Evolution of Earth Observation With TDI Sensors

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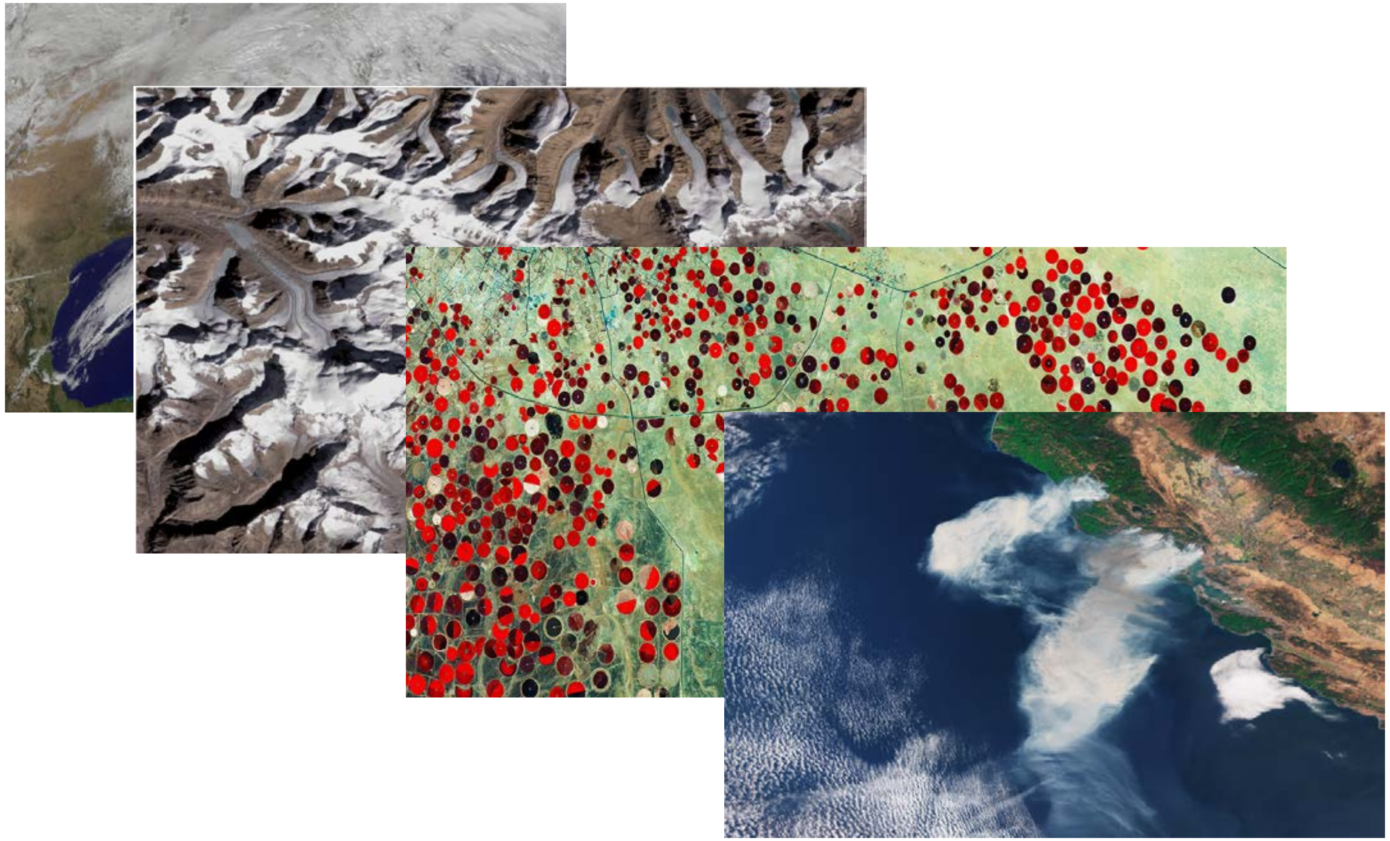
Earth Observation

Applications

+ Earth Observation Programmes have application in a number of fields, including:

- Weather
- Climate Change
- Security/Defence
- Mapping
- Disaster monitoring



Earth Observation

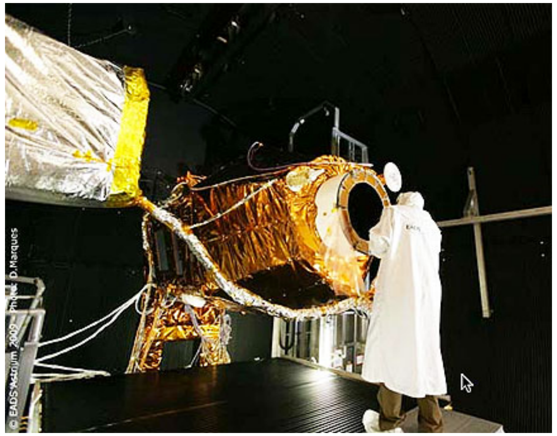
System and Sensor Requirements

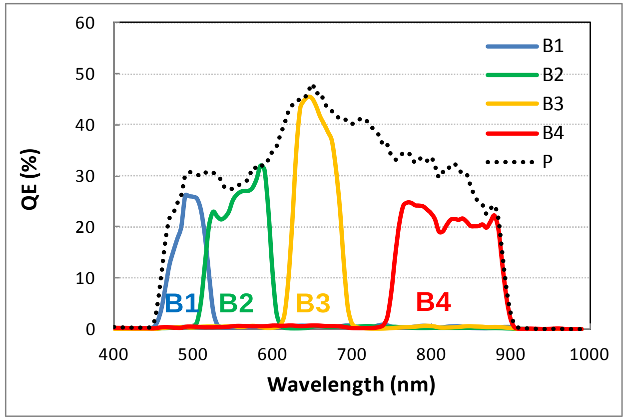
+ Cost
  + Reduced Weight + Increased Integration.
  + Constellations → Greater Revisit Time
  + LEO → Reduced Focal Length

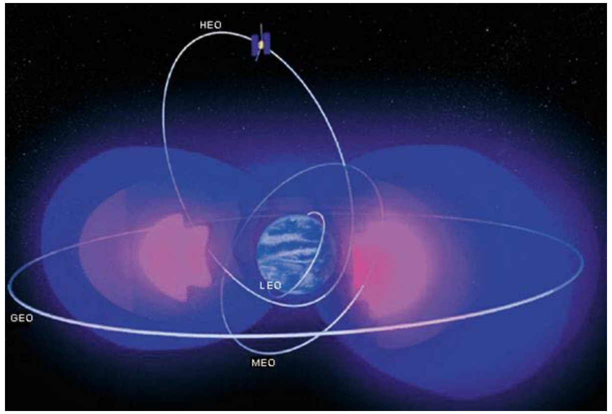
+ Spatial Resolution
  + Small Pixels → High GSD
  + High Data Rates → High Swath Widths

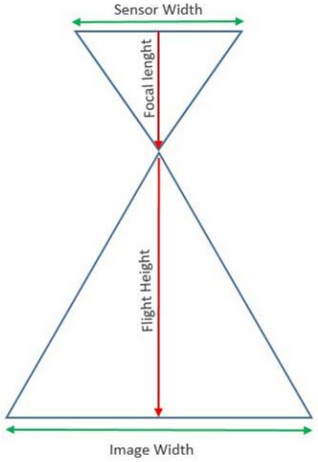
+ Spectral Resolution
  + Well Defined Channels
  + Optimised Modulation Transfer Function (MTF)
  + Optimised Quantum Efficiency (QE)
  + Strong Out-of-band Rejection

+ Radiation Hardness
  + Small Interaction Cross Sections
  + Shielding
  + Optimised Operational Modes





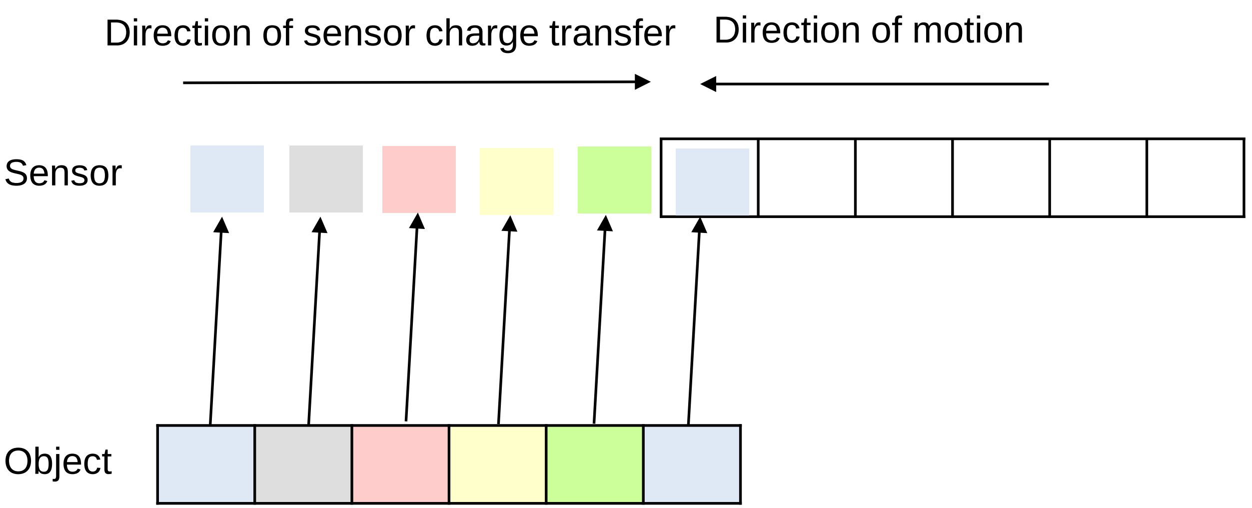




Time, Delay and Integration

Principles

+ Time Delay and Integration (TDI) sensors combine integration with charge transfer such that integration occurs as charge is being transferred.



- Charge transfer speed is synchronised with the relative speed between satellite and object of interest.
- Repeated exposure of a scene from pixel to pixel effectively increases optical gain.
- Since charge is summed in the transfer process, SNR improves with number of transfers.
- Integration times on the scale of sensor readout rates make for improved resolution of moving targets compared with staring mode operation

Sensor Technology

TDI CCDs

- Charge Coupled Devices inherently support TDI mode of operation through their characteristic charge transfer process.
- In Low Earth Orbit (LEO), the relative motion between satellite and target is extremely fast. TDI becomes crucial to maintain resolution over staring mode.
- E.g. Pleiades (e2v) and GeoEye (ITT), both of which boast ~0.3m GSD.

✓ Inherent Charge Transfer Capability
✓ Low Noise

❑ Speed Limited to read out rate
❑ Typically Larger Pixels than CMOS
❑ Off Chip Video Chain and Clock Generation Electronics
❑ High Power Consumption

❑ The Above contribute to High Cost

VHR Satellite Comparison

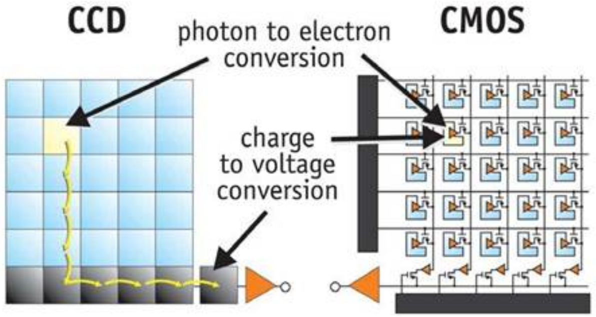
TELEDYNE e2V Everywhereyoulook™

		KompSAT-3A	Pleiades-1A/B	GEOEye-1	WorldView-1
Launch		2015	2011 & 2012	2008	2007
Orbit Height	km	528	695	681	496
Focal Length	m	9	13	13	9
F#		10.75	19.85	12.09	14.67
Pixel Pitch	um	9	13	8	8
Imager Mass	kg	300	200	450	400
Satellite Mass	kg	1100	1015	1955	2500
GSD	m	0.54	0.70	0.41	0.45
GRD	m	0.54	0.85	0.36	0.68
Mission Cost		$250M	$425M	$450M	$500M

Sensor Technology

TDI CMOS

- Minimum possible pixel size capability in CMOS is significantly smaller than for CCDs:
  - Allows for improved resolution for the same sized telescope → Performance Driver:
  - Or, a smaller sized telescope for the same resolution → Cost Driver
- CMOS allows for much higher data rates:
  - Each pixel has it's own readout → massively parallel read-out compared with CCD
  - Approx. 0.15Gbit/s for CCD compared with 60Gbit/s for TDI CMOS
  - Permits higher swath widths without compromising on satellite speed → Higher resolution
- On chip functionality – Video chain and bias control.
  - Lower power consumption
  - Lower voltage requirements reducing the need for high capacity power supplies → reduced mass



But **<u>charge transfer is not inherent to CMOS devices as it is for CCDs</u>**.

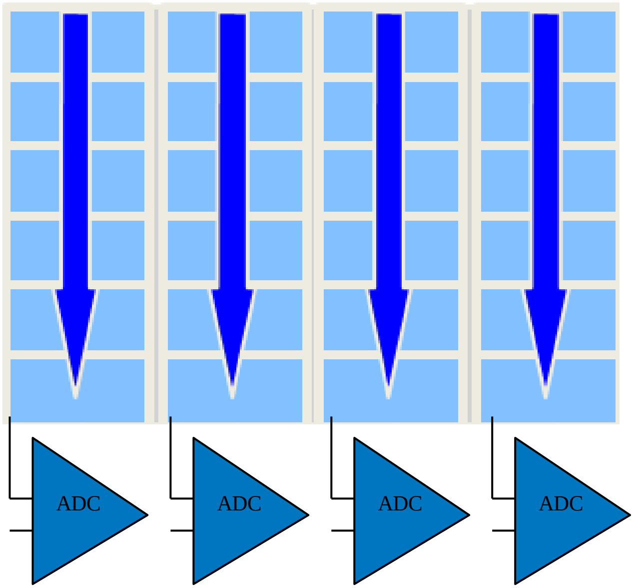
Sensor Technology

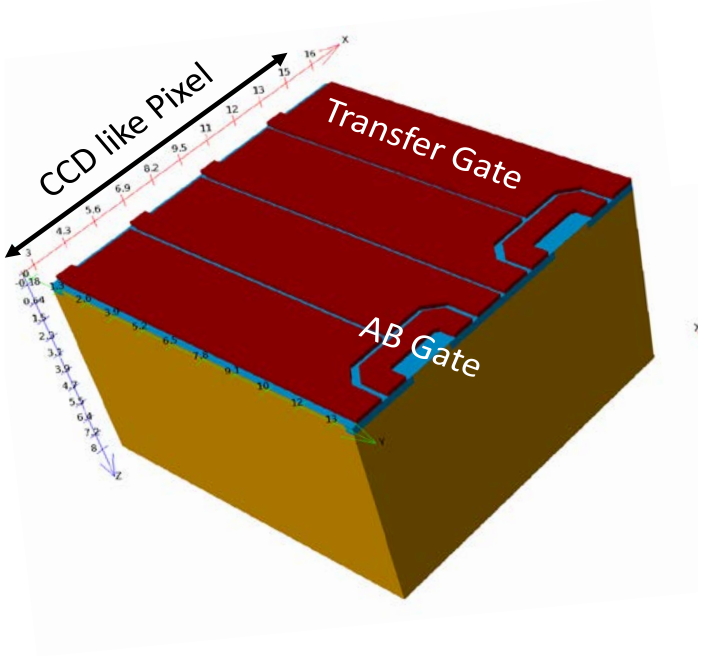
Optimising TDI CMOS

+ One option used is to sum in the digital domain of a staring image (Digital TDI)
  + Using traditional CMOS architecture, Improvements still to be made around noise, power consumption, memory requirements and MTF.

+ Combining the benefits of CCD and CMOS is a CCD-on-CMOS approach (charge domain CMOS TDI)

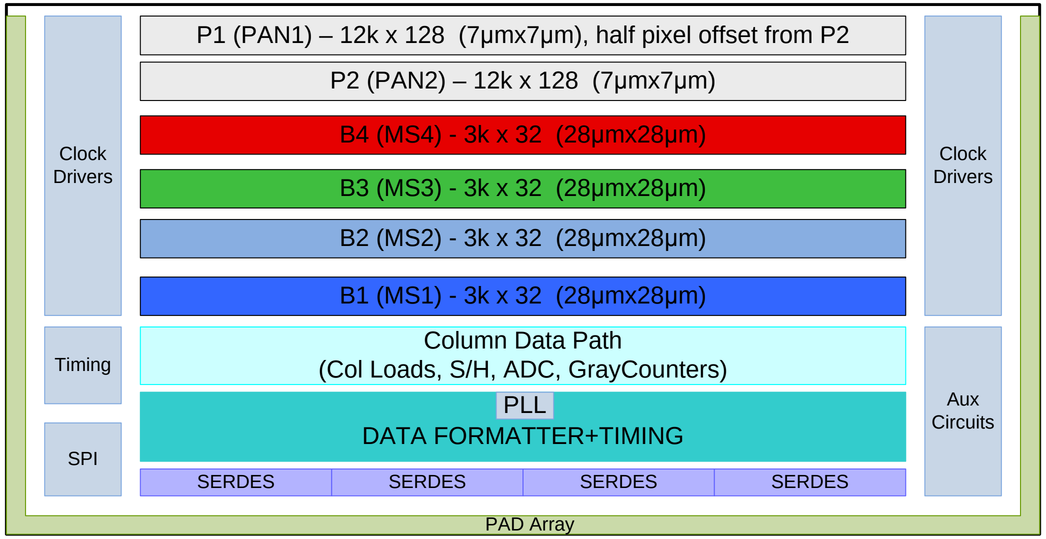
- Noiseless charge transfer across CCD-like pixel structure produced on a CMOS process
  - Reduced power consumption
  - Increased radiation hardness
  - Very high data rates
  - High spatial resolution
  - On-Chip Functionality



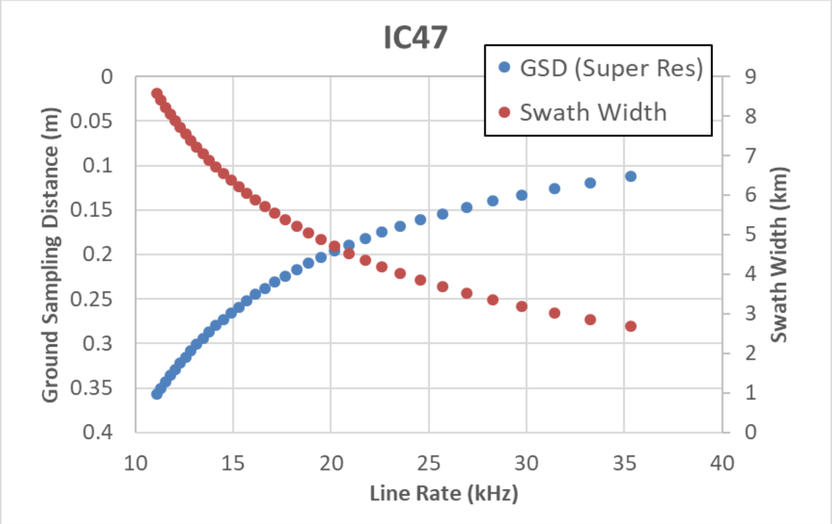


Teledyne Multispectral qTDI CMOS

IC-47 (FSI) and IC-49 (BSI)

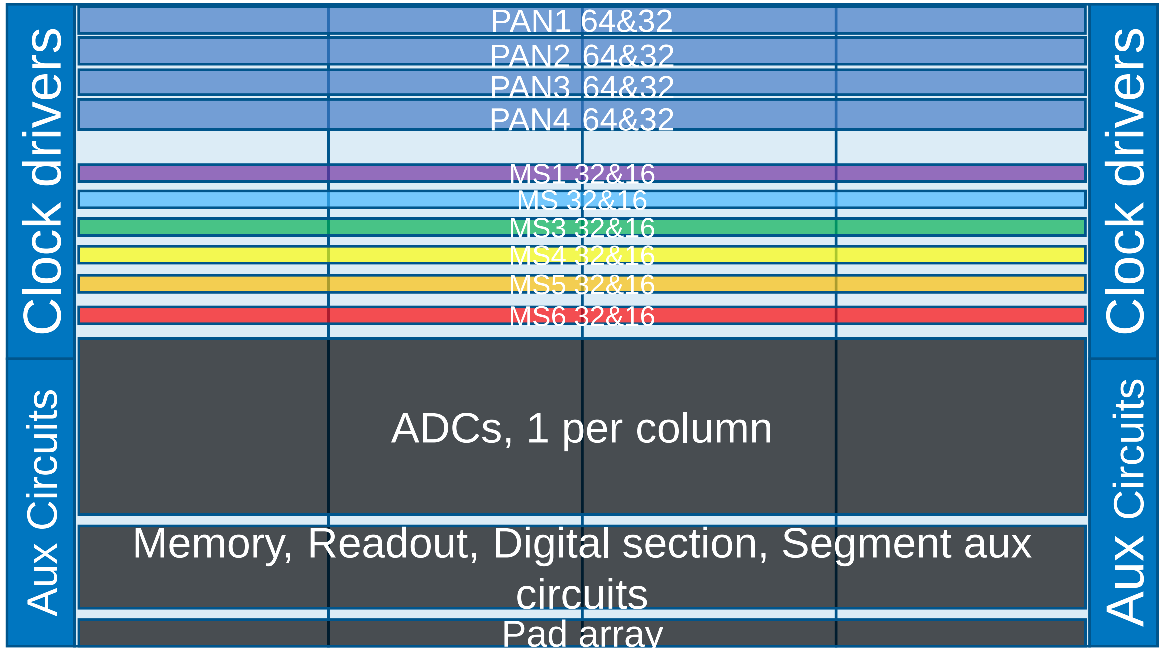


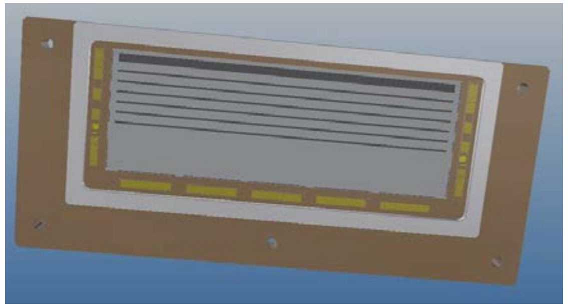
PAN Channels	2 (half pixel offset)
MS Channels	4
Pixel pitch	7µm PAN, 28µm MS
Number of pixels	PAN: 12k columns MS: 3k columns
GSD at max line rate (cm)	11
Swath width at line rate ~10KHz (km)	4.2



Teledyne Multispectral qTDI CMOS

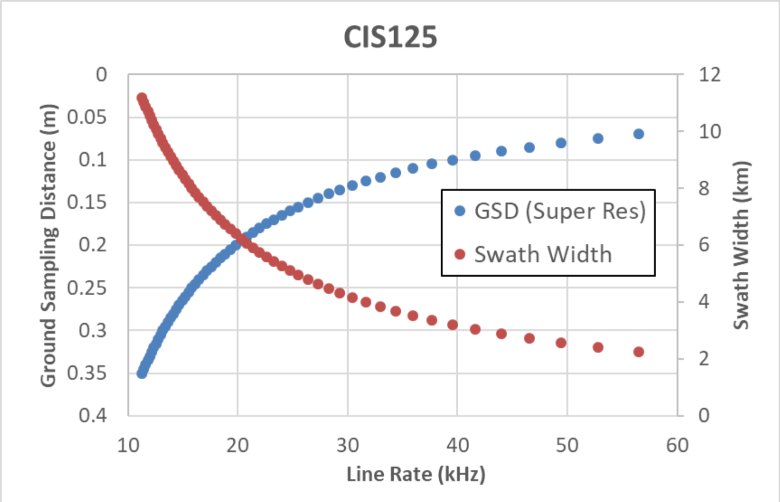
CIS125 – In Development



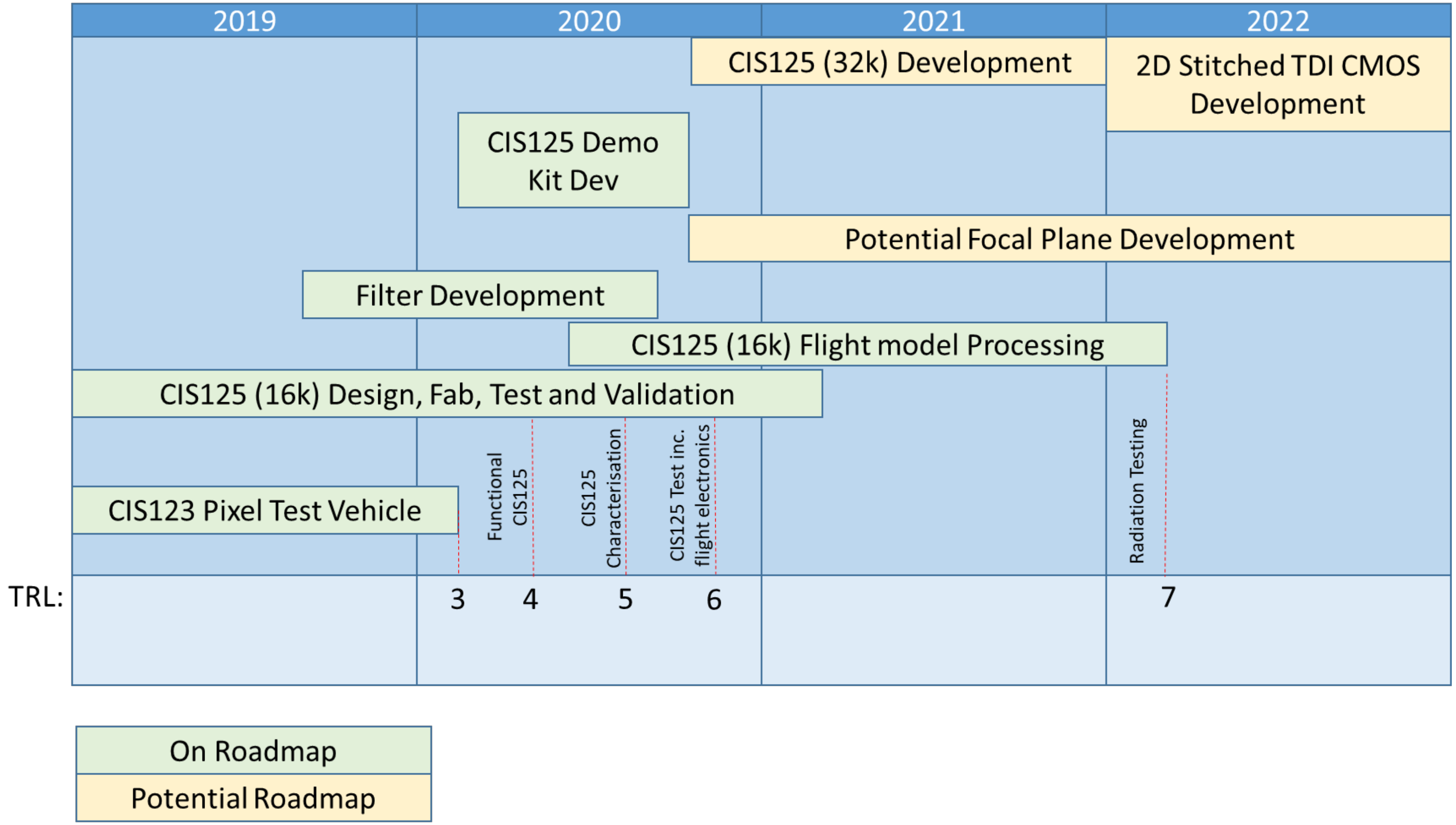


Pan Channels	4
MS Channels	6
Pixel pitch µm	5µm PAN, 10µm MS
Number of pixels	PAN: 16k columns MS: 8k columns
GSD at max line rate (cm)[1]	7
Swath width at line rate ~10KHz (km)	11

[1]Customisation required to use 2 x PAN only



CIS125 Roadmap



Thank you