Project Report
LSP-251

CRISP Flight Campaign: FY18 Optical Systems Technology Line-Supported Program

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17 January 2019

Lincoln Laboratory
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LEXINGTON, MASSACHUSETTS

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EXECUTIVE SUMMARY

The CRISP multiplexing architecture enables high performance and low SWaP hyperspectral imaging systems. A flight ruggedized CRISP spectrometer was designed and built for a flight demonstration on Lincoln Laboratory's Cessna aircraft. Flight tests to collect emissivity spectra of sand and ocean water over the Plum Island and Cape Cod regions have demonstrated that the CRISP concept is robust under real-world conditions.

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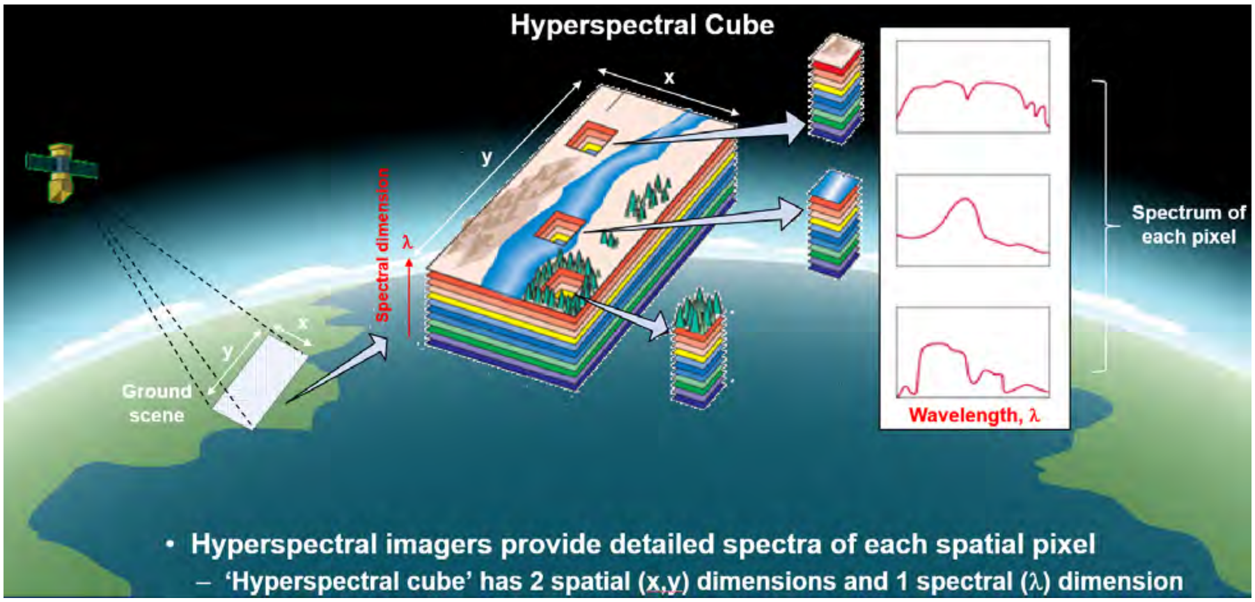
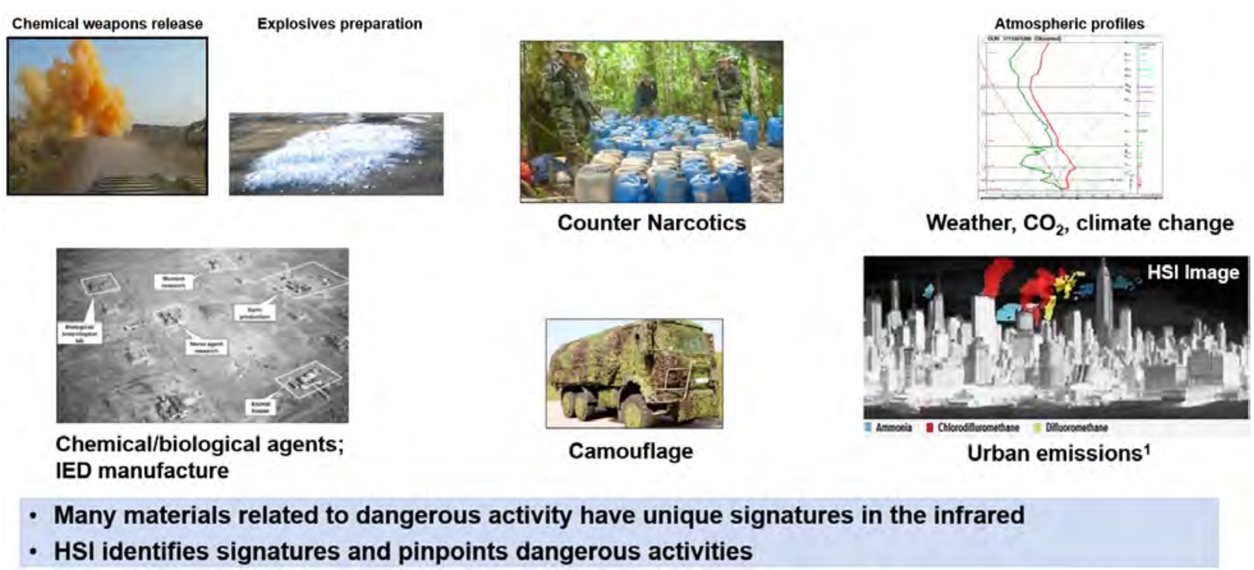
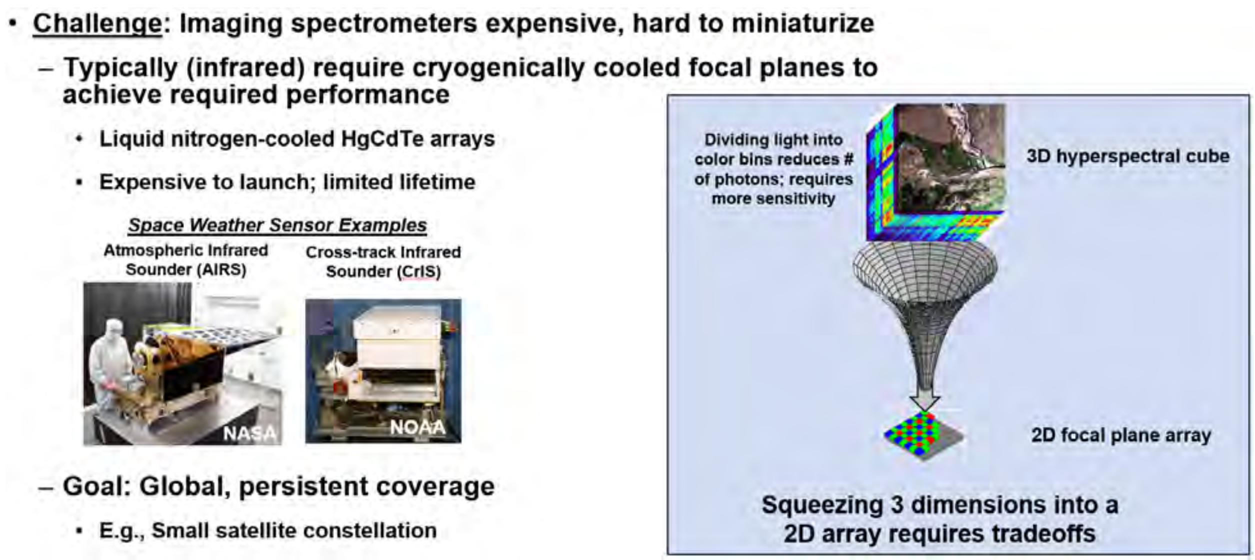
1.1 WHAT IS HYPERSPECTRAL IMAGING (HSI)?



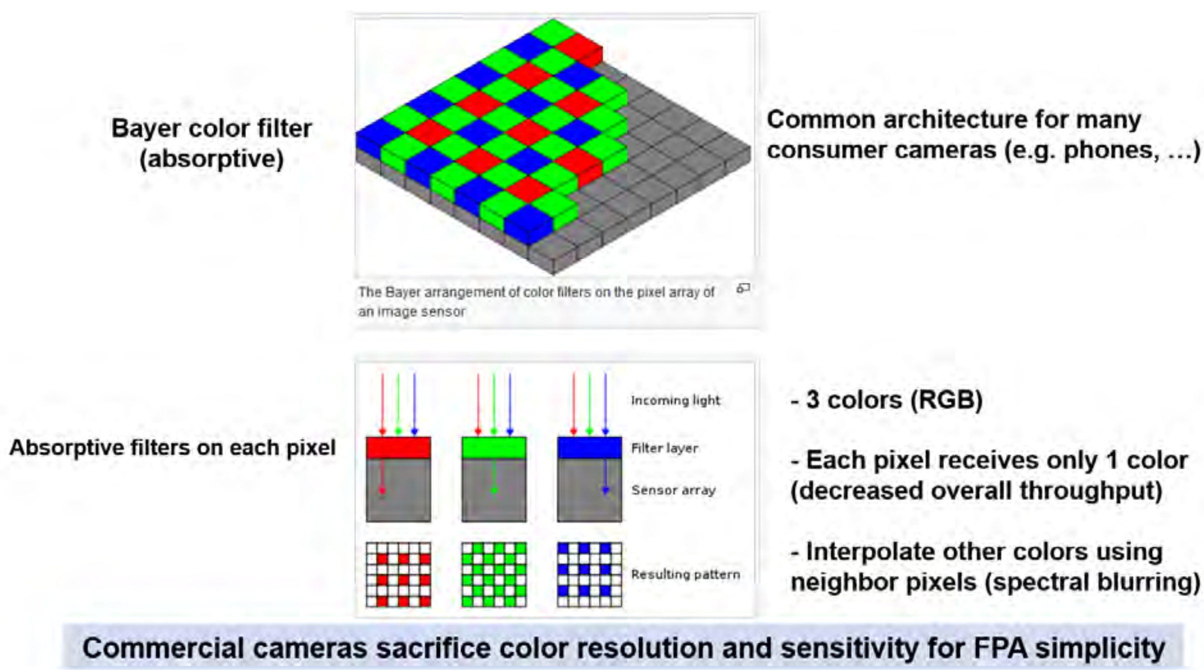
1.2 WHY HYPERSPECTRAL IMAGING?



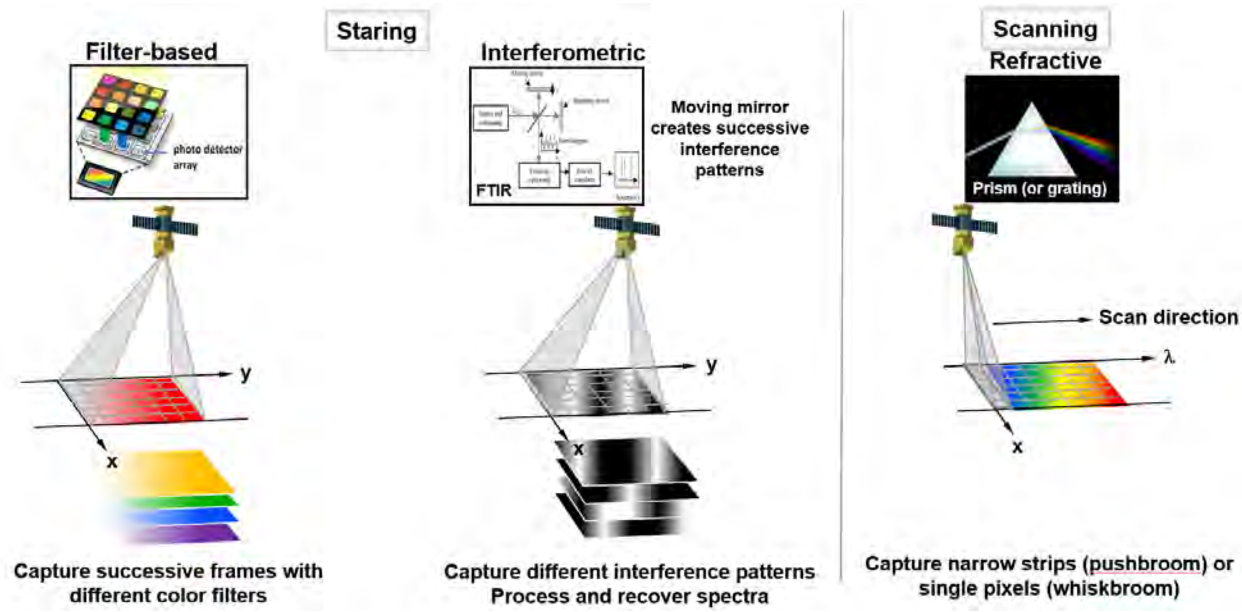
1.3 IMAGING SPECTROMETER CHALLENGES



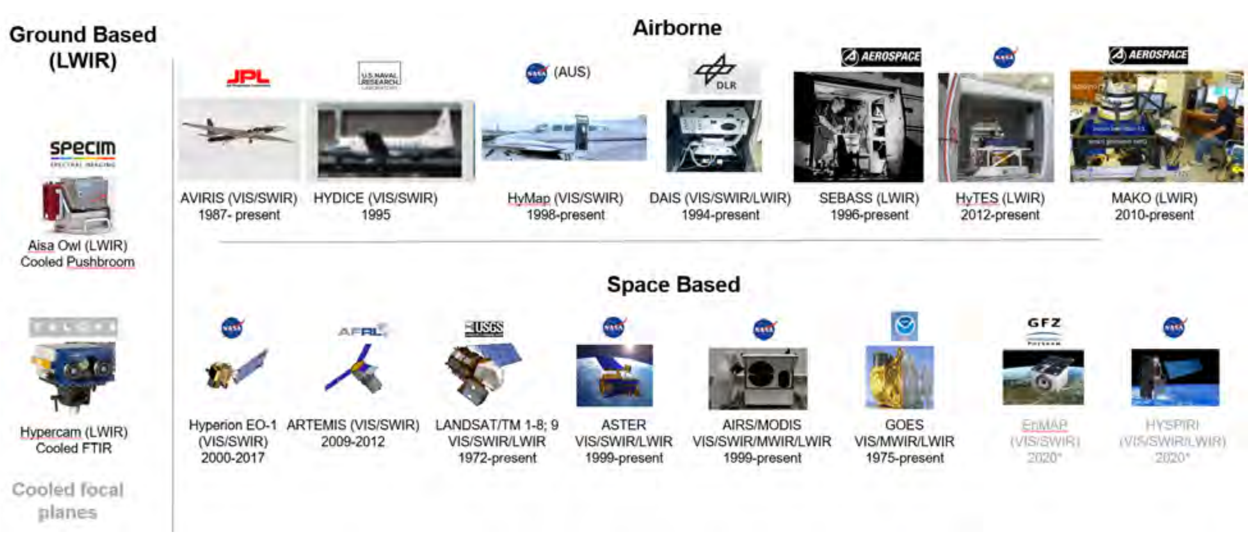
1.4 CONVENTIONAL 3-COLOR RGB IMAGING



1.5 PASSIVE IMAGING SPECTROMETERS

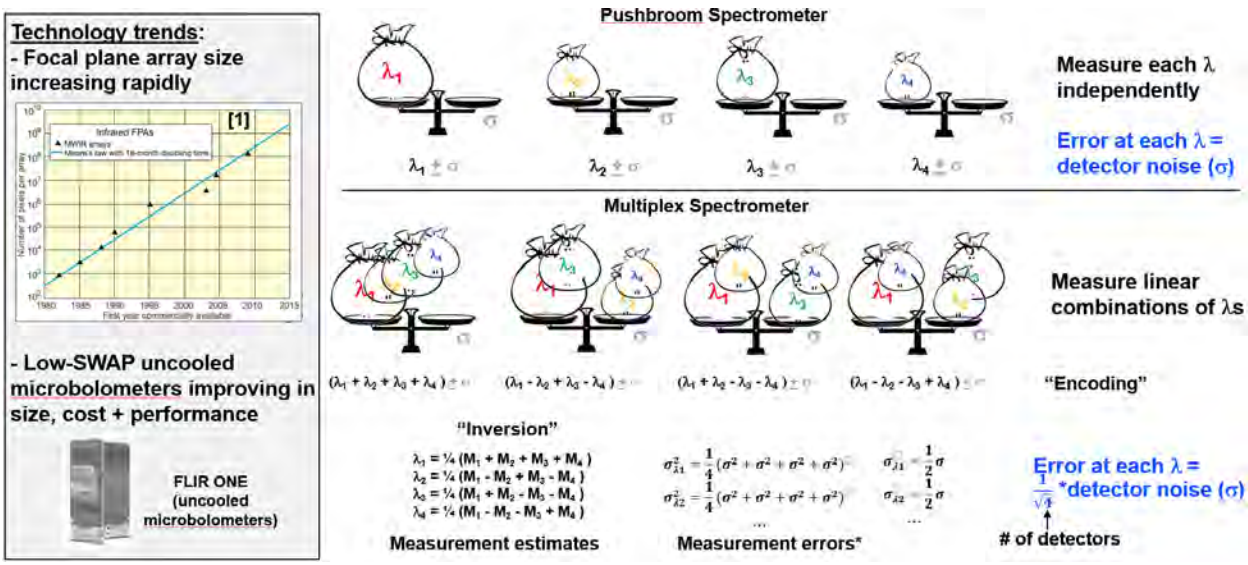


1.6 SPECTRAL IMAGING SYSTEMS

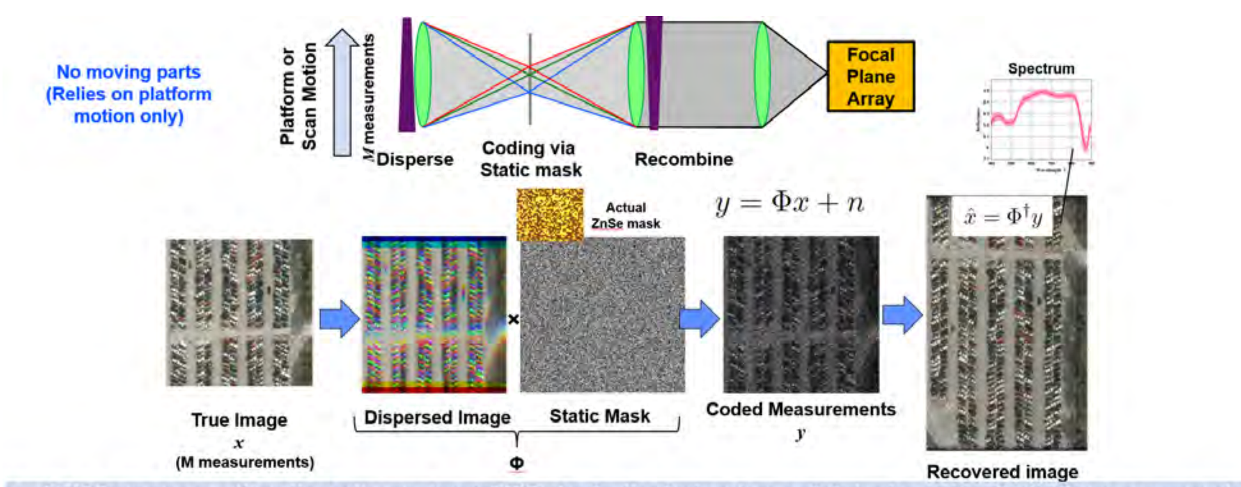


2. MULTIPLEXING, COMPUTATIONAL IMAGING, AND CRISP… DOING MORE WITH LESS

2.1 MICROBOLOMETERS AND MULTIPLEXING

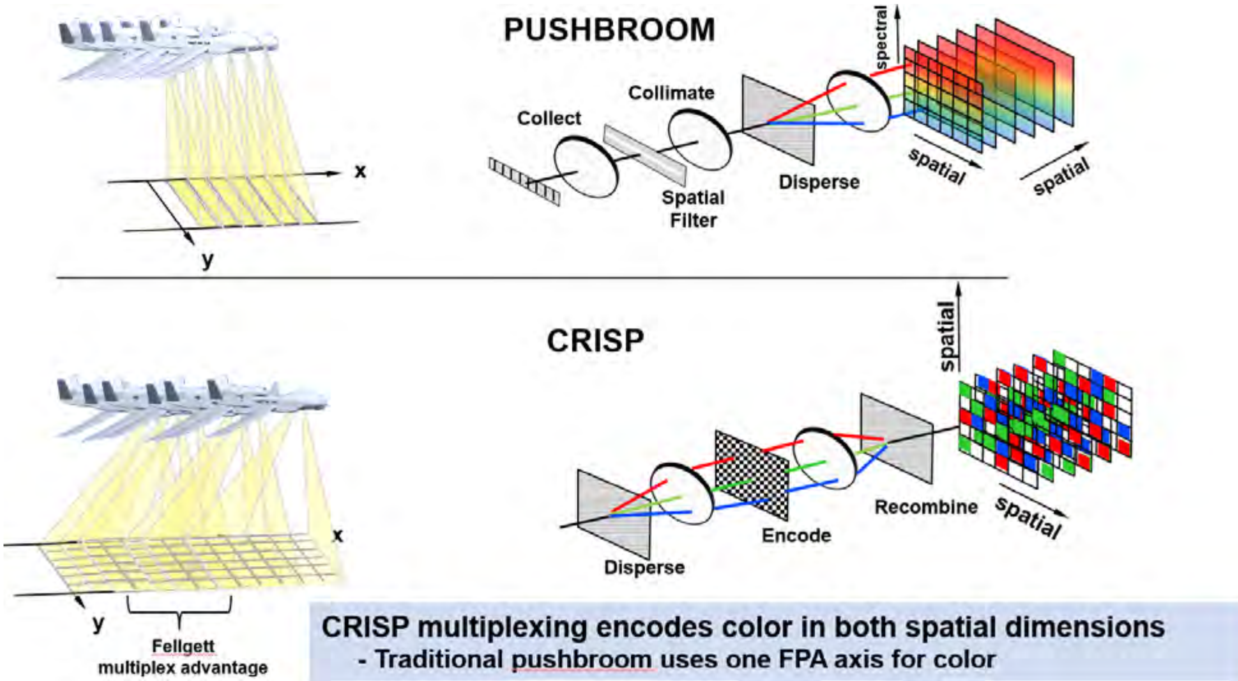


2.2 CRISP SPECTRAL DECODING

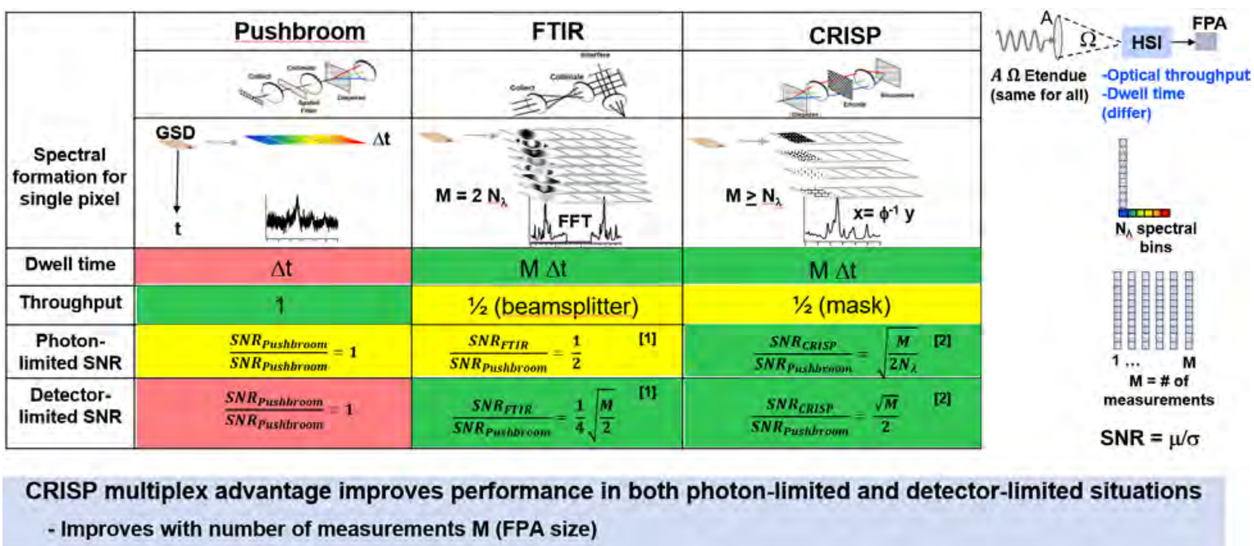


- CRISP more sensitive than dispersive + FTIR, for both shot-noise and detector-noise limited measurements
- CRISP advantage maximized with noisy detectors

2.3 HYPERSPECTRAL IMAGER OPERATION



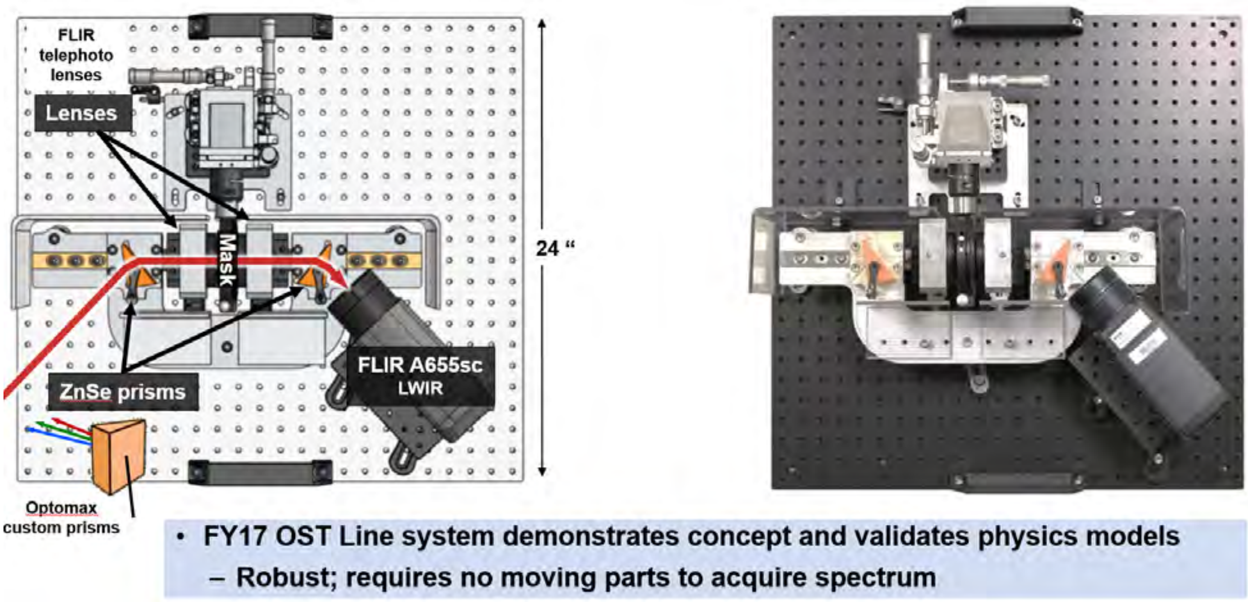
2.4 COMPARISON OF HSI SYSTEMS



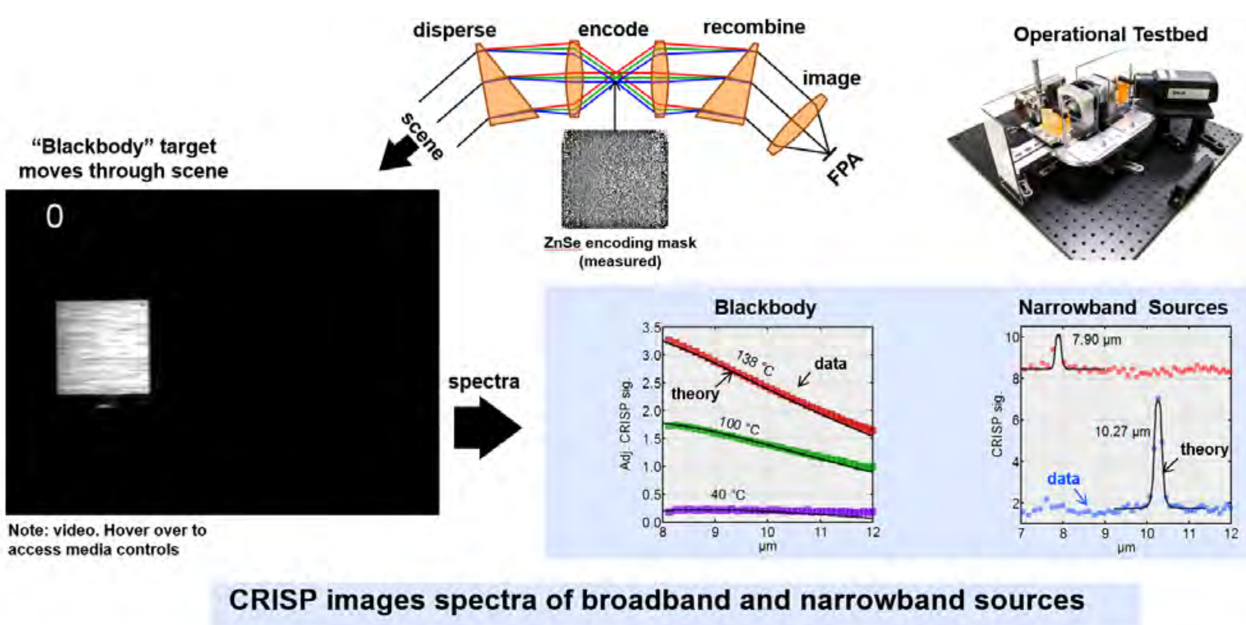
	Pushbroom	FTIR	CRISP
Spectral formation for single pixel	GSD, Δt, t	$M = 2 N_\lambda$, FFT	$M \geq N_\lambda$, $x = \phi^{-1} y$
Dwell time	Δt	$M \Delta t$	$M \Delta t$
Throughput	1	½ (beamsplitter)	½ (mask)
Photon-limited SNR	$\frac{SNR_{Pushbroom}}{SNR_{Pushbroom}} = 1$	$\frac{SNR_{FTIR}}{SNR_{Pushbroom}} = \frac{1}{2}$ [1]	$\frac{SNR_{CRISP}}{SNR_{Pushbroom}} = \sqrt{\frac{M}{2N_\lambda}}$ [2]
Detector-limited SNR	$\frac{SNR_{Pushbroom}}{SNR_{Pushbroom}} = 1$	$\frac{SNR_{FTIR}}{SNR_{Pushbroom}} = \frac{1}{4}\sqrt{\frac{M}{2}}$ [1]	$\frac{SNR_{CRISP}}{SNR_{Pushbroom}} = \frac{\sqrt{M}}{2}$ [2]

3. CRISP PROOF-OF-CONCEPT

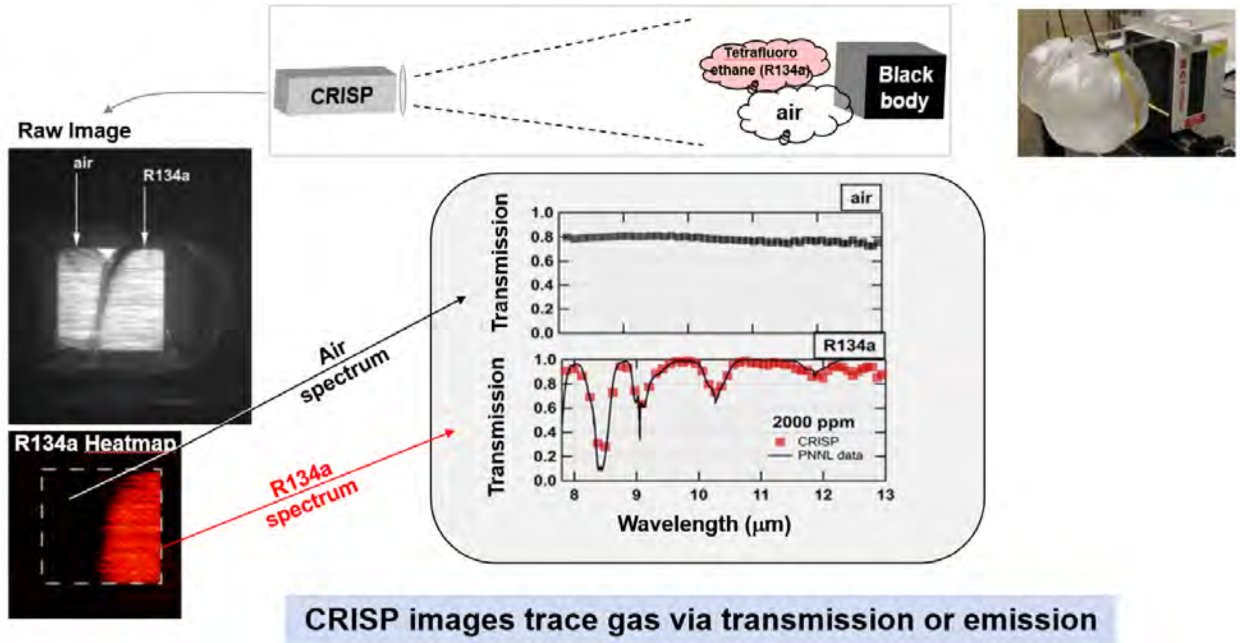
3.1 CRISP PROOF-OF-CONCEPT TESTBED



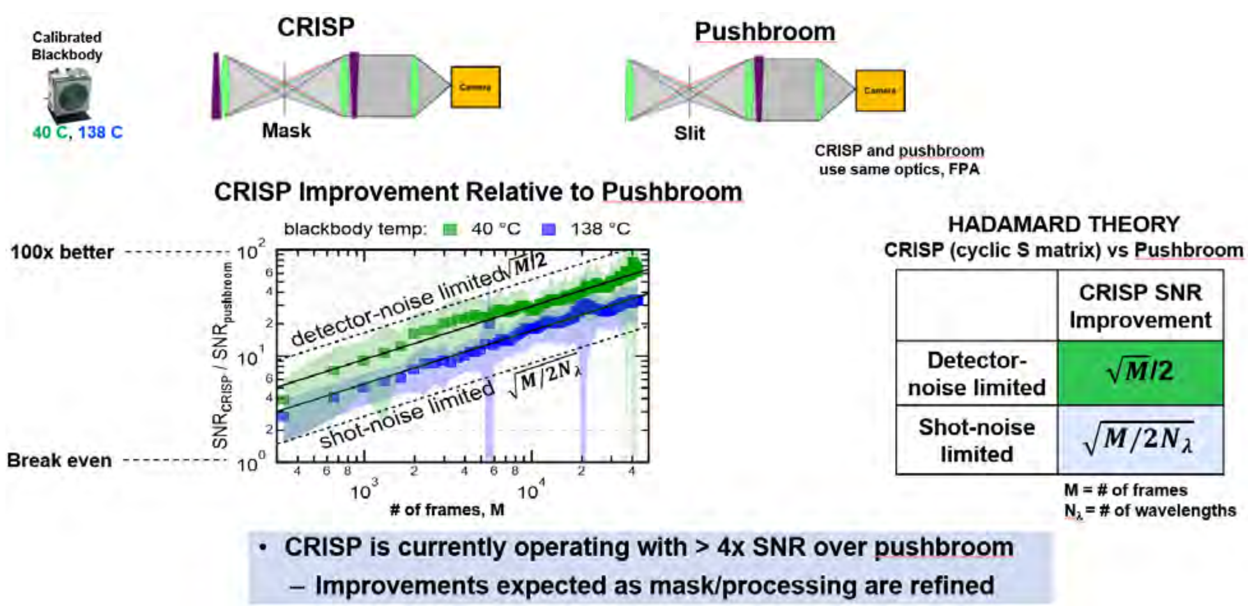
3.2 CRISP HYPERSPECTRAL IMAGERY



3.3 CRISP APPLICATION: TRACE PLUME DETECTION

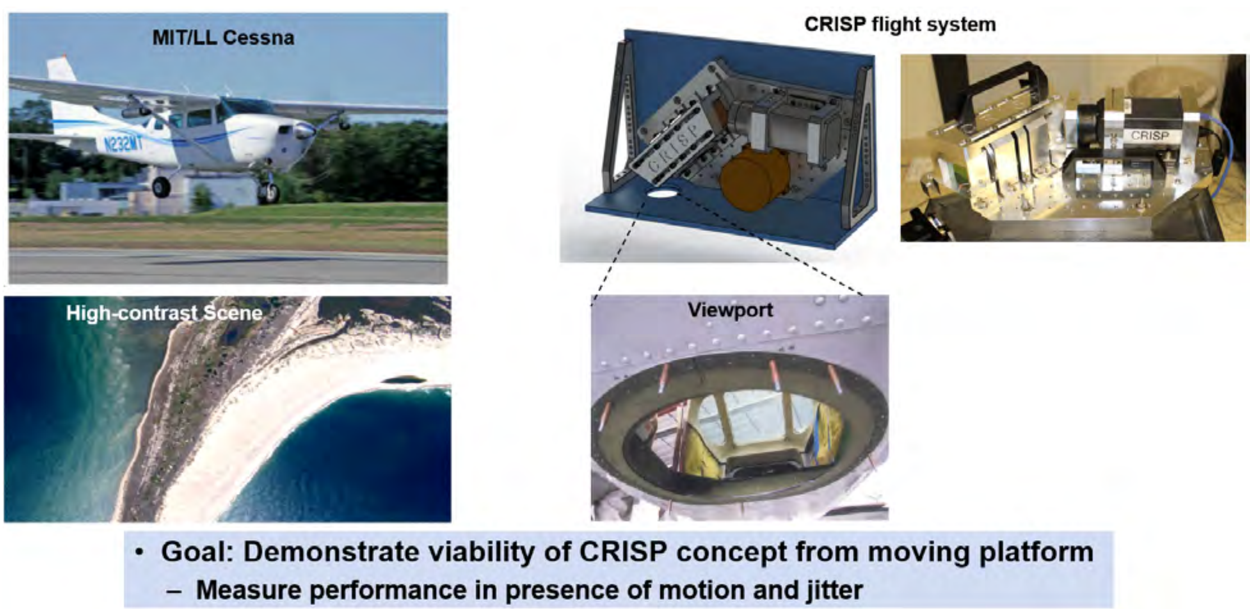


3.4 CRISP SENSITIVITY ADVANTAGE

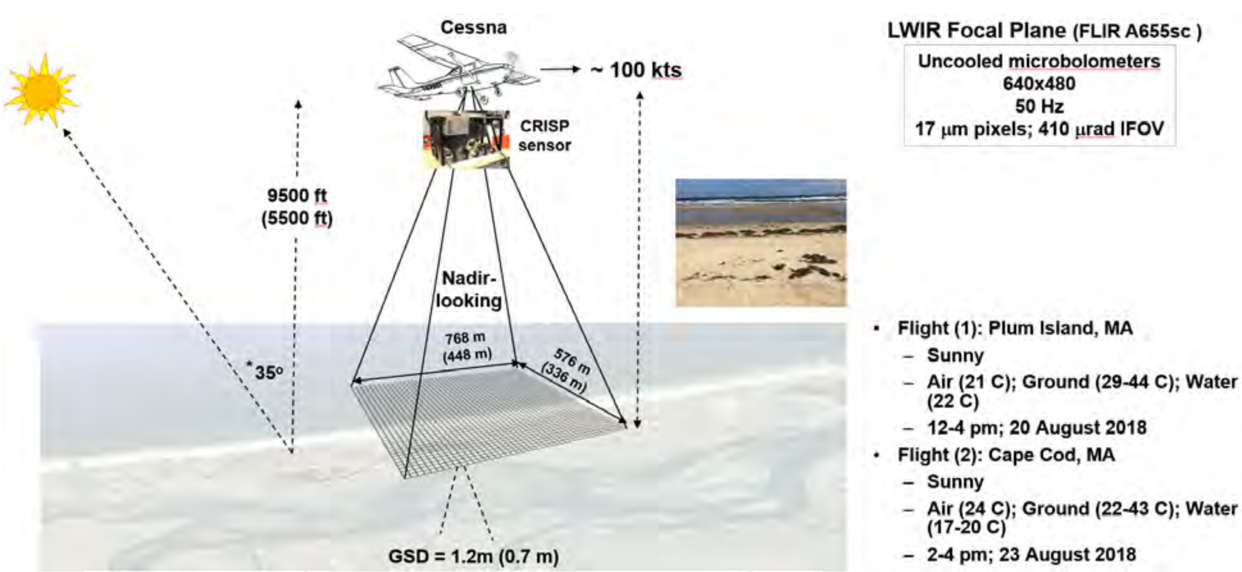


4. CRISP FLIGHT TESTS

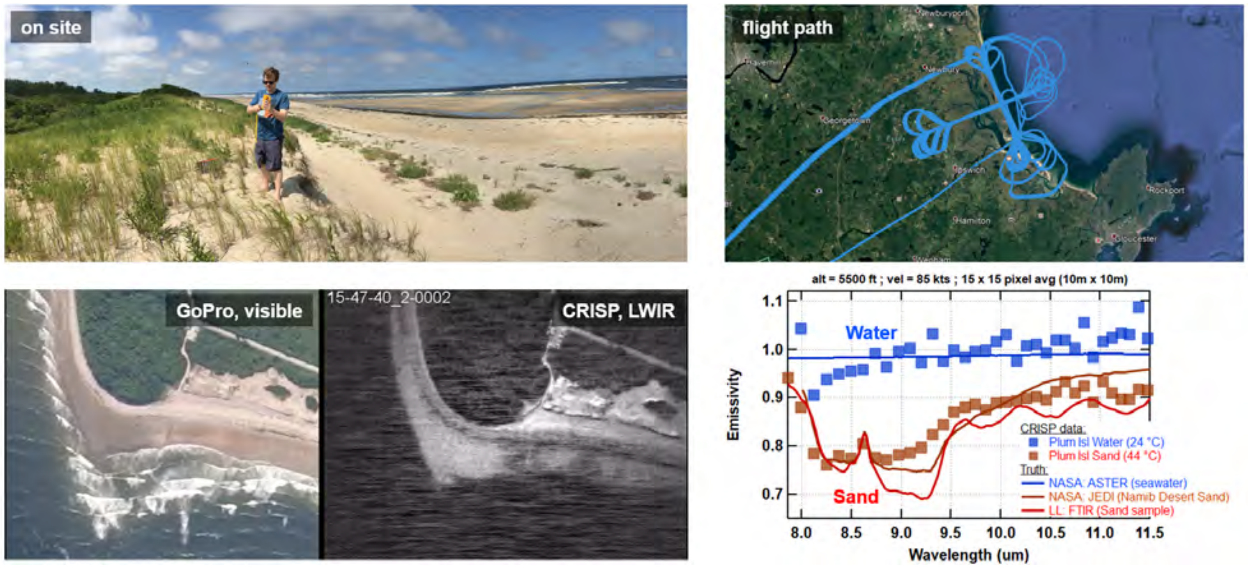
4.1 CRISP FLIGHT TEST PROGRAM FY18 OST LINE



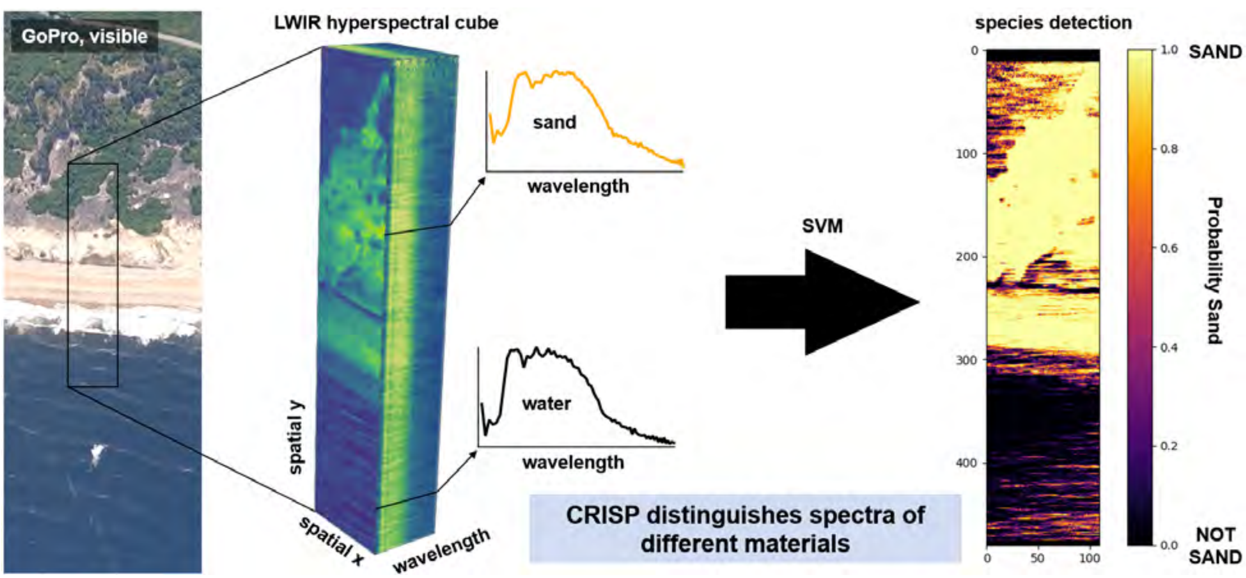
4.2 CRISP FLIGHT COLLECTIONS



4.3 CRISP SPECTRA: PLUM ISLAND COASTLINE



4.4 CRISP HYPERSPECTRAL IMAGERY



5. ACKNOWLEDGEMENTS

- CRISP team
  - Ryan Sullenberger, John Lessard, Yaron Rachlin, Zach Palmer, Sumanth Kaushik (Gp 91)
  - Adam Milstein (Gp 97)
  - Corrie Smeaton, Phil Chapnik (Gp 78)
- Funding
  - OST Line support
  - NASA (ACT)

- Publications
  - "Computational reconfigurable imaging spectrometer", R. M. Sullenberger, A. B. Milstein, Y. Rachlin, S. Kaushik, and C. M. Wynn, *Opt. Expr.* 25, 31960 (2017).
  - Invention disclosure: "Computational reconfigurable imaging spectrometer (CRISP)", A. Milstein, Y. Rachlin, C. Wynn, R. Sullenberger, S. Kaushik; Filed 2017.

REFERENCES

Sullenberger, Ryan M, Adam B Milstein, Yaron Rachlin, and Kaushik Sumanth, "Computational reconfigurable imaging spectrometer," *Opt. Expr.* 25 (31960), 2017.