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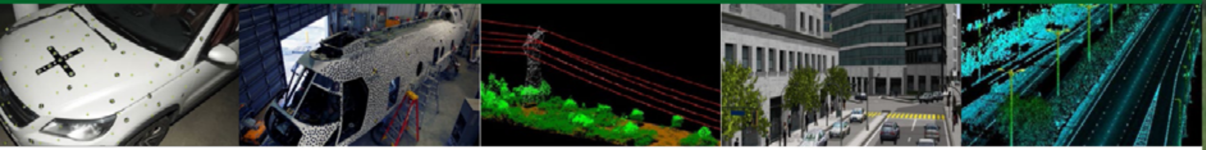
MAPPING FROM UAVS

HOW TO OPTIMIZE ACCURACY AND EFFICIENCY USING GNSS-INERTIAL SOLUTIONS



Thursday, April 7 2016

WELCOME TO
Mapping from UAVs
How to Optimize Accuracy and Efficiency Using GNSS-Inertial Solutions



Mohamed M.R. Mostafa
Chief Technology Officer
Navmatica Corporation

Mike Hogan
Business Development Manager
Avyon

Trond Løke
Chief Technology Officer
Hyperspectral Group

Co-Moderator: Lori Dearman, Sr. Webinar Producer

Who’s In the Audience?

A diverse audience of over 600 GNSS and unmanned professionals registered from 58 countries, 29 states and provinces representing the following categories:

50% GIS/Surveying

12% Precision Agriculture

10% Transportation

6% Critical Infrastructure/Utilities/ Power Grid

5% Natural Resource Management

4% Oil and Gas

13% Other

Welcome from *Inside GNSS*

Richard Fischer
Publisher of Inside Unmanned Systems
Director of Business Development
Inside GNSS

Welcome from *Applanix*

Joe Hutton, MASc
P.Eng, Director
Inertial Technology and
Airborne Products

Demoz Gebre-Egziabher
Aerospace Engineer and Mechanics Faculty
University of Minnesota

Poll #1

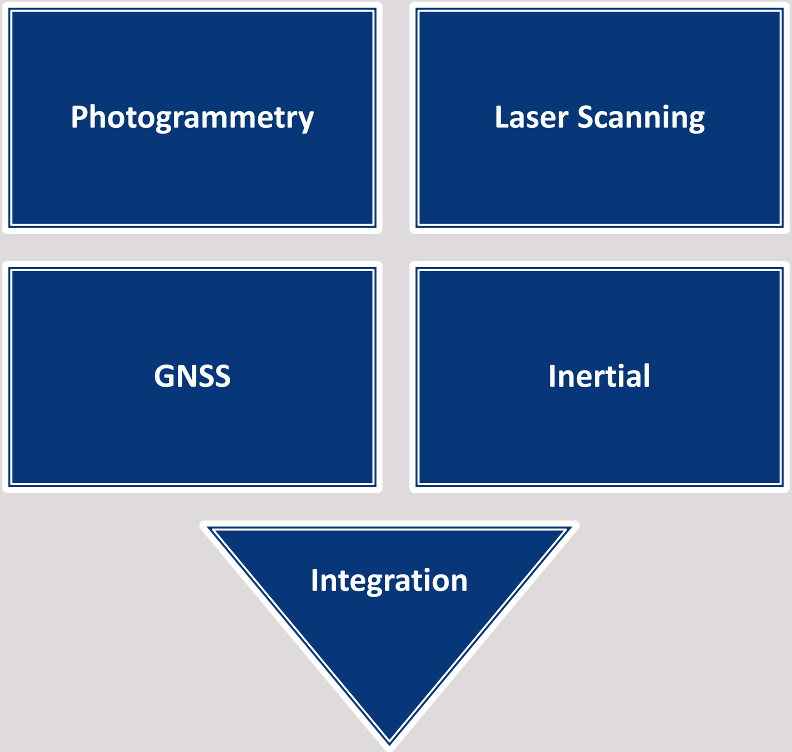
What type of sensor payload are you interested in using for mapping applications from UAV? ***(Select all that apply)***

a. RGB
b. Infra-red Camera
c. LiDAR
d. Multi-spectral Camera
e. Hyperspectral Camera

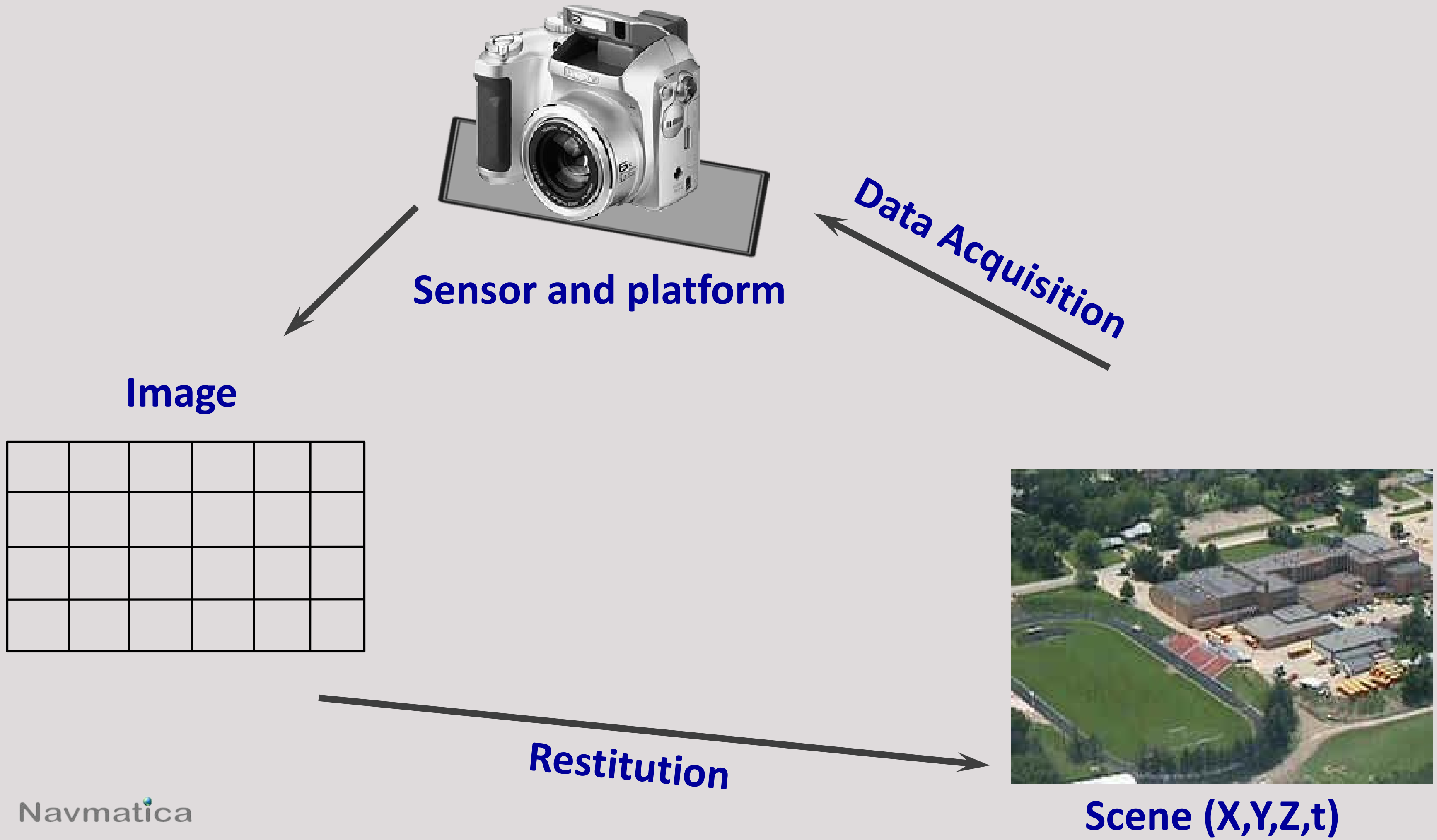
UAV Data Georeferencing: Theory and Applications

Mohamed MR Mostafa
Chief Technology Officer
Navmatica

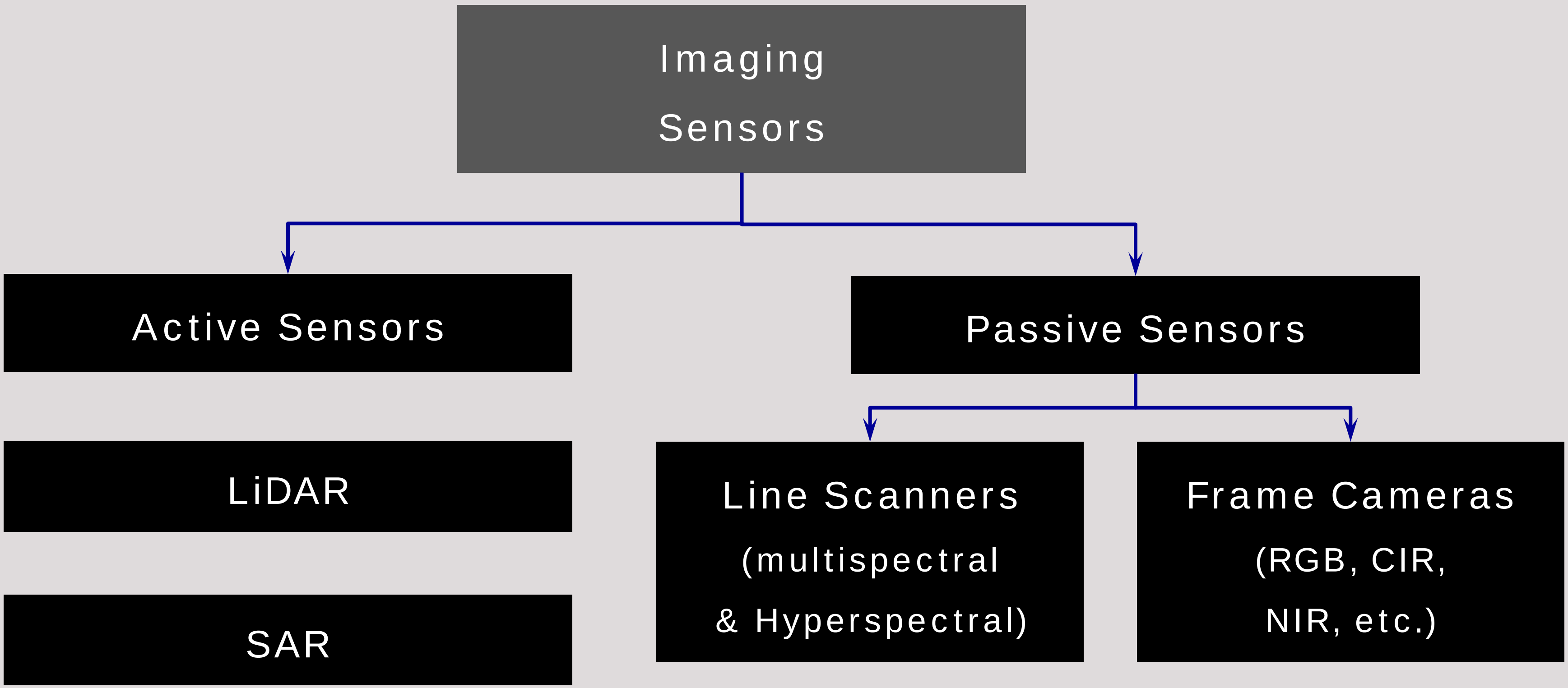
Navmatica


Photogrammetry
Laser Scanning
GNSS
Inertial
Integration

Photogrammetry



Sensors



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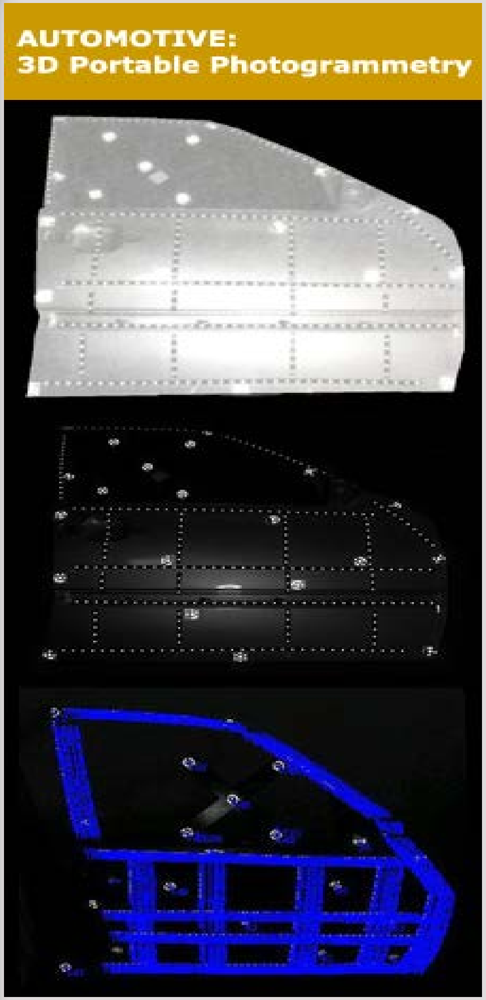
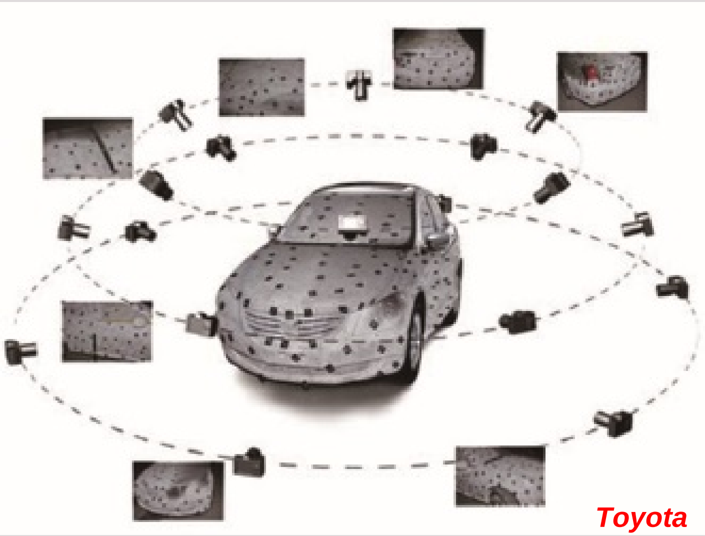
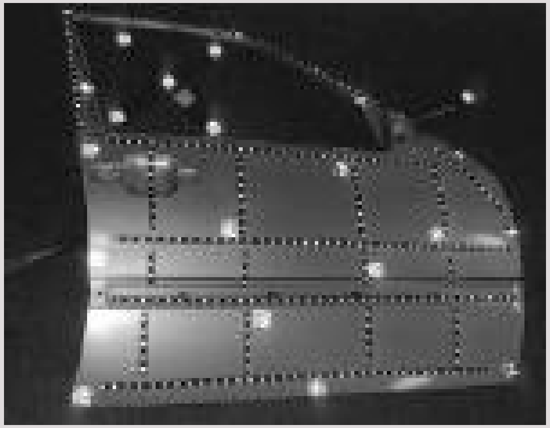
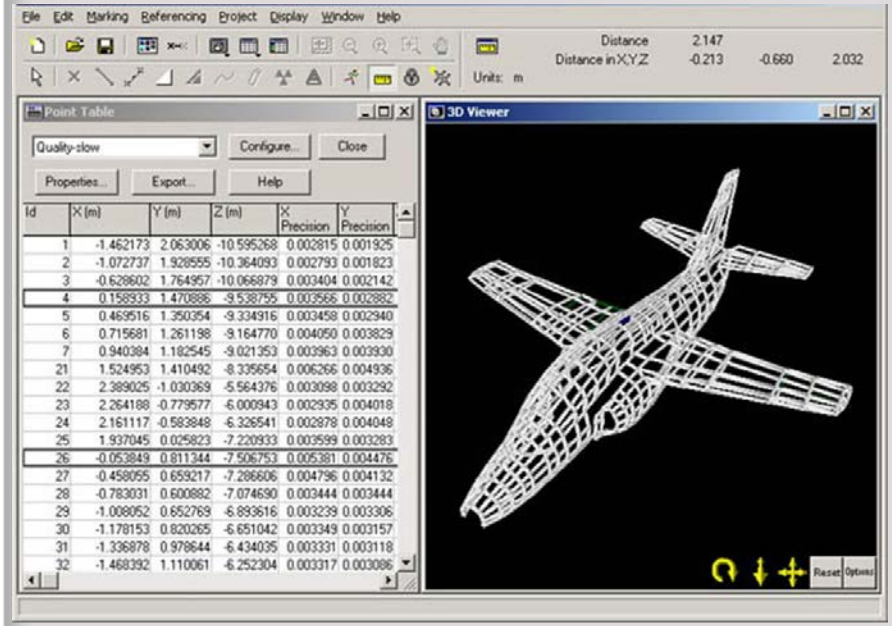
Automotive Applications





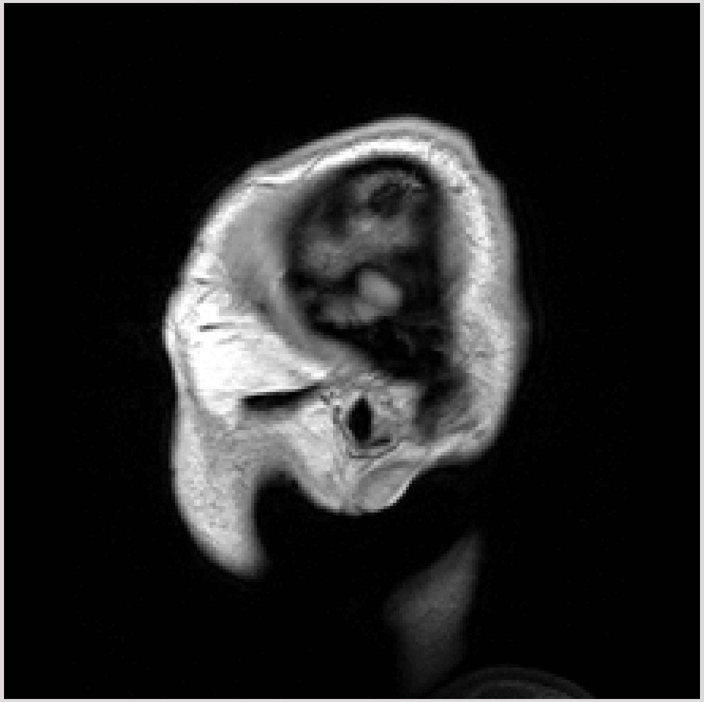


Aerospace Engineering Applications



Courtesy of NASA, US Navy, FAA, DLR

Medical Engineering Applications



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Courtesy of University of Toronto

Mapping Applications

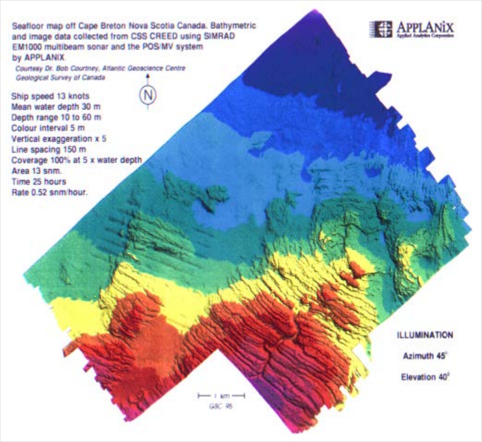
InsideGNSS applanix inside unmanned systems

Airborne Mapping

Mobile Mapping

Indoor Mapping

Seafloor Mapping



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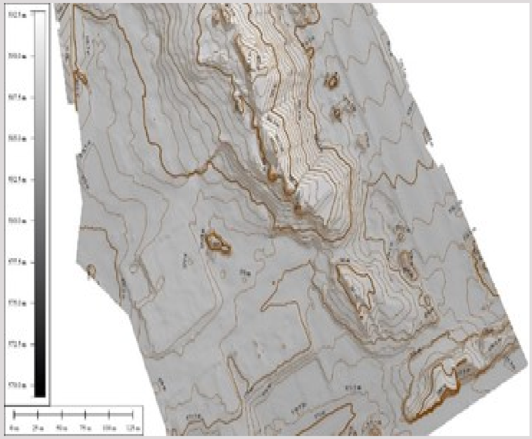
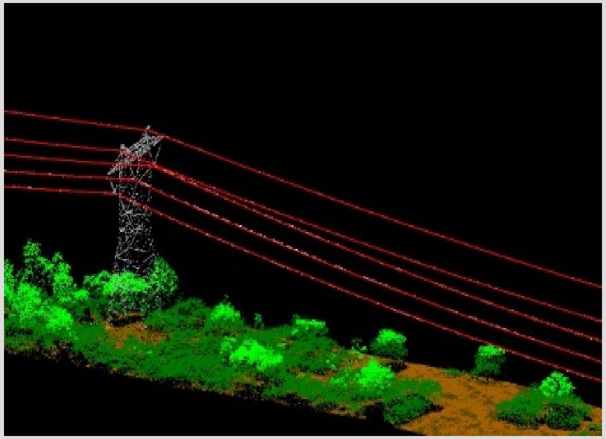
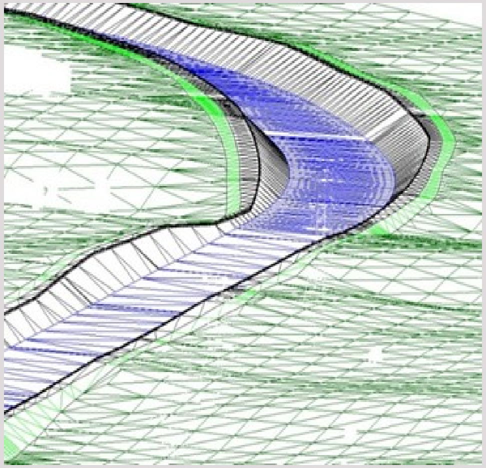
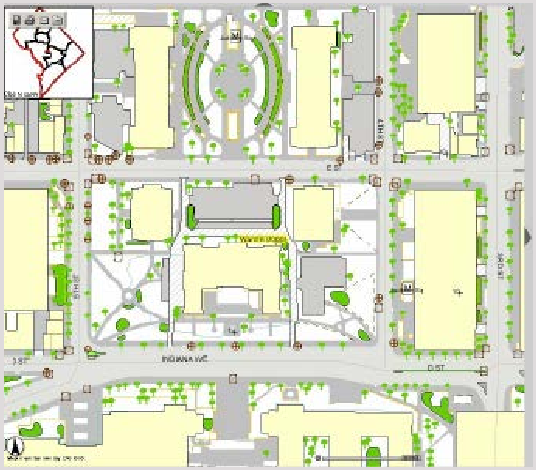
Mapping Products









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Sensors

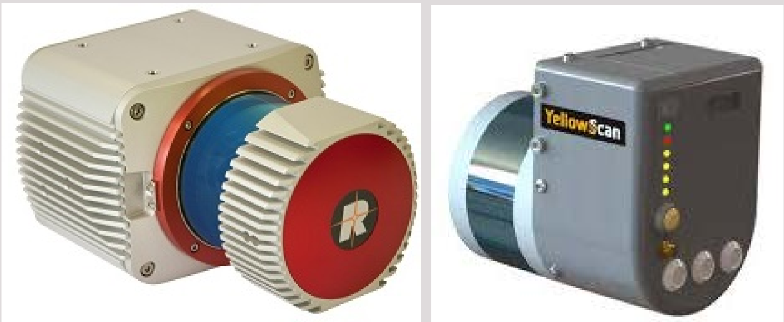
Large Format Cameras

Medium Format Cameras

Spherical Camera

Small Format Cameras

Sensors



LiDAR

Hyperspectral

SAR

Multispectral

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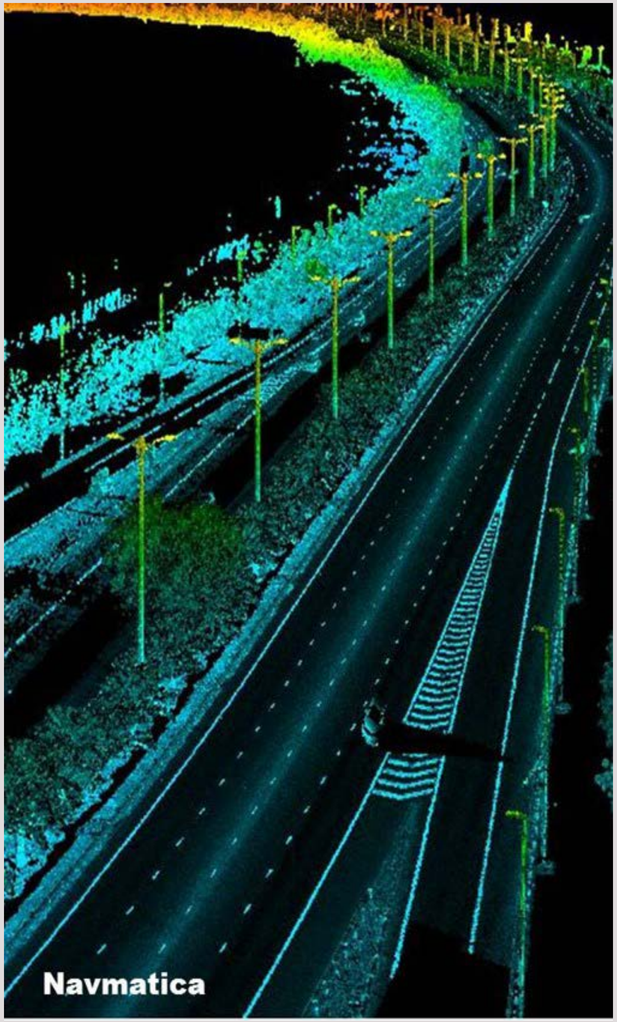
Data Examples

Digital Frame imagery

Video frames



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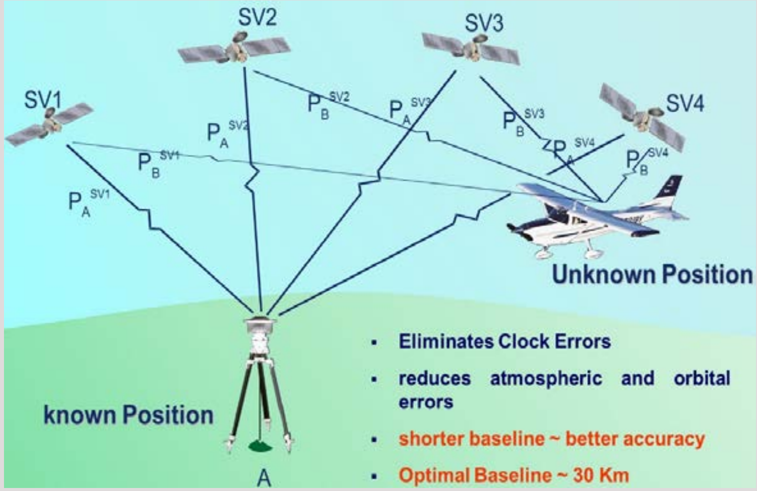
GNSS Revisited

- GNSS includes GPS, GLONASS, BeiDou, Galileo
- Autonomous positioning accuracy ≅ 1.5 - 3 m.
- Relative Positioning allows for cm level accuracy using:
  - Base Stations
  - CORS
  - IGS
  - Real-time or post-processed VRS

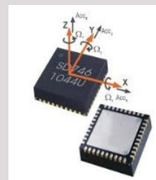


GNSS	Real Time Accuracy	Post-Processing needed	Range	Integration	Applications
RTK	**~ 5 cm**	**No**	• **Limited to radio link range of 5 km**	• **Limited to loosely coupled**	• **Emergency Response** • **Reconnaissance** • **Surveillance** • **Monitoring** • **Moderate precision mapping**
PPK	**~ 5 m**	**Yes**	• **Unlimited**	• **unlimited**	• **High precision mapping**

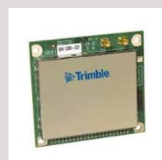
GNSS-Aided Inertial revisited

Distance travelled = $\iint$ specific force

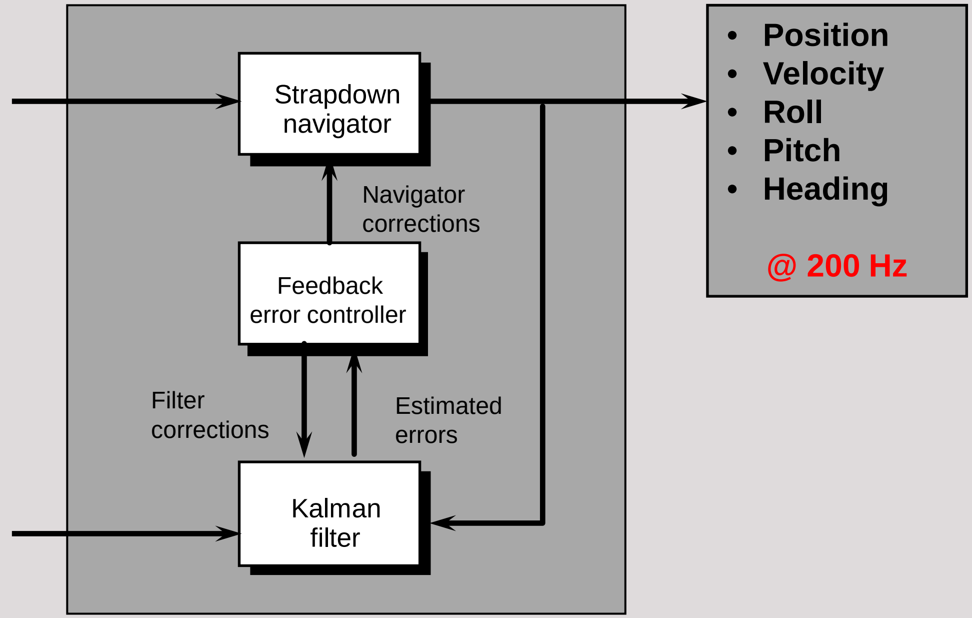
Orientation Change = $\int$ angular rate



IMU



GNSS



- GNSS is used to aid the inertial navigation solution.
- In airborne applications, this is best done on the tightly coupled level
- When GPS-drops out, the inertial navigation solution continues unaided
- Continuous closed-loop error controller maintains optimal performance by bounding position and orientation errors and calibrating inertial sensor errors

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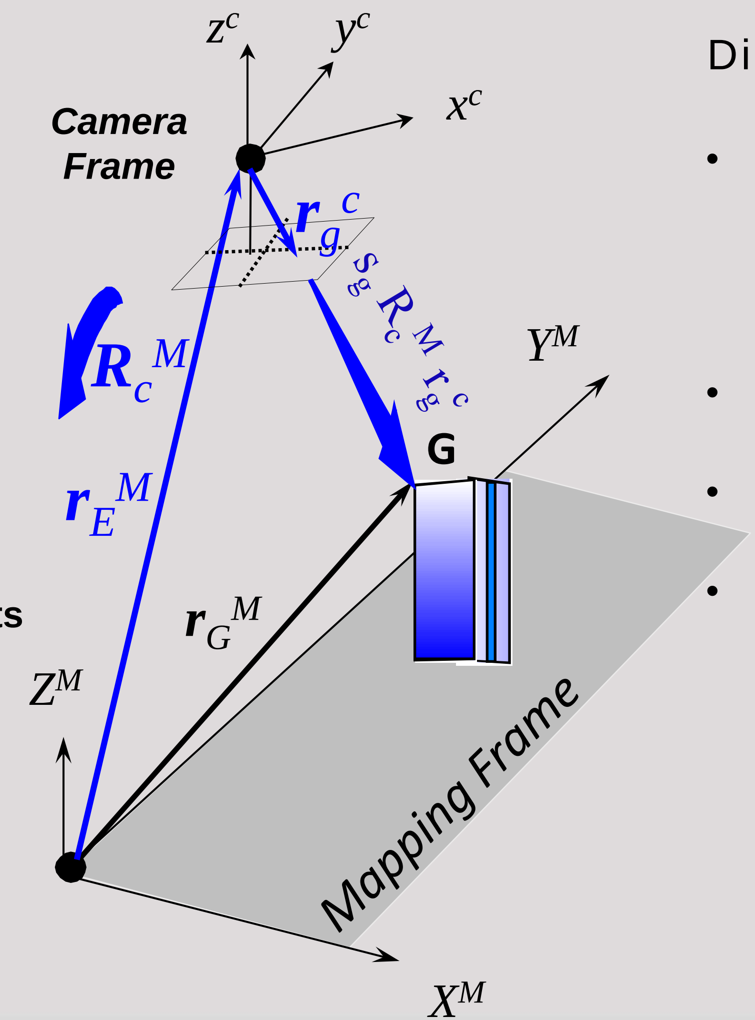
Georeferencing in Photogrammetry

Aerial Triangulation

- **Establish & Survey GCPs**
- **Measure image points**
- **Compute camera position & orientation using AT**
- **Produce mapping products**



Direct Georeferencing

- **Measure camera position & orientation using GNSS/Inertial**
- **QC the data**
- **Produce mapping products**
- **No GCP needed**

Ground Control Points (GCP)

GCP (Established or paneled)

Photo-Identifiable GCP

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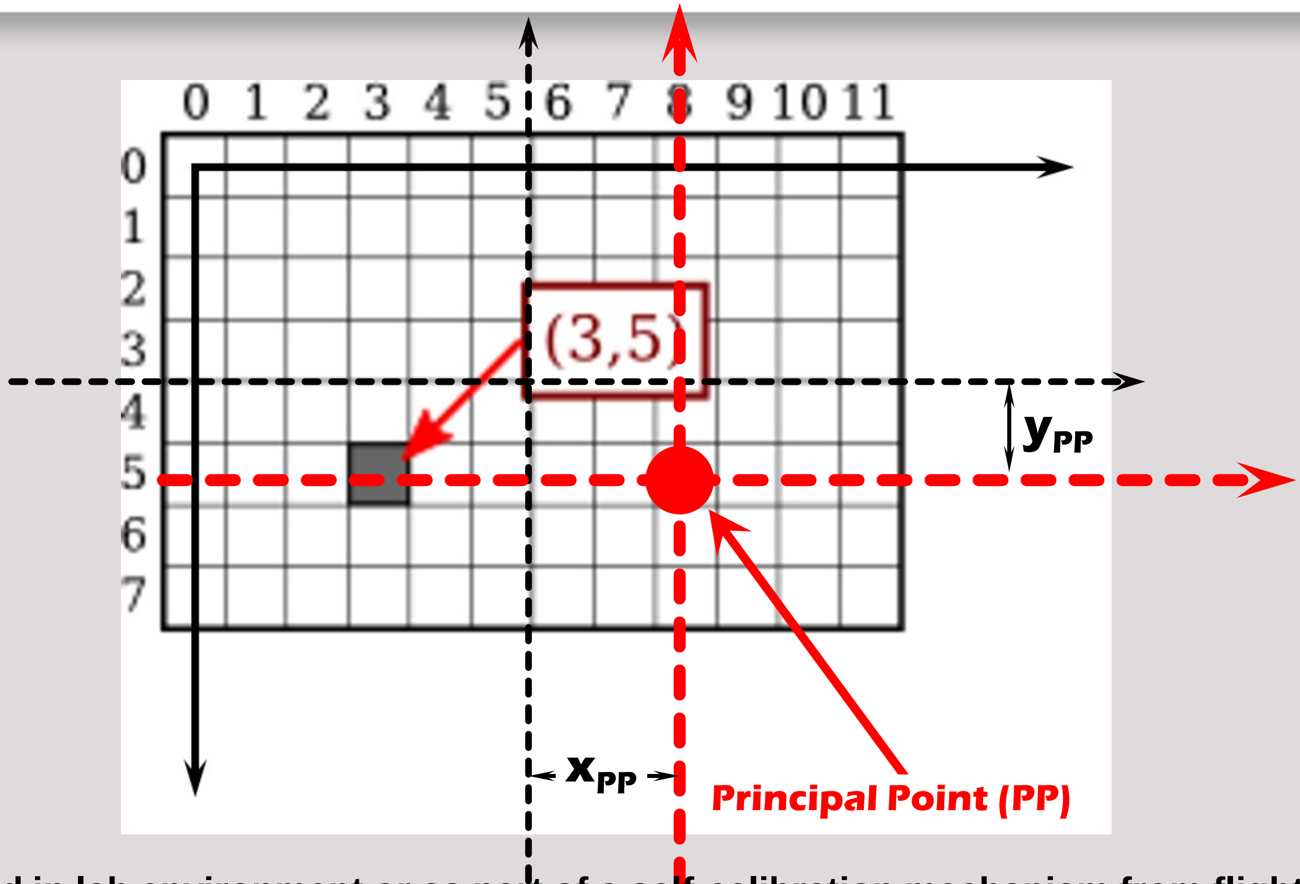
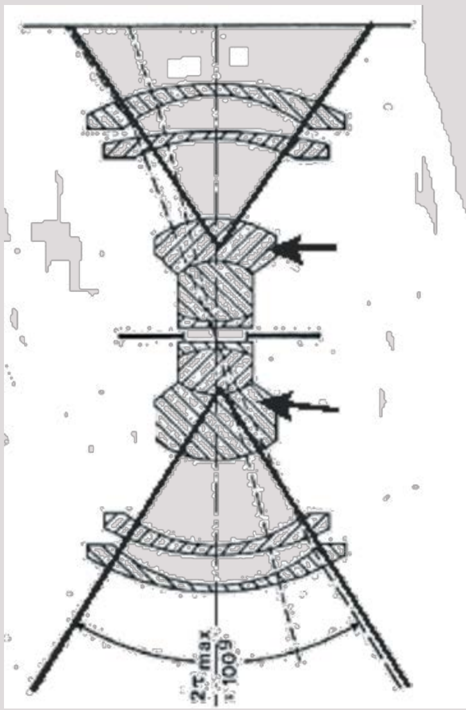
Camera interior geometry

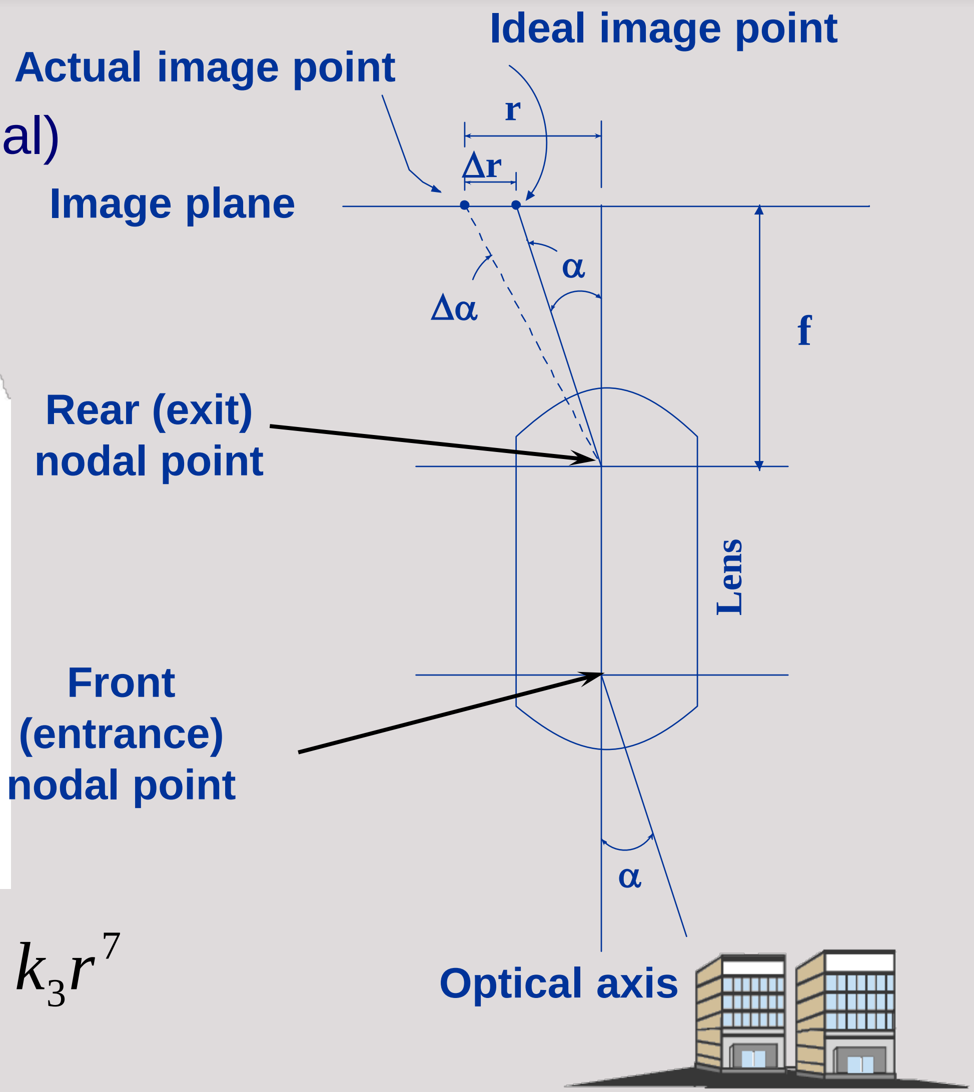


- Calibrated in lab environment or as part of a self-calibration mechanism from flight data
- Correlated with boresight angles
- Its Stability is engineered in professional grade cameras
- If calibrated over a calibration field, it could be held fixed (known) for the rest of the mission

Lens Distortion

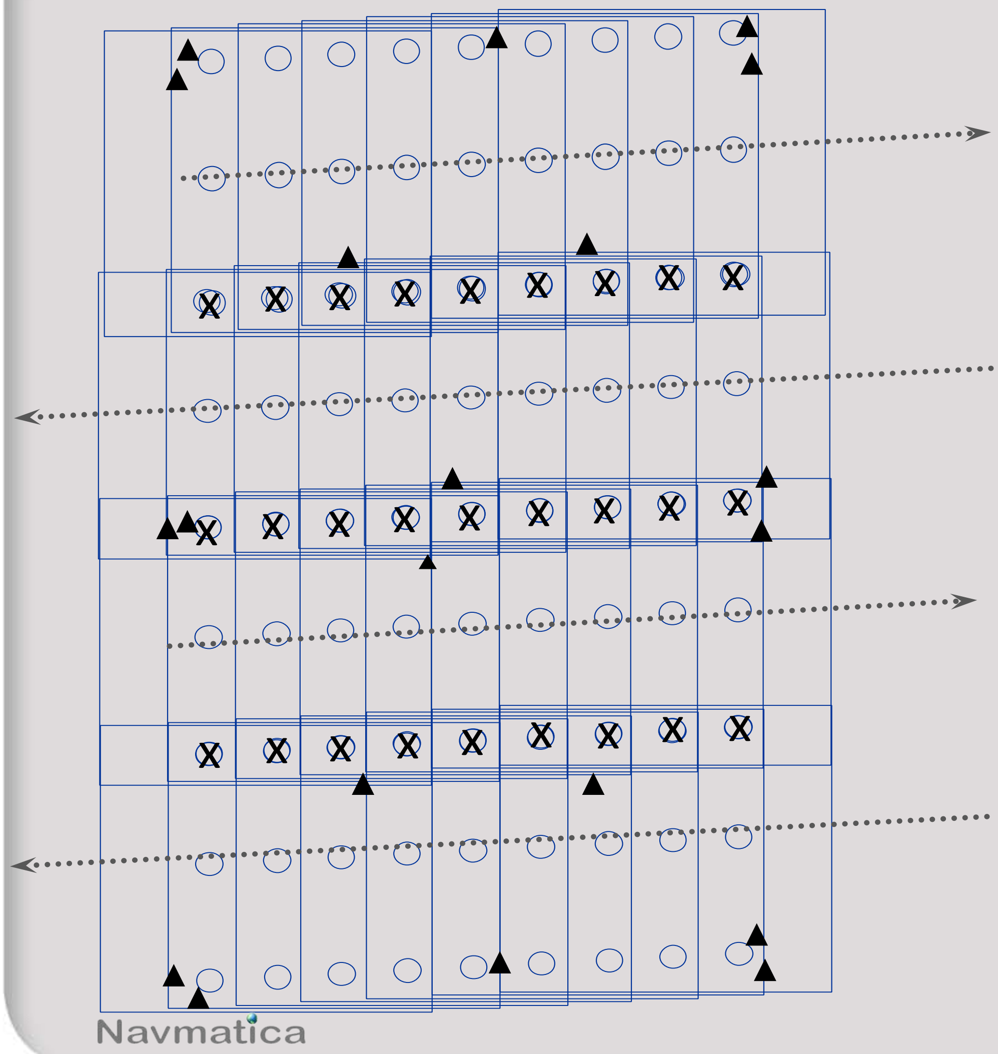
LENS Distortion (radial)





$$\Delta r = k_1 r^3 + k_2 r^5 + k_3 r^7$$

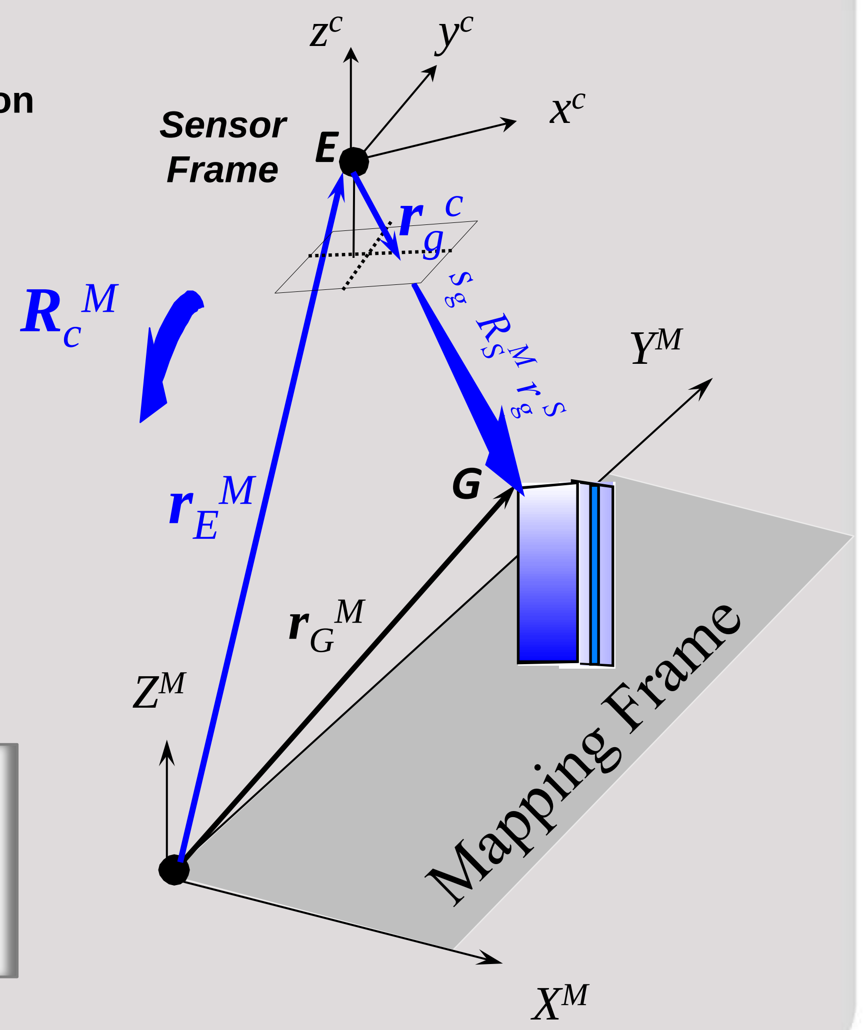
Aerial Triangulation (AT)



- Fly a block of images
- Must fly 80% x 80% image overlap &sidelap
- Measure tie/pass/GCP on all images
- GCPs are necessary
- An Image Block is necessary
- Block Geometry Strength is necessary
- Thousands of tie/pass points are necessary
- In non-urban environments, tie/pass points are challenging to find
- Self Calibration is necessary

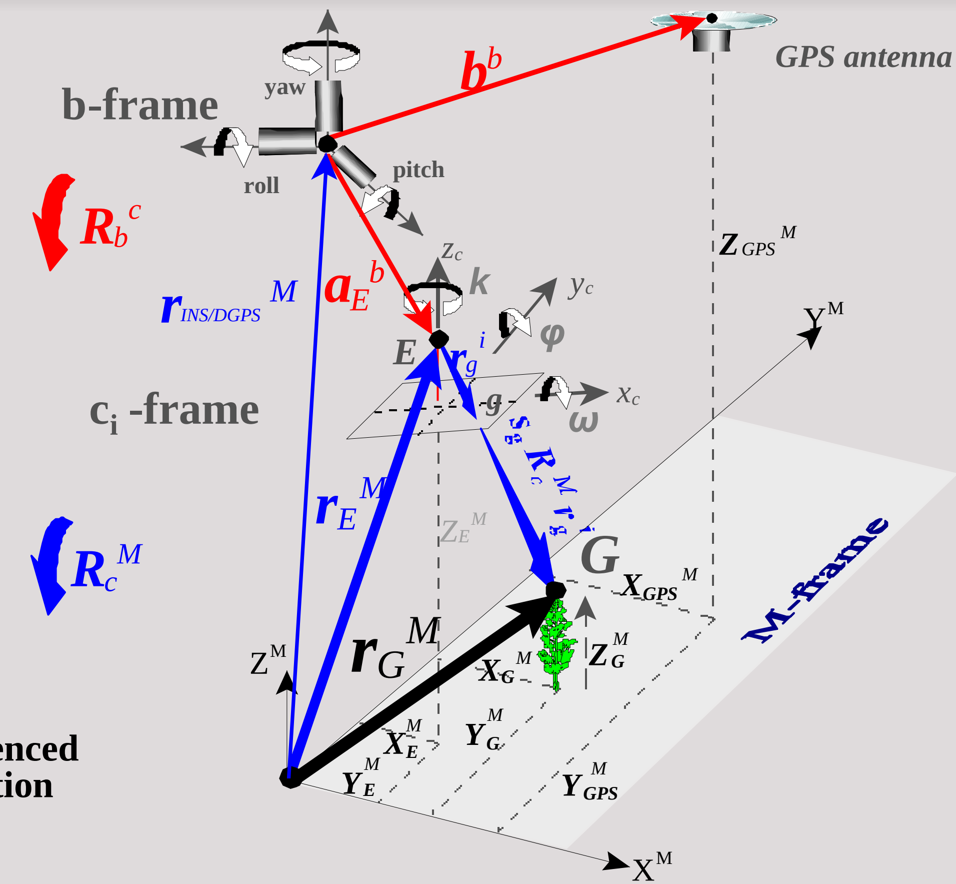
What is Direct Georeferencing?

- **Measure imaging sensor position & orientation using GNSS/Inertial**
- **QC the data**
- **Produce mapping products**
- **No GCP needed**



- **DG can be used with any type of Imaging Sensor**
- **DG must be used with LiDAR, SAR and Scanning sensors**

Direct Georeferencing



Georeferenced 3D Position

$$r_G^M = r_{INS/DGPS}^M(t) + R_b^M(t)\; a_E^b \; + \; s_g \; R_b^M(t) \; R_c^b \; r_g^c(t)$$

- $r_{INS/DGPS}^M(t)$: IMU/GPS
- $R_b^M(t)$: IMU
- a_E^b: Lever Arm Calibration
- s_g: Stereo Processing
- $R_b^M(t)$: IMU
- R_c^b: Boresight Calibration
- $r_g^c(t)$: Image Measurement and Camera Calibration

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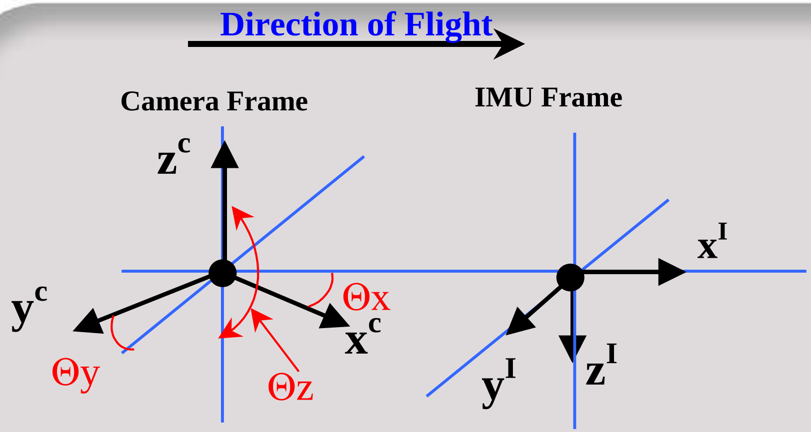
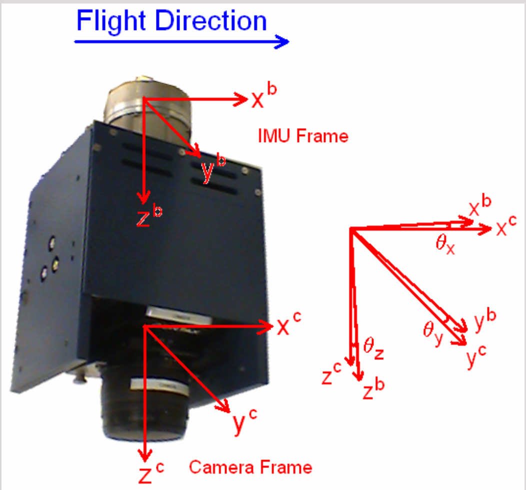
Boresight Calibration





- Boresight is the physical mounting angles of an IMU w.r.t. a camera
- Boresight matrix is assumed constant at all times
- Boresight is computed using:
  - Image rotation matrix
  - IMU-derived rotation matrix
- How well the imaging geometry is established (camera calibration?)
- Correlation between the camera calibration and boresight ?
- This necessitates the simultaneous calibration of boresight and camera

$$\mathbf{R}_c^b = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\Theta_x & \sin\Theta_x \\ 0 & -\sin\Theta_x & \cos\Theta_x \end{bmatrix} \begin{bmatrix} \cos\Theta_y & 0 & -\sin\Theta_y \\ 0 & 1 & 0 \\ \sin\Theta_y & 0 & \cos\Theta_y \end{bmatrix} \begin{bmatrix} \cos\Theta_z & \sin\Theta_z & 0 \\ -\sin\Theta_z & \cos\Theta_z & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} \cos\Theta_y \cos\Theta_z & \cos\Theta_y \sin\Theta_z & -\sin\Theta_y \\ \sin\Theta_x \sin\Theta_y \cos\Theta_z - \cos\Theta_x \sin\Theta_z & \sin\Theta_x \sin\Theta_y \sin\Theta_z + \cos\Theta_x \cos\Theta_z & \sin\Theta_x \cos\Theta_y \\ \cos\Theta_x \sin\Theta_y \cos\Theta_z + \sin\Theta_x \sin\Theta_z & \cos\Theta_x \sin\Theta_y \sin\Theta_z - \sin\Theta_x \cos\Theta_z & \cos\Theta_x \cos\Theta_y \end{bmatrix}$$

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Simplified Error Budget

Georeferencing Errors

GNSS errors
- Easting
- Northing
- Height
- V_E
- V_N
- V_D

Inertial errors
- Roll
- Pitch
- Heading
- Gyro bias stability
- Accel bias

Sensor Errors

Image Interval
- Distance based
- Time based
- rectification

Geom Stability
- Boresight
- Lever Arms
- IO

Meas Noise
- laser
- imagery

Calibration Errors

Lever Arms
IMU ⇨ Laser 1
IMU ⇨ Laser 2
IMU ⇨ Cam 1
IMU ⇨ Cam 2
IMU ⇨ ant 1
IMU ⇨ ant 2

Boresights
IMU ⇨ Laser 1
IMU ⇨ Laser 2
IMU ⇨ Cam 1
IMU ⇨ Cam 2
IMU ⇨ ant 1
IMU ⇨ ant 2

Camera IO
- f
- x_{PP} y_{PP}
- $K_0, k_1, k_2, k_3, p_1, p_2$

Other Factors

Cam Geometry
- Space Intersection
- Space Resection
- Number of Cam

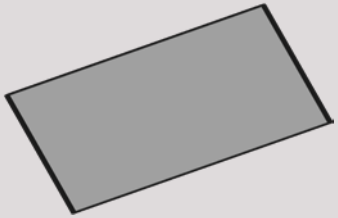
Cam Resolution
- Image Size
- Pixel Size
- Number of Cam

Feature Ext
- Laser
- Imagery

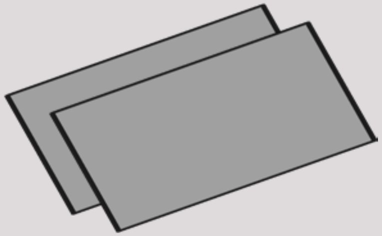
Direct Georeferencing

- GCPs are not needed (control is in the air)
- Single image + DEM = Orthophoto generation
- One stereo pair with minimum overlap for Topo Mapping & DEM Extraction
- NO Image Blocks needed
- Fly any Overlap
- Fly any Sidelap
- No Tie Points needed (QC only)
- No Self Calibration is necessary (QC only)

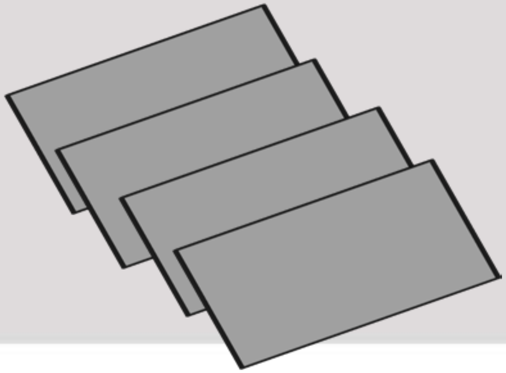
Single image + DEM = Ortho



Stereo pair for Topo Mapping & DEM Extraction



One or more image strips for Corridor mapping



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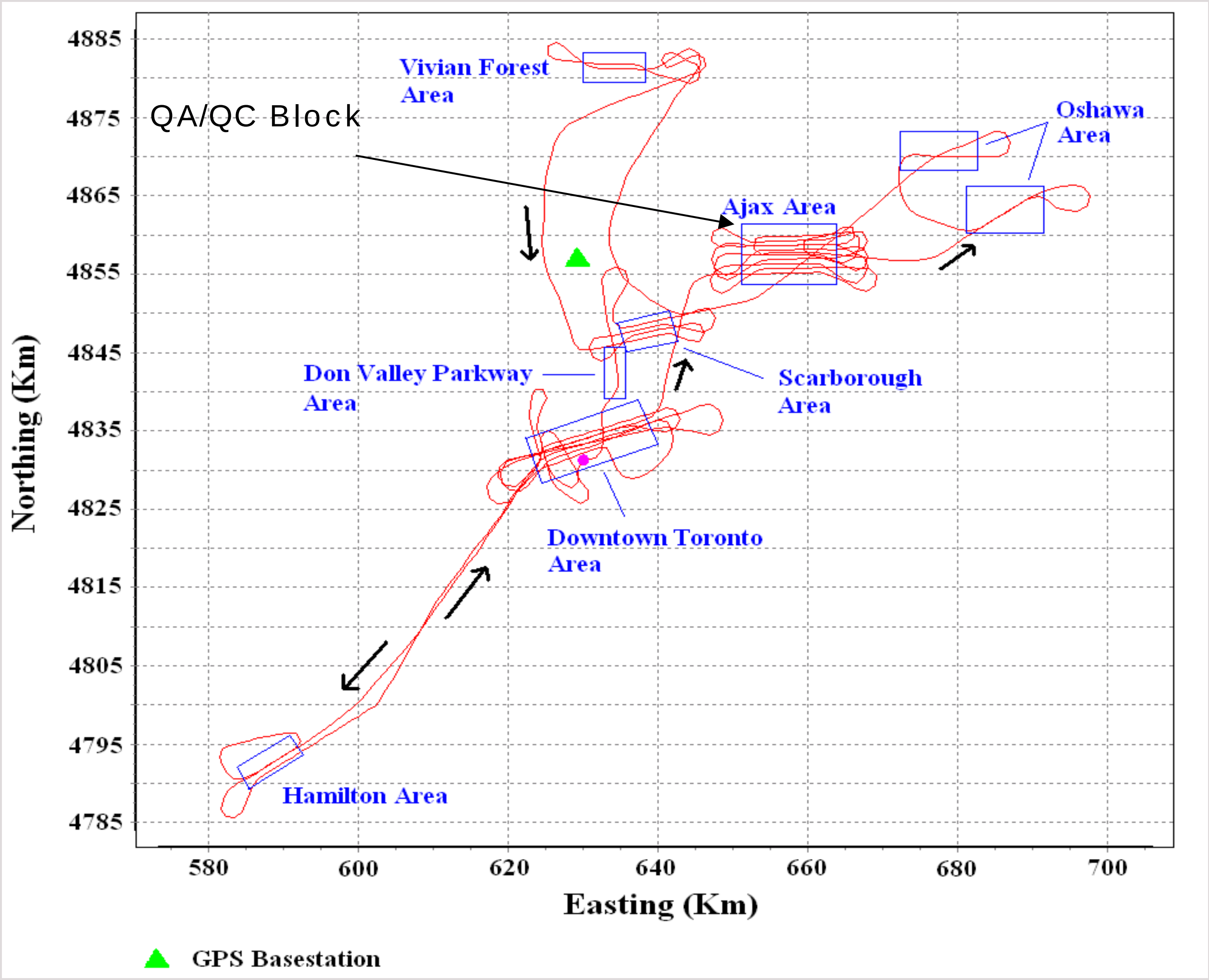
Direct Georeferencing QC Example



Aerial Triangulation

- Must fly 80% overlap
- Must fly 80% sidelap
- Tie Point quality & volume depends on AOI
- An image Block is necessary
- Block geometric strength is necessary
- Self-Calibration every mission
- GCP always required

Direct Georeferencing

- Can fly any overlap (to address mapping)
- minimal sidelap (to address mapping)
- Tie Points are not required– (only for QC)
- Can fly one or more strips
- No Need for Blocks
- No Self Calibration necessary (only QC)
- No GCP required (only QC)

Real-World Examples (1/2)

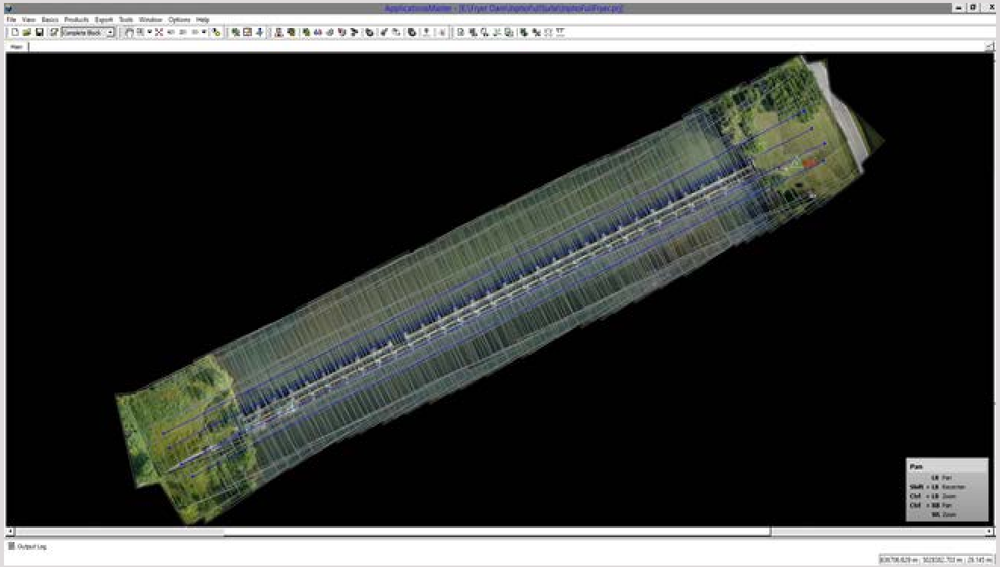
- **Company**
  - Avyon
- **Project**
  - Location: Fryer Dam near Richelieu, QC
  - 450 m x 100 m block (0.7cm GSD)
- **Platform**
  - microdrones md4-1000
- **Payload**
  - Sony a7R camera with APX-15 UAV
  - Zeiss Sonnar T* 35 mm lens
- **Flight profile**
  - 2 flight lines ~30% sidelap & ~85% endlap
  - 12-minute flight time
  - 14 km/h platform speed
  - 5 GCP's distributed at each end of the dam




Real-World Example (2/2)

Processing Workflow

- POSPac:
  - GNSS/Inertial processing
  - Boresight calibration
  - Interior geometry calibration
  - Lens distortion held fixed
- Inpho photogrammetric SW:
  - Extract DSM from stereo imagery
  - Generate 1 cm GSD orthomosaic



	dE	dN
Number of Points	5	5
Mean Error	0.031	-0.009
Standard Deviation (m)	0.017	0.014
RMSE (m)	0.034	0.015

Mian, O., Lutes, J., Lipa, G., Hutton, J. J., Gavelle, E., and Borghini, S.: Accuracy Assessment of Direct Georeferencing for Photogrammetric Applications on Small Unmanned Aerial Platforms. IAPRS, Spatial Inf. Sci., XL-3/W4, 77-83, doi:10.5194/isprs-archives-XL-3-W4-77-2016, 2016.

md4-1000 High Precision Solution: Accuracy and Efficiency

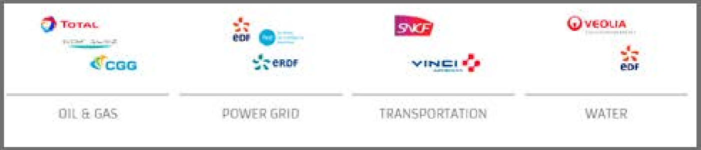
Mike Hogan
Business Development
Avyon

Avyon Background

- Avyon provides professional small Unmanned Aerial System (UAS) solutions to various industries and markets in North America
- Main focus: survey and mapping
- Avyon Partners: Delair-Tech and microdrones

delair-tech AIRBORNE SENSORING

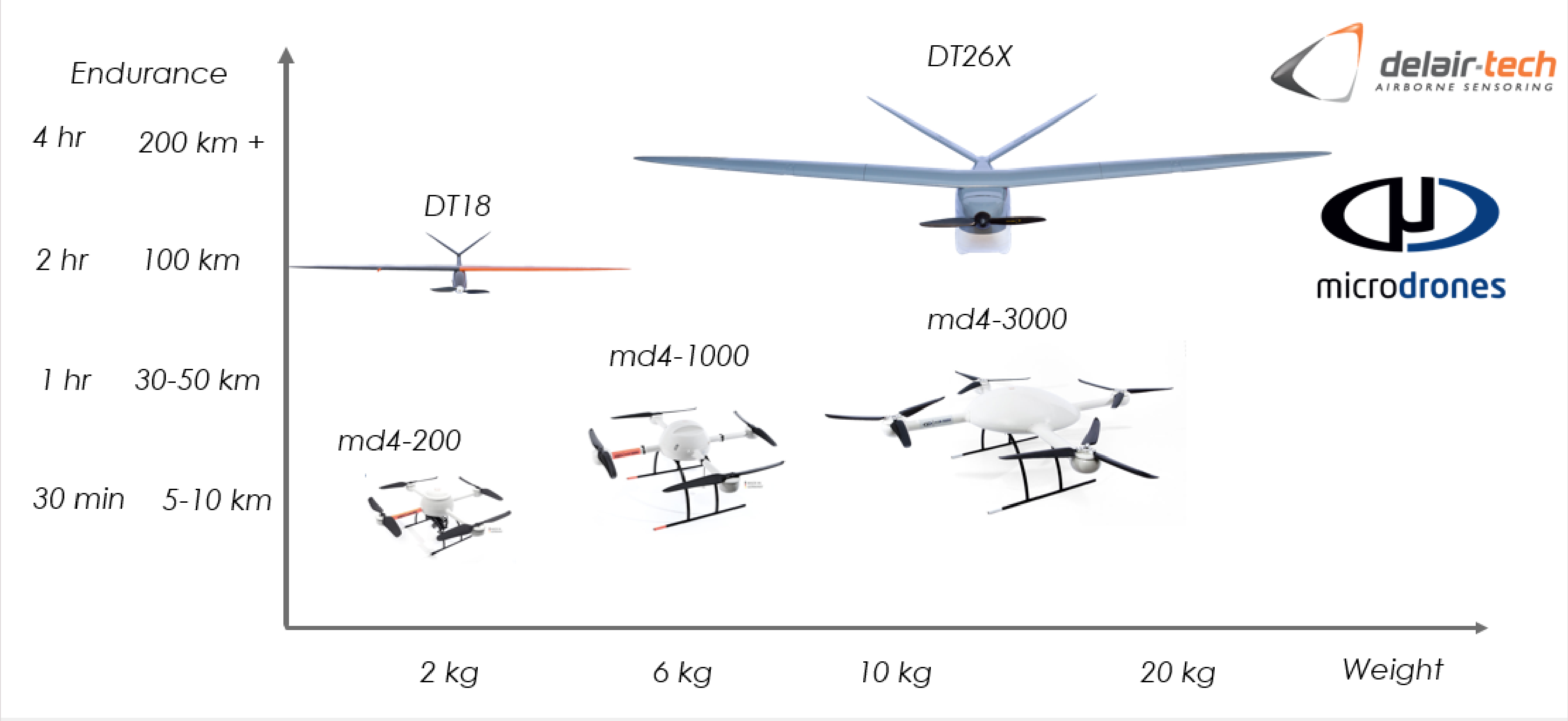
- Founded in 2011
- Toulouse, France
- Professional Long Range Fixed Wing UAS Focused on Industry
- BLOS approved



microdrones

- Founded in 2005
- Siegen, Germany
- Professional Multi-Rotor UAS Focused
- BLOS Operations

Fleet of Systems

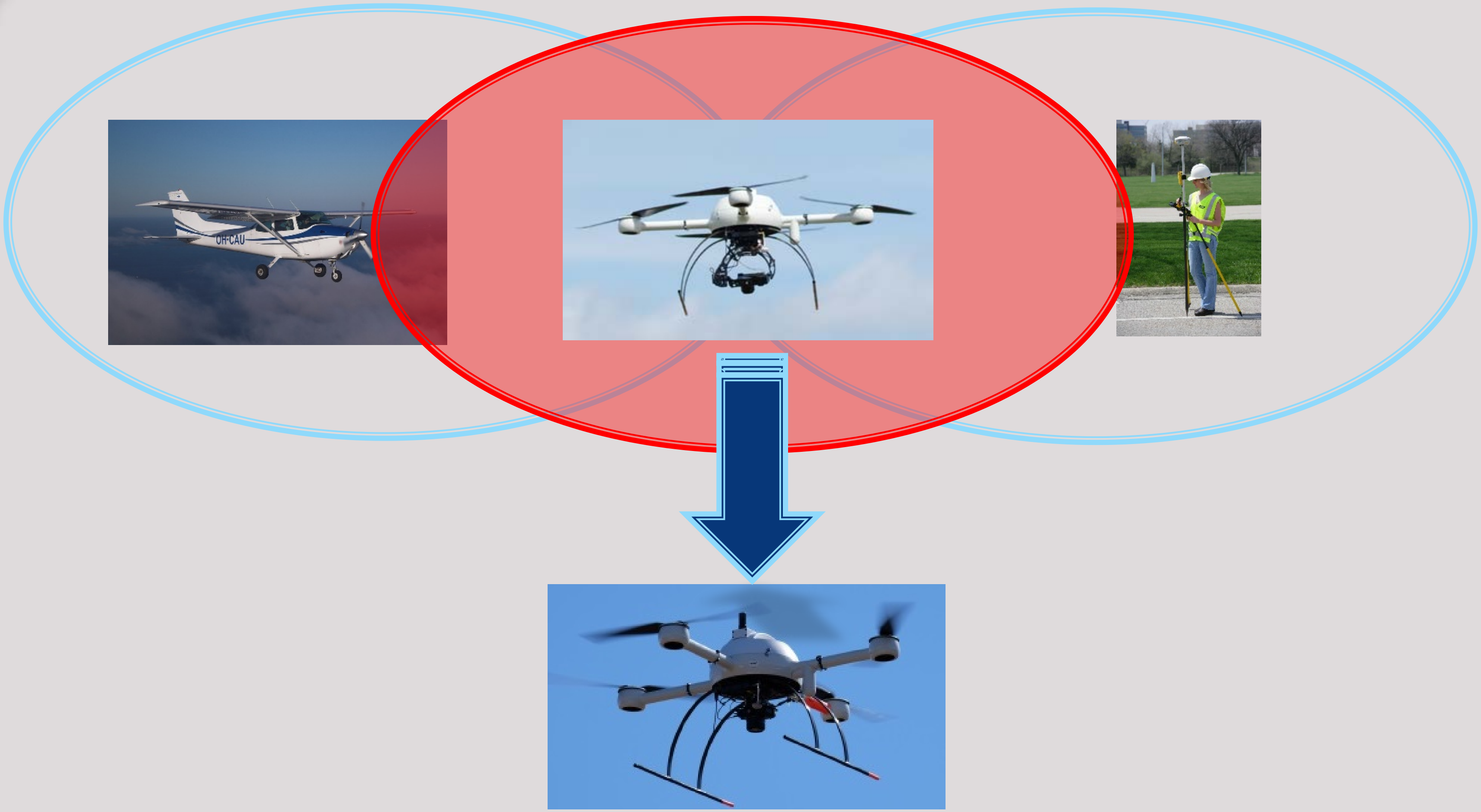


Small UAS – Surveyor Tool

- Efficiency
- Safety
- Flexibility
  - Multiple Sensors
- Economical
- Repeatability

= Greater Access to Geospatial Data

Small UAS – Surveyor Tool



- How to make small UAS more efficient and accurate?

md4-1000 High Precision Solution

- md4-1000 platform + Direct Georeferencing = md4-1000 High Precision
- Output – Accurate position, orientation and timing
- Total payload of approx. 800 g

- Light Weight GPS/GLONASS Antenna
- 25 g

- Full Frame COTS camera – 42 MP
- 35 mm fixed lens
- Calibrated
- 507 g

- 220 channel GNSS Receiver
- Calibrated IMU with Data rate of 200 Hz
- 60 g

Ask the Experts – Part 1

Mike Hogan
Business Development Manager
Avyon

Trond Løke
Chief Technology Officer
Hyperspectral Group

Mohamed M.R. Mostafa
Chief Technology Officer
Navmatica Corporation

Poll #2

The accuracy of which PNT measurement is most important for direct geo-referencing? (please select your top two)

a. Accurate position
b. Accurate attitude
c. Sensor geometric accuracy
d. Accurate time tagging

md4-1000 High Precision Solution: Accuracy and Efficiency

Mike Hogan
Business Development
Avyon

Opportunities for Efficiency

Potential Savings

- Project planning
- GCP layout and installation = no requirement for GCP
- Flight time – less side lap = decrease flt time or more area covered
- Data processing

Other opportunities

- Corridor mapping
- Mapping inaccessible areas

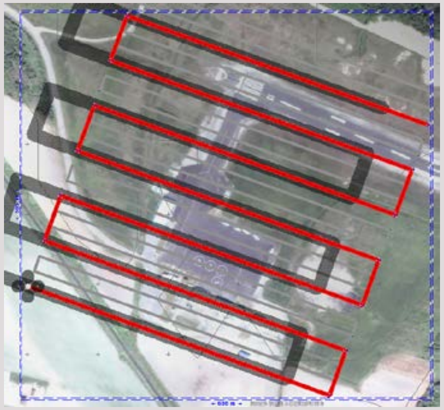
Example One (1/3) – Efficiency

- Sample Area: 500 m x 500 m
  - Typical area for Line of sight small UAS operations
- Flying Ht: 120 m
- Flying Speed: 6 m/s
- Camera: Sony RX1R ii
- Front lap: 80%
- Side lap: will depend on mapping configuration

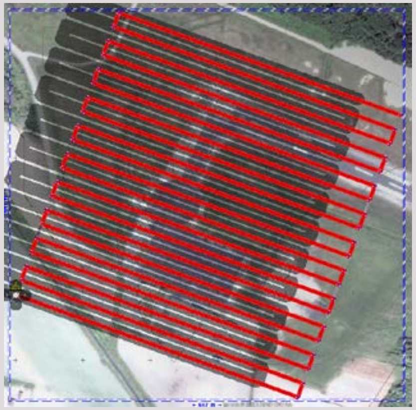
Example One (2/3) – Flight Time Comparison

md4-1000
High Precision
40% Side Lap

md4-1000
80% Side Lap



15 mins	Flt Time	35 min
215	# Photos	650



Example One (3/3) – Time comparison

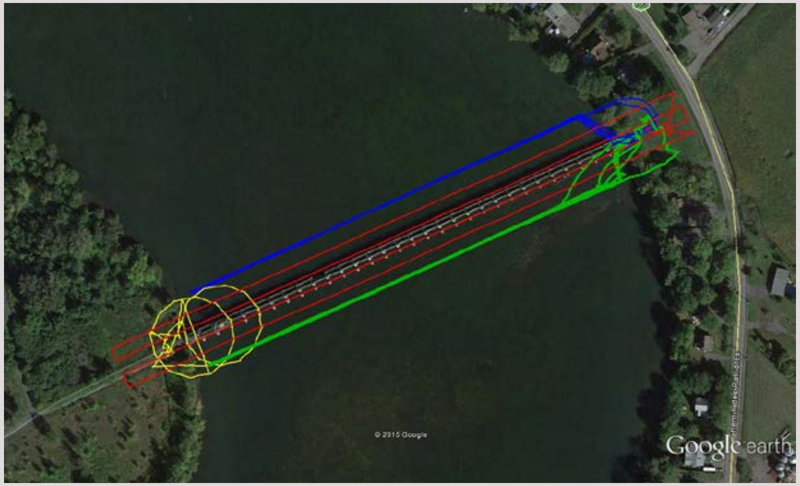
Workflow Task	md4-1000 (Aerial Triangulation)	md4-1000 High Precision (Direct Georeferencing)	Difference
Plan Project	1 hrs	1 hrs	-
GCP Layout	2 hrs	-	2 hrs
Flight	35 mins	15 mins	20 mins
Data Processing	12 hrs	4 hrs	8 hrs
Total	**15hrs 35 mins**	**5 hrs 15 mins**	**10 hrs 20 min**

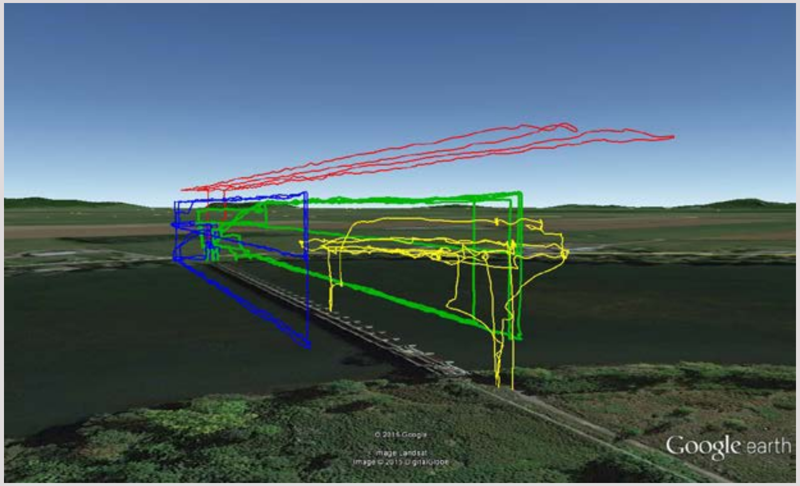
Example Two (1/3) Accuracy

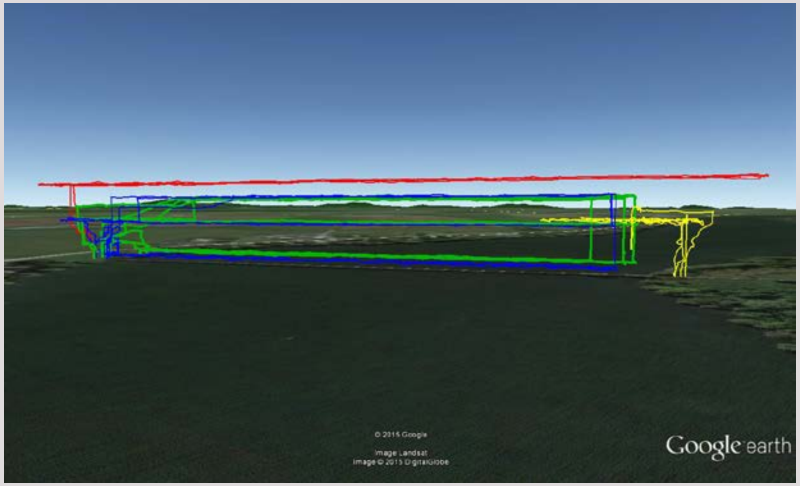
- Fryer Dam
- Challenges
  - Could not access
  - Crossing river
- Requirement
  - Orthomosaic/DSM – Sub meter

Example Two (2/3) Accuracy

- 11 Flights
  - 1 NADIR – APX-15 UAV (red)
  - 4 – North (blue)
  - 4 – South (green)
  - 3 Over structures (yellow)
- Flight Time ≅ 3 hrs





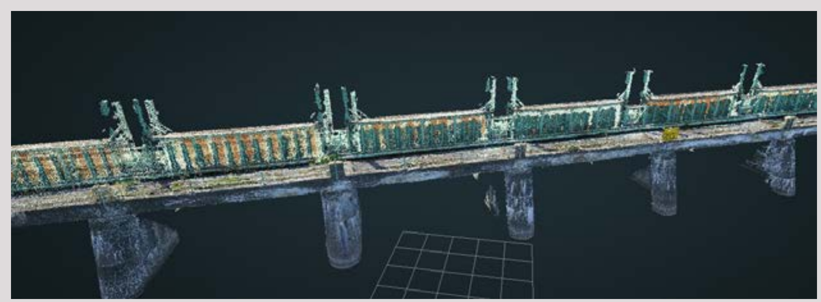


Example Two (3/3) Accuracy

- Horizontal accuracy was less than 4 cm (RMS) approx. 4 x GSD
- Vertical accuracy was less than 10 cm (RMS) or approx. 10 x GSD

	dE	dN	dH
Number of Points	5	5	5
Mean Error	0.031	-0.009	-0.023
Standard Deviation (m)	0.017	0.014	0.101
RMSE (m)	0.034	0.015	0.093

Mian, O., Lutes, J., Lipa, G., Hutton, J. J., Gavelle, E., and Borghini, S.: Accuracy Assessment of Direct Georeferencing for Photogrammetric Applications on Small Unmanned Aerial Platforms. IAPRS, Spatial Inf. Sci., XL-3/W4, 77-83, doi:10.5194/isprs-archives-XL-3-W4-77-2016, 2016.



Summary

- md4-1000 High Precision provides:
  - Potential for considerable efficiency in operations (Time/Money)
  - Ability to meet required accuracy standards using proven methodologies and workflow
- Under development:
  - md4-3000 High Precision
    - Medium format professional cameras
    - LiDAR
    - Hyperspectral
  - BVLOS
    - Corridor mapping

Scientific Grade Hyperspectral UAV Solution: HySpex Mjolnir-1024

Key Specifications and Performance

Trond Løke
CTO
HySpex Division

norsk elektro optikk

HySpex

Hyperspectral imaging = Imaging spectrometry

Imaging: Measurement of light (radiance) as a function of spatial position
Spectrometry: Measurement of light (radiance) as a function of wavelength

- Different substances have different reflection spectra
- Hyperspectral imaging provides a detailed spectrum from each pixel in a 2d image

-> *Very well suited for automatic image processing and quantitative measurements*

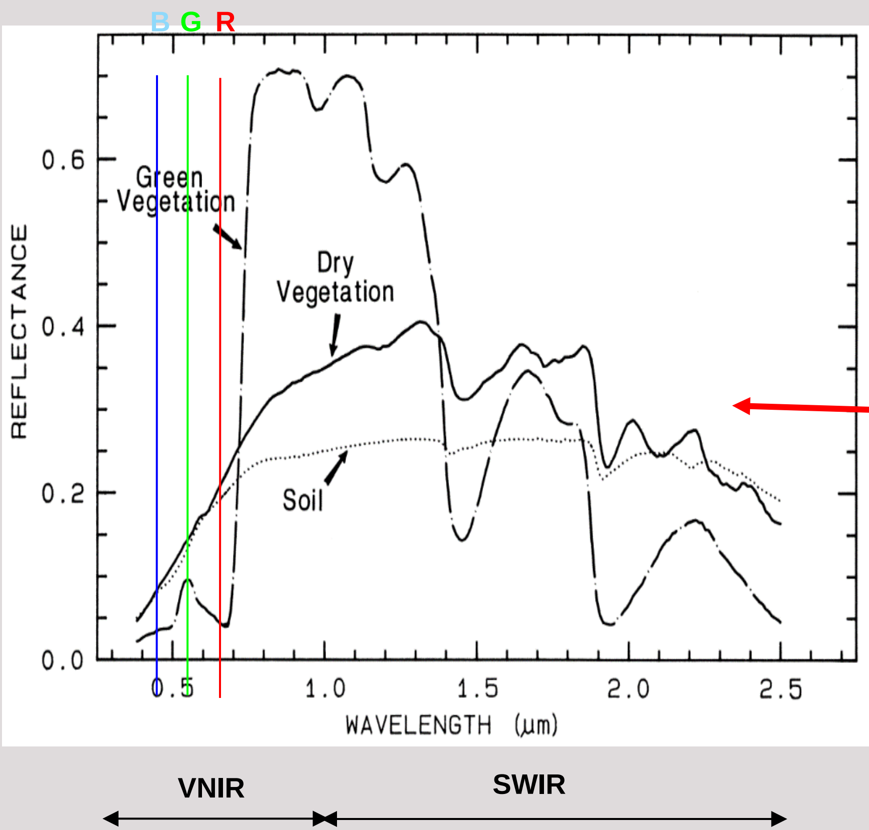
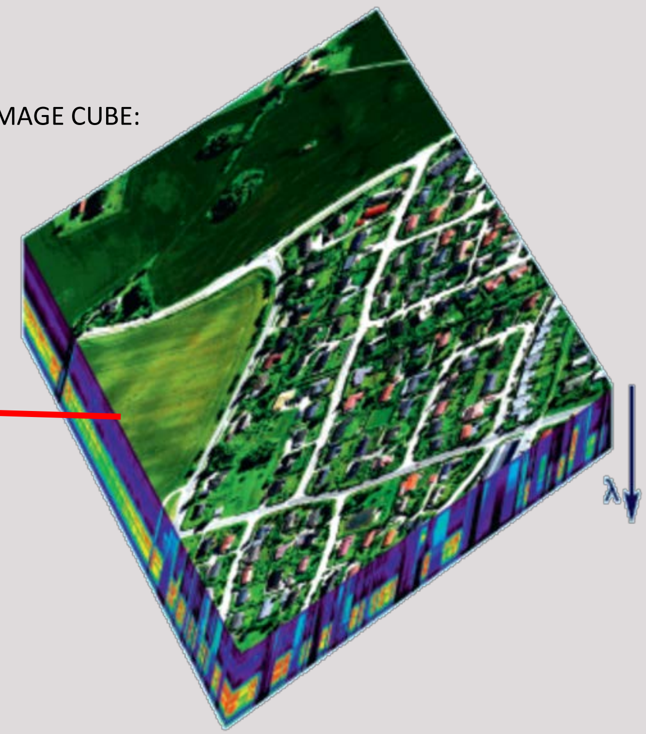


IMAGE CUBE:

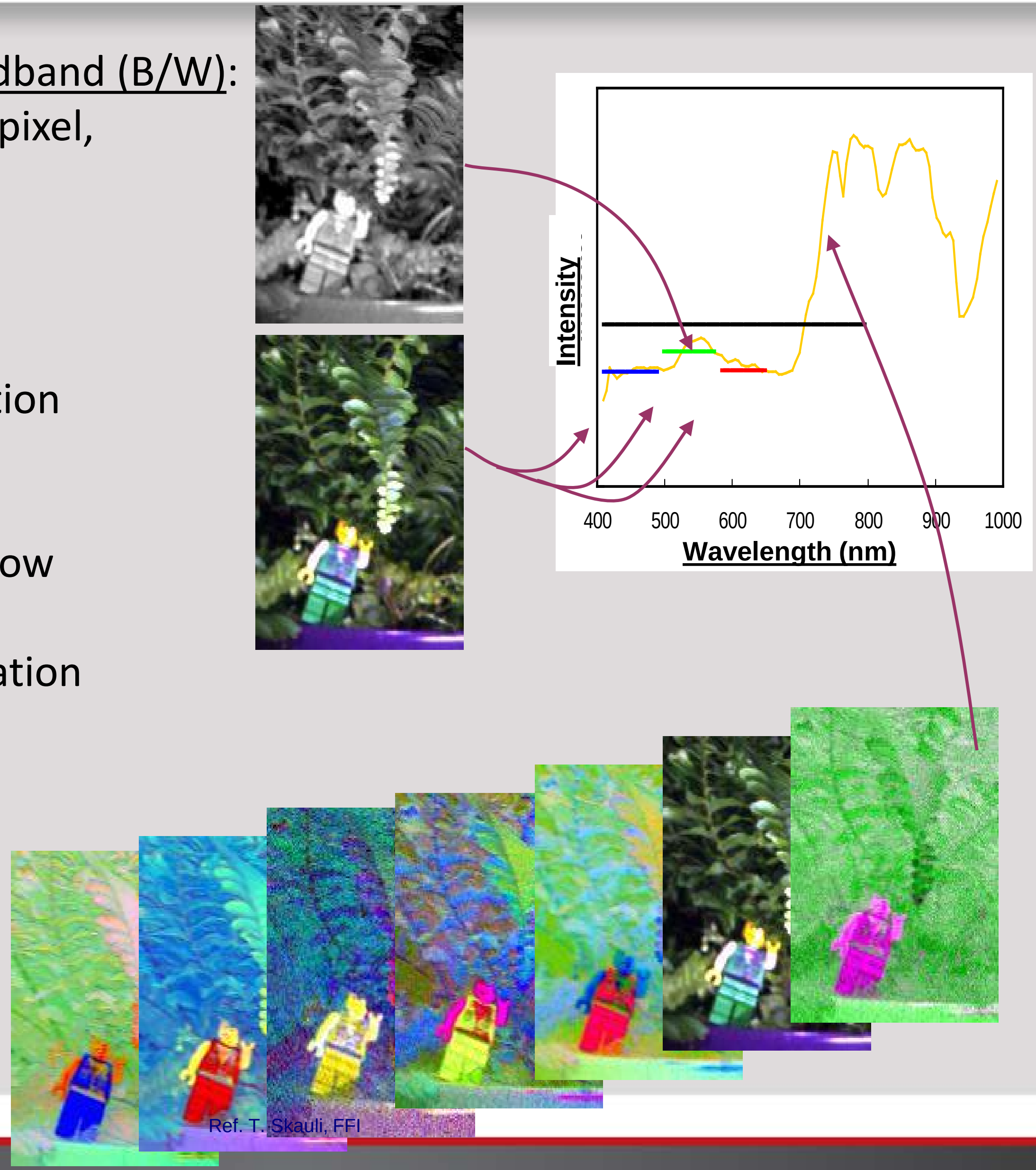


- For illustration, consider this model landscape containing
  - plants, one of which is artificial (which?)
  - a Lego "missing person" (where?)

Ref. T. Skauli, FFI

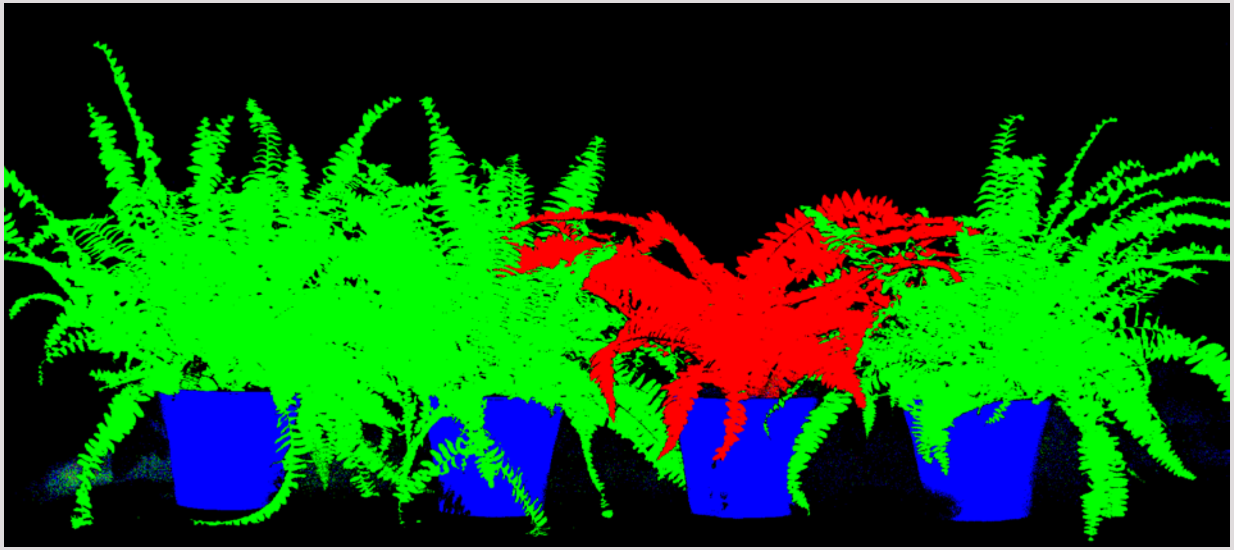
Spectral properties of cameras

- Monochromatic or broadband (B/W): one grey level value per pixel, no spectral information
- Multispectral (incl RGB): 3 – 10 spectral bands, limited spectral information
- Hyperspectral*: tens or hundreds of narrow and contiguous bands, detailed spectral information



*Also known as imaging spectroscopy or spectroscopic imaging

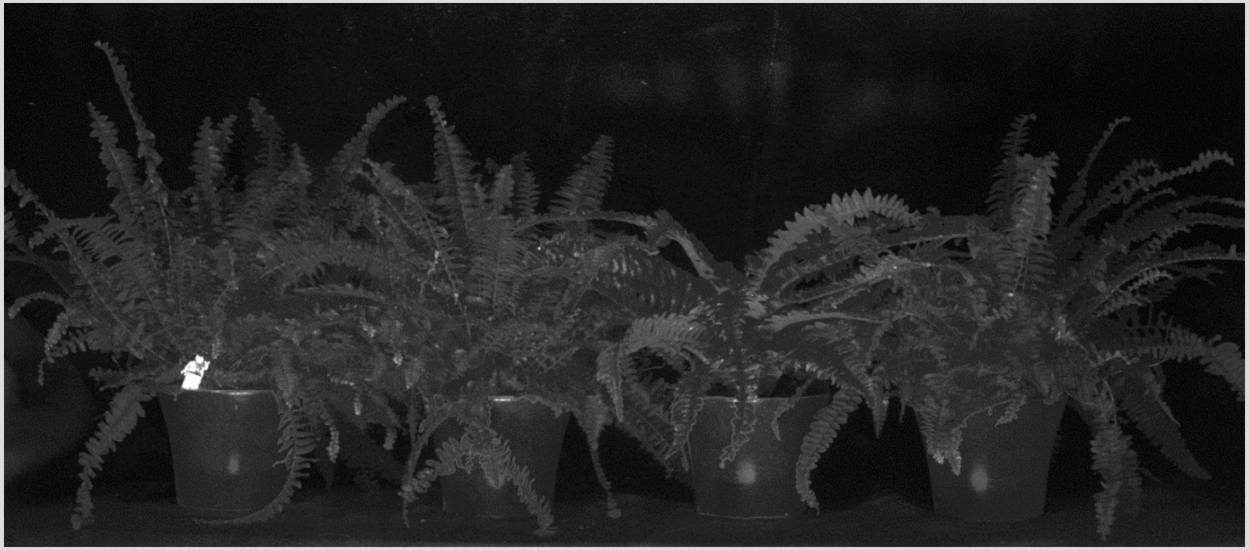
Ways to exploit spectral images



Result from spectral classification

- Classification
  - pixels assigned to classes representing different materials
  - classifier trained on a small part of data for which class is known
  - classification is automatically generalized to the entire image
- Here, the artificial plant is easily separated out

Ways to exploit spectral images



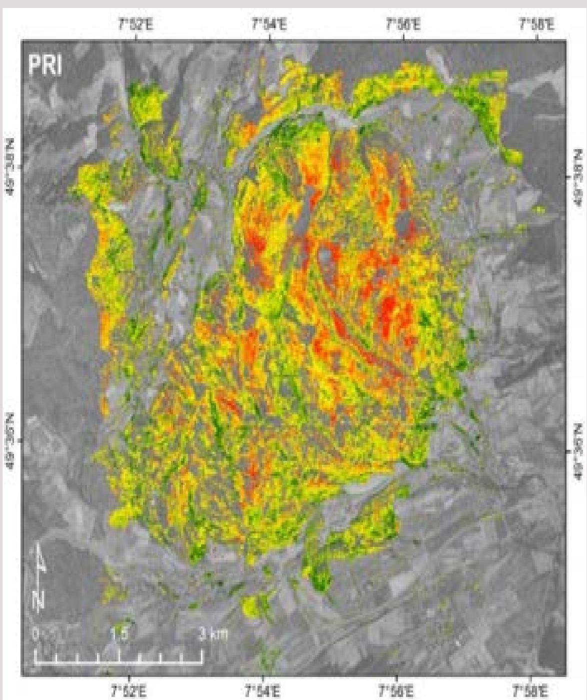
Result from spectral anomaly detection

- Detection
  - searches for extraordinary pixel spectra (anomaly detection) or for spectra consistent with a known material (signature detection)
  - finds needles in haystacks!
  - can automate search tasks in military and civilian applications
- Here, the Lego man is detected as a strong spectral anomaly

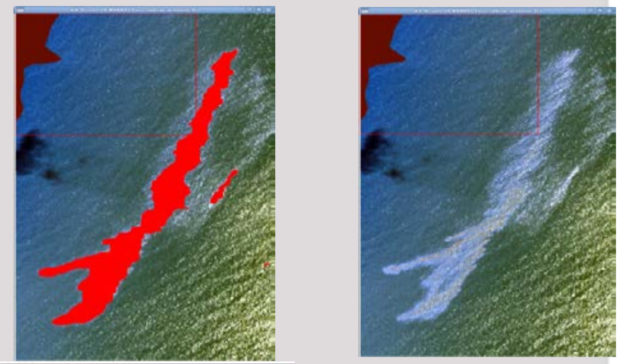
Some applications of airborne hyperspectral imaging

- Defense and security: *Military target detection/identification, surveillance, search and rescue.*
- Forestry: *Forest mapping/classification, forest health monitoring*
- Agriculture: *Precision farming, growth monitoring, yield prediction*
- Geology: *Mineral mapping, environmental impact around mine areas*
- Environmental: *Algae blooming, oil spill detection, land and sea monitoring*
- Government: *Land use monitoring, urban planning/management*

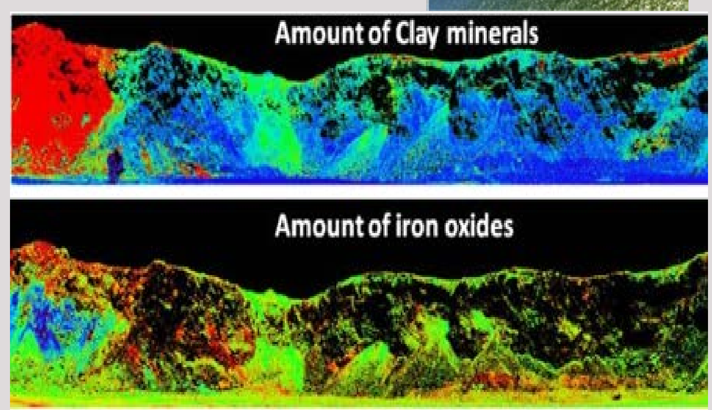
Forestry:



Oil spill detection and identification:



Mineral mapping:



The first (and only?) truly scientific grade hyperspectral solution for small UAVs….

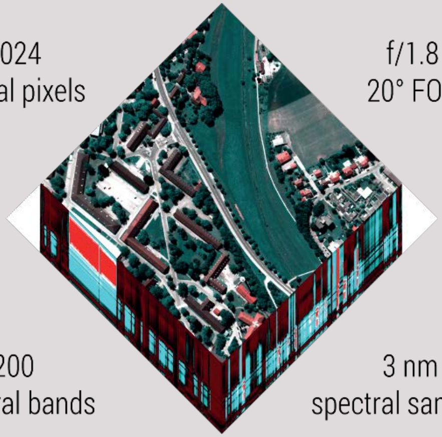
Demo in Toulouse 04/04-16

HysSpex Mjolnir-1024

- Based on ODIN optical design
- Key components:
  - PicoITX i7 computer
  - Hyperspectral camera based on resampling (1392x480 -> 1024x200)
  - Mjolnir controller card (IOs, shutter, frequency divider, 3,3V ->5V, APX interface)
  - Applanix APX-15 UAV
- Optional:
  - Video link
  - HD RGB video camera (GoPro/BlackMagic)
  - FLIR Video camera (IR)
  - Video from mission computer screen
  - CamFlight FX8HL UAV

HySpex Mjolnir-1024

Camera specifications:



Spectral range	400 – 1000 nm
Spatial pixels	1024
Spectral channels and sampling	200 bands @ 3 nm
F-number	F1.8
FOV	20°
Pixel FOV across/along	0.34/0.34 mrad
Bit resolution	16 bit
Noise floor	2.34 e^-
Dynamic range	4400
Peak SNR (at full resolution)	> 180
Max speed	285 fps
Power consumption*	50 W
Dimensions (l–w–h)*	250 – 175 – 170 mm
Weight*	< 4.5 kg

HySpex spectrometer calibration and characterization

Instrument calibration:

Radiometric/sensor:
- Dark signal (automatic shutter)
- Pixel responsivity, nonuniformity
- Bad pixels

Spectral:
- Wavelength as a function of sensor row number (band number)

Geometric:
- FOV per pixel (for georeferencing)

Calibration data for image calibration.
Essential!

Instrument characterization:

Radiometric/sensor:
- Linearity
- Noise, SNR, NER
- Dynamic range
- Stray light

Spectral:
- Spectral resolution, spectral misregistration

Geometric:
- FOV per pixel (sensor model)
- Total FOV
- Spatial resolution,
- Spatial misregistration

Documenting system performance.
Nice to have!

All hyperspectral instruments should be delivered with:
- Calibration data
- Detailed test/calibration report
- Sensor model

http://www.hyspex.no/guide/

Performance and accuracies – Navigation System

- Applanix APX-15 UAV

	SPS	DGPS	RTK[4]	Post-Processed[5]
Position (m)	1.5 - 3.0	0.5 - 2.0	0.02 - 0.05	0.02 - 0.05
Velocity (m/s)	0.05	0.05	0.02	0.015
Roll & Pitch (deg)	0.04	0.03	0.03	0.025
True Heading[3] (deg)	0.30	0.28	0.18	0.080

- The APX-15 provides the best weight/size/price/performance trade-off on the market

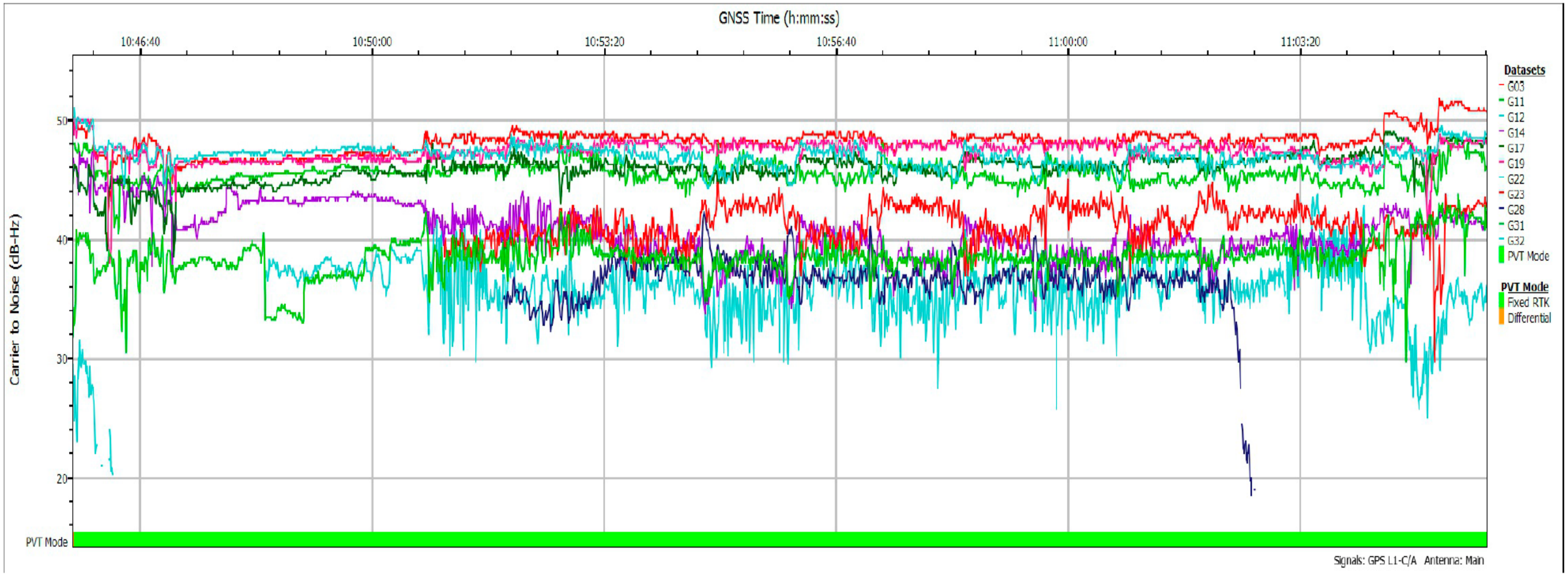
- Mjolnir will work with any external INS as well with an event input.

Antenna:
Selected the best antenna when it comes to suppressing PWM noise from the UAV on L2

Grounding plane:

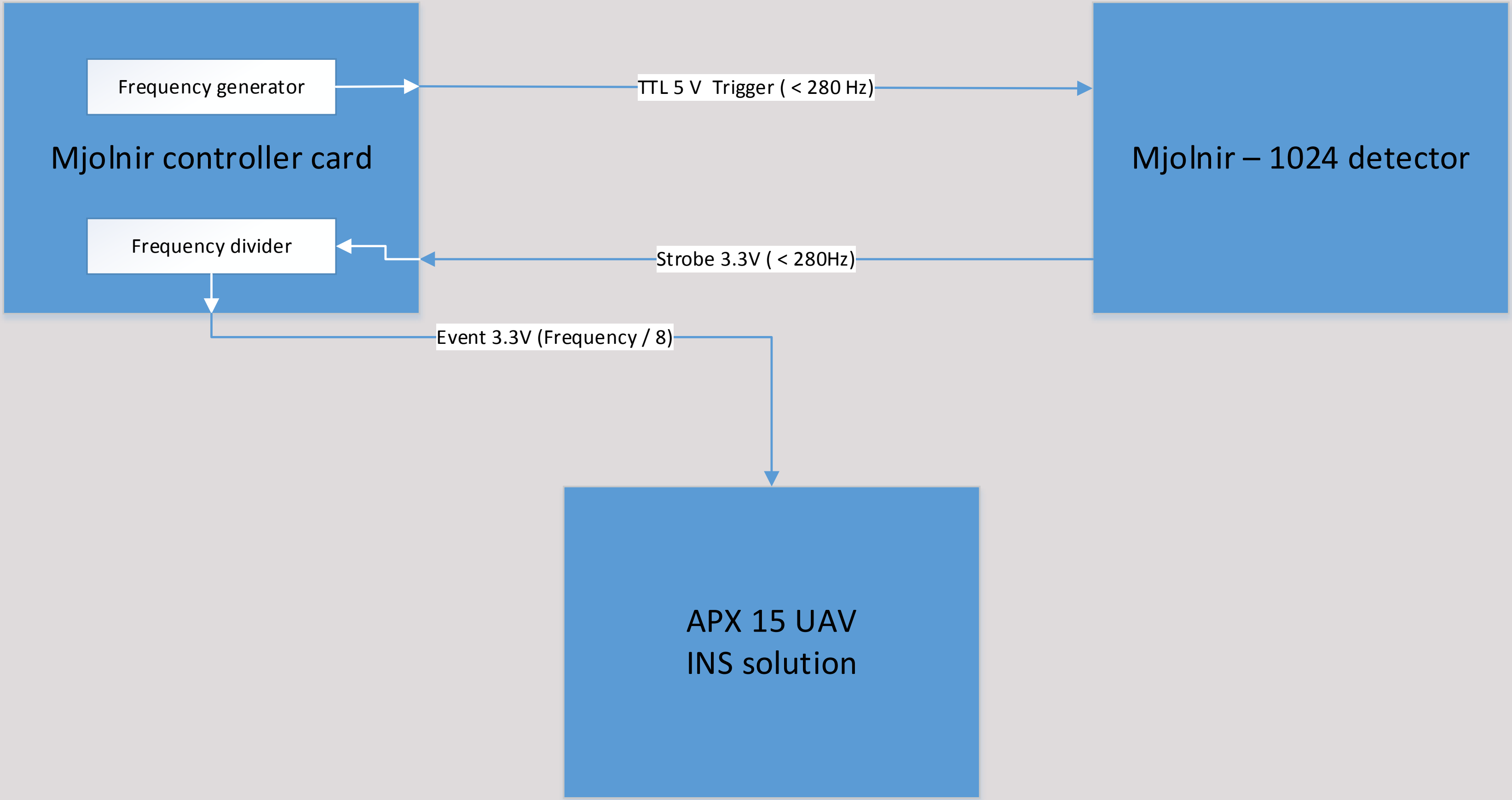
Putting a 10cm diameter aluminum plate under the GPS antenna reduces the noise further.

Signal to noise ratio:



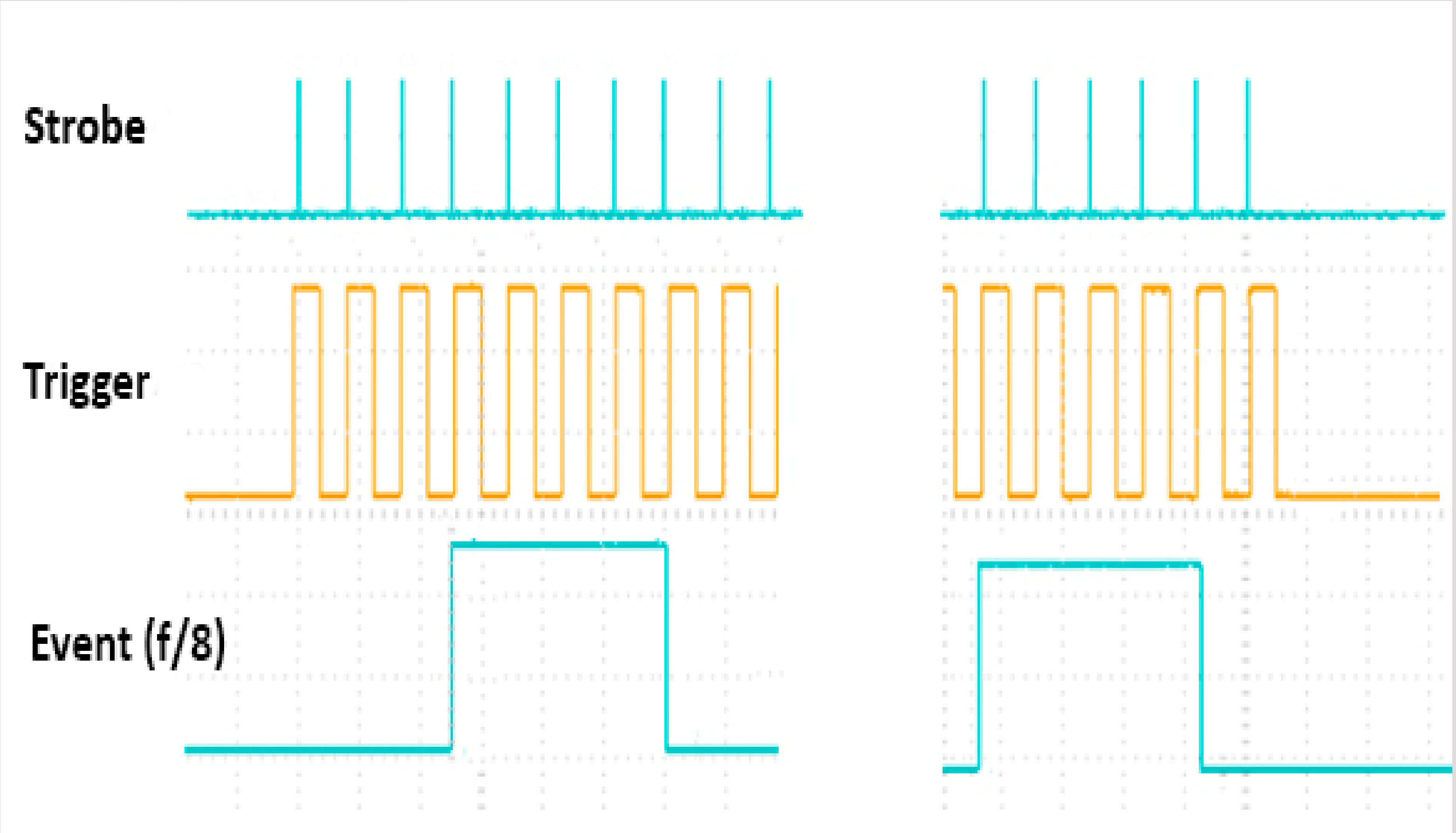
Timing of every frame

- Normal timing accuracy on the event input on different navigation system is< 1us.

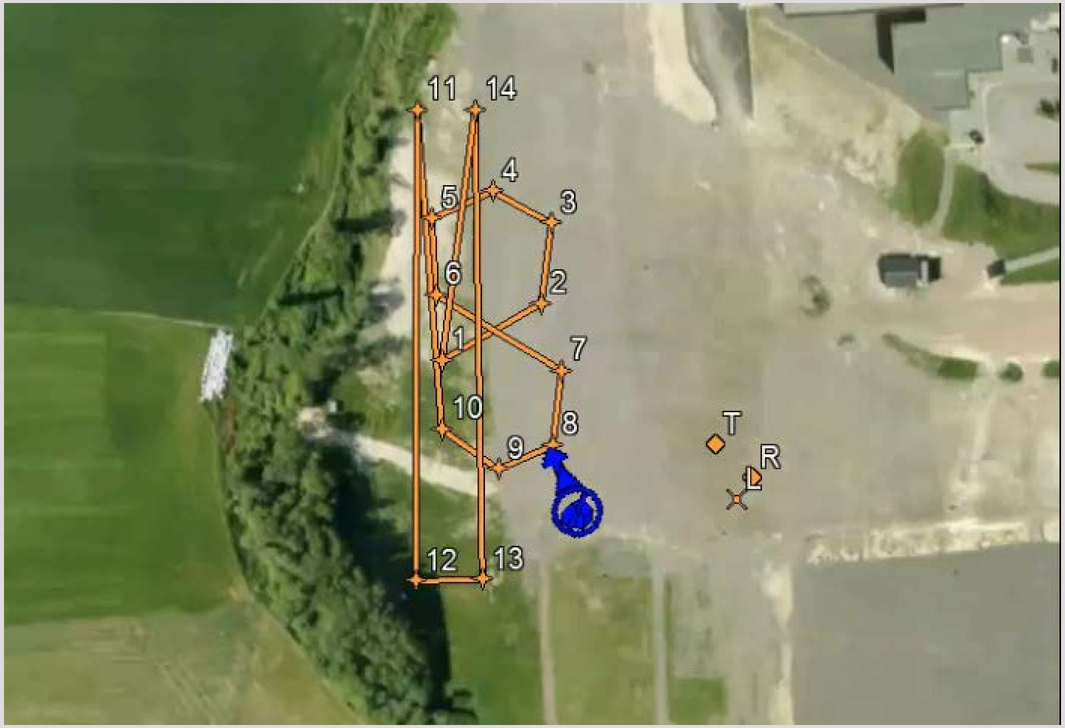


Frequency divider

Timing accuracy on the event input on APX-15 UAV is better than 1µs.

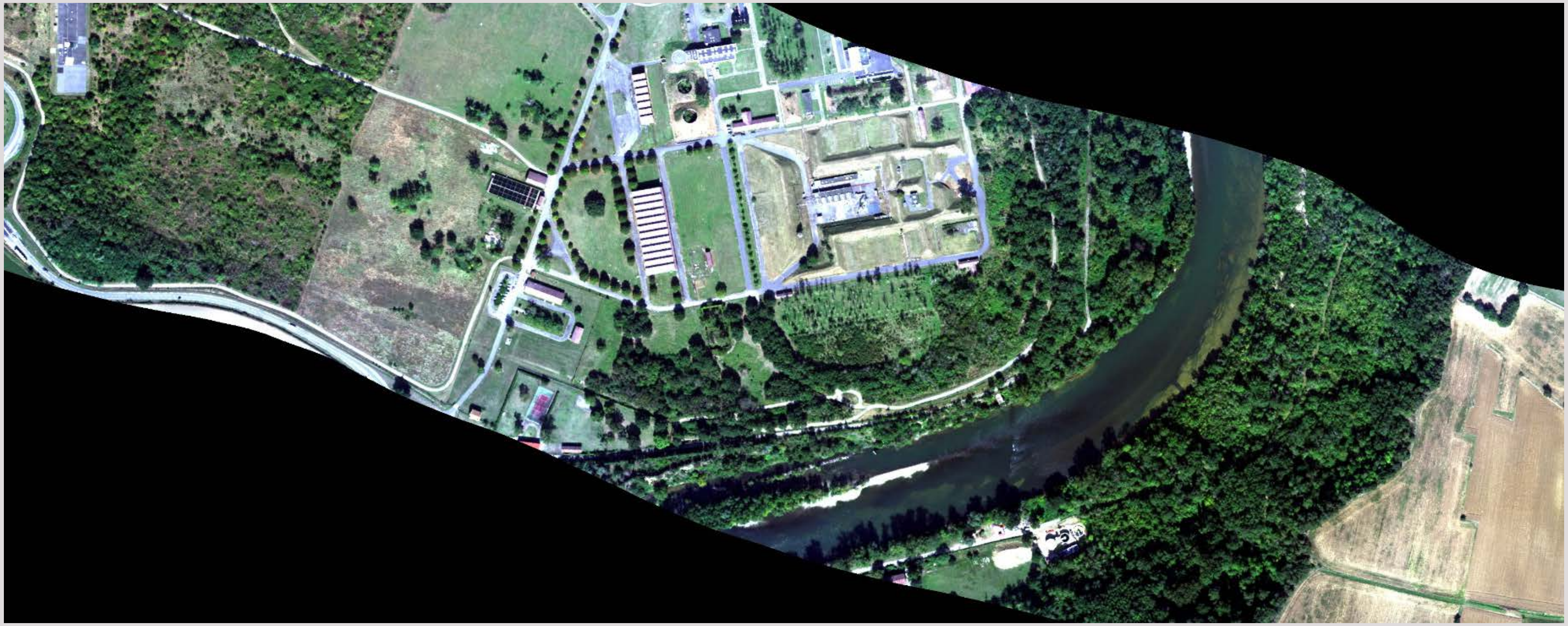


- Having all the hardware and timing accuracies mentioned above gives us the potential to get extremely good georeferencing results.
- For UAS flight we need to align the INS fast. We do this by first flying a straight line for 30s, then flying an 8.



- Find offsets between the coordinate system of the camera and the coordinate system of the IMU.
- Needs at least 20 GCPs on the ground
- Only necessary to do this once.
- After you have the offsets, direct georeferencing is possible without GCPs.

- Pixel size of Mjolnir – 1024 is approx. 0.02 degrees.
- For post processed INS data we can achieve 0.025 degrees roll/pitch accuracy, this is 125% of a pixel.
- On 100m altitude flights, the pixel size is 3.4cm, with post processed GPS data you can achieve down to 2cm absolute accuracy.
- So the errors we are getting is on pixel level.

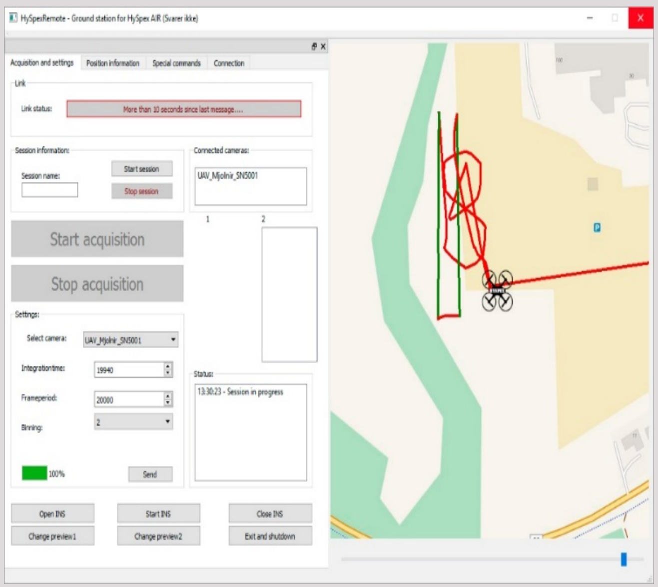


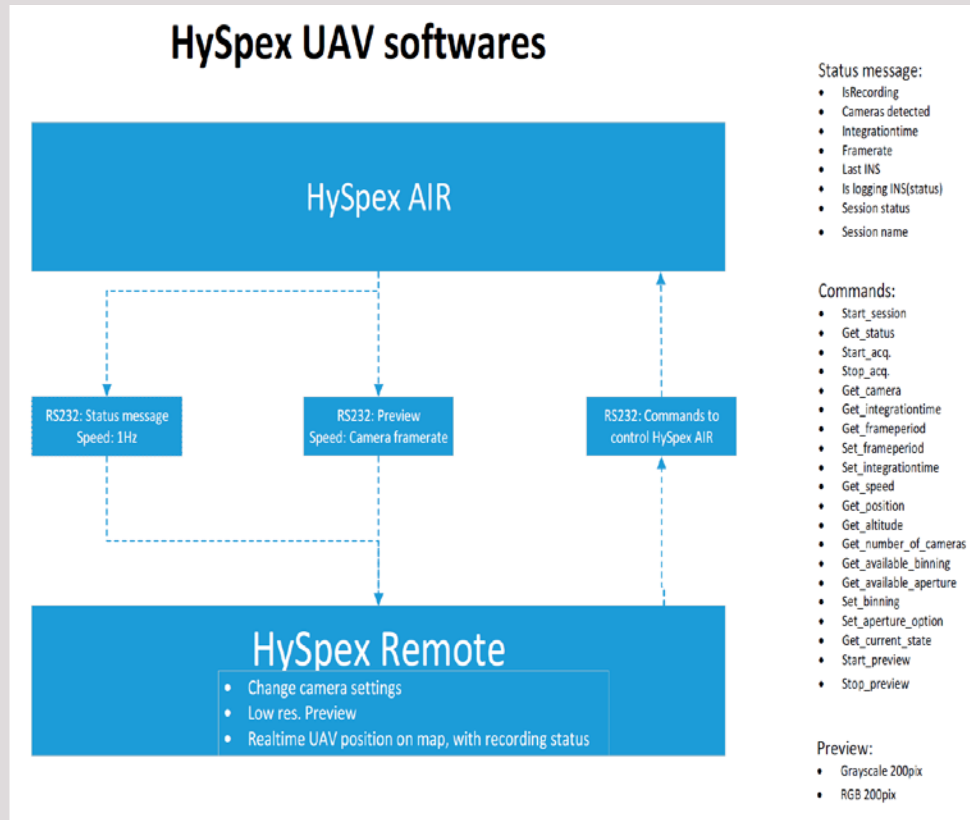
Mjolnir-1024: A generic camera system

- We supply Mjolnir-1024 as a complete package with APX-15 INS solution and the Camflight UAV.
- Mjolnir is a generic system and can be interfaced to any navigation system (only requirement is an event input). The event can even be divided down by a customized value if the navigation system cannot handle the full rate.
- It should also be compatible with most UAVs that can lift the weight of Mjolnir.
- Via a breakout cable, all outputs from the mission computer is available.
- The battery is galvanically isolated from all the electronic inside Mjolnir. There is a lot of filtering being done to be sure that there is no noise inside Mjolnir.
- Removing ripple on the voltage will also increase the lifespan of the LiPo batteries.

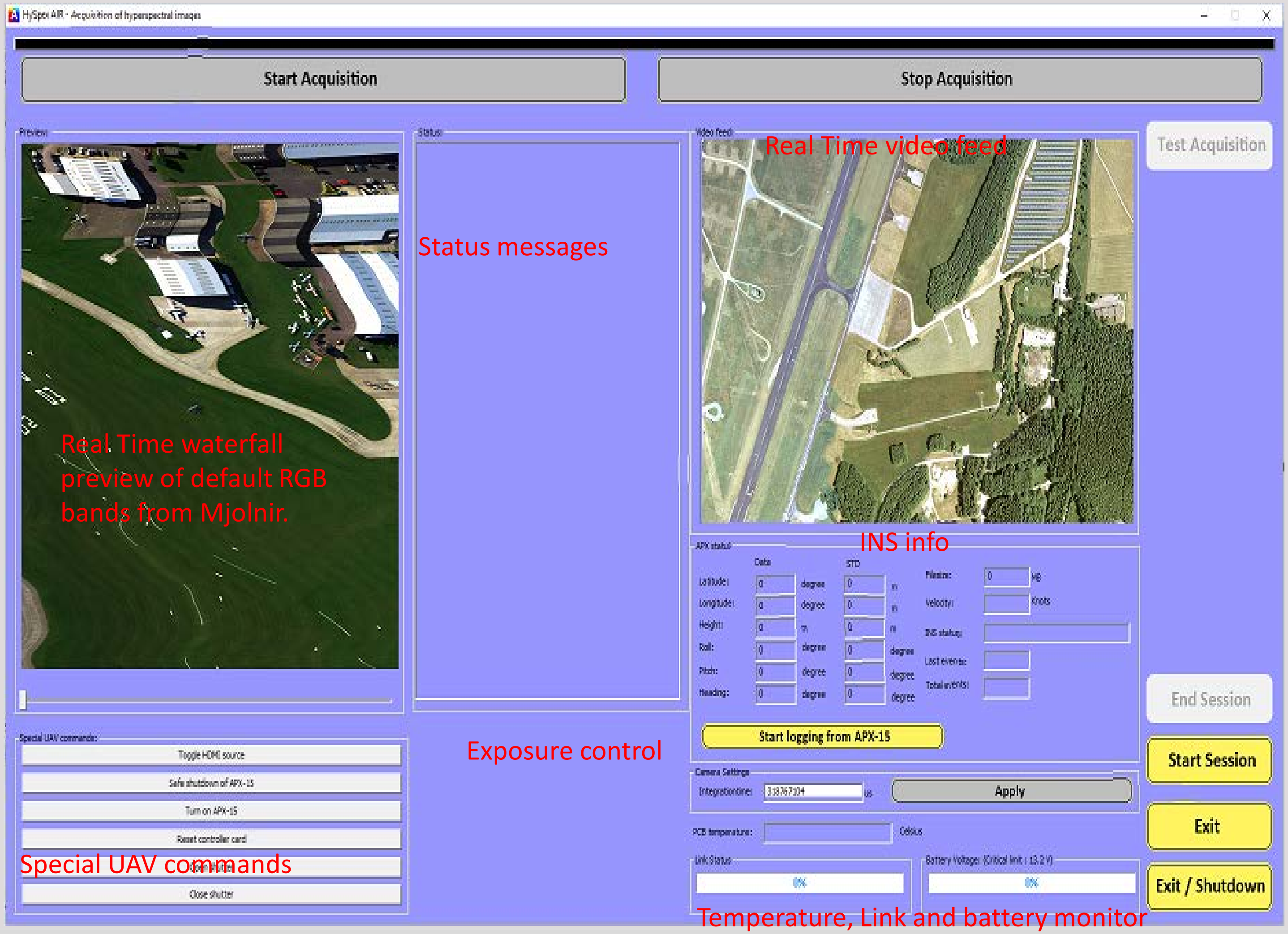
Operational modes

- Link options:
  - TCP/IP link
  - HD Video link + serial link
  - Only serial link.

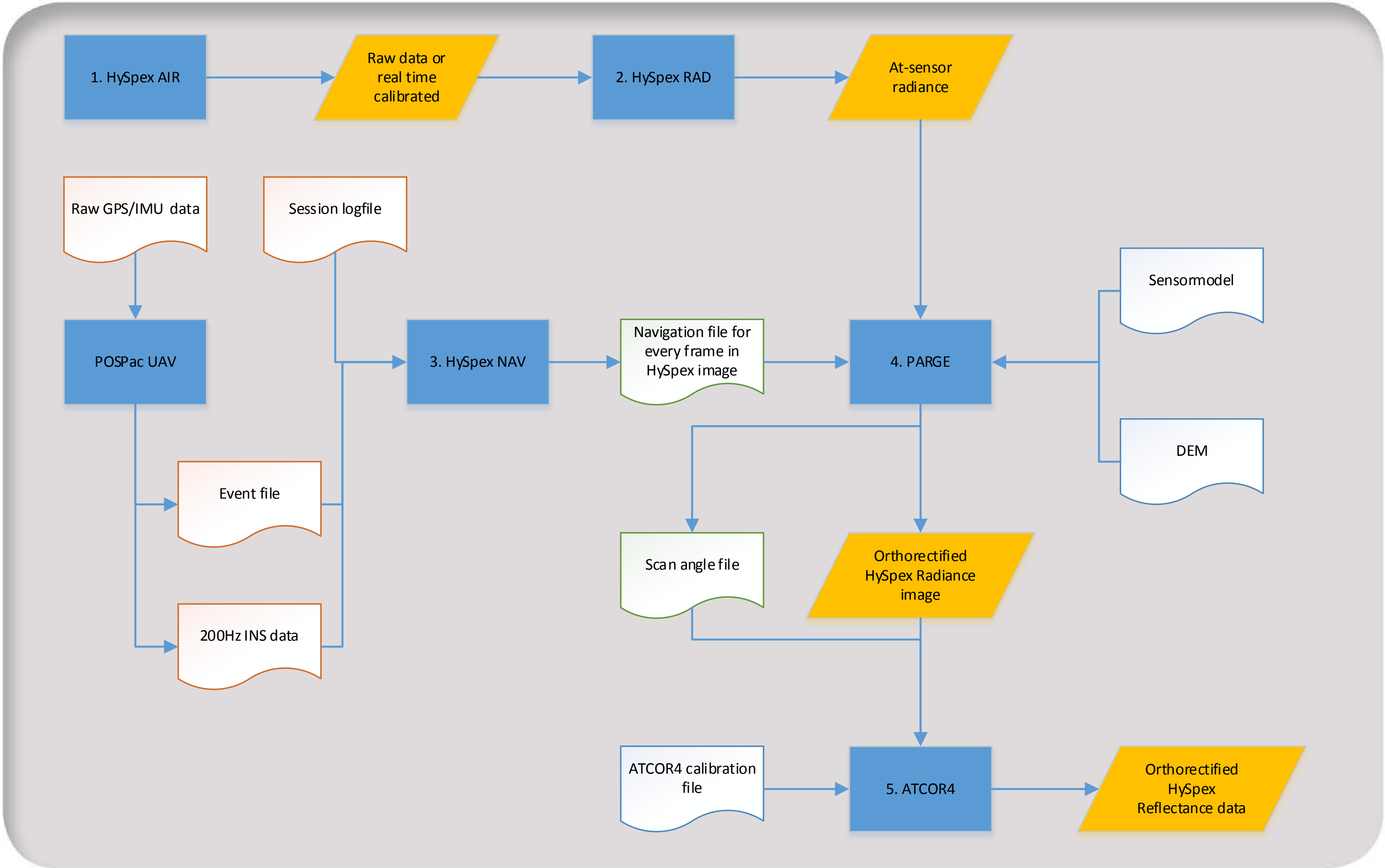




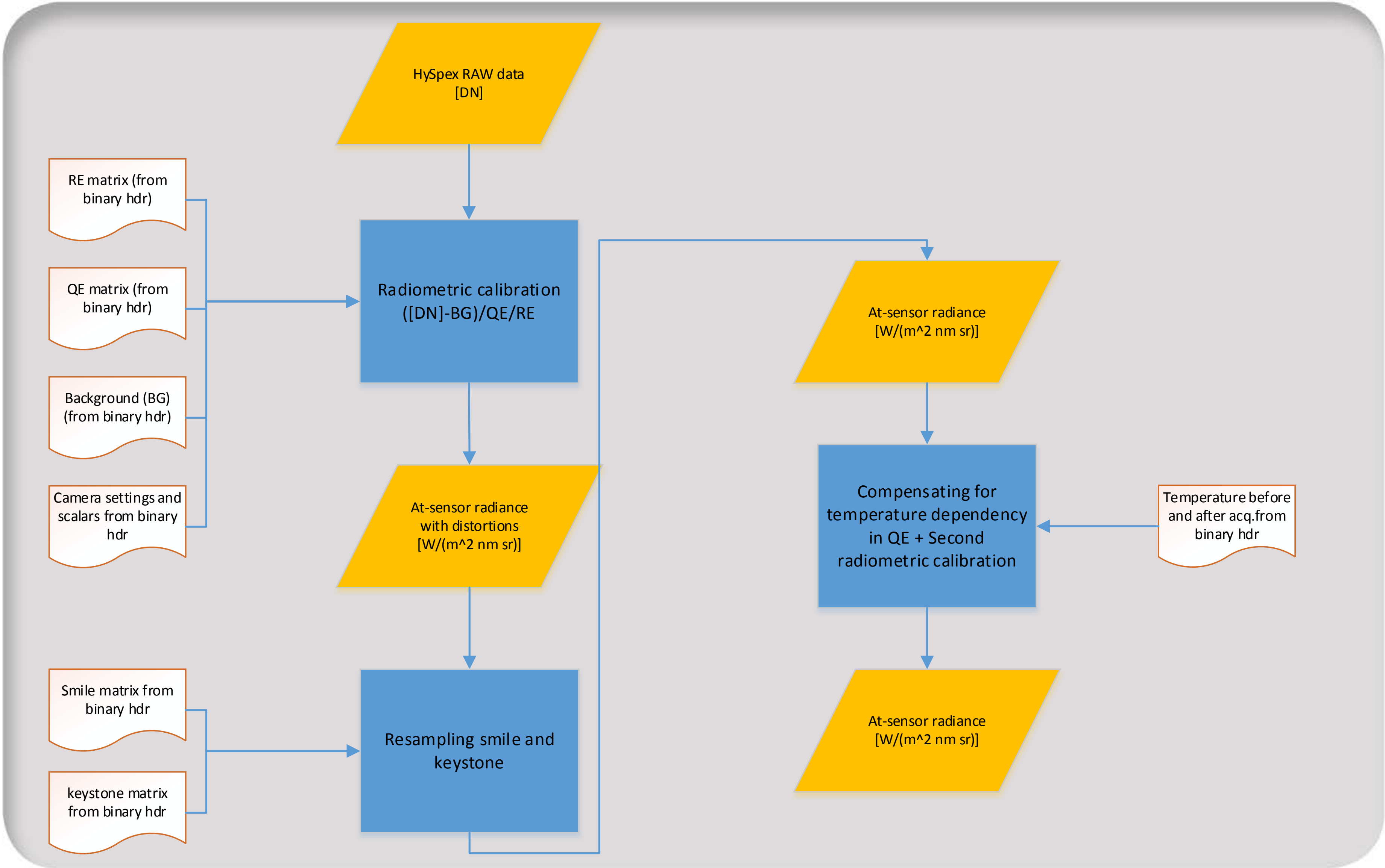
HysSpex AIR – Acquisition software



Airborne/UAV processing chain



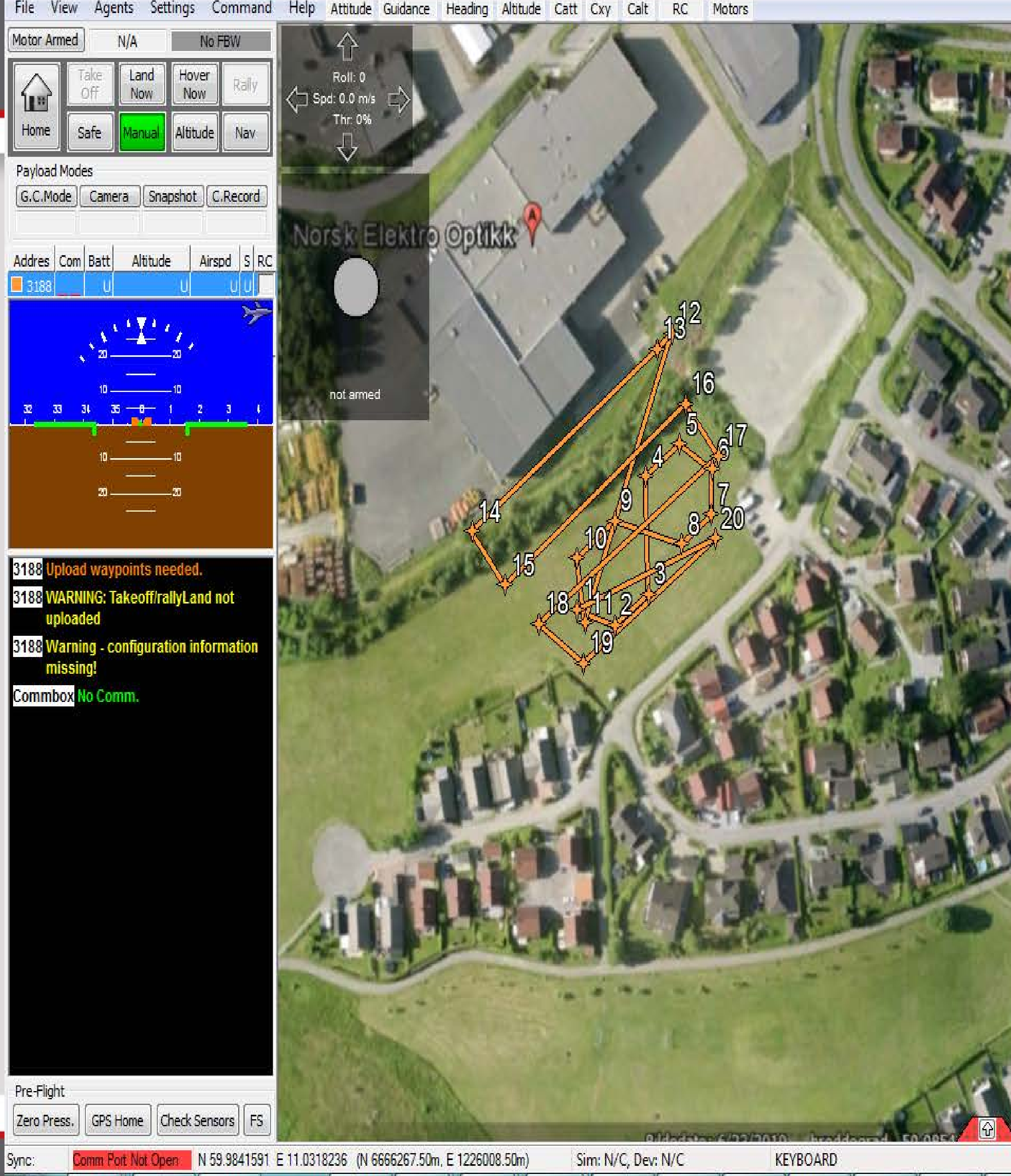
HySpex RAD


HySpex RAW data
[DN]
RE matrix (from binary hdr)
QE matrix (from binary hdr)
Background (BG) (from binary hdr)
Camera settings and scalars from binary hdr
Radiometric calibration
([DN]-BG)/QE/RE
At-sensor radiance with distortions [W/(m^2 nm sr)]
Smile matrix from binary hdr
keystone matrix from binary hdr
Resampling smile and keystone
At-sensor radiance
[W/(m^2 nm sr)]
Compensating for temperature dependency in QE + Second radiometric calibration
Temperature before and after acq.from binary hdr
At-sensor radiance
[W/(m^2 nm sr)]

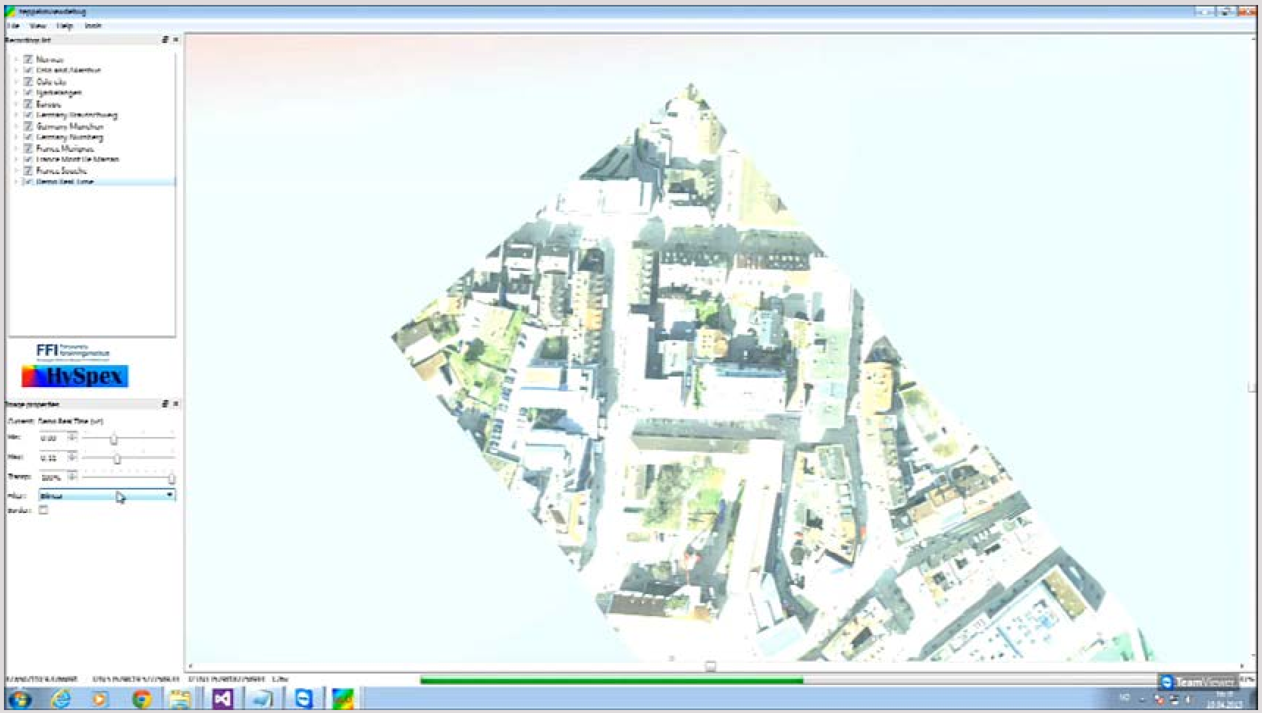

CAMFLIGHT
FX8HL

Virtual Cockpit

- Flight planning
- UAV operation
- Payload control



- Real time georeferencing and visualization
- Real time classification: CRX, PCA , MNF
- A goal in the long run is to implement custom algorithms to make real-time classified maps, real-time “target” detection, real-time indices maps etc.
- RTGEO was tested successfully already in 2013, we have one beta customer using it in Germany
- Our goal is to include this software in the UAV package.


FFI
HySpex

Conclusions

- Mjolnir-1024 is a state of the art scientific grade hyperspectral imaging system designed specifically for UAVs.
- Based on NEO's more than 20 years experience in hyperspectral imaging
- High quality components and rigorous testing ensures optimal performance

- Demo data set available for evaluation, contact me and I will send you ftp info.

Questions/comments?

Contact info: trond@neo.no, hyspexsales@neo.no

Next Steps

- **Visit www.insidegnss.com/webinars** for a PDF of the presentations and a list of resources.
- Review the recorded version of today's webinar

Contact Info:

- **Inside GNSS- www.insidegnss.com**
- **Applanix - www.applanix.com/**

- **Mohamed M.R. Mostafa- Mostafa@navmatica.com**
- **Mike Hogan- mike@avyon.com**
- **Trond Løke- trond@neo.no, hyspexsales@neo.no**

Poll #3

Having attended today's webinar, my plans to purchase or acquire a GNSS-inertial solution:(please select one)

a. Increased
b. Was just researching but now intend to purchase
c. Was just researching but now see no need
d. Decreased

Ask the Experts – Part 2

Mohamed M.R. Mostafa
Chief Technology Officer
Navmatica Corporation

Mike Hogan
Business Development Manager
Avyon

Trond Løke
Chief Technology Officer
Hyperspectral Group

Joe Hutton, MASc
P.Eng, Director
Inertial Technology and Airborne Products

Inside GNSS @ www.insidegnss.com/
www.applanix.com/

Thank you!

Joe Hutton, MASc
P.Eng, Director
Inertial Technology
and Airborne Products