NATIONAL SPACE CONFERENCE 2024

Space Science and Innovation for Sustainability

The SAR-C Payload

Designed for µsat constellations

Willie Nel, Chief Engineer, CSIR

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Introduction

Commercial SAR satellite constellations have grown since 2017 and are having a drastic impact on the earth observation landscape

SAR satellites are the only 24/7 sensors – imaging day and night in ALL weather

Constellations has reduced revisit rates to be daily or every few hours hourly

Resolutions achievable in commercial satellites are as fine as 25cm

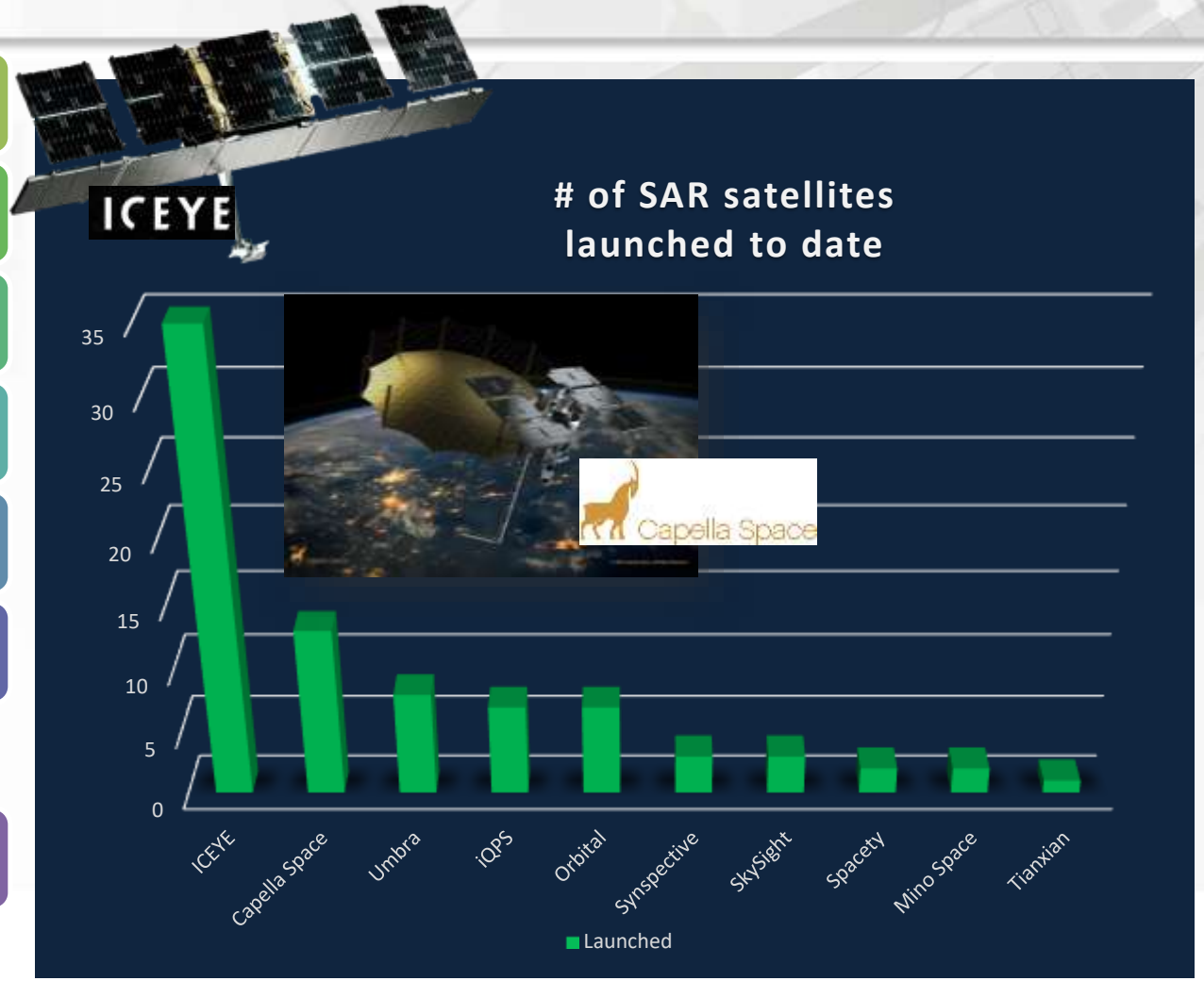
Unprecedented capability to image the earth for a myriad of applications

However, requirements for imaging still far exceed the capability of current satellite constellations

- SAR payloads operate typically < 5% of orbit
- Most of these satellites do not provide polarimetric information
- Almost all commercial satellites are at X-band (not suited to certain applications)

Additionally, recent reductions in launch costs allows for more complexity in the satellite with optimal performance vs mass likely in the 100 – 200 kg range

- Onboard processing to reduce data rates
- More advanced modes



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Introduction

C-Band Payload Design Requirements	
Payload Mass	Ideally < 150 kg
Payload Power	Ideally < 2 kW average during operation
Frequency	5.25 to 5.85 GHz
Resolution	<1m in high res
Polarisation	Ideally Quad Pol (VV,VH,HV,HH)
Modes	Wide Swath for Maritime Surveillance (ideally with onboard detection)
	High Resolution for Security and Infrastructure Monitoring
Cost	Affordable for Developing Countries
Design	Easy to manufacture in high numbers

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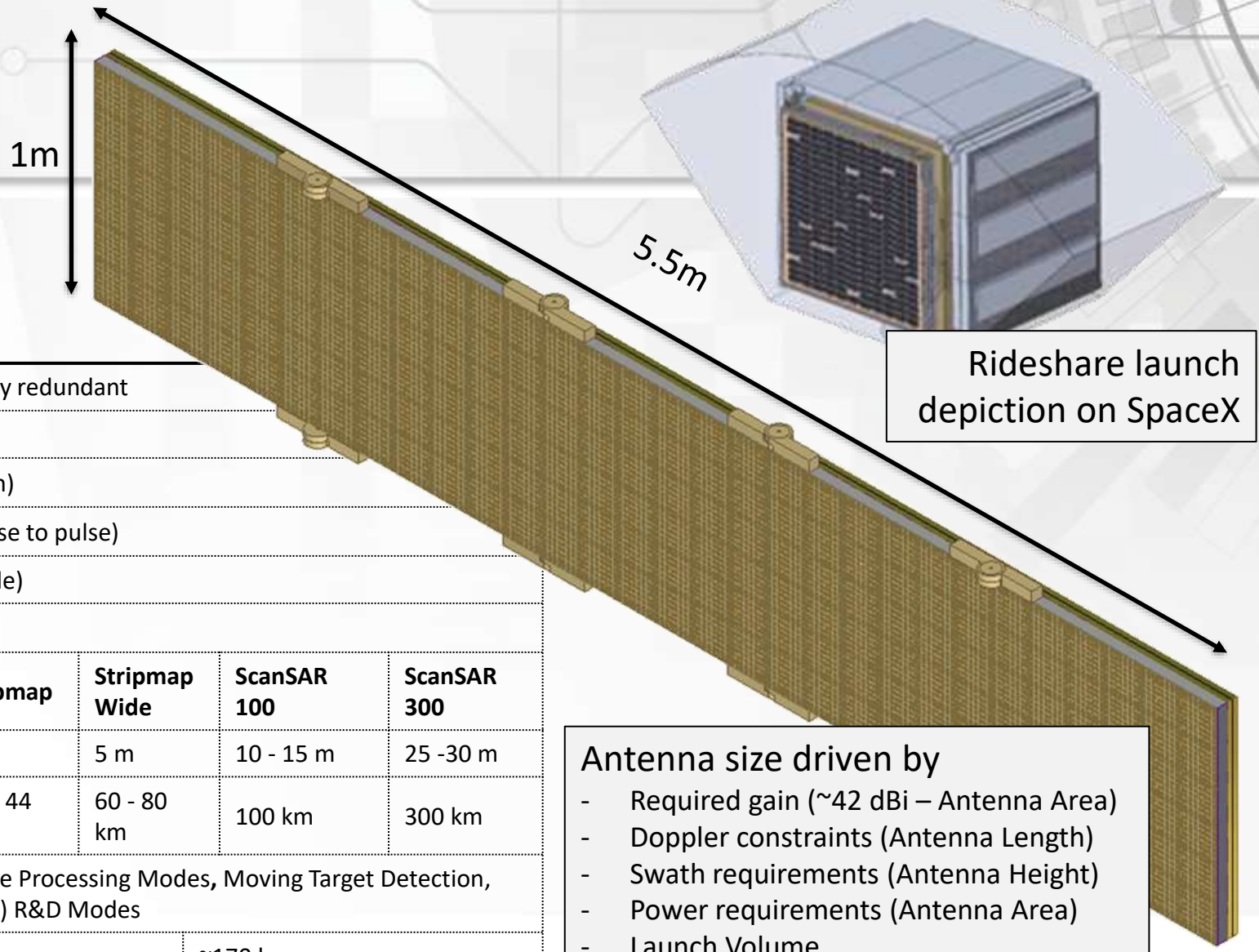
The SAR-C Payload

A flexible design for C-band μsat SAR missions



Rideshare launch depiction on SpaceX

Operational Lifetime	5 years, Payload and Avionics fully redundant					
Operating Band	C-band (5.5 GHz)					
Bandwidth	600 MHz (0.25m range resolution)					
Polarisation	Quad Pol (VV, VH and HV, HH pulse to pulse)					
Peak Transmit Power	Up to 16 kW (up to 18% duty cycle)					
Imaging Time per Orbit	Up to 5 min					
Imaging Modes (Resolution / Swath)	**Spotlight**	**Sliding Spotlight**	**Stripmap**	**Stripmap Wide**	**ScanSAR 100**	**ScanSAR 300**
	0.5 – 1.5 m	1-2 m	3 m	5 m	10 - 15 m	25 -30 m
	10 x 10 km	20x20 km	20 – 44 km	60 - 80 km	100 km	300 km
Extended Imaging Modes to allow further R&D	VideoSAR, Onboard and Real-time Processing Modes**,** Moving Target Detection, Multi-Input Multi-Output (MIMO) R&D Modes					
Mass	Payload			~170 kg		
Launch	Foldable to typical ride-share launch volumes					
Interfaces	Standard interfaces to data recorders and mission computers					
Onboard Processing	(design goal) Parallel output datapath that allows processing whilst still recording					

Antenna size driven by

- Required gain (~42 dBi – Antenna Area)
- Doppler constraints (Antenna Length)
- Swath requirements (Antenna Height)
- Power requirements (Antenna Area)
- Launch Volume

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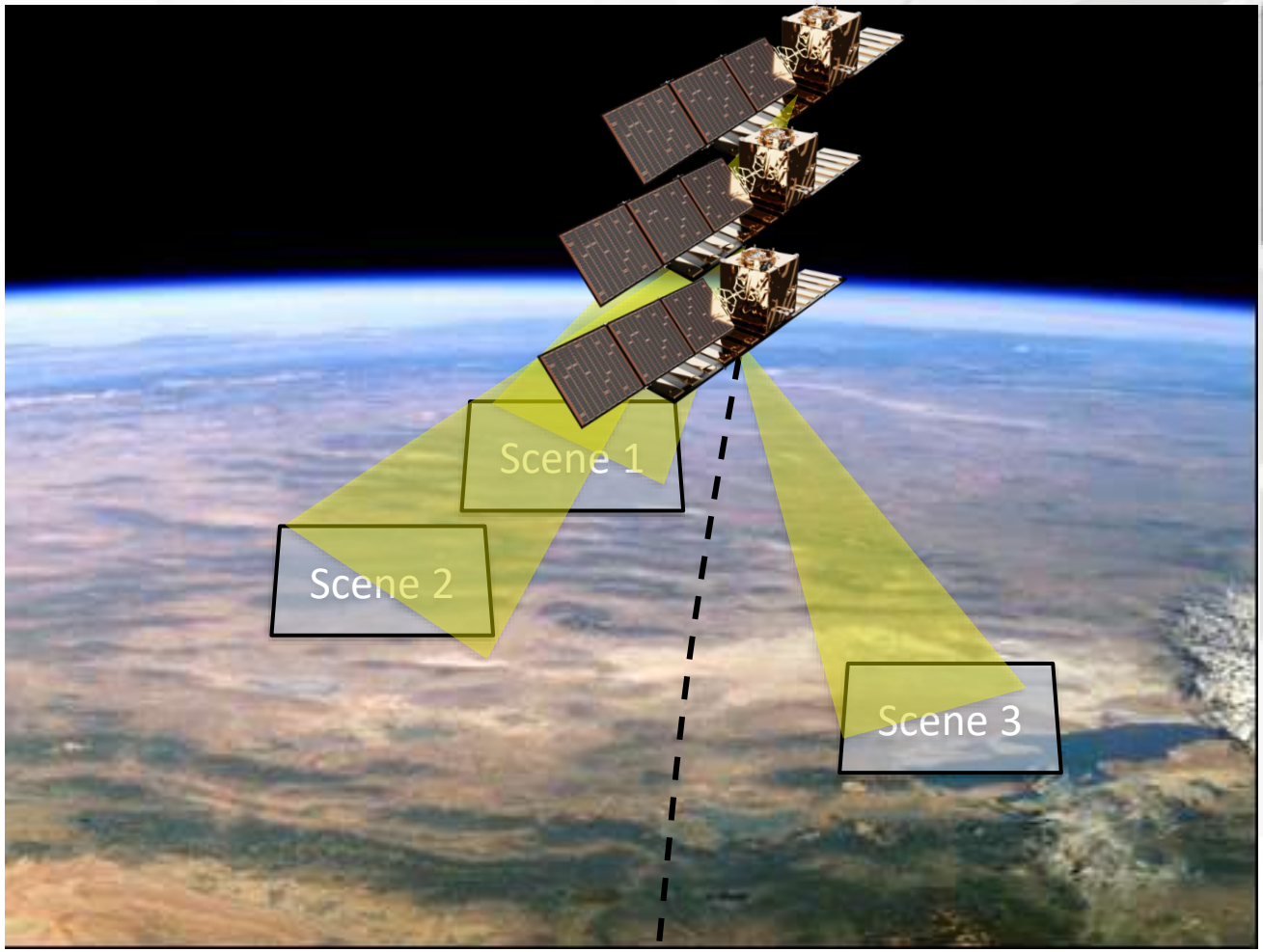
Key elements of the SAR-C Payload Design

- Electronic beam steering allows for fast swath switching and left/right imaging
- Multi phase-center antenna with digital beamforming allows for HRWS and ATI modes
- Antenna front end designed to support dual/quad polarisation
- Based largely on proven technology that has been flown in airborne tests and which is used in other radar designs
- Designed for production in volume as is required for constellations
- Redundancy to align with a 5 year lifetime
- Digital architecture allows for evaluation of onboard processing in tech-demo phase



Element Spacing allows for 90 deg of elevation scanning (+- 45 deg)

Supports ScanSAR and Wide angle Spotlight / VideoSAR modes

Rapid scene switching beyond mechanical steering capabilities

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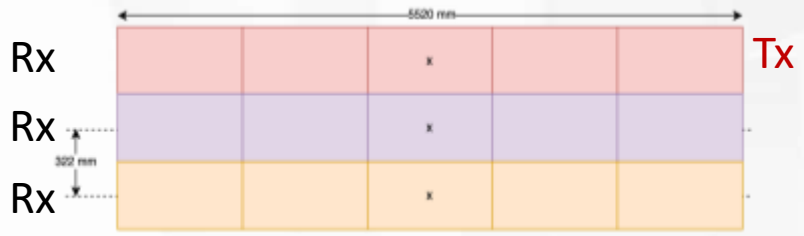
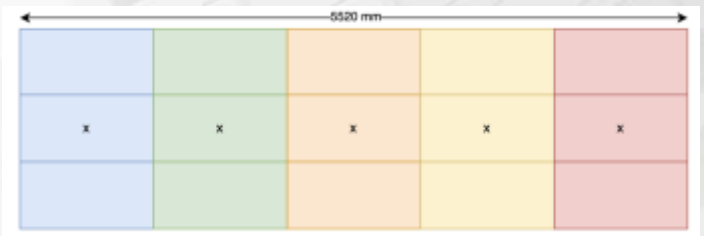
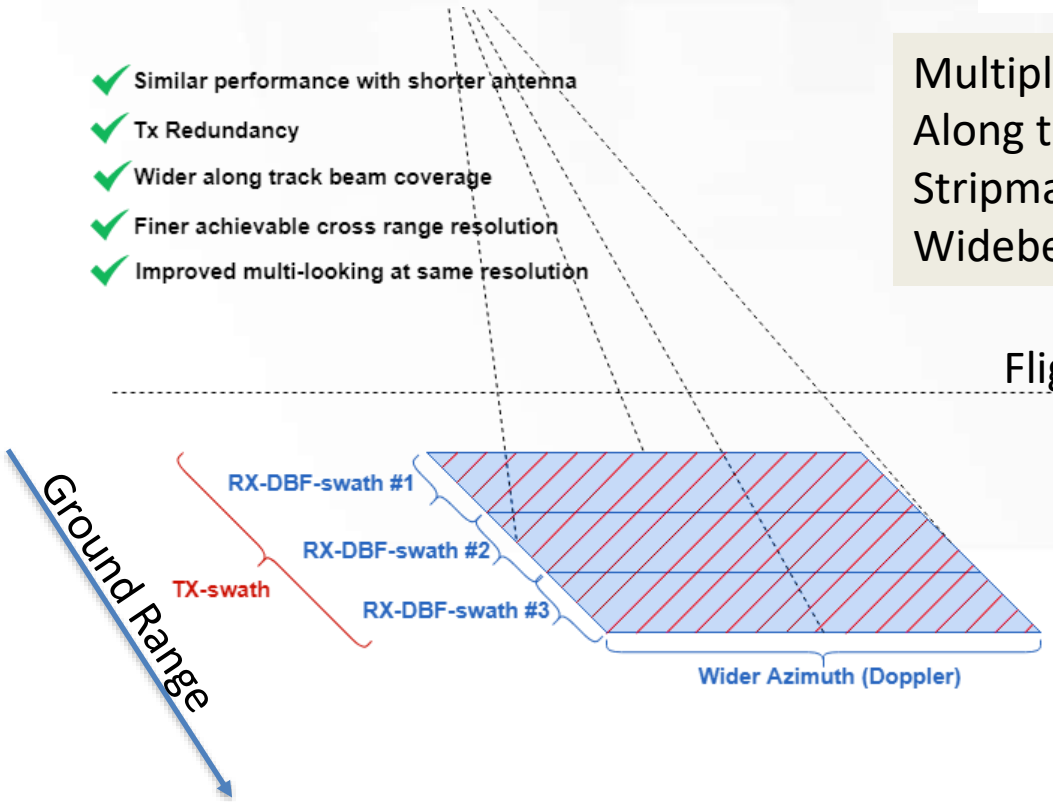




- Similar performance with shorter antenna
- Tx Redundancy
- Wider along track beam coverage
- Finer achievable cross range resolution
- Improved multi-looking at same resolution

Multiple Rx beams along track
Along track interferometry
Stripmap modes with resolution < L/2
Widebeam Spotlight modes



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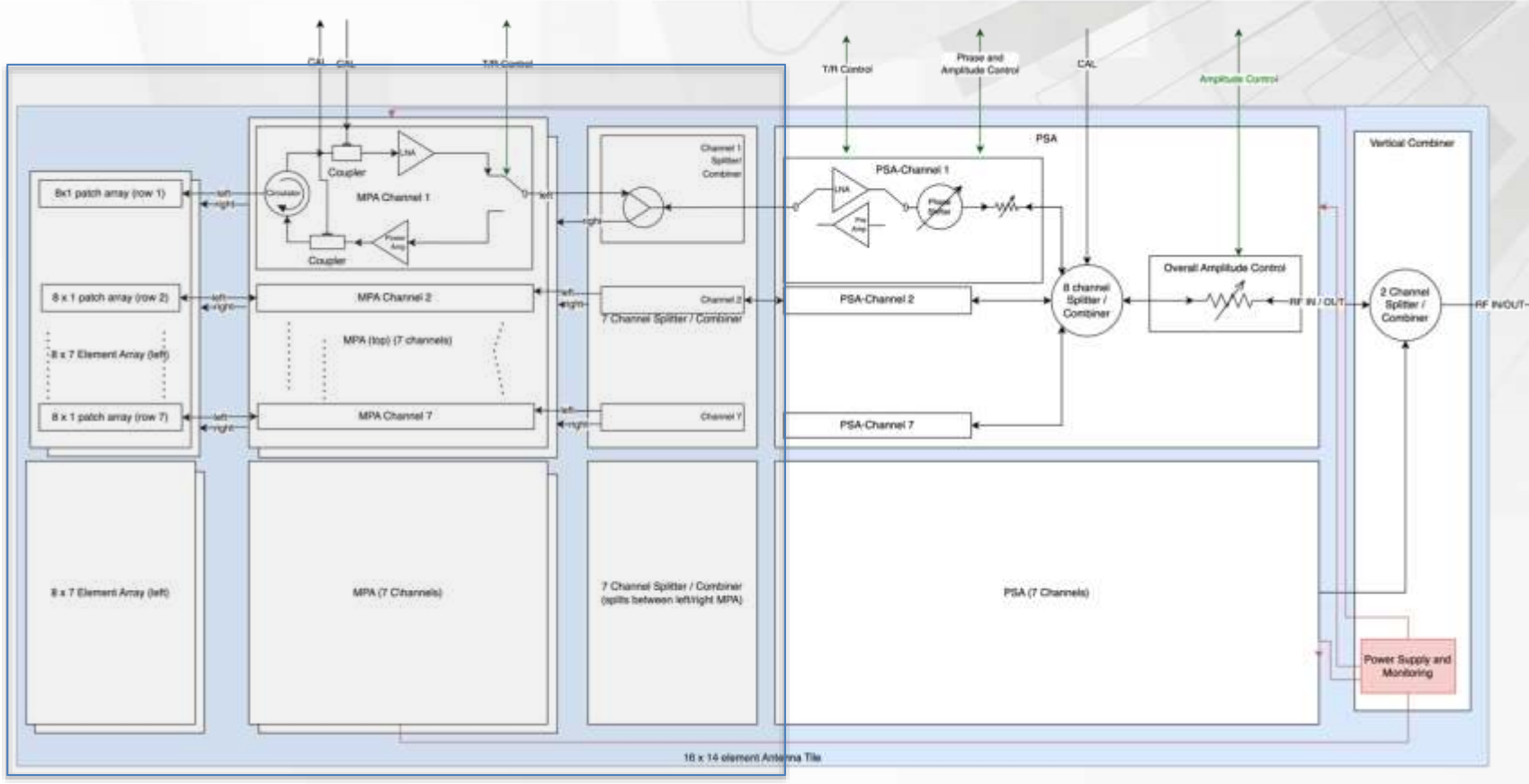

Dual Channel Design in Tx / RX Front End provides for easier path to upgrade to Dual or Quad Polarisation

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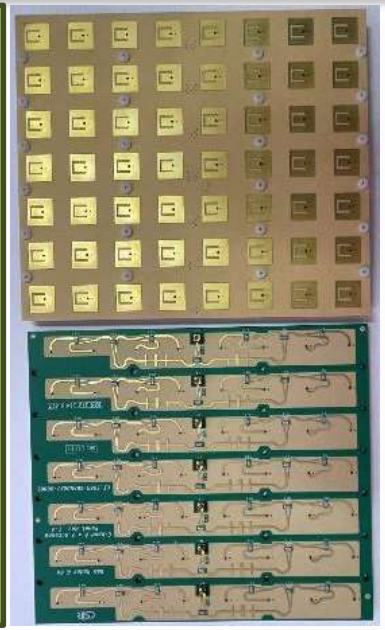
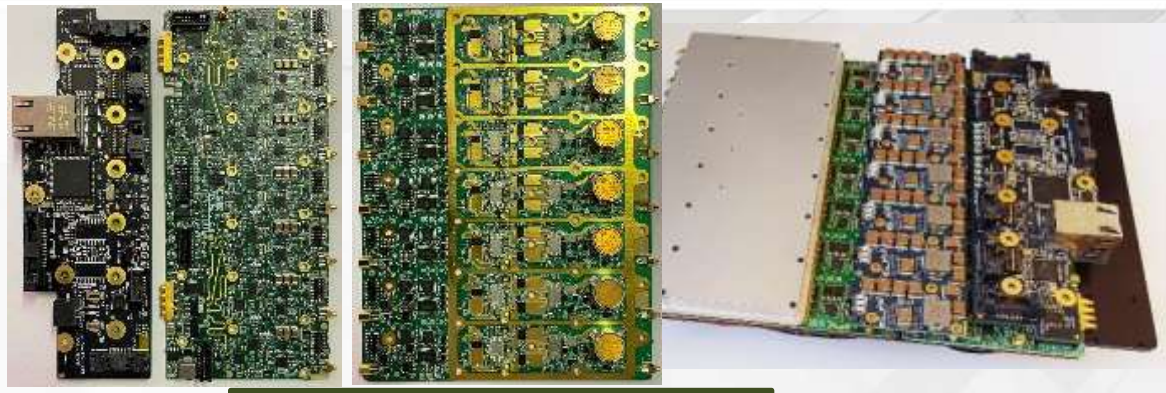
Wideband patch array antennas





Phase array front ends

Airborne multi-channel array antenna

Real-time Processor

C-Band multi-channel Receiver/Exciter

Regular Airborne SAR Flight Campaigns

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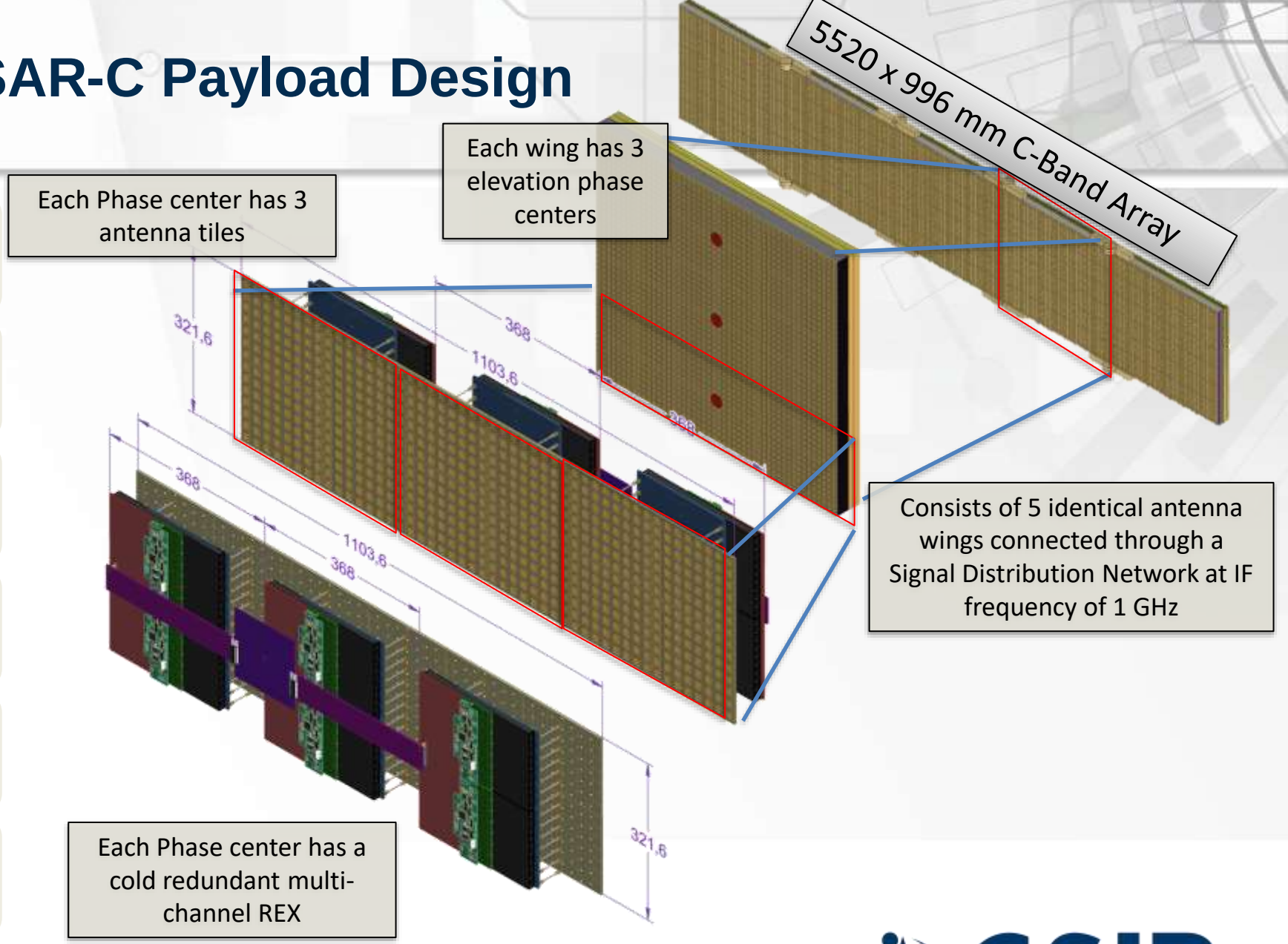

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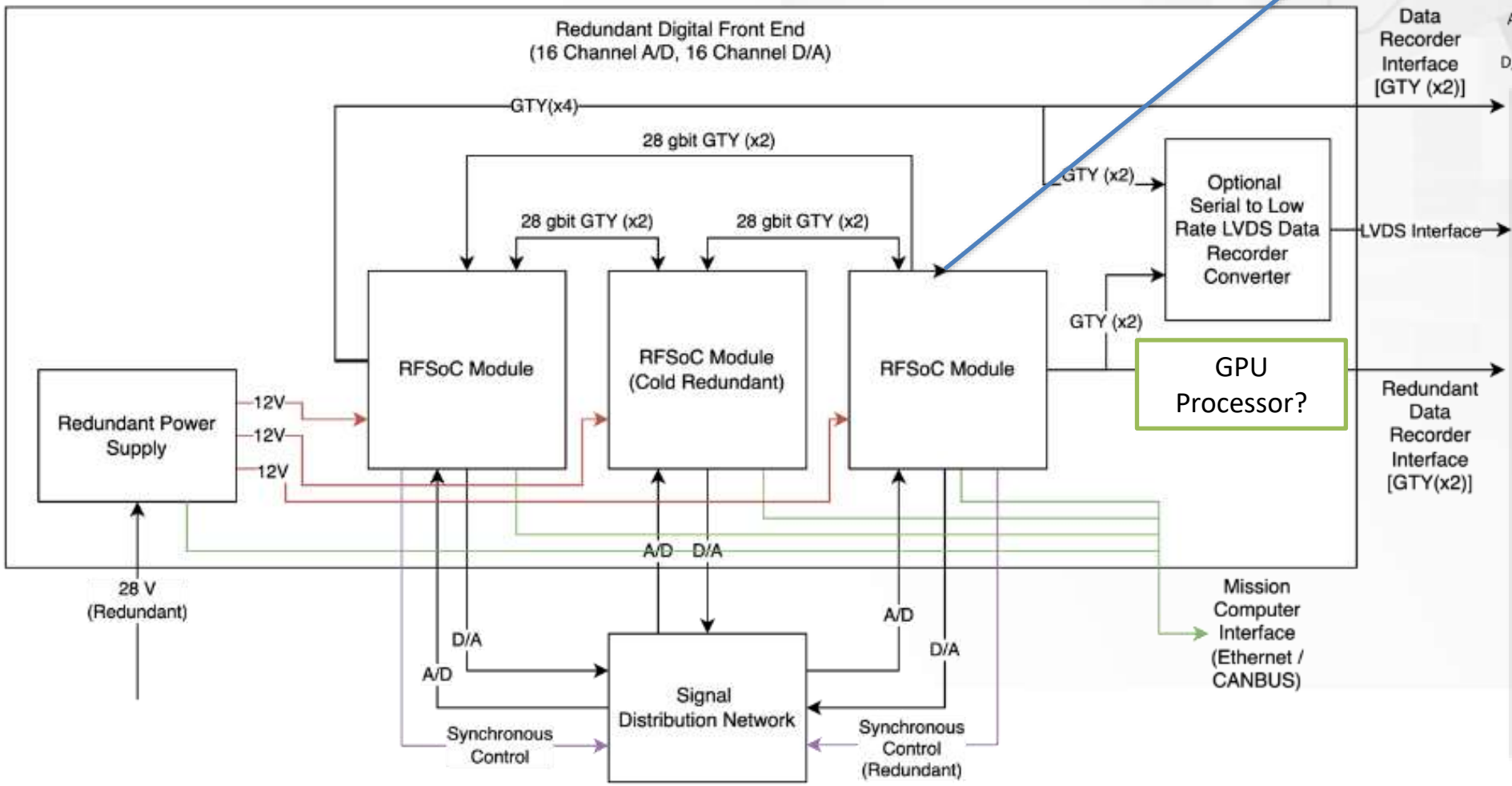
Onboard Processing
(Digital Front End Redundancy)



- **Based on COTS RF SoC Modules**
  - 3rd Gen
  - 8 x 14bit A/Ds (up to 5 GSPS)
  - 8 x 14 bit D/As (up to 10 GSPS)
- **CSIR provides firmware, software and integration and testing for space environment**
  - Cold redundant spare unit
- **Similar modules (Gen 1) has been rad tested**
  - Supplier willing to fix issues resulting from rad testing
- FPGA and Arm Processor allows for data compression and first level of pre-processing (equalization, etc)
- GTY data paths allow for parallel online processor development

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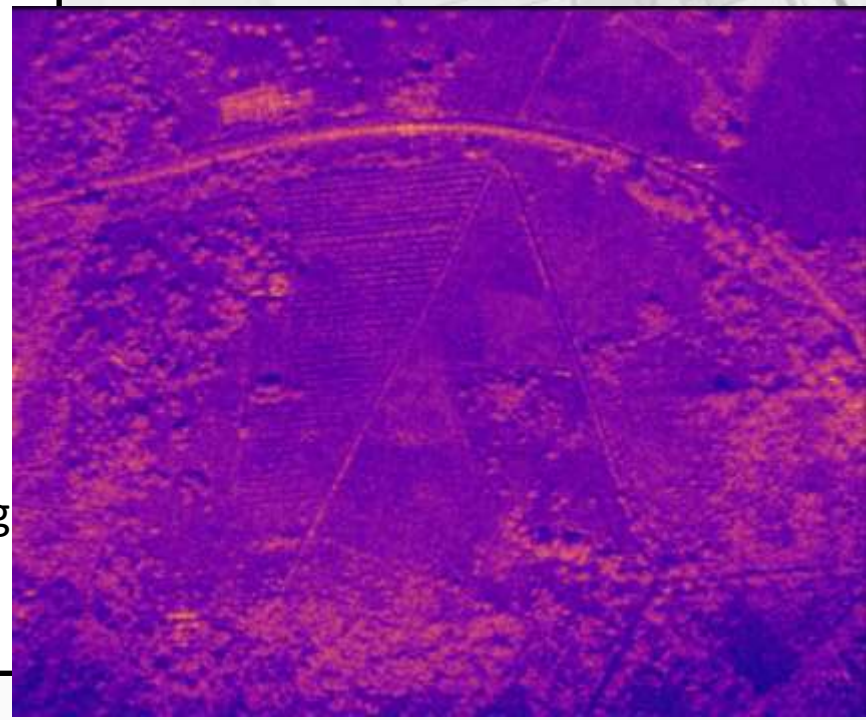
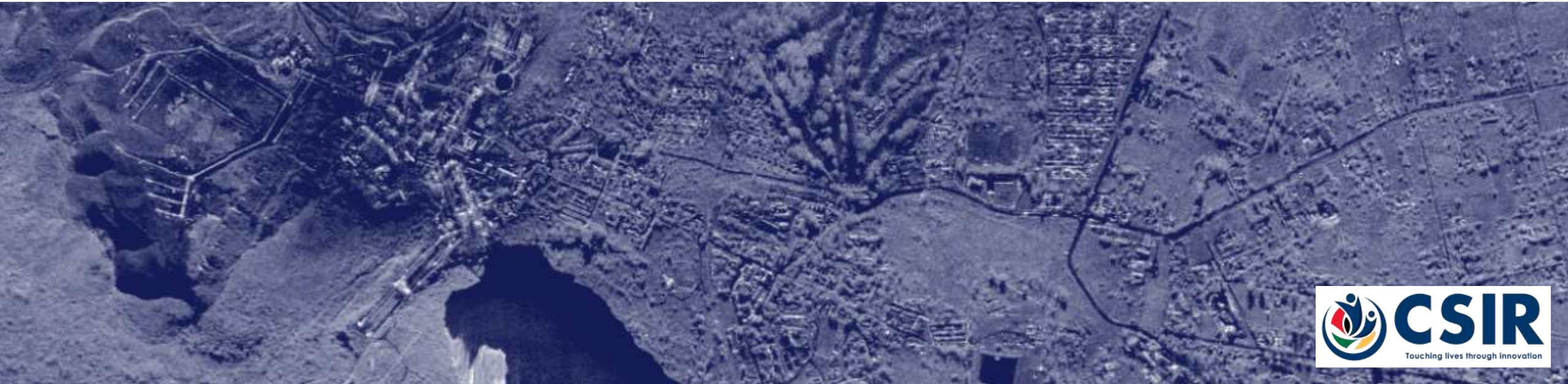
SAR Processor

- **Back-projection** and more traditional SAR algorithms (Chirpscaling, RD, etc)
- Allows for **advanced modes** including Long Dwell and VideoSAR
- Can handle **extreme squint angles**
- Proven in airborne radar scenarios where requirements are more stringent due to unknown platform motion
- Data **outputs in industry standard formats** (including cooperation with industry players) to allow integration into industry workflows
- **GPU acceleration** to reduce processing lag – can already process fine resolution airborne SAR data in real-time
- **Allows for cluster / cloud-based compute scaling** to enable constellation scaling
- Development of **processing for advanced modes** and constellation level processing forms **part of HCD programme** to train a next generation
- **Grow towards on-board real-time processing through the program**





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CSIR Radar (and DFA Space) know-how spans decades

and is applied to the SAR-C design

Airborne Radar / SAR

- SAR system design and development capability
- SAR system performance modelling
- SAR Signal Processing for Image formation
- Wideband Radar Calibration and equalisation

Tracking Radar

- Real-time FPGA based, high throughput Radar Signal Processors
- Accurate antenna design and simulation
- Wideband radar Calibration and Equalisation
- Inverse Synthetic Aperture Radar Processing (similar to Spotlight SAR)

Surveillance Radar

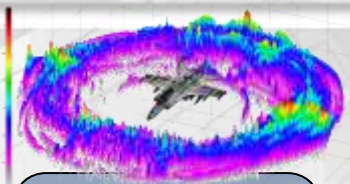
- C-Band phased array antenna technology
- C-band integrated receiver and LO modules

Multi-Static Radar

- Radar synchronisation across multiple nodes
- Digital Beamforming

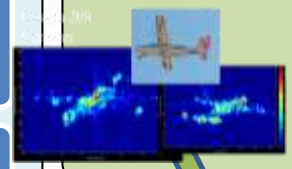
RCS Measurement

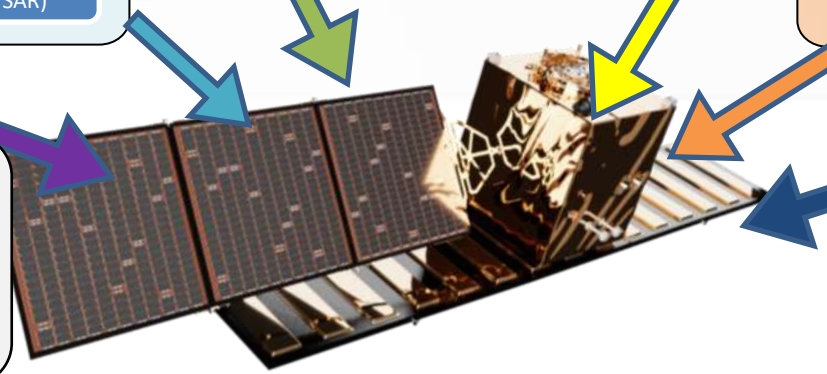
- High accuracy, high stability radar design for accurate cross-section (backscatter) measurement
- Radiometric Calibration techniques
- Wideband receiver equalisation to achieve high-contrast HRR, micro-Doppler, ISAR and SAR measurements

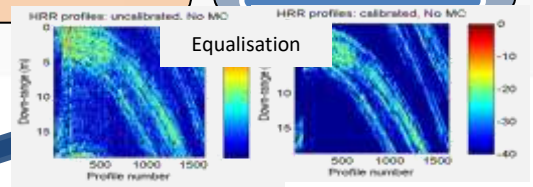


General Radar Capability

- Radar Cross Section modelling (deep expertise in Electromagnetic modelling)
- Modelling based radar system design (experience down to bit-level modelling where required)
- PCB Design, Development, Assembly and Testing, etc







DFA Space Expertise (spanning decades)

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Thank you

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- For your body, please use Arial 14/16
- Please use these colours for your presentation. 
- Please ensure high-res images are used.
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- Ensure consistency on the above throughout your presentation.

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