ISRAEL AEROSPACE INDUSTRIES

MBT Space Division - SYSTEMS MISSILES & SPACE GROUP

GENESIS – Generator of Spectral Image Simulations

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Scope

- **GENESIS**: End-to-end simulation of hyper-spectral (HS) imaging by a space-craft payload
- **Motivation**:
  - Lack of HS data from space (only HYPERION)
  - HS S\C planning and design
  - Algorithms and HS data analysis development
- **Goals**:
  - Performance analysis at various geometric and atmospheric conditions
  - Test sensor design influence on performance
  - Verification and validation of HS data analysis

Scenario model: Graphical Illustration

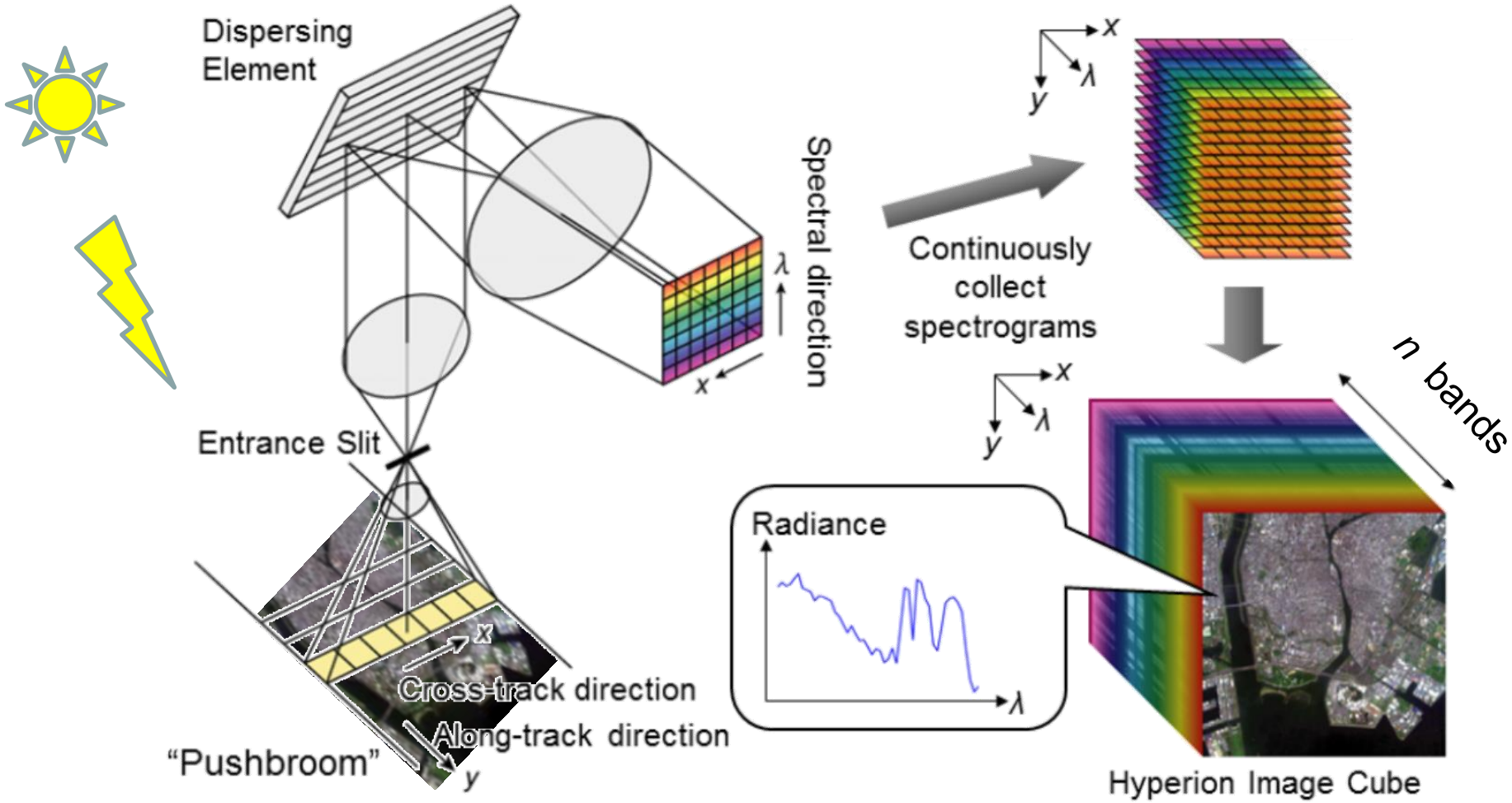
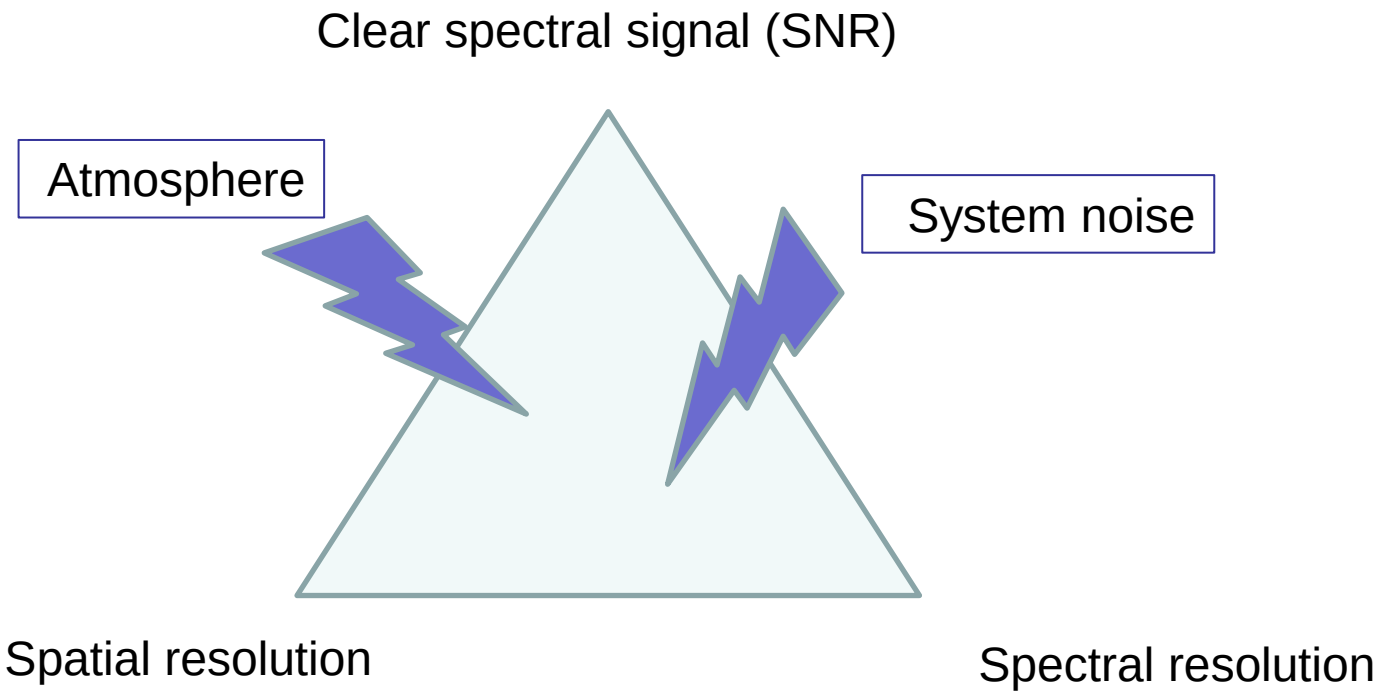
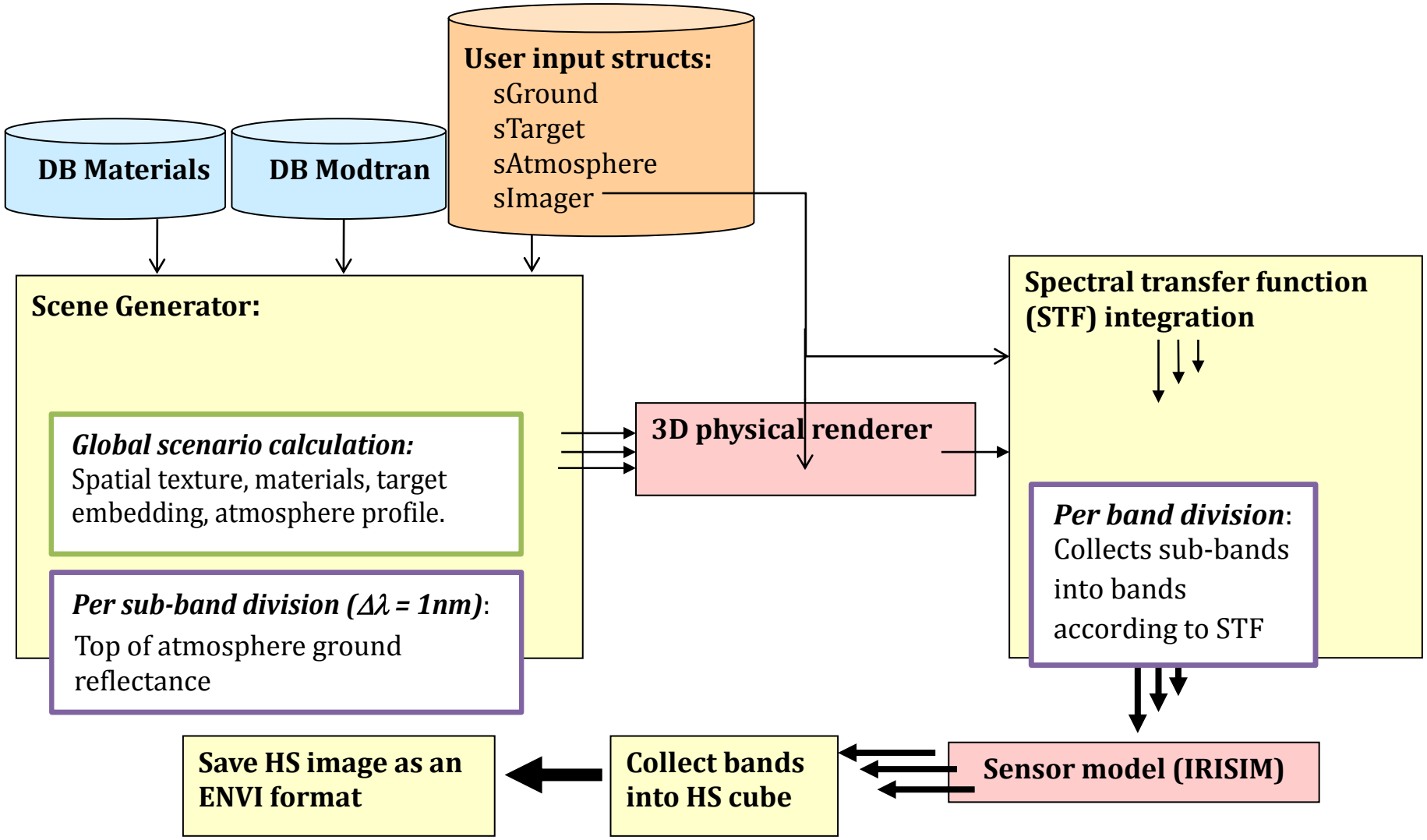


Figure 1. Hyperspectral imaging

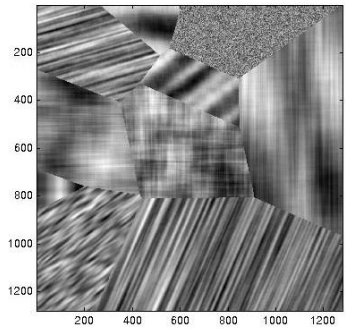
Main challenge – system design



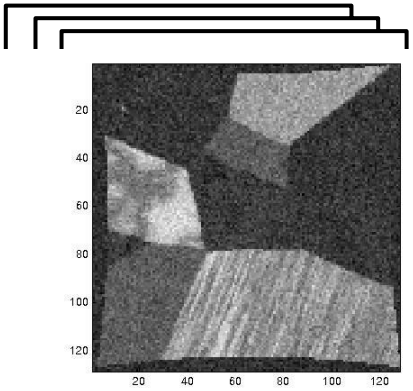
GENESIS Workflow



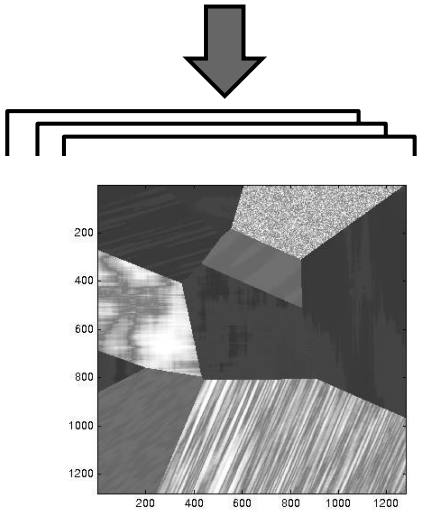
GENESIS – workflow example



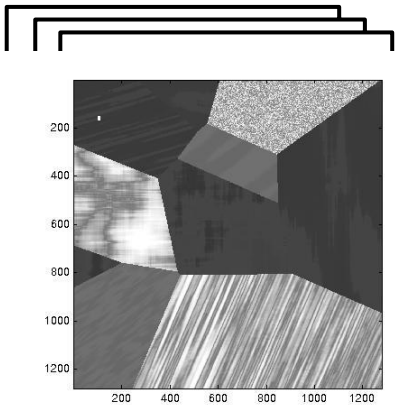
Texture map of ground to be imaged. In this example ground cell size is $1m^2$



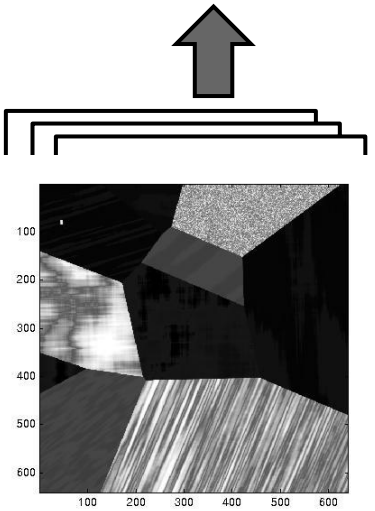
Gray level image after at sensor output. In this example spatial resolution is $100m^2$, and spectral resolution of 10nm.



Ground reflectance map. Calculated in spatial resolution of $1m^2$, and spectral resolution of 1nm



Ground reflectance map with target blended



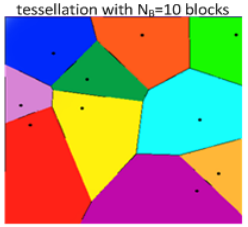
Radiance at sensor plane – Calculated in resolution of 1nm using MODTRAN + FLAASH atmospheric model

Generation of spatial reflectance data cube

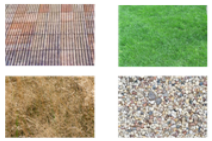
1.2 Define the grid for a 1280×1280 ground area, with 1m grid resolution
(k_x, k_y) [1,…,1280] × [1,…,1280]

1.3 Generation of polygons map

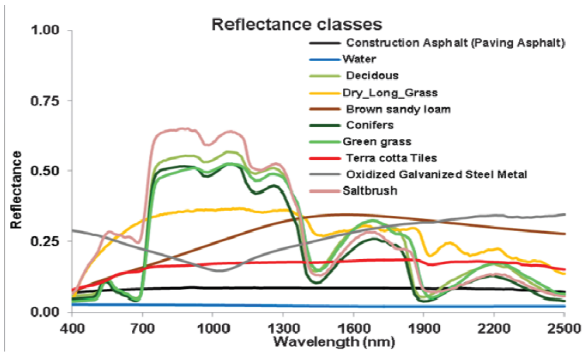
An example of Voroni tessellation with N_B=10 blocks

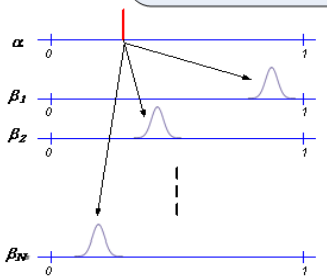


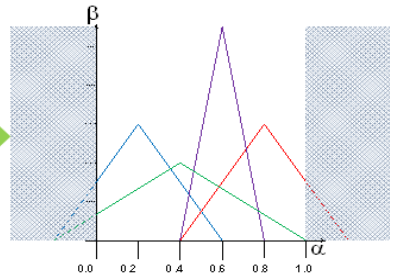
1.4 Generation of spatial texture



1.5 Generation of hyper-spectral reflect. map

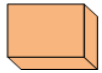




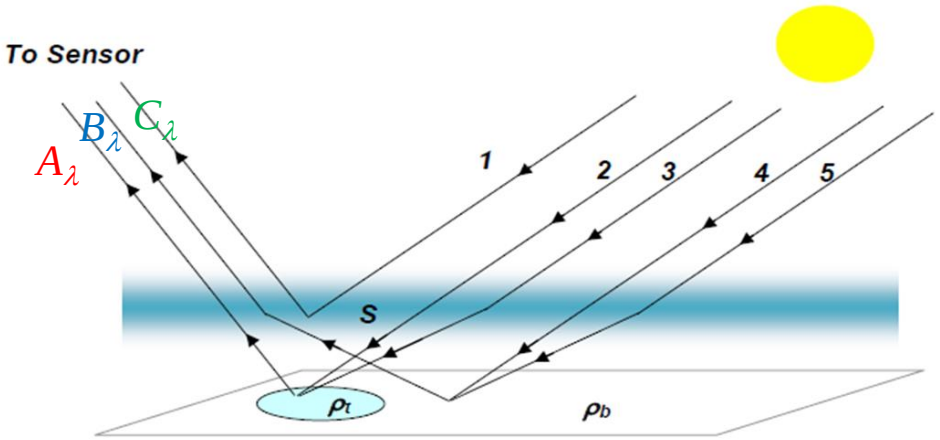


$i=$	1	2	3	4
α_{0i}	0.2	0.4	0.6	0.8
Δ_i	0.4	0.6	0.2	0.4

1.6 Embed target(s)



Simulation – Atmosphere



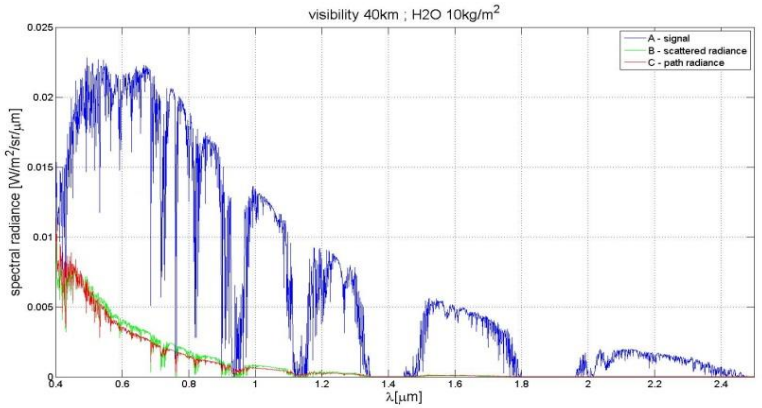
- MODTRAN input:
  - Atm. type and parameters
  - Aerosols, etc.
  - Sun-target-sensor geometry
  - Reflectance

•Aim – Top of the atmosphere (TOA) spectral radiance map

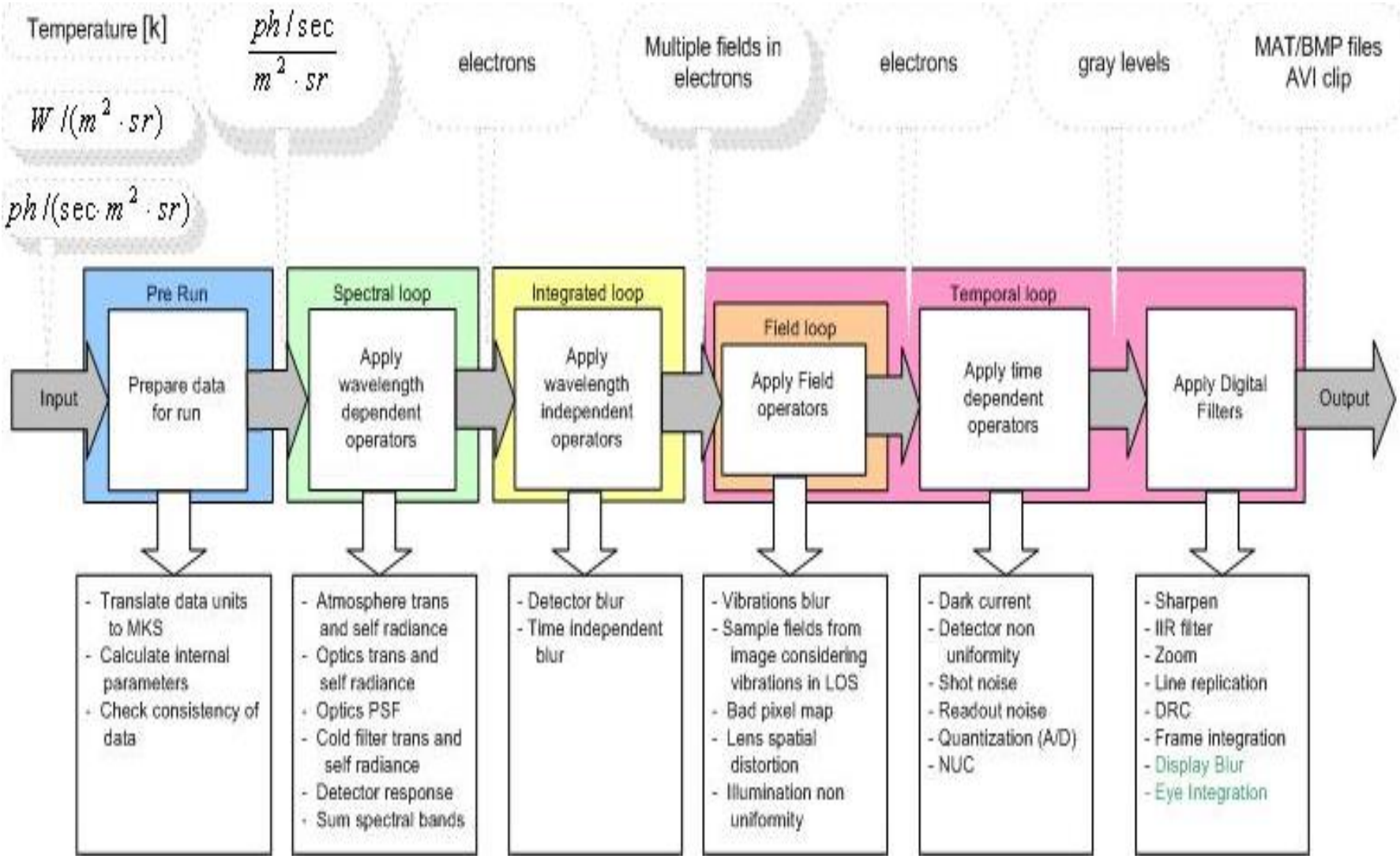
$$L_\lambda(x) = \frac{A_\lambda \rho(x)}{(1-\rho_b(x)S_\lambda)} + \frac{B_\lambda \rho_b(x)}{(1-\rho_b(x)S_\lambda)} + C_\lambda$$

Ground reflected radiance

Solar scattered radiance

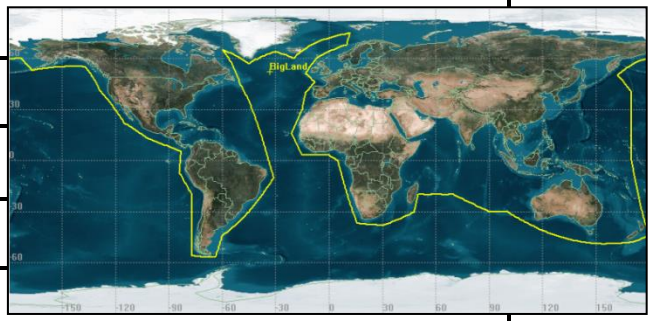


IRISIM - model architecture

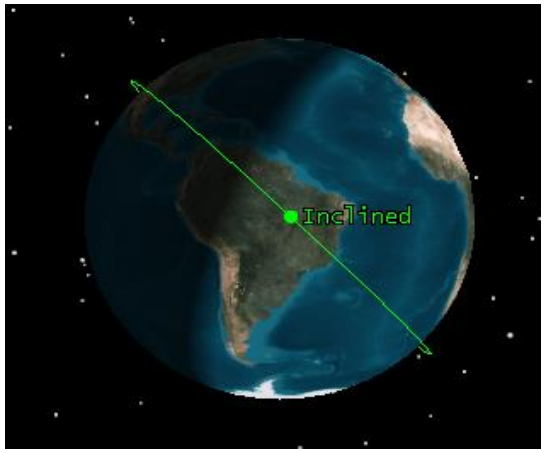


SHALOM - Main mission requirements

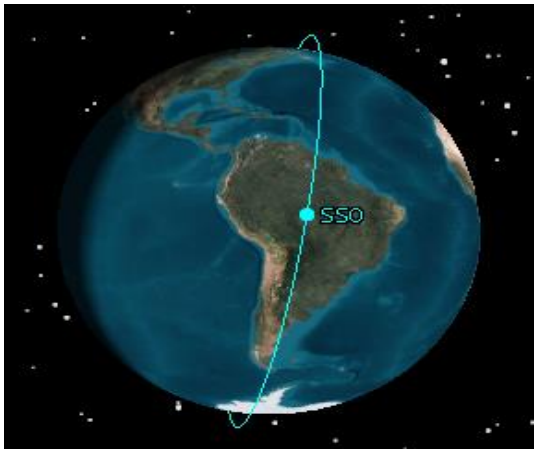
Parameter	Required value
GSD	Less than 10m (NADIR)
Swath width	More than 10km
Revisit time	Less than 4 days
Spectral band	0.4-2.5μm
Spectral bins	10nm quasi-uniform
Quantization	12bit/pixel/spectral-bin
Daily area coverage	More than 200,000km^2
SNR (Sun zenith 30^o, ρ=0.3, 23km vis)	VNIR: SNR > 200 1000nm – 1750nm : SNR > 200 1950nm – 2350nm : SNR > 100
PAN Camera	2.5-5.0m GSD, 10km Swath, VNIR band SNR > 240
Geo-location accuracy	Better than 30m CEP 90%

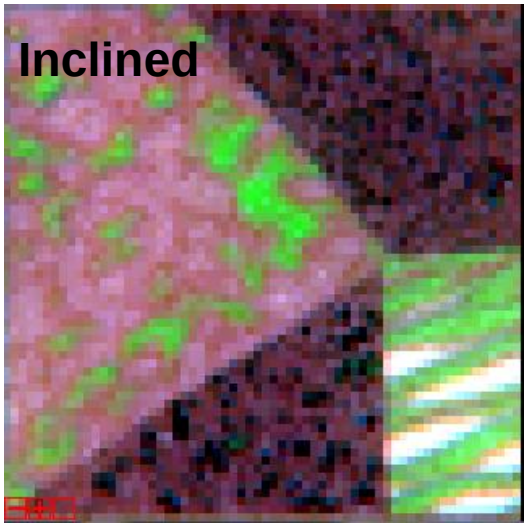


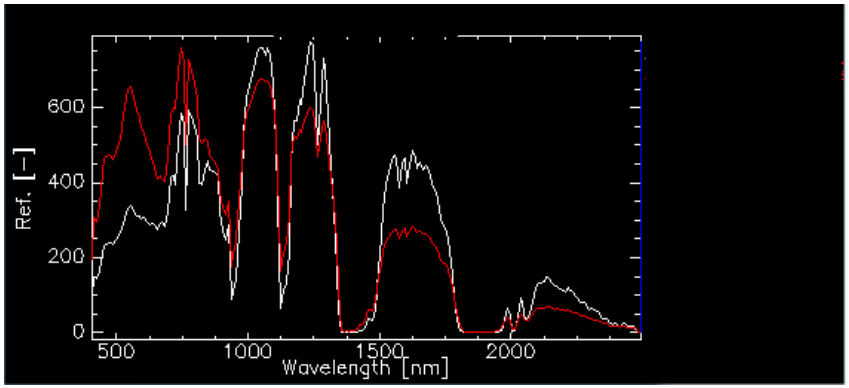
Acquisition opportunities

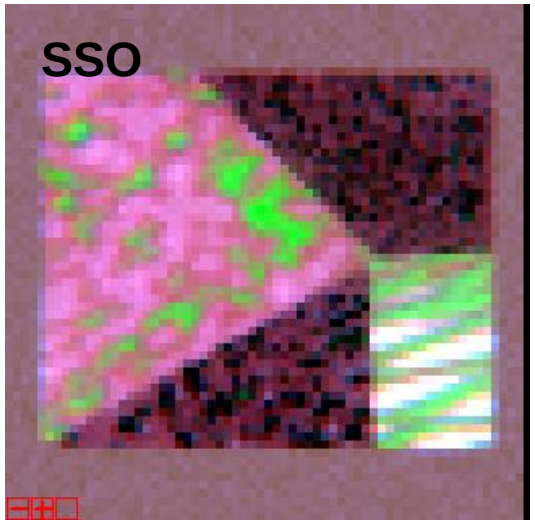


- Inclined:
  - Low sun
  - Short atmospheric path
- Sun synchronic orbit (SSO):
  - Constant illumination
  - Off-Nadir acquisition

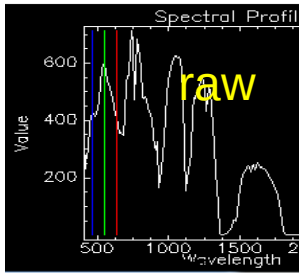


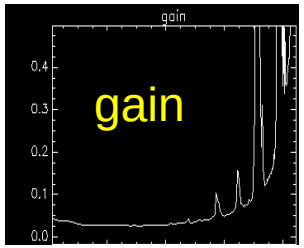


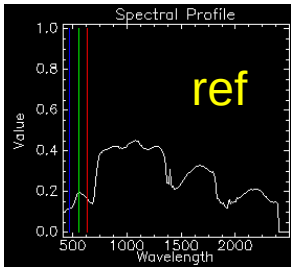


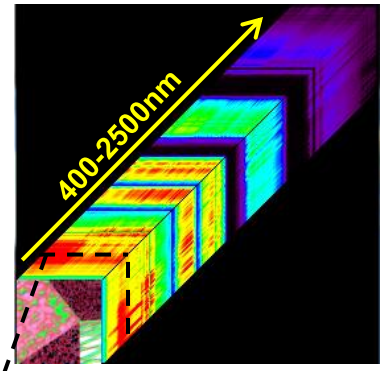


Target detection: performance analysis

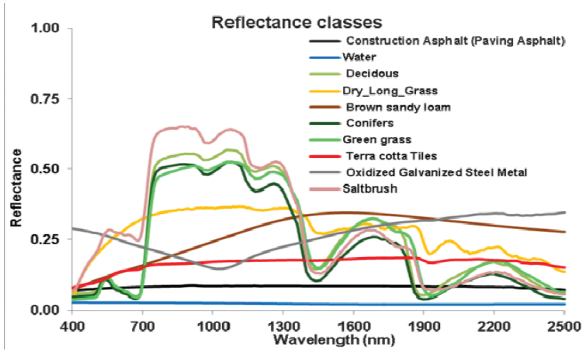






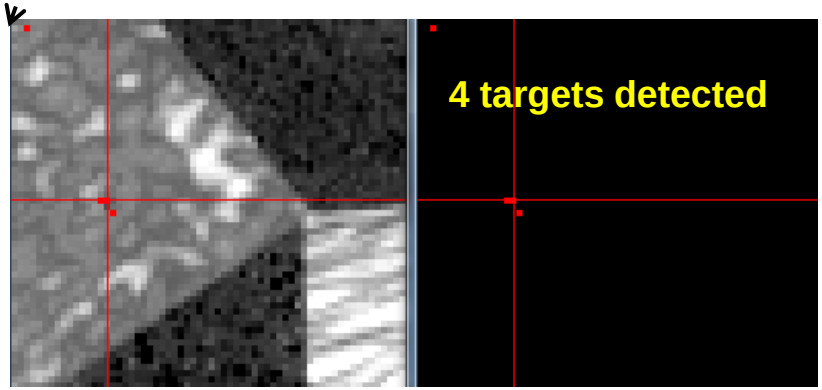


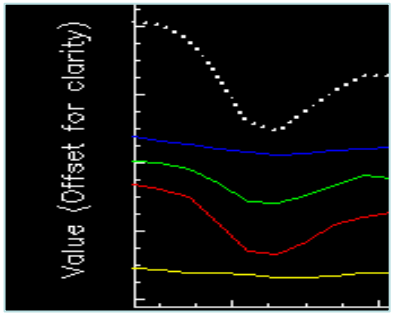
Shalom HS cube simulation (210 channels GSD 10m)



Spectral library of various materials

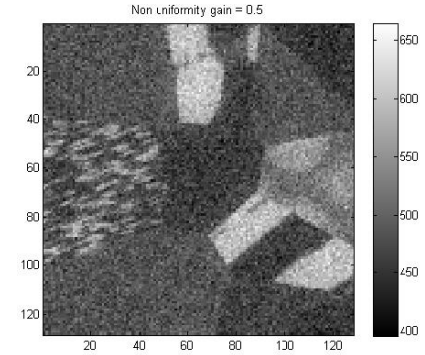
4 detected targets on the 550nm channel

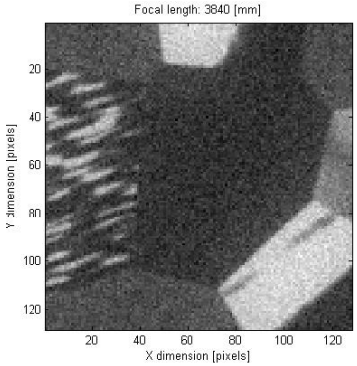


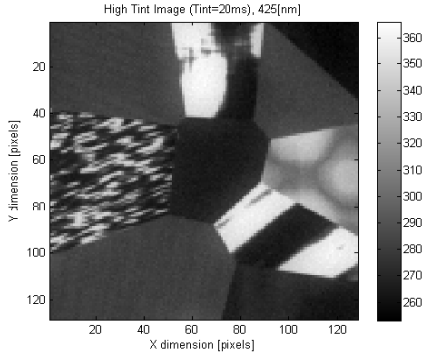


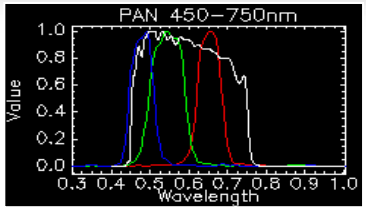
Found 4 matching spectral signatures

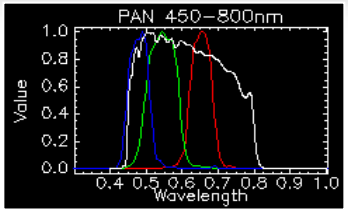
Sensor design

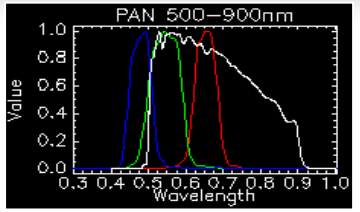






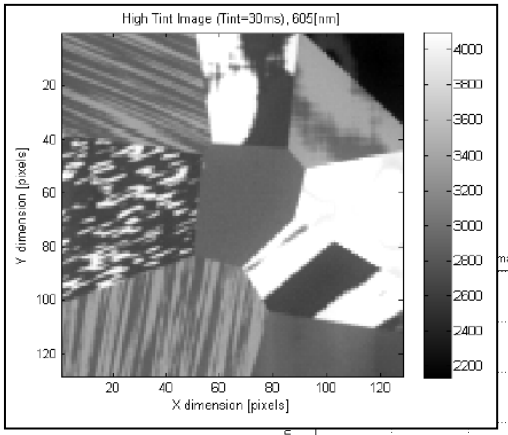




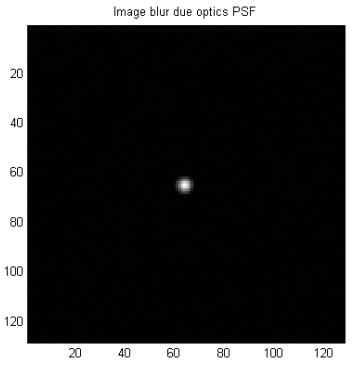


V&V - GENESIS

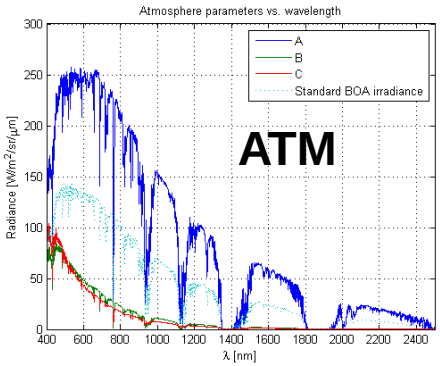
- 44 different tests
  - Ground & target generator
  - Renderer
  - Atmosphere modelling
  - IRISIM – the sensor model
  - Input / output, interfaces etc.
- End-to-end tests vs. real Hyperion data



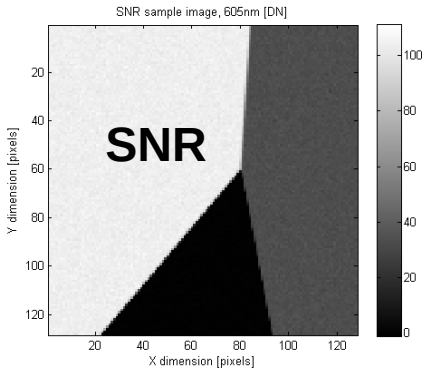
Tint



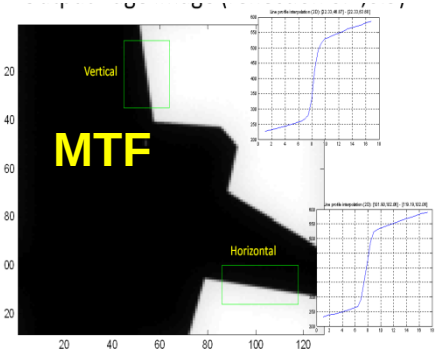
PSF



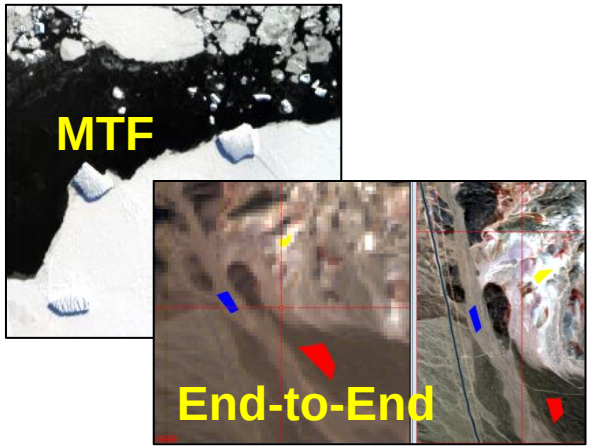
ATM



SNR



MTF



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