



# Bridge Modeling and Application For Determining In-Flight Sensor Spatial Resolution

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Program

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# Outline



Background

Cal/Val & Bridges

Bridge Simulations

Public Sensor Assessments

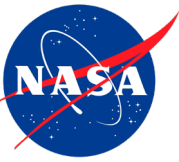
- Landsat 8/9
- Sentinel-2

Commercial Sensor Assessment

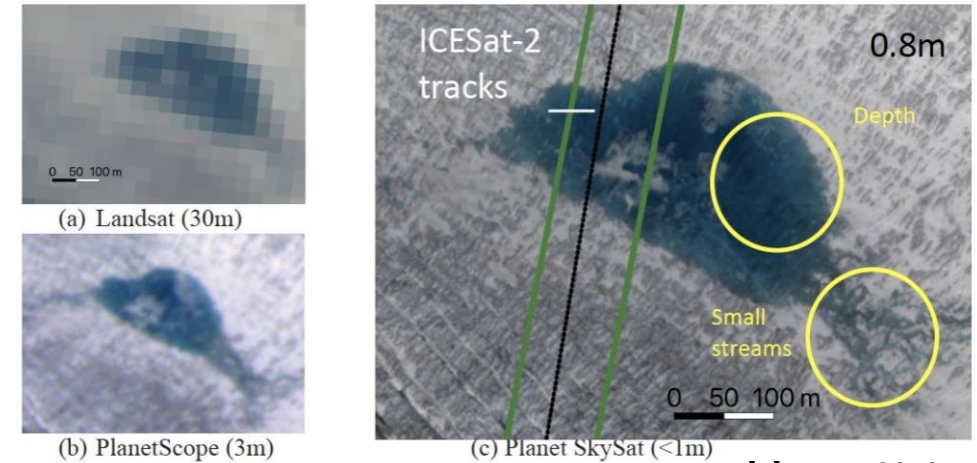
- GHGSat

Summary

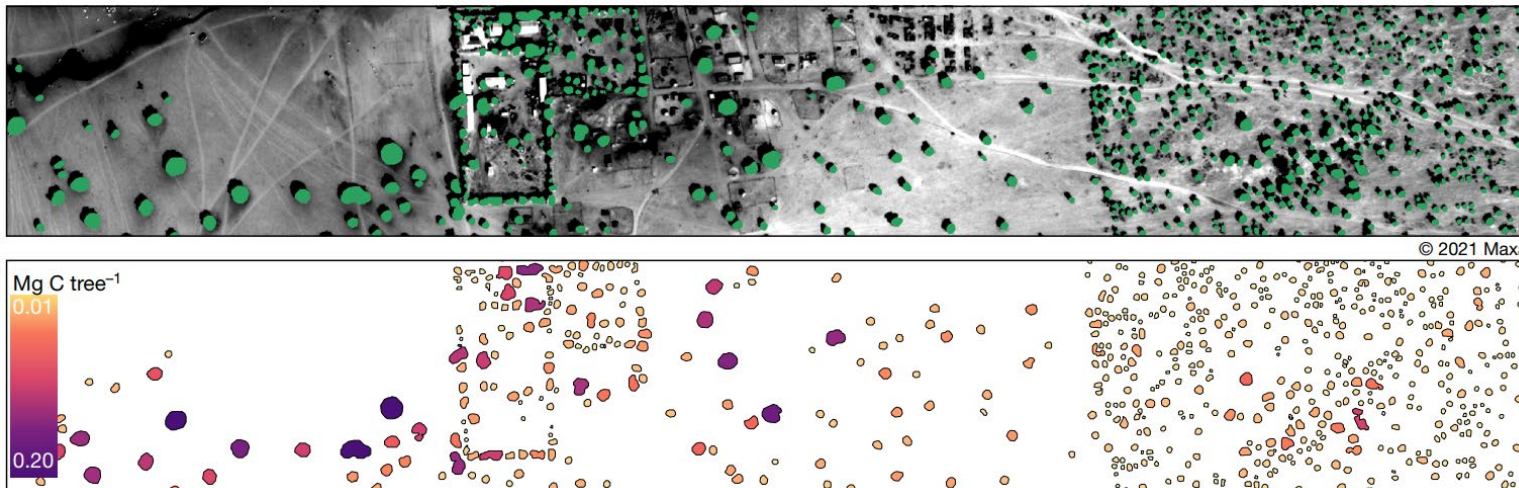
# Background



- Characterize sensor footprint size of satellite data for NASA's Commercial Satellite Data Acquisition (CSDA) program.
- Sensor footprint size is a determining factor in scientific studies.
- Sensor footprint size is not always equivalent to image pixel size.



[1] Datta, 2019

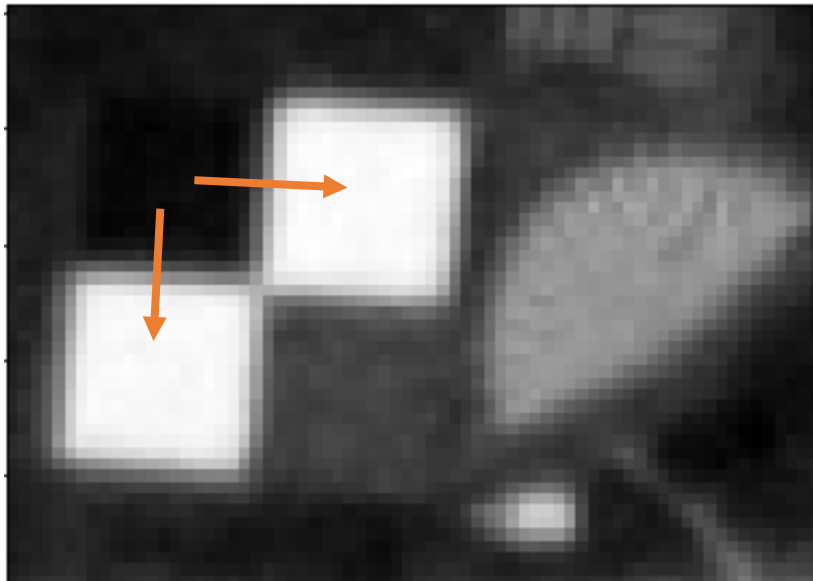


[3] Tucker et al, 2023

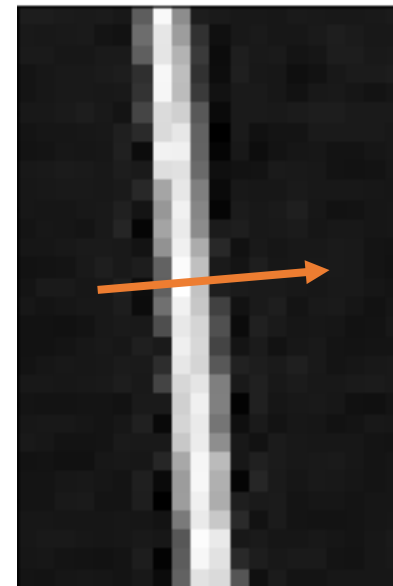
# Determining Sensor Resolution - Find transitions

- Current Cal/Val sites for <math><6\text{m}</math> pixels
- Local (skinny) bridges for  $\sim 10\text{m}$  pixels
- Wide bridges over water for  $>30\text{m}$  pixels

**Cal/Val sites**

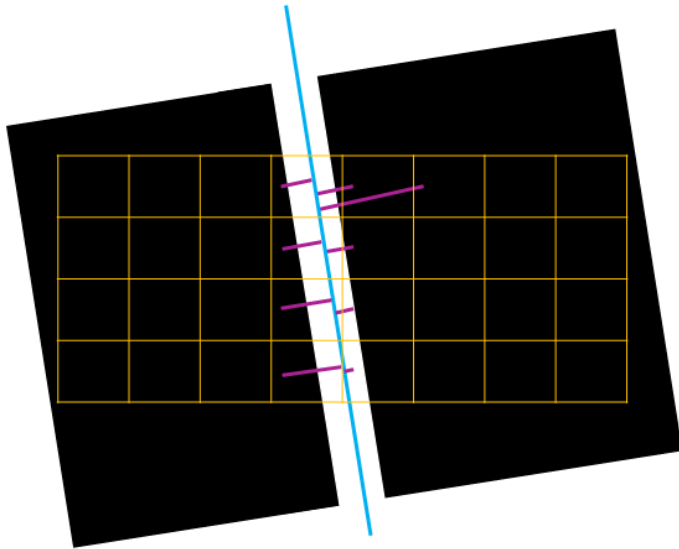


**Bridges**

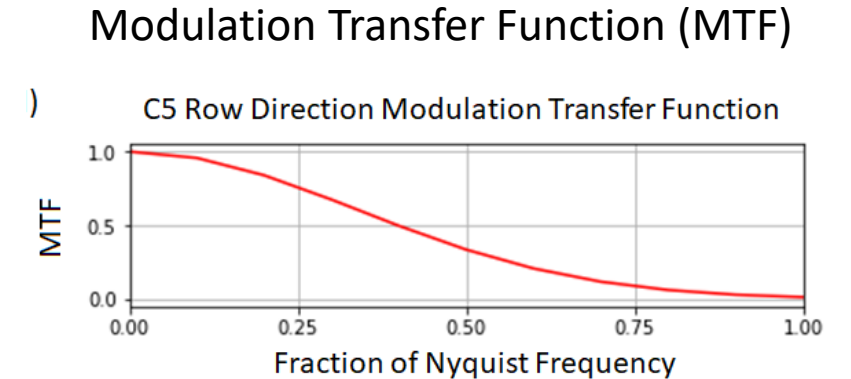
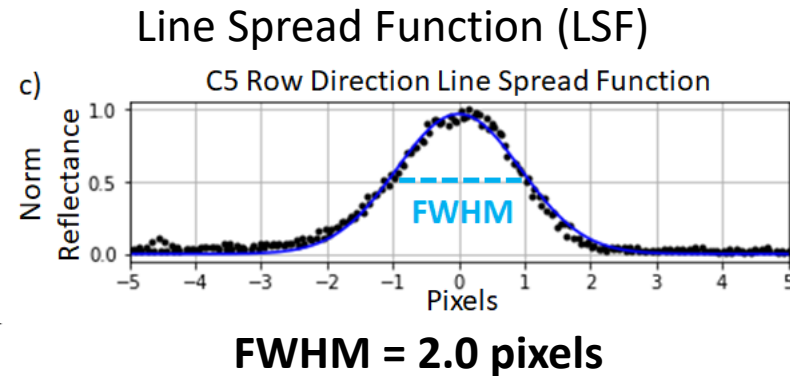


# Bridge "Slit" Methods

- Extract pixels along the bridge.
- Transform from pixel number to distance from bridge center.
- Fit a line to the points, this is the Apparent Line Spread Function (LSF).
- Fourier transform the LSF to find Modulation Transfer Function (MTF).

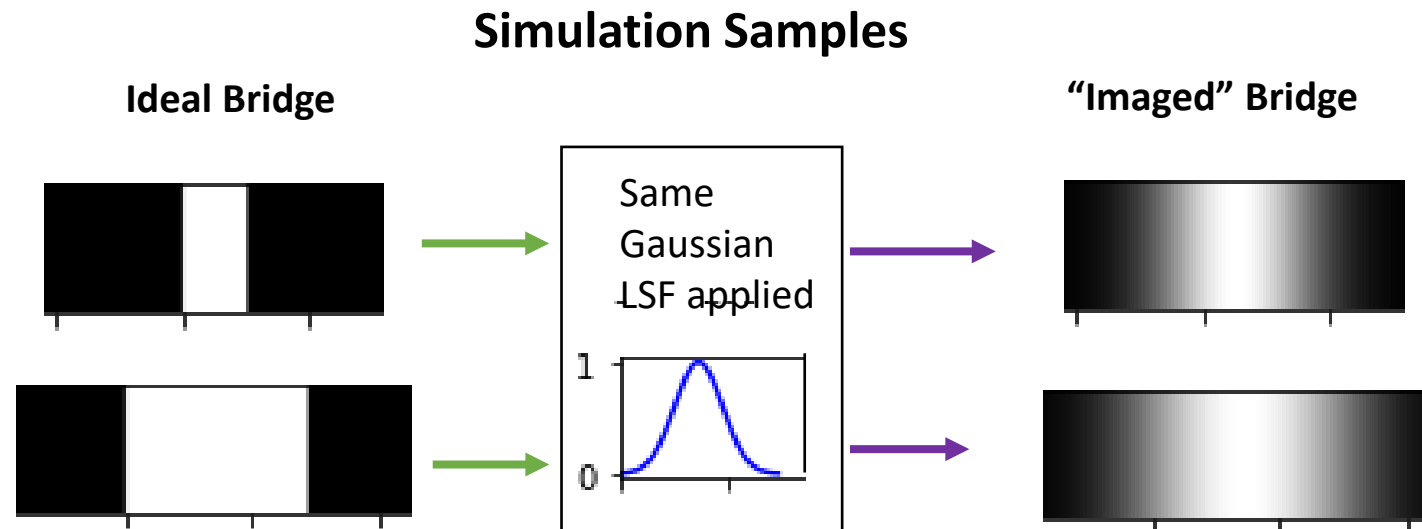


\*NOT TO SCALE, sizes exaggerated for demonstration



# Bridge Simulations

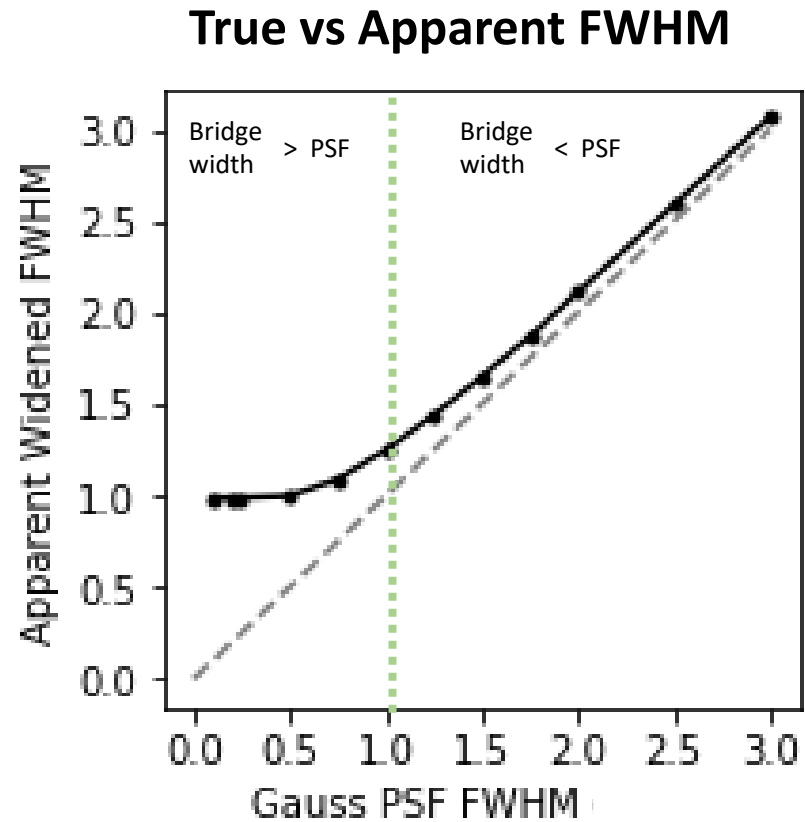
- Simulate impacts of bridge width on LSF estimation.
  - Gaussian LSF is applied to an idealized white 'bridge' on a black background
  - Difference in returned apparent LSF FWHM and applied Gaussian FWHM is determined.
  - Various combinations of  $\frac{\text{Bridge width}}{\text{Pixel size}}$  ratios are tested and an empirical relationship established.
- Use simulation results to remove impacts of bridge width on LSFs retrieved from bridge images.



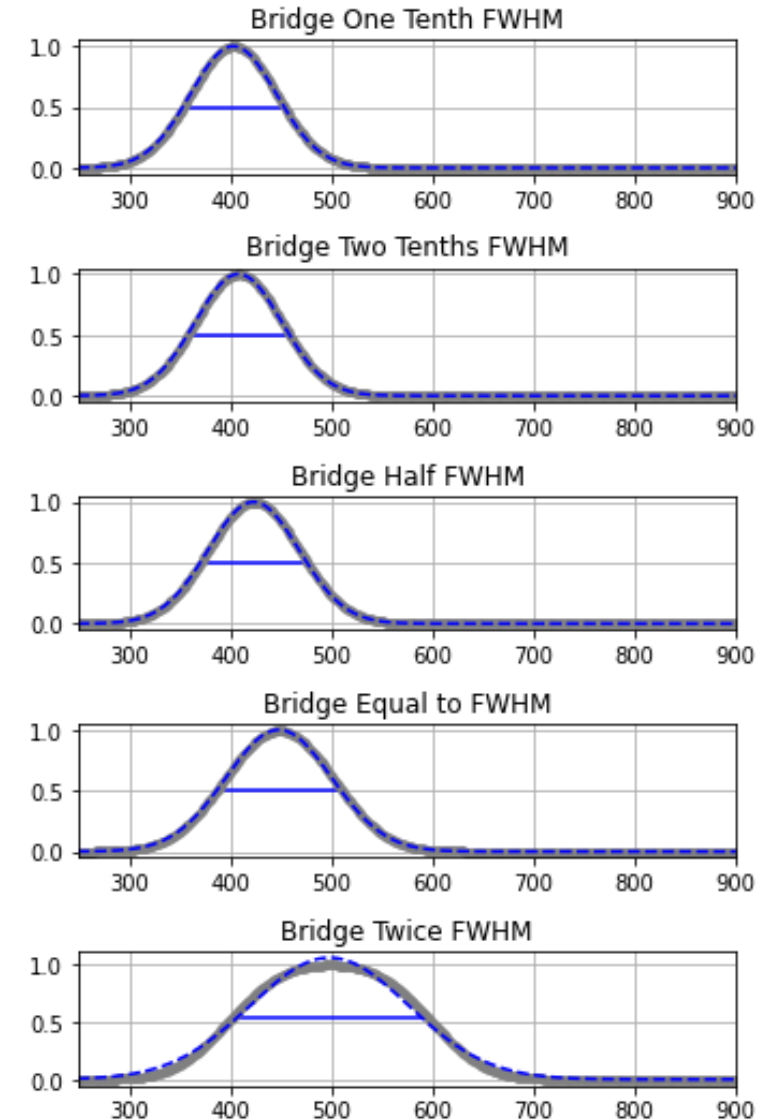
Same Gaussian LSF applied, different apparent FWHM returned due to different  $\frac{\text{Bridge width}}{\text{Pixel size}}$  ratios

# Apparent vs True FWHM

- Various combinations of  $\frac{\text{Bridge width}}{\text{Pixel size}}$  ratios are tested and an empirical relationship between true and apparent FWHM established.

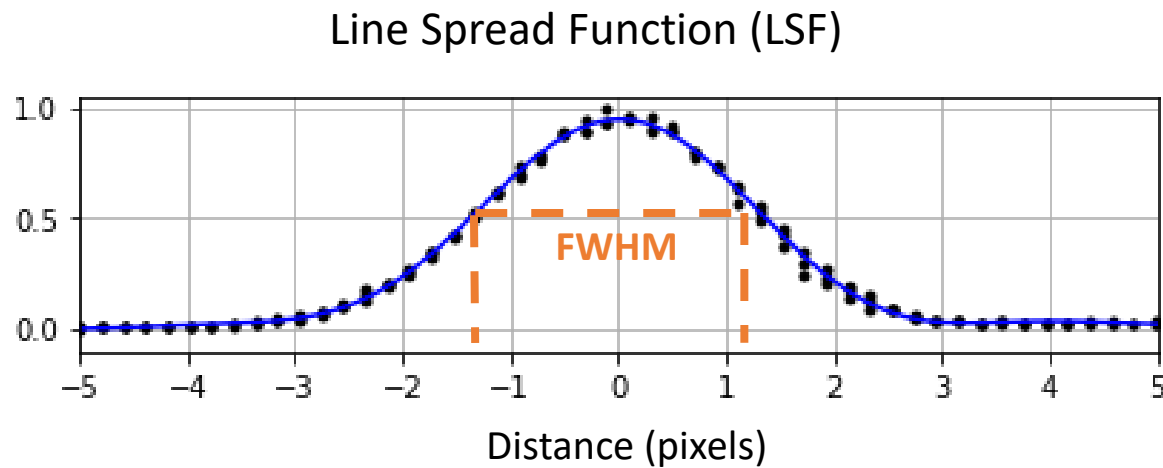


## Simulated “Imaged” LSFs



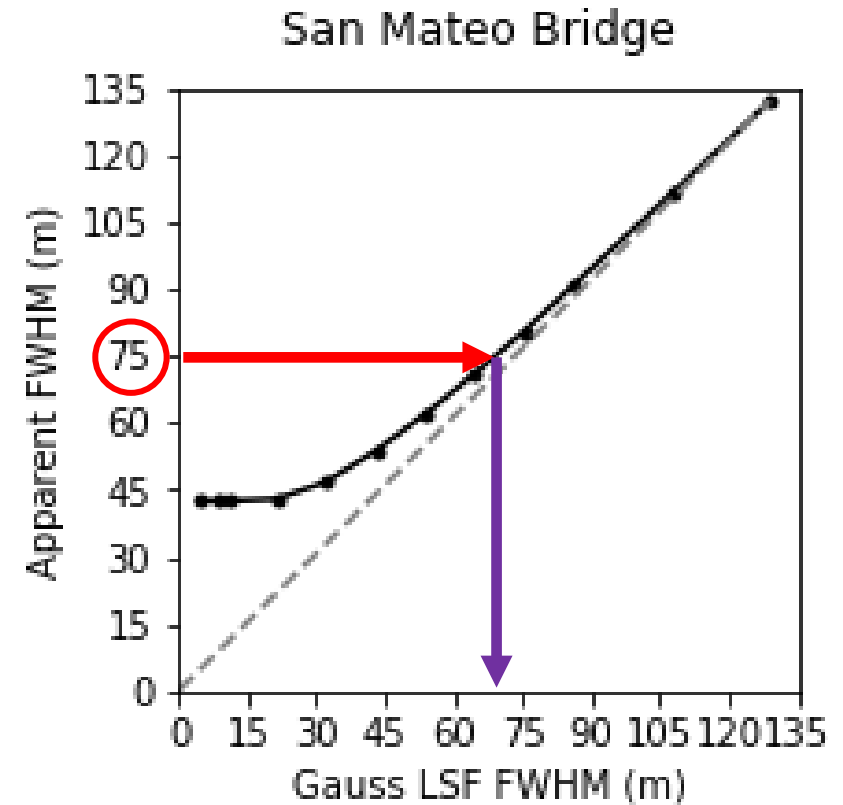
# Application Example

- An example application of removing bridge width interference from the LSF
- Use simulation results to remove impacts of bridge width on LSFs retrieved from bridge images.
- To use: Multiply the axis by bridge width/pixel size for your use case



**Apparent FWHM = 2.8 pixels, 75 m**

**True FWHM = 2.5 pixels, 70 m**



\*San Mateo Bridge = 43m wide in this view angle.

# Testing the Model

- We test the validity of our modeling with Landsat-8 and Sentinel-2A images
- Bridges used in tests for 30m images are:
  - San Mateo Bridge, California
  - Golden Gate Bridge, California
- Bridges used in tests for 10 m & 15 m images are:
  - Navarre Beach Causeway, Florida
  - Old Bahia Honda Bridge, Florida

# Catalog of Bridges

- [EROS CalVal Center of Excellence Spatial Sites Catalog](#)

Google Earth Picture

State, Country

Bridge Name

Approximate Width

Coordinates

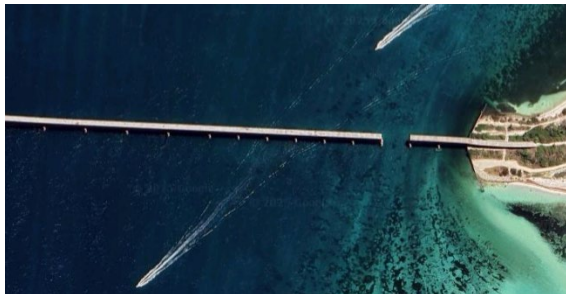


Florida,  
USA

Navarre Beach  
Causeway

11 m

30.40, -86.86



Florida,  
USA

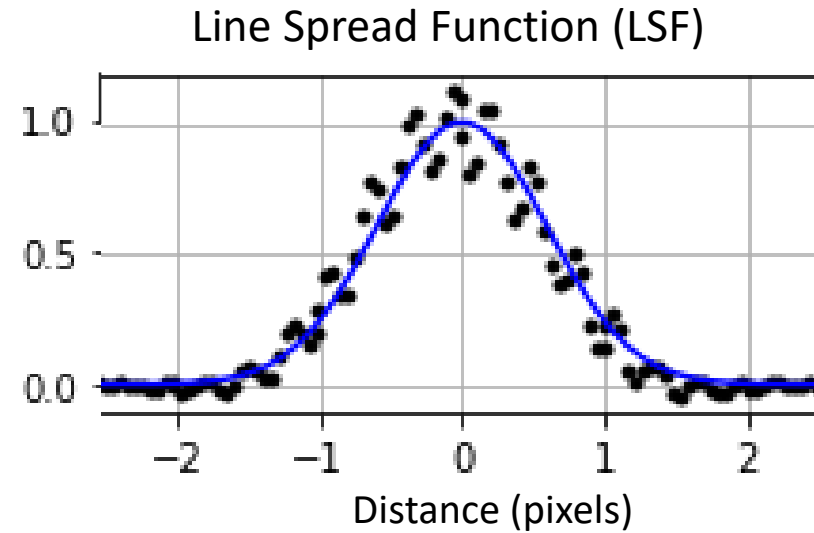
Old Bahia  
Honda Bridge

7.5 m

24.66, -81.29

# Landsat-8/9 assessment

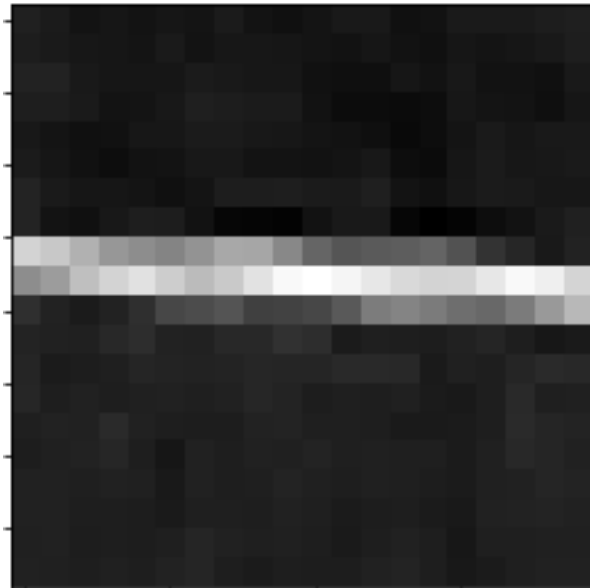
- 30m band 2 (blue) assessed at King Fahd Causeway
- Bridge width  $\sim 25$  m



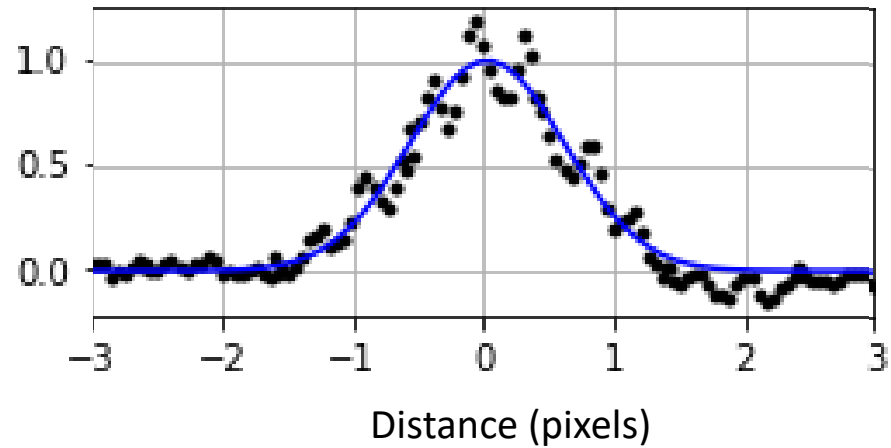
Apparent FWHM = 1.3 pixels  
Adjusted FWHM = 1.0 pixels

# Sentinel-2 Assessment

- 10m RGB bands assessed at a Florida, USA bridges.
- Bridge width  $\sim 7.5\text{m}$



Line Spread Function (LSF)

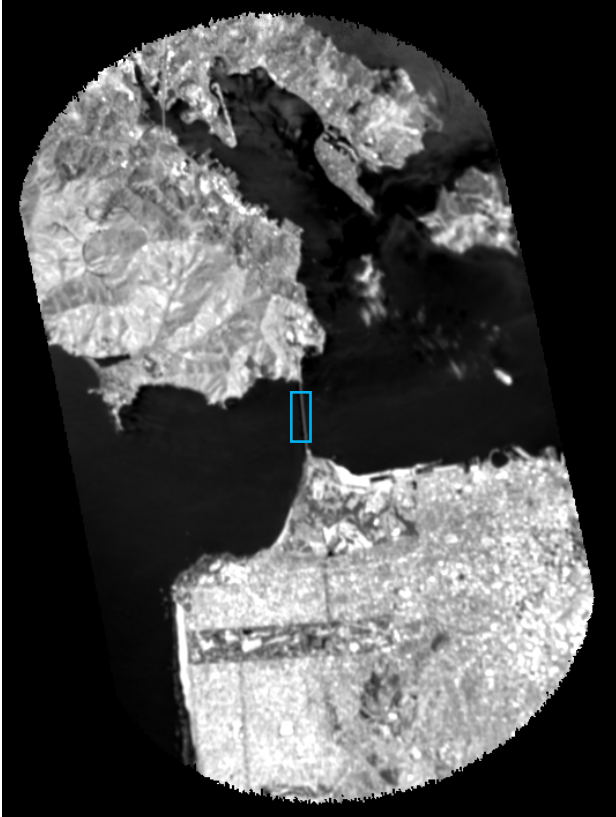


Apparent FWHM = 1.3 pixels  
Adjusted FWHM = 1.1 pixels

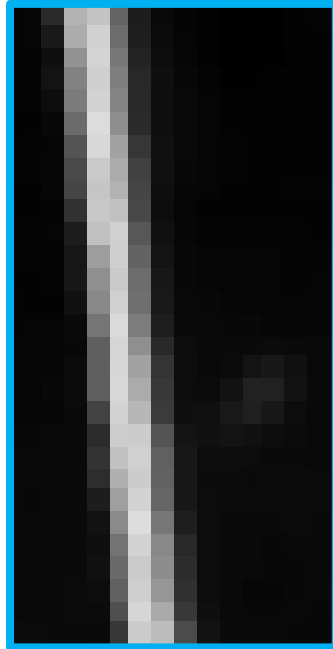
# Application to GHGSat Evaluation

- CSDA evaluated GHGSat for geometric accuracy, ~30m pixels with resolution of 50 m.
- 4 images from 3 sensors were obtained over two bridges:

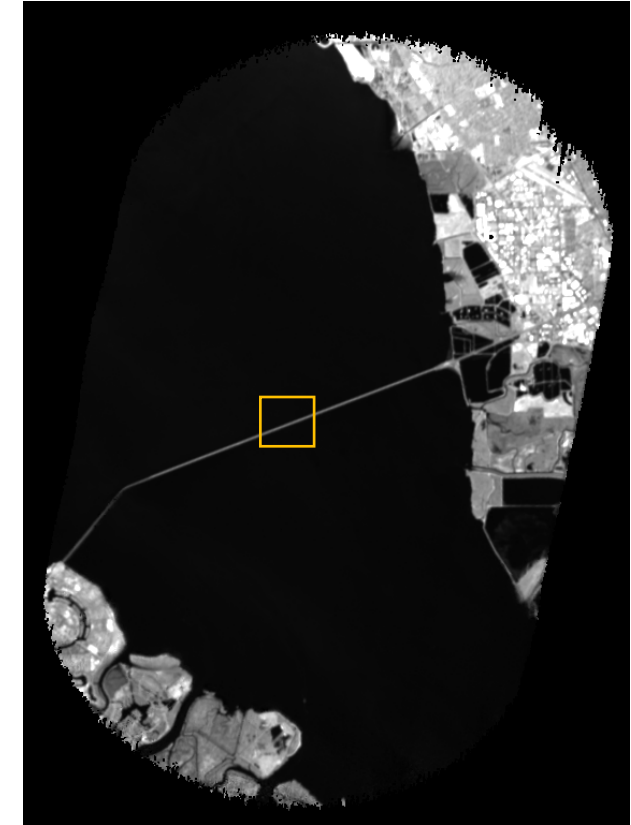
**Golden Gate Bridge (row direction SSR)**  
**23 m wide, 23 m effective width (5° tilt)**  
GHGSat C5 - Surface Reflectance (ALB) image



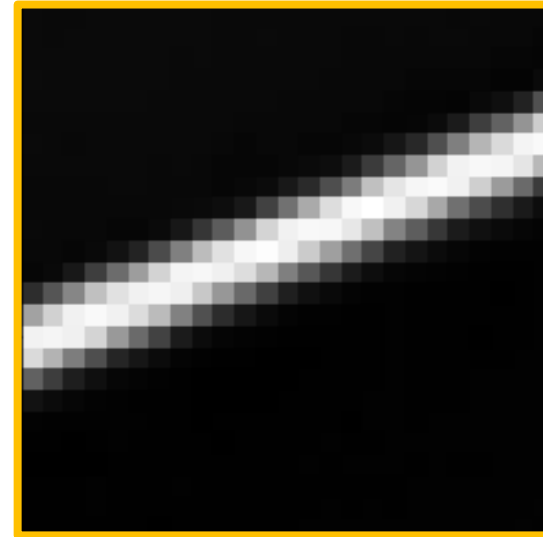
Zoom on bridge



**San Mateo Bridge (column direction SSR)**  
**41 m wide, 43 m effective width (20° tilt)**  
GHGSat C5 - Surface Reflectance (ALB) image



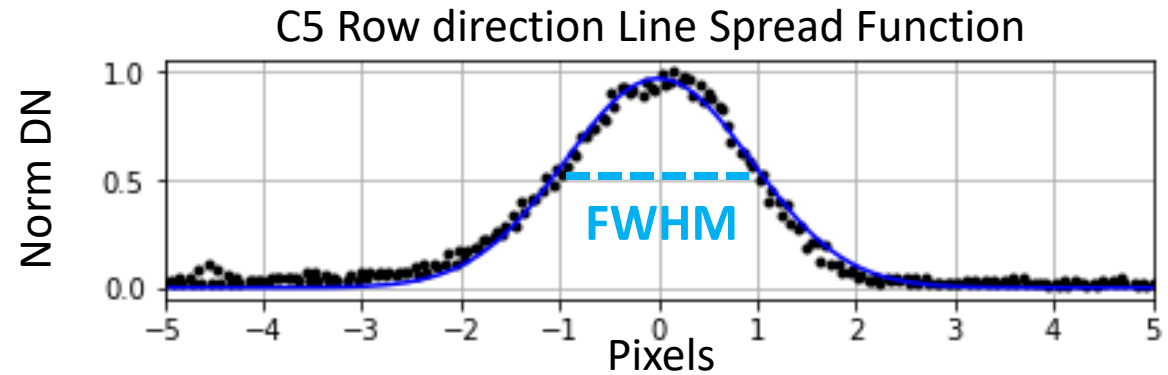
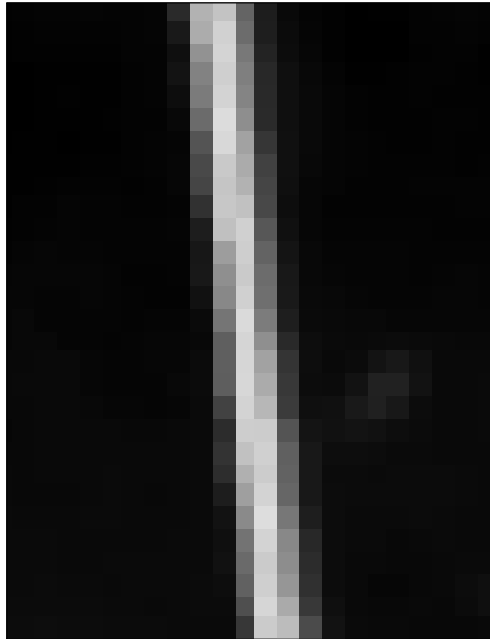
Zoom on bridge



# GHGSat's C5 Row SSR Analysis

Pixel size here is 32.6 m

Bridge width = 23 m



Apparent FWHM = 2.0 pixels, 65.2 m

Adjusted FWHM = 1.9 pixels, 61.9 m

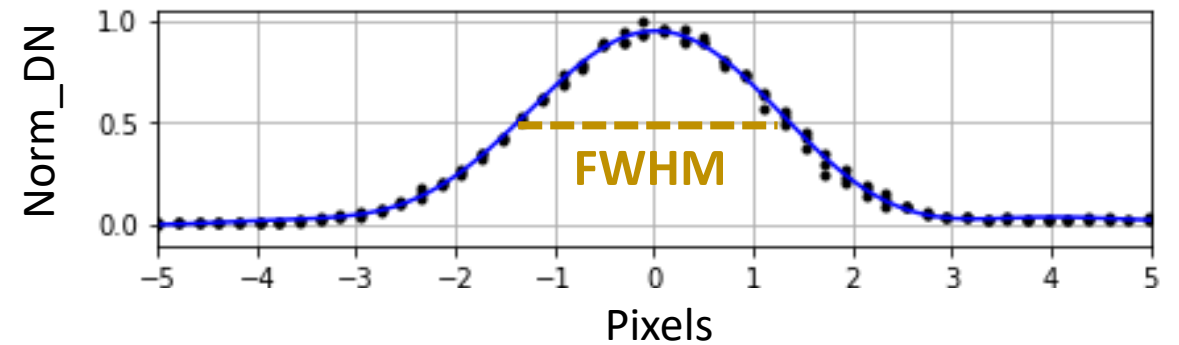
# GHGSat's C5 Column SSR Analysis

Pixel size here is 27.0 m

Bridge width = 43 m



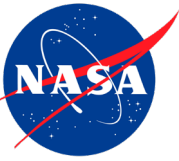
C5 Column direction Line Spread Function



Apparent FWHM = 2.8 pixels, 75 m

Adjusted FWHM = 2.5 pixels, 69 m

# Summary



- Bridges have been used to successfully evaluate sensor footprint size for in-flight sensors ranging from pixel size 10-33 m.
- Bridge modeling has improved certainty of retrieved FWHM from bridge analysis.
- Bridge modeling has been validated on Landsat8 and Sentinel-2A sensors.
- GHGSat's C2, C5, & C7 sensor spatial resolution ranges from 62 - 70 m.