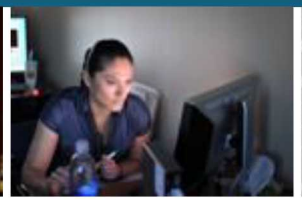
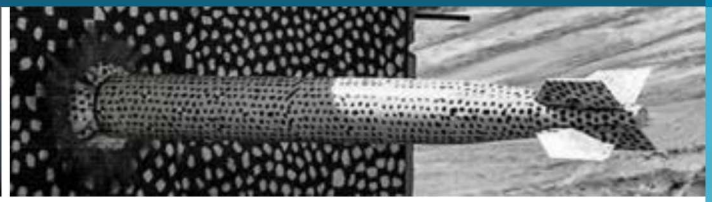
SAND2018-3810C

Sandia National Laboratories

Ongoing work and Improvements at the Sandia Fog Facility





PRESENTED BY

Jeremy B. Wright

John D. van der Laan, Karl Westlake, Brian Redman, Jacob Segal

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Addressing Fog Science

Cloud/Fog Physics Micromodels

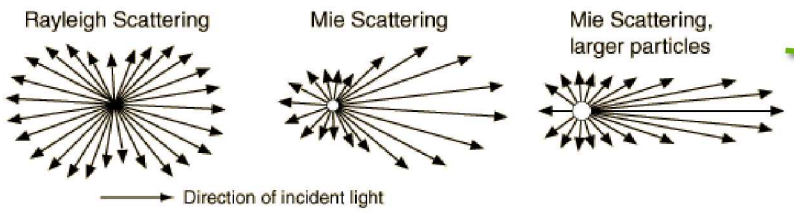
Weather Prediction

Meteorology

Bridging Together

Metrics Relevant to Optics

??



Optical Scattering

Optical Engineering

System Design

Outline

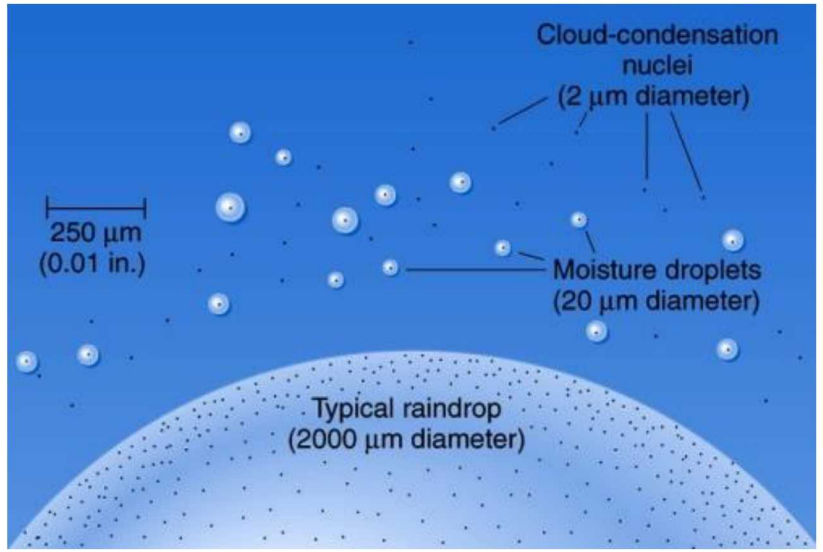
What is Fog, Why do we care?

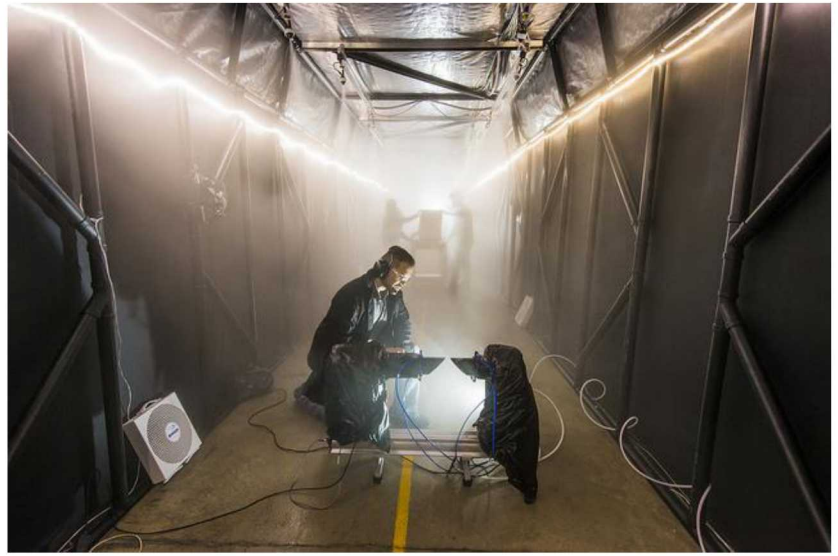
Visibility

Sandia Fog Facility Overview

How we characterize fog

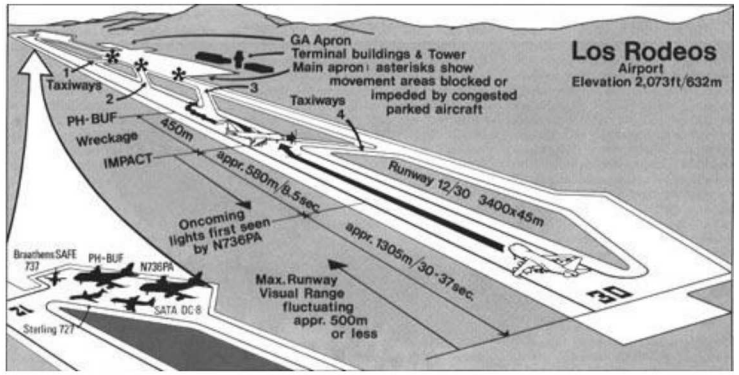
Current and Future work





Why do we care about fog?

11 dead in helicopter crash off Florida Coast due to thick fog: WINK News, March 11, 2015



Tenerife Airport Disaster –Fog a major contributor- 583 dead March 27,1977

2 separate accidents 90 vehicles 2 dead. Tule Fog SFGATE Feb 5, 2002

What is fog?

Fog - a thick cloud of tiny water droplets suspended in the atmosphere at or near the earth's surface that obscures or restricts visibility.

- Dewpoint temperature spread is <3 °C
- <1km of visibility
- Low Elevation

Mist – Between fog and haze particles less than 5µm.

- 95-100% RH
- >1km visibility

Haze – Does not contain activated droplets according to Köhler theory.

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The most common types of fog

Radiation Fog – Most Common

Moist air is cooled near the ground causing supersaturation

Advection Fog – More Prevalent in Coastal Climates

Atmospheric patterns play more of a role than radiation fog

Advection Fog – Many Flavors

Defining Visibility

Visibility
a measure of the distance at which an object or light can be clearly discerned. It is reported within surface weather observations and METAR code either in meters or statute miles, depending upon the country.

Wikipedia

Visibility
a) the greatest distance at which a black object of suitable dimensions, situated near the ground, can be seen and recognized when observed against a bright background;
b) the greatest distance at which lights of 1,000 candelas can be seen and identified against an unlit background.

International Civil Aviation Organization

Visibility
the length of path in the atmosphere required to reduce the luminous flux in a collimated beam from an incandescent lamp, at a color temperature of 2700 K, to 5 per cent of its original value, the luminous flux being evaluated by means of the photometric luminosity function of the International Commission on Illumination. For aeronautical purposes, the surface MOR is measured at a height of 2.5 m above the surface.

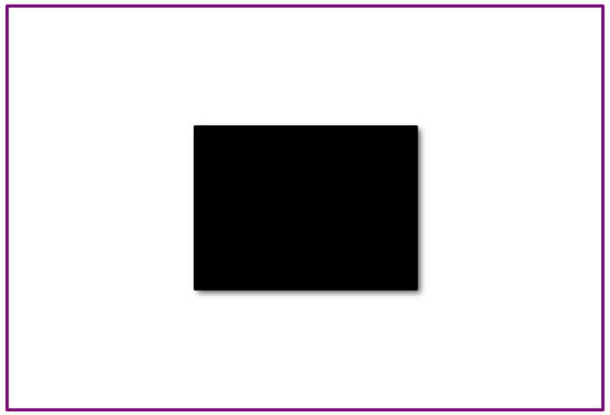
World Meteorological Organization

Contrast and visibility

Adding quantitative to a qualitative description

$$C_{\mathrm{V}}(x) = \frac{F_{\mathrm{B}}(x) - F(x)}{F_{\mathrm{B}}(x)}$$

Visual contrast at distance x



$$C_{\mathrm{V}}(x) = \exp(-b_{\mathrm{ext}} x)$$

Assuming that F is diminished proportionally with distance (Beer-Lambert Law)

$$x_{\mathrm{V}} = \frac{3.912}{b_{\mathrm{ext}}}$$

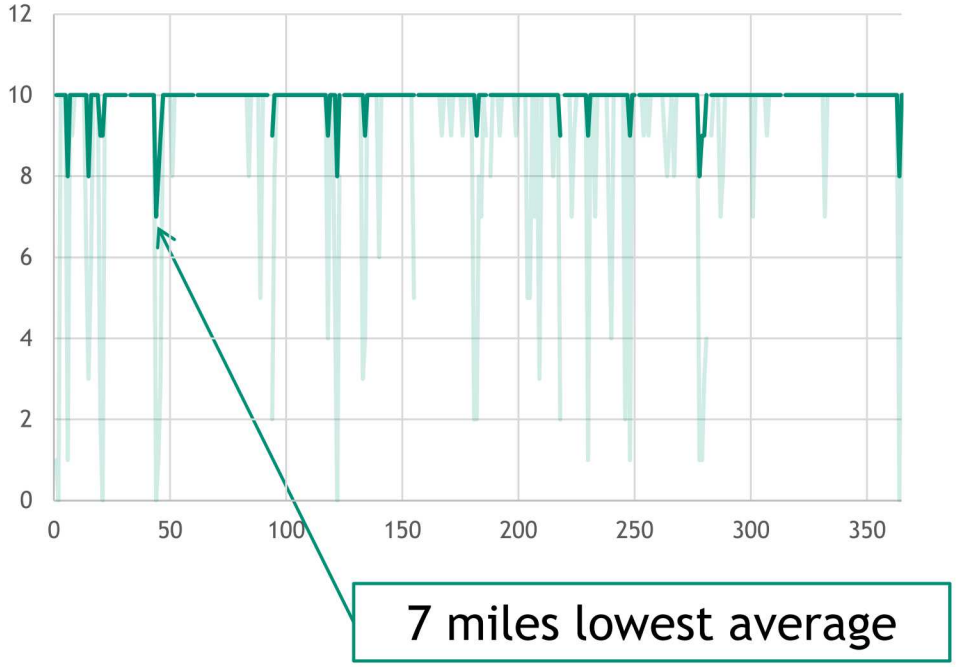
Koschmieder equation – Assumes 2% contrast

Does this represent imaging in fog?

No spatial frequency!
Simplification of Extinction

Doesn't inform system design

Weather in ABQ



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How do we control the weather?

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The Sandia Fog Tunnel

Constructed in 2014

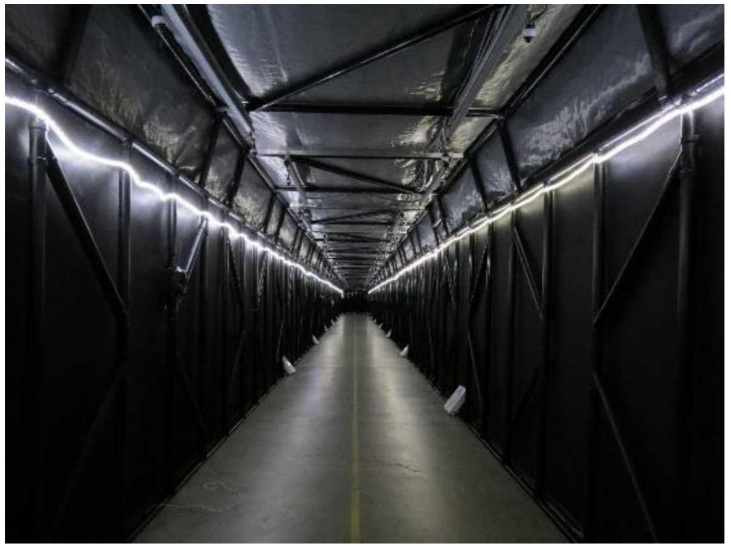
Initially Navy Research Funded

10’ x 10’ x 180’
- 6% grade (no pooling)

64 spray nozzles
- 3 selectable sections

Indoors
- Stable Environment

LDRD Funded improvements



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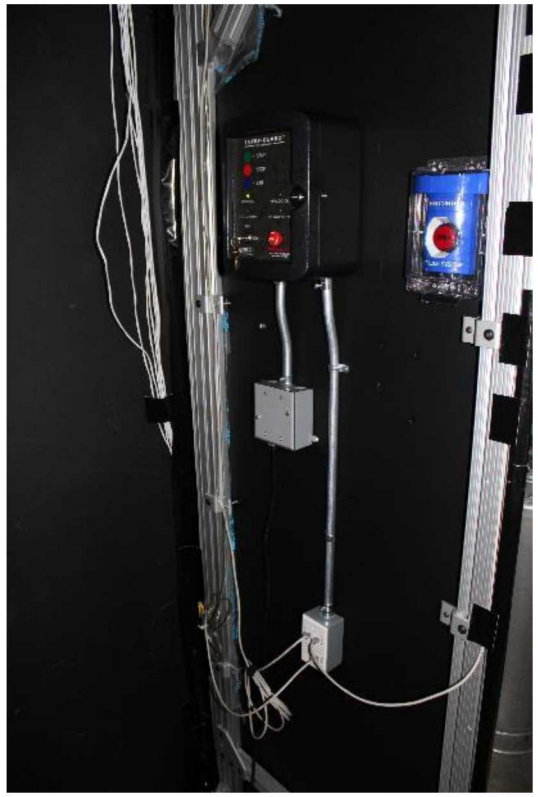
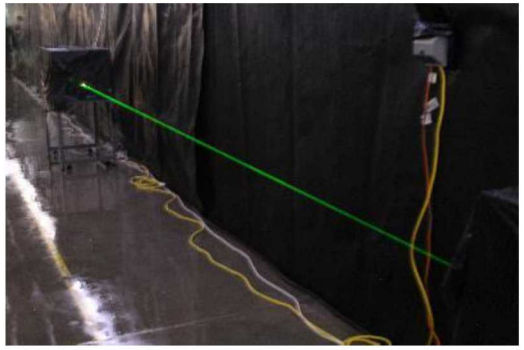
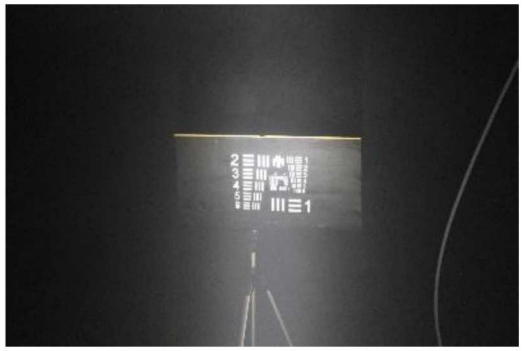
Sandia Fog Tunnel – Living Laboratory







- Continue to upgrade
  - Temperature Control
  - Plastic Sheeting
  - Roll Doors
  - Instrumentation (time correlated)
    - Visibility (MOR)
    - Particle Sizers
      - Malvern
    - Temperature, Humidity, Dew Point
- Customer inspired upgrades
  - Additional Power
  - Class IV lasers
  - Positive Pressure Dry Boxes
- Upcoming
  - Automation
  - Real-time Particle/Transmission Metrology

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Malvern- Spraytek

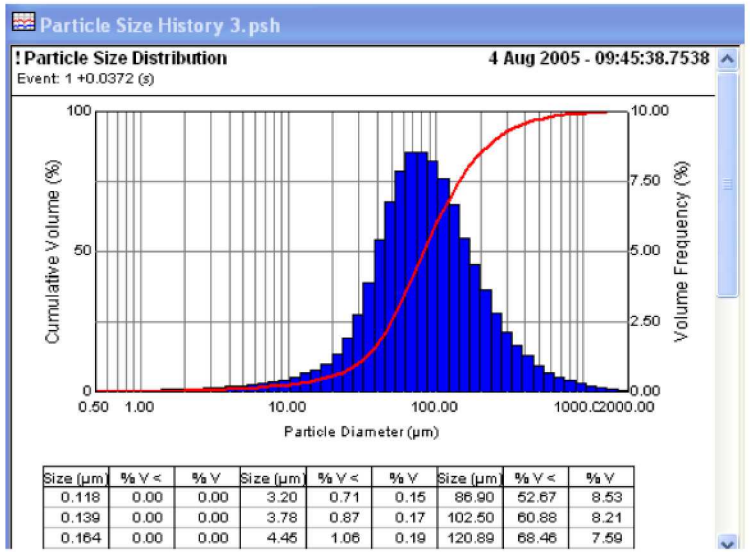
Laser diffraction system

Large particle range

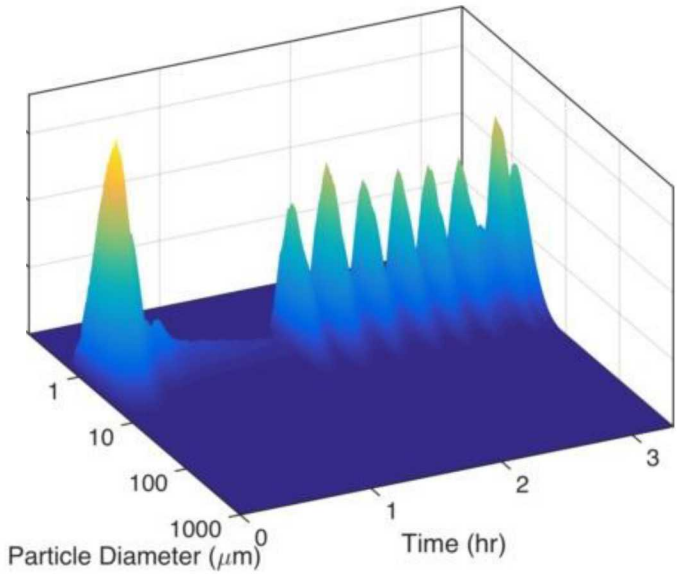
- 0.1 – 900 microns

Multiple Scattering Model

1Hz Continuous



Size (µm)	% V <	% V	Size (µm)	% V <	% V	Size (µm)	% V <	% V
0.118	0.00	0.00	3.20	0.71	0.15	86.90	52.67	8.53
0.139	0.00	0.00	3.78	0.87	0.17	102.50	60.88	8.21
0.164	0.00	0.00	4.45	1.06	0.19	120.89	68.46	7.59



Inhalation Cell

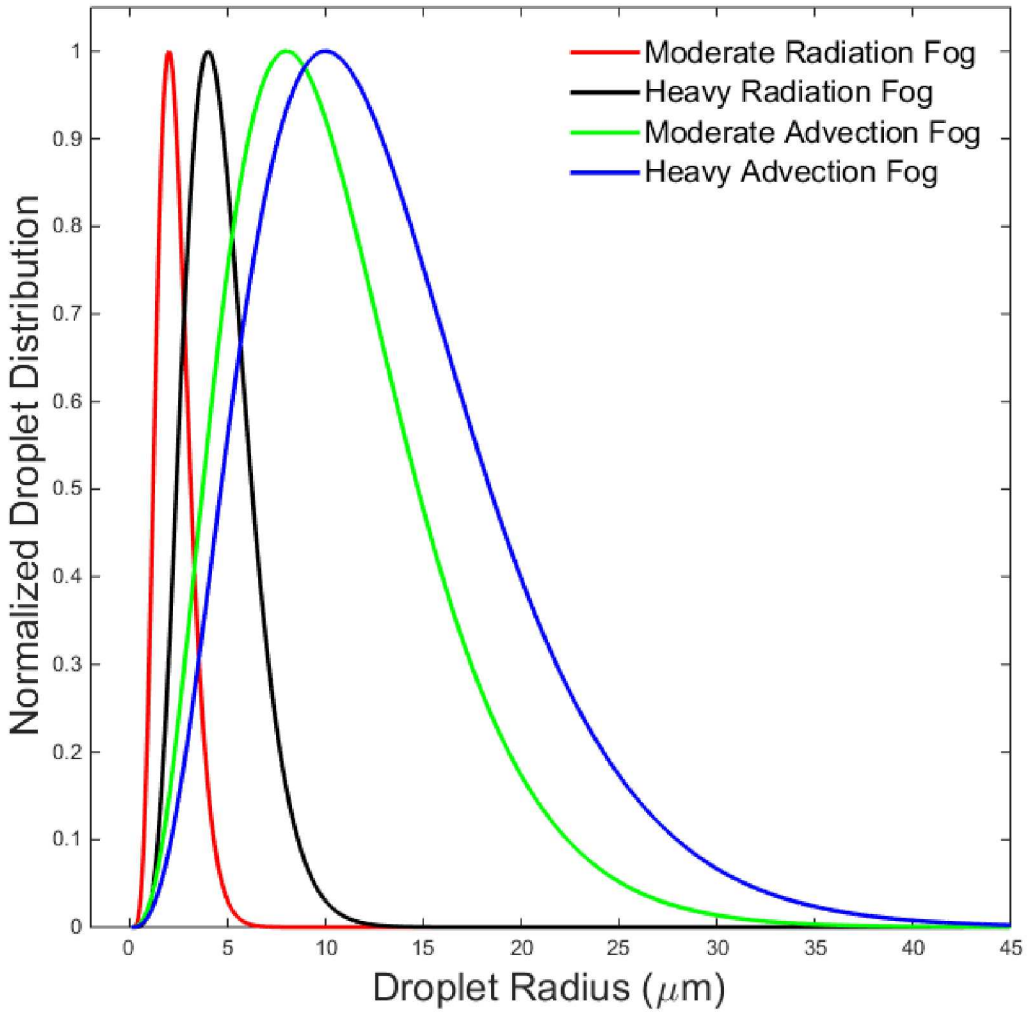
- Moving particles
- Flow Rate

Number Concentration

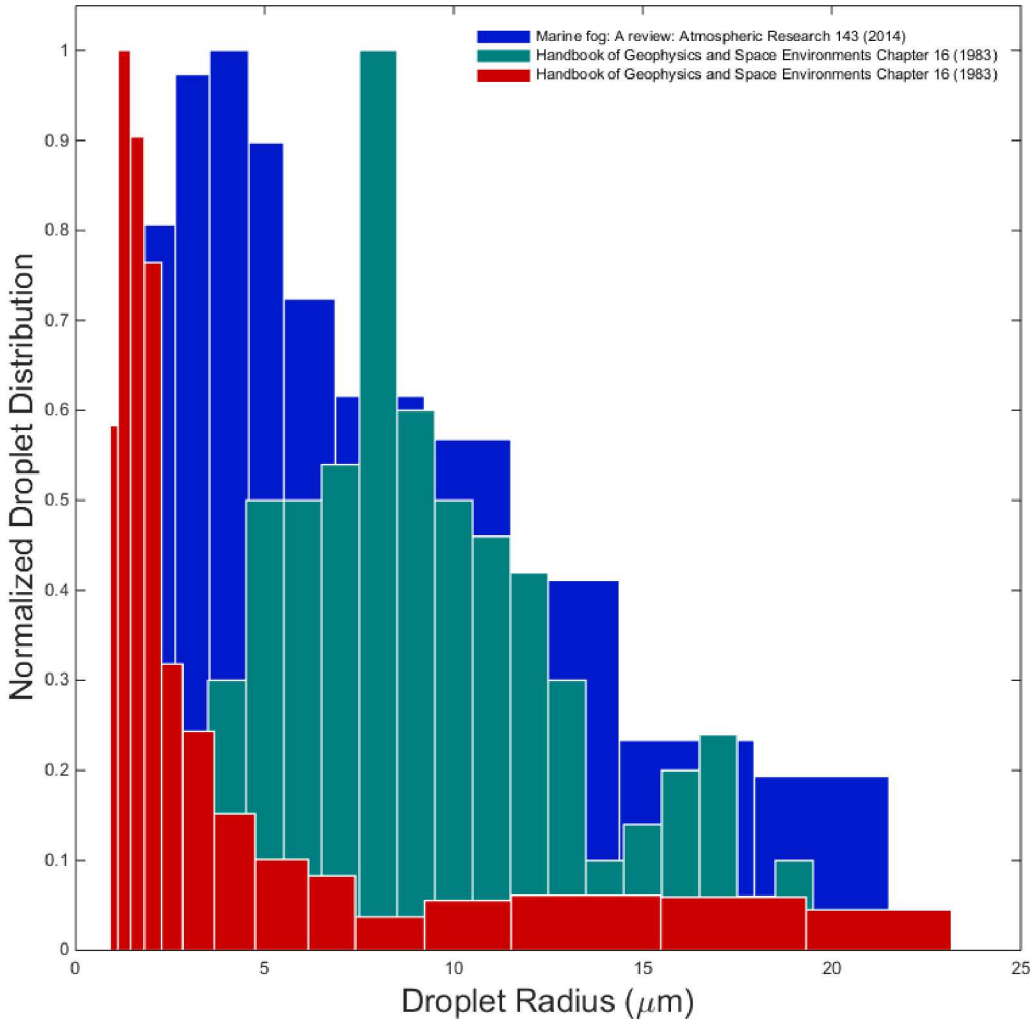
MODTRAN Fog Models

"Industry Standard"

Averaged from historical records (1970s)



Not all fog is the same



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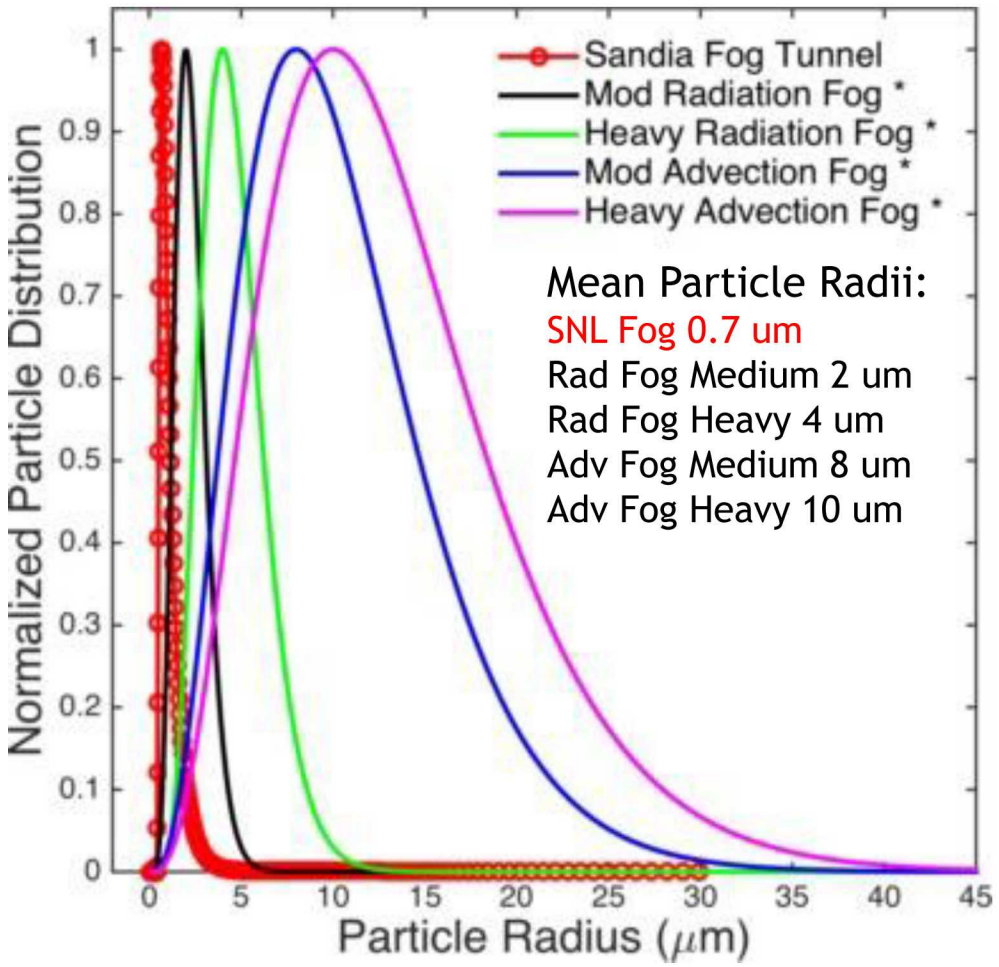
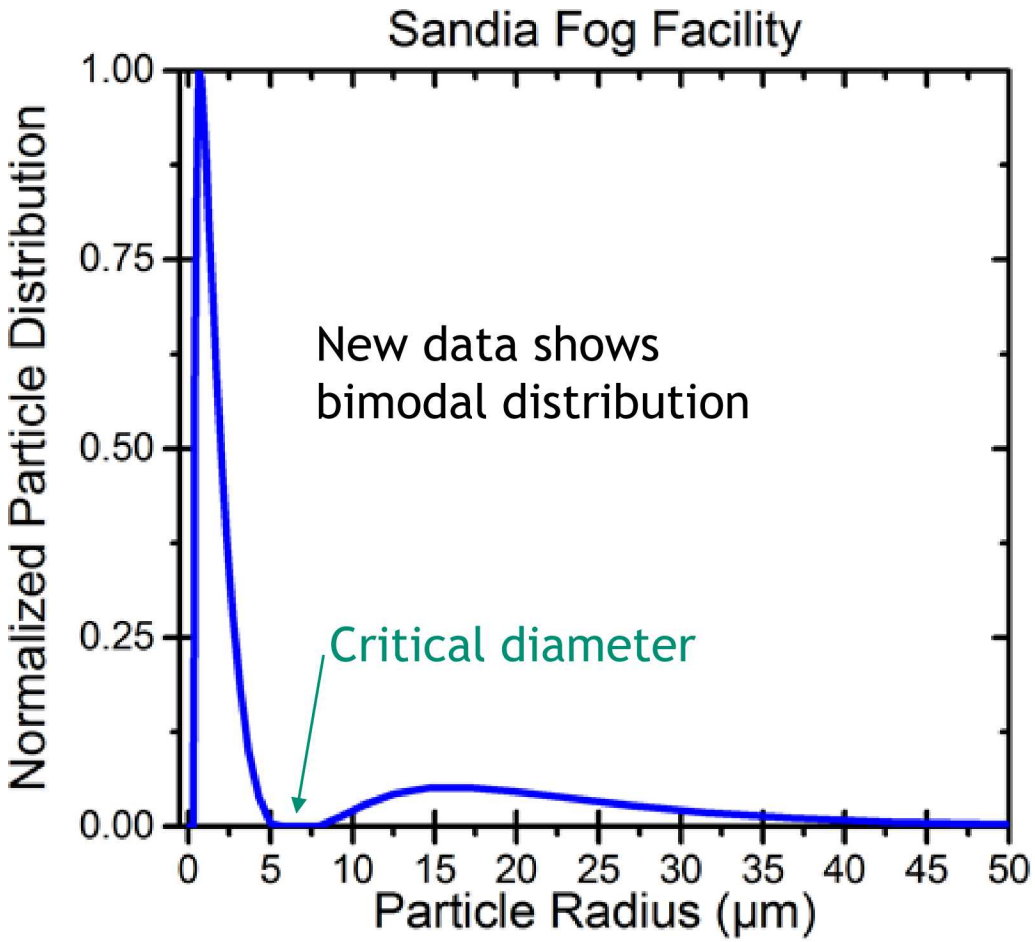
Developing and Characterizing Fog Analogs

Previous Results





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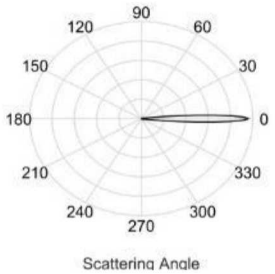
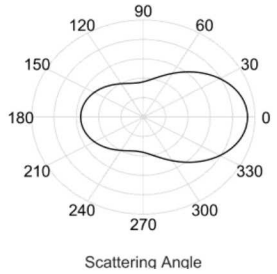
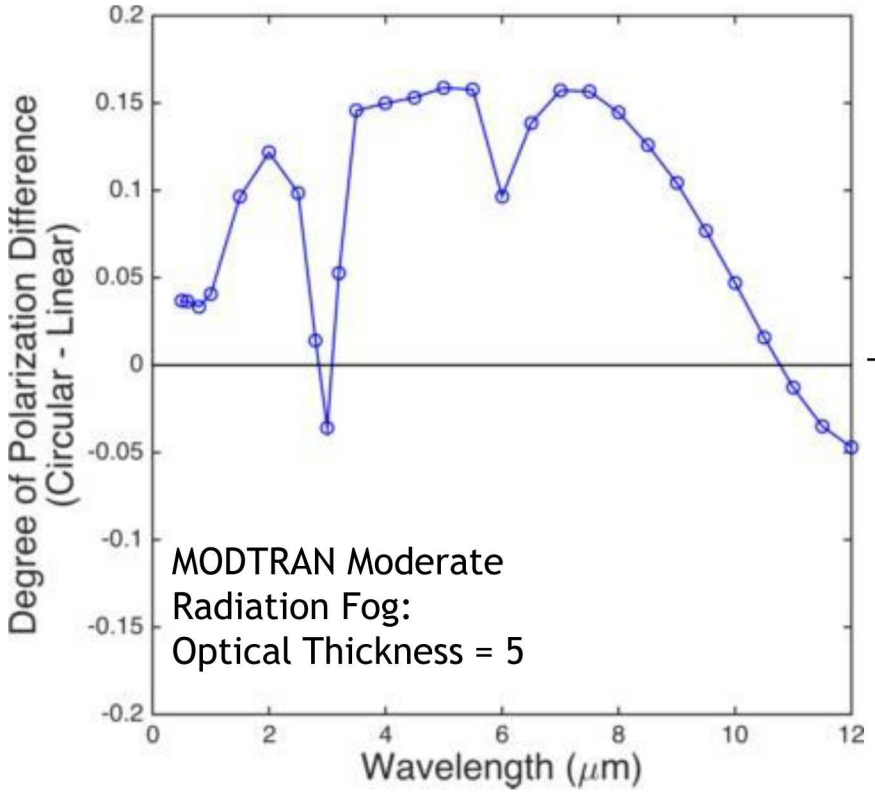
Why Fog Particle Size Matters

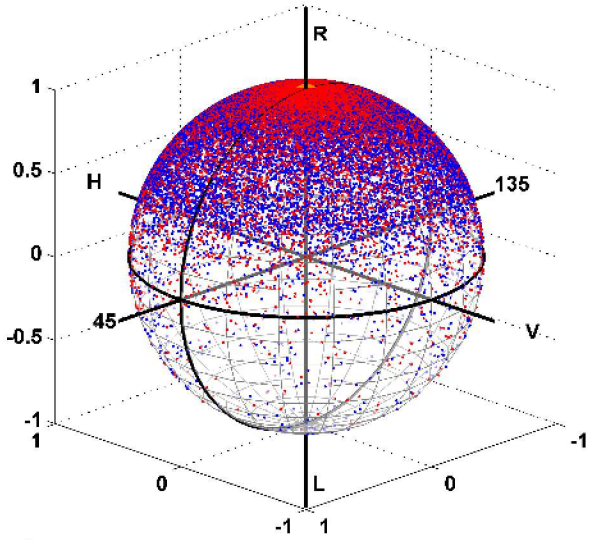
Forward scattering



Isotropic scattering

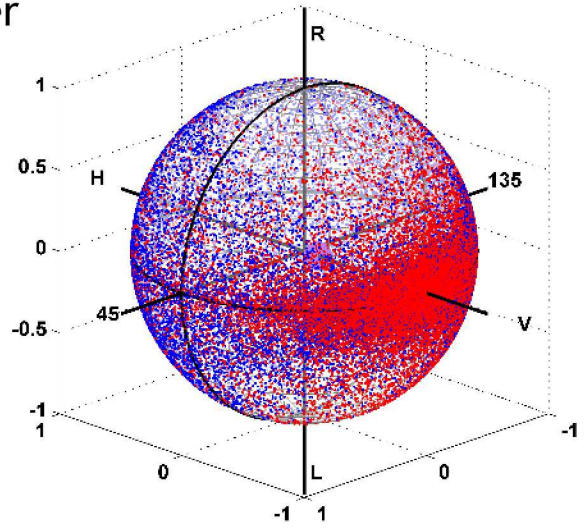




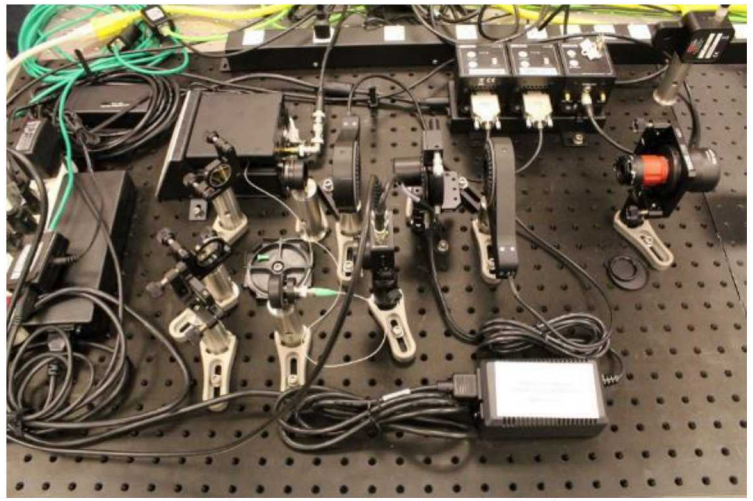


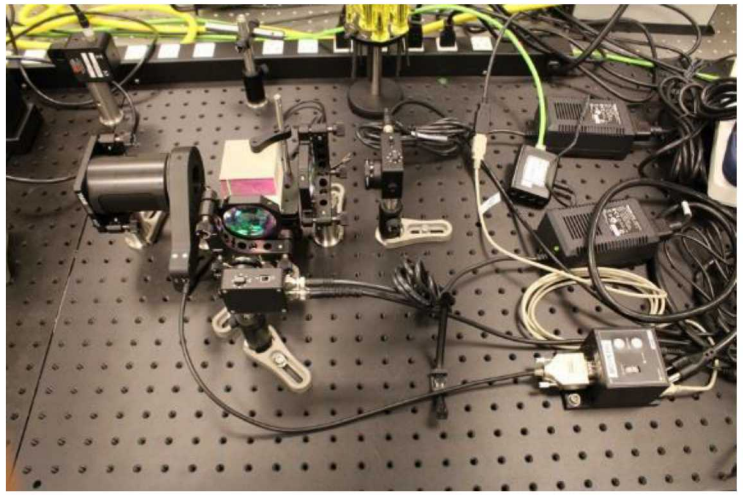
Circular Better

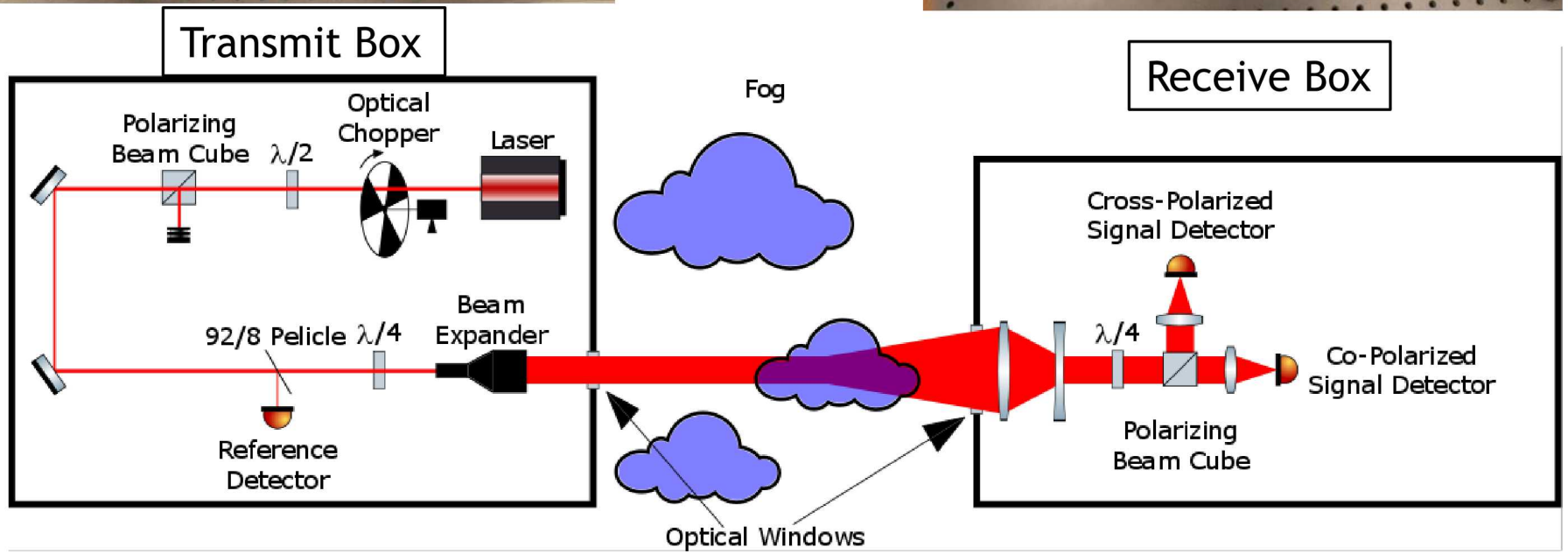
Linear Better

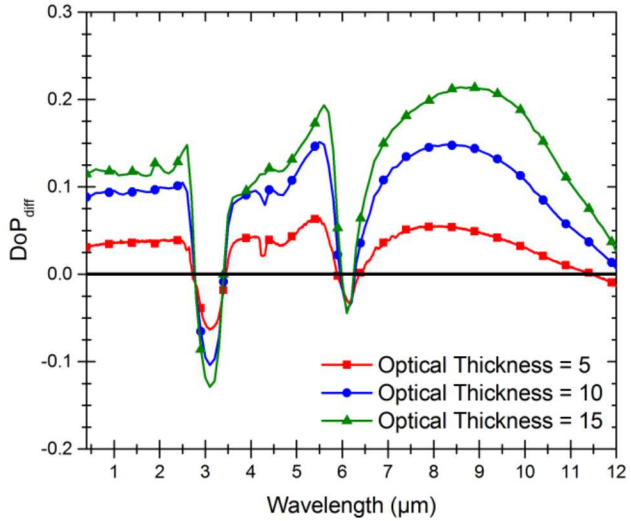


Previous Work– Model Validation



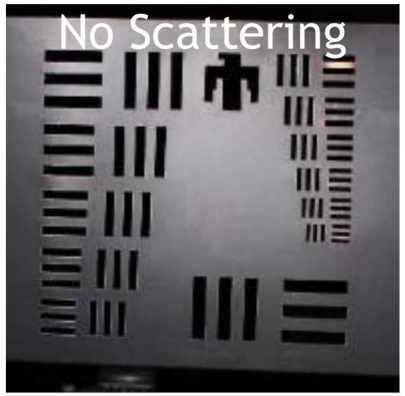




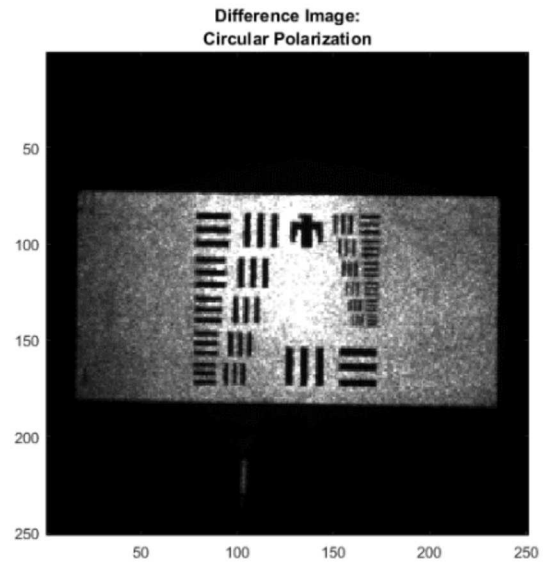


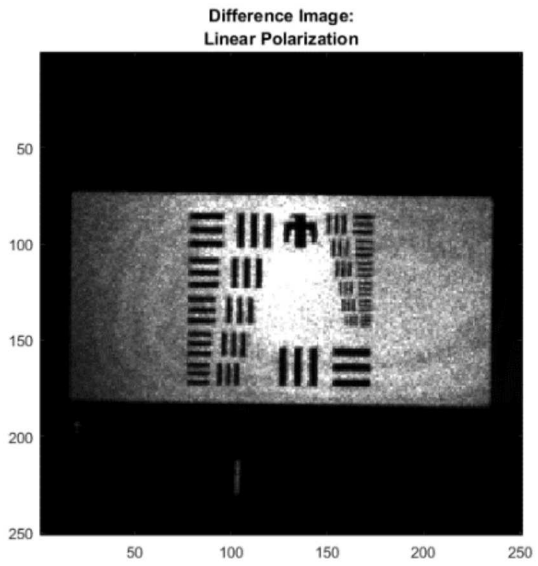
Current Work

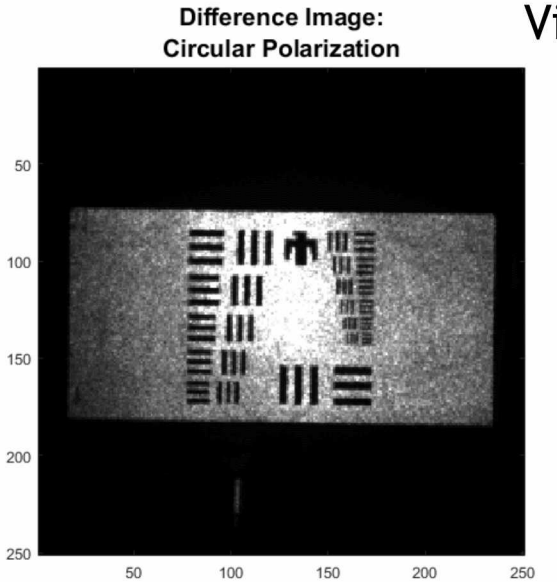
- Our current proof of concept design was assembled with COTS components
- 1550 nm System: FLIR Tau SWIR
  - Polarization difference imager
    - Linear or Circular polarization configuration

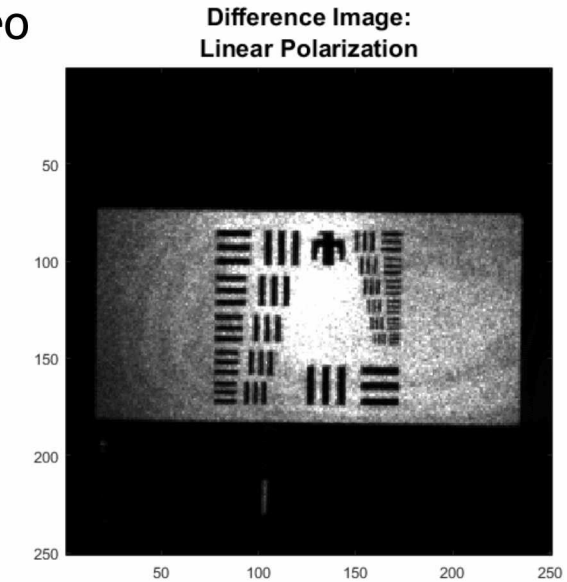


Video

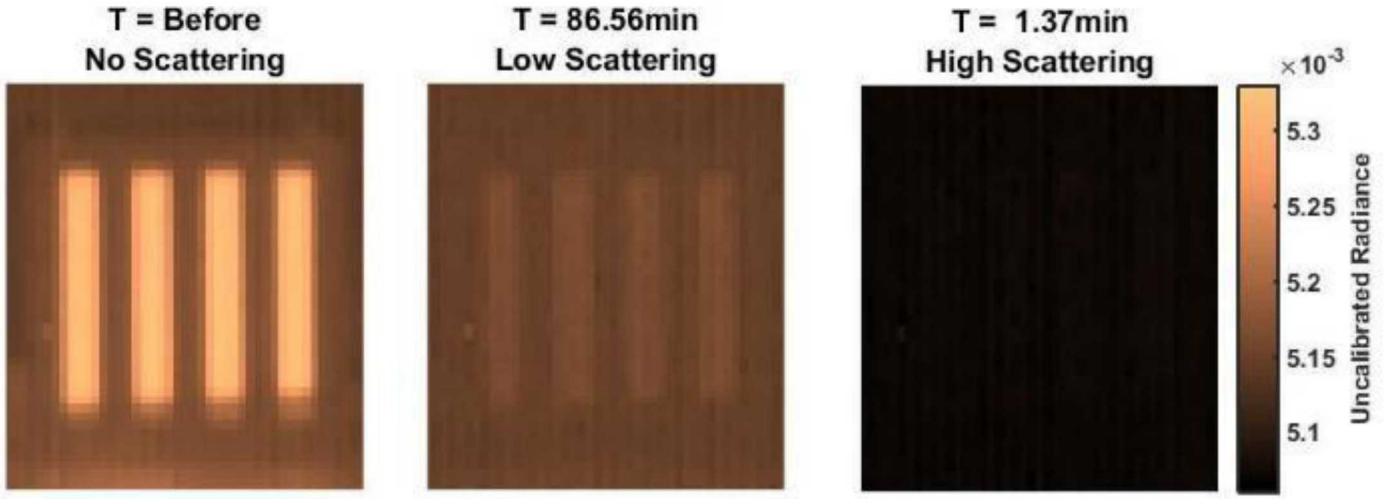




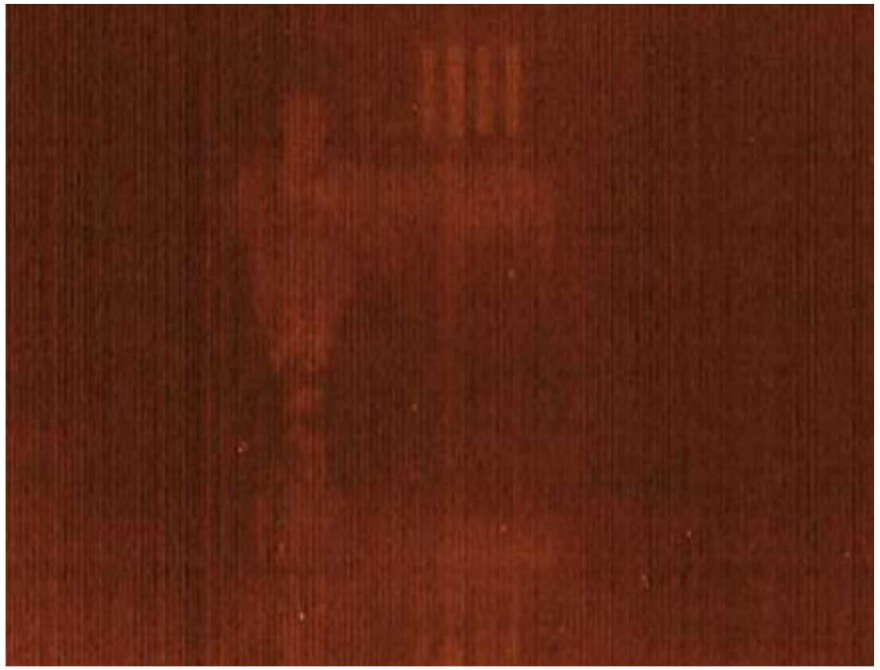




Future Work

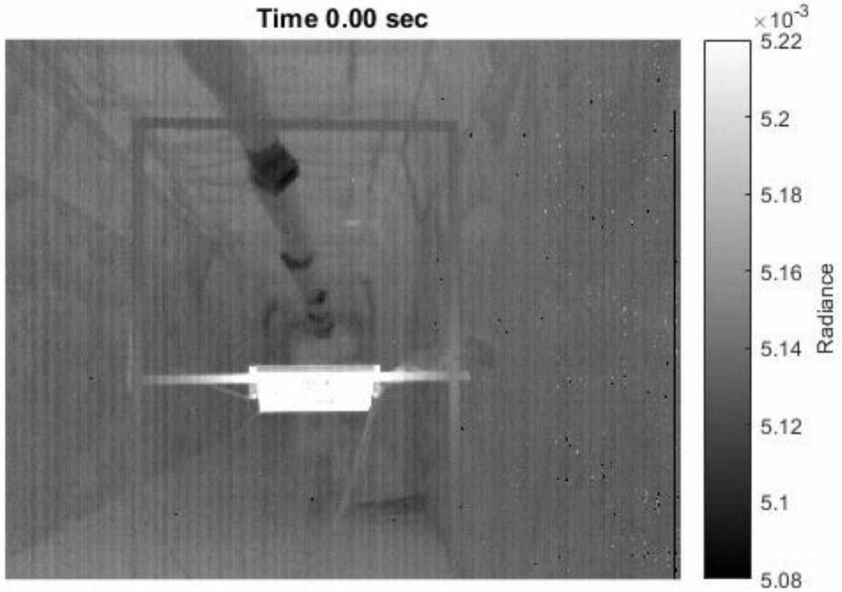


Polaris – LWIR Polarimeter



LWIR measurements
Emitters in fog

Future work
Active illumination



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Technologists in the fog

Any Questions?

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