Innovative Imaging & Research

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Aerial Imaging Quality Assurance

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Electro-Optical Image Quality

- Sensor calibration and data product validation is more than just metric calibration…
- Spatial Resolution
  - A measure of the smallest feature that can be resolved or identified within an image
- Radiometric Accuracy
  - A measure of how well an image DN can be related to a physical engineering unit
  - Engineering units are required to perform atmospheric correction to pull out surface reflectance or temperature values from within a scene.

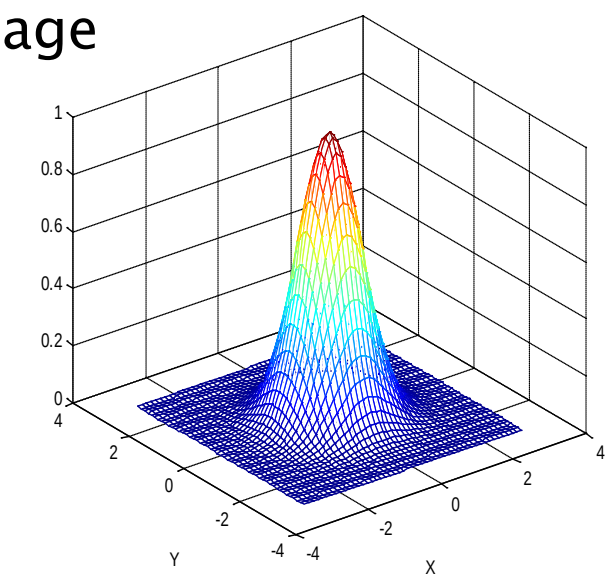
ASRPS Spatial Resolution Digital Imagery Guideline

Background

- Several years ago a Digital Imagery Guideline was developed and prototyped as a tool to help select imagery characteristics beyond just GSD
  - Based on image chips
- The tool has been updated and made interactive
- The goal is to improve data specifications for digital imagery

Spatial Resolution

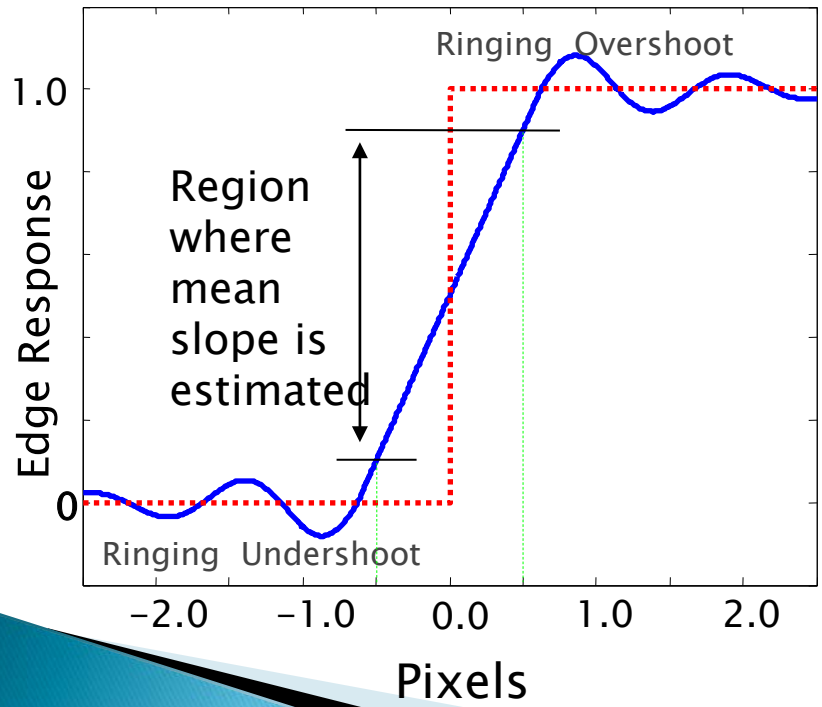
- Depends on:
  - Pixel size, measured by:
    - Ground Sample Distance (GSD)
  - Point Spread Function (PSF) – the response that an electro-optical system has to a point source
    - The sharper the function, the sharper the object will appear in the system output image
    - Difficult to directly measure
      - MTF
      - RER
  - Flight operations/installation



Common Spatial Resolution Metrics

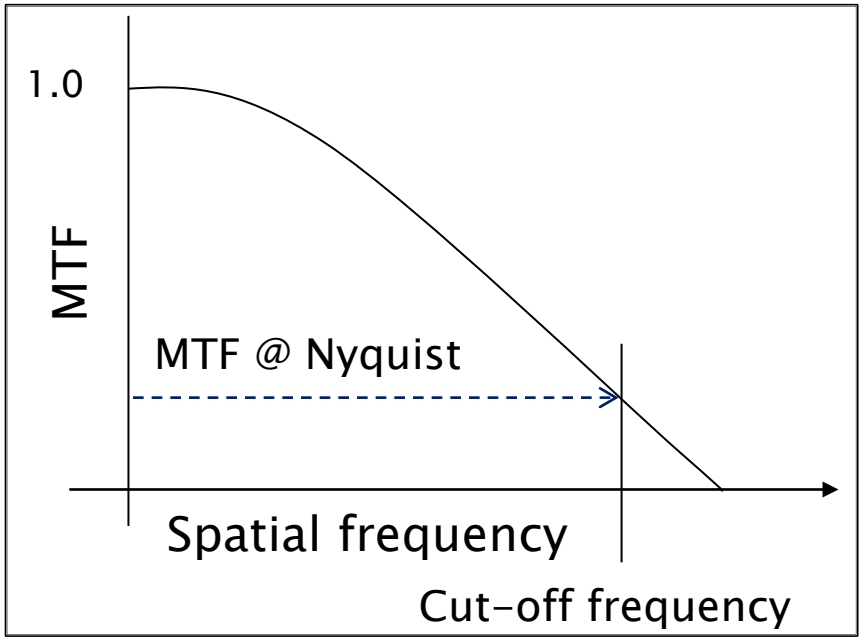
Spatial Domain

- Relative Edge Response (RER)

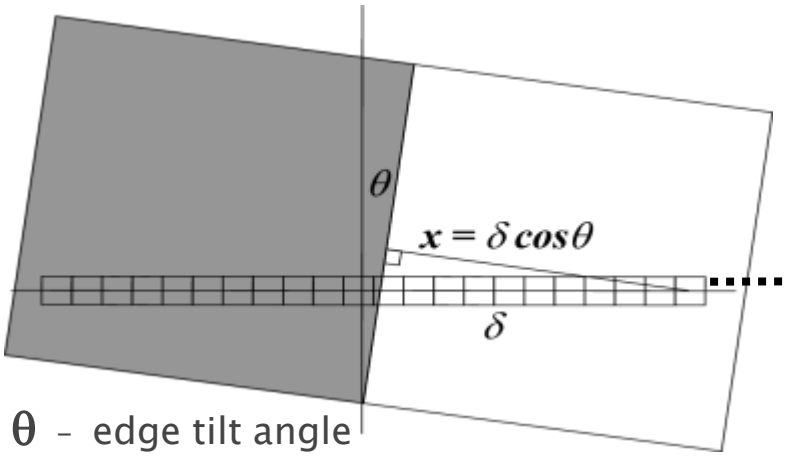


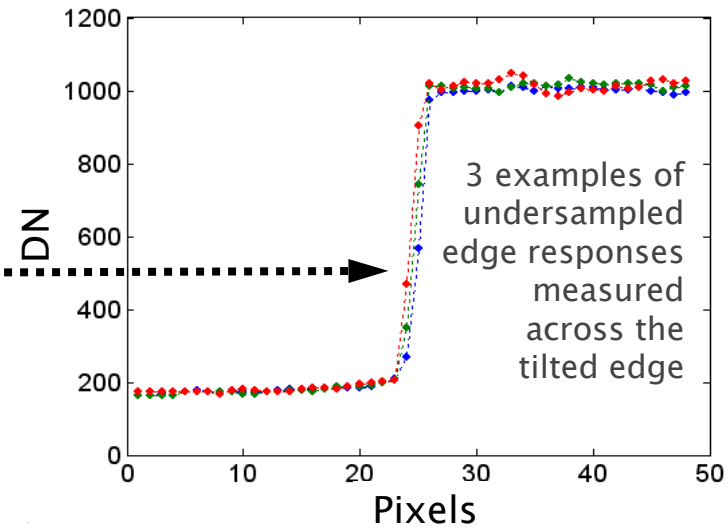
Frequency Domain

- Modulation Transfer Function (MTF)
  - MTF at Nyquist typical parameter



Estimating MTF/RER Tilted Edge Technique





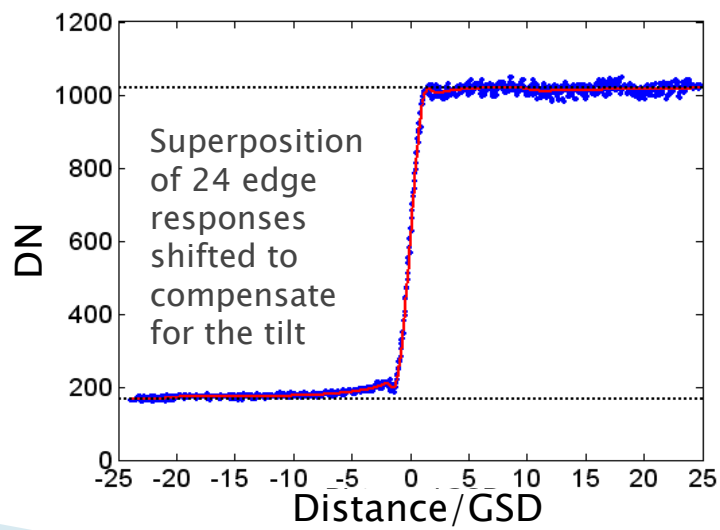
θ – edge tilt angle

δ – pixel index

x – pixel's distance from edge (in GSD)

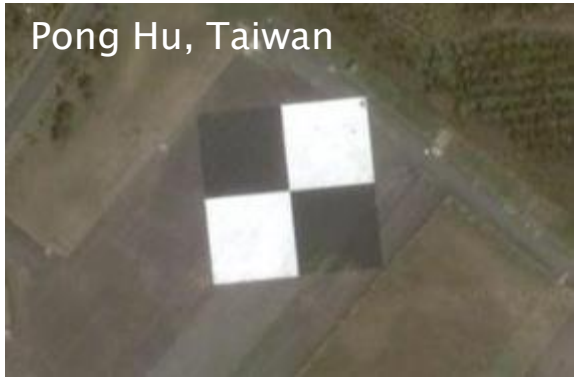
Problem: Digital cameras undersample edge target

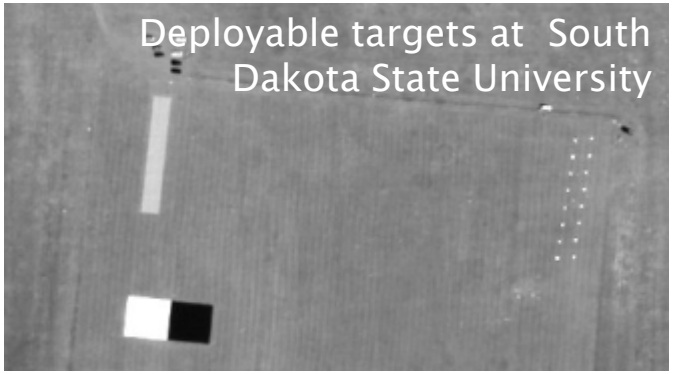
Solution: Image tilted edge to improve sampling



Traditional Engineered Spatial Resolution Targets

These types of targets however, will not generally be available in the imagery to validate spatial resolution

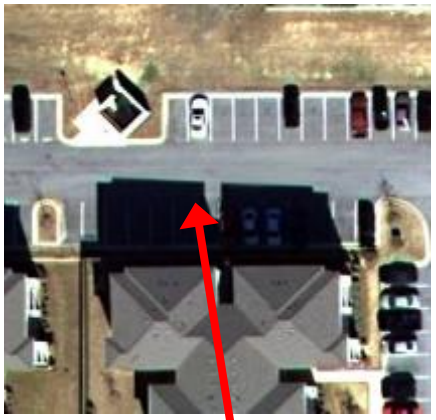




Digital Globe provided satellite imagery

Natural Edge Target Spatial Resolution Estimation

- Exploit edge features in nominal imagery
  - Edge response estimation is performed without dedicated engineered targets
- Automated process after algorithm optimization
  - Identifies edges and screens them
  - Constructs resulting edge response
  - Calculates MTF and RER
- Results validated with IKONOS and QuickBird JACIE results



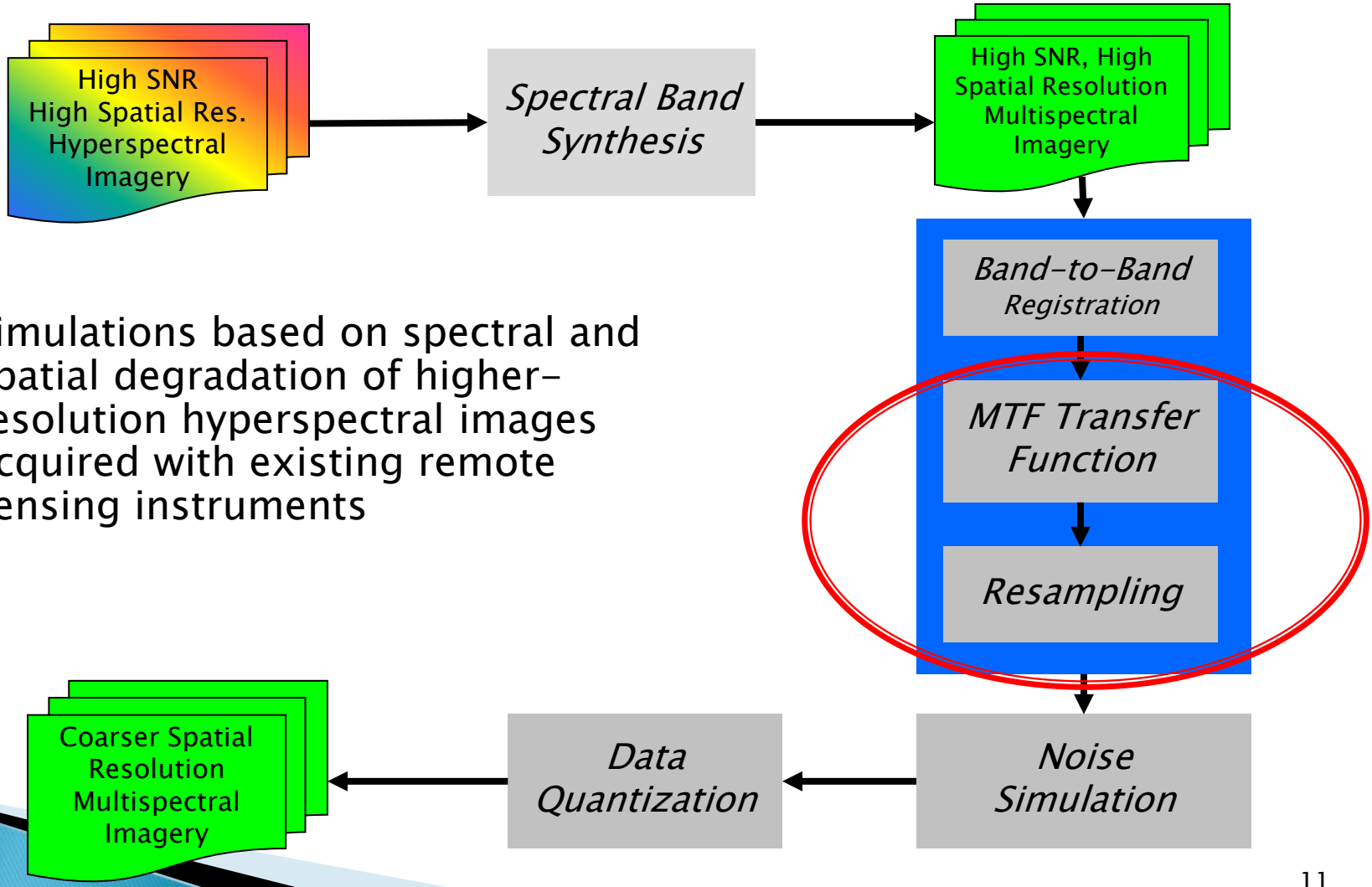
Building Shadows

Rooflines

Digital Imagery Guideline Tool

- Hexagon's Z/I Imaging provided several high quality very high resolution DMCII scenes
  - 0.75in GSD
  - 0.1 MTF@Nyquist
- Developed an interactive tool to degrade the input scene's spatial resolution and display results
  - Based on the Application Research Toolbox

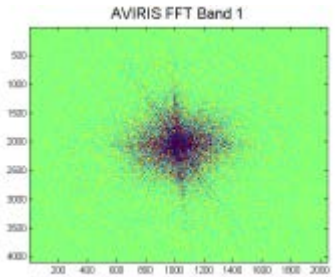
Image Simulation using the Applications Research Toolbox (ART)

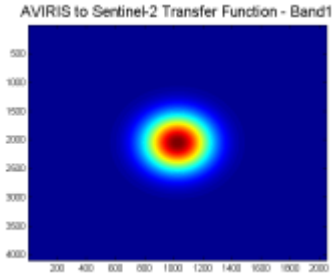


- Simulations based on spectral and spatial degradation of higher-resolution hyperspectral images acquired with existing remote sensing instruments

Frequency Domain Spatial Synthesis

$I(x, y)$	Input Image
$\tilde{I}(f_x, f_y) = F[I(x, y)]$	Fourier Transform Input Image
$H(f_x, f_y) = \dfrac{MTF(f_x, f_y)_{Out}}{MTF(f_x, f_y)_{In}}$	Transfer Function
$O(x, y) = F^{-1}[\tilde{I}(f_x, f_y) H(f_x, f_y)]$	Simulated Output Image (Inverse Fourier Transform –Resampled)





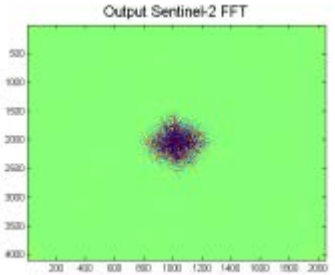
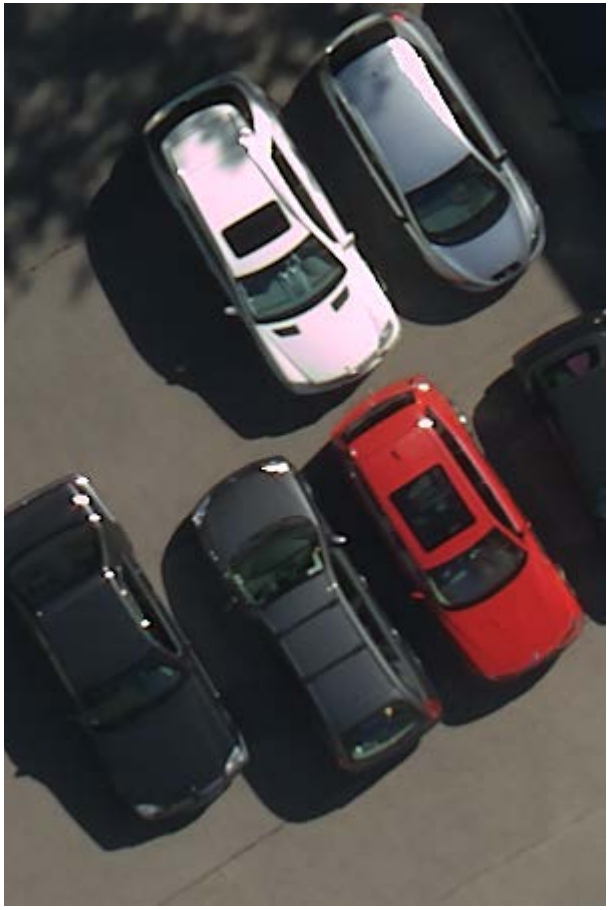


Image Chips

Original GSD 0.75 in/2 cm, MTF 0.1 Cars



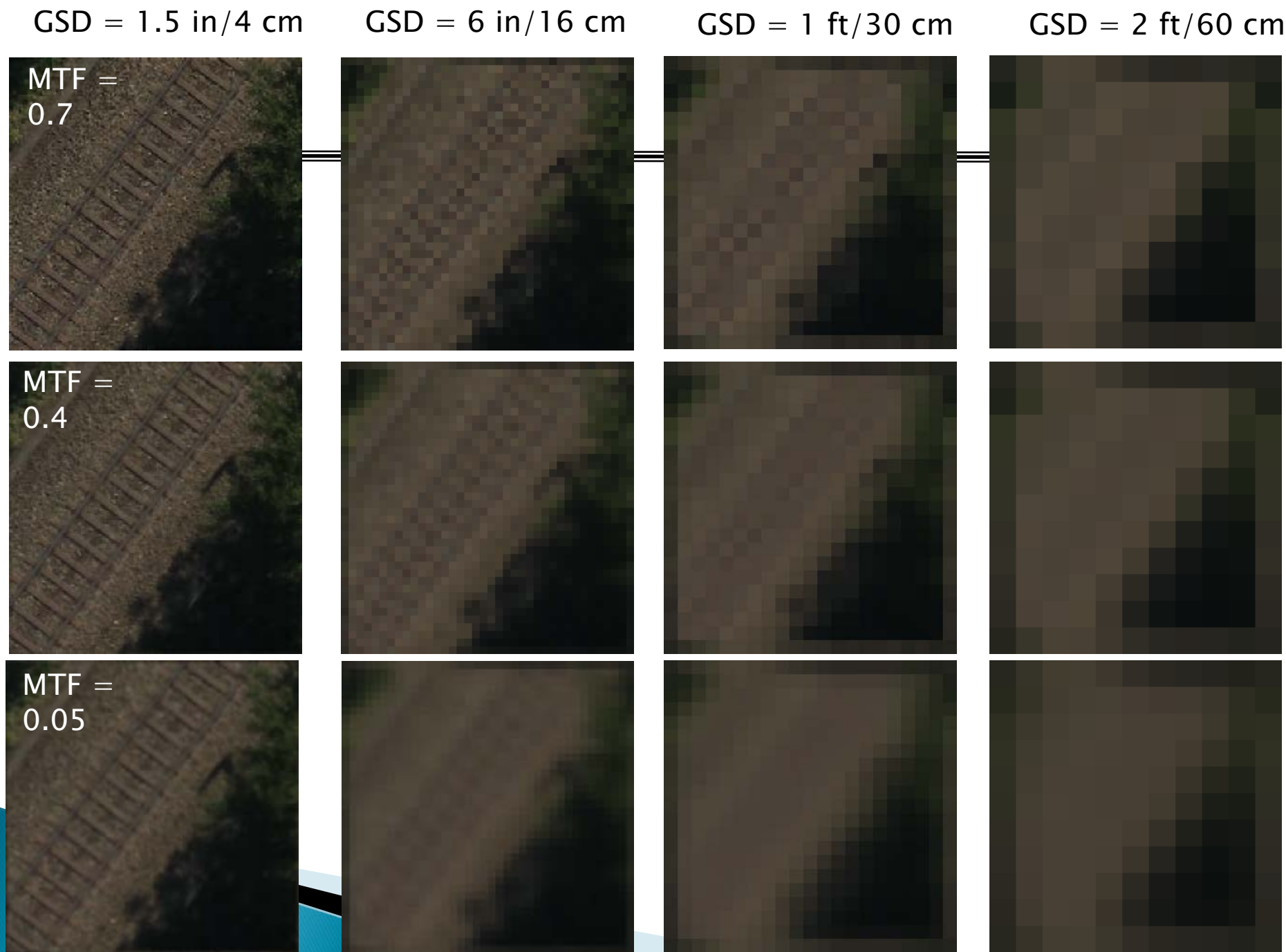
GSD = 1.5 in/4 cm GSD = 6 in/16 cm GSD = 1 ft/30 cm GSD = 2 ft/60 cm

MTF = 0.7

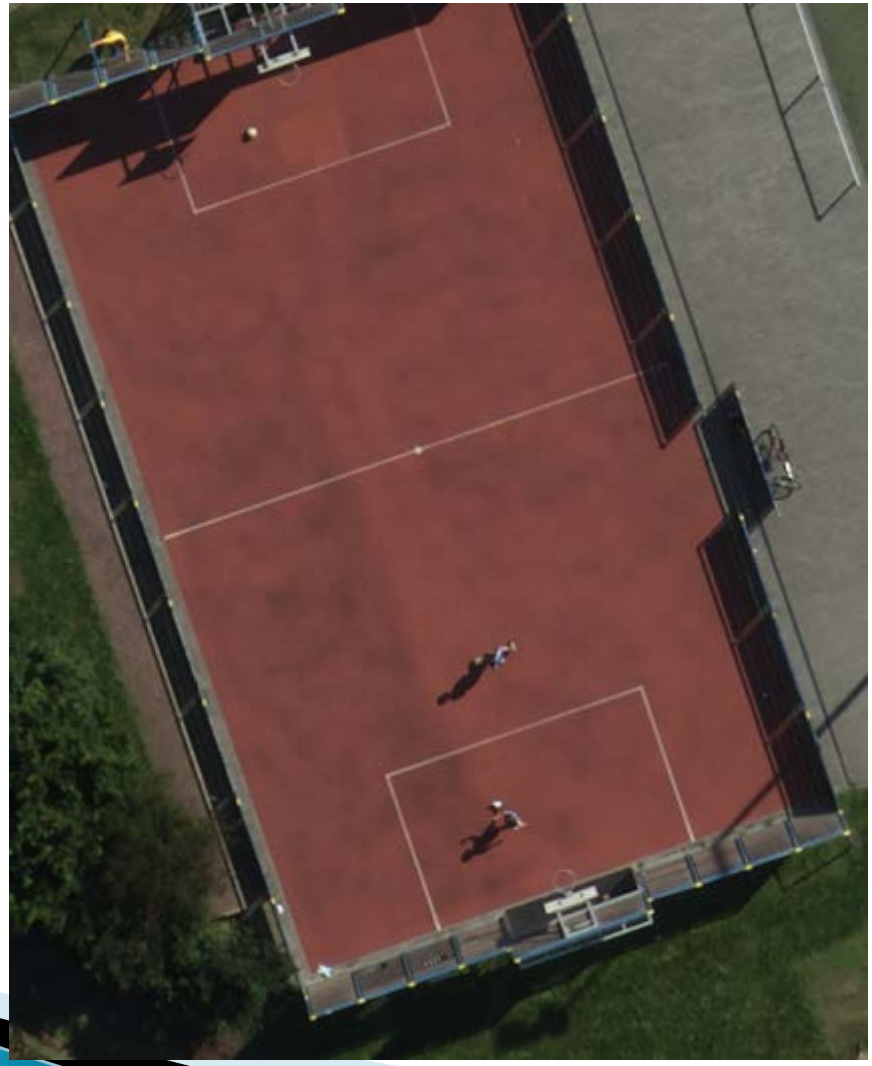
MTF = 0.4

MTF = 0.05

Original GSD 0.75 in/2 cm, MTF 0.1 Railroad Tracks


GSD = 1.5 in/4 cm
GSD = 6 in/16 cm
GSD = 1 ft/30 cm
GSD = 2 ft/60 cm
MTF = 0.7
MTF = 0.4
MTF = 0.05

Original GSD 0.75 in/2 cm, MTF 0.1 Basketball Court



GSD = 1.5 in/4 cm | GSD = 6 in/16 cm | GSD = 1 ft/30 cm | GSD = 2 ft/60 cm

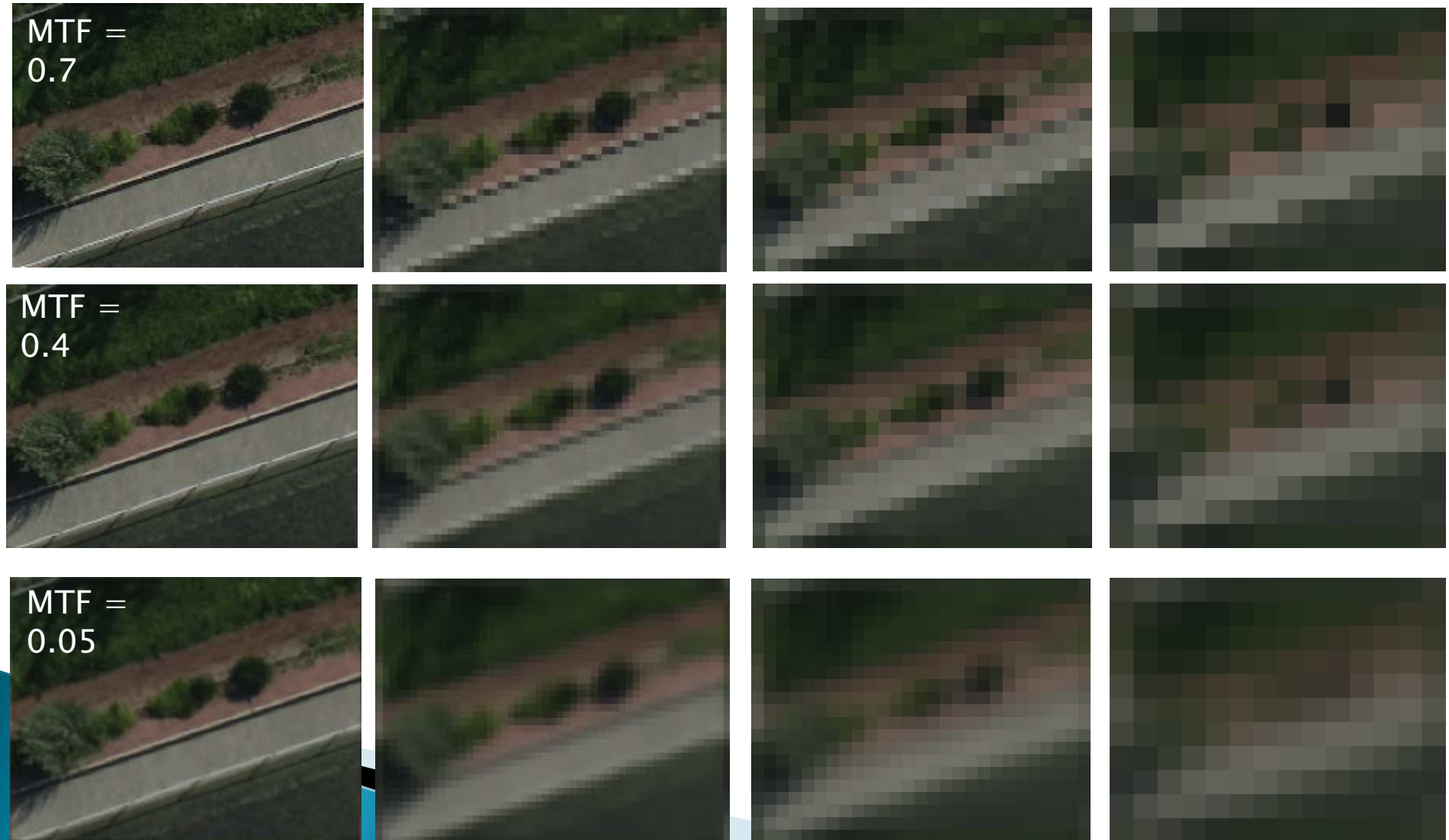
MTF = 0.7

MTF = 0.4

MTF = 0.05

Original GSD 0.75 in/2 cm, MTF 0.1 Dirt Path

GSD = 1.5 in/4 cm GSD = 6 in/16 cm GSD = 1 ft/30 cm GSD = 2 ft/60 cm



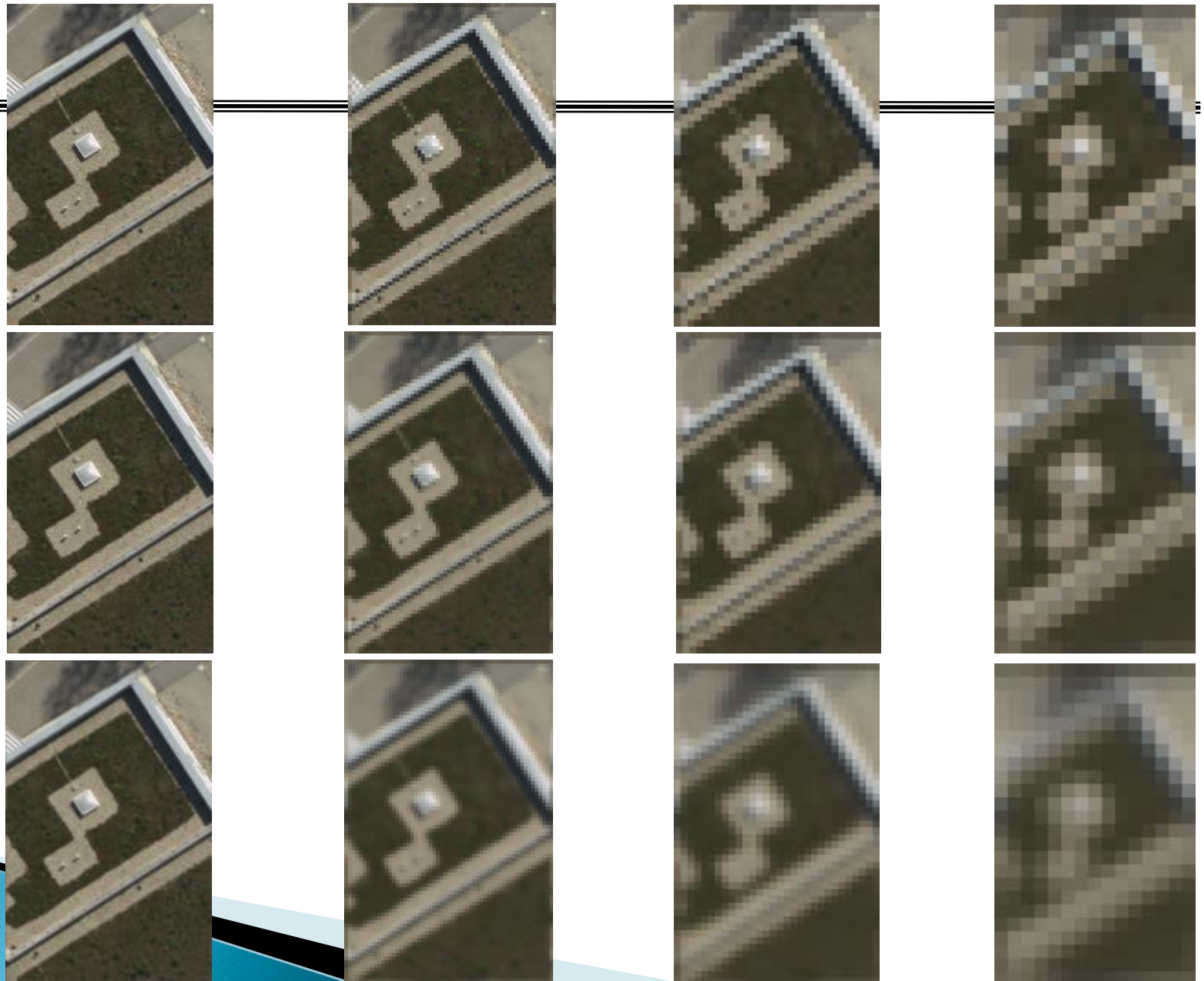
Original GSD 0.75 in/2 cm, MTF 0.1 Green Roof

GSD = 1.5 in/4 cm | GSD = 6 in/16 cm | GSD = 1 ft/30 cm | GSD = 2 ft/60 cm

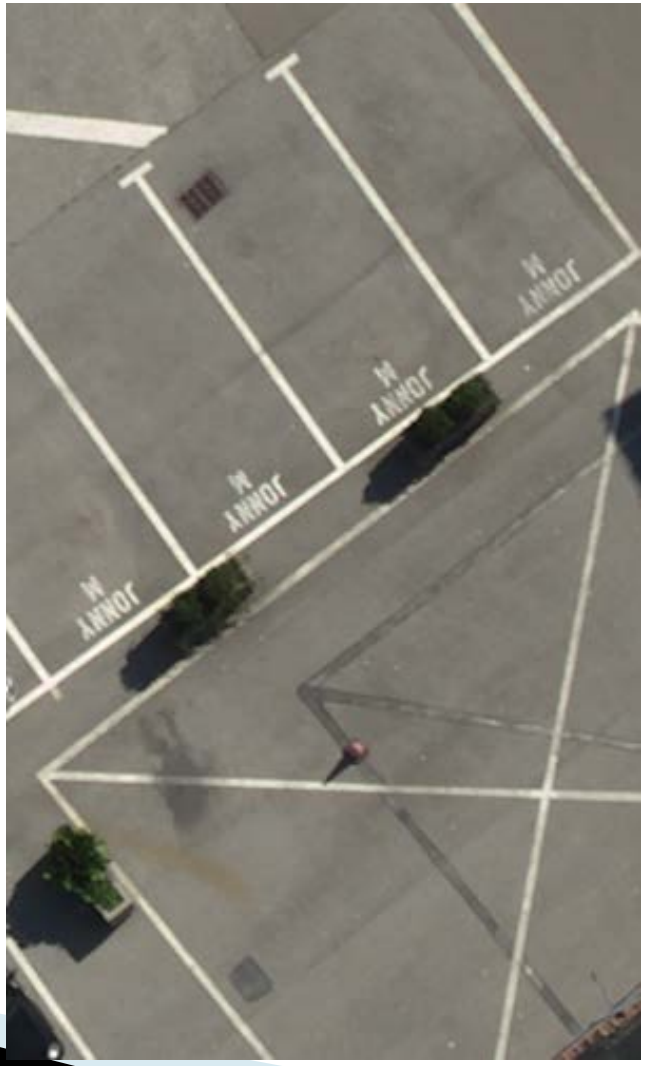
MTF = 0.7

MTF = 0.4

MTF = 0.05



Original GSD 0.75 in/2 cm, MTF 0.1 Parking Lot Lines

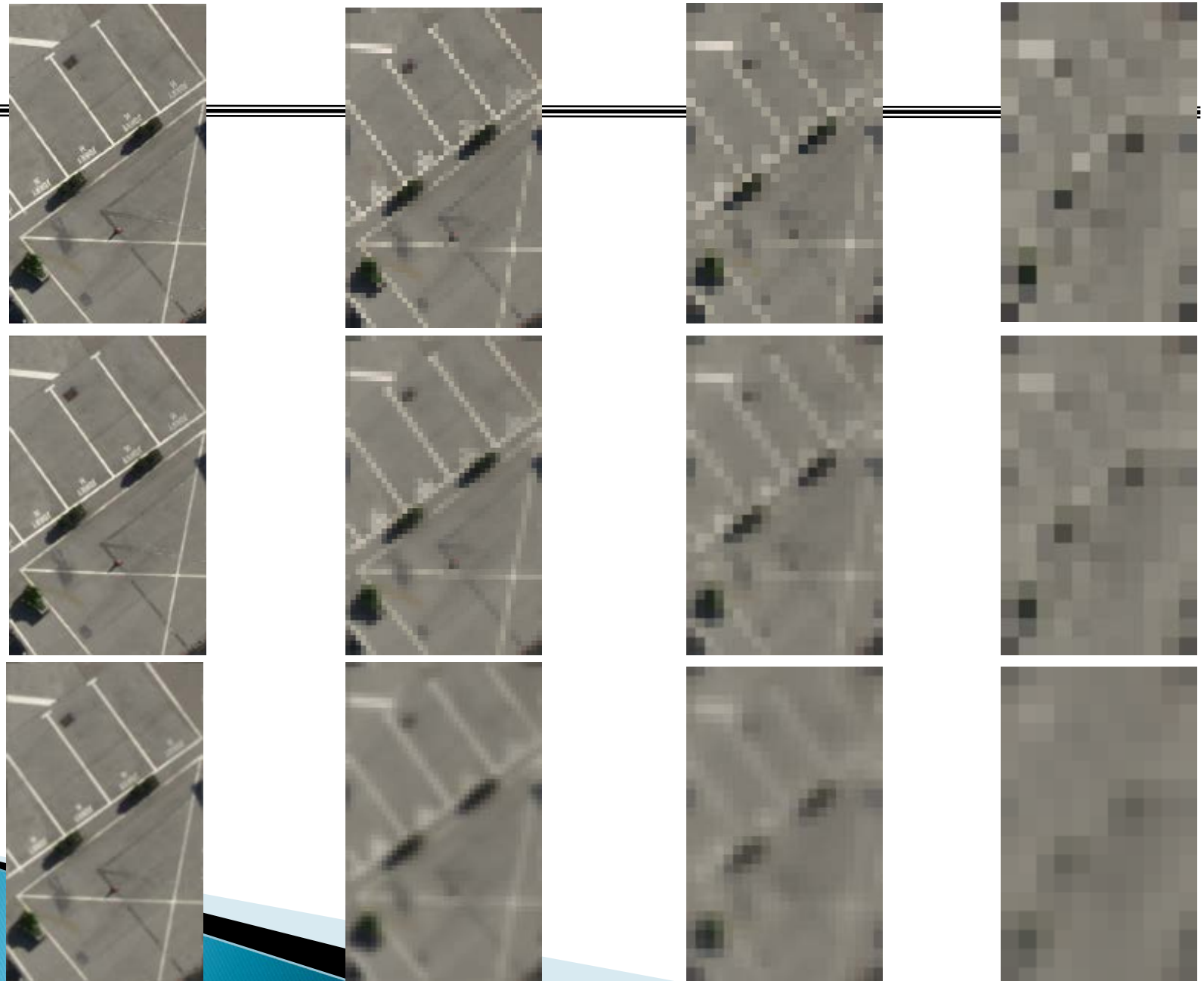


GSD = 1.5 in/4 cm | GSD = 6 in/16 cm | GSD = 1 ft/30 cm | GSD = 2 ft/60 cm

MTF = 0.7

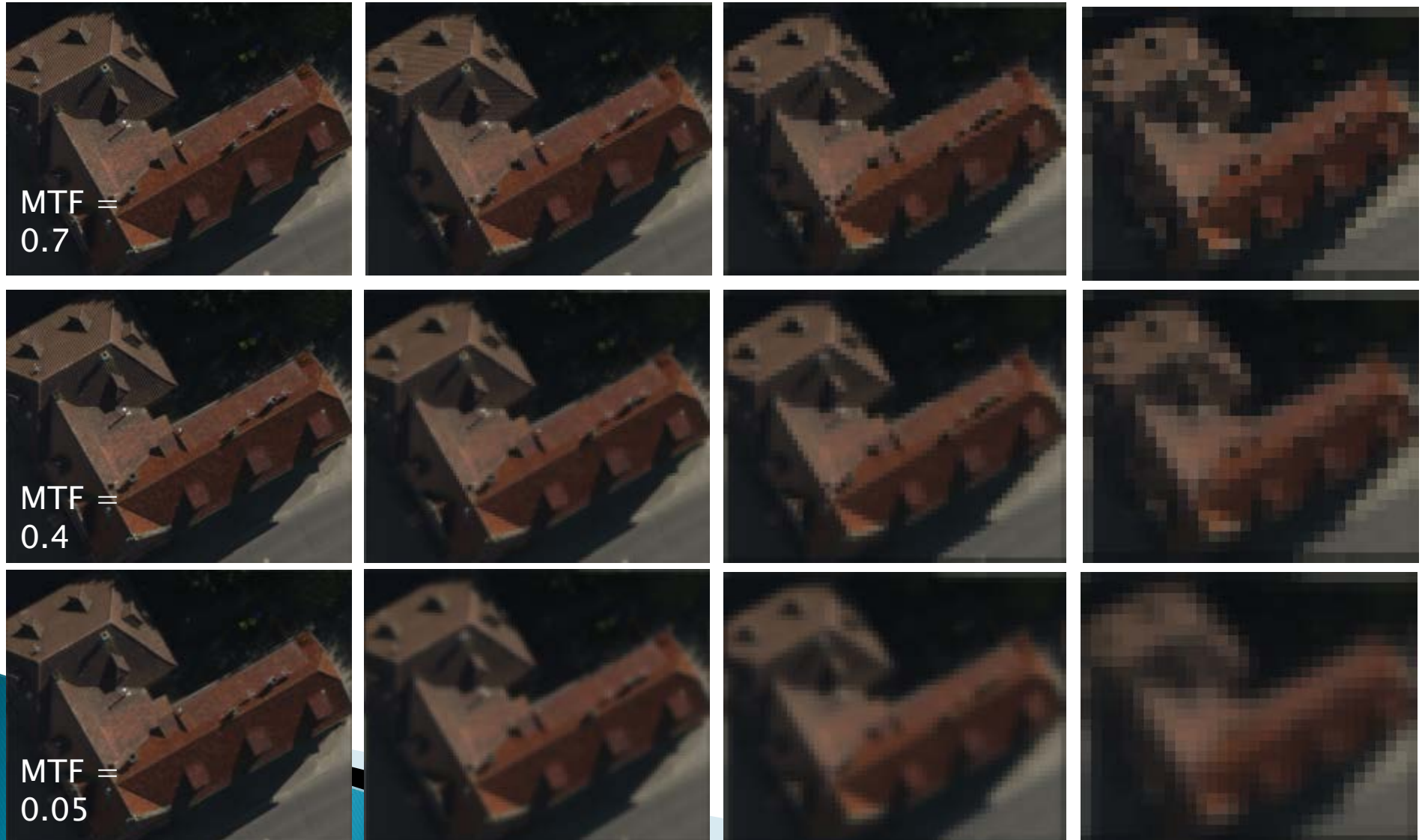
MTF = 0.4

MTF = 0.05



Original GSD 0.75 in/2 cm, MTF 0.1 Peaked Roof

GSD = 1.5 in/4 cm GSD = 6 in/16 cm GSD = 1 ft/30 cm GSD = 2 ft/60 cm



Next Steps…

- Validate the tool with in-flight imagery
- Host the tool on a website
  - Potentially expand tool to include user provided imagery

ASRPS Radiometric Calibration Guideline

Introduction

- The ASPRS Remote Sensing Application Division (RSAD) has a strong interest in the use of remote sensing data to study Climate Change
- The Primary Data Acquisition Division (PDAD) has a strong interest in fostering scientific quality products from the aerial imaging community
- PDAD and RSAD teamed to develop an ASPRS Radiometry Guideline

Aerial Digital Camera Radiometry Guideline

- Purpose
  - Articulate benefits of absolute radiometry
  - Provide framework to produce absolute radiometrically calibrated products

Radiometry Terms (Relative)

- Digital Number (DN) functional relationship with brightness (radiance) and integration time
- Pixel-to-pixel (image normalization or flat fielding, non-uniformity correction)
- Camera head-to-camera head consistency (color balancing)
- Typical remote sensing industry goal <1% (Landsat Data Continuity Mission (LDCM) Data Specification, March 2000)

Radiometry Terms (Absolute)

- Conversion of DN to engineering units of radiance (remote sensing)
- Typical remote sensing industry goal <5% difference from a National Standard (Landsat Data Continuity Mission (LDCM) Data Specification, March 2000)

Why Have An Absolute Radiometrically Calibrated Aerial Imaging System?

- Predicts the performance of the imager a priori under various conditions
- Simulates satellite remote sensing systems
- Supports the ability to atmospherically correct products to surface reflectance
- Improves quality control in manufacturing process by measuring camera sensitivities during laboratory calibration
- Reduces need to update LUT used in color balancing with post processing software

Guideline Outline

- Purpose/Scope
  - Need for Absolutely Calibrated Systems
  - Performance goals
    - Relative pixel-to-pixel
    - Absolute radiometric accuracy requirements for Climate Change
  - Scope
    - Visible-SWIR Multispectral & Hyperspectral imagers
- Laboratory
  - Spectral response measurements
  - Flat fielding and absolute calibration
    - Integrating spheres
    - Illuminated walls
- In-flight Validation
  - Vicarious calibration
- Product Generation
  - Algorithms
- Derivative Products
  - Atmospherically corrected products
- References

Volunteers

- PDAD
  - Mary Pagnutti (I2R) Lead
  - Robert Ryan (I2R)
  - Greg Stensaas (USGS)
- RSAD
  - John McCombs (NOAA Coastal Data Center)
- Needs
  - Climate Change Requirements Experts (NASA AMES TBD)
  - Aerial Camera Manufacturers/Data Providers