UK FPA Plans

Focal Plane Array Workshop

20-21 June 2005

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Systems

- OCRA
- Methanol Multibeam
- PHAROS
- Dual Polarisation All-Digital tile – **2-PAD**

EC Framework 5: FARADAY (2001)

- to produce affordable 2-D receiver arrays to be installed at the focus of large radio telescopes

- to greatly enhance the capabilities of the existing European radio astronomy infrastructure.

- horn arrays with radio frequency (rf) switching stages for high frequency continuum surveys (OCRA at 30 GHz)

- horn arrays with down-conversion stages for radio spectroscopy (IRA 18-24 GHz 7 beam system)

- phased arrays to synthesise multiple beams to improve the efficiency of individual telescopes and to open up the field-of-view. (ASTRON Faraday prototype)

OCRA
A **O**ne **C**entimetre **R**eceiver **A**rray

University of Manchester

University of Torun

University of Bristol

What is OCRA?

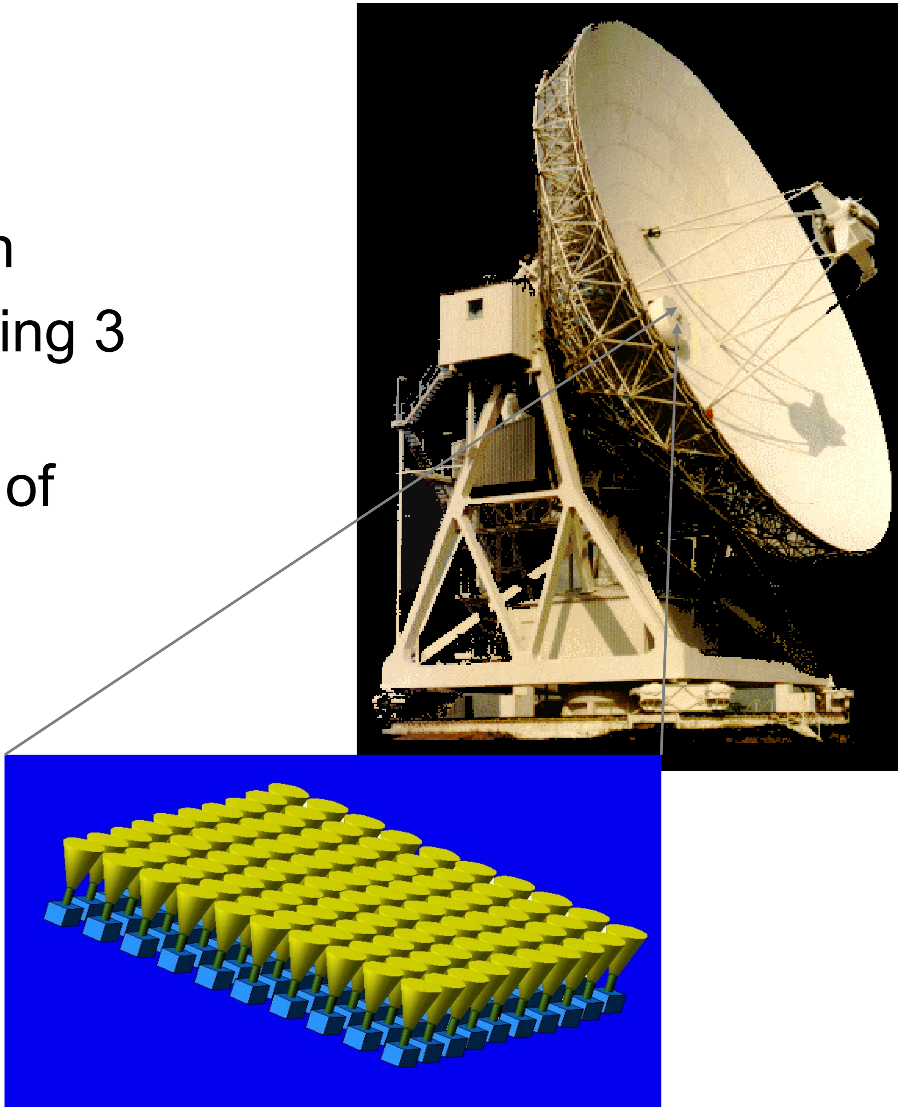
- A ~100 beam wide-field focal plane array for surveying the sky at ~30 GHz
- Mounted on Torun 32m telescope & possibly on other telescopes eg Effelsberg 100m
- Source surveys: important foregrounds for CMBR
  : new types of radio source?
- Has possibilities for blind SZ surveys

OCRA: concept

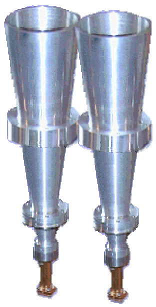
- Based on radiometers on *Planck/LFI* (similar to WMAP)
- Configured as 50 continuously-switched pairs
- Switching allows:
  - subtraction of atmospheric fluctuations
  - removal of semiconductor 1/f gain variations
- Pre-detection is all at RF (non-heterodyne)
  - Offers stability and cost advantages

OCRA on Torun 32-m

- beam size 1.2 arcmin
- minimum beam spacing 3 arcmin
- set by minimum size of feeds (8.5 cm)
- 10 x10 array ~85cm square

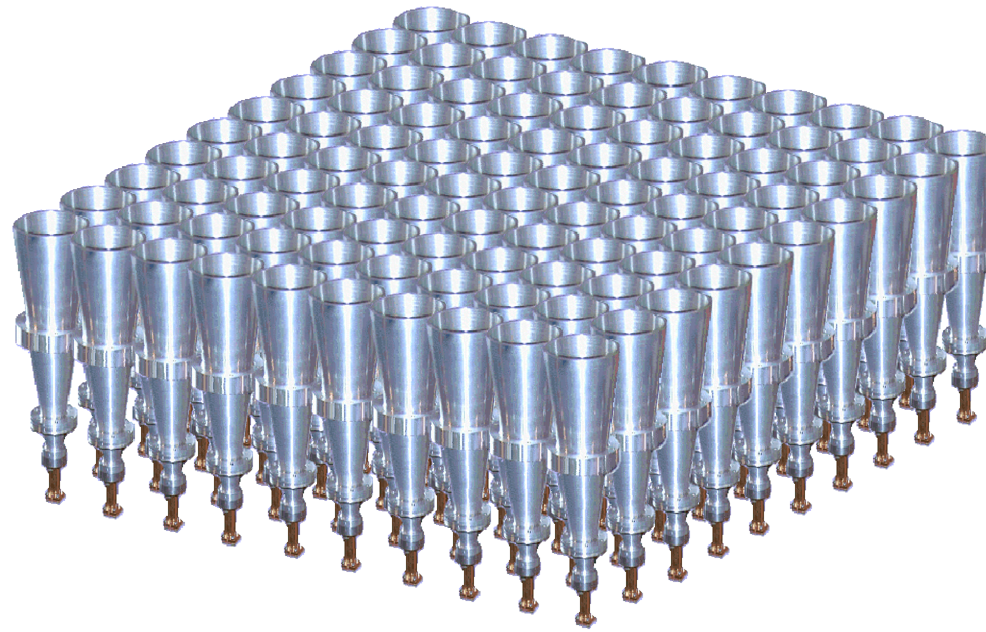


Progression

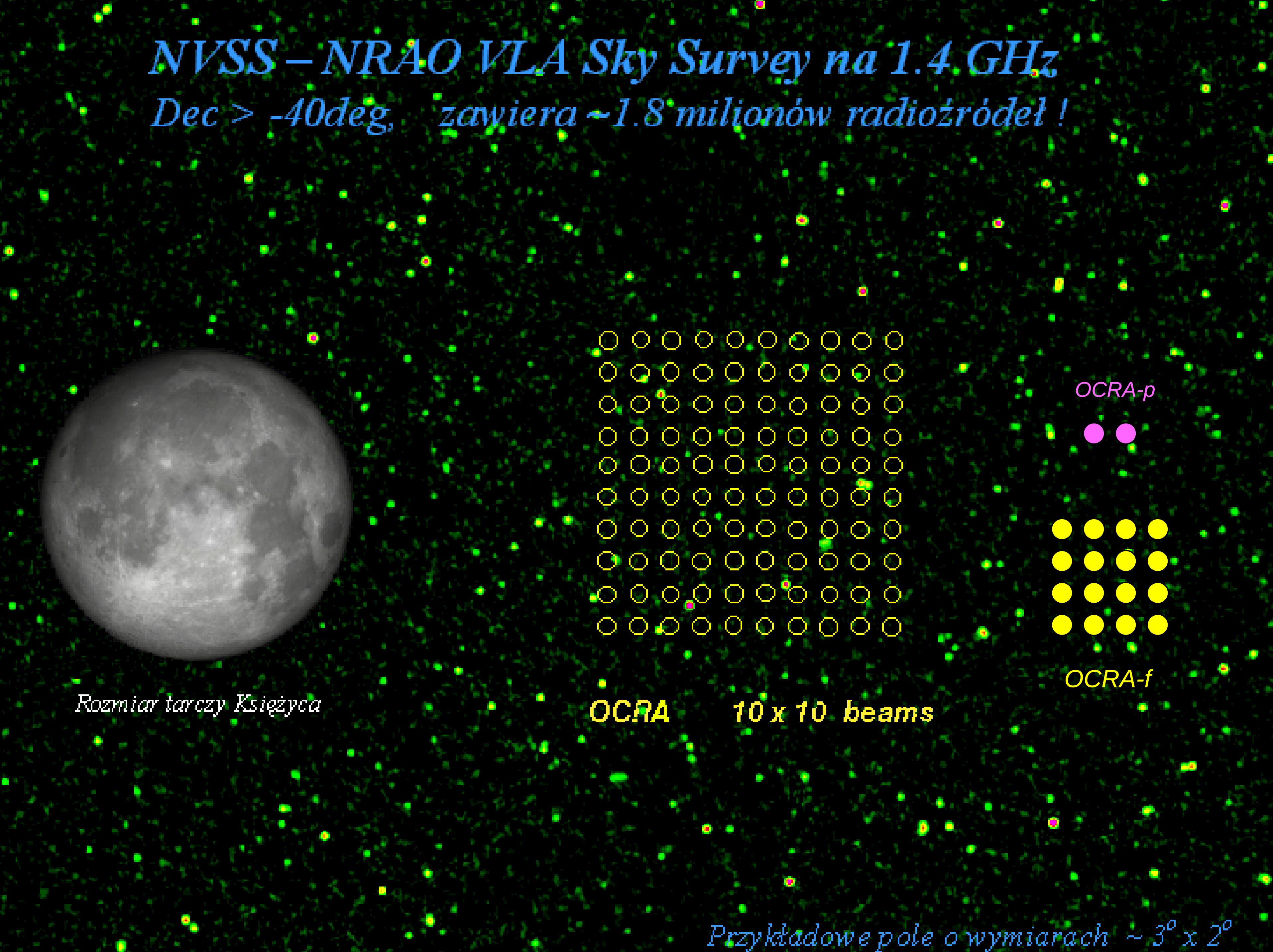


OCRA-p

OCRA-f



OCRA


NVSS – NRAO VLA Sky Survey na 1.4 GHz
Dec > -40deg, zawiera ~1.8 milionów radioźródeł !
OCRA-p
OCRA-f
Rozmiar tarczy Księżyca
OCRA 10 x 10 beams
Przykładowe pole o wymiarach ~ 3° x 2°

Timeline

- Stage 1 (operating):
  - 2-beam system 2002-2004/5
  - proof-of-concept for receiver design
  - proof-of-performance of 32-m telescope

- Stage 2 (funded):
  -16-beam system 2005-2007/8
  - develop MMIC technology enabling production of much larger system at realistic cost.

- Stage 3 (final system):
  - 100-beam system 2008→?

First operating prototype

“OCRA-p”

The next step “OCRA-f”

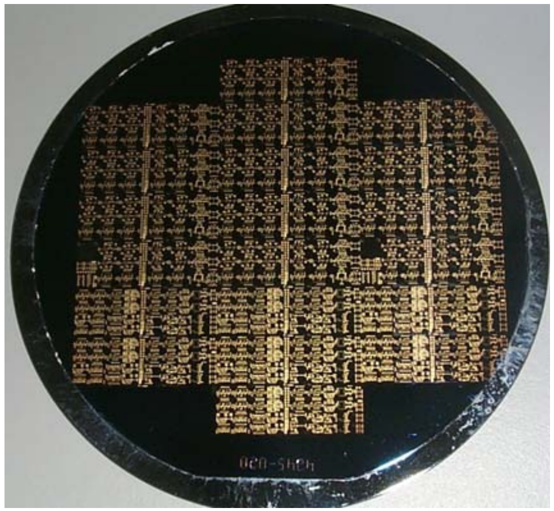
- Too expensive to scale OCRA-p to 100 beams

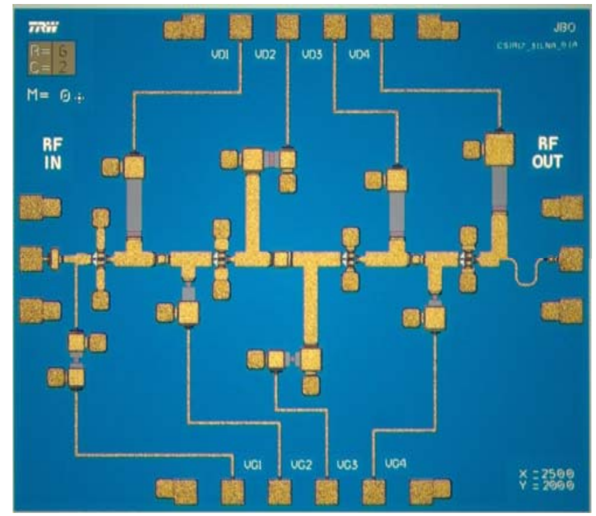
- Need to integrate as many components as possible → MMIC technology

- European FP5 RTD project “FARADAY”
  - JBO, Italy, Netherlands, Poland, Australia
  - 16-beam OCRA-f module in Q3 2006

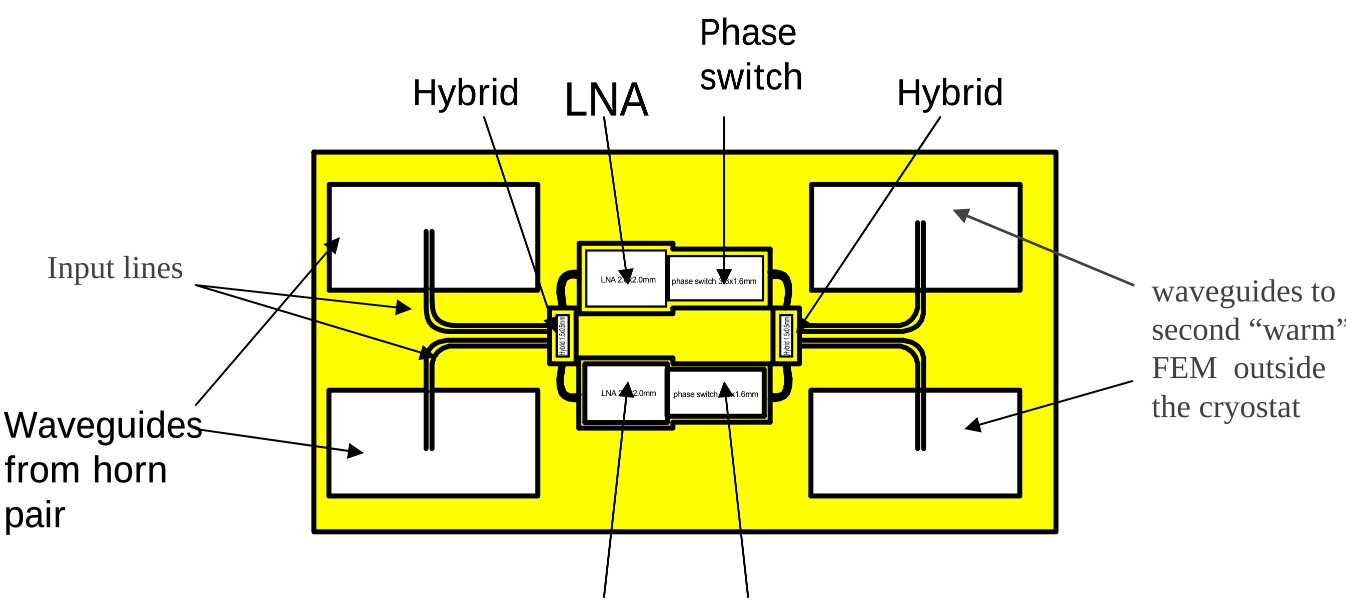
InP MMIC development with CSIRO

A Wafer



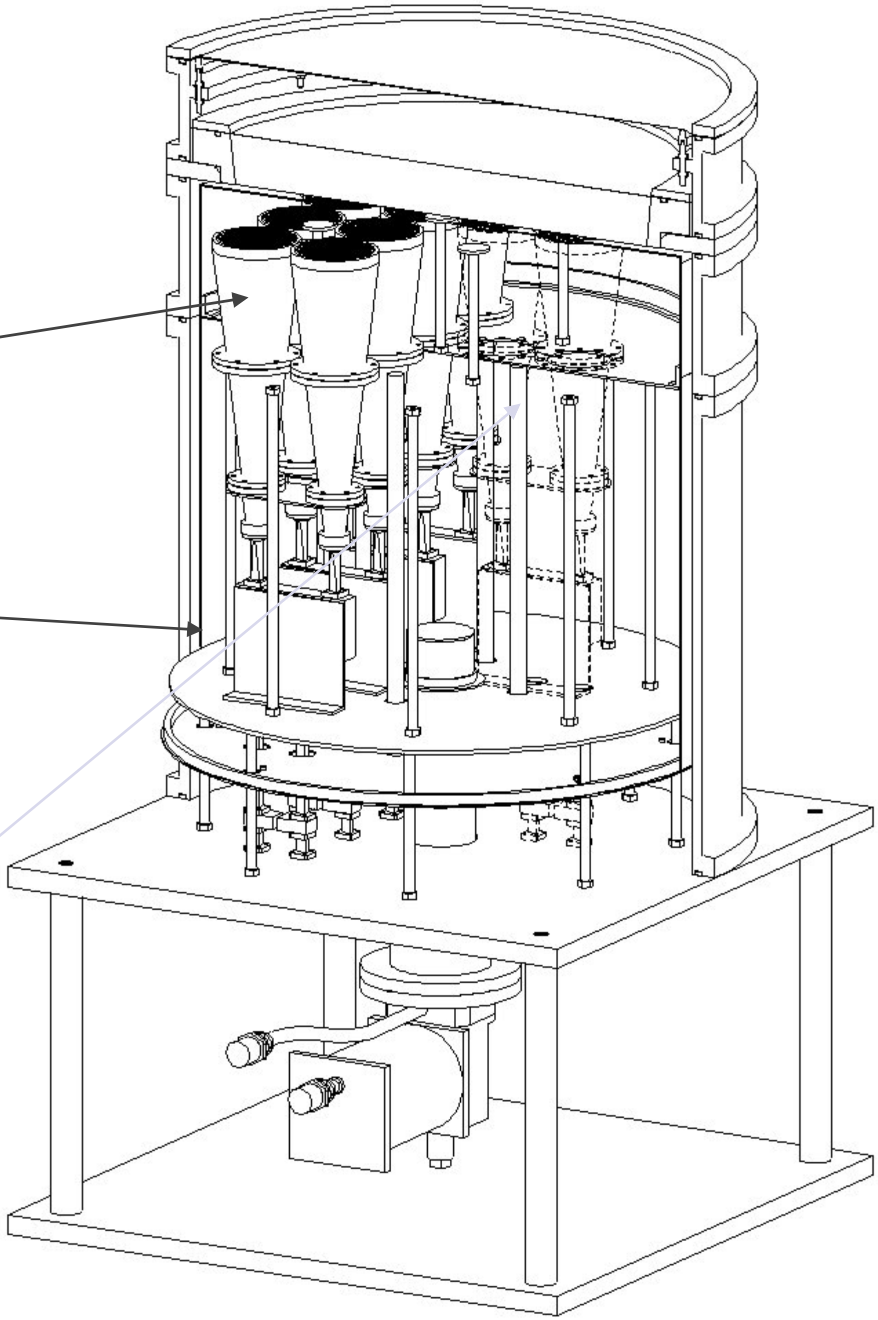


An LNA



Front-end module

OCRA-f general arrangement



Horn pair

Front end module

Horn+20K load
for atmospheric
subtraction tests
(testing total power mode?)

Methanol Multibeam

- 7-Beam 6-7 GHz system
- Classic multi-horn array
- Spectroscopy & pulsars
- Joint development JBO/ATNF
- Mounted on Parkes end 2005
- Mounted on Lovell end 2007

PHAROS

- RadioNet JRA demonstrator project
- Co-ordinated by ASTRON
- Target cryogenically cooled phased array at 5GHz
- Analogue beamforming networks JBO+Birmingham
- Tests on existing EVN telescopes eg Westerboork, Lovell etc…
- Target 2007?

2-PAD

- Development within SKA Design Study (SKADS)
- Suitable for aperture array or focal plane array
- Full development in 4 years
- Innovative, dedicated front-end semiconductors

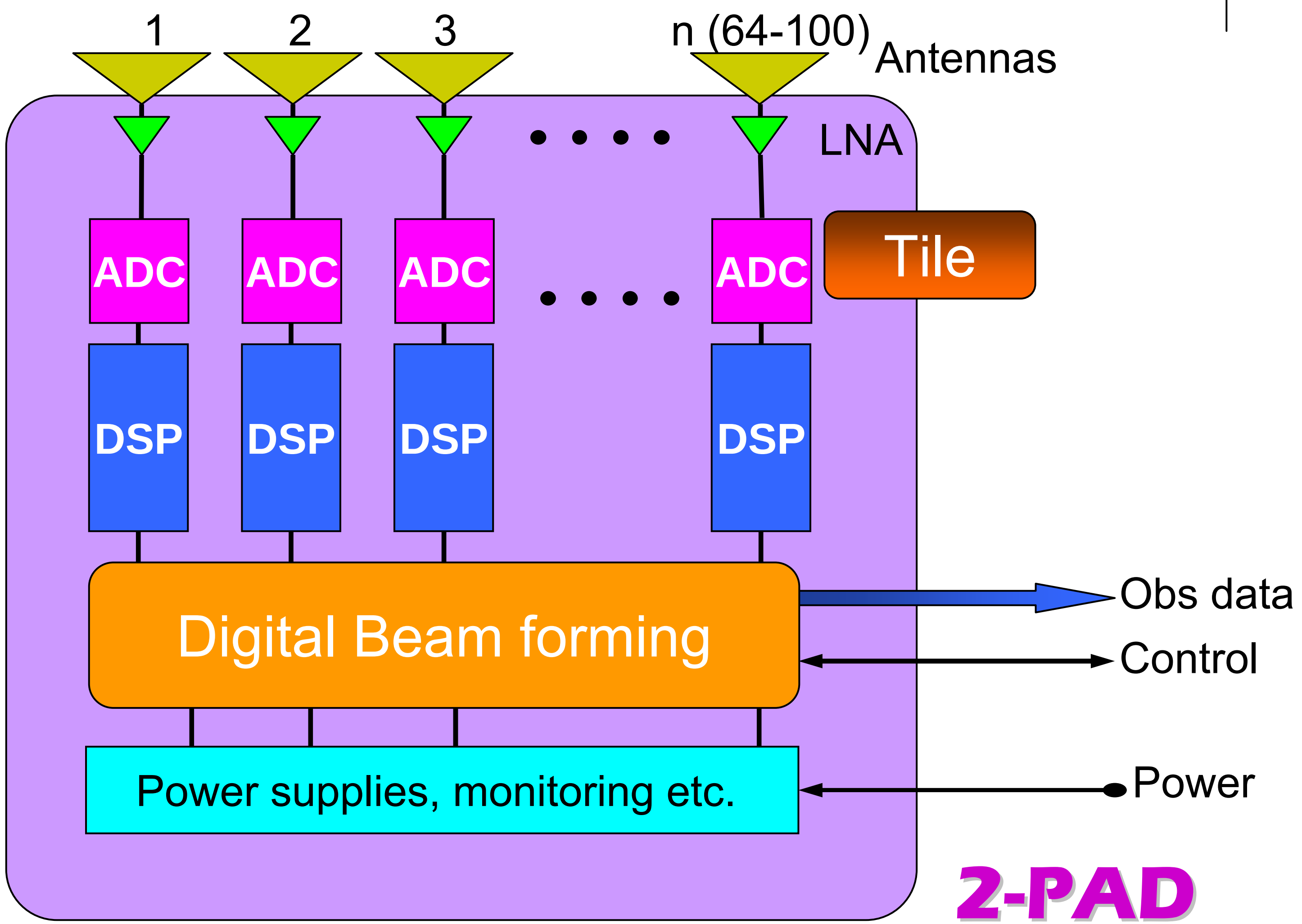
Design Objectives

- A ‘tile’ for the SKA as an *aperture array*
- Manfacturable up to 10^6 devices
- Low cost
- Uncooled
- Good ambient temp performance
- Re-programmable
- Dual polarisation

2-PAD Target Specification

Size:	~1m x 1m
Frequency range:	0.5 → 1.8 GHz
Bandwidth:	>500MHz
Beamforming:	All digital
Max scanning angle:	±60°
Polarisations:	dual, residual error <40dB (total power)
System Temp:	<50K at 1.4 GHz
Operating temp:	Ambient
No. of FOV’s:	TBD

Outline Design



Why Digital?

- Wide bandwidth, uses true **time** delays
- RFI mitigation, can use sophisticated algorithms
- Many Fields-of-View (FOVs)
- Consistency, low temp variation and ageing
- Self-calibration capability
- Programmable – implement new concepts

Re-configurable as a Focal Plane Array

Technologies to develop

- Cheap, dual polarisation antenna elements
- Close packed (<0.5λ) antenna elements
- Low cost, low noise high performance room temp LNA
- Low cost, very high speed, low power ADC
- Extremely high performance digital processing

Other Issues

- Self interference
  - Massive processing near sensitive front end
- Reliability
  - Essential for operating [illegible]ity of S[illegible]A
- Consistency
  - Calibration an[illegible] unit [illegible] essential
- Resistance to R[illegible]
  - Always sees a lot of sky, RFI excision is essential
  - Satellites, mobile phones TV etc etc
  - Site selection a key feature

COST!!

Antenna

- Close packed array
  - Causes mutual coupling
- Dual Polarisation
  - Complicates design
- Bandwidth >3:1
  - VSWR 1.1 @ 1.5GHz and ~1.5 @ 0.5GHz
- Very wide scan angle ±60°

LNA

- Optimised for low noise at room temp
- Coupling configured for chosen antenna
- Must compliment the ADC
- Robust to assembly and environment
  - High break down voltage
- High linearity
  - Avoid intermodulation products from RFI
- **LOW COST**

ADC

- Target 4G samples sec^{-1}
- Min 4-bit and max 8-bit conversion
  - Requirement determined from RFI studies
- Low power
  - Commercial devices >5 watt ea → 1KW for tile!!
- Customised interface to digital electronics
  - Reduce data rate to practical levels
- Low cost

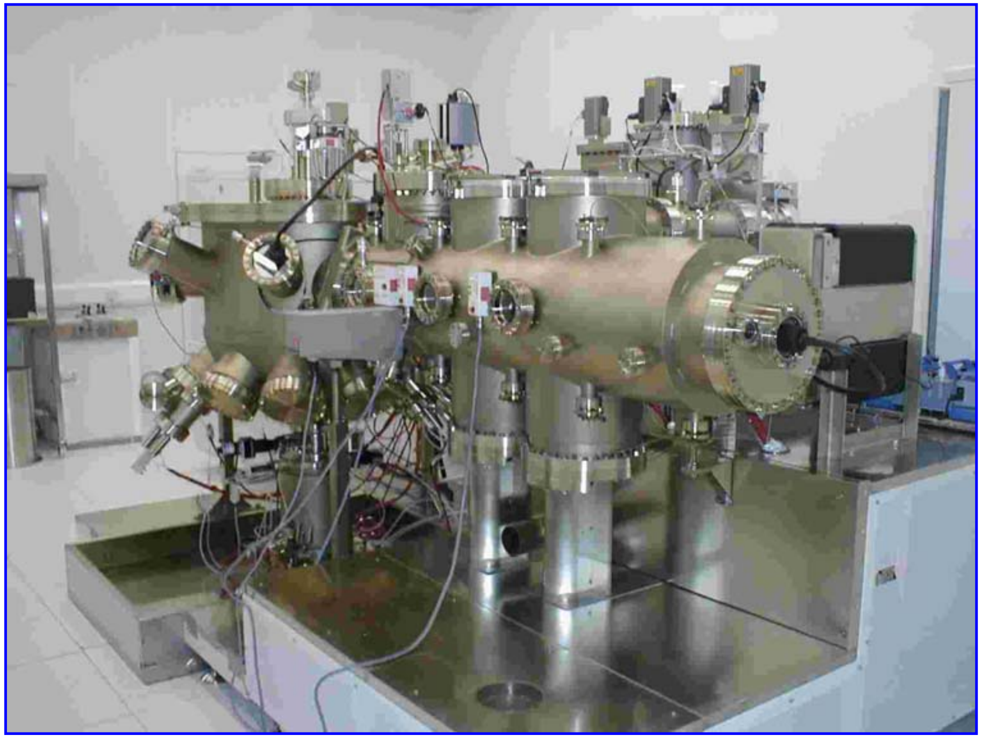
Digital Electronics

- Ideally process all the bandwidth at baseband
  - This is ~25Tops for a 100 element array!!
- Current obvious choice is FPGA
  - But relatively high power and cost
- Possible multi-processor solutions
  - Likely lowest power per MIP
  - Custom configurations in SKA?
- Commercial DSP’s
  - Cheap processing but probably not fast enough

LNA & ADC implementation

- Develop custom semiconductors on *custom substrate*
- Use InP III/V material
- Optimised components for Radio Astronomy
- We have a unique facility in Manchester….

Optimal Device Fabrication



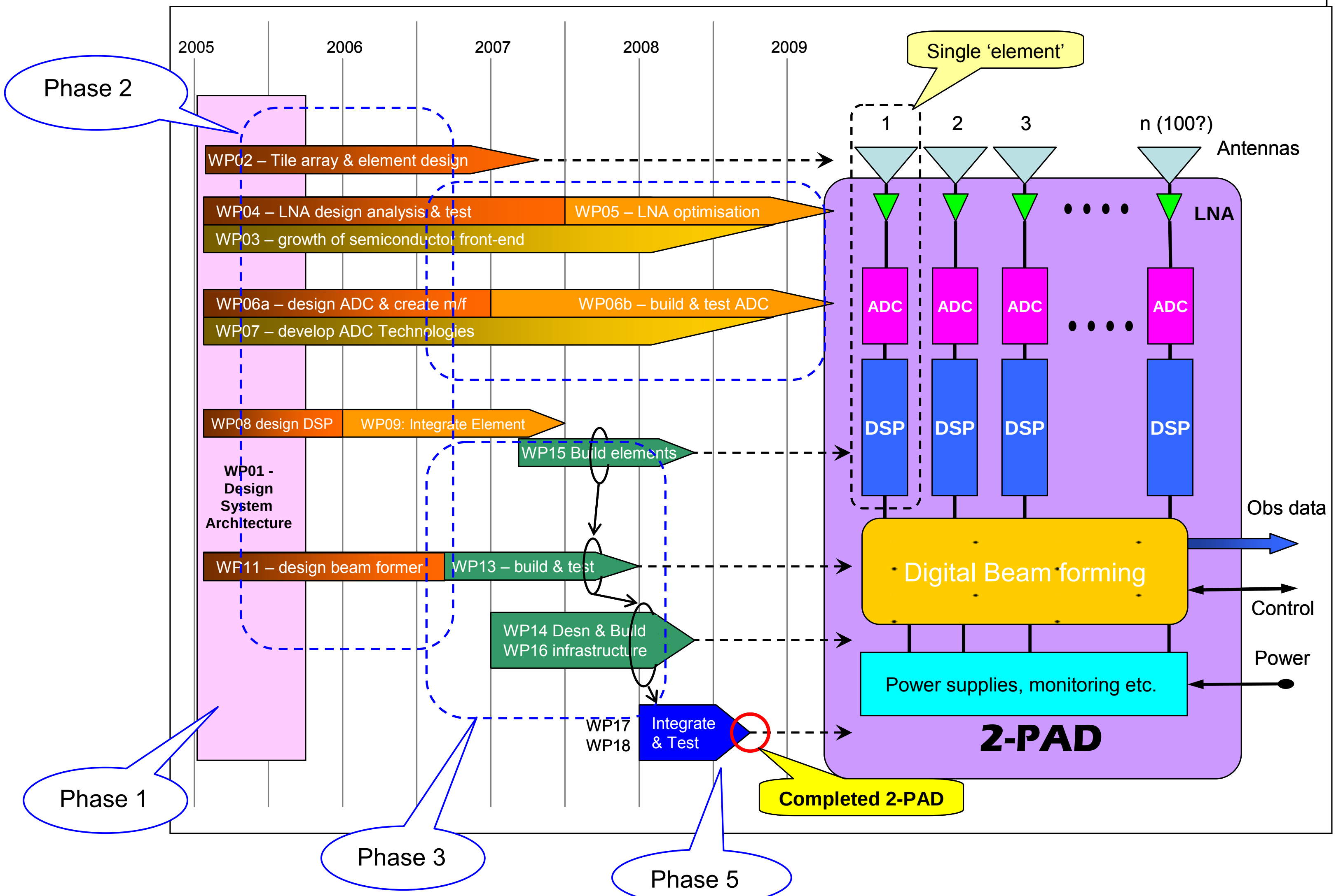
Oxford Instruments V100+ & V90H etc.

200 mm wafer size, multi x 100 mm

Si & III/V Technologies

Quantum manufacturability

2-PAD Plan – detail….



Potential Show-Stoppers

Fundamental Electromagnetic (Polarisation purity, constancy of output impedance etc.)

- Study in 3 universities + industry

RF noise temp at ambient temps

- Custom semiconductor *devices*

Impact of RFI

- Siting + French SKADS study

Affordable high speed DSP

- New technologies – FPGA, DSP, multi-processors per chip

Operation of SKA – reliability & maintainability

- Involve industry early

The 2-PAD Team

Manchester:	Antennas, semiconductors, digital processing, infrastructure, Manufacture
Oxford:	Digital processing, antennas
Cambridge:	Antennas, testing
SA/Australia:	Demonstrator FPA systems
ASTRON:	Antennas, testing
British Aerospace:	Antenna testing and environmental
Qinetiq:	Semiconductor design

Timeline

3Q05	Start project
3Q07	Prototype Antenna elements LNA prototypes 4-bit functional ADC Simulated and specified Digital electronics
3Q08	Operating antenna ‘element’ (ant.-LNA-ADC-digital filter)
3Q09	Full 2-PAD system

We have:

- a lot of the people
- ideas, collaborations – now we only need….

Money!!