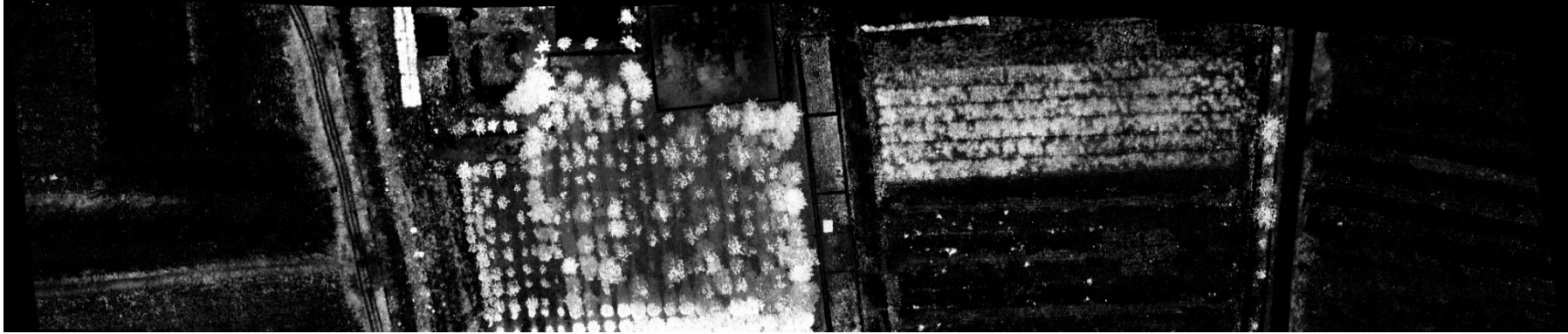

HySpex Mjolnir-1024 – the first scientific grade hyperspectral camera for UAVs.

Norsk Elektro Optikk AS

Trond Løke, Ivar Baarstad, Julio Hernandez, Pesal Koirala, Andrei Fridman

*Lukas Paluchowski

HySpex

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Outline

- Mjolnir spesifications
- What is «scientific grade» data from UAV platform?
- Performance of Mjolnir V - 1240
- Real time processing
- New Mjolnir products

Mjolnir-1240 System

- Key components:
  - HySpex VNIR-1240 sensor head
  - PicoITX i7 computer
  - Mjolnir controller card (IOs, shutter, frequency divider, 3,3V ->5V, APX interface)
  - APX-15 UAV
  - TCP/IP modem
  - (Gremsy gimbal (Copter platforms))

Mjolnir V - 1240

	Mjolnir V - 1240
Spectral range (nm)	400 - 1000
Spectral sampl. (nm)	3
Spatial pixels	1240
Spectral channels	200
Field of view (deg)	20
Pixel FOV (mrad)	0.27/0.27
Bit resolution	12
Noise floor (e-)	2.34
Dynamic range	4400
Peak SNR	>180
Max speed (fps)	285
Power cons. (W)	50 (with DAU/INS)
Dimensions (cm)	25 - 17.5 – 17
Weight (kg)	3.9

HySpex Mjolnir on CamFlight UAV.
With standard battery packs the system can stay autonomous for ~30 min.

Scientific grade data quality (from UAV platform)

- Optical quality
- Good detector
- Traceable calibration
- Characterized and well documented
- Stability of system
- Georeferencing
- Correct operation

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Optical quality

- Smile
- Keystone
- Spatial resolution
- Spectal resolution
- Straylight
- PSF

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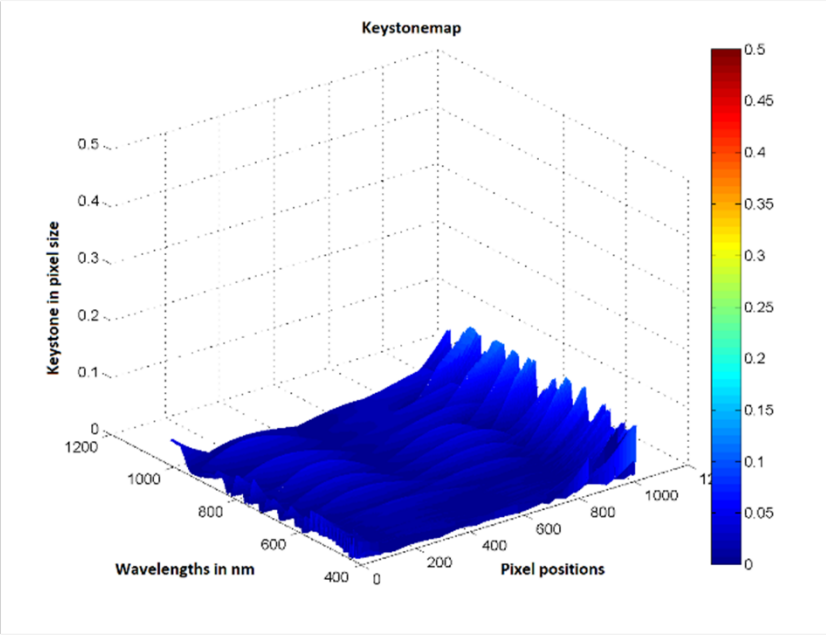
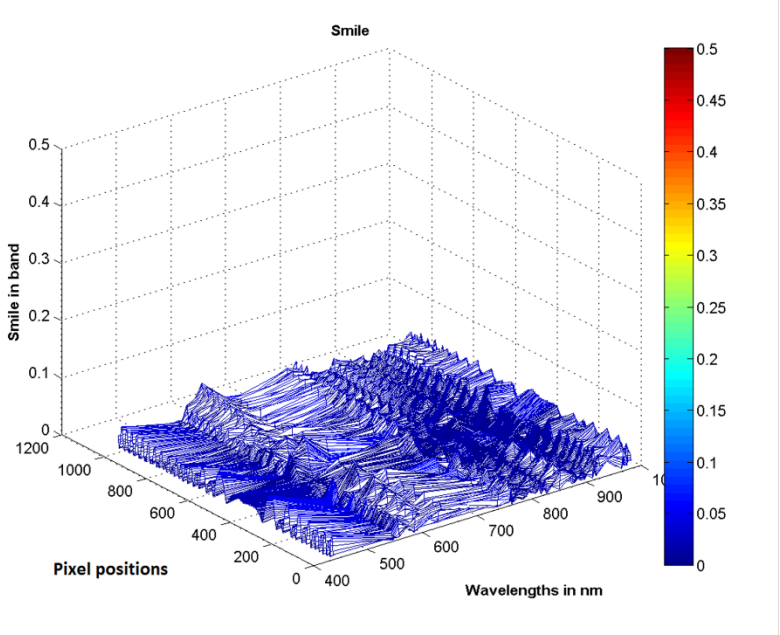
Optical performance – Spatial and spectral misalignment (Keystone and Smile)

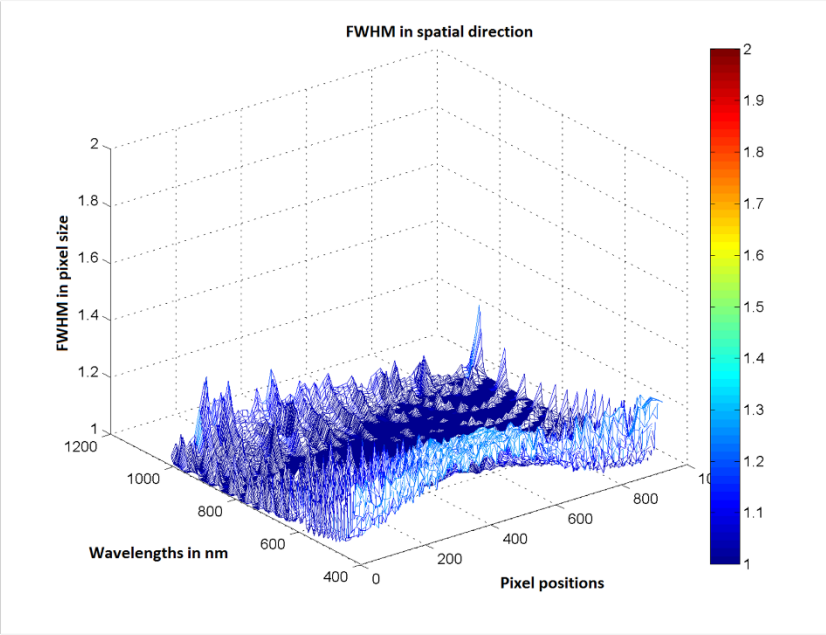


(a)

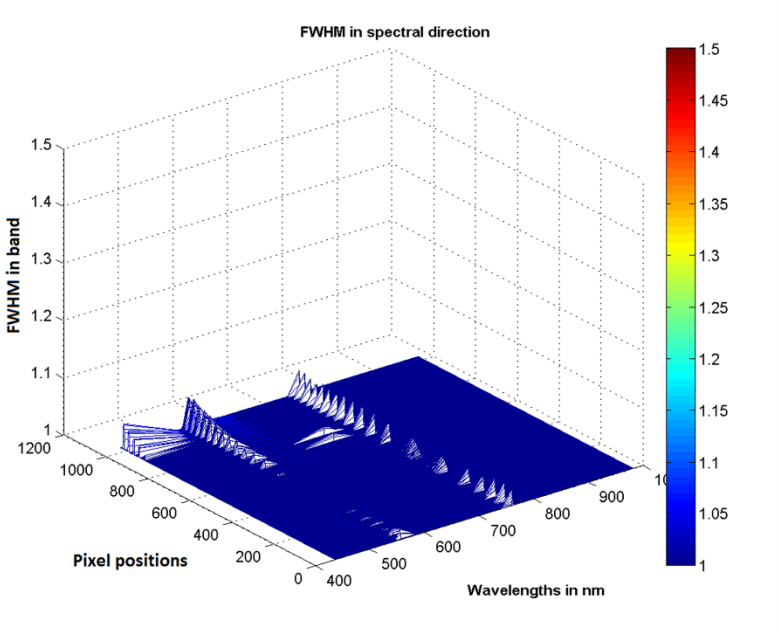


(b)

Optical performance – Spatial and spectral resolution (FWHM)



(a)



(b)

Detector

- Low noise floor (2.37 e^-)
- Large full well
- Peak SNR (at full resolution >180)

- Keep up with industry

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 pr pixel (for georeferencing)

Instrument characterization:

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

Spectral:
-Spectral resolution, spectral misregistration

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

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

Stability

- Spectral and radiometric stability with
  - Temperature
  - Pressure
  - Vibrations

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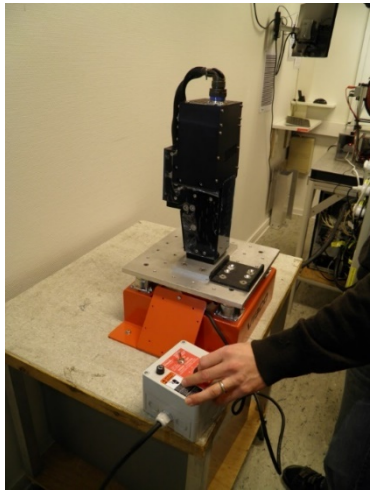
Environmental Tests - Vibration

No point in going through all the calibration steps if it is invalidated by UPS during shipment!

- Factory vibration test on every camera:
- 0 – 100 Hz in 5 minutes sweep
- Vibration sequence performed with camera oriented both horizontally and vertically

- Check the spectral and radiometric calibration before and after the vibration test
- Pass: The camera is stable and the calibration will remain valid also after transportation and during operation.



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Georeferencing performance and accuracies

What is needed to get optimal georeferencing result?

- INS system with high performance
- Good GPS antenna
- Good timing accuracies
- Alignment of INS
- Boresight calibration
- High resolution DEM
- Gimbal with encoder for INS
- Mechanical stability
- Accurate sensormodel

Since it's a pushbroom scanner we need longitude, latitude, altitude, roll, pitch heading for every scan line to rectify the images.

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

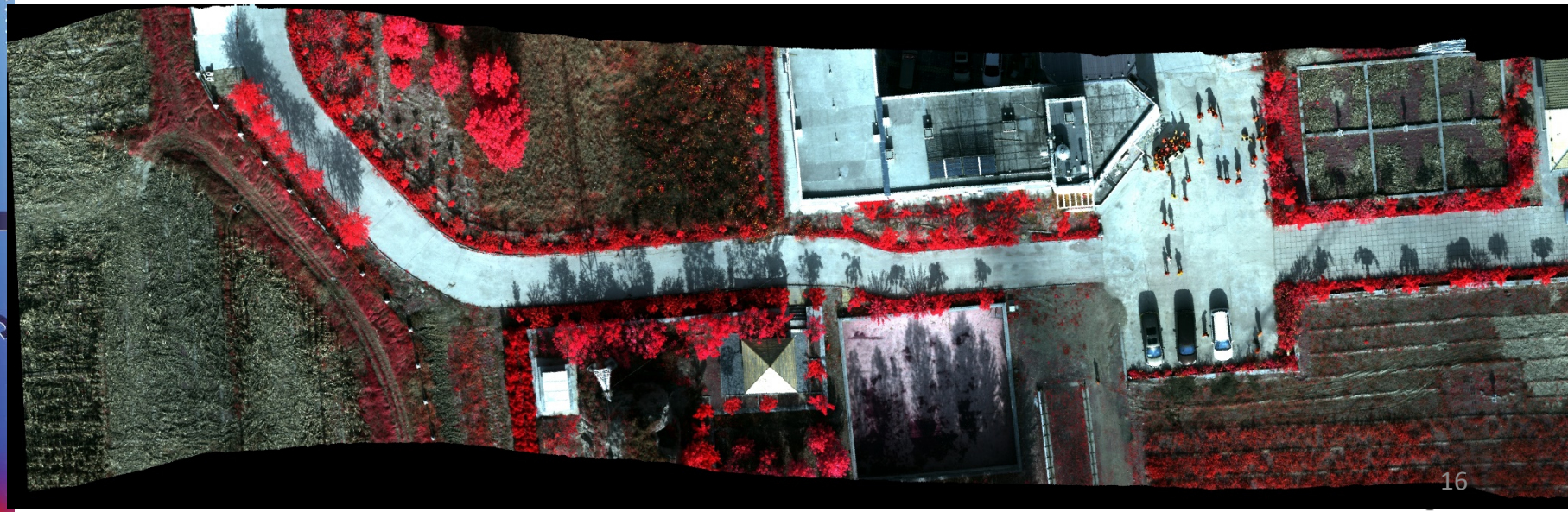
- Mjolnir will work with any external INS with an event input logging option.

Performance and accuracies – Boresight calibration

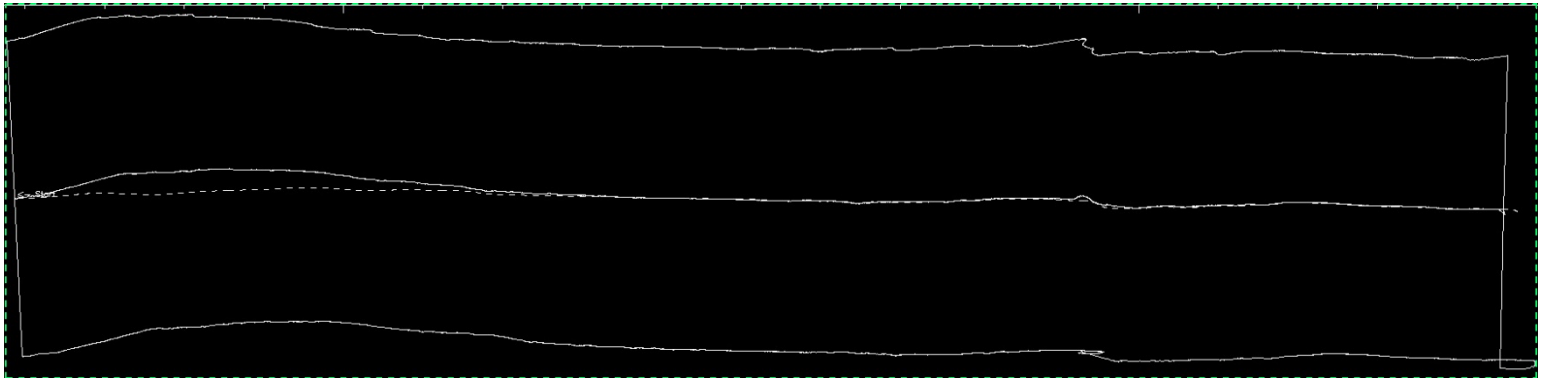
- Find offsets between the coordinate system of the camera and the coordinate system of the IMU.
- **A good boresight calibration cannot be achieved without a good sensormodel.**
- Need at least 20 GCPs on the ground
- Only necessary to do this once.
- After the offsets are found, direct georeferencing is straightforward without GCPs.

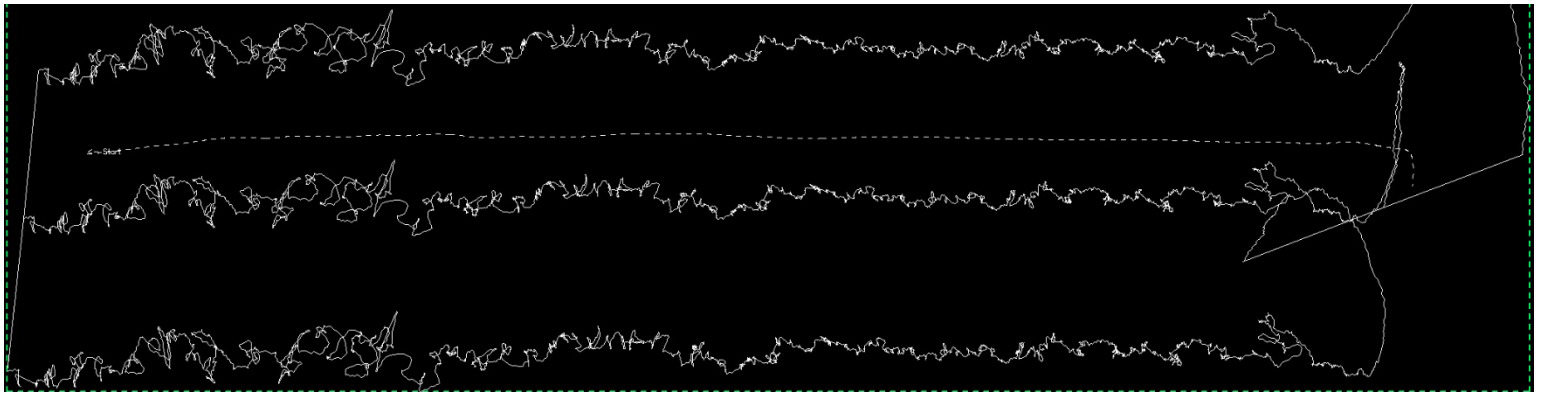
Performance and accuracies
Georeferencing Accuracy

- Pixel size of Mjolnir V – 1240 is approx. 0.02 degrees (~0.34mrad).
- For post processed INS data we can achieve 0.025 degrees roll/pitch accuracy, this is 1.25 pixels.
- On 100m altitude flights, the pixel size is 3.4cm, with post processed GPS data you can achieve down to 2cm absolute accuracy.
- Georeferencing errors are on pixel (cm) levels.



Gimbal vs No gimbal on octocopters





Flightpath taken from PARGE

Scientific grade data quality (from UAV platform)

- Optical quality
- Good detector
- Traceable calibration
- Characterized and well documented
- Stability of system
- Georeferencing
- Correct operation

RT-GEO: Real time processing software for UAV applications

- Real time georeferencing
- Real time visualization of image
- Real time image enhancement
- Real time multiple types of Image processing
- Visualization of different output as a layer

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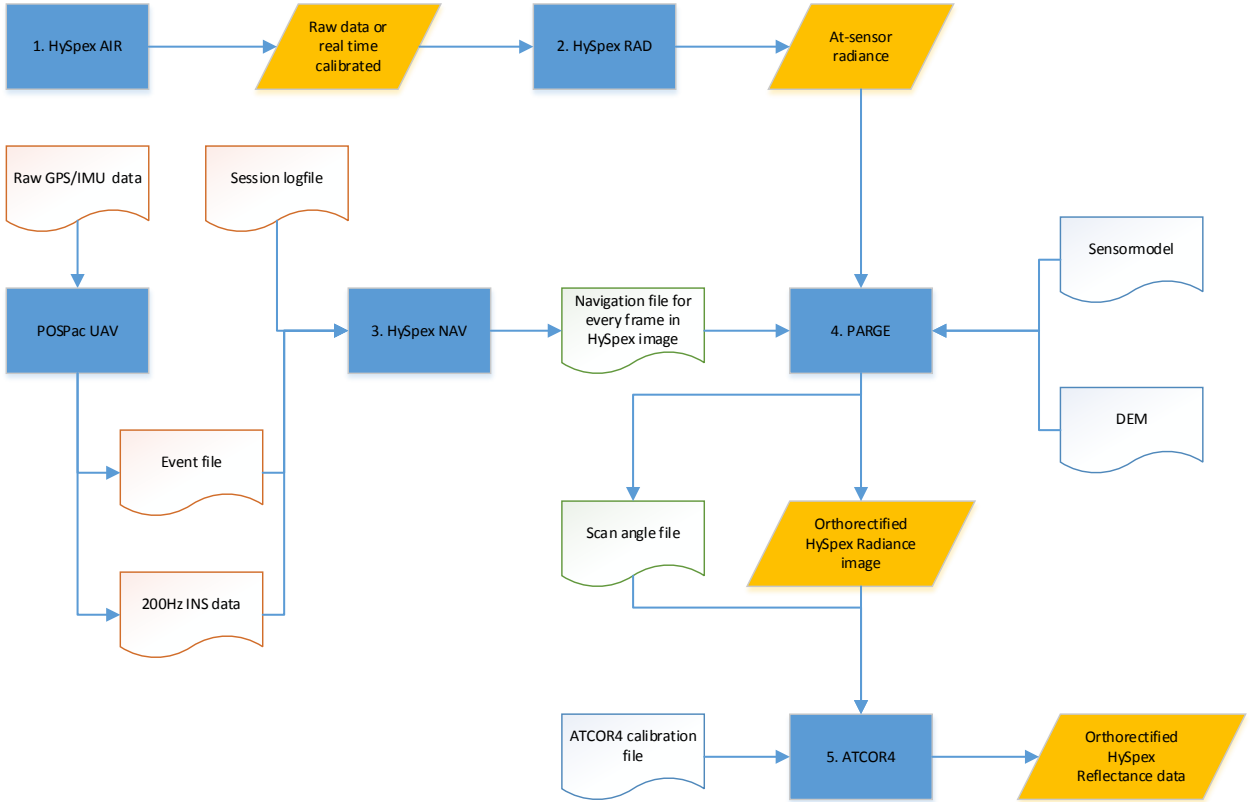
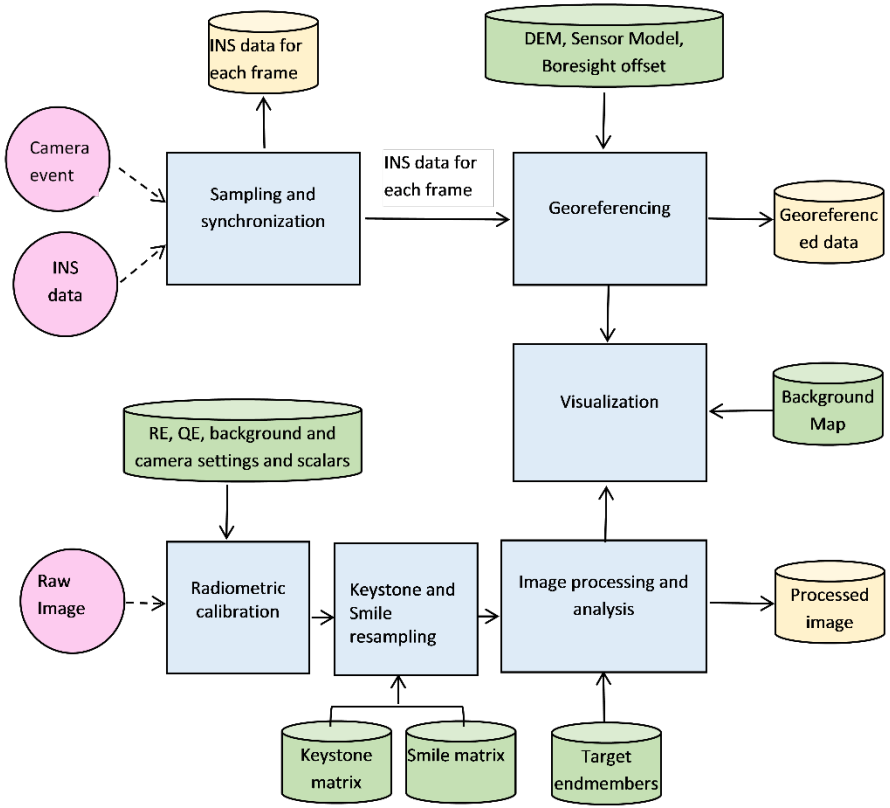
- RTGEO was tested successfully already in 2013 during Sysiphe project
- Currently implementing custom algorithms to make real-time classified maps, real-time “target” detection, real-time indices maps etc.

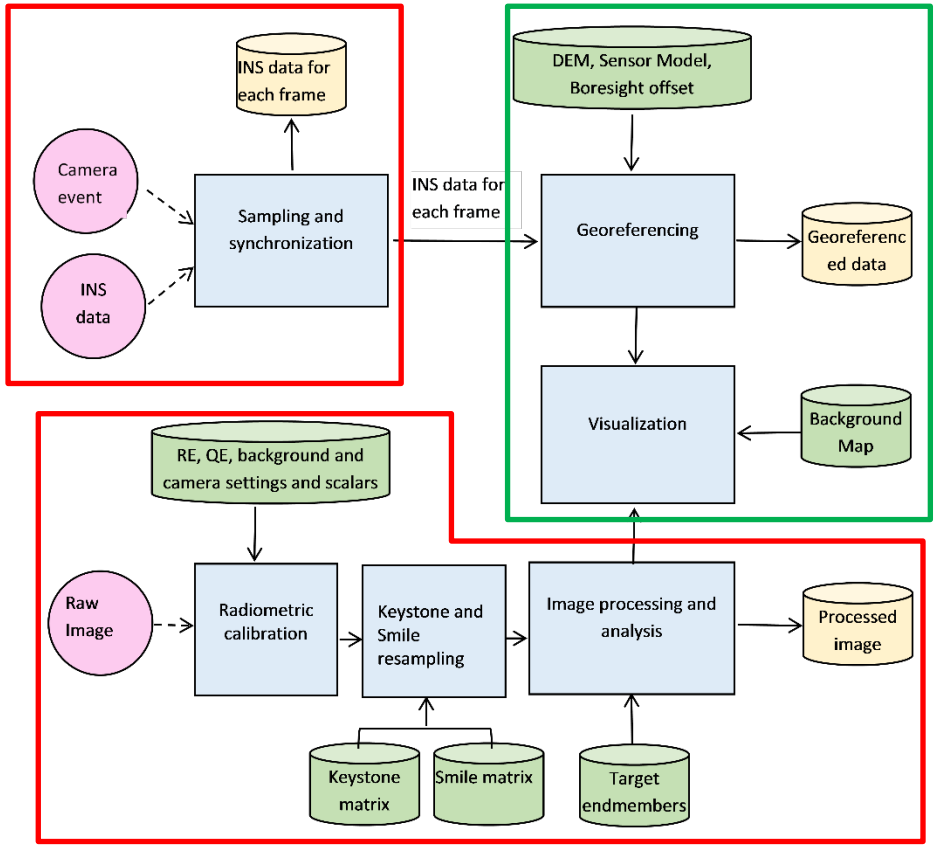
Airborne/UAV processing chain



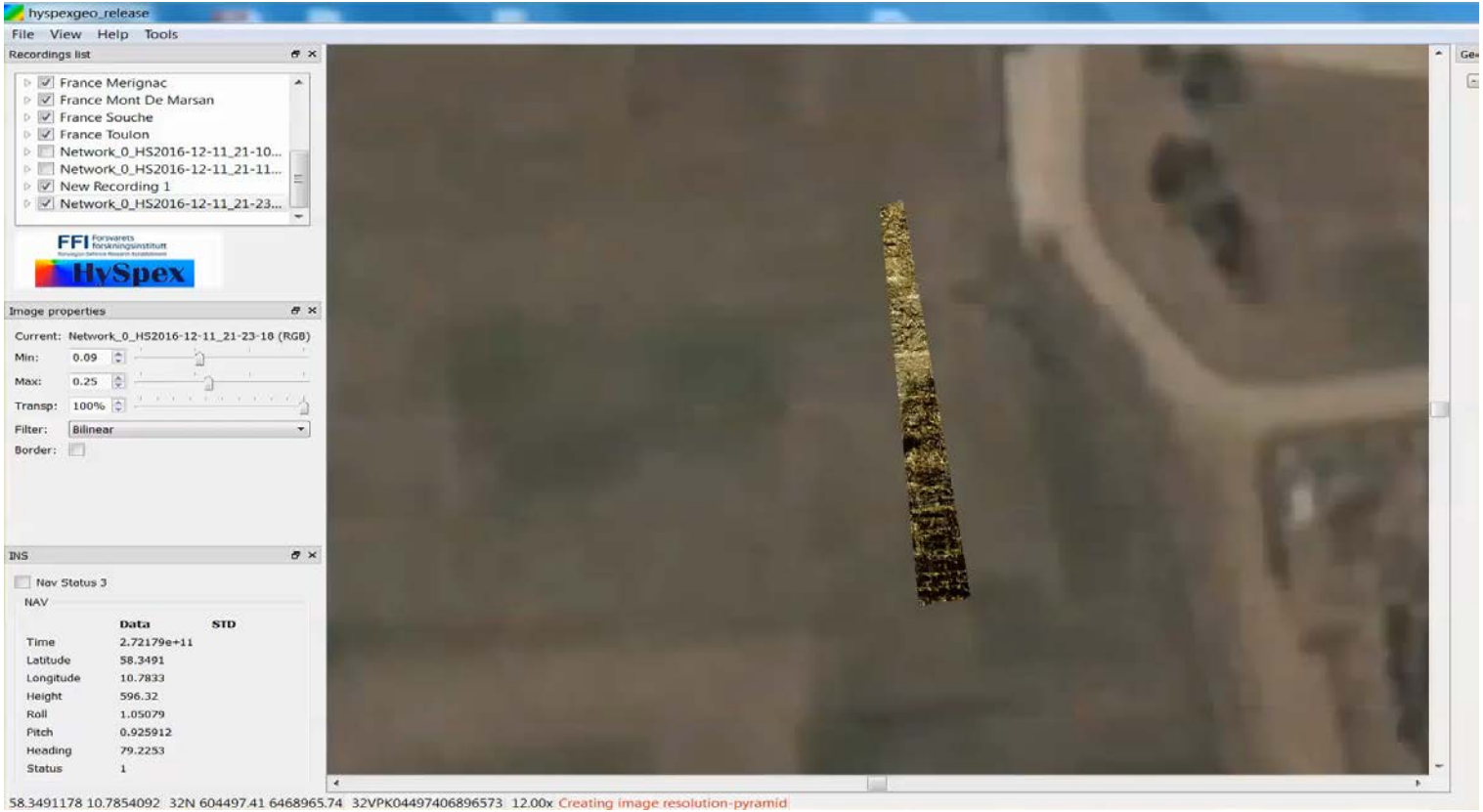
Real time georeferencing and image processing



Real time georeferencing and image processing as distributed system



RT-GEO DEMO : Georeferencing, CRX, NDVI



What's next?

- Upgraded Mjolnir VNIR system: V - 1240 (available now!)
- Mjolnir SWIR system (Mjolnir S - 620) (Q4 2017).
- Full range VNIR and SWIR UAV system: VS - 620 (Q1 2018)

- Camflight FX8 HL and other drones in the same class will be able to carry all Mjolnir configurations.
- Gremsy H16 and Letus Mag gimbal compatible with all Mjolnir configurations

Mjolnir S-620

Mjolnir VS-620

Overview of specifications for new Mjolnir models.

	V-1240	S-620	VS-620	
Spectral range [nm]	400-1000	970-2500	400 - 2500	
Spatial pixels	1240	620	620	
Spectral channels	200	300	490	
Spectral sampling [nm]	3.0	5.1	3.0	5.1
FOV	20°	20°	20°	
Pixel FOV across/along [mrad]	0.27/0.27	0.54/0.54	0.54/0.54	
Bit resolution (raw data)	12 bit	16 bit	16 bit	
Noise floor [e^-]	2.34	80	2.34	80
Dynamic range	4400	10000	4400	10000
Peak SNR (at full resolution)	>180	>900	>180	>900
Max speed (at full resolution)	285 fps	100 fps	100 fps	
Power consumption	50 W	50 W	50 W	
Dimensions (l–w–h) [cm]	25-17.5-17	25.4-17.5-17	37.4-20-17.8	
Weight [kg]	< 4.0*	< 4.5*	< 6.0*	

Mjolnir systems for field applications

- All Mjolnir systems are **easily deployable for field work** by mounting it on a tripod with a rotation stage.
- The systems deliver optimal optical performance for working distances from 20m to infinity.
- The **compac**t and self-contained design, **low weight and low power consumption** make it possible for just **one person** to carry and operate it in even **remote locations**.
- Scan speed fully synchronized with camera frame rate
- Easy wireless operation from tablet or laptop
- The system is ideal for field work related to applications like geology, vegetation, cultural heritage and many more

Mjolnir S-620 on tripod

Why choose HySpex Mjolnir?

- The only scientific grade UAV system on the market
- PTB traceable radiometric calibration
- Spectral calibration accuracies: 0.2nm
- Calibration stable with pressure and temperature variations
- Smile and Keystone distortions less than 10% of a pixel (<0.345um)
- Extremly sharp system both spectrally and spatially
- Test report with every system
- Turn key solution for UAV and Field applications

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Conclusion

- Mjolnir systems provide 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 is available on FTP or drop by our booth to get a pendrive with various demo data.

Questions/comments?

Contact info: hyspex@neo.no