

# HYPXIM: A NEW HYPERSPECTRAL SENSOR COMBINING SCIENCE/DEFENCE APPLICATIONS

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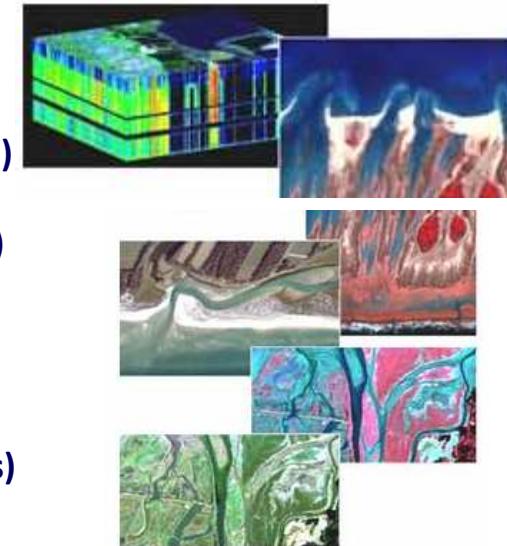
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## HYPXIM: A NEW RESPONSE

SPATIAL RESOLUTION OF CURRENT  
and FUTURE HYPERSPECTRAL  
MISSIONS (EnMAP, PRISMA,  
HypIRI, etc.)  $\geq 30$  m  
ILL SUITED FOR SOME FIELDS OF  
APPLICATION



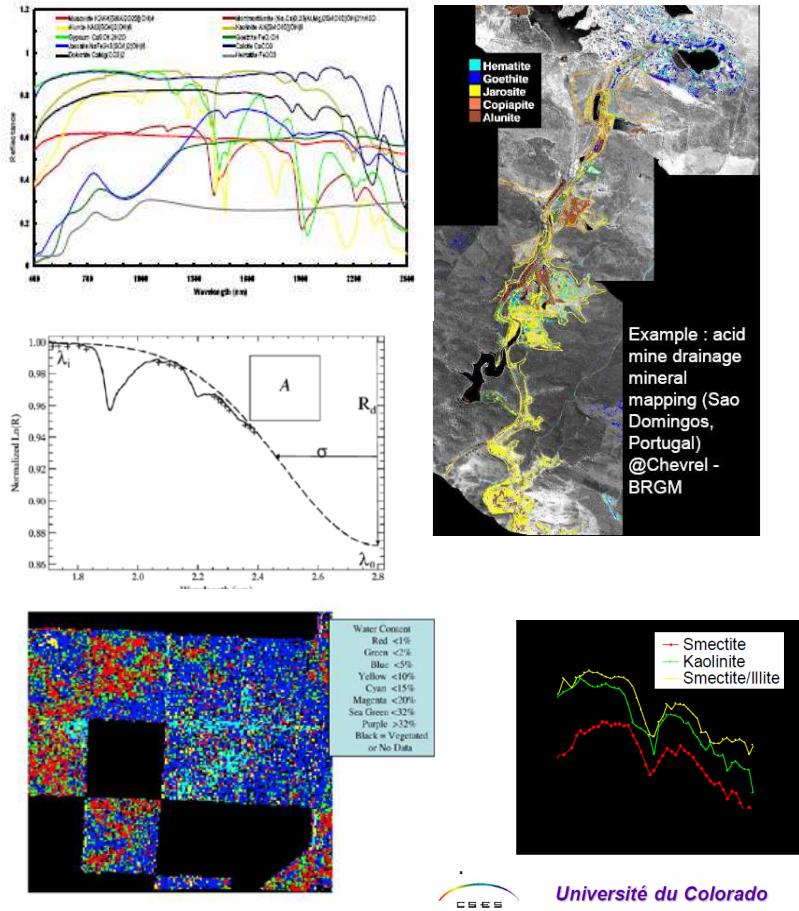
**HYPXIM COMBINES:**  
HIS: HIGH SPECTRAL RESOLUTION (10 nm) + HIGH SPATIAL RESOLUTION ( $< 8$  m)  
+  
VERY HIGH SPATIAL RESOLUTION ( $< 2$ m)  
+  
GLOBAL ACCESS  
+  
REGULAR REVISIT TIME  
19 (nadir) to 3 days (pointing capabilities)



HYPXIM DATA CHARACTERISTICS CLOSE TO AIRBORNE AND IN SITU:

- 1- ACCESS TO NEW INFORMATION FROM SPACE
- 2- ACCURATE MEASUREMENTS OF PARAMETERS POORLY RETRIEVED AT LOWER RESOLUTION
- 3- BETTER ESTIMATE AT A MORE LOCAL SCALE OF HUMAN IMPACT ON HIS ENVIRONMENT

# HYPERSPECTRAL MAIN USERS NEEDS: GEOSCIENCES



*Spectral characteristics: 0.4-2.5 $\mu$ m, resolution < 10nm in VNIR/SWIR - SNR >300:1 in VNIR, > 100:1 in SWIR*  
*Geometric characteristics: GSD ~5-20m*  
*Temporal characteristics: less than monthly for certain environmental monitoring applications (10 days), Can be critical during a crisis (3-5 days).*

## Objectives:

Mineral mapping  
 Environmental impact  
 Hazards  
 Soil degradation  
 Soil properties

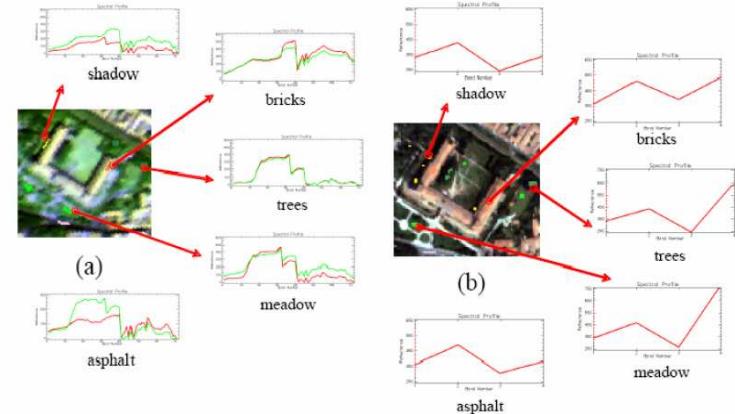
⇒ Relevant scale = mining sites, river banks, geologic formation

## Parameters:

Mineral composition, concentration/quantity, C organic content, soil moisture content, grain size, clay

⇒ Requires taking into account intimate mixtures and alteration crusts

# HYPERSPECTRAL MAIN USERS NEEDS: URBAN ECOSYSTEM



Spectra of some covers in DAIS data (a) and in Quickbird data (b), from Dell'Acqua et al., 2006.

Class	30 m	10 m	5 m	2.5 m	1 m
Trees	Group				
Grass					
Park					
Dense buildings					
High buildings					
Road	Except motorway				
Railways			area		
Water	river				
Shadow					

Puissant A., Hirsch J., 2004, Télédétection urbaine et résolution spatiale optimale : intérêt pour les utilisateurs et aide pour les classifications, *Revue Internationale de Géomatique*, 14(3-4), 403-415.

## Objectives:

Urban planning

Biodiversity: species, vegetation status

Cartography: urban material, impervious soil, vegetation species

Urban microclimatology: air quality, urban heat island, health

Hydrology: water quality

⇒ Relevant scale = small spatial scale

## Parameters:

composition of urban materials (chemistry, permeability, moisture content, dangerous materials), temporal evolution, sanitary state, manmade/natural surfaces

⇒ Fusion Panchromatic + hyperspectral

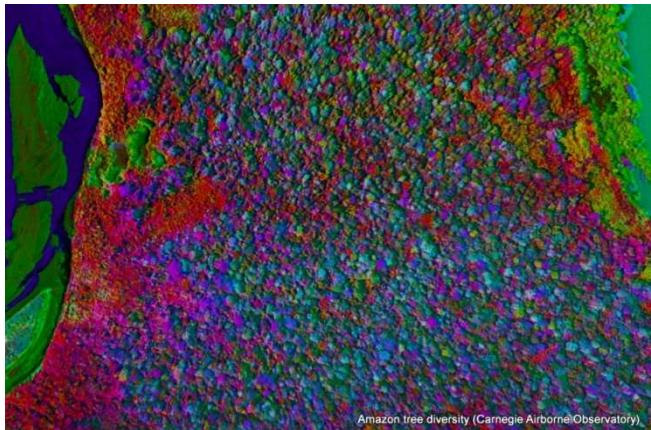
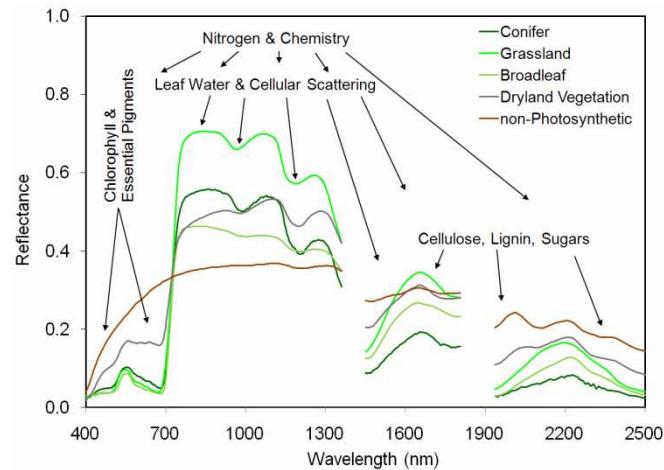
⇒ Requires taking into account intimate mixtures

*Spectral characteristics: 0.4-2.5µm, resolution < 10nm VNIR/SWIR - SNR>250:1 VNIR, >100:1 in SWIR*

*Geometric characteristics: GSD < 5m*

*Temporal characteristics: critical during the growing season and during a crisis (3-5 days).*

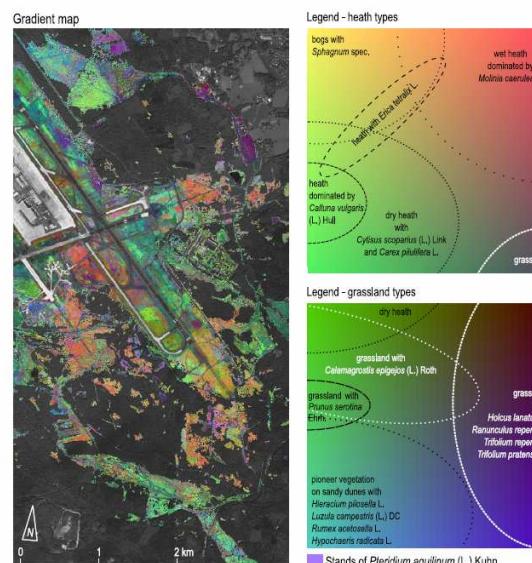
# HYPERSPECTRAL MAIN USERS NEEDS: PLANT BIODIVERSITY



*Spectral characteristics:* 0.4-2.5μm, resolution < 10nm

*Geometric characteristics:* resolution ~5-10m is useful for some applications

*Temporal characteristics:* critical during the growing season (10 days)



## Objectives:

**Biodiversity:** taxonomic distribution of plants, chemical composition, texture, detection of invasive plants (e.g. meadow)

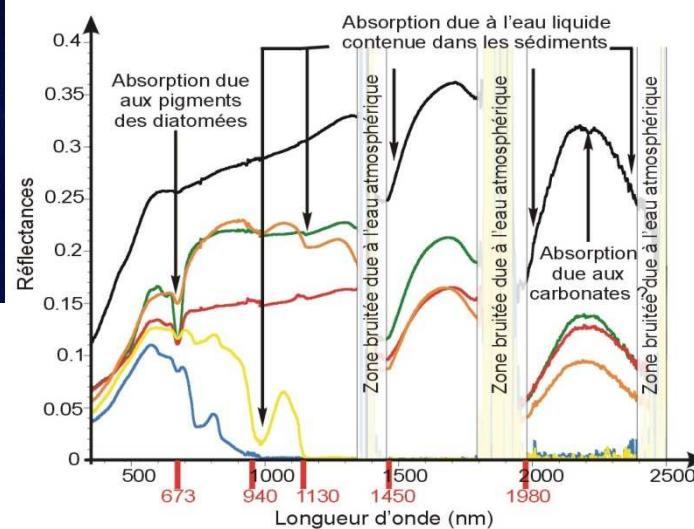
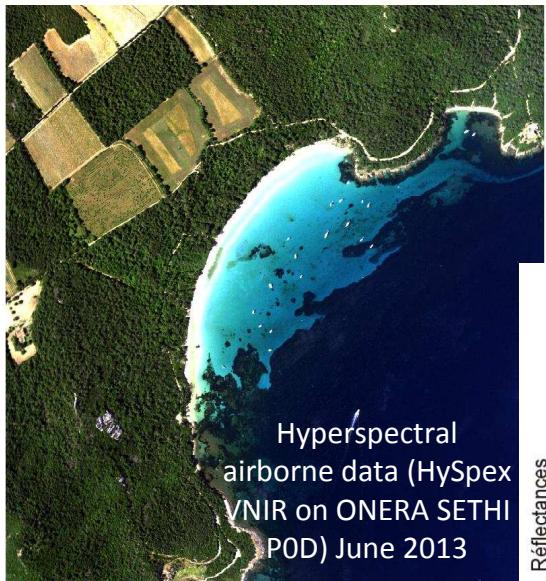
**Precision agriculture:** crop monitoring, weed detection, yield forecasting

**Forestry:** species, tree health, CO<sub>2</sub> fluxes, fire hazard assessment

**Necessity of data at an intermediate scale between *in situ* and global**

**Parameters of interest:**  
pigments, water and dry matter content, C:N, LAI, light-use efficiency

# HYPERSPECTRAL MAIN USERS NEEDS: COASTAL ECOSYSTEM



*Spectral characteristics:* 0.3-1 $\mu$ m for the majority of applications.  
Extended to 2.5  $\mu$ m for characterisation of sediments, resolution < 10nm.  
SNR >400 in VNIR.

*Geometric characteristics:* GSD <10m

*Temporal characteristics:* Variable, strong constraints for certain applications (1 day)

## Objectives:

Harmful algal blooms → impact on tourism activity  
Eutrophisation  
Phytoplankton algal groups → coastal primary production and carbon cycle  
Impact of turbulence on phytoplankton spatial distribution → coastal ocean dynamics and fisheries  
River discharges → marine pollution  
Bathymetry → military applications  
Seabed mapping → sand, benthic species, corals...

⇒ Relevant scale = small spatial scale

## Parameters:

pigments, mineralogy, grain size, moisture content, species

⇒ Requires taking into account intimate mixtures

# HYPERSPECTRAL MAIN USERS NEEDS: ATMOSPHERE

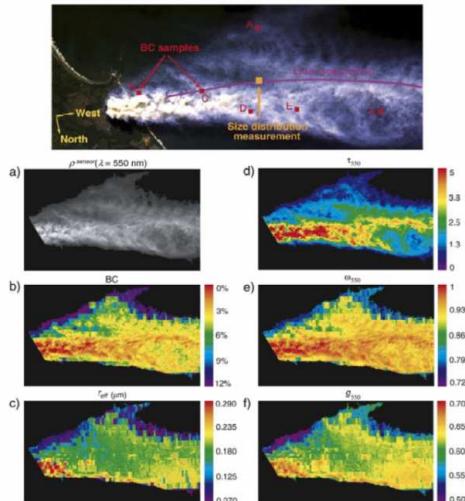
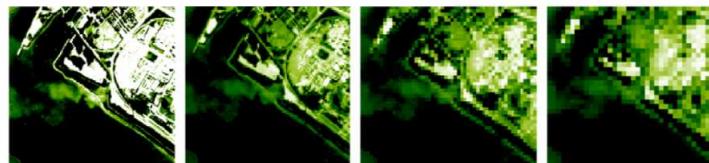


Figure 9: Quinault biomass burning aerosol plume analysis; a) image of  $p_{\text{sensor}}$  at 550 nm, b) map of BC (%), c) map of  $r_{\text{eff}}$  ( $\mu\text{m}$ ), d) map of  $\tau_{550}$ , e) map of  $g_{550}$  and f) map of  $g_{550}$ . Scales are given in the right side of each image, from Alakian et al., 2009.



Effect of spatial resolution of plume detection; from left to right: 3.4 m; 10m; 20m; 30m (Courtesy R. Marion).

*Spectral characteristics:* 0.4-2.5 $\mu\text{m}$ , resolution < 10nm

*Geometric characteristics:* GSD < 20 m

*Swath:* 10-50 km

*SNR* > 250:1 (VNIR), > 150:1 (SWIR)

*Temporal characteristics:* Can be critical during a crisis (3-5 days).

## Objectives:

**Plumes characterization:** air pollution, biomass burning, volcano event

**Air Traffic**

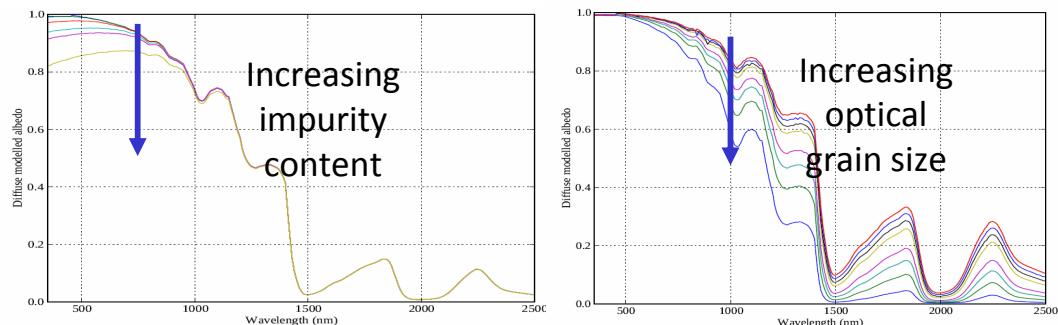
⇒ Relevant scale = small spatial scale

## Parameters:

**Gases:** type, abundance

**Aerosols:** type, Abundance, particule size

# Science requirements: Cryosphere



*Spectral characteristics:* 0.3-2.5 $\mu$ m, resolution < 10nm  
SNR >500:1 in the VIS, > 250:1 elsewhere  
*Geometric characteristics:* GSD  $\sim$ 5-10m  
*Temporal characteristics:* < 5 days

## Objectives:

**Climate:** surface energy budget  
**Hydrology**

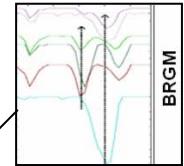
⇒ Relevant scale = small spatial scale

## Parameters:

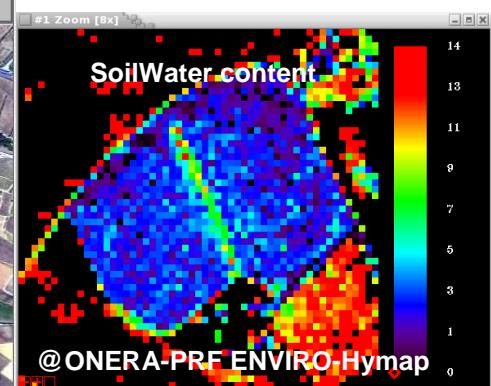
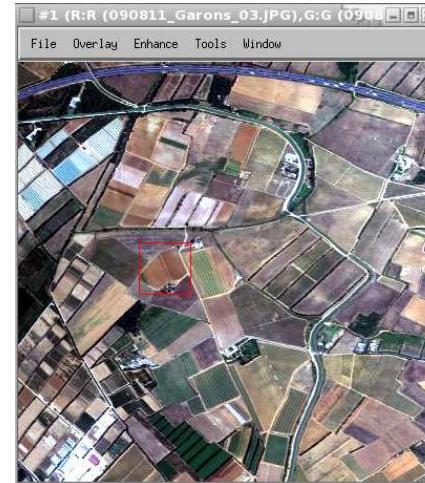
**grain size**, water liquid content, impurities type and content

⇒ Requires taking into account intimate mixtures

# HYPERSPECTRAL MAIN USERS NEEDS: DEFENCE



Namibian Hyperspectral simulated image  
(CNES/BRGM)



**Key applications identified.**

Among these, three should be noted in particular :

- trafficability indices
- detection/characterisation of objects/anomalies
- characterisation of coastal zones (bathymetry)

*Spectral characteristics: 0.4-2.5μm, resolution < 10nm in VNIR/SWIR*

*Geometric characteristics: GSD < 5 m (urban) and ~10 m (geosciences)*

*Temporal characteristics: short revisit period required.*

# Science requirements: Summary

From these different science requirements, the sensor characteristics are summarized as follow:

Domain	$\delta\lambda$ (nm)	GSD (m)	Swath (km)	Revisit Period	SNR
Geosciences	$\leq 10$	10	50 - 100	Non critical	>300:1 in VNIR >100:1 in SWIR
Coastal ecosystem	$\leq 10$	$\leq 10$	Variable	Critical for inter tidal monitoring	> 400:1 in VNIR
Vegetation biodiversity	$\leq 10$	$\leq 10$	Variable	Critical during growth period	TBC
Urban ecosystem	$\leq 10$	5	20 - 50	Critical during crisis	>250:1 in VNIR >100:1 in SWIR
Cryosphere	10	5-10	20- 50	< 5 days	>500:1 in VNIR >250:1 in SWIR
Atmosphere	$\leq 10$	20	10 - 50	Variable	>250:1 in VNIR >150:1 in SWIR

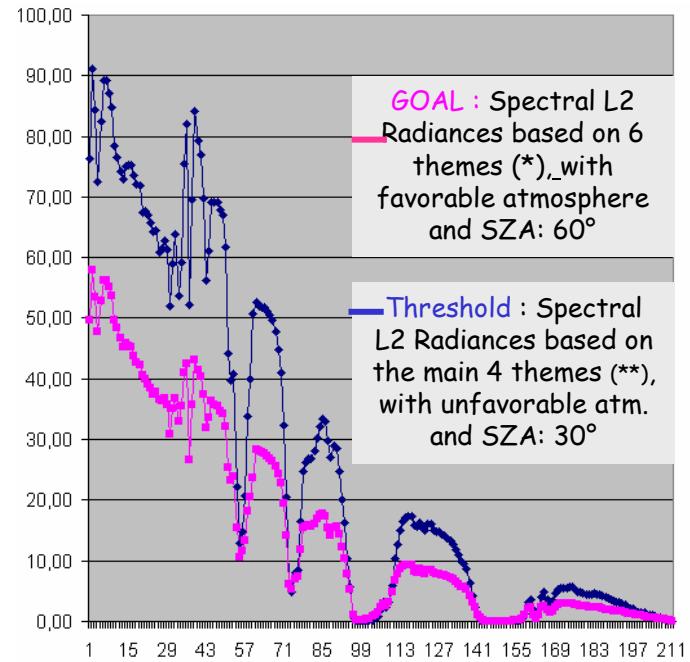
Summary table of mission requirements expressed by the six science user groups where  $\delta\lambda$  is the spectral resolution, GSD the ground sample dimension and SNR the signal-to-noise ratio, the spectral range is [0.4, 2.5 $\mu$ m].

All these requirements have to be refined

# HYPXIM : main mission requirements

Domain	Spectrum (nm)	Spectral res. $\delta\lambda$ (nm)	SNR@L2
VIS	400-700	10	$\geq 250:1$
VNIR	700-1100	10	$\geq 200:1$
SWIR	1100-2500	10	$\geq 100:1$
PAN	400-800	400	$\geq 90:1$

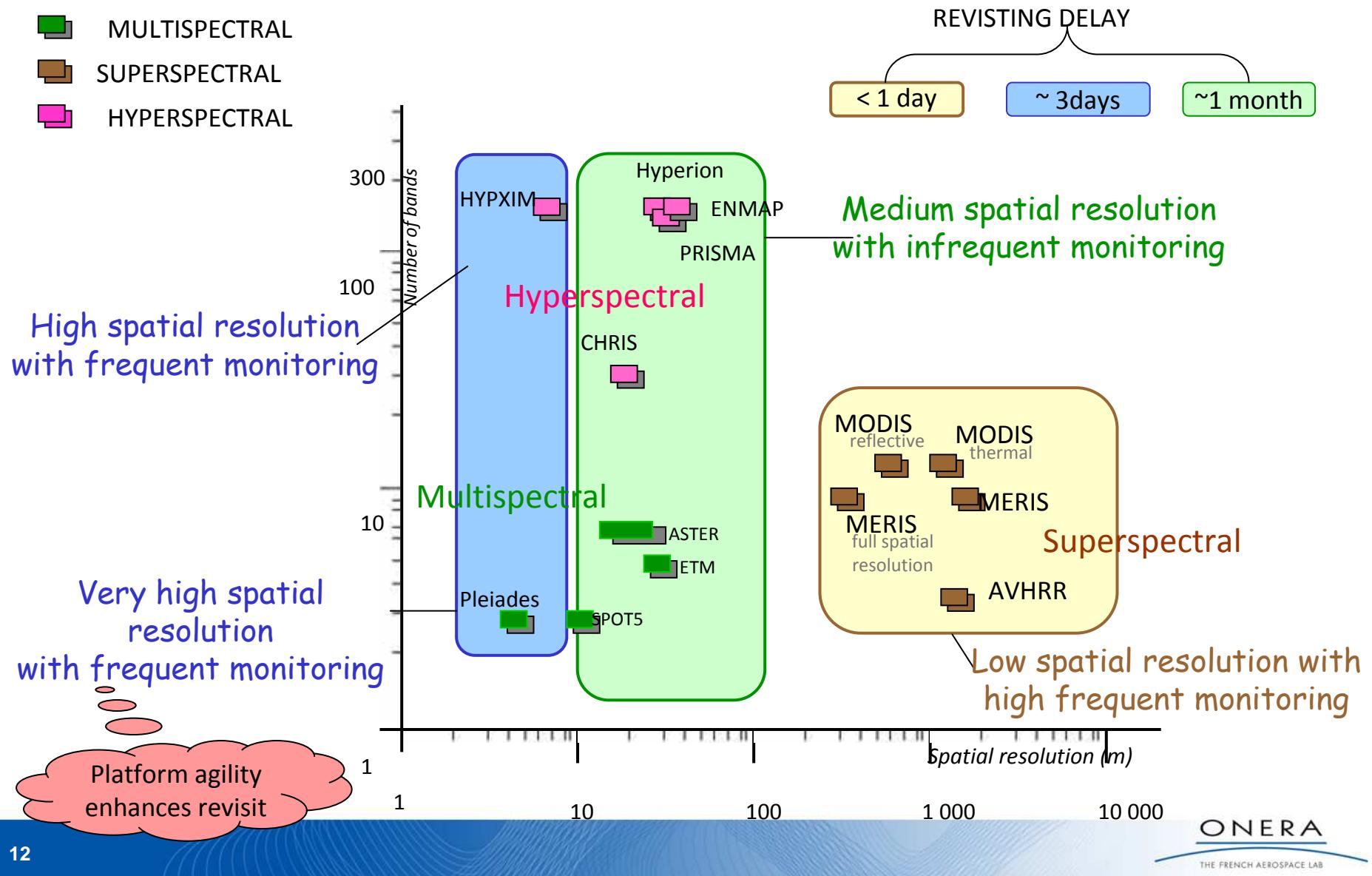
- ⇒ Spectral continuum required from VIS to SWIR, spectral resolution of 10 nm,
- ⇒ Spectral SNR with 2 levels of L2 ( goal and threshold)
- ⇒ GSD HIS < 8m, and a panchromatic channel (GSD < 2 m) will enhance the scene analysis
- ⇒ Swath : 15 km minimum
- ⇒ Revisit: daily revisit required for some applications , 3-5 days acceptable for Defence



(\*) Goal: Geosciences, Vegetation, Urban, Defence, Atmosphere and Coastal zones

(\*\*) Threshold: Geosciences, Vegetation, Urban, Defence

## HOW IS THE POSITION OF HYPXIM IN THE INTERNATIONAL CONTEXT ?



# Conclusions

Seven scientific/defence domains have been identified by a group of science and defence users of imaging spectroscopy.

Scientific requirements have to be refined in Phase A to find a tradeoff with existing technology

A phase 0 study conducted by CNES from 2009 to 2012 proved the mission's feasibility. CNES decided then to pursue with a phase A study but it was put on hold, pending on budget.

Phase A may restart in 2014, the growing scientific community is pushing.

High resolution hyperspectral imagery from space is foreseen to be a powerful tool for numerous scientific applications in many different areas, thus serving a wide scientific community