

Peta-Flop Radio Astronomy Signal Processing and the CASPER Collaboration

Dan Werthimer and 800 CASPER Collaborators

<http://casper.berkeley.edu>



CASPER

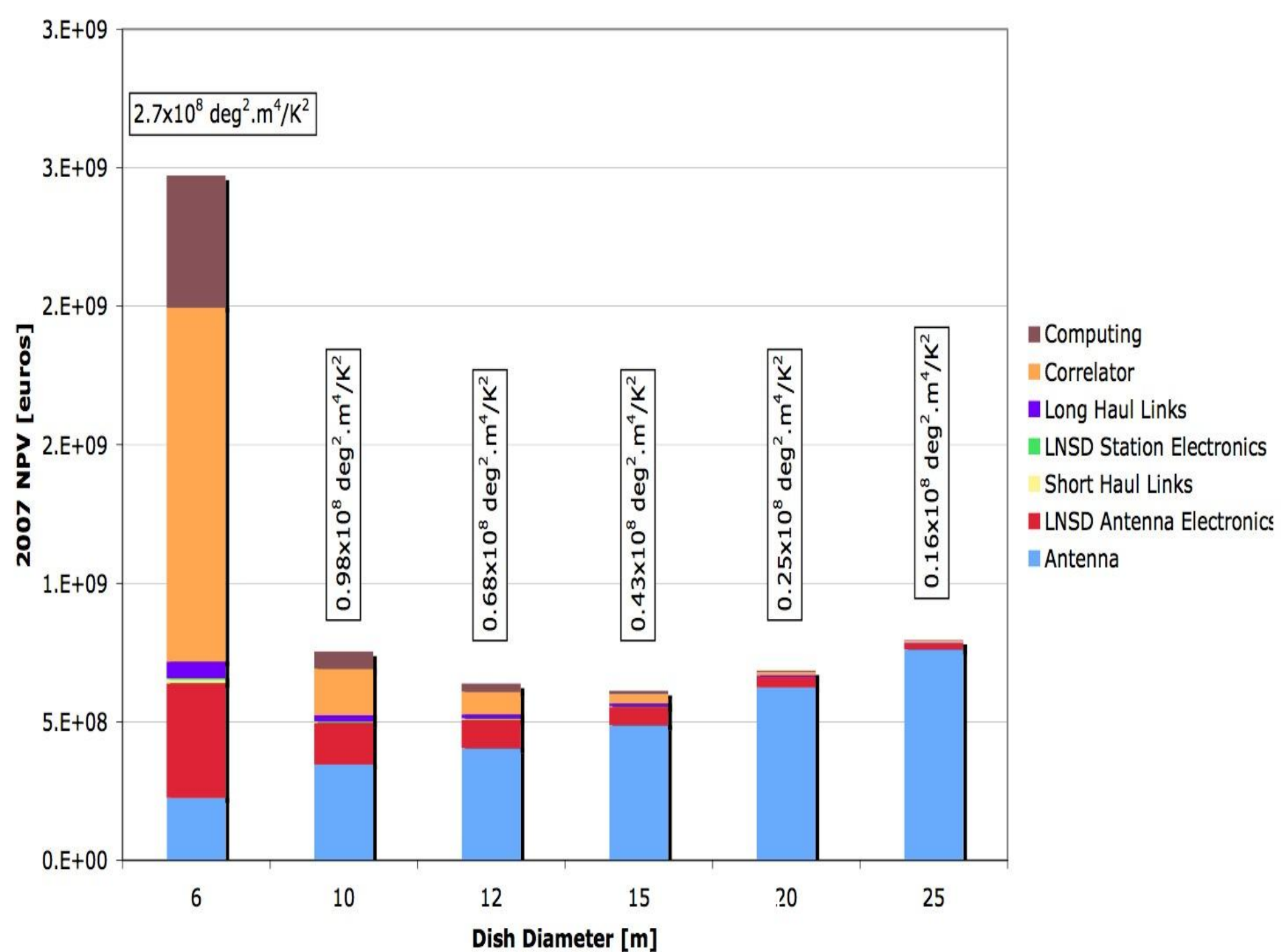
Collaboration for Radio Astronomy
Signal Processing and Electronics Research

Some of the CASPER Collaborators:

Xilinx, Fujitsu, HP, Sun/Oracle, Nvidia, NSF, NASA, NRAO, NAIC,
CFA (Harvard/Smithsonian), Haystack (MIT), Caltech, Cornell, CSIRO/ATNF,
JPL/DSN, South Africa KAT, Manchester/Jodrell Bank, GMRT (India),
Oxford, Bologna, Metsahovi Observatory/Helsinki University,
University of California, Berkeley; Swinburne University (Australia),
Seti Institute, University of California, Santa Barbara;
University of California, Los Angeles; CNRS (France), University of Maryland
Nancay Observatory, University of Cape Town (South Africa),
ASTRON (Netherlands), Academia Sinica (Taiwan), Cambridge,
Brigham Young University, Rhodes University (South Africa)

HERA Array 547 x 15 meter dishes





Correlators and Beamformers

Correlator Ops and Bits

$$\begin{aligned}\text{CMAC/sec} &= \text{bandwidth} \times \text{Nantenna}^2 \\ &= 1 \text{ GHz} \times 3000^2 \\ &= 1\text{E}16 \text{ CMACS per beam}\end{aligned}$$

$$\begin{aligned}\text{Bits/sec} &= \text{bandwidth} \times \text{Nantenna} \times 16 \text{ bits} \\ &= 1 \text{ GHz} \times 3000 \times 16 \\ &= 50 \text{ Tbit/sec per beam}\end{aligned}$$

Correlator References

Thompson, Moran, Swenson, 2nd edition

Interferometry and Synthesis in Radio Astronomy

Parsons, A Scalable Correlator Architecture Based
on Modular FPGA Hardware and Data Packetization

<http://casper.berkeley.edu/wiki/Papers>

<http://casper.berkeley.edu/>

CASPER Correlator Collaboration

Allen Telescope Array (90 uS imaging)

PAPER (Epoch of Reionization)

Carma Next Generation

MeerKAT/SKA South Africa

GMRT next gen

Bologna

ISI (Infrared) – 6 Gbps (3 GHz)

SKADS (Oxford)

SMA next gen (CFA, ASIAA)

MIT FFT direct imaging correlator

FASR?, Baryon Acoustic Oscillation ?

LEDA (CFA GPU X engine)

Berkeley Correlator Team

- Dan Werthimer (28 years correlator design)
- Matt Dexter (20 years correlator design)
- David McMahon (10 years correlator design)
- Aaron Parsons (6 years correlator design)
- Rick Raffanti (ADC and RF/analog board designer – 30 years)
- Dave Deboer (project manager)
- Andrew Siemion (Post Doc – correlators, transient, pulsars, SETI)
- Hong Chen (Astr. Undergrad – parameterized FPGA designs)

Correlator Technologies

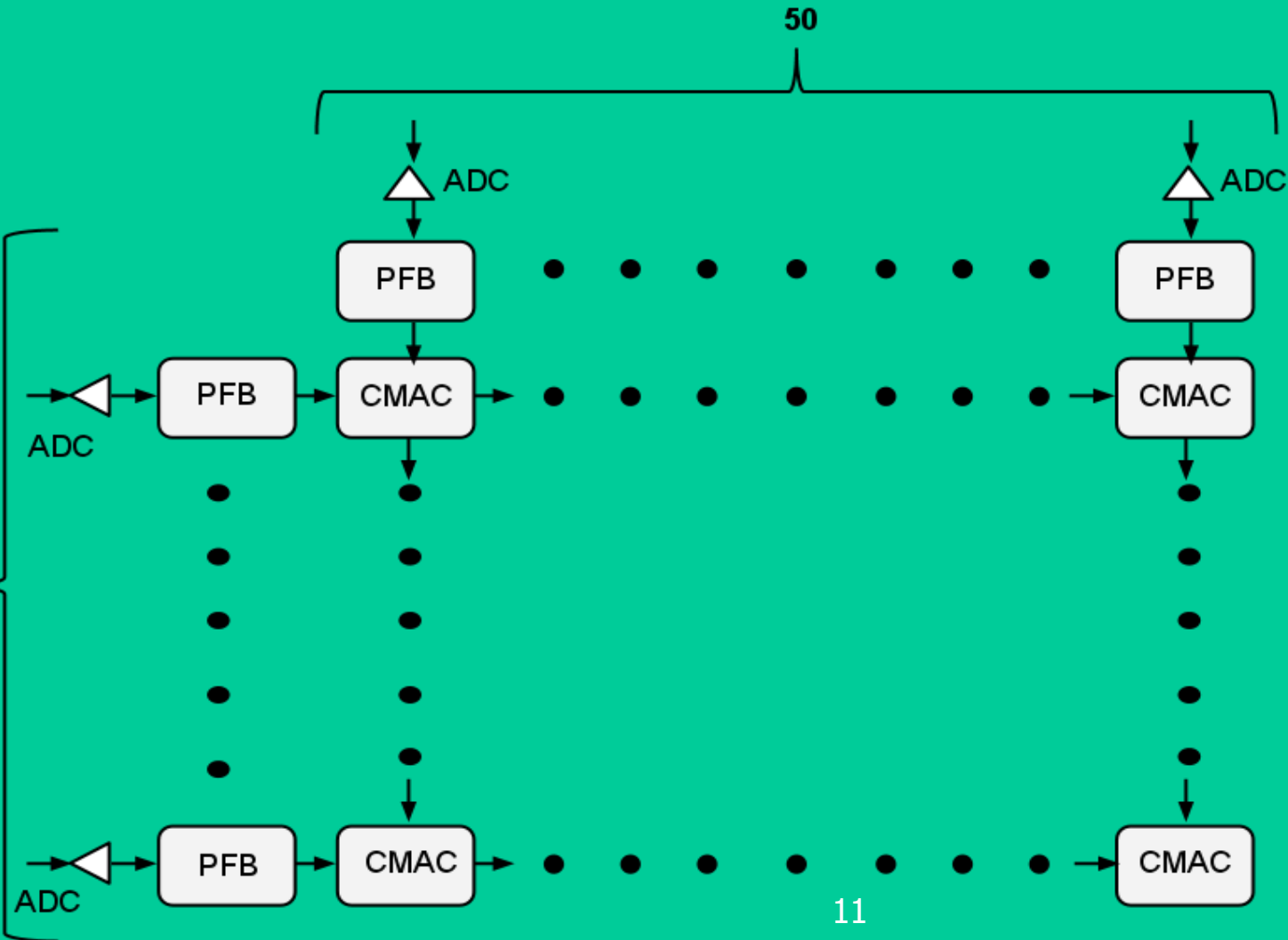
Software Correlators (DiFX – Adam Deller)

GPU Correlators (CASPER, Xgpu – Mike Clarke)

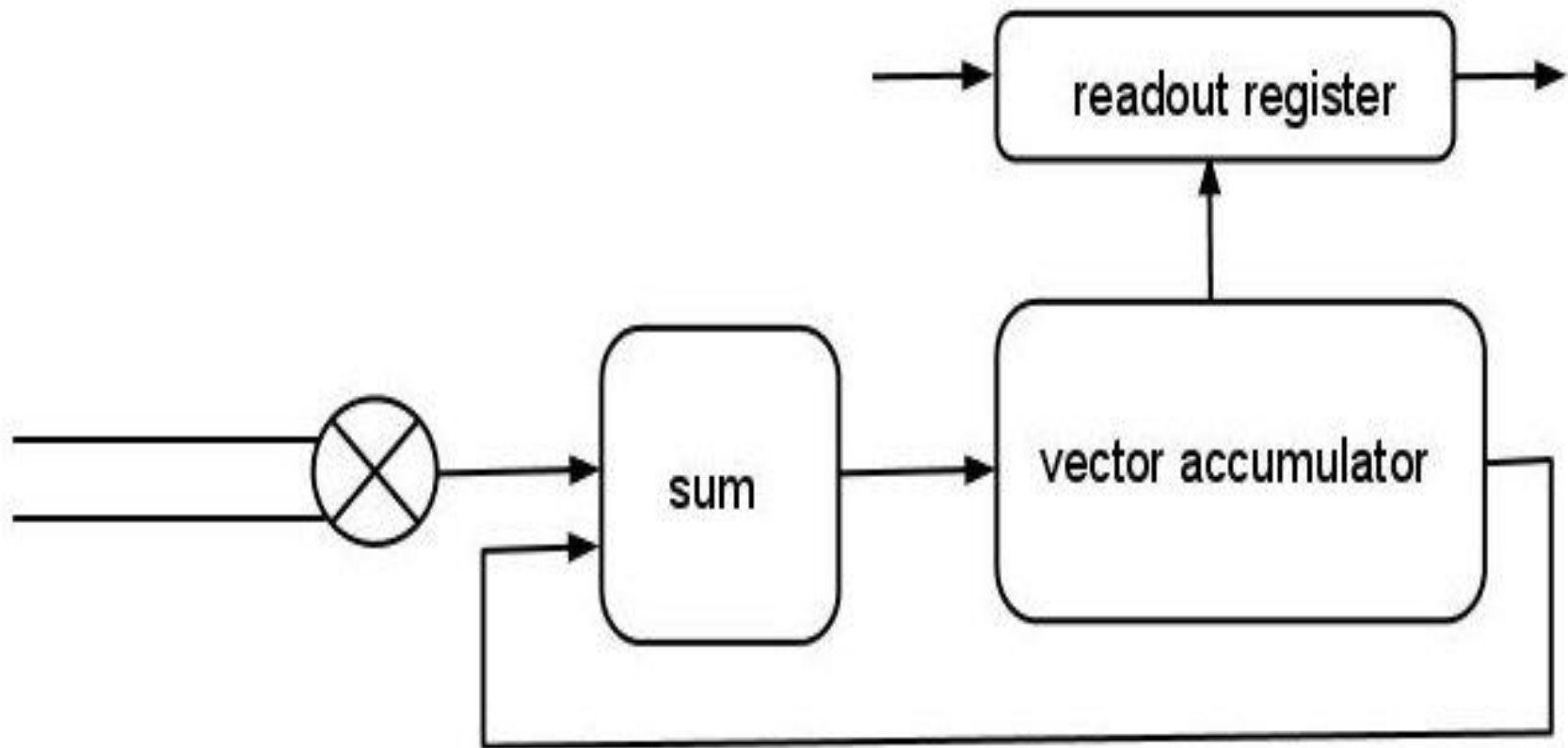
FGPA Correlators (CASPER, F and X engines)

ASIC Correlators (NRAO, DRAO, JPL...)

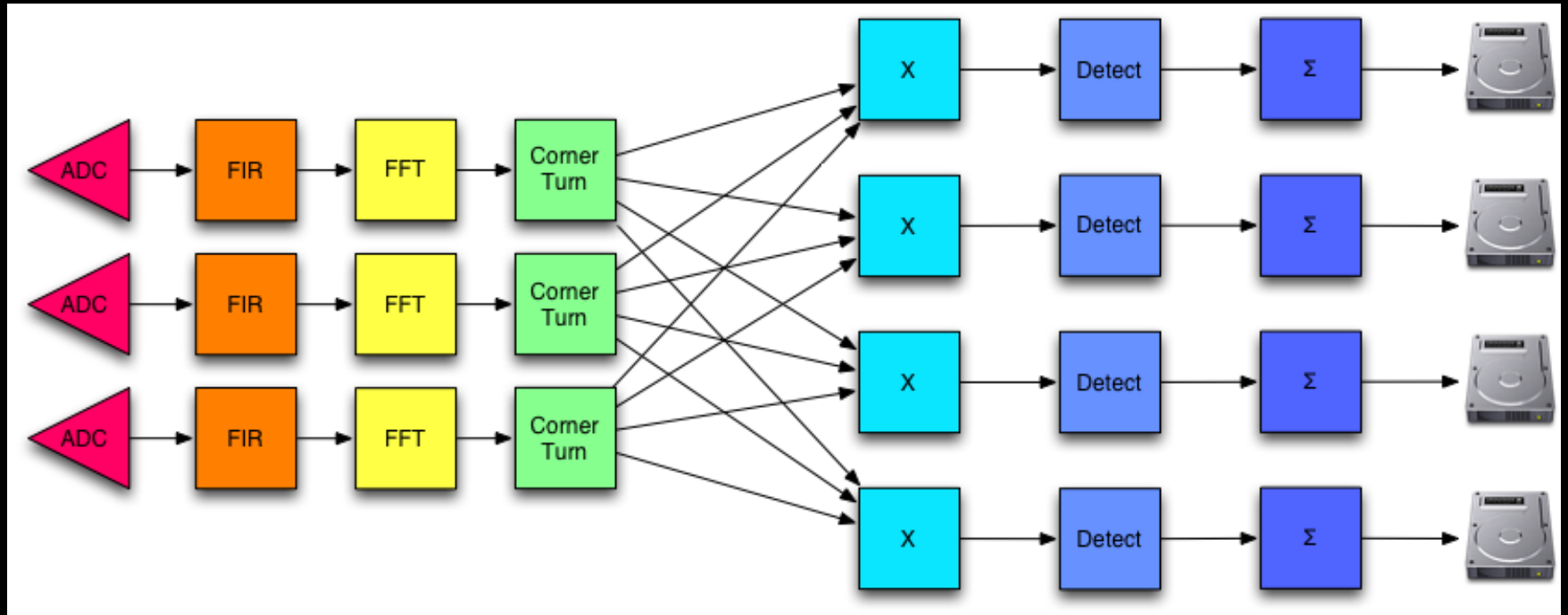
What ELSE ??? (Intel Phi??)

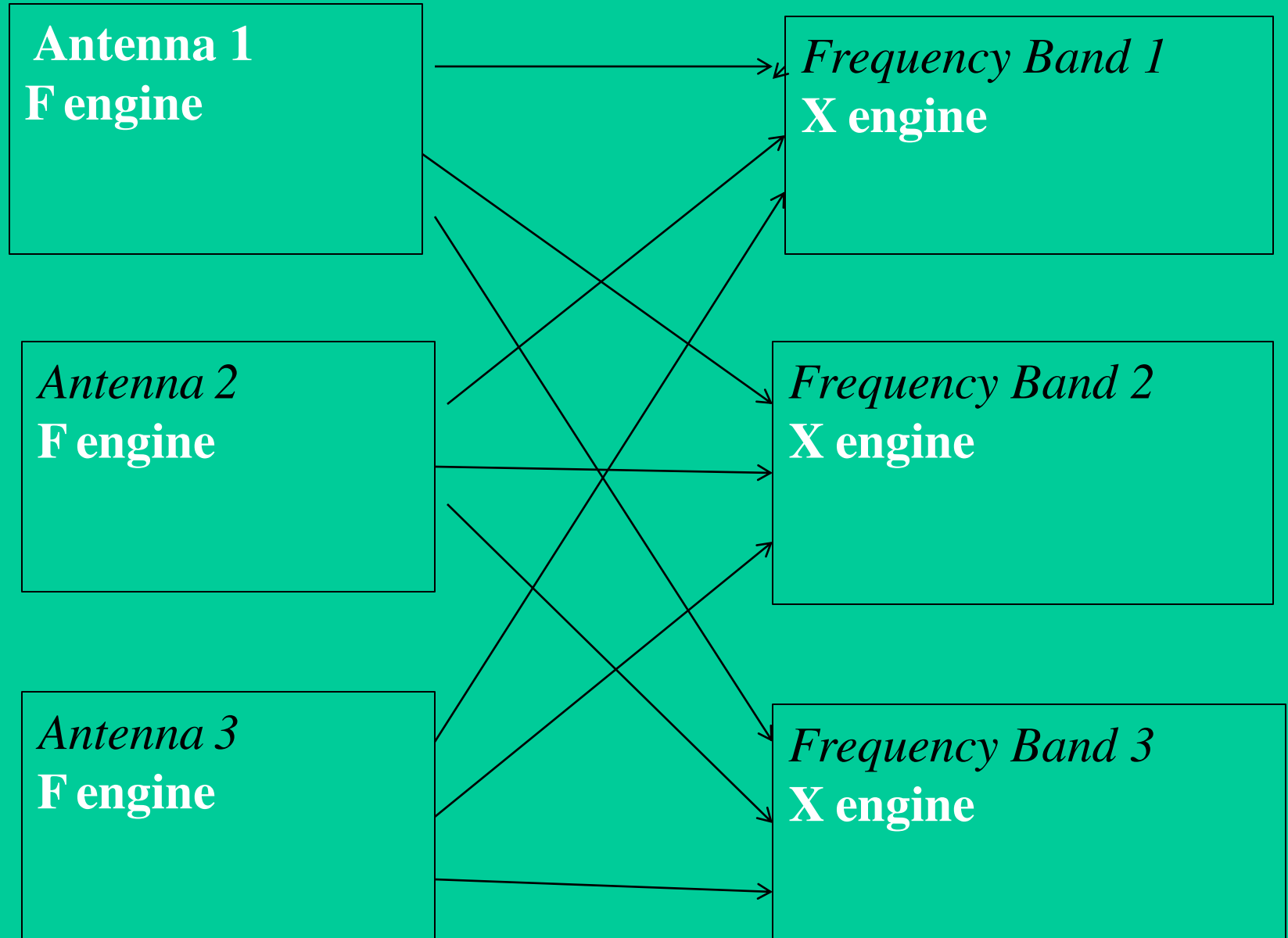


CMAC Complex Multiplier Accumuator



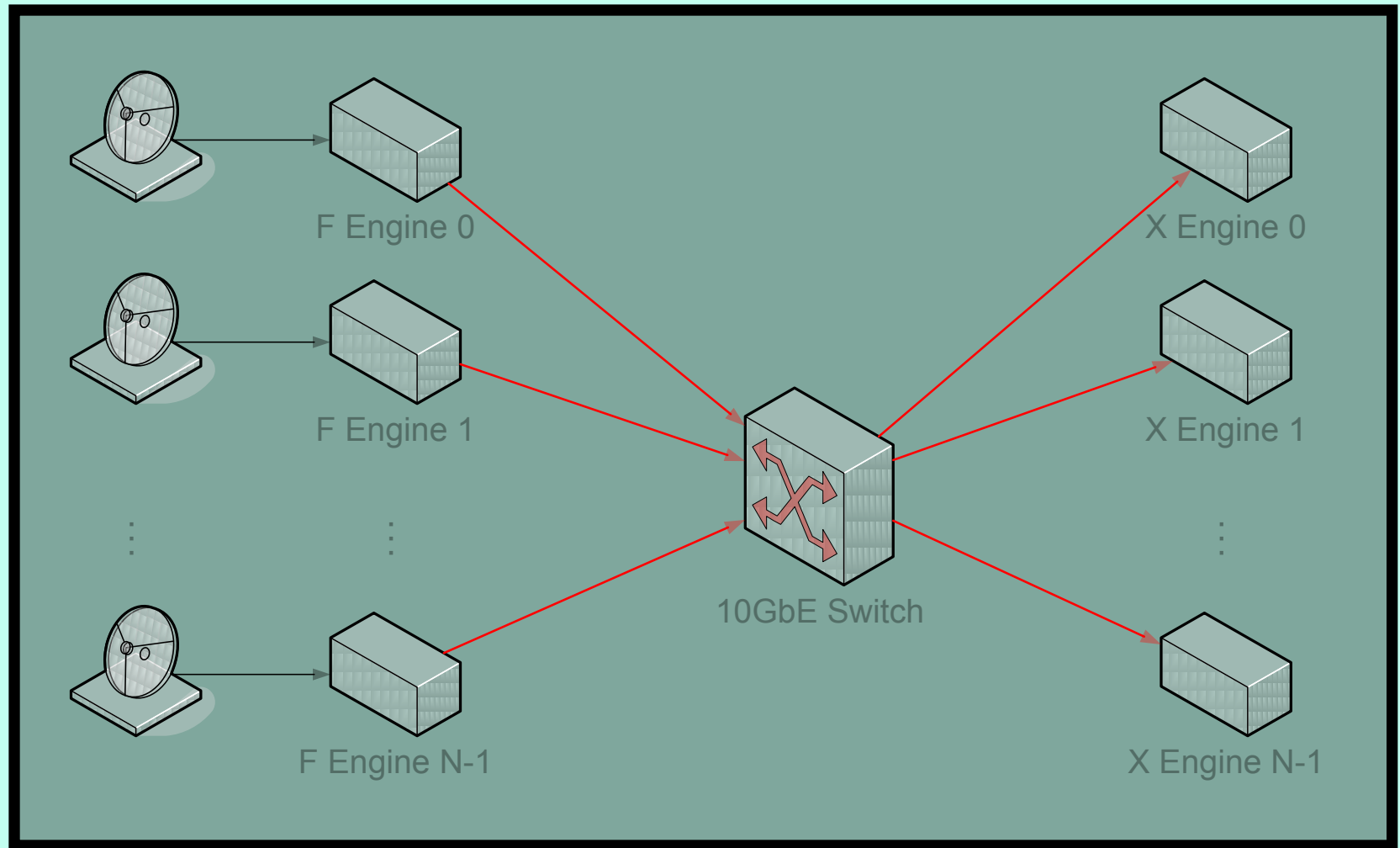
FX Correlator



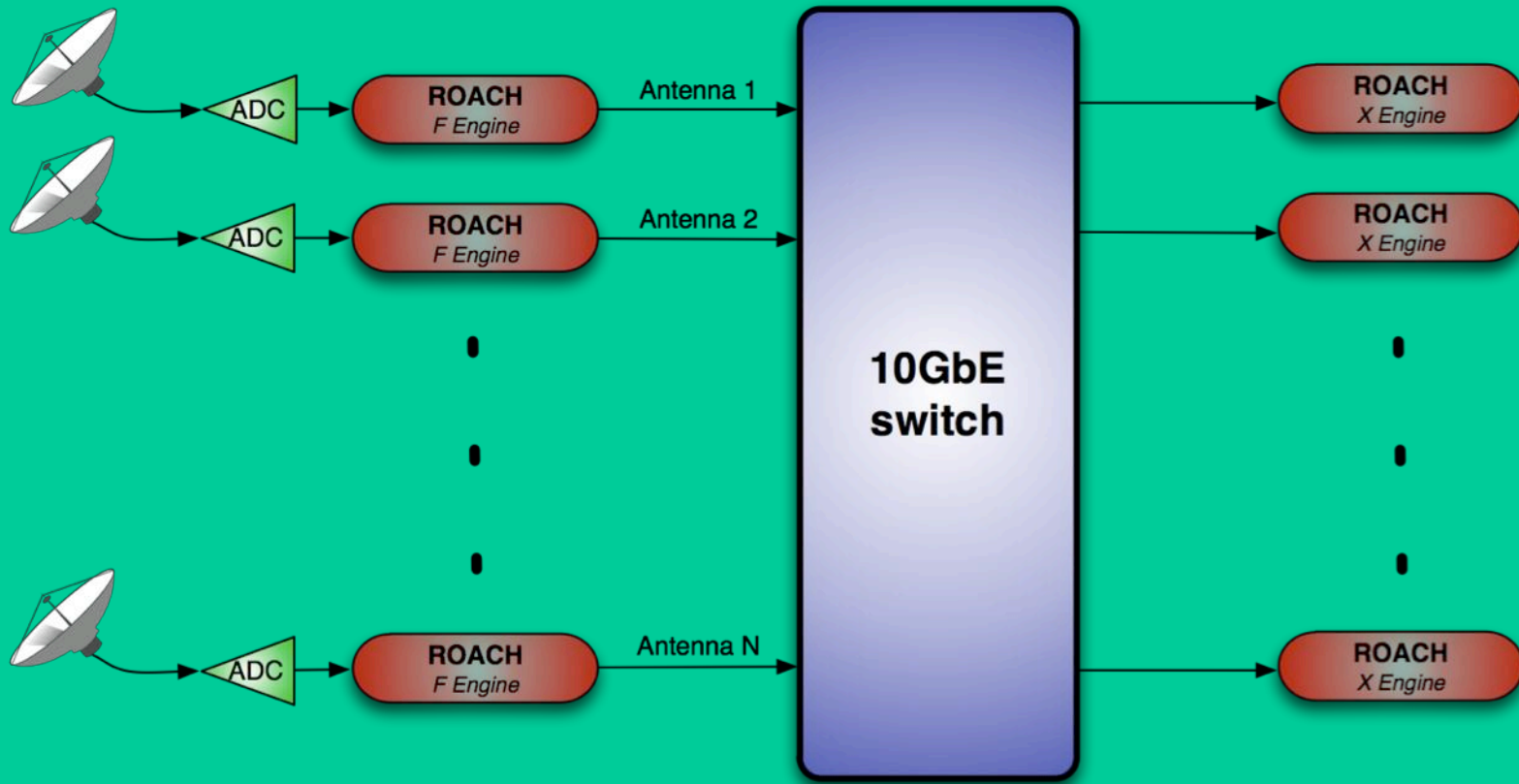


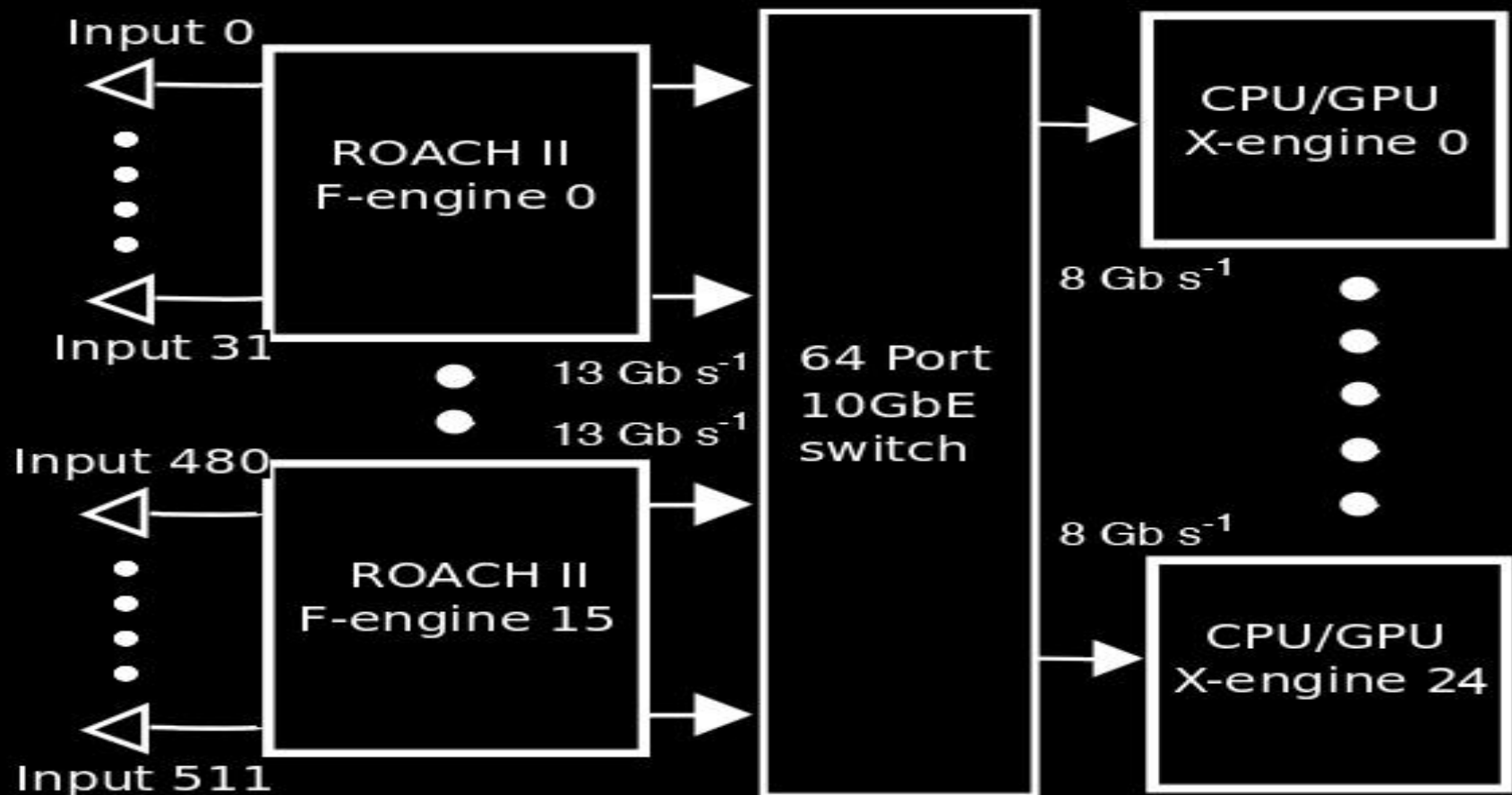
CASPER FXB Correlator/Beamformer

(correlator needed to calibrate beamformer)

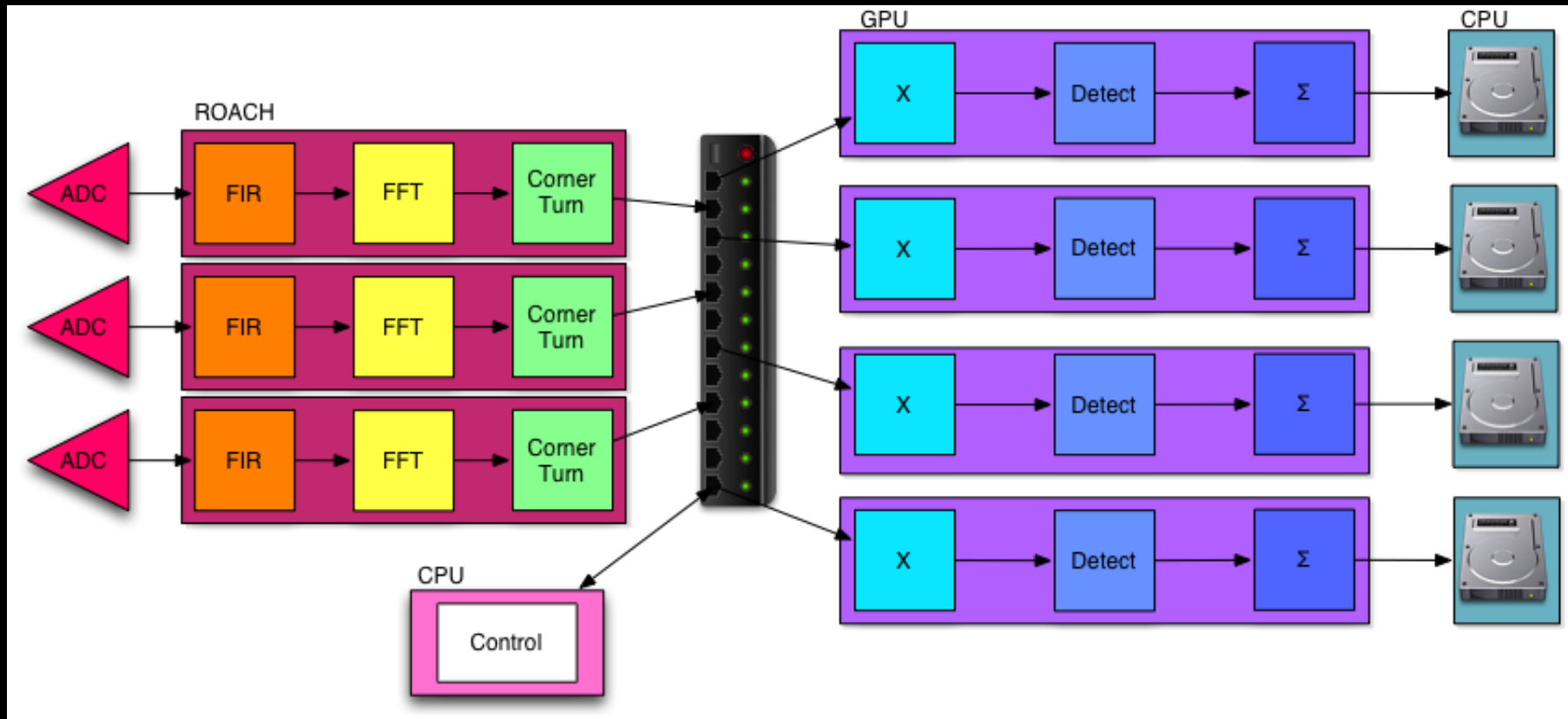


CASPER FPGA Packetized Correlator

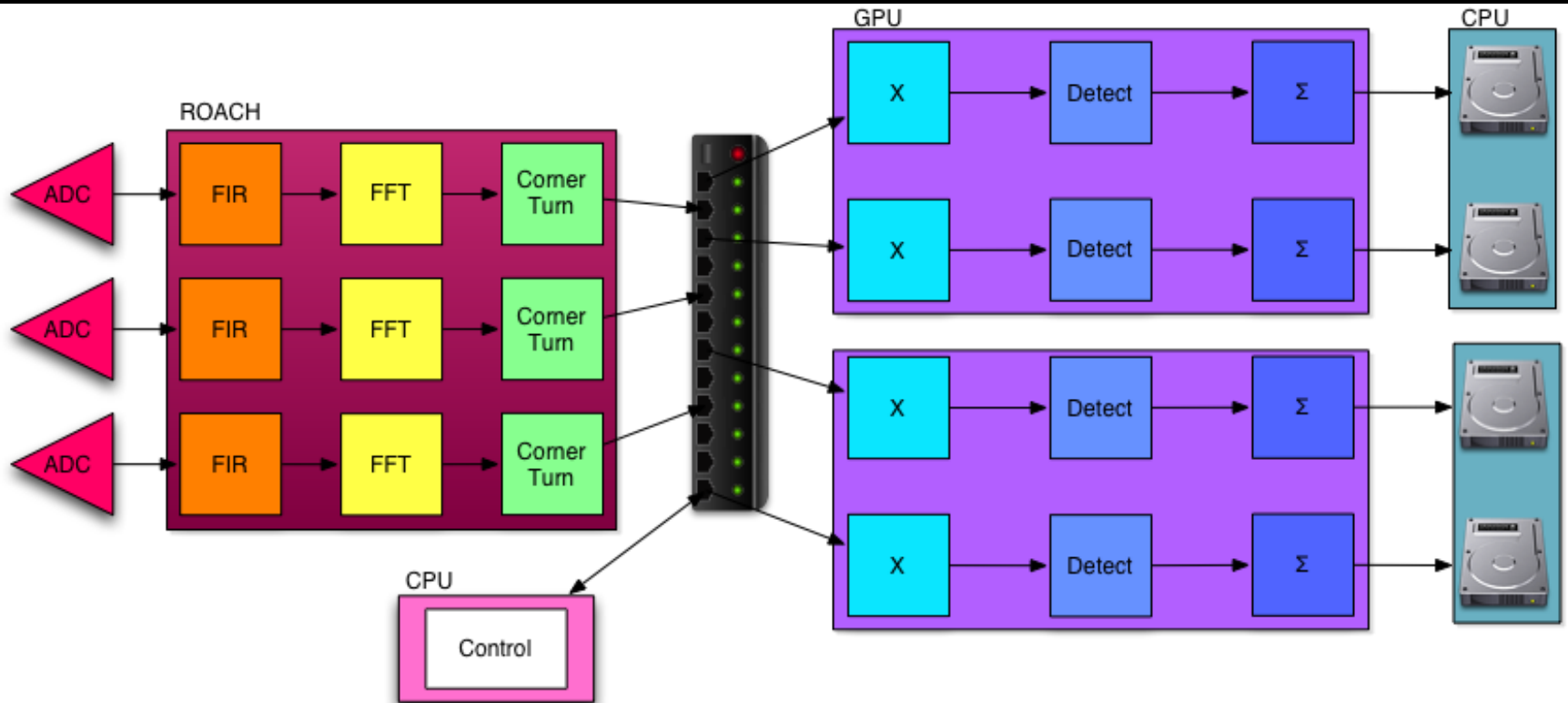




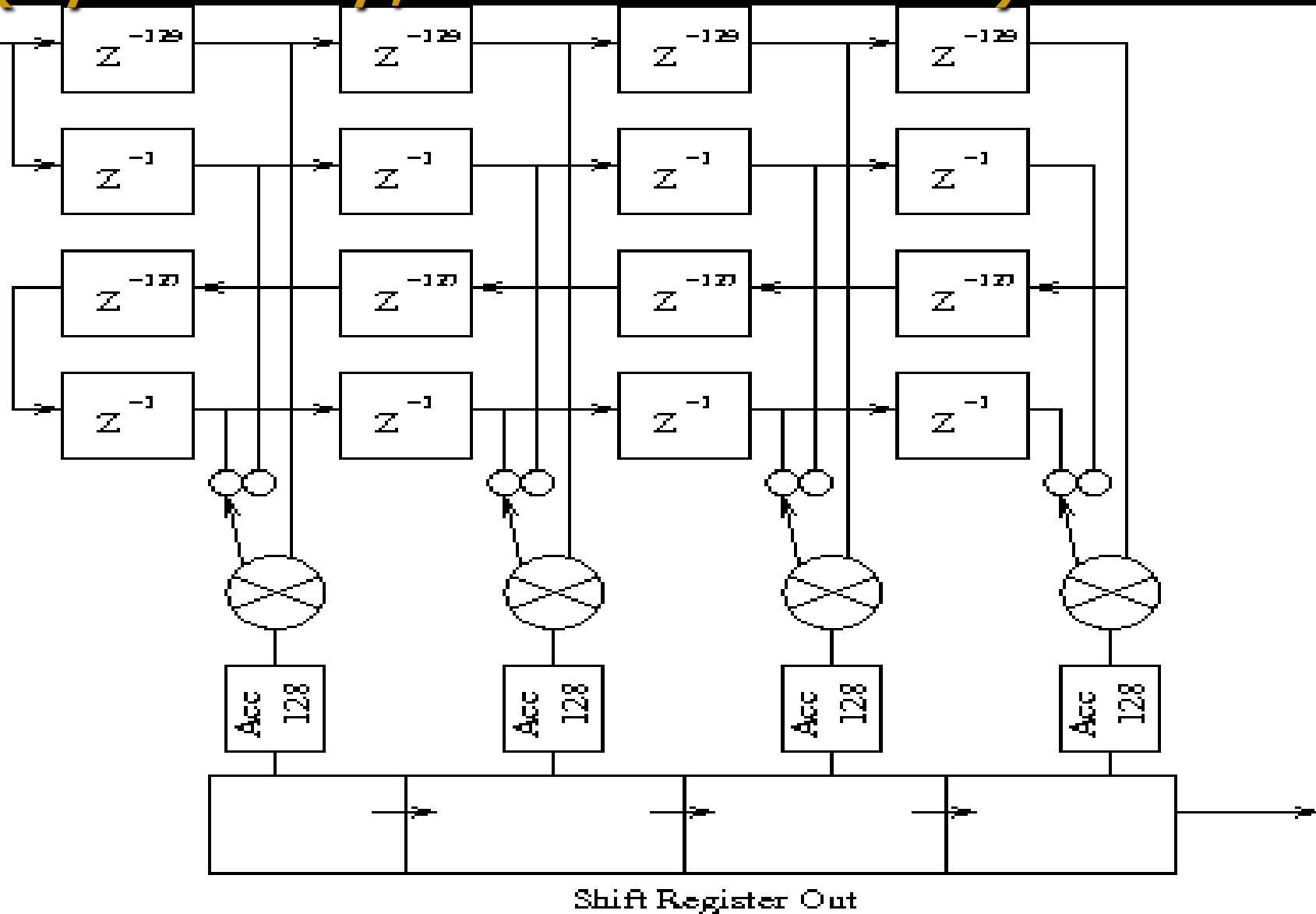
Packetized FX Correlator



Heterogeneous Correlator



X-Engine Correlation Architecture (Lynn Urry, Aaron Parsons)

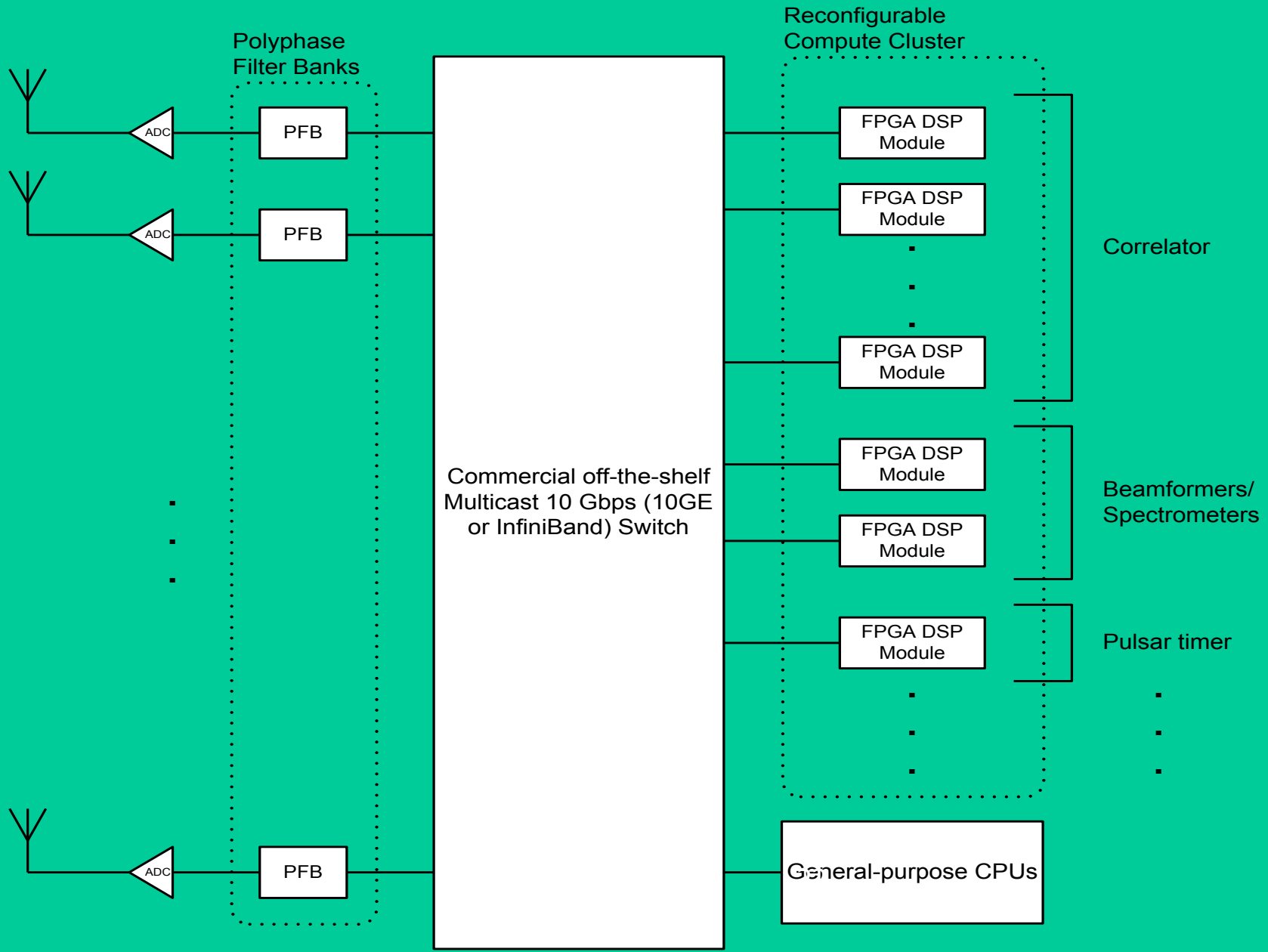


Correlators and Beamformers

- Globally Asynchronous (like a computer cluster)
- Data is time stamped with 1 PPS at ADC
- Locally Synchronous, Globally Asynchronous
- Solve problem of correlator/beamformer interconnect problem by using 10 Gbe switches (for both interconnect and fast readout)
- No need for high density complex boards
- Use Fifo's to align data before correlation or beamforming...

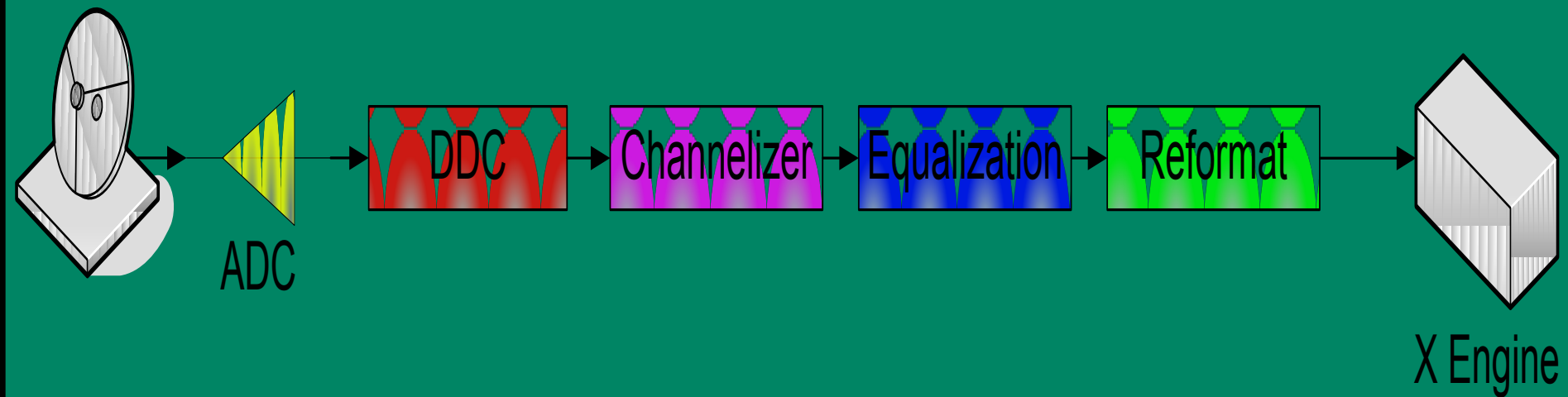
Beowulf Cluster Like General Purpose Architecture

Dynamic Allocation of Resources, need not be FPGA based

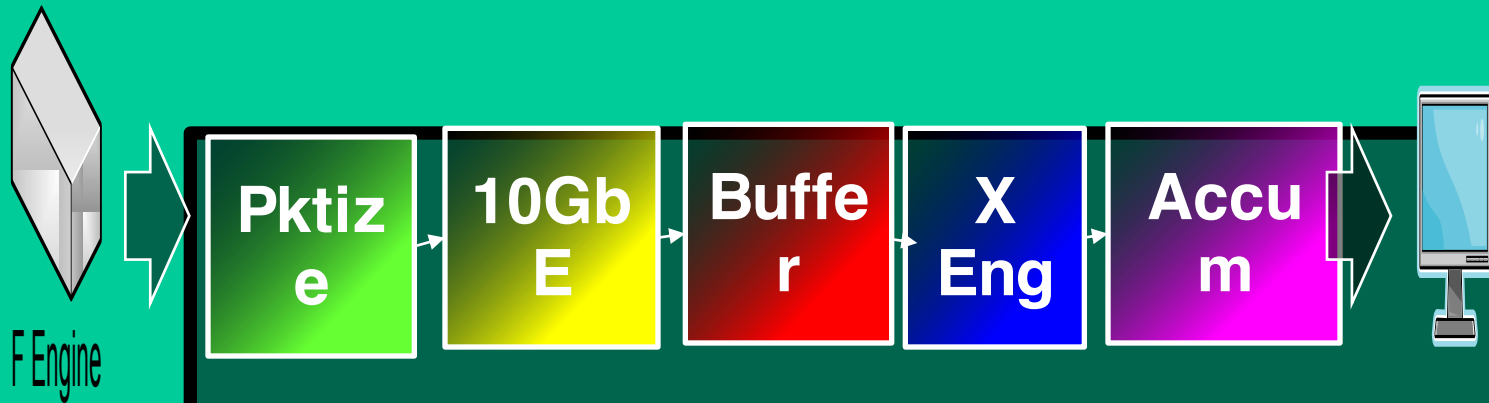


F Engine Overview

- Dual polarization design



X Engine Overview

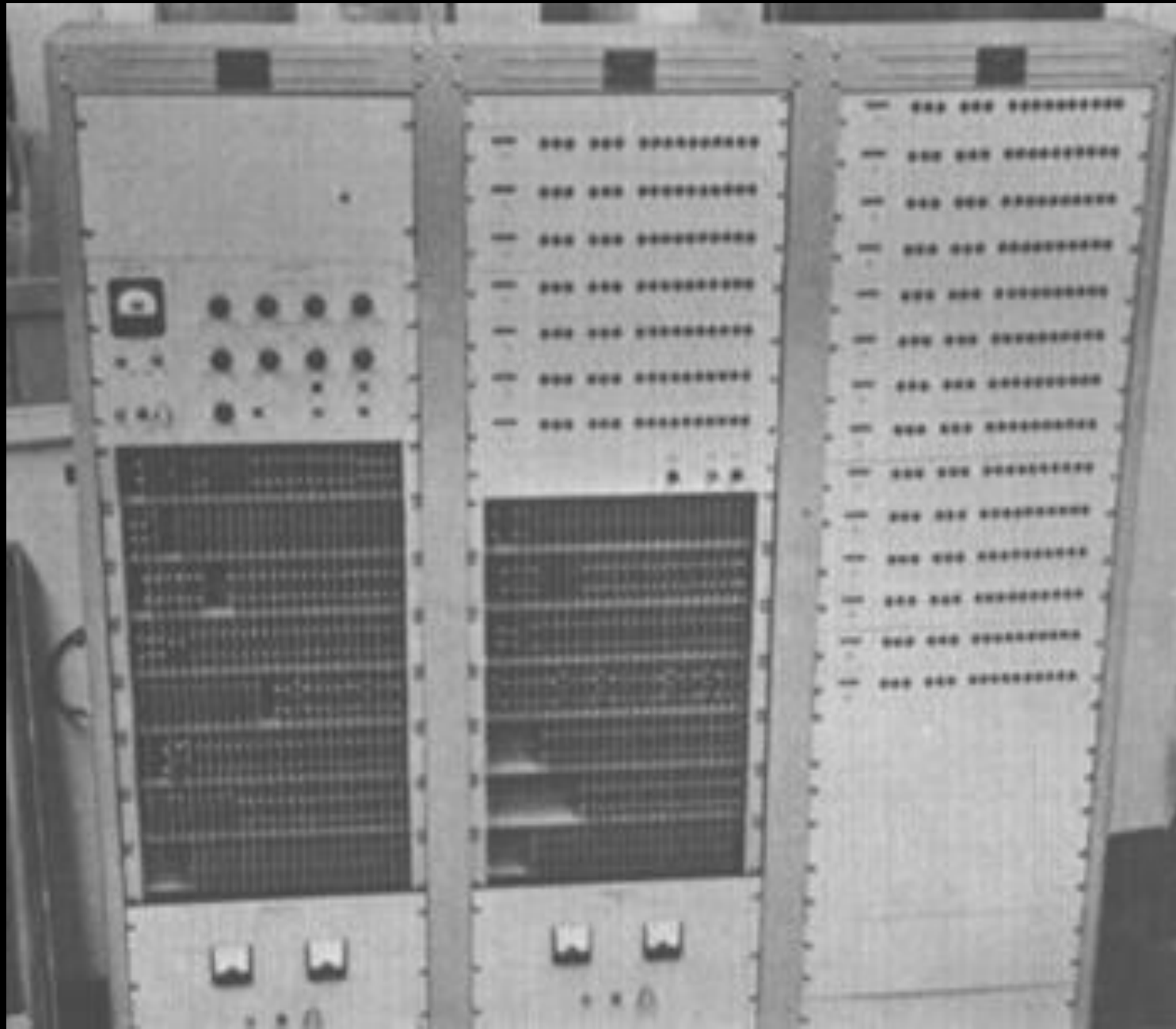


1960 – First Radio Astronomy Digital Correlator

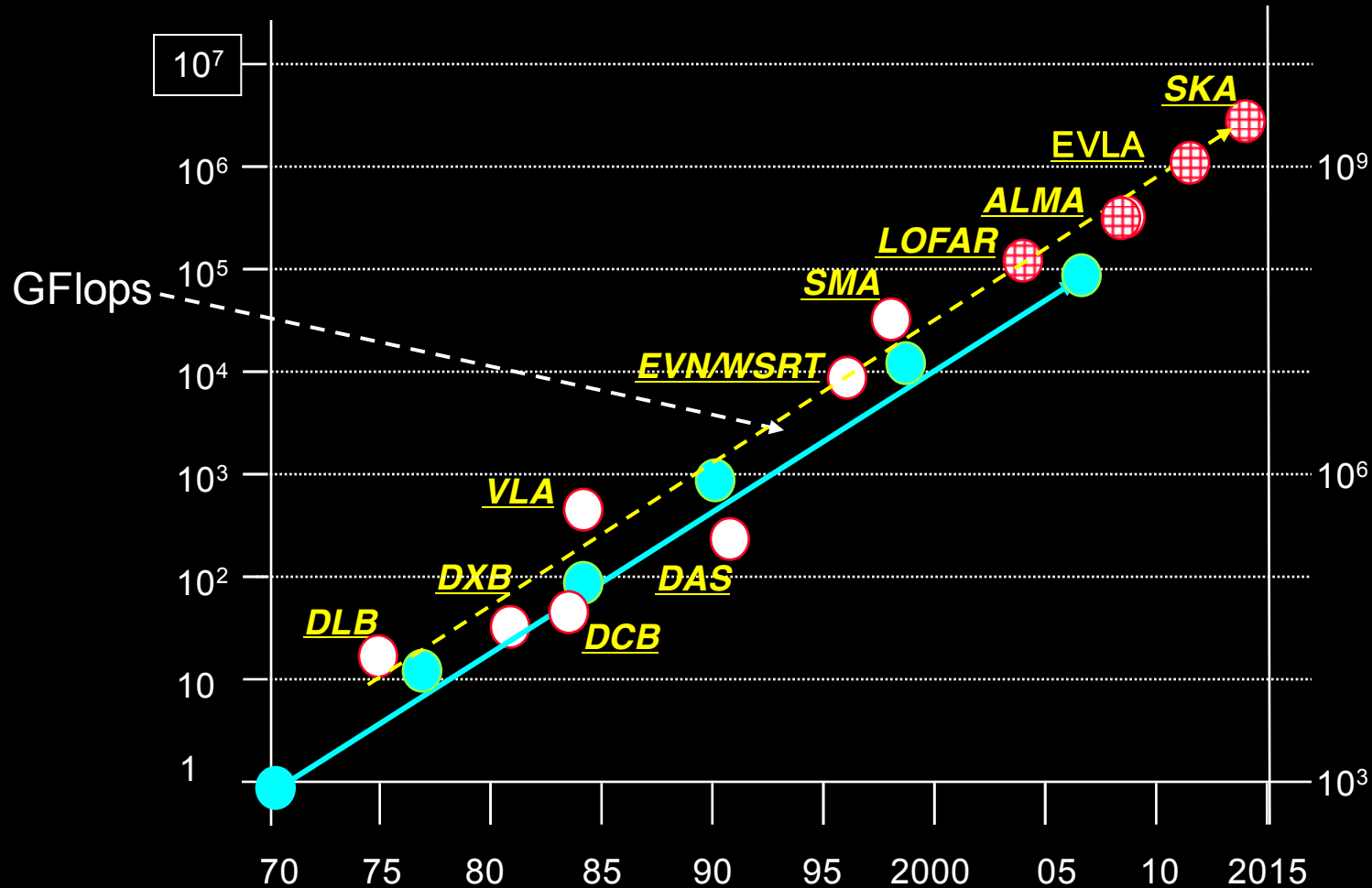
21 lags
300kHz clock
discrete transistors

\$19,000

Sandy
Weinreb



Correlator processing power



source: Arnold van Ardenne

Ray Escoffier

“With correlator performance having gone up by a factor of 922,000 over the last 30 years, its only fair that correlator design engineers' salaries should have gone up by a similar factor!!”

Correlator Projects

- Communications - \$100M/SKA

CWDM, DWDM, 40/100Gbe, BIG Switches

- Help us design HERA Correlator

(600 antenna, 250 MHz, South Africa)

- New Platforms – Intel Phi?, FGPA, ASIC?, Next Gen GPU, CPU Arrays,
- Optimize Code (FPGA, GPU...)
- Design Study (power(t), cost(t)...)
- New Architectures (Upgradable, Scalable...)
- Build a Prototype Correlator and improve it