YOUR HUB
FOR GEOSPATIAL
APPLICATIONS

HSIS: PRISMA Image Simulator

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Primo Workshop Nazionale

Data Exploitation della missione PRISMA, precursore delle missioni iperspettrali nazionali

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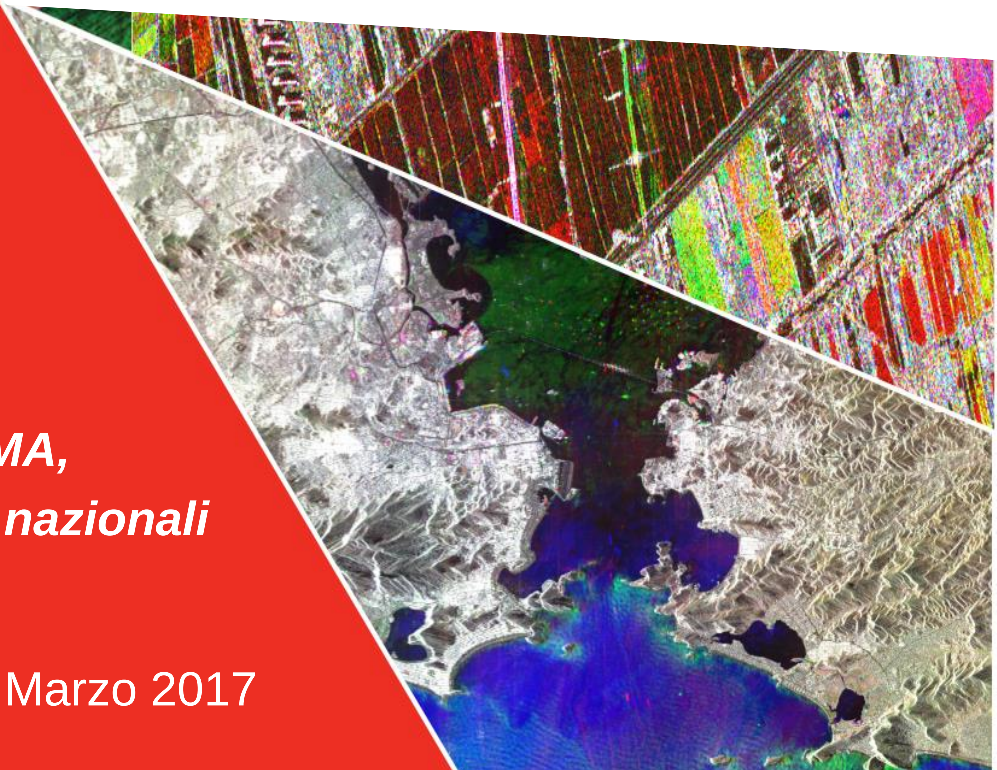


OVERVIEW

- Introduction of Hyper-Spectral Image Simulator (HSIS)
- Functions and Algorithms
  - Satellite orbit/attitude and acquisition Geometry model
  - Scattering and Atmosphere models
  - PRISMA Sensor Model
- Architecture
- Operational workflow
- Graphic User Interface
- Examples
  - From Hyperion and ALI data
  - From AVIRIS data

HSIS FUNCTIONALITIES

Hyper-Spectral Image Simulator simulates the imaging of the PRISMA Hyperspectral and Panchromatic satellite sensors taking into accounts:

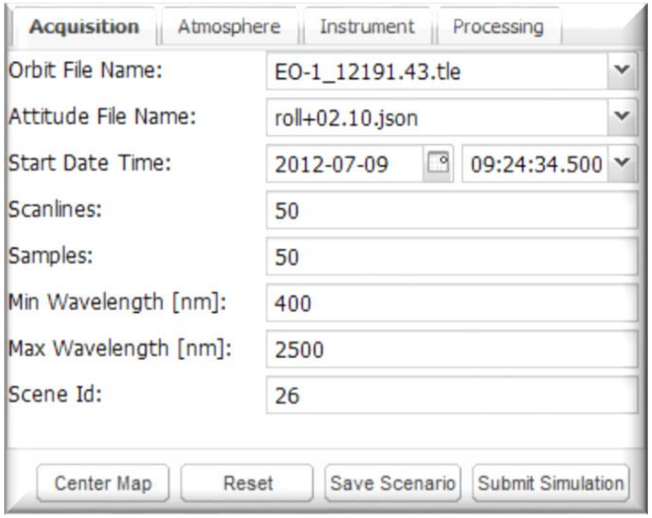
- Geometry:
  - Satellite orbit, pushbroom mechanism for imaging
  - Attitude and eventual slow disturbances on it during acquisition
- Sun elevation and Atmosphere effects:
  - Sun ephemerides, surface scattering, atm. transmissivity, path radiances. DEM is used for retrieval of incidence angles and shadow calculation
- Sensor Simulator:
  - Geometry degradation (loss of contrast)
  - Spectral degradation
  - Radiometry and noise modelling
  - DN generation (and generation of L0 CCSDS packets)
  - Radiance retrieval from DN (tool for basic calibration model)

SATELLITE ORBIT/ATTITUDE AND ACQUISITION GEOMETRY MODEL

- Geometry module of HSIS performs the mapping from Earth surface to sensor detector array, taking into account the geometry of image acquisition (satellite position, orbit and attitudes, lines of sights of the detectors (HYP and PAN) pixels and the digital elevation model of the acquisition scene).

- Inputs:
  - Orbit: TLE
  - Attitude: Pitch, Roll, Yaw (time functions)
  - Ground Surface: SRTM DEM, Geoid, others defined by User

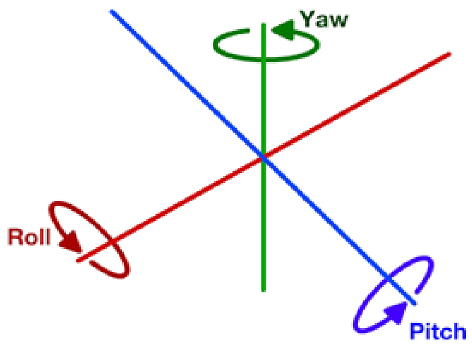
- Outputs
  - Pixel line-of-sight / ground-surface intersection X, Y, Z (ECR) for Panchromatic and Hyperspectral sensors
  - Mapping on the focal plane (through sinc sampling)



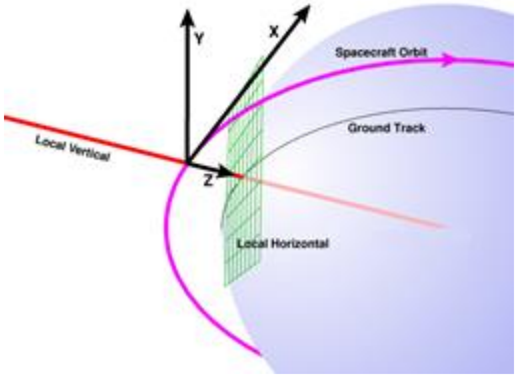
GEOMETRY – ORBIT AND ATTITUDE MODELLING

- Orbit is modelled by propagating TLE files as using pyEphem libraries
- The attitude is defined by three rotation angles with respect to the Orbital RS

Pitch Roll Yaw



Orbital RS



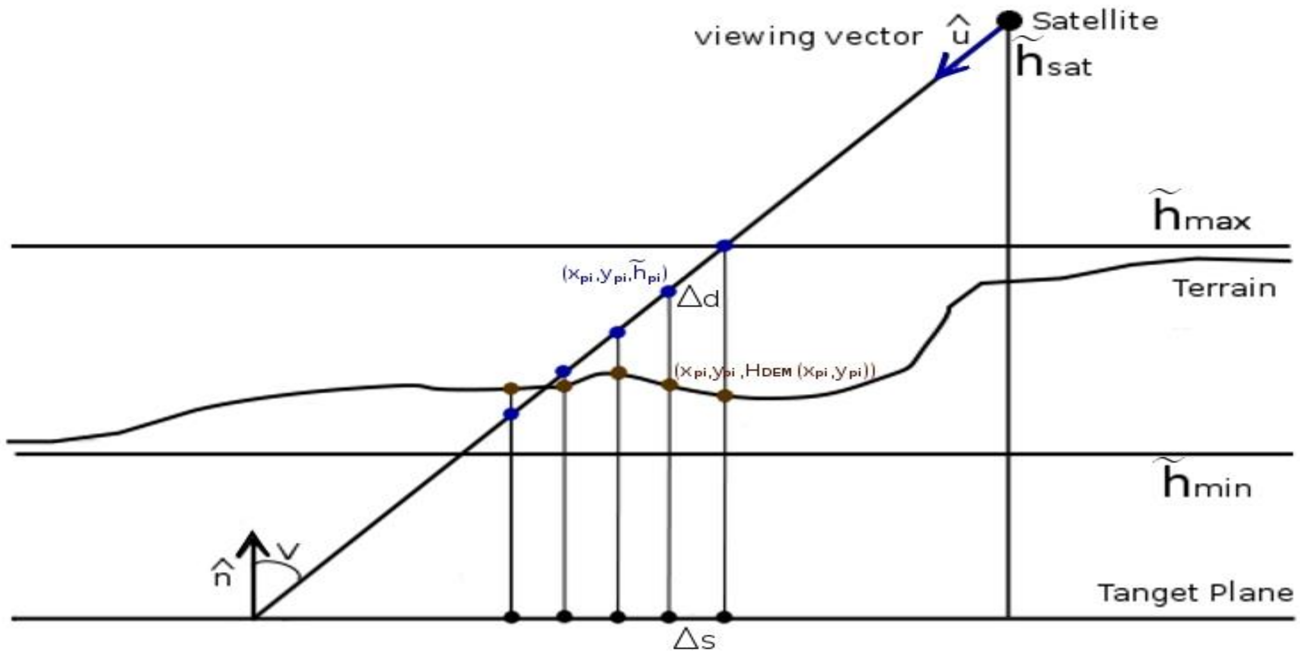
HSIS allows to ingest a generic symbolic function to model the effect of slow varying attitude profiles during the acquisition into the simulated images.

```
{
    "roll": "-2 / 180. * pi",
    "yaw": "sin(20 * t * 2 * pi) * (0.1 / 180. * pi) ",
    "pitch": "-1 / 180 * pi + (0.1 /180 * pi) t "
}
```

GEOMETRY - INTERSECTION ALGORITHM

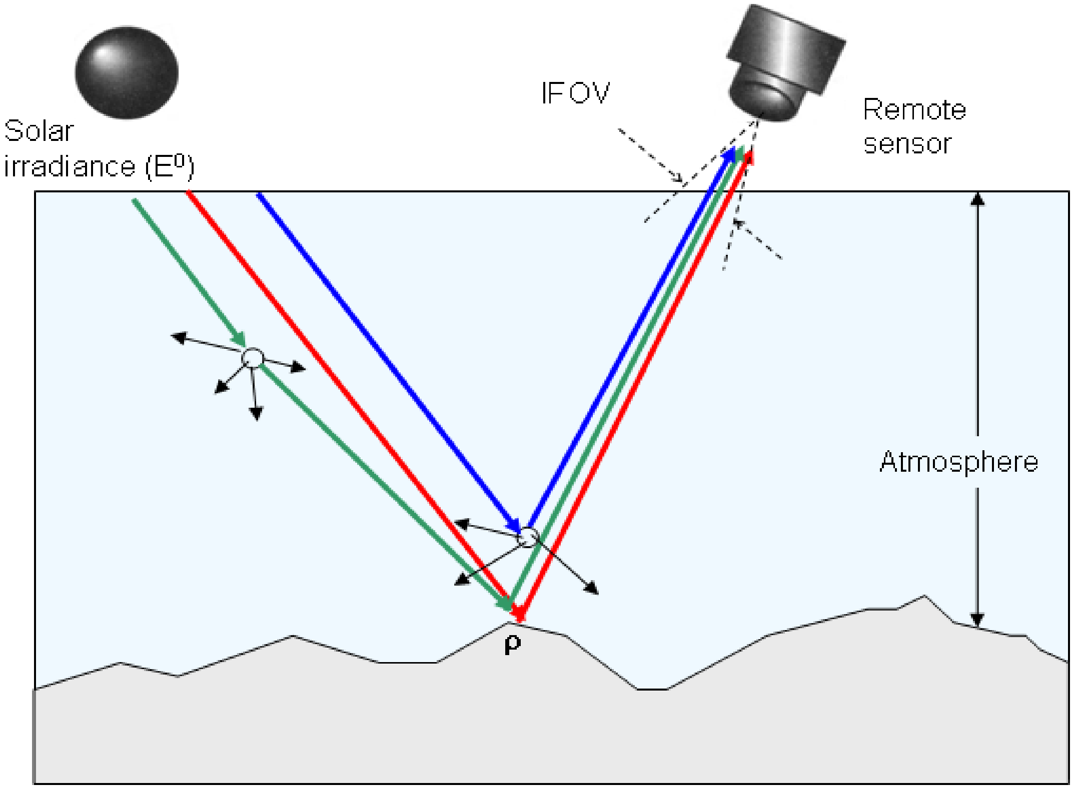
Intersection is computed by moving along the line of sight of a fixed step and searching for the intersection with the ground surface. The step size depends on the DEM resolution.

Interpolation is performed through cardinal sampling (sinc interpolation) in order to preserve the spatial correlation of the input data (except for stretching due to DEM).



Scattering and Atmosphere models (based on MODTRAN 5):

- L^{su} : the un-scattered surface reflected radiation (Lambertian surface)
- L^{sd} : the down-scattered surface reflected skylight
- L^{sp} : the up-scattered path radiance (combination of both *Rayleigh scattering* and *Mie scattering*)

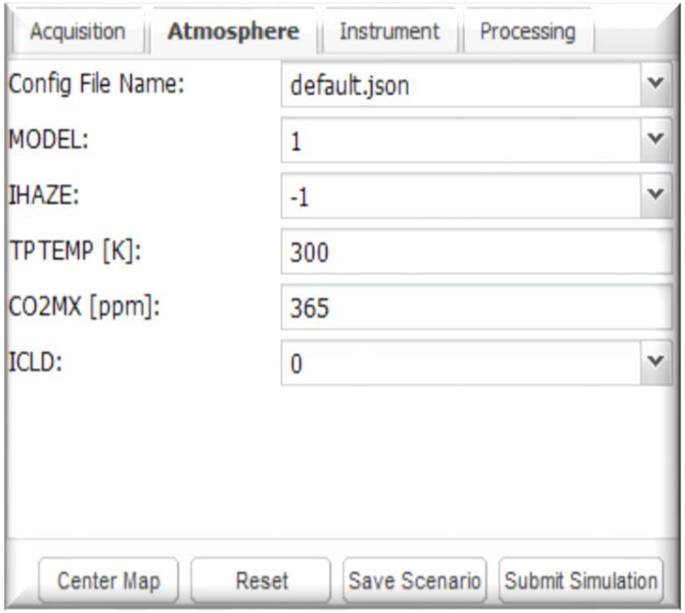


Shading effects and shadows are calculated by using digital elevation models DEM.

ATMOSPHERE MODEL IMPLEMENTATION

MODTRAN parameters can be managed through GUI:

- Atmosphere MODEL: there are six geographical-seasonal model atmospheres:
- IHAZE: define type and default metereological areosol models
- TPTEMP: Temperature
- CO2MX: the CO_2 mixing ratio in ppmv
- ICLD: specifies the cloud and rain models used (with CEXT)



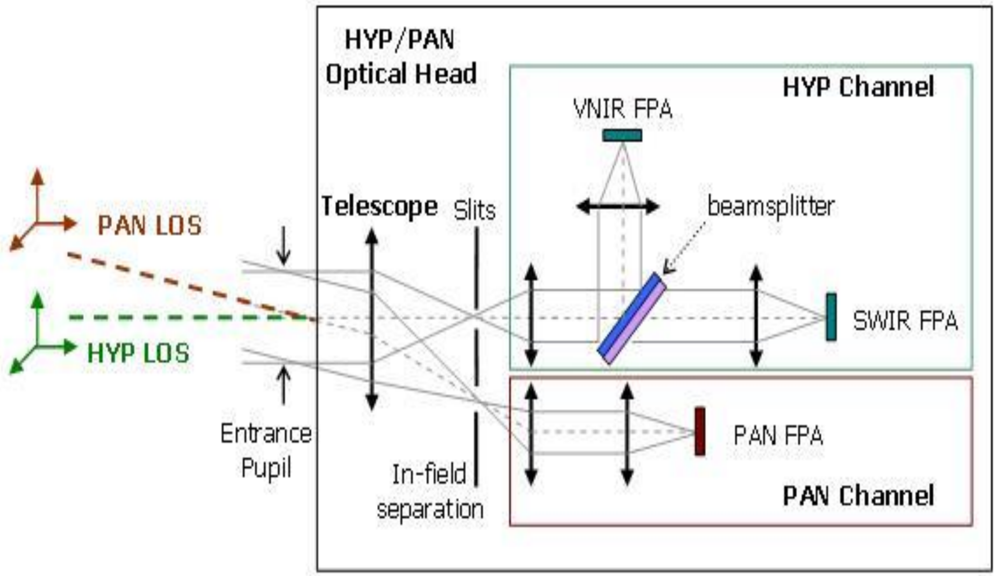
Some parameters can be introduced through the ingestion of maps:

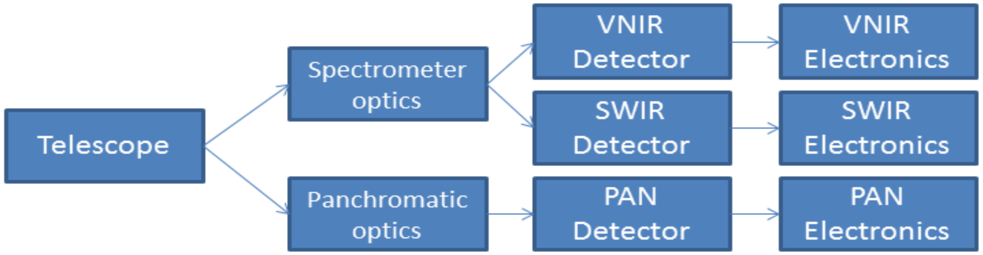
- H2OSTR [g/cm^2]: Vertical water vapour column [g/cm^2]
- VIS and ASTMX: visibility and Angstrom Law offset to define the aerosol optical depth
- CEXT [km^{-1}]: the extinction coefficient for accurate cloud model

SENSOR MODEL (DEVELOPED BY LEONARDO)

Electro/Optical System:

- Hyperspectral: 30 m GSD, 400nm-2500nm VNIR (65 Bands) and SWIR (171 Bands)
- Panchromatic: 5 m GSD





Input Parameters:

- Keystone
- Smile
- Slit Curvature
- Jitter Across Track
- Jitter Along Track

Input Data:

- TOA Pancromatic Radiance
- TOA Hyperspectral Radiance

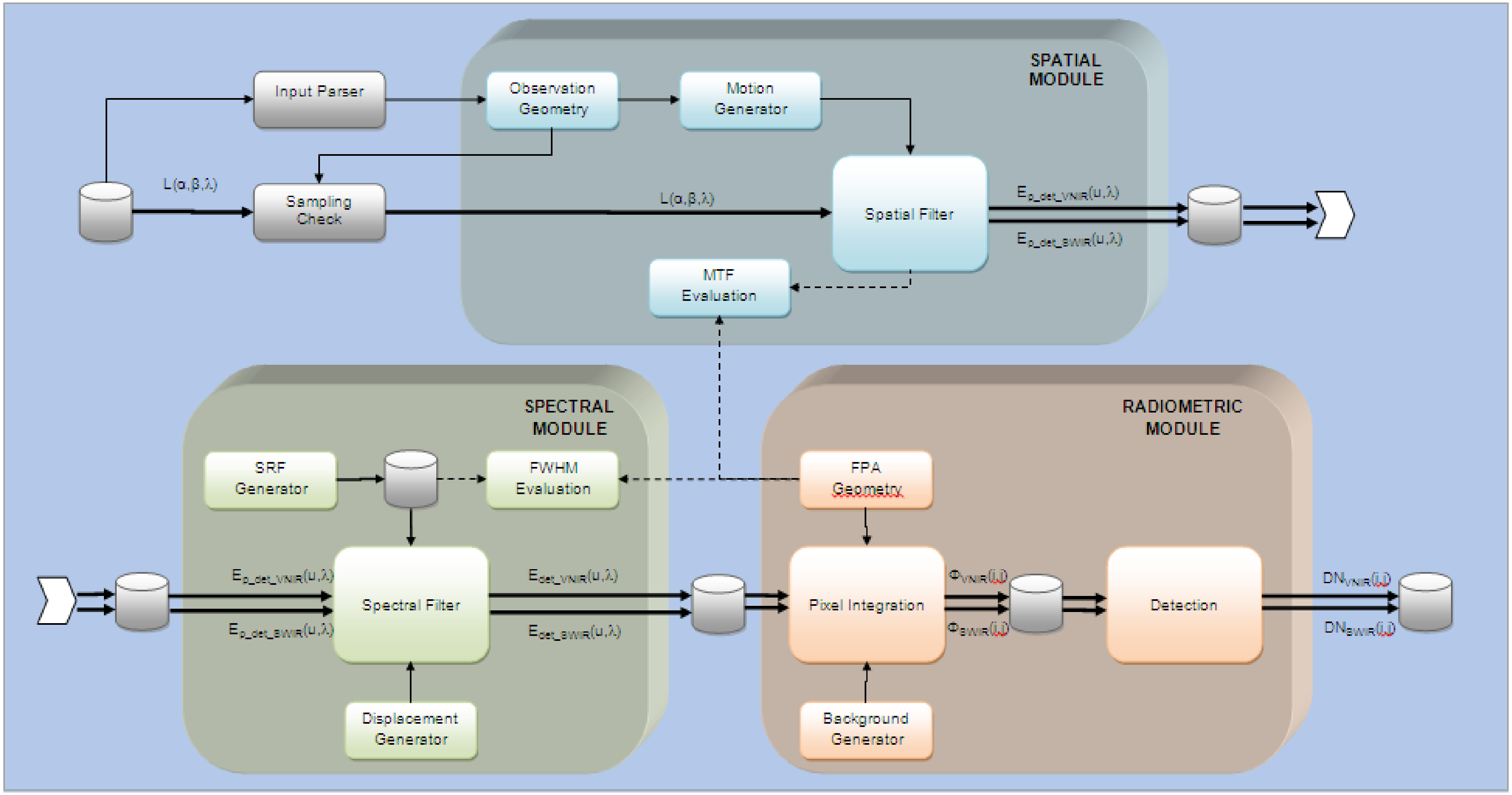
Output:

- Digital Number
- L0 in CSSDS Packet Format

Radiometric sources of noises:

- Spatial Pattern noise (PRNU)
- Dark Signal Non-Uniformity (DSNU)
- Signal and shot noises (photon shot noise, readout n., flicker n., off-chip n.)

HYPERSPECTRAL SENSOR MODEL DIAGRAM



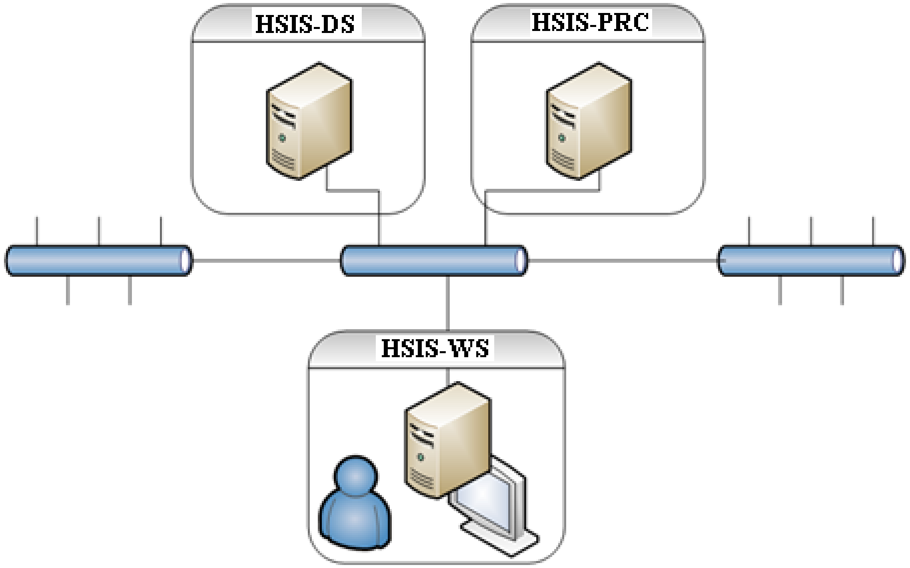
ARCHITECTURE AND HW/SW DEPLOYMENT

HSIS is decomposed into three components:

- **HSIS-HMI:** this component provides the operator graphical interface with functions to define and run simulation scenarios.
- **HSIS-Core:** this component is the algorithmic core of the simulator. It performs all computations of the simulations.
- **HSIS-Server:** this component wraps the simulator process and communicates with HSIS-HMI to start the process itself, copy simulation parameters, monitor running simulations, manage data.

SW deployment on three HW systems:

- **HSIS-WS:** 1 Workstation (Windows) for interface.
- **HSIS-DS:** 1 Server (Linux) for data server and services provision.
- **HSIS-PS:** 1 Server (Linux) for data processing.



OPERATIONAL WORK-FLOW

- Operator must define the scenario:
  - Reflectance/radiances ingestion
  - processing parameters
  - Footprint definition
- Once the Scenario is defined, the simulation can be run, monitored and controlled.
- Finally, the produced intermediate and output products can be retrieved by the Operator to perform data analysis and post processing.

Reflectance/radiances data gathering

- Real data from airborne/satellite optical sensor
- Synthetic data

Reflectance/radiances pre-conditioning

- Spatial resampling
- Cropping
- Geocoding

Scenario definition

- DEM/Geoid selection/ingestion
- Atmosphere parameters
- Sensor instrument parameters
- Orbit/attitude file load

Simulation Start and Monitoring

- Start
- Monitor
- Suspend/Resume and Stop actions

Analysis

- Image browsing
- Image filtering
- Image profile plotting

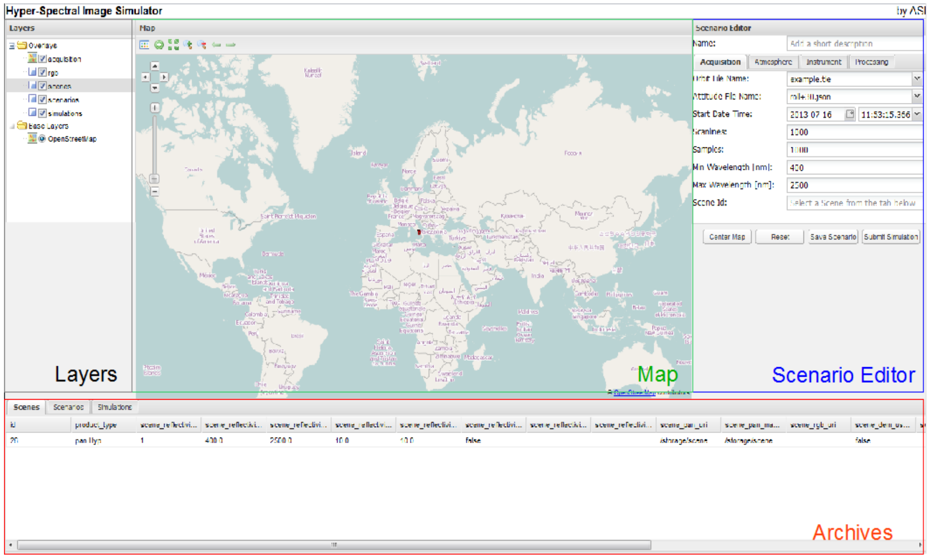
GRAPHICAL USER INTERFACE (1/2)

WEB GIS Application

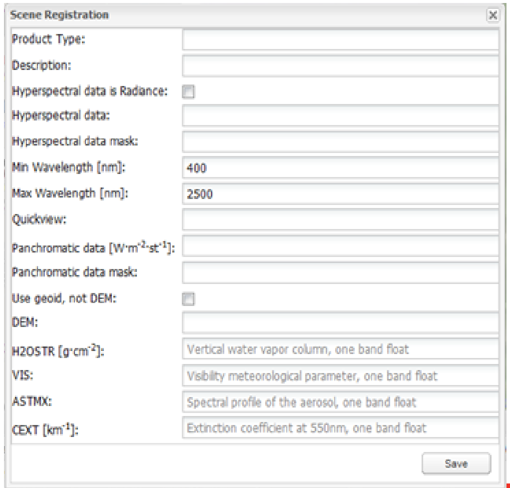
- Client on HSIS-WS:
  - Browser with JavaScript application providing the GUI
- Server on HSIS-DS:
  - HSISController: WEB application that responds to the client for data ingestion, job submission, processing control, load/save scenarios from/to DB.
  - GeoServer: provider of geographic data to the client through OGC protocols like WMS and WFS
  - Shared folder for data exchange

ENVI provides functionalities for:

- Input data pre-conditioning
- Data analysis of results



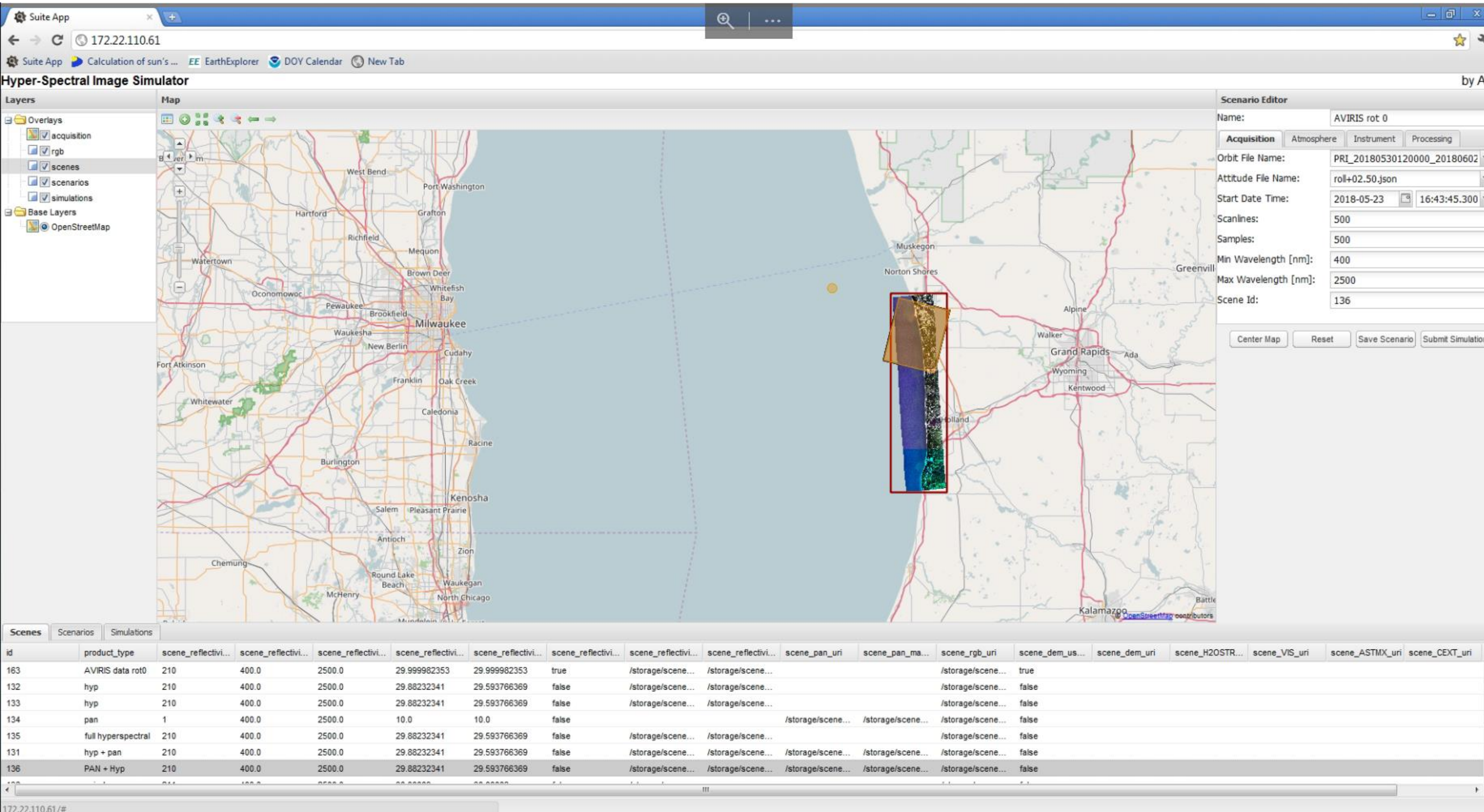
Main Window with Scenario Editor, Map, Archives and Layers



Interface for radiance/reflectance input data ingestion

GRAPHICAL USER INTERFACE (2/2)

The HSIS-HMI provides a webGIS to preview input products and insert parameters



EXAMPLES

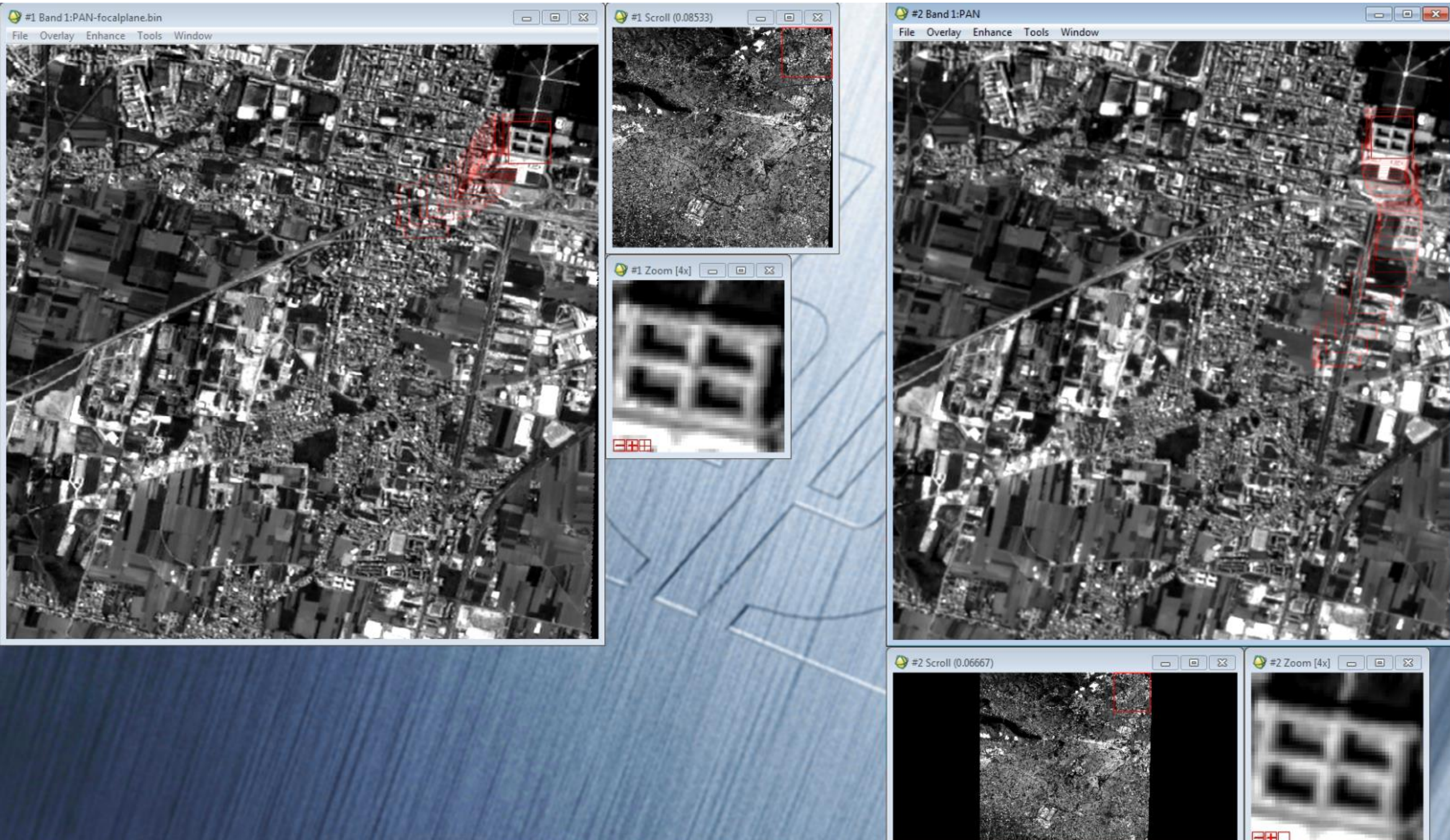
Example 1 - end-to-end processing to simulate Hyperspectral and Panchromatic products from EO-1 data:

- Reflectivities from Hyperion data 2002 04 02 9:30 on Napoli area
- PAN Radiances from ALI data 2002 04 02 9:30 on Napoli Area

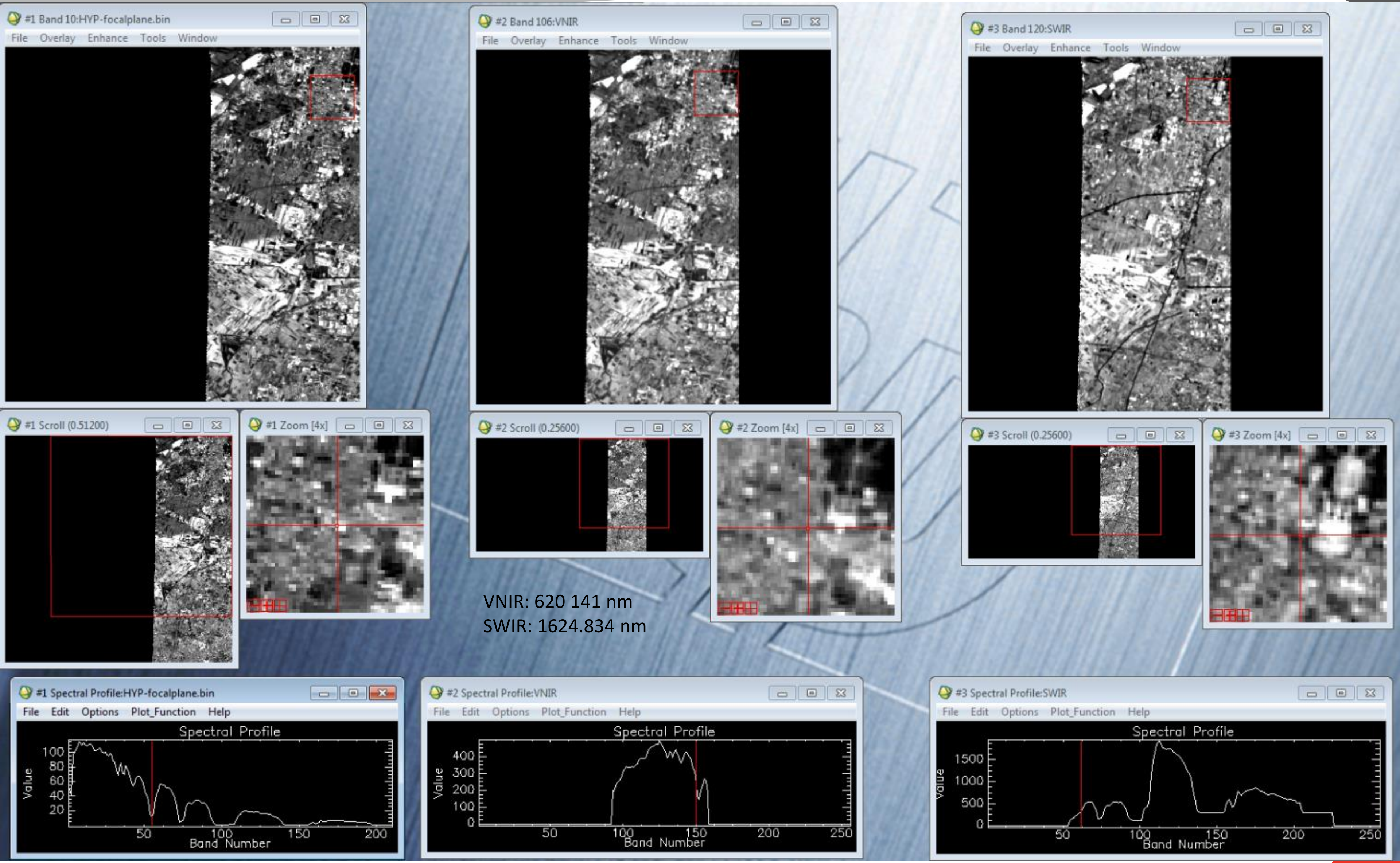
Example 2 - end-to-end processing to simulate Hyperspectral products from AVIRIS data (data code: f080709t01p00r13rdn):

- Radiance from AVIRIS data acquired in 2008, 8th July in 2002 04 02 9:30 over the coast Michigan lake south of Manistee National Forest (Grand and Kalamazoo River Outlets, MI)

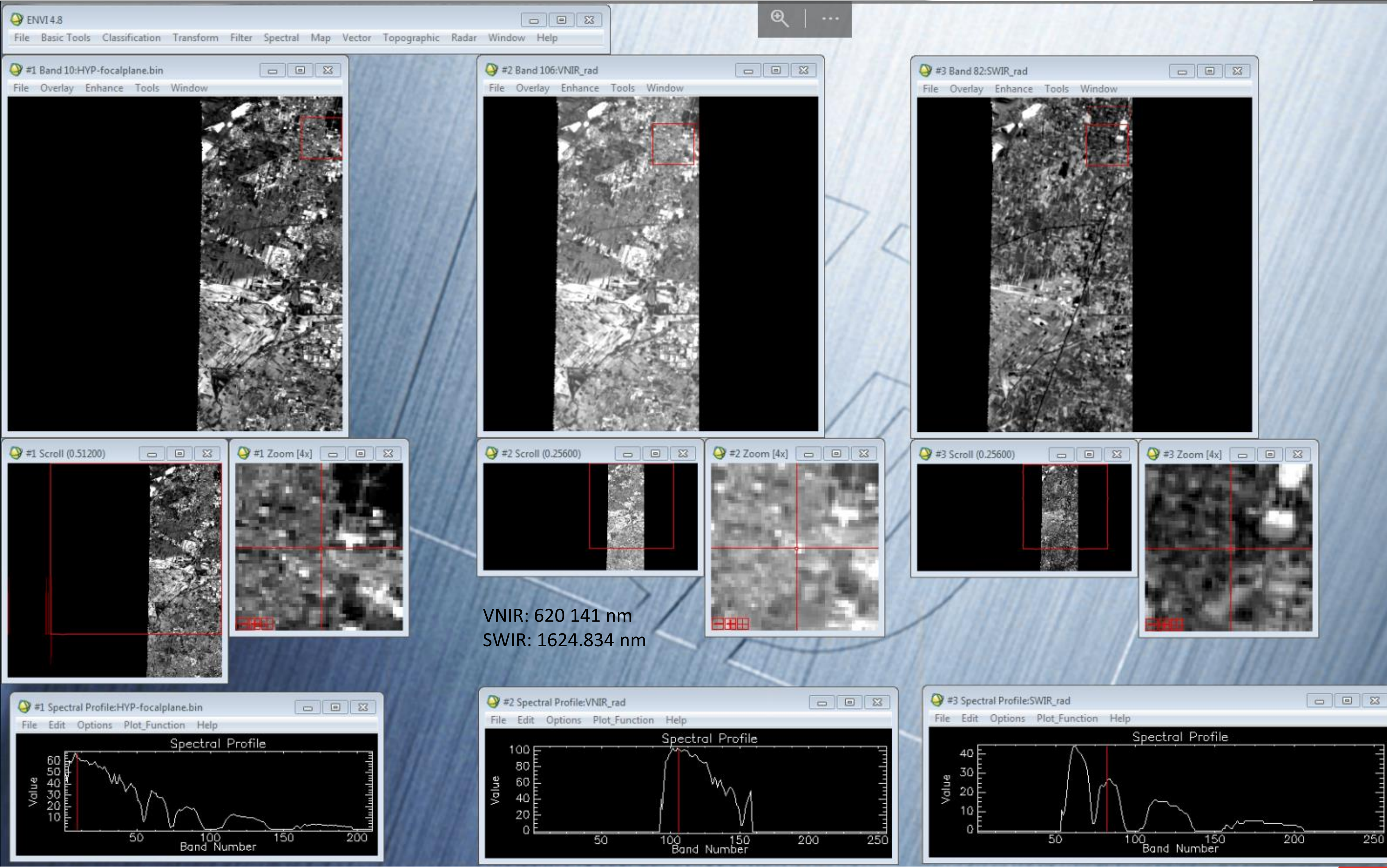
EO-1 ALI RESULTS: PAN



EO-1 HYPERION RESULTS: VNIR AND SWIR DC

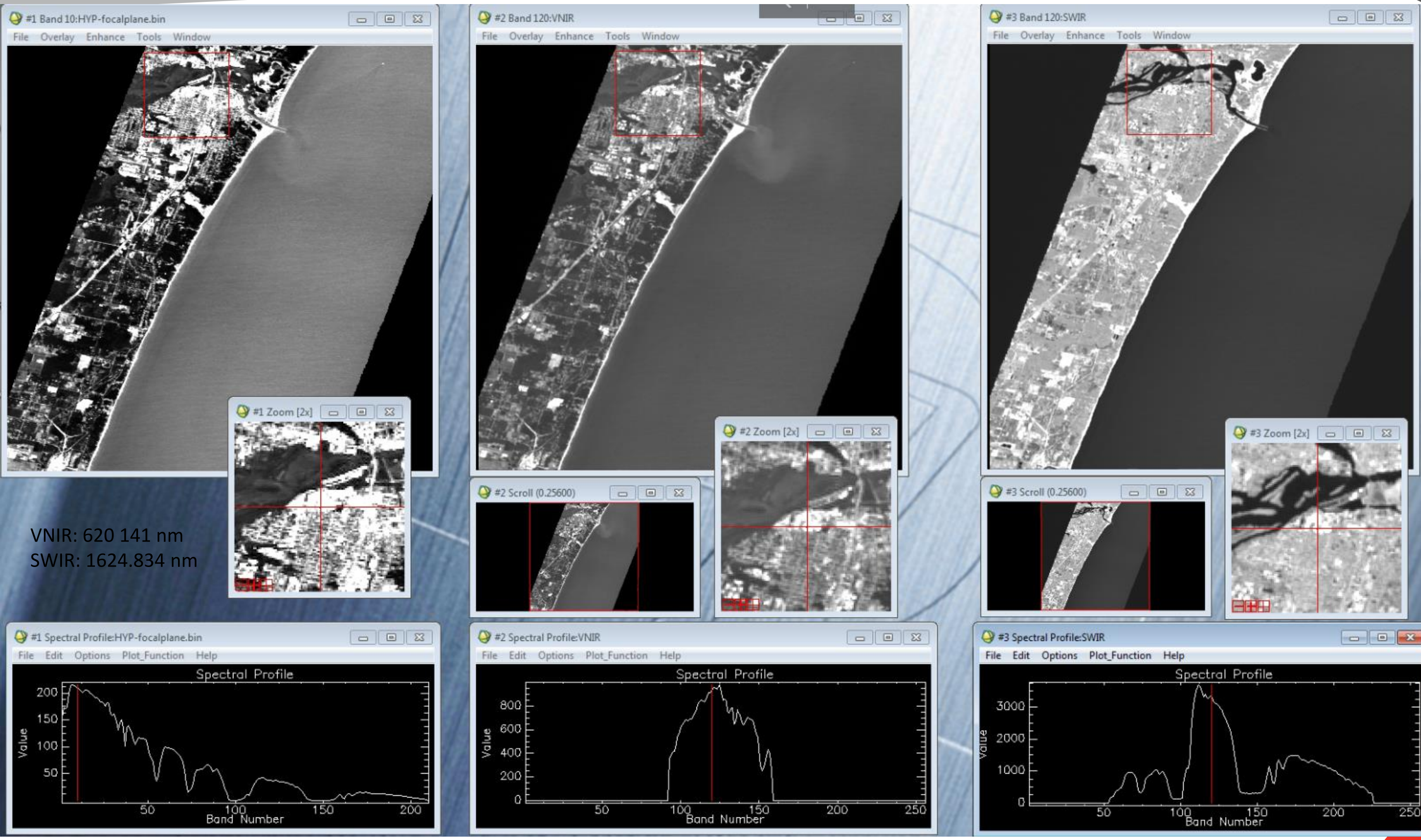


EO-1 HYPERION RESULTS: VNIR AND SWIR RAD



VNIR: 620 141 nm
SWIR: 1624.834 nm

AVIRIS RESULTS: VNIR AND SWIR DC



VNIR: 620 141 nm
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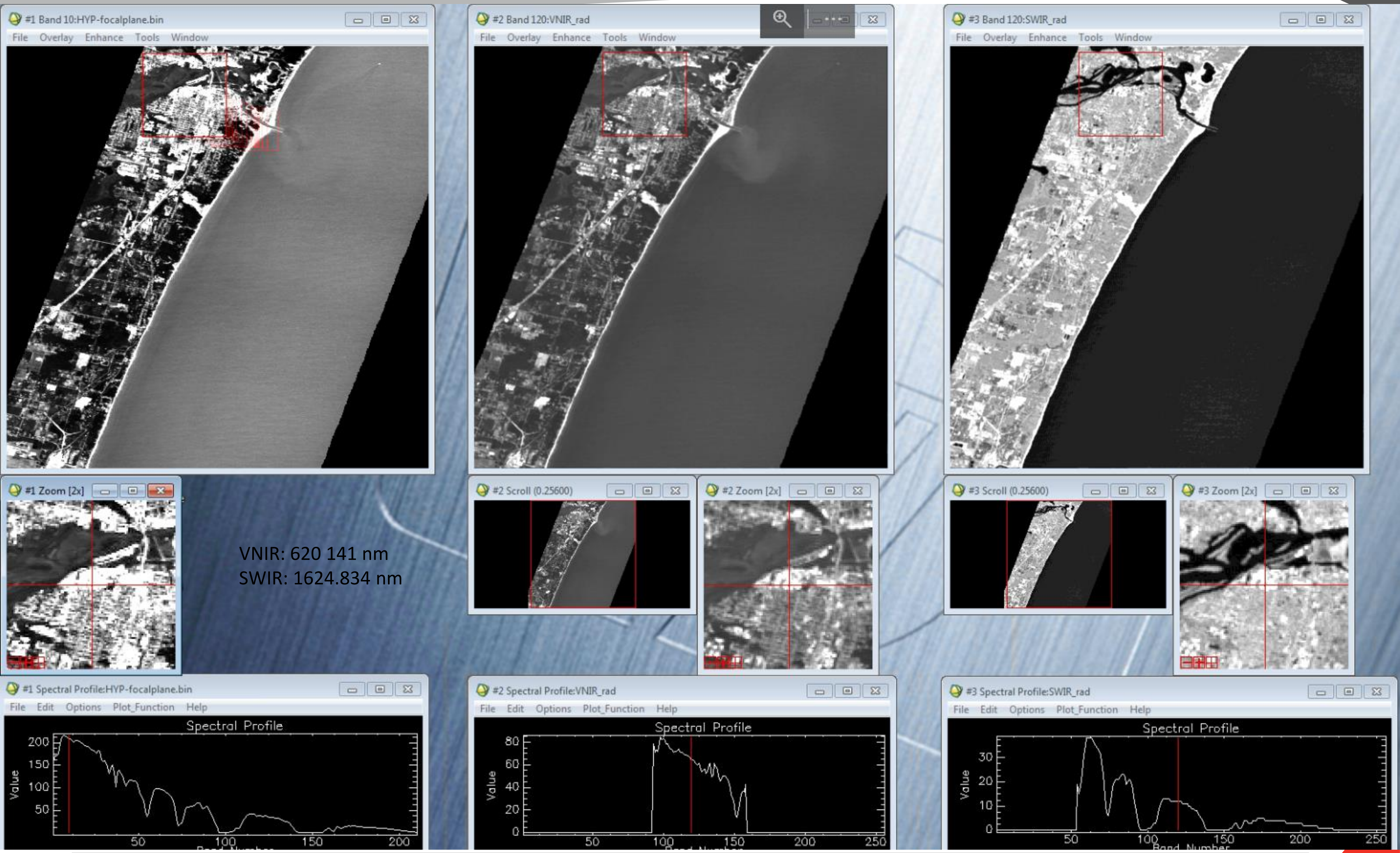
AVIRIS RESULTS: VNIR AND SWIR RAD



VNIR: 620 141 nm
SWIR: 1624.834 nm

Thank you

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AN ASI / TELESPAZIO COMPANY