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

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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
Multi-Sensor Systems in Geomatics

- Photogrammetry
- Laser Scanning
- GNSS
- Inertial

Integration
Photogrammetry

Data Acquisition

Sensor and platform

Image

Restitution

Scene (X,Y,Z,t)
Sensors

Imaging Sensors

Active Sensors
- LiDAR
- SAR

Passive Sensors
- Line Scanners (multispectral & Hyperspectral)
- Frame Cameras (RGB, CIR, NIR, etc.)
Automotive Applications

AUTOMOTIVE: 3D Portable Photogrammetry

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Toyota

Zeiss
Aerospace Engineering Applications

Courtesy of NASA, US Navy, FAA, DLR
Mapping Applications

Airborne Mapping

Mobile Mapping

Indoor Mapping

Seafloor Mapping

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Mapping Products
Sensors

Large Format Cameras

Medium Format Cameras

Spherical Camera

Small Format Cameras
Sensors

LiDAR

Hyperspectral

SAR

Multispectral
Data Examples

Digital Frame imagery

Video frames

Navmatica

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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

<table>
<thead>
<tr>
<th>GNSS</th>
<th>Real Time Accuracy</th>
<th>Post-Processing needed</th>
<th>Range</th>
<th>Integration</th>
<th>Applications</th>
</tr>
</thead>
</table>
| 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 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
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
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 (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

DG can be used with any type of Imaging Sensor

DG must be used with LiDAR, SAR and Scanning sensors
Direct Georeferencing

\[
\mathbf{r}_G^M = \mathbf{r}_{\text{INS/DGPS}}^M(t) + \mathbf{R}_b^M(t) \mathbf{a}_E^b + \mathbf{s}_g + \mathbf{R}_c^M(t) + \mathbf{r}_g^c(t)
\]

- **IMU/GPS**
- **IMU Leverage Arm Calibration**
- **Stereo Processing**
- **Boresight Calibration**
- **Image Measurement and Camera Calibration**

Georeferenced 3D Position

\[ a^b \]

\[ R^b_c \]

\[ r^b \]

\[ Z^M \]

\[ Y^M \]

\[ X^M \]
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

\[
R^b_c = \begin{bmatrix}
1 & 0 & 0 \\
0 & \cos \Theta_x & \sin \Theta_x \\
0 & -\sin \Theta_x & \cos \Theta_x
\end{bmatrix} \begin{bmatrix}
\cos \Theta_y & 0 & -\sin \Theta_y \\
0 & 1 & 0 \\
\sin \Theta_y & 0 & \cos \Theta_y
\end{bmatrix} \begin{bmatrix}
\cos \Theta_z & \sin \Theta_z & 0 \\
-\sin \Theta_z & \cos \Theta_z & 0 \\
0 & 0 & 1
\end{bmatrix}
\]

\[
= \begin{bmatrix}
\cos \Theta_y \cos \Theta_z & \cos \Theta_y \sin \Theta_z & -\sin \Theta_y \\
\sin \Theta_x \sin \Theta_y \cos \Theta_z - \cos \Theta_x \sin \Theta_z & \sin \Theta_x \sin \Theta_y \sin \Theta_z + \cos \Theta_x \cos \Theta_z & \sin \Theta_x \cos \Theta_y \\
\cos \Theta_x \sin \Theta_y \cos \Theta_z + \sin \Theta_x \sin \Theta_z & \cos \Theta_x \sin \Theta_y \sin \Theta_z - \sin \Theta_x \cos \Theta_z & \cos \Theta_x \cos \Theta_y
\end{bmatrix}
\]
### 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 $\leftrightarrow$ Laser 1
  - IMU $\leftrightarrow$ Laser 2
  - IMU $\leftrightarrow$ Cam 1
  - IMU $\leftrightarrow$ Cam 2
  - IMU $\leftrightarrow$ ant 1
  - IMU $\leftrightarrow$ ant 2
- Boresights
  - IMU $\leftrightarrow$ Laser 1
  - IMU $\leftrightarrow$ Laser 2
  - IMU $\leftrightarrow$ Cam 1
  - IMU $\leftrightarrow$ Cam 2
  - IMU $\leftrightarrow$ ant 1
  - IMU $\leftrightarrow$ 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)
Direct Georeferencing QC Example

QA/QC Block

- Vivian Forest Area
- Oshawa Area
- Ajax Area
- Don Valley Parkway Area
- Scarborough Area
- Downtown Toronto Area
- Hamilton Area

GP Basestation

Easting (Km)

Northing (Km)
<table>
<thead>
<tr>
<th><strong>Aerial Triangulation</strong></th>
<th><strong>Direct Georeferencing</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Must fly 80% overlap</td>
<td>- Can fly any overlap</td>
</tr>
<tr>
<td>- Must fly 80% sidelap</td>
<td>(to address mapping)</td>
</tr>
<tr>
<td>- Tie Point quality &amp; volume depends on AOI</td>
<td>- minimal sidelap</td>
</tr>
<tr>
<td>- An image Block is necessary</td>
<td>(to address mapping)</td>
</tr>
<tr>
<td>- Block geometric strength is necessary</td>
<td>- Tie Points are not required—</td>
</tr>
<tr>
<td>- Self-Calibration every mission</td>
<td>(only for QC)</td>
</tr>
<tr>
<td>- GCP always required</td>
<td>- Can fly one or more strips</td>
</tr>
<tr>
<td></td>
<td>- No Need for Blocks</td>
</tr>
<tr>
<td></td>
<td>- No Self Calibration necessary</td>
</tr>
<tr>
<td></td>
<td>(only QC)</td>
</tr>
<tr>
<td></td>
<td>- No GCP required (only QC)</td>
</tr>
</tbody>
</table>
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

Fryer Dam, Quebec, Canada
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

<table>
<thead>
<tr>
<th>Number of Points</th>
<th>dE</th>
<th>dN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Mean Error</td>
<td>0.031</td>
<td>-0.009</td>
</tr>
<tr>
<td>Standard Deviation (m)</td>
<td>0.017</td>
<td>0.014</td>
</tr>
<tr>
<td>RMSE (m)</td>
<td>0.034</td>
<td>0.015</td>
</tr>
</tbody>
</table>

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
- 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

- **DT18**
  - Endurance: 200 km +
  - Weight: 2 kg

- **md4-200**
  - Endurance: 100 km
  - Weight: 6 kg

- **md4-1000**
  - Endurance: 30-50 km
  - Weight: 10 kg

- **md4-3000**
  - Endurance: 5-10 km
  - Weight: 20 kg

- **DT26X**
  - Endurance: 4 hr
  - Weight: 10 kg
Small UAS – Surveyor Tool

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

Greater Access to Geospatial Data
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
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

<table>
<thead>
<tr>
<th></th>
<th>md4-1000 High Precision</th>
<th>md4-1000 80% Side Lap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Time</td>
<td>15 mins</td>
<td>35 min</td>
</tr>
<tr>
<td># Photos</td>
<td>215</td>
<td>650</td>
</tr>
</tbody>
</table>
Example One (3/3) – Time comparison

<table>
<thead>
<tr>
<th>Workflow Task</th>
<th>md4-1000 (Aerial Triangulation)</th>
<th>md4-1000 High Precision (Direct Georeferencing)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan Project</td>
<td>1 hrs</td>
<td>1 hrs</td>
<td>-</td>
</tr>
<tr>
<td>GCP Layout</td>
<td>2 hrs</td>
<td>-</td>
<td>2 hrs</td>
</tr>
<tr>
<td>Flight</td>
<td>35 mins</td>
<td>15 mins</td>
<td>20 mins</td>
</tr>
<tr>
<td>Data Processing</td>
<td>12 hrs</td>
<td>4 hrs</td>
<td>8 hrs</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15hrs 35 mins</strong></td>
<td><strong>5 hrs 15 mins</strong></td>
<td><strong>10 hrs 20 min</strong></td>
</tr>
</tbody>
</table>
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 \(\cong 3\) 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

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<td>0.015</td>
<td>0.093</td>
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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
**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
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

Ref. T. Skau, FFI
Ways to exploit spectral images

- **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

*Result from spectral classification*

Ref. T. Skauli, FFI
Ways to exploit spectral images

- 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

*Result from spectral anomaly detection*

Ref. T. Skauli, FFI
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:**

**Mineral mapping:**

**Oil spill detection and identification:**
The first (and only?) truly scientific grade hyperspectral solution for small UAVs....
Demo in Toulouse 04/04-16
HySpex 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
## Camera specifications:

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

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

Calibration data for image calibration. Essential!

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/
Applanix APX-15 UAV

- 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.

<table>
<thead>
<tr>
<th></th>
<th>SPS</th>
<th>DGPS</th>
<th>RTK^4</th>
<th>Post-Processed^5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position (m)</td>
<td>1.5 - 3.0</td>
<td>0.5 - 2.0</td>
<td>0.02 - 0.05</td>
<td>0.02 - 0.05</td>
</tr>
<tr>
<td>Velocity (m/s)</td>
<td>0.05</td>
<td>0.05</td>
<td>0.02</td>
<td>0.015</td>
</tr>
<tr>
<td>Roll &amp; Pitch (deg)</td>
<td>0.04</td>
<td>0.03</td>
<td>0.03</td>
<td>0.025</td>
</tr>
<tr>
<td>True Heading^3 (deg)</td>
<td>0.30</td>
<td>0.28</td>
<td>0.18</td>
<td>0.080</td>
</tr>
</tbody>
</table>
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:
Normal timing accuracy on the event input on different navigation systems is < 1us.

Timing of every frame:
- Frequency generator
- Frequency divider
- TTL 5 V Trigger (< 280 Hz)
- Strobe 3.3V (< 280 Hz)
- Event 3.3V (Frequency / 8)
- APX 15 UAV
- INS solution
- Mjolnir controller card
- Mjolnir – 1024 detector
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.
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.

HySpex UAV softwares

- Status message:
  - User recording
  - Camera detected
  - Integration time
  - Frame rate
  - Last INS
  - Is logging (INS status)
  - Session status
  - Session name

- Commands:
  - Start session
  - Get status
  - Start acq.
  - Stop acq.
  - Get camera
  - Get integration time
  - Get frame period
  - Set frame period
  - Get integration time
  - Get speed
  - Get position
  - Get altitude
  - Get number of cameras
  - Get available storage
  - Get available aperture
  - Set storage
  - Set aperture option
  - Get current state
  - Start preview
  - Stop preview

HySpex AIR

- RS232: Status message
  - Speed: 115200

HySpex Remote

- Change camera settings
- Low res. Preview
- Realtime UAV position on map, with recording status

Preview:
- Grayscale 200pix
- RGB 200pix
HySpex AIR – Acquisition software

- Real Time waterfall preview of default RGB bands from Mjolnir
- Status messages
- Exposure control
- Special UAV commands
- Temperature, Link and battery monitor
- Real Time video feed
- INS info
1. HySpex AIR
- Raw data or real time calibrated

2. HySpex RAD
- At-sensor radiance

3. HySpex NAV
- Navigation file for every frame in HySpex image

4. PARGE
- Orthorectified HySpex Radiance image

5. ATCOR4
- Orthorectified HySpex Reflectance data

Raw GPS/IMU data
- POSPac UAV
- Event file
- 200Hz INS data

Session logfile

Scan angle file

ATCOR4 calibration file

Sensormodel

DEM

Orthorectified HySpex Reflectance data
HySpex RAD

HySpex RAW data [DN]

Radiometric calibration \([\text{[DN]} - \text{BG}] / \text{QE/RE}\)

At-sensor radiance with distortions \([W/(m^2 \text{ nm sr})]\)

Compensating for temperature dependency in QE + Second radiometric calibration

At-sensor radiance \([W/(m^2 \text{ nm sr})]\)

Temperature before and after acq. from binary hdr

RE matrix (from binary hdr)

QE matrix (from binary hdr)

Background (BG) (from binary hdr)

Camera settings and scalars from binary hdr

Smile matrix from binary hdr

Keystone matrix from binary hdr
Camflight FX8 up to 8.3 kg.

- Heavy payload: 8.3 Kg
- 25 - 30 min flights with 6 Kg.
- > 50 min flights with 1.5 Kg.
- Campos-m positioning system
- RTK link to base station
- Post processing of positions possible
- Photogrammetry without GCPs
- Autopilot from Lockheed Martin for high precision flights
- 15 m² rescue parachute with backup battery and safety switch on remote controller
- Virtual cockpit ground control software for advanced flight plans

FX8HL
Virtual Cockpit

- Flight planning
- UAV operation
- Payload control
Real-time processing software for airborne applications

- 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.
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

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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