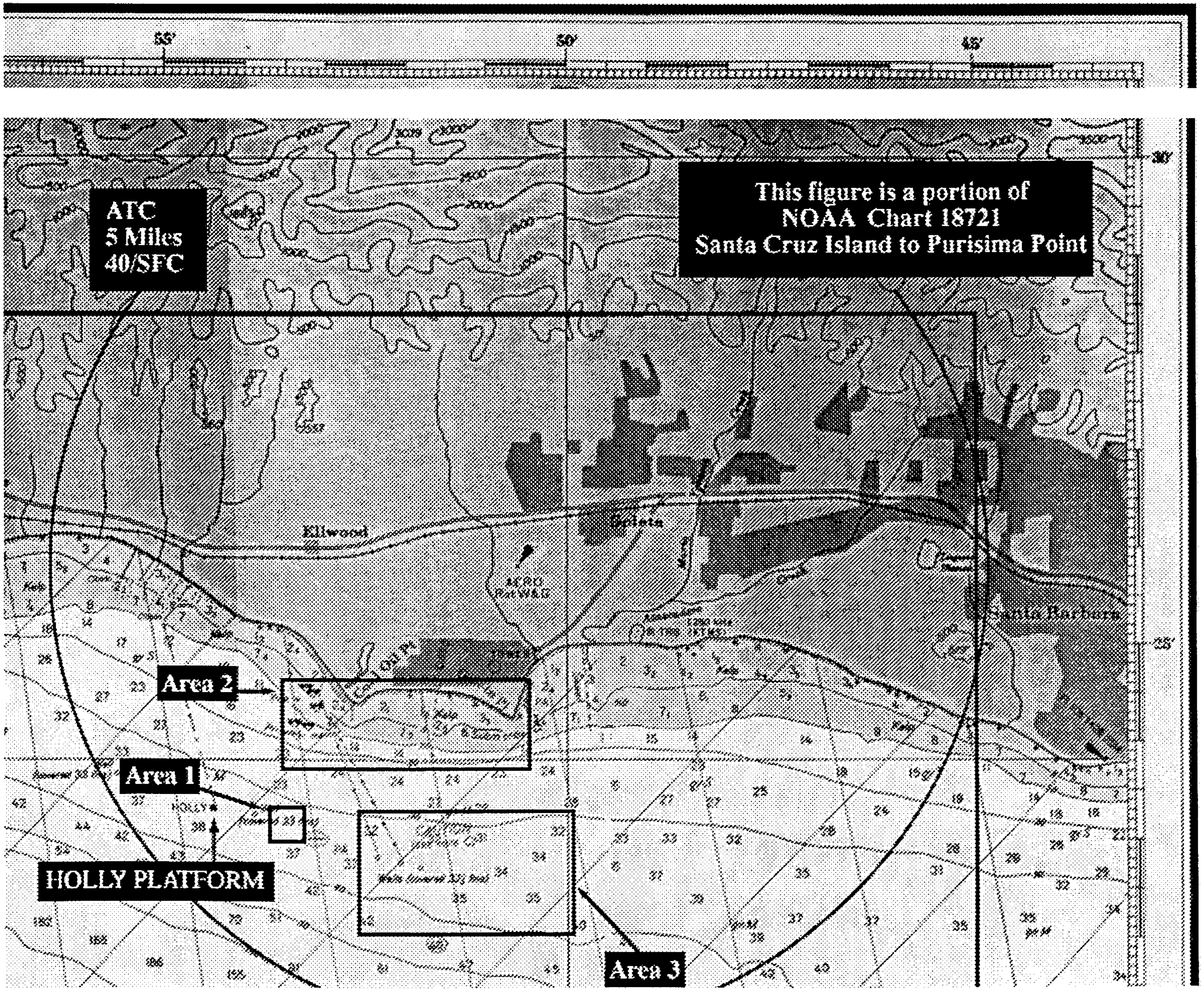

Figure 1-7. Santa Barbara Test Site With Selected Regions of Interest Marked

Video footage from the daytime sorties was reviewed after the HH-60J returned to the airport to finalize region-of-interest selection. The air crew and IR sensor operator were then alerted to data collection requirements for the nighttime sorties. Nighttime video data collection was conducted at altitudes of 500 to 800 feet and was designed to obtain images from all sensors in both white=hot and black=hot video polarities over each of the oil slick regions. Several orbits around each slick feature were executed for each hand-held IR imager to ensure sufficient image data were obtained for post-experiment analysis. Hand-held IR sensor data were recorded in sequential time blocks over each target area. Concurrent FLIR 2000 data were recorded to provide baseline reference image data.

Image data were obtained from all sensors on each data collection night with the following exceptions:

- The IRRIS-256ST was not onboard the helicopter on 14 November.
- The IRC-160ST was not onboard the helicopter on 15 November.
- The Agema 1000 was inadvertently switched to an unsynchronized mode on 17 November and no usable image data were obtained on that night.

When key features within an oil slick region were seen with an IR sensor, an attempt was made to capture comparable images with each of the other sensors.

1.5 ENVIRONMENTAL PARAMETERS

Appendix A contains the data logs for environmental conditions. Environmental parameters were recorded every half hour during airborne video data collection sorties and whenever a significant environmental change occurred. Environmental data were recorded from onboard the R/V CALIFORNIA RESPONDER or from its rigid hull inflatable (RHI) boat. Air temperature data were transferred from a national weather service meteorological buoy (CBY) located in the Santa Barbara Channel west of the test area.

Recorded data elements and data collection instructions included:

a. GMT Time: Hours and minutes recorded in 24-hour clock format from the GPS time source. (HH:MM)

b. Latitude: North latitude of the data collection unit in degrees, minutes, and tenths of minutes. (DD:MM.M)

c. Longitude: West longitude of the data collection unit in degrees, minutes, and tenths of minutes. (DDD:MM.M)

d. Visibility: Estimated to the nearest whole nautical miles with 15 nmi as unlimited visibility.

e. Visible Moon: Record if the moon is visible or not. If the moon is visible, record the phase.

f. Significant Wave Height (H_S): The height of the prominent local-wind-driven wave pattern in whole feet.

g. White Caps: None (n), some (s), or many (m).

h. Swell Direction: The magnetic compass direction in which the swells are propagating to the nearest 10 degrees.

i. Wind Speed: The wind speed to the nearest knot.

j. Wind Direction: The magnetic compass direction from which the wind is blowing to the nearest 10 degrees.

Relative humidity was recorded from a psychrometer onboard the R/V CALIFORNIA RESPONDER.

The range of environmental conditions experienced on each experiment day is shown in table 1-1. Visibility was unrestricted during all sorties, with the significant exception being brief periods of scattered low clouds and showers on the night of 15 November. The moon was visible at a full to three-quarter phase during the test period. A 1- to 2-foot sea swell out of the west with a 10- to 15-second period was present during all data collection sorties.

Table 1-1. Range of Environmental Conditions Encountered

Date	SEA STATE H_S* (ft)	SEA STATE Direction	WIND Speed (kts)	WIND Direction (°M)	Air Temperature (°C)	Water Temperature (°C)	Relative Humidity (%)
14 Nov.	0	N/A	0 - 4.7	010 - 084	11.2 - 11.6	17.7 - 17.8	71 - 79
15 Nov.	1 - 2	None**	11.5 - 20/8	Shifting**	9.0 - 10.5	17.3 - 17.5	77 - 88
17 Nov.	4	260	16.0 - 22.0	285 - 302	6.7 - 8.0	16.7 - 16.8	69

* H_S=significant, locally-generated wind driven waves observed from the R/V CALIFORNIA RESPONDER.

** Strong, gusty, shifting winds associated with an approaching front kicked up a 1- to 2-foot chop, but did not generate a swell pattern.

1.6 IMAGE DATA PREPARATION

1.6.1 Video Frame Capture

Video tapes of daylight visible spectrum and nighttime infrared images were reviewed to identify segments that provided representative demonstrations of operational sensor performance. In selecting representative segments of tape, an effort was made to obtain images of a particular feature from the same look angle to permit comparative evaluation across sensors. Individual video frames from within the selected video segments were digitized using a video capture board that provided input to an IBM PC-compatible 486/DX desktop computer. These images were initially saved in 24-bit color bit-mapped (BMP) format, imported to ALDUS PhotoStyler software for conversion to 8-bit gray-scale TIFF formatted files, and processed as described below.

1.6.2 Software Manipulation of Captured Video Frames

When a video tape is playing, the scene is continuous and the observer must integrate a series of individual image frames into an understandable moving picture. During normal playback, video noise on a television monitor is integrated over successive frames at a rate such that the human viewer perceives a clearer, more detailed image than is available in a single video frame. When the video tape is stopped or slowed to the point where individual frames can be viewed, the image quality is often significantly worse than the perceived quality in the moving video. Since only single video frames could be captured and digitized for analysis, a method of simulating real-time sensor image quality was employed when individual frames were judged to be of low fidelity. This method required that two or more video frames be captured and summed. Typically, these were successive frames; however, if successive frames could not provide satisfactory single-frame image quality, video frames in close time proximity were captured.

To construct the simulated real-time images, each pair of captured video frames was opened in Atlantis Scientific Systems' EarthView software. This software was used to co-register important scene features in the image pairs so that they overlapped exactly. The pixel gray-scale values in each frame were then divided by two and the resultant images were summed. This frame manipulation had the net effect of strengthening actual image features and reducing some of the noise. This resulted in a "best approximation" to the image perceived in the moving video. Where ancillary information (cross hairs, tuning status bar, etc.) was superimposed by some sensors on the infrared images, the co-registration of scene features and subsequent frame summation occasionally blurred or created a double of the superimposed information. This effect, while annoying to look at, did not adversely affect the quality of the infrared images. The summed images were saved to 8-bit gray-scale TIFF files and opened in PhotoStyler for final processing and printing. Final report images were printed on a Kodak XLT-7720 digital continuous tone printer to produce high-quality prints for reproduction.

Figures 1-8 and 1-9 depict typical video frames. Figure 1-8 is a typical FLIR 2000 frame and figure 1-9 is a typical frame from the hand-held IRC-160ST. Each video frame presented in chapters 2 and 3 will contain similar graphical information.

The FLIR 2000 (figure 1-8) provides a scale along the top and right-hand side that indicates azimuth position on top (with 0 indicating on the nose and the longer hash mark on either side indicating 90-degrees rotation) and depression angle on the right (with 0 indicating horizontal, the longer hash mark below zero indicating a straight downward direction, and marks below this indicating a rearward look). There is some header information at the top of the FLIR 2000 image that displays input from aircraft systems, but that header information is not pertinent to this evaluation. On the bottom of the FLIR 2000 image are latitude and longitude (left side) and date and time (right side). These display the helicopter's GPS information with time and date in Greenwich Mean Time (GMT).

The overlay information for all hand-held sensors (figure 1-9) is contained in two rows along the bottom of the image. The first row provides the latitude (left) and longitude (right) obtained from the portable GPS unit in the R&D Center video capture system. On this line, the first four digits of latitude and first five digits of longitude are displayed, followed by N latitude/W longitude indicators, then two-digit seconds of latitude or longitude. The left side of the second row provides GMT time from the portable GPS unit and on the right, a fix quality (Q1 or Q0) followed by local date (GMT minus 8 hours) are displayed. The IRC-160ST itself provides a gray-scale contrast bar on the right of the image (this also indicates white or black=hot video polarity at the top of the contrast bar). The IRRIS-256ST has a similar feature and the ability, if calibrated, to provide thermal measurements. The Agema 1000 displays an information bar along the bottom of the image that provides focus, tuning, and zoom information (the majority of this was overwritten by the R&D Center GPS position and time information). The LOCUSP has a crosshair centered in the image.

For this evaluation, time and position information is most critical to ensure that similar features are compared in the same relative position and approximate time frame. This facilitates fairer sensor comparisons by minimizing environmental and target differences among images being compared. Where displayed, contrast bars helped to determine the video polarity of images. The audio portion of the S-VHS tapes and handwritten logs provided additional sources of video polarity information.

1.7 IMAGE ANALYSIS OVERVIEW

Chapters 2 and 3 present the results of analyses conducted on selected IR video frames. Chapter 2 presents images from each of the IR sensors that illustrate that all of the systems tested are capable of detecting oil slicks at night. Chapter 3 presents images that depict how variations in certain critical parameters can influence the quality of information presented by the IR sensors.

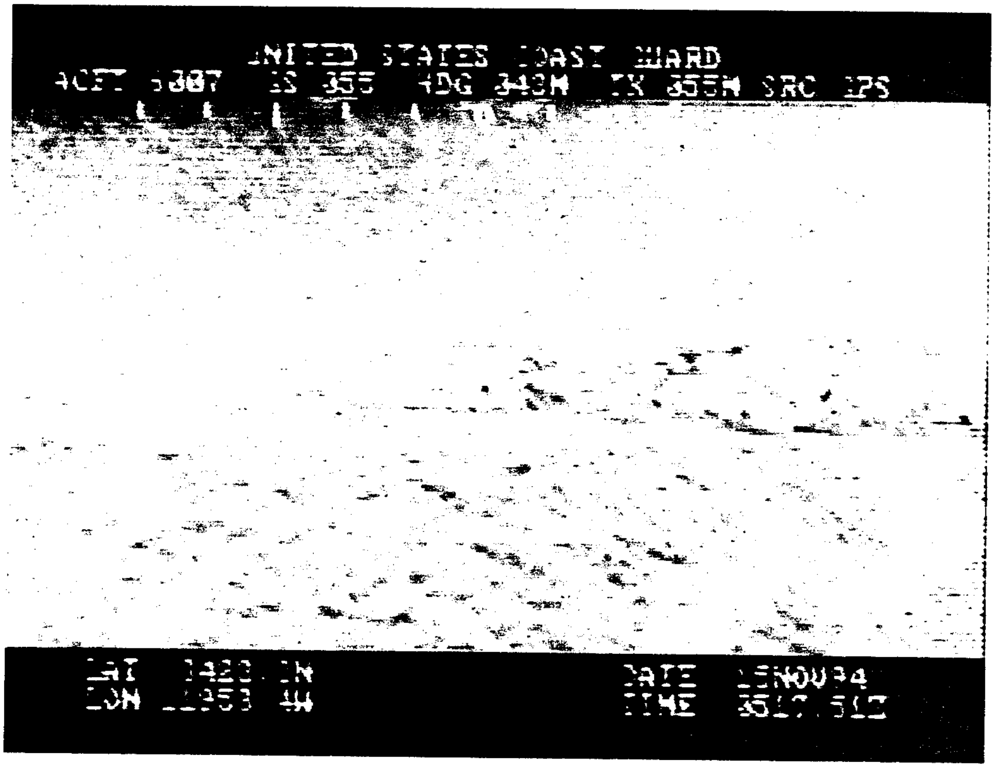

Figure 1-8. Example FLIR 2000 Image

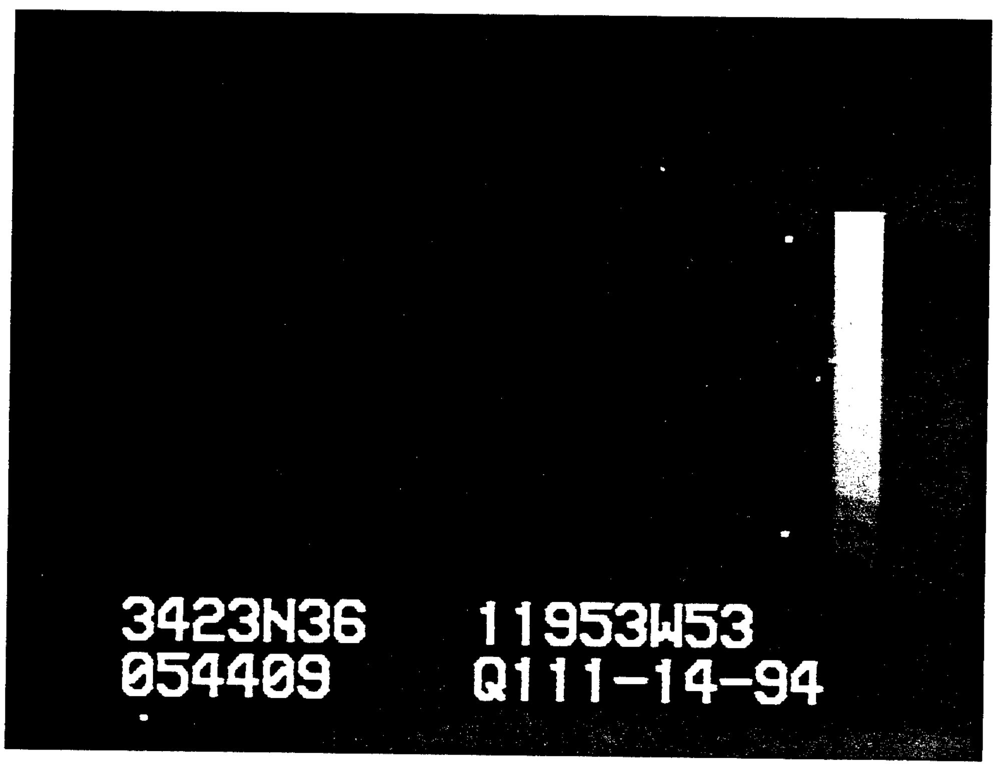

Figure 1-9. Example Hand-held Sensor Image

CHAPTER 2
SENSOR PERFORMANCE OVERVIEW

This chapter documents the ability of each IR sensor evaluated to detect oil on water at night. Section 2.1 presents long distance/wide FOV images from the visible spectrum camcorder (daylight surface truth) and all IR sensors (night images). Section 2.2 documents the ability of each sensor to delineate, at close range, fine features such as oil slick thickness variations that present small thermal energy differences within the imaged scene. Section 2.3 discusses the man-machine interface (MMI) aspects of the hand-held IR sensor operation.

In each set of images discussed, a daytime visible spectrum image, a FLIR 2000 image, and images from all hand-held sensors will be represented. Whenever possible, an effort was made to depict similar features from the same look direction on the same night. When this correlation could not be done, an effort was made to match scene detail and environmental factors as closely as possible. Environmental factors associated with each set of IR images will be summarized.

2.1 WIDE-AREA AND LONG-DISTANCE OIL SLICK DETECTION

During the nighttime imaging of the large oil slick (area 3) on 17 November, the IR sensor operators obtained a well-matched set of IR video footage looking west toward Holly Platform from the eastern edge of the slick region. Because the Agema 1000 was not able to provide an image on the 17th due to an inadvertent technical error, a similar view obtained on the night of 15 November will be used. This image depicts a section of the area 3 oil slick from a shorter distance. Review of position data and the audio portion of the recorded video tape indicated that Holly Platform was 3 to 5 nmi from the helicopter when the following images were obtained.

Visible Spectrum: Figure 2-1 is a wide-area, visible spectrum reference image of the area 3 oil slick. The reference image was taken from an altitude of 2500 feet on 15 November. Several oil seep sources are evident in the figure along the western (top) edge of the slick areas. These were being blown eastward by winds of about 10 knots out of 270°M. The trailing oil seeps appear to merge and then separate into distinct streamers as they are pushed away from the sources. Near the top right edge of the image, the black dot is Holly Platform (approximately 5 nmi from the helicopter). The oil slick immediately below Holly Platform surrounds the natural gas bubble of area 1. It was approximately 4 nmi from the helicopter at the time this image was obtained.

FLIR 2000: Figure 2-2 provides a long-range FLIR 2000 image of the area 3 oil slick. It was obtained in black=hot video polarity, wide FOV from an altitude of 800 feet. Holly Platform is the black spot near the top of the image, just left of center (approximately 5 nmi from the helicopter). Oil streamers visible downwind of the large sheen area are at the bottom and right edges of the image. The slick around the natural gas bubble is depicted immediately below and slightly to the right of Holly Platform. It was approximately 4 nmi from the helicopter at the time the image was obtained. Most of the distinct seep sources evident in the visible spectrum image are not discernible in this image because of the distance and angle in this field of view; however, the stepped look apparent in the visible spectrum image is maintained.

Figure 2-3 was imaged during the same time frame as figure 2-2, but presents a narrow FOV image. It is black=hot, taken from an altitude of 800 feet. The scene features further from the helicopter are significantly more detailed than with wide FOV. Holly Platform is the hot target at scene center, and the physical appearance of the oil slick surrounding the natural gas source is better defined. The oil streamers that make up the large oil slick are readily seen in the lower portion of this image where no detail could be seen in the wide FOV image.

Agema 1000: Figure 2-4 depicts a long-range view of the area 1 slick in white=hot video polarity. It was taken with the Agema 1000 in wide FOV from an altitude of 800 feet. Holly Platform (white object in upper right image corner) is approximately 2 nmi from the helicopter and a small slick is visible around the platform. The larger slick area in the center of the image is the oil slick around the natural gas source. Natural gas breaks the surface in the small arm of the slick near the right side of the image. Position data and the audio portion of the tape indicated that marker buoys near the natural gas source were approximately a mile and a half from the aircraft. Oil streamers similar to those depicted in the FLIR 2000 images are visible along the leading edge of the slick. The full motion video provides significantly better image clarity than can be demonstrated here.

LOCUSP: Figure 2-5 is a long-range view of the area 3 slick obtained with the LOCUSP sensor. It is black=hot, taken from an altitude of 800 feet on 17 November. Holly Platform is the black (hot) spot left of center near the top of the image. It was approximately 5 nmi from the helicopter at the time this image was obtained. The oil slick around the natural gas bubble is the cooler (whiter) region that begins below Holly Platform and reaches toward the right-hand side of the image. Barely visible in this image and only slightly more noticeable in the full motion video is the smaller slick region at the base of Holly Platform. Oil streamers are clearly present in the slick that dominates the lower portion of the image.

IRC-160ST: Figure 2-6 depicts the area 3 slick as imaged by the IRC-160ST. The image is the sum of two black=hot frames taken from an altitude of 800 feet on 17 November. Camera motion caused the shift of superimposed time and position data when frame co-registration and summation were performed. Bad pixels appear double imaged, but oil slick features much more closely match what the sensor operator was able to view through the sensor viewfinder. Holly Platform appears hot (black) in the upper right portion of the image at a distance of approximately 4 nmi. The oil slick around the natural gas seep is similar in appearance to both the narrow FOV FLIR 2000 and LOCUSP images. The appearance of the streamers in the larger oil slick is also similar when the slightly different look angle is accounted for.

IRRIS-256ST: Figure 2-7 depicts a long-range view of the area 3 slick from the IRRIS-256ST, taken in black=hot video polarity from an altitude of 800 feet on 17 November. Holly Platform appears as a hot (black) object, nearly centered, close to the top of the image at a distance of approximately 5 nmi. This image is similar to the wide FOV image from the FLIR 2000 presented in figure 2-2. Multiple oil sources at the upwind edge of the slick area appear much more clearly in the full-motion video than is depicted here, even though frame-summing was used in an attempt to improve clarity.

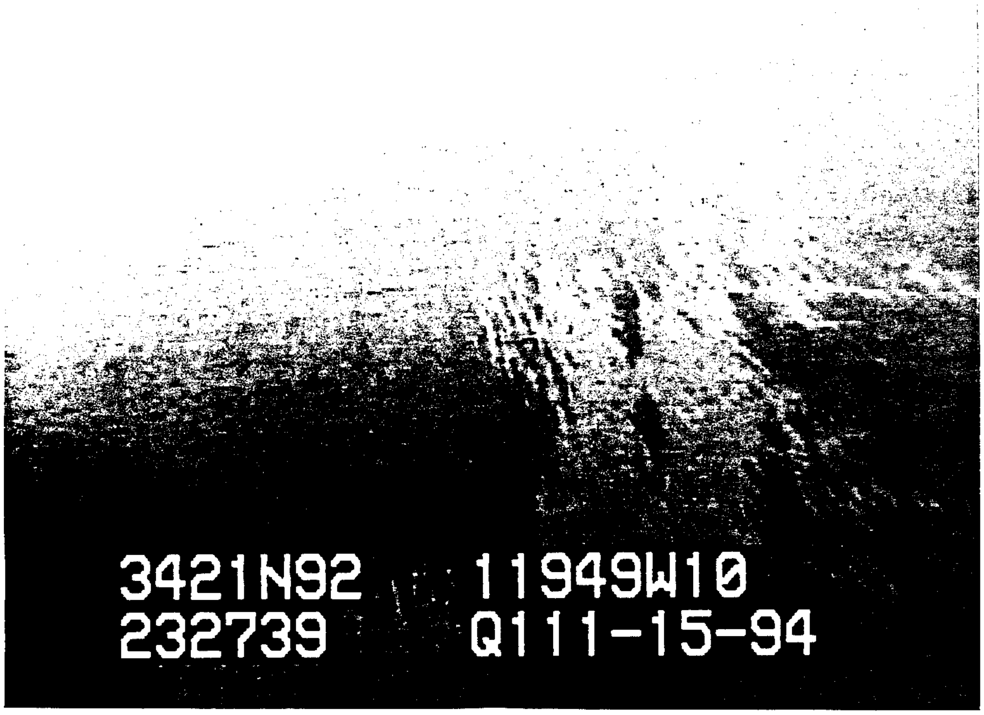

Figure 2-1. Visible Spectrum Image of the Area 3 Slick, 15 November 1994

Figure 2-2. FLIR 2000 Image of the Area 3 Slick, 17 November 1994

(Black = Hot, Wide Field of View)

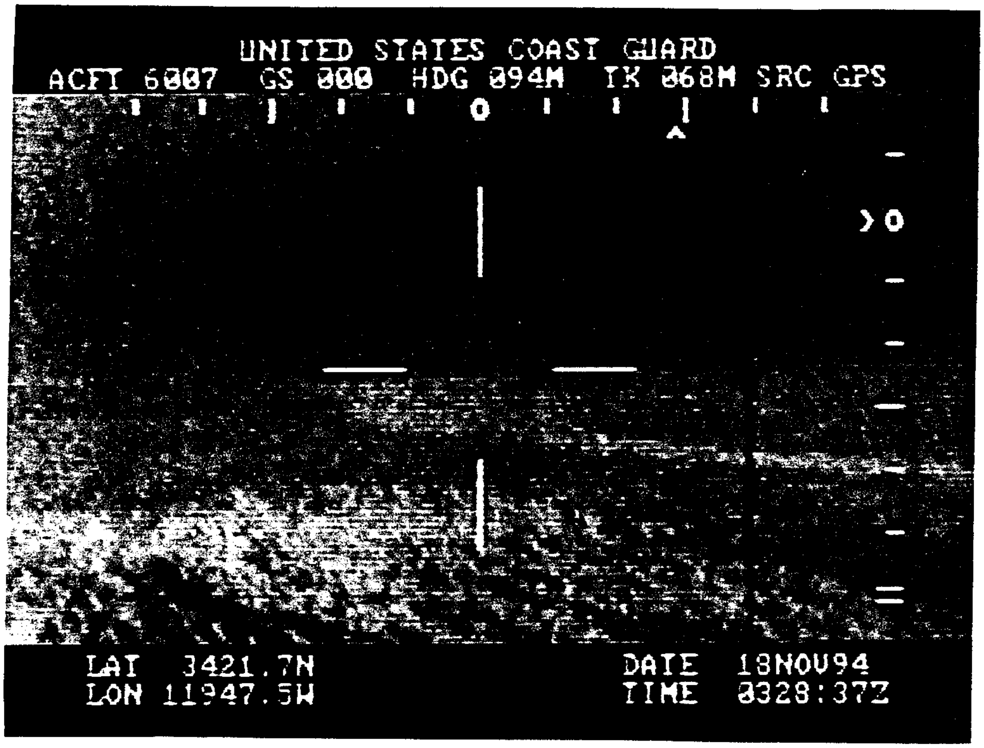

Figure 2-3. FLIR 2000 Image of the Area 3 Slick, 17 November 1994
(Black = Hot, Narrow Field of View)

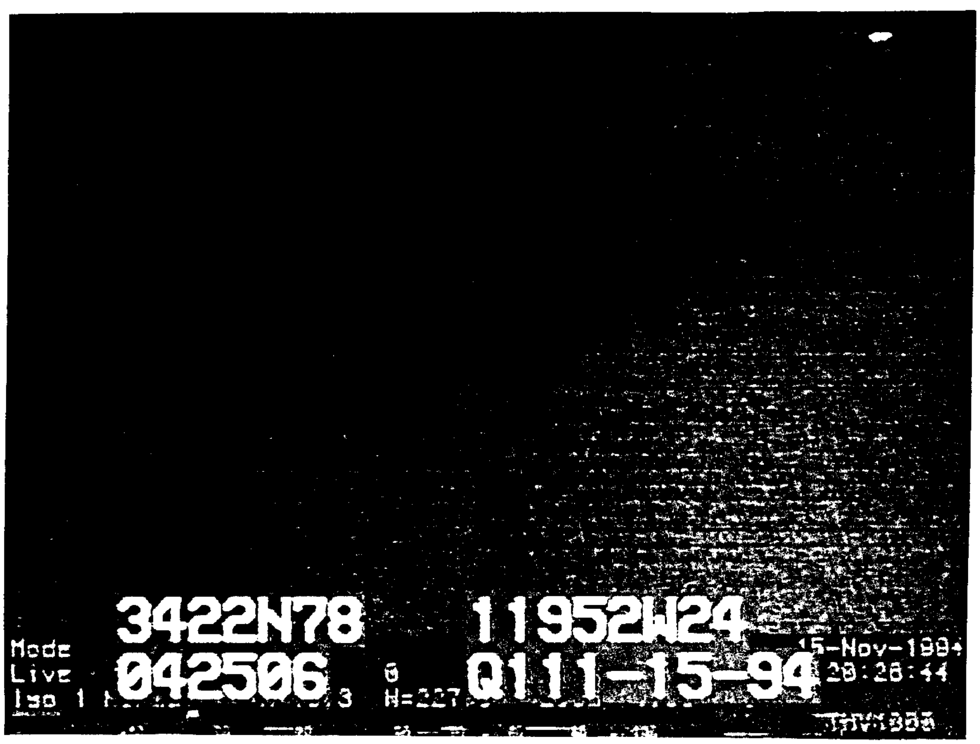

Figure 2-4. Agema 1000 Image of the Area 1 Slick, 15 November 1994
(White = Hot, Wide Field of View)

Figure 2-5. LOCUSP Image of the Area 3 Slick, 17 November 1994
(Black = Hot)

Figure 2-6. IRC-160ST Image of the Area 3 Slick, 17 November 1994
(Black = Hot)

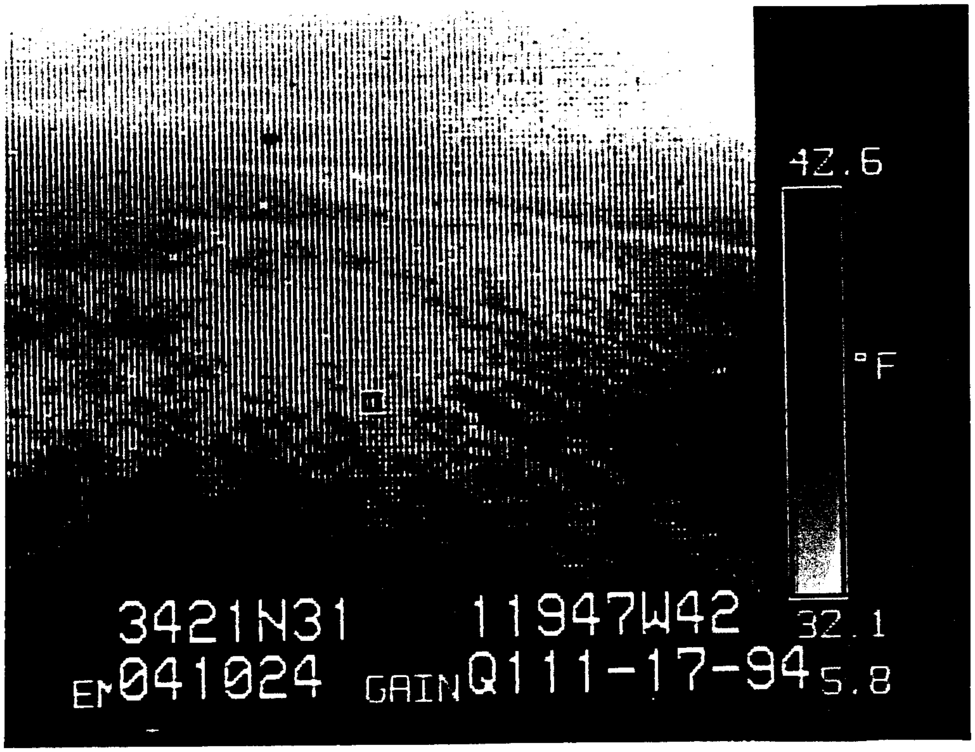

Figure 2-7. IRRIS-256ST Image of the Area 3 Slick, 17 November 1994
(Black = Hot)

Each sensor demonstrated the ability to detect large-area, low-contrast oil slicks to a minimum distance of 2 nmi, and to depict sufficient scene detail to identify streamers and separations within the slick at approximately one to one-and-a-half miles. Hot, high contrast targets such as Holly Platform were usually visible to the limit of the sensor's spatial resolution.

Operationally, these data demonstrate that within the environmental constraints experienced during this field test, all of the sensors tested were capable of locating an oil slick within a few miles of the sensor's location. The ability to delineate low-contrast oil slick boundaries that cover an area of several square nautical miles was also demonstrated.

2.2 DETECTION OF SMALL VARIATIONS IN OIL SLICK THERMAL CONTRAST

The oil slicks viewed in the previous section consist primarily of thin oil sheen with tarballs and small quantities of organic material entrained in localized regions. Even within these thin sheens, variations in thermal contrast were registered by the sensors when imaging at close range and steep depression angles. These variations were particularly evident in the oil slick surrounding the natural gas source (area 1). A daytime, visible-spectrum image of this oil slick is depicted in figure 2-8. The location where natural gas breaks the surface and an adjacent marker buoy appear left of image center (white).

Figure 2-9 is a FLIR 2000 image taken on 15 November in black=hot video polarity with a wide FOV from an altitude of 800 feet. This image depicts the northwestern edge of the area 1 oil slick. Clean water dominates the upper portion of the image and appears warmer (darker) than the lower portion, which consists primarily of thin oil sheen. Within the oil sheen, there are cooler (lighter gray) streamers. In the daytime images, this sheen area shows little variance in the silvery sheen and no emulsified oil was apparent. These cooler streamers appear to be oriented along a near-downwind path and most likely represent the main flow of oil seeping from the source.

Figure 2-10 provides a close-up of the oil within one of the streamers. The image, taken on 14 November, is in white=hot, wide FOV at a near-nadir depression angle. Thermal energy variations (due to thickness variations and/or weathering) in both the streamers and surrounding oil sheen are evident in the image. Similar close-up views of these streamers are provided in figures 2-11 and 2-12 for the Agema 1000 and LOCUSP, respectively. Neither figure 2-11 nor 2-12 depicts the thermal detail provided by the FLIR 2000; however, both demonstrated some ability to image small thermal differences within the larger slick area. No comparable IRC-160ST or IRRIS-256ST images were obtained during the data collection flights, so the close-up imaging capabilities of these sensors cannot be evaluated against the area 1 oil streamers.

Because these imagers display the contrast between adjacent surfaces, a surface that appears cool at one location can appear warm when compared to another feature in the scene. Figure 2-9 depicts an area a few hundred meters wide in which clean water in the upper portion of the image is distinguished from the oil sheen in the lower portion of the image. Oil streamers are visible within the oil sheen as whiter (cooler), almost linear features. Figures 2-10 through 2-12 provide close-up views of a single oil streamer a few meters wide. Although these images were obtained on the night before the image in figure 2-9 they depict similar streamer formation within a wider area oil sheen. Because there are no clean water regions within these narrow fields of view, it would be possible to mistake the oil sheen surrounding the streamers for clean water and potentially underestimate the areal extent of the oil slick. The clarity available in the FLIR 2000 close-up image (figure 2-10) also demonstrates that there are variations in thickness that can be depicted by this sensor even within the thinner sheen areas. This is the IR equivalent of a "rainbow sheen" in visual oil slick observations. It is also possible that the sheen is thin enough that it does not completely mask the thermal signature of the water, and warmer streaks or blotches could be separations in the sheen with clean water beneath.

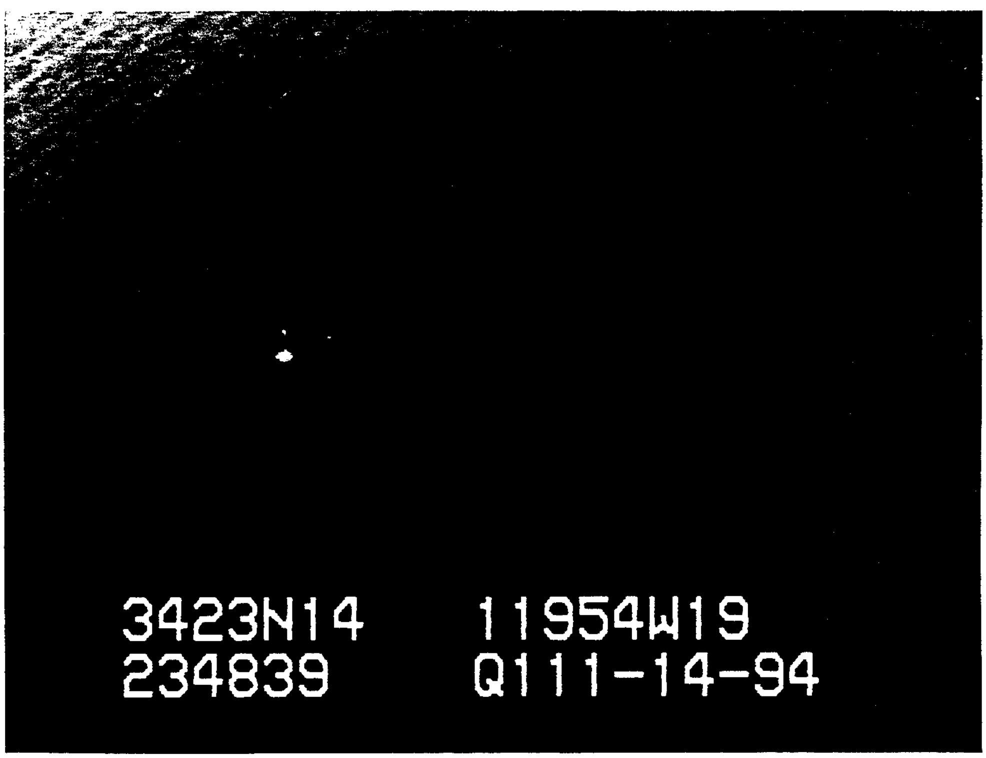

Figure 2-8. Visible Spectrum Image of the Natural Gas Bubbles, 15 November 1994

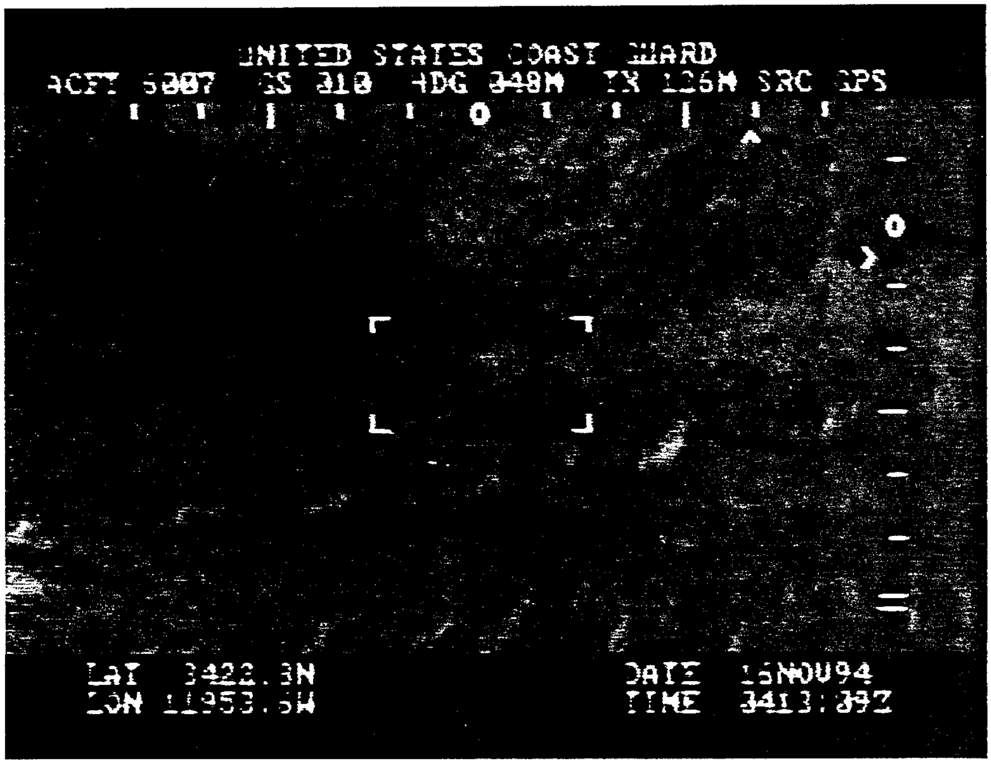

Figure 2-9. FLIR 2000 Image of the Natural Gas Bubbles, 15 November 1994
(Black = Hot, Wide Field of View)

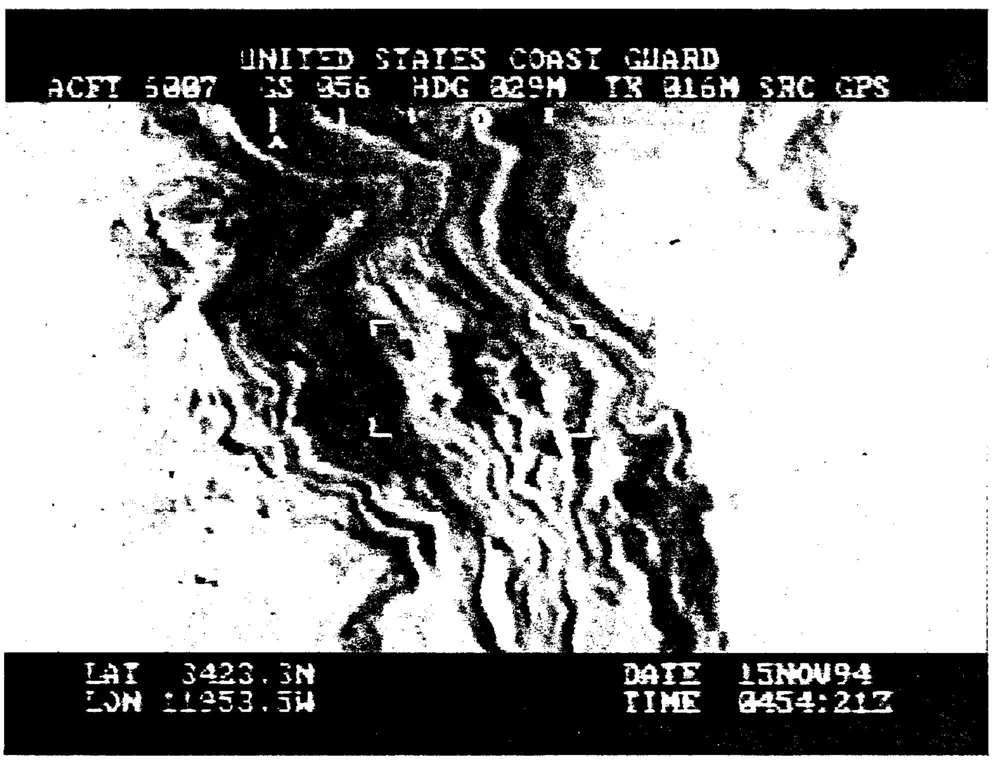

Figure 2-10. FLIR 2000 Close-up Image of an Oil Streamer, 14 November 1994
(White = Hot, Wide Field of View)

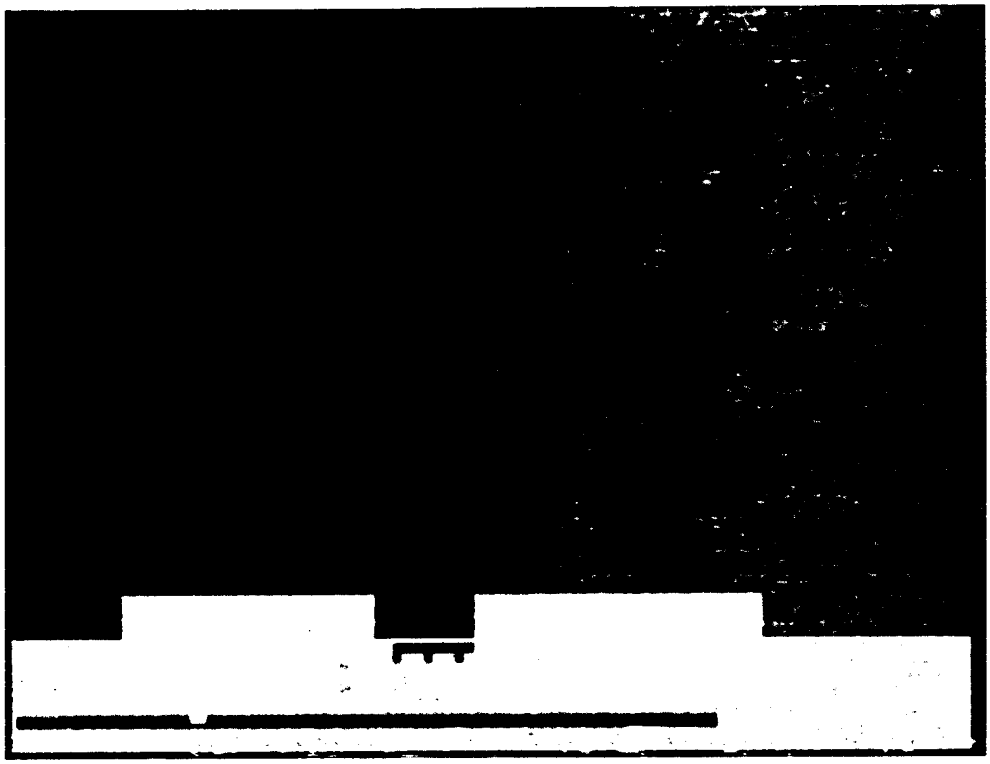

Figure 2-11. Agema 1000 Close-up Image of an Oil Streamer, 14 November 1994
(Black = Hot, Wide Field of View)

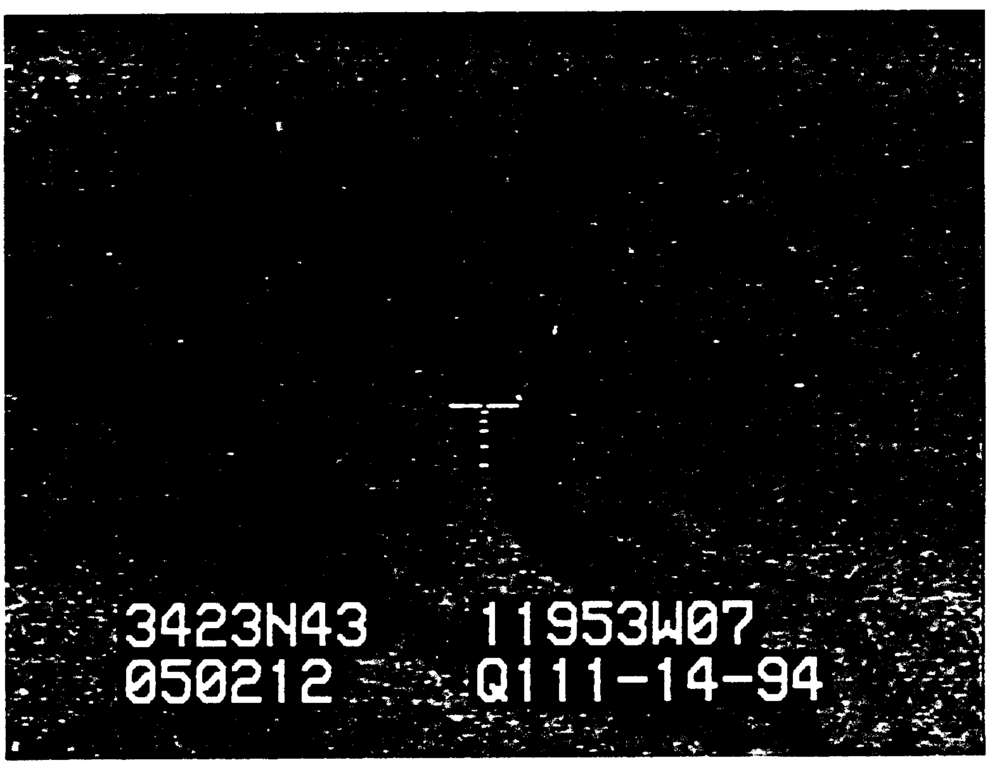

Figure 2-12. LOCUSP Close-up Image of an Oil Streamer, 14 November 1994
(White = Hot)

2.3 ERGONOMICS

Ergonomic considerations discussed in this section are based upon comments from the data logs, verbal comments captured on the audio portion of the S-VHS tapes, and post-experiment comments from the sensor operators and data recorders.

2.3.1 Video Presentation

Interpreting scene features when flying over the water where infrequent heat sources are present was made easier by those sensors that provided an on-screen video polarity indication.

FLIR 2000: The FLIR 2000 was capable of providing the best image presentation with the least effort from the sensor operator. The greatest difficulty with the FLIR 2000 is that at low airspeeds (below 50 knots), uncompensated helicopter vibrations result in significant image jitter that is especially bothersome with the narrow FOV. This induced sensor motion at low air speeds is a known problem with the HH-60J FLIR. During the experiment, sensor operators and helicopter pilots worked together to minimize the jitter problem while remaining at airspeeds low enough to provide sufficient time over the target to capture scene detail.

AGEMA 1000: The size, weight, and complexity of the Agema 1000 made it the most difficult of the hand-held sensors to operate. When an image was properly tuned and in focus however, scene detail was very good. Video tapes provided by Agema demonstrate that, when used in a typical installation (full resolution operator display and stabilized turret) this sensor is capable of providing significantly higher video resolution than demonstrated in this test. The dual FOV optics and on-screen tuning status indications were both deemed useful features by those who operated this sensor.

LOCUSP: The LOCUSP exhibited significant motion-induced blurring in much of its captured video. This motion appeared to be the result of two factors: first, its light weight permitted the operator to scan and maneuver the sensor quickly within the scene resulting in blurring; second, helicopter vibrations were readily transmitted through the sensor operator when he was attempting to focus on a particular scene area. It was much easier to maintain focus on distant targets because the scene is much less dynamic. The additional weight from some form of stabilization, such as a portable camera gyro, would most likely be offset by improvements in image quality. The operator felt that a slightly wider FOV would improve the utility of this sensor for imaging close-in targets. Analysis of the recorded video data supports this opinion.

IRC-160ST and IRRIS-256ST: The IRC-160ST and IRRIS-256ST both provided clear images. Although the contrast bar obscured a portion of the image and reduced its usable size, it provides very useful data concerning video polarity and tuning status. Although the effect may be a result of tuning, the IRC-160ST appears to provide a softer or fuzzier image than the IRRIS-256ST. Of the four hand-held sensors tested, the operator was most familiar with the layout of these cameras, and this familiarity contributed to the fact that clear images were most easily maintained with these sensors. With sufficient operator training and experience, more consistent image quality may have been obtainable with the Agema and LOCUSP sensors.

2.3.2 Sensor Controls

FLIR 2000: The FLIR 2000 is controlled by a hand-held system controller. This permits the operator to move and perform other tasks without losing control of the system. The controller pistol grip design leaves all control buttons at the operator's fingertips and during this field test no negative comments were made concerning the operation this system.

AGEMA 1000: As noted in the previous section, the Agema 1000 was difficult to work with in its laptop configuration. The size, weight, system complexity (see figure 1-2) and closely nested button layout on the hand controller unit, coupled with the operator's unfamiliarity with the sensor package, resulted in significant difficulties tuning and focusing this sensor while strapped into the dark, exposed helicopter door seat. The wide range of controls available to the operator, while providing a variety of sophisticated imaging options, was too complex for hand-held airborne operation. Specific comments about this sensor's controls included the need for back lighting on the controller for use at night , that the digital tuning control response was too slow when imaging a rapidly changing scene, and that the auto-adjust tuning button should be better labeled.

While providing more flexibility, the range of controls also had the potential to create problems for the operators. One such incident was the inadvertent change in video synchronization that occurred on 17 November.

Potentially useful features include the ability to select temperature ranges outside of which contrast is ignored, and the ability to save a series of task-related settings. For example, an operator might be able to select a range of temperatures around local water temperature to create finer contrast within that range and save it for MEP cases. After changing the setup and using the sensor for a law enforcement patrol, significant re-tuning time might be saved by retrieving the saved MEP setup.

LOCUSP: The LOCUSP was originally designed for use as a mounted weapon sight, and was adapted to the pistol grip for this field test. It provided the simplest controls; however, in the quickly changing helicopter environment, their layout on the sensor housing hindered operator response to scene changes. Moving the focus from the top front of the sensor and co-locating brightness and contrast on the same side of the housing, with a hand strap, would allow the operator to hold and aim the sensor with one hand while tuning and focusing with the other. At night, the operator preferred to use the sensor with the rubber eye-piece removed.

IRC-160ST: The hand strap and brightness/contrast rocker switches on the IRC-160ST provided the most usable control layout of any of the hand-held sensors. It permitted the operator to tune and follow the changing scene with one hand while holding the sensor stable and focusing with the other. It was recommended that the video polarity switch be moved from the back of the camera to nearer the front. A standby mode would improve battery life during transit periods.

IRRIS-256ST: Although provided by the same manufacturer as the IRC-160ST, the IRRIS-256ST tuning controls are small buttons instead of rocker switches, and are located on the opposite (left) side of the sensor. For these reasons, the operator thought it was more difficult to control than the IRC-160ST. The automatic brightness control was useful for viewing distant scenes but roamed when interfering heat sources passed between the sensor and the target scene. The operator also noted that the plastic sensor casing did not seem sturdy. He thought a metal case like that of the IRC-160ST would withstand the rigors of field use better.

CHAPTER 3
PARAMETERS AFFECTING IMAGE INTERPRETATION

Chapter 2 presented images to demonstrate that all of the sensors tested can detect and display oil slicks at night under favorable conditions. This chapter discusses some factors that limit the sensors' capability to detect the oil or affect the way the information within the image can be interpreted. Unless specifically noted, all of the sensors evaluated were capable of depicting the scene features discussed; however, only images necessary to the discussion will be presented here.

Section 3.1 introduces the topic of false positives (features that appear to be petroleum oil slicks but are not) and their possible origins. Section 3.2 discusses the physical appearance of oil slicks and how they can affect image interpretation. Section 3.3 discusses how high atmospheric moisture conditions can degrade a scene's thermal signal at the sensor. Section 3.4 uses the natural gas and oil seep of area 1 to demonstrate how it is necessary to understand the content of the scene before making conclusions about the thermal information that is viewed.

3.1 FALSE ALARMS AND THEIR ORIGINS

Although these sensors can image oil slicks under favorable environmental conditions, it must be understood that they do this by detecting a thermal contrast between two adjacent surfaces. At night, when few visual cues may be present, this fact becomes increasingly important since biogenic oils (concentrated fish or plant oils), upwellings, effluent plumes, and other phenomena can be presented as thermal contrast in an infrared view. When interpreting an infrared scene, knowledge of the local area and on-scene environmental conditions must be used to decipher scene detail. In figure 3-1, obtained on 17 November with the FLIR 2000 in narrow FOV and white=hot video polarity, there are two distinct oil slicks. The oil slick centered in the view is caused by a petroleum oil seep, while the oil slick closer to shore (top of the image) appears to be caused by biogenic oil released from the large kelp beds that grow in this area of the coastline. Local area knowledge helps prevent mistaking the two slicks. All of the sensors evaluated during this test were capable of detecting both the biogenic and petroleum oils.

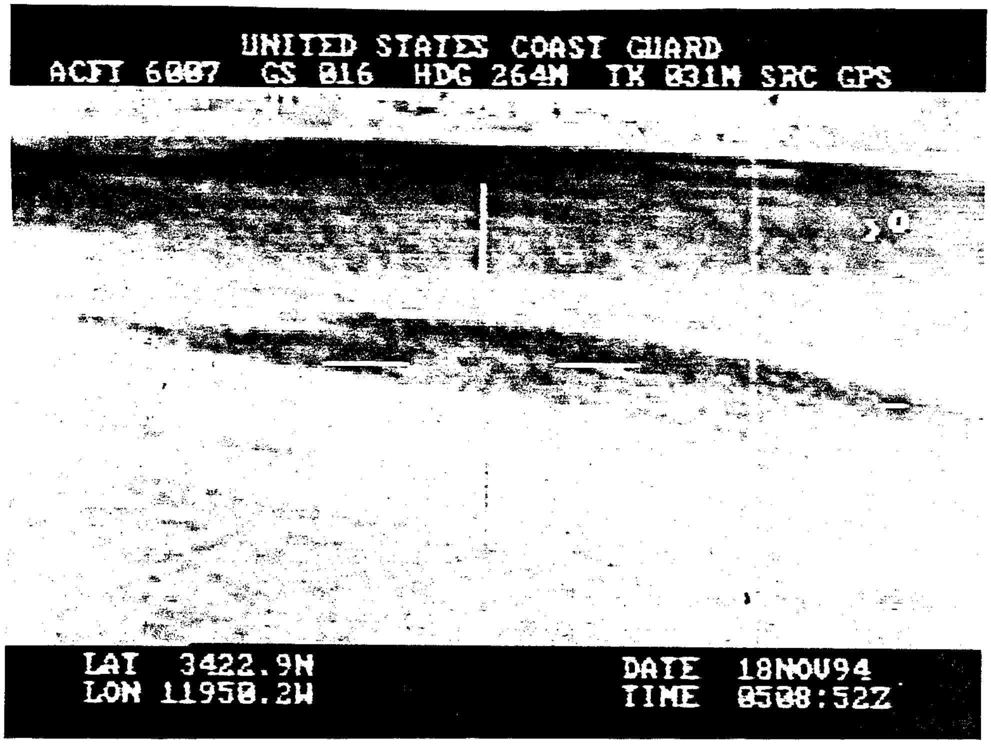

Figure 3-1. FLIR 2000 Image of Kelp and Petroleum Oil
(White = Hot, Narrow Field of View)

3.2 PHYSICAL APPEARANCE OF OIL SLICKS

The appearance of an oil slick can vary depending on the view angle relative to wind or surface current direction and range to the sensor from the target. As illustrated in section 2.2, viewing a slick at close range results in a shorter path length for the thermal radiation and provides good separation of linear features as well as depicting the more subtle thickness variations. When viewing an oil slick at longer ranges, the view angle relative to the wind or surface current direction becomes more important. Figure 3-2 provides an image obtained on 17 November with the FLIR 2000 in wide FOV and white=hot video polarity from an altitude of 800 feet. In this crosswind view, the oil slick is depicted as a cool (dark) area in the image center. Figure 3-3 provides a FLIR 2000 image (same FOV, polarity and night) of the slick looking into the wind. In this image, streamers are visible and the body of the oil slick has much more definition than presented in figure 3-2. This aspect dependance of scene detail is not unique to IR sensors, but an awareness of these effects is more critical to scene interpretation when operating in a disorientating nighttime environment.

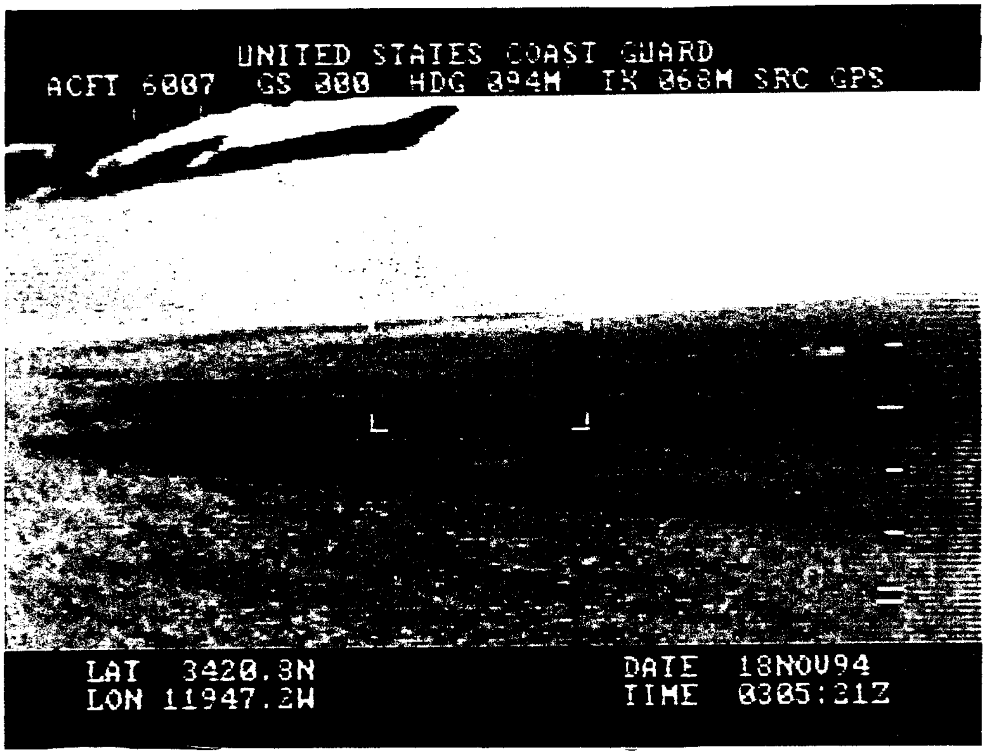

Figure 3-2. FLIR 2000 Image of Wind Rows Looking Crosswind (White = Hot, Wide Field of View)

Figure 3-3. FLIR 2000 Image of Wind Rows Looking Upwind (White = Hot, Wide Field of View)

3.3 HIGH ATMOSPHERIC MOISTURE LEVELS

Atmospheric moisture can have a detrimental effect on the ability of an IR sensor to detect thermal contrast within a scene. The effects are generally more significant within the LWIR bandwidth than within the MWIR bandwidth (reference 4); however, their ultimate impact on mission performance depends on other factors such as target versus background contrast and range to the sensor. For the short path lengths that can be expected while imaging oil slicks at night (altitudes below 1000 feet and fairly steep depression angles), the problem of atmospheric moisture other than fog or precipitation should be minimized. In the conditions experienced during the November field test (maximum humidity = 88%), only the LOCUSP demonstrated a marked degradation in image quality when imaging outside of rain or low clouds. None of the sensors tested demonstrated a significant ability to detect an oil/water contrast through light rain or low-level clouds. Even images of stronger heat sources, such as the R/V CALIFORNIA RESPONDER, were degraded when viewed through clouds or rain.

Figures 3-4 through 3-6 provide images obtained from an altitude of 800 feet in the presence of low clouds on the night of 15 November. The R/V CALIFORNIA RESPONDER (hot spot near image center in each figure) is within the large area 3 oil slick east of Holly Platform. Figure 3-4 was obtained with the FLIR 2000 in black=hot video polarity and narrow FOV, figure 3-5 was obtained with the LOCUSP in white=hot video polarity, and figure 3-6 was obtained with the IRRIS-256ST in black=hot video polarity. The cooler streaks and regions in each image are oil streamers and sheen. The LOCUSP image was obtained approximately ten minutes prior to the other two images and, although the relative humidity had risen to the highest experienced during this test period, the low clouds were not yet within the scene. In the LOCUSP image, the bow of the R/V CALIFORNIA RESPONDER is pointing toward the right-hand side of the page. The engine exhaust stacks are the hot (white) spot near the stern of the vessel. During this pass around the eastern edge of the slick, the FLIR 2000 image remained clear and little, if any, degradation in image quality due to humidity was observed. The grey streaks within the image show that the LOCUSP was able to detect oil/water contrast, but that clarity was significantly degraded. The FLIR 2000 and IRRIS-256ST images are nearly time coincident (there was approximately a 40-second difference in clocks) and both show the low clouds that were moving through the area at that time. The bow of the R/V CALIFORNIA RESPONDER is pointing toward the left-hand side of the page. The vessel is beneath the low passing clouds, but the helicopter itself was operating clear of the clouds. In both the FLIR 2000 and IRRIS-256ST images, oil/water contrast is detectable outside the low cloud formations. A similar degradation of image quality was observed later that night while the helicopter was flying in moderate, scattered rain showers over the kelp beds close to Coal Oil Point. The ability to detect objects within the field of view was severely degraded when the target scene was within an area affected by the rain showers. None of the sensors used were able to detect contrast on the water surface during these showers, and even high contrast targets such as the shore and boats could only be described as hazy contrast changes that could not be used to describe scene detail.

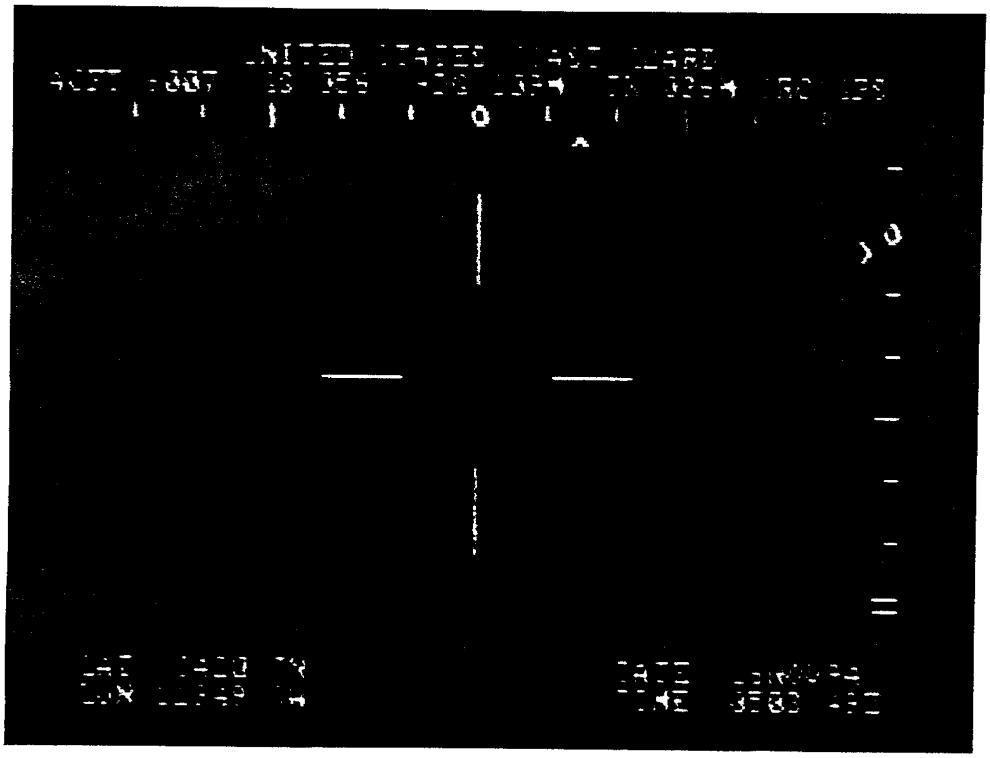

Figure 3-4. FLIR 2000 Image in High Atmospheric Moisture Conditions
(Black = Hot, Narrow Field of View)

Figure 3-5. LOCUSP Image in High Atmospheric Moisture Conditions
(White = Hot)

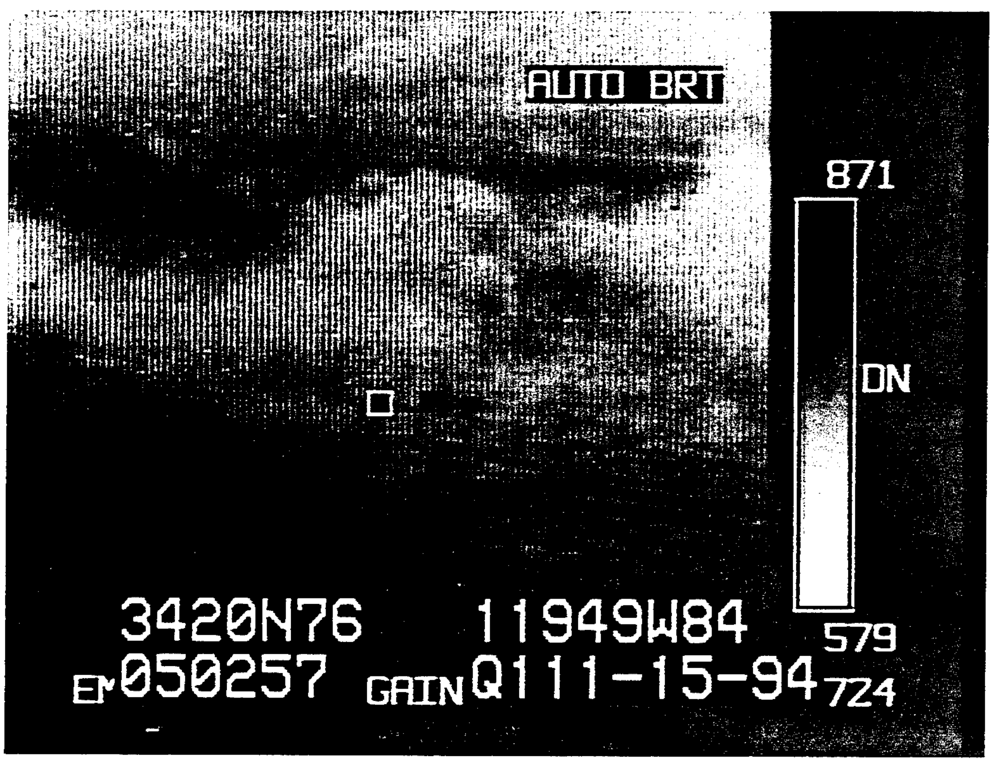

Figure 3-6. IRRIS-256ST Image in High Atmospheric Moisture Conditions
(Black = Hot)

3.4 NATURAL GAS BUBBLE WITH OIL SEEP

As stated earlier, the natural gas and oil seep in area 1 does not necessarily represent a scene that would typically be expected during oil spill response operations; however, this location has several thermal features that are useful to examine. The first thermal characteristic is shown in figures 3-7 and 3-8. Both images were obtained with the FLIR 2000 in wide FOV and white=hot video polarity from an altitude of 800 feet. In figure 3-7, obtained on 14 November, the location where natural gas breaks the surface appears warmer than the surrounding oil slick area. The oil streamers appear radiometrically cooler (progressively darker) in the image as they drift further from the source. Weathering effects more evident in the thicker streamers are perhaps the cause of this cooler appearance. In figure 3-8, obtained on 15 November, the natural gas source appears cooler than the surrounding oil slick area. Visually, the natural gas and petroleum oil source looked similar on both days.

These differences in the IR appearance of area 1 are most likely due to differences in environmental conditions between the two nights. On 14 November, the winds were calm and petroleum oil reaching the surface pooled in the vicinity of the surface source. The natural gas reaching the surface disrupted the radiometrically cool oil slick, exposing warmer subsurface water. The winds on 15 November were stronger and spread the oil more quickly. The remaining oil sheen was likely too thin to fully mask the subsurface water and this warmer thermal signature dominates the scene. The radiometrically cool appearance of the natural gas/oil source was caused by petroleum oil blooming at the surface.

Figure 3-9 provides a series of images that were obtained with the FLIR 2000 on 17 November from an altitude of 800 feet. The images were obtained in black=hot video polarity and narrow FOV as the helicopter conducted a pass close to the natural gas bubbles. This night, a stiff wind prevented petroleum oil from pooling around the seep source. The image series depicts a pocket of petroleum oil reaching the surface as a cooler (white) spot and spreading on the surface downwind of the source. During the day, this phenomenon was masked by the visual appearance of the silvery sheen that covered area 1. This series of images illustrates that differences between thermal and visual scenes require some effort to interpret. The thermal image may not always display features that are observed visually, but can display other features, such as relative thickness, that were not as observable in the visible spectrum.

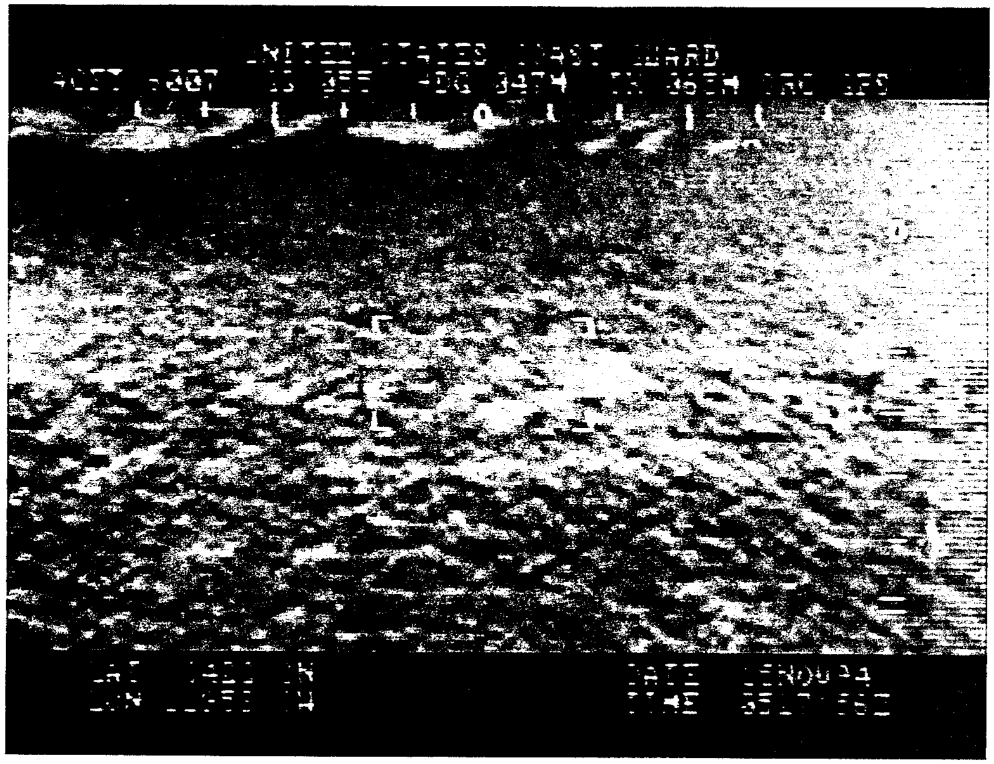

Figure 3-7. FLIR 2000 Image the Natural Gas Seep, 14 November 1994
(White = Hot, Wide Field of View)

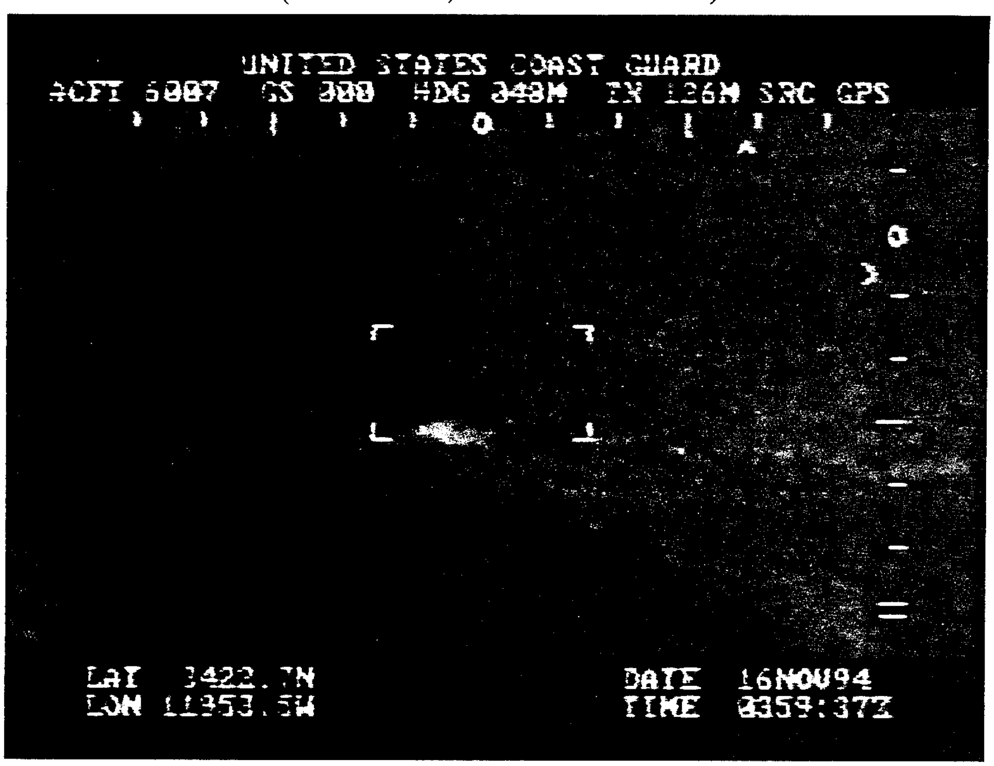

Figure 3-8. FLIR 2000 Image the Natural Gas Seep, 15 November 1994
(Black = Hot, Wide Field of View)

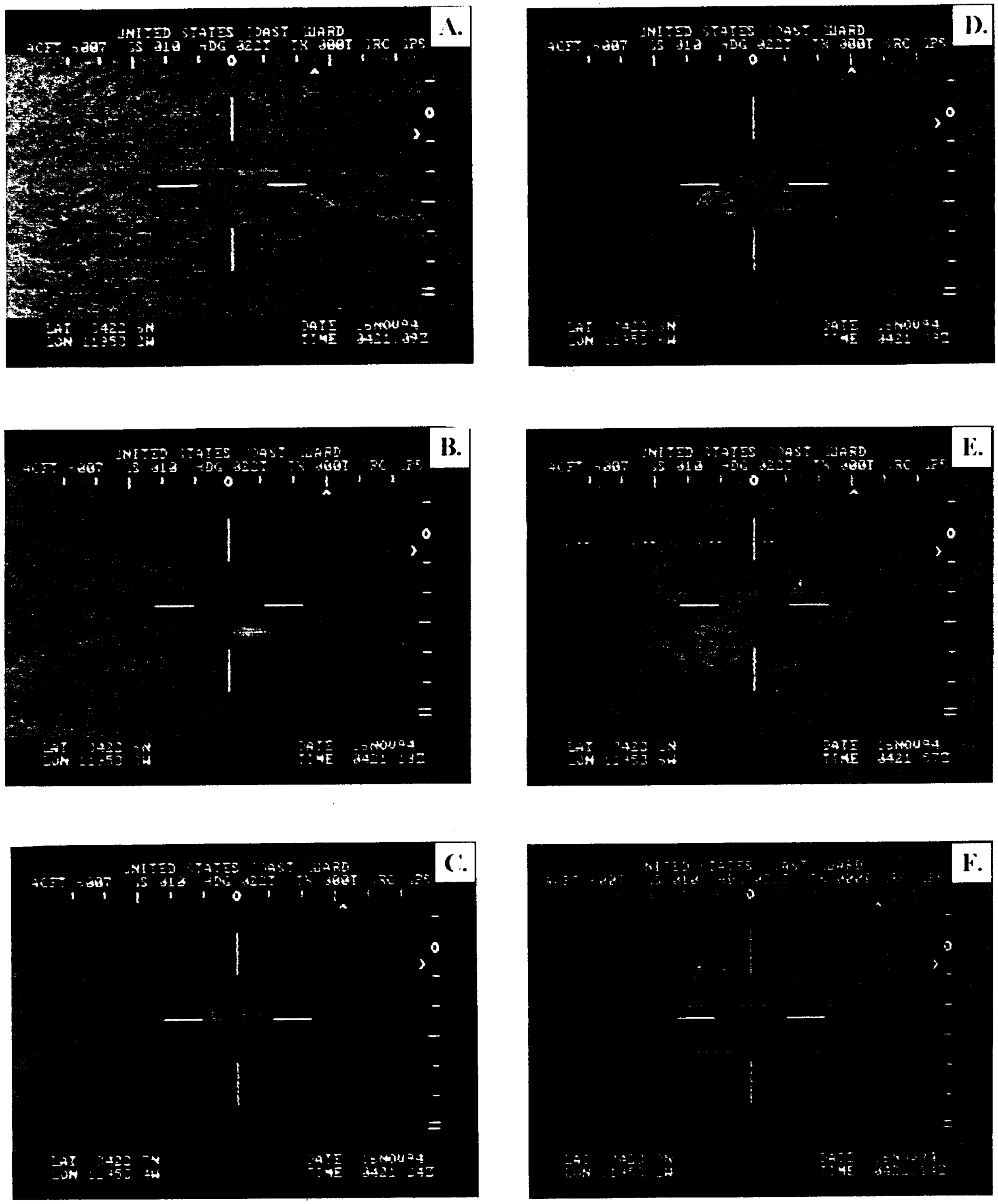

Figure 3-9. FLIR 2000 Image Series of Petroleum Oil Reaching the Surface
(Black = Hot, Narrow Field of View)

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CHAPTER 4
CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

All of the sensors evaluated during the field test were able to depict oil/water contrast within several miles of the sensor position. The image quality achieved with the hand-held IR sensors was less consistent than that achieved with the installed FLIR 2000 system. Although the amount and type of oil, orientation and distance of the slick feature relative to sensor position, and the prevailing environmental conditions can all exert significant influence on the quality of the oil slick images, ultimately, imaging performance depended on the target versus background contrast and the path length from the target to the sensor.

While all of the sensors evaluated demonstrated the ability to detect oil slicks at night, the following constraints apply:

- The LOCUSP sensor appeared to be most susceptible to the adverse effects of camera motion, high humidity, low clouds and precipitation. Nonetheless, based on projected mass production costs this compact sensor offers potential as a simple, low-cost oil spill surveillance tool for use at night in clear weather.

- The two MWIR sensors appeared to provide sufficient nighttime oil imaging capability and ease of use to support Coast Guard oil spill surveillance operations, even in high humidity and light precipitation. This conclusion must be qualified with the caution that some oil types may present very low thermal contrast in the MWIR band (reference 6). This limitation was not encountered during the Santa Barbara field test.

- The auto-brightness control available on the IRRIS-256ST provided a significant improvement in the operability of the camera in all but high atmospheric moisture conditions.

- The Agema 1000 provided very good image detail, expanded functionality (e.g., dual fields of view), and sufficient ease of use to warrant investigation for use as a gimbal-mounted sensor, especially in weight-critical applications such as on the USCG HH-65A helicopters. The sensor's bulk and complexity of cabling are not conducive to hand-held operation at this time. Portable gimbal mounting for use on selected aircraft-of-opportunity types may warrant consideration where multi-mission applications that require a high-resolution field of view are contemplated.

Although IR sensors can image oil slicks under favorable environmental conditions, it must be understood that they do so by detecting a thermal contrast between two adjacent surfaces. At times, local knowledge of the region where the oil is present will be necessary to discriminate oil slicks from other phenomena within the thermal scene. For instance, thermal contrast caused by vessel wakes, river outflows, or biogenic oils can present a confused IR scene.

Imaging a potential oil slick from more than one look direction helps resolve spatial details that can assist the responder in reducing false alarms and in determining slick movement due to wind and surface currents. Imaging a slick at close range can provide greyscale information in the IR image that can assist with identifying areas of relatively thick oil. These tactics may facilitate more effective clean-up equipment deployment during night spill response operations.

Atmospheric moisture had a detrimental effect on the ability of the IR sensors to depict spatial and thermal details within a scene. All of the sensors tested exhibited decreased imaging performance against the low-contrast oil slicks due to rain showers and low clouds experienced during one night of the field test. Only targets with high thermal contrast (i.e., vessel exhaust stacks) were visible through low clouds and in rain showers steep look-down angle were required to maintain even marginal oil/water contrast levels.

Image interpretation was made easier by sensors that provided an on-screen video polarity indication. This was particularly true when flying over open water in the absence of easily-identified heat sources such as vessels or shoreline. Both the white = hot and the black = hot video polarity provided similar contrast, clear image detail, and equivalent resolution.

On-screen mission data overlays including date/time, position, altitude, and aircraft heading added substantial value to the IR image data. During post-experiment data analysis, this information made it easier to interpret the image detail and provided a sense of scale for oil slick features.

In the open door of an airborne helicopter, sensors with the simplest controls were the easiest to aim and tune. Operator familiarity with the sensor controls directly impacted the effectiveness with which a sensor could be used. A means of controlling unwanted camera motion and vibration would substantially improve image quality.

4.2 RECOMMENDATIONS

4.2.1 Infrared Sensor Operation

1. Oil slicks should be viewed with IR imagers from several look-angles and ranges in order to obtain a complete tactical picture in support of oil spill response operations. Slick limits and orientation can be imaged at altitudes up to 1000 feet and up to a few kilometers from the imaging platform, and should incorporate information from several look-angles. Relative thickness and concentrations of oil within slick regions are best estimated at altitudes of 500 feet or less, and at steep depression-angles, imaging within a few hundred meters of the aircraft.

2. Portable gyrostabilizers on vibration isolation mounts may significantly improve image quality by reducing motion-induced smearing. These devices are commercially-available and should be investigated for use with light-weight hand-held IR sensors in the airborne environment.

3. When viewing an infrared image, knowledge of the local area and on-scene environmental conditions must be used to interpret scene details. Biogenic oils (concentrated fish or plant oils), upwellings, effluent plumes, and other phenomena can present slick-like thermal contrast in an infrared view. When possible, following a slick from an established datum (e.g. a known oil source) is the best method of determining slick extent and movement.

4. Daytime use of infrared sensors should be investigated as a complement to visual and video methods for airborne surveillance of areas with intense shipping or petroleum-related activity. This could enhance the capability to locate vessels and fixed facilities that are illegally dumping or pumping waste and provide the opportunity to more effectively focus CG response units.

4.2.2 Procurement and Integration of Infrared Technology

1. The Coast Guard should consider providing portable IR imagers and mission-specific training to many or all of its marine environmental response units. The IR imagers should be incorporated into routine operations of these response units, particularly at night. Mechanisms for documenting lessons learned and incorporating them into future sensor procurements and training programs should be established.

2. As mass production drives down the cost of uncooled, portable LWIR imagers, they should be

considered for use by smaller Coast Guard pollution response units that do not require the sophisticated capabilities of the cooled MWIR imagers evaluated during this test.

3. Training should be conducted to educate Coast Guard users in the principles of IR imaging. The training should relate these principals to mission-specific tactics for employing IR sensors in the marine environment. These tactics should be illustrated with actual videotape of IR oil slick image data obtained in a variety of marine environments.

4. A low-cost , simple means of mission data annotation should be identified and incorporated with portable IR sensors.

5. Recommended specifications for hand-held IR sensors suited to the Coast Guard's oil spill detection and monitoring missions have been provided to the project sponsor under separate cover.

6. As part of any sizable purchase of portable infrared imagers, the Coast Guard should require both independent laboratory performance tests to ensure advertised specifications are met and field demonstrations to ensure operability requirements are met.

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APPENDIX A

USCG AIRCRAFT REPAIR SUPPLY CENTER ELIZABETH CITY, NC
ENGINEERING SPECIFICATION H60710100.01

19 OCTOBER 1994

U.S. COAST GUARD
AIRCRAFT REPAIR SUPPLY CENTER
ELIZABETH CITY, NC 27909

ARSCES
60710100

ARSC ENGINEERING SPECIFICATION H60710100.01 OCT 19 1994

Subj: TEMPORARY INSTALLATION OF R&D CENTER PORTABLE DIFFERENTIAL GPS DATA LOGGER AND REPORTING SYSTEM

1. PURPOSE

This specification provides instructions for temporary installation of USCG Research & Development Center's (R&DC) portable Differential GPS Data Logging/Reporting System.

2. CANCELLATION

Not Applicable.

3. DOCUMENTS AFFECTED

Aircraft maintenance records should indicate installation and removal of this system, and inoperability of LF/ADF while installed.

4. APPLICATION

Applies only to HH-60J helicopters designated for support of R&D Center sweepwidth experiments. CGAS maintenance personnel will perform installation.

5. GENERAL INFORMATION

R&DC periodically conducts experiments utilizing various aircraft. Precise and accurate position information is required to be recorded and transmitted to a ground base station. R&DC developed a portable system for this function consisting of a GPS receiver, differential beacon receiver, VHF data link transceiver, and a notebook personal computer. The portable unit requires connection to GPS and beacon signal sources, a VHF antenna, and 28VDC power. This specification provides for the requirements of the R&DC portable system without permanent alteration of the aircraft. Existing aircraft systems are minimally affected and configuration and removal times are reasonable. Performance and effect of the R&DC portable system installed IAW this specification has been evaluated by ARSC.

The existing GPS and LF/ADF beacon antennas on the H60 will be utilized to provide signals to the portable equipment. A splitter will be connected to the aircraft GPS antenna providing adequate signal strength for both the existing H60 GPS (ARN-151) and the portable unit to function properly. The H60 LF/ADF receiver will be disabled for the duration of the flights supporting the R&DC experiment and the portable Differential Beacon Receiver will be connected to the LF/ADF antenna. These connections will be made in the helicopter's transition area and coaxial cables will be routed over the fuel tank into the cabin.

A bent whip VHF antenna for the portable datalink transceiver will be mounted on a replaceable access panel on the lower fuselage. The coaxial cable will be routed up aft of the CSC and into the cabin.

Primary power for the portable unit will be 28VDC via the cabin utility receptacle.

6. ACTION REQUIRED

The installation procedures are divided up into three sections (a.–c.) to allow for installation of all or any part to support the particular mission at hand.

a. Installation of GPS Antenna connection.

(1) Install the GPS Splitter/Amplifier bracket between the aircraft GPS antenna amplifier and it's mount by removing the four mounting screws, inserting the temporary bracket, and reinstalling the screws. Insure the bracket is properly oriented; splitter and amplifier are to the rear of the bracket.

(2) Disconnect the antenna cable from the aircraft GPS amplifier (center cable) and connect to the adapter cable connected to the input of the splitter. Remember the outer part (nut portion) of the aircraft GPS antenna connection is part of the amplifier and not on the antenna cable.

(3) Connect the adapter cable from the output of the splitter to the aircraft GPS amplifier input.

(4) Install end of coax cable marked GPS AMPLIFIER to the amplifier output on the newly installed bracket.

(5) Route coax along toward right side of aircraft, behind ECU intake duct, and forward toward cabin over the fuel tank and entering cabin in vicinity of night sun control connector bracket. Follow existing wire bundles in all routing.

(6) If Differential Beacon connection is required then proceed to section (b.) before securing cable. Otherwise secure coax cable with ty-wraps insuring cable does not interfere with flight controls or will be subjected to undue stress during temporary installation.

b. Installation of Differential Beacon connection.

(1) Remove main connector from front of LF/ADF receiver and install provided adapter cable to both the receiver and the disconnected aircraft cable. Secure connectors using long (or chain connected) ty-wraps around the receiver.

(2) Remove the antenna cable from the LF/ADF receiver and connect the antenna cable to end of coax cable marked BEACON ANTENNA CABLE. Route cable up and join routing of GPS cable installed in section (a.) above all the way into the cabin.

(3) Secure both coax cables with ty-wraps insuring cables do not interfere with flight controls or will be subjected to undue stress during temporary installation.

(4) In cabin route both cables to vicinity of the 28VDC utility receptacle under the left cabin window. Secure cable runs to prevent an egress hazard.

c. Data Link Antenna installation.

NOTE:

If aircraft has a VHF/FM DES antenna installed, this antenna maybe used for the datalink. Disconnect antenna cable from ARC-513 DES radio and connect provided datalink cable to the antenna cable using a barrel connector then proceed with step 5. Otherwise, if DES antenna not installed, perform all of the following steps.

(1) Remove small access panel on bottom of aircraft under the cockpit near FS 240 (in center of star) and retain the screws.

(2) From inside cabin, route end of coax cable marked DATA LINK ANTENNA through the cage aft of the CSC and down to the access hole opened in step (1.) above.

(3) Connect the end of the coax routed to the access hole to the provided data link antenna and install the antenna and bracket in place of the of the removed access panel.

(4) Secure coax cable with ty–wraps insuring cable does not interfere with flight controls or will be subjected to undue stress during temporary installation.

(5) Route coax cable in cabin to below the left cabin window.

d. Connection of Portable GPS Data Logger.

(1) This equipment is all contained in a portable case (suitcase style) that will be brought aboard by the R&D Center observer. The case will be placed on the cabin floor under the left side window. Connections will be made to each of the antenna cables installed in above sections and to the 28VDC receptacle under the left cabin window.

e. Deinstallation.

(1) Deinstallation is performed by reverse of installation. Take care when removing ty–wraps as not to damage aircraft wiring.

7. SUPPLY DATA

All parts for this installation will be provided in an approved kit either by R&D Center or ARSC.

8. MAN–HOURS REQUIRED

Two (2) man–hours required for installation.

One (1) man–hour required for deinstallation.

9. EFFECT ON WEIGHT AND BALANCE

The total weight of all items installed on the aircraft (bracket, cables, antenna) is less than five pounds and has negligible effect on aircraft weight and balance.

The portable GPS Data Logger that will be carried aboard for the R&DC experiments weighs 36 lbs.

M.A. Newsel
For E. J. MOUKAWSHER
By Direction

Parts List for R&DC Differential GPS Data Logger

Part #	Item	Qty	Source
PE-3664-12	Cable Assy	02	1
PE-2011	Power Divider	01	1
PE-8210	DC Block	01	1
PE-9076	Adapter; SMA/M-TNC/M	01	1
PE-9099	Adapter; TNC/F-F	01	1
PA-6817C	GPS Amplifier	01	2
DMC 63-3/A	Antenna, datalink	01	3
	#20 aircraft wire	6ft	4
	RG-142 coaxial cable	70ft	4
	50 pin sub D connector	01	4
	50 socket sub D connector	01	4
	TNC male 90deg coax connector	03	4
	UHF male (PL-259) coax connector	01	4
	BNC female jack	01	4
	BNC male plug	01	4
	Ty-wraps (12inch)	1bag	4
	Screw,washer, nut for GPS bracket	04	4
	Bracket, GPS Splitter-Amp	01	5

Sources:

1. Pasternack Enterprises 714-261-1920
   PO Box 16759
   Irvine, CA 92713

2. Leica 310-719-6165
   23820 Hawthorne Blvd. Suite 200
   Torrance, CA 90505

3. Dorne & Margolin 516-585-4000
   2950 Veterans Memorial Hwy
   Bohemia, NY 11716

4. From ARSC local stock.
   Available from various sources.

5. Fabricated at ARSC.

APPENDIX B

ENVIRONMENTAL DATA SHEETS

ENVIRONMENTAL CONDITIONS SUMMARY

Date: 11-14-94   Weather Description: ***Clear***, Haze, Fog, Rain, (include extent)

Moon Phase: N/A, 1/4, 1/2, *3/4*, 1.0

GPS DATA					SEA STATE			WIND		TEMPERATURES		
PAC Time (hh:mm)	Latitude (dd:mm.m)	Longitude (ddd:mm.m)	Visibility (nm)	Visible Moon	H_s* (ft.)	Whitecaps (N,S,M)	Swell Dir (°M)	Speed (kts)	Direction (°M)	Dry Bulb (°C)	Water (°C)	Rel. Hm. (%)
4.15 PM	N34° 22.0	W 119° 53.4	15	Yes 3/4	0	N	320	9.5	303	11.4	17.7	43
4:45 PM	N34° 21.9	W 119° 53.3	15	Yes 3/4	0	N	320	9.7	315	11.5	17.7	43
5:15 PM	N34° 23.6	W 119° 54.3	15	Yes 3/4	0	N	290	8.2	300	11.5	17.8	43
5:45 PM	N34° 23.1	W119° 55.8	15	Yes 3/4	0	N	290	6.4	346	11.9	17.8	43
8:30 PM	N34° 23.0	W119° 53.6	15	Yes 3/4	0	N	0	0	0	11.4	17.8	71
9:00 PM	N34° 22.9	W119° 53.5	15	Yes 3/4	0	N	0	4.7	0	11.2	17.8	71
9:30 PM	N34° 22.9	W119° 53.5	15	Yes 3/4	0	N	0	4.7	0	11.2	17.8	79
10:00 PM	N34° 22.9	W119° 53.5	15	Yes 3/4	0	N	0	3.8	0	11.4	17.7	79
10:30 PM	N34° 23.9	W119° 54.3	15	Yes 3/4	0	N	0	0	0	11.6	17.7	79

* Significant wave height.

8:30 Samples taken from RIB tied along side the R/V CALIFORNIA RESPONDER
10:45 END TEST

OBSERVER: Jeff Howe

ENVIRONMENTAL CONDITIONS SUMMARY

Date: 11-15-94 Weather Description: Clear, ***Haze, Fog, Rain,*** (include extent)

Moon Phase: *N/A*, 1/4, 1/2, 3/4, 1.0

GPS DATA					SEA STATE			WIND		TEMPERATURES		
PAC Time (hh:mm)	Latitude (dd:mm.m)	Longitude (ddd:mm.m)	Visibility (nm)	Visible Moon	H_S* (ft.)	Whitecaps (N,S,M)	Swell Dir (°M)	Speed (kts)	Direction (°M)	Dry Bulb (°C)	Water (°C)	Rel. Hm. (%)
15:15 PM	N34° 24.1	W 119° 53.8	12	No	1-2	S	260	13.7	270	7.8	17.5	60
15:15 PM	N34° 23.5	W 119° 54.2	12	No	1-2	S	260	9.3	271	8.0	17.5	60
16:15 PM	N34° 22.1	W 119° 50.8	12	No	1-2	S	260	16.0	271	8.0	17.5	60
16:45 PM	N34° 23.9	W119° 53.2	12	No	1-2	S	260	10.2	290	8.6	17.5	64
20:00 PM	N34° 23.6	W119° 55.9	12	No	1-2	S	260	16.2	289	10.5	17.5	77
20:30 PM	N34° 22.9	W119° 53.4	12	No	1-2	S	260	20.3	283	9.0	17.5	77
21:00 PM	N34° 22.1	W119° 51.3	10	No	1-2	S	260	20.8	302	9.0	17.4	88
21:30 PM	N34° 21.7	W119° 51.2	8	No	1-2	S	260	11.5	296	9.0	17.4	86
22:00 PM	N34° 17.5	W119° 43.6	12	No	1-2	N	260	12.9	283	9.2	17.3	86

* Significant wave height.

1620 MRSC Aircraft on Station.
Scattered showers in low level cloud and general haze.

OBSERVER: Jeff Howe

ENVIRONMENTAL CONDITIONS SUMMARY

Date: 11-17-94 Weather Description: ***Clear***, Haze, Fog, Rain, (include extent)

Moon Phase: N/A, 1/4, 1/2, 3/4, ***1.0***

GPS DATA					SEA STATE			WIND		TEMPERATURES		
PAC Time (hh:mm)	Latitude (dd:mm.m)	Longitude (ddd:mm.m)	Visibility (nm)	Visible Moon	H_s* (ft.)	Whitecaps (N,S,M)	Swell Dir (°M)	Speed (kts)	Direction (°M)	Dry Bulb (°C)	Water (°C)	Rel. Hm. (%)
15:00 PM	N34° 22.6	W 119° 49.6	15	–	6	M	260	25.1	300	5.5	16.3	43
15:30 PM	N34° 21.9	W 119° 50.5	15	–	6	M	260	26	291	6.8	16.4	43
19:00 PM	N34° 22.1	W 119° 51.4	15	Yes Full	4	S	260	20.3	290	6.7	16.8	69
19:30 PM	N34° 21.6	W119° 50.6	15	Yes Full	4	S	260	20.2	293	6.7	16.8	69
19:57 PM	N34° 21.1	W119° 50.3	15	Yes Full	4	S	260	19.3	302	8.0	16.8	69
20:02 PM	N34° 21.8	W119° 49.9	15	Yes Full	4	S	260	16.6	285	8.0	16.8	69
20:30 PM	N34° 21.7	W119° 50.7	15	Yes Full	4	S	260	16.0	285	8.0	16.8	69
21:00 PM	N34° 21.7	W119° 48.1	15	Yes Full	4	S	260	17.7	285	7.8	16.7	69
21:30 PM	N34° 21.4	W119° 48.9	15	Yes Full	4	S	260	22.0	295	7.8	16.7	69

* Significant wave height.

19:47 PM began moving 1 NM to the North.
20:02 PM on new position can see the oil sheen.
Closed Helo ops 21:42.

OBSERVER: Jeff Howe