Guidelines for a Remote Multispectral Emissions Monitoring System

Luciano Triolo
Advisors: Dr. Barry Bunin & Dr. Thomas Wakeman
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Background

• In 2012, international maritime trade accounted for
  • 2.2% of global CO₂ emissions
  • 2.1% of global Greenhouse Gas emissions
  • 13% of worldwide NOₓ emissions
  • 12% of worldwide SO₂ emissions

• Annex VI of MARPOL addresses air pollution prevention requirements
  – Marine diesel fuel cannot exceed 0.1% sulfur content (2015)
  – Engines in emission control areas must achieve an 80% reduction in NOₓ emissions (2016)

• EPA & USCG’s responsibility for enforcement
What is the problem?

- The USCG and EPA are limited to the amount of inspections they can perform.
- In 2016, only 9,400 ships out of 81,900 total ships that visited the U.S. were inspected.

- Current inspection methods include analyzing bunker fuel samples at a laboratory.
RESEARCH GOAL: To propose development guidelines for a system that can detect ship emissions remotely and in real-time.
Literature Review

• Some previous research
  – None suggest an operational system
  – Proposed systems are exploratory and scientific research tools
  – Too large, overcomplicated, impractical & unsuitable

• A need exists to develop a practical and ready-to-use system
How can remote emissions monitoring be performed?

- Multispectral imaging technology
  - Captures image data within specific wavelength ranges across the electromagnetic spectrum

Examples of multispectral imaging
Band Determination

• Minimum transmittance values = maximum emittance values, where 
  \[ \varepsilon_S + \tau_S = 1 \]
Band Determination

- Wavelengths for detection of various vessel emissions form common "communities" or bands
Detection Distance

- A sample calculation was performed

**Exhaust Plume**
- $R_0 = 5 \text{ m}$
- $T_H = 266^\circ \text{C}$
- $\varepsilon = 0.17$

**Imager**
- $A_{Lens} = 0.0144 \text{ m}^2$
- $N = 7.92 \times 10^{-5} \text{ W/m}^2$
- $SNR = 1.0$

**Atmosphere**
- $T_c = 20^\circ \text{C}$
Market Survey

- Is there a system commercially available that meets our needs?
  - 22 imagers were investigated

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Spectral Region (μm)</th>
<th>Weight (lb)</th>
<th>Stated Detection Range (mi)</th>
<th>Cost (USD)</th>
<th>Suitable for VEMS?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MULTISPECTRAL IMAGERS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>AgroWing Multi-Spectral Ev. Package</td>
<td>0.45 - 0.85</td>
<td>0.6</td>
<td>2</td>
<td>$2,800</td>
<td>X</td>
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<tr>
<td>Pixelteq's SpectroCam VIS-SWIR</td>
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<td>2</td>
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<td>Silios Technologies CMS-S</td>
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<td>SlantRange 3P</td>
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<td>0.77</td>
<td>2</td>
<td>$3,950</td>
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<tr>
<td>Telops MS-M2k</td>
<td>3 - 5</td>
<td>29</td>
<td>3</td>
<td>NA</td>
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<tr>
<td>Telops MS-V350</td>
<td>7.5 - 12</td>
<td>29</td>
<td>3</td>
<td>NA</td>
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</tr>
</tbody>
</table>

Notes:

- VEMS - Vessel Emissions Monitoring System

- O - Partially Suitable
- X - Not Suitable
Mobility Considerations

• Modularity
  – Standardized design scheme that can be used interchangeably between detection platforms
Mobility Considerations - UAV

Port of New York & New Jersey
Mobility Considerations - UAV

Port of Los Angeles and Long Beach
Conclusions & Recommendations

• System guidelines show plausibility to provide enforcement
  – Can allow for more frequent emission measurements by using a mobile detection platform
• Recommend to modify existing equipment to fit our needs
• Next Steps:
  – Hardware/software design
  – Real world testing
• End Goal:
  – Cleaner skies and seas for all
Acknowledgements

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Questions?
Thank You!