Availability as a design criterion - Simulation of SKA1_MID Dish Power Infrastructure

IS2017 Conference 2017

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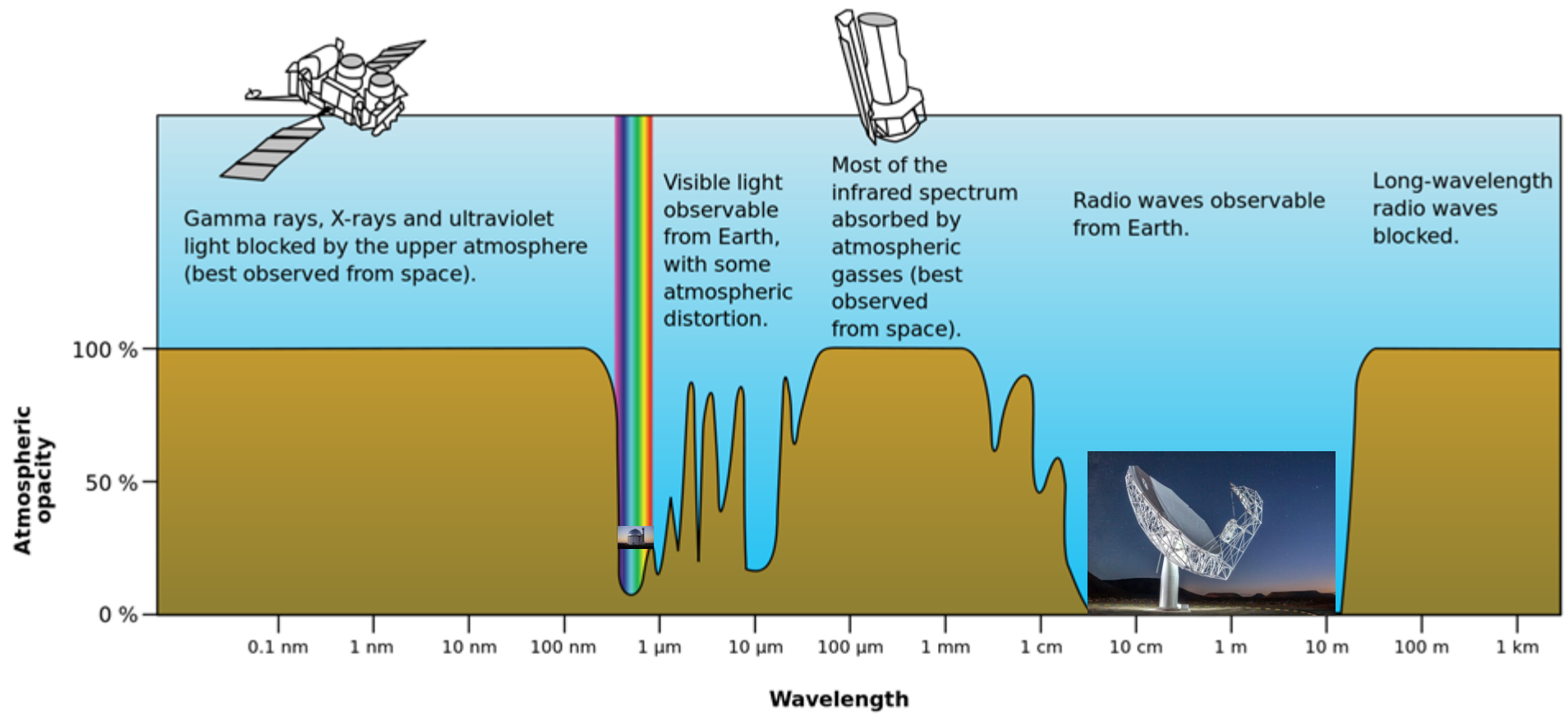
impact advantage

SKA AFRICA
SQUARE KILOMETRE ARRAY

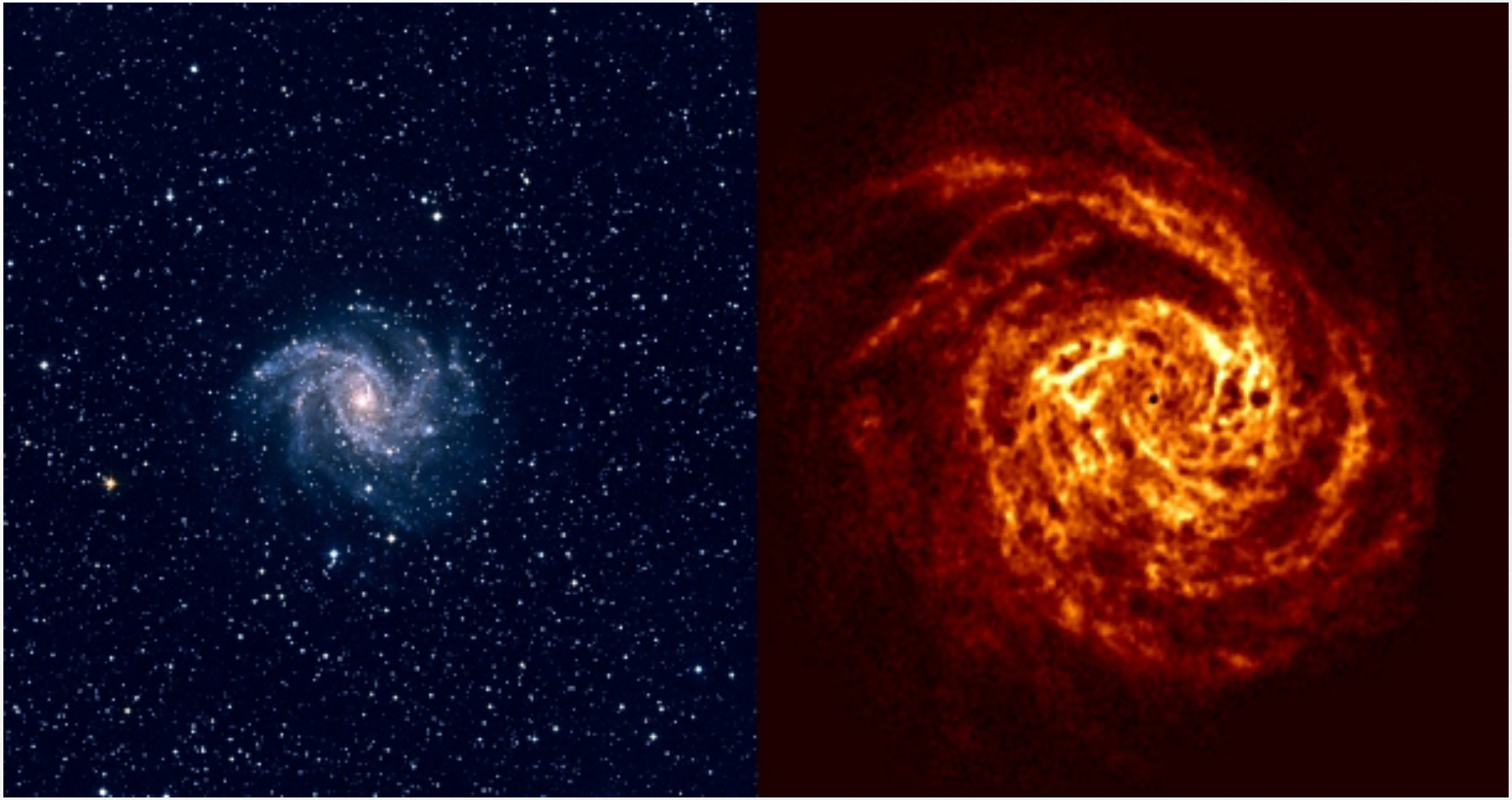

It was a dark
and stormy night.
3-13


But I don’t care
because I am a
RADIO TELESCOPE

Why a radio telescope?



Why a radio telescope?



http://blogs.discovermagazine.com/badastronomy/2011/05/15/the-belch-of-a-gassy-galaxy/#.V8A4Qvl96Cg

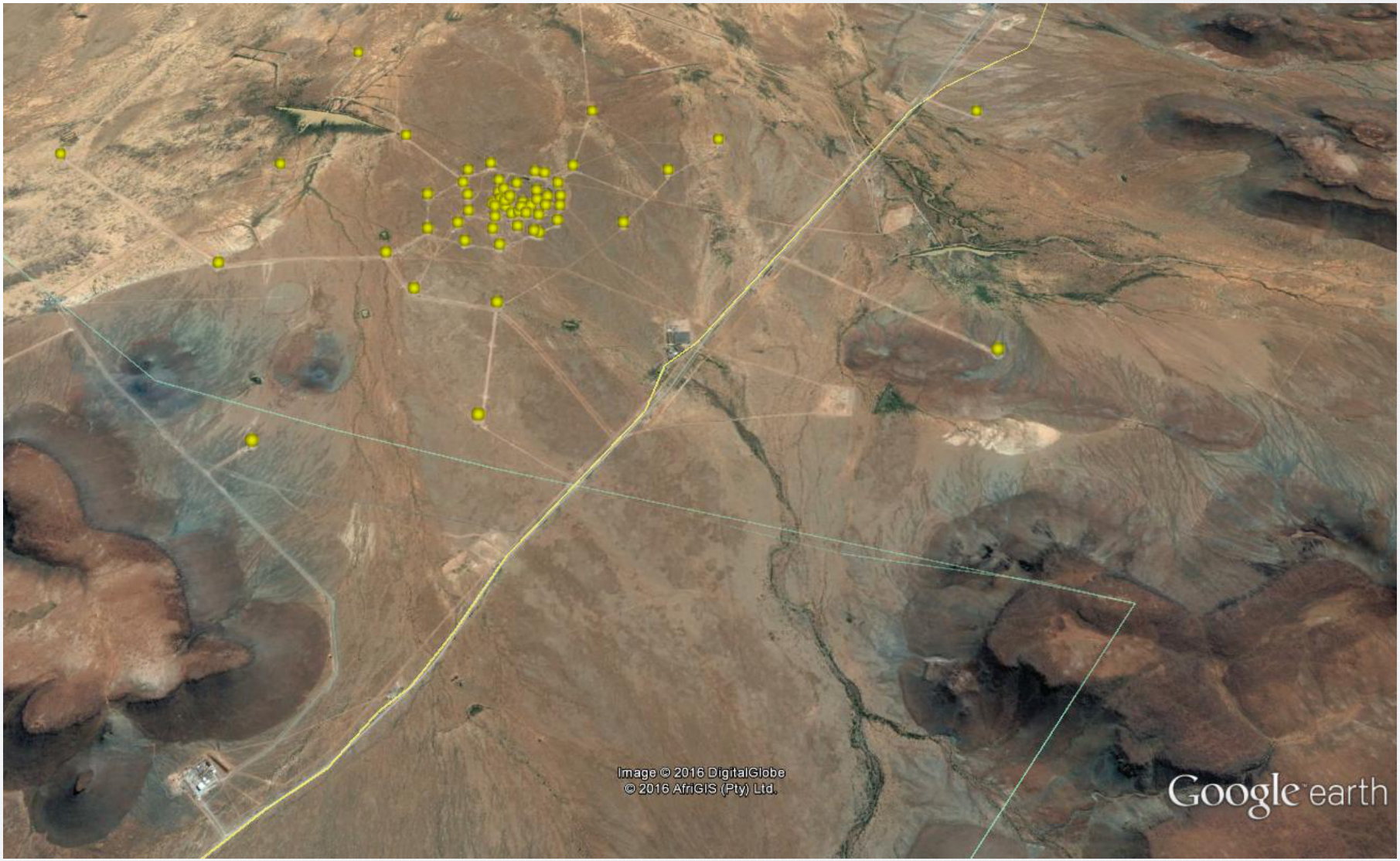
Why a radio telescope?

Why a radio telescope?

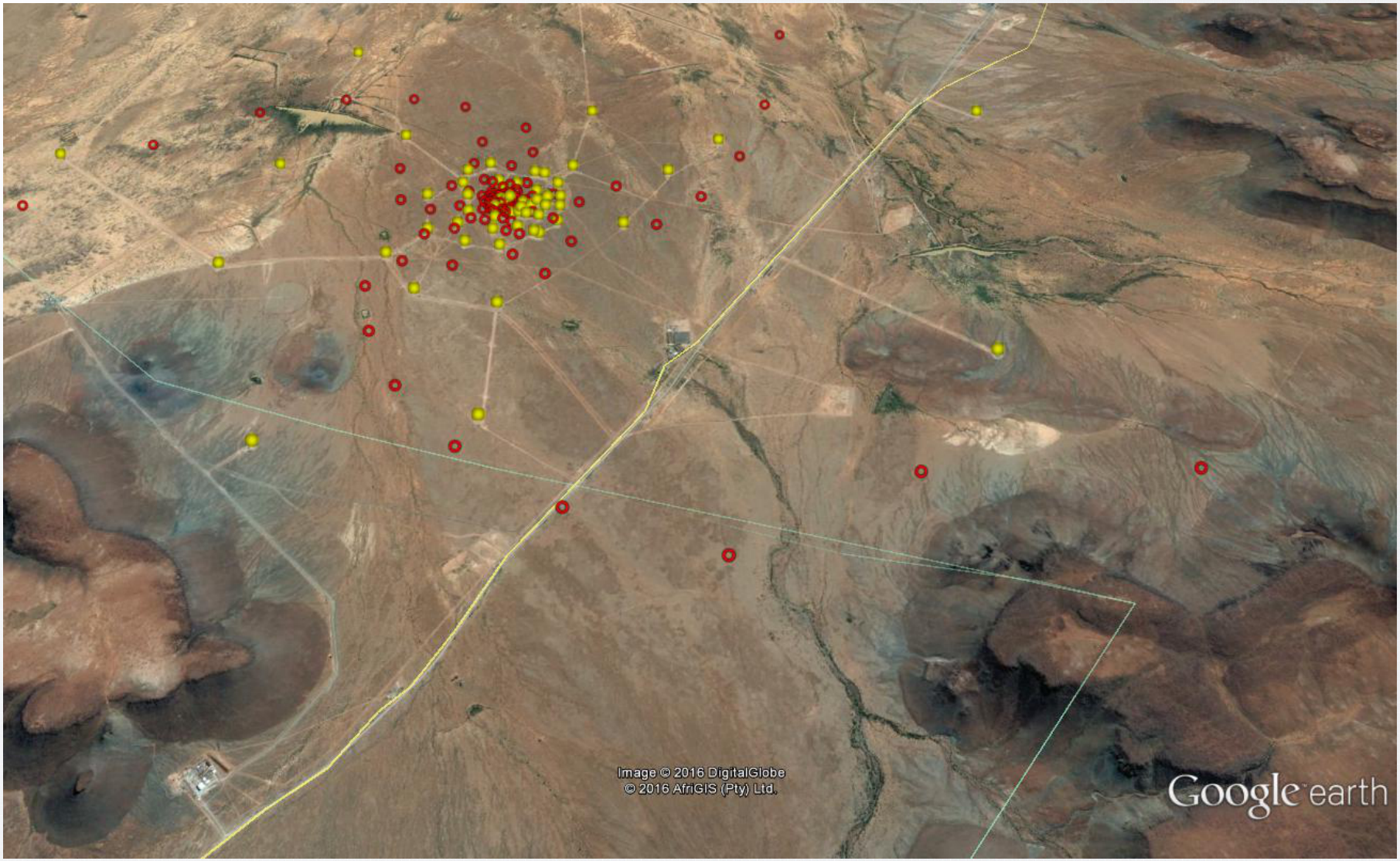
Jets of particles accelerated by the black hole at the centre to near the speed of light emit radio waves

MeerKAT single receptor

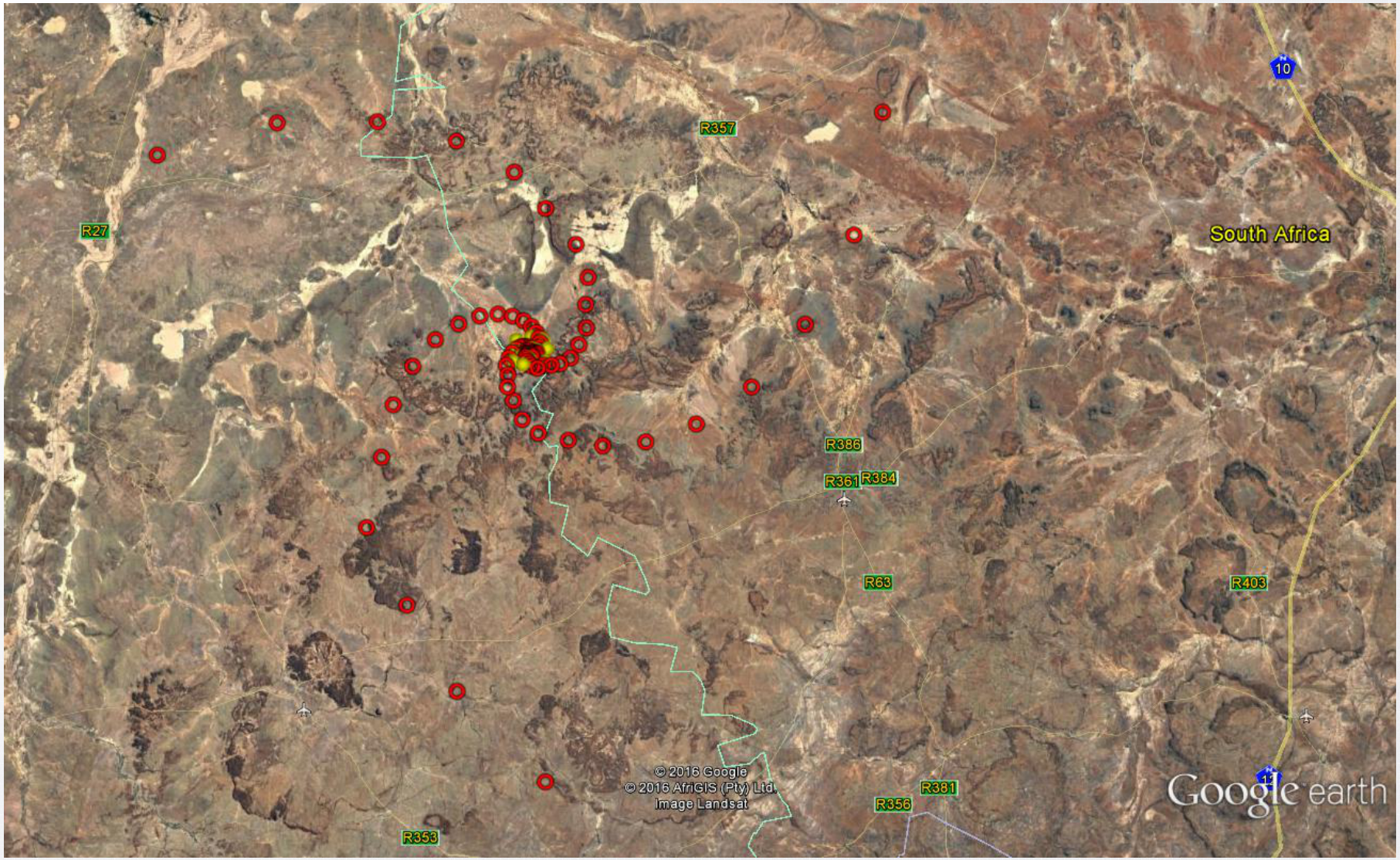
MeerKAT layout



SKA1 layout



SKA1 layout


R357
R27
South Africa
10
R386
R361
R384
R63
R403
R381
R356
R353
11
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Availability

- System level 95%
- Dish power network 99.9%

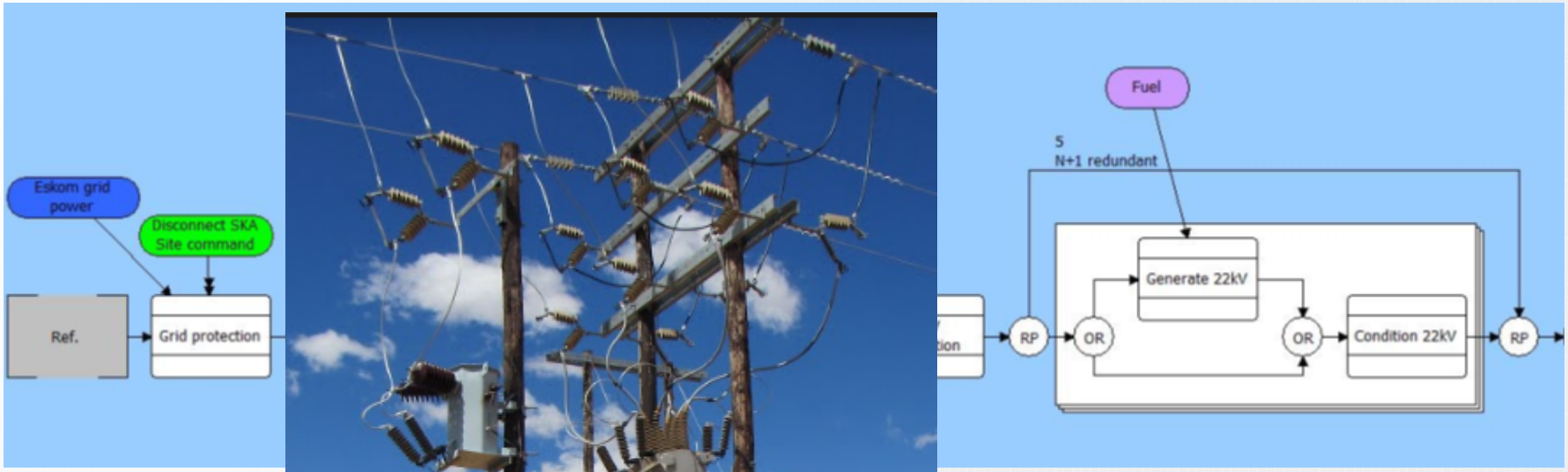
- -> propose a realistic number

Approach

- Complex network
- 189/197 powered = success
- If Excel can't do it, it doesn't need to be done

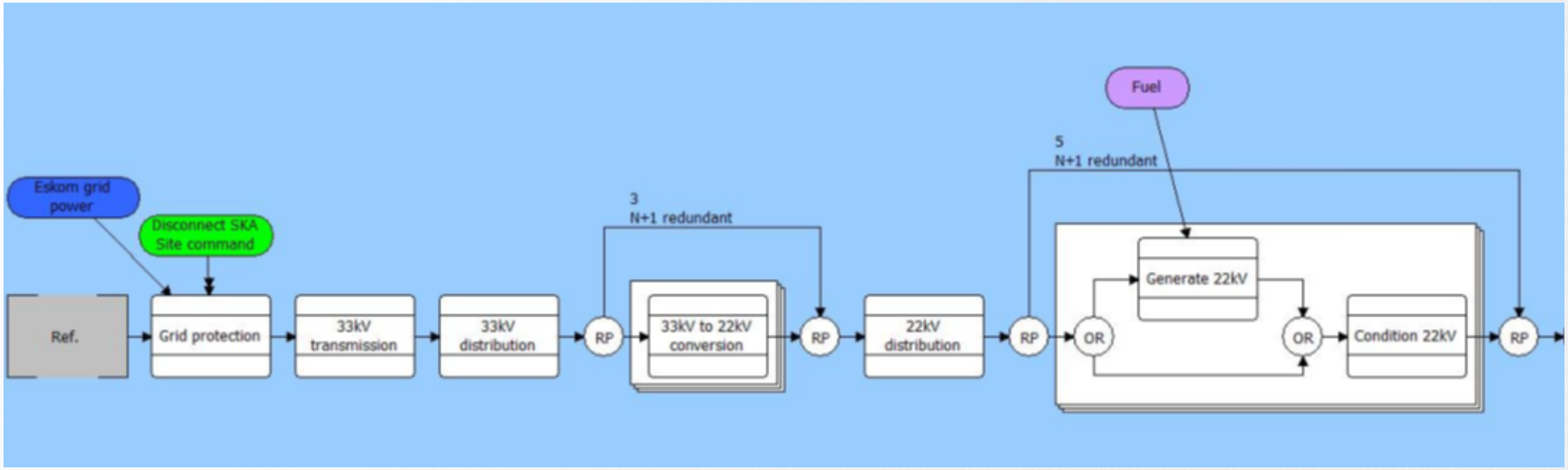
- Reliability Block Diagram
- Fault Tree Analysis
- Discrete Event Simulation Model

Reliability Block Diagram



Reliability Block Diagram

Reliability Block Diagram



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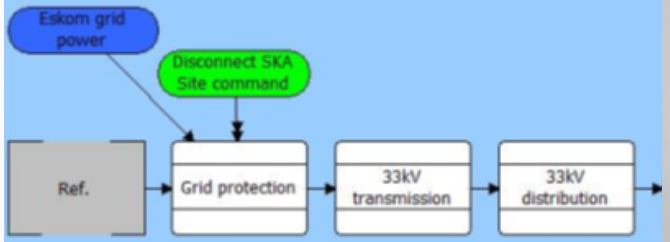

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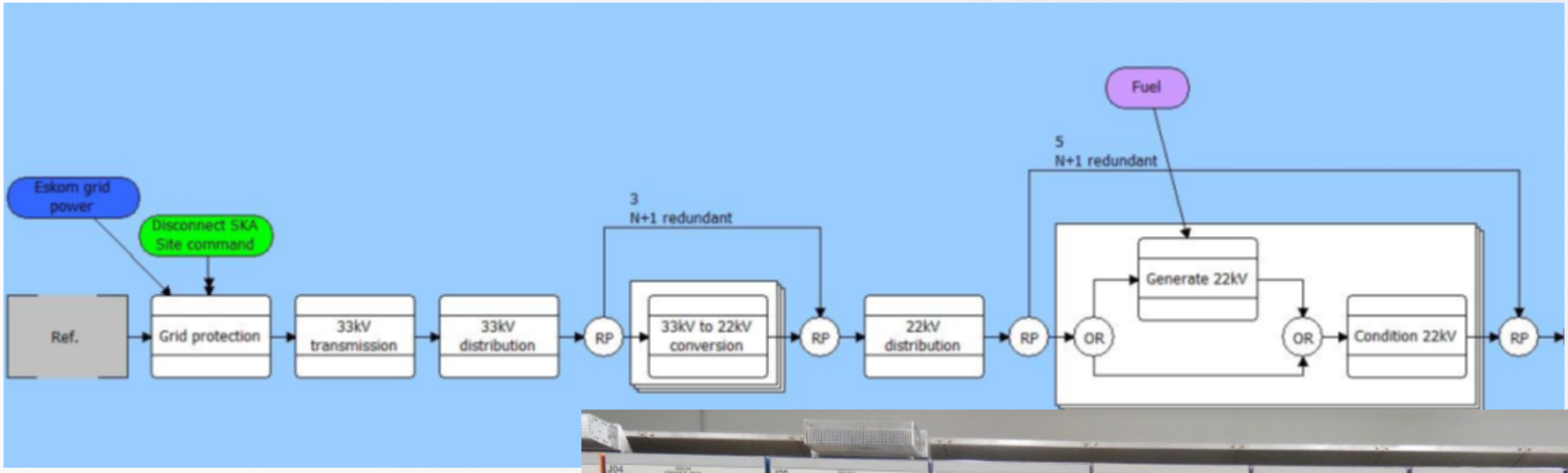
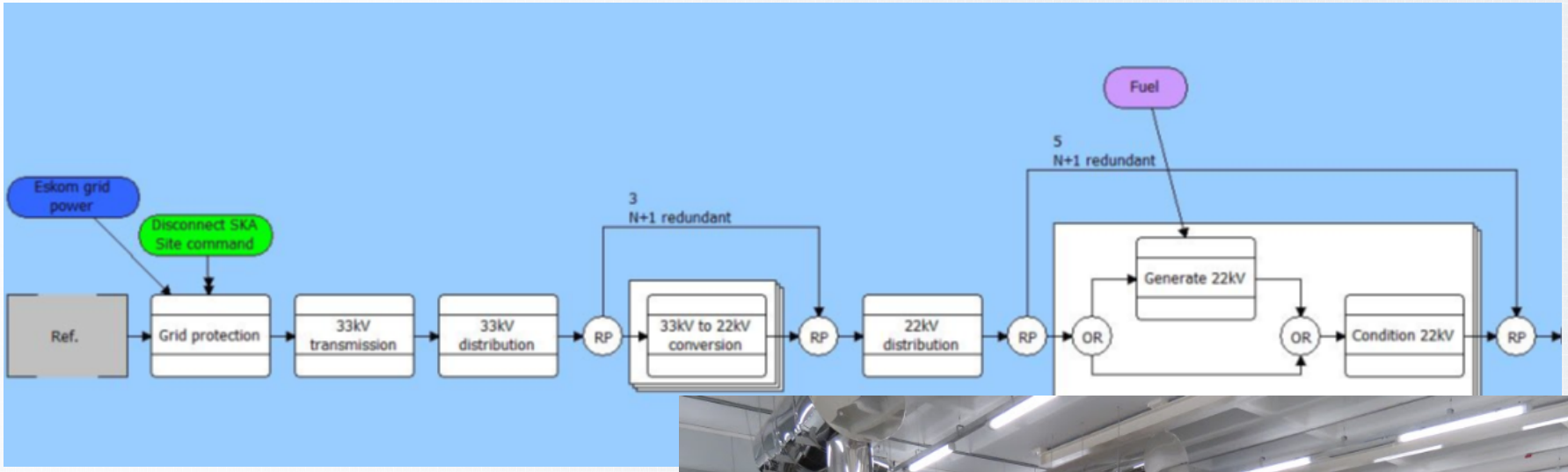


Reliability Block Diagram



Reliability Block Diagram

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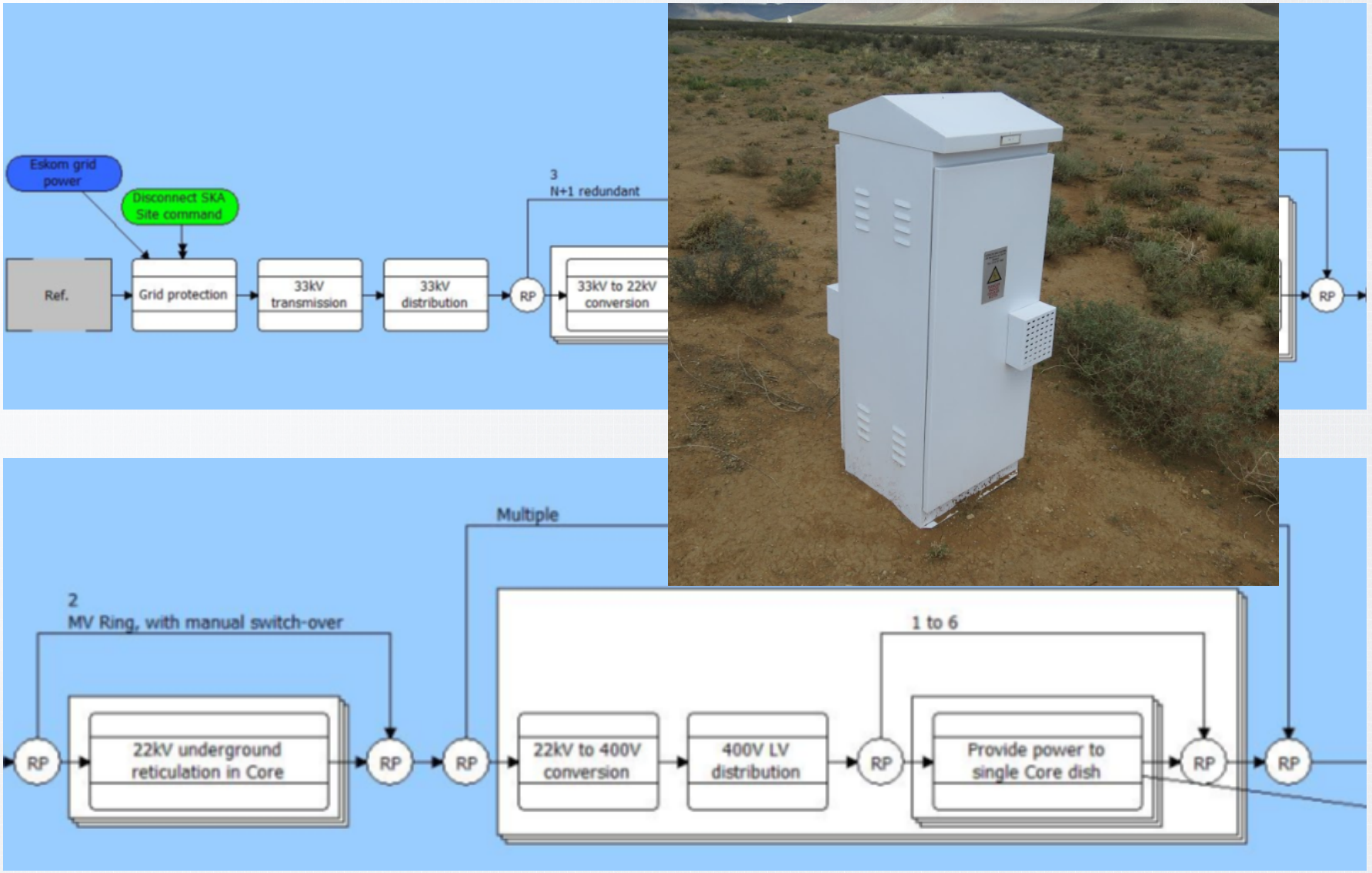

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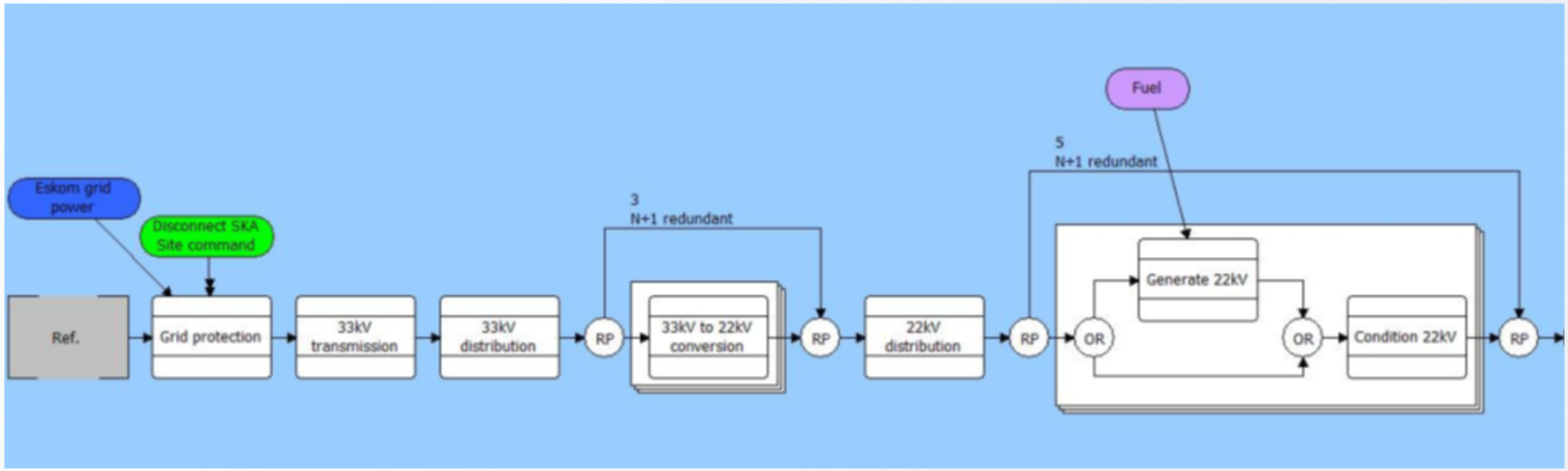
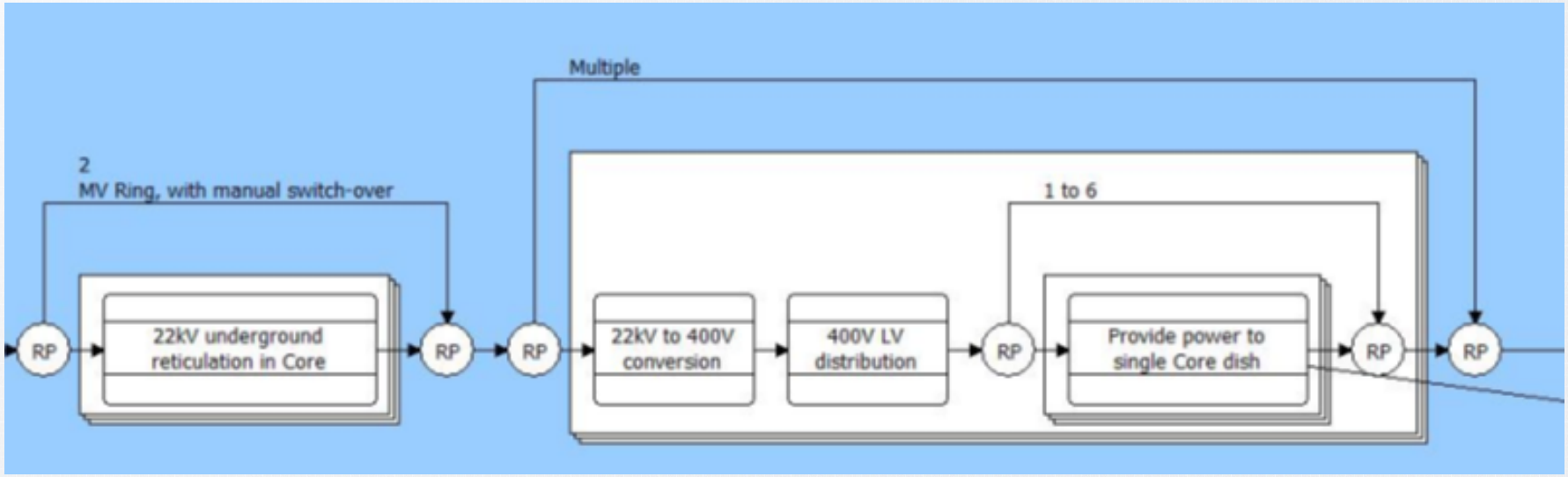
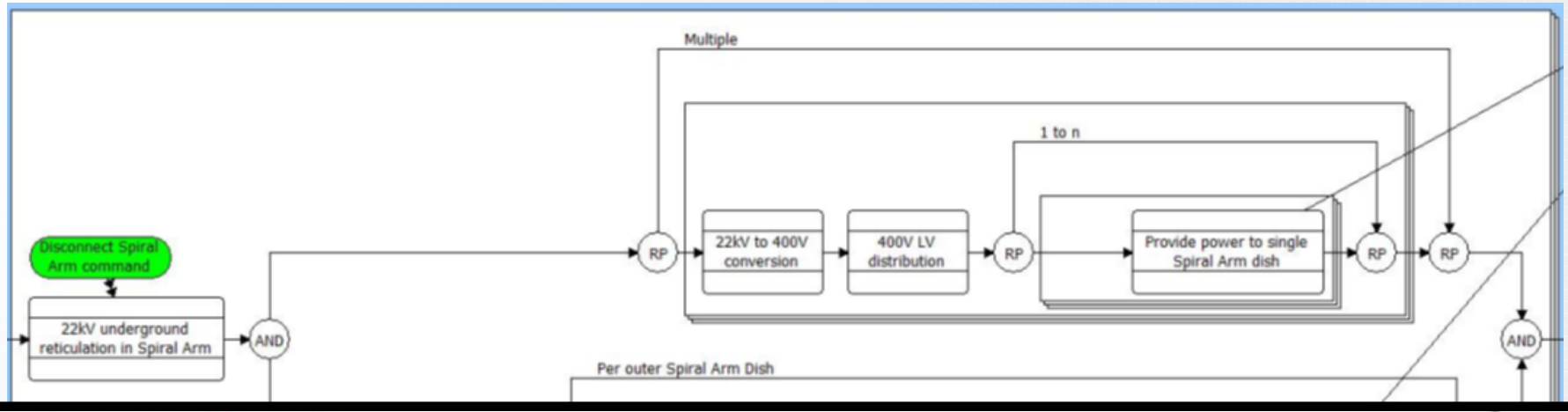
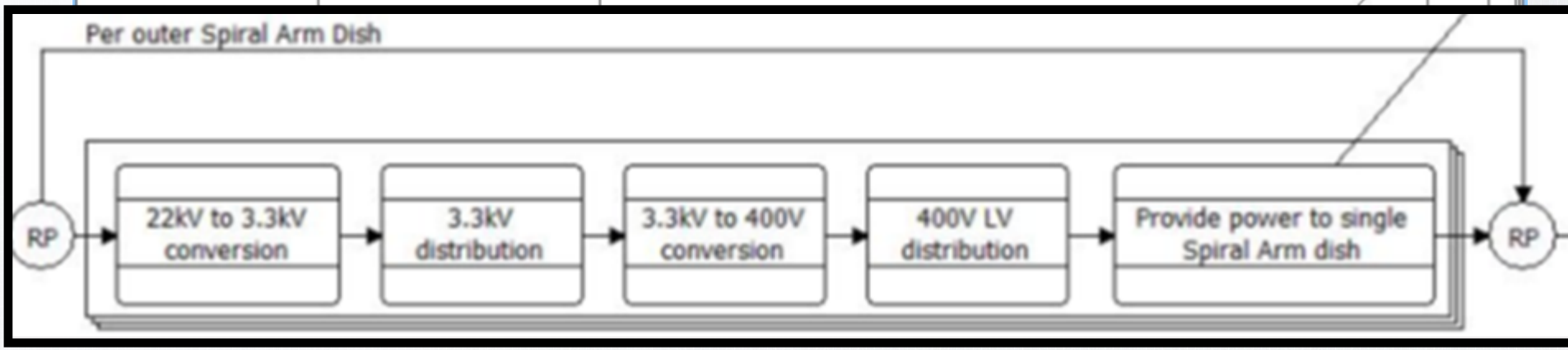


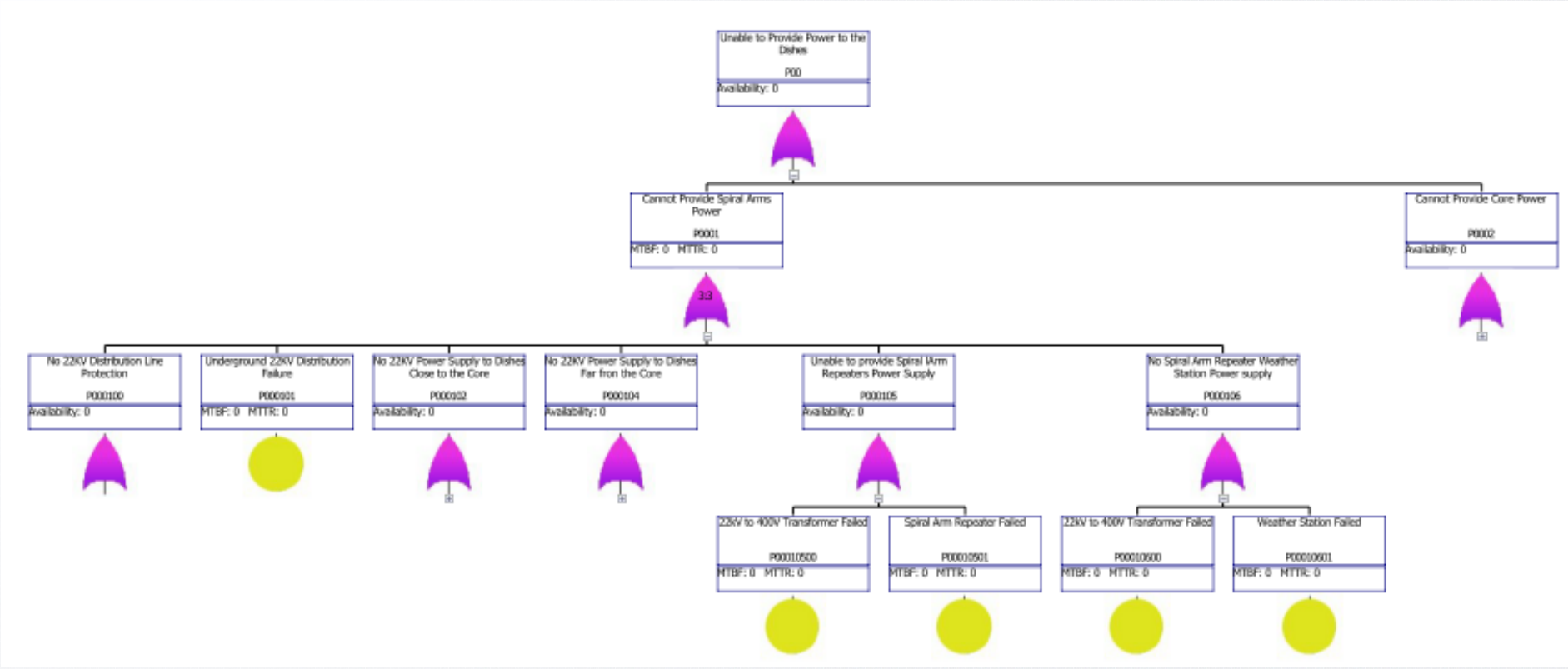


Reliability Block Diagram

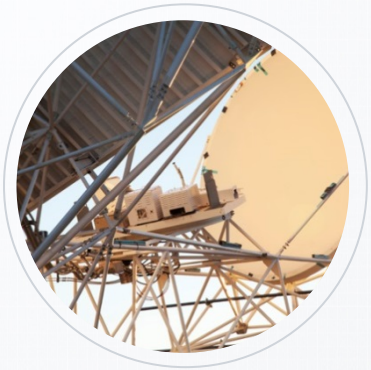




Fault Tree Analysis



Simulation Model

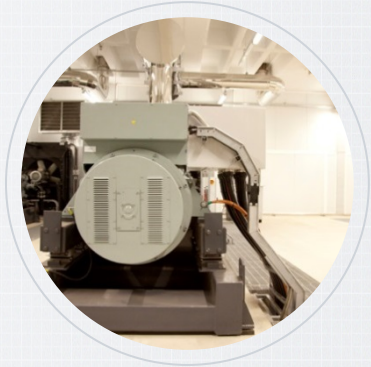


Flexible

Cater for multiple possible architectures

Self-generating

No coding to change architectures



Compute

189/197 dishes being powered

Compare

Support design decisions

Configurable component failure data

Function	MTBF (hours)	Probability distribution	MTTR (hours	Probability distribution		MTBF (days)	MTBF (years)
Eskom Grid power	720	UNIFORM	4	NORMAL	99.4444%	30	0
Grid protection	87600	WEIBULL	24	NORMAL	99.9726%	3650	10
33kV transmission	8760	UNIFORM	24	NORMAL	99.7260%	365	1
33kV distribution	87600	WEIBULL	72	NORMAL	99.9178%	3650	10
33kV to 22kV conversion	219000	WEIBULL	72	NORMAL	99.9671%	9125	25
22kV distibution	87600	WEIBULL	72	NORMAL	99.9178%	3650	10
DRUPS generate 22kV	87600	WEIBULL	168	NORMAL	99.8082%	3650	10
DRUPS condition 22kV	131400	WEIBULL	168	NORMAL	99.8721%	5475	15
22kV to 400V conversion	219000	WEIBULL	72	NORMAL	99.9671%	9125	25
400V cable minisub to kiosk	438000	WEIBULL	4	NORMAL	99.9991%	18250	50
Kiosk	131400	WEIBULL	24	NORMAL	99.9817%	5475	15
400V cable to dish	438000	WEIBULL	4	NORMAL	99.9991%	18250	50
RMU	876000	WEIBULL	4	NORMAL	99.9995%	36500	100
Ring_Disconnect_Switch	876000	WEIBULL	4	NORMAL	99.9995%	36500	100
Ring_cable	438000	WEIBULL	12	FIXED	99.9973%	18250	50
Spiral_underground_cable	438000	WEIBULL	12	NORMAL	99.9973%	18250	50
Spiral_22kV_transmission	17520	UNIFORM	24	NORMAL	99.8630%	730	2.0
22kV tapoff to transformer	219000	WEIBULL	72	NORMAL	99.9671%	9125	25
22kV to 3.3kV conversion	219000	WEIBULL	72	NORMAL	99.9671%	9125	25
3.3kV cable	438000	WEIBULL	12	NORMAL	99.9973%	18250	50
3.3kV to 400V conversion	219000	WEIBULL	72	NORMAL	99.9671%	9125	25
400V to 3.3kV conversion	219000	WEIBULL	72	NORMAL	99.9671%	9125	25
Single dish PV	8760	WEIBULL	24	NORMAL	99.7260%	365	1

- MTBF, MTTR, distributions configurable per component type
- Uniform for acts of God, Weibull for wear-out, lognormal for repair time
- Standard deviation and shape

Configurable core architecture

Core	5	have	1	kiosks with outputs	1
	2	have	3	kiosks with outputs	1,1,1
	2	have	2	kiosks with outputs	1,1
	1	have	2	kiosks with outputs	2,5
	1	have	3	kiosks with outputs	4,3,2
	1	have	3	kiosks with outputs	1,2,4
	1	have	3	kiosks with outputs	6,1,3
	1	have	4	kiosks with outputs	3,2,5,3
	1	have	2	kiosks with outputs	3,4
	1	have	3	kiosks with outputs	6,6,3
	1	have	3	kiosks with outputs	5,3,6
	1	have	4	kiosks with outputs	3,2,2,4
	1	have	2	kiosks with outputs	3,6
	1	have	2	kiosks with outputs	2,1
	1	have	1	kiosks with outputs	3
	21	minisubs		123	core dishes

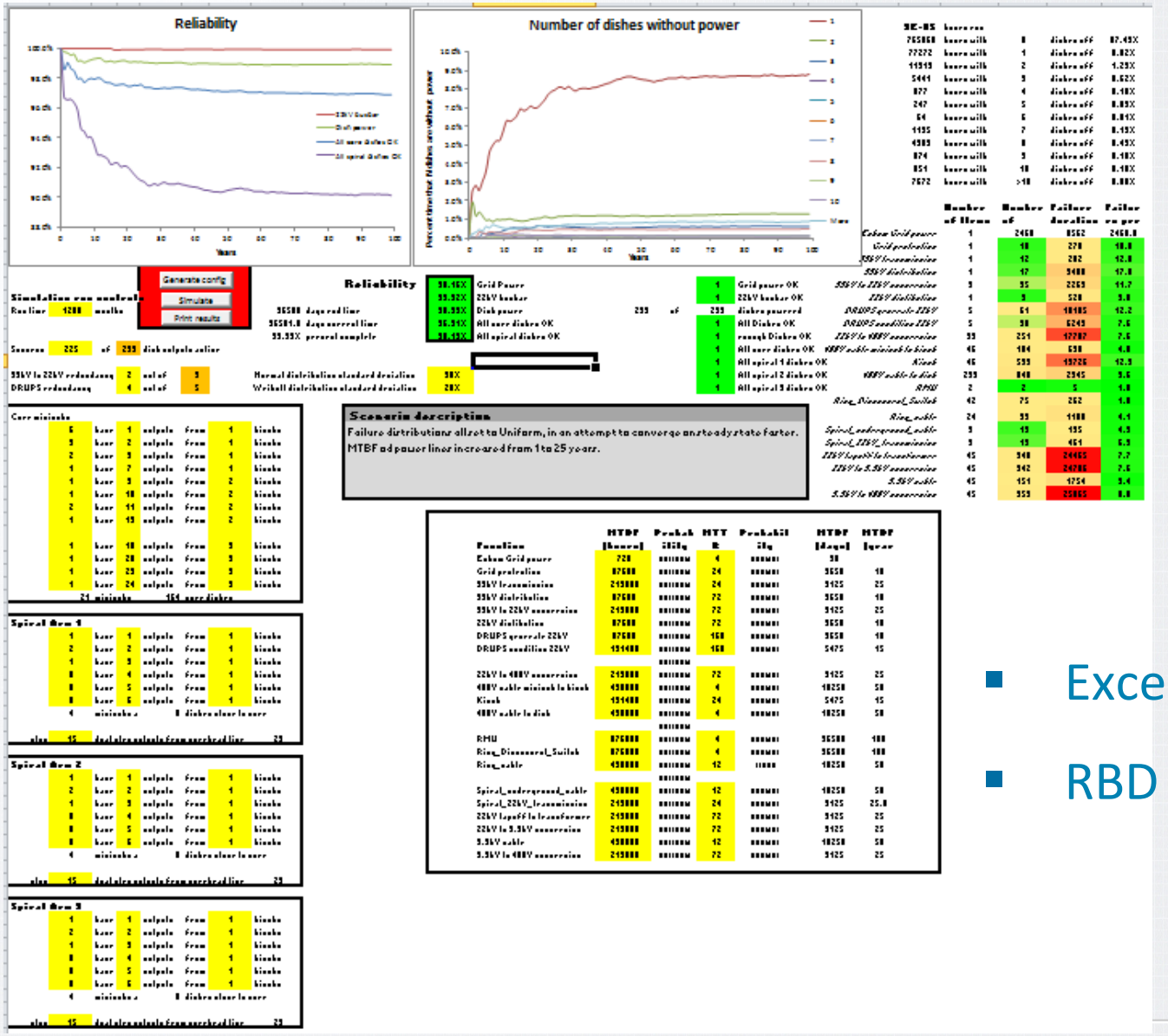
- Number of mini-subs
- Number of kiosks per mini-sub
- Number of receptors fed per individual kiosk

Configurable spiral arm architecture

Spiral Arm 1							
	4	have	1	outputs	from	1	kiosks
	0	have	0	outputs	from	0	kiosks
	0	have	3	outputs	from	1	kiosks
	0	have	4	outputs	from	1	kiosks
	0	have	5	outputs	from	1	kiosks
	0	have	6	outputs	from	1	kiosks
	4	minisubs and		4	dishes close to core		
plus	5	dual step outputs from overhead line					12

- Buried 22kV cable section with single minisub, single kiosk, single dish feed
- Overhead 22kV power line with dual-step outputs per dish
- PV plant per dish added later

Simulation Model



- Excel 2010, lots of VBA
- RBD and FTA as input

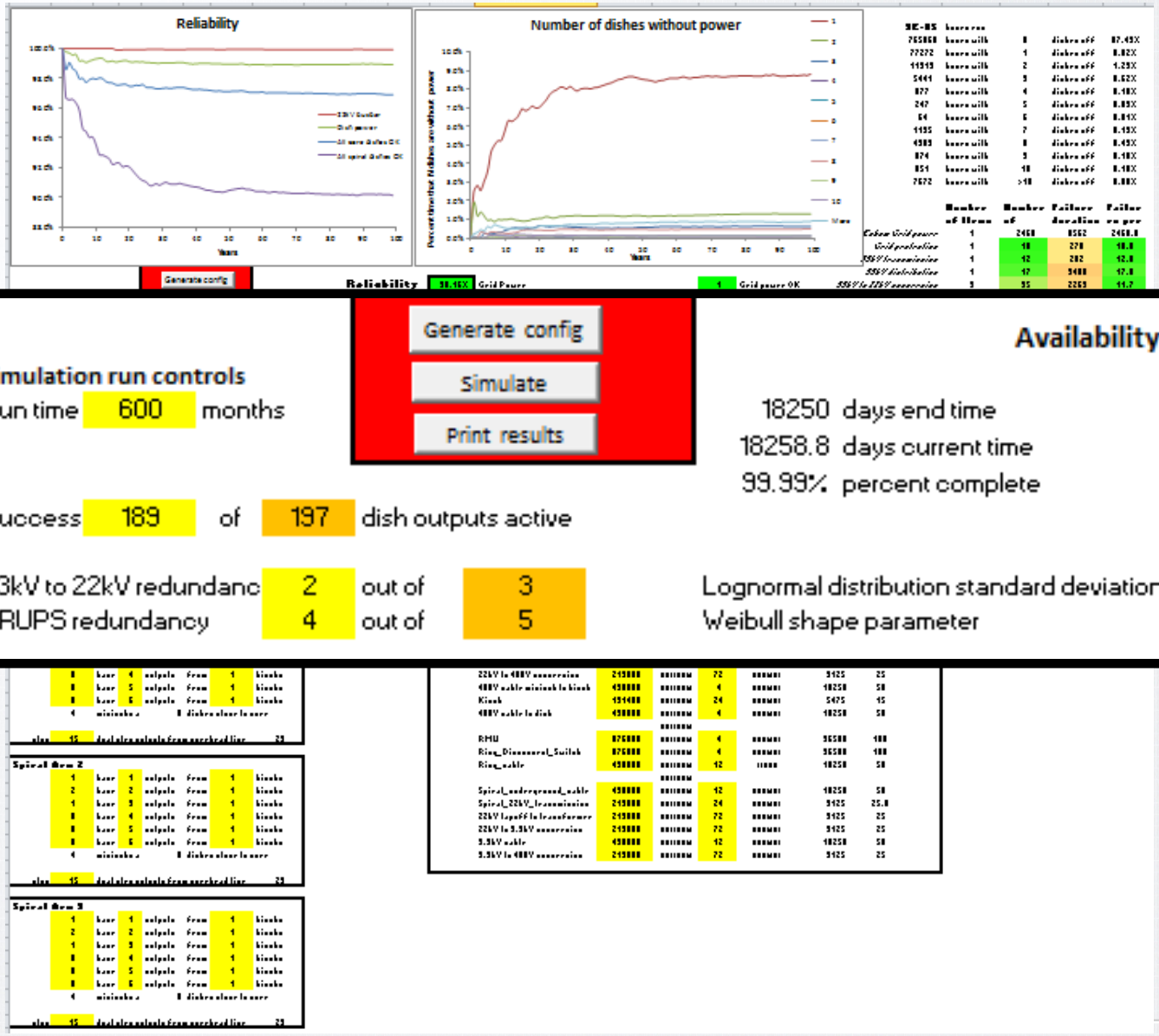
Simulation Model

- What it does:
  - For a selected configuration
  - …with selected failure probability distributions
  - ..it generates the equations
  - ..for that configuration
  - ..then predicts failures
  - ..and determines the end effect
  - ..considering selected redundancy
  - ..to compute availability over a selected time

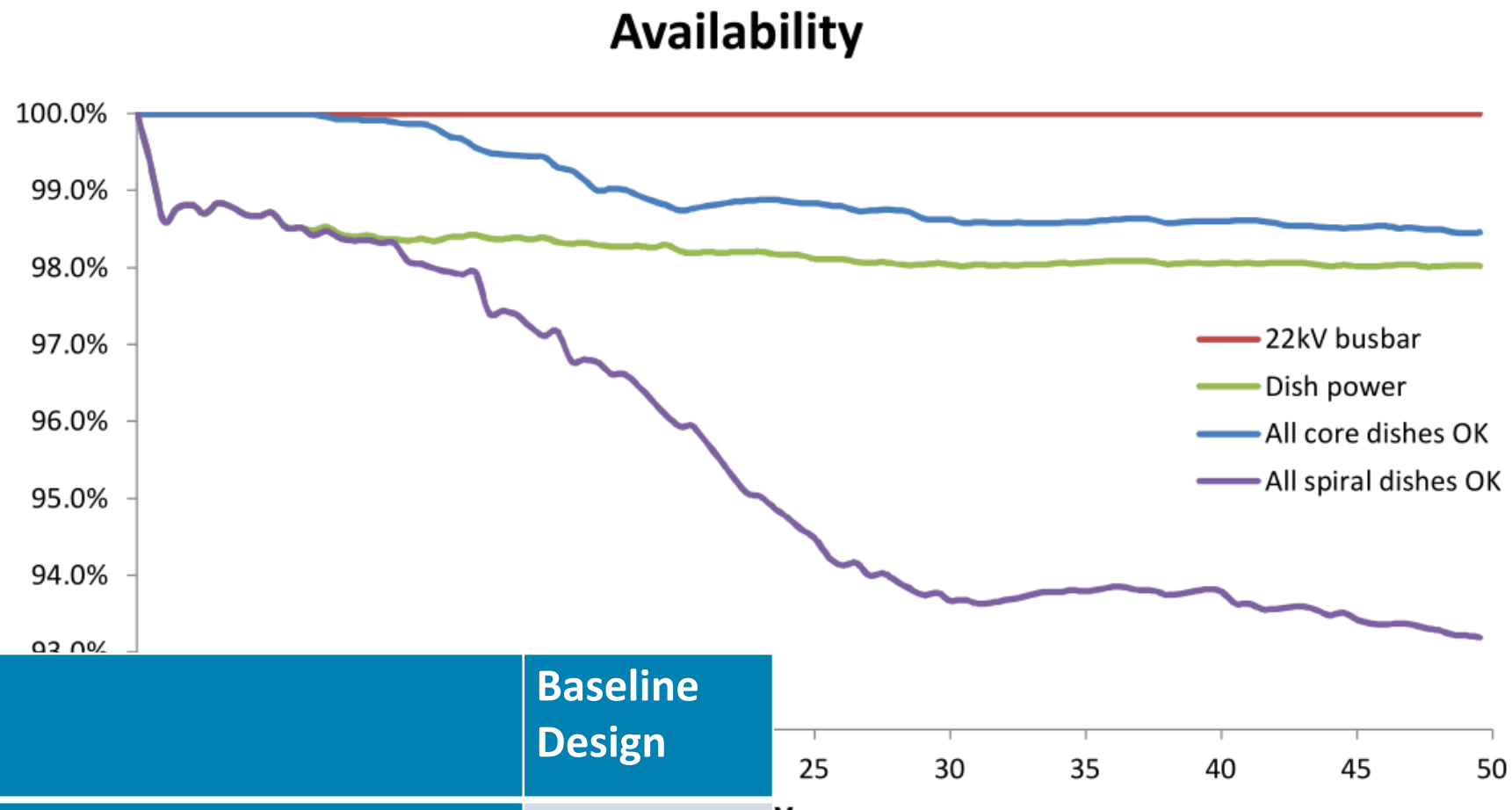
Simulation Model

- What it doesn't do:
  - Predict *achieved* availability
  - Predict maintenance trends
  - Predict absolute numbers for inherent availability
    - ✓ *(the best I can do is **relative** numbers for different configurations)*

Simulation Model

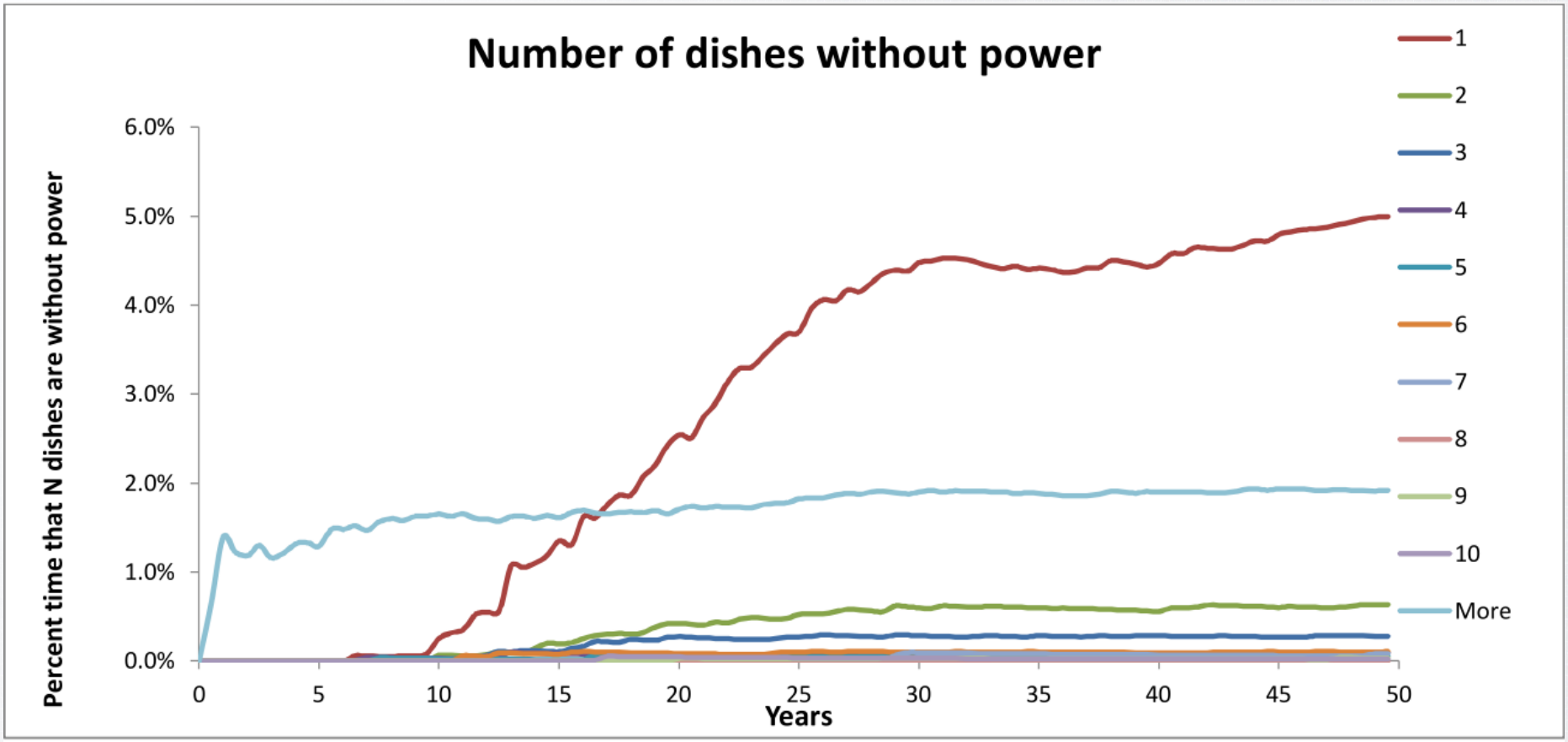


Baseline Design

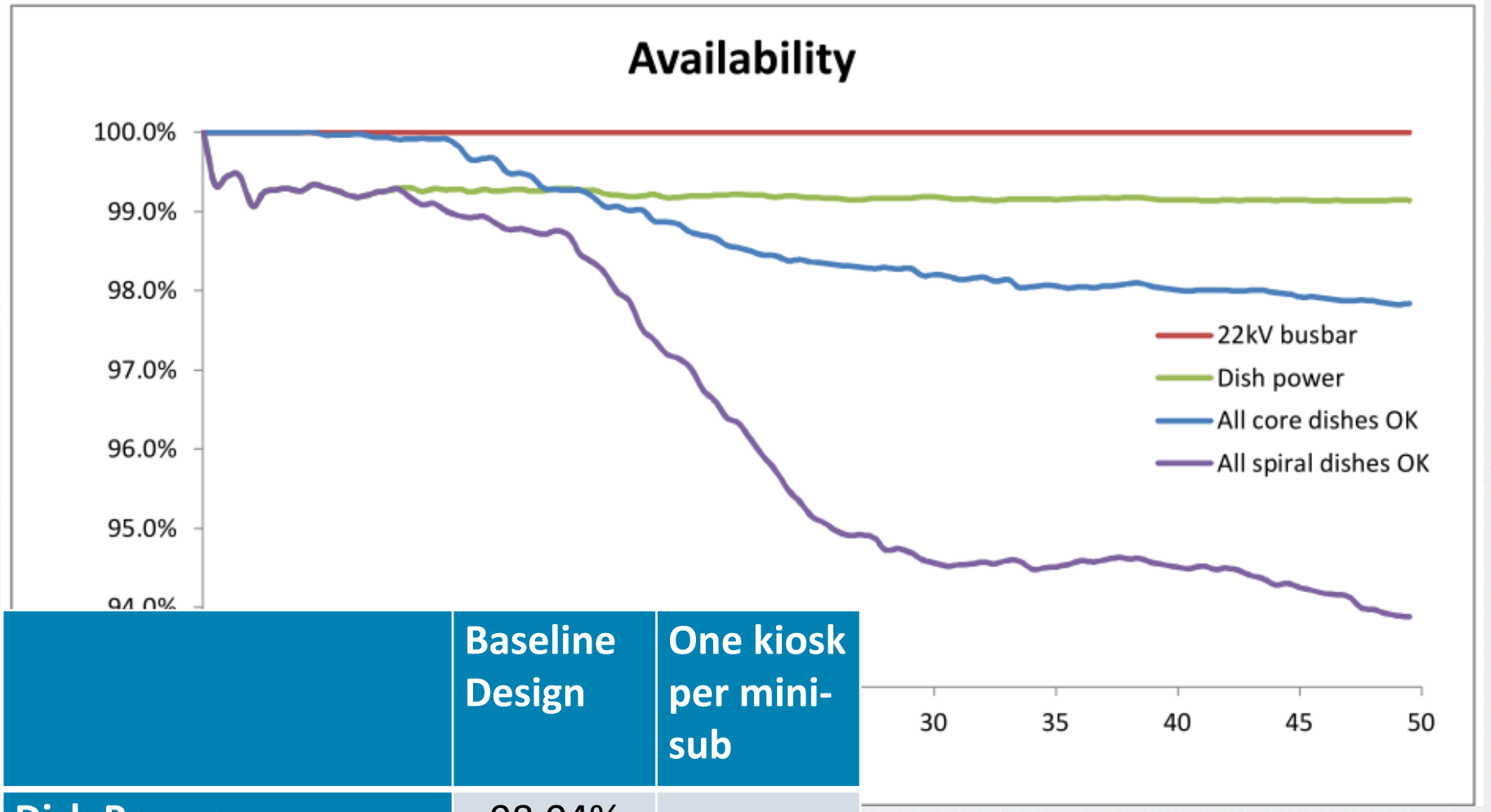


	Baseline Design
Dish Power	98.04%
All core dishes OK	98.02%
All spiral arm dishes OK	93.18%

Baseline Design

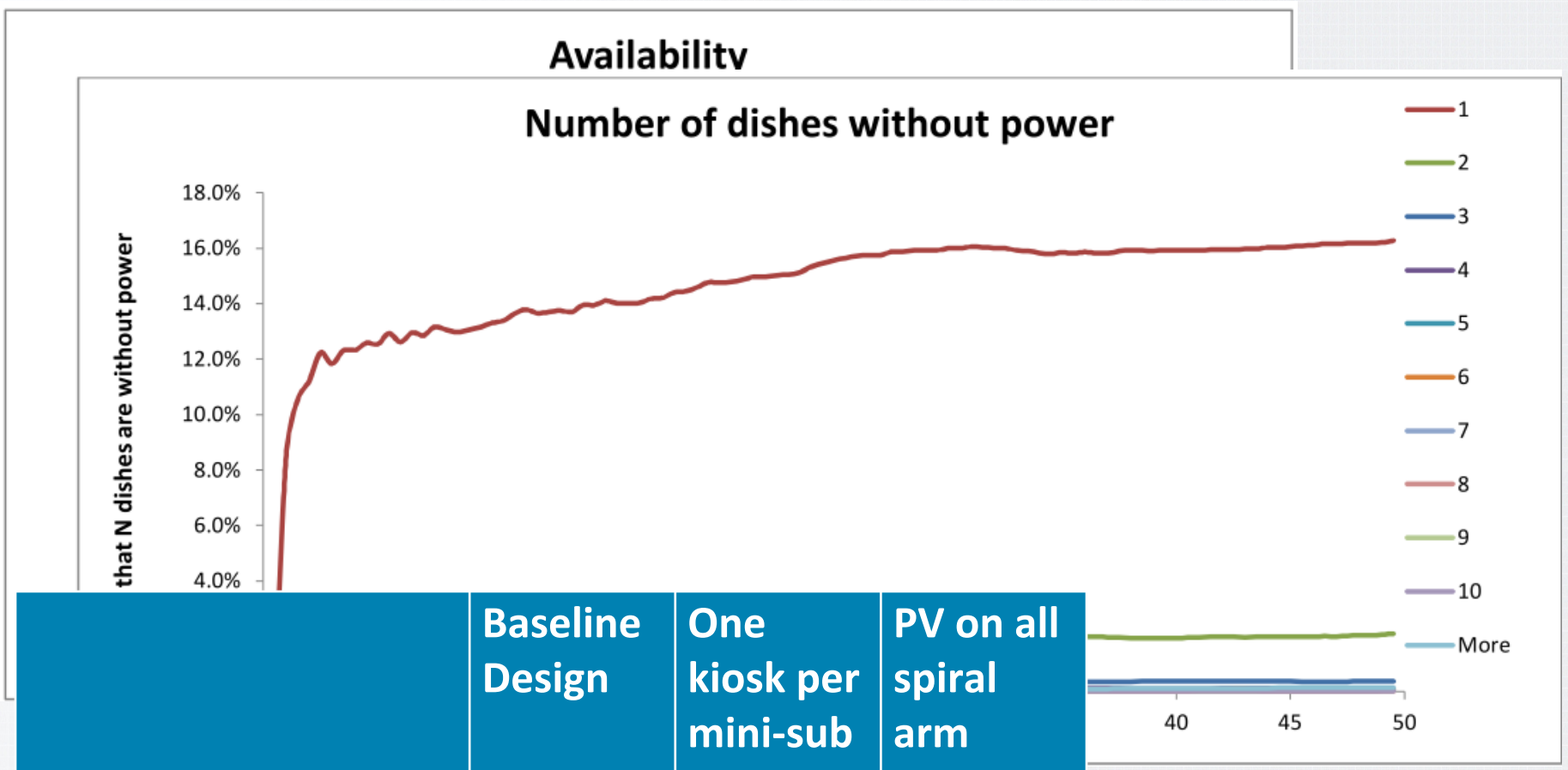


One kiosk per mini-sub, better 22kV overhead



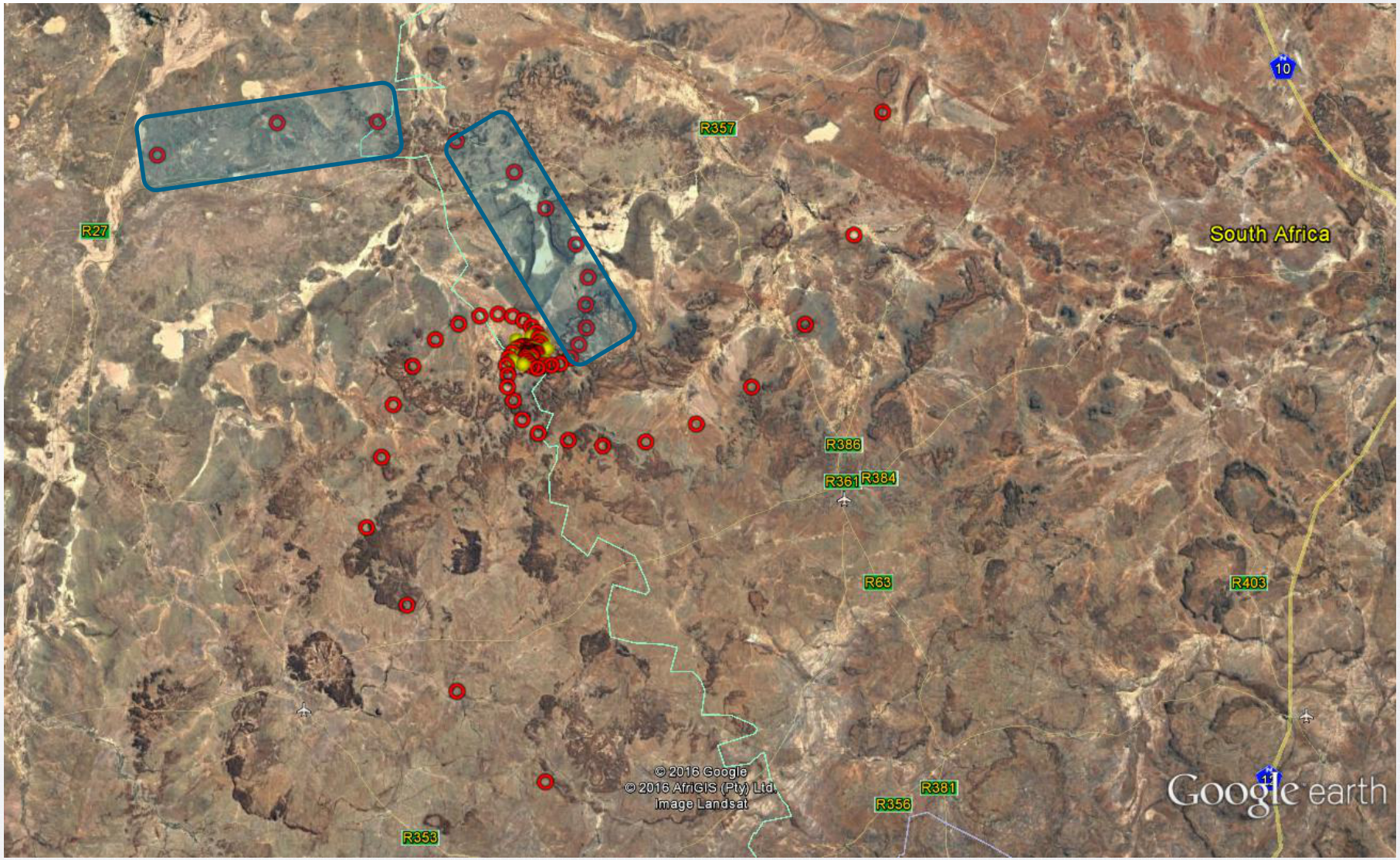
	Baseline Design	One kiosk per mini-sub
Dish Power	98.04%	---------
All core dishes OK	98.02%	97.83%
All spiral arm dishes OK	93.18%	93.82%

PV on outer spiral arm receptors

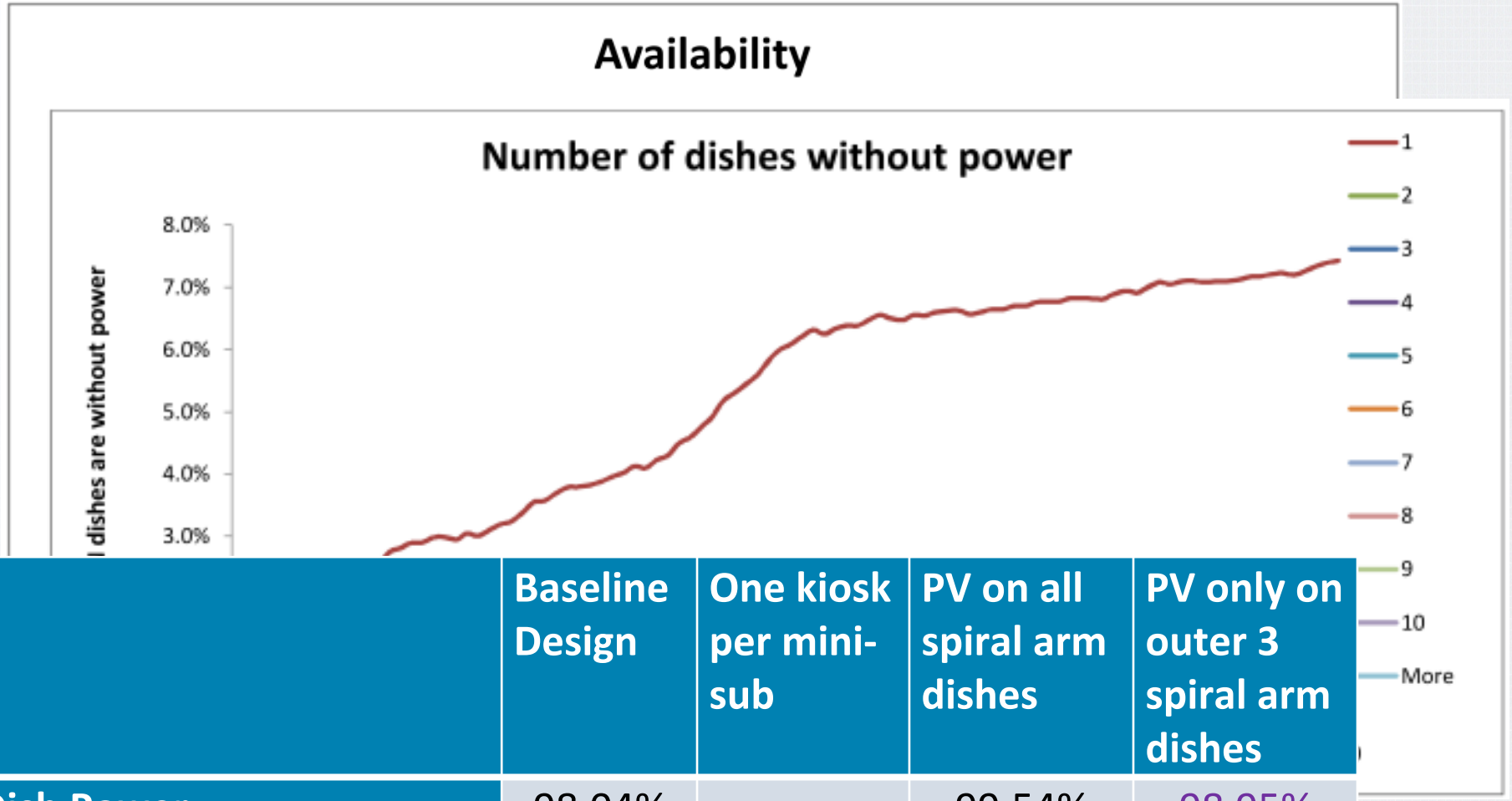


	Baseline Design	One kiosk per mini-sub	PV on all spiral arm dishes
Dish Power	98.04%	-----	99.54%
All core dishes OK	98.02%	97.83%	98.43%
All spiral arm dishes OK	93.18%	93.82%	81.77%

PV on last three spiral arm receptors

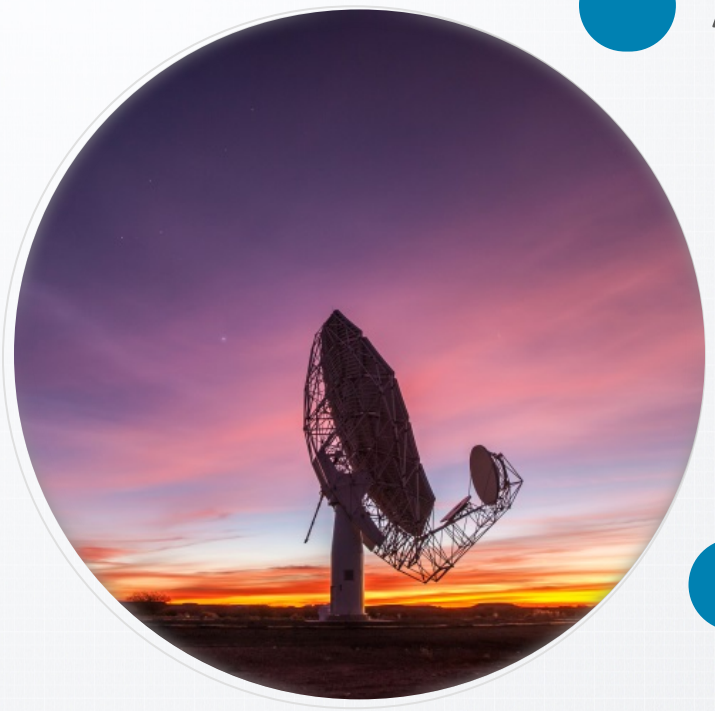


PV on last three spiral arm receptors



	Baseline Design	One kiosk per mini-sub	PV on all spiral arm dishes	PV only on outer 3 spiral arm dishes
Dish Power	98.04%	-----	99.54%	98.95%
All core dishes OK	98.02%	97.83%	98.43%	98.40%
All spiral arm dishes OK	93.18%	93.82%	81.77%	91.58%

Reflections and Conclusions



- Availability doesn't always cost more…
- ..if designed for up front
- Implications visible, iterate
- Excel/VBA vs commercial
- PV being investigated
- Power network design ongoing

science & technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

SKA South Africa, a Business Unit of the National Research Foundation.

We are building the Square Kilometre Array radio telescope (SKA), located in South Africa and eight other African countries, with part in Australia. The SKA will be the largest radio telescope ever built and will produce science that changes our understanding of the universe