EuroSDR Commission 1 Special Interest Group workshop:

Data acquisition, processing and distribution within NMCA

29 January 2025

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Hexagon / Leica Geosystem's Sensor Technology Update

Layton Hobbs

Product Line Director- Airborne Solutions

Hexagon Geosystems

Hexagon in brief

INNOVATION
at scale

10-12% of revenues for R&D

~5,000 R&D employees

Thousands of active patents

Complementary emerging tech through acquisitions (170+ in 21 yrs)

RELEVANCY
that is vital

Serving manufacturing, infrastructure, construction, city services and more

Solutions that drive fewer inputs, less waste and less pollution from efficiency, productivity, quality and safety gains

STABILITY
that is proven

€500mn (2000) to €5.2bn (2022)

More than 24,000 employees across 50 countries

Increasing role in customers' businesses

SUSTAINABILITY
integral to our strategy

Committed to driving profitable business value that ensures economic growth, but not at the expense of the planet or people

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Geospatial Content Solutions (GCS) Core capabilities

AIRBORNE

Sensing Technology

Researching, developing, producing and distributing cutting-edge airborne imaging, LiDAR and hybrid sensors and data processing software to provide customers with higher data capture efficiency and more data from every flight.

Increase in productivity

MAPPING

Services

Providing data acquisition and processing services to selected, strategic Hexagon customers and partners to expand their capacities to serve their clients and local markets.

Creative business models

CONTENT

Capture & Distribution

Capturing and distributing high-resolution airborne data, including orthophotos, elevation data, 3D models and analytics as a service to provide customers with immediate access to geospatial information.

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Airborne sensor product update

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Leica CityMapper-2 (Release 2020)

High-performance urban hybrid mapping sensor designed for creating digital city twins

- Mechanically compensated forward motion for clear aerial images
- 1x Leica MFC150 RGB camera nadir, 4x Leica MFC150 RGB camera oblique
- Hyperion2+ LiDAR Unit
- Up to 2 MHz collection rate, 300 m to 5,000+ m AGL
- Suitable for diverse terrains, handling up to 35 pulses (MPiA zones)
- Circular LiDAR scan for even point density across field of view
- Adjustable FOV (20°– 40°) and scan speed up to 7,500 RPM for high-density mapping

Versions:

- CityMapper-2L
- CityMapper-2S
- CityMapper-2H

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Leica DMC-4 (Release 2022)

Superior image fidelity for multiple photogrammetric and remote sensing applications

- Mechanically forward-motion-compensation for clear aerial images
- 31,500 to 54,400 pixels across swath
- Fast 0.7-second frame interval for forward overlap and aircraft speed freedom
- Leica MFC150 cameras
  - 3 to 4 RGB wide to maximize swath
  - 2 x landscape-oriented NIR
- Improves the imaging performance by 20% to 100% compared to prior generation systems

Versions and field of view

- DMC-4S 58.0°
- DMC-4H 45.0°
- DMC-4W 66.2°
- DMC-4X 71.0°

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Leica TerrainMapper-3 (Release 2024)

Supporting the widest variety of applications in a single system

- High-performance 2 MHz LiDAR with an expanded 60-degrees adjustable field of view allows users to collect more data with fewer flight lines
- Reduced laser divergence enables greater accuracy, especially for small objects like power lines and building edges
- Higher scan speeds for TerrainMapper-3 enable users to fly faster while collecting high-quality data
- Circle, Ellipse and Skew Ellipse configurations for wide-area mapping, steep terrain and urban canyons, vegetation studies, as well as power and infrastructure corridors

- New waveform capabilities
  - Waveform attributes offering new opportunities for advanced and automated point classification
  - Full waveform recording at max PRF

- Steep Terrain Mode- flight planning and processing option which allow for enhanced MPiA zone resolution in areas of significant elevation change

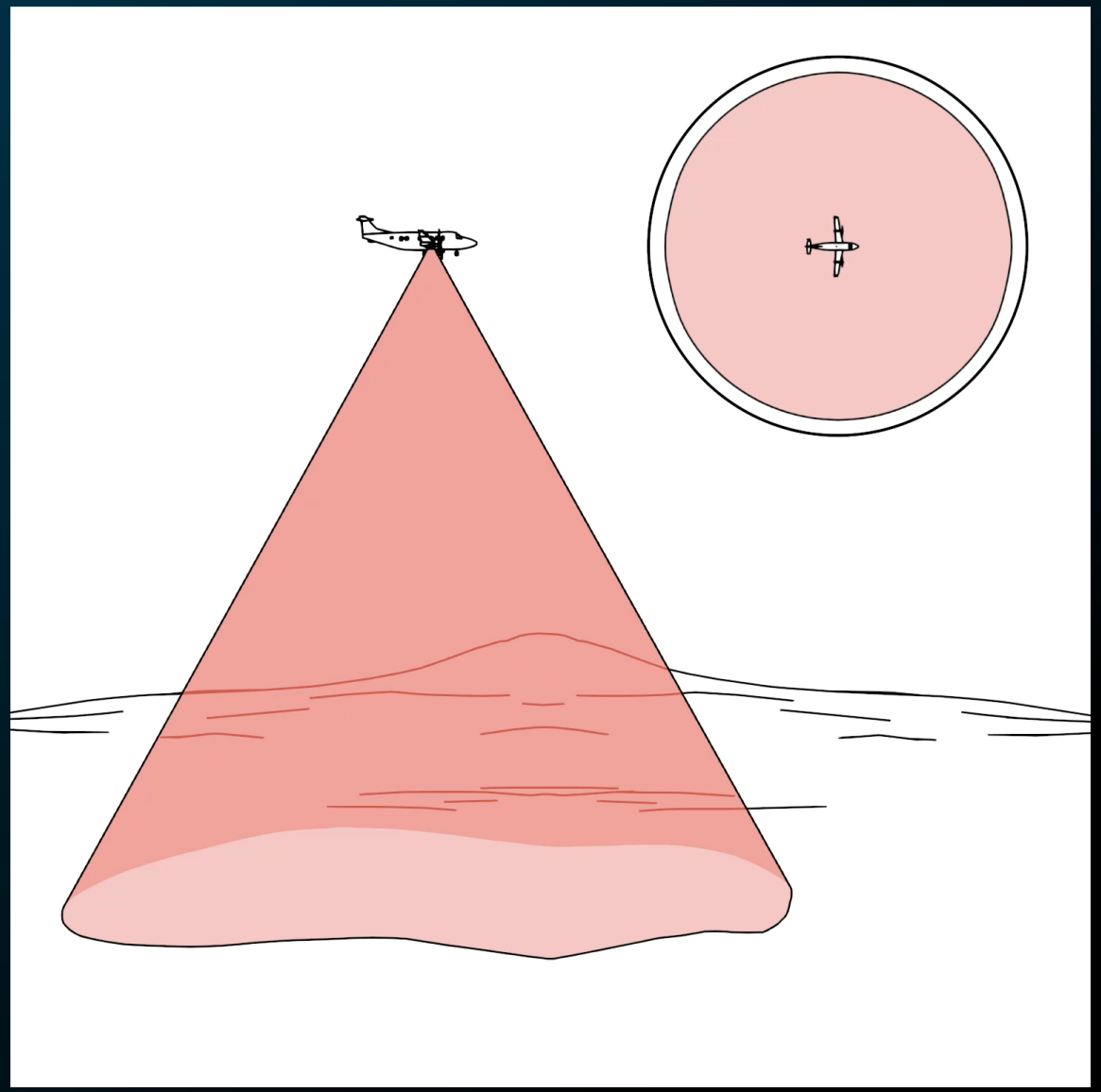
- 2x MFC150 – RGB & NIR

Leica TerrainMapper-3

Cricle scan option

Traditional Hyperion scan

- Configurable for 10° to 60° field of view suited for 3D modelling of lower-density urban areas or steep terrain
- Excellent pattern for modelling vertical infrastructure and vegetation especially in steep terrain



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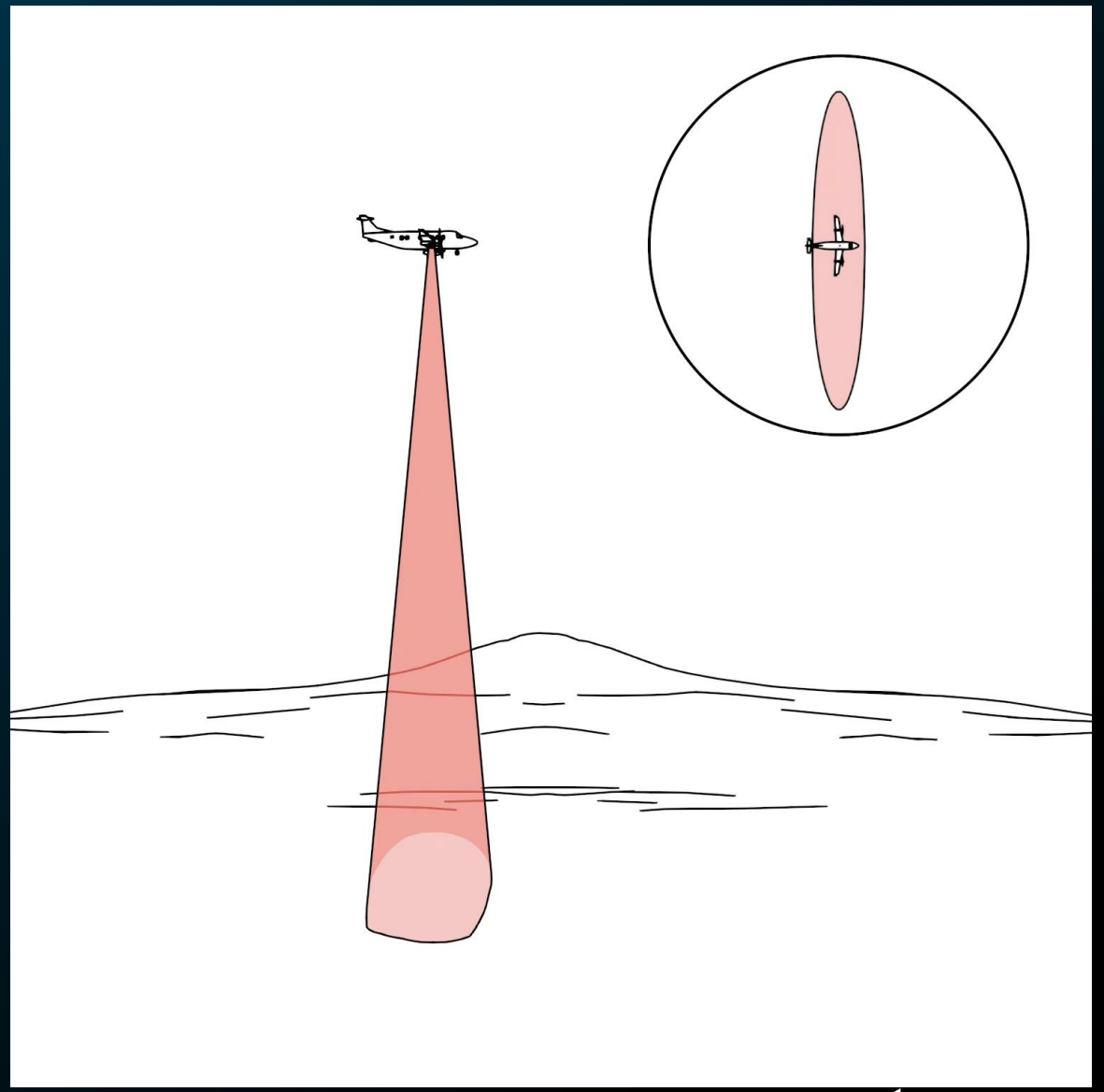
Leica TerrainMapper-3

Ellipse scan option

New, exclusive scan option!

- 10° by 60° field of view
- Excellent pattern for collecting urban canyons
- Well-suited for collecting in tall grass or crops
- Strong water surface returns for hydro-flattening or extracting land/water transition line
- Foliage penetration in flat terrain and/or ground points in dense, leaf-off vegetation



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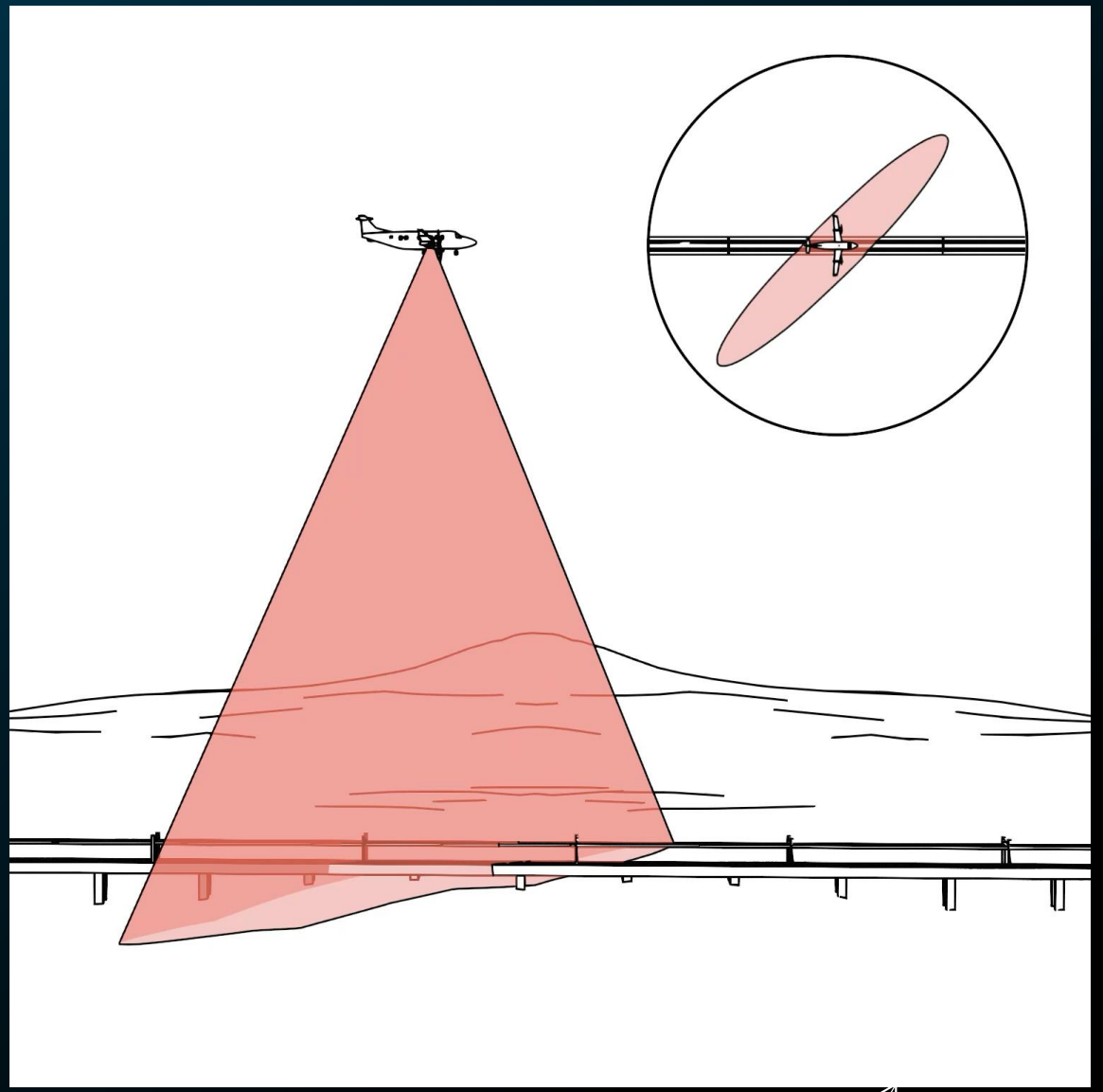
Leica TerrainMapper-3

Skew ellipse scan option

New, exclusive scan option!

- **Ideally suited to corridor applications**
- 10° **by** 60° skewed or rotated scan
- Skew angle is adjustable from perpendicular to flight, to parallel to flight
- Excellent wire and rail returns w/ near-nadir points
- **Balanced along-track/cross-track point spacing** for reliable extraction of linear features



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Leica CountryMapper (Release 2023/24)

The world’s only hybrid sensor for large-area mapping

Accurate and comprehensive 2D and 3D data products to support a wide variety of customer applications

- Mechanically compensated forward motion for clear aerial images
- **Matching DMC-4**, 31,500 cross-track pixel count
- Fast 0.7-second frame interval for forward overlap and aircraft speed freedom
- Leica MFC150 cameras
  - 3 x portrait-oriented RGB to maximize swath
  - 2 x landscape-oriented NIR
- **Matching TM-3**, Hyperion3 LiDAR Unit
- Up to 2 MHz collection rate, 300 m to 5,000+ m AGL
- Expanded 10-60 degrees FOV range for side-overlap flexibility

Versions and field of view:

- CountryMapper-S 58.0°
- CountryMapper-H 45.0°
- CountryMapper-W 66.2°

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Proven Leica MFC150 Camera Modules – Built for the Real World

- Leica MFC150: designed from the start for aerial imaging
- 150 MP, 14,192 x 10,640 pixels (Bayer RGB, pan for NIR)
  - Pixel size, type: 3.76 um, Back Side Illuminated (BSI) CMOS
  - Dynamic range: 83 dB
  - Resolution A/D converter: 14-bit
  - Frame interval: 0.8 sec
- Lenses: specially coated for RGB and NIR
- Motion compensation: mechanical FMC for superb low-light performance

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Supporting flight systems, compatible with all Leica sensors

Leica MissionPro
- Software to plan your missions

Leica FlightPro
- Flight management and sensor control system for more efficient, effortless survey flights

Leica PAV200
- Stabilizes the sensor for flight path deviations in roll, pitch and yaw
- Minimizes image blur and improves LiDAR data distribution

Pod Lifter
- Retracts pod into aircraft during take-off and landing to protect the sensors from debris

OC61 Operator Console
- 12.1” screen hosting the Sensor Operator interface

PD61 Pilot Display
- 6.3” screen hosting the Pilot Interface

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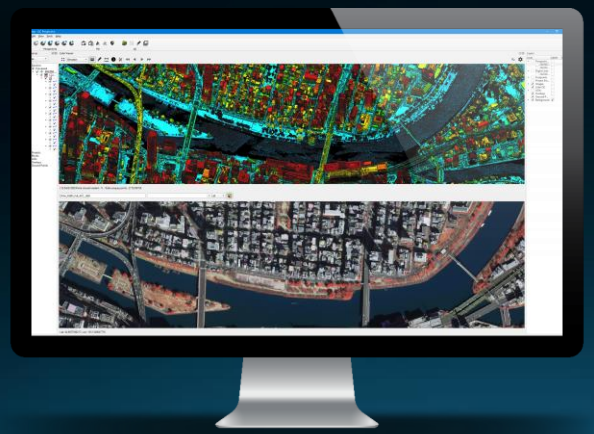
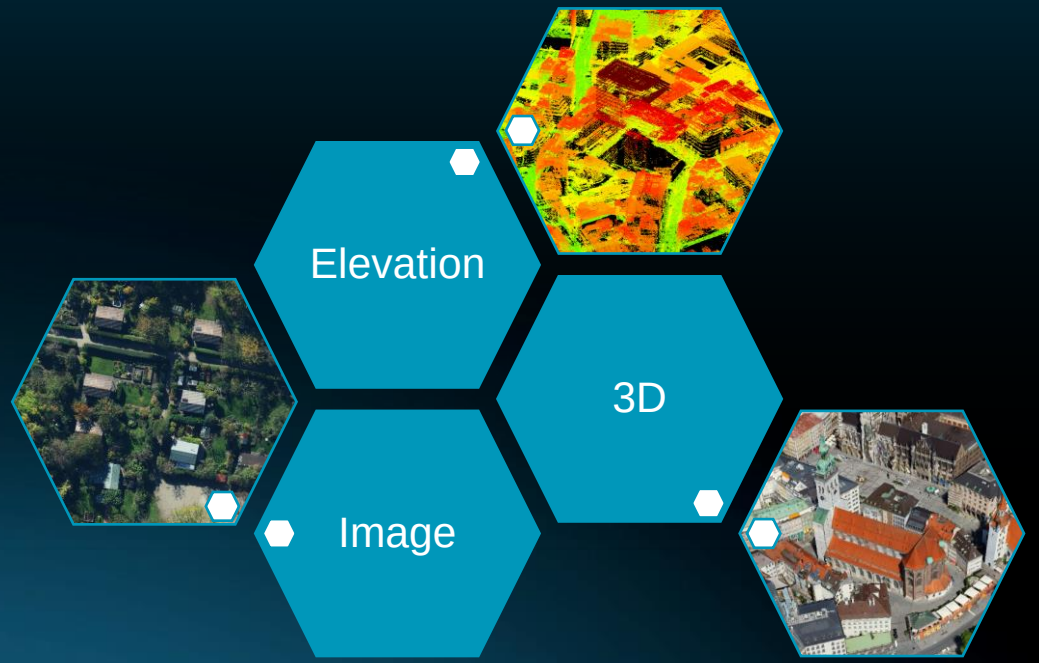
Leica HxMap

High-performance, integrated workflow solution supporting multiple inputs and multiple products

Leica Hybrid Sensors



Leica HxMap



One Sensor → **One** Workflow → **Unlimited** number of Data Products

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Leica HxMap Product generation

Product templates can be defined and saved for common output

LiDAR

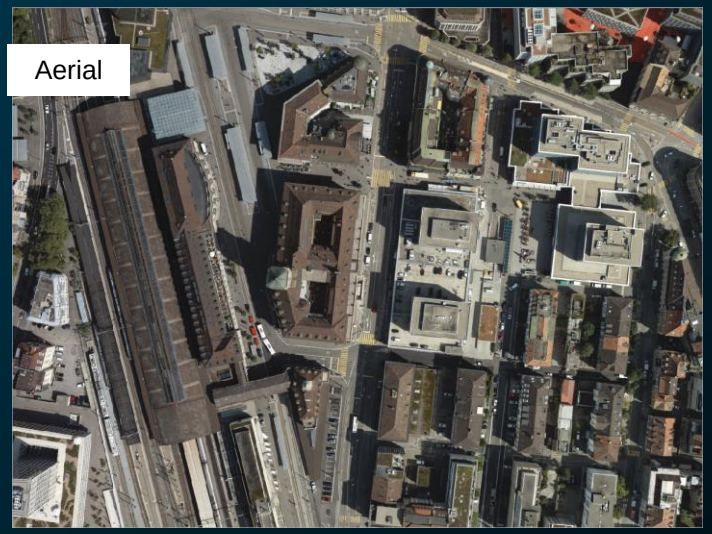
- XYZ
- Reflectivity
- RGBN
- Ground / non-Ground

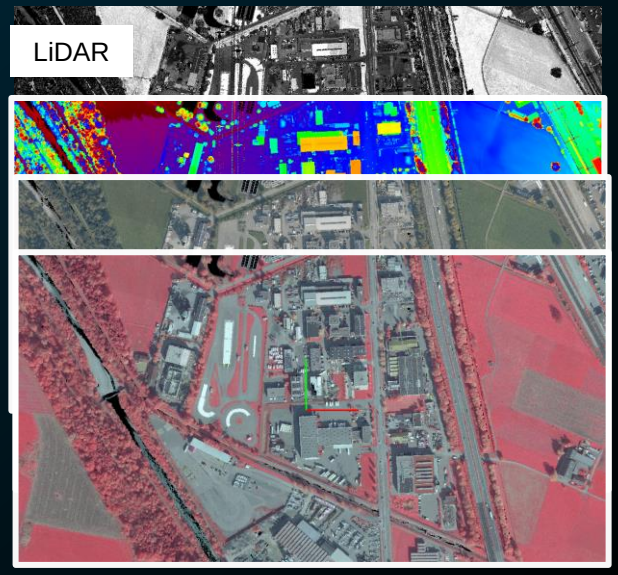
Images

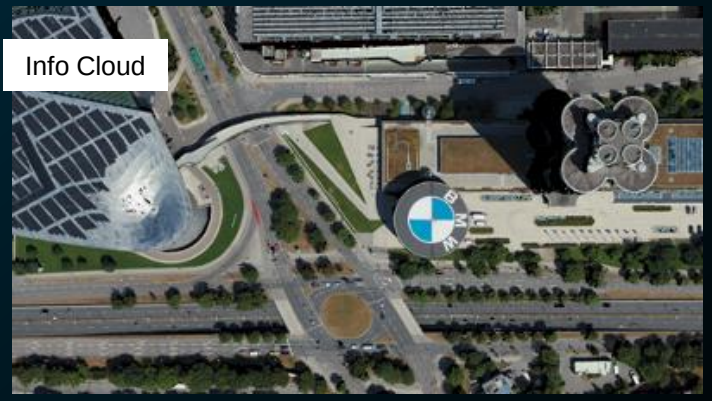
- Aerial Images
- Ortho Images
- Dense Image Matching-based point cloud

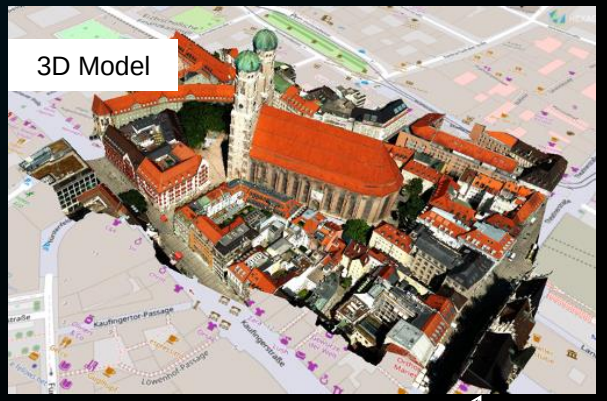
3D Output

- 3D textured mesh
- Textured LOD building models
  - With/out building footprint as input
- True ortho image









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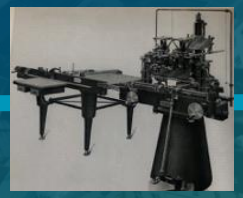
100 years of aerial acquisition … and anxiety

1923



2000

2024

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What drives technology decisions for an airborne sensor manufacturer?

Why change..?

New advances in component technology (or lack thereof)

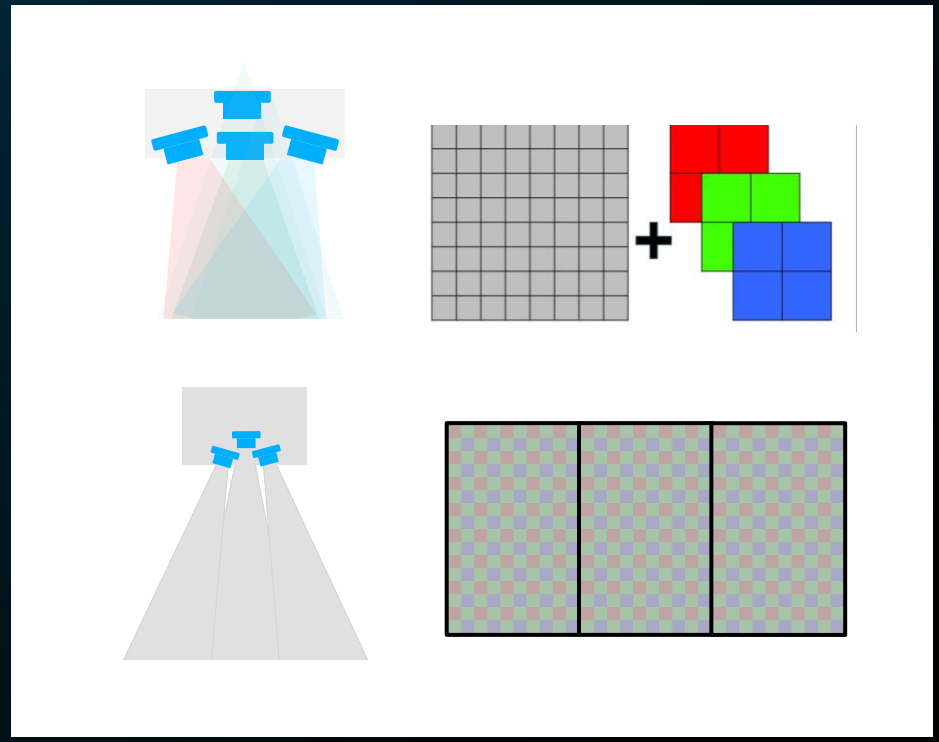
- Image sensors advanced from CCD to CMOS
- Smaller pixels with the same form factor
  - DMC I had 12 micron pixel
  - DMC 4 has 3.76 micron pixel, around 3X smaller
- Lack of availability of large, monolithic chips

New products and changing end-user demands

- 3D models, meshes and digital twins
- Building / feature lean restrictions
- Projects combing imagery and LiDAR requirements

Customer demands for more efficiency

- **Higher collection rates to reduce time in the field**
- **Aerial data collection accounts for 30% to 60% of project costs**
- **Missed weather opportunities are a significant risk for the aerial survey firm and their customer**



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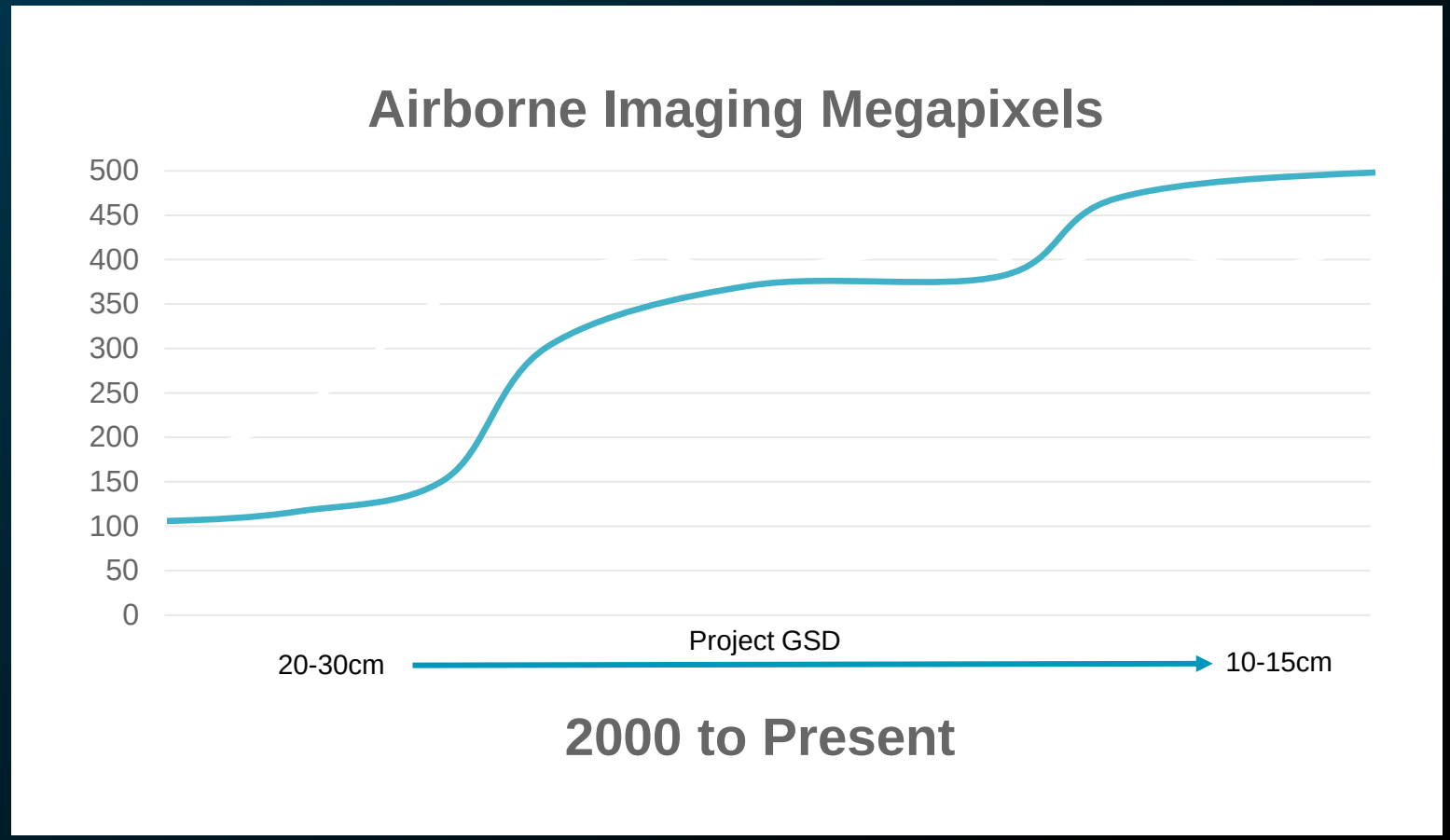
Airborne imaging pixel-count increases over 25 years

- Commercial, airborne systems have increased megapixels by 5X over last 25 years
- GSD requirements have followed but not at the same rate
- Field-of-View of sensors remained relatively constant
- **Added efficiency has influenced higher flying altitudes and flight speeds for many 2D imaging products = lower costs**



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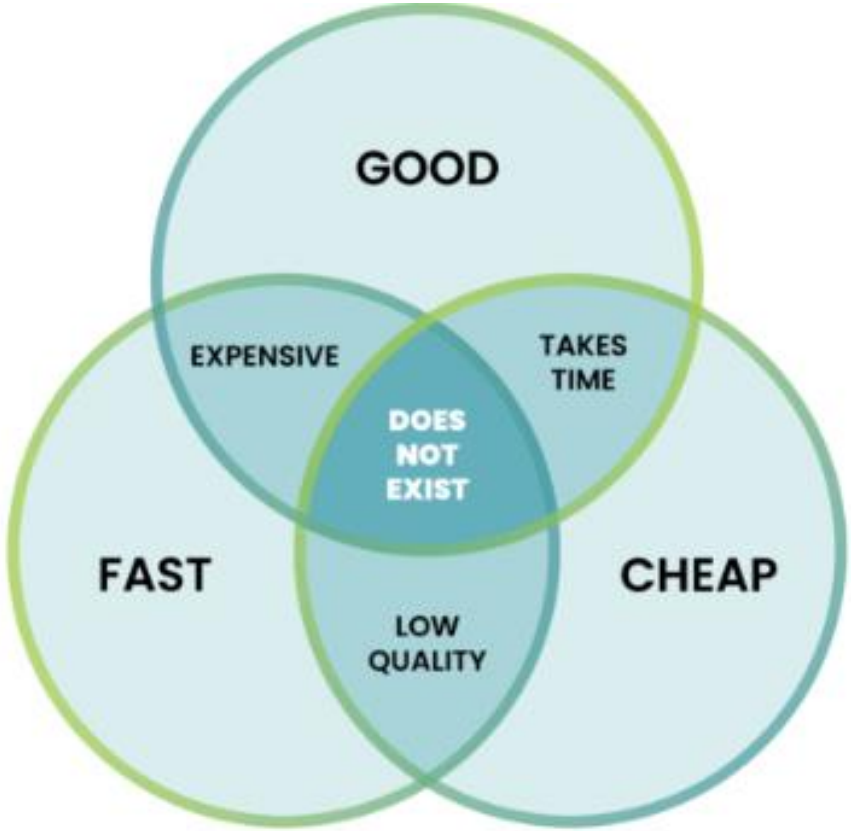
Efficiency advancements and potential data buyer impacts

- Data buyers must balance costs, schedule and quality
- Defining, measuring and validating quality can a challenge
  - **Controllable quality criteria**
    - Accuracy / ground control checks
    - Lean restrictions
    - Clouds and shadows
    - Sun angle
    - GSD (Ground Sample Distance)
  - **Subjective quality criteria**
    - Color balance “Too red, too blue”
    - Variable tone or shadows between days
    - Highlight and shadow detail
    - Noise
    - GRD (Ground Resolved Distance)

Resolution?



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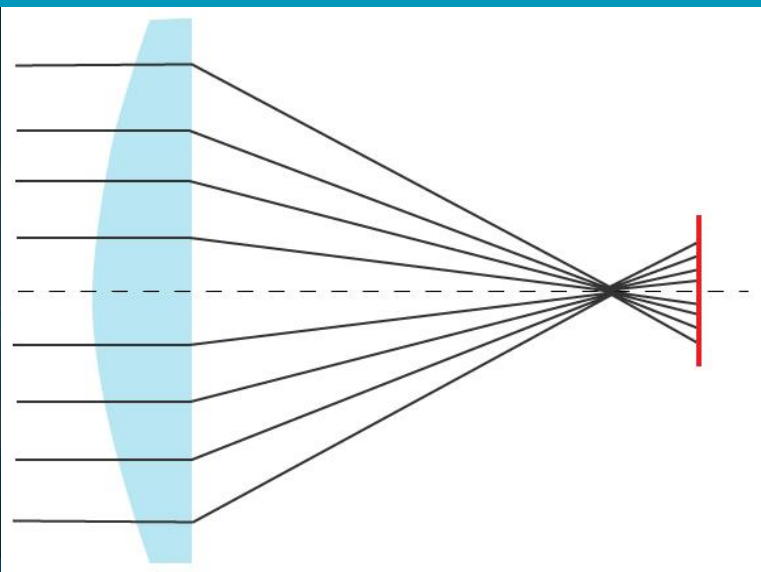
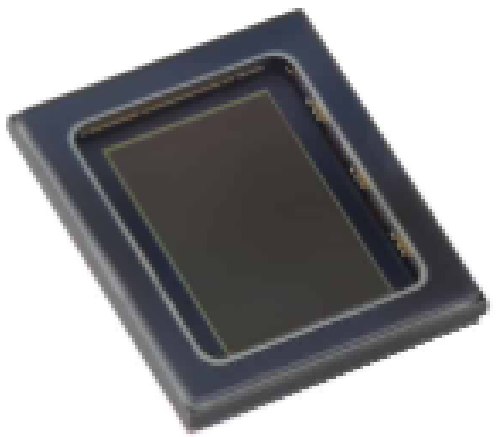
Contributors to **sensor** resolution

- **Resolving power of the lens**
  - **Resolution at the center of the lens**
  - **Resolution across the lens and at different apertures**
  - **Focus**
- **Sensitivity and noise of the imaging chip**
  - **Exposure (light signal) and QE (quantum efficiency)**
    - **Including Bayer coatings or panchromatic filter**
  - **Blooming and bleed-over (cross- talk)**
  - **Gain (signal amplification) noise**

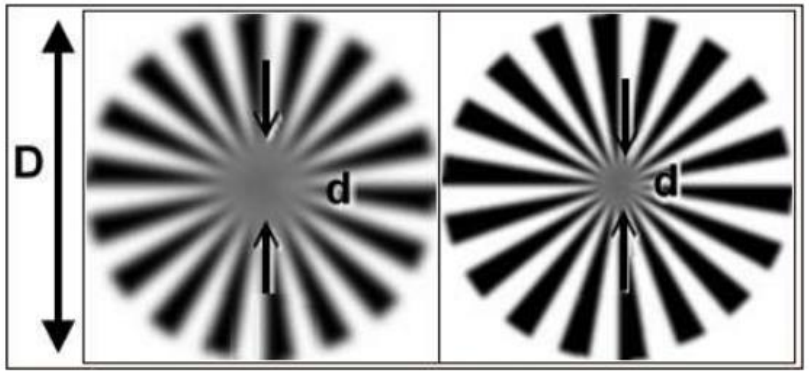




Contributors to **system** resolution

- **Sensor resolution**
- Image motion / blur
  - Change in scene during exposure
  - Vibration
- Atmospheric effects
  - Refraction
  - Scattering from aerosols and molecules
    - Water vapor
    - Dust
    - Smoke
- Contaminates
  - Port glass or lens dirt/oil/debris
  - Aircraft exhaust
- Post processing and resampling prior to testing
  - Sharpening and/or deconvolution
  - De-Bayer/De-mosaic algorithms
  - Over-compression
  - Resampling methods for ortho-rectification

Resolution testing (airborne application)



D : Out Circle Diameter
d : Inner Circle Diameter

$$\text{Visual Resolution}(\ell) = \frac{\pi \times (\frac{d}{D})}{32} \times 2$$

Ex) ℓ = 3.14x(1.1/2.05)/16 = 0.10

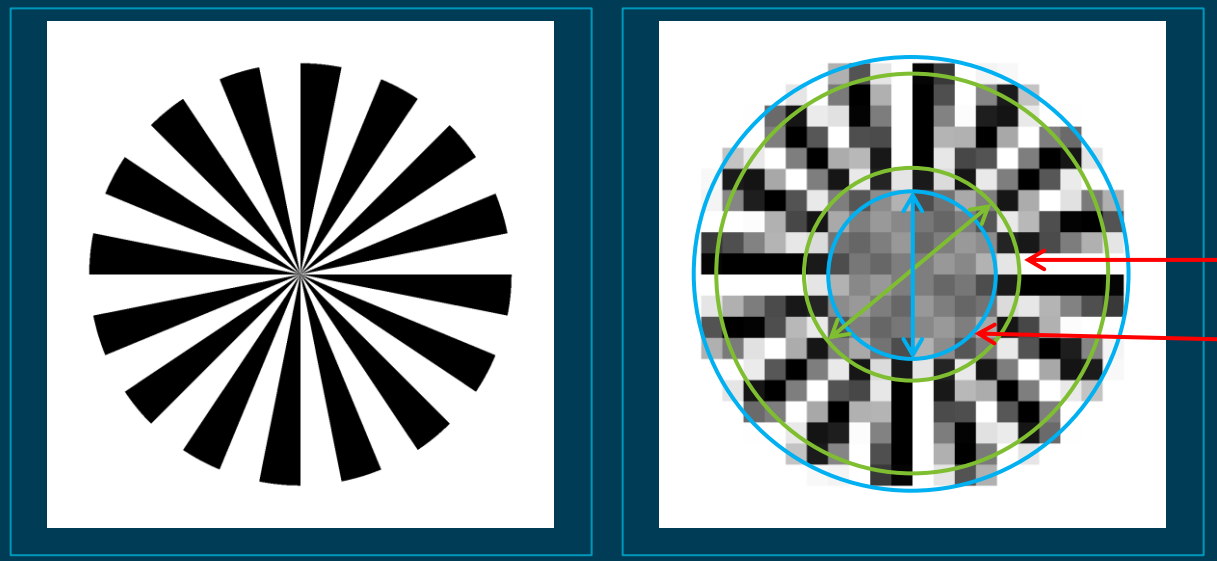
GSD Checking = $_{\text{visual(calculated)}}$ GSD / $_{\text{wanted}}$ GSD = 0.1/0.1 = 1

Siemens star target to measure optical performance

The inner diameter is a criteria for the resolution of an optical systems.

This is applicable as long as no significant limitations apply in the test setup and the target is captured at a high resolution. Possible limitations introduced by a test setup are resolution of the image sensor, ambient light, atmosphere, ...

Considerations in resolution **testing**



Siemens star target sampled with limited resolution

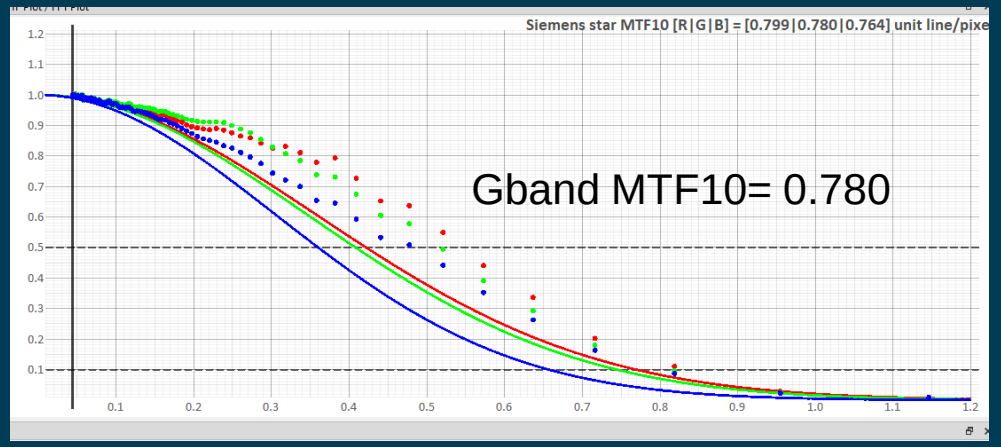
The center is blurred, directional effects and quantization is introduced. Therefore, measurements become ambiguous.

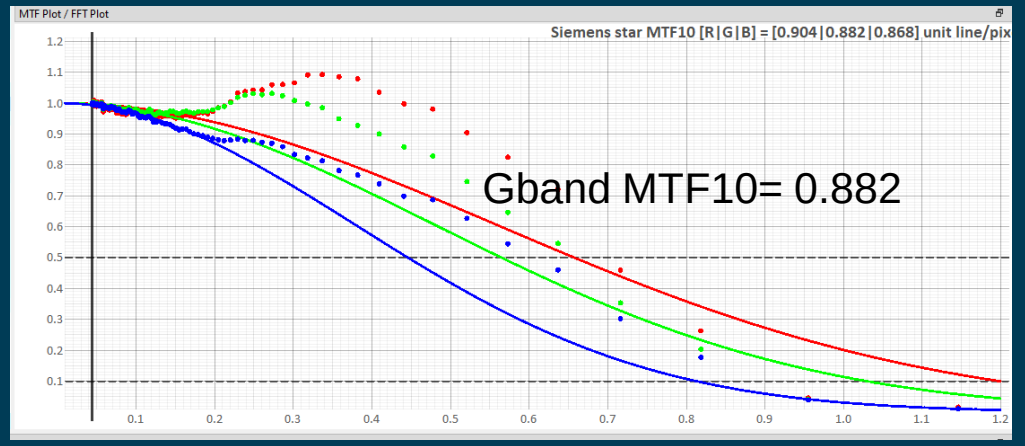
Depending on the circle chosen the diameter can differ by more than one GSD … or 10+% in above case.

The same applies to the outer circle.

Considerations in resolution **testing**

Edge and/or deconvolution sharpening increases measured GRD





Considerations in resolution **testing**

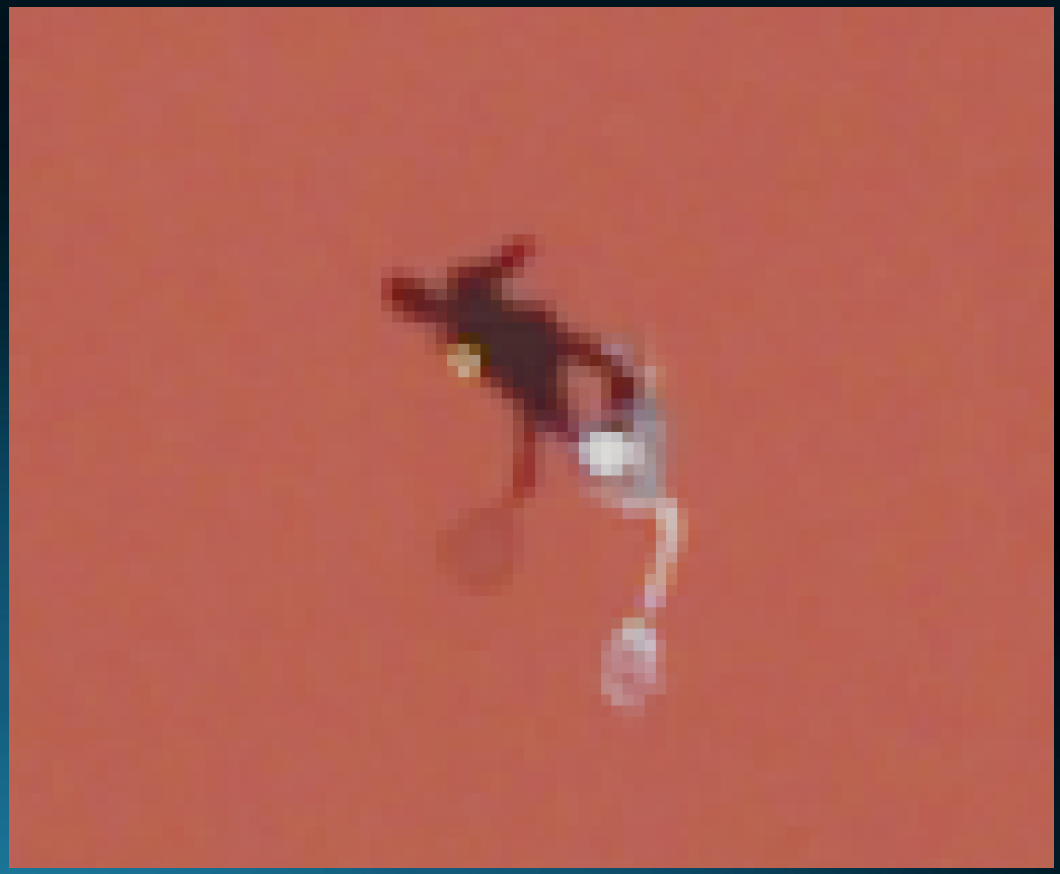
- Target type and size
  - Siemens star generally accepted, de-facto
  - Star configuration, number of ‘legs’
  - Large enough for isolated pure pixels on outer legs (Diam = GSD X 50)
  - Contrast of surrounding area (auto-exposure impact)
- Target quality
  - Material
  - Reflectivity
  - B/W contrast
- Illumination
  - Sun angle
  - Clouds
- Measurement technique
  - Industry standards for calculating GSD vs GRD
  - Manual measurement reliability
  - Automated measurement standards

Aerial imaging technology will continue to evolve…

- What can we (manufactures) do better to help ensure product quality and proper application of available technology (while continuing to provide best possible value)?
  - Testing standardization, system or product
  - Input on in-situ test procedures
  - Training and support on subjective quality measures
- Industry alignment on manufacturer's role in certifying 'system' capabilities for accuracy and quality in a global market
  - "Calibration Certificates" vs. performance assurance
  - Alignment across international institutions

Leica DMC-4 Data Sample

Munich - 5cm GSD



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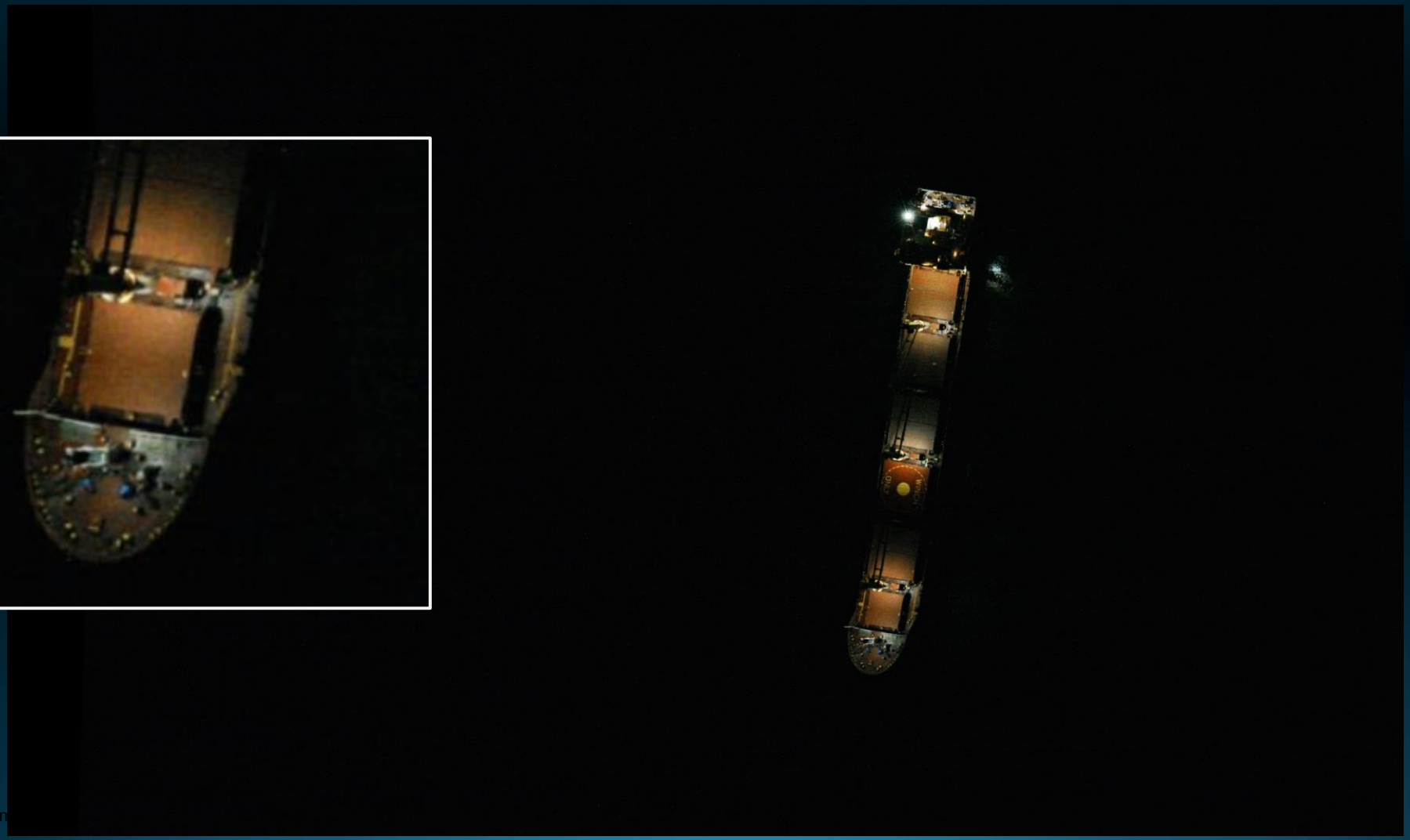
Leica DMC-4 Night Flight Sample

Montreal, Canada 10cm



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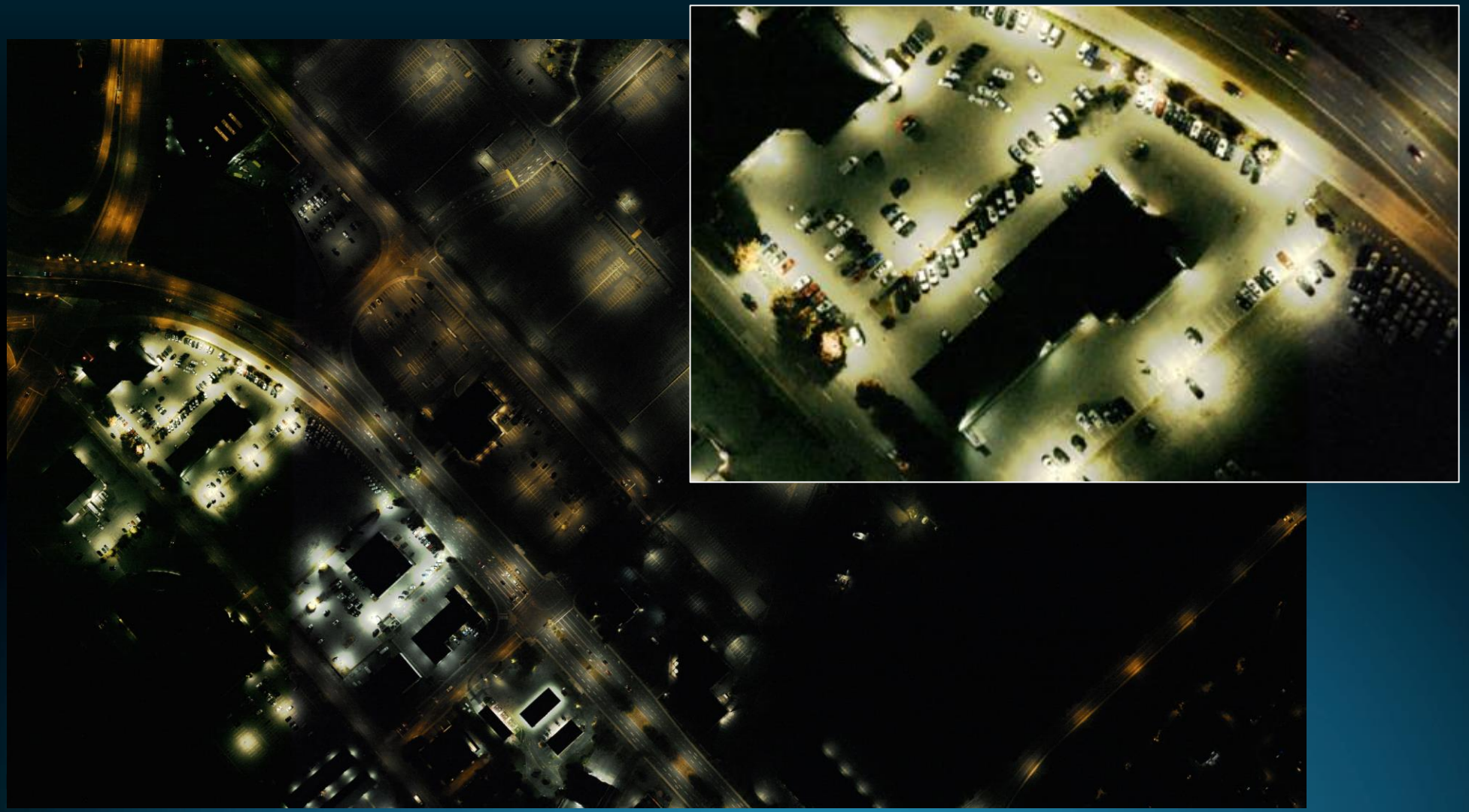
Leica DMC-4 Night Flight Sample

Montreal, Canada 10cm



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Thank you!