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Atmospheric Effects on Long Stand-off HSI Applications

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Atmospheric Effects on Long Stand-off HSI Applications

Objective

- Develop an end-to-end System Performance Model to understand atmospheric effects on long stand-off missions

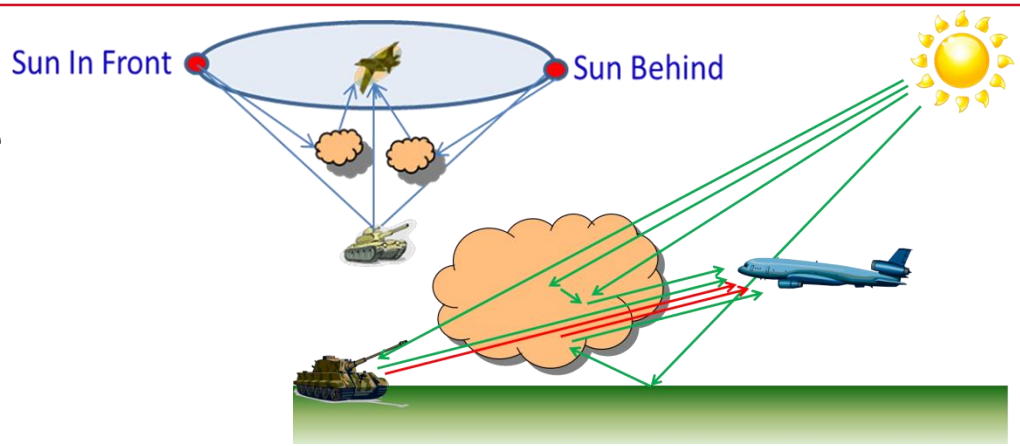
- Model includes:
  - Environmental Component
  - Concepts of Operations (CONOPS)
  - Imaging Systems

- Describe Expected Performance:
  - Noise Equivalent Spectral Radiance (NESR)
  - Signal-to-Noise Ratio (SNR)

Stand-off Hyperspectral Imaging System

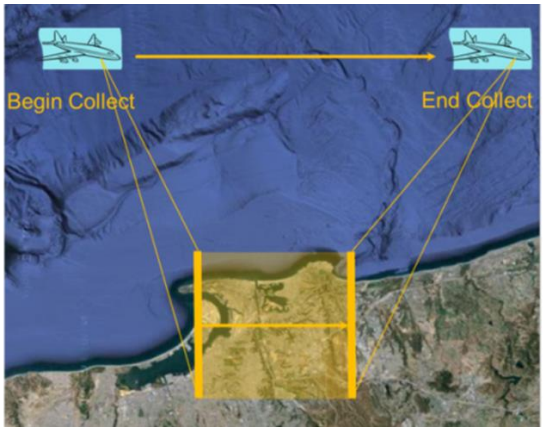
Mission Requirements

- Long Stand-off Performance
- Large Off-Nadir look angles
- Mid Altitude aircraft
- Turreted system
- Solid Targets
- Spot Mode Coverage Rate (CR)



Mission Performance Needs

- NESR and SNR



Model Drivers:

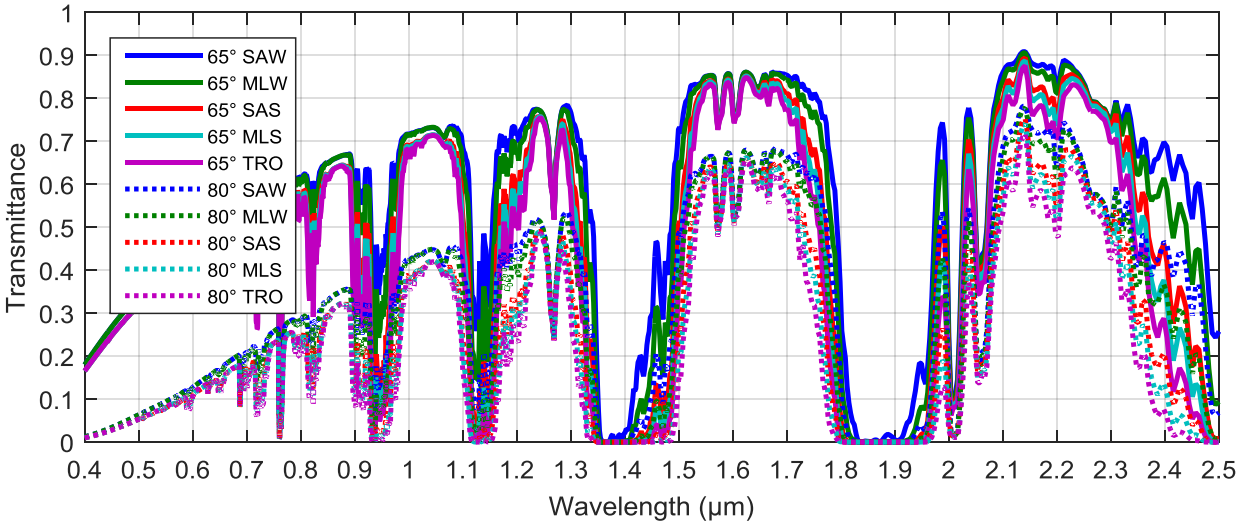
- Look angle of 65° & 80° Off Nadir
- Altitude from 50kft
- Aircraft speed = 100kts

- CONOPS Defined by:
  - Altitude,
  - Speed,
  - Look Angle,

VNIR/SWIR Atmospheric transmittance for 50kft AGL

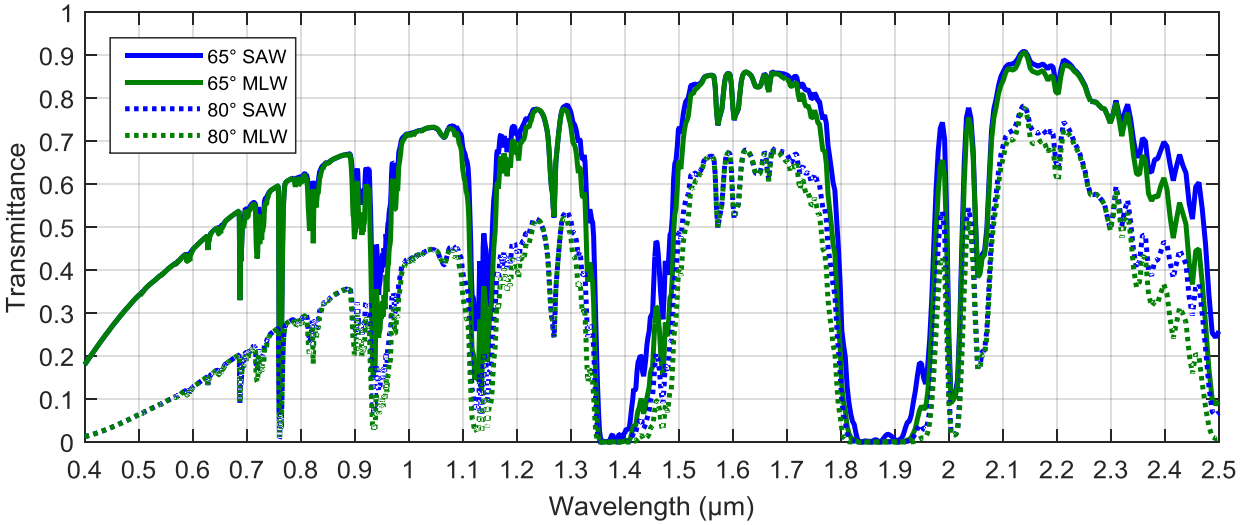
Scenario 1

Evaluating a wide range of atmospheric conditions (SAW, MLW, MLS, TRO)



Scenario 2

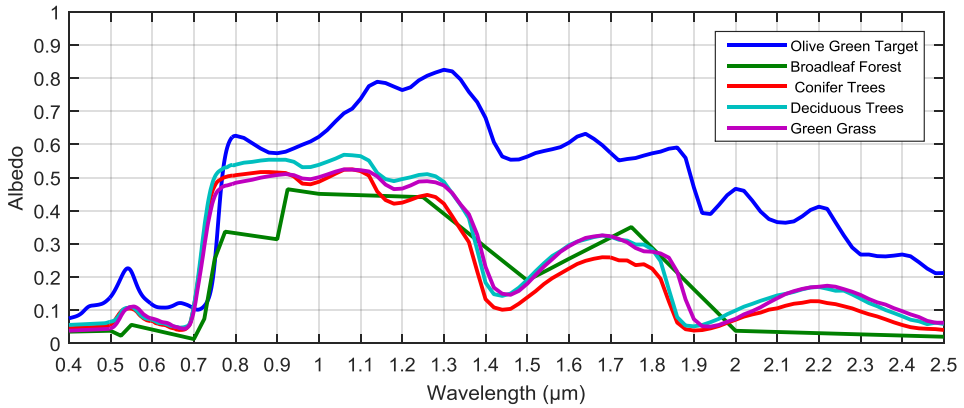
Focus on best conditions



SAW: Sub-Arctic Winter
MLW: Mid-Latitude Winter
SAS: Sub-Arctic Summer
MLS: Mid-Latitude Summer
TRO: Tropical

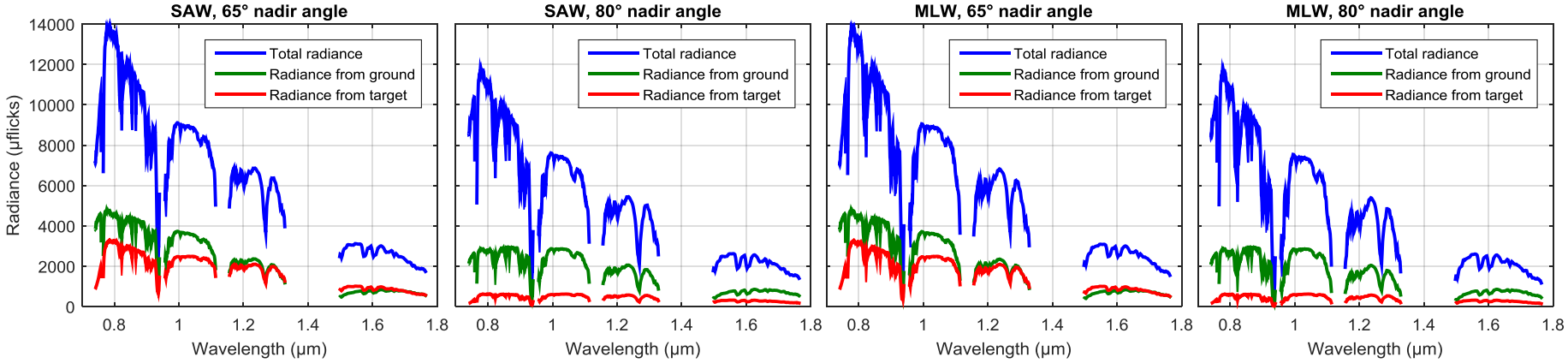
VNIR/SWIR Scenario 2 Spectral Radiance

- 50 kft altitude
- Sun behind platform, 45° zenith angle
- Rural aerosols
- Sub-pixel target
  - ➢ Fills 14% of the pixel at 80°
  - ➢ Fills 35% of the pixel at 65°
- Plots below illustrate radiance contributions in the target pixel



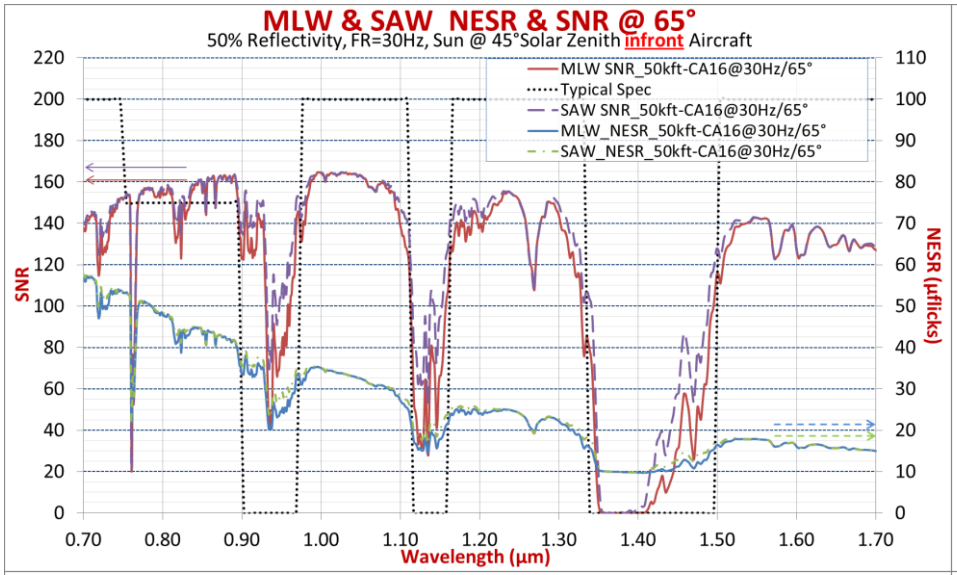
Spectral Albedos used in Model

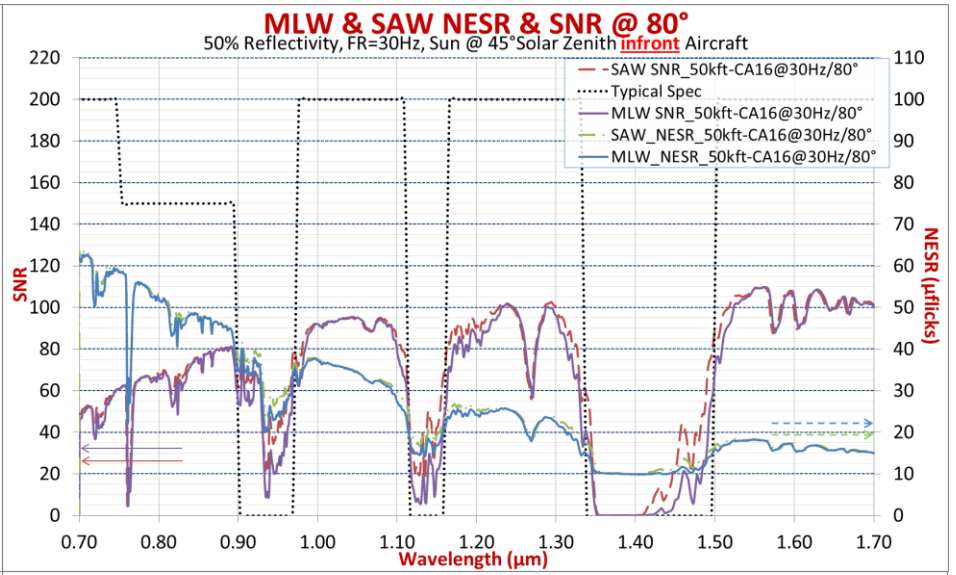
Nadir angle	Slant range (km)	Ground range (km)
65°	36	33
80°	91	90

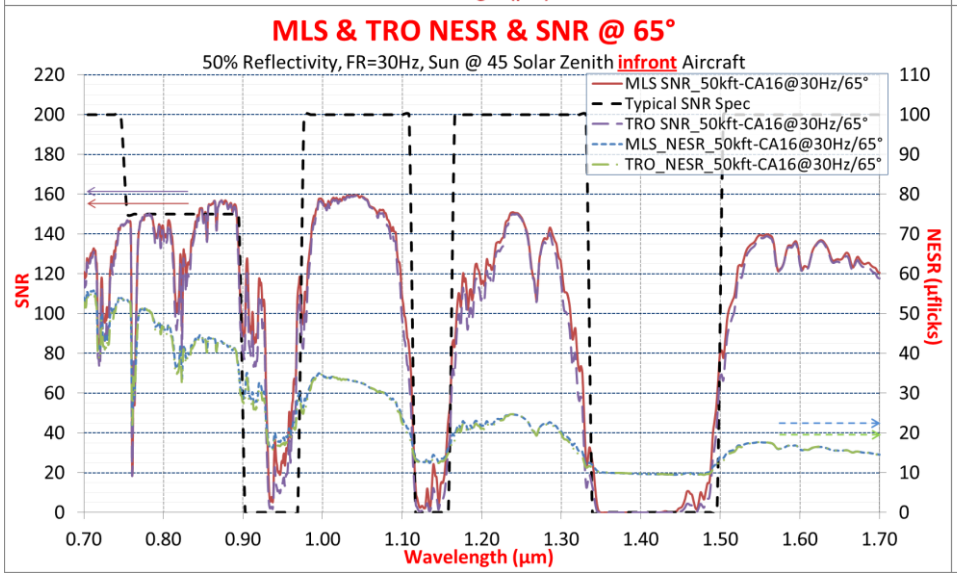


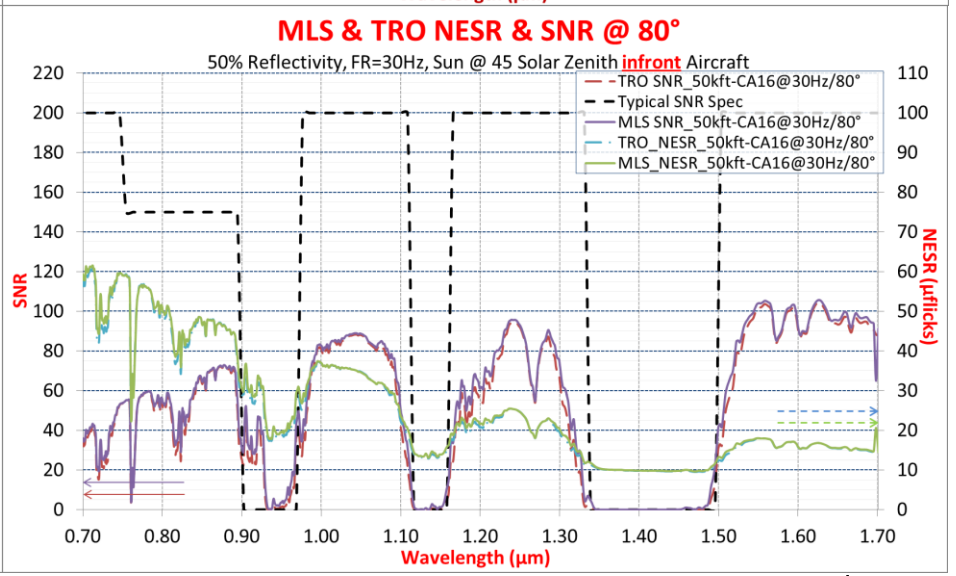
Average Spectral Radiance at the Aperture

NIR/SWIR Scenario 1 Performance Results – Sun In-front

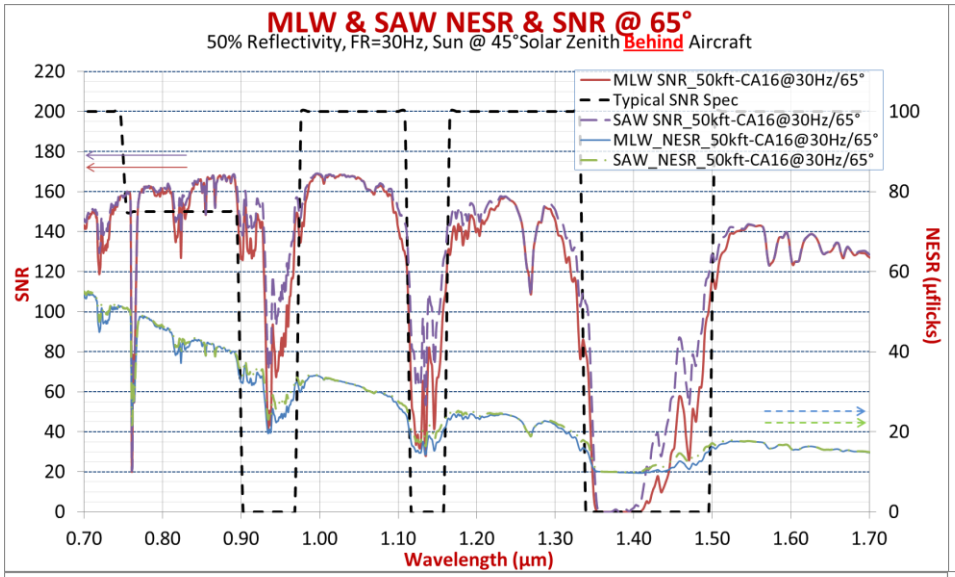


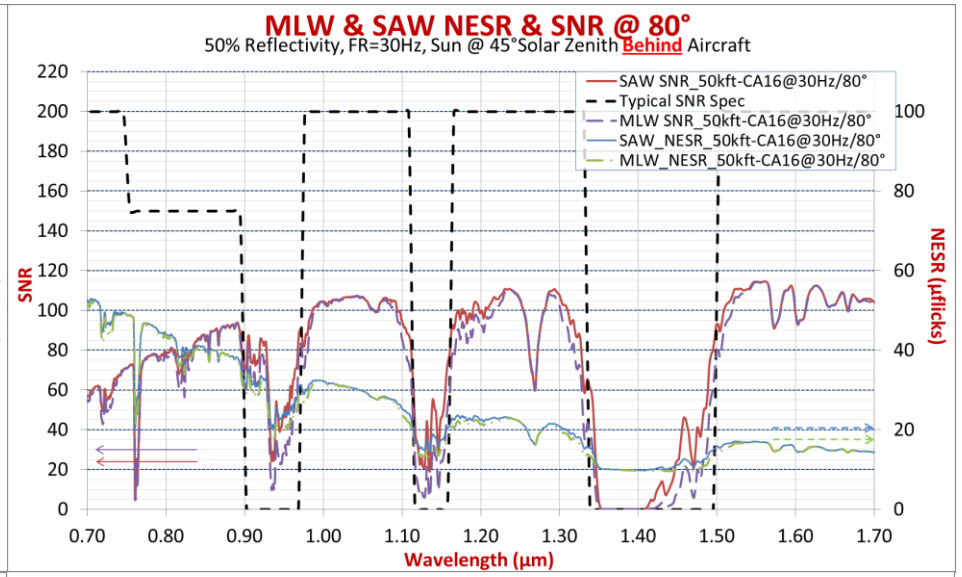


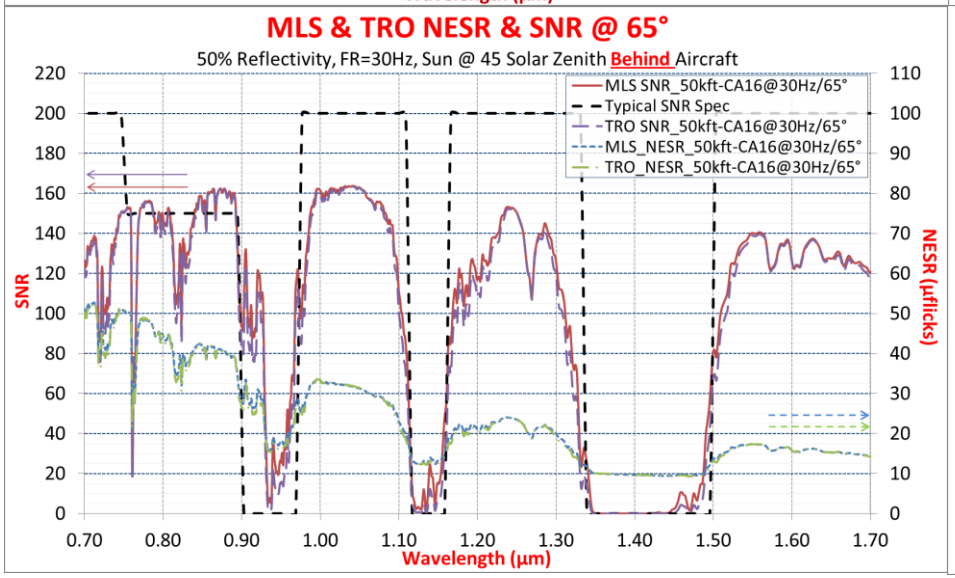


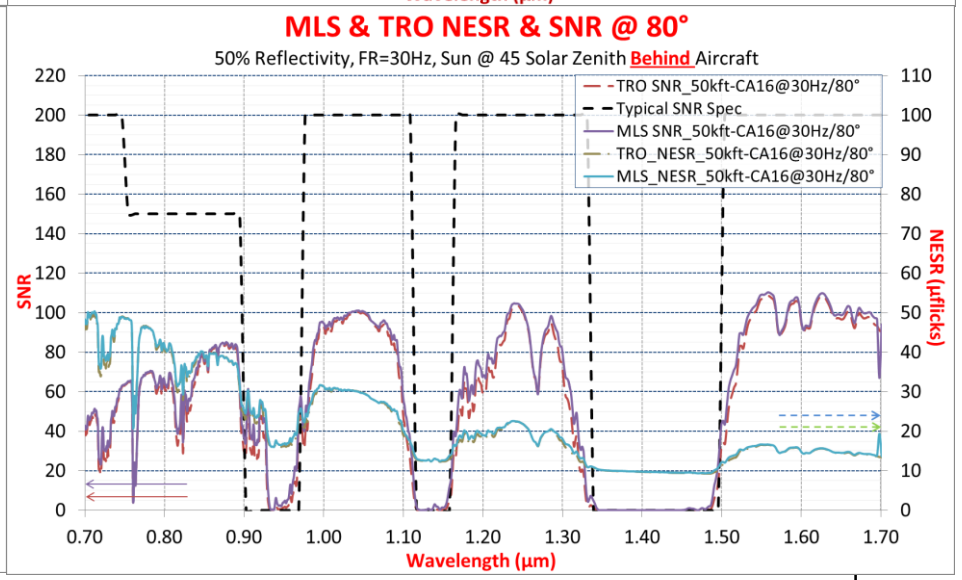


NIR/SWIR Scenario 1 Performance Results – Sun Behind



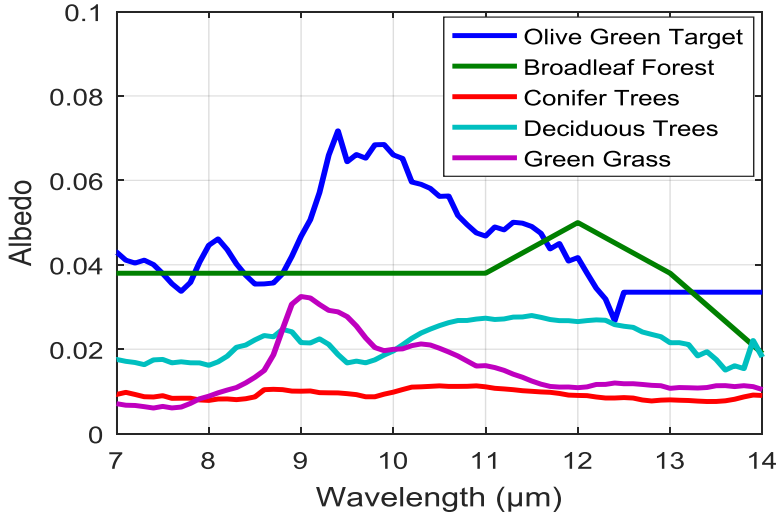


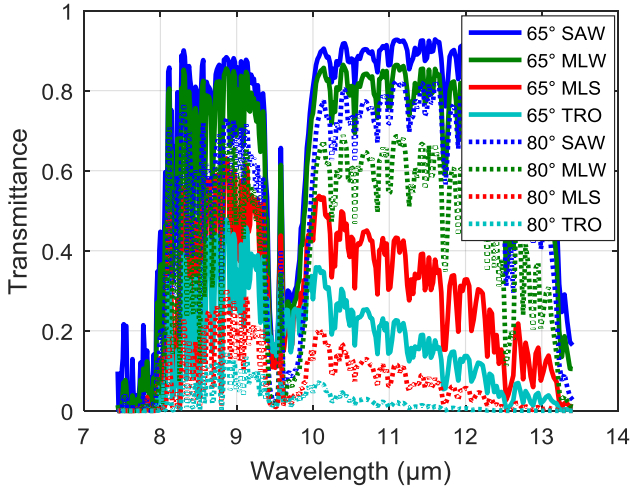


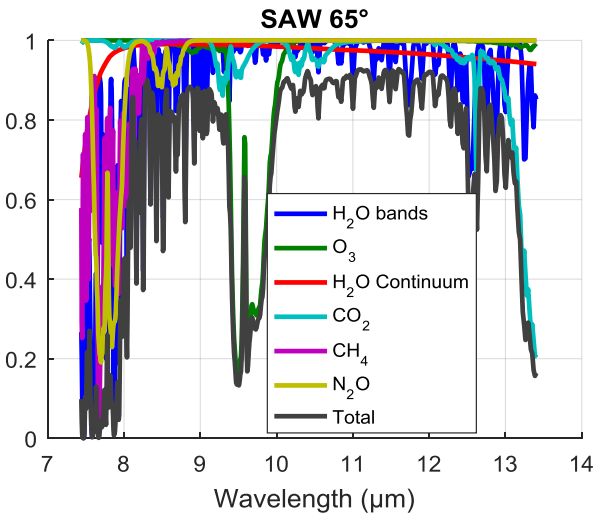


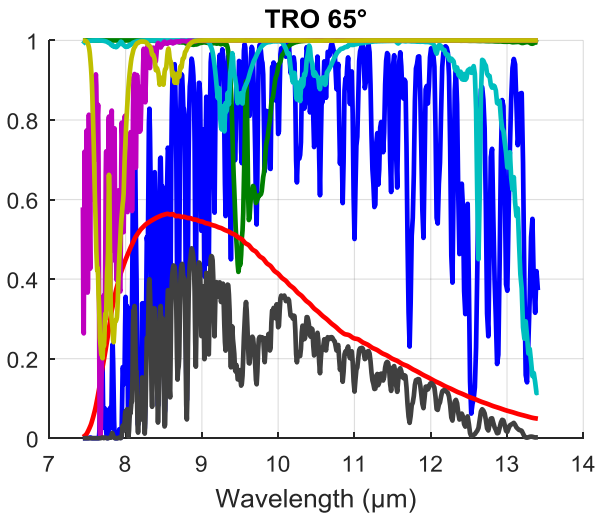
LWIR Transmittance & Scenario 2 Albedo

- All materials studied are essentially black bodies in the LWIR
- Water vapor causes large transmittance variations across different atmospheric conditions

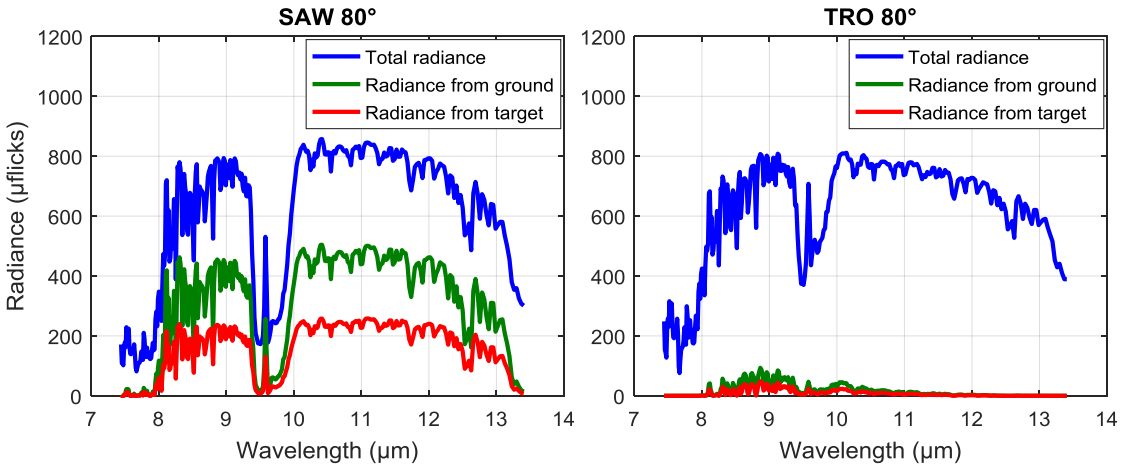




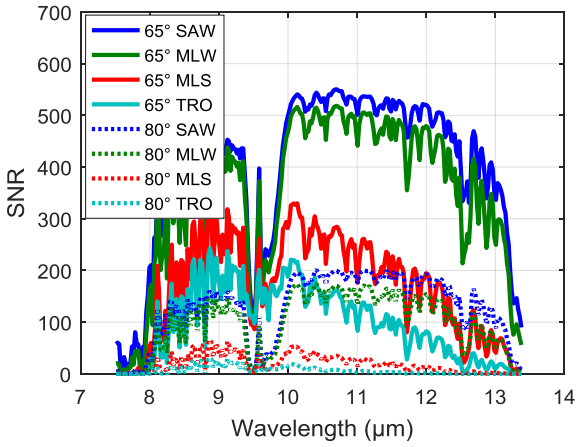


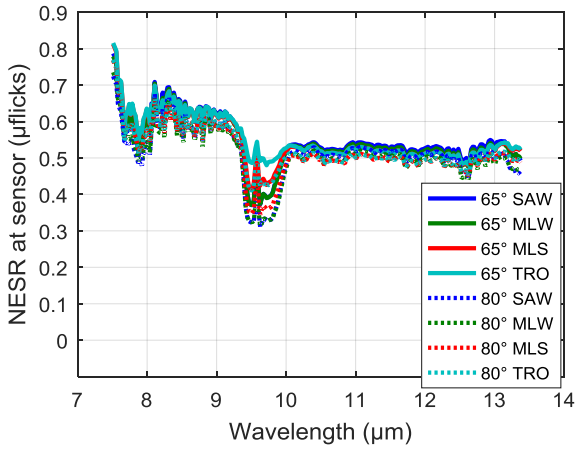


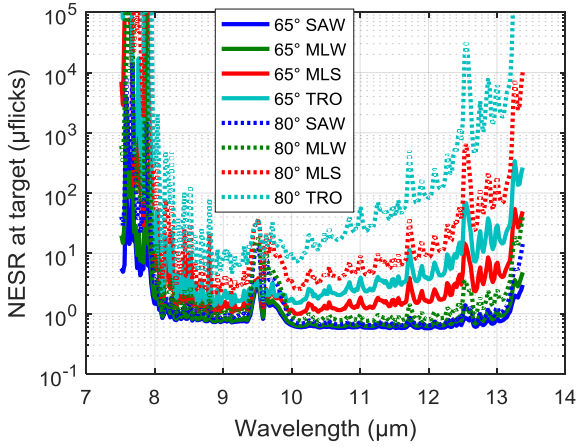
LWIR Scenario 2 Radiance, SNR, & NESR



- Examples of radiance at aperture shown here
- SNR variations due to slant range and target size
- NESR at aperture does not reflect performance differences for these cases







Scenario 2 Performance Results – Sun Behind

VNIR/SWIR

Parameters	Scenario 2 (50,000ft; Sensor System Performance Results)							
CONOPS	80° Off Nadir; 60Hz; 1 co-adds; 50m/s Back Scan	80° Off Nadir; 30Hz; 1 co-adds; 50m/s Back Scan	80° Off Nadir; 60Hz; 4 co-adds; 50m/s Back Scan	80° Off Nadir; 30Hz; 4 co-adds; 50m/s Back Scan	65° Off Nadir; 60Hz; 1 co-adds; 50m/s Back Scan	65° Off Nadir; 30Hz; 1 co-adds; 50m/s Back Scan	65° Off Nadir; 60Hz; 4 co-adds; 50m/s Back Scan	65° Off Nadir; 30Hz; 4 co-adds; 50m/s Back Scan
Parameters	**Mid Latitude Winter Performance Results**							
$NESR_{(@1um\ in\ MLW/SB)}$ # (uf)	10.89	7.67	5.42	3.83	11.99	8.47	5.99	4.24
$SNR_{(@\ 1um\ in\ MLW/SB)}$ #	381.98	540.42	763.96	1080.84	590.53	835.41	1181.06	1670.82
Parameters	**Sub Arctic Winter Performance Results**							
$NESR_{(@1um\ in\ SAW/SB)}$ # (uf)	10.91	7.71	5.46	3.86	12.03	8.50	6.02	4.25
$SNR_{(@\ 1um\ in\ SAW/SB)}$ #	383.11	542.01	766.21	1084.02	591.68	837.04	1183.36	1674.08

LWIR

Parameters	Scenario 2 (50,000ft; Sensor System Performance Results)			
CONOPS	80° Off Nadir; 200Hz; 1 co-adds; 50m/s Back Scan	80° Off Nadir; 100Hz; 1 co-adds; 50m/s Back Scan	65° Off Nadir; 200Hz; 1 co-adds; 50m/s Back Scan	65° Off Nadir; 100Hz; 1 co-adds; 50m/s Back Scan
Parameters	**Tropical Performance Results**			
$NESR_{(@10um\ in\ MLW/SB)}$ # (uf)	0.50	0.34	0.53	0.36
$SNR_{(@\ 10um\ in\ MLW/SB)}$ #	14	20	188	274
Parameters	**Mid Latitude Summer Performance Results**			
$NESR_{(@10um\ in\ SAW/SB)}$ # (uf)	0.48	0.33	0.52	0.35
$SNR_{(@\ 10um\ in\ SAW/SB)}$ #	38	56	282	412
Parameters	**Mid Latitude Winter Performance Results**			
$NESR_{(@10um\ in\ MLW/SB)}$ # (uf)	0.47	0.32	0.51	0.35
$SNR_{(@\ 10um\ in\ MLW/SB)}$ #	135	199	466	682
Parameters	**Sub Arctic Winter Performance Results**			
$NESR_{(@10um\ in\ SAW/SB)}$ # (uf)	0.48	0.32	0.52	0.35
$SNR_{(@\ 10um\ in\ SAW/SB)}$ #	160	236	497	727

Conclusions

- Presented initial findings for atmospheric effects on Long Stand-off Airborne Dual Band HSI systems performance.
- Model took into account atmospheric conditions, CONOPS and the imaging System for two scenarios:
  - A 25% and 50% reflectivity target and
  - An Olive Green target in mixed background.
- The initial results showed:
  - MLW and SAW were the best conditions for Mission Operations
  - Tropical was the worst conditions for Mission Operations
    - VNIR/SWIR 50% reflective target showed better results for Mission CONOPS of Sun **Behind** the sensor
- Results for Scenario 2 showed:
  - VNIR/SWIR NESR < 1μf and SNR ~100.
  - LWIR NESR ~ 0.5 μf and SNR 14–727 depending on atmosphere and slant range
  - The VNIR/SWIR Model Concept System results for Tropical showed NESR ≤ 5μf and SNR ~ 1000.
- **Atmospheric effects severely degrade long standoff HSI detection due to poor SNR, GRD, & SCR/contrast**
- Additional work still needs to be performed to better understand and describe the:
  - Complex Target/Background configuration
  - The effects of large Off-Nadir refractive atmospheric conditions

Acknowledgements

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  - Randall Zywicki
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