The Spectral NITF Implementation Profile (SNIP): A New Standard for Multispectral and Hyperspectral Imagery Datasets

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BLUF: NGA/Research has built a new standard for MSI & HSI datasets

The "Spectral NITF Implementation Profile (SNIP)" improves MSI & HSI utility and quality compared to the 2011 tactical (i.e., airborne) HSI NITF implementation profile (NGA.IP.0006)

- SNIP uses the National Imagery Transmission Format (NITF) Standard (NITFS)
- Ratified 17 June 2019, in the NSG Standards Registry: https://nsgreg.nga.mil/doc/view?i=4829

SNIP Stakeholders & Interested Organizations

- SNIP Reviewers: NGA, NASIC, NGIC, JITC, LANL, ORNL, Army GEOINT Office, ...
- NATO Imagery Working Group (IMWG) also interested → Very favorable response

SNIP Advances: Compared to 2011 airborne HSI NITF implementation profile (NGA.IP.0006)

- Space, ground, and airborne platforms
- MSI , HSI, and any spectroradiometric product (e.g., single band)
- Latest geopositioning metadata for electro-optical (EO) systems
  - Wide range of sensor designs, most accurate metadata for wide range of collection geometries
- Per pixel metadata: e.g., spectral smile, dark level, radiometric gain and offset, smear, etc.
- Augmented illumination metadata: camera-to-target-to-sun angle, solar illumination amount, etc.

Low-cost integration & interoperability, plus high quality & utility, when MSI & HSI datasets conform to the SNIP

Topics

- National Imagery Transmission Format (NITF) Standard Overview
- Genesis of the Spectral NITF Implementation Profile (SNIP)
- SNIP Version 1.0 Scope
- SNIP Design
- Prototype Datasets, aka “Reference Implementation Products” (RIPs)
- Next Steps
- Systems Utilizing the SNIP
- Summary
- Points of Contact

Acronyms are defined in the Notes section of each slide

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NITF Standard Overview

The NITF Standard (NITFS) is the principal imagery transmission format of the National System for Geospatial Intelligence (NSG)

- First developed in 1980s and actively managed by the NITFS Technical Board (NTB) under the auspices of NGA's Geospatial Intelligence Standards Working Group (GWG)

The NSG is used by the Intelligence Community (IC), including

- Director of National Intelligence (DNI)
- Central Intelligence Agency (CIA)
- Defense Intelligence Agency (DIA)
- National Security Agency (NSA)
- National Geospatial-Intelligence Agency (NGA)
- Intelligence elements of other agencies and the Armed Services

The NITFS supports

- Commercial, civil, and DoD image sources
- Different sensor types, both still & motion imagery, including
  - Electro-optical (EO) sensors: panchromatic, multispectral, hyperspectral, and infrared
  - RADAR: Real (RAR) and synthetic aperture radar (SAR)
- Different sensor designs, including panoramic, pushbroom, whiskbroom, & framing
- Various sensor platforms, including ground, air, and satellite platforms

Genesis of the Spectral NITF Implementation Profile (SNIP)

Several advanced HSI & MSI systems are currently under development (since ’16)

NGA/Research (NGA/R) realized that a single HSI standard will reduce integration costs

NGA/R determined that the tactical HSI NITF standard (NGA.IP.0006) does not meet needs for advanced exploitation of future HSI systems

Work began on a new HSI standard (late ’16)

NGA/R decided to change scope to a single spectral standard (MSI, HSI, etc.)

- No general MSI NITF standard existed
- MSI & HSI dataset needs are very similar, so effort to add MSI to scope was relatively small

USAF funded Oak Ridge National Lab (ORNL) to create a spectral NITF standard (early ’17)

- Upon learning of NGA’s SNIP task, ORNL agrees to partner with NGA on SNIP (Aug ’17–Apr ’19)

Dr. Eckstein & Dr. Jason S. Smith wrote SNIP v1.0 (NGA.STND.0072_1.0_SNIP) (Sep ’17–Jun ’19)

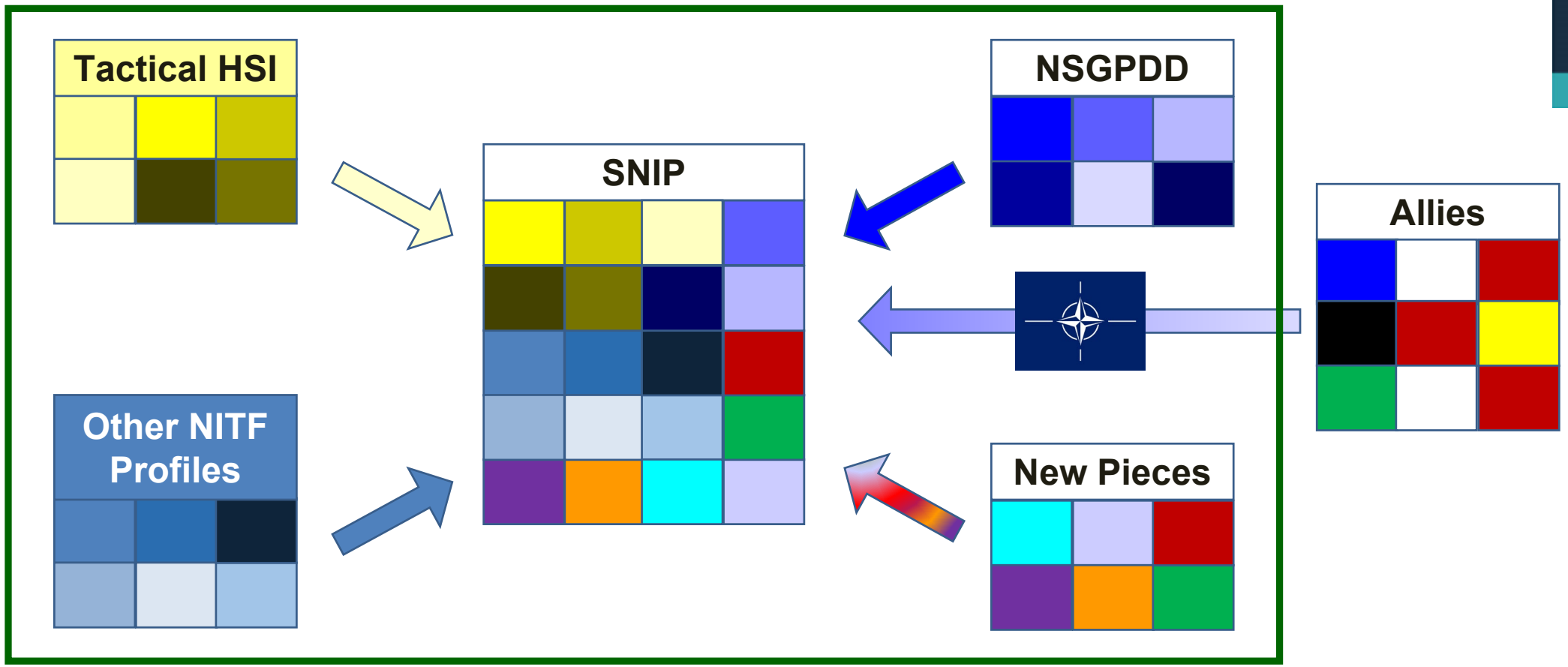
- In close partnership with other subject matter experts
- Also wrote new TREs (i.e., headers) for per-pixel metadata, dataset mates, and illumination conditions
- Included definitions of NSG Spectral Data Product Levels (NGA.SIG.0034_1.0_SPECTDL) (31 Oct ’18)

The SNIP v1.0 and 3 new TREs completed & approved by the NTB (Feb ’18–Jun ’19)

SNIP DNA

The SNIP leverages existing standards as well as new additions to the standards compendium

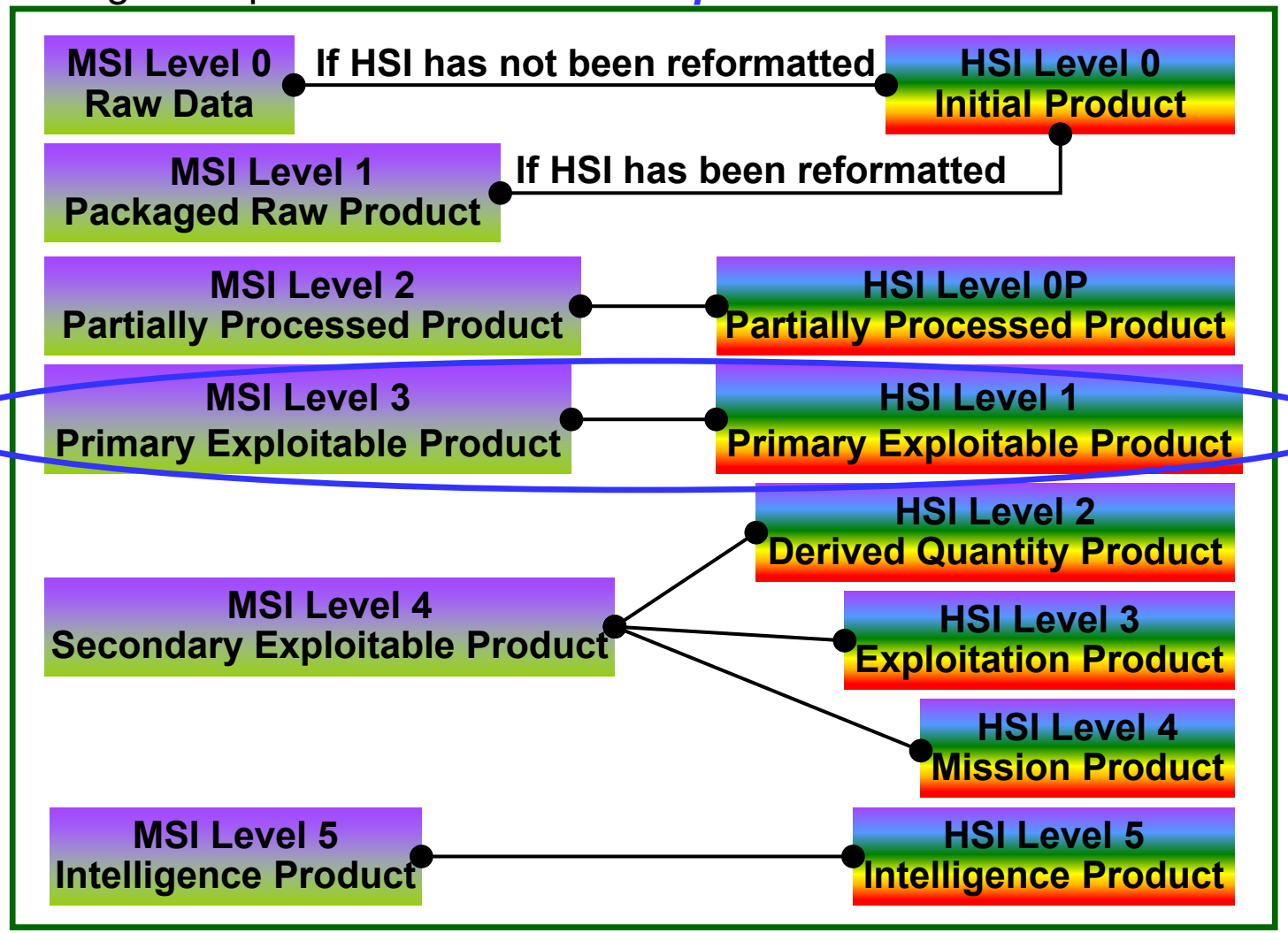
- Guiding Principle: ***Invent as little as possible***



NSG Spectral Data Product Levels (NGA.SIG.0034_1.0_SPECTDL)

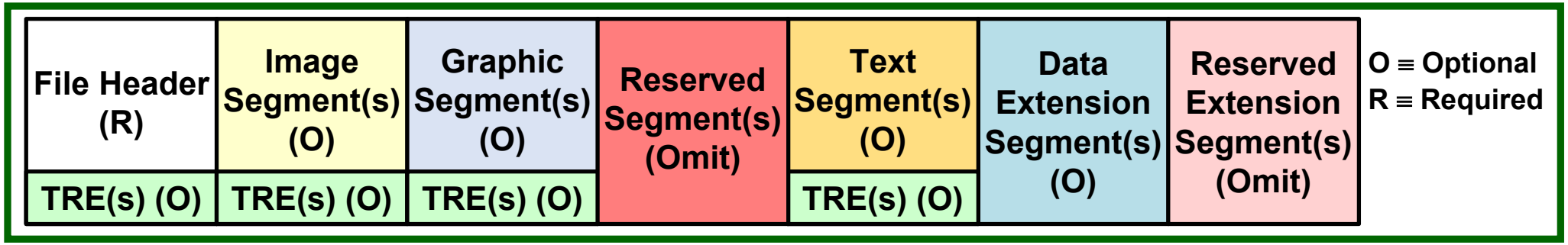
The SNIP utilizes spectral data product level definitions tailored to the NSG

- Guiding Principle: ***Invent as little as possible***



The SNIP v1.0 addresses MSI Level 3 and HSI Level 1 data products

NITF Dataset Design



The NITF Standard (NITFS) consists of a file header and different "segment" types

- Some segments may include "tagged record extensions" (TREs), i.e., metadata headers

NITFS segment types must occur in a pre-defined order:

1. Image segments, i.e., rasters, of various types
   - Collected images, clouds, location, elevation, bad pixels, per-pixel metadata, wind, water current, barometric pressure, change detection, X-ray, magnetic resonance (MRI), etc.
2. Graphic segments: Annotation overlays to the image segments
3. Text segments: For storing text information
4. Data extension segments (DESs): For non-raster information

Most of the NITFS uses fixed order, hard parsed field structures

A valid NITF dataset need only include a single segment of any type

- Not necessarily an image segment

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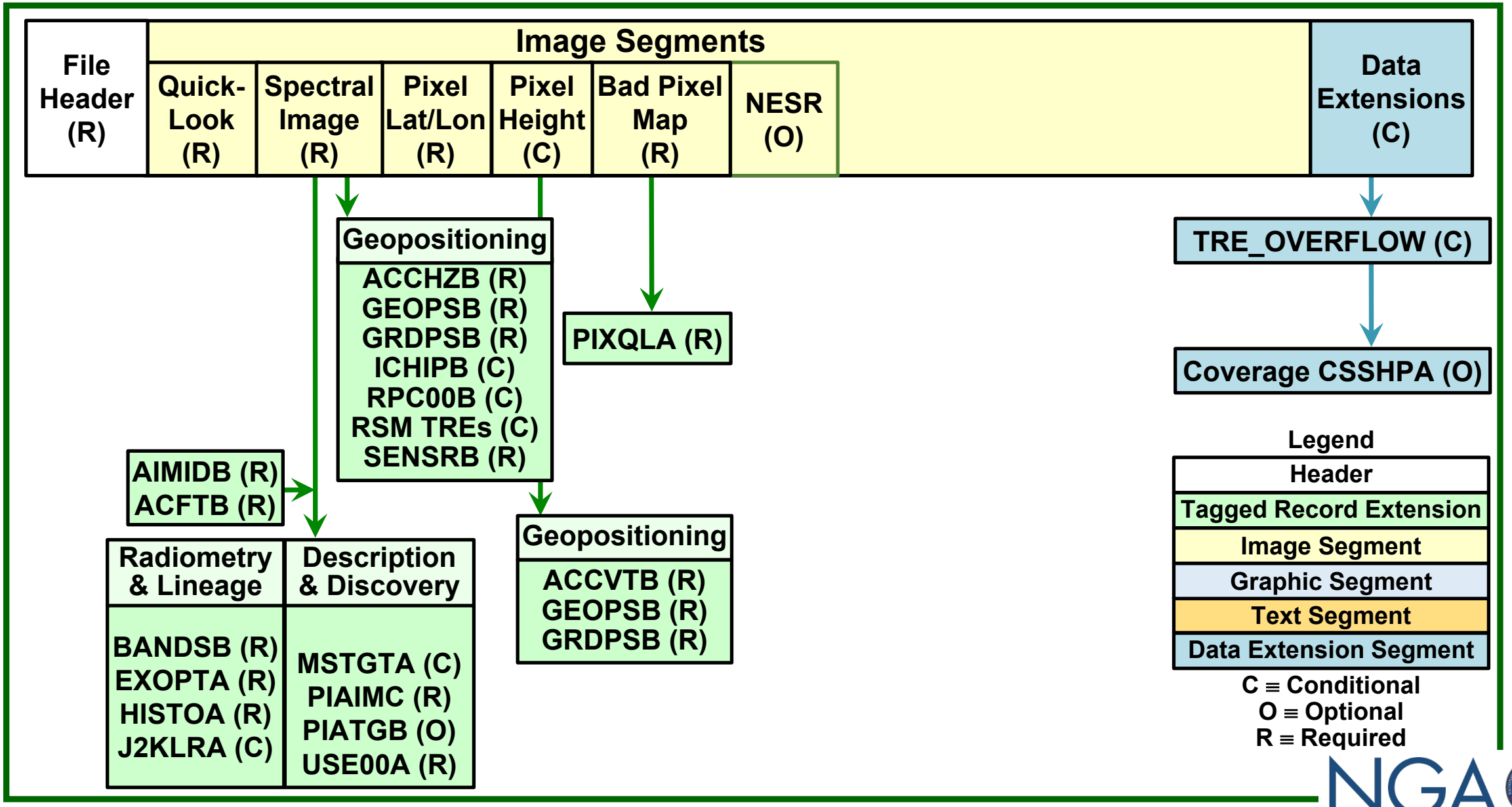
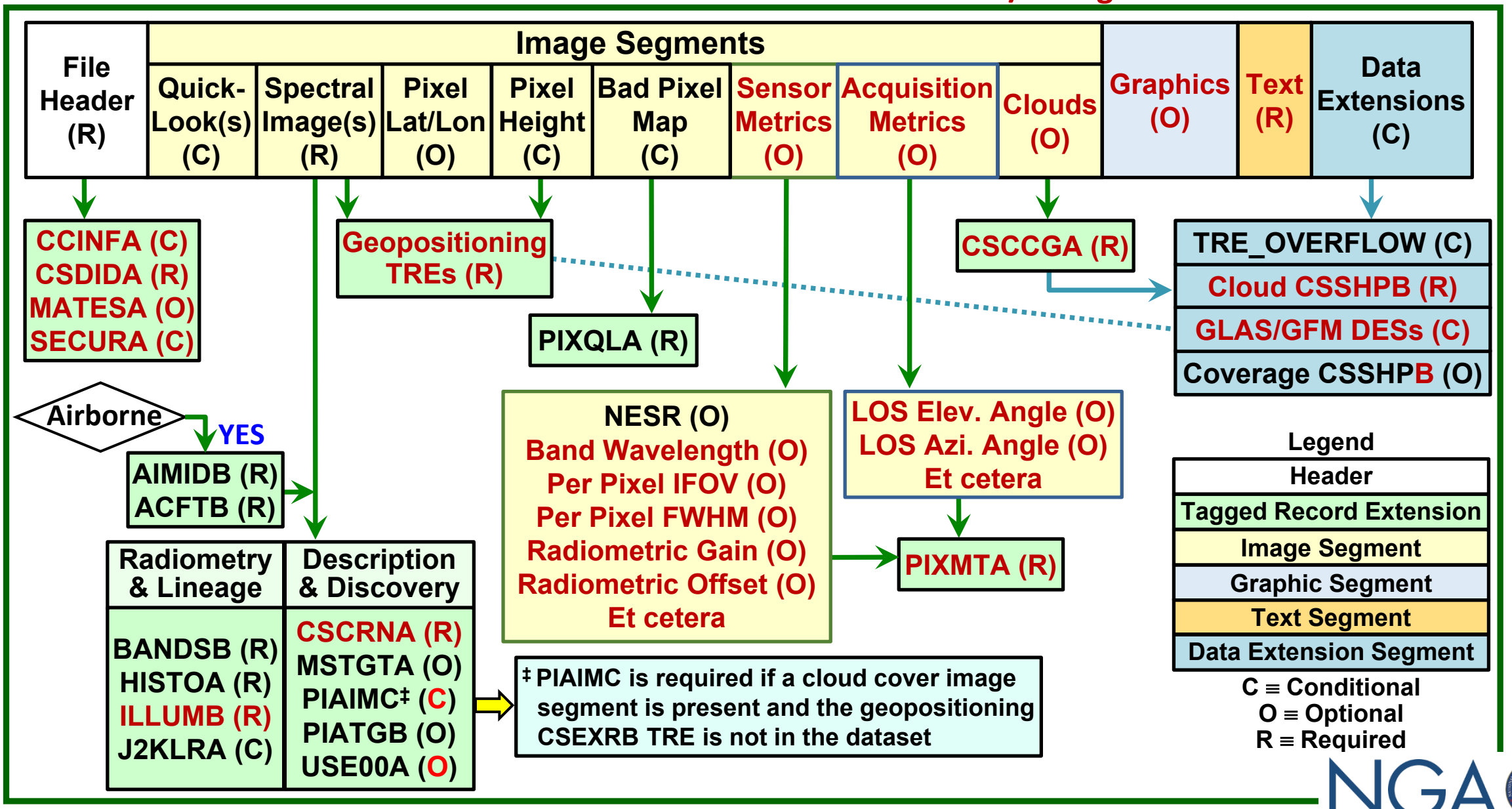
2011 Tactical (i.e., Airborne) HSI NITF Implementation Profile (NGA.IP.0006)



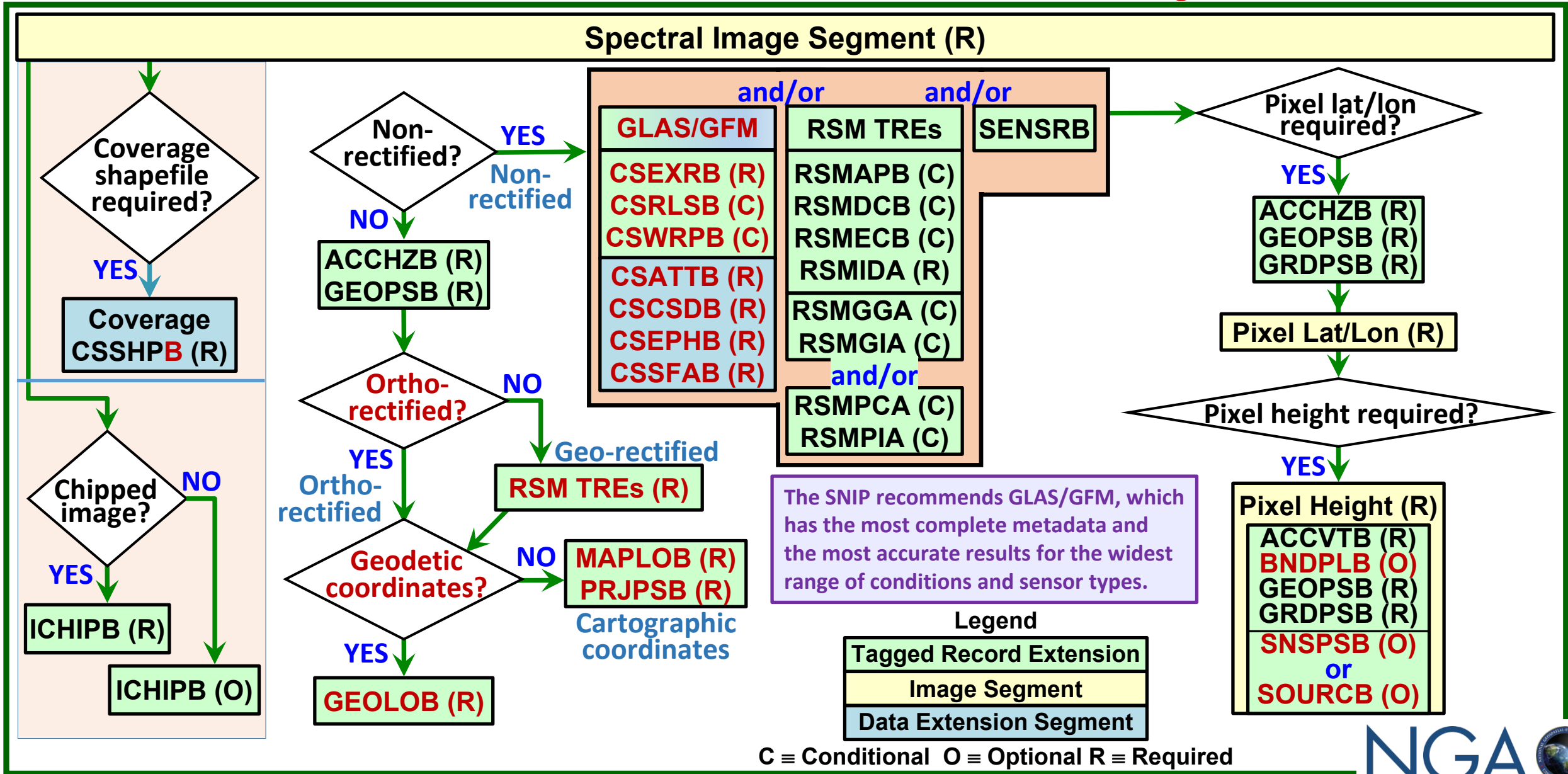
2019 SNIP Version 1.0 Design

Red: Additions/Changes to 2011 HSI NITF Profile



2019 SNIP v1.0 Geopositioning Options

Red: Additions/Changes to 2011 HSI NITF Profile

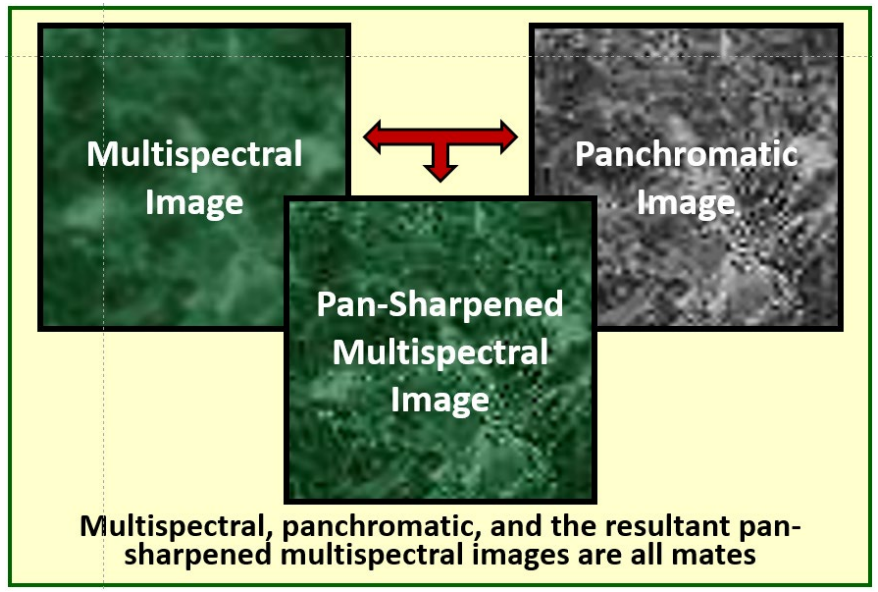


New Metadata Option: Image Mates → MATESA TRE

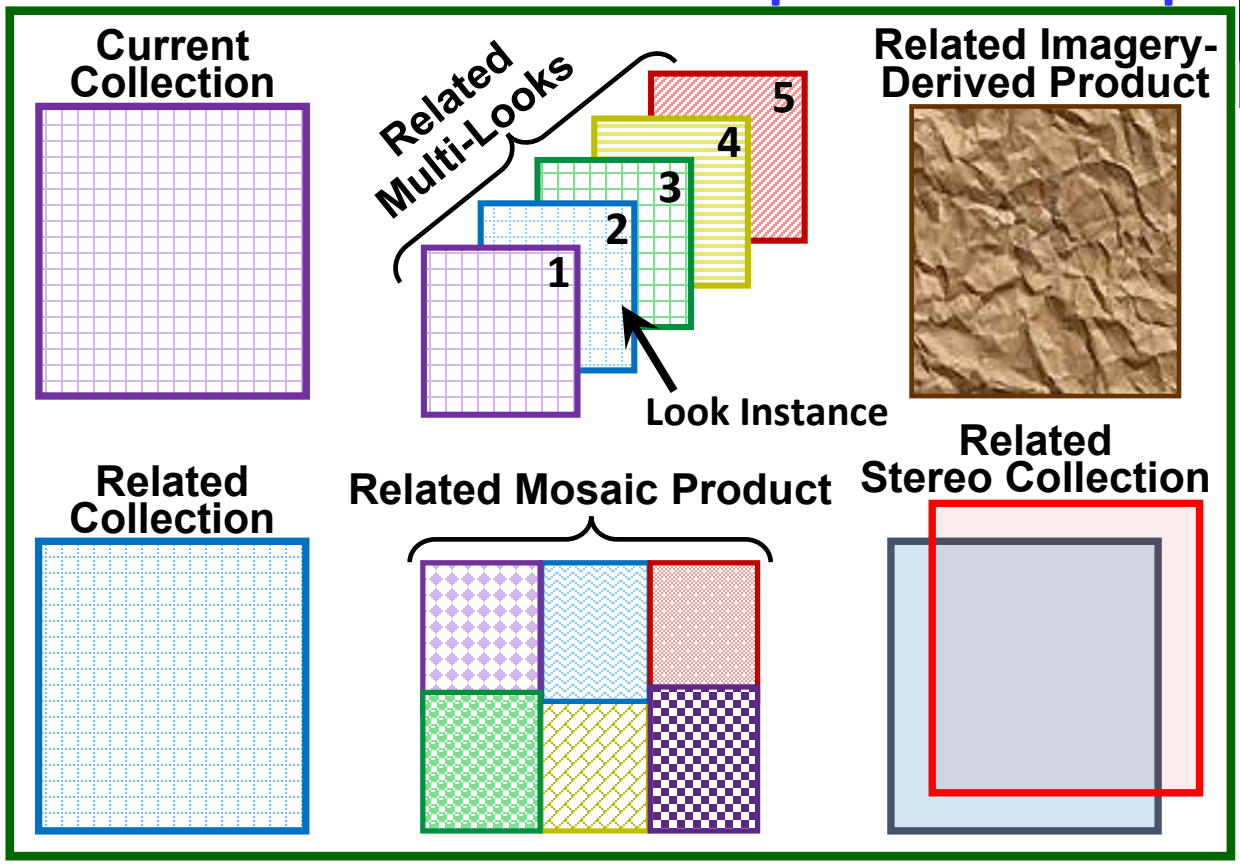
Provides mates of the file in which the MATESA TRE is located, i.e., the "current file"

- The relationship of each mate to the current file is also provided
  - 33 total RELATIONSHIP values
  - New RELATIONSHIP values may be submitted to the NTB for approval
- Mates may be images or non-images
- Mate ID varies with mate type: image, URL, etc.

Ratified by the NTB on 1 Dec 2018



Example Relationships



New Metadata Option: Per-Pixel Metadata → PIXMTA TRE

Per-pixel metadata: Pixel Metric Image Segment (PMIS) and PIXMTA TRE

- Metadata may be specified per band, and for each pixel or for a sparse grid of pixels
- Per-pixel metrics are organized by metric type
  - Spectroradiometric: Band wavelength, IFOV, FWHM, NESR, spectral smile, spectral keystone, etc.
  - View & illumination geometry: LOS azimuth & elevation angles, solar azimuth & elevation angles, etc.
  - Measurement quality: Dark level, saturation level, smear magnitude & direction, etc.
  - Image statistics: Row and column averages, row and column standard deviations
  - Miscellaneous: Equation coefficients
- PIXMTA TRE provides
  - Each metric's unit of measure (UoM)
  - Mapping between PMIS pixels and the associated image segment's pixels in [row, column, band]
  - Equation to convert stored PMIS pixel values to actual values, e.g., stored integers → real numbers

PMIS/PIXMTA specification was ratified by NTB on 23 May 2019

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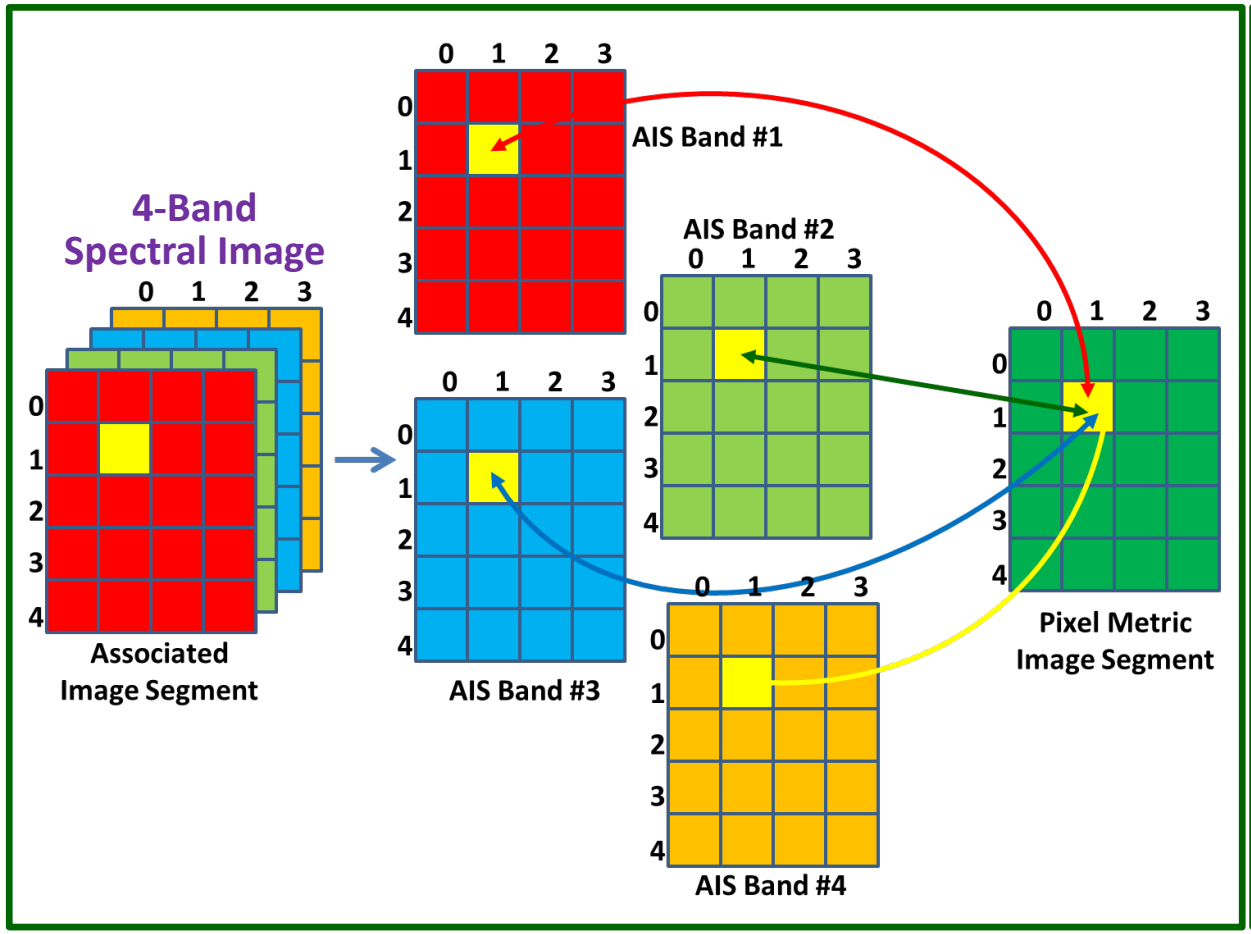
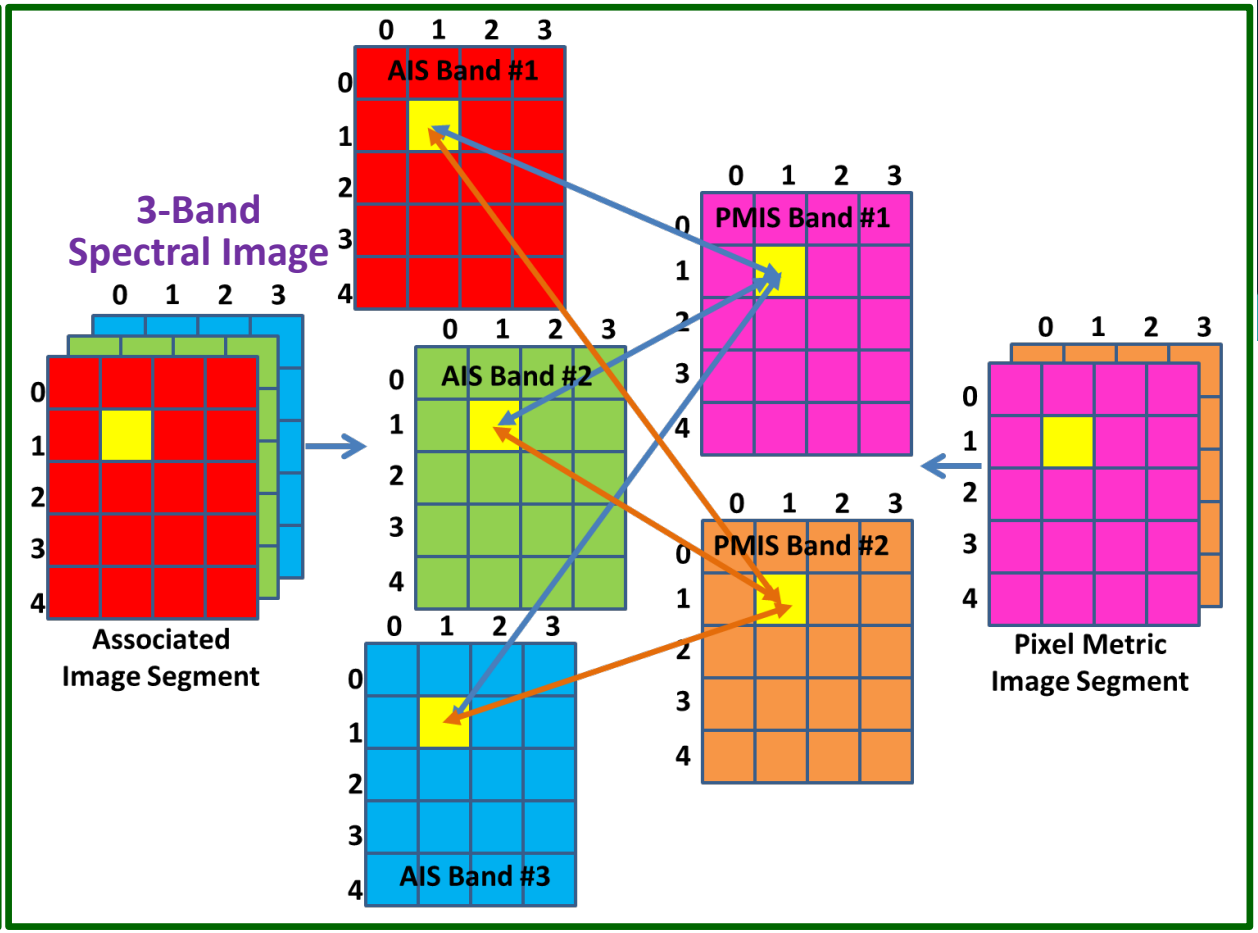
Per-Pixel Metadata: Examples of Relationships to Spectral Image





4-Band Spectral Image
Single-Band Pixel Metric Image that applies to each Spectral Image Band

3-Band Spectral Image
2-Band Pixel Metric Image with 2 Metrics that apply to each Spectral Image Band

New Metadata Option: Illumination Conditions → ILLUMA & ILLUMB TREs

ILLUMA TRE was created around 2017 → XML-encoded TRE

- Provides solar, lunar, and artificial illumination in radiance (W m^{-2} sr^{-1})

The ILLUMB TRE was created in 2018 because more illumination metadata were needed

- At the request of the user community, additional metadata were added to ILLUMA fields
  - Wavelength range of the illumination
  - Option to provide illumination in other radiometric quantities, e.g., spectral radiance (W m^{-2} sr^{-1} μm^{-1})
  - When & where illumination conditions exist: date, time, location
  - If a sensor is present:
    - Sensor elevation & azimuth angles
    - Latitude and longitude of solar and lunar glint
- Ability to specify multiple sets of illumination data: by wavelength ranges, times, & locations
- ILLUMB is a traditionally encoded TRE, i.e., fixed-length fields in a pre-defined order

The ILLUMA/B TREs were ratified by the NTB on 23 May 2019

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SNIP-Conformant Prototype Datasets, aka "Reference Implementation Products" (RIPs)

RIPs created to test the SNIP and its components

- And to test SNIP-conformant tools, Mensuration Services Program (MSP), etc

RIP #1: April 2005 cloud-free HDF4 Hyperion HSI of Baghdad → conformed to SNIP v0.1

- 172 band SWIR FPA: Quick-look, spectral, bad pixels, & 3 PMISs* (smile, FWHM, radiometric gain)
- Non-rectified: GLAS TREs & DESs supporting MSP; two RSM TREs derived from GLAS
- Includes BANDSB, CSCRNA, CSDIDA, HISTOA, ILLUMA*, MATESA*, PIXMTA*, and USE00A TREs
- Interoperability tested against ENVI → ***Success***

RIP generation and testing proved valuable to SNIP development and to tools, revealing

- Need for new types of image mates → MATESA TRE modified
- Older version of MSP (v1.5.0) does not handle multiple image segments well

NGA/R has shared RIP #1 at least 23 times, including …

- NGA groups, AFLCMC, LANL, ORNL , etc
- Contractors: Aerospace, BAE, Ball, L3Harris, Hexagon US Federal, Centauri (formerly IAI), UTAS
- Australian Dept of Defence, Australian GEOINT Office (AGO)

RIPs are available upon request

NGA/R has recently completed a Hyperion-derived RIP that conforms to SNIP v1.0

- Using final versions of ILLUMB, MATESA, and PIXMTA TREs

* Draft version

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Hyperion SNIP-Conformant Reference Implementation Product (RIP)

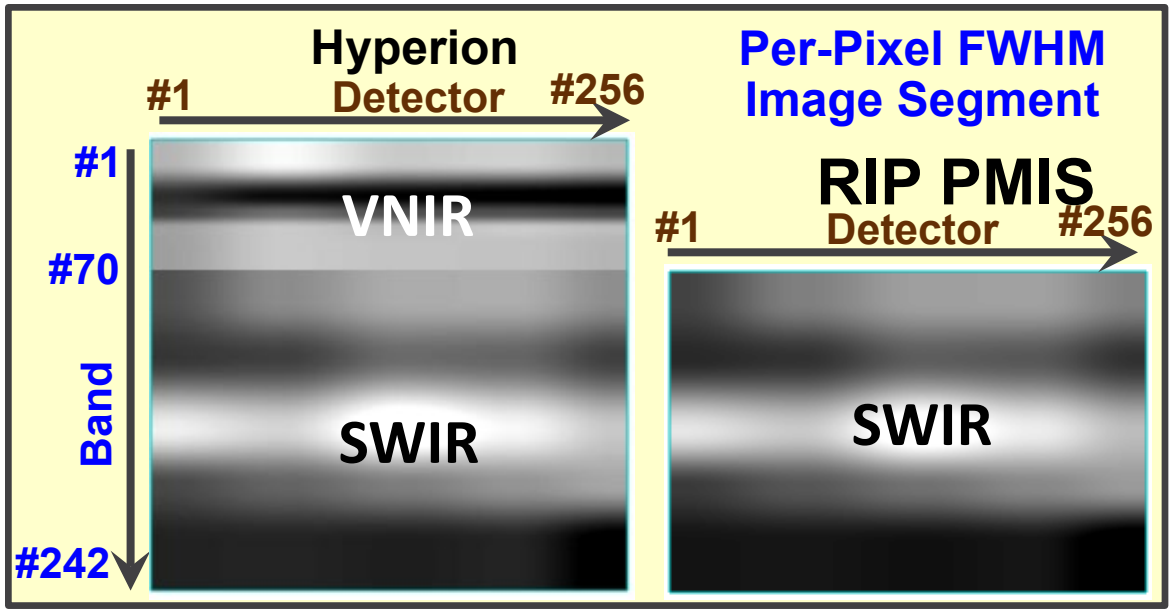
Hyperion scene ID EO1H168037200509711OPZ

RIP file name: 07APR2005_Hyperion_331405N0442002E_SWIR172_001_L1R.ntf

Original HDF4

RIP Quick-Look

RIP HSI



Black background of RIP image segments results from the value of the FBKGC (file background color) field in RIP file header

Hyperion dataset courtesy of the U.S. Geological Survey

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Next Steps: Enable More Advanced Spectral Analysis

Address more data product levels: HSI Levels 0 to 2; and MSI Levels 1 to 4

Create SNIP-v1.0-conformant RIP(s): Currently in work

Improve existing metadata containers, including

- Augment [row, column] chipping to [row, column, band]
- Improve lineage metadata (HISTOA TRE)
  - Currently designed for IDEX (1991 to 2003) processing
- Add weather metadata

Create new NITF container for polynomials and tables

- For example: spectral response function either as a shape or as a table of values

Continue collaborating with NATO Allies and their NSIF/STANAG 4545 requirements

If resources permit: Add support for Color Management (CM) solutions per NGA Softcopy Image Processing Standard (SIPS)

- ICC_PROFILE_SUPPORT_DES (*may need to update structure*)

Systems Utilizing the SNIP

Some HSI airborne platforms

USAF is looking to standardize MSI products from

- U-2 SYERS-2C
- Global Hawk MS-177

Exploitation Light Tables (ELTs) Utilizing the SNIP

ENVI: Spectral exploitation (L3Harris product)

MSP: Testing MSP's geopositioning and mensuration functions on SNIP-conformant RIPs

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Summary

NGA/Research has created the Spectral NITF Implementation Profile (SNIP), a new MSI/HSI standard that improves utility, quality, and interoperability while reducing integration costs:

- Includes the first ever general MSI NITF implementation profile
- New content: Per-pixel metadata, illumination conditions, image and non-image mates
- Improved geopositioning for a wider range of systems and collection conditions
- Platform independent; applies to non-, geo-, and ortho-rectified data

The SNIP is in the NSG Standards Registry: https://nsgreg.nga.mil/doc/view?i=4829

Several new MSI and HSI systems that provide data to the NSG are in the process of leveraging the SNIP

NGA/Research is creating SNIP-conformant Reference Implementation Products (RIPs)

- RIPs are usually shareable upon request

NGA/Research is actively working to add more advanced capabilities to the SNIP

NGA

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