In preparation for the follow-up breakouts we present:

HyspIRI and the Art of Geo-Location

Dealing with substantial differences between the VSWIR and TIR measurement patterns

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HyspIRI Science Symposium – NASA GSFC – May 17, 2010

What I am going to present and why I am presenting it to <u>you</u> !

- The geometric properties of HyspIRI level-1 data.
- Exposing the myth of *(defining limitations in)* achieving coincident individual observations between instruments and over time.
- Options for generating VSWIR, TIR and combined level-1 *(calibrated)* products.
- ***<u>You</u>*** determine higher level product requirements needed to meet your research goals.
- Higher level products depend, both qualitatively and quantitatively, on the level-1 products from which they are generated.

Geometric Factors Influencing VSWIR/TIRS Combined Product Utility

- Final Satellite Orbit
- Satellite Pointing Accuracy
  - Attitude Control System (ACS)
  - Star Trackers
- Satellite Positioning Accuracy
  - GPS
- Instrument Models & Geometry
- **Science Users Geolocation Expectations??**
- Low-latency Product Geolocation Expectations!

Preliminary Geometric *Nominal* Parameters for the HyspIRI

The Satellite

- Platform: Sun-synchronous Circular Ground-track Repeat Orbit
- Altitude: 623 km (mean sea-level)
- Velocity: ~7 km/sec (ground speed)
- Repeat Cycle:19 days
- 10:30 am MLT at Equator (descending node crossing)

The VSWIR Spectrometer

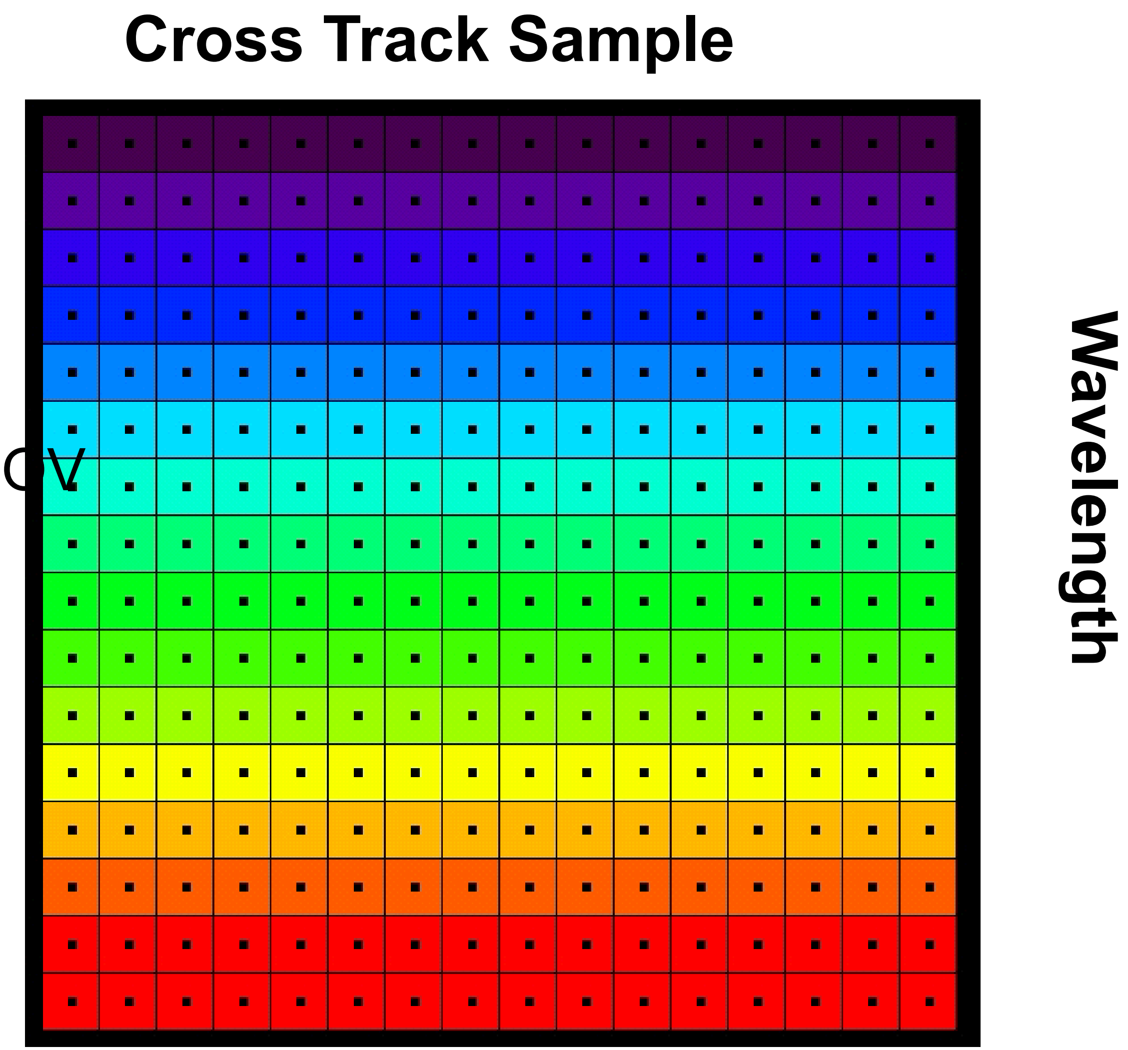
- Pushbroom Technology
- Revisit Cycle at Equator: 19 days
- Detectors/wavelength: 2*1280 (2 FPAs)
- Swath Width: 145 km
- Pixel size/GSD: 60 m

The TIR Instrument

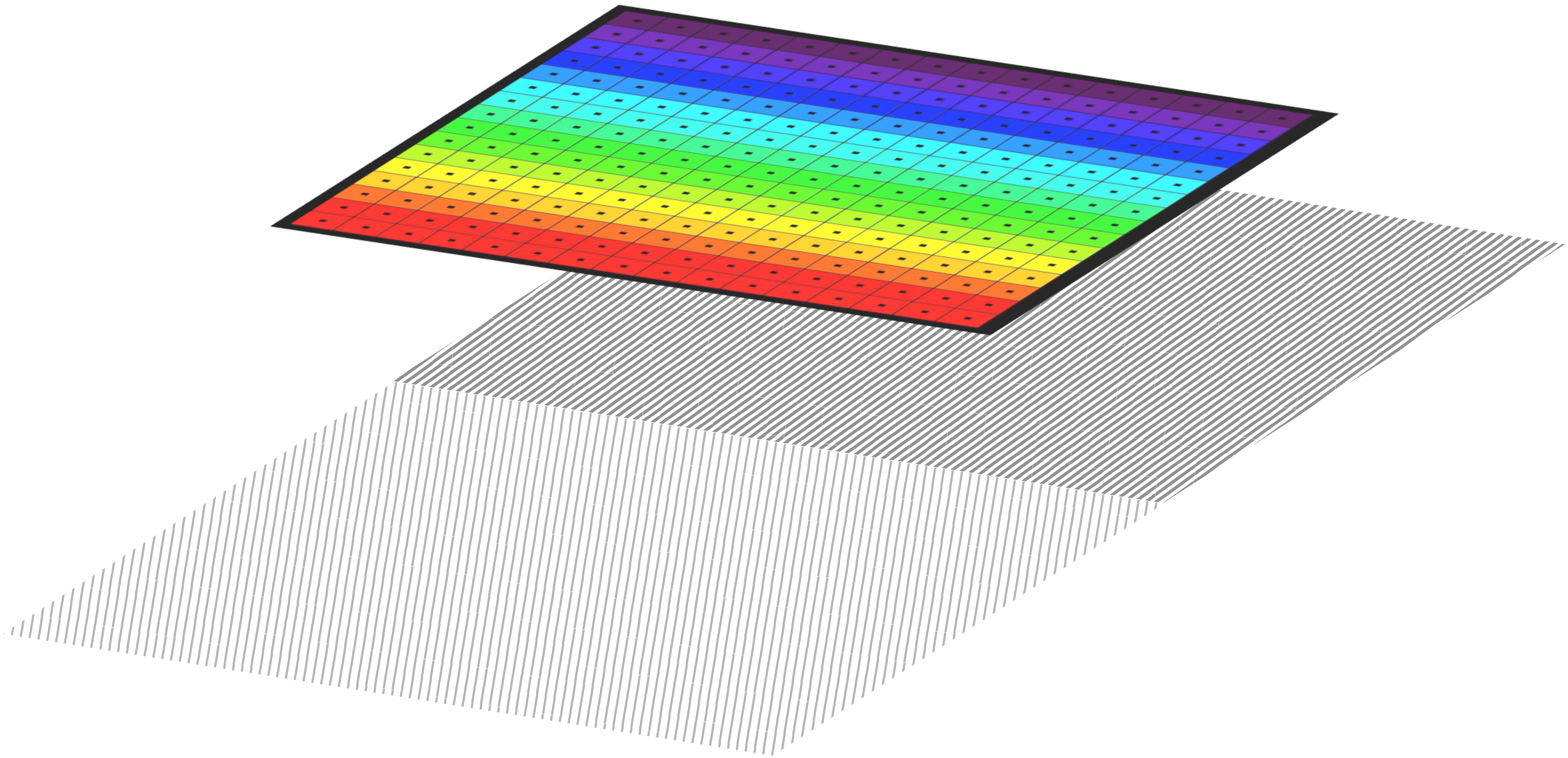
- Whiskbroom *(2-sided rotating mirror)*
- Revisit Cycle at Equator: 5 days
- Detector Elements/band: 256
- Mirror Scan Frequency: 14.2 RPM
- Swath Width: 600 km
- Long-track Swath: 15.4 km at Nadir
- Nadir Pixel GSD: 60 m

Pushbroom Observing System

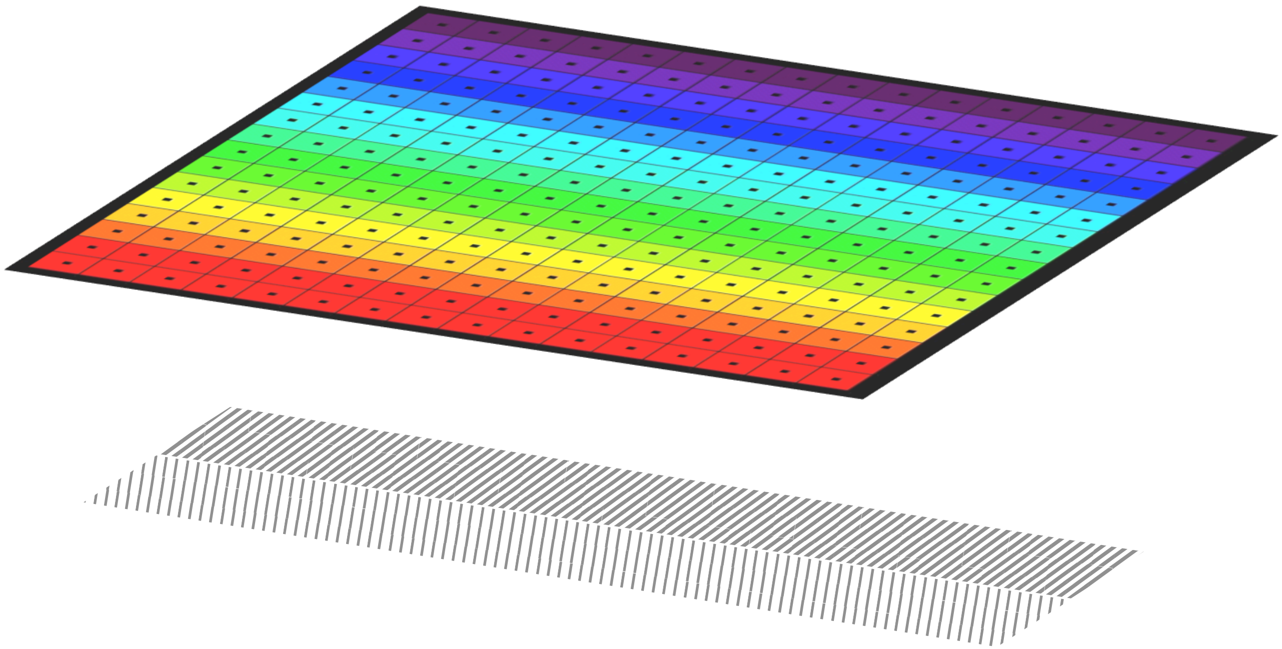
Depiction
-Grids are the detectors
-Spots are the IFOV centers
-Colors are the wavelengths



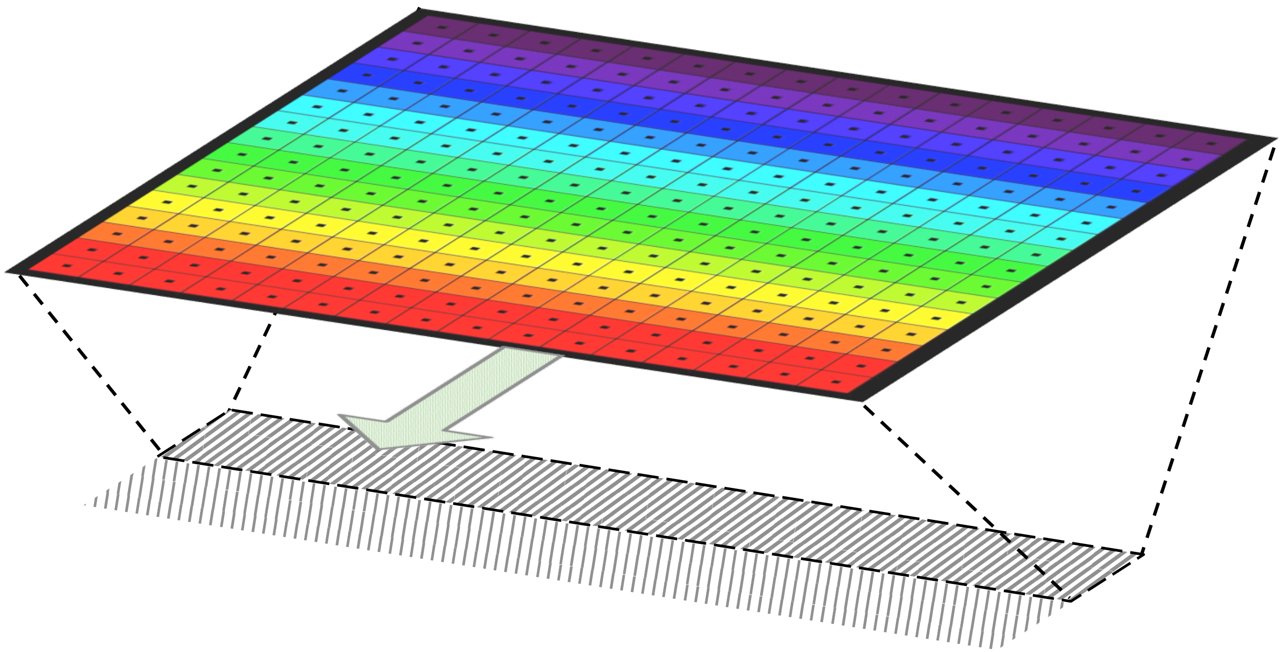
Pushbroom Observing System



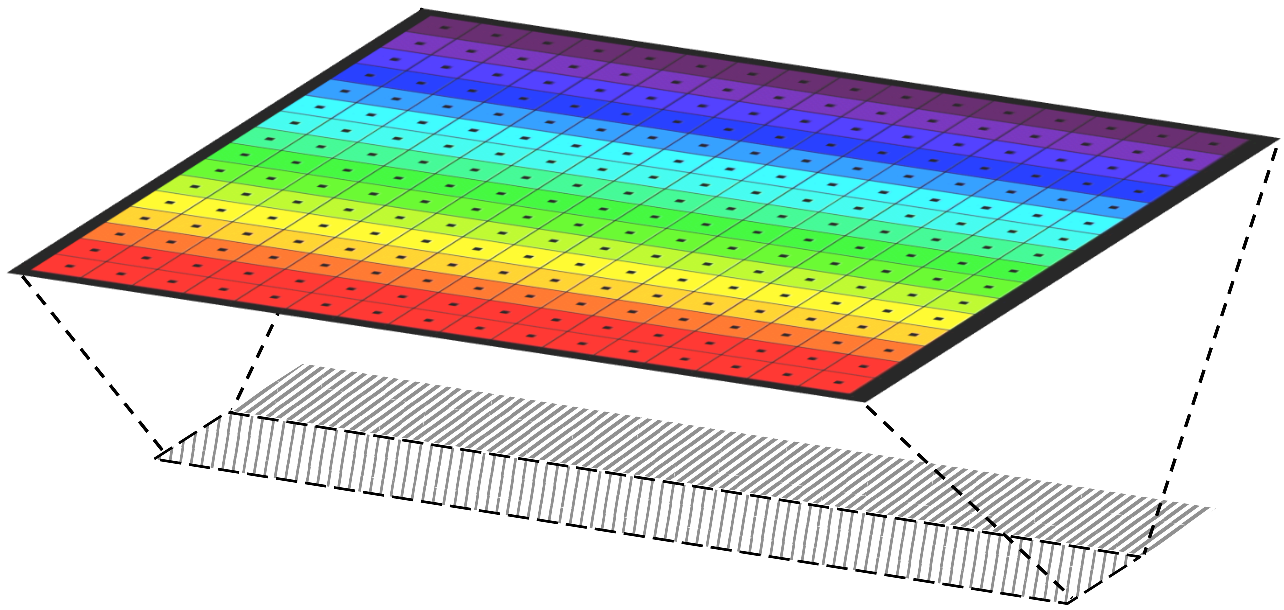
Pushbroom Observing System



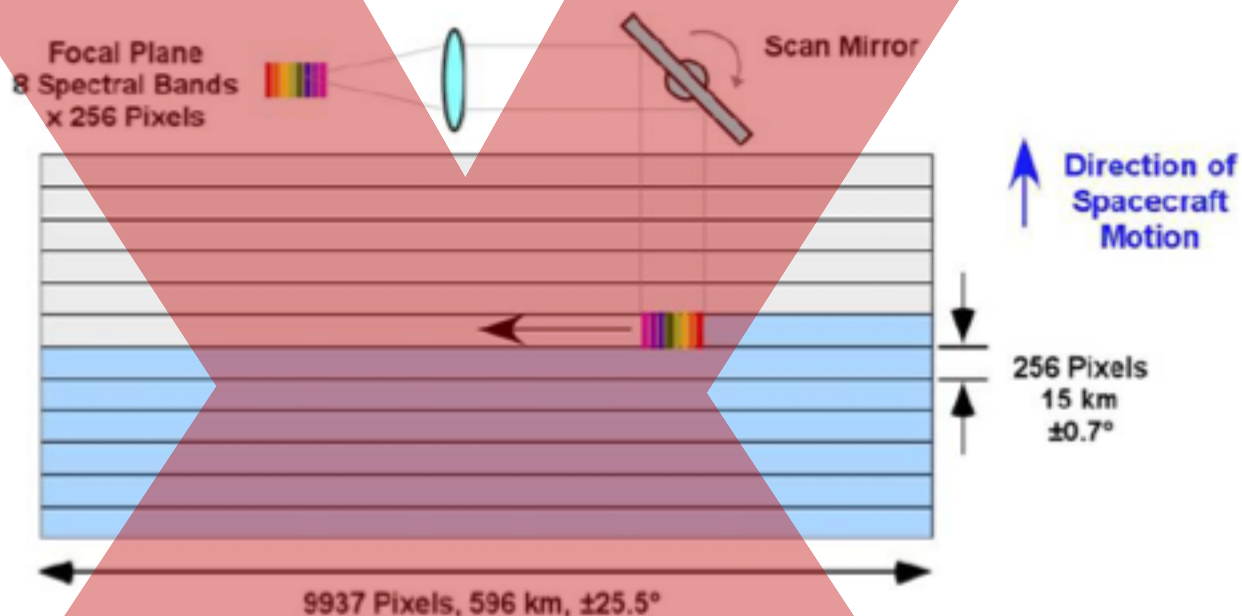
Pushbroom Observing System



Pushbroom Observing System

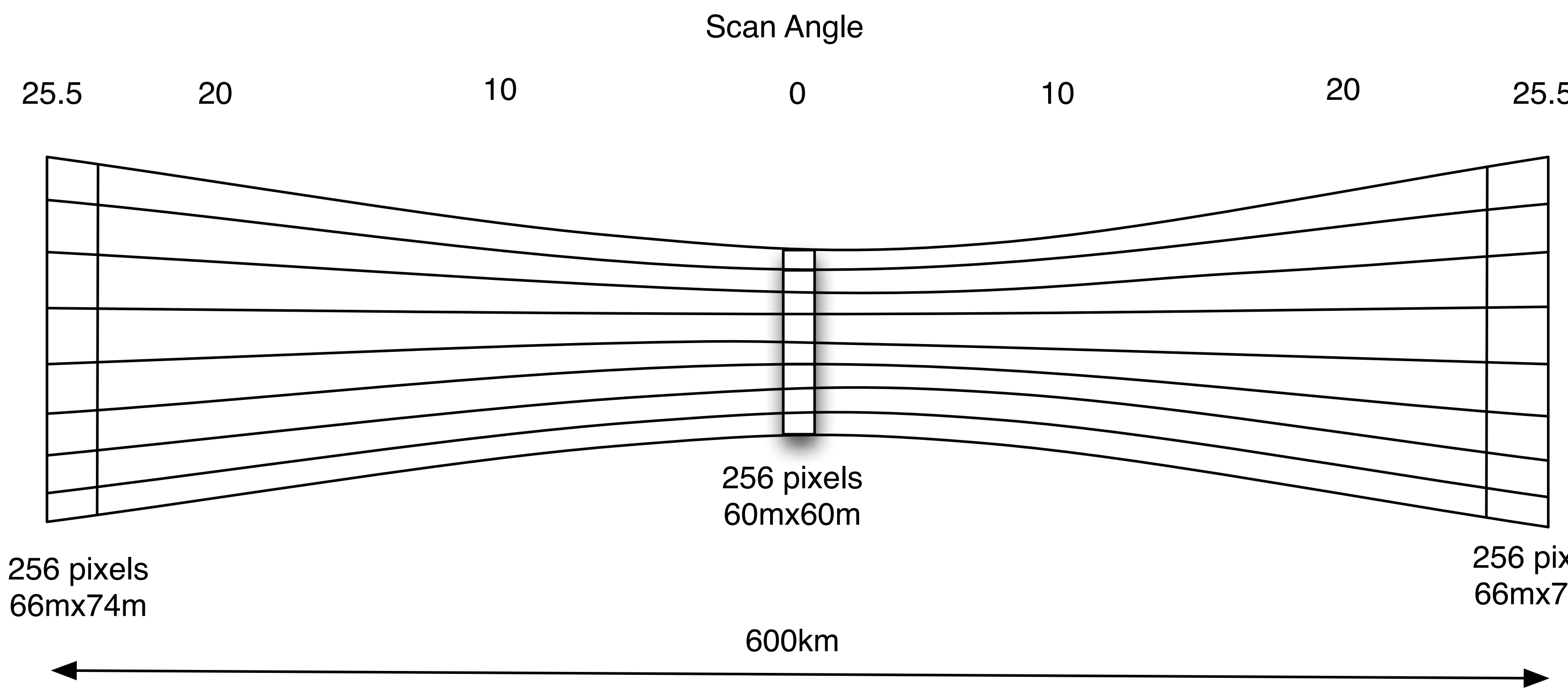


HyspIRI TIR Scan Method

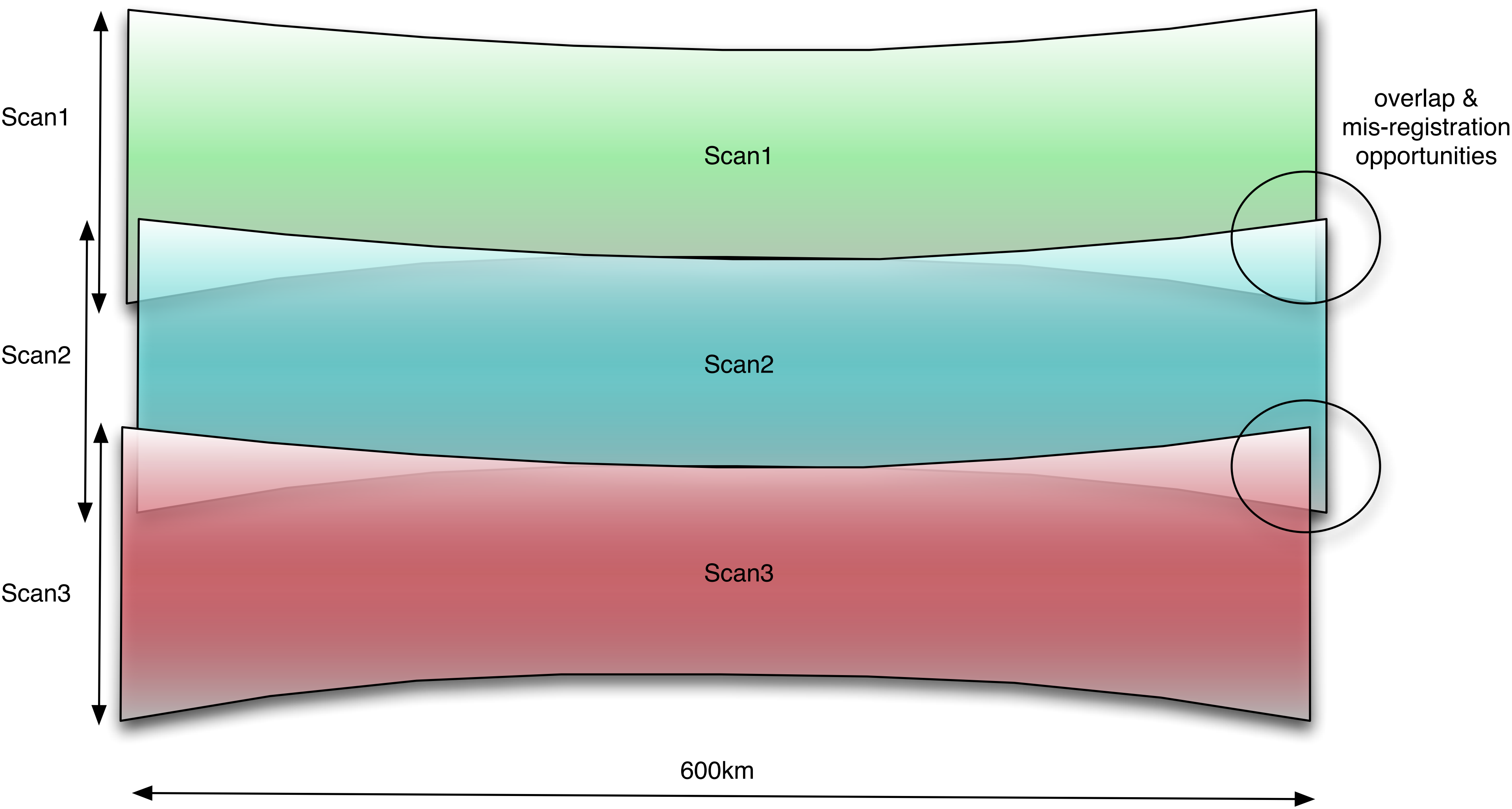


8 Thermal bands
Band to band co-registration: 0.2 pixels (12m)
Pointing Knowledge: 10 arcsec (0.5 pixels, 30m)

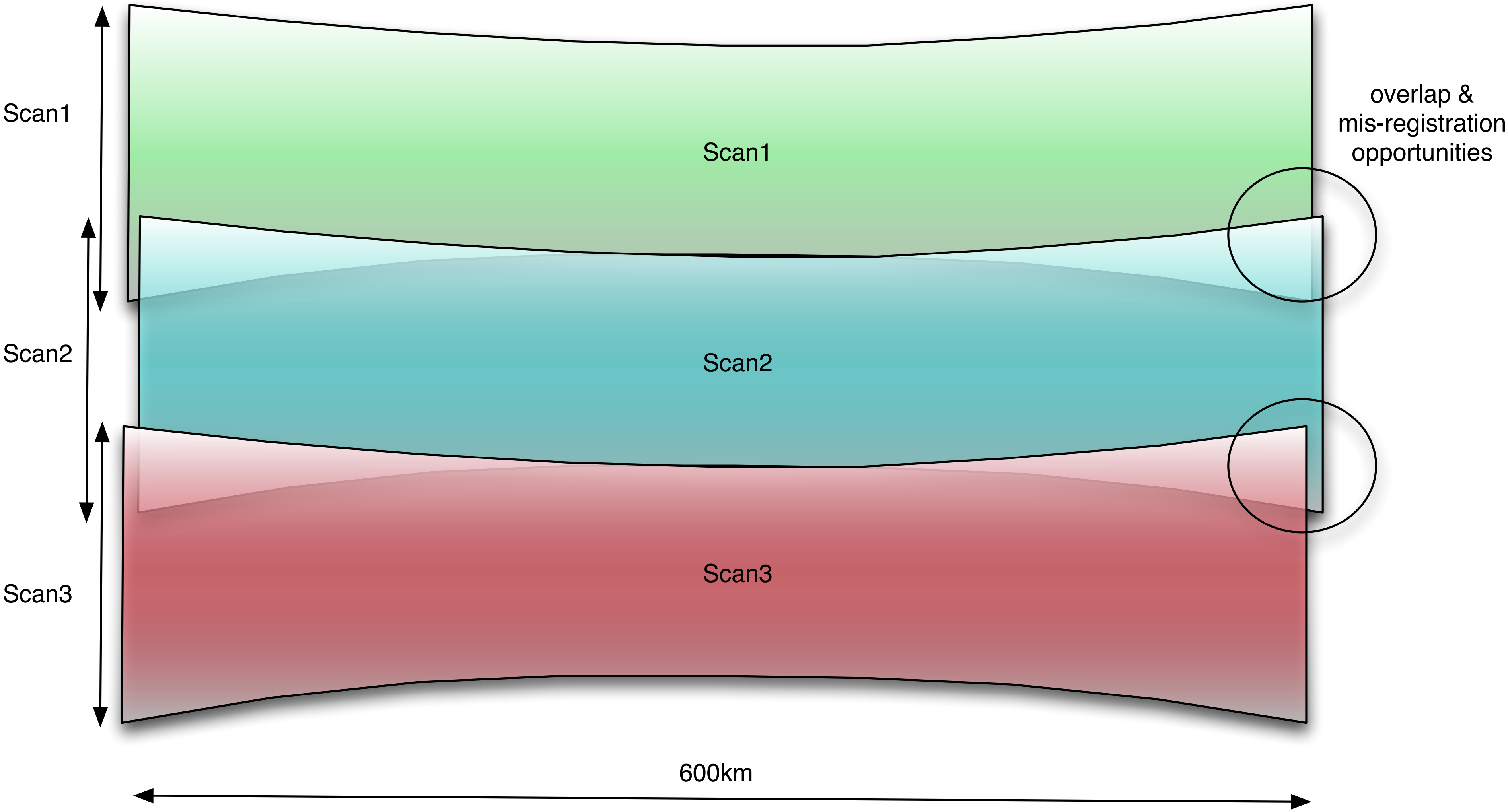
HyspIRI TIR Scan Method



HyspIRI TIR Scan Method



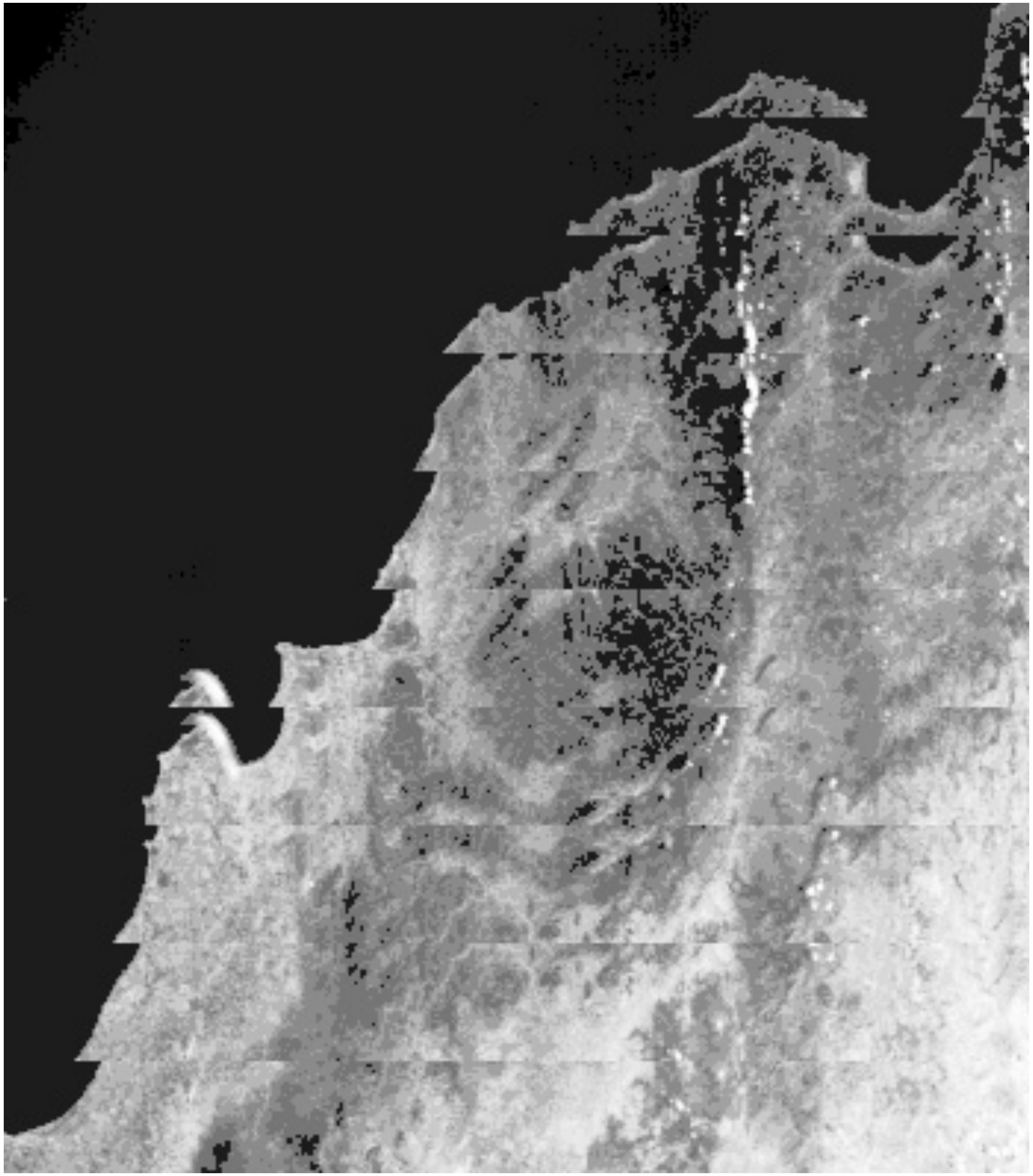
HyspIRI TIR Scan Method



Odd numbered scans are acquired with scan mirror side 1
Even numbered scans are acquired with scan mirror side 2

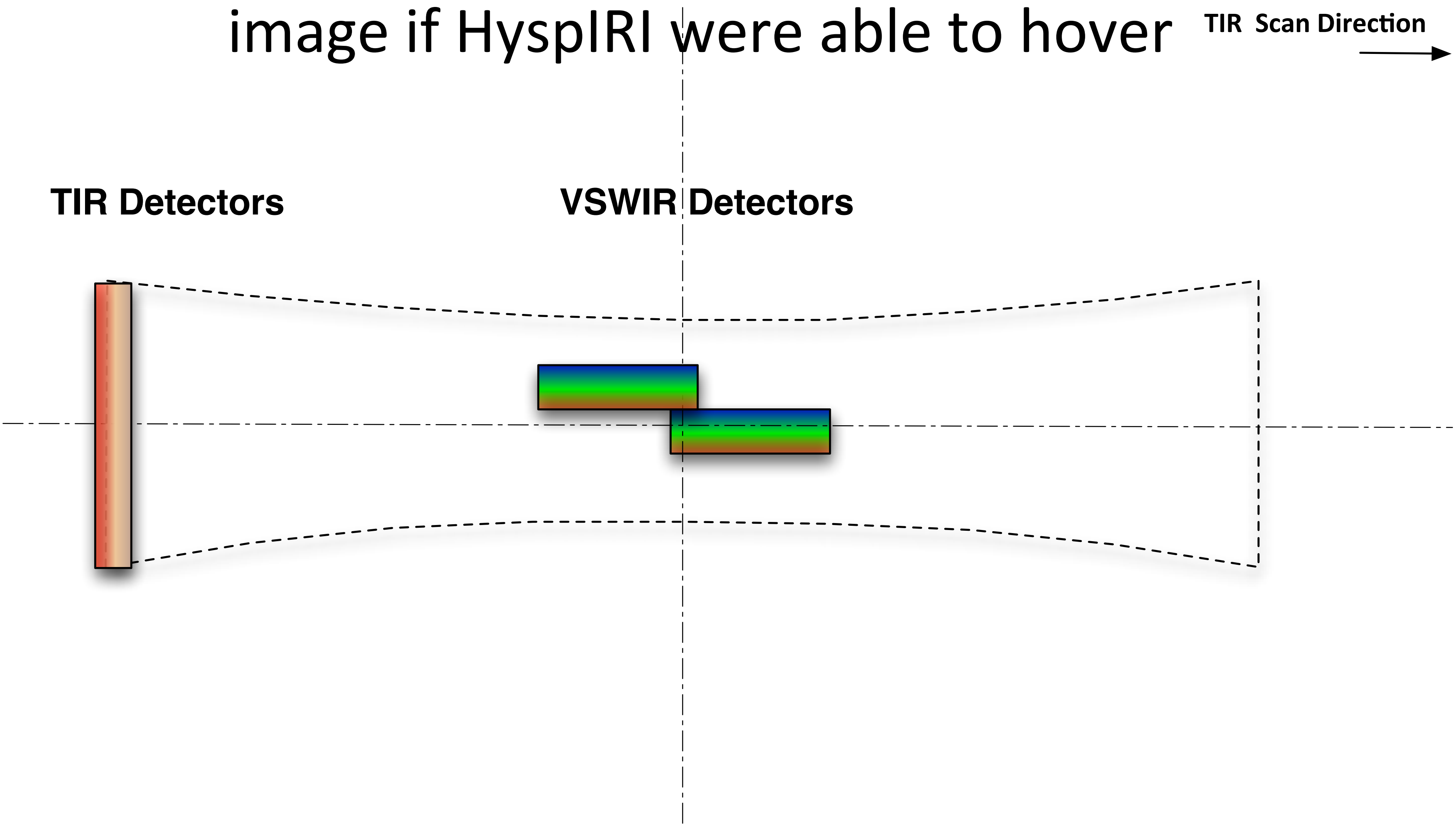
The Bow-Tie effect is an artifact of the arrangement of sensors on the MODIS instrument.

An example of the bow-tie effect (near the right-hand edge of a 250 m band) :

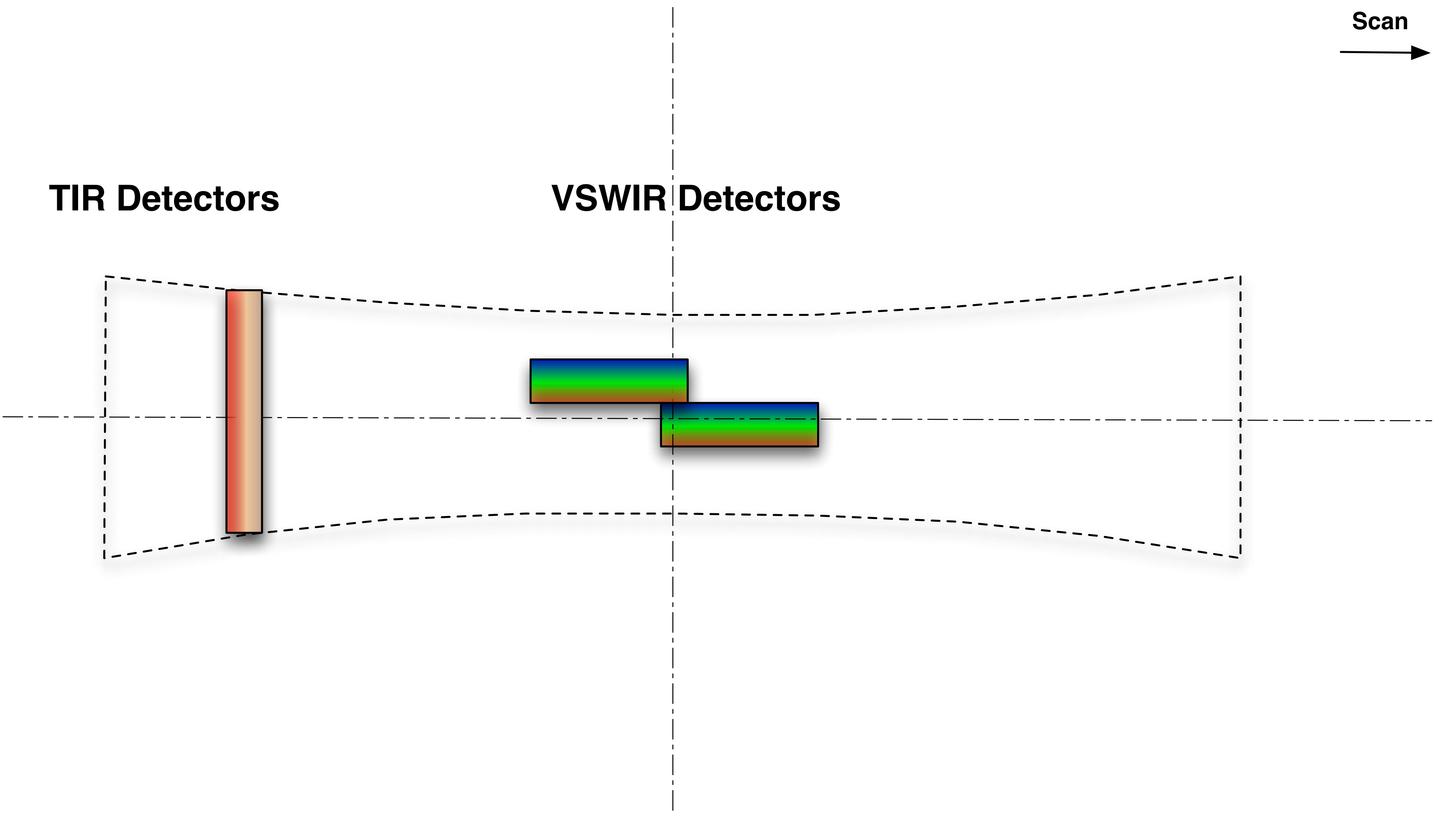


Stationary View

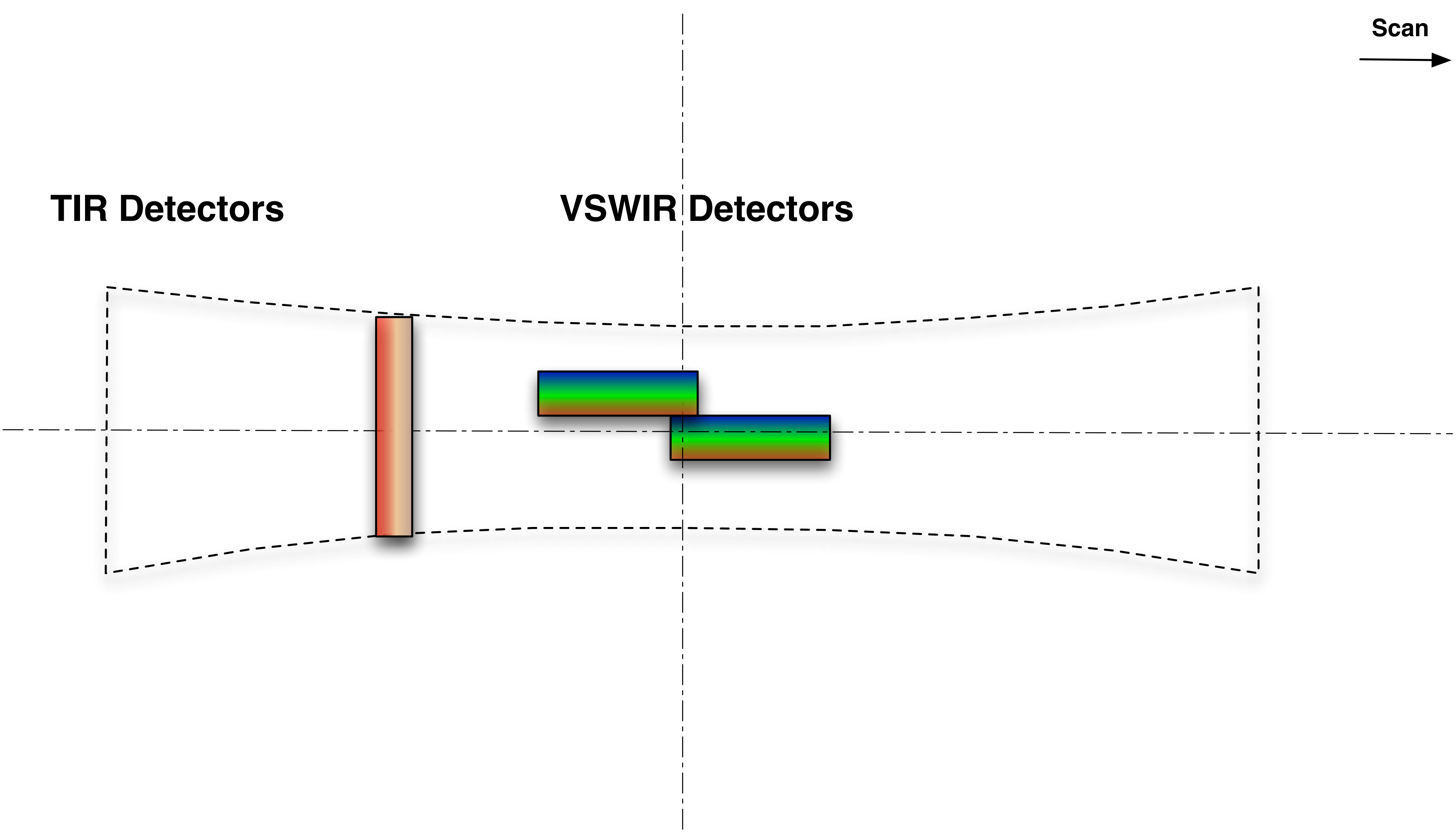
How the VSWIR and TIR would image if HyspIRI were able to hover



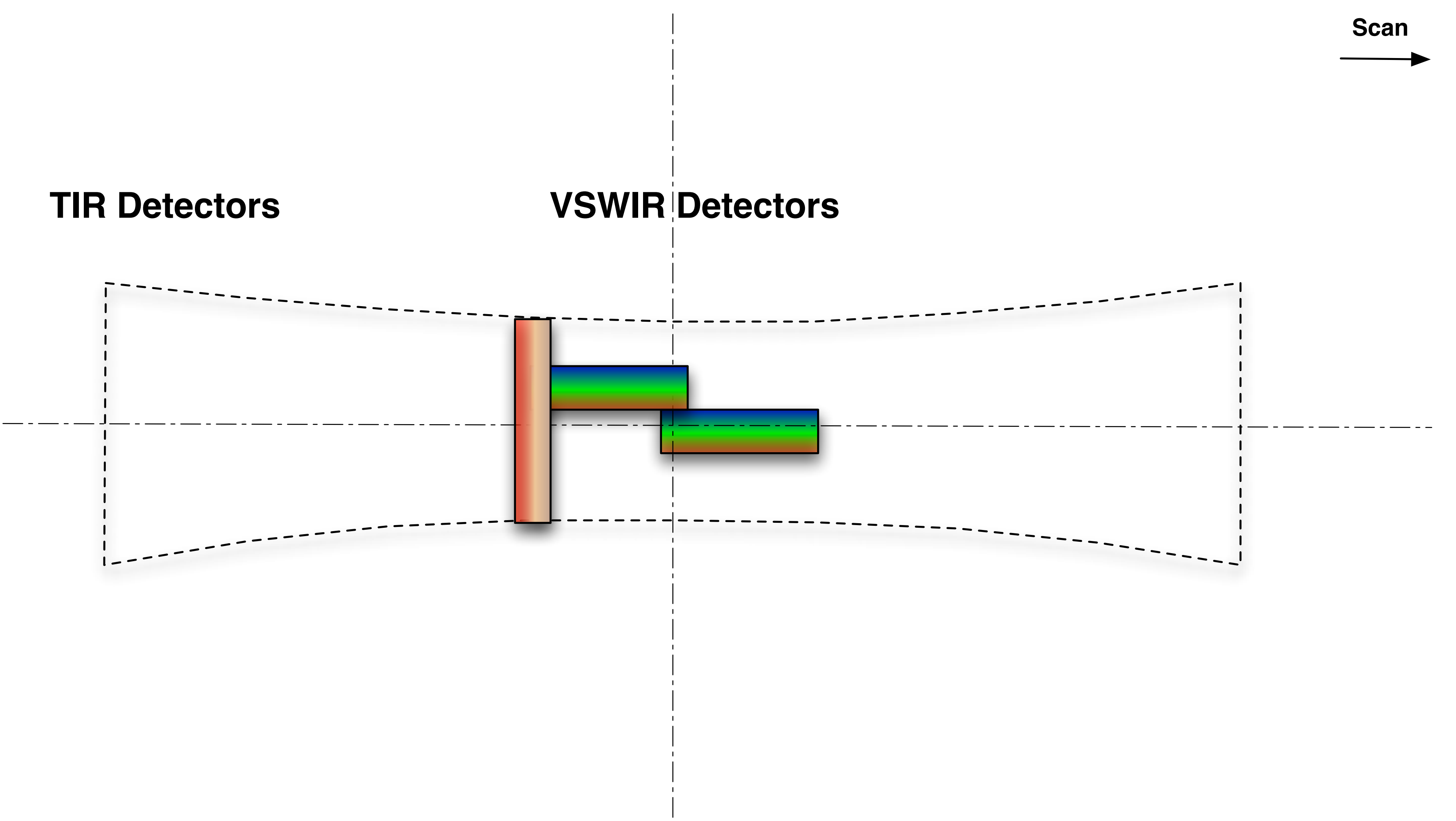
Stationary View



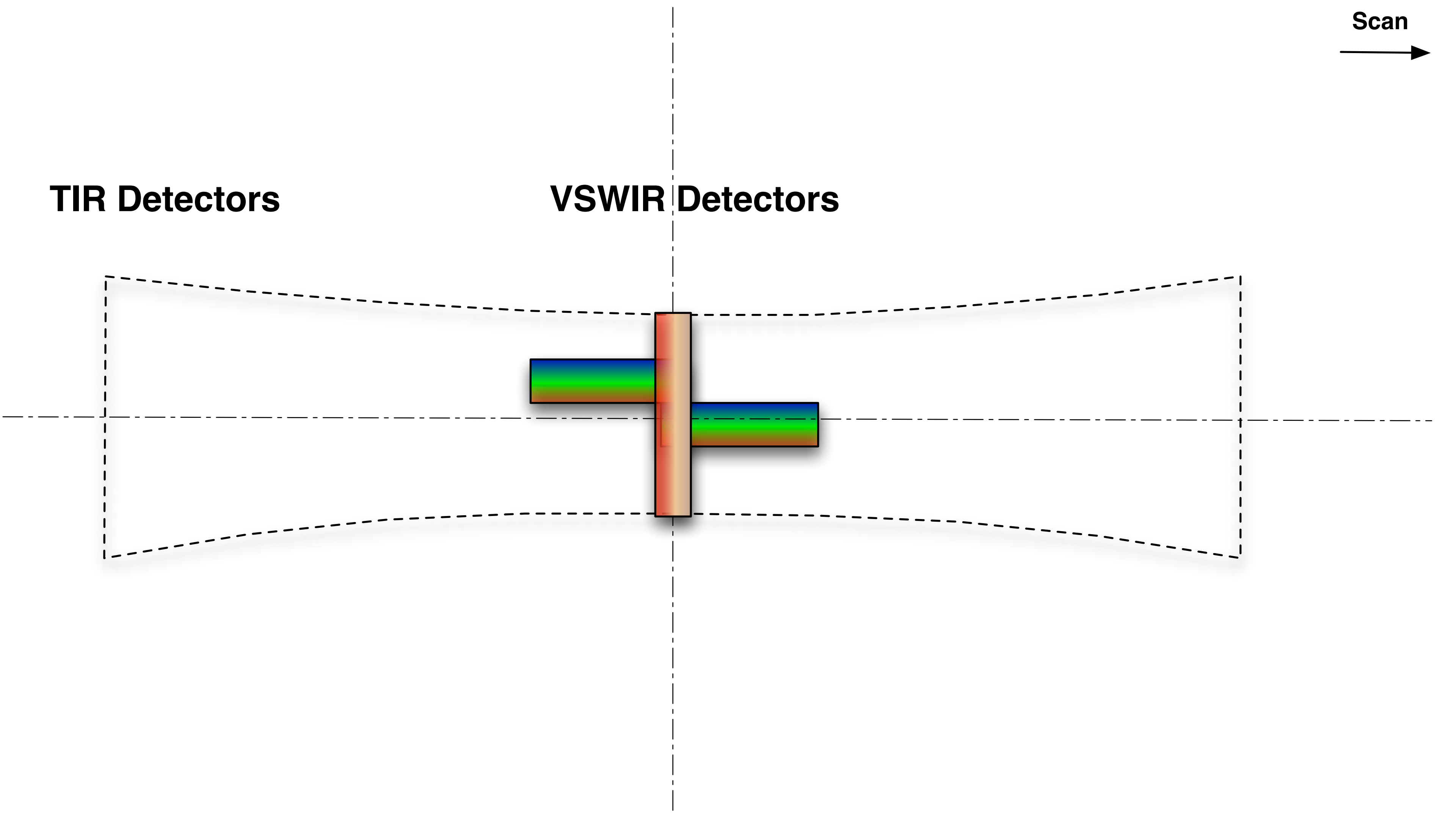
Stationary View



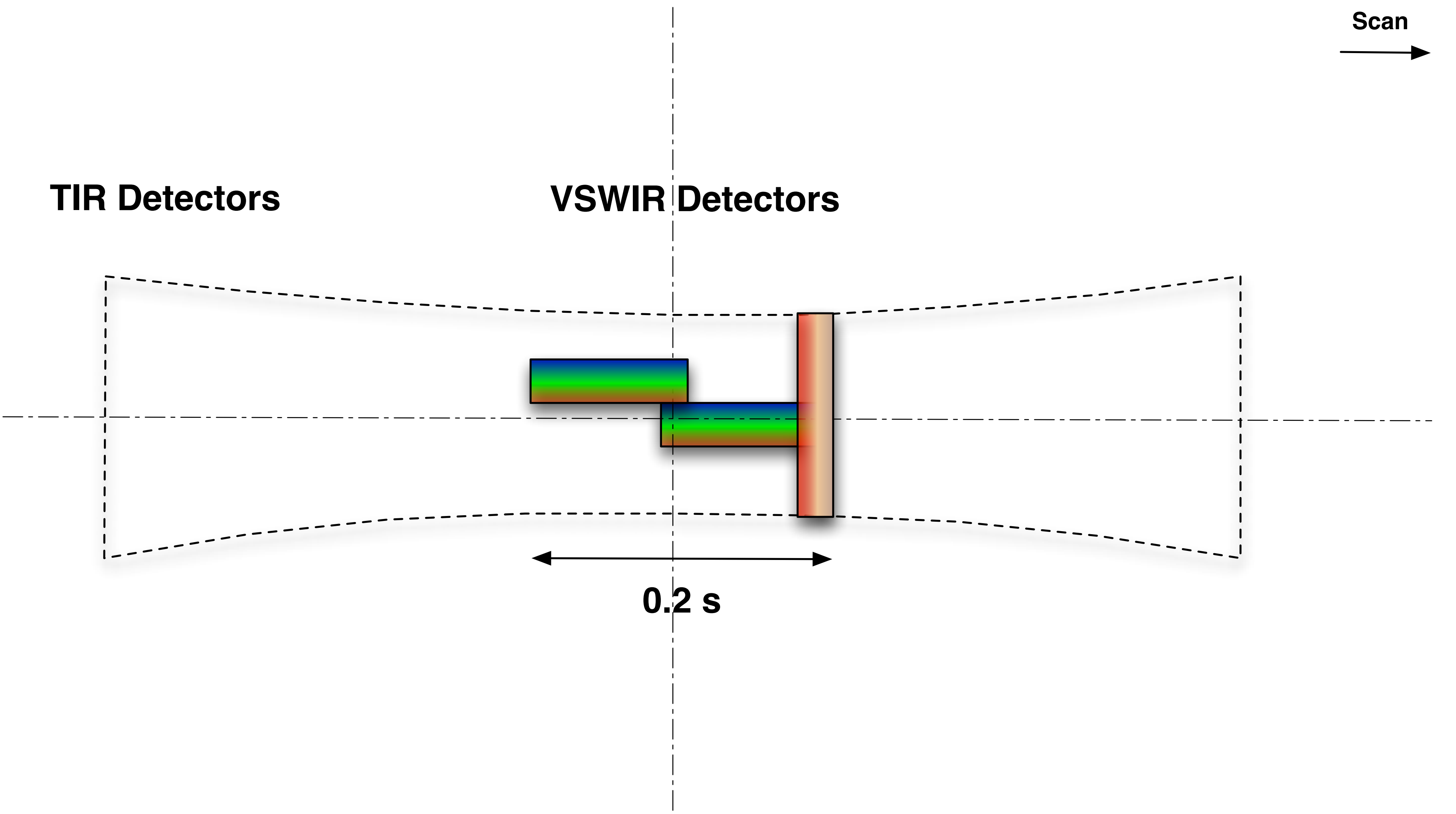
Stationary View



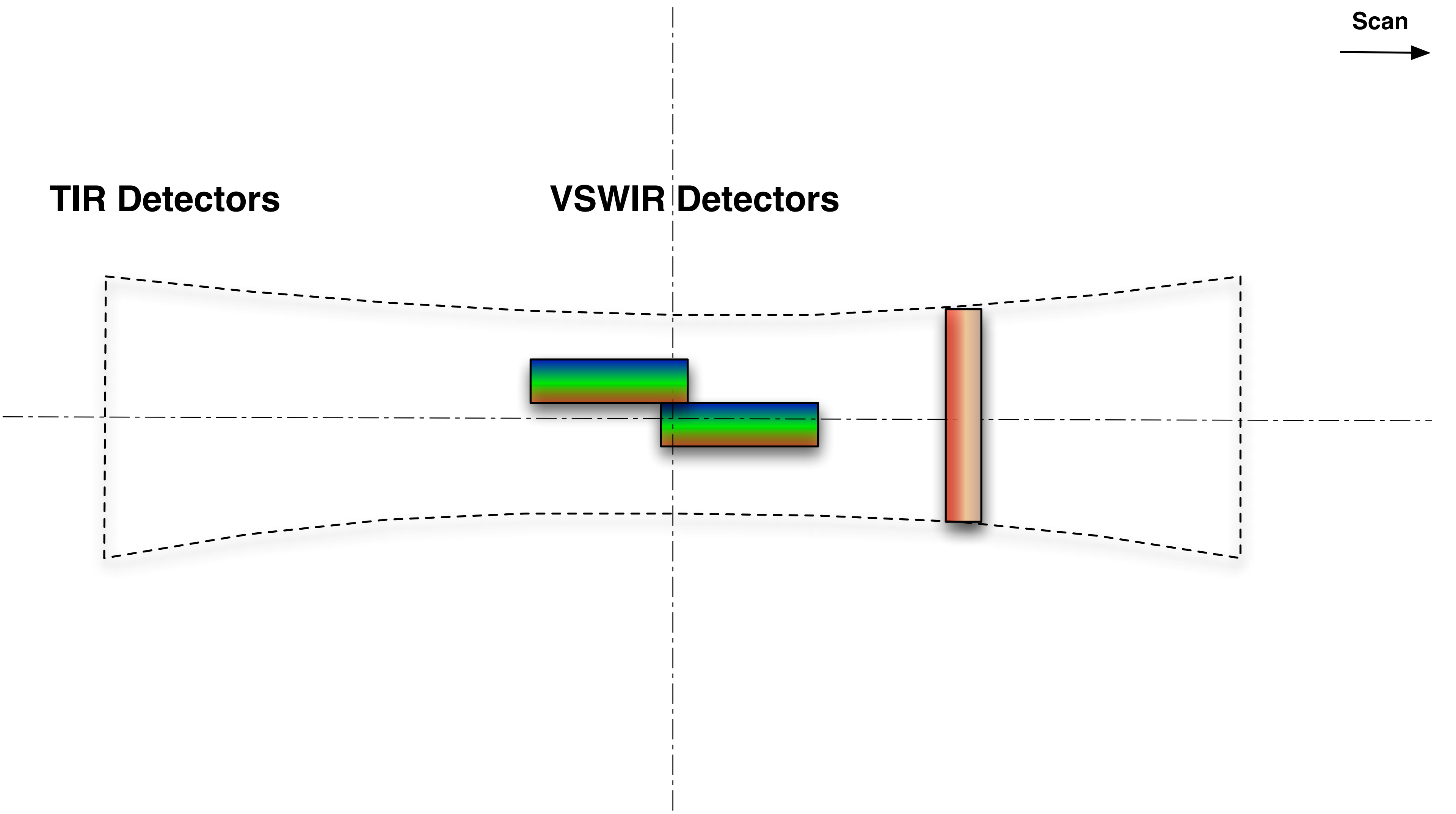
Stationary View



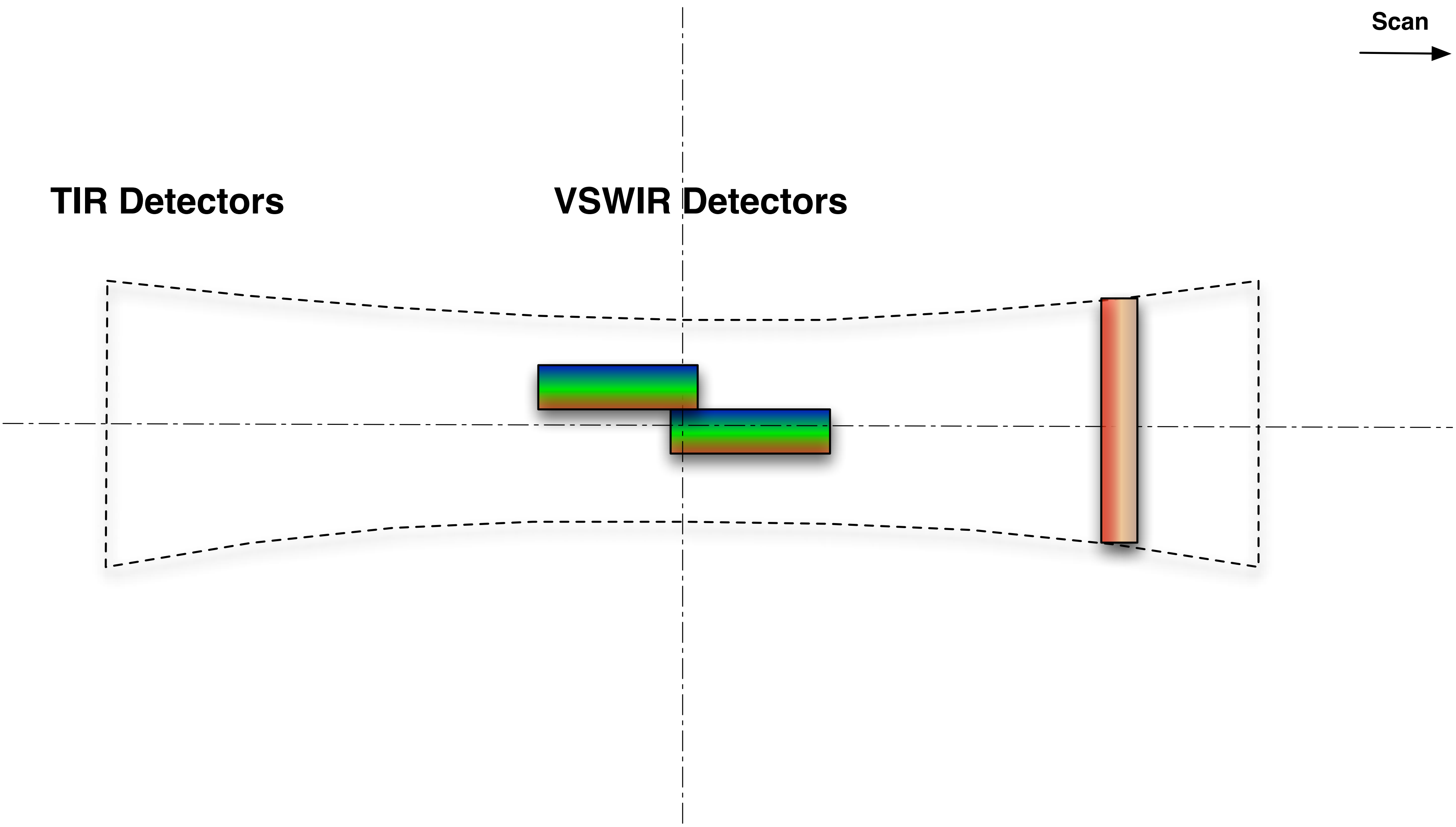
Stationary View



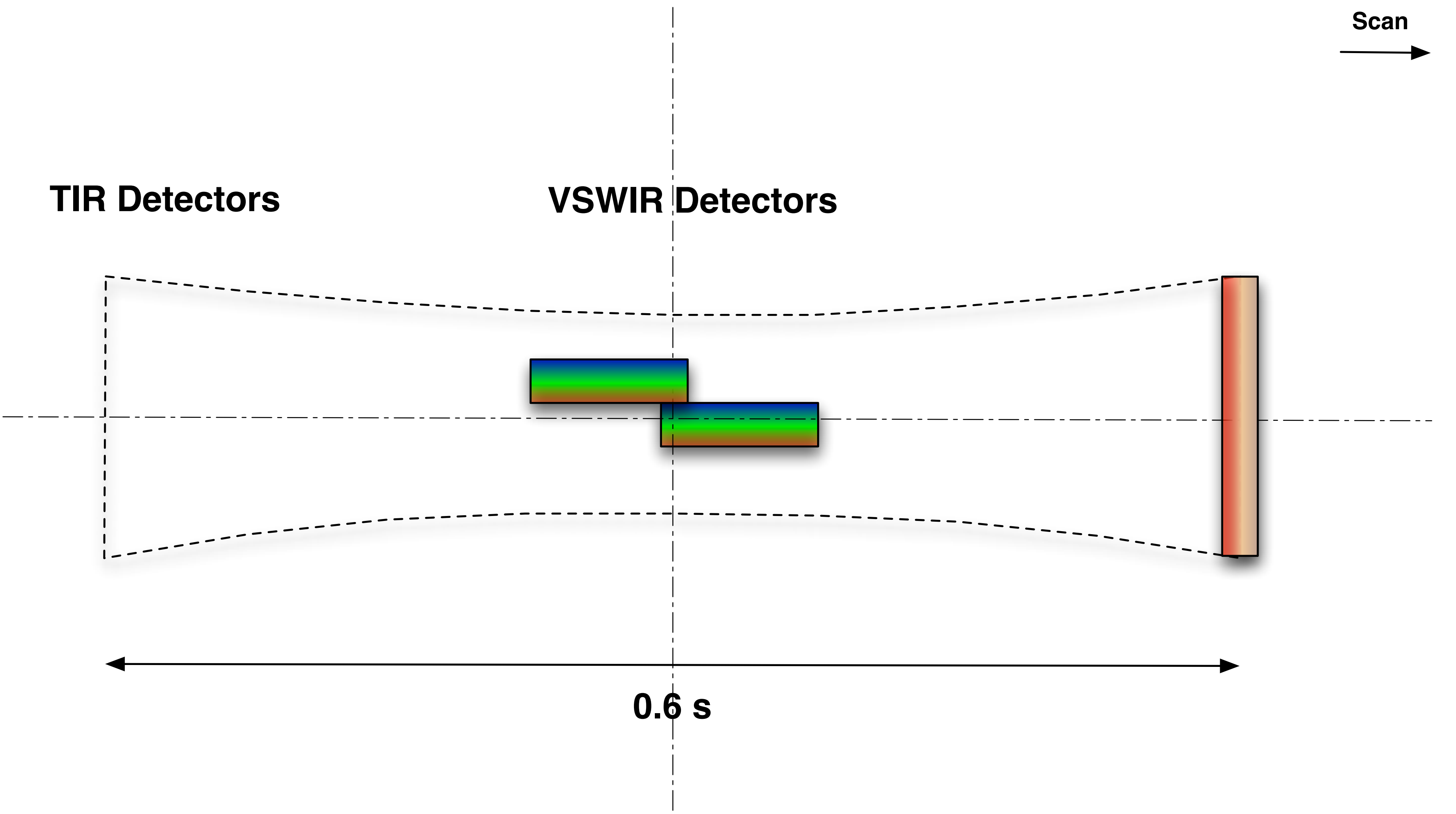
Stationary View



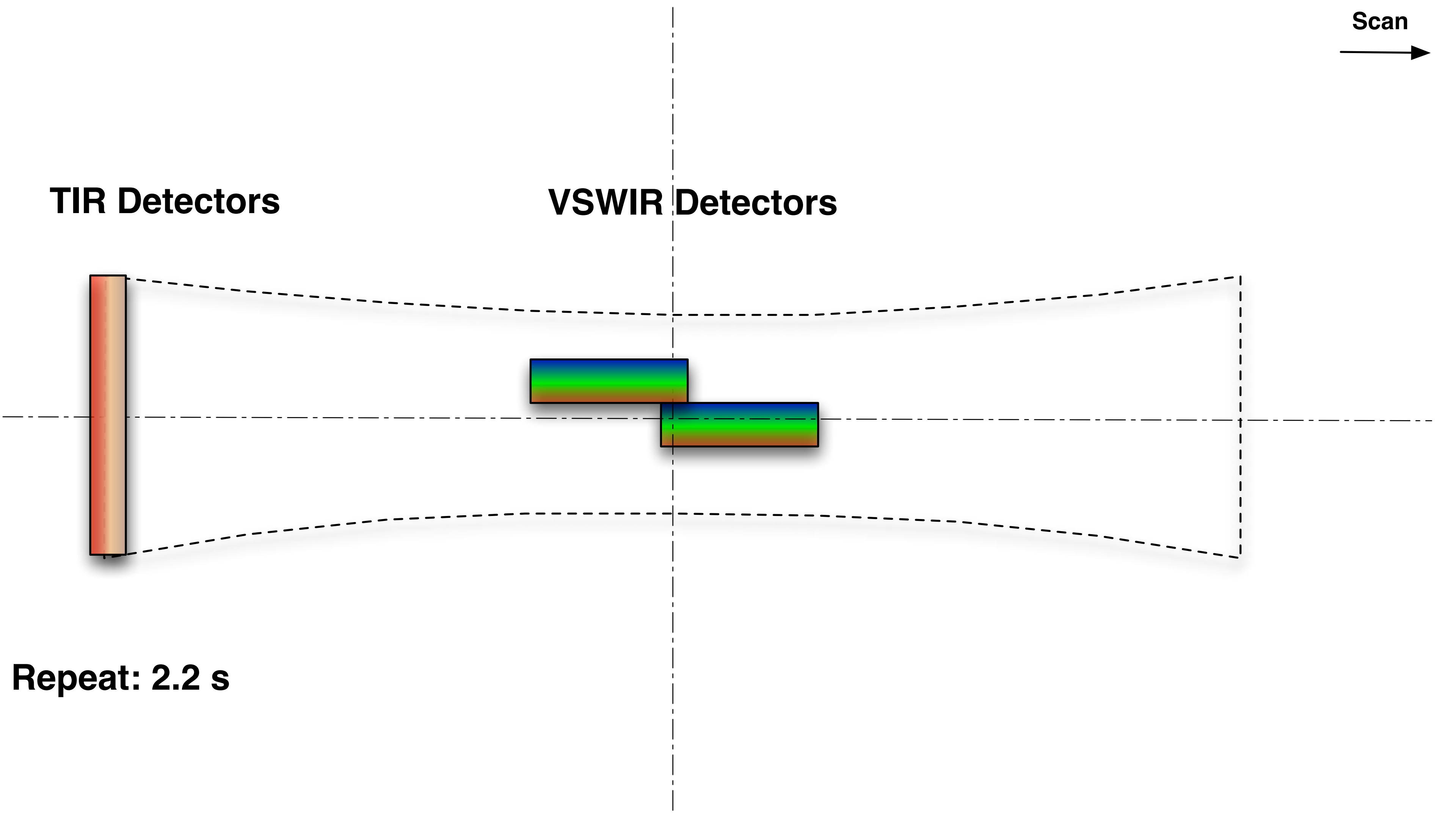
Stationary View



Stationary View

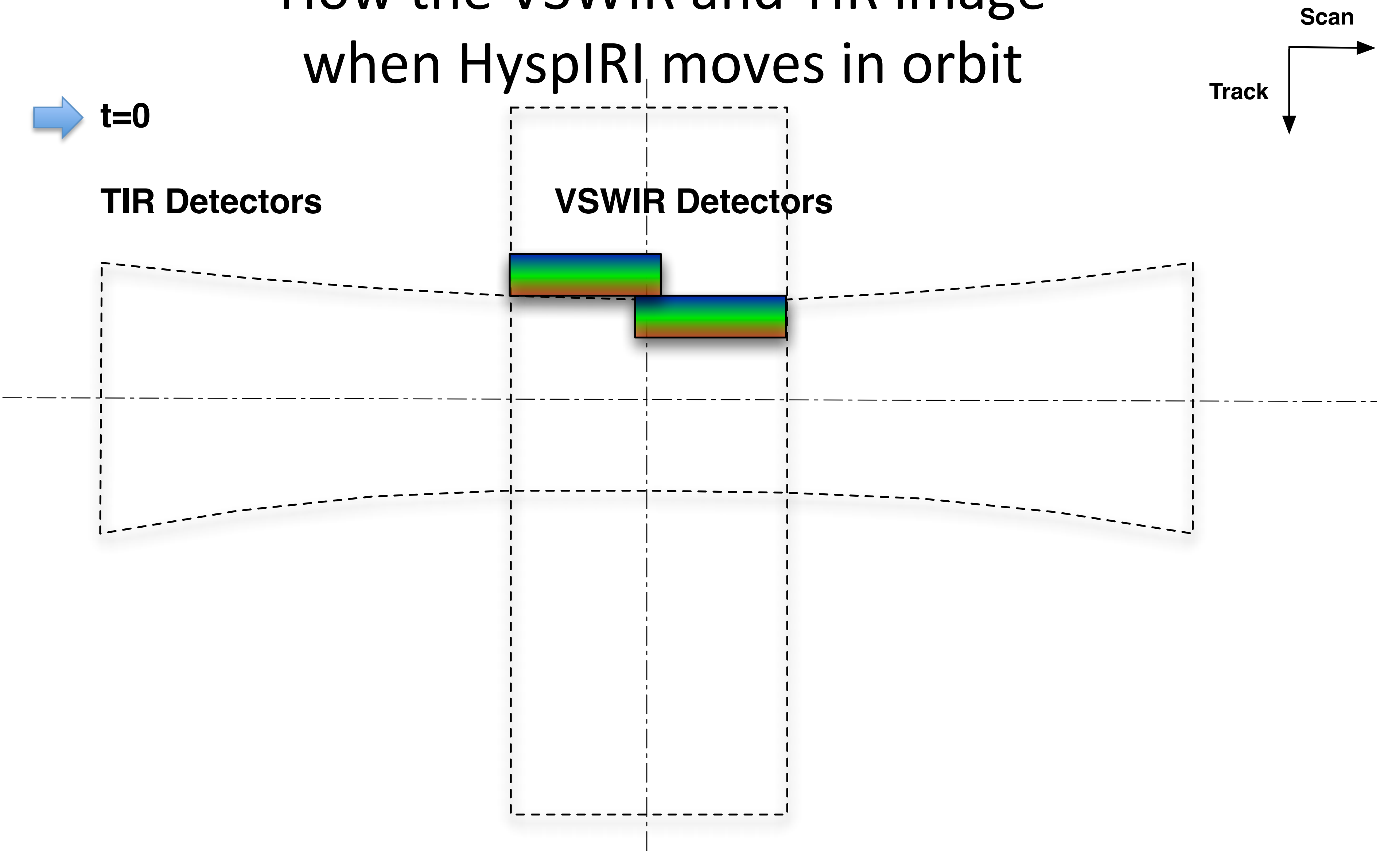


Stationary View

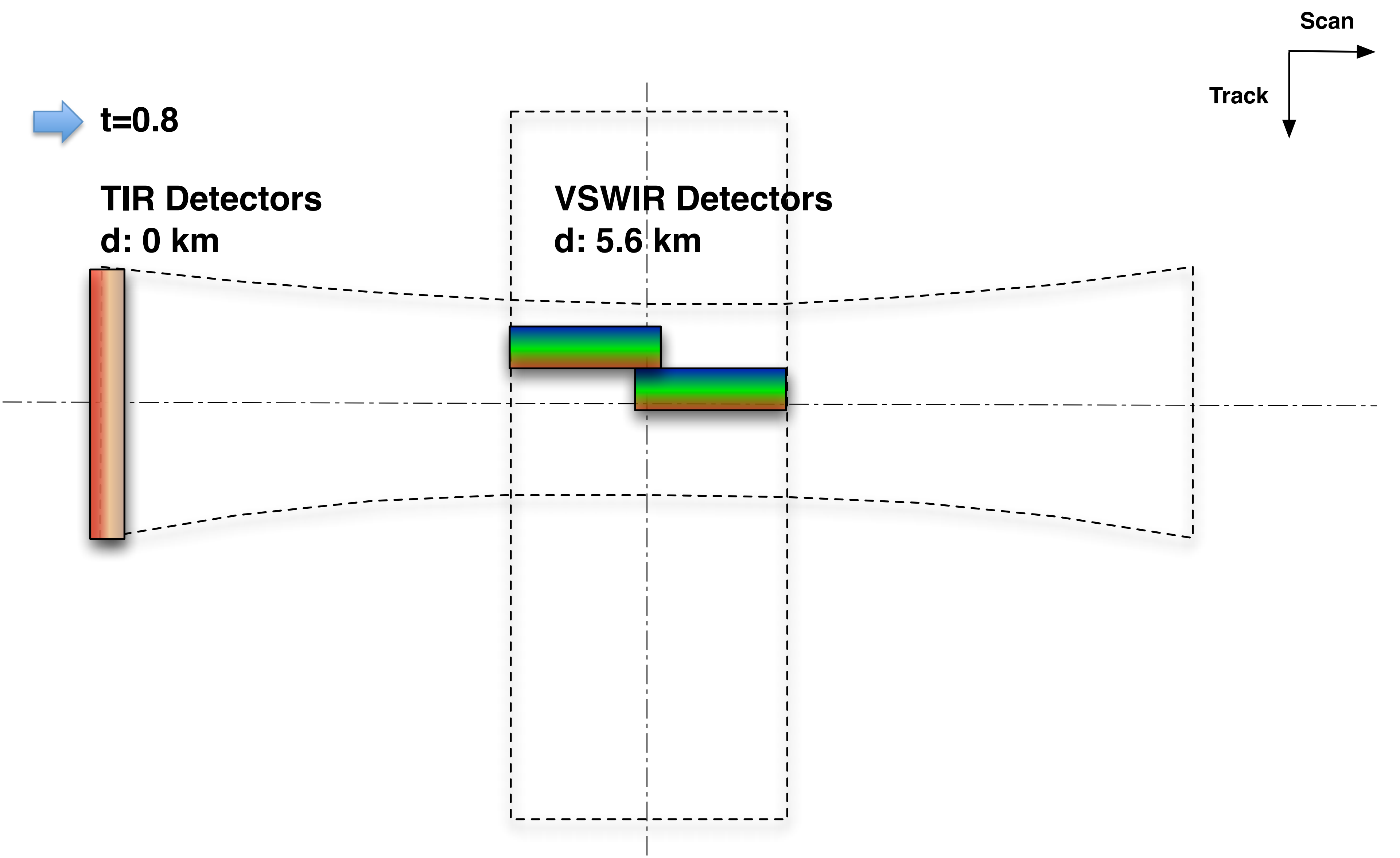


With Spacecraft Forward Movement

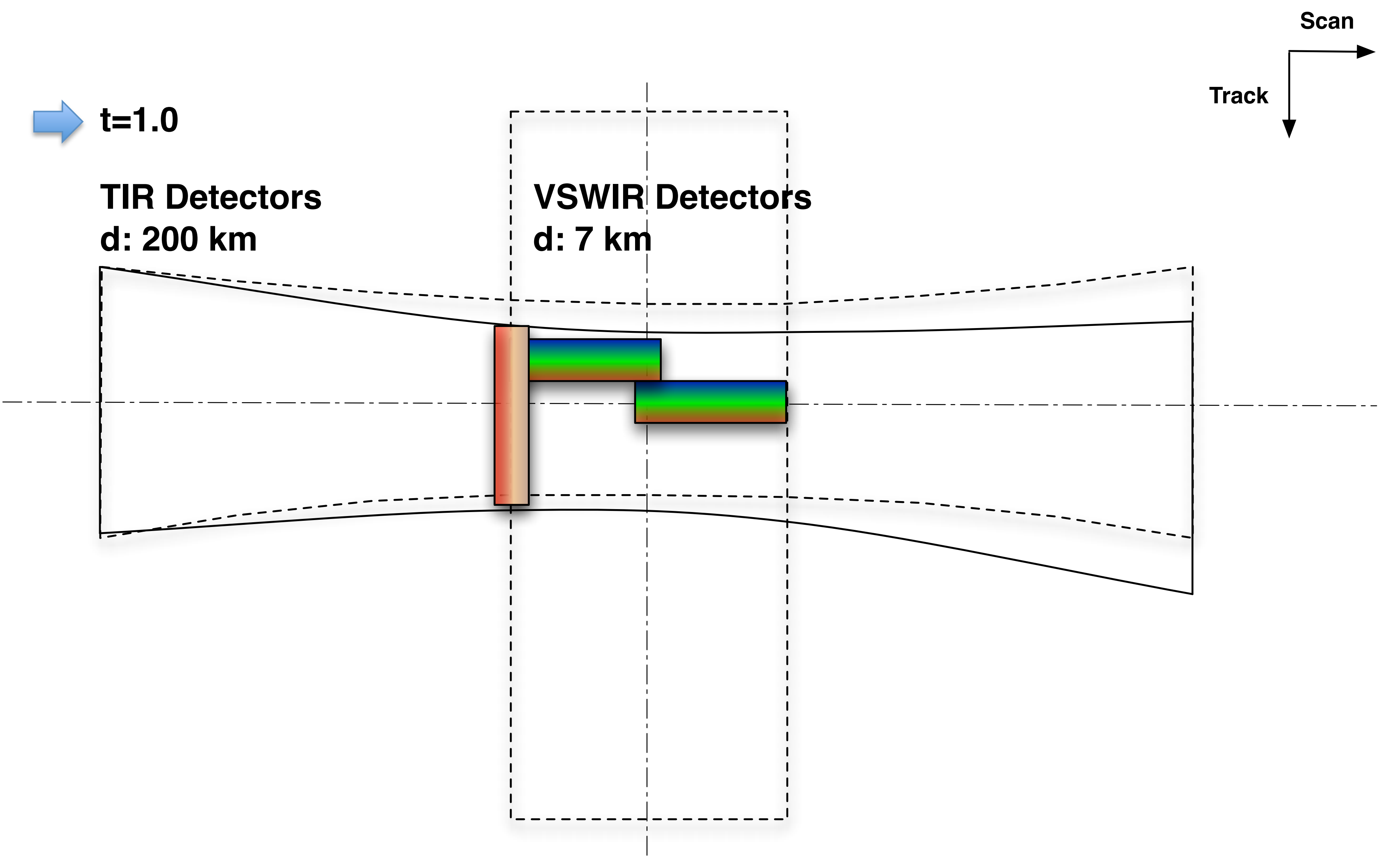
How the VSWIR and TIR image when HyspIRI moves in orbit



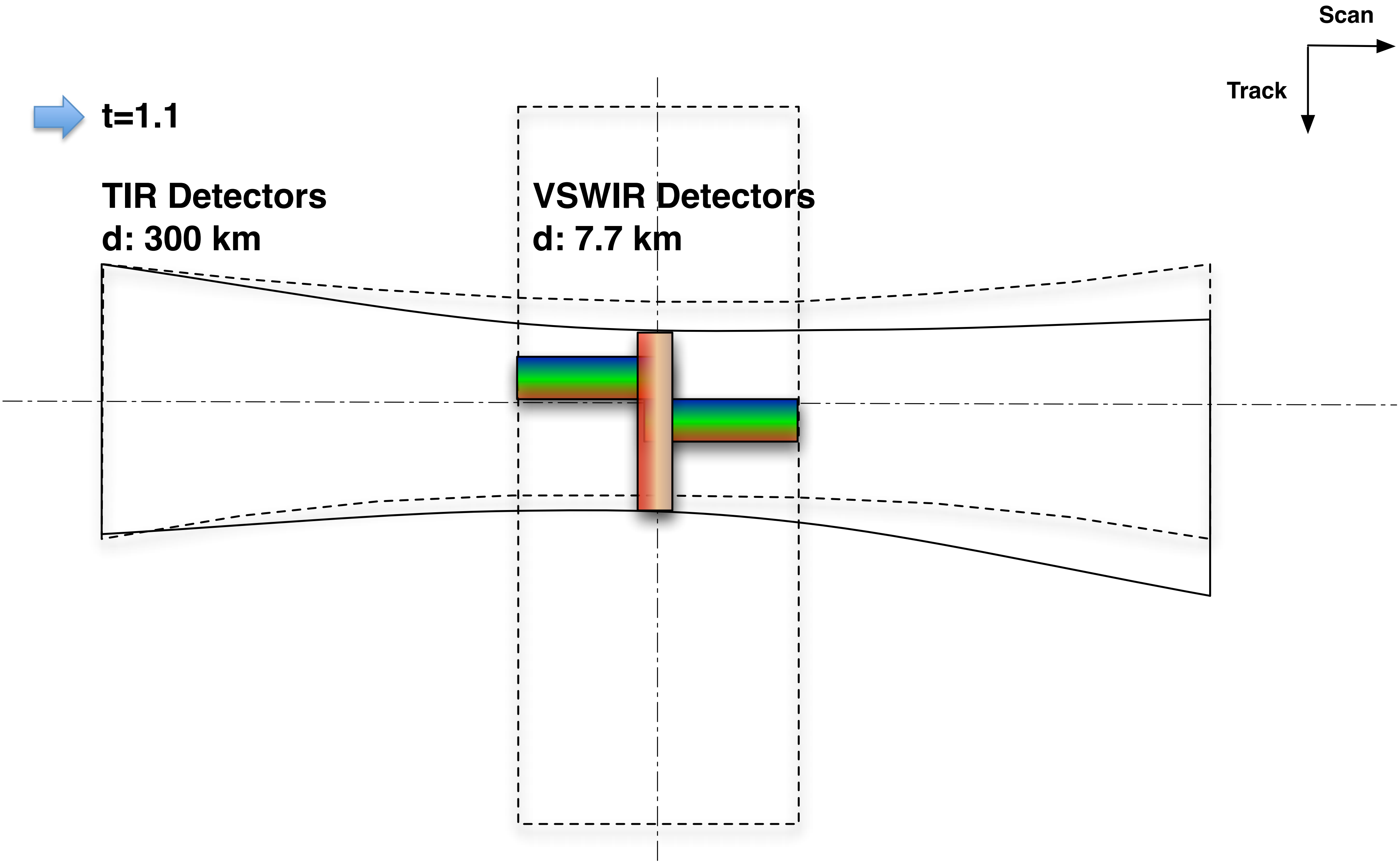
With Spacecraft Forward Movement



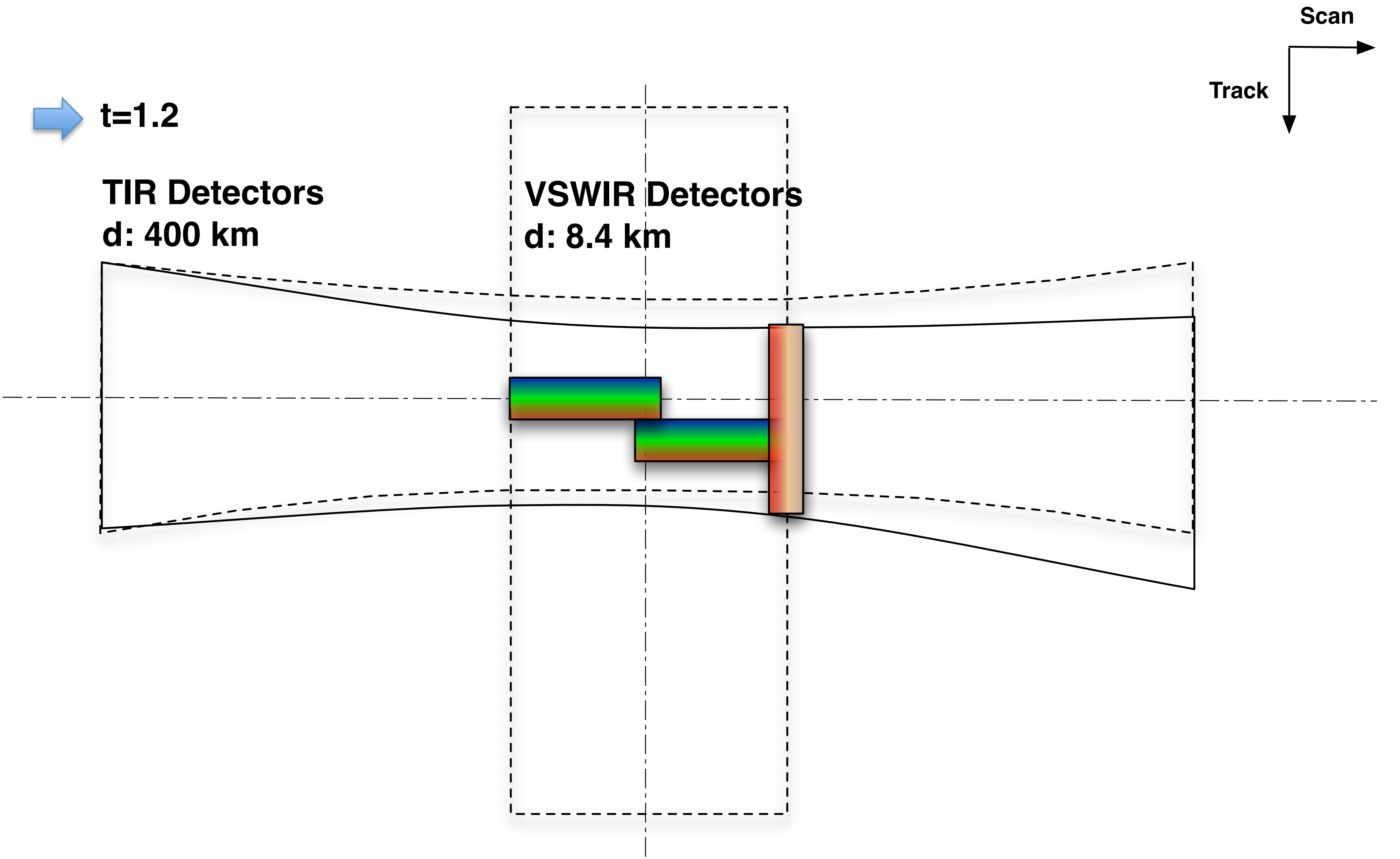
With Spacecraft Forward Movement



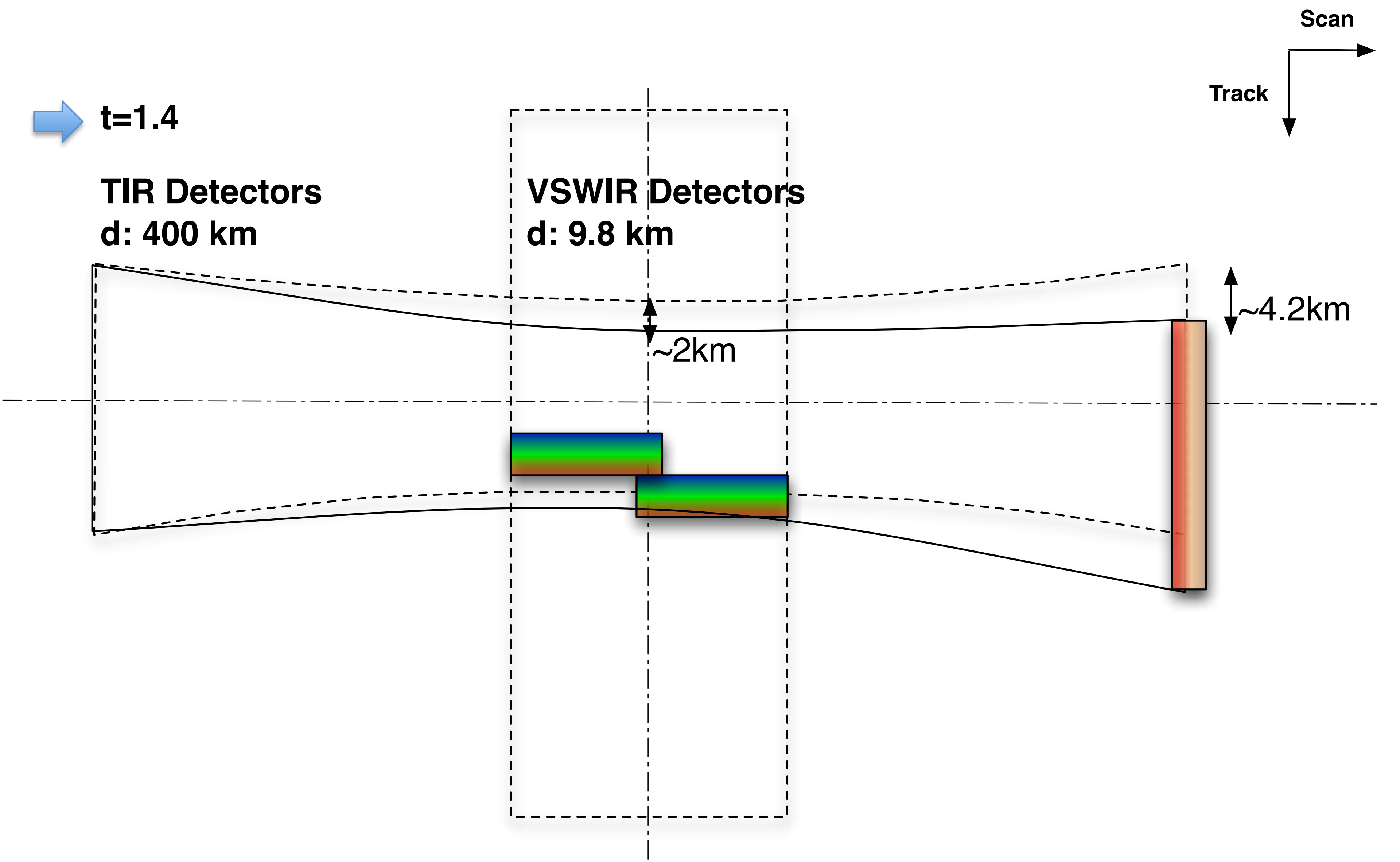
With Spacecraft Forward Movement



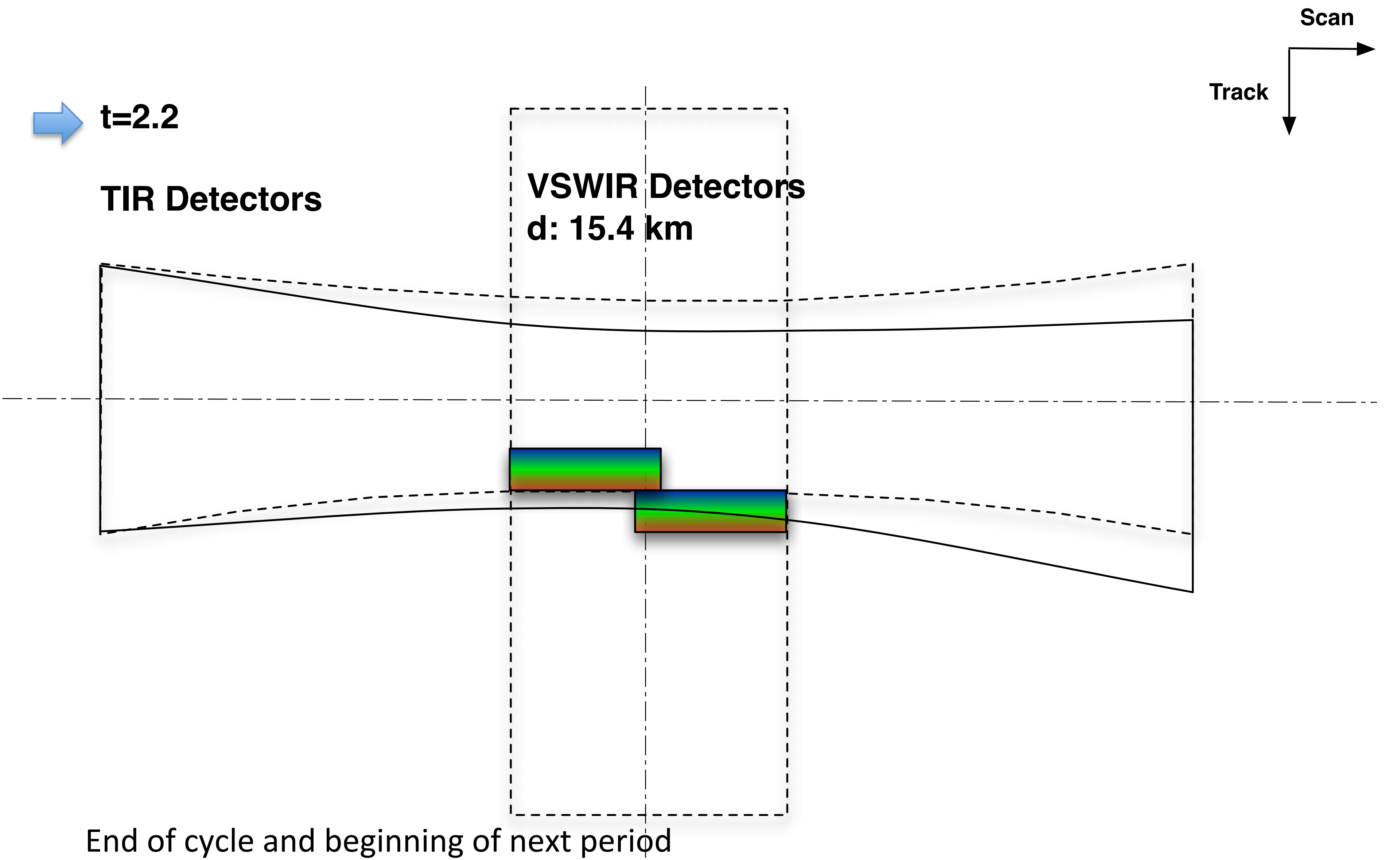
With Spacecraft Forward Movement



With Spacecraft Forward Movement

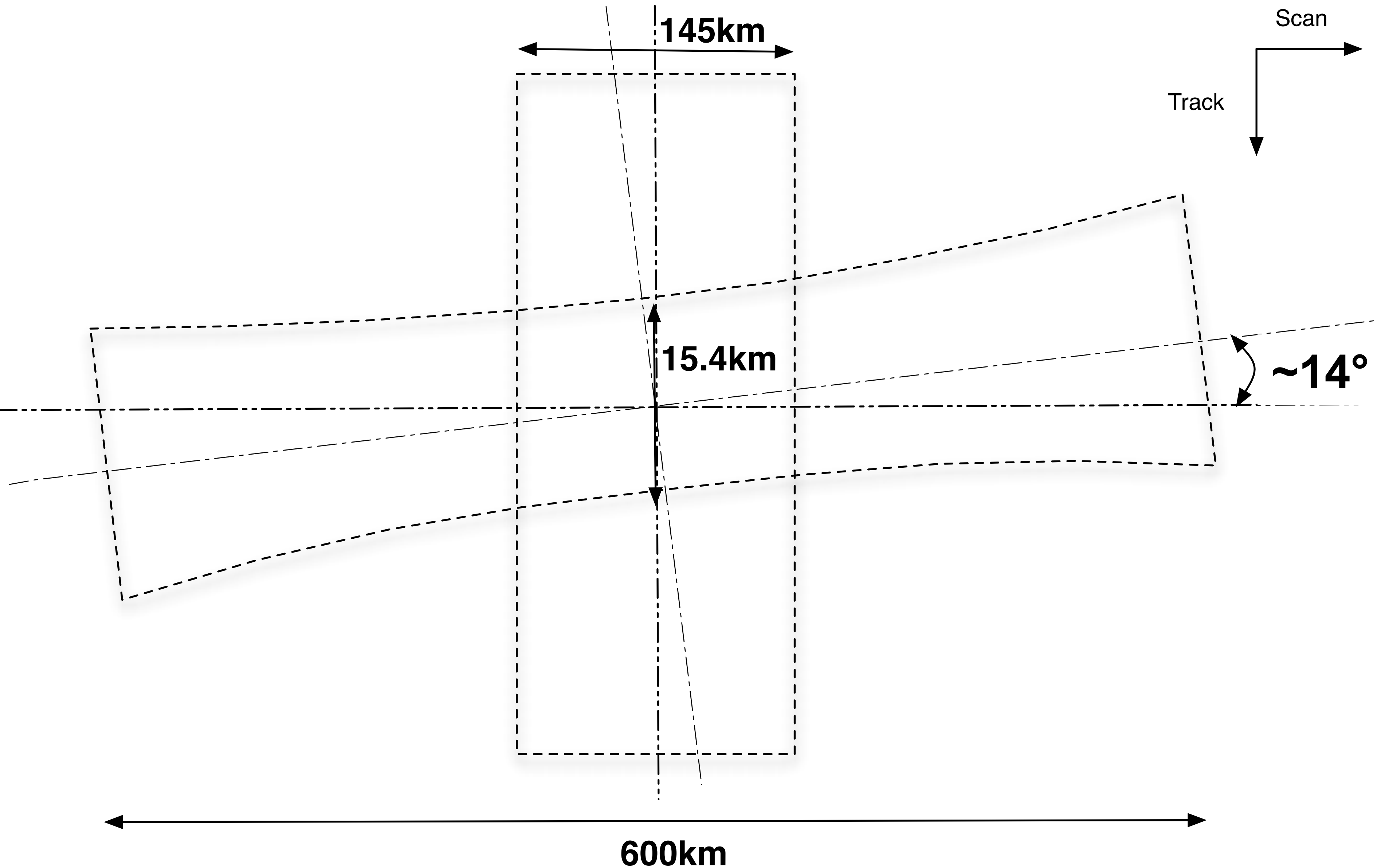


With Spacecraft Forward Movement

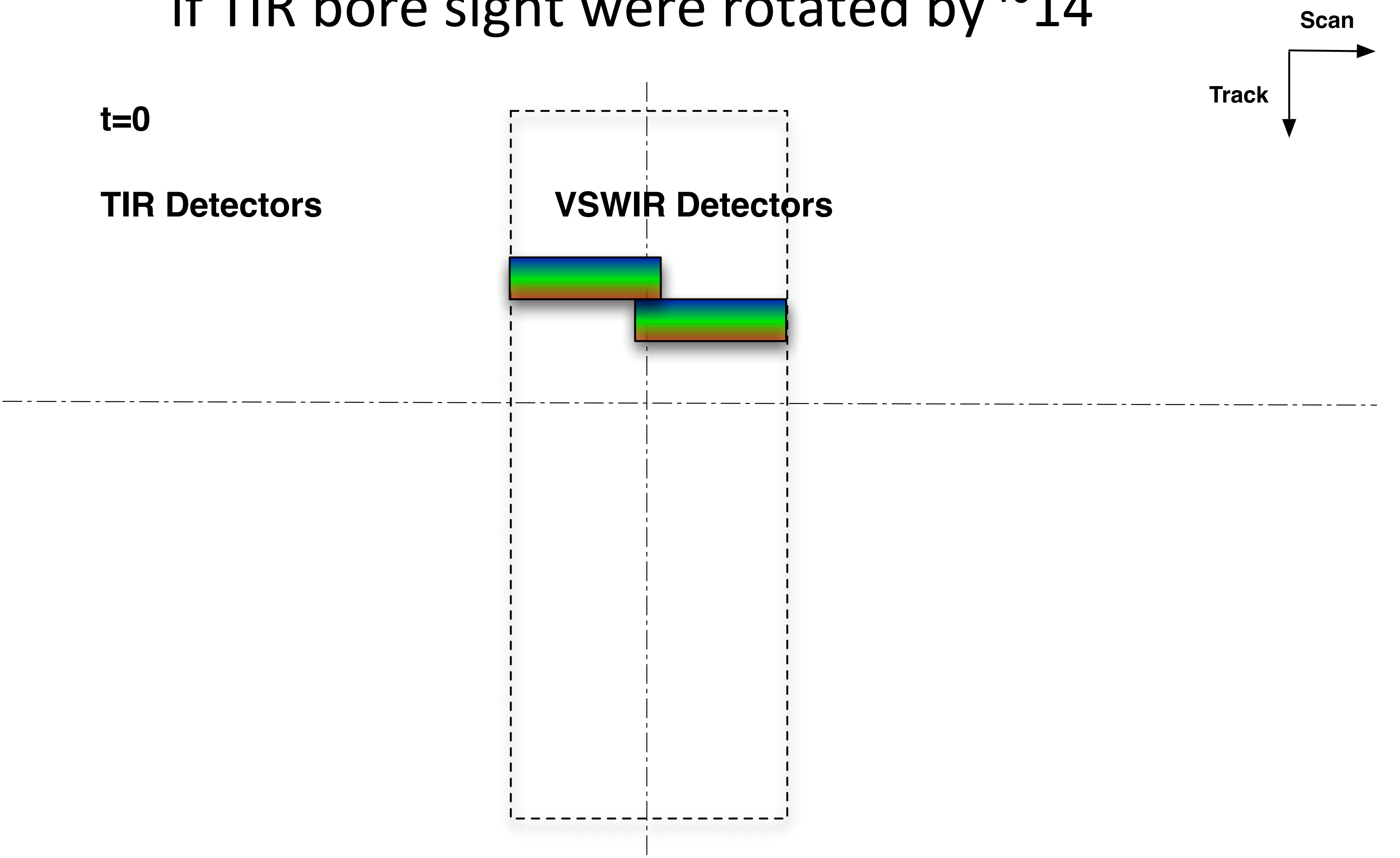


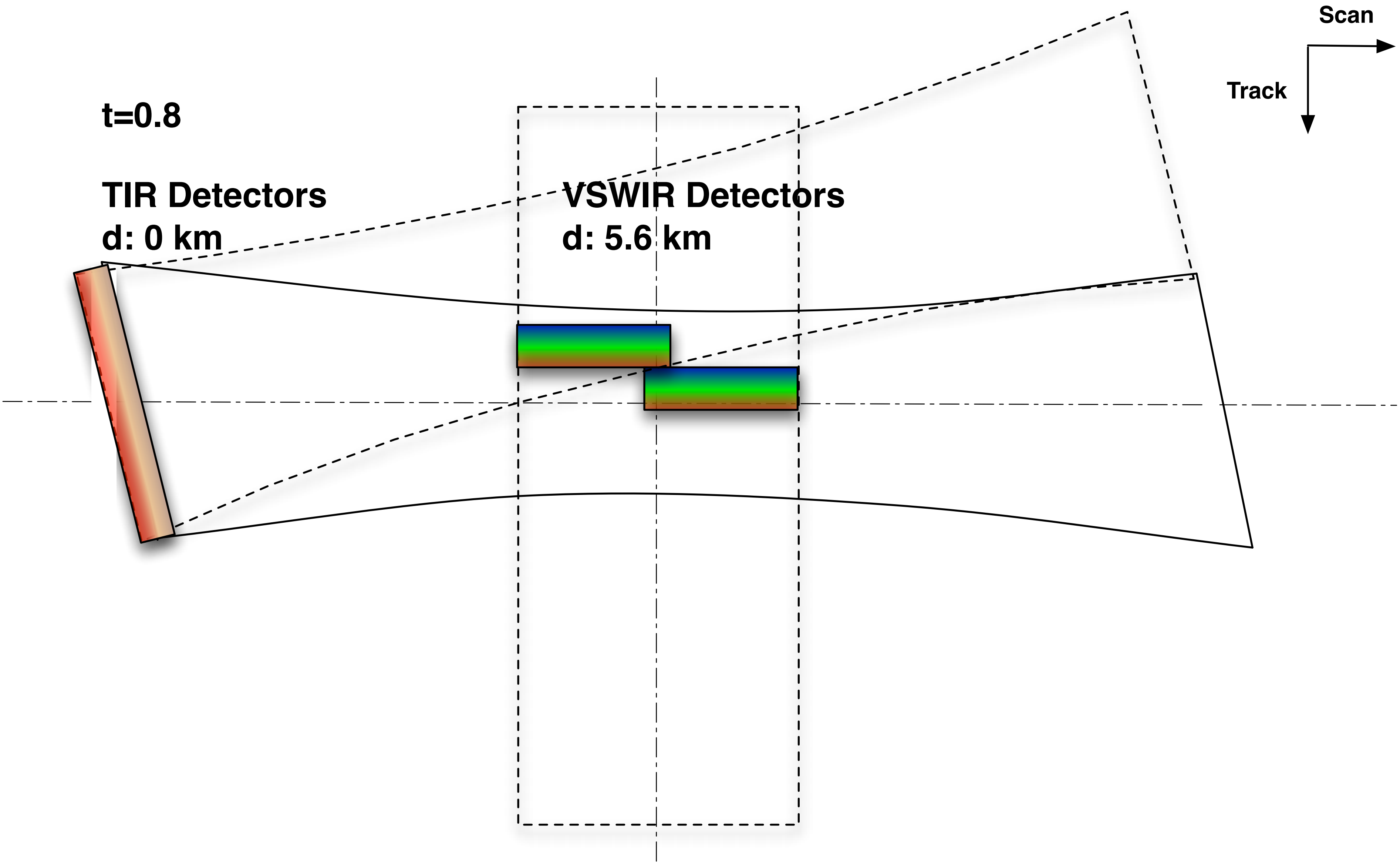
End of cycle and beginning of next period

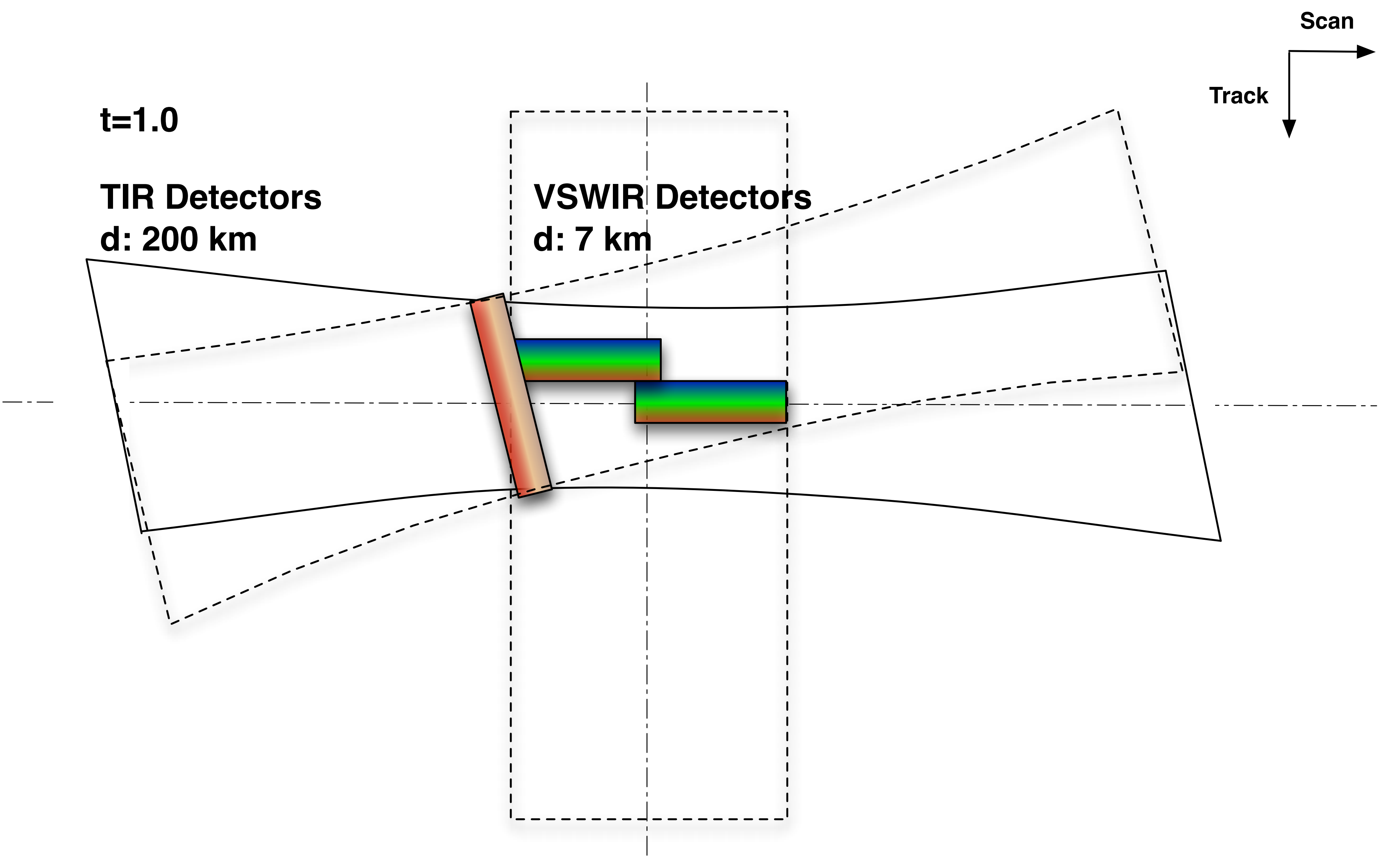
VSWIR / TIR Alignment Correction?

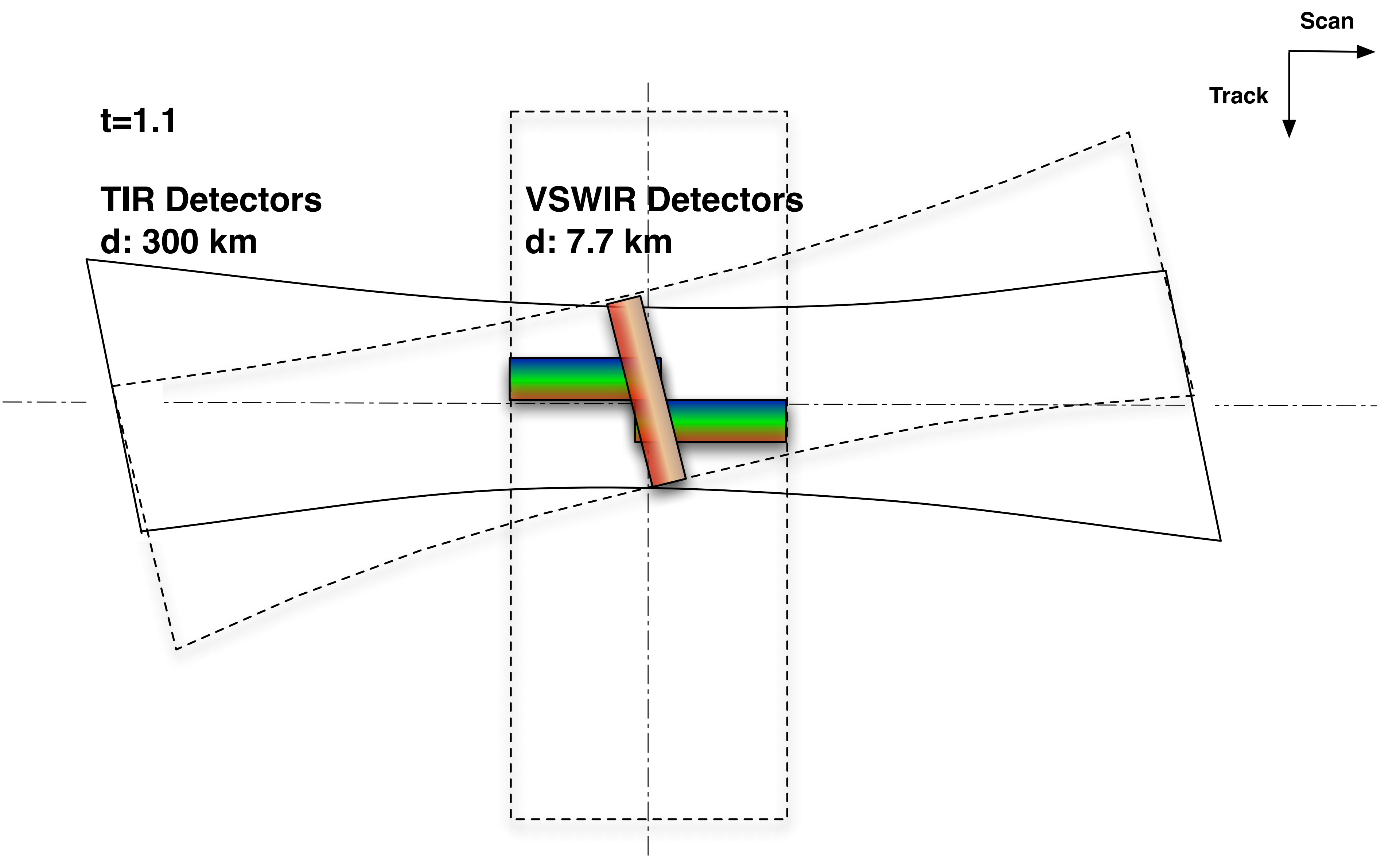


How the VSWIR and TIR would image if TIR bore sight were rotated by ~14°

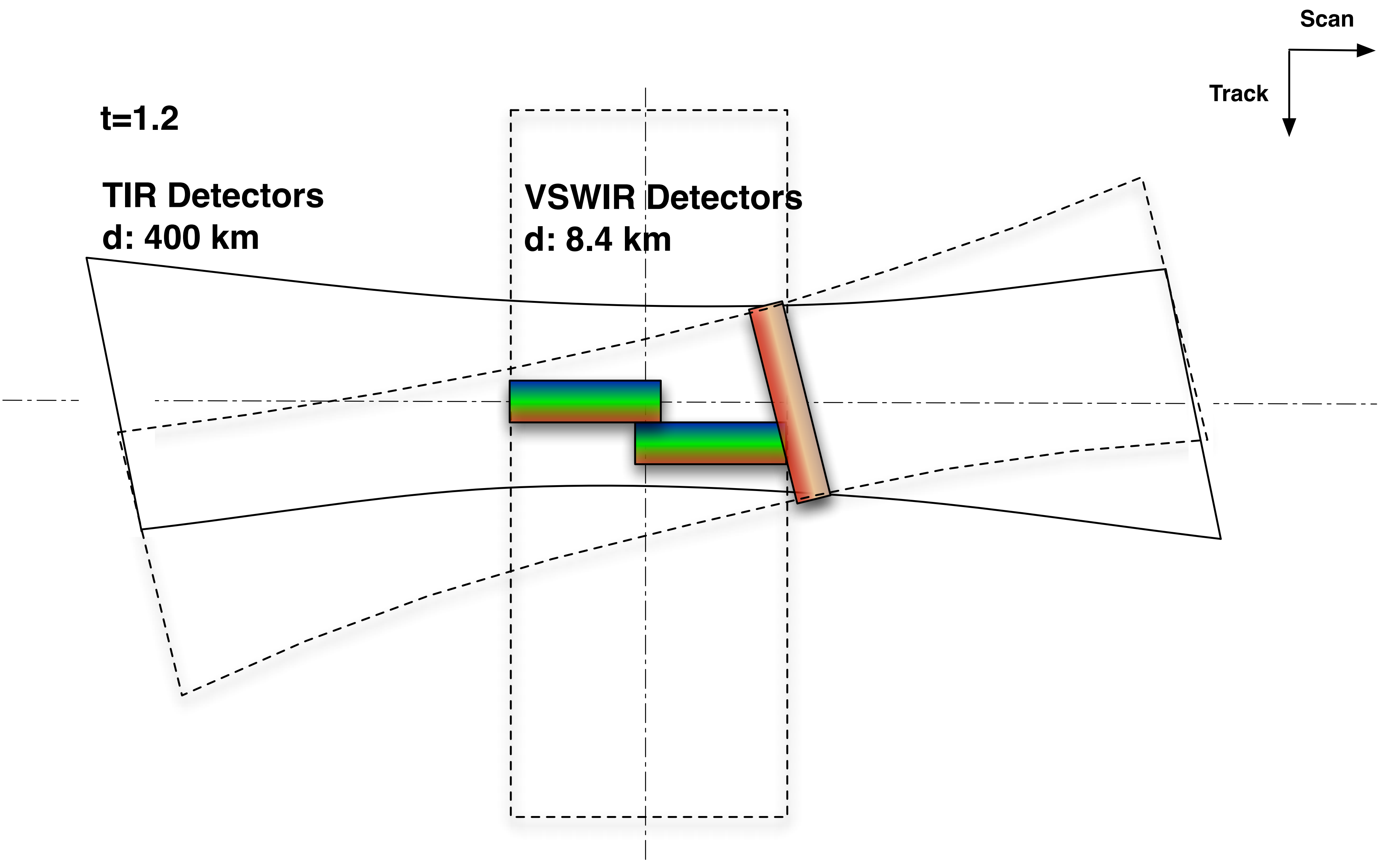



Scan
Track
t=0.8
TIR Detectors
d: 0 km
VSWIR Detectors
d: 5.6 km

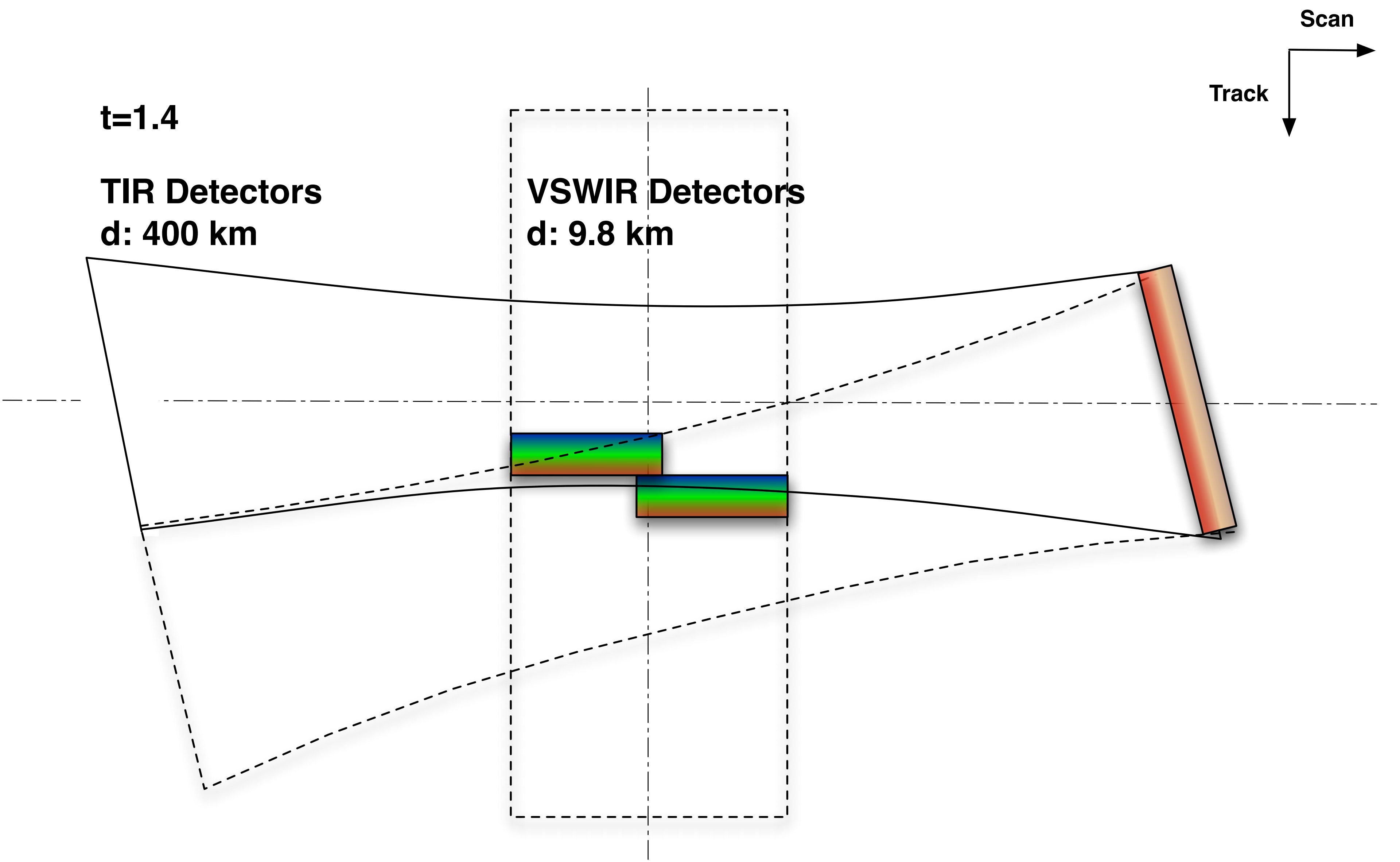

t=1.0
TIR Detectors
d: 200 km
VSWIR Detectors
d: 7 km
Scan
Track

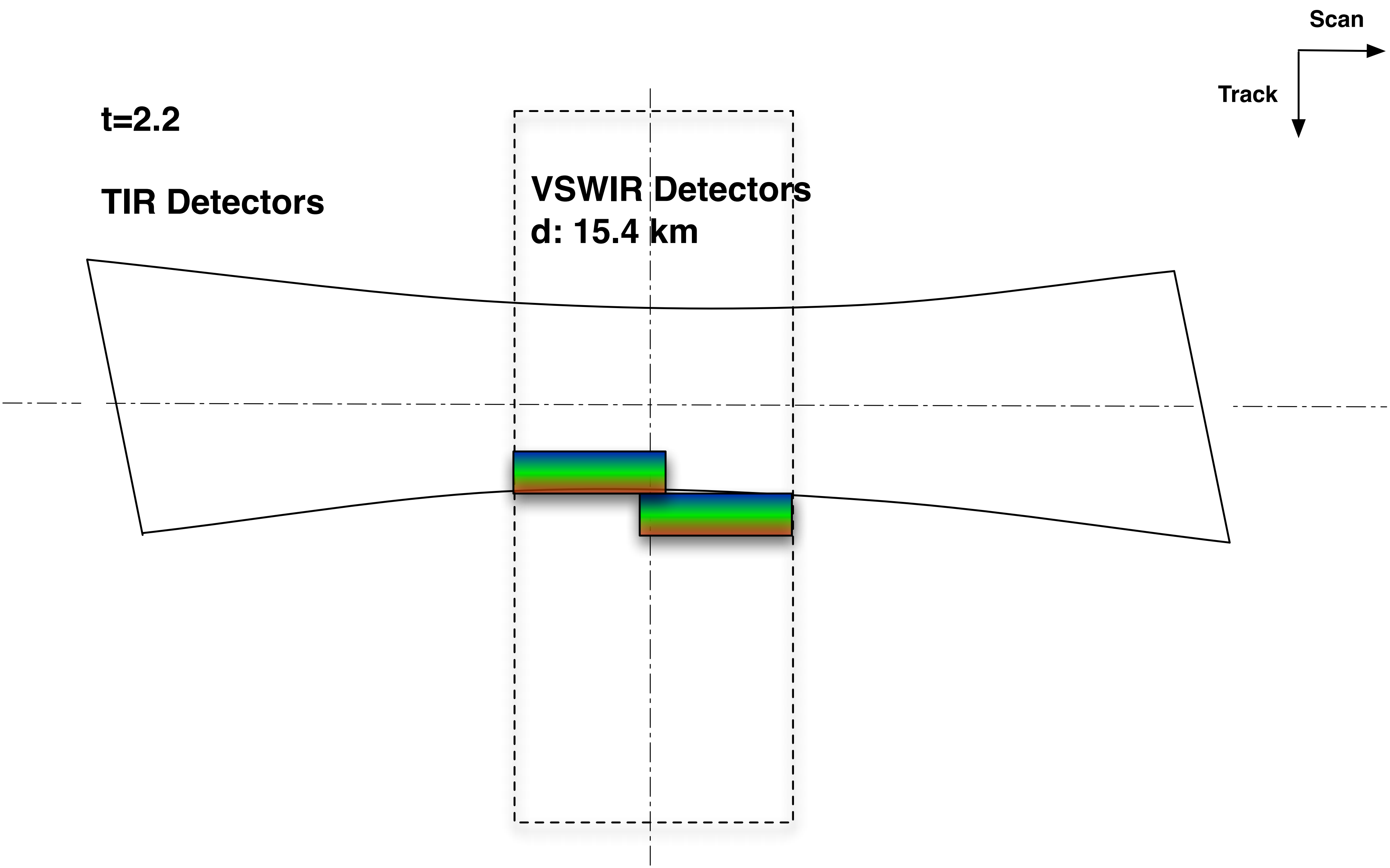


t=1.1
TIR Detectors
d: 300 km
VSWIR Detectors
d: 7.7 km
Scan
Track



t=1.2
TIR Detectors
d: 400 km
VSWIR Detectors
d: 8.4 km
Scan
Track


t=1.4
TIR Detectors
d: 400 km
VSWIR Detectors
d: 9.8 km
Scan
Track



Scan
Track
t=2.2
TIR Detectors
VSWIR Detectors
d: 15.4 km

What's the problem with making level-1 VSWIR, TIR and combined products?

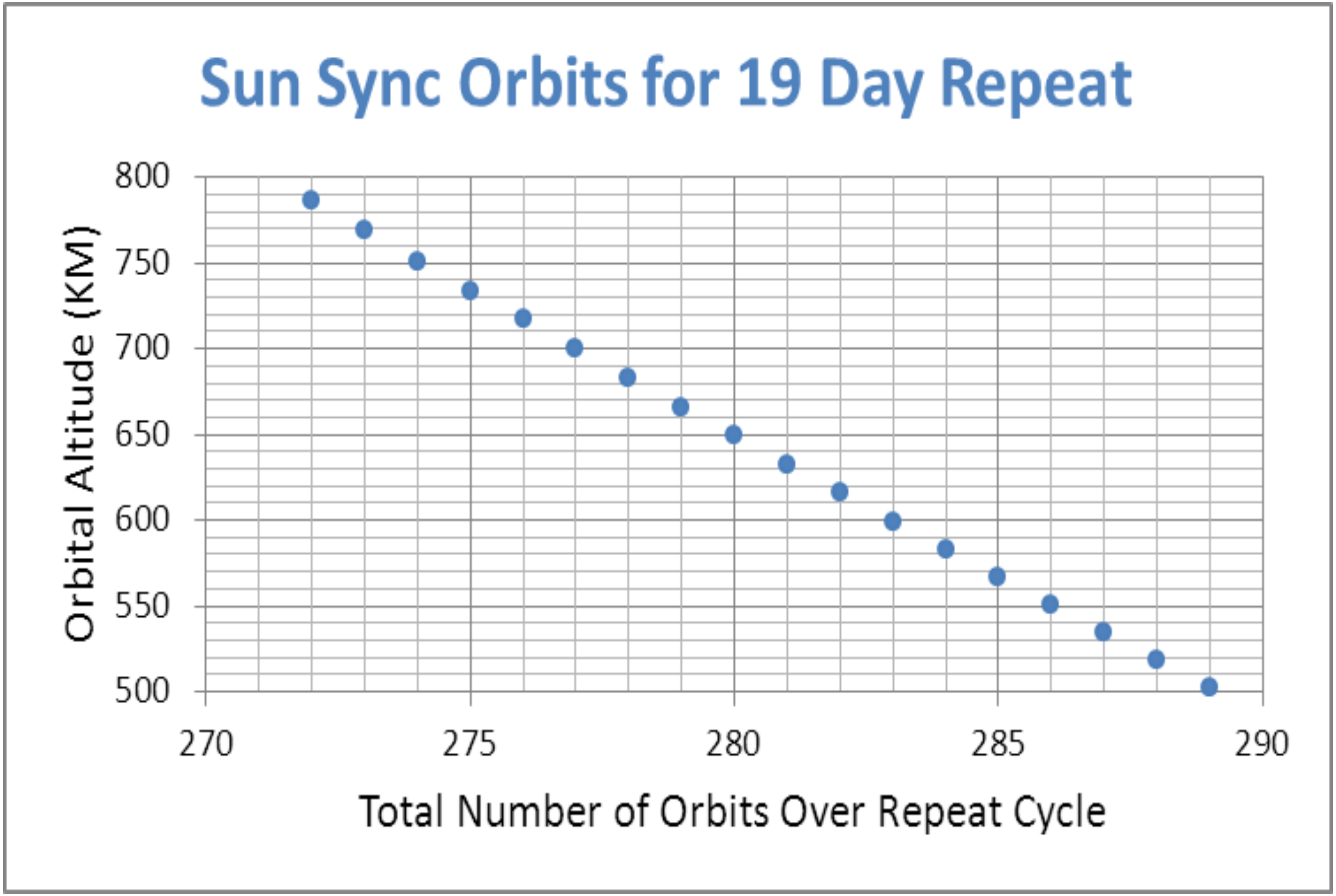
- By definition level-1 data must be entirely reversible back to the original level-0 data.
  - Geo-tag *radiometrically* corrected data.
  - Re-grid data using nearest neighbor values and geo-tag back to original pixel data positions *(need to deal with multiple values for the TIR)*.
- VSWIR and TIR observations are inherently misaligned in a manner which is both geographically and temporally sensitive.

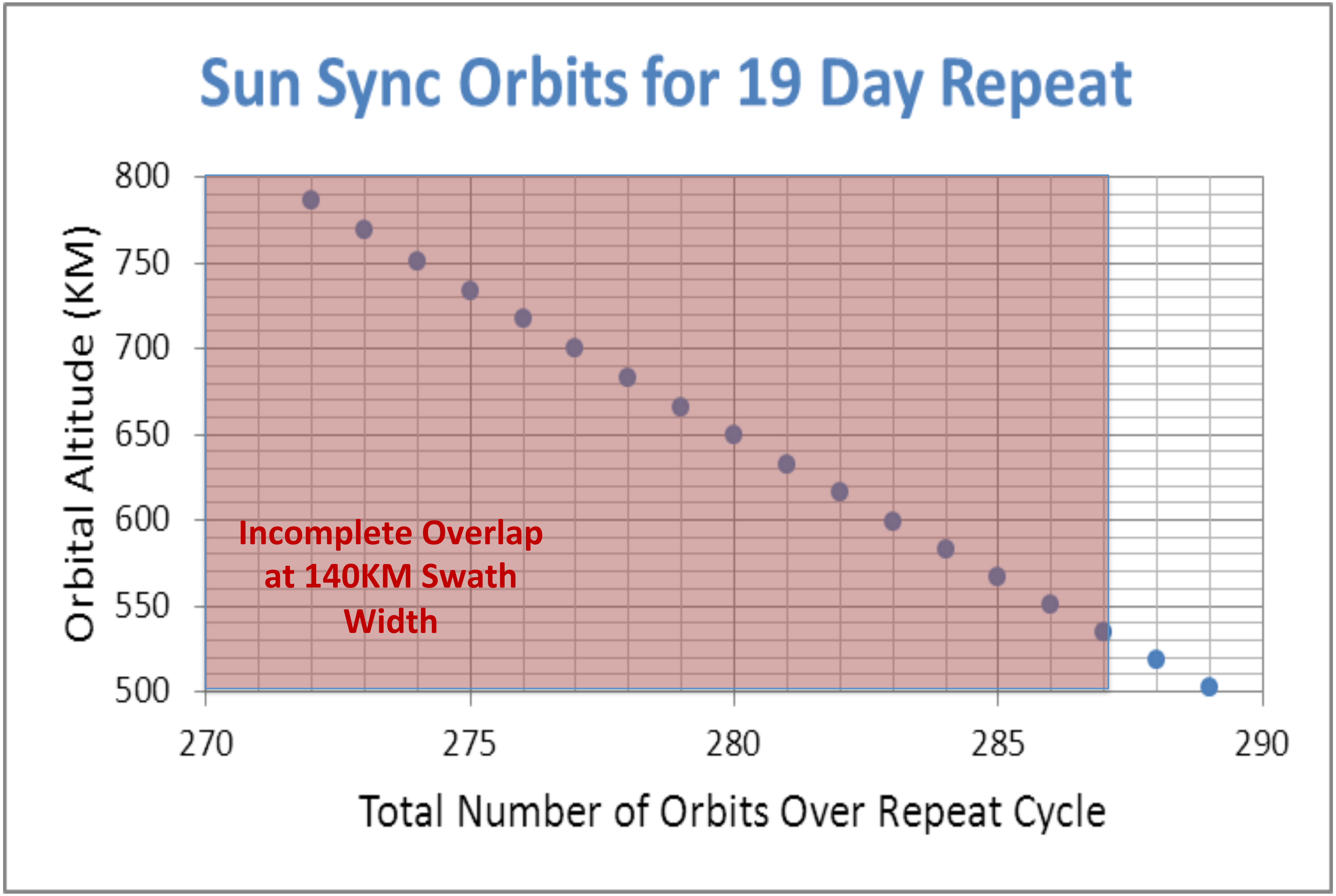
Issues with sun synchronous orbits which impact geo-location control

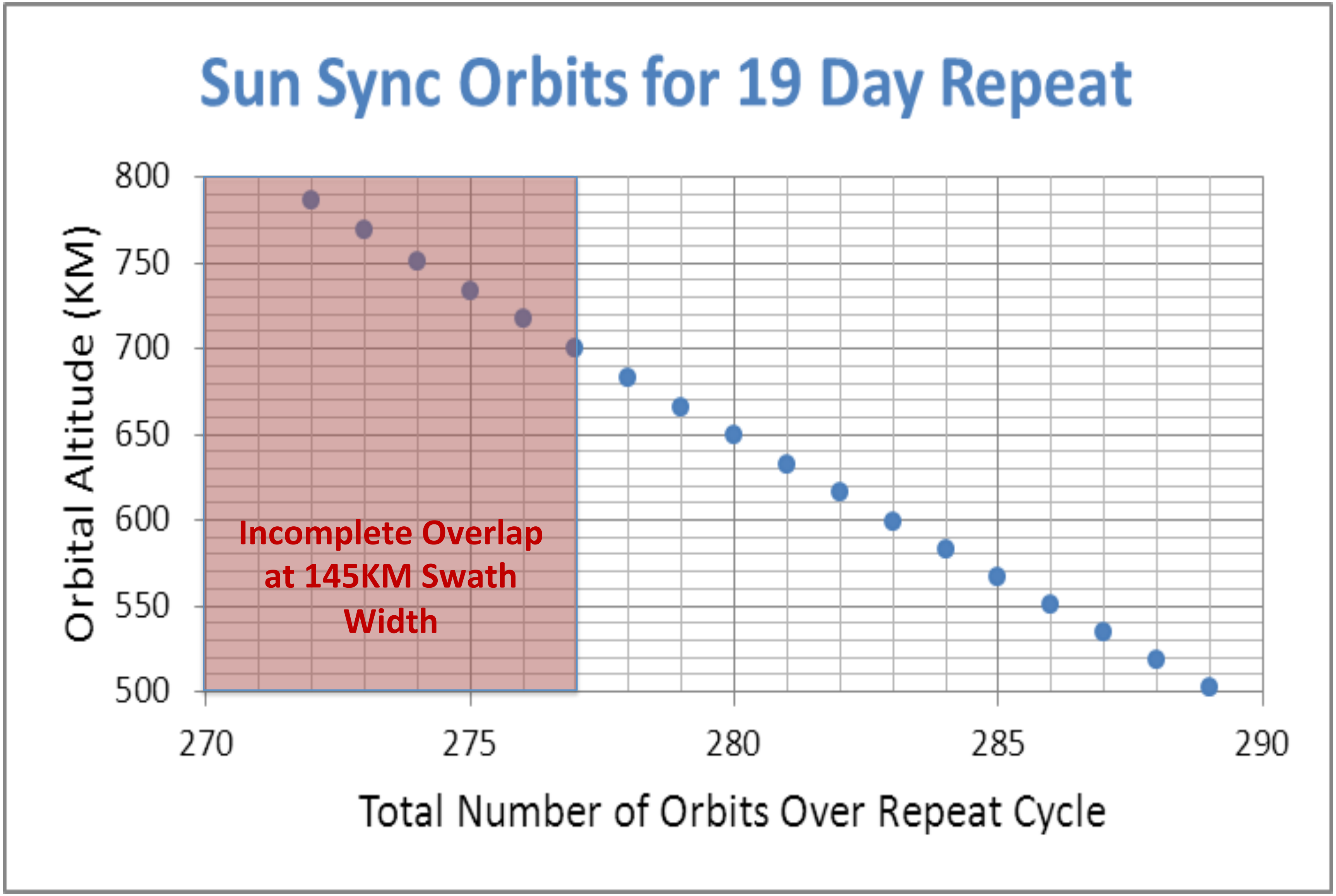
- The selected 19 day sun synchronous circular repeat cycle orbit is not truly synchronous.
  - All sun-sync orbits are designed *(and must be maintained)* to have a fixed precession rate which will exactly match the target MLT only 2X annually
- Many factors influence the position of the sub-satellite ground track and variations of several kilometers are tolerated even in high resolution platforms (e.g. Landsat)

Why a 19 day repeat cycle and how do we determine the satellite altitude?

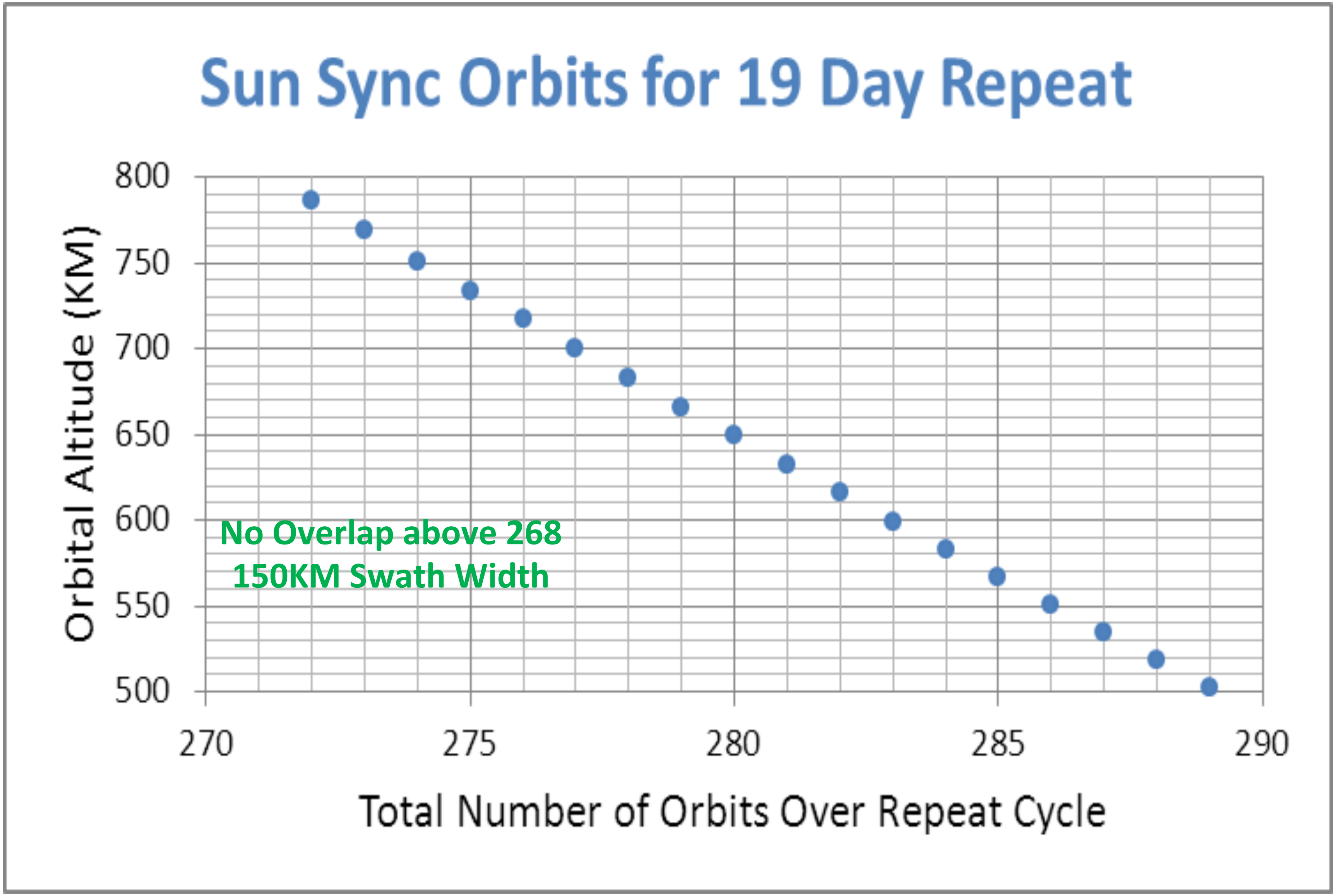
- We want global coverage in the shortest amount of time commensurate with achievable FOVs within the mission’s cost constraints.
- There are a variety of altitudes which produce the same repeat cycle.
  - Orbital with period **T** that divide into 19 days as an exact integer **N** provide a perfect repeat cycle.
  - If **T** is in minutes, then **N*T = 12360** (= **19***24*60)
  - $\mathbf{N > 2\pi R_{Earth}}$ **/Swath-width** ensures global coverage


Sun Sync Orbits for 19 Day Repeat
Orbital Altitude (KM)
800
750
700
650
600
550
500
270
275
280
285
290
Total Number of Orbits Over Repeat Cycle


Sun Sync Orbits for 19 Day Repeat
Orbital Altitude (KM)
800
750
700
650
600
550
500
270
275
280
285
290
Total Number of Orbits Over Repeat Cycle
Incomplete Overlap at 140KM Swath Width

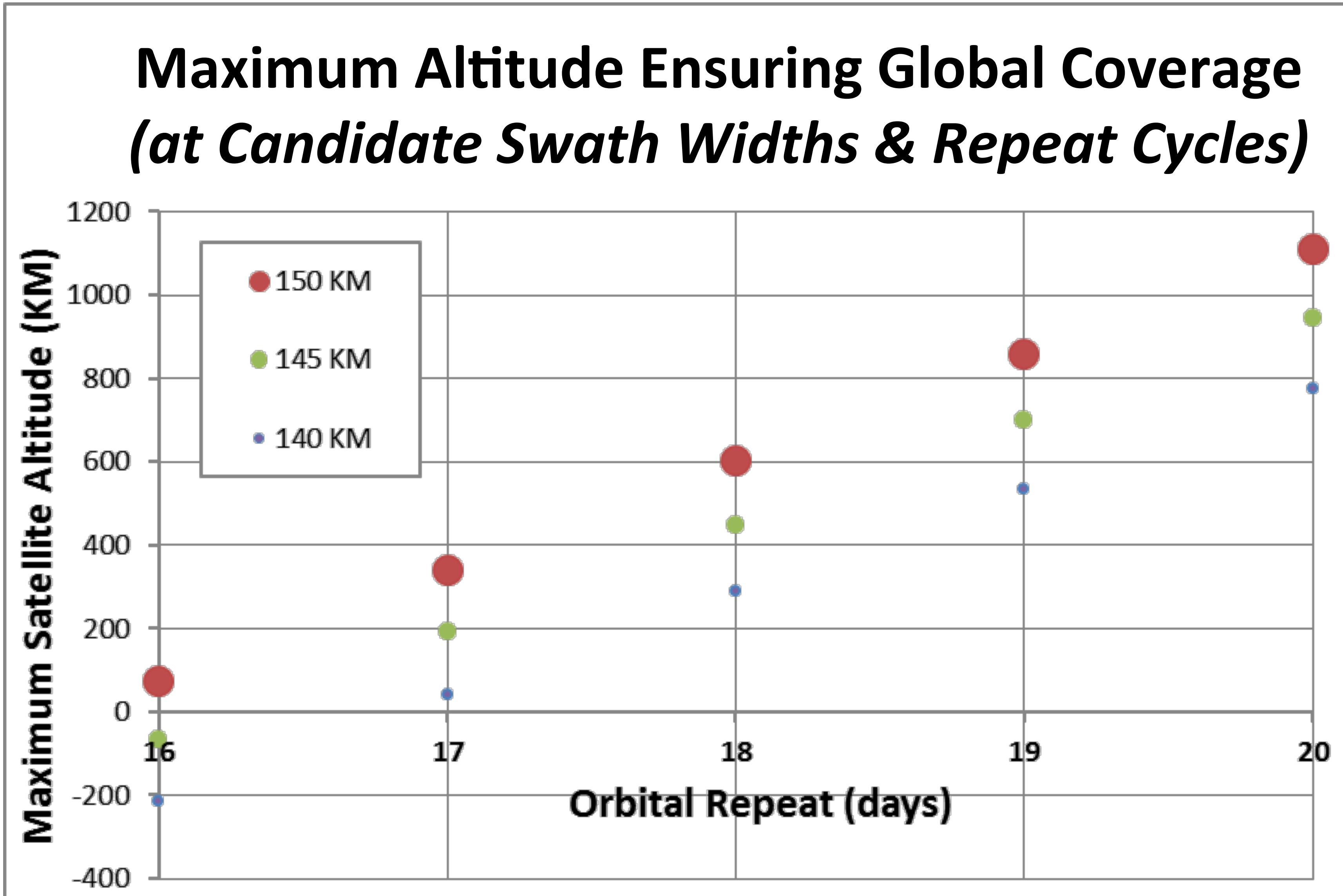


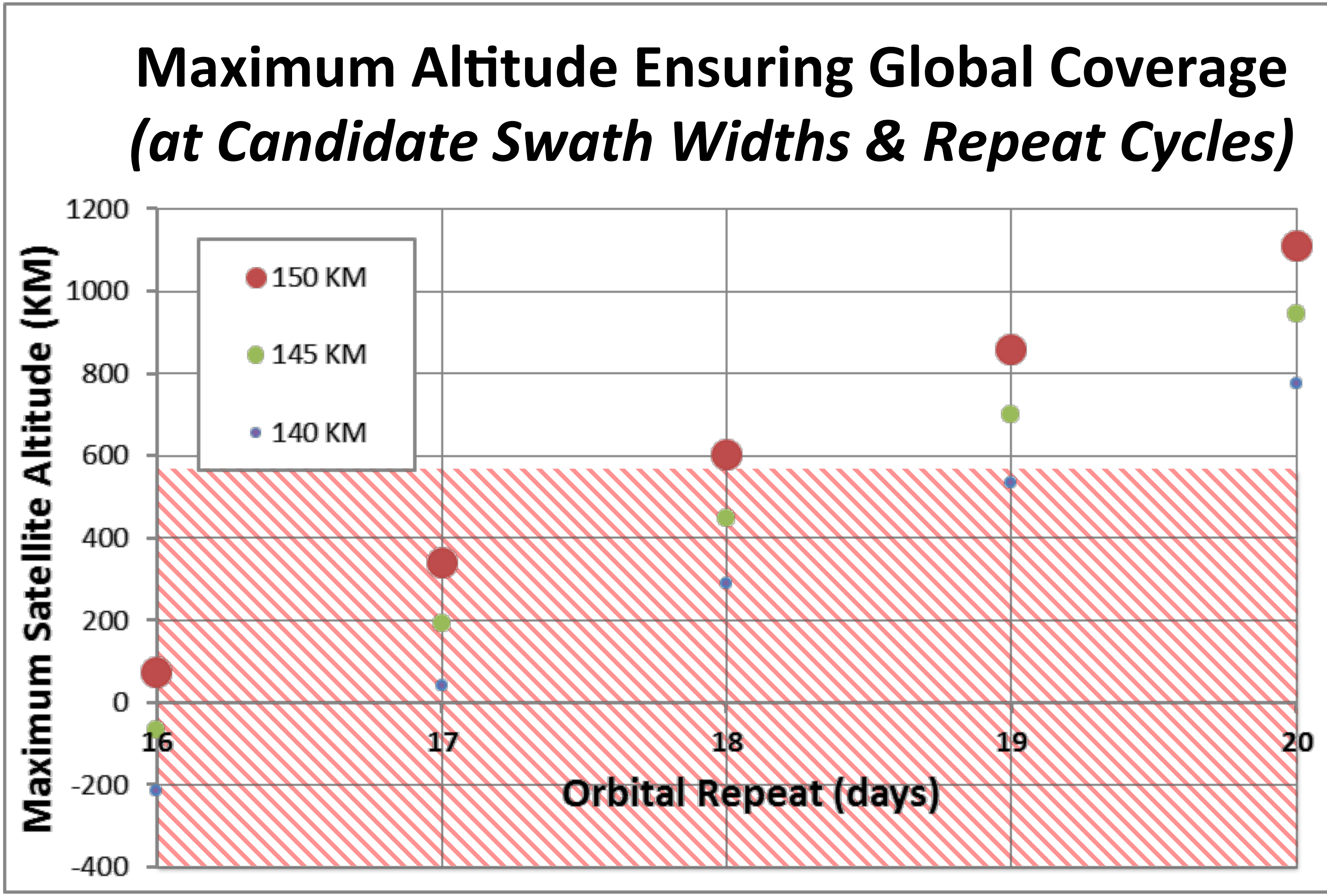
Sun Sync Orbits for 19 Day Repeat
Orbital Altitude (KM)
800
750
700
650
600
550
500
Incomplete Overlap at 145KM Swath Width
270
275
280
285
290
Total Number of Orbits Over Repeat Cycle


Sun Sync Orbits for 19 Day Repeat
Orbital Altitude (KM)
800
750
700
650
600
550
500
270
275
280
285
290
Total Number of Orbits Over Repeat Cycle
No Overlap above 268
150KM Swath Width

Can we have a shorter repeat cycle consistent with the current concept

- Maybe?


Maximum Altitude Ensuring Global Coverage
(at Candidate Swath Widths & Repeat Cycles)
Maximum Satellite Altitude (KM)
1200
1000
800
600
400
200
0
-200
-400
150 KM
145 KM
140 KM
16
17
18
19
20
Orbital Repeat (days)



Maximum Altitude Ensuring Global Coverage
(at Candidate Swath Widths & Repeat Cycles)
150 KM
145 KM
140 KM
Maximum Satellite Altitude (KM)
1200
1000
800
600
400
200
0
-200
-400
16
17
18
19
20
Orbital Repeat (days)

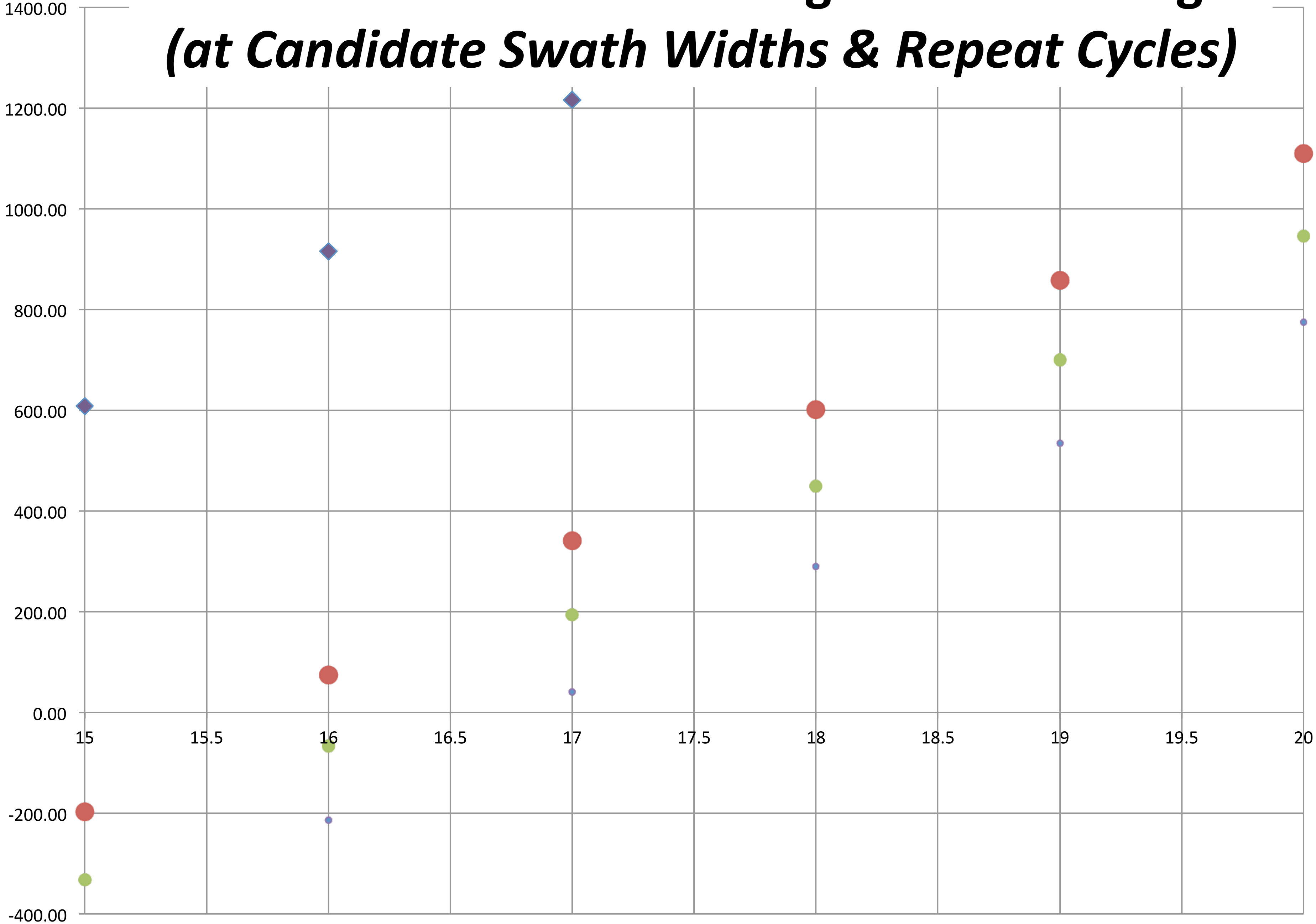
Onboard Low Latency Products

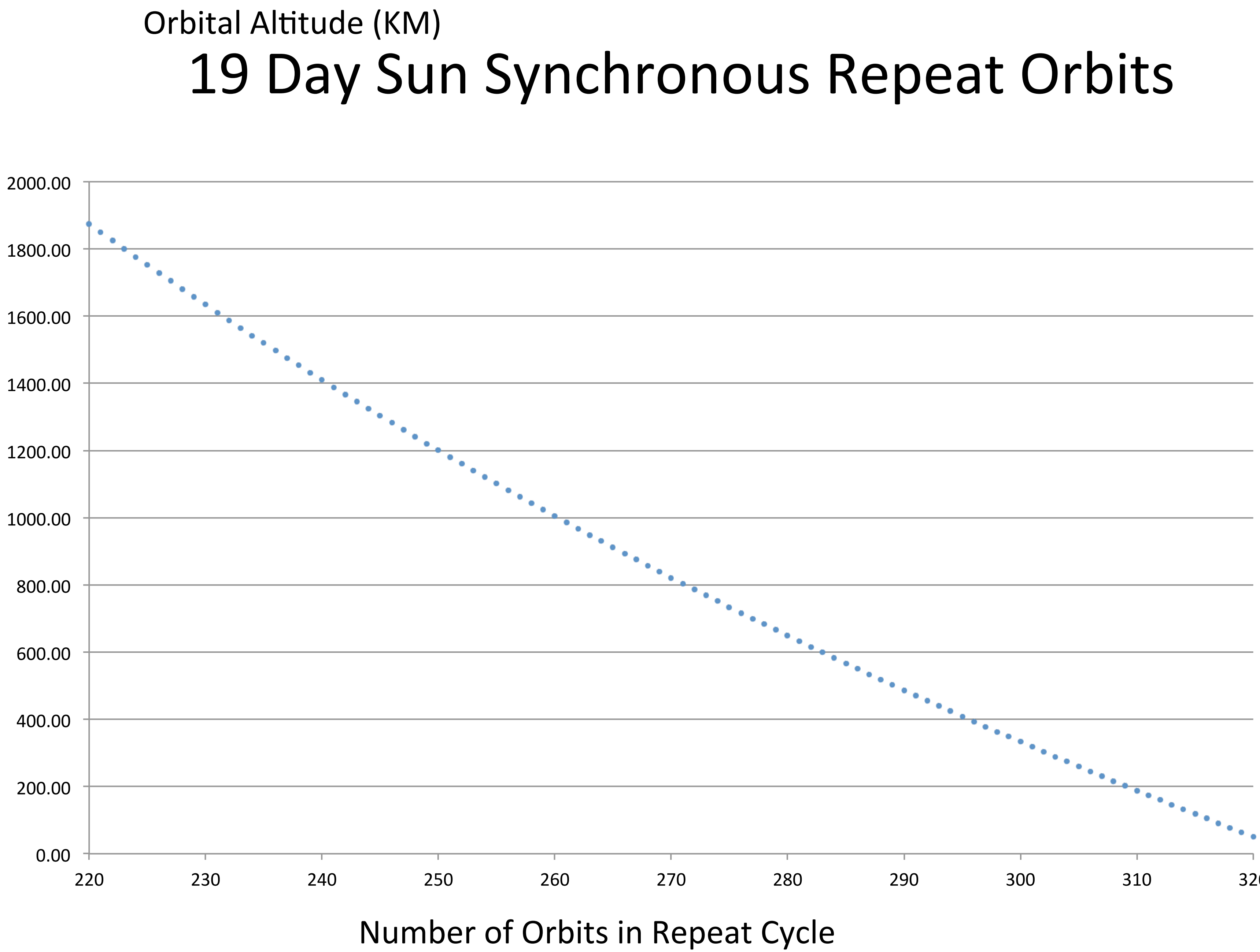
- VSWIR, TIR, VSWIR / TIR Gridded?
- > 15.4km?
- Radiometric Correction
- Atmospheric Correction (VSWIR)
- AC TIR?
- DEM Corrected?
- VSWIR/TIR Co-Registration?
- Actual Product Generation (WCPS)

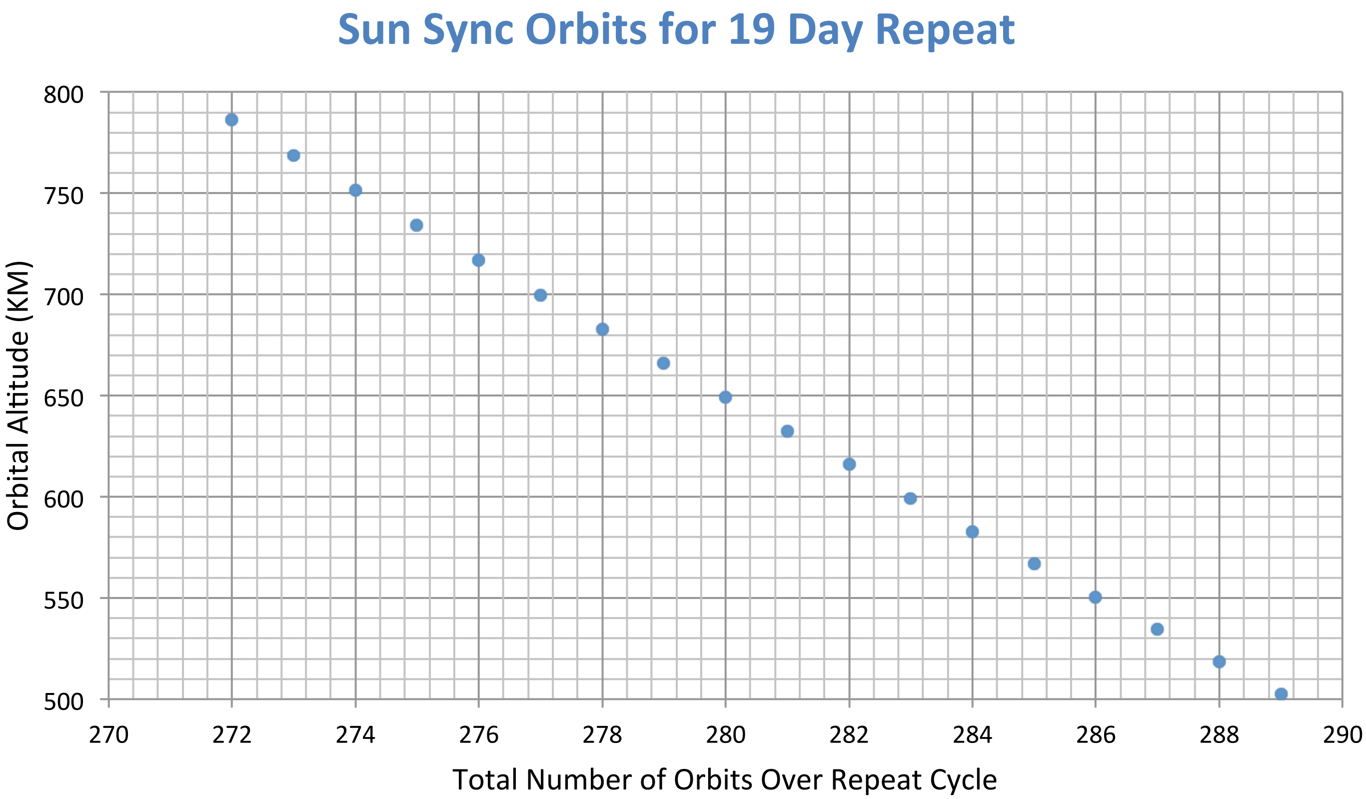
Finally!!

- The preceding descriptions are not merely a simplification --- they are an oversimplification.
- We need to take the effects of the Earth's rotation into account.
  - The ground sampling distance (GSD) for each instrument and the VSWIR pixel shape vary with latitude.
  - The nadir TIR and VSWIR ground tracks will not be congruent because of acquisiton time differences.
- Effects related to Earth's shape and topography
- **In my opinion none of these effects need impede the scientific utility of the data provided that we use them intelligently.**

Maximum Altitude Ensuring Global Coverage
(at Candidate Swath Widths & Repeat Cycles)




Orbital Altitude (KM)
19 Day Sun Synchronous Repeat Orbits
2000.00
1800.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
220
230
240
250
260
270
280
290
300
310
320
Number of Orbits in Repeat Cycle


Sun Sync Orbits for 19 Day Repeat
Orbital Altitude (KM)
800
750
700
650
600
550
500
270
272
274
276
278
280
282
284
286
288
290
Total Number of Orbits Over Repeat Cycle

All you need to know about spatial impact without going into way too much detail !

Steve Ungar – NASA/GSFC Scientist Emeritus
HyspIRI Science Symposium – NASA GSFC – May 17, 2012