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e-MERLIN

e-MERLIN: Digital Developments

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University of Manchester

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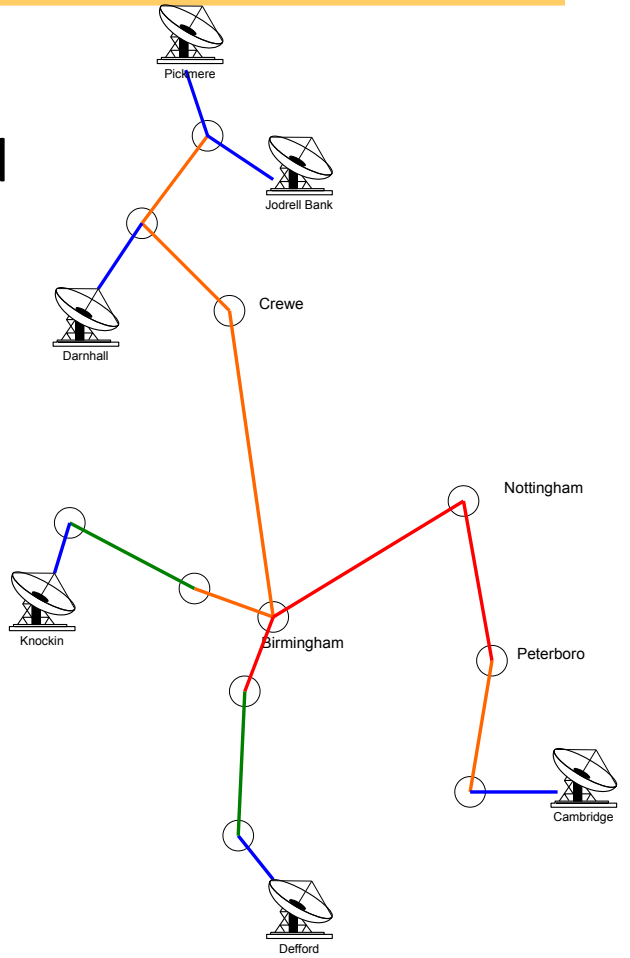
WP6: Digital Upgrade

- Motivation
  - Maximise bandwidth in C(4-8GHz) and X(8-16GHz) bands
    - Currently 2 x 2 GHz
  - Sensitivity; uv-coverage; frequency lever-arm; many simultaneous lines
  - Flexible correlator/beamformer; increased processing capability
- Project elements
  - Data acquistion (samplers)
  - Data Links (optical network)
  - Central Signal Processor
  - Synchronisation
- Final system strongly mimics SKA



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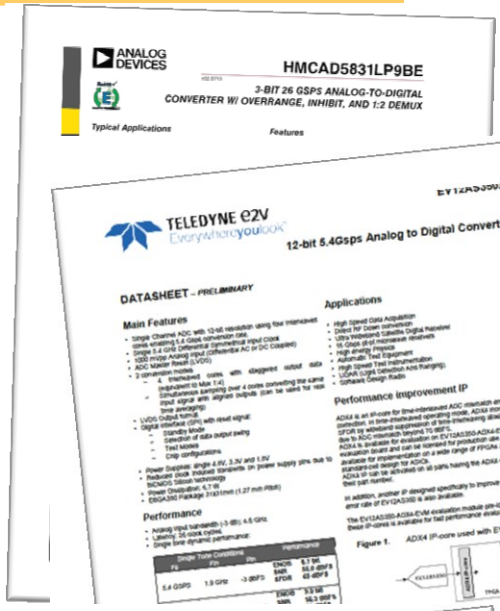
Science Drivers

Work packages		High priority science objectives areas													
		Time-Domain				Galactic science				Galaxy evolution				Cosmology	
	Desirable / Highly Desirable / Essential	Gravitational Waves astronomy	Pulsars astrophysics	Explosive events	Fast-radio Burst	Planet formation	Star-formation physics	Stellar evolution	Fundamental physics	Star-formation physics	Low luminosity Accretion physics	AGN / Jet physics	Distant Universe (Galaxy evolution)	Strong lensing	Weak lensing
STFC Key Science Challenges		D2	A6 D1	A6 D1 D2 D3	D1	B1	A6	A6 D3	D1	A5 A6	A5	A4 D1 D2 D3	A5	A3 C4 C5	A3 A5 C4 C5
WP2 – Software															
WP3 – S-Band															
WP4 – X-band															
WP5 – PAF															
WP6 - Digital															
WP7 – new Defford															

Data acquisition

- Direct sampling / heterodyne?
- Range of 5-26 Gs/s digitisers now available (e2v, TI, Analog Devices)
  - JESD204 Standard interfacing to FPGA
- Course frequency channelisation in FPGA?
- DAQ boards in design by Oxford/AASL



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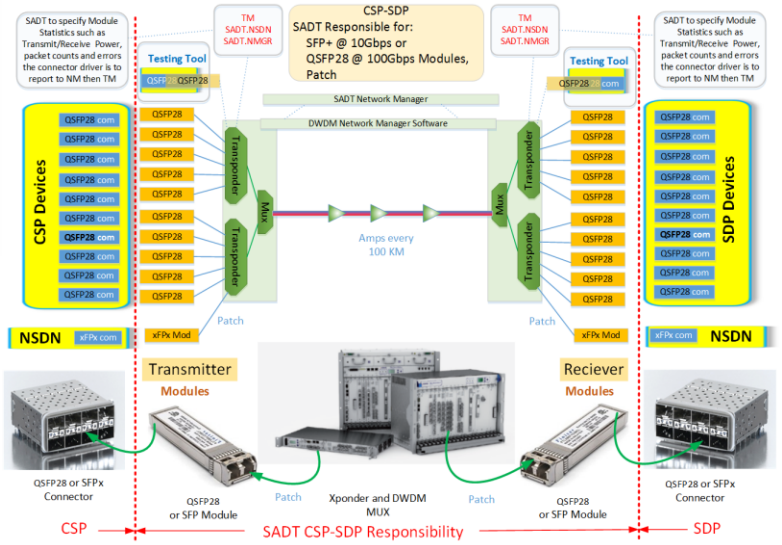
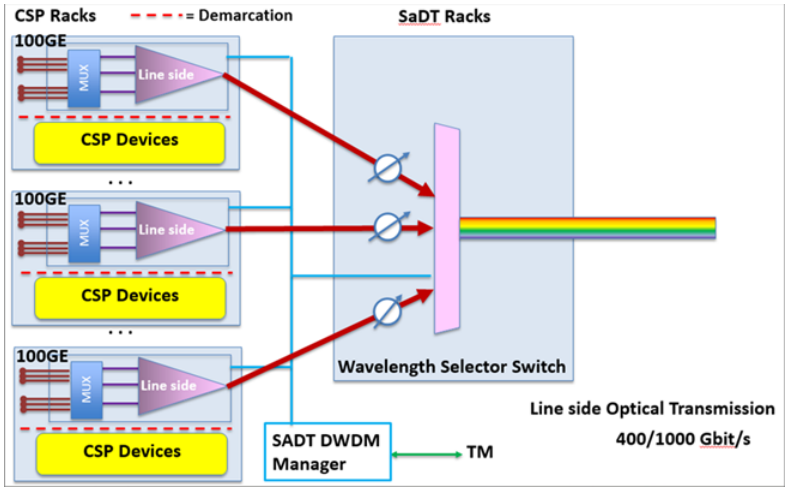
Digital Data Backhaul





- Solutions developed for SKA
- 100 Gb/s transmission now standard; will be used for SKA
- Use WDM COTS hardware
- Managed network
- n x 1/10/100 Gigabit Ethernet
  - Telescope voltages
  - Time (White Rabbit)
  - Non-Science Data Network

Network Manager functionality

- **Fault Management**
  - Reception and processing of SNMP traps, Syslog messages, ICMP pings, etc.
  - Performing diagnostics
  - Performing monitoring for network devices, servers and applications.
- **Performance Management**
  - Polling regularly by SNMP (or other standard protocol) for performance counters.
  - Rolling up counters at predefined intervals
  - Storage of performance counters
- **Configuration Management**
  - Inventory management
  - Network maps
  - Configuration backup and restore
  - Configuration audits & compliance reports
  - Configuration templates & bulk configuration
  - Change automation
  - Change notifications
  - Scheduled tasks
  - Power cycle network element
  - Startup / shutdown card / port
  - Image file management
  - Software / firmware upgrade

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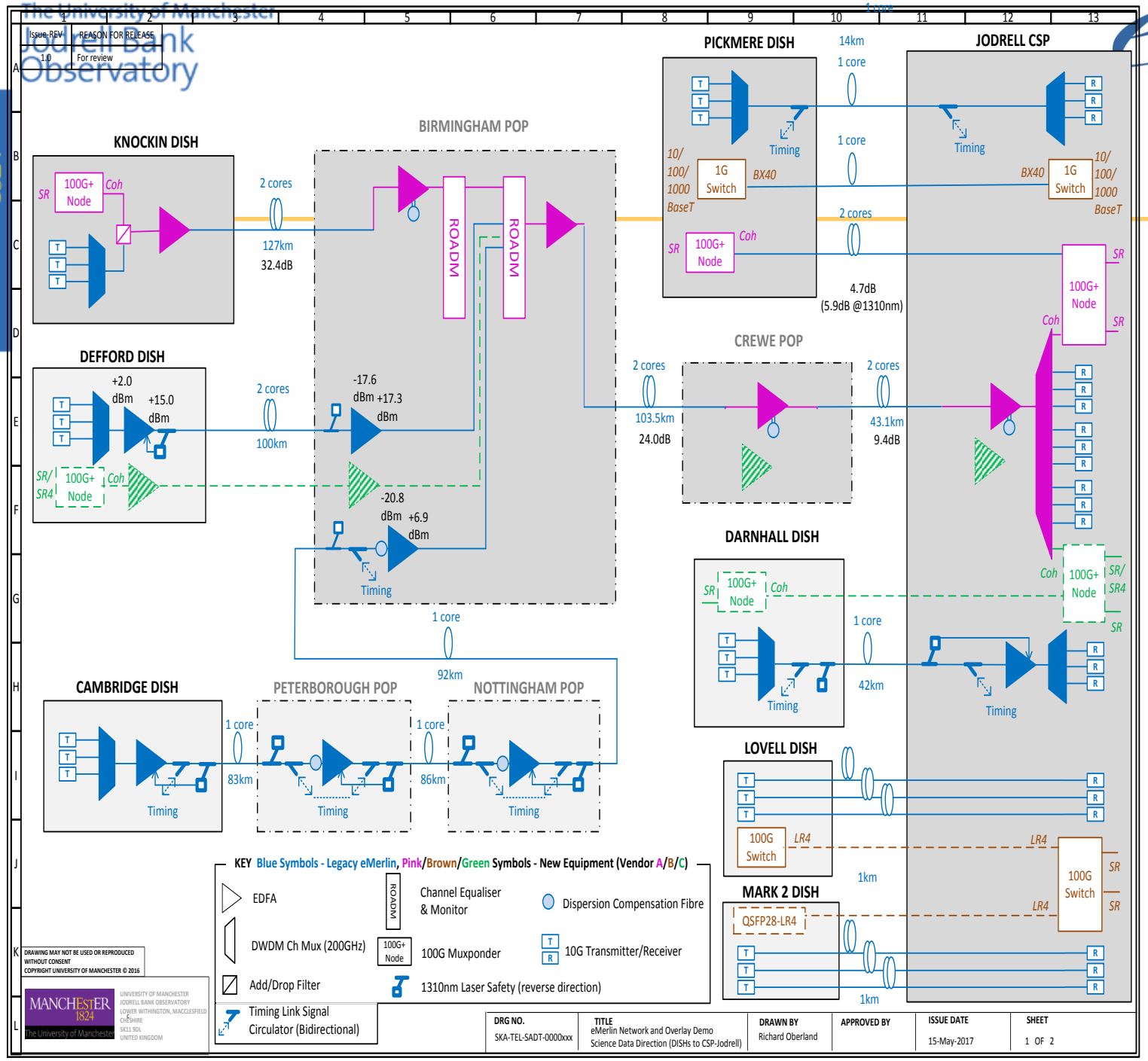
SKA DDBH Prototype

- eMERLIN as test-bed for SKA technology
  - 14km link
  - 270 km link
- Monitoring and control connectivity; network management
- Contract with Cisco/BT, ADVA, Coriant, Nagios and Insight/Mellanox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Issue REV 1.0
REASON FOR RELEASE For review
KNOCKIN DISH
100G+ Node
Coh
SR
2 cores
127km
32.4dB
BIRMINGHAM POP
ROADM
ROADM
PICKMERE DISH
14km
1 core
1 core
2 cores
Timing
10/ 100/ 1000 BaseT
1G Switch
BX40
100G+ Node
Coh
SR
4.7dB
(5.9dB @1310nm)
JODRELL CSP
Timing
BX40
1G Switch
10/ 100/ 1000 BaseT
100G+ Node
SR
Coh
SR
DEFFORD DISH
+2.0 dBm
+15.0 dBm
2 cores
100km
SR/ SR4
100G+ Node
Coh
-17.6 dBm
+17.3 dBm
-20.8 dBm
+6.9 dBm
Timing
CREWE POP
2 cores
103.5km
24.0dB
2 cores
43.1km
9.4dB
Coh
100G+ Node
SR
Coh
100G+ Node
SR/ SR4
SR
1 core
92km
DARNHALL DISH
SR
100G+ Node
Coh
1 core
42km
Timing
Timing
CAMBRIDGE DISH
1 core
83km
Timing
PETERBOROUGH POP
1 core
86km
Timing
NOTTINGHAM POP
Timing
LOVELL DISH
100G Switch
LR4
1km
LR4
100G Switch
SR
SR
MARK 2 DISH
QSFP28-LR4
1km
LR4
KEY Blue Symbols - Legacy eMerlin, Pink/Brown/Green Symbols - New Equipment (Vendor A/B/C)
EDFA
DWDM Ch Mux (200GHz)
Add/Drop Filter
Timing Link Signal Circulator (Bidirectional)
ROADM
Channel Equaliser & Monitor
100G+ Node
100G Muxponder
1310nm Laser Safety (reverse direction)
Dispersion Compensation Fibre
10G Transmitter/Receiver
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DRG NO. SKA-TEL-SADT-0000xxx
TITLE eMerlin Network and Overlay Demo Science Data Direction (DISHs to CSP-Jodrell)
DRAWN BY Richard Oberland
APPROVED BY
ISSUE DATE 15-May-2017
SHEET 1 OF 2

Central Signal Processor

- Need a new flexible signal processor
- Increased processing capacity (wideband)
- Increased flexibility
  - Include Lovell PAF beams
  - Commensal observing
  - Tied-array beams
    - Pulsars
    - VLBI

Central Signal Processor Specs

- Data ingest:
  - 10 antennas
  - 16 independent PAF beams from LT
- 8 GHz bandwidth
- Full polarisation
- 4 independent tied array beams
- 64k frequency channels across 8 GHz

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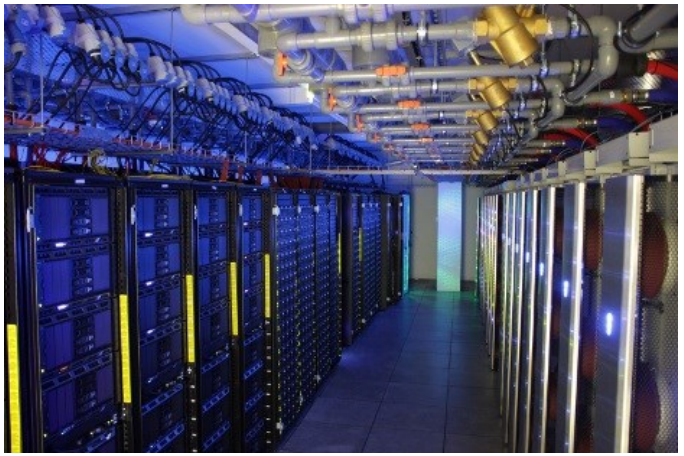
Central Signal Processor Implementation

- Last generation of big ASIC correlators
  - Approaching traditional refresh time
- Range of new options
  - FPGA, GPU, CPU
- Expect to use hybrid

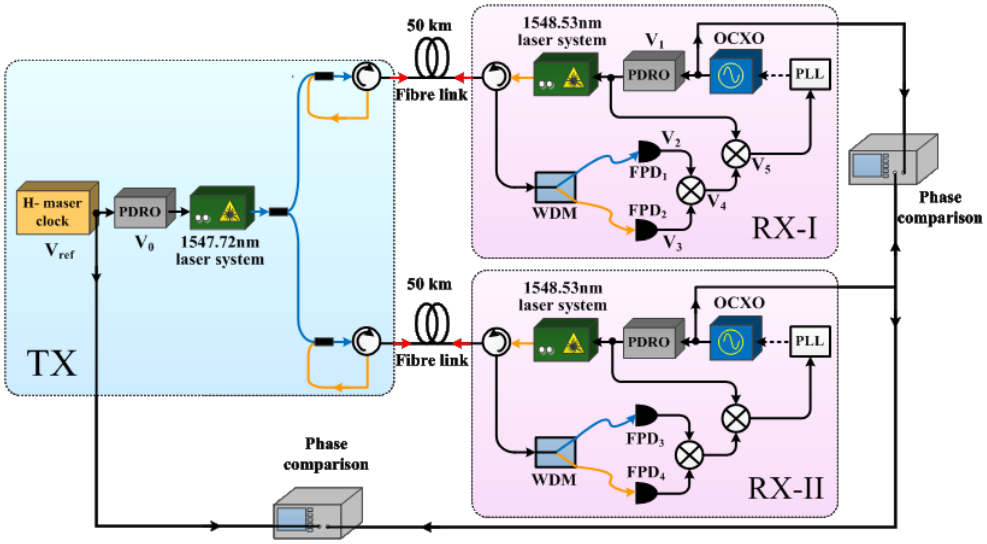
  FPGA -> GPU cluster

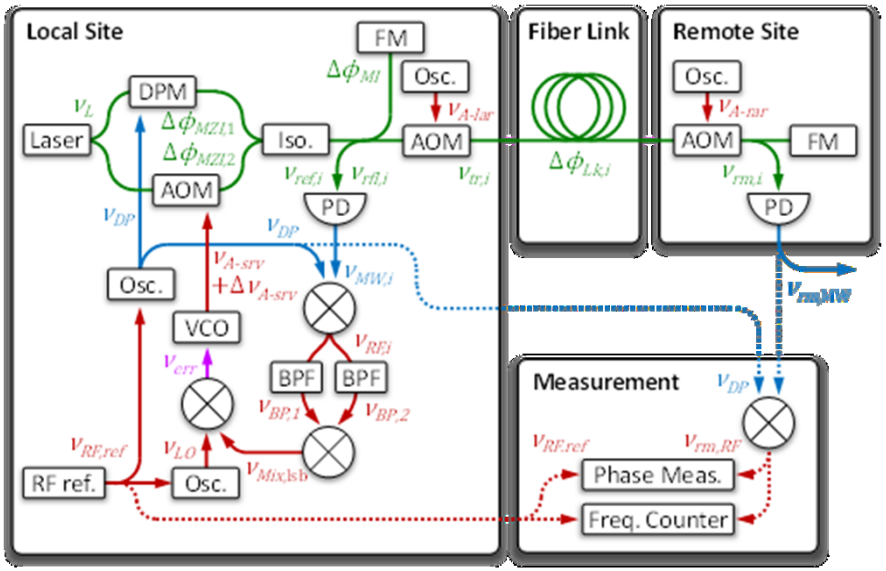
  Re-use Wilkes Cluster



Synchronisation

- Upgrade synchronisation distribution system
  - Replace current 1980s system
  - Exploit SKA STFR design work
  - Simplify correlator delay correction and interfaces





Summary

- Necessary for many of the upgrades
- High science return
- Builds on SKA

		High priority science objectives areas													
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Extra Slides

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WP6.1 Data Acquisition

- D6.1 Report on options for digitiser devices and frequency conversion
- D6.2 Prototype 4 GHz bandwidth data acquisition sub-system,
- D6.3 Expansion to 8 GHz bandwidth prototype data acquisition sub-system,
- D6.4 Integration of 4 GHz bandwidth with data links
- Resources:
  - 5.0 FTE Digital Processing Engineer (Manchester)
  - 2.0 FTE Electronic Engineer (Oxford)
  - £350k consumables

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WP6.2 Data Links

- D6.5 Design report on data transmission options
- D6.6 Prototype 100G data link to single telescope
- D6.7 Replacement eMERLIN data network
- Resources:
  - 2.5 FTE Optical fibre Comms Engineer
  - £200k consummables

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Correlator / Beamformer

- D6.8 Report on correlator and beamformer design options
- D6.9 Prototype 4-station correlator (4 or 8 GHz B/W) and beamformer with 500 MHz B/W
- D6.10 e-MERLIN correlator and beamformer
- Resources:
  - 5.0 FTE Digital Engineer (Manchester)
  - 2.5 FTE Digital Engineer (Oxford)
  - 50% of the Cambridge Wilkes GPU/CPU Cluster

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WP 6.4 Synchroniation

- D6.11 Extend SKA STFR design to use wavelength division multiplexing
- D6.12 Prototype STFR to single remote telescope in conjunction with 100G link
- D6.13 Replacement e-MERLIN STFR system
- Resources:
  - 2.5 FTE Synchronisation and Timing Engineer
  - £172k consumables