Brazilian EO Satellite Program Update

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Launching Schedule

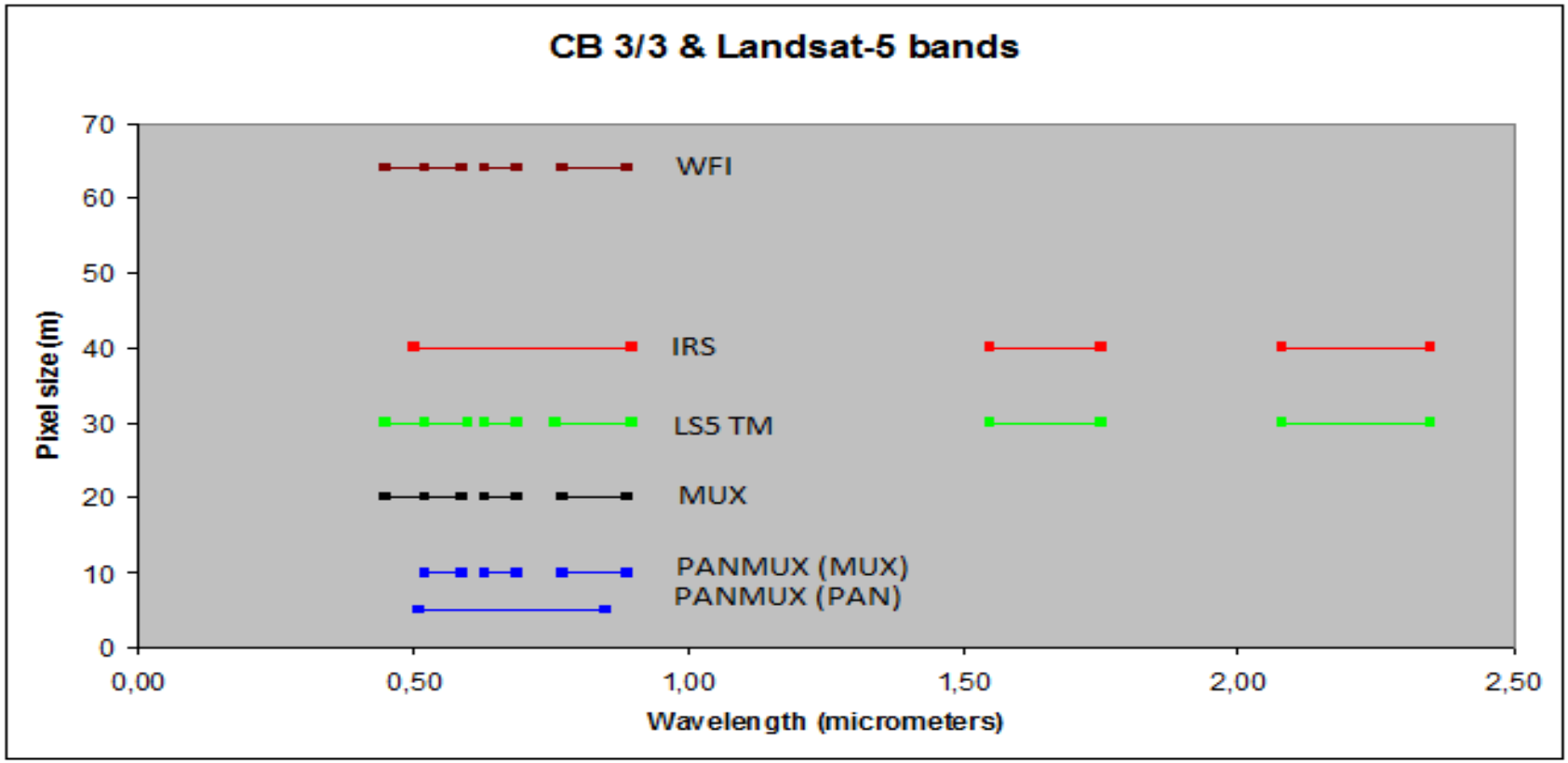
- CBERS 3
  - Delayed, originally planned for first semester of 2012
  - Ready for Space Center transportation: 5/19/2012
  - Launch: 12/2012
    - From China, Long March rocket
- CBERS 4
  - Launch planned for 8/2014
- Amazonia 1
  - 2014
- Talk focus
  - Geometry: using GPGPU for faster processing
  - Radiometry: internal calibrator workings

CBERS 3 / 4 payload overview

	MUX	WFI	IRS	PANMUX
Country	Brazil	Brazil	China	China
Type	Push-broom	Push-broom	Scanning mirror	Push-broom
Swath (km)	120	866	120	60
Revisit (days)	26	5	26	52 (*)
Quantization (bits/pixel)	8	10	8	8
GSD (m)	20	65	40	10/5

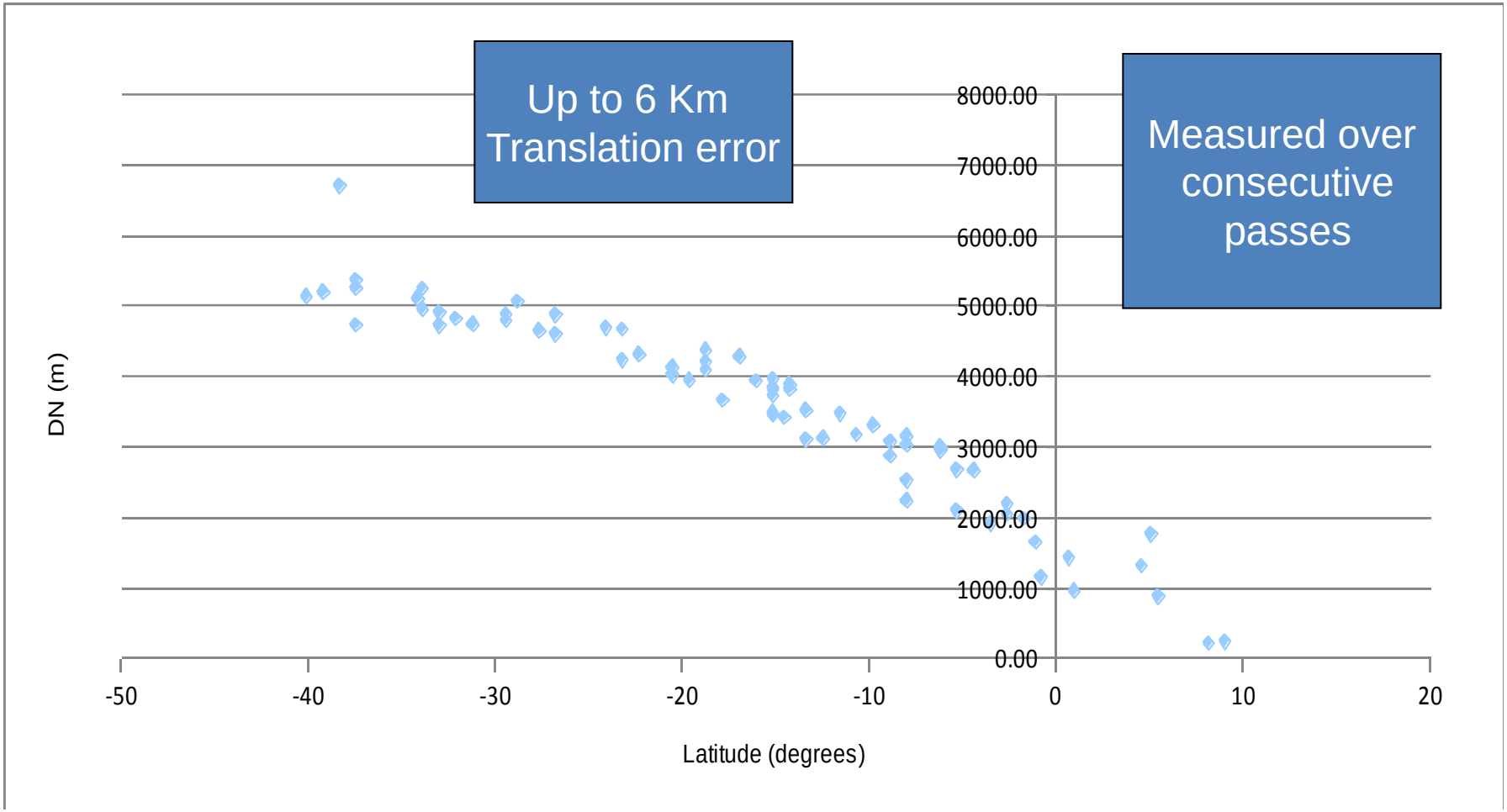
(*) Mirror may be used to revisit the same place within 3 days if necessary

CBERS 3/4 bands resolution and wavelengths



IRS also has a thermal band in 10.4 – 12.5 range, 80m GSD

Geometry issue: CBERS 2B Along Track Error



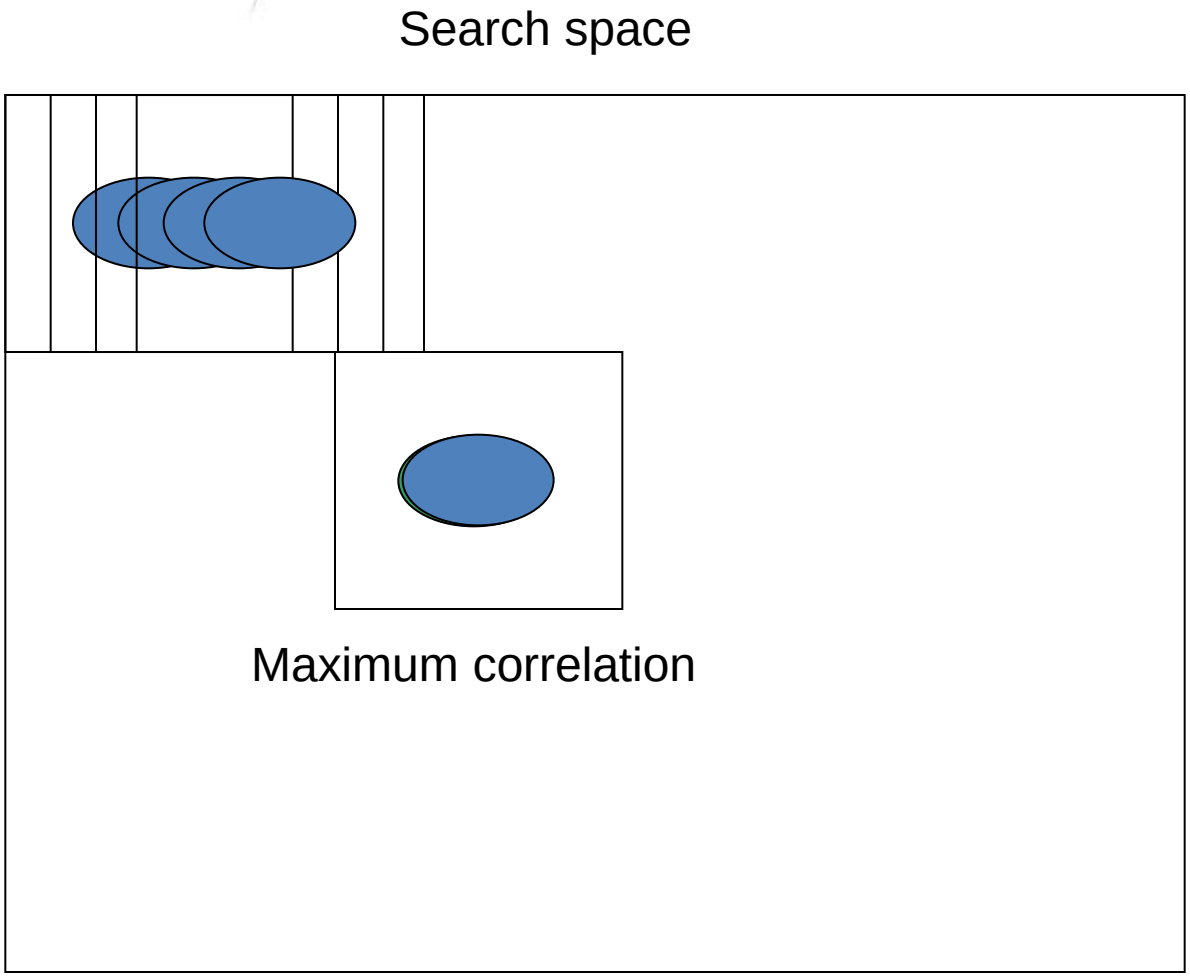
Discussion

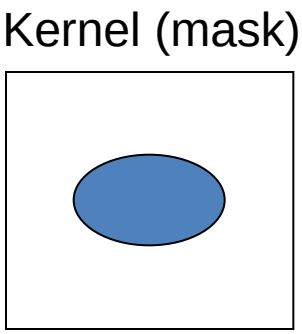
- Probably due to wrong attitude information
- Makes automatic registration harder
  - Big search space to deal with general case, long processing time
    - Around 3 hours for each scene
- CBERS 3,4 and Amazonia will be better…
  - GPS and improved star trackers into the control loop
- … But we want to:
  - Be prepared for surprises
  - Improve the archive quality
- Approach: GPGPU

GPGPU

- **G**eneral **P**urpose computing on **G**raphic **P**rocessing **U**nits
  - GPUs originally developed for high performance graphics applications (games, CAD, virtual reality)
  - Cheap massive parallel processing environment
    - =~ 400 cores against 4-6 typically found on CPUs
  - Lately the graphic card manufacturers have been pushing SDKs for general purpose programming on GPUs
    - CUDA (NVIDIA)
    - OpenCL (Consortium)
- Ground system processing is being extended to use GPGPU
  - Start with Normalized Cross-Correlation (NCC) computation

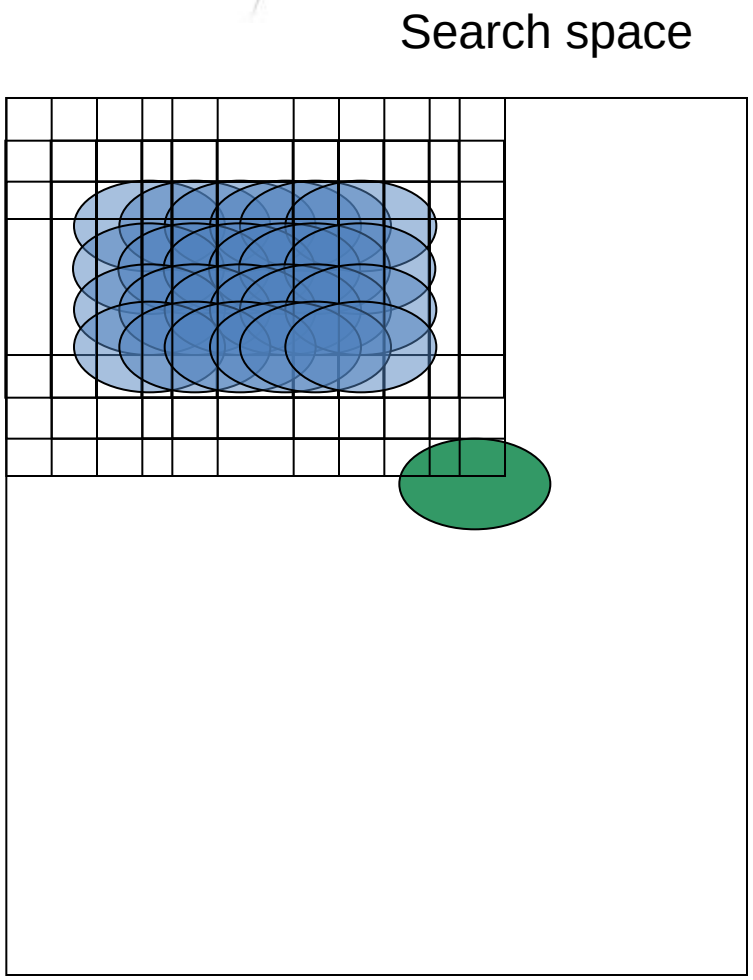
Sequential NCC





- Kernel center is a control point
  - Landsat GLS
- NCC computed for all search space, highest value is match candidate

Parallel NCC



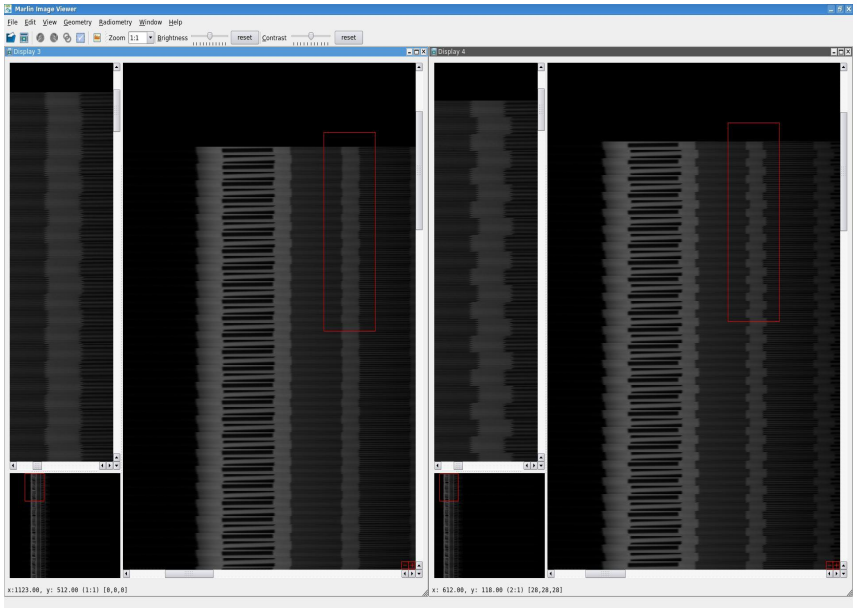
- Data parallelism
- One thread is created for each candidate position
  - Each GPU core handle multiple threads
- "Easy" parallel algorithm
  - No communication or synchronization between threads
  - Single image transfer to the GPU memory, avoid memory transfer bottleneck

Preliminary Results

- 3000 x 3000 pixels search space
- 33 x 33 pixels kernel
- NVIDIA GTX 560 Ti
  - 384 cores @ 1.64 GHz
  - Cost: 240 USD
- Performance comparison
  - Sequential: 33 seconds (Intel Xeon E5410 @ 2.33 GHz)
  - GPU: less than 1 second

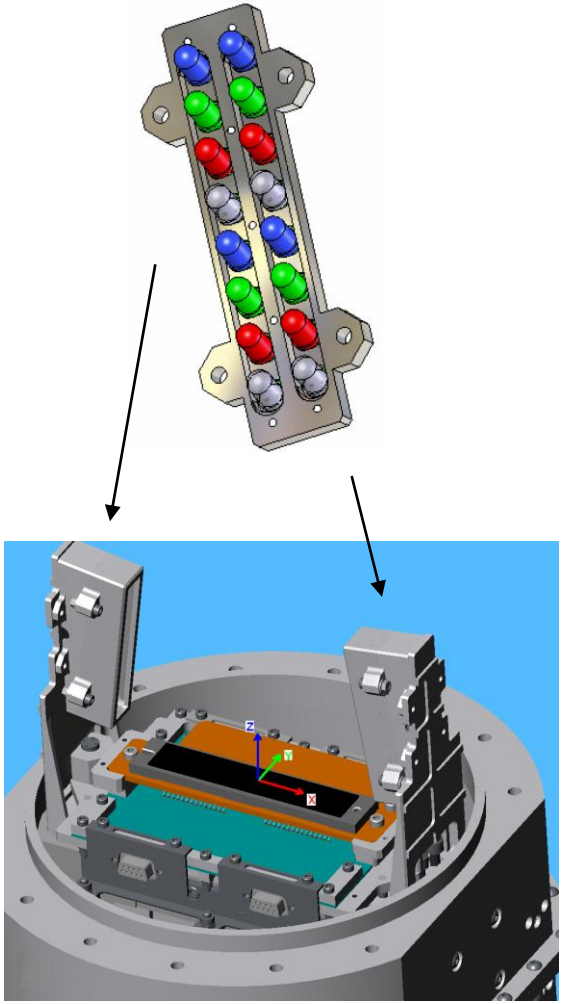
Perspectives

- NCC may be applied in other areas
  - IRS mirror model refinement
    - Scan alignment problem
  - Registration between camera bands
  - Registration between distinct cameras images
- New products planned for Amazonia-1

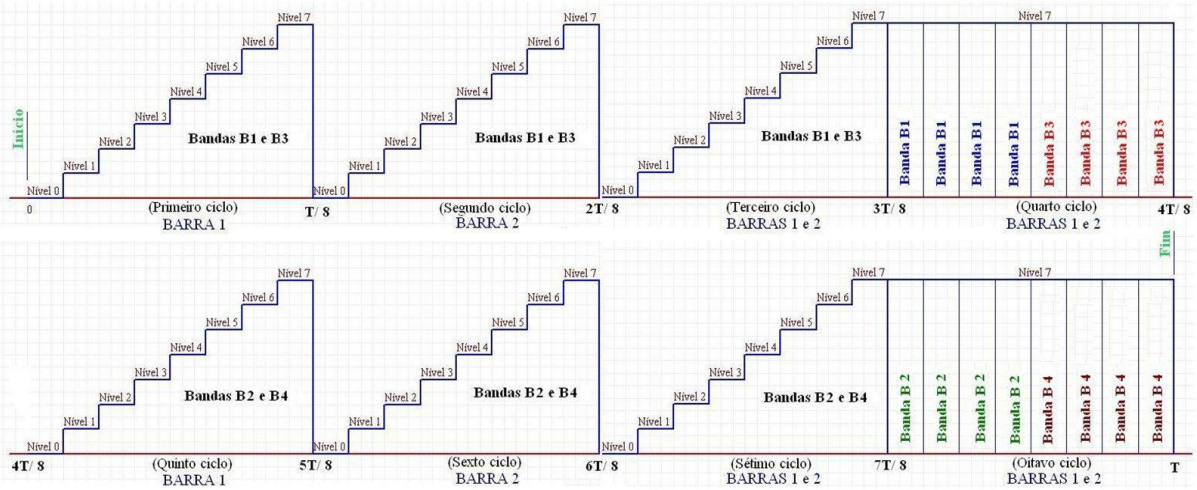


MUX Internal Calibrator (IC)

- ICs not regularly used for CBERS 1/2/2B cameras
  - Lamp based, poor stability
  - Non-uniform lighting
  - Lack of detailed procedures
- LED based
  - Improved stability
- Distinct LED groups for each spectral band
  - Closest match to detector's filters
- Different light path for IC and direct imaging modes



MUX IC Cycle



Right Left Both

Right LED bar

Left LED bar

Both bars simultaneously

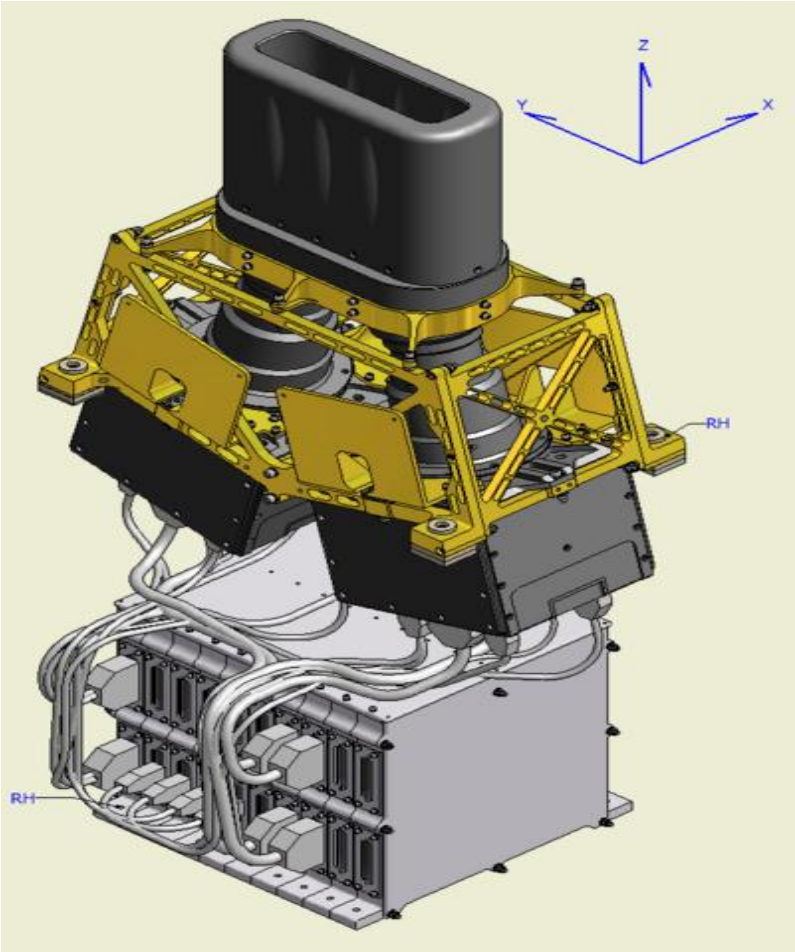
- 8 distinct illumination levels
- Normally we will use both bars data
  - Single bar data for backup, lower SNR

IC Data Usage Procedure

- We will not assume a uniform lighting
- Relative and absolute calibration is performed in the lab, prior to launch, with an integrating sphere
  - Generate an initial set of gains and offsets for each detector
- Right after, still on the lab, an IC cycle data is acquired
  - The resulting image, after calibration, is stored as a “reference image”
  - The reference image, even calibrated, is not expected to be uniform
    - Non-uniformity due to lighting
- On board IC data is compared to the reference image
  - Differences are modeled multiplicative coefficients adjustments for each detector´s gain
  - For example, we expect these adjustments to be 1.0 right after launch

WFI IC

- Similar to MUX IC
  - One IC assembly for each focal plane
- Identical procedure
- Cross-calibration with MUX for validation

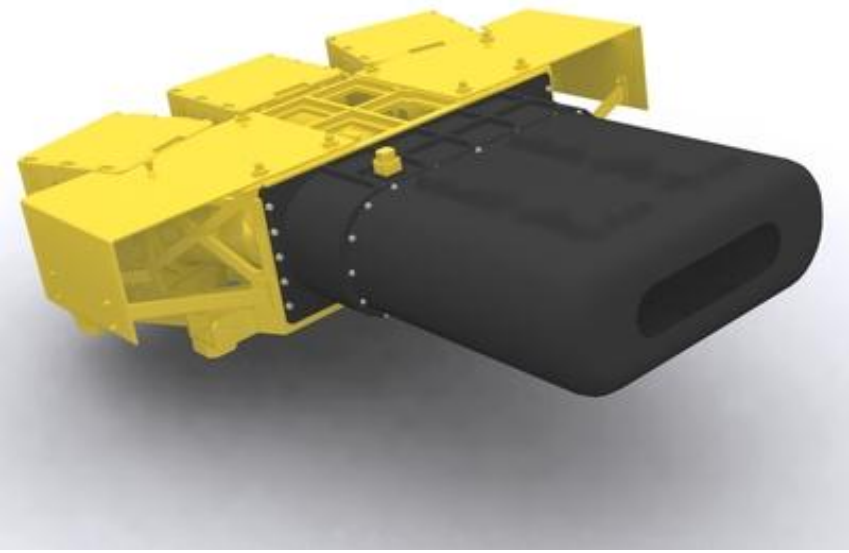


IC: Concluding remarks

- Here we cover the Brazilian cameras
  - We expect to have similar procedures for the Chinese cameras
- The software will deliver, as metadata, the coefficients to transform digital numbers to radiance for each band
  - Initially based on lab and IC calibration, possible updates from vicarious calibration campaigns
  - No more need to search for these coefficients on published papers

Amazonia 1

- Brazilian
- Payload: AWFI camera
  - Same detectors and filters used in CB3/4 MUX and WFI cameras
  - 3 optical systems
  - GSD: 40m
  - Swath: 720 Km
  - Revisit: 5 days



- Similar IC hardware & procedures
- New products
  - “MODIS style” composite images
  - Changes detection

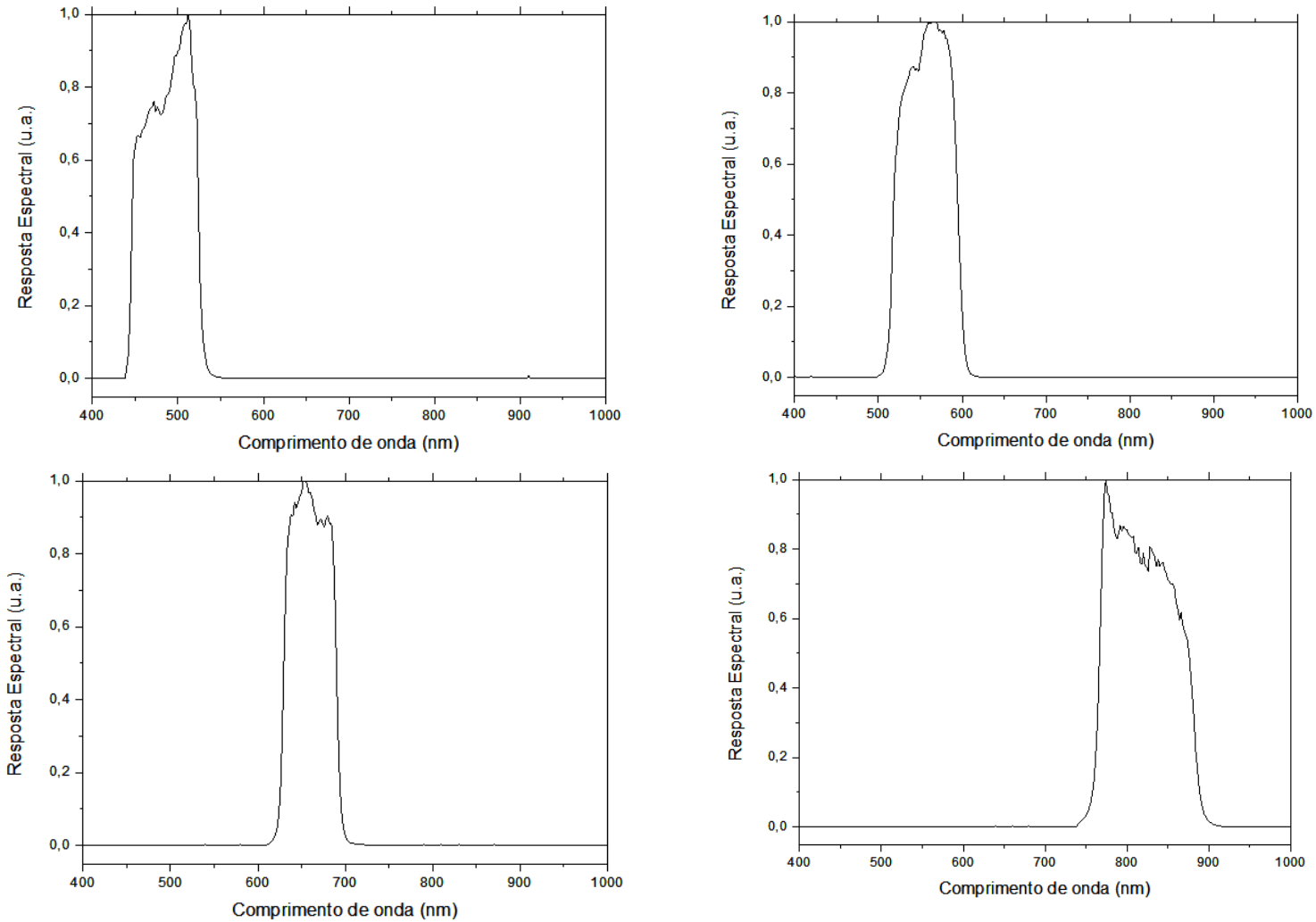
Image Distribution Figures

Satellite	Images	Subtotal
CBERS-2	498,747	
CBERS-2B	507,056	1,005,803
Landsat-1	9,453	
Landsat-2	22,236	
Landsat-3	8,274	
Landsat-5	754,018	
Landsat-7	26,332	820,313
Resourcesat-1 (LISS and AWIFS)	33,644	36,644
Aqua	840	
Terra	1,497	2,337
		1,865,097

Questions?

Backup slides

MUX filters (flight model)



Overview

- CBERS 3 and 4 characteristics
  - Differences from previous CBERS satellites (CBERS 1/2/2B)
    - Geometric processing
    - Radiometric processing
  - General and camera specific changes
- CBERS 3 launch schedule
- CBERS for Africa update

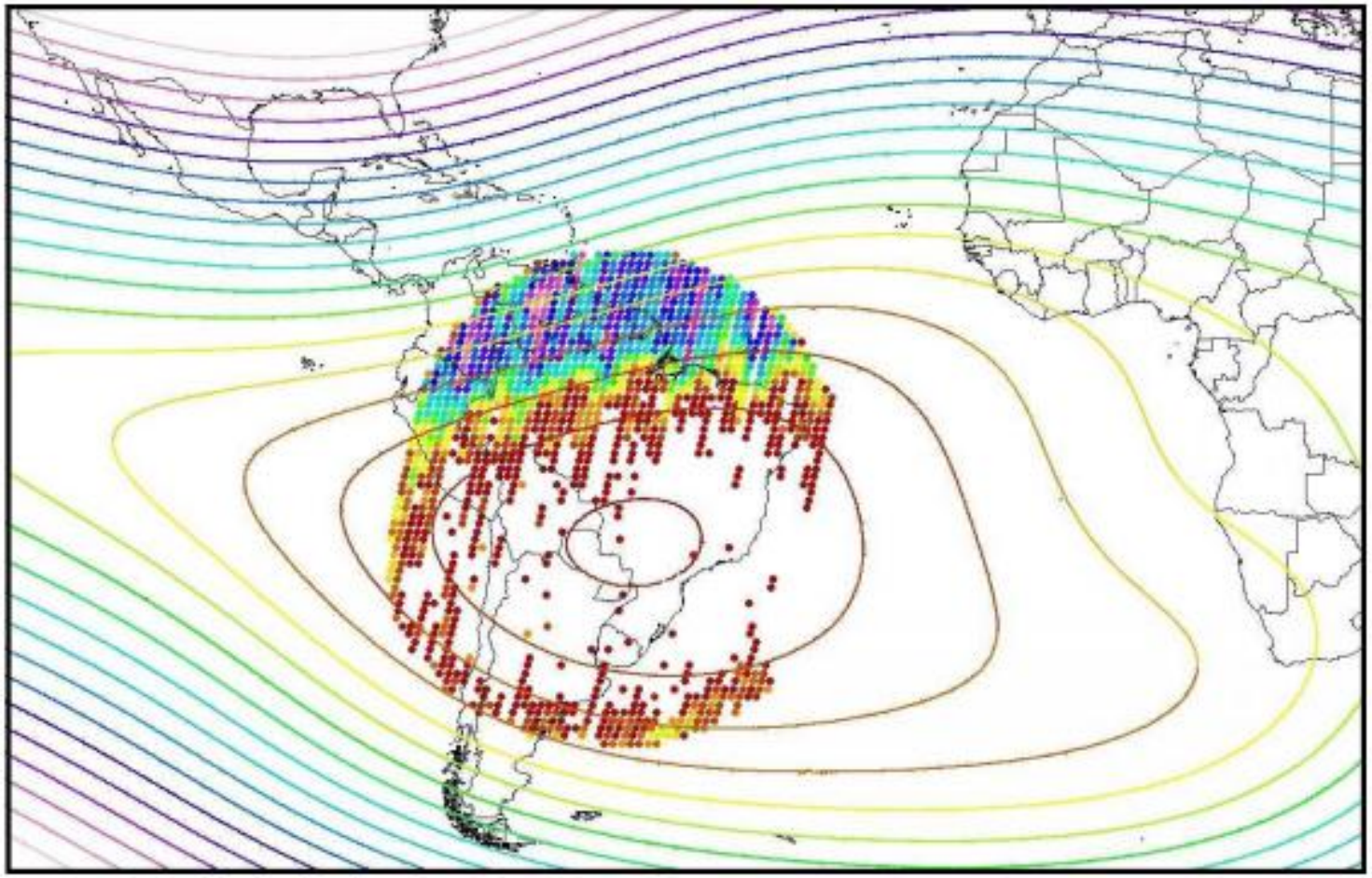
CBERS 3 and 4 sun synchronous orbit

- Semi-major axis (average): 7148.8 Km
- Inclination: 98.5 (o)
- Eccentricity: 1.0x10-3
- Argument of Perigee: 90 degrees
- Local Time at descending node: 10:30 AM
- Orbital period: 100.26 minutes
- Repeat cycle: 26 days
- Revolution/Day: 14 + 9/26
- Distance inter ground track at equator: 107.4 km
- Time interval between adjacent tracks: 3 days
- Local time stability at descending node mean: +- 5 min.
- Orbit traces stability at the equator: +- 5 km

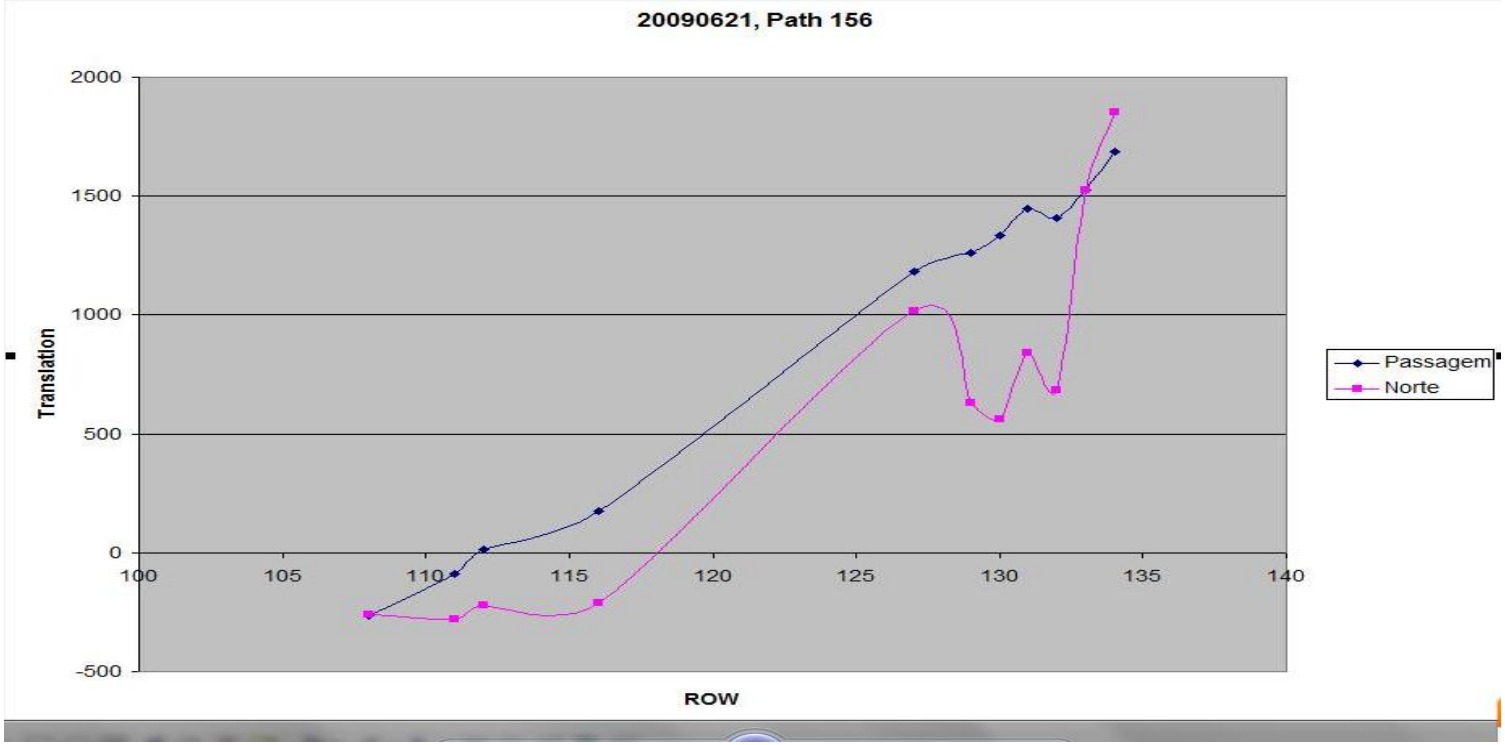
Attitude and Orbit Control System (AOCS)

- Starting in CBERS 2B
  - GPS
  - Star Sensors
  - Same satellite control mechanism used in CBERS 1/2
    - Informational only, not in the satellite control loop
- CBERS 3 and 4
  - New Star Sensors to avoid South Atlantic Anomaly (SAA) related problems
  - AOCS software upgraded to use GPS and Star Sensor information
  - Better position and pointing accuracy
    - Attitude knowledge ≤0.03 deg (3 sigma)
  - Without GPS and SS (degraded mode)
    - Attitude knowledge ≤0.15 deg (3 sigma)

Star sensor data and the SAA



CB2B Translations along track example (L1G)



- Translation in meters
- Harder to make automatic registration with ground control chips

Better time stamping for image lines

- CBERS 1/2/2B
  - A new timestamp was generated every 2-3 seconds
  - No practical image line counters, small ranges
- CBERS 3/4
  - Will transmit the GPS time of the first image line acquisition for all cameras
  - Line counters with sufficient range to cover all pass
  - Precise frame period

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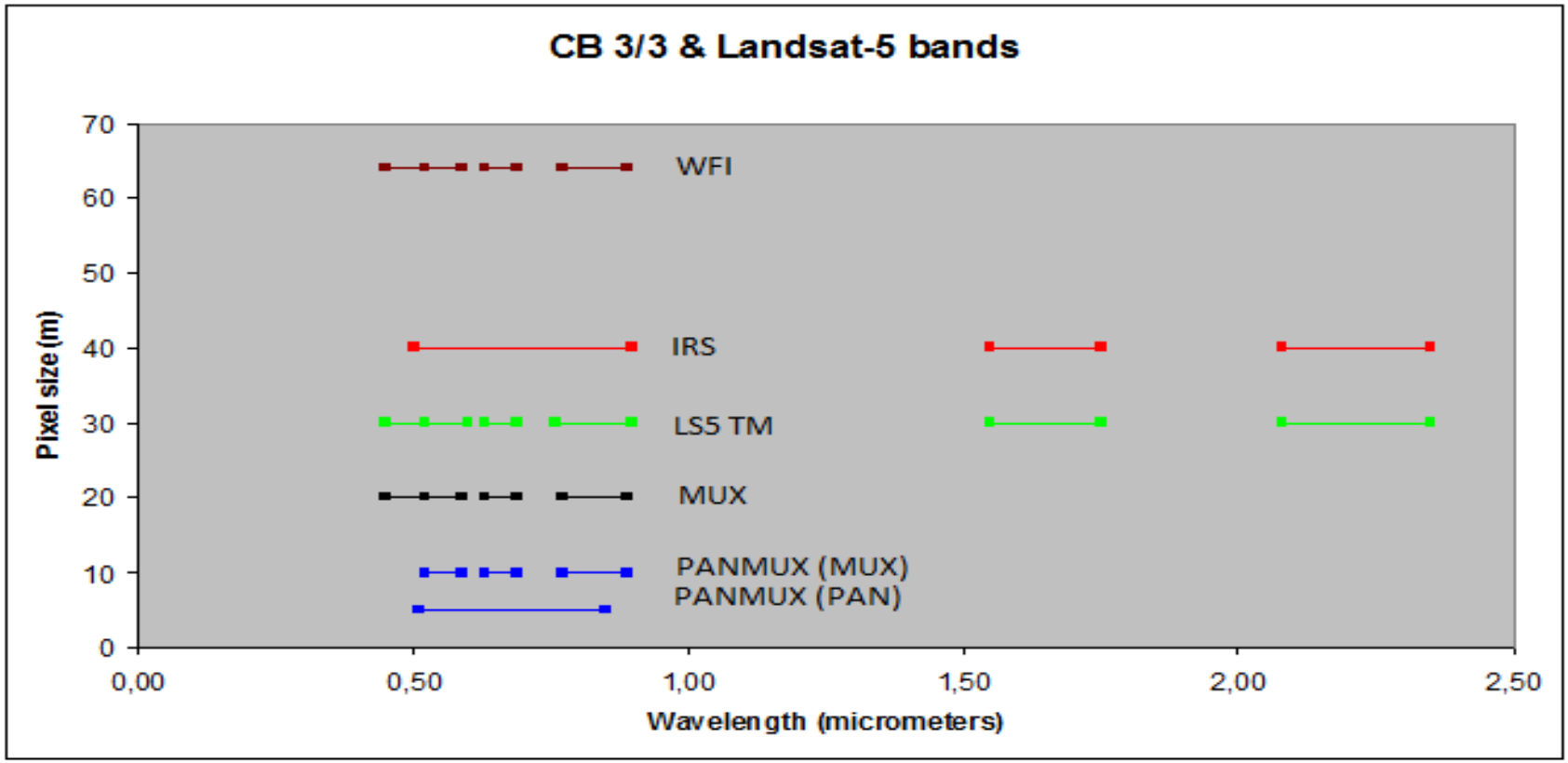
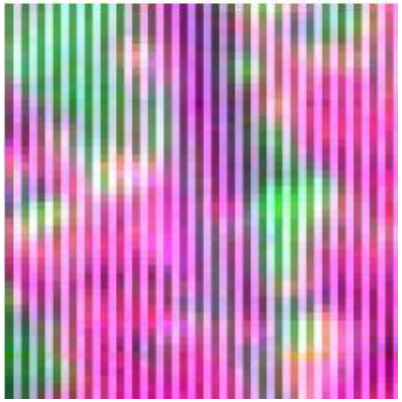


IRS also has a thermal band in 10.4 – 12.5 range, 80m

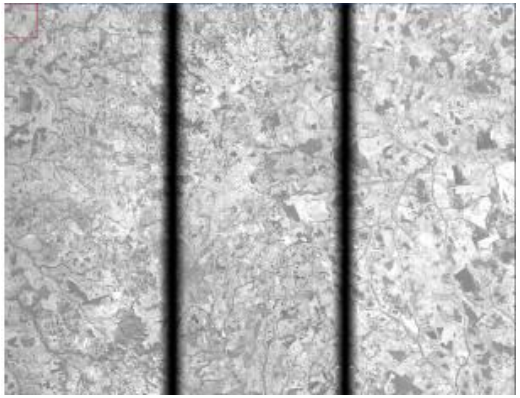
MUX

- Replaces CBERS 1/2/2B CCD camera
- Differences
  - Positive
    - Single CCD array for each band instead of 3 arrays for each band;
    - No odd/even striping effect
    - Internal calibration (LED based)
    - Focal plane position adjustment
    - Individual gain adjustment
  - Negative
    - No panchromatic data
      - May use PANMUX data, but swath is half of the MUX scene
- Challenges
  - No beam splitter: difference of up to .5 s between acquisition times for different bands

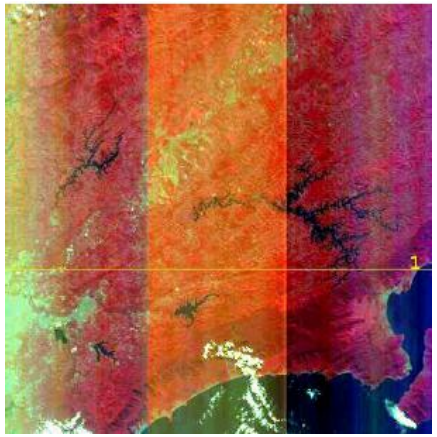
CBERS 1/2/2B CCD artifacts



Odd/Even striping

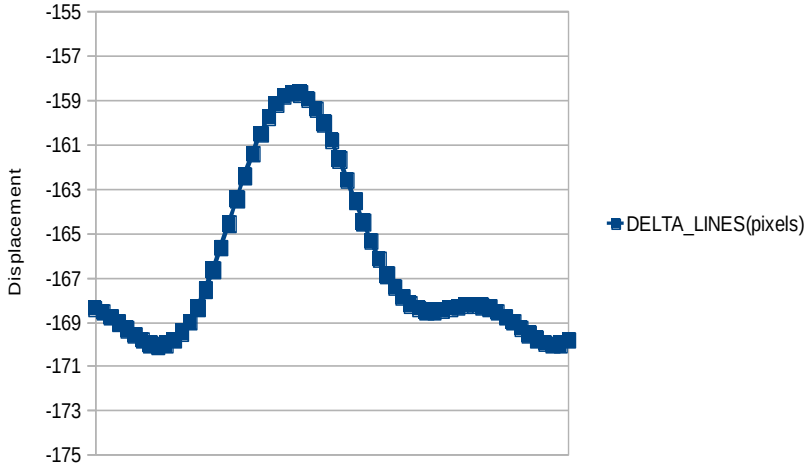


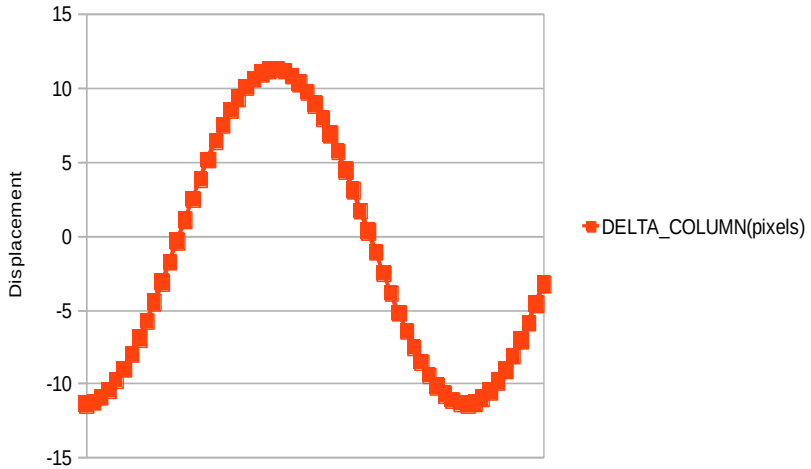
Inter array processing



Distinct behavior for each Array, for each band

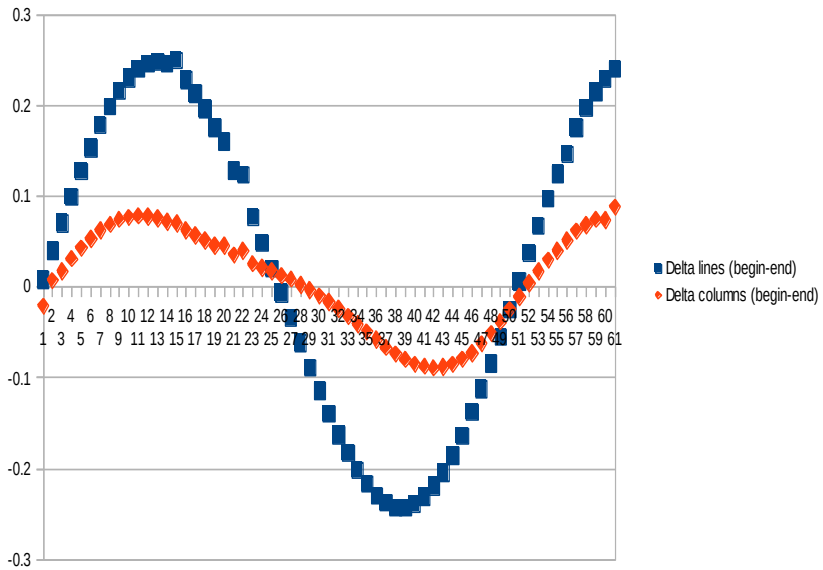
Simulation for MUX center pixel registration (worst case)

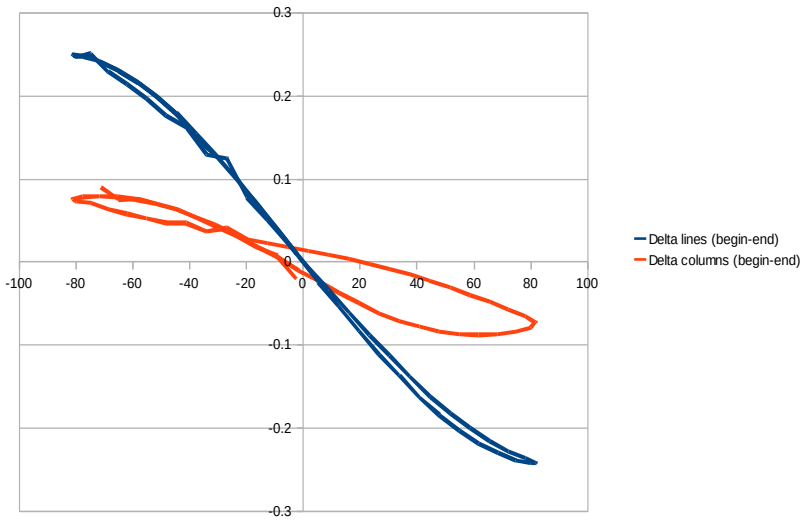




- Displacements must be computed according to the latitude
  - L0R will need to use position and attitude data
- What about variation within the scene lines?
  - Graphs above consider central pixel only

Simulation for MUX displacements for initial and final pixels

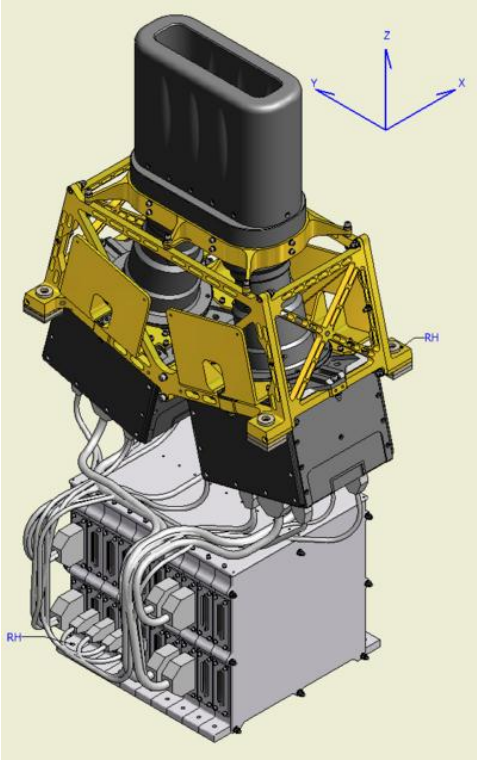




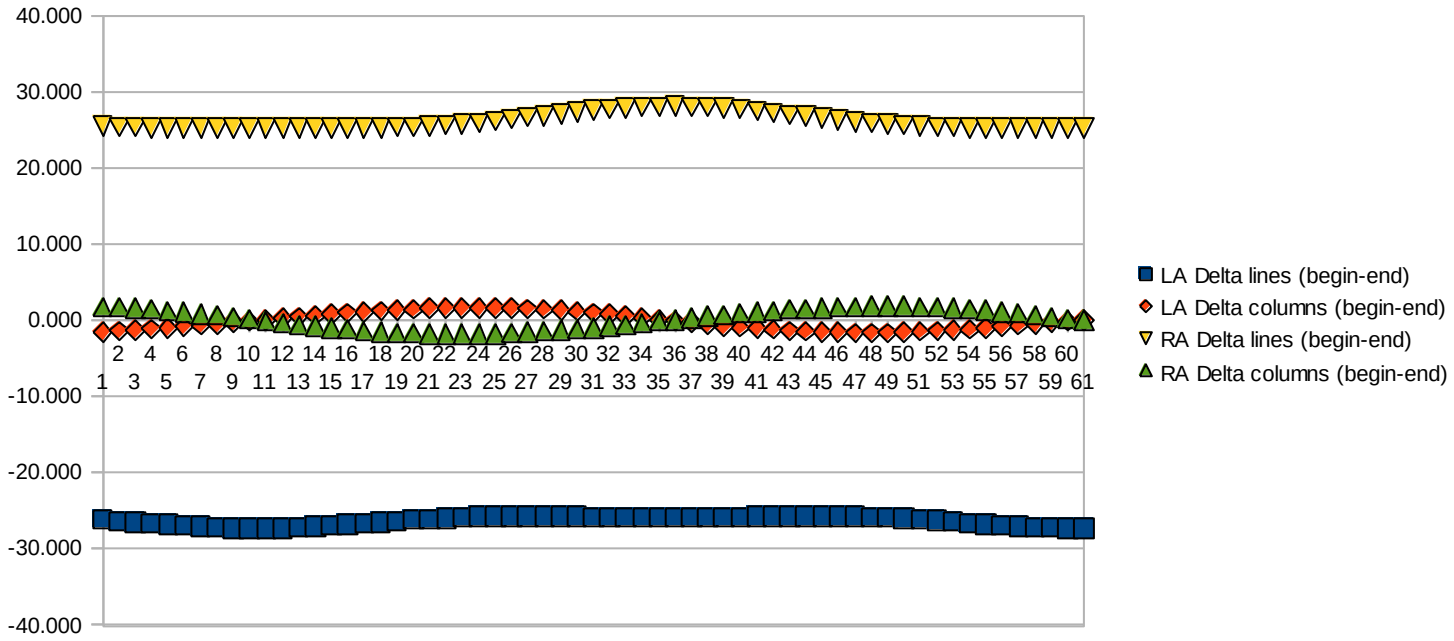
- Up to 0.25 pixels difference for line displacement
  - More critical in high latitudes
- Data above is for a single typical orbit
  - Changes are not significant if satellite nominal orbit is maintained

WFI

- Replaces CBERS 1/2/2B WFI camera
  - Two distinct optical systems
- Differences
  - Positive
    - 10 bits quantization instead of 8 bits
    - Better resolution, 64m instead of 260m
    - 4 spectral bands instead of 2
    - No odd/even striping effect
    - Internal calibration (LED based)
    - Individual gain adjustment
- Challenges
  - No beam splitter: difference of up to 1.9 s between acquisition times for different bands



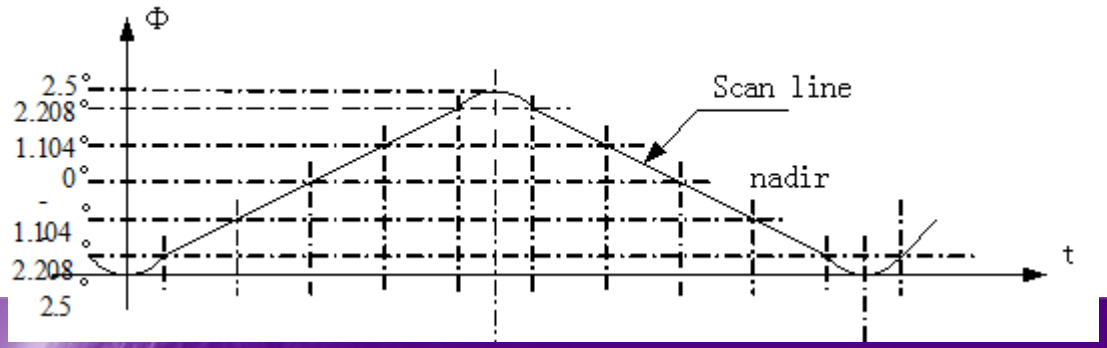
Simulation for WFI displacements for initial and final pixels, For left and right cameras



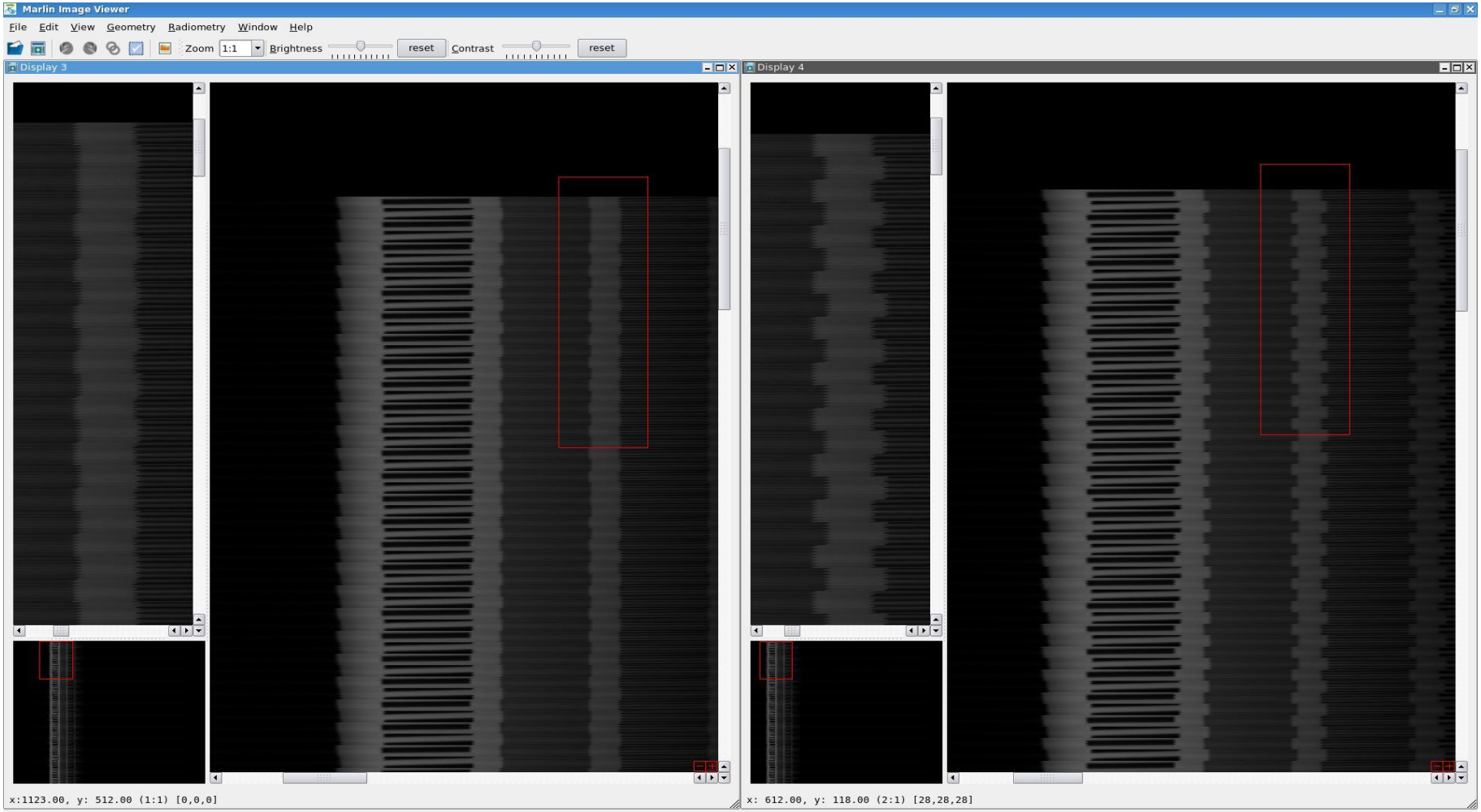
- Combined with the panoramic effect the changes in displacement values between initial and final pixels is up to 30 pixels for lines
  - Unfeasible to generate a L0R product with simple translations

IRS

- Replaces CBERS 1/2 IRS
- Differences:
  - Positive
    - Better spatial resolution, 40m instead of 80m (80m instead of 160m for thermal)
- Challenges
  - Same model for scanning mirror movement
    - Linear within 4 defined sections
    - Problems in matching direct and reverse scans in CBERS 1 and 2



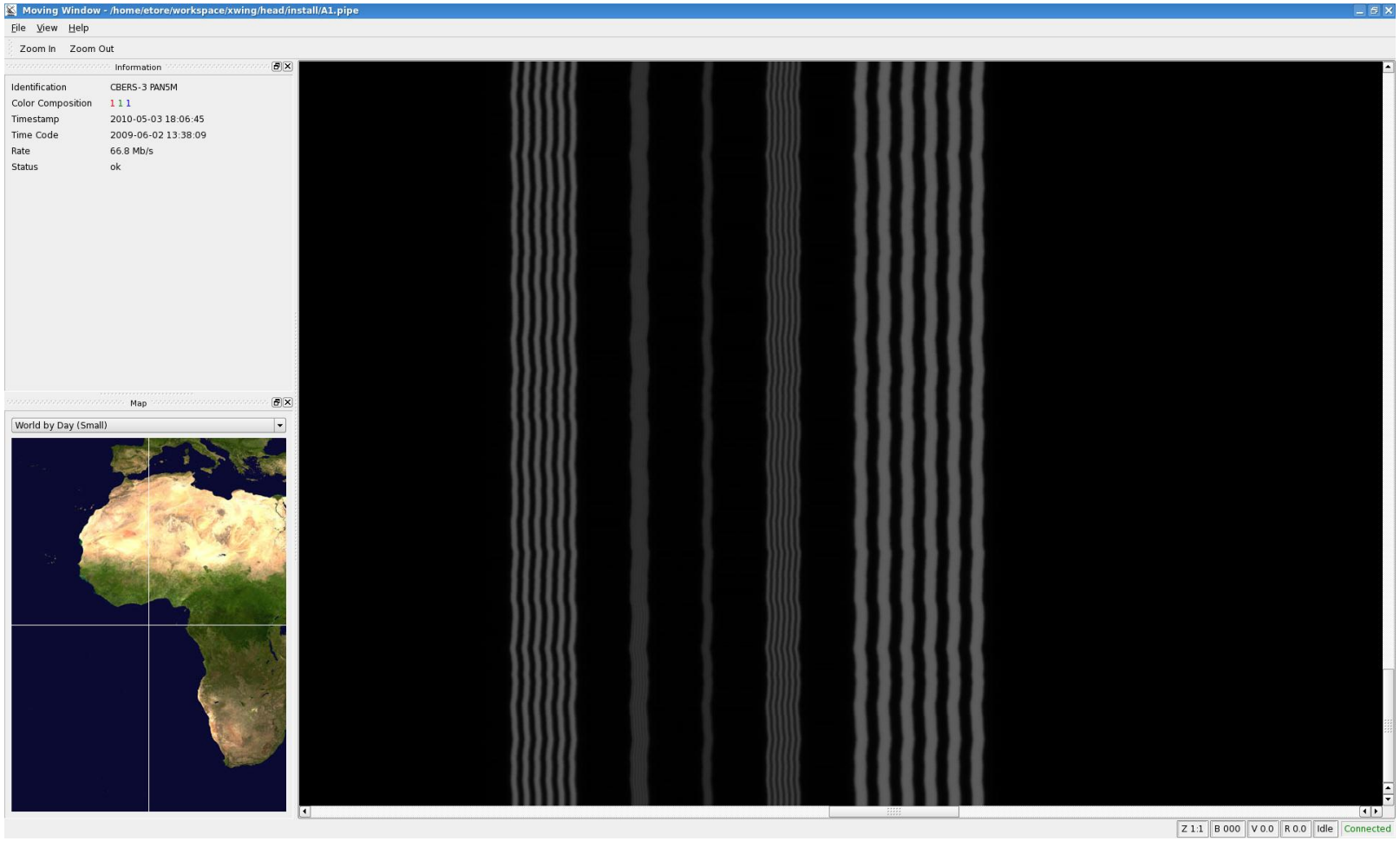
IRS scan match test



PANMUX

- No similar camera in CBERS 1/2/2B
- Bands
  - 3 Multi-spectral (10m resolution)
    - Uses beam splitter to separate spectral bands
  - 1 Panchromatic (5m resolution)
  - Individual gain adjustment
- Focal plane position adjustment
- Internal calibration
- Challenges
  - Impact from IRS scanning mirror movement
  - Around 4s difference acquisition time between PAN and MUX bands
  - Panchromatic band data will be compressed (line based DPCM algorithm)

IRS interference in PAN5m imaging



CBERS 3 launch schedule

- Satellite to be integrated and tested until Dec. 2011
- Wait for a launch window in the first semester of 2012
  - Launch from China using a Long March rocket

CBERS for Africa planned ground stations