Signal processing

(in RA)

A Radio Observatory is a *signal processing and computing facility* with an unusual source of data…

… Astronomers are always wanting more (of everything) !

Signal Processing…

Why?

– To see what we are looking for!

What?

– Add up signals

– Take bits away from signals

– Select the bits of signals we want

– Process signals from one form to another

When?

– At the time

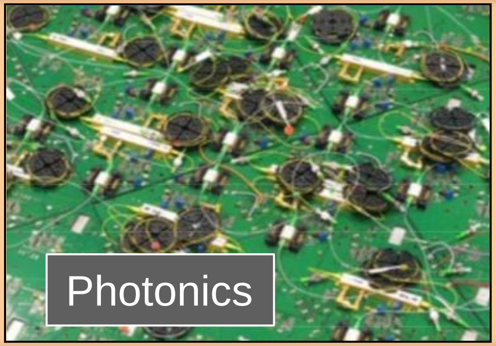
– After an observation

Some signal processing

Metal mirrors



Cables & Switches

Photonics

Some Others

Lipson Beever strips

LC Delay Line

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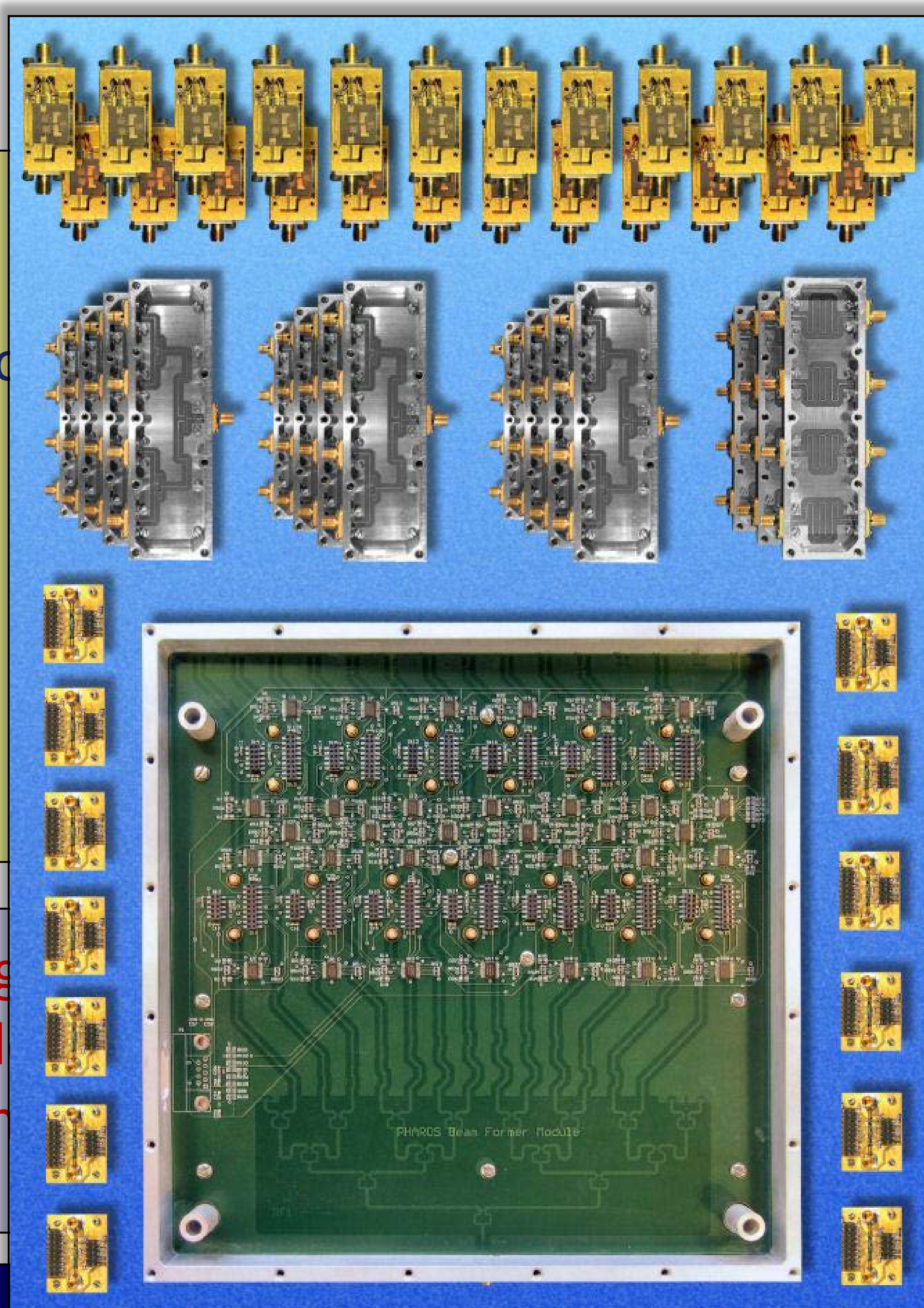
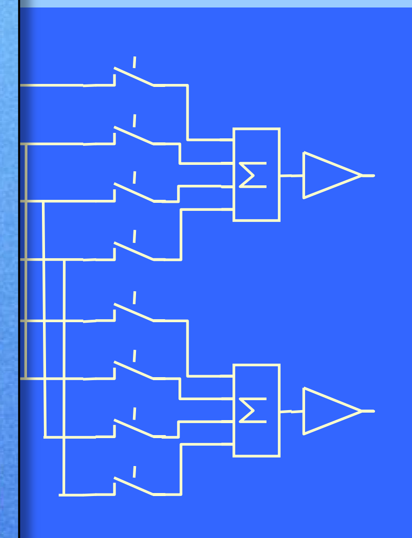
Electronics

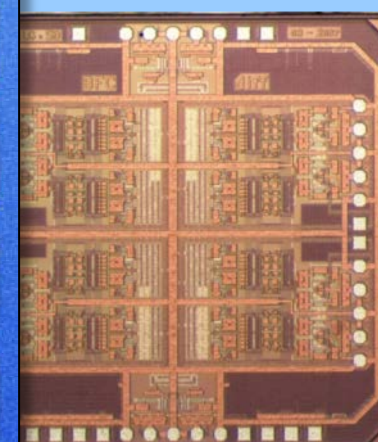
Analogue

- Phase rotati
- Time delay
- Level adjust
- Summing channels
- etc.

- Special desig
- Channels=el
- Stability, co







Digital Electronics

Digital is:

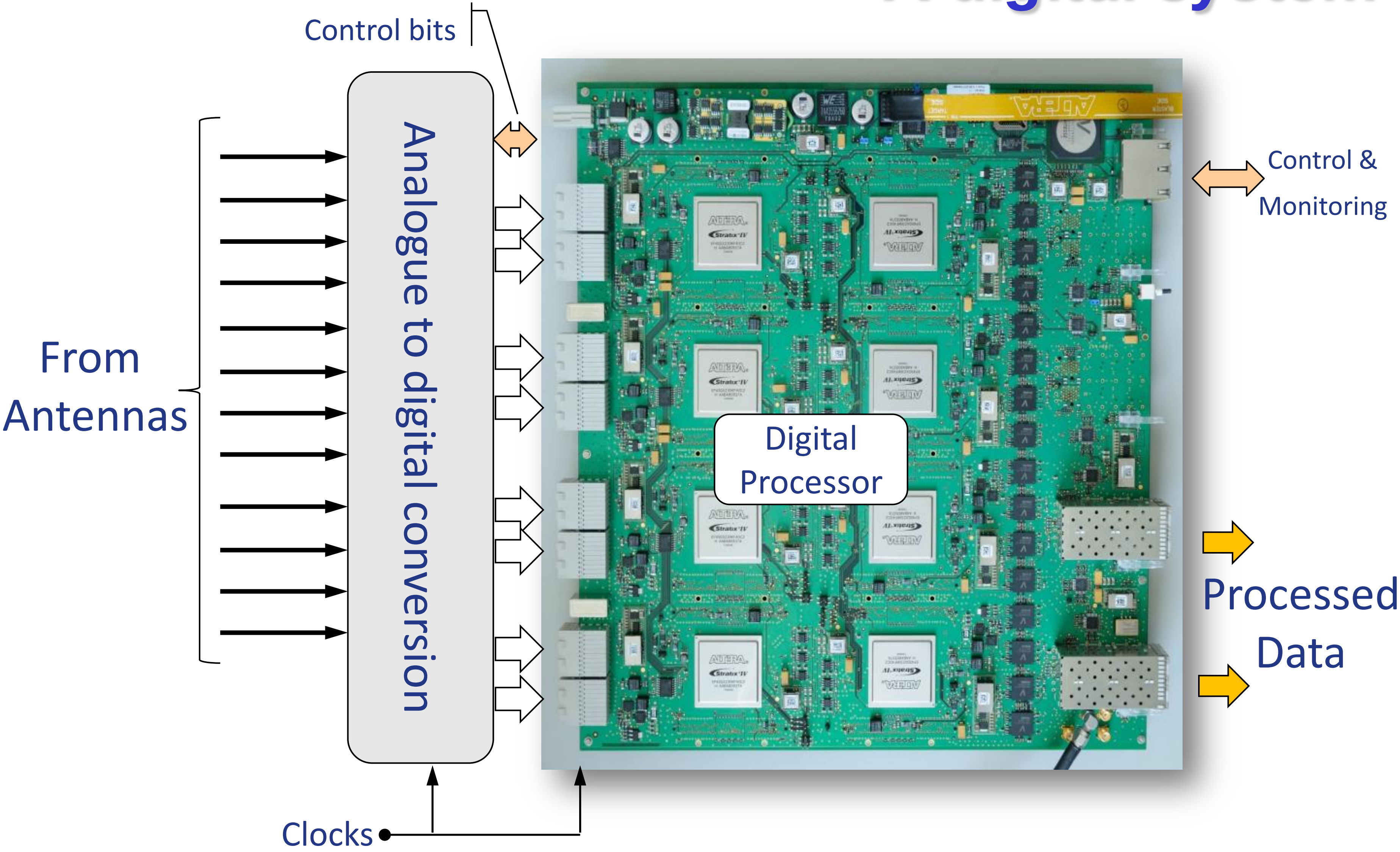
- Flexible
- Compact
- Programmable
- Driven by the **ICT industry**
- Highly integrated …

Digital is also:

- Tricky
- Power hungry
- Abstracted
- Interference causing

Communication capability is also critical!

A digital system



Digital Processing types

Type	Pros	Cons
Custom/Asics	Low power High performance Low cost in high volume	Long Development Expensive NRE Inflexible
FPGA	Low-Medium power Programmable High performance	Expensive parts Hard to program Specialist boards
CPU	Very easy to program Very flexible COTS systems available	Low performance for SP High power
Many core processors	Medium Power/performance Very flexible Easy to program COTS systems available	Limited I/O

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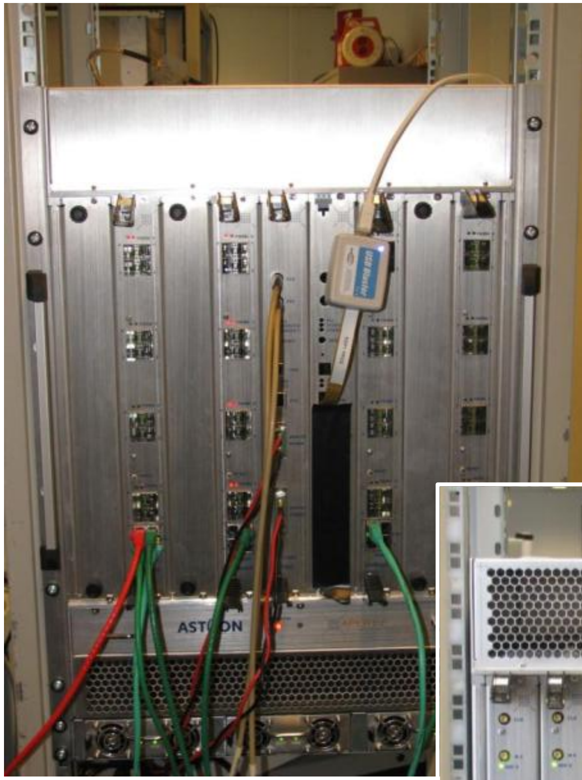
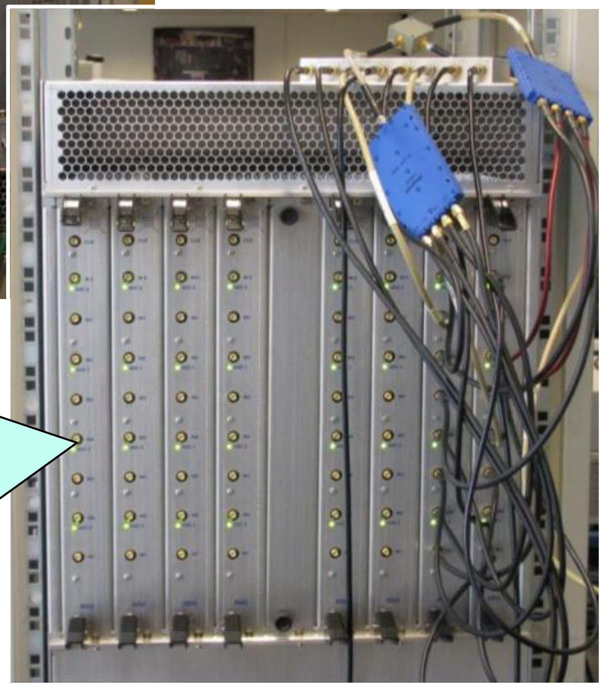
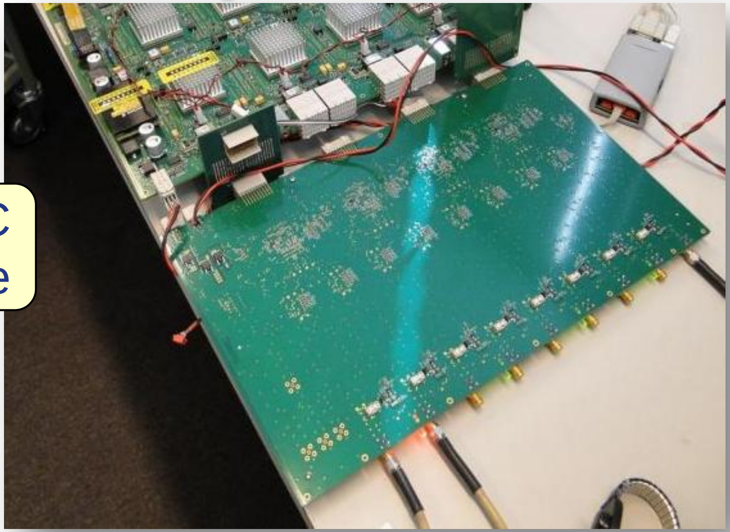
Uniboard 1 Implementation

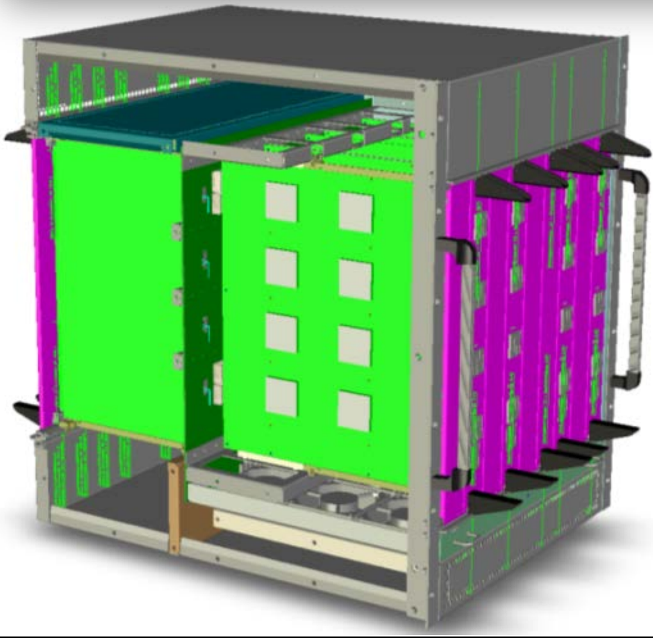




Shelf:
- 4 Processors
- 8 ADC interfaces
- 64 inputs (32 elements)

ADC Interface





More is Better!

- Fi
- Ba
- Re
- Pr
- Dy
- Flexibility
- Interference excision

More, smaller receptors

gives

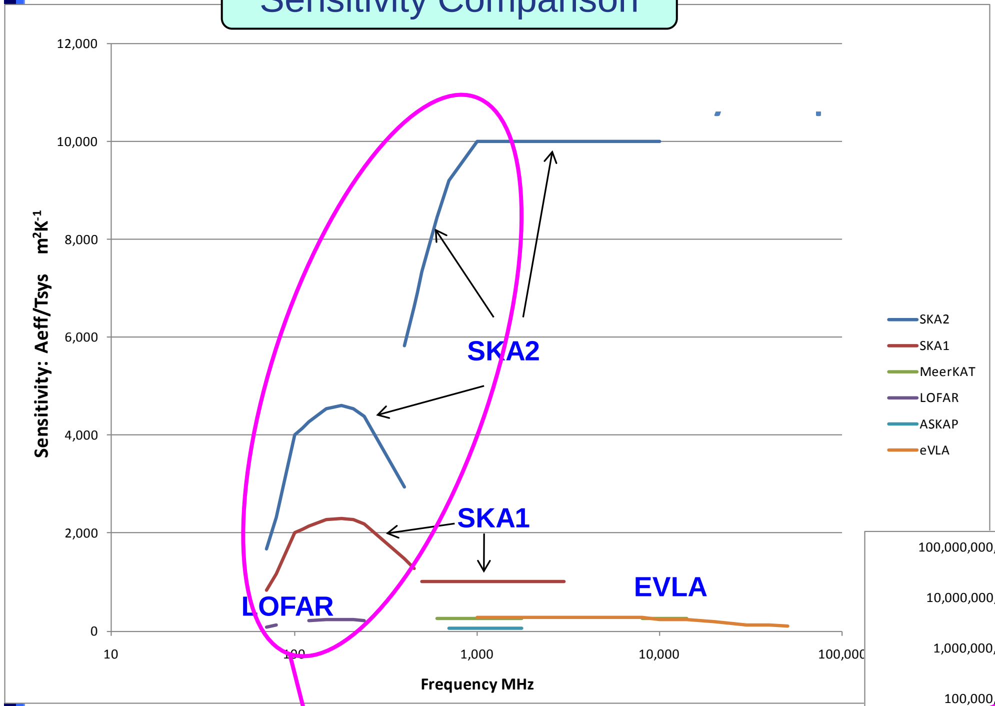
Bigger Field of View

using

Much more Signal Processing

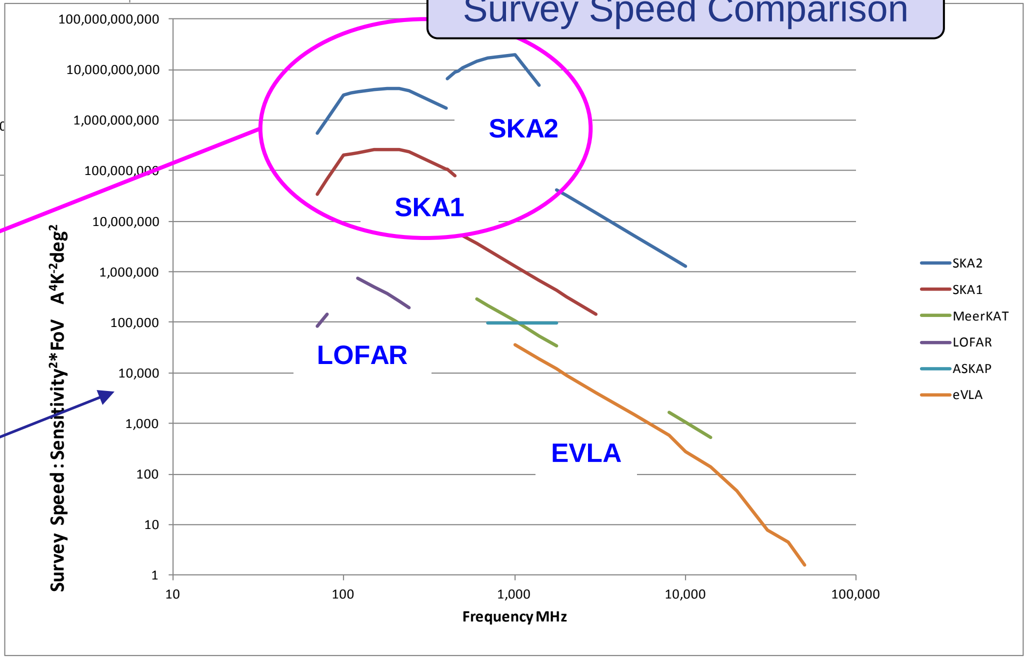
Small dishes & Phased arrays

Sensitivity Comparison



SKA$_1$ & SKA$_2$ will have very high sensitivity & survey speeds

Survey Speed Comparison



Aperture Arrays

Note: log scale!

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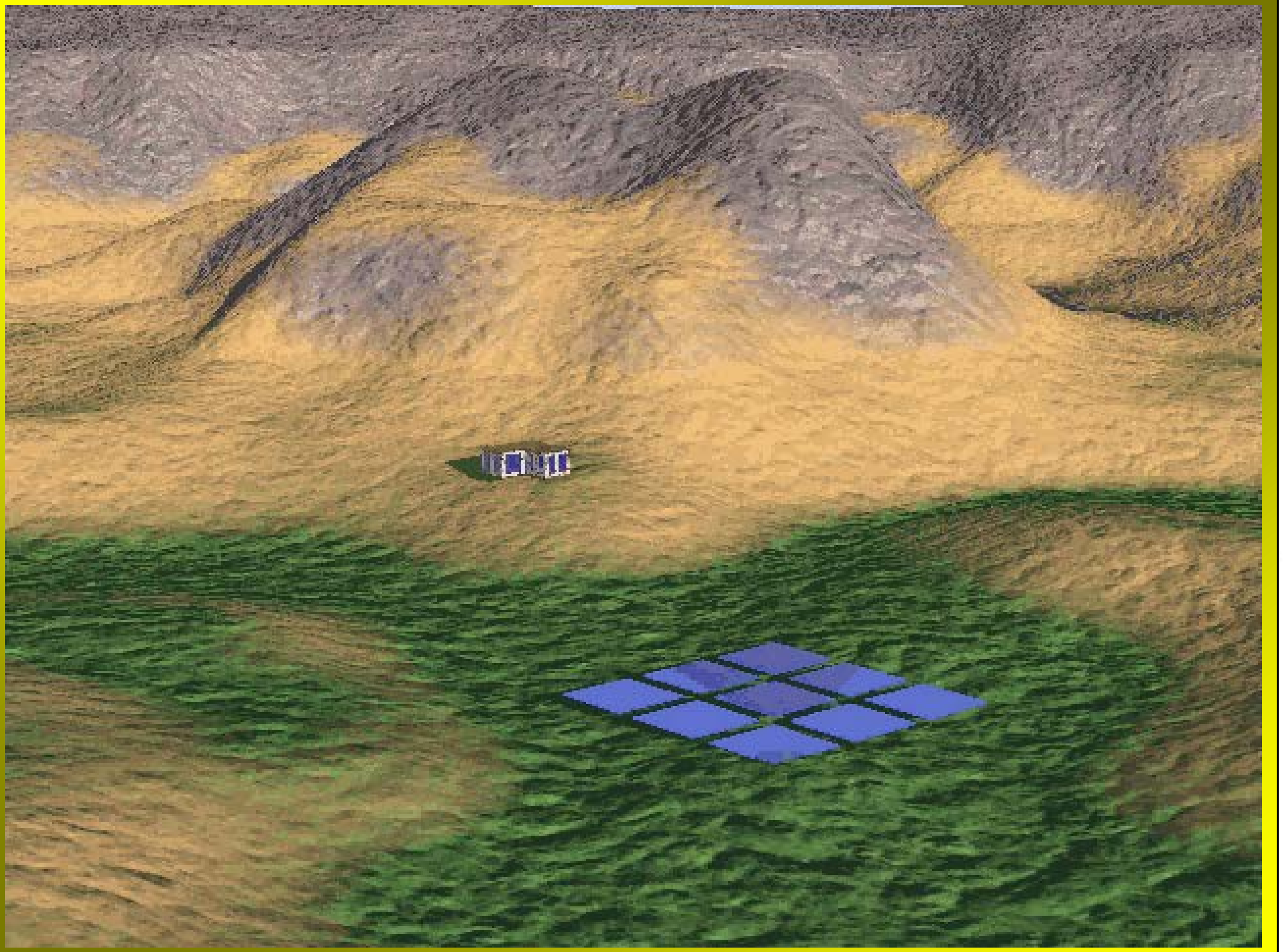
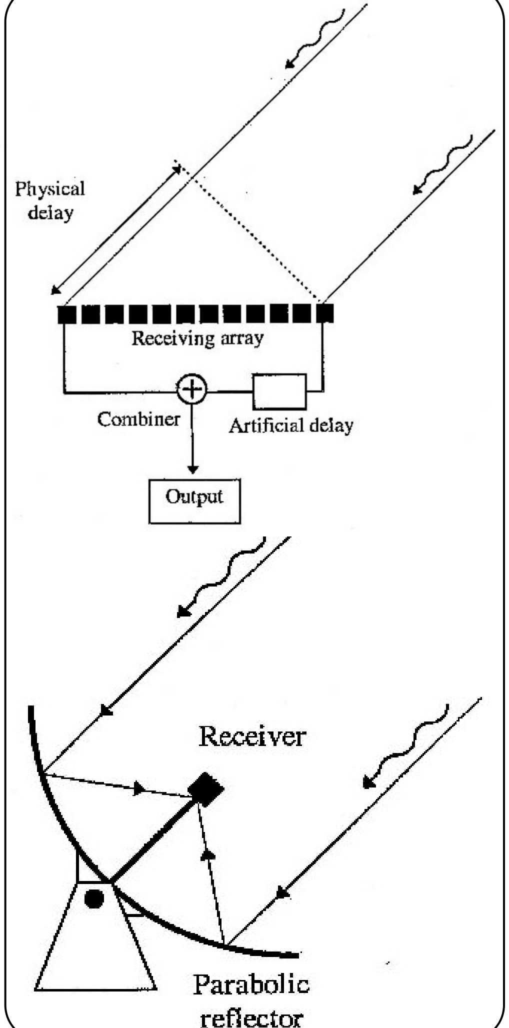
Aperture Arrays

Aperture Arrays



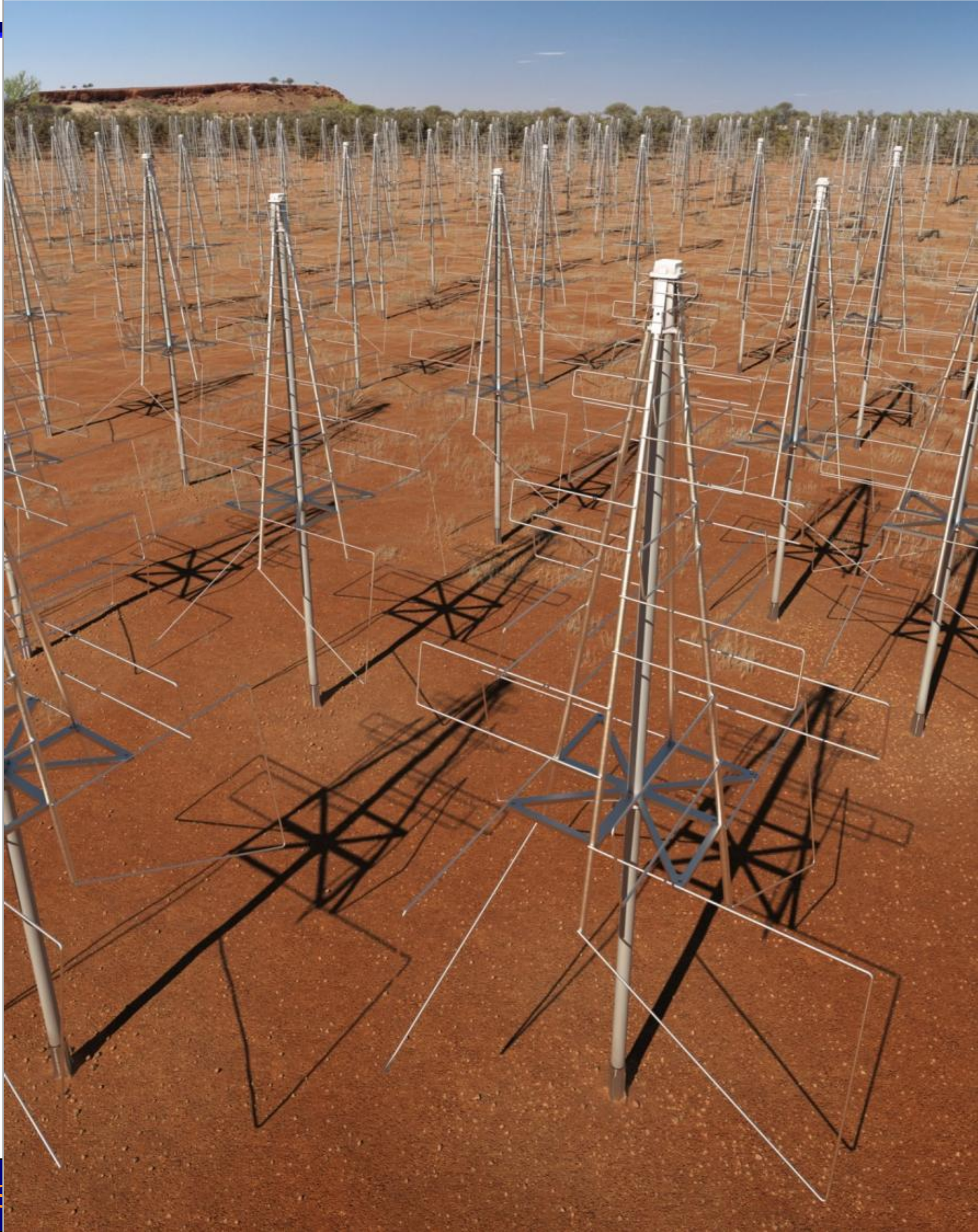
Michael Kramer

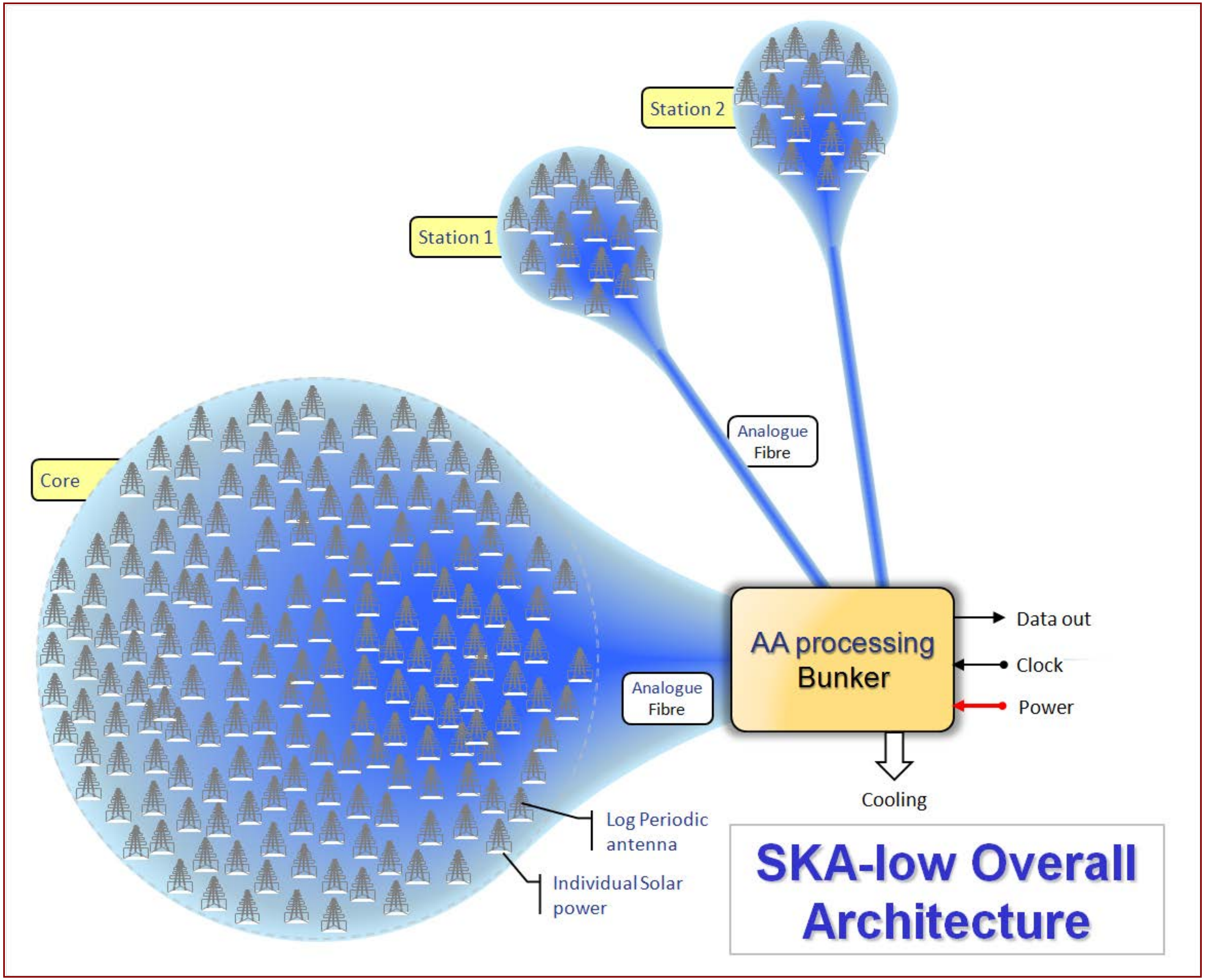



LOFAR station

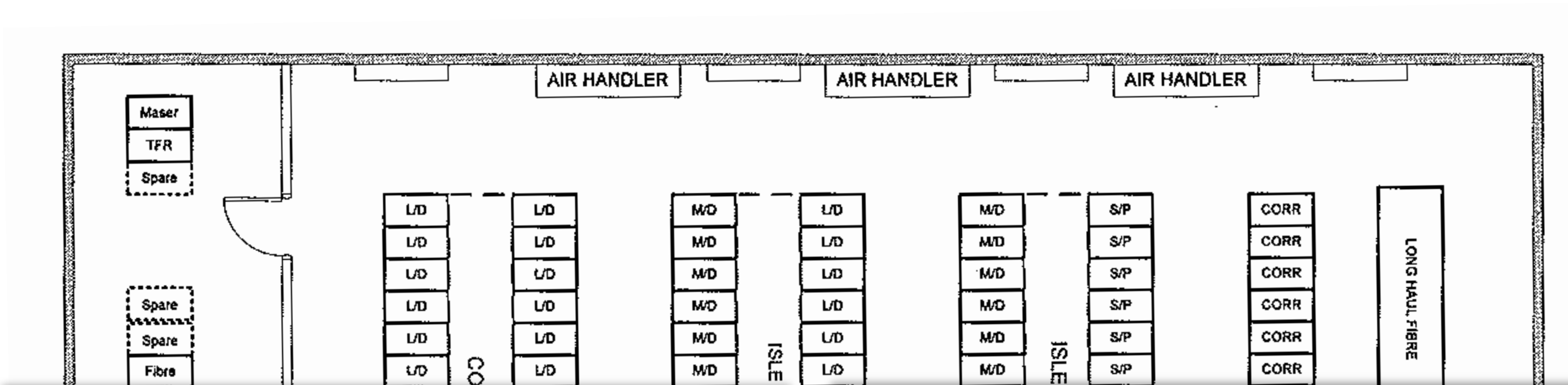
SKA-low Design Overview (proposed)

Target	Parameters
50 – 650	MHz
256,000	Antennas
300	MHz B/W
~250 – ≥911	Stations
10 – 20	Tb/s
Multiple	Beams



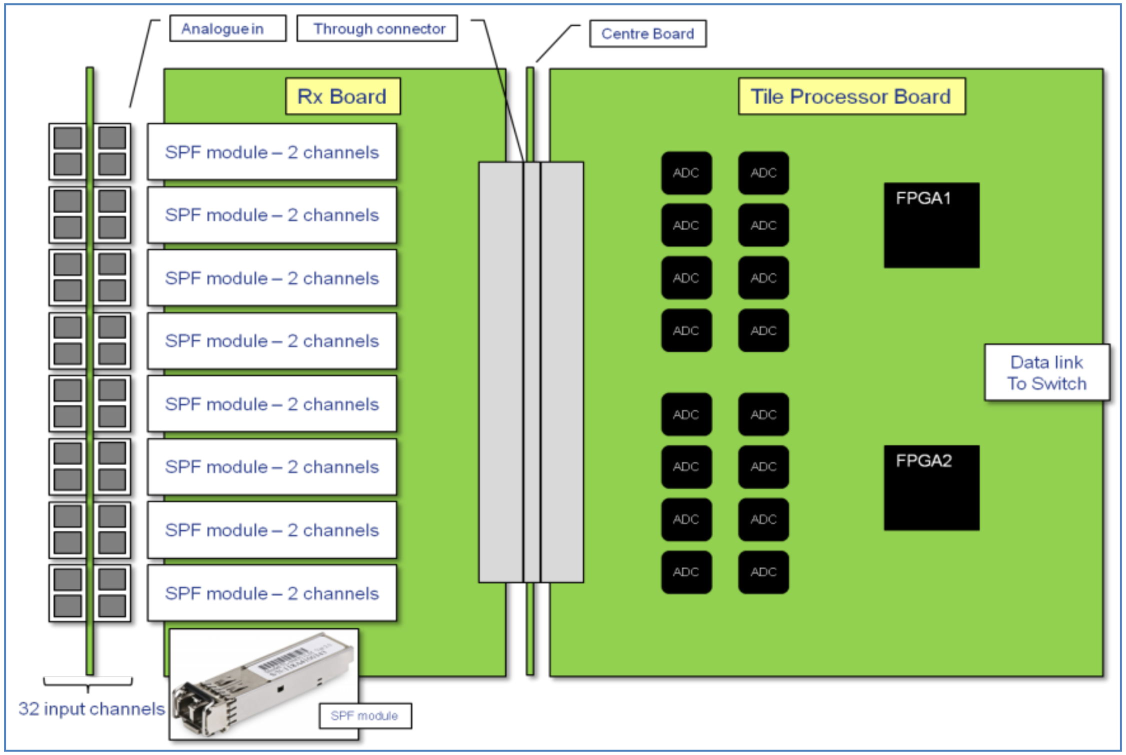

Station 2
Station 1
Core
Analogue Fibre
Analogue Fibre
AA processing Bunker
Data out
Clock
Power
Cooling
Log Periodic antenna
Individual Solar power
SKA-low Overall Architecture

Example bunker…



SKA-low processing trail:

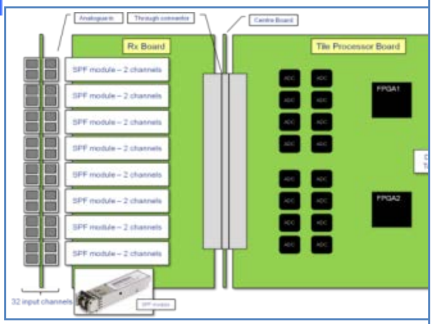
SKA-low processing trail:

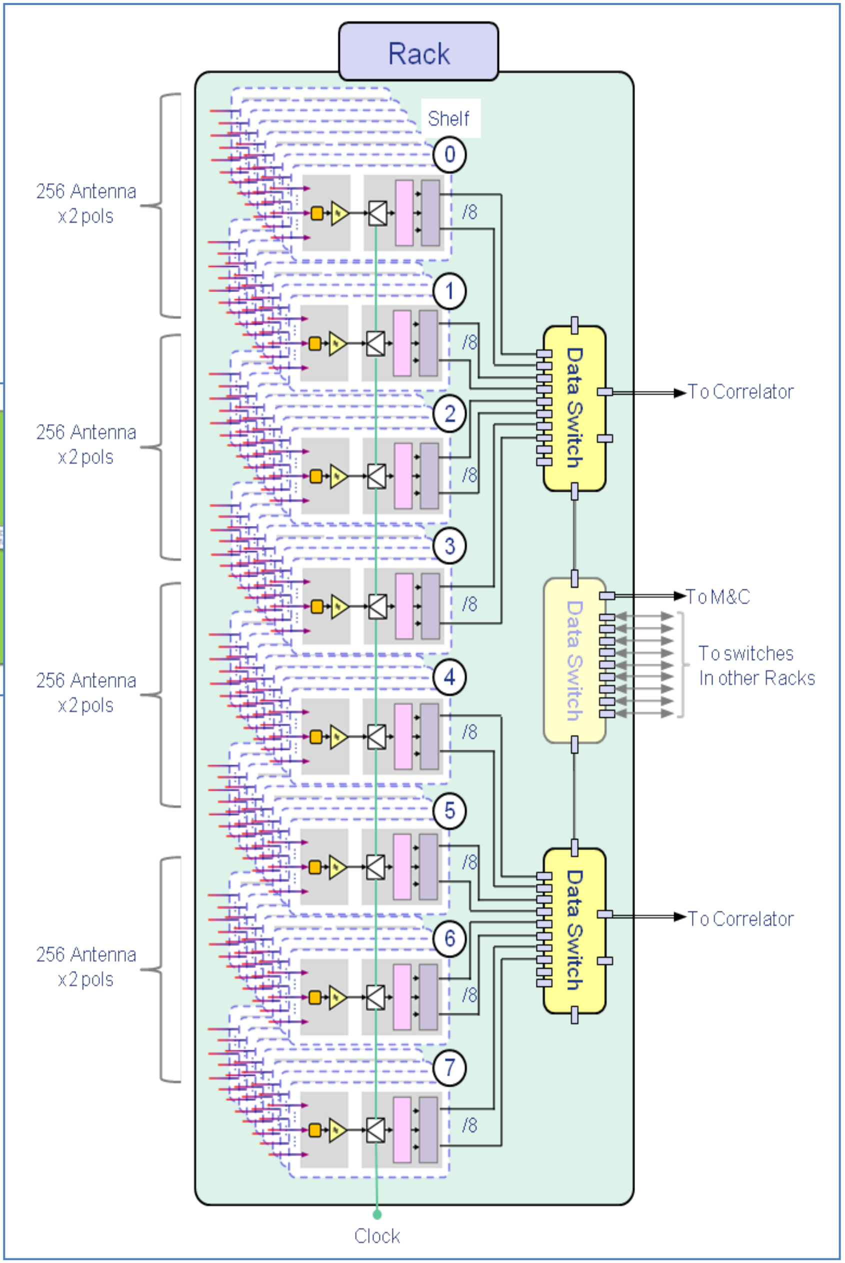


Analogue inputs

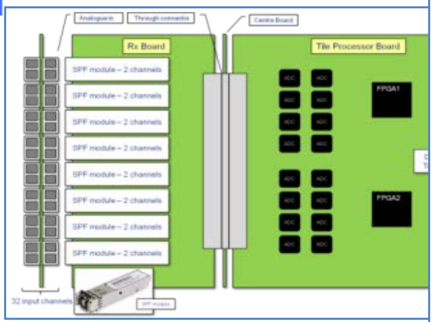
16 dual pol. antennas

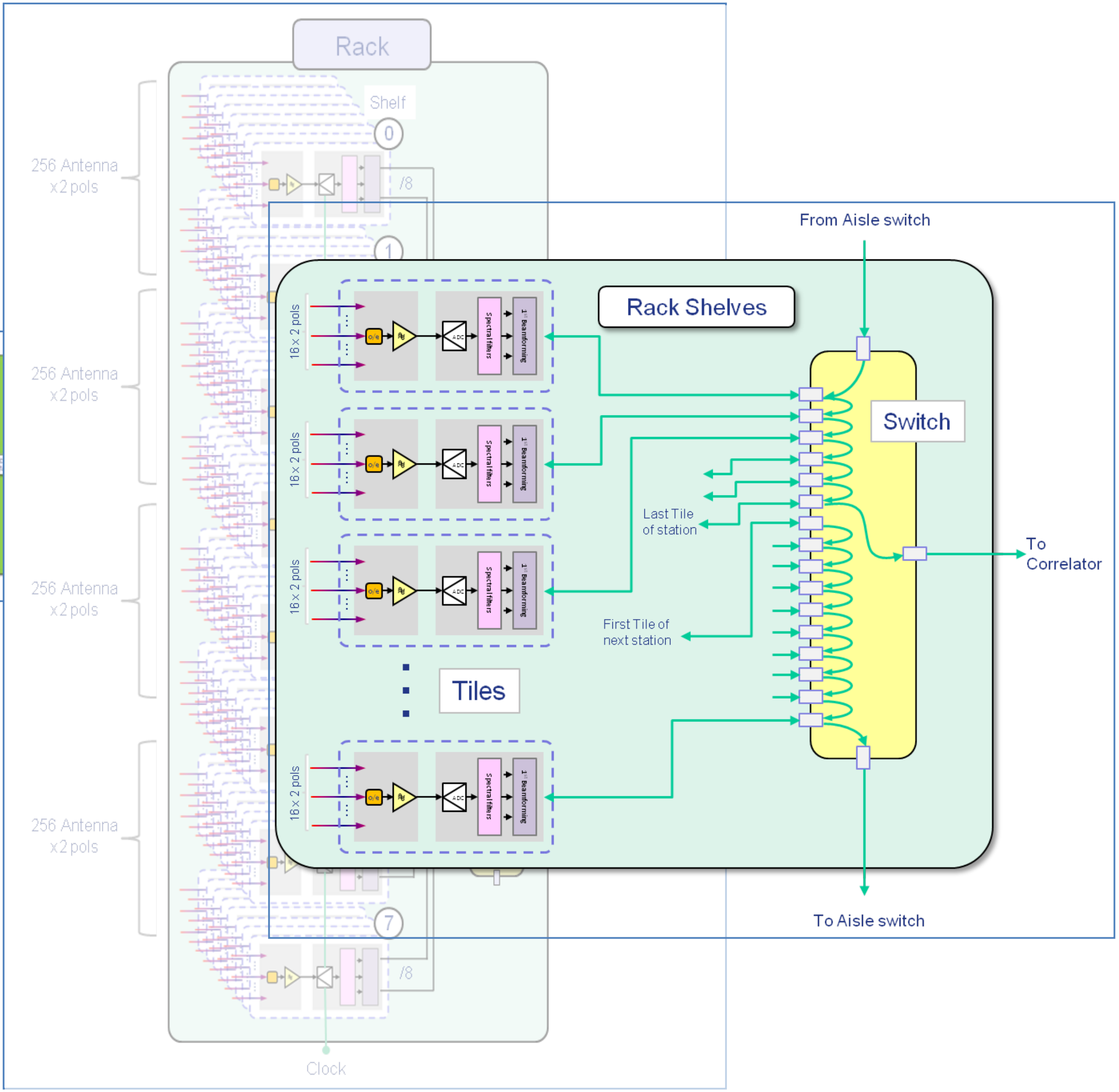
Digitise and beamform

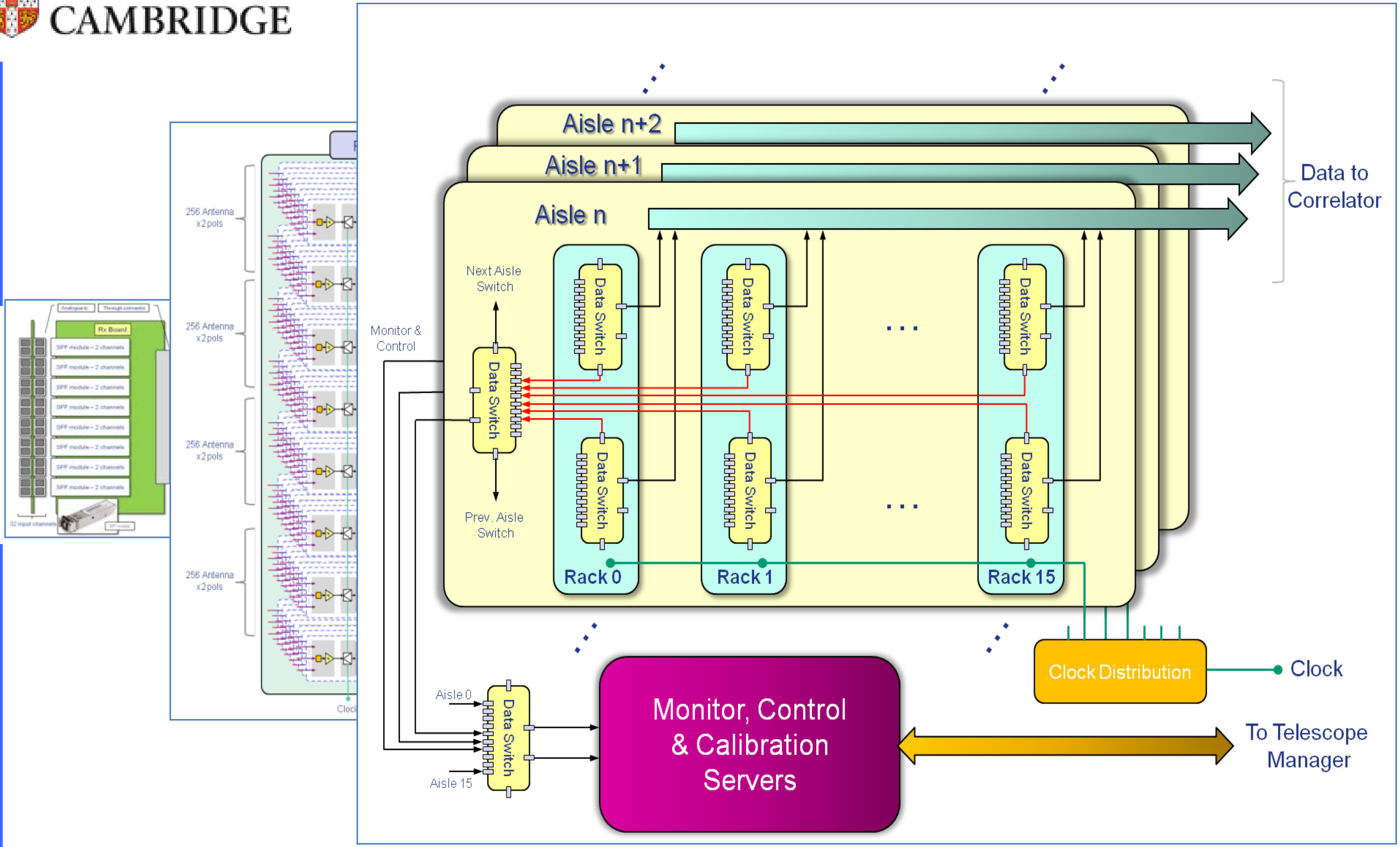




- 64 Tile processors in a rack
- 2048 fibres into each rack
- Switch network to handle the data
- Power supplies


Rx Board
Tile Processor Board
FPGA1
FPGA2


Rack
Shelf
0
1
7
256 Antenna
x2 pols
256 Antenna
x2 pols
256 Antenna
x2 pols
256 Antenna
x2 pols
/8
/8
Clock
From Aisle switch
Rack Shelves
Switch
16 x 2 pols
16 x 2 pols
16 x 2 pols
16 x 2 pols
Last Tile
of station
First Tile of
next station
Tiles
To
Correlator
To Aisle switch



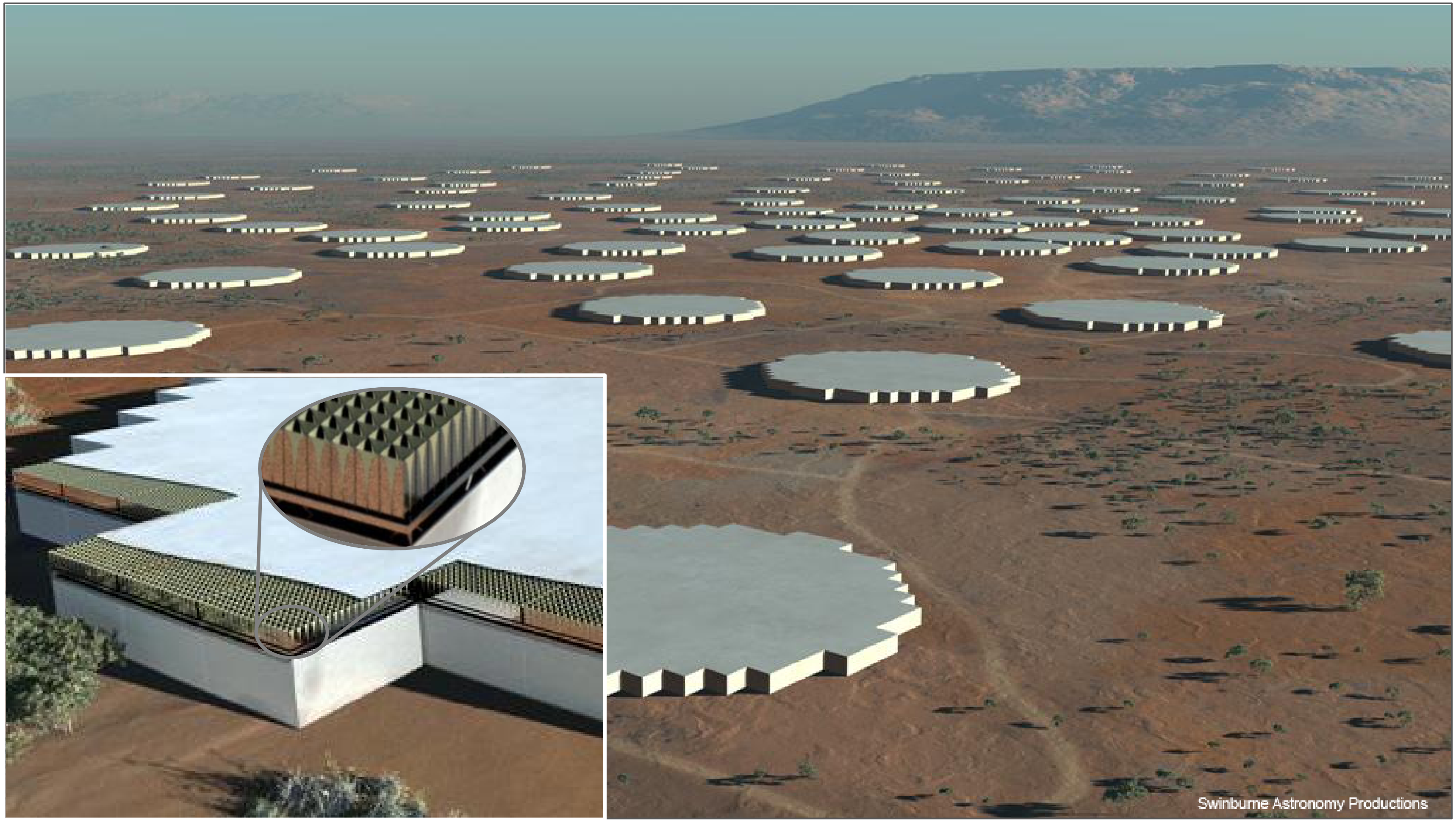
256 racks in 16 aisles

Flexible beamforming

High speed switched network

Overlayed monit. & control

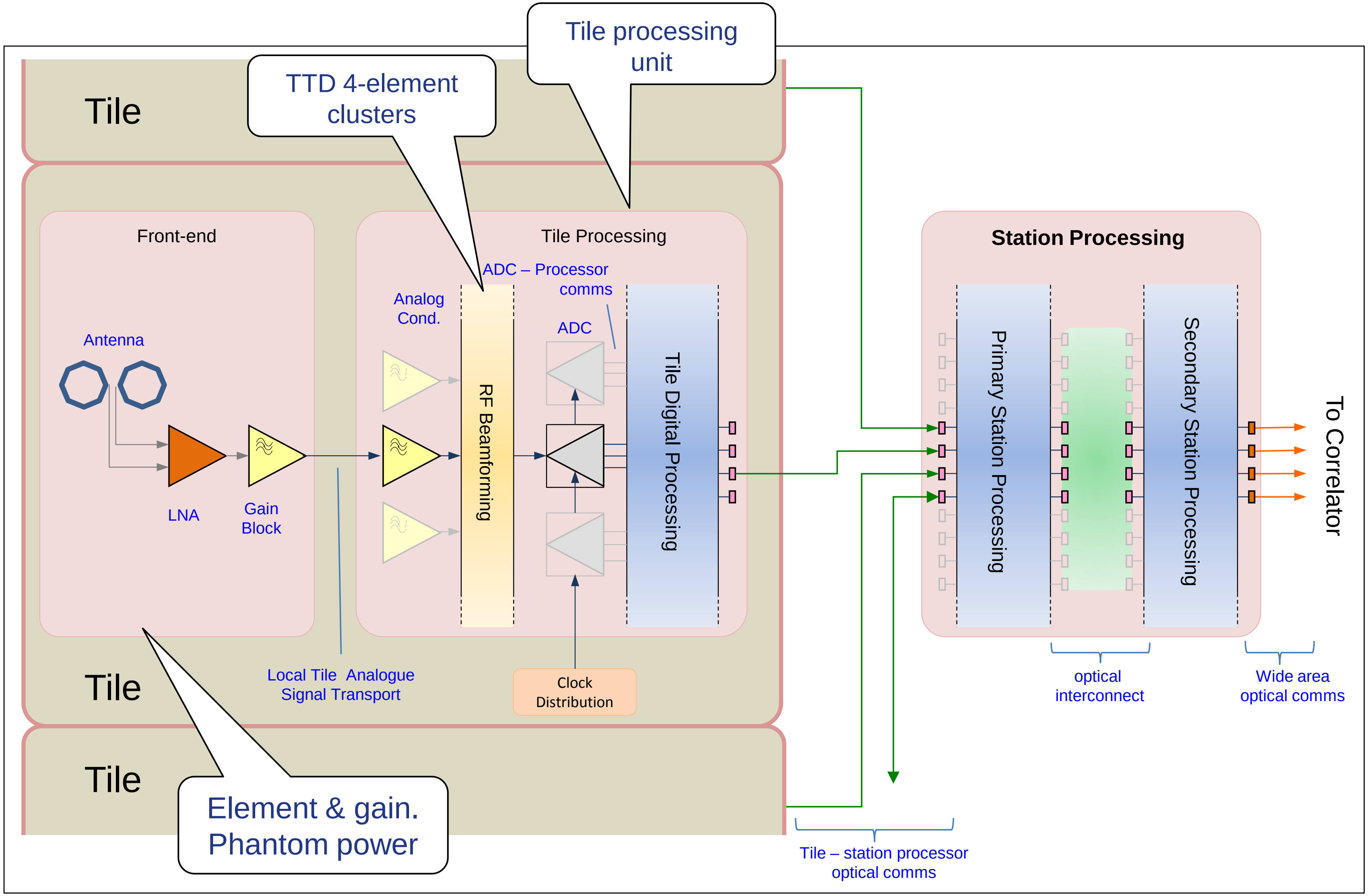
AA-mid Array – SKA_2



AA-mid station design

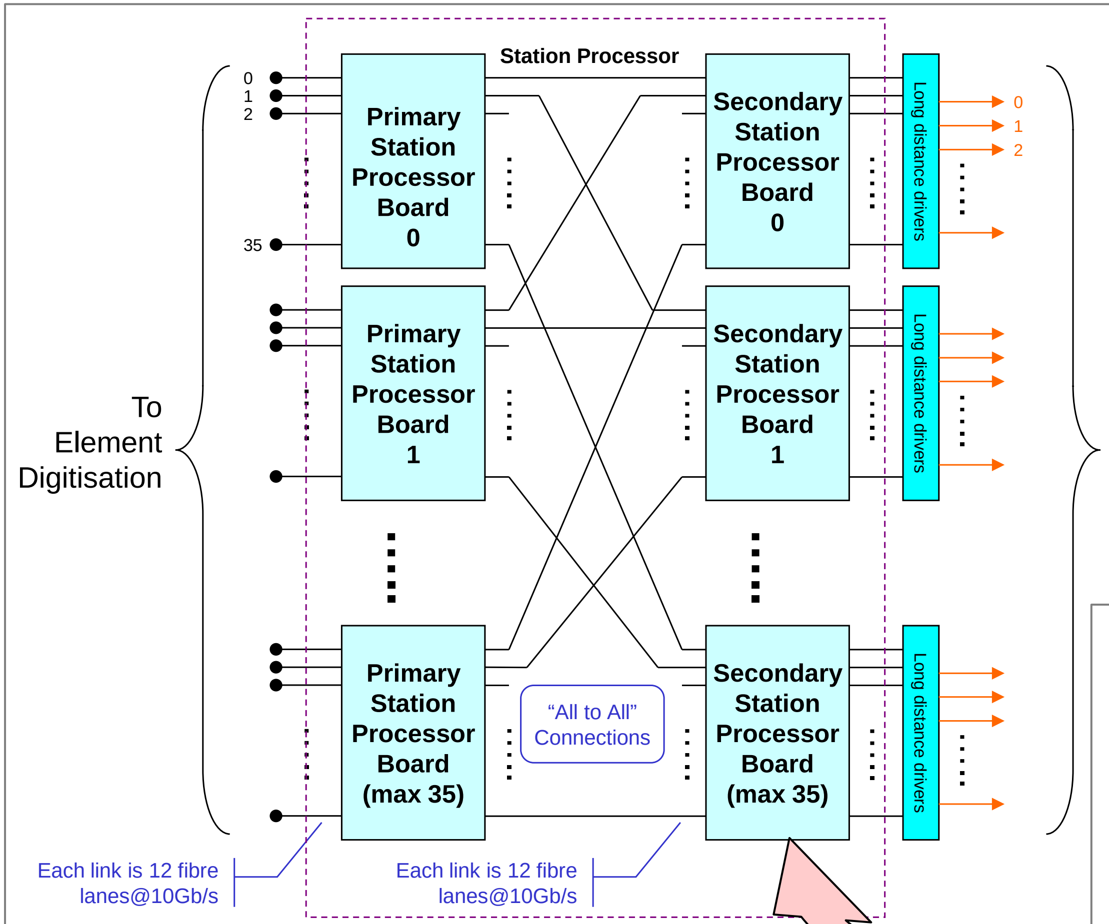
Parameter	Value	Comments
Type of array	Single element	Dense array using Vivaldi or ORA.
Number of elements	**110,000**	**30 million total**
Pitch of elements	15 cm	λ/2 at 1000MHz
No. of polarisations	2	Each element has two receiver chains
Diameter of station	56m	
Cluster size	4 elements	Uses true time delay beamforming
Tile size	16 x 16 elements	Built out of 4 x 4 clusters
No. of Tiles	430	Each tile is ~2.4m square
Number of stations SKA_2	250	Anticipated number of Phase 2 SKA Stations
Element communication	Copper	Includes Phantom power
Layout	Dense rectangular	Regularly spaced
Frequency range	400-1450 MHz	
Digitisation rate	3GSamples/s	There is no frequency conversion,
Digitisation depth	6/8-bit	Required for RFI environment at these frequencies
Beamforming technology	Digital	Using cluster outputs
Max inst. bandwidth	1000 MHz	Covers operating band of array
Max output data rate	**16Tb/s**	Organised as 4+4bit complex data

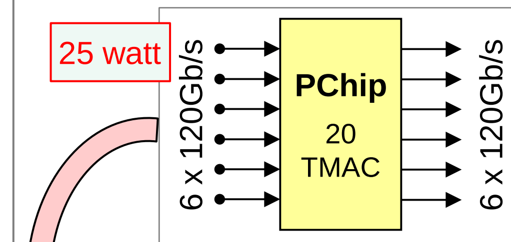
AA-mid possible signal path

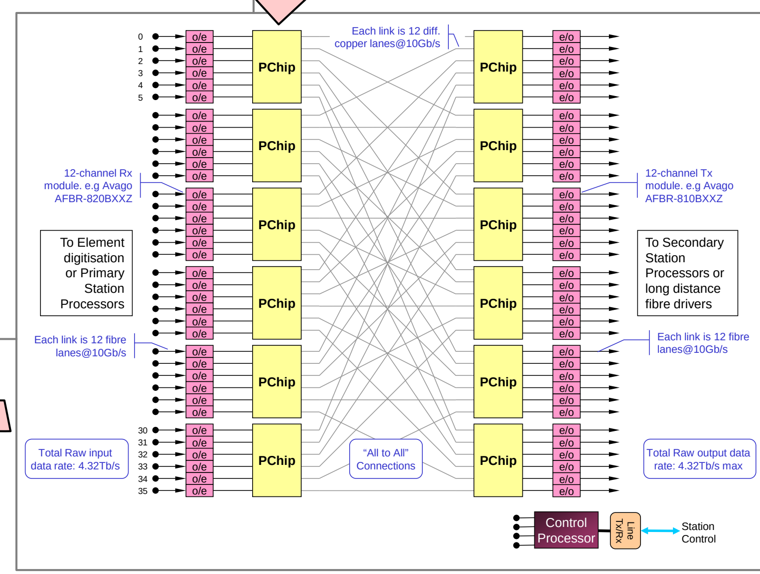


SKA$_2$ AA Station processor

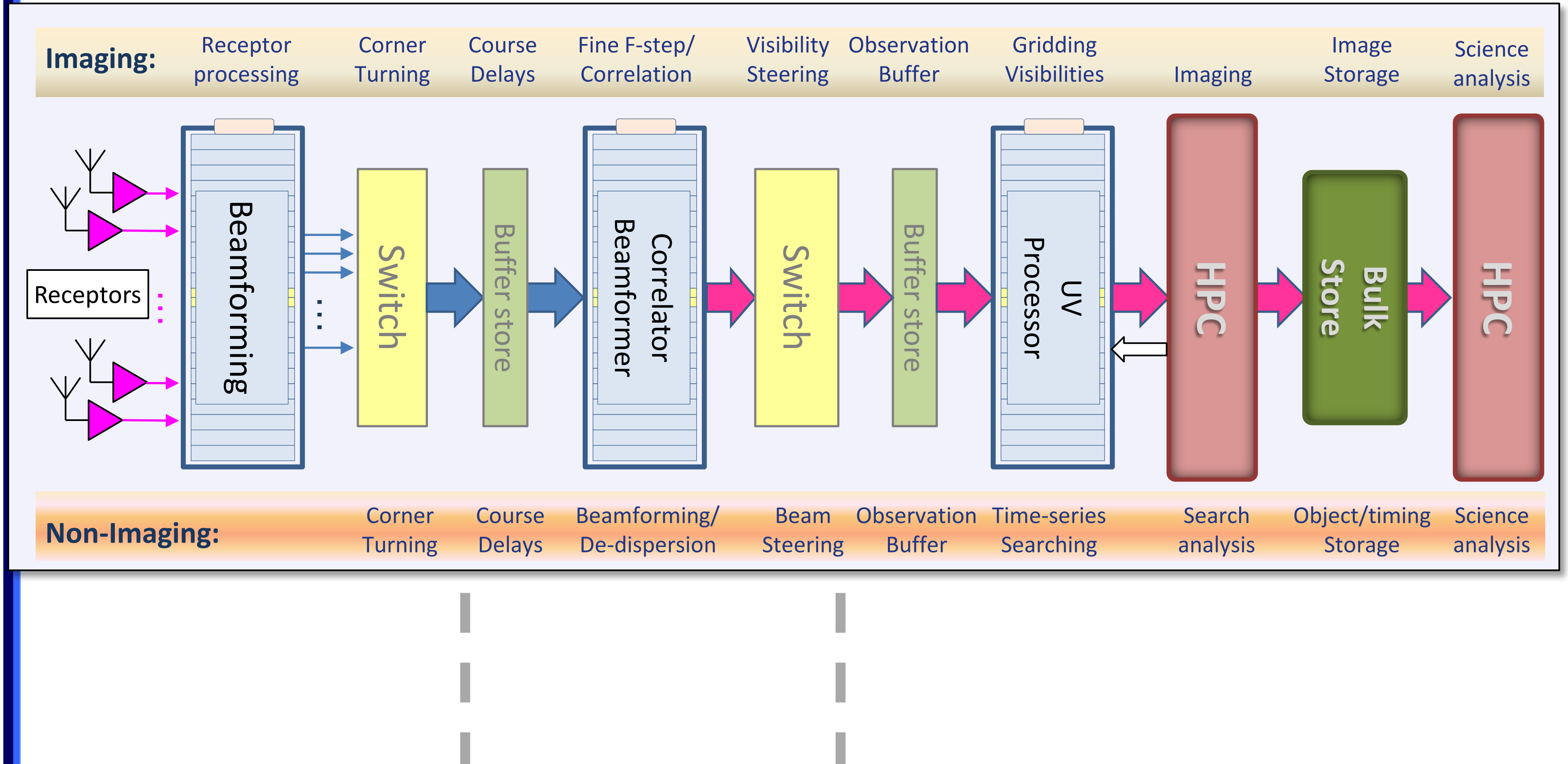
Requirements:
- High bandwidth in
- High bandwidth out
- Largely cross connected
- Scaleable at various levels
- Programmable beamforming







Processing: signal to science



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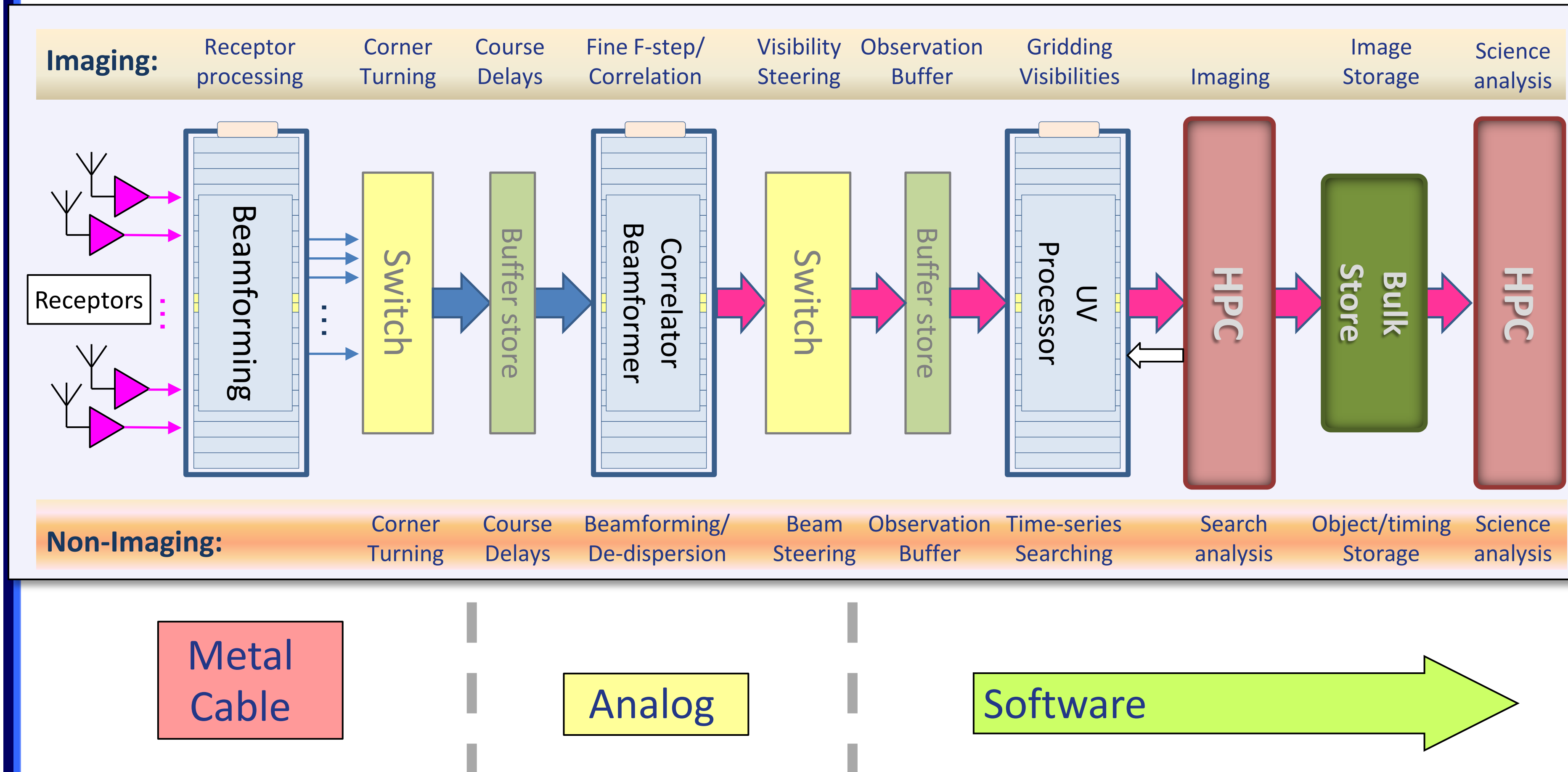
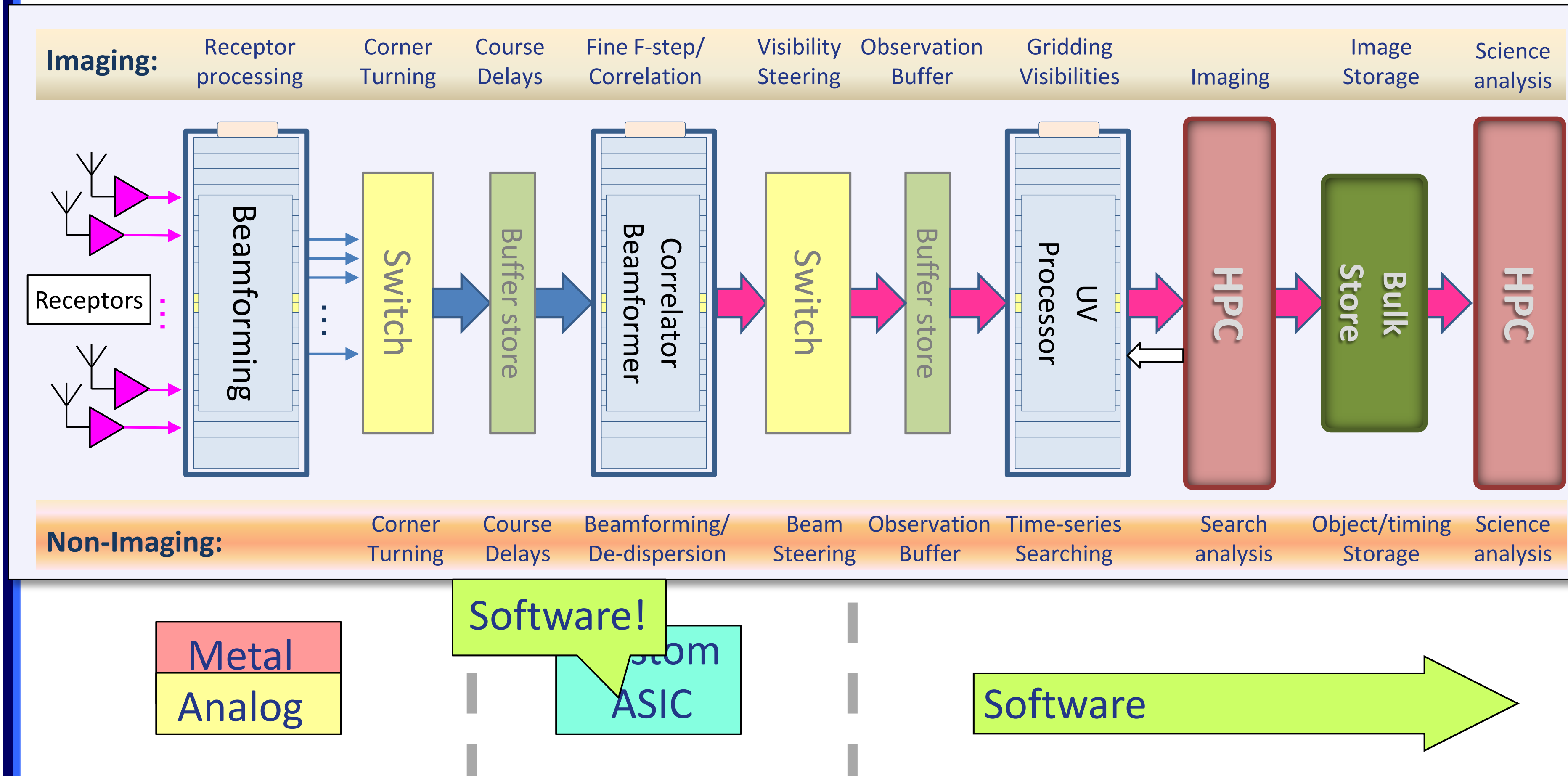
Processing: signal to science



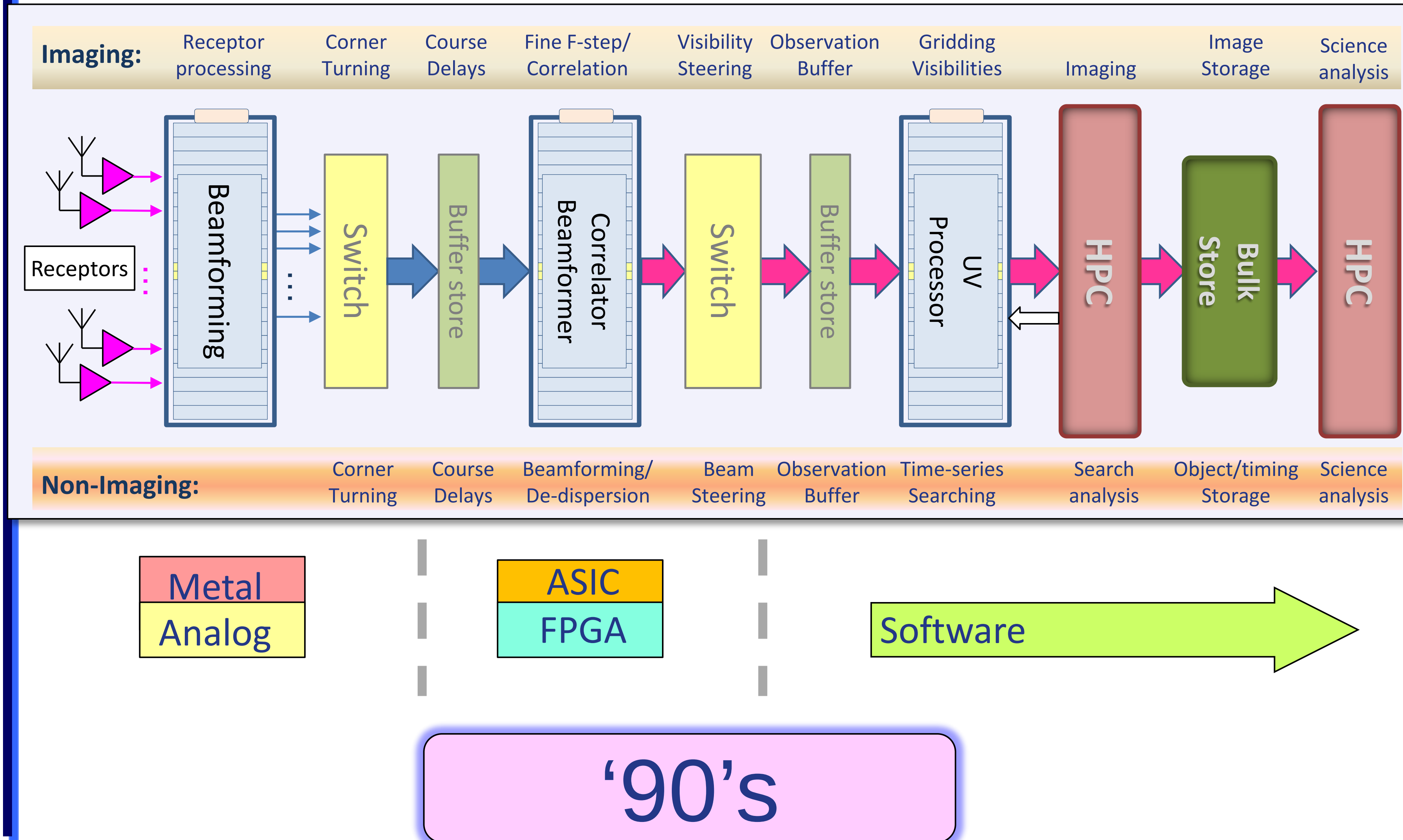
‘60’s – ‘70’s

Processing: signal to science

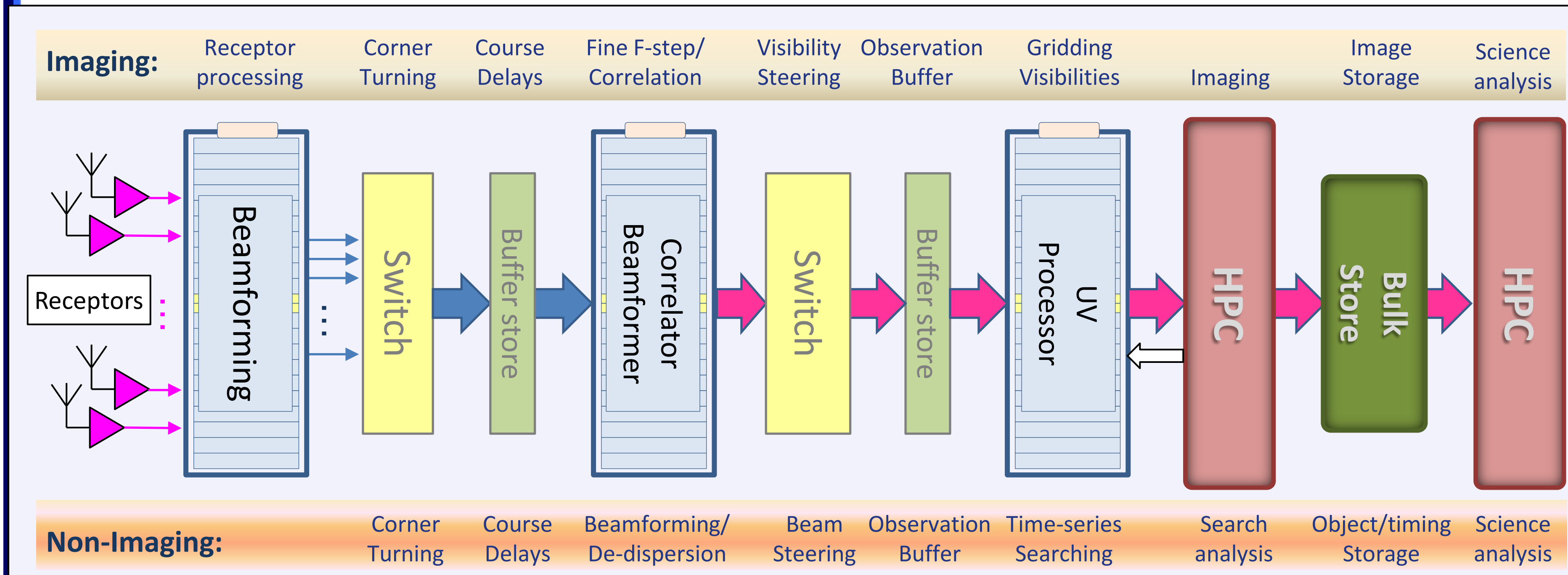


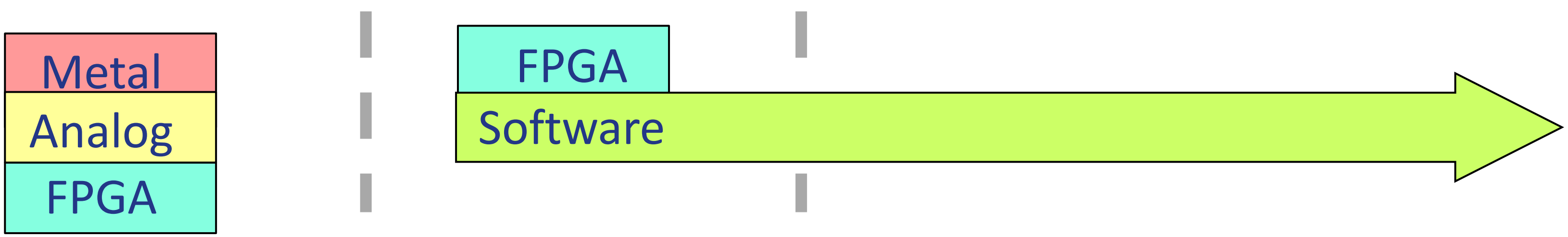
‘70’s – ‘80’s

Processing: signal to science



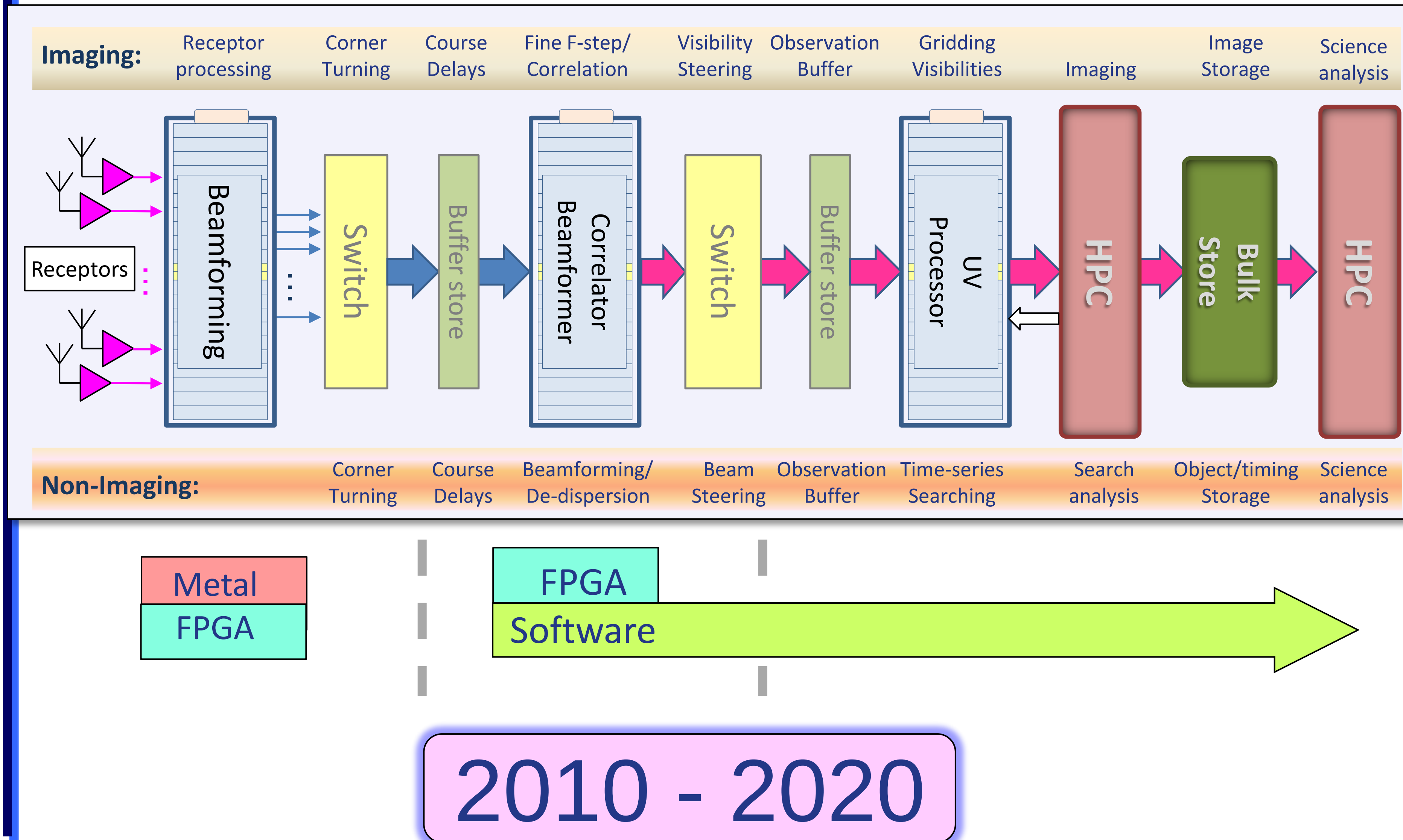
Processing: signal to science





2000's

Processing: signal to science



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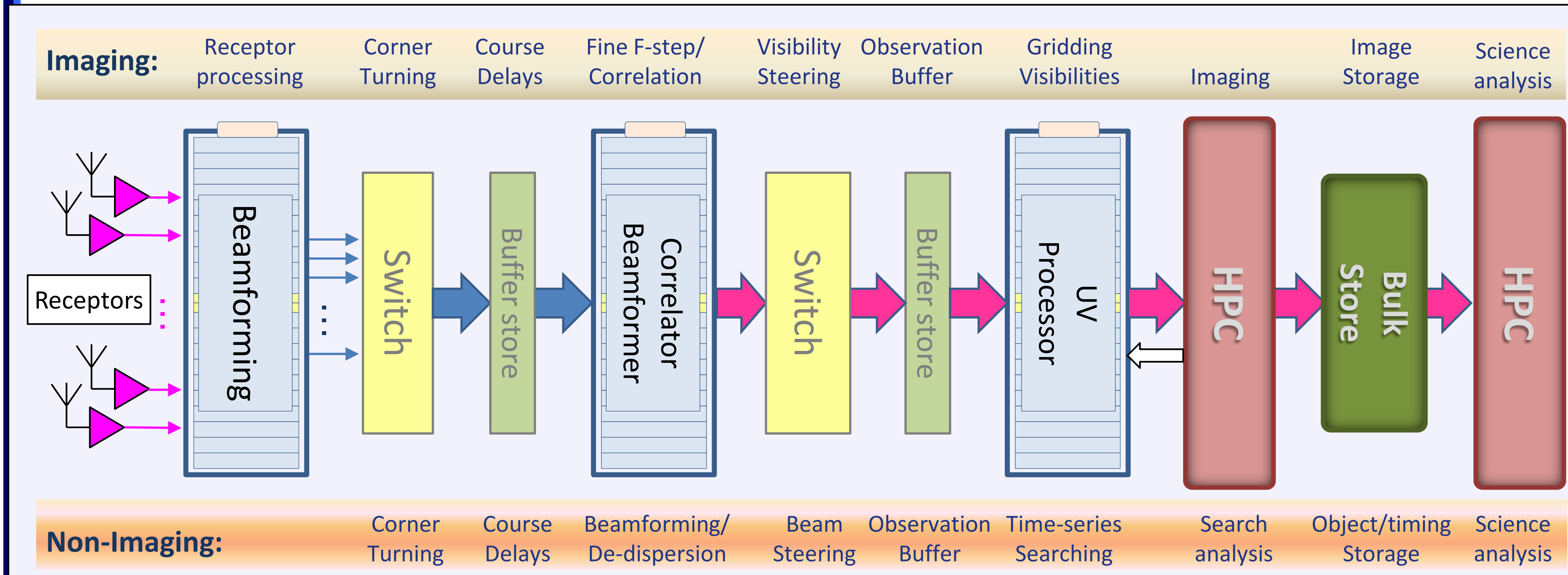
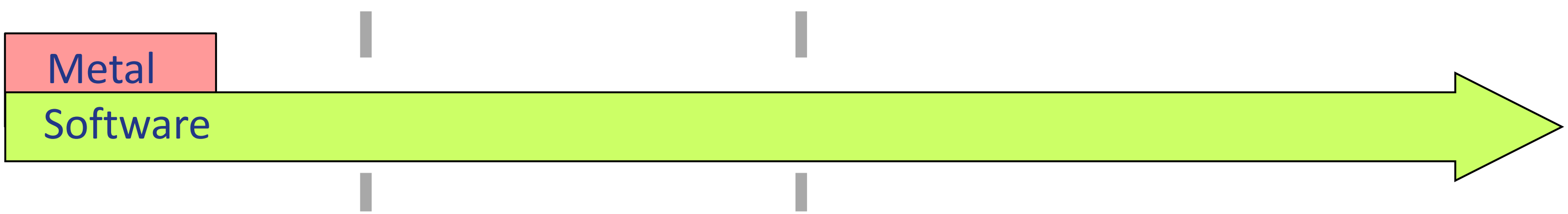
Processing: signal to science





Future

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And finally…

It's always fun travelling with Arnold!!