SYSPHE, an airborne hyperspectral imaging system

- Airborne hyperspectral imaging system for defence/scientific research applications
- Full wavelength range (VNIR/SWIR/MWIR/LWIR) with ~500 bands
- Large swath and fine spatial resolution (500m, 0.5m @2000m)

Sysiphe development consortium:
- Built by Onera (France), FFI (Norway) and NEO (Norway)
- Supported by French and Norwegian MoDs

- Development started in 2007, first flight in Fall 2013
SYSIPHE components

Spectral imager
MWIR / LWIR
SIELETTERS (ONERA)

Spectral imager
VIS/SWIR
Hyspex Odin-1024 (NEO)

Real time image processing System (FFI/NEO)

Archiving and processing data system
STAD (ONERA)

Products
- Spectral reflectance / emissivity and temperature maps
- Spectral radiance

Calibrated & georeferenced
Archiving and processing data system (STAD)

The STAD will:

- register all the images delivered by the two instruments in a common georeferenced spectral image from VIS to LWIR;
- perform atmospheric compensation at all wavelengths.
HySpex ODIN-1024 main characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>VNIR</th>
<th>SWIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral range</td>
<td>400 – 1000 nm</td>
<td>950 – 2500 nm</td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>5.0nm</td>
<td>6.1nm</td>
</tr>
<tr>
<td>Pixel FOV</td>
<td>0.25mrad</td>
<td>0.25mrad</td>
</tr>
<tr>
<td>Total across track FOV</td>
<td>15°</td>
<td>15°</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>1024px</td>
<td>1024px</td>
</tr>
<tr>
<td>F-number</td>
<td>F1.64</td>
<td>F2.0</td>
</tr>
</tbody>
</table>

- Consists of two pushbroom imaging spectrographs
- Common fore-optics to ensure perfect registration between VNIR and SWIR
- VNIR sensor has 2048 spatial pixels but is downsampled to 1024 pixels
- Low F-numbers for high throughput
HySpex ODIN-1024 acquisition mode

FPA

transmissive grating

intermediate image plane with slit

front lens

along track direction
HySpex ODIN-1024 mounted in aircraft

- VNIR sensor
- SWIR sensor
- INS
- Cooler

Rugged aluminum structure for high mechanical stability

flight direction
Optical system may slightly change properties from laboratory to airborne operation

Difference air pressure at different altitudes

ODIN has facility to monitor changes

Reference calibration measurement is done on-ground in Lab

Airborne calibration measurement is made for comparison

Camera shutter to outside world closed for calibration measures

Airborne actual images with shutter open can be adjusted to compensate for changes using onboard-calibration data
## Sieleter’s main characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MWIR</th>
<th>LWIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral range</td>
<td>3.0 - 5.4 µm</td>
<td>8.1 – 11.8 µm</td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>13 cm⁻¹</td>
<td>6 cm⁻¹</td>
</tr>
<tr>
<td>Pixel FOV</td>
<td>0.25mrad</td>
<td>0.25mrad</td>
</tr>
<tr>
<td>Total across track FOV</td>
<td>15°</td>
<td>15°</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>1016px</td>
<td>1016px</td>
</tr>
<tr>
<td>F-number</td>
<td>F4.0</td>
<td>F3.0</td>
</tr>
</tbody>
</table>

- Two separate static Fourier transform spectral imagers
- MCT IR-FPAs from Sofradir, 1016x440 pixels
- Entirely cryogenic (liquid nitrogen, 77K)
- Stabilized
Lateral shearing interferometer

FPA: superposing of interference fringes and scene image

Imaging system

Along track direction
Sielecters mounted in the aircraft

- flight direction
- LWIR sensor
- MWIR sensor
- Stabilization platforms
SYSIPHE first flight campaign: Cazaux, September 2013

- Aircraft: Do-228 from DLR (73m.s\(^{-1}\), 2000m)
- 4 flights during 3 days:
  Toulouse and Cazaux (Cobra IR pattern)
Cobra IR pattern (French airbase of Cazaux)

Cobra IR pattern (20x20m², ΔT~20°C)

patterns for VIS-NIR-SWIR images
Sieletes flight stabilization

- Stabilization: < 90 µrad
- Control loop optimization: <1 pix. residual error over 440 images gliding window
- Position (WGS84): < 15 cm
Sieletes MTF flight measurements

- MTF measurement on Cobra IR pattern
  - MTF @ 0.88 m\(^{-1}\) > 0.71 (>0.45 required)
  - MTF @ 0.33 m\(^{-1}\) > 0.22 (>0.10 required)

Sieletes panchromatic image

0.5 m GSD
Orthorectified Hyspex-Odin-1024 image
Hyspex-Odin 1024 first results

White = Polystyrene
Red = Asphalt

Spectral Profile

Value

Wavelength

500 1000 1500 2000 2500

White = Polystyrene
Red = Asphalt
First Sieleters preliminary spectral results

Spectral radiance SNR is being improved
SYSIPHE conclusions

👍 Uniquely wide spectral area: 0.4 µm to 11.8 µm

👍 Very good SNR expected (still to be flight validated)

👍 Very high spatial resolution: 500 m swath, 50 cm ground sampling pitch

👍 Integrated processing chain will allow georeferenced products of spectral radiance, spectral emissivity/reflectance, and surface temperature (in progress)
First flight in September, 2013 (images being processed for instruments validation), acceptance expected for Summer 2014.

Sysiphe will then be open to external users:
- NATO, EDA or others
- EUFAR, European Facility for Airborne Research
- national and international community: scientific, industrial or institutional
Thank you for your attention!

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