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Energy requirements for the SKA Pathfinders

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SKA Pathfinder Energy requirements

1. What is an SKA Pathfinder ?

2. How do they compare to other interferometers ?

3. A case study – ASKAP
    1. Requirements – what is ASKAP ?
    2. Location – why put it somewhere so remote ?
    3. Demand side management
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    5. The future for ASKAP power

4. SKA

5. Current Status

SKA Pathfinders

- A facility that meets the appropriate criteria from the SKA Project Development Office – a "precursor" on a candidate site.

- These include:
  - ASKAP (Australia and New Zealand – at the MRO)
  - MeerKat (Southern Africa)
  - MWA (MRO)
  - (LOFAR)

- A range of other telescope projects in the 30 MHz – 3 GHz range have been labelled as precursors or pathfinders

- They are all interferometers.

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Power consumption – some interferometers

	# antennas	Cooled	Power/ antenna kW	Central procesor power	Total Power kW	Procesor cooling kW
ASKAP	36	No	13.5	300	1100	110
MeerKat	64	No	10	200	1500+	250
LOFAR		No	(224)	170	430	-
MWA	512	No	90	100	190	(incl)
CARMA	23 (3.5-10m)	Yes	4 - 16	60	282	35
eVLA	27	Yes	28	274	1400	100
ATCA	6	Yes	30	8	245	6
SMA	8	Yes	12	46	200	71

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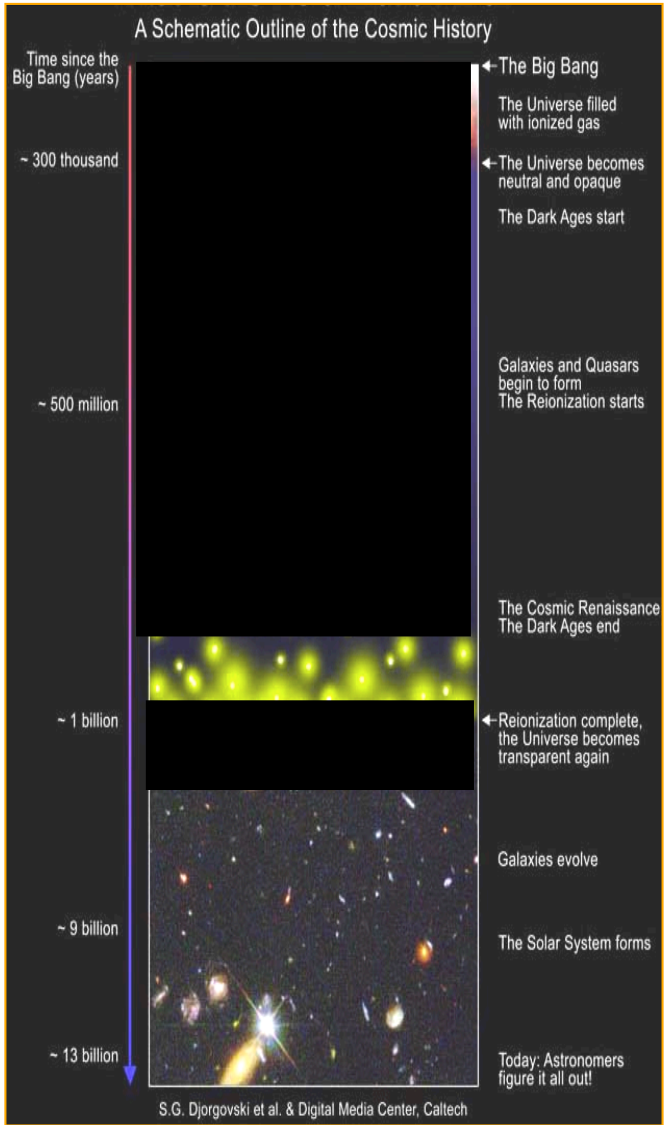
Australian SKA Pathfinder (ASKAP)

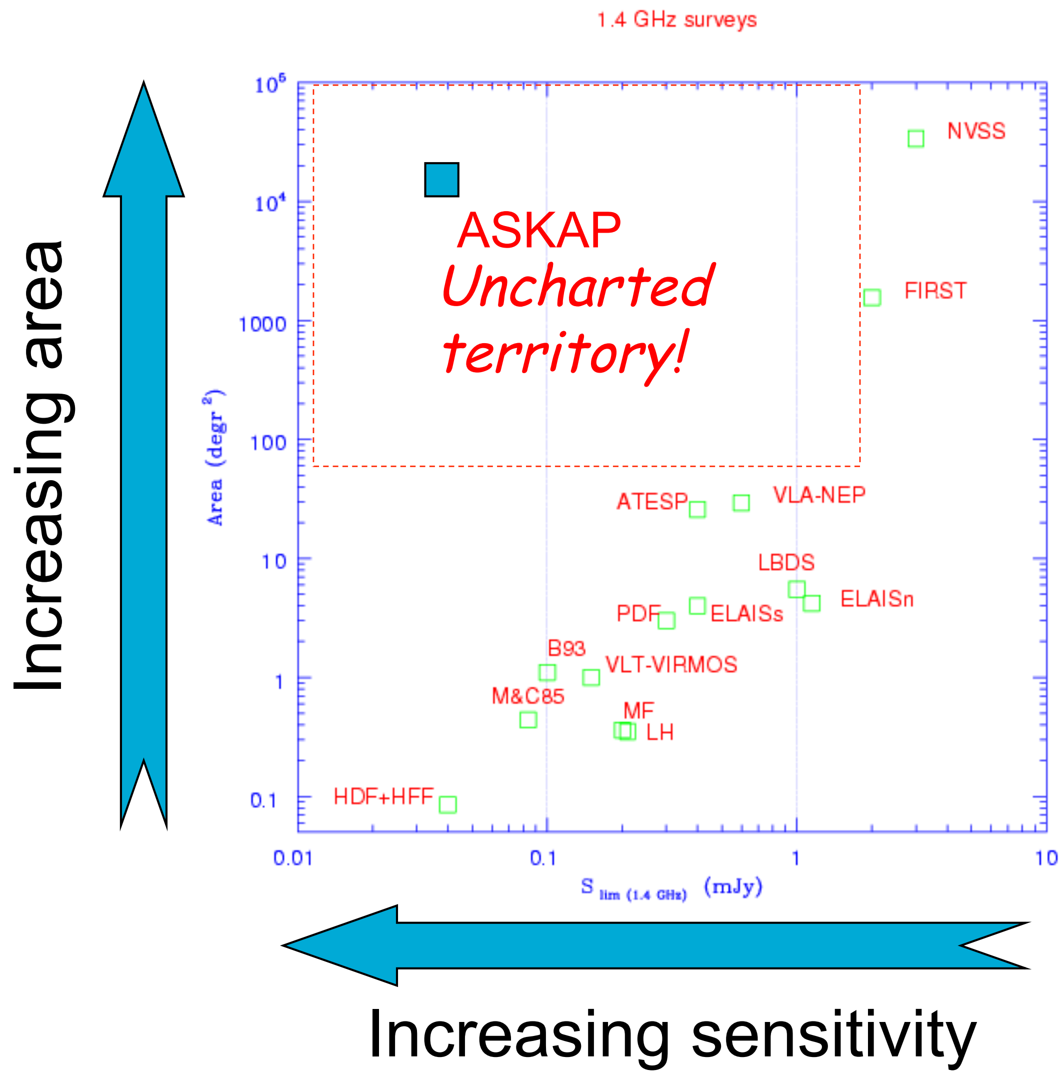
•ASKAP Key Science Goals

- •Probing the Dark Ages
- •Galaxy Evolution, Cosmology and Dark Energy
- •Origin and Evolution of Cosmic Magnetism
- •Was Einstein right?
- •Cradle of Life



- 4 countries (95% Aus)
- $152 M (AU)
- Sited in Western Australia

Exploration of the Universe



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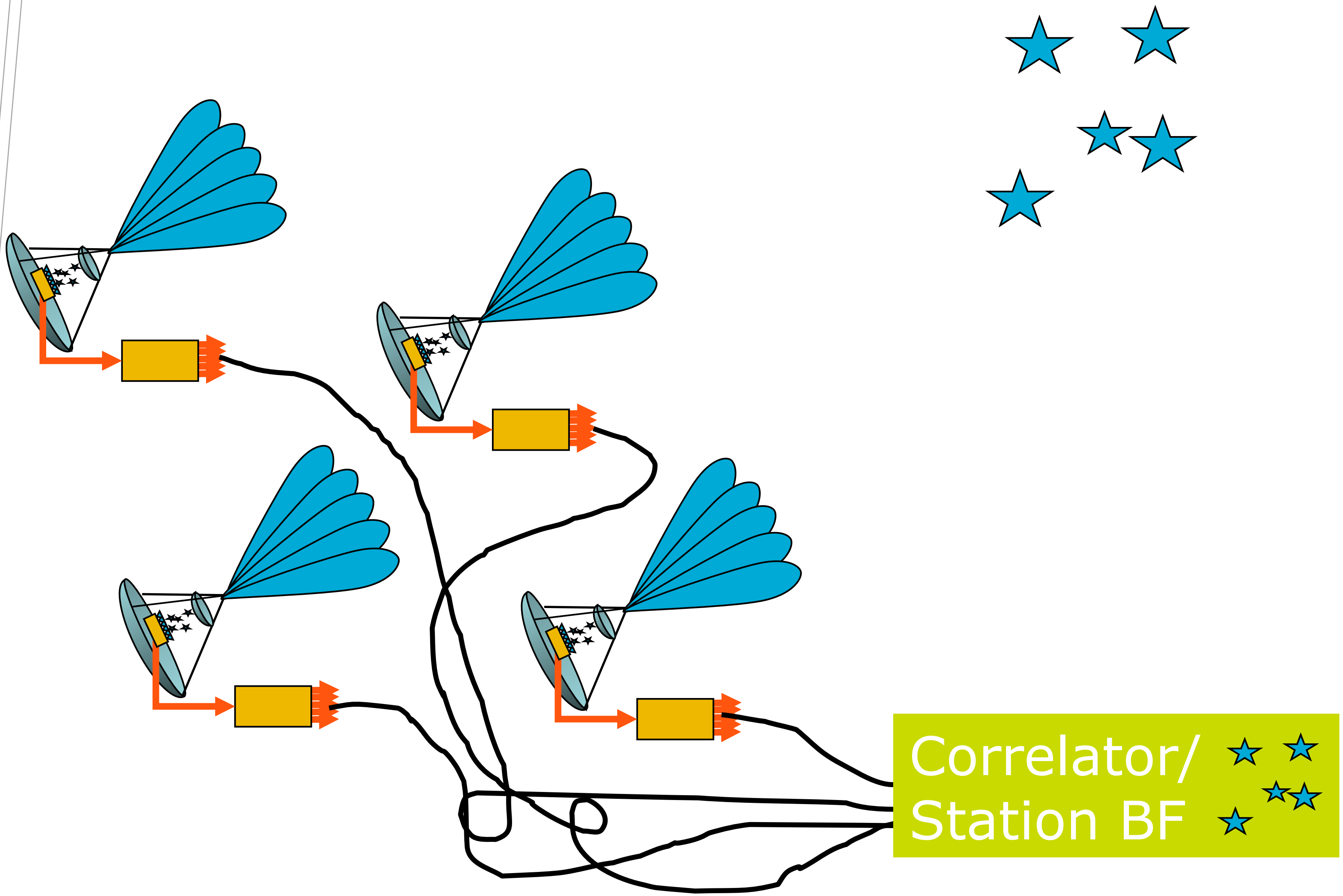
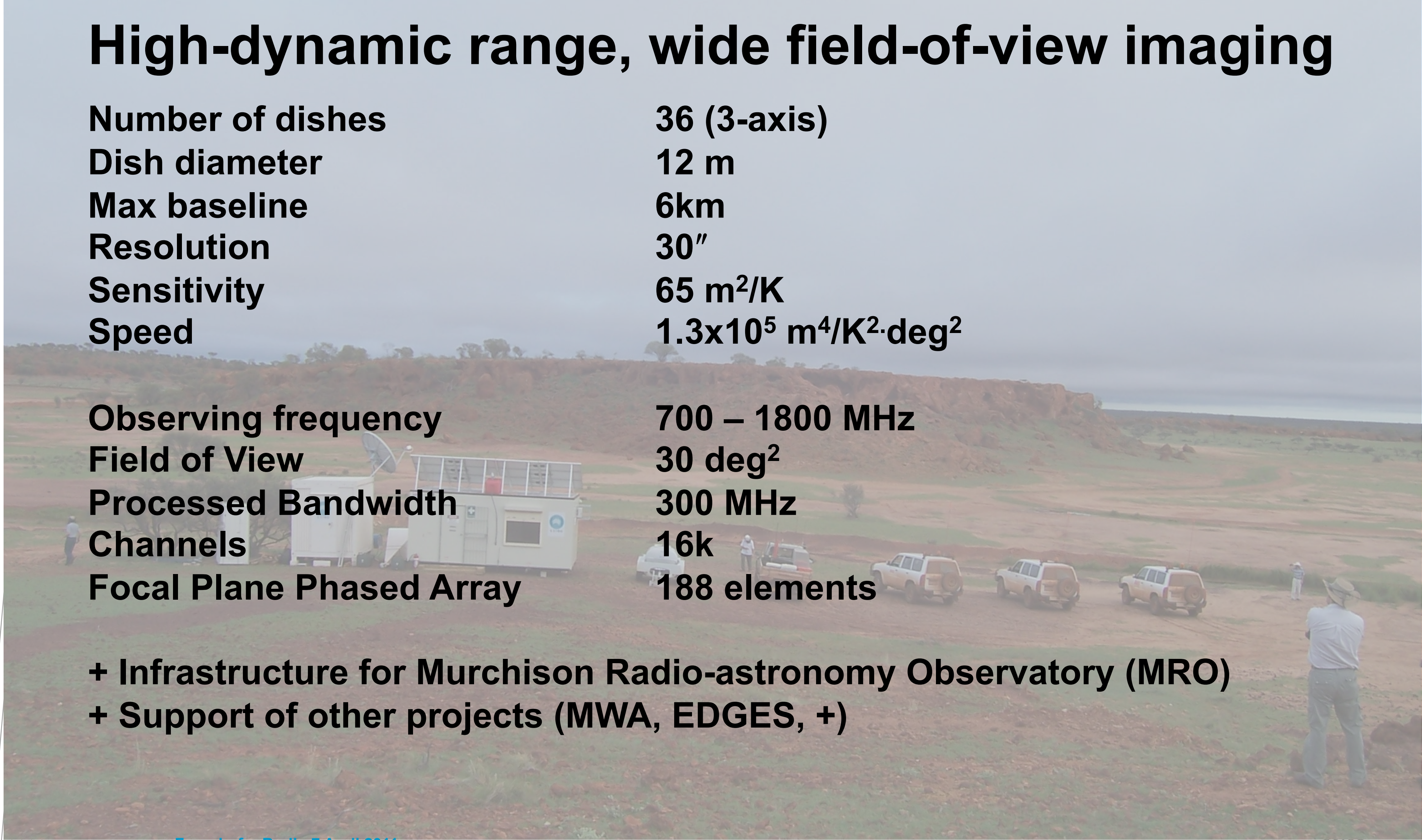
VLBI


Darwin
Northern Territory
Queensland
Australia
Adelaide
ACT
Hobart
5500 km
LBA

ASKAP Beamforming



ASKAP Scope and Design Goals



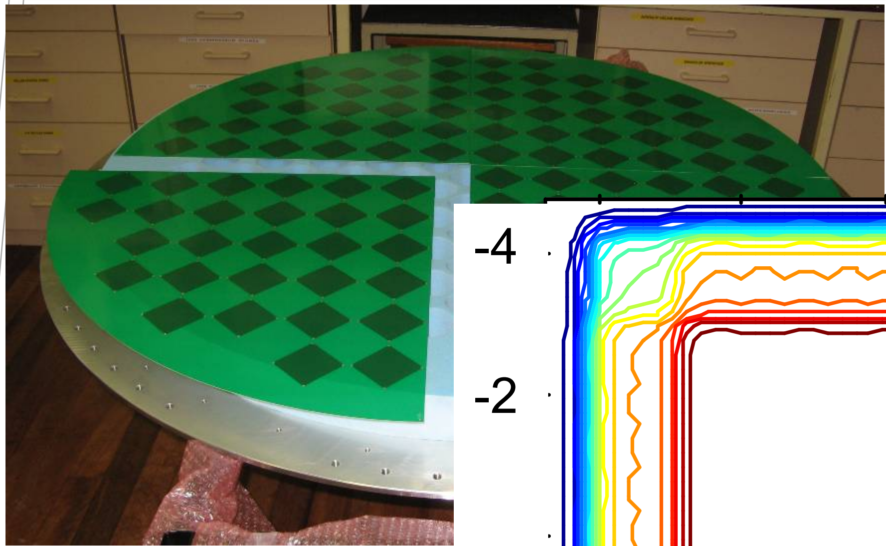
High-dynamic range, wide field-of-view imaging

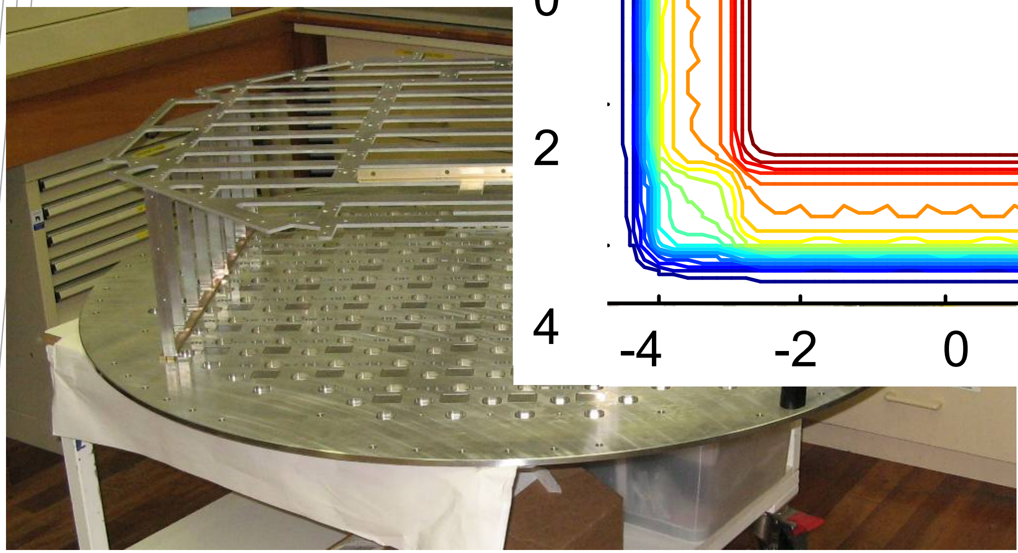
Number of dishes	**36 (3-axis)**
Dish diameter	**12 m**
Max baseline	**6km**
Resolution	**30″**
Sensitivity	**65 m^2/K**
Speed	**$1.3x10^5$ $m^4/K^2 \cdot deg^2$**
Observing frequency	**700 – 1800 MHz**
Field of View	**30 deg^2**
Processed Bandwidth	**300 MHz**
Channels	**16k**
Focal Plane Phased Array	**188 elements**

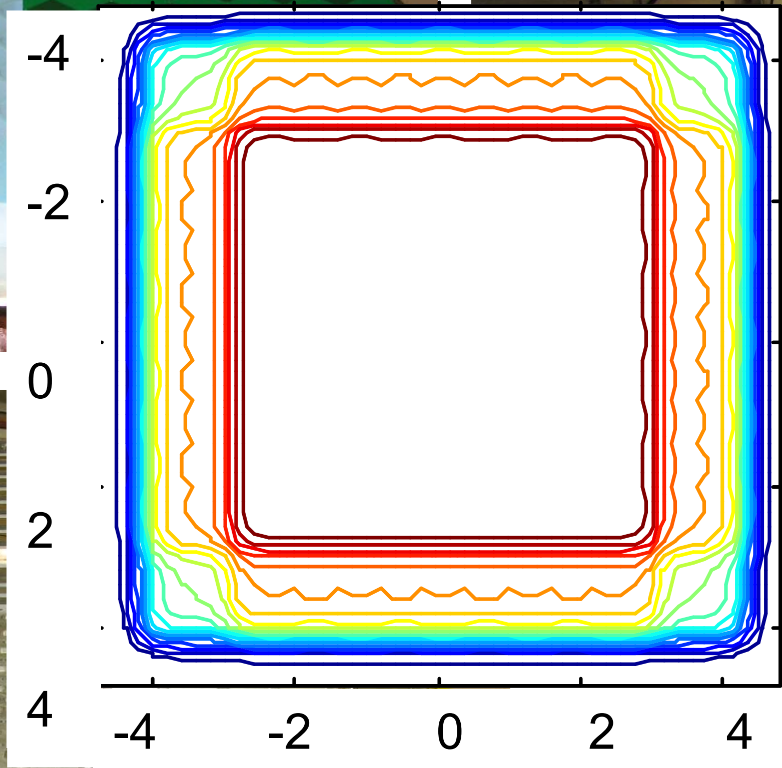
+ Infrastructure for Murchison Radio-astronomy Observatory (MRO)

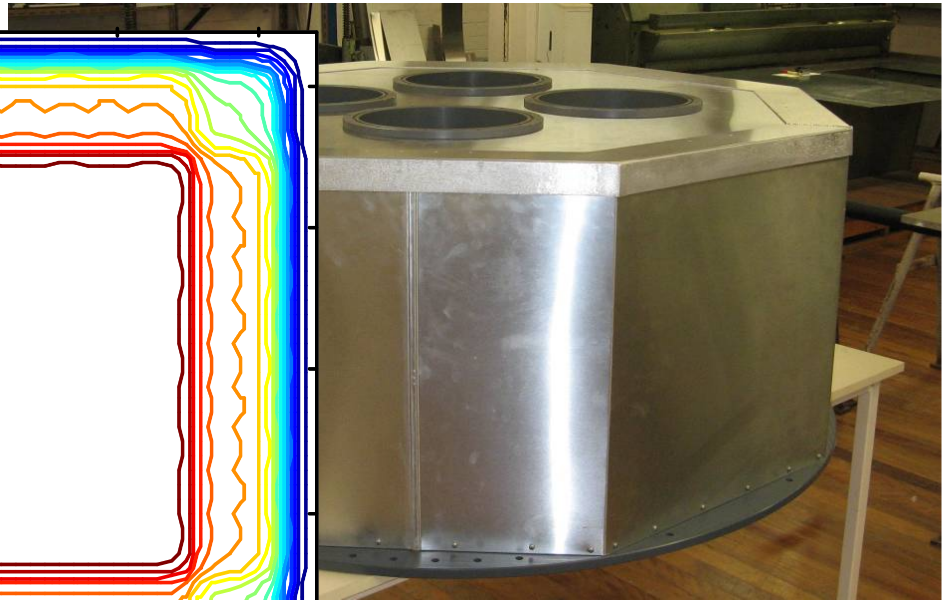
+ Support of other projects (MWA, EDGES, +)

Phased Array Feed

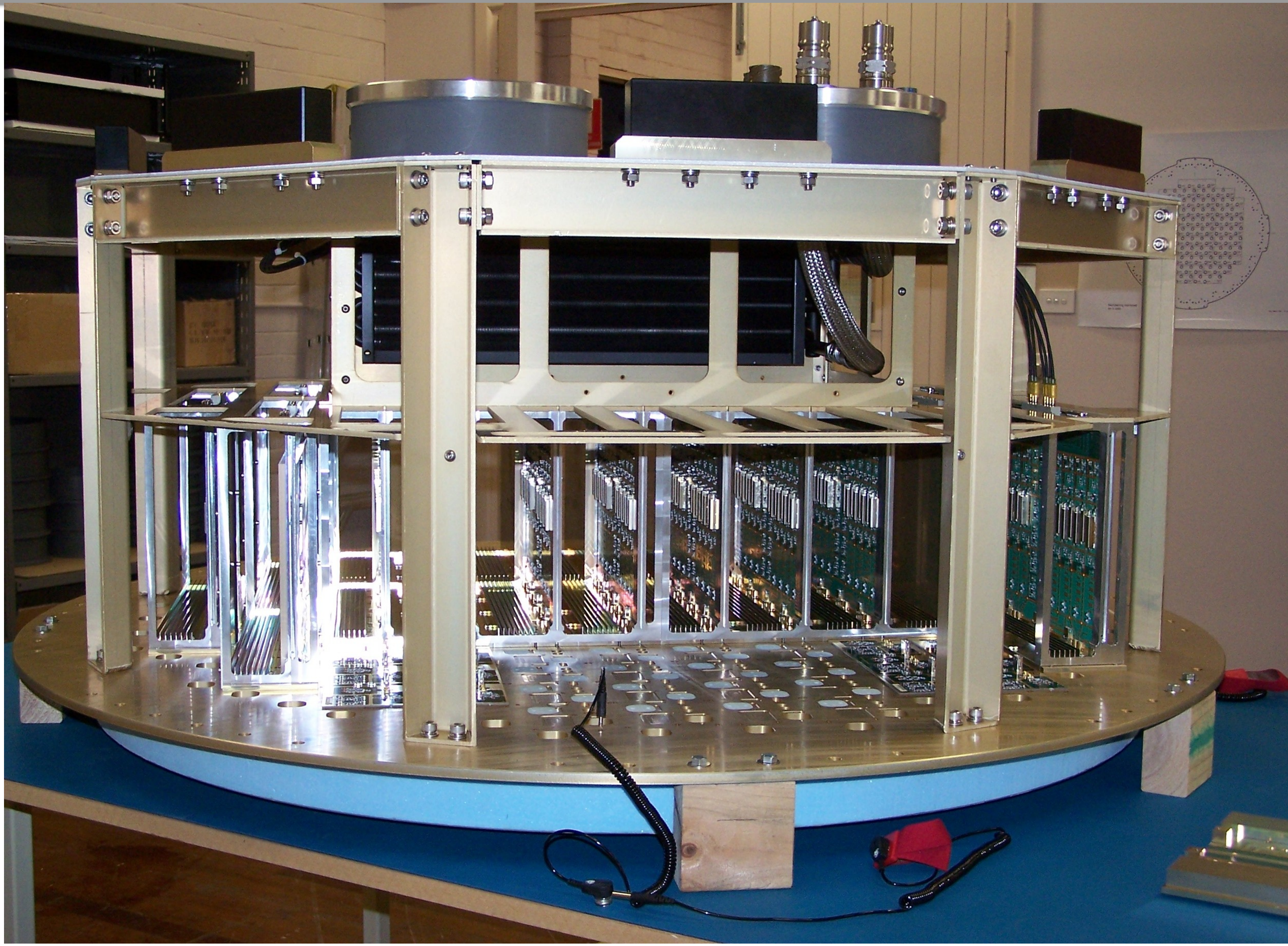








Phased Array Receiver – a “camera” for radio astronomy



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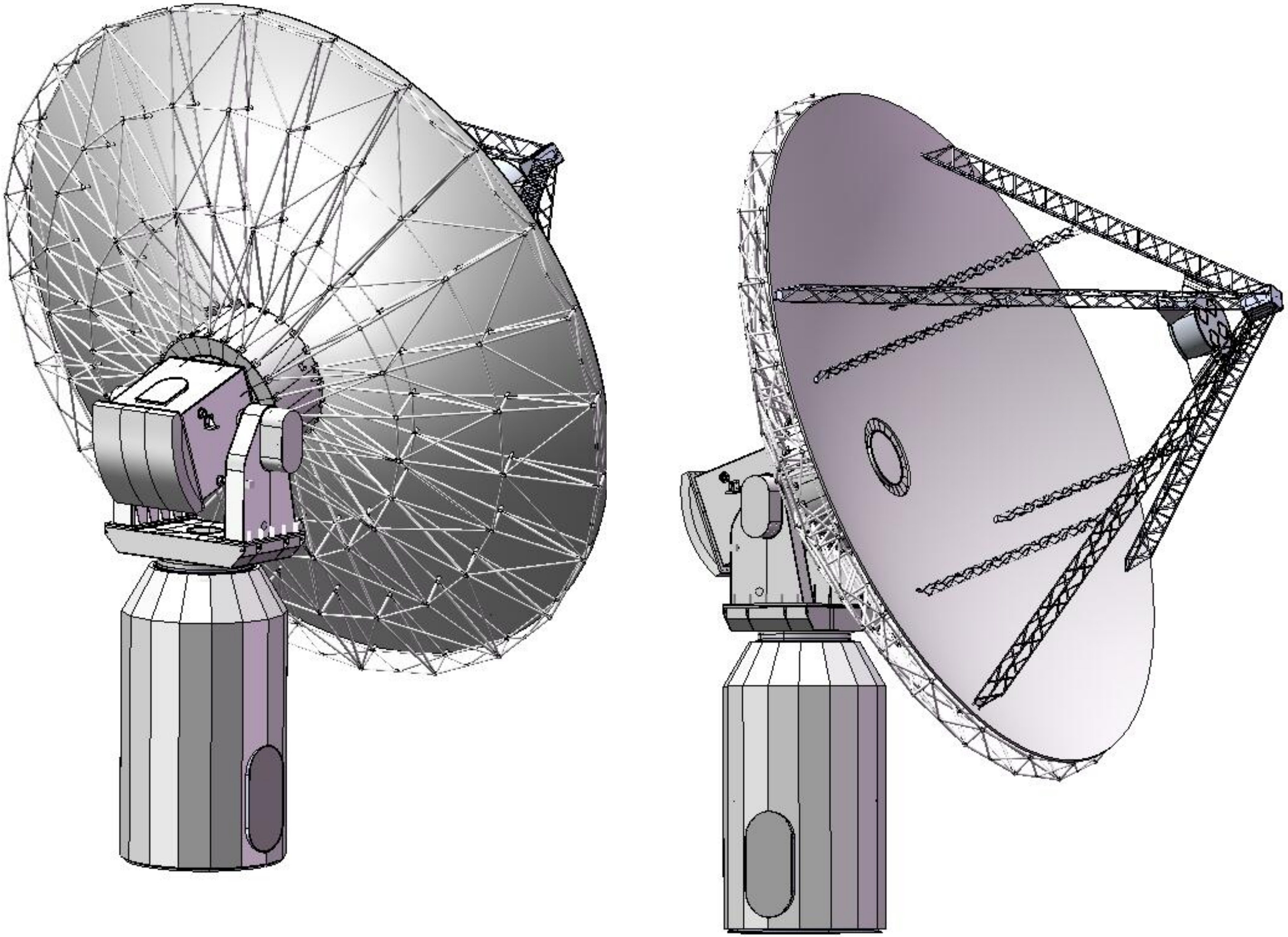
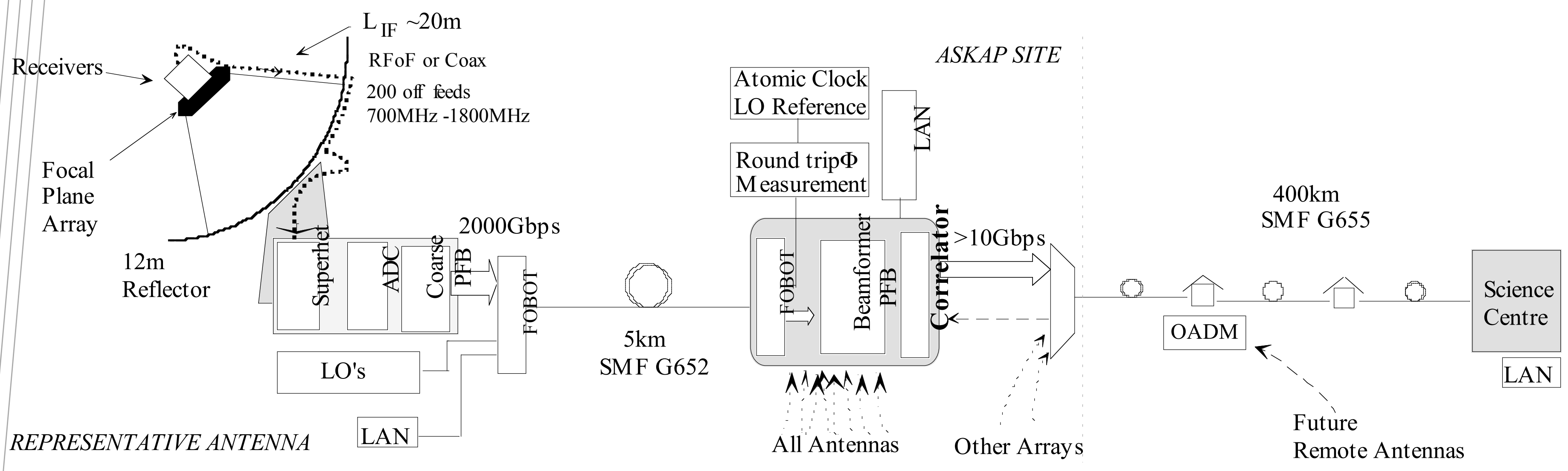
ASKAP Antenna



System Architecture



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RF environment

Sydney

Pop. 4 million

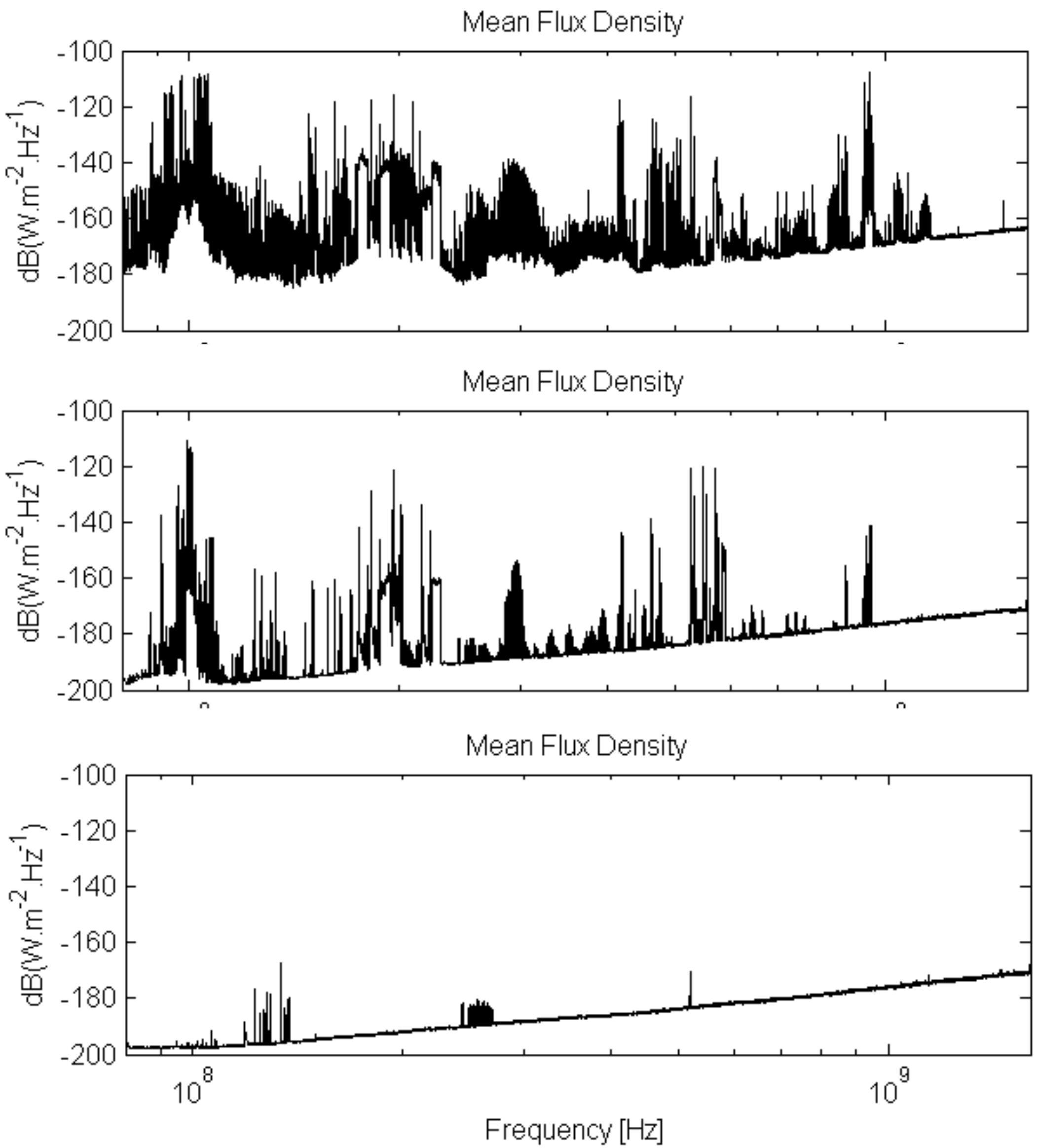
Narrabri (ATCA)

Pop. 6,000

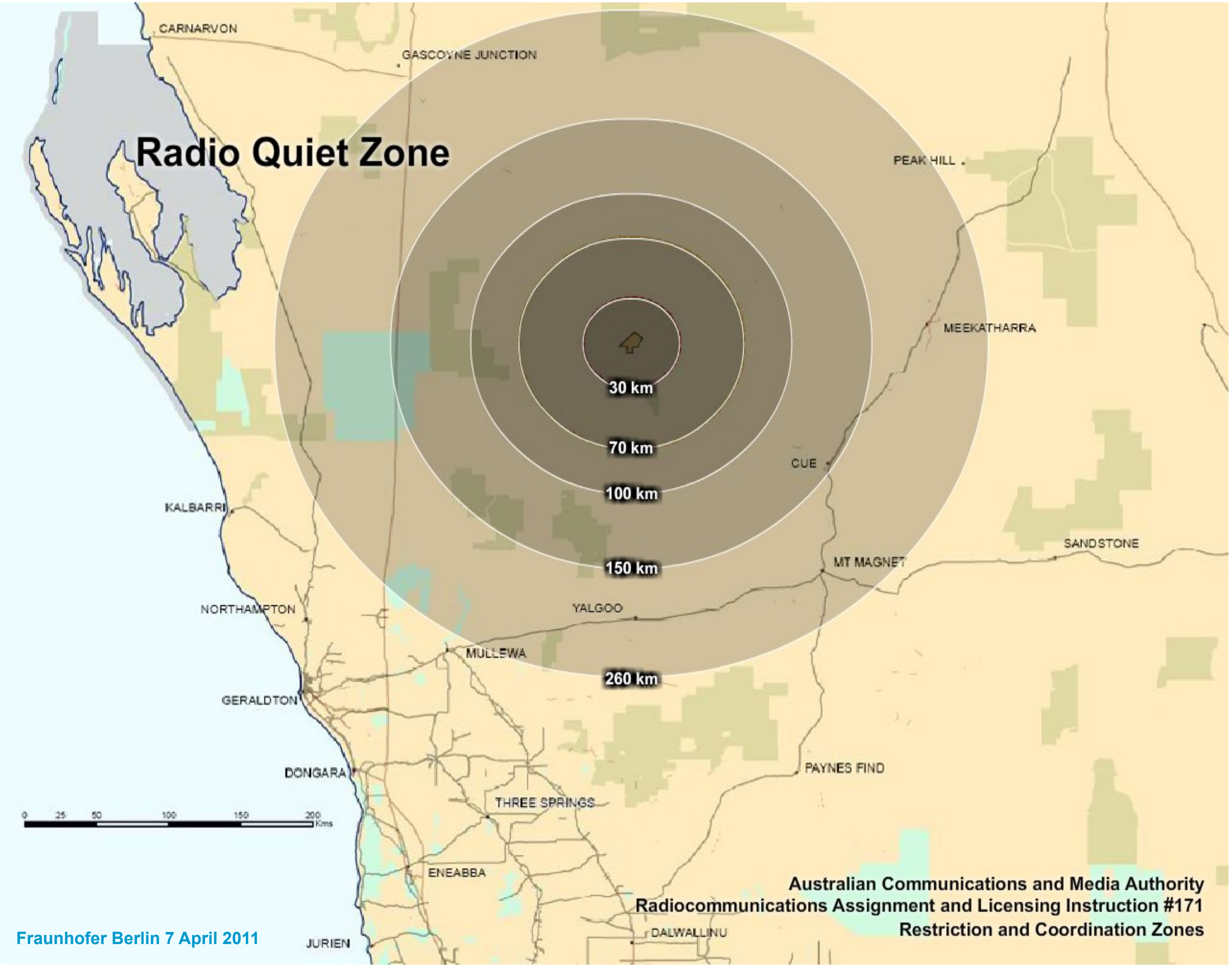
Murchison Shire

(Equal area MA)

Pop. 100 (shrinking)



MRO Protection



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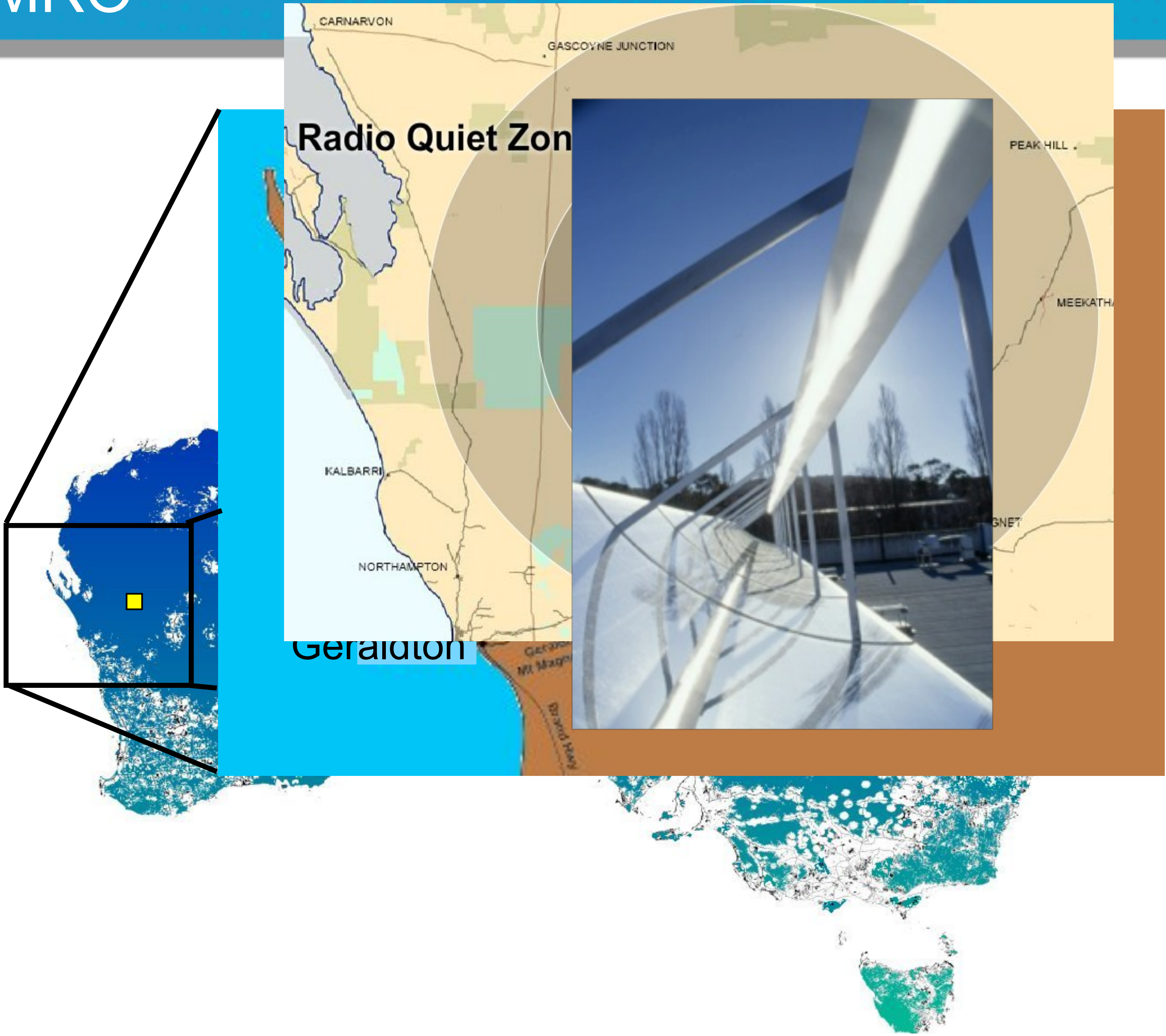
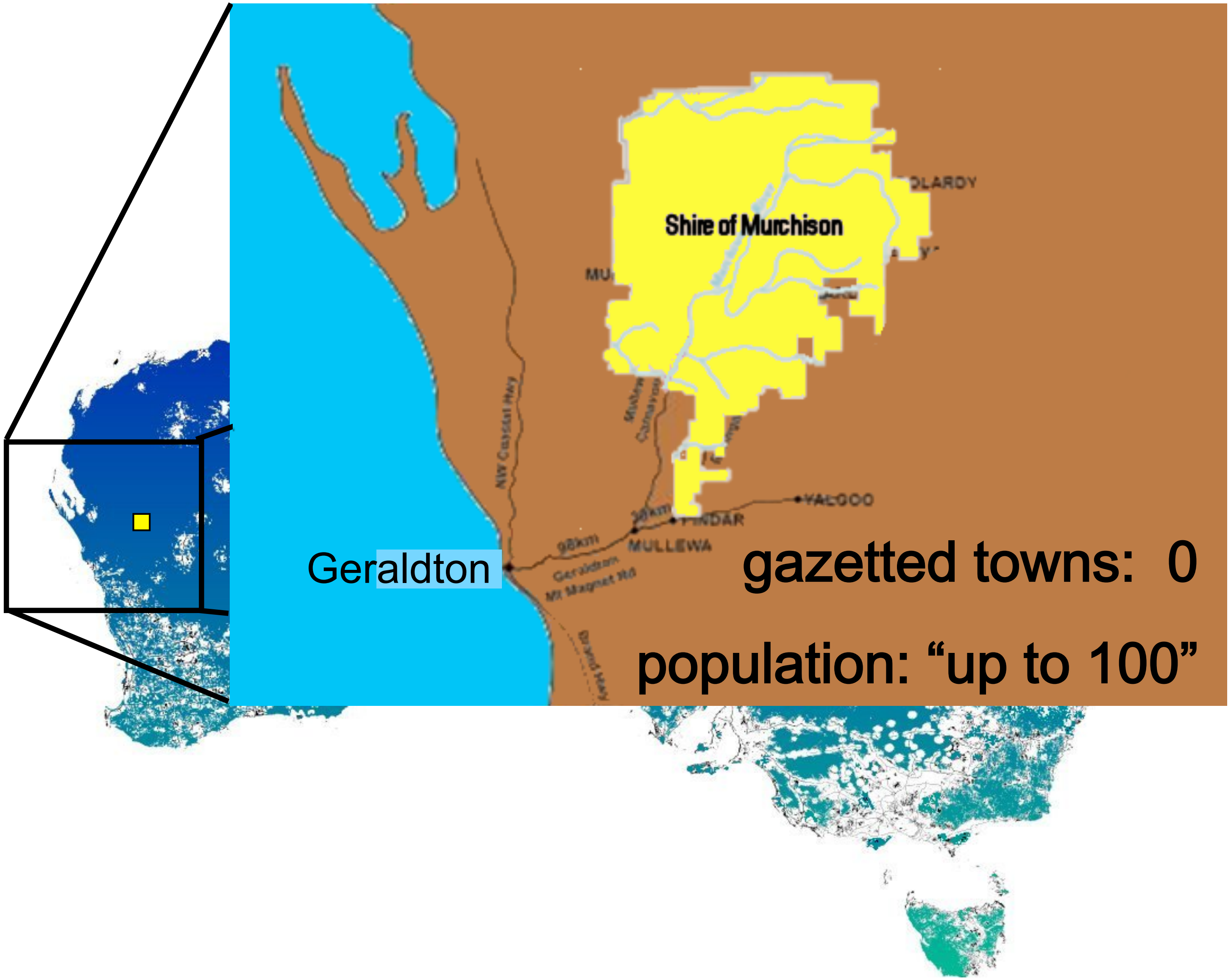
MRO

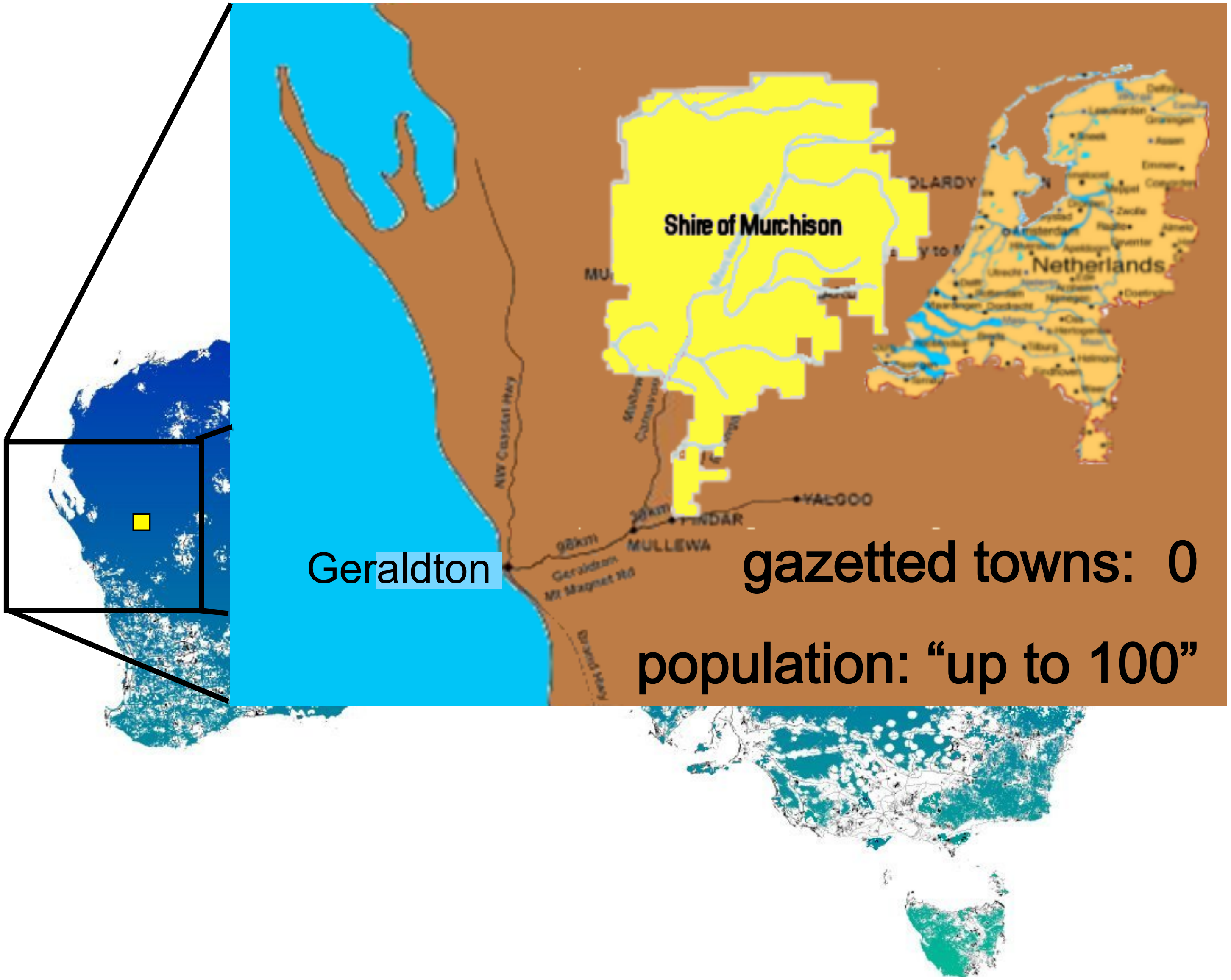


Radio Quiet Zon
CARNARVON
GASCOYNE JUNCTION
PEAK HILL
MEEKATHA
KALBARRI
NORTHAMPTON
Geraldton

MRO


Shire of Murchison
Geraldton
MULLEWA
YALGOO
gazetted towns: 0
population: “up to 100”

MRO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Netherlands
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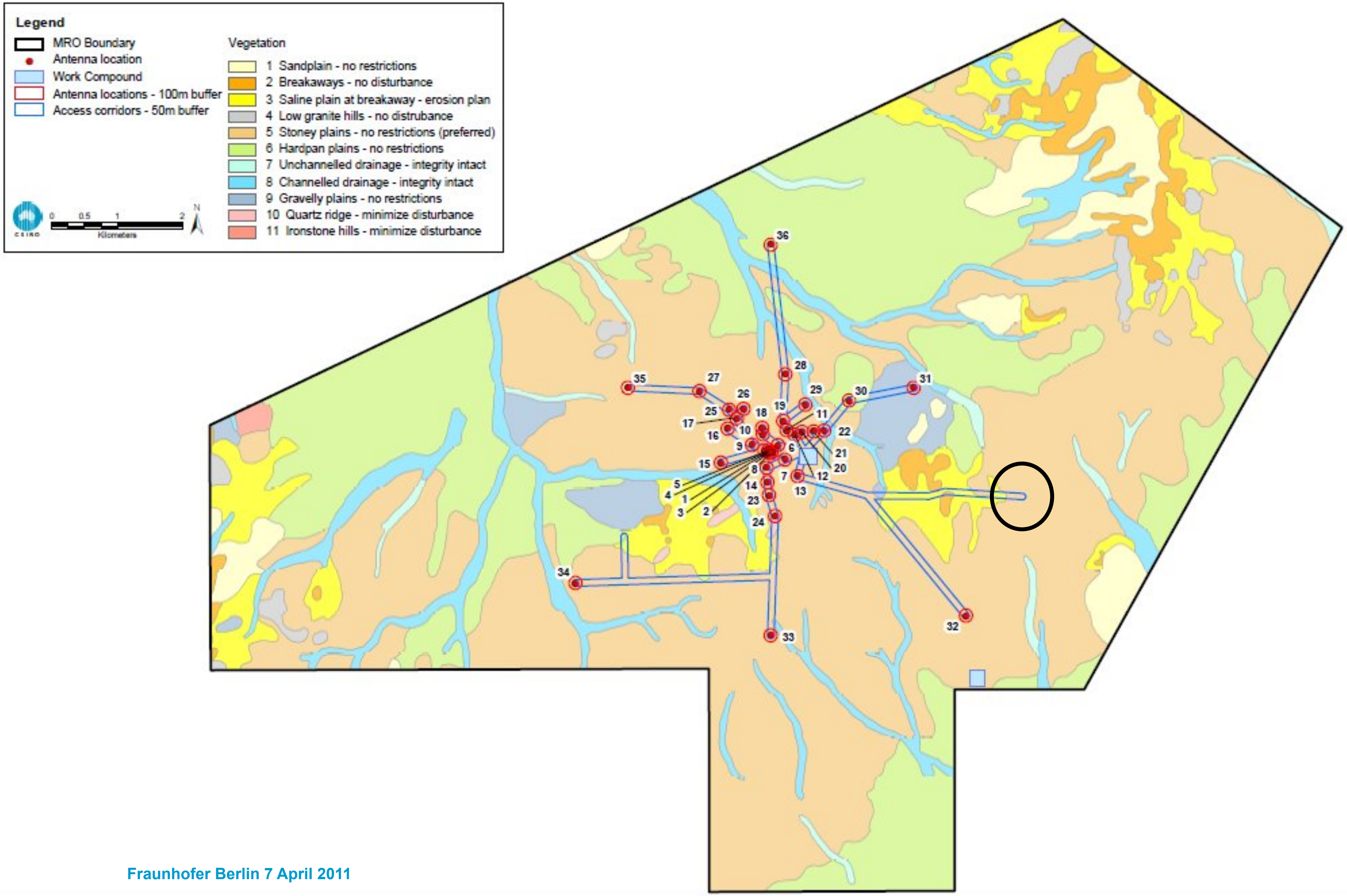
Site Layout



Legend
MRO Boundary
Antenna location
Work Compound
Antenna locations - 100m buffer
Access corridors - 50m buffer
Vegetation
1 Sandplain - no restrictions
2 Breakaways - no disturbance
3 Saline plain at breakaway - erosion plan
4 Low granite hills - no distrubance
5 Stoney plains - no restrictions (preferred)
6 Hardpan plains - no restrictions
7 Unchannelled drainage - integrity intact
8 Channelled drainage - integrity intact
9 Gravelly plains - no restrictions
10 Quartz ridge - minimize disturbance
11 Ironstone hills - minimize disturbance
0 0.5 1 2
Kilometers
N

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ASKAP – demand side management I

Two obvious areas:

1. Design – overall design to minimise power consumption. Includes :
    1. Instrumental – low power CPU’s, “clock speed control” on CPU’s
    2. Infrastructure – efficient cooling systems, building thermal design
    3. Location of equipment
2. Operations
    1. Scheduling electrically demanding activities to minimise “peaks” or match them to available power peaks (e.g. sunny afternoons)

ASKAP – demand side management II

For a number of reasons:

- maintenance support and staff
- RFI minimisation
- local power generation of power

it is marginally better to move as much of the "telescope" away from the MRO site as practical.

A high bandwidth fibre connection to Geraldton and ongoing to Perth and the world means supercomputing, operations etc can be based elsewhere.

Other "demand side management" includes operations planning, such as:

- staggered antenna slews to minimise power peak requirement
- control of water chillers to

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ASKAP – demand side management example Computing

Data rate is enormous:

- wideband spectral imager/survey instrument –
  - 188 individual raw beams (~ 30 "processed")
  - 16,000 spectral channels, 36 antennas

→ 72 Tbits raw data rate into the Beamformers

- Approximately 40 Gb/sec data post-correlation to the imaging computer (Perth, 900 kilometres away)

Result:

A Petaflop scale machine in Perth required by mid 2013

→ Power requirements: 10 + MW …. Plus cooling

Initially a 100 Tflop computer needed for sub-section of array at Murdoch – installed Feb 2011, 87th most powerful supercomputer in the world

$80 million granted to iVEC by Federal Government in 2009 to create the Pawsey High Performance Computing Centre for SKA Science (Perth)

ASKAP and MRO cooling

Challenging !

Cooling Load: provide a continuous 9 kW_th chilling of water to 13 – 15 C.

- for a traditional "air chiller" this is a challenge in summer, due to 45+ deg C ambient (low CoP at these temperatures - 2 ?)

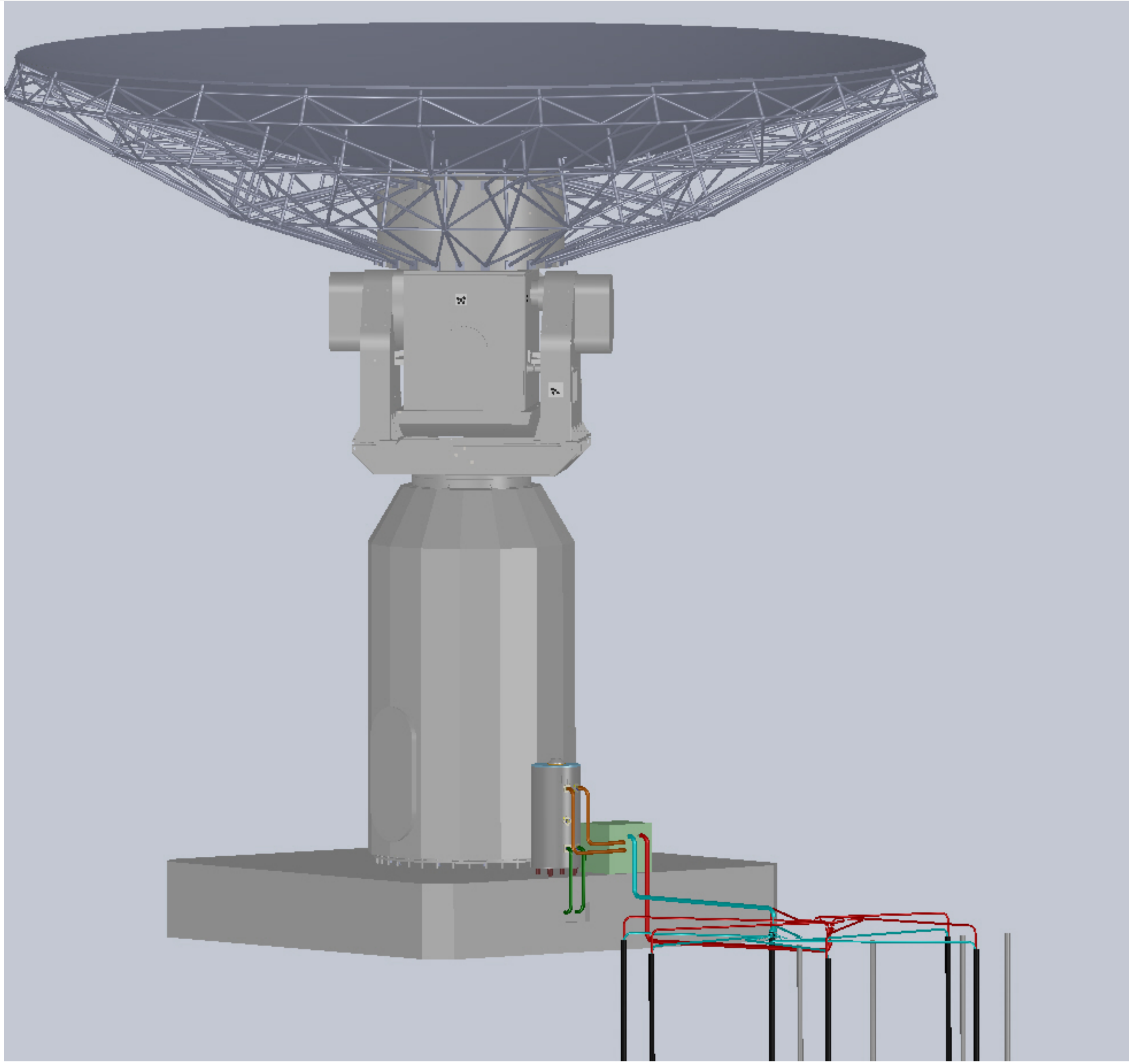
- **so dump heat to a cooler waste body (earth at 26 deg)**

Ground Loops: 6 x 30-m deep earth loops + 4 x 30-m deep data bores.

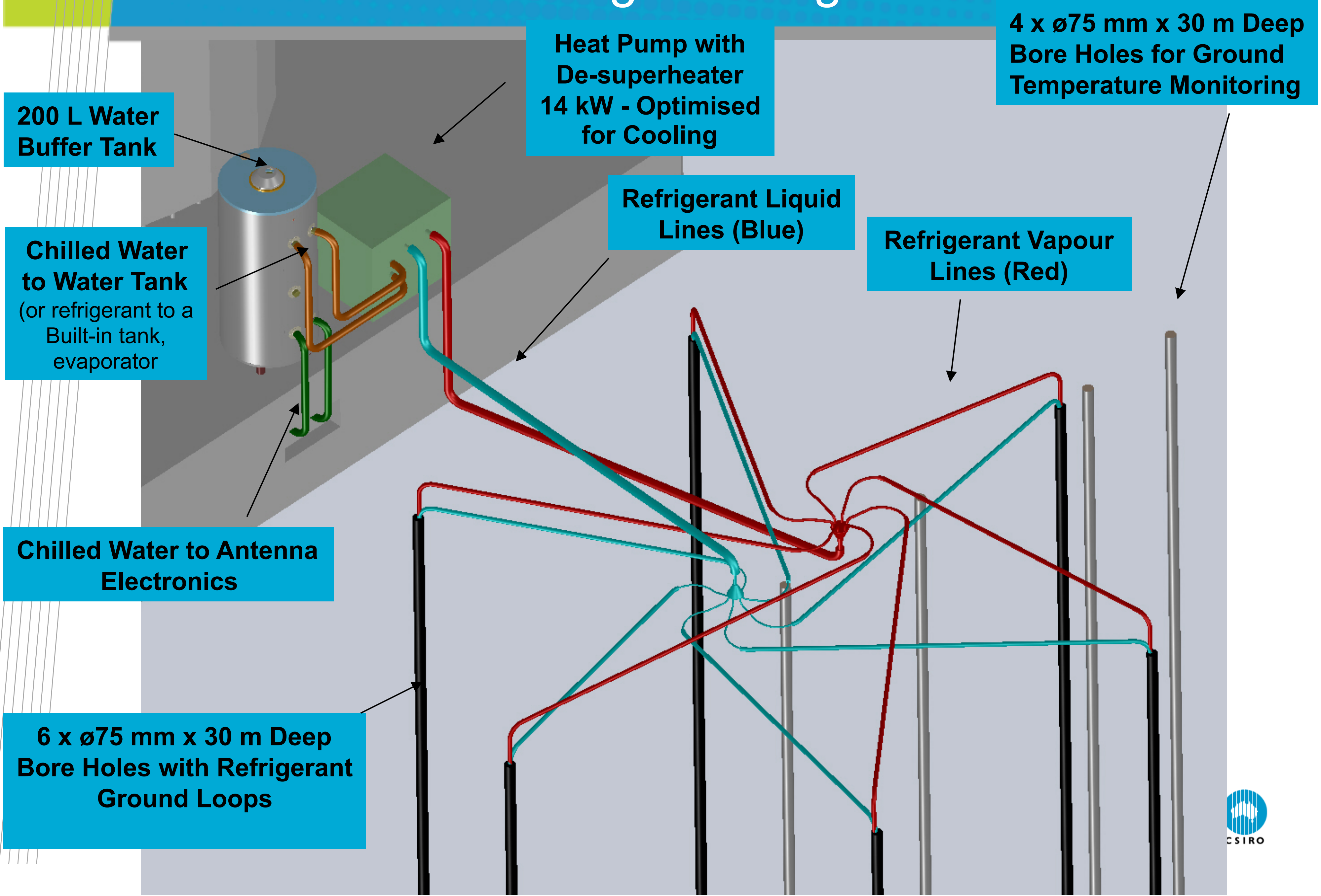
Expected COP: of over 3 overall in MRO conditions.

Geoexchange system for central building currently in design.

ASKAP Geoexchange cooling



ASKAP Geoexchange cooling



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MRO - Power Generation - constraints

Site characteristics:

- 250 km from nearest “grid” power (would need upgrading)
- 190 km from gas line
- hot – up to 48 C daytime temperatures for many months
- RFI emissions MUST be controlled to maintain pristine RFI quiet nature of the MRO

The last adds a significant new technical challenge.

- **Options:**
  - Install grid connection
  - Gas line to local turbine plant
  - Build own power plant
  - Collaborate with an experienced remote power provider.

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MRO - Power Generation

CSIRO is committed to maximising the use of renewable power sources

MRO Requirements:

- approximately 1MW, 24 hours, 365 days (1.4 MW peak)

- “medium” reliability (compared to DoD, communications, medical etc)

- major load is the electronics and processing (50 - 60 %)

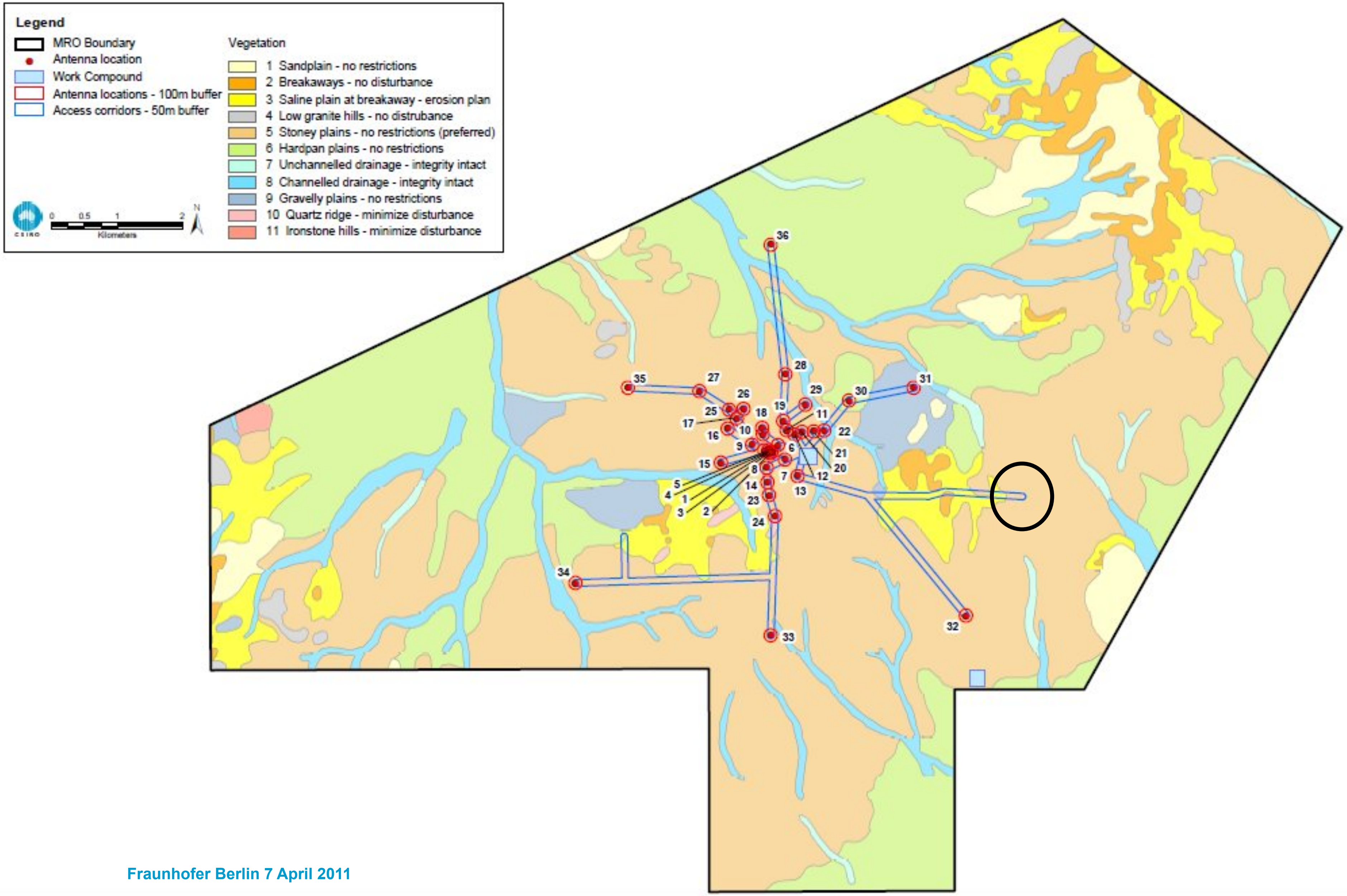
- load variations dominantly due to diurnal cooling load

- RFI emission control to maintain pristine radio quiet site standards

“Demand side” management during design and operations planning critical

Working with Horizon Power to develop the design and supply model

Site Layout



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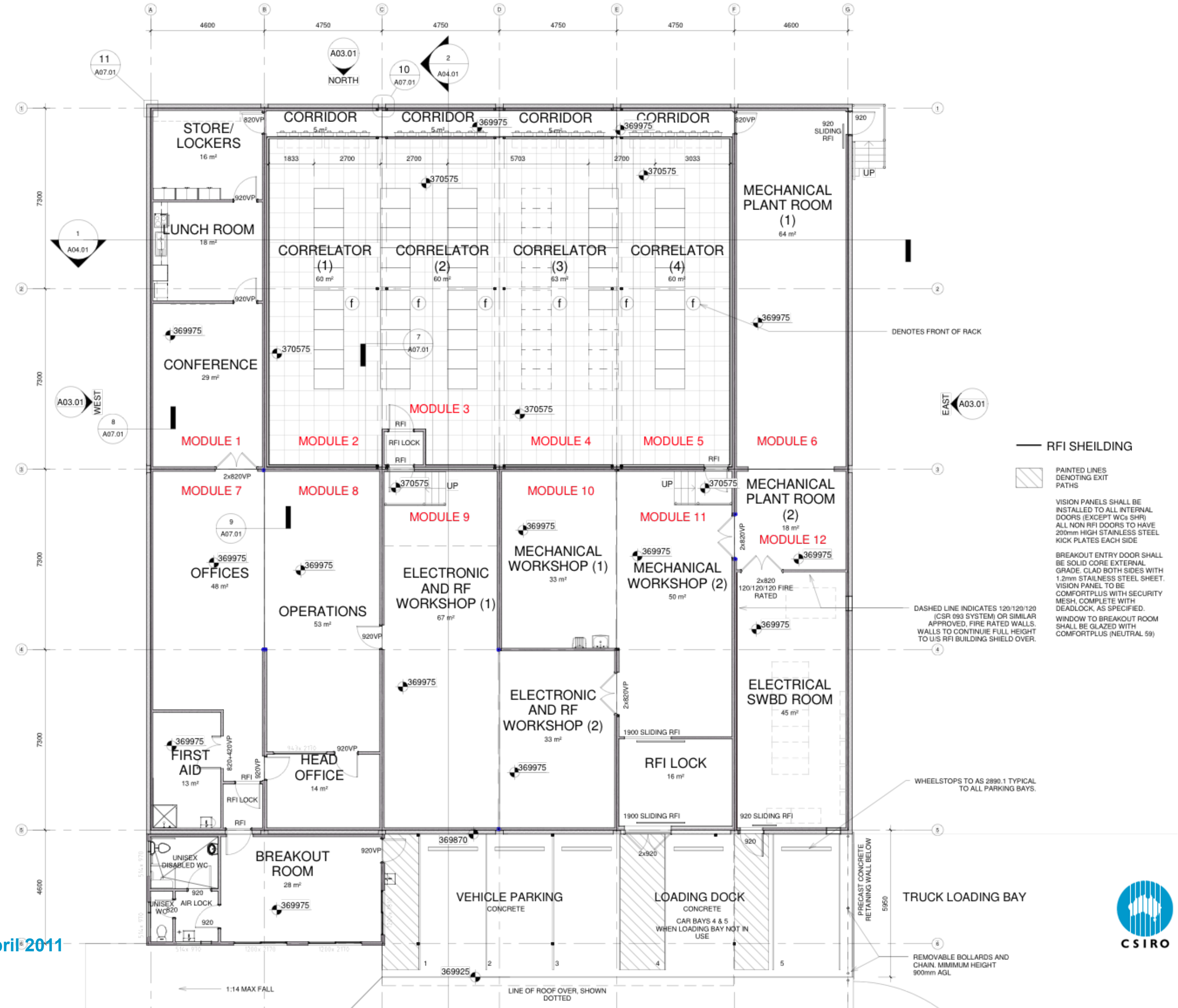
MRO – Control Building



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MRO - Power Generation (Horizon Power)

Current model :

- 4 diesels (440 kVA each), 10% load tolerant
- initial 500 kW of photovoltaic cells
- “short term” power storage using either 1MW flywheel or “supercaps”
- flexibility to add more renewable/storage in the future

Future:

Pursuing further options to significantly increase the penetration of renewable sources from 2013+ onwards (EIF Phase 2). Funding of up to AU$11.0 million across a range of renewable areas.

Options include:

- more photovoltaic arrays
- solar thermal generation
- “long term” storage – electrical, thermal, chemical ?
- other ?

Could be generation/storage in a more “leading edge” technology than currently planned.

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SKA

SKA

- 1.5 + billion Euro project
- SKA Project Development Office in Manchester, UK
  - Moving to Jodrell Bank 1 Jan 2012
- Agreement signed on 1 April for the “Founding Board: - 9 partner countries:
  - Australia, China, France, Germany, Italy, the Netherlands, New Zealand, South Africa and the United Kingdom
- Scope :
  - thousands of “receptors” over 3,000 – 5,500 km distances
  - 50 times as senstive as any telescope
  - 10,000 times the survey speed
- Timescale:
  - Pre-construction funding from 2012 – 2016 around 70m+ Euros for final design
  - Site decision (Southern Africa or Australia + New Zealand) April 2012
  - Phase 1 construction starts 2016
- Power
  - Large and distributed over thousands of kilometres

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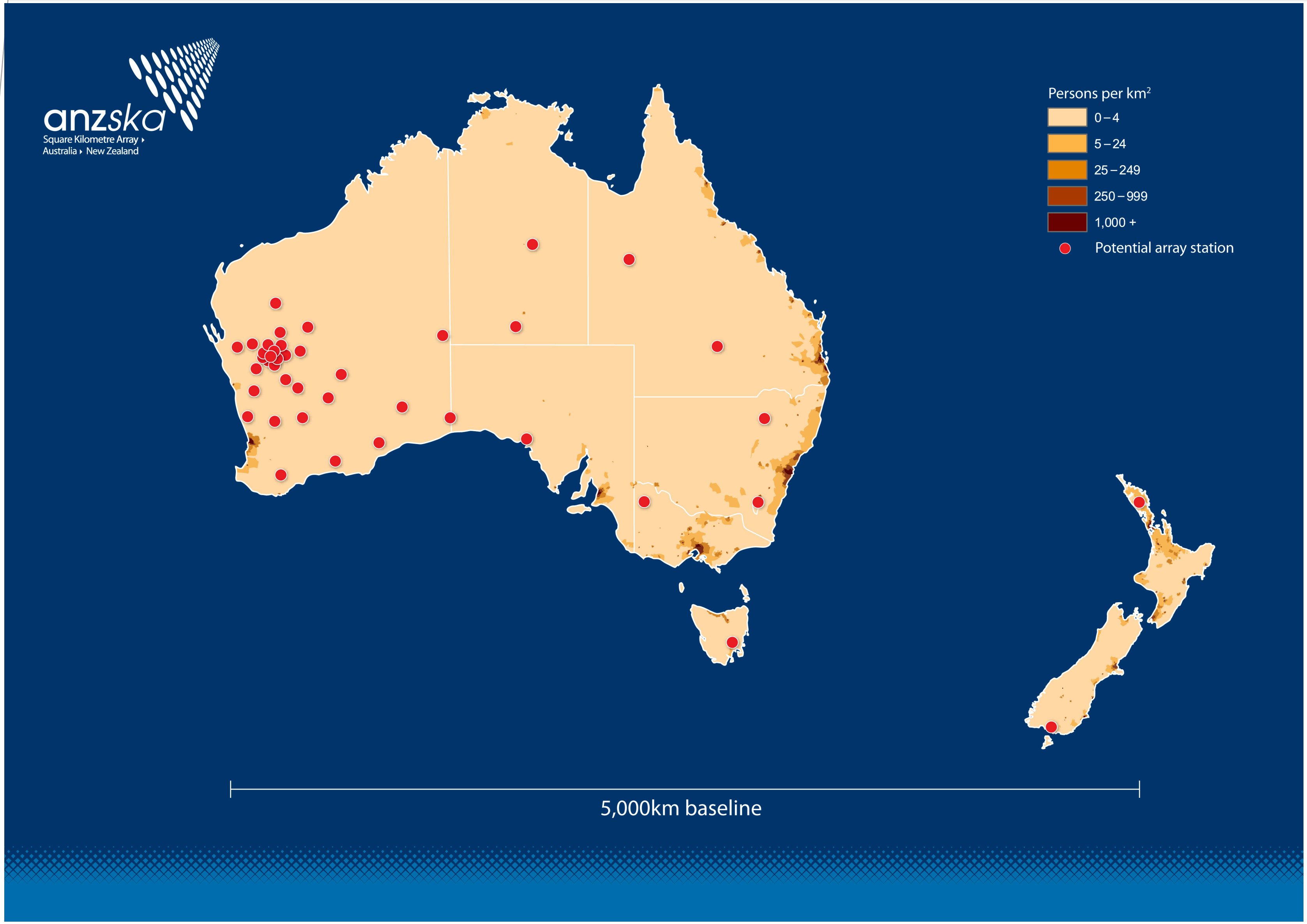
SKA – possible configuration



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MRO - Timelines

Start Date	Event	Outcome
Feb 2010 – Apr 2011	MRO - Ger fibre link procurement and installation	Fibre operational
May - Dec 2010	MRO Infrastructure construction tender	Signed contract
Jan 2011 - Oct 2011	MRO infrastructure construction	Site complete
June 2011 - Feb 2012	MSF Construction	Construction complete
2009 – Sept 2011	Develop RFI-compliant power station design	RFI compliant power station design
March 2012 – Dec 2012	Construct power station	Phase 1 Hybrid power station
Oct 2011 – Dec 2013	Design, develop and install EIF phase 2 additional renewable components	Increased renewable penetration

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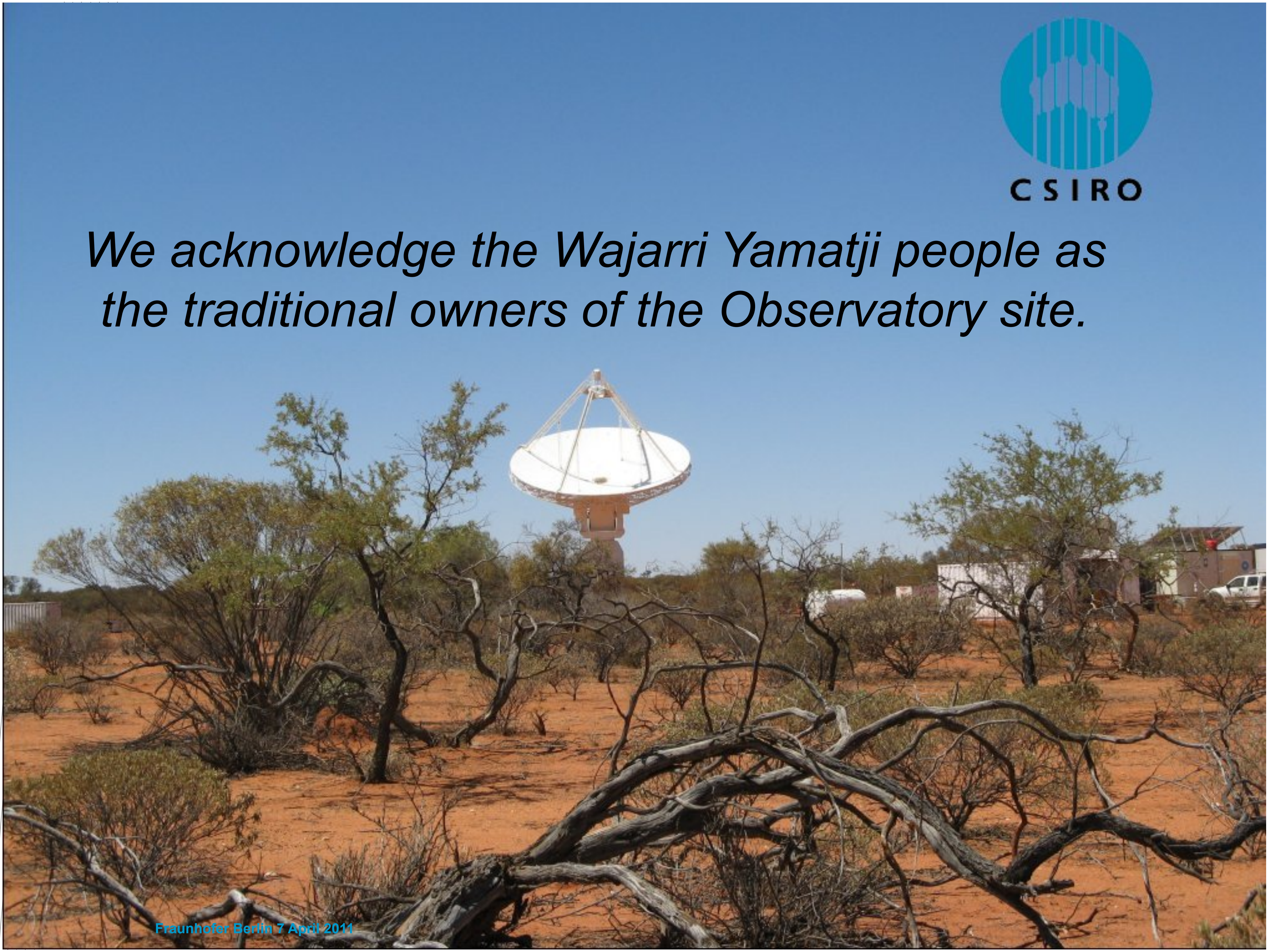
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We acknowledge the Wajarri Yamatji people as the traditional owners of the Observatory site.
Fraunhofer Berlin 7 April 2011

More information: www.atnf.csiro.au/projects/askap

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Thank you

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