SKA1 - Infrastructure Element Australia

SKA Engineering meeting
13 June 2017

Antony Schinckel (Consortium Lead)
Shandip Abeywickrema (Project Engineer)
Rebecca Wheadon (Project Manager)

Outline

- HSE
- Introduction
- Who is INAU
- Key areas of design:
  - Location, roads and access
  - Flood studies and ground preparation
  - Power distribution and solar PV
  - Buildings
  - Site monitoring, communications
- Hosting items:
  - Existing power station
  - Site status and ILUA
- Some deliverables
- Costing
- Issues and opportunities
- Summary

HSE

- Health, Safety and Environment
  - Underlying principles in all aspects of design :
    - You won't get safe designs as a by-product of the normal design process
      - Focus is wrong
      - HSE needs to be an engineering requirement
    - You need the design process to naturally include HSE
      - HSE identification in process of designing
        - Examine all aspects of design at each stage
        - Start – and finish – key design meetings with the question:
  - Don't forget HSE of your staff in design process !
    - Will prompt them in their design work
    - Aurecon's "Take 5"

HSE

Personal real time hazard check

STOP Identify your task hazards by completing this Take 5

THINK Is your task high risk but with the hazards controlled in your SWMS?

NO — YES

IDENTIFY Has your task or work environment changed but with the hazards identified and controlled in your SWMS?

NO — YES

PLAN Have you implemented supplementary hazard controls (if required) in your Take 5?

NO — YES

PROCEED Safely

STOP Complete or review your SWMS

Hierarchy of control

- **Elimination** — Removing the hazard altogether
- **Substitution** — Substituting the hazard for something less hazardous
- **Engineering control** — Isolation or control of hazard by way of engineering solutions
- **Administrative control** — Procedures, training, signage
- **PPE** — Providing personal protective equipment

Hard controls (most effective defence)

Soft controls (least effective defence)

HSE

- Health, Safety and Environment

Is there an HSE aspect to this widget in any area :

- **Manufacture:**
  - **material choice,**
  - **energy impacts (manufacturing, use),**
  - **ergonomics of staff,**
  - **environmental impacts,**
  - **disposal**
- **Construction:**
  - **installation process**
- **Maintenance and Operations:**
  - **power use,**
  - **access,**
  - **ergonomics**

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Introduction

- 2017 :
  - Slow …..... But busy !
  - Requirements evolution
    - Level 1 Rev 10
  - 2 years since PDR + Lvl 1 Rev 10 release:
    - Are we on the right path ?
    - Are design assumptions still appropriate 2 years later with evolutions to design (requirements), budget constraints, etc
    - ICD development
  - So – we undertook workshops to review from scratch
  - Update Studies
    - Powerline tradeoff
    - Use of small solar power stations for remote Low stations
  - “Honing” of cost estimates

Introduction

Workshops on:

- Building
  - Operations requirements ?
    - What spaces ?
    - How do people flow ?
    - How does equipment move ?
    - What are the HSE issues ?
    - How is it different to model used (ASKAP, other telescopes – MeetKAT, ALMA, MK obs, VLA, etc)
  - RFI control
    - Process to clarify actual requirements
    - Trade-off between different requirements – but still meeting RFI standards
- Power
  - Distribution models
  - Very complex requirements – very low resistive load with very long highly inductive cables.

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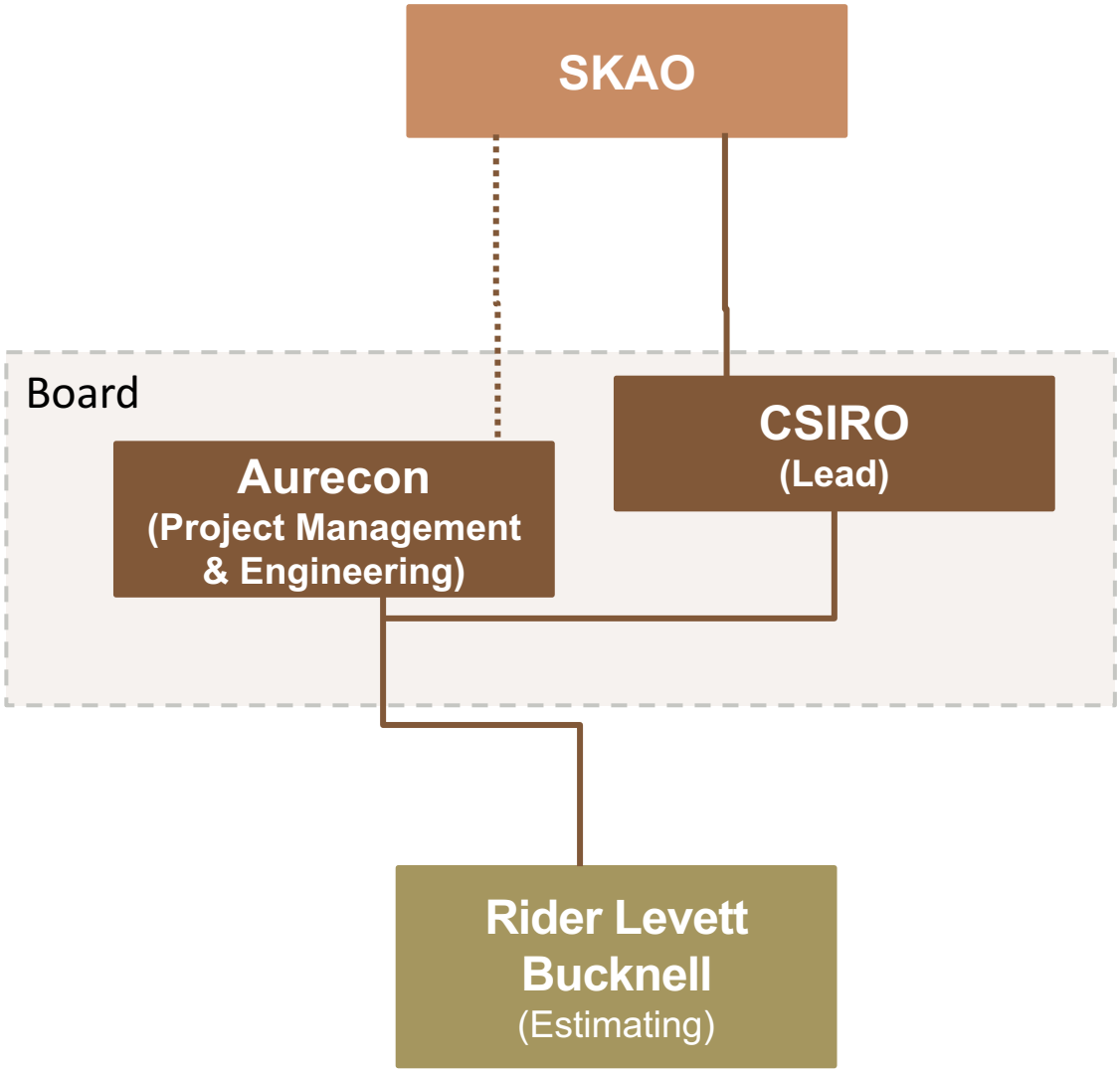
Consortium members



Resources

Aurecon

Name	Role
Rebecca Wheadon	Project Manager
Shandip Abeywickrema	Project Engineer
James Massoud	Lead Subsystem Engineer - Power
Matt Burley	Lead Subsystem Engineer - - Water & Sanitation, Access
Mark Davie	Lead Subsystem Engineer - Buildings
Kjeld Madsen	System Engineer
Angus Leitch	Verification Team Leader
Paul Burrows	Risk Manager
Khawar Durrani	Project Controls
Wai Chan	Health & Safety Manager

CSIRO

Name	Role
Antony Schinckel	Consortium Lead
Graham Allen	Subsystem Engineer – Power & Vehicles
Carol Wilson	Subsystem Engineer – RFI Lead
Kate Chow	Science Officer
Howard d'Costa	Exec Officer, RFI
Ron Beresford	Subsystem Engineer , Comms, RFI
Raji Chekkala	Configuration Manager
Kerry Ardern	General engineer, HSE

RLB

Name	Role
Mark Bendotti	Cost Estimating Lead
Alistair Aitken	Cost Estimating
Asitha Perera	Cost Estimating

*Not all team members shown

INAU Board: Douglas Bock (CASS)
Steve Negus (Chair, Aurecon)
SKAO, DIIS Observers

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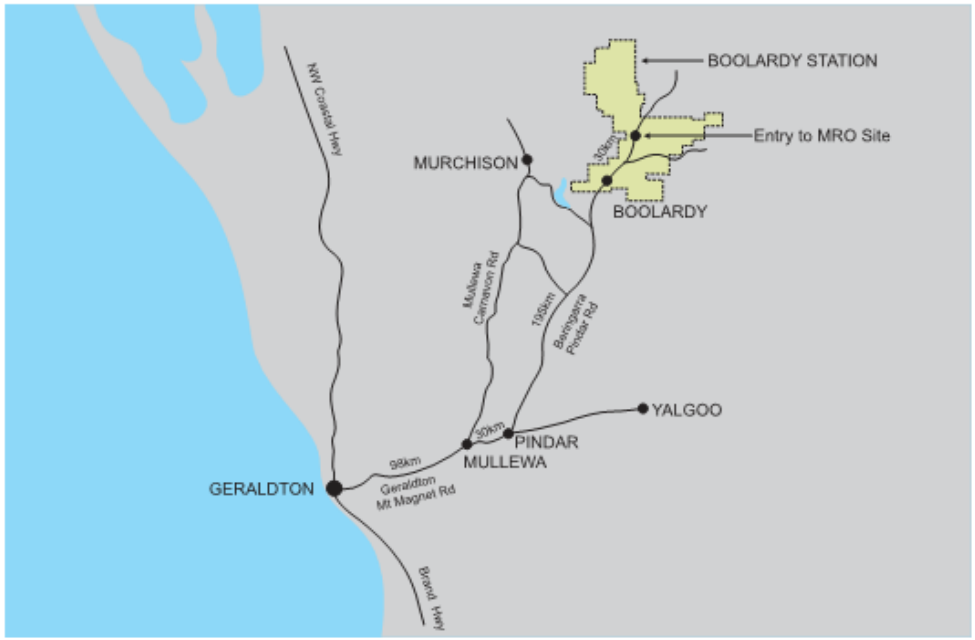
SKA1-LOW Location

- SKA1-LOW located within Boolardy Station, Murchison, WA (3,560 sq km)
- LOW core location selected, approx. 19.5km between LOW core and ASKAP core
- Working to released configuration 0422 (May 2016 release)



Site Accessibility – external road network

WA State Govt. Main Roads on upgrades to the route from Geraldton.

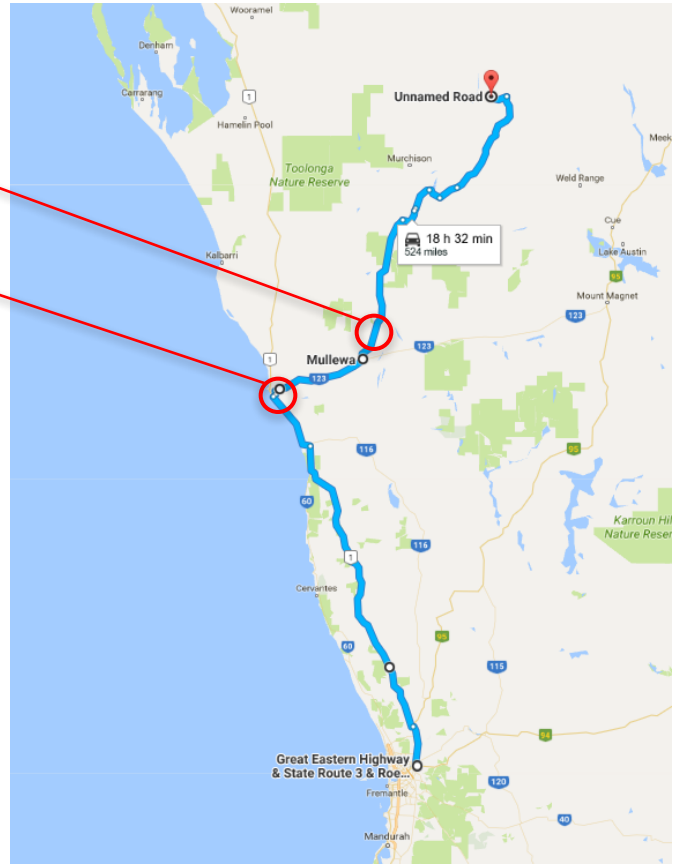
A high-level route assessment from the Perth to site has identified a route that maximises available vehicle height clearances

Western Power height restrictions at;

- North of Mullewa – 5.90m
- Geraldton – 5.89m

Width restrictions :
- a width of less than 5.5m will not require traffic escorts

Ongoing discussions on road upgrades from Mullewa to SKA entrance and maintenance during SKA construction (out of SKA scope – WA)



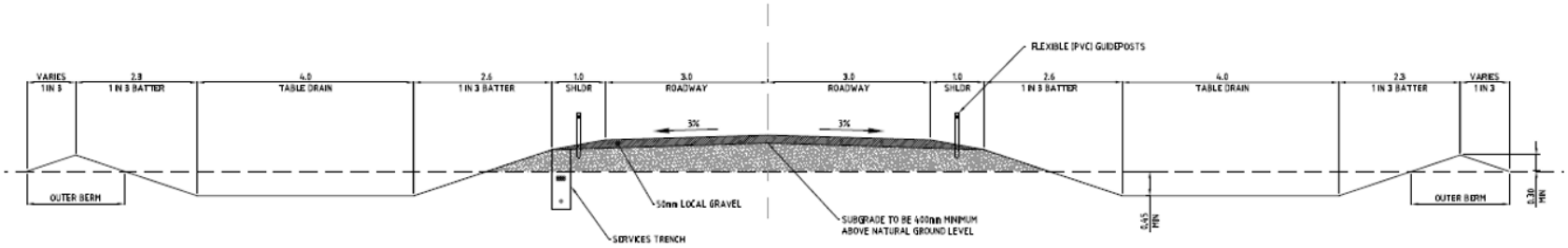
Main internal Site Access Road to CPF

Access to SKA via a new road from the Kalli Road (in-scope)

Final route subject to CPF location decision

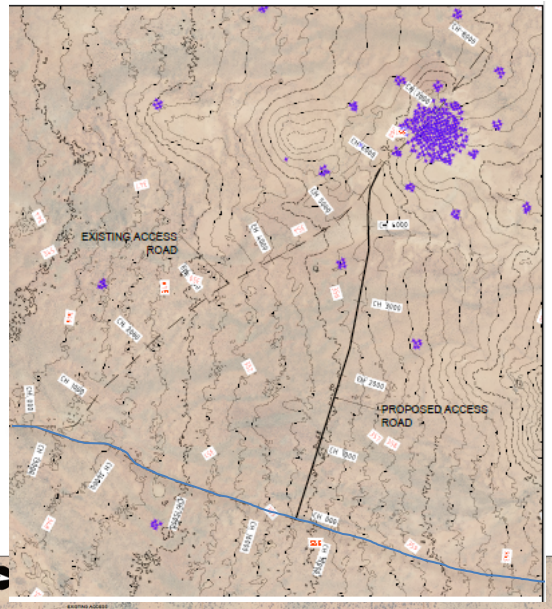
Typical cross-section, following the established design principles used for previous works

Not for spiral arms except in limited locations

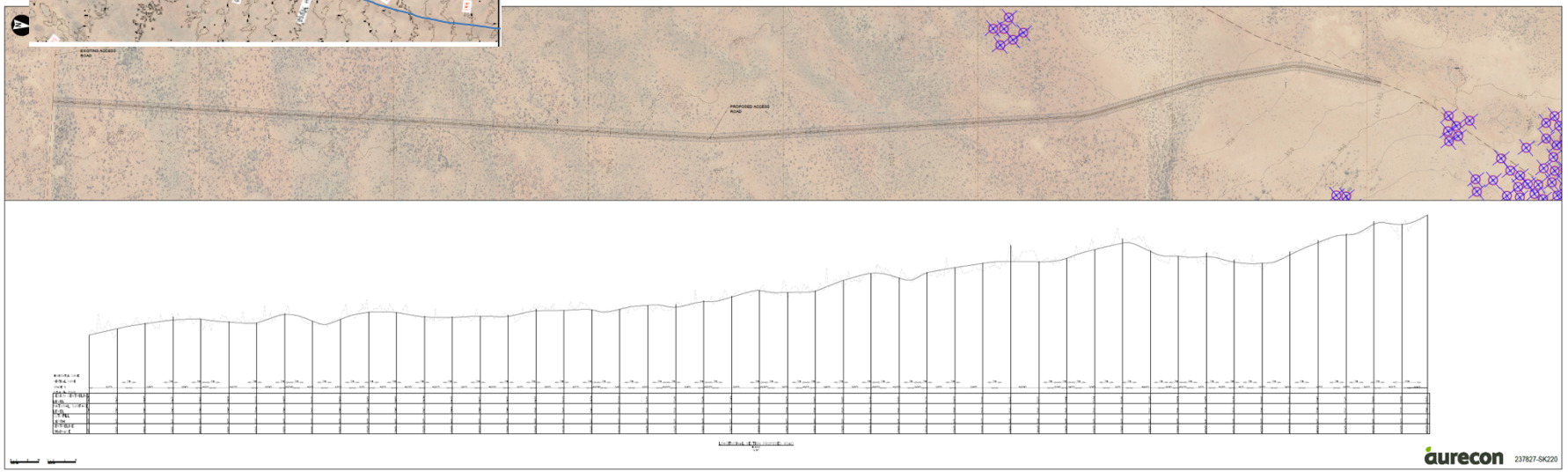


Main Access Road Cross-Section

Site Access Road to CPF



- 4.8km (+/-) access road linking CPF (anticipated locations) and the existing Boolardy-Kalli Road
- All weather 4WD accessible
- Width of 6m and a designed vehicle speed of 40km/hr



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Access - Flood Study

A Flood Investigation Report developed

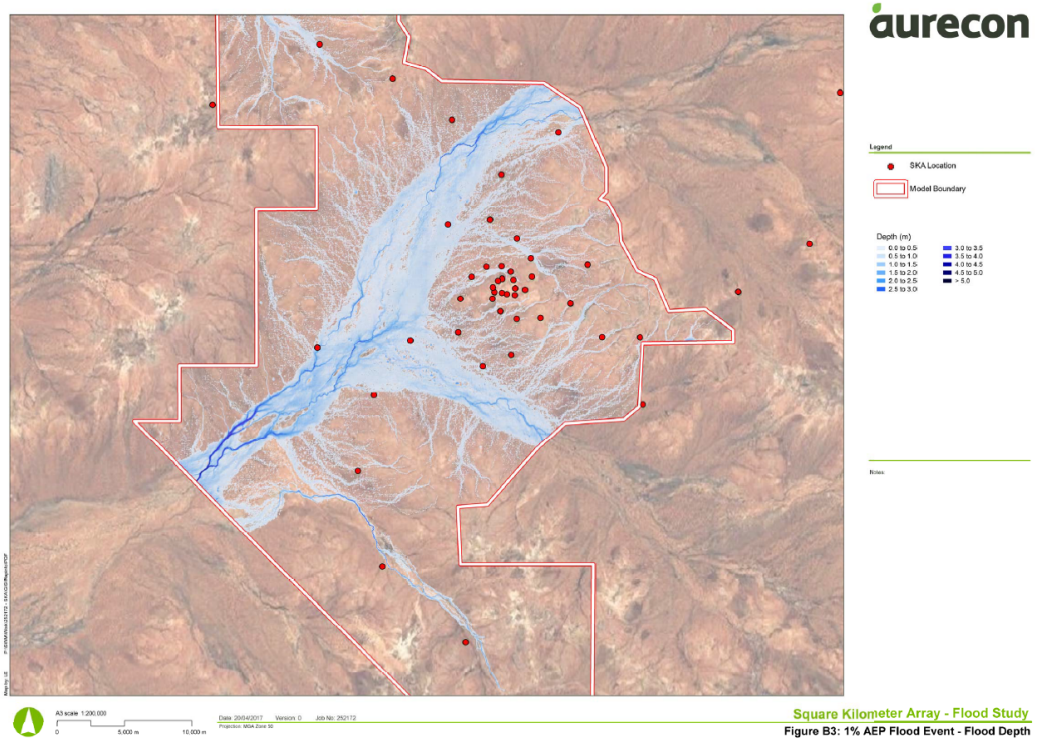
Interactive model

- used to predicted surface water levels at any location across the site

- 9 Station cluster locations are nominally affected by surface water flooding during a 1% Annual Exceedance Event

- Proposed access route to preferred CFP locations unaffected (on site)

- Location of HSE emergency access runway TBD



Station Ground Preparation

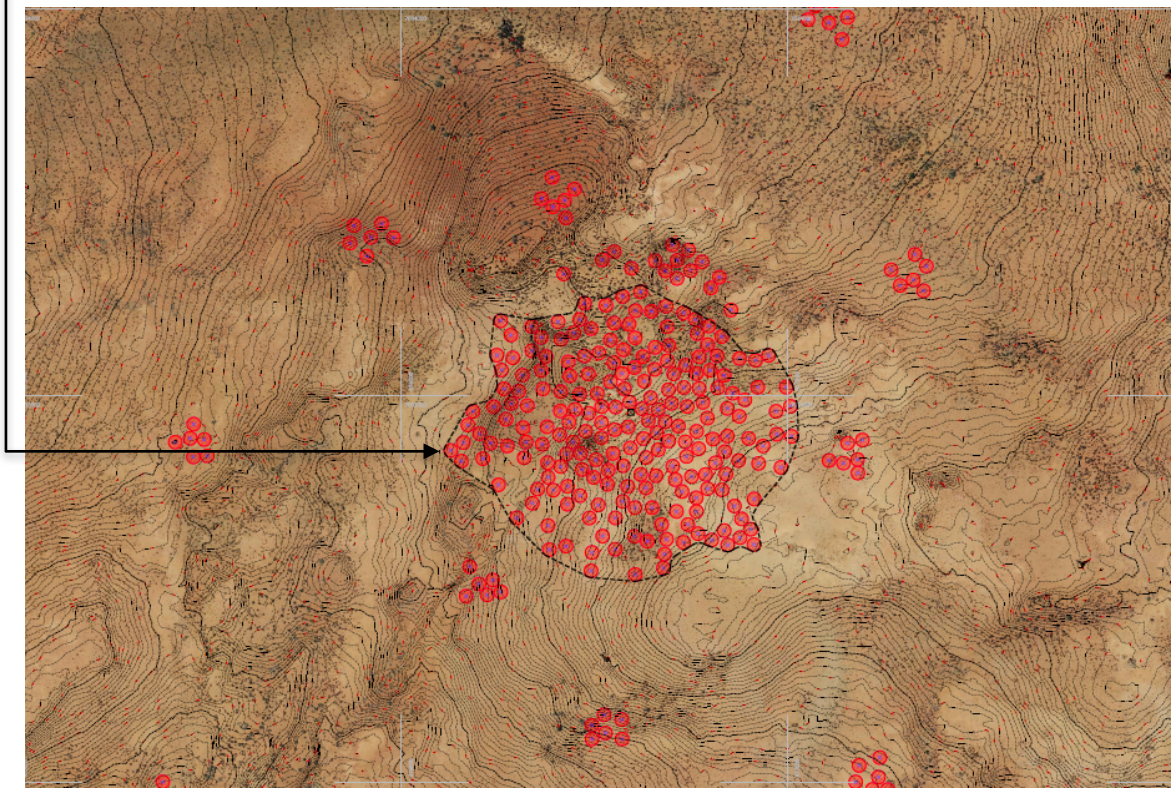
Station ground preparation specifications;

- *Maximum slope across any Station is 2%*
- *The slope of the prepared ground for any Station to be in multiple directions from its centre (i.e. that generally the area can retain its existing topography)*
- *Each Station to be prepared individually with minimal disturbance to the surrounding ground*
- *Zero imported material*

Ground Preparation – 35m Stations

Total central core clearance requirement = 201,058 m**2 (42% fill factor)
Total central core area = 500,000 m**2

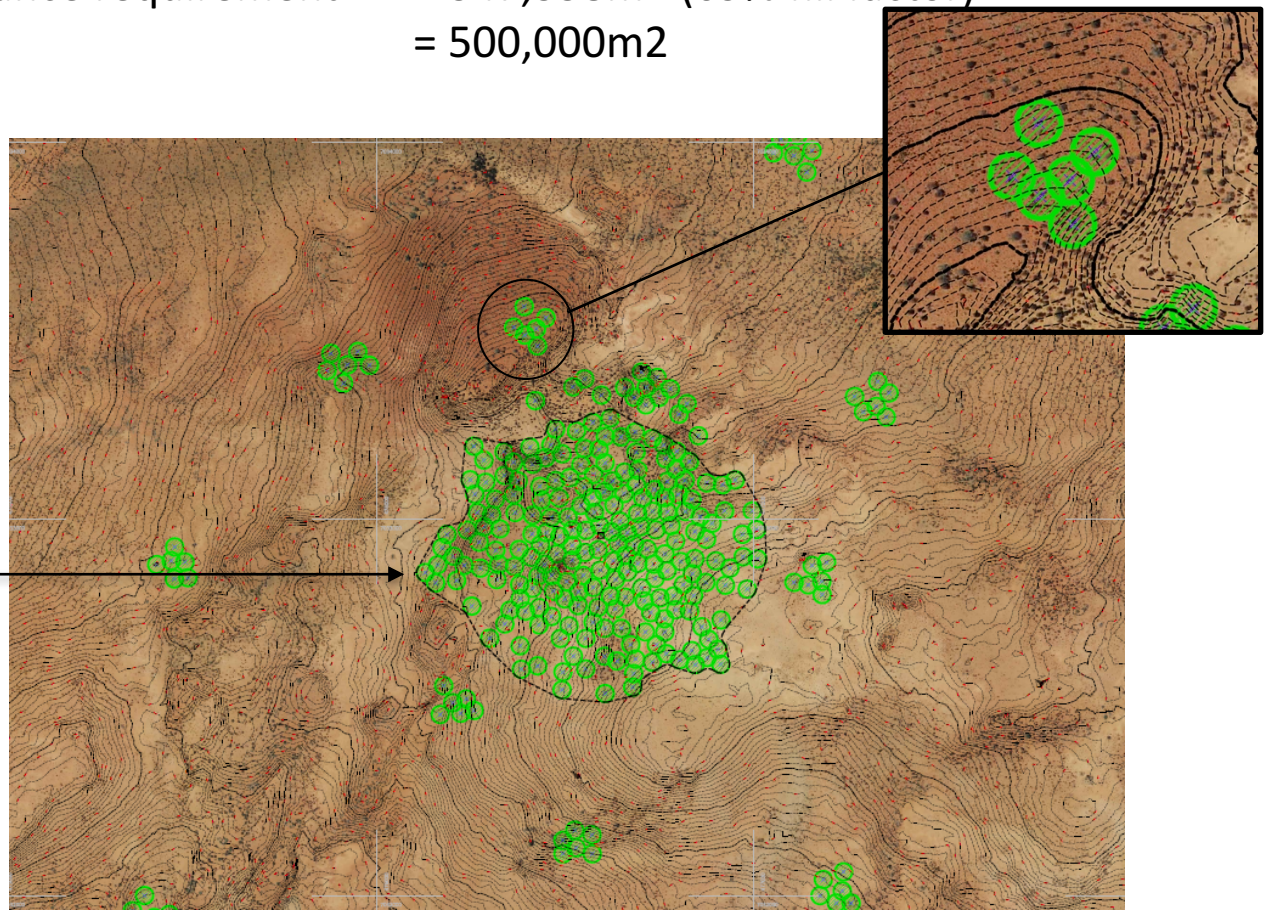
- Existing 35 m dia. stations and array configuration has no overlapping stations
- Access routes within central core complex but workable



Ground Preparation – 45m Stations

Total central core clearance requirement = 347,358m2 (69% fill factor)
Total central core area = 500,000m2

- Overlapping stations result based on current array configuration
- Wholesale clearance to be undertaken for a proportion of the central core (configuration dependant) – erosion control concern
- Further consideration to be given to access routes within central core

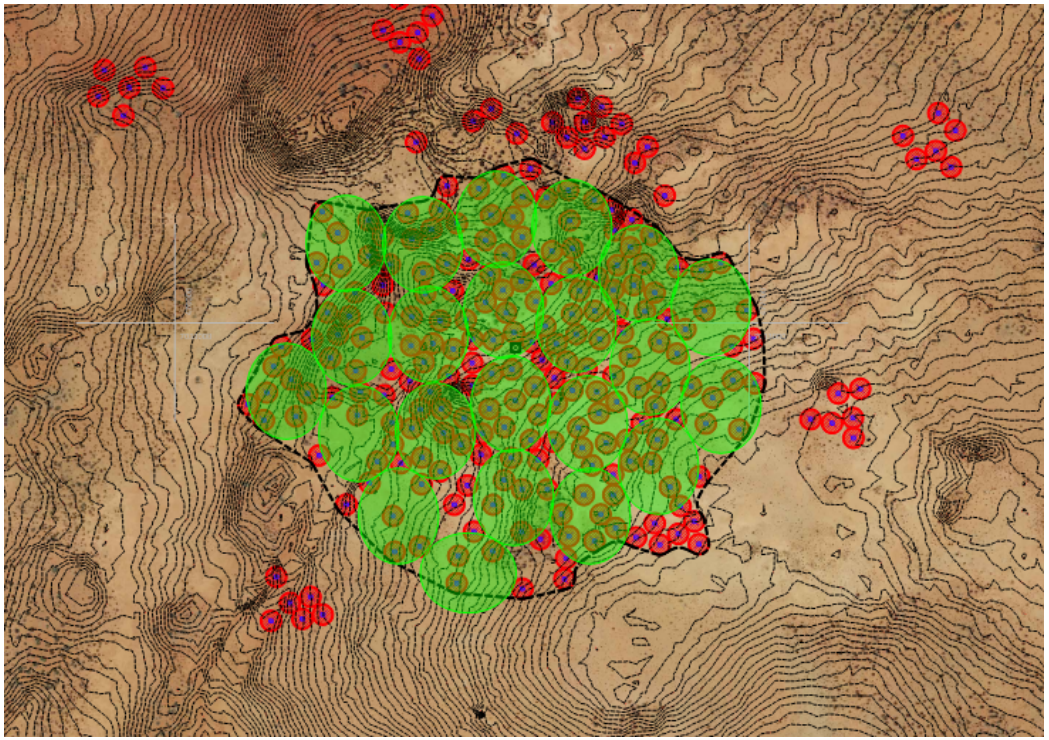


Ground Preparation – scale…

Ground Preparation – scale…

22 MCG's within the central core… Playing field only, not the full stadium

= 1 MCG



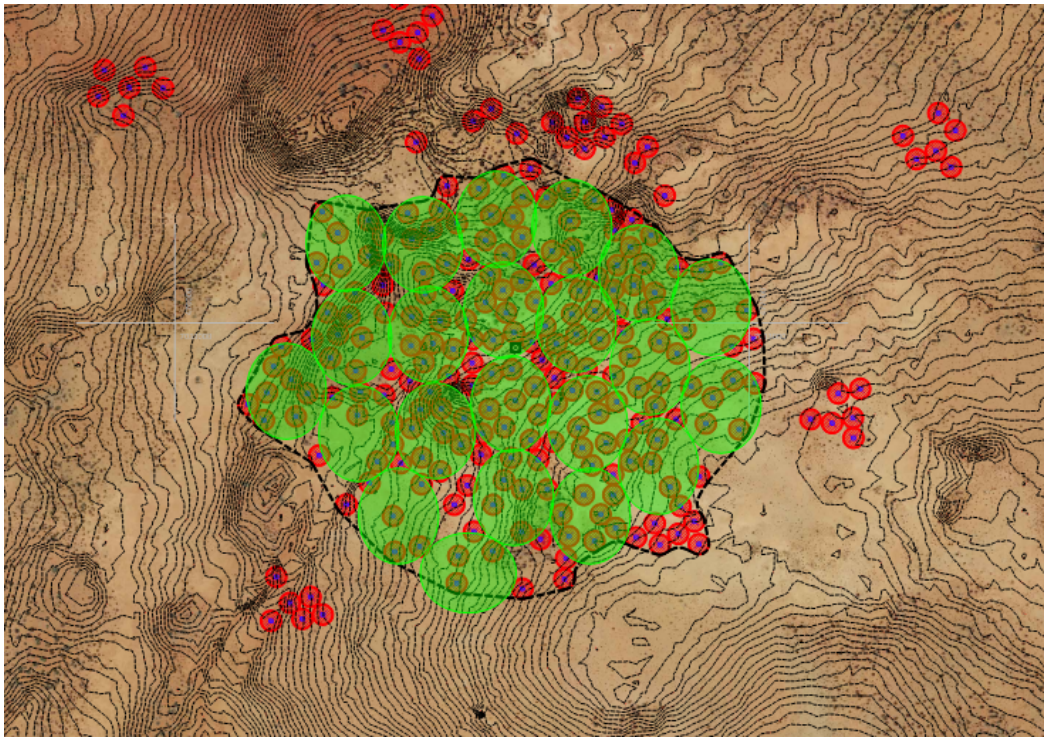
Ground Preparation – scale…

22 MCG's within the central core…

= 1 MCG
= 171 x 143 m

Lords 160 x 130 m
Old Trafford 116 x 76 m
The Oval 141 x 146 m
Wembley 105 x 69 m

-



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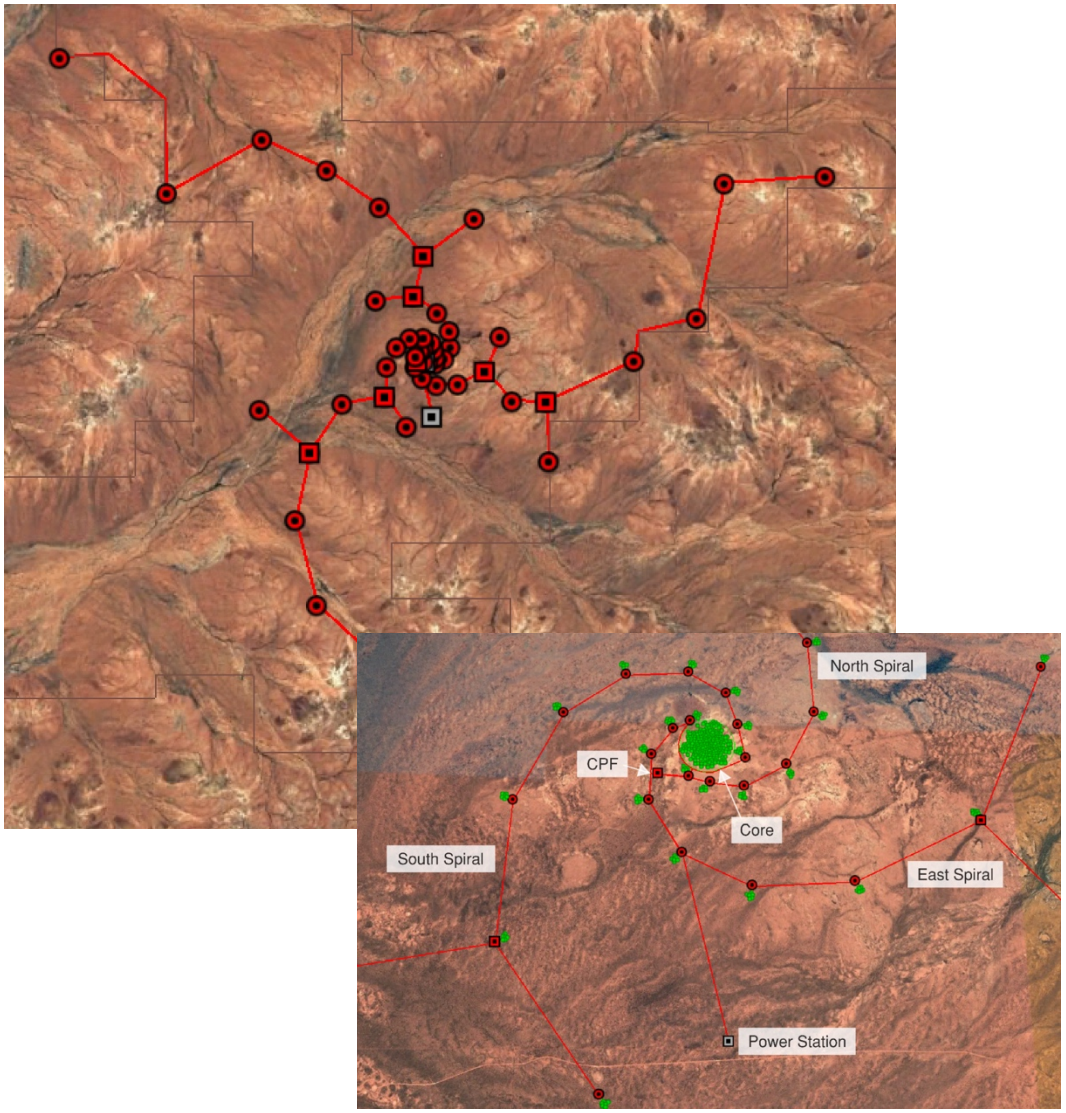
Power Distribution – Design Update

- Initial power system modelling has been undertaken
- Draft Detail Design report and drawings have been issued
- Supplier investigation has commenced for switchgear and cabling:
  - Improved model
  - Improved costing
- Optimisation of system configuration, component selection and route to be undertaken once design inputs are finalized from other consortia



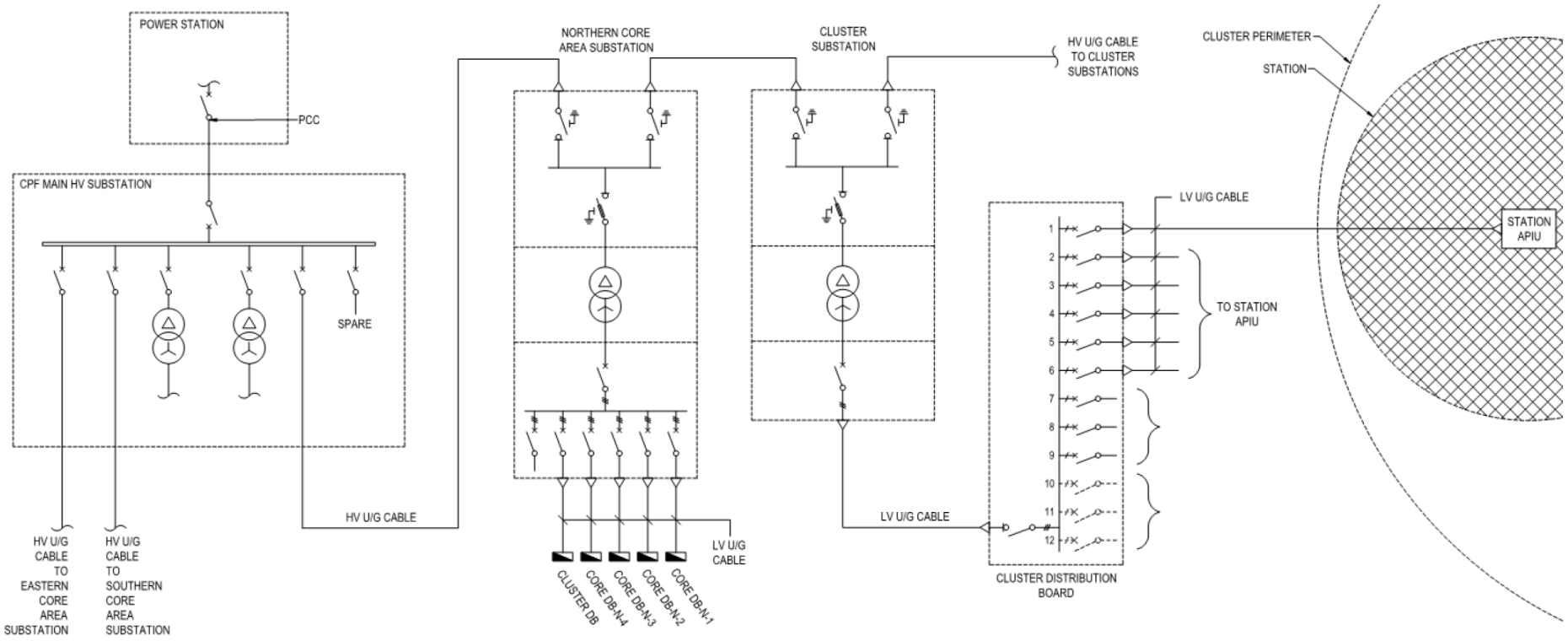
Power Distribution - Overview

- Power transmitted over a large distance for tiny electrical loads
- Number of unique challenges
- Approximately 200km of high voltage power distribution cabling to be installed
- Enough to reach places as shown from Rotterdam to Amsterdam or …..

Power Distribution - Overview

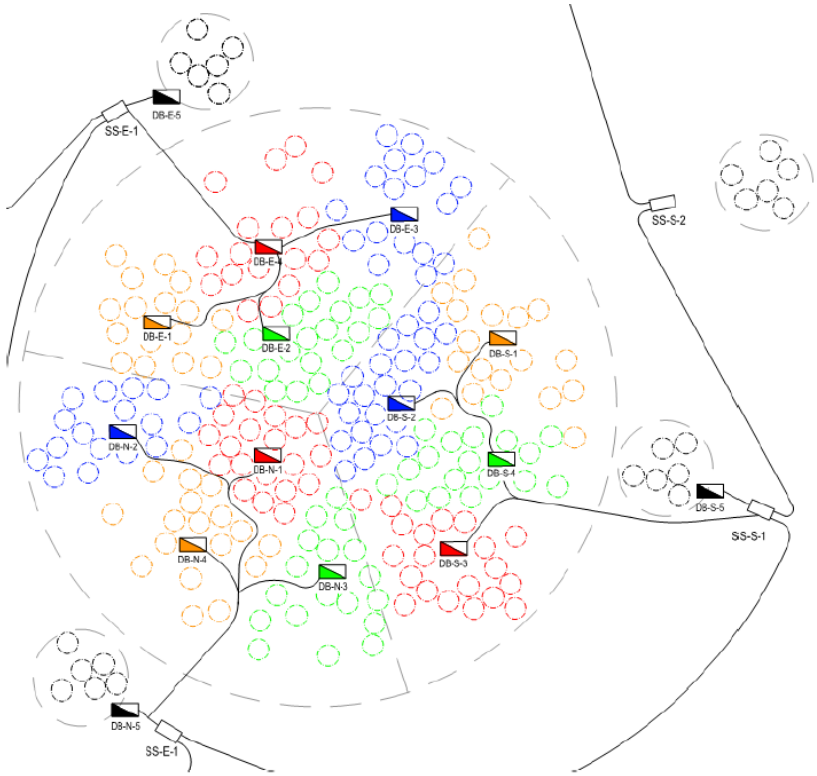
Power Distribution – High Voltage Network

- System overview showing the power distribution path from the power station through to a station



Power Distribution – Core

- Power will be distributed in the dense core at low voltage
- A number of topologies and options are being considered to deliver a cost effective solution



Power Distribution – Remote Stations Solar

Note: Costs in €

	SKA Solar PV Study	Option 2A 98% Availability								
	Distance point to point (+15%) (m)	N15-N16 16,940	E15-E16 9,798	E14-E15 13,214	N14-N15 10,684	S15-16 8,200	S14-S15 9,683	E13-E14 7,257	E11-E13 9,350	S13-S14 8,441
	Capital Costs	(570,611)	(14,442)	(280,456)	(83,437)	110,000	(5,486)	183,434	20,446	91,232
	Net Present Value over 25 years (4%)	(570,069)	(13,900)	(279,914)	(82,895)	110,542	(4,944)	183,976	20,988	91,774
	CUMULATIVE CAPITAL COST	(570,611)	(585,053)	(865,509)	(948,946)	(838,946)	(844,433)	(660,998)	(640,553)	(549,321)
	CUMULATIVE NPV	(570,069)	(583,969)	(863,883)	(946,778)	(836,236)	(841,180)	(657,204)	(636,217)	(544,442)
-10%	Battery Cost - reduction in capital Cost by 10%									
	Capital	(589,104)	(32,934)	(298,948)	(101,929)	91,507	(23,978)	164,942	1,953	72,740
	NPV	(599,028)	(42,858)	(308,873)	(111,854)	81,583	(33,903)	155,018	(7,971)	62,816
	CUMULATIVE CAPITAL COST	(589,104)	(622,038)	(920,986)	(1,022,915)	(931,408)	(955,386)	(790,445)	(788,491)	(715,751)
	CUMULATIVE NPV	(599,028)	(641,886)	(950,759)	(1,062,612)	(981,029)	(1,014,931)	(859,914)	(867,885)	(805,069)
-20%	Battery Cost - reduction in capital Cost by 20%									
	Capital	(607,596)	(51,426)	(317,441)	(120,422)	73,015	(42,471)	146,449	(16,539)	54,248
	NPV	(627,986)	(71,816)	(337,831)	(140,812)	52,625	(62,861)	126,059	(36,929)	33,857
	CUMULATIVE CAPITAL COST	(607,596)	(659,022)	(976,463)	(1,096,885)	(1,023,869)	(1,066,340)	(919,891)	(936,430)	(882,182)
	CUMULATIVE NPV	(627,986)	(699,803)	(1,037,634)	(1,178,446)	(1,125,821)	(1,188,682)	(1,062,623)	(1,099,553)	(1,065,695)
-50%	Battery Cost - reduction in capital Cost by 50%									
	Capital	(663,073)	(106,903)	(372,918)	(175,899)	17,538	(97,948)	90,973	(72,016)	(1,229)
	NPV	(714,862)	(158,692)	(424,707)	(227,688)	(34,251)	(149,737)	39,184	(123,805)	(53,018)
	CUMULATIVE CAPITAL COST	(663,073)	(769,976)	(1,142,894)	(1,318,792)	(1,301,254)	(1,399,202)	(1,308,229)	(1,380,245)	(1,381,474)
	CUMULATIVE NPV	(714,862)	(873,554)	(1,298,260)	(1,525,948)	(1,560,199)	(1,709,935)	(1,670,752)	(1,794,556)	(1,847,574)

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Buildings

Buildings that require major RFI shielding:

- Central Processor Facility (CPF) ~ 1555 sq metres
- Remote Processor Facility (RPF) ~ 36 of 20+ sq m

Other facilities required:

- Storage of spares (appropriate location: MRO, Accommodation, Geraldton EOC)
- Maintenance facilities (location location location)
- Accommodation:
  - Temporary construction camp (~200 people, 4 years)
  - [Permanent accommodation facility (~50+ people, 50 years)]
    - Travel distance optimisation :
      - RFI impacts ? Shielding / restrictions may apply

- [Engineering Operations Centre (**EOC**) and Integration and Test Facility (**ITF**)]
  - Clear requirement for both for SKA
  - Possible initial use of EOC as ITF (schedule dependent)
  - A path for the provision of these buildings has been started in Australia

Buildings – CPF Rack Budgets

- Central building (CPF) only
- Current estimates

LOW CPF		
Element	Cabinets	Comments
LFAA Signal Processing	148	From LFAA ICD [AD2]
LFAA Control System	4	From LFAA ICD [AD2]
CSP-Low.CBF	5	From CSP ICD [AD3] amended. Incorporates the CSP-Low.LMC requirements
CSP-Low.PSS	17	From CSP ICD [AD3]
CSP-Low.PST	2	From CSP ICD [AD3]
TM Low	2	From TM ICD [AD4]
SADT Low	9	From SADT ICD (General racks) [AD5]
SADT Masers*	3	From SADT ICD [AD5]
SADT Masers*	5	From SADT ICD (Racks supporting the Masers) [AD5]
INAU Control	1	Work in progress estimate
Spares	4	TBC (noting margins)
Total	200	Note 8 of these are associated with the Maser room – hence 192 cabinets in area

- New facility "close" to Low core
- Building area ~1550+ sq m required.
- Modular building concept, similar to successful strategy for ASKAP
- Minimal additional rooms
  - Operations / Maintenance models require certain key facilities.
- RPFs (aka "huts") required on the spiral arms for housing station ADC, SaDT etc
  - Design may be semi-COTS e.g. containerised
    - RFI shielding of internals and cooling key
  - Tradeoff study:
    - Local solar power vs distributed
    - Dependent on power consumption in RPF

Buildings – Design Thinking Workshops

Example CPF Location :

- Minimise cost for maximum functionality

Fibre core to CPF
Expensive (60,000 fibres)
Keep short

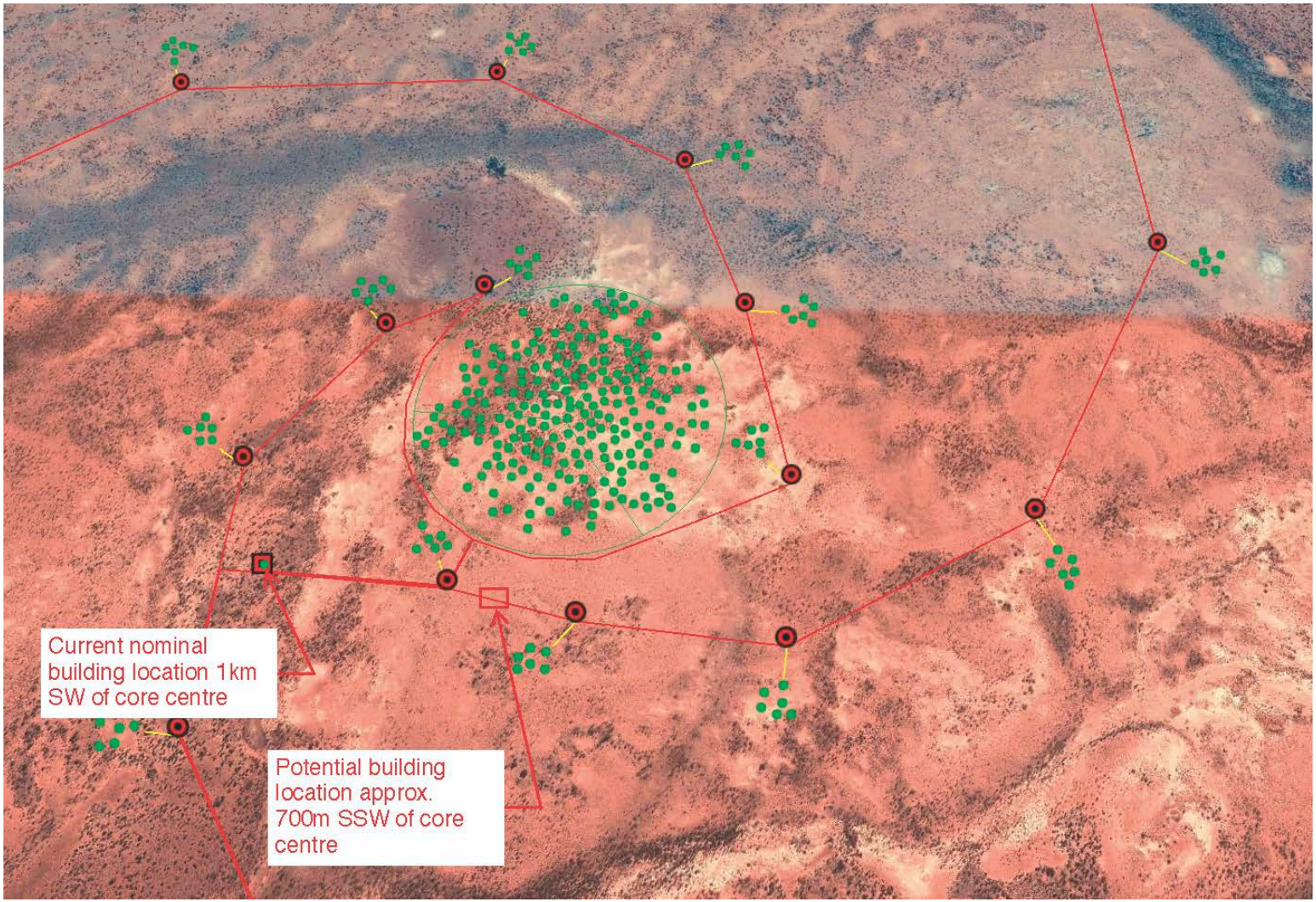
Location choice

RFI shielding
Expensive
Building far from antenna

A few of the other parameters:

- Maintenance use and Ops impacts
- Distance to spiral arm cables
- Power station relationship
- Local terrain
- etc

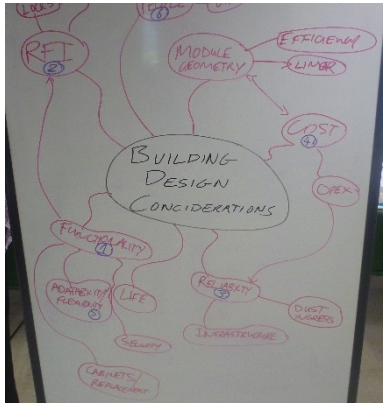
CPF Locations

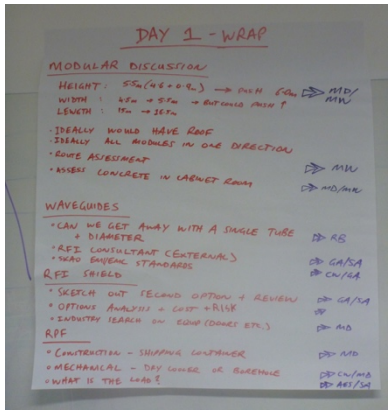


Buildings – Design Thinking Workshops

Topics of Discussion

- Modular Building Design
- Cost Update
- Waveguides for Fibre Re-Entry
- RFI Shield
- Remote Processing Facility
- Community Engagement
- Building Layout Optimisation

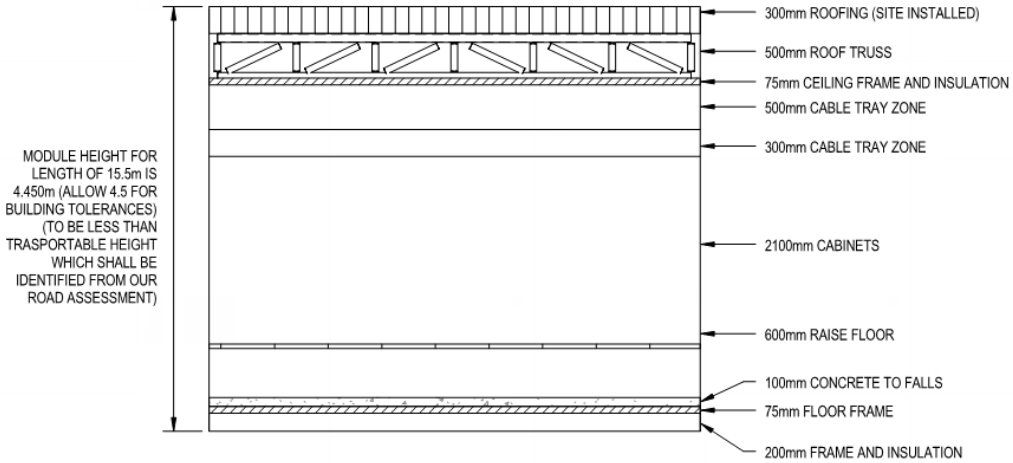




Buildings – Optimum Module Sizes

Optimum Module Size Considerations

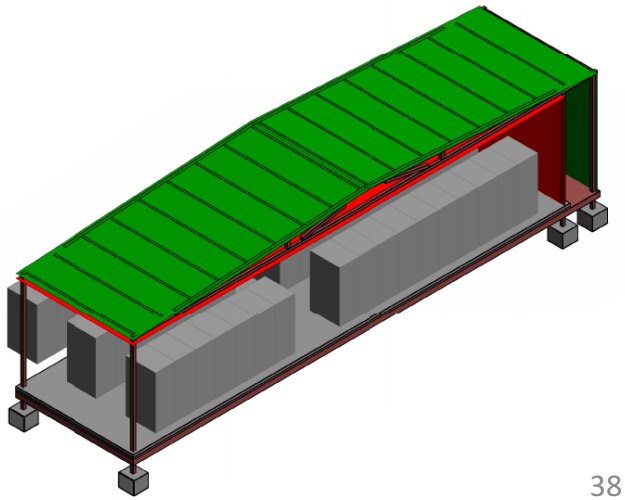
- Factory Construction
- Logistics
- Police Escort



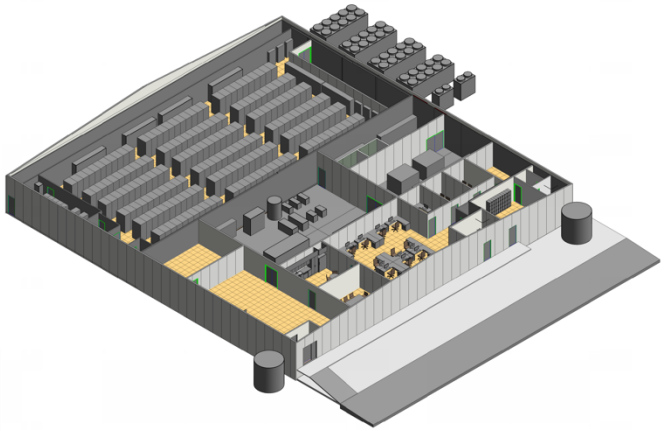
Module Cross Section

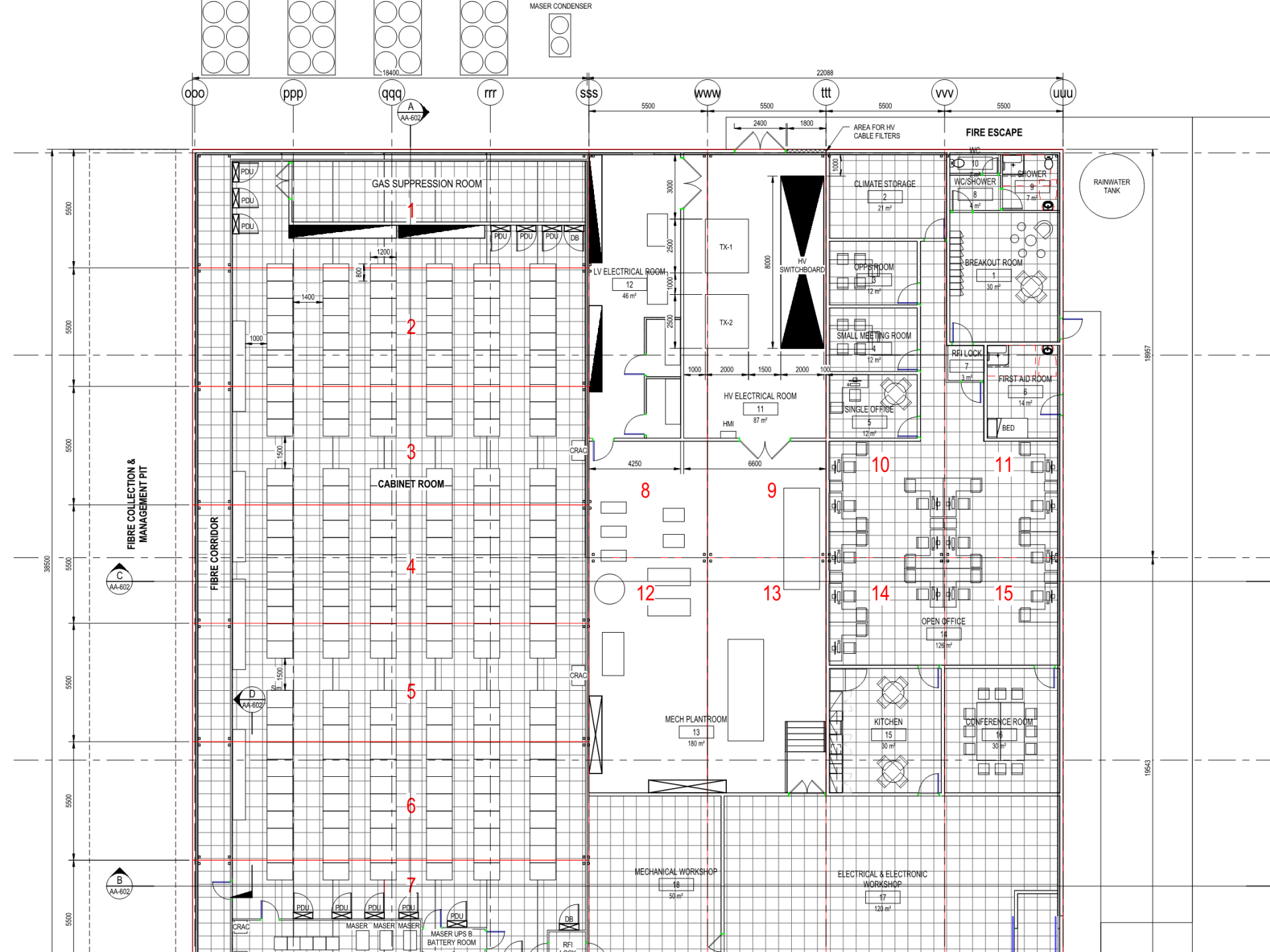
Optimum Size

- Height 5.5m
- Width 4.5m to 5.5m
- Length 15m to 16.5m



Buildings – Building Optimisation




MASER CONDENSER
18400
22088
oooo
pppp
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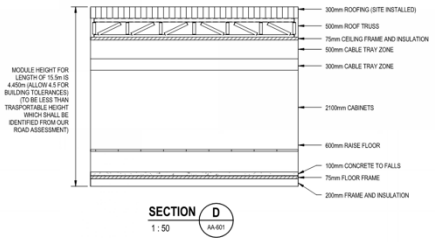
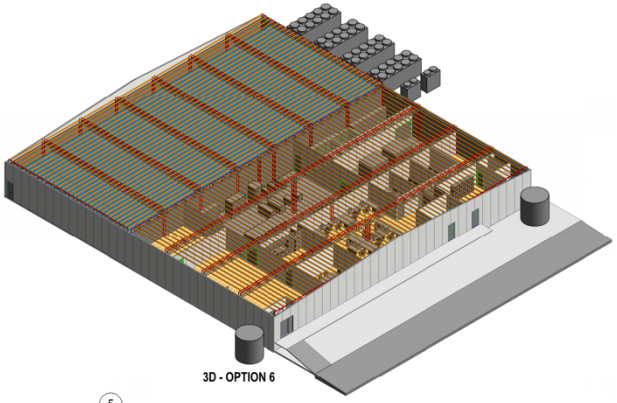
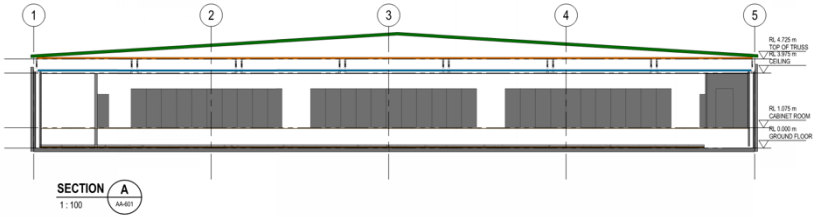
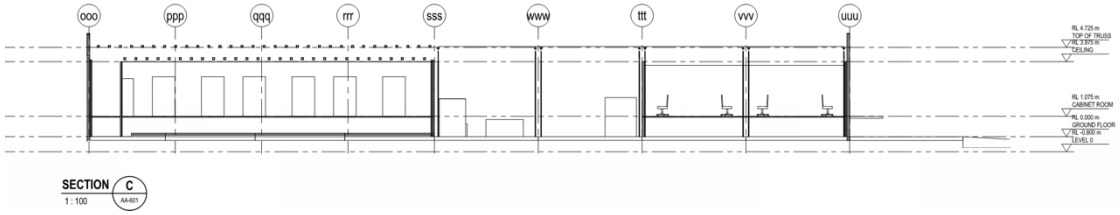
rrrr
ssss
wwww
tttt
vvvv
uuuu
5500
2400
1800
AREA FOR HV CABLE FILTERS
FIRE ESCAPE
RAINWATER TANK
GAS SUPPRESSION ROOM
1
PDU
DB
LV ELECTRICAL ROOM
12
46 m²
TX-1
TX-2
HV SWITCHBOARD
CLIMATE STORAGE
2
21 m²
WC
10
WC/SHOWER
8
4 m²
SHOWER
9
7 m²
BREAKOUT ROOM
1
30 m²
OPP'E ROOM
3
12 m²
SMALL MEETING ROOM
4
12 m²
RFI LOCK
7
3 m²
FIRST AID ROOM
6
14 m²
BED
SINGLE OFFICE
5
12 m²
HV ELECTRICAL ROOM
11
87 m²
HMI
CRAC
2
3
4
5
6
7
8
9
10
11
12
13
14
15
CABINET ROOM
FIBRE COLLECTION & MANAGEMENT PIT
FIBRE CORRIDOR
MECH PLANTROOM
13
180 m²
OPEN OFFICE
14
126 m²
KITCHEN
15
30 m²
CONFERENCE ROOM
16
30 m²
MECHANICAL WORKSHOP
18
50 m²
ELECTRICAL & ELECTRONIC WORKSHOP
17
120 m²
MASER
MASER UPS B BATTERY ROOM
RFI
A
AA-602
B
C
D
38500
18957
19543

Buildings – Building Optimisation



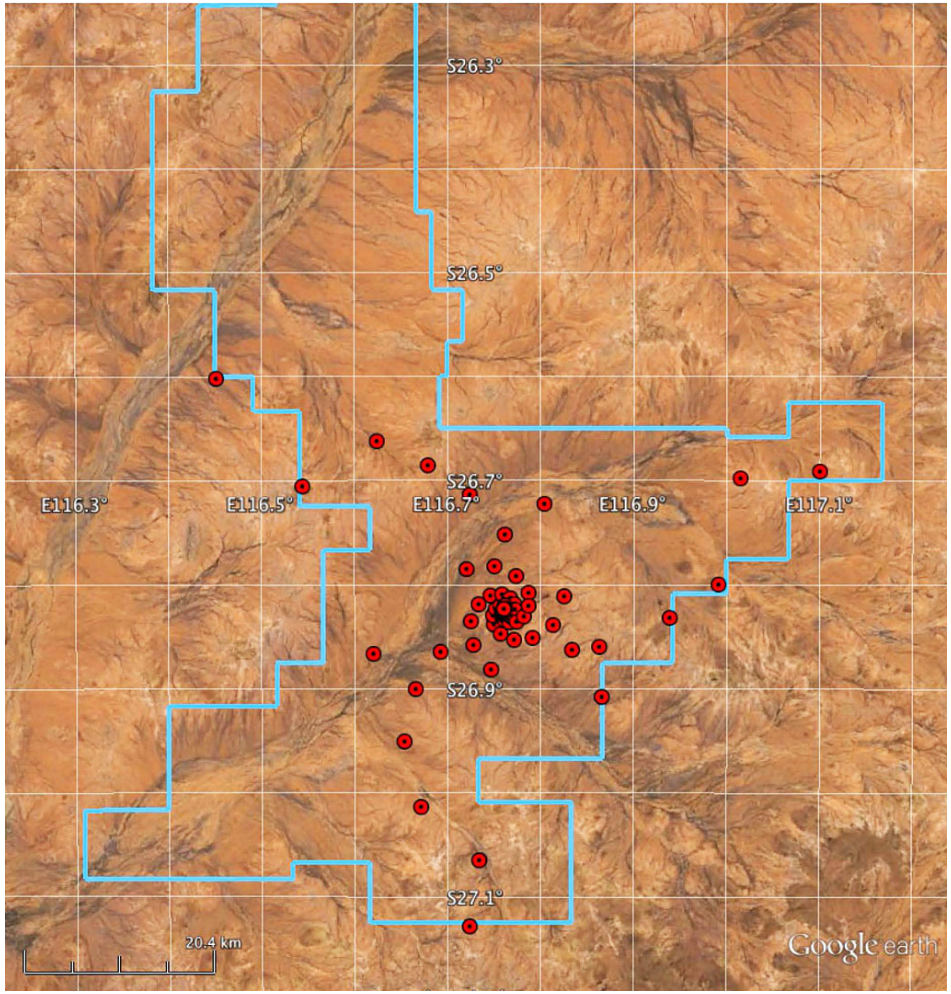






Site monitoring – PDR concepts

- *Visual, Weather, RFI, Tropospheric, (Lightning)*



Monitoring

RFI:

- *27 meter tower*
- *600 m west of ASKAP CPF*
- *3 antennas (plan:4)*
- *Fibre optic connection to CPF*

Weather:

- *CSIRO design (modified COTS)*

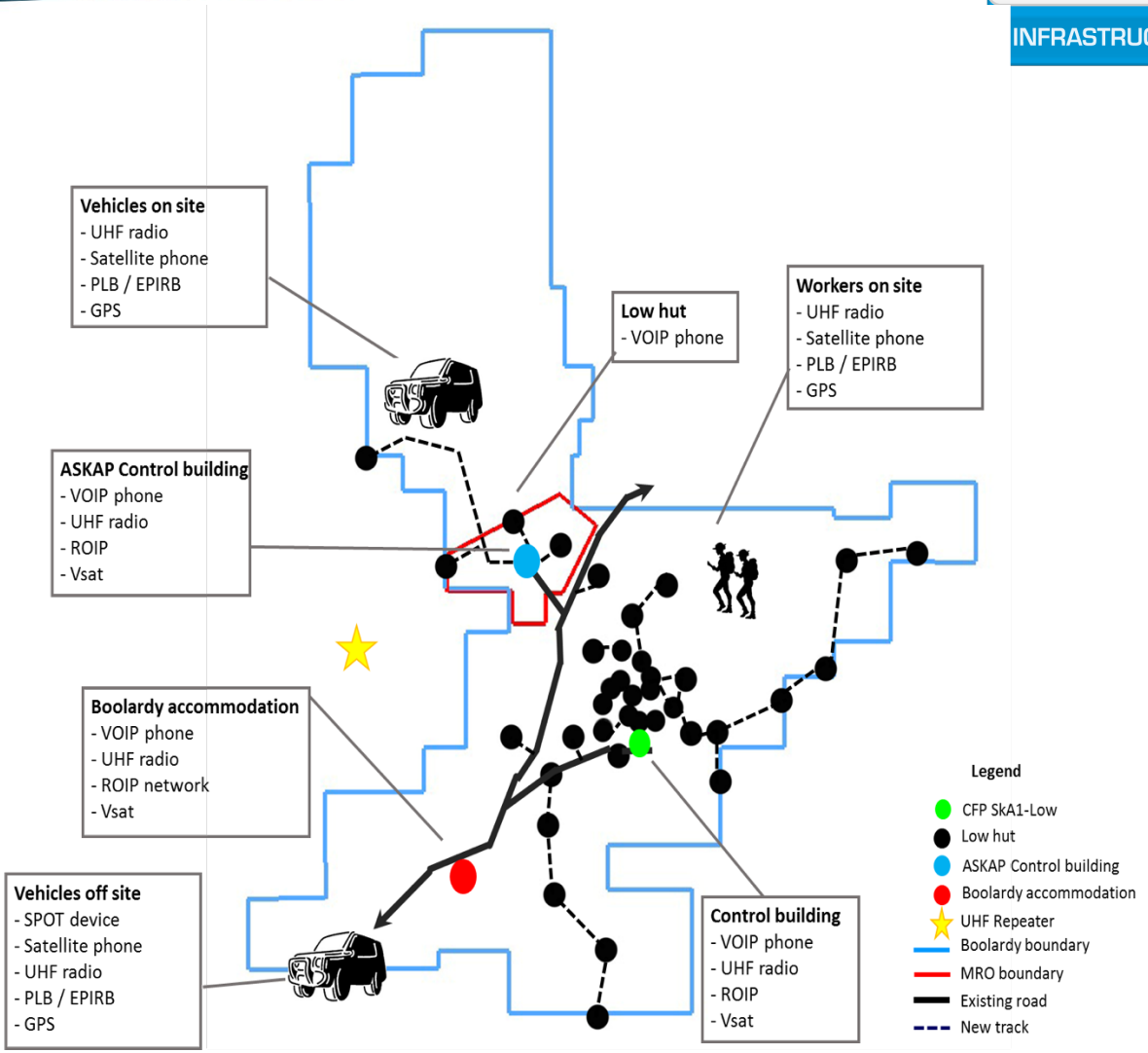
Visual:

- *Fixed and PZT (minimal)*
- *CSIRO (modified COTS)*
- *RFI compliant*

Tropospheric:

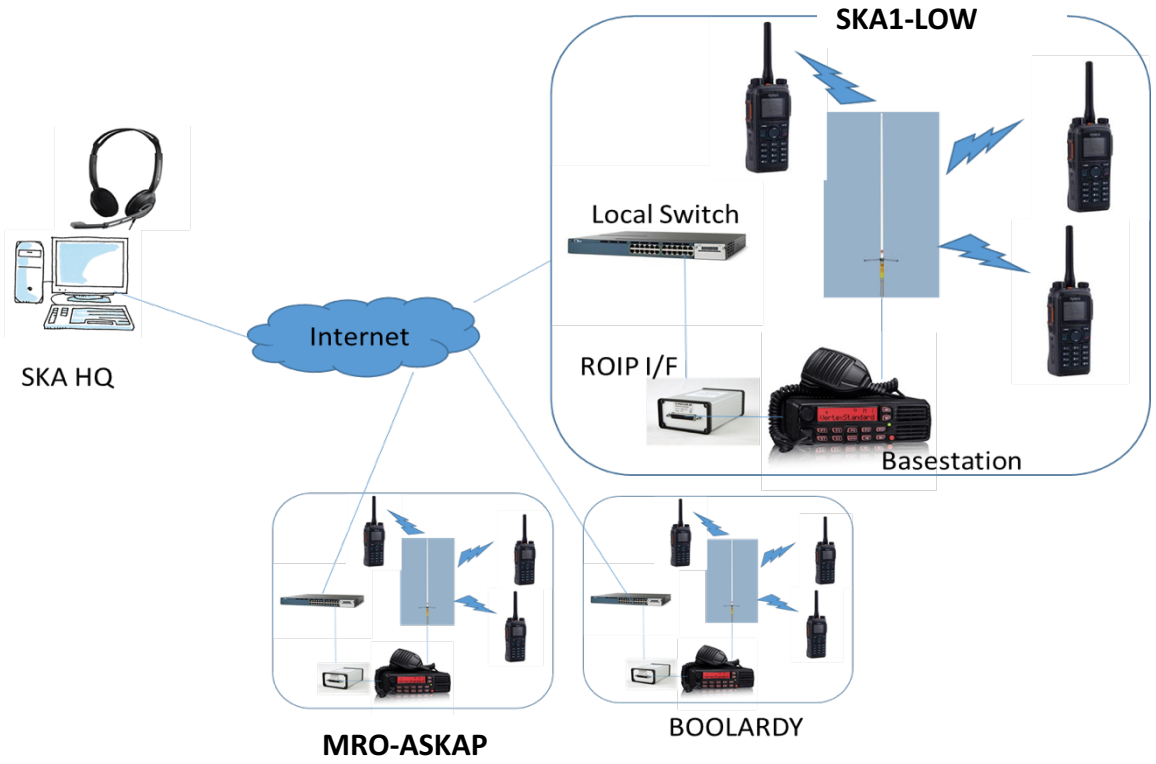
- *Current 2 station unit (near ASKAP)*
- *3rd antenna, relocation (?)*

Communications



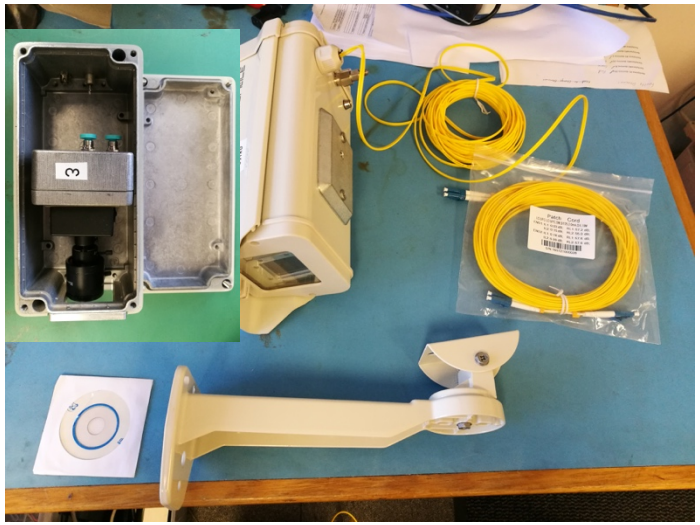
Communications (Radio on IP) 477MHz COTS

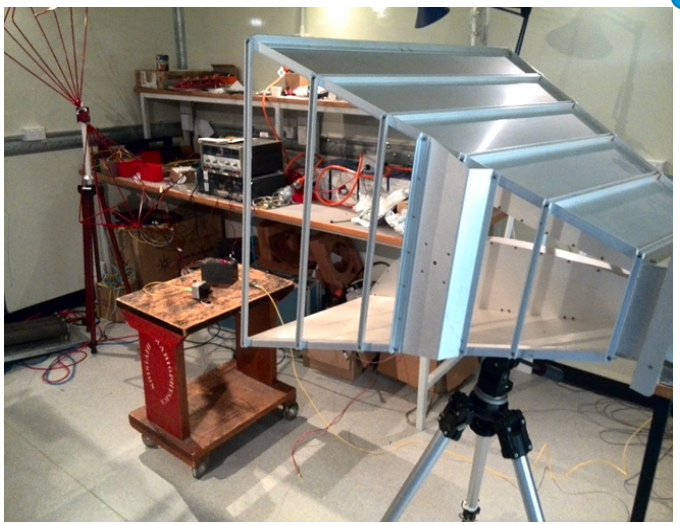
Enables seamless integration of all radios at the site(s) with HQ operations



Note: The ROIP IF will use SMF optical SFP to a CFP network switch port
ROIP I/F, radio and RF filter(s) in shielded headend box (CSIRO design TBD)
Alternative Bands being examined with ACMA and stakeholders

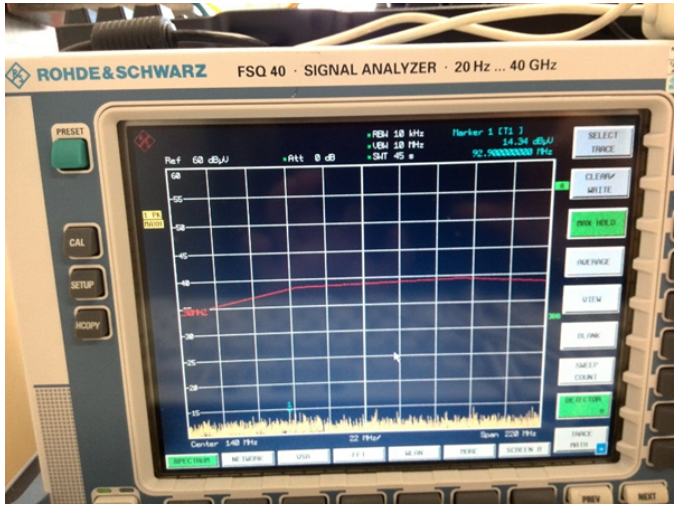
Monitoring (video fixed focus)





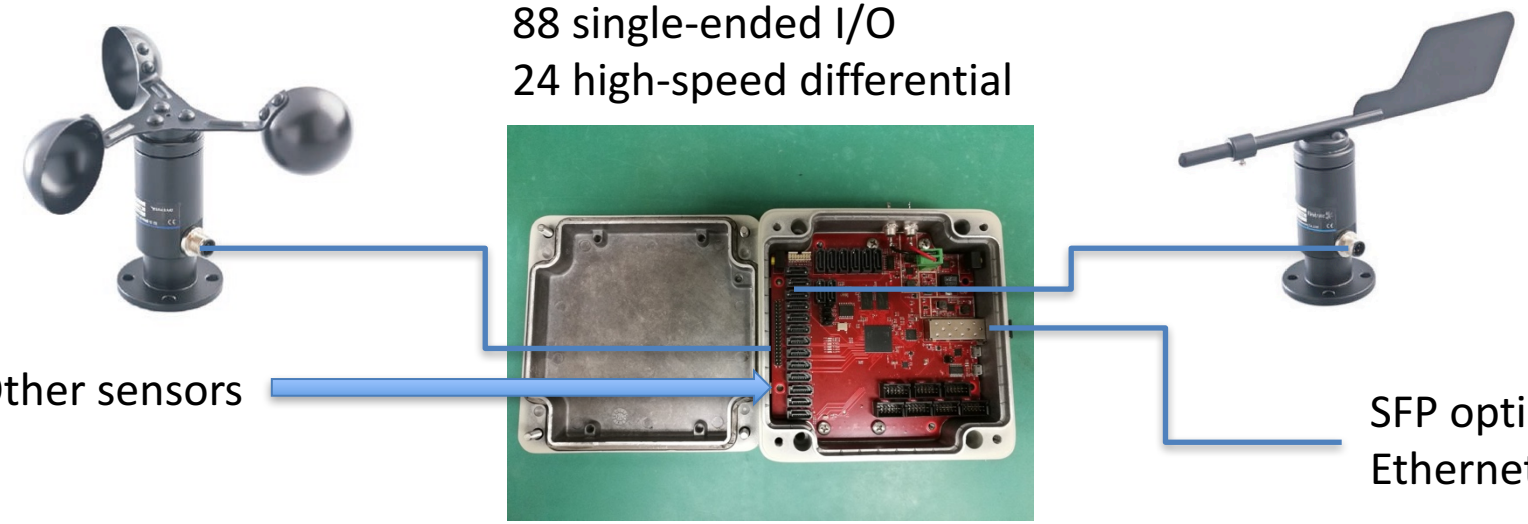
EMC compliant fixed FOV IP camera H.264 codec standard
Vari-focal shown. CSIRO designed duplex fiber I/F

- RFI is MIL461F – 20dB at VHF
- Second stage enclosure takes to better MIL461F-60dB
- Environmental testing to 50C
- Low cost



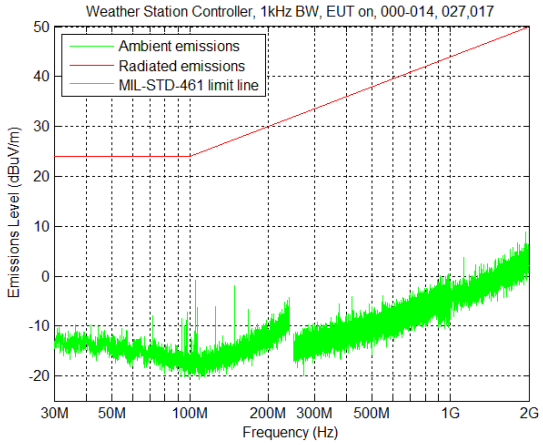
Monitoring (EMC compliant Weather station)

CSIRO designed controller
(Xilinx ZYNQ7020)
88 single-ended I/O
24 high-speed differential



Development of EMC compliant Weather Station

- RFI at MIL461F – 20dB at VHF
- SFP optical output
- Second stage RF enclosure probably required
- Environmental testing to be done
- Sensors being acquired



Outline

- HSE
- Introduction
- Who is INAU
- Key areas of design:
  - Location, Roads and access
  - Flood studies and Ground preparation
  - Power distribution and solar PV
  - Buildings
  - Site monitoring, Communications
- Hosting items:
  - Existing Power station
  - Site status and ILUA
- Some deliverables
- Costing
- Issues and opportunities
- Summary

(Power Generation – not in INAU)

Two power working groups established; both chaired by SKAO:

- Australian Power Strategy Working Group (APSWG), Alistair McPherson
- Power Supply Options Workgroup (PSOW), Adriaan Schutte

APSWG was formed:

- to explore funding options for the provision of power in Australia, including how to minimize whole of life cost.
- members from SKAO, CSIRO, the Department of Industry, Innovation and Science, and the WA Office of Science.

PSOW group is focussed on :

- technical aspects
- investigate power supply options
- covers a broader scope of work (South Africa and Australia).
- RFI

“Prescriptive customer” will NOT produce not cheapest solution

Power Generation – MRO Power Station

- Horizon Power – Now operational!
  - 4 diesel generators
    - 2 x 240 kW, 2 x 1005 Kw
  - 250 kW solar photovoltaic online

- CSIRO renewable expansion - EMC
  - July 2017 integration
  - Large solar array
    - 5,280 PV panels
    - 1.6 MW peak
  - Very large battery
    - Largest in Australia
    - Lithium ion
    - 2.6 MWh

MRO Power Station

MRO Power Station

2.6 MWhr lithium ion battery

Site status

Currently two separate CSIRO Leases:

- Boolardy Station (3420 km**2) – pastoral activity only
- Murchison Radio-astronomy Observatory (120 km**2) - radioastronomy

New integrated multi-purpose lease being negotiated between CSIRO and WA State Govt

New Indigenous Land Use Agreement (ILUA)

- Being negotiated now between Federal Govt (DIIS), CSIRO and Wajarri Yamatji
- 5 meetings completed
- 2 (?) more to go
- Many areas agreed

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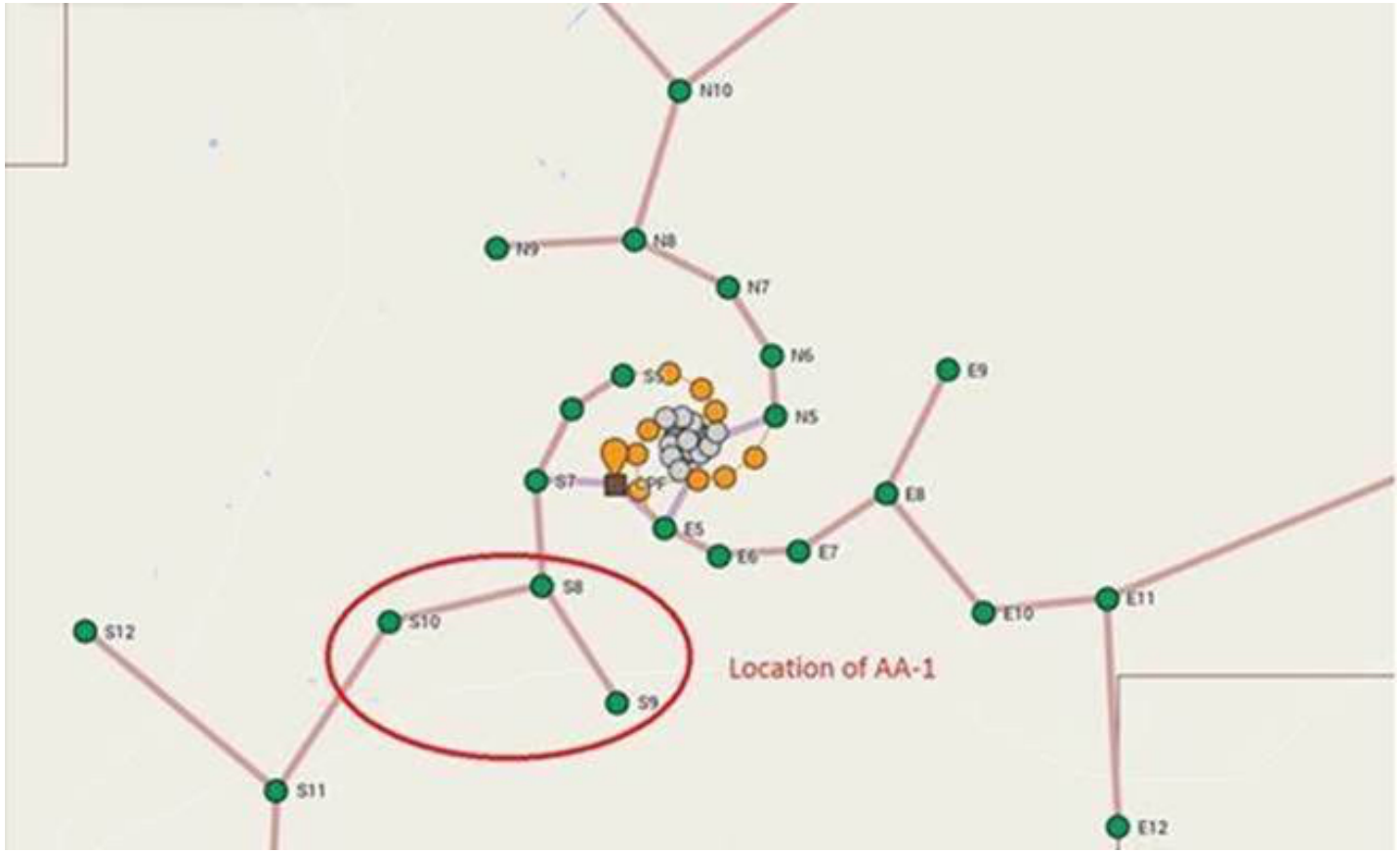
Early Deployment



- Requirement to support early deployments - AR1 etc
- Support with temporary location of RPF

(Image Courtesy AIV)

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Costing

	Sept 2016	June 2017	% change
Total (includes 21% contingency)	**98,816,000**	**94,056,000**	**- 4.8**
- Power distribution	56,625,000	50,982,000	- 9.9
- CPF (1100 m**2, 1555 m**2)	15,838,000	18,941,000	+ 19.6
- Tracks and road	8,385,000	8,581,000	+ 2.3

Budget : 77,800,000 Euro

Includes preliminaries, profit etc

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Issues and opportunities

Issues /Risks

- *ICD completion*
- *Cost Control*
  - *Major change means much design work needs to be re-done*
  - *Impacts schedule, budget, increased risk*
- *Design maturity of (some) interfacing work packages*
- *RFI*
- *ECP process – requires rework, schedule and budget impacts*
- *Scope changes*
- *Heritage survey – delays cause increased risk with possible moves of components*
- *Geo and hydro survey dependence on heritage process*
- *Infrastructure – last to start, first to deliver*
- *Pre-con Funding*

Opportunities

- *Solar power stations for remote outlying Low Stations*
- *Re-assessment of core requirements*
- *Introduction of new member country partners (power solutions)*
- *Whole of Life cost reductions – Capex vs Opex*

Questions?