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# Enhanced Oil Spill Detection Sensors in Low-Light Environments

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APPROVED FOR PUBLIC RELEASE

# Enhanced Oil Spill Detection Sensors in Low-Light Environments

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# Enhanced Oil Spill Detection Sensors in Low-Light Environments

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## Oil Spill Response Research (OSRR) Program

| | |
|---|---|
| **Project Number** | 1013 |
| **Date of Summary** | January 6, 2015 |
| **Subject** | Enhanced Oil Spill Detection Sensors in Low-light Environments |
| **Performing Activity** | US Army Research Development and Engineering Command (RDECOM) |
| **Principal Investigator** | Lenard Ramboyong |
| **Contracting Agency** | Bureau of Safety and Environmental Enforcement |
| **Estimated Completion** | June 30, 2016 |
| **Description** | The goal of this collaborative effort is to enhance the methods currently in place to detect oil in a marine environment. The methods currently in place are not conducive to oil spill recovery operations during periods of low light and rely heavily on time-delayed aerial remote sensing technologies, or visual observation. This project will leverage the knowledge and expertise of RDECOM's Night Vision and Electronic Sensors Directorate (NVESD) personnel to assist BSEE in the identification and documentation of existing capability gaps; identification and assessment of technology gaps; test and evaluate potential new or alternative hardware; and if necessary, support the design, development and demonstration of new technologies to meet identified needs. |
| **Progress** | Imaging experiments were conducted at Ohmsett during November 2014 using Hydrocal and Alaskan North Slope crude oil. Airborne data collection field work was conducted on the Santa Barbara seeps during December 2014. |

**Joint program between the U.S. Departments of the Interior and Defense to bring knowledge, expertise and military low-light level and hyperspectral imaging technologies to remote oil spill detection.**

# Short Wave Infrared Imaging

- Until recently, the SWIR waveband has been an untapped region of the electromagnetic spectrum for high resolution, passive imaging due to the lack of low light level imagers in this region.
- Over the past 15 years the U.S. military has made an investment in the development of Indium Gallium Arsenide (InGaAs) array based sensors.

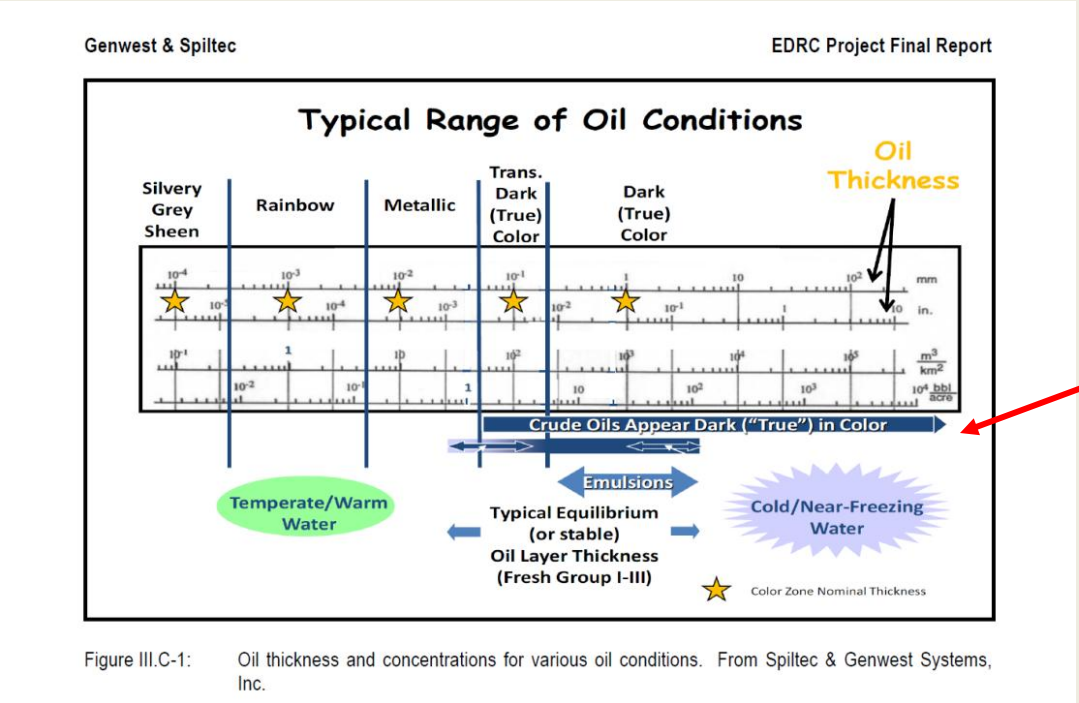
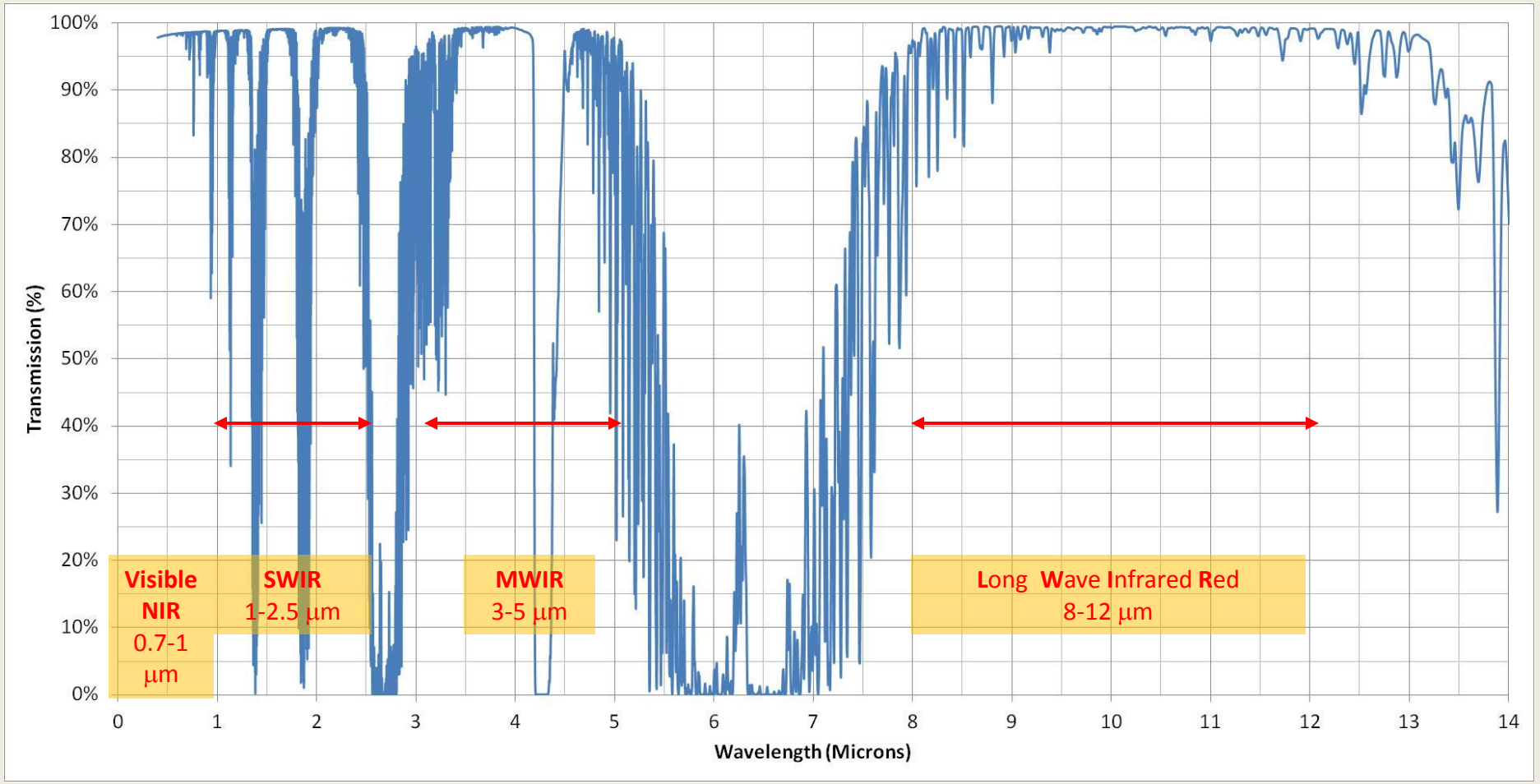



Figure III.C-1: Oil thickness and concentrations for various oil conditions. From Spiltec & Genwest Systems, Inc.

**Areas of Emphasis**

Taken from: EDRC Project Final Report, December 7, 2012, by Alan A. Allen, Dean H. Dale, Jerry A. Galt, and John A. Murphy, Genwest System and Spiltec, Edmonds, WA.

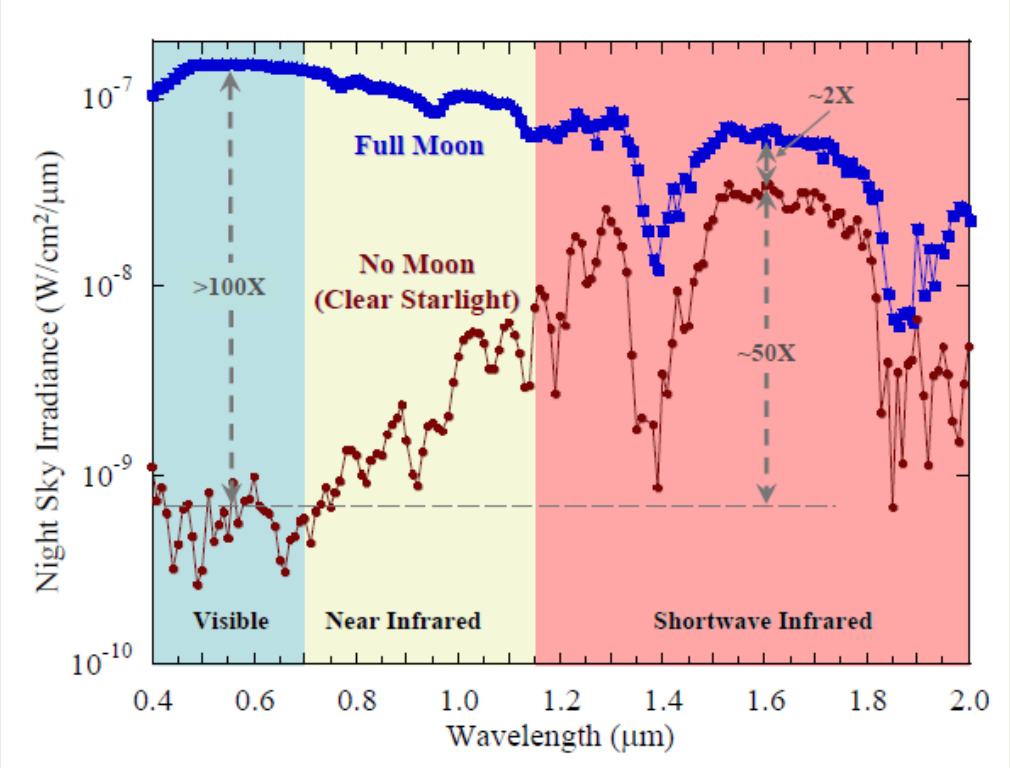
# SWIR (1-2.5 µm region)




Reflective Region | Thermal Region

**Attenuation attributed to $CO_2$ and $H_2O$ molecules**

# Night Sky Irradiance



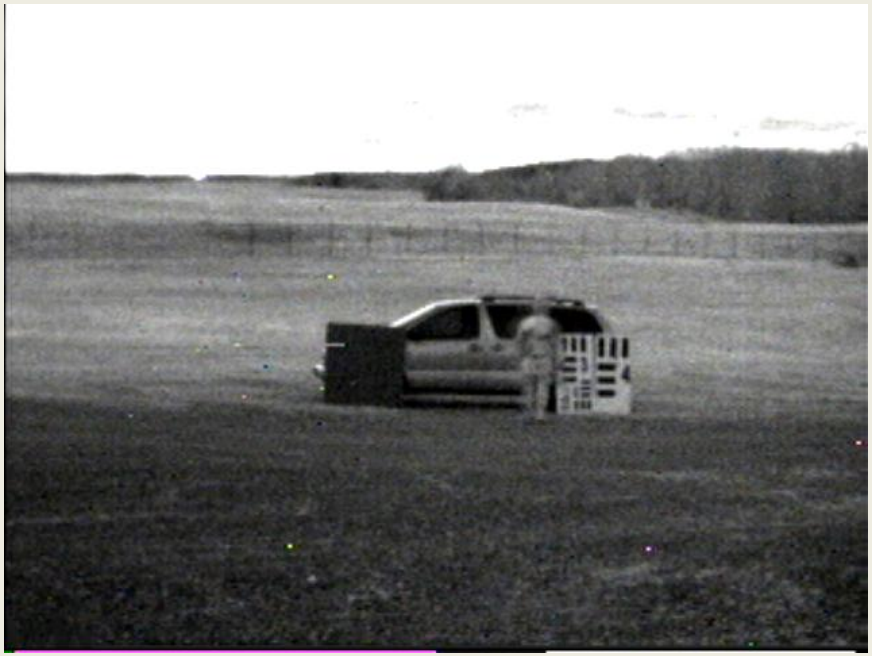

Research has shown high levels of SWIR radiation from the night sky in the form of night glow.

It is widely accepted that the available SWIR radiation is greater than radiant NIR energy when there is no moon.

Nightglow is comprised mostly of hydroxyl ion ($OH^-$) emissions due to vibrational/rotational transitions originating at altitude ranges of 70-110 km, contributing significantly to the night sky NIR/SWIR irradiance.

## Image Intensified (I2)CCD and SWIR Cameras (No Moon - Starlight)

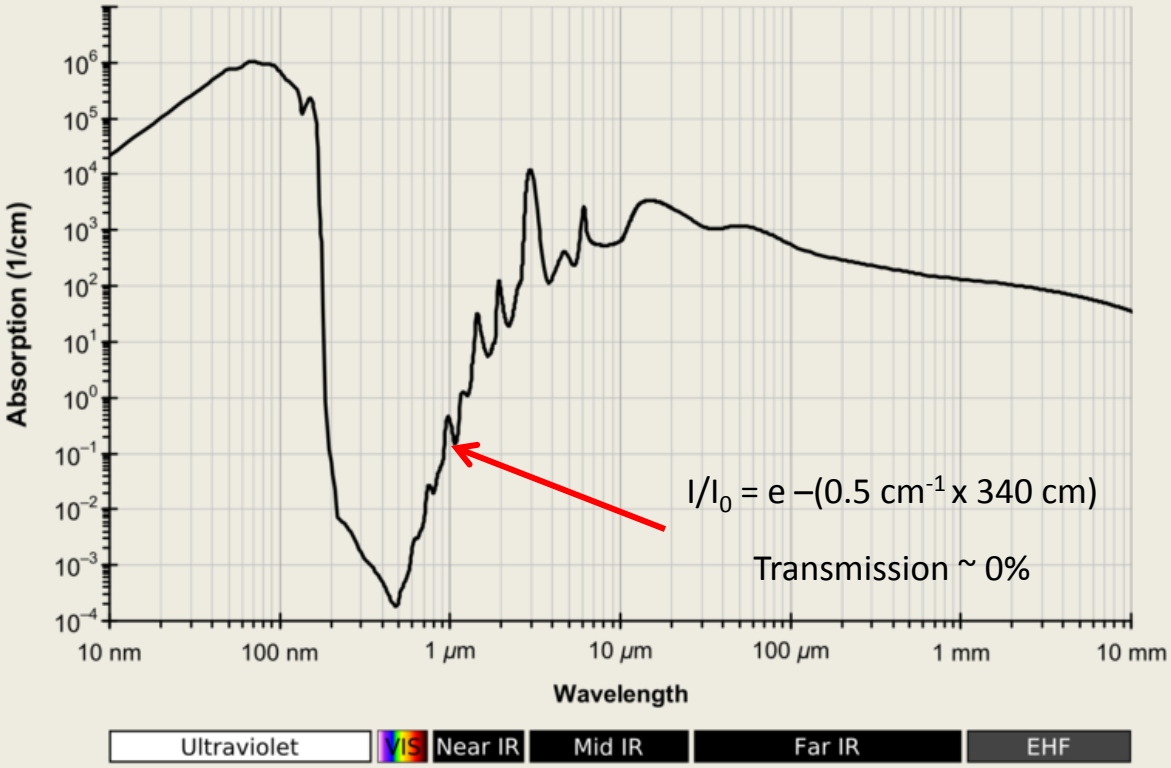
I2CCD Camera

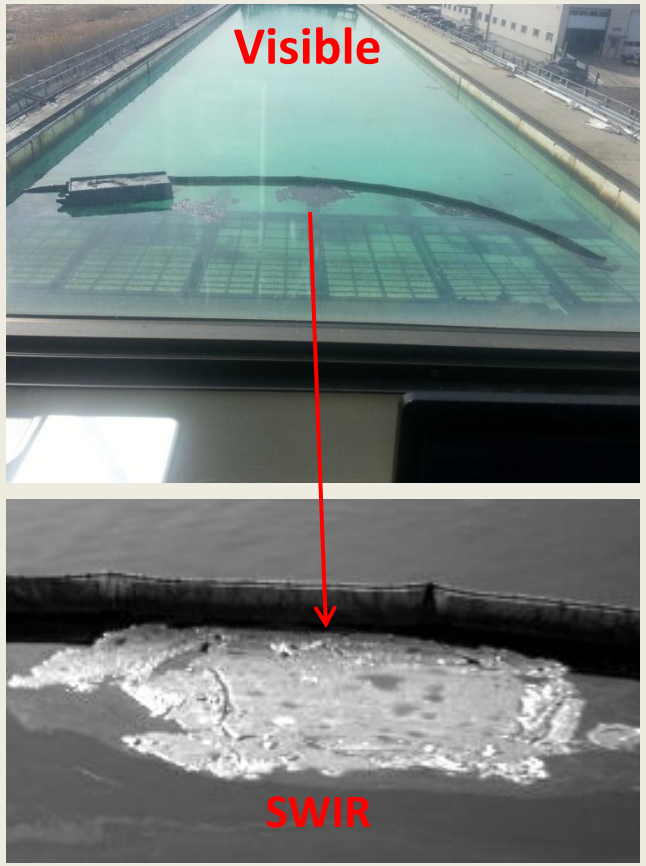


SWIR Camera

# Attenuation of Water

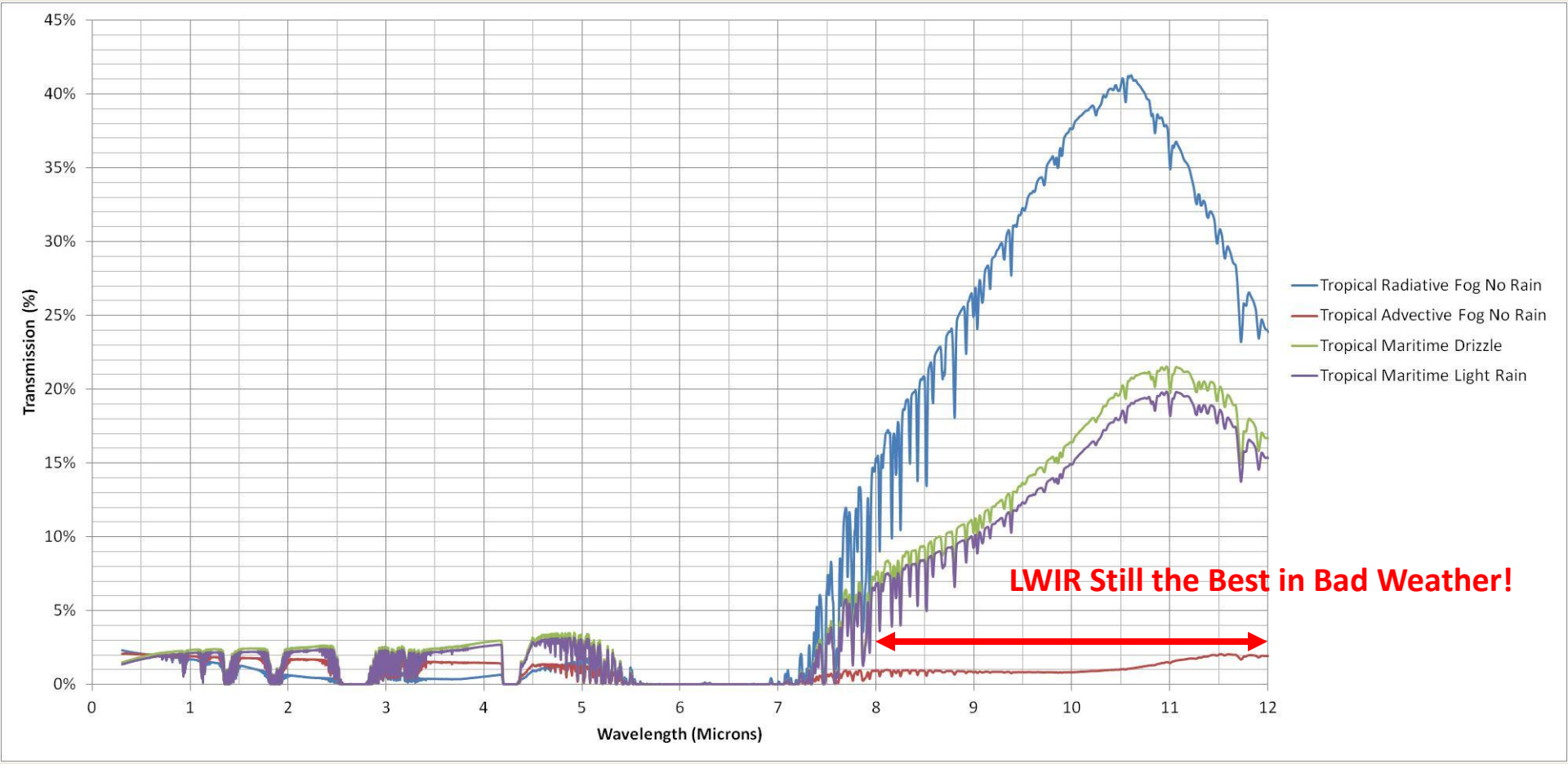
## Ohmsett NJ, Weathered ANS




Surface effects are seen in the IR spectrum

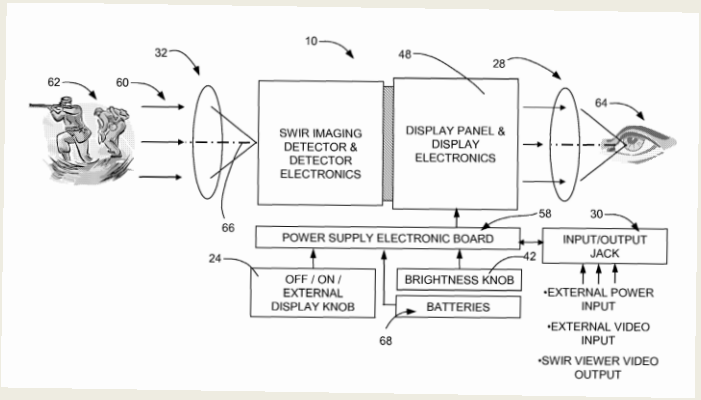
# 100 m Visibility and Range




**Rain and Fog Attenuates Transmission in the Visible, NIR, SWIR and MWIR.**

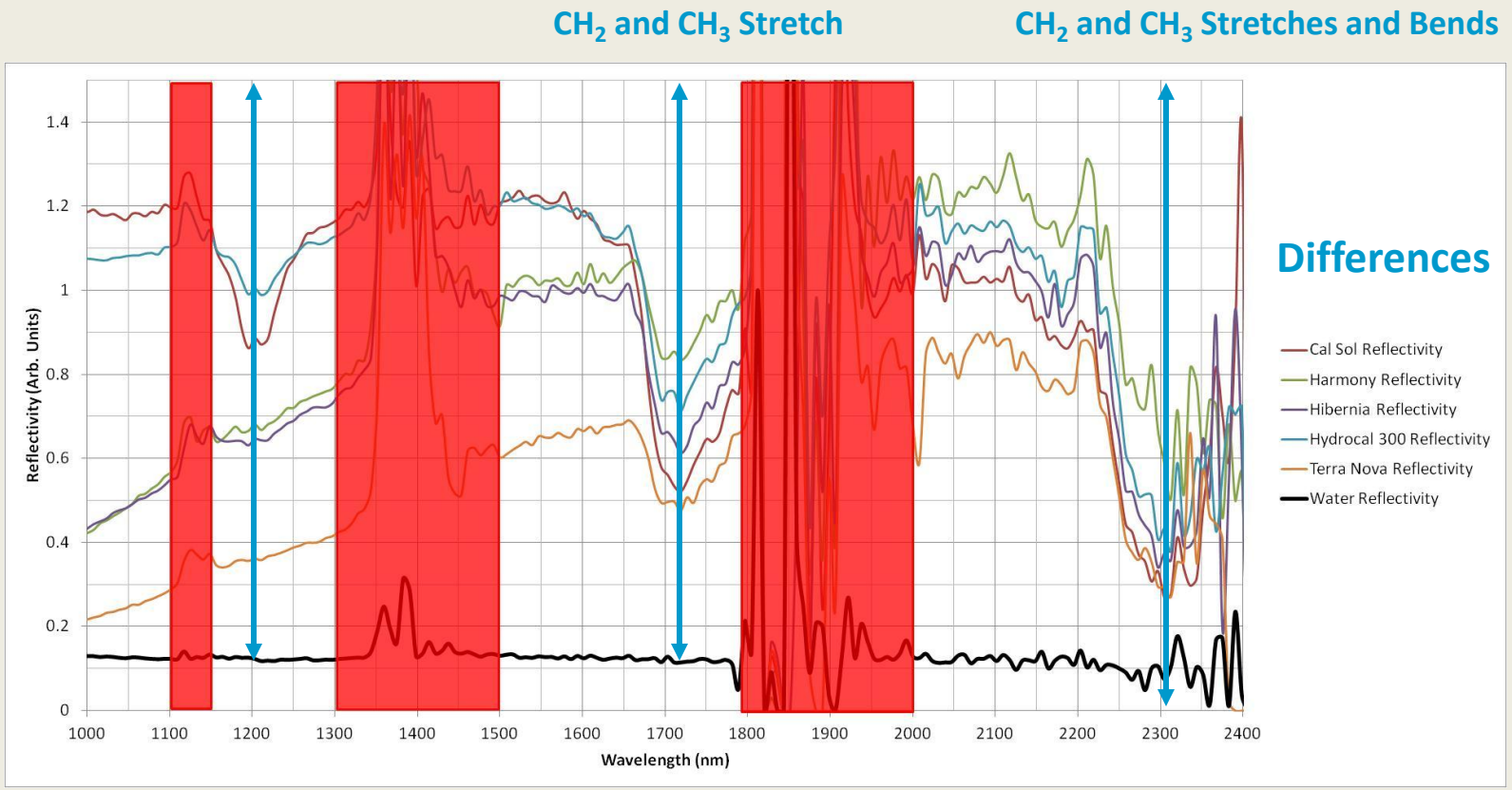
# Direct-View SWIR Viewers

- A night vision device includes an objective lens assembly, an image detector assembly, an eyepiece lens assembly and a housing.
- The objective lens assembly receives low intensity light. The image detector assembly converts the low intensity light into a visible output image.
- The eyepiece lens assembly provides for viewing the output image from the image detector assembly.




SWIR Monoculars with Various SWIR optimized lenses and telescopes.

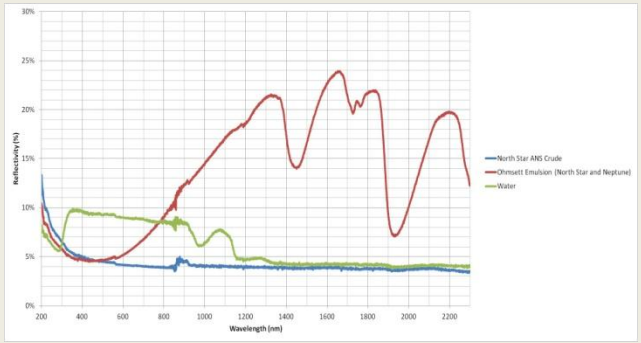
# Oils/Emulsions have Contrast against Water in the SWIR




Spectral analysis of the hyperspectral data. The three red bands are wavelength regions where the atmospheric transmission is too opaque for analysis.

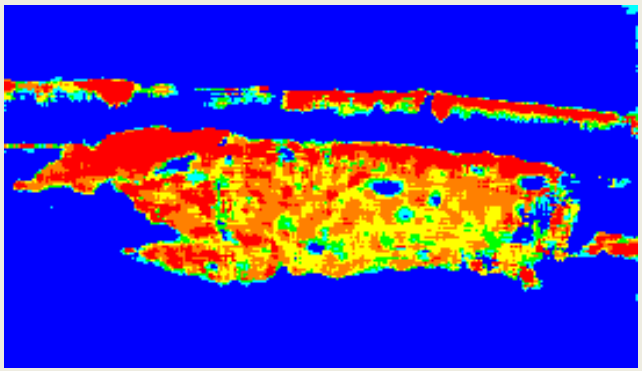
# Ohmsett Field Testing

**Visible Image**




**Crude & Emulsion Spectra**

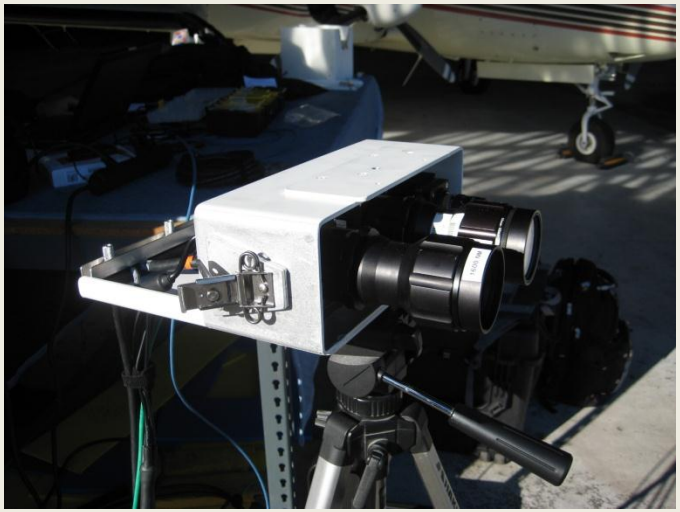
**1200 nm SWIR Image**

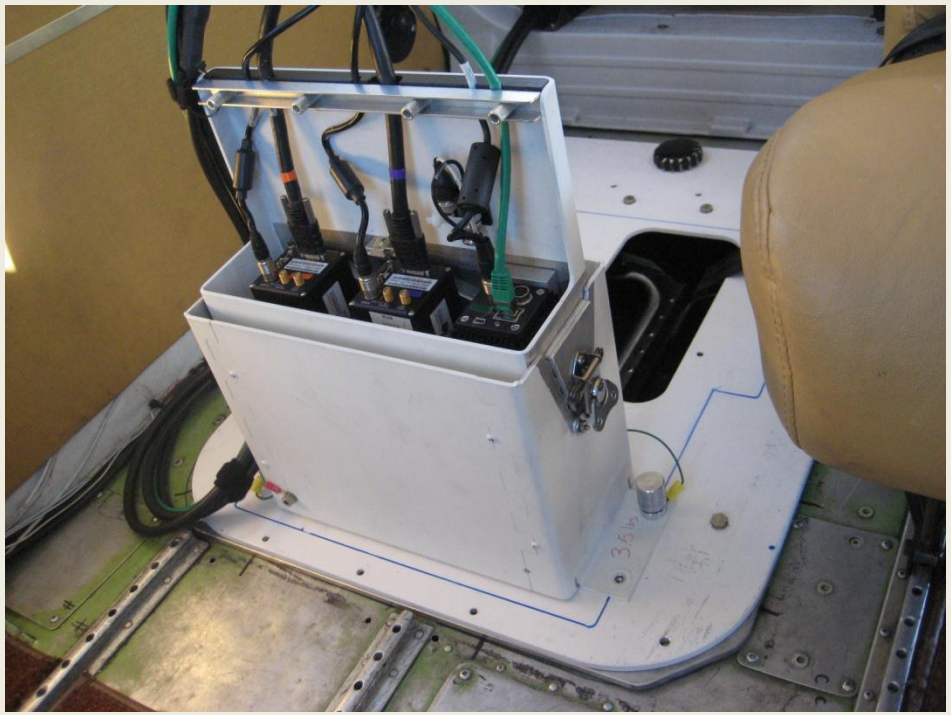


**1200 nm/1250 nm ratio**

Testing was performed at Ohmsett facilities in March 2014. Weathered emulsions were viewed from a second story office (through glass window).

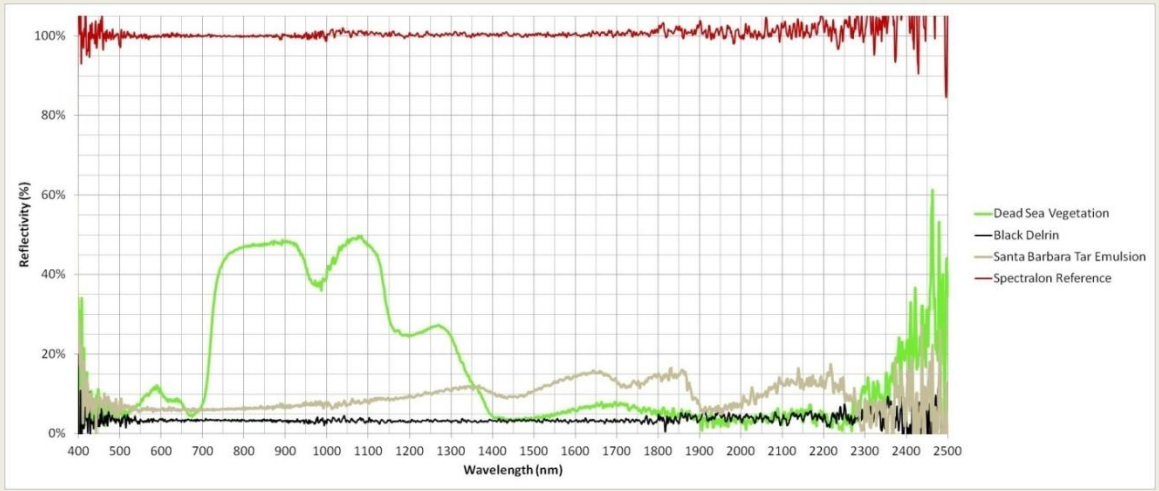
# Santa Barbara Data Collection

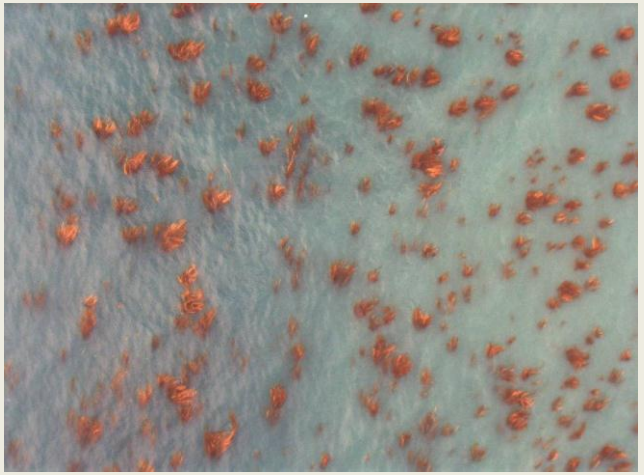




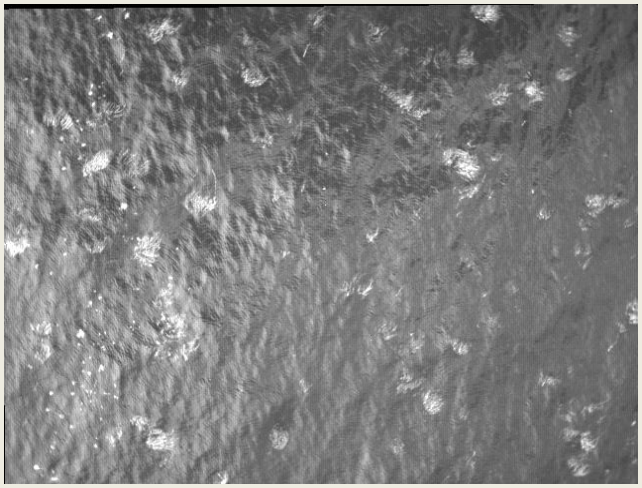
Testing Performed With Ocean Imaging Corp.
December 2014

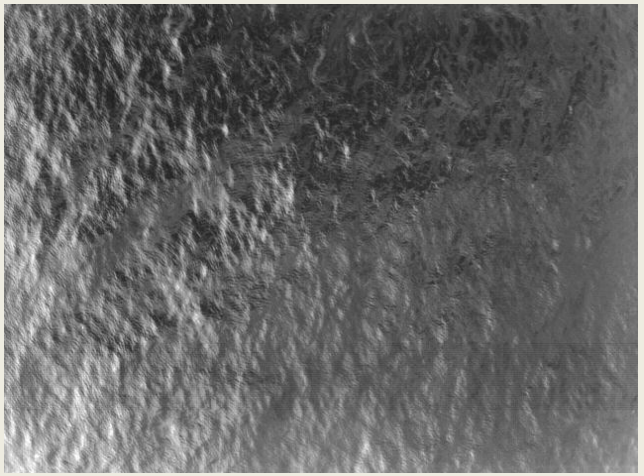
# Vegetation Clutter



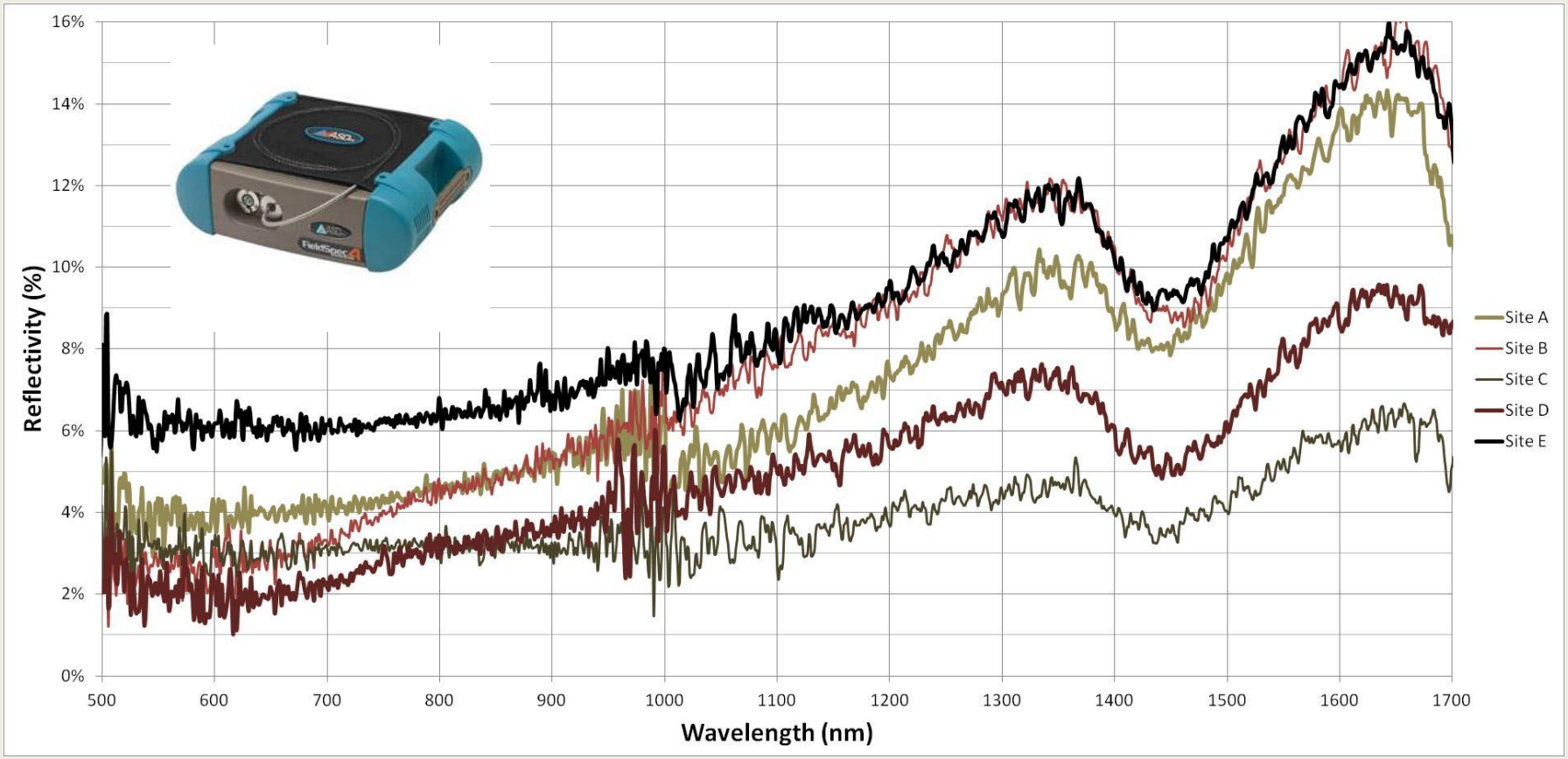
**SWIR Images 975 nm (left) and 1600 nm (right).**





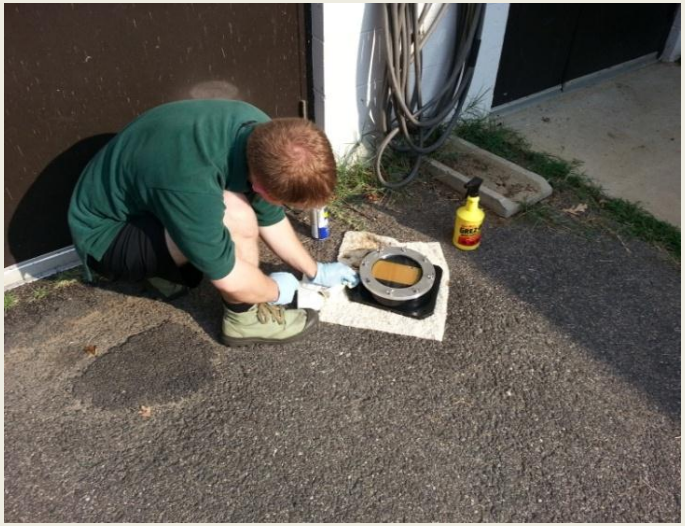
**Vegetation has comparable reflectivity to water at 1600 nm.**

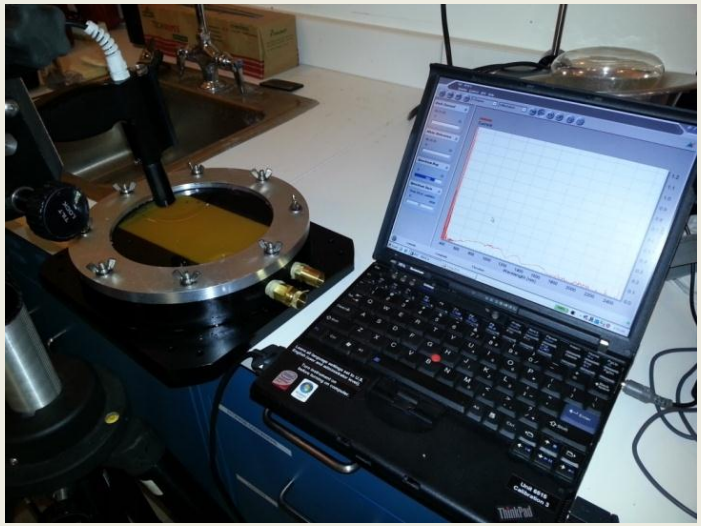
# Santa Barbara Tar

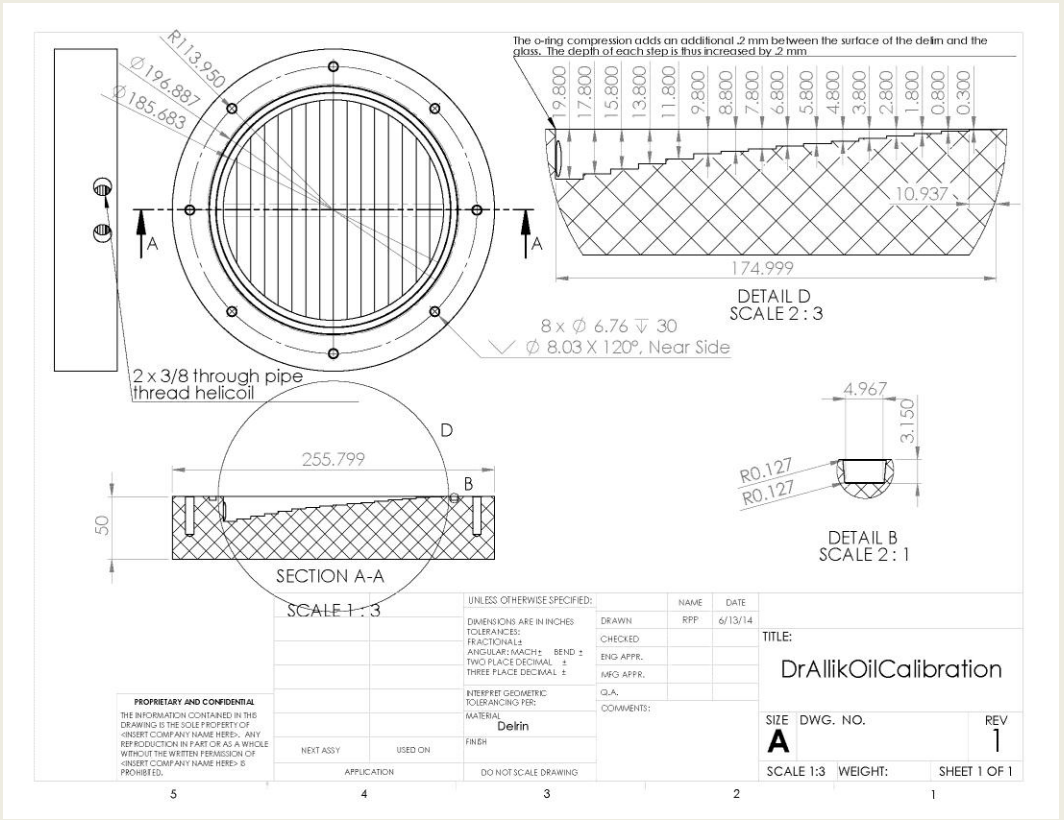



**Reflectivity spectra of the five collected Santa Barbara samples.**

# Thickness Calibration Cell

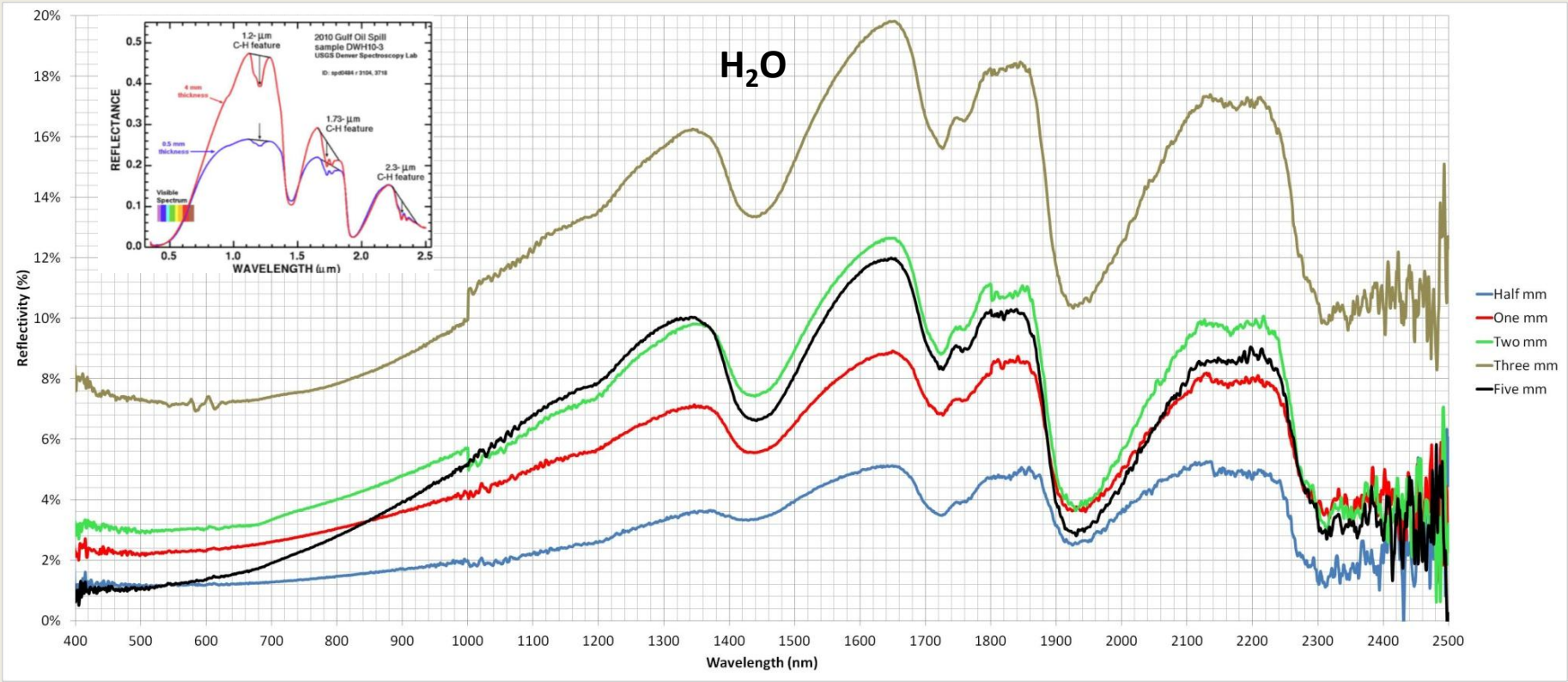




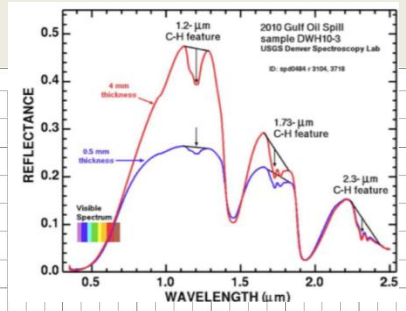



## The Importance of Ground Truth

# Santa Barbara Oil Seeps



# Alaskan North Slope (ANS) and Weathered State (Emulsion)




$H_2O$

Emulsions

UV/Visible (All the same)

Crudes

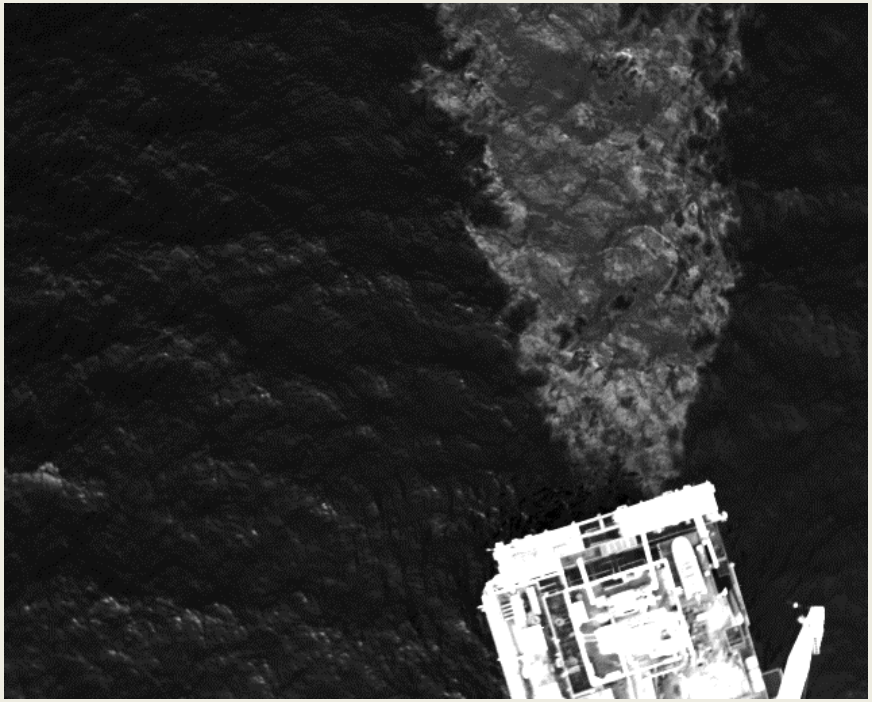
Reflectivity (%)

Wavelength (nm)

- Microns Emulsion
- 1 mm Emulsion
- 2 mm Emulsion
- 5 mm Emulsion
- 10 mm Emulsion
- 20 mm Emulsion
- Paint Black
- Microns ANS
- 1 mm ANS
- 2 mm ANS
- 5 mm ANS
- 10 mm ANS

# Visible and SWIR Images of Natural Oil Seeps off the Coast of Santa Barbara, CA

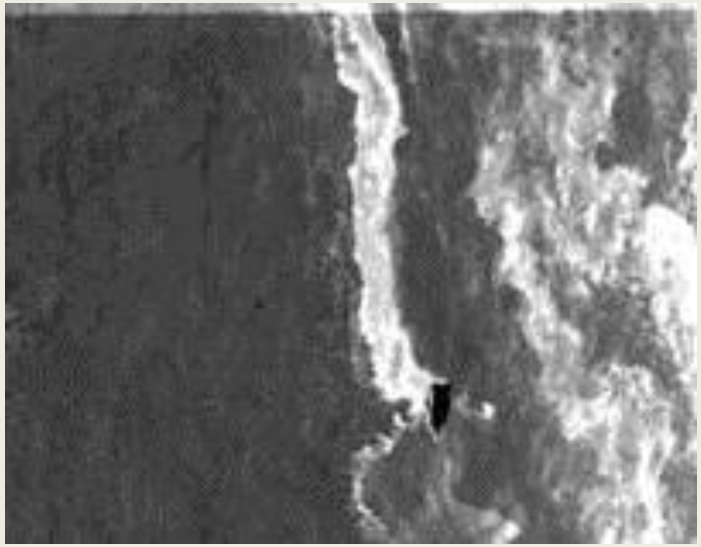
Visible



Broadband SWIR

## *Santa Barbara Oil Seep Testing - December 2014*

We have identified two SWIR wavelengths that provide relative thickness measurements in the field. The images below show the processed SWIR image and visible photograph. The boat crew had determined that this area had a high thickness of weathered oil.



**Processed SWIR Image (1600 nm – 975 nm)**

**Visible**

# Conclusions

- **Improvements in Short Wave Infrared (SWIR) cameras have made them useful for military, pharmaceutical, and chemical detection.**
- **SWIR airborne hyperspectral cameras have shown their usefulness in oil spill detection.**
  - However, their high instrument and operational cost, coupled with the logistical issues in providing real-time spectral maps to Oil Spill Response Organizations (OSROs) are problematic.
- **Benefits of the SWIR spectral region over the Visible are:**
  - Slightly better atmospheric transmission in certain weather conditions,
  - Increased irradiance in very low light (starlight) conditions,
  - Increased contrast between oil emulsion reflectivity and water,
  - Additional hydrocarbon spectral signatures and spectroscopic differences between crude oil and weathered emulsions.
- **Hand-held SWIR imagers** use room temperature detectors with small pixels (15 microns), formats comparable to uncooled microbolometer LWIR cameras, and noise reduction allowing for passive low-light level imaging.
- **We discussed our SWIR camera and spectral characterization that generate real-time imagery.** Demonstrated two SWIR wavelength approach for remote oil thickness measurements.

# Acknowledgements


- The authors would like to thank the following:
  - Lori Medley
  - Jan Svejkovsky and Mark Hess
  - Ohmsett Staff