

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

IS2017 Conference 2017

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It was a dark
and stormy night.

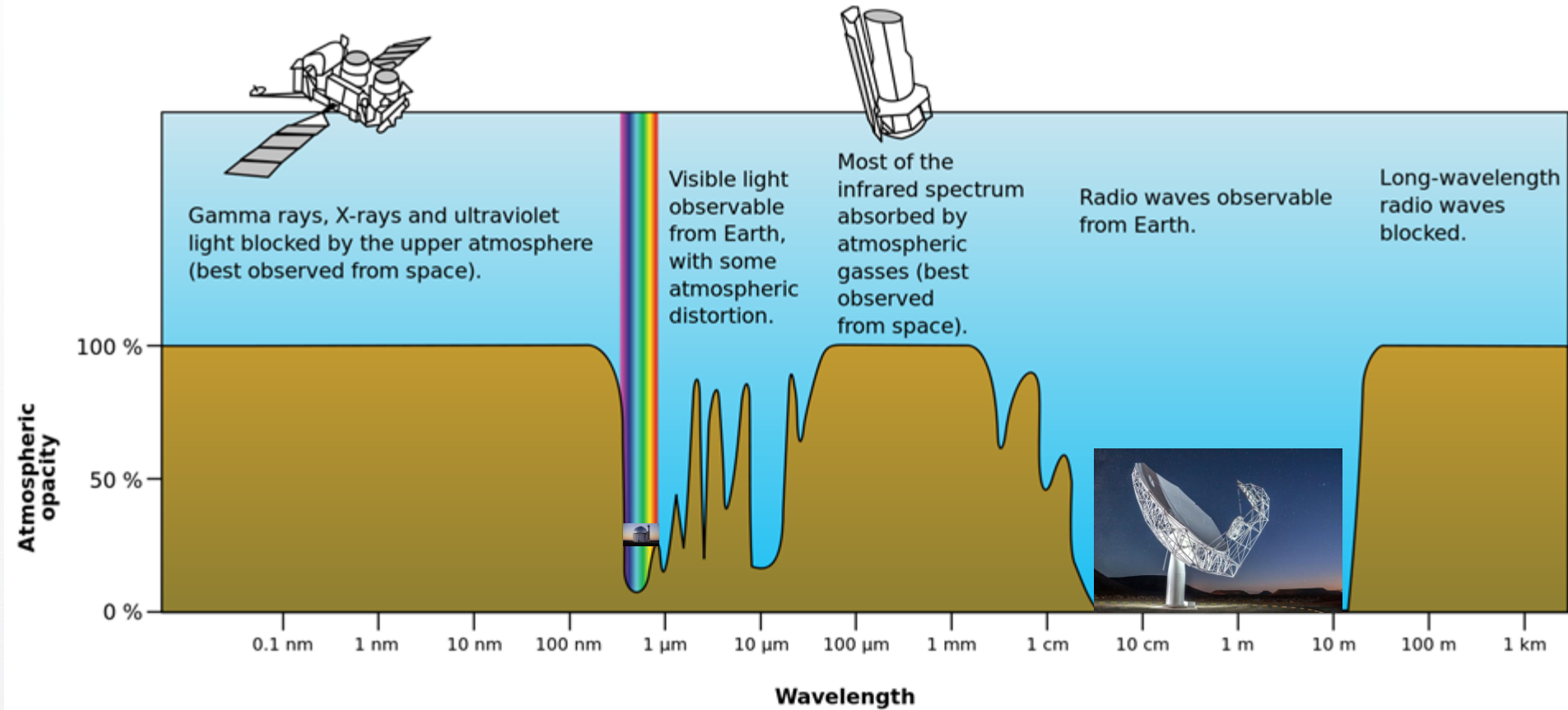


3-13

A large radio telescope dish is positioned on the left side of the frame, its white support structure and metal mesh dish clearly visible. The dish is angled towards the right. In the background, a smaller dish is also visible. The scene is set in a desert landscape with sparse, low-lying vegetation. The sun is low on the horizon, creating a bright orange glow and long, dark shadows. The sky is a mix of blue and orange hues. A blue speech bubble with a white border points from the right towards the telescope dish.

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/#.V8A4QvI96Cg>

Why a radio telescope?



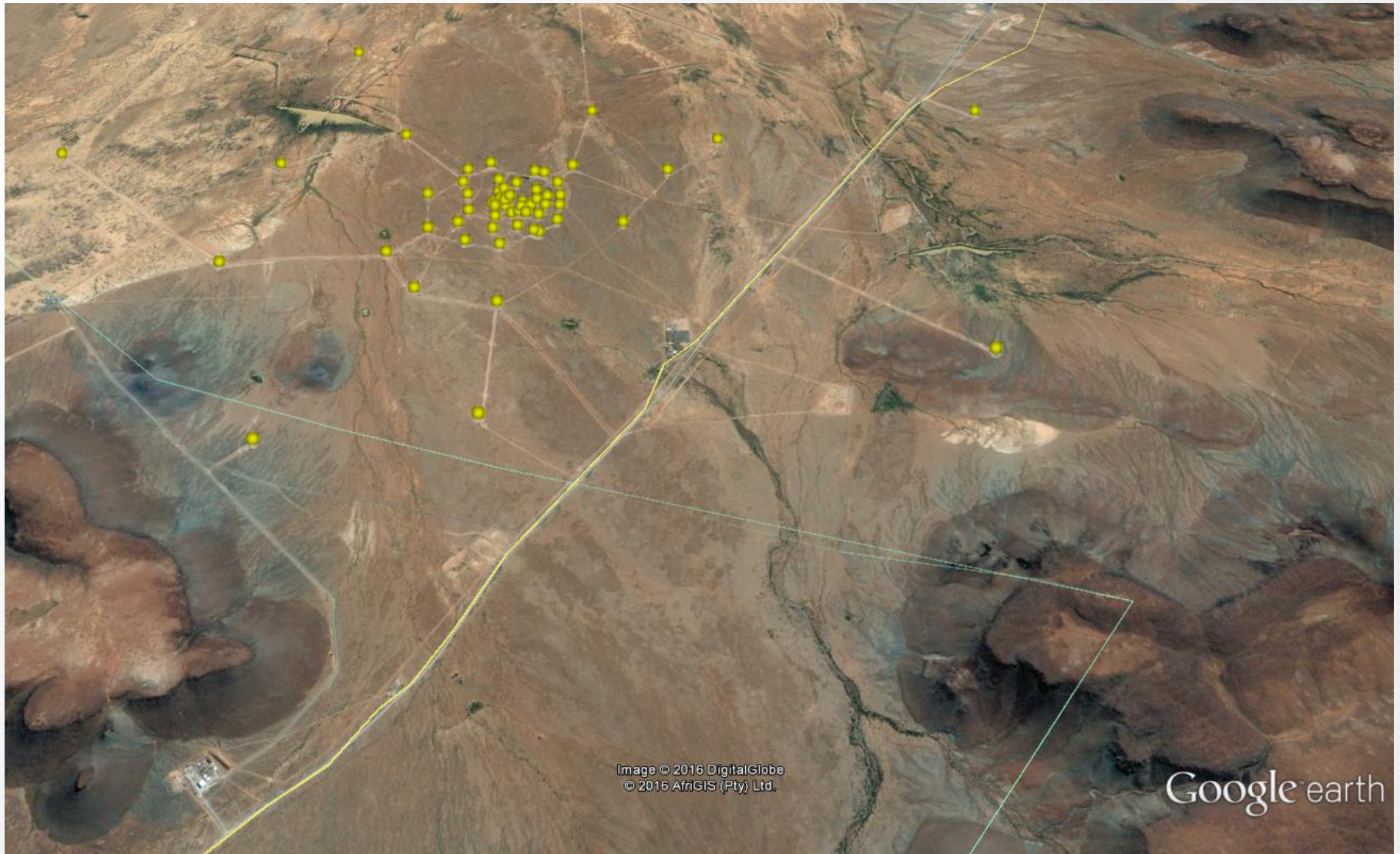
Why a radio telescope?

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

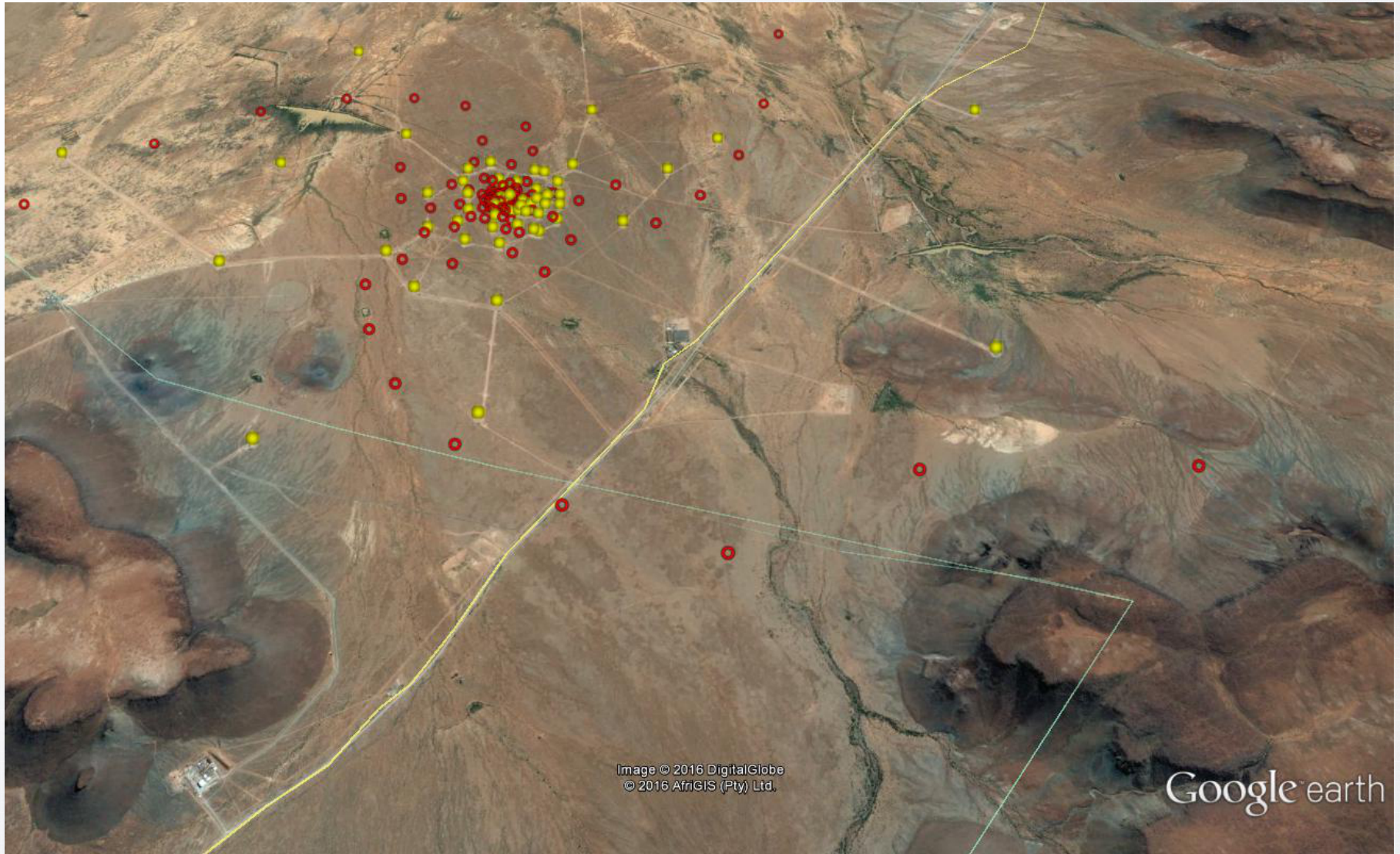
MeerKAT single receptor



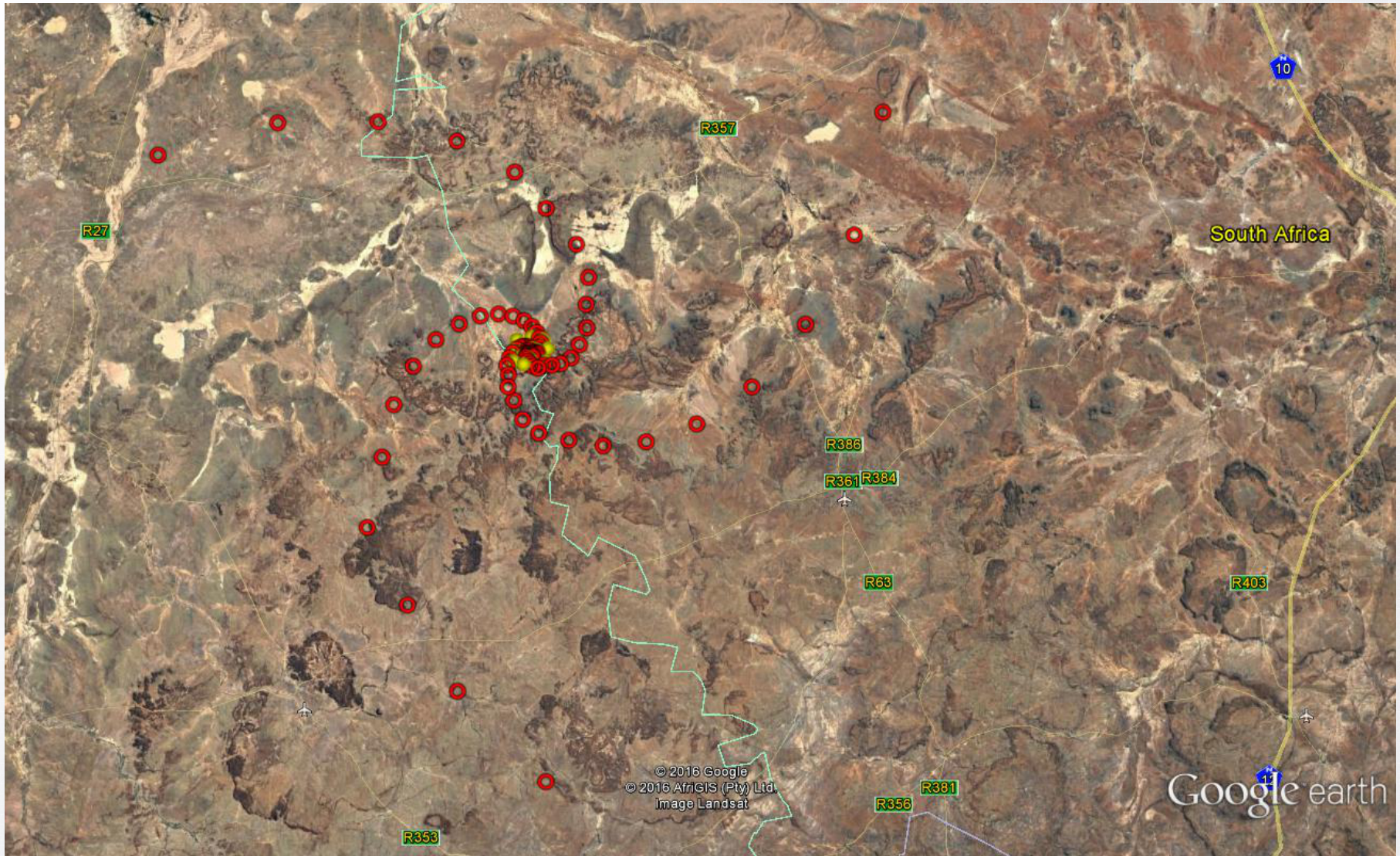
MeerKAT layout



SKA1 layout



SKA1 layout



Availability

System level 95%

Dish power network 99.9%



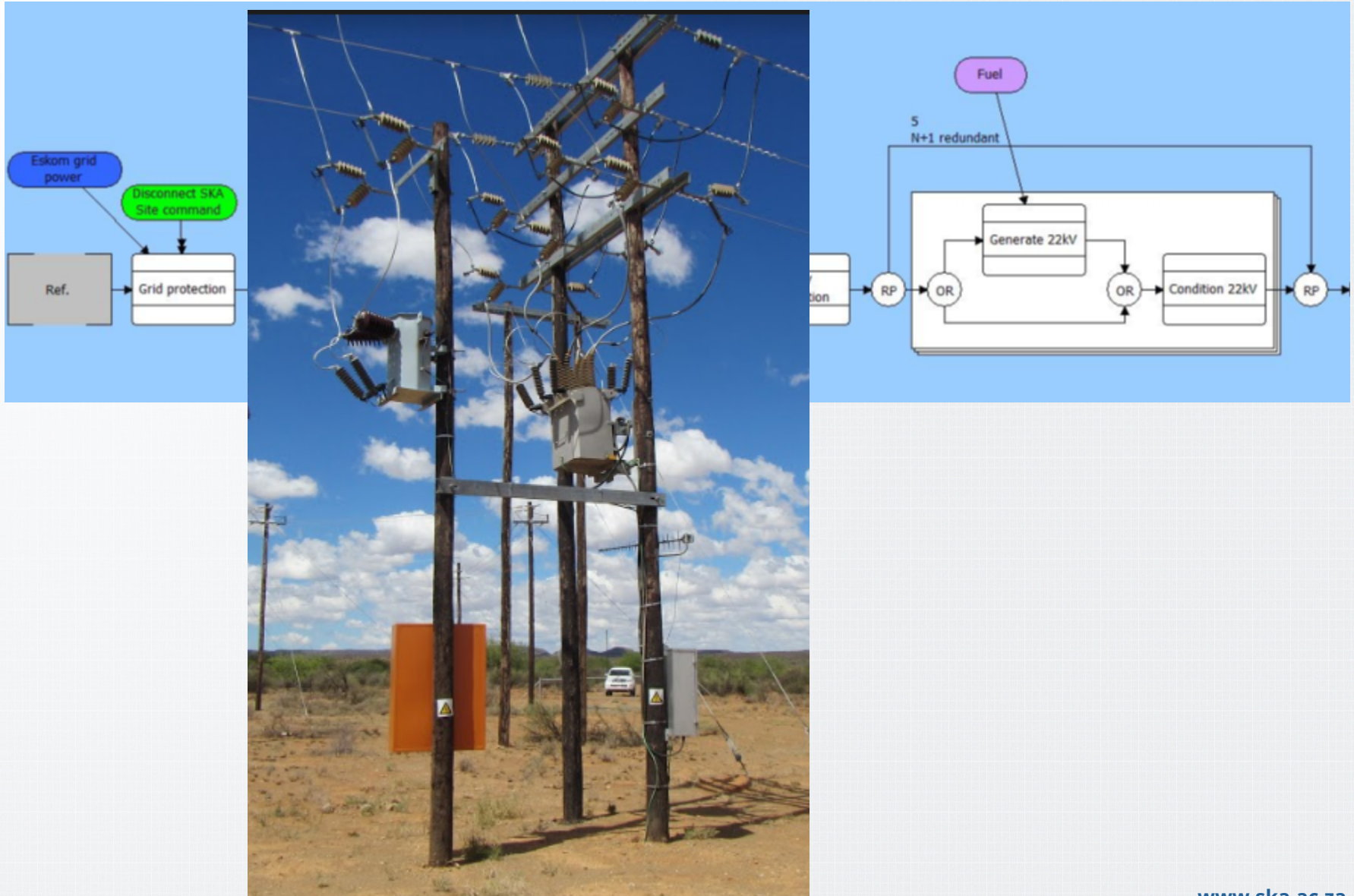
-> propose a realistic number



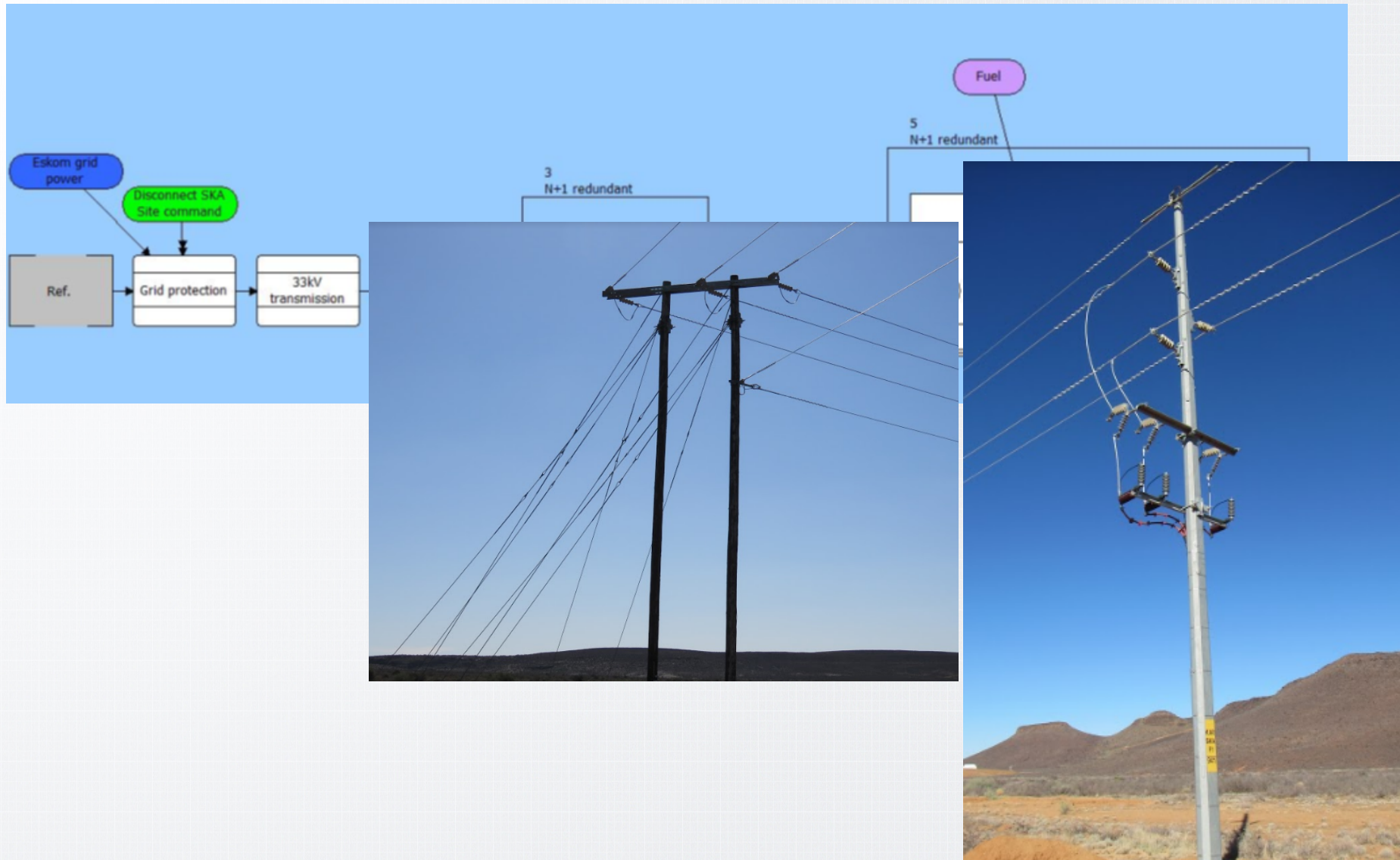
Approach

- 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

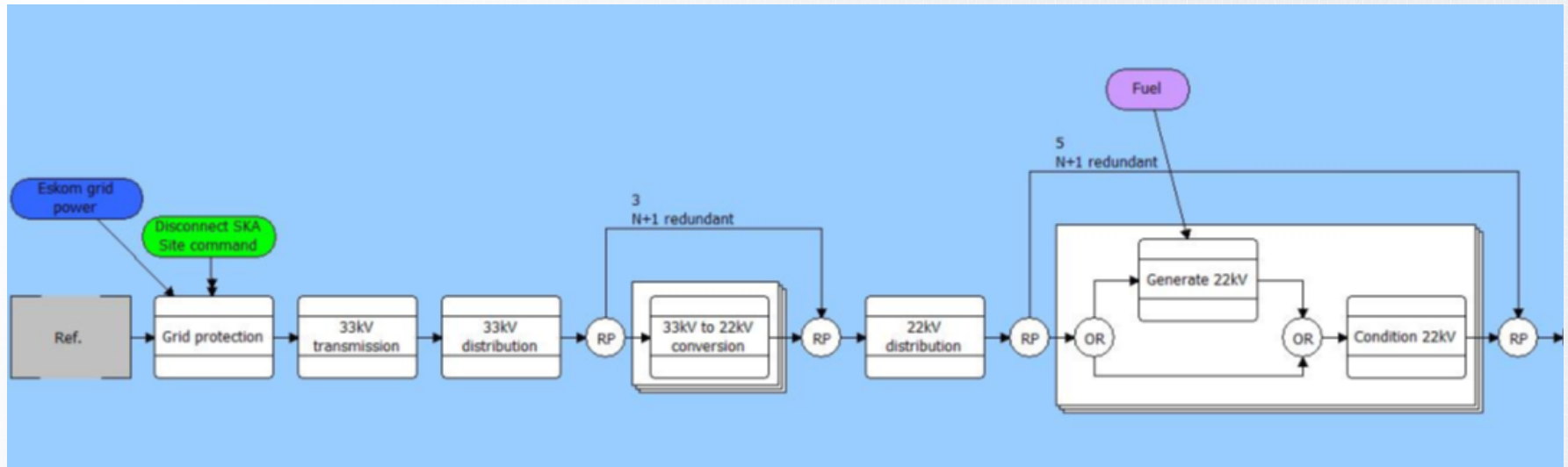
Reliability Block Diagram



Reliability Block Diagram



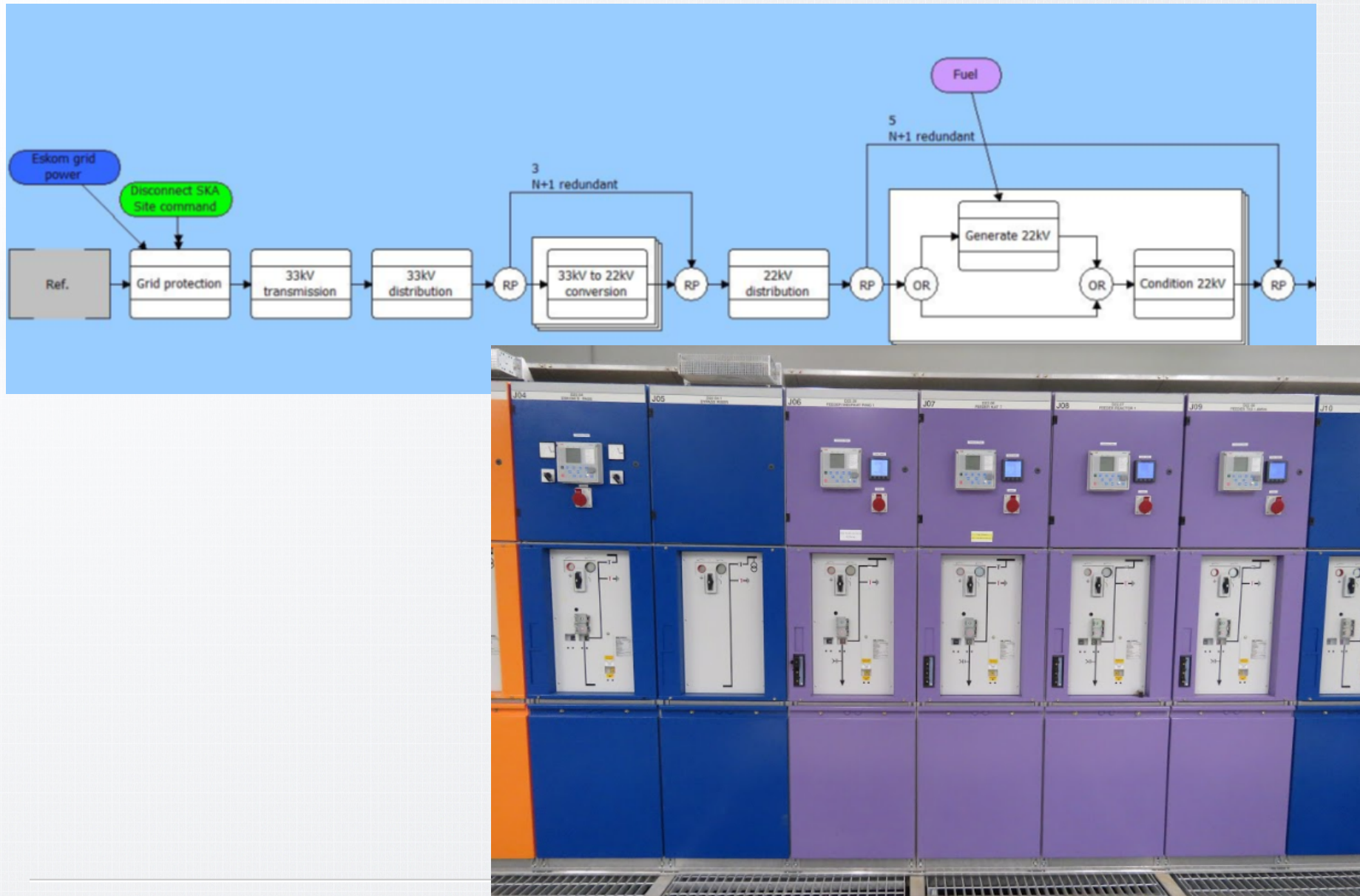
Reliability Block Diagram



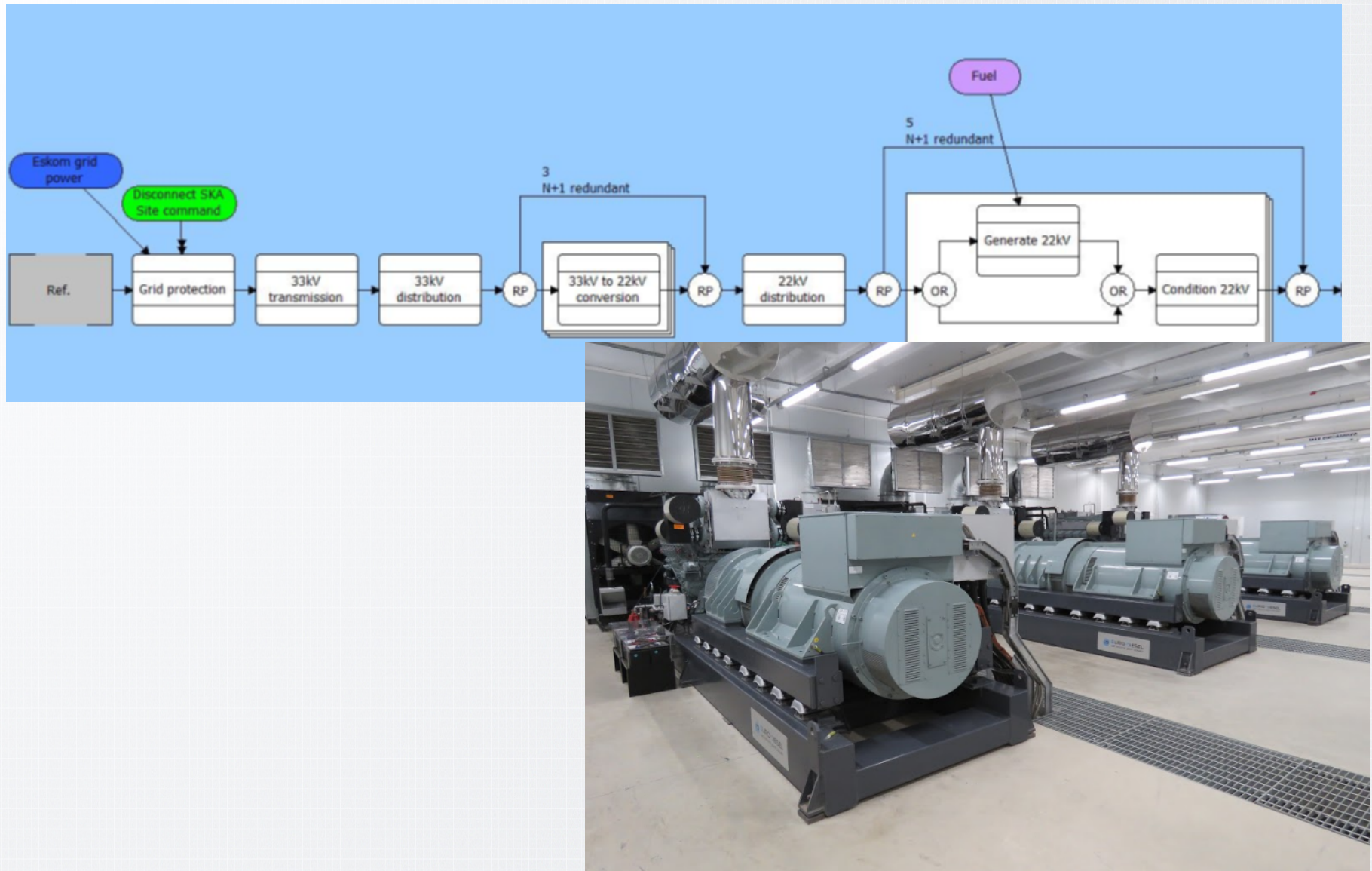
Reliability Block Diagram



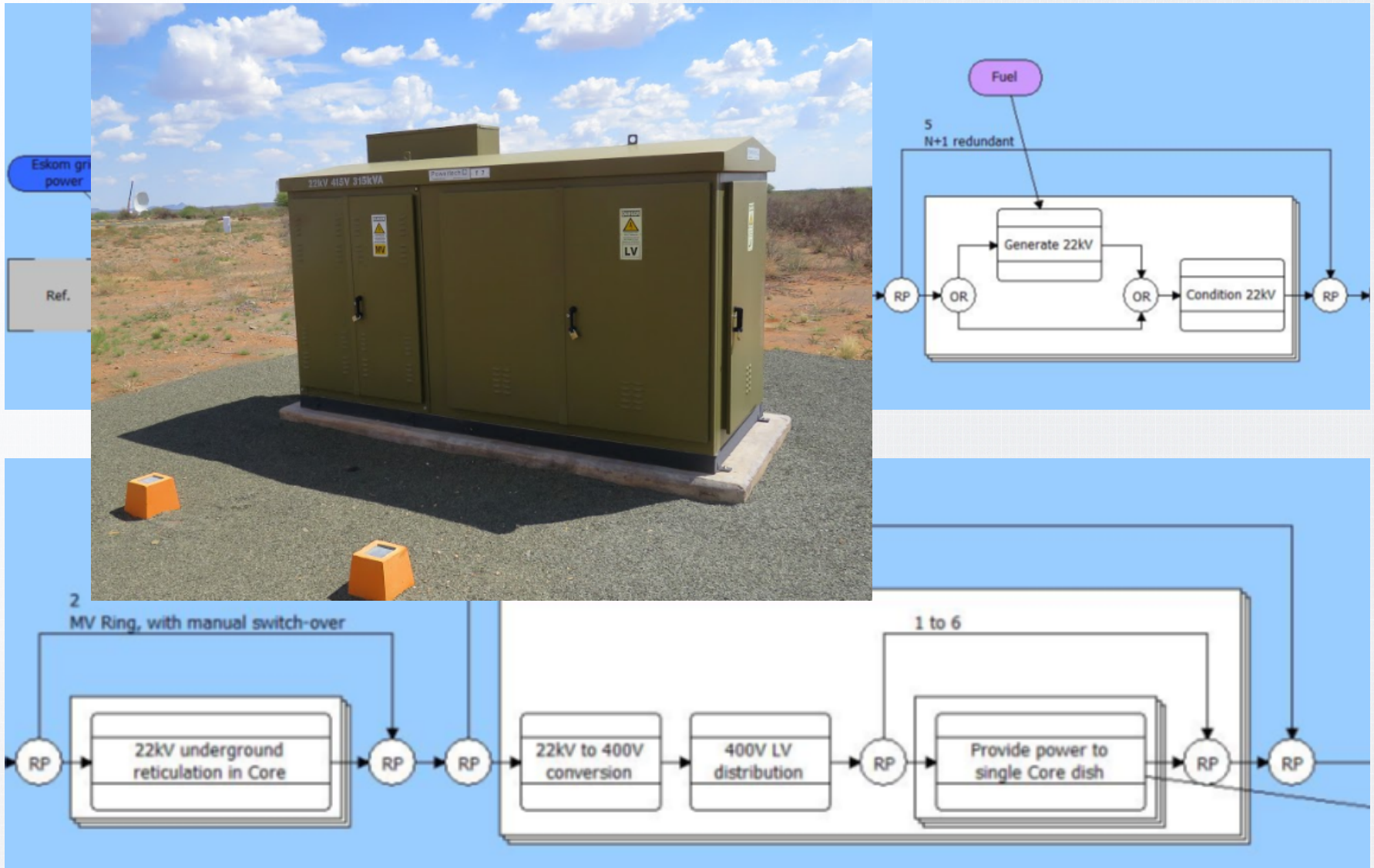
Reliability Block Diagram



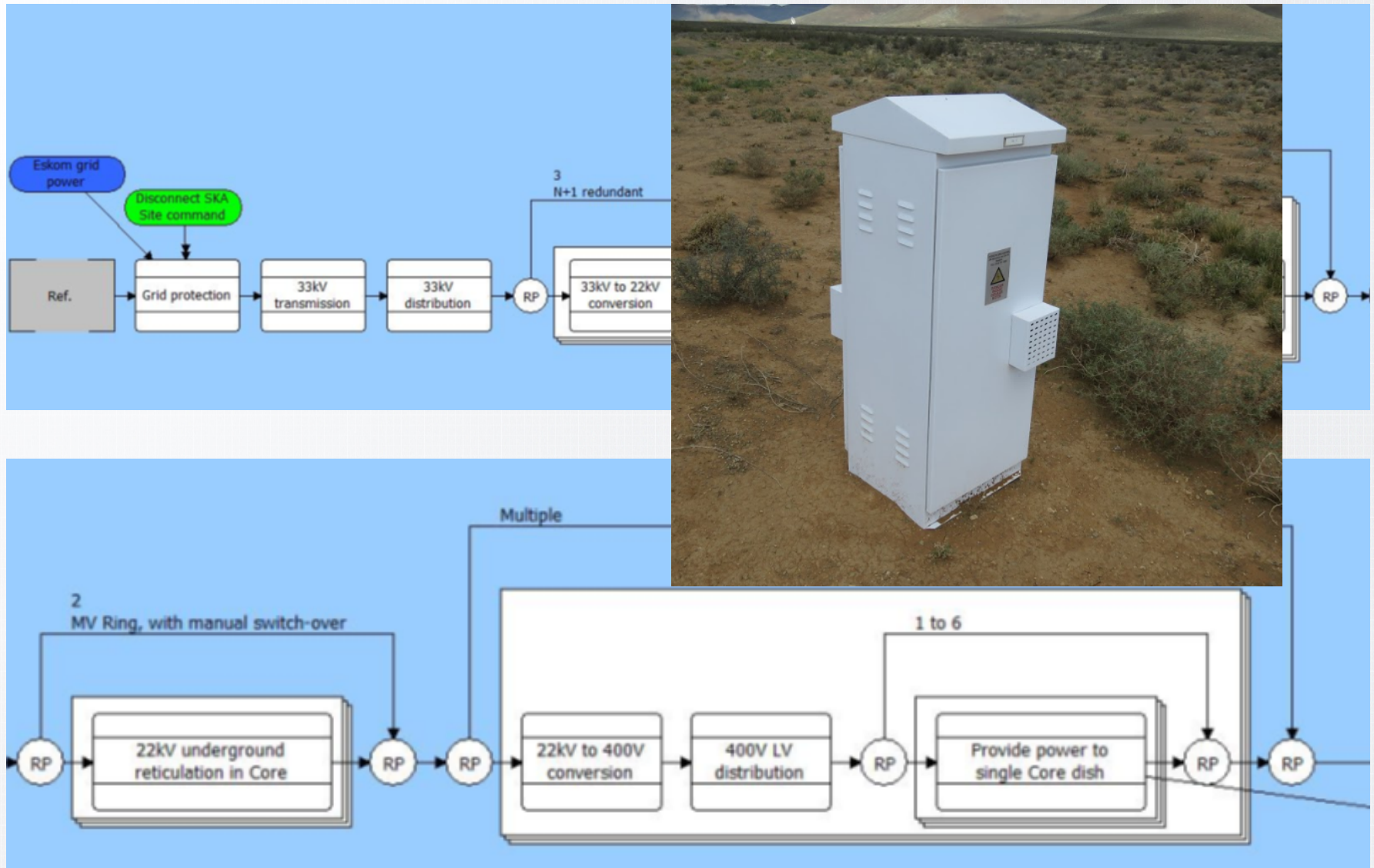
Reliability Block Diagram



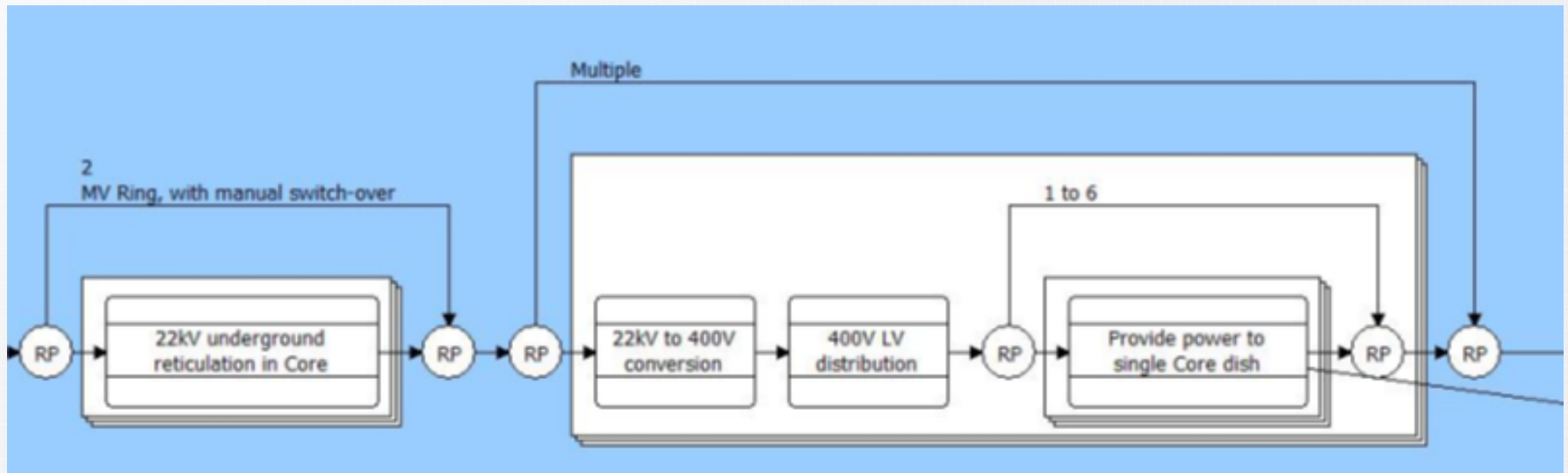
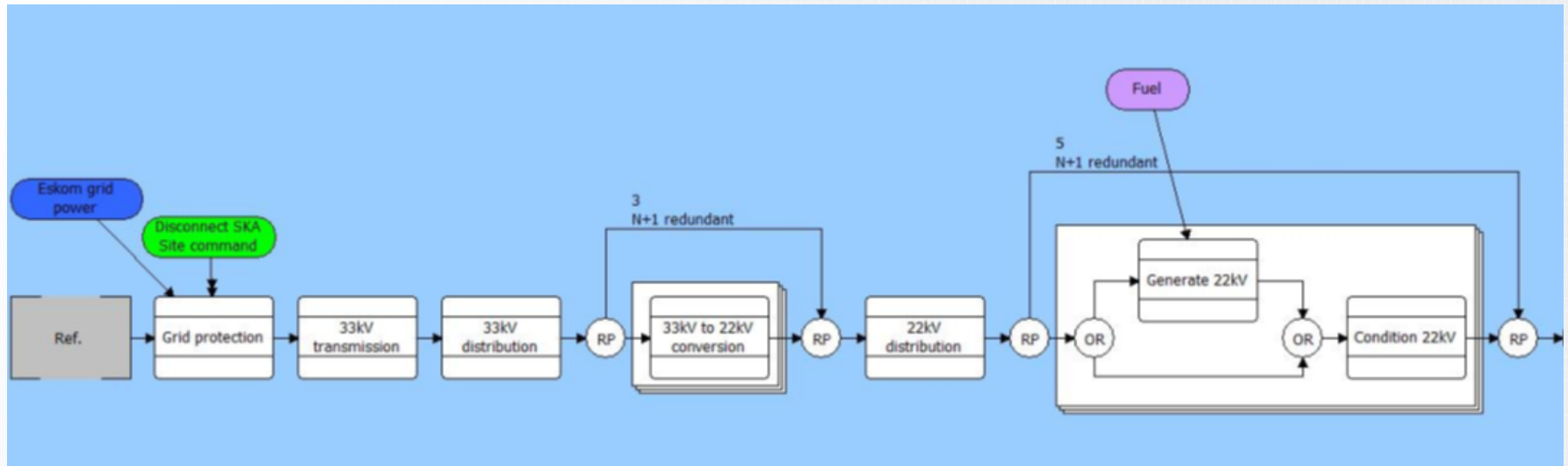
Reliability Block Diagram



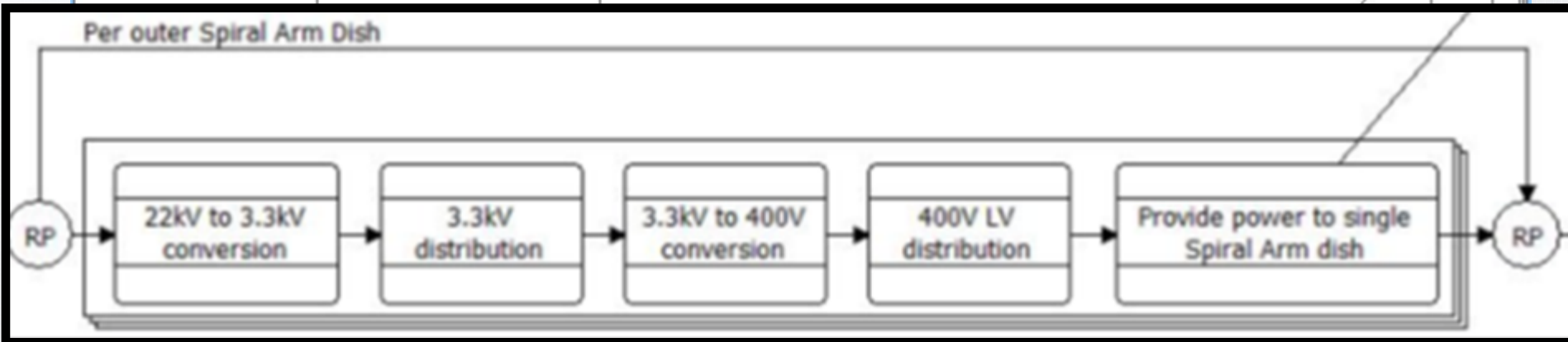
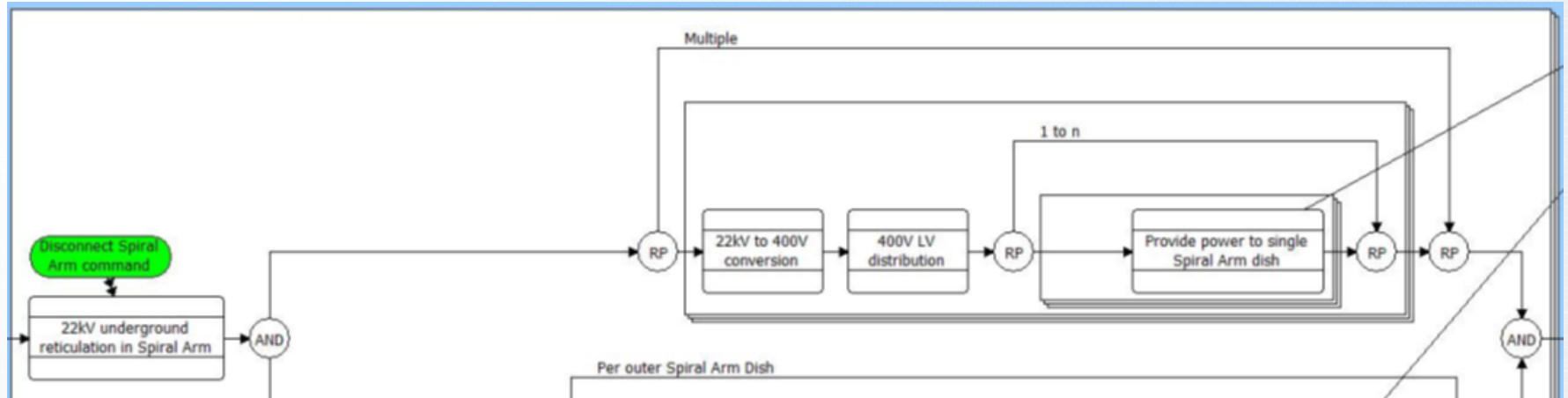
Reliability Block Diagram



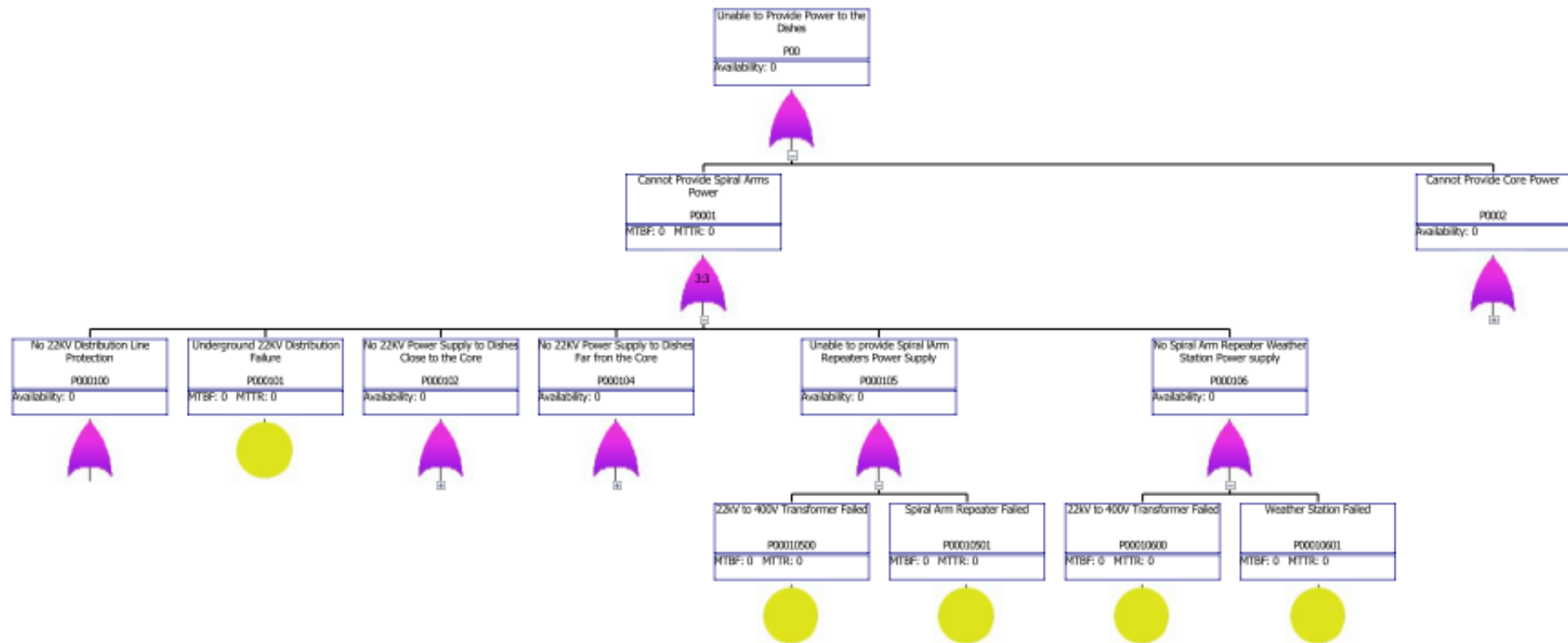
Reliability Block Diagram



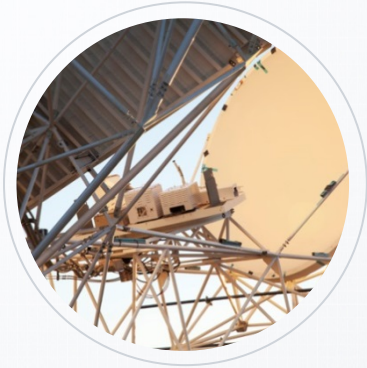
Reliability Block Diagram



Fault Tree Analysis



Simulation Model



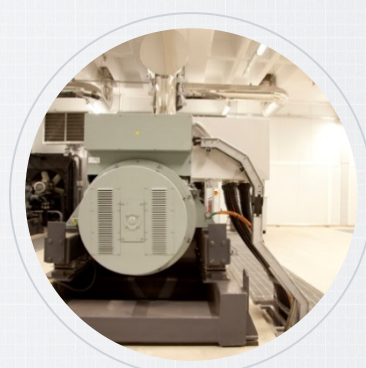
Flexible

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 distribution	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	



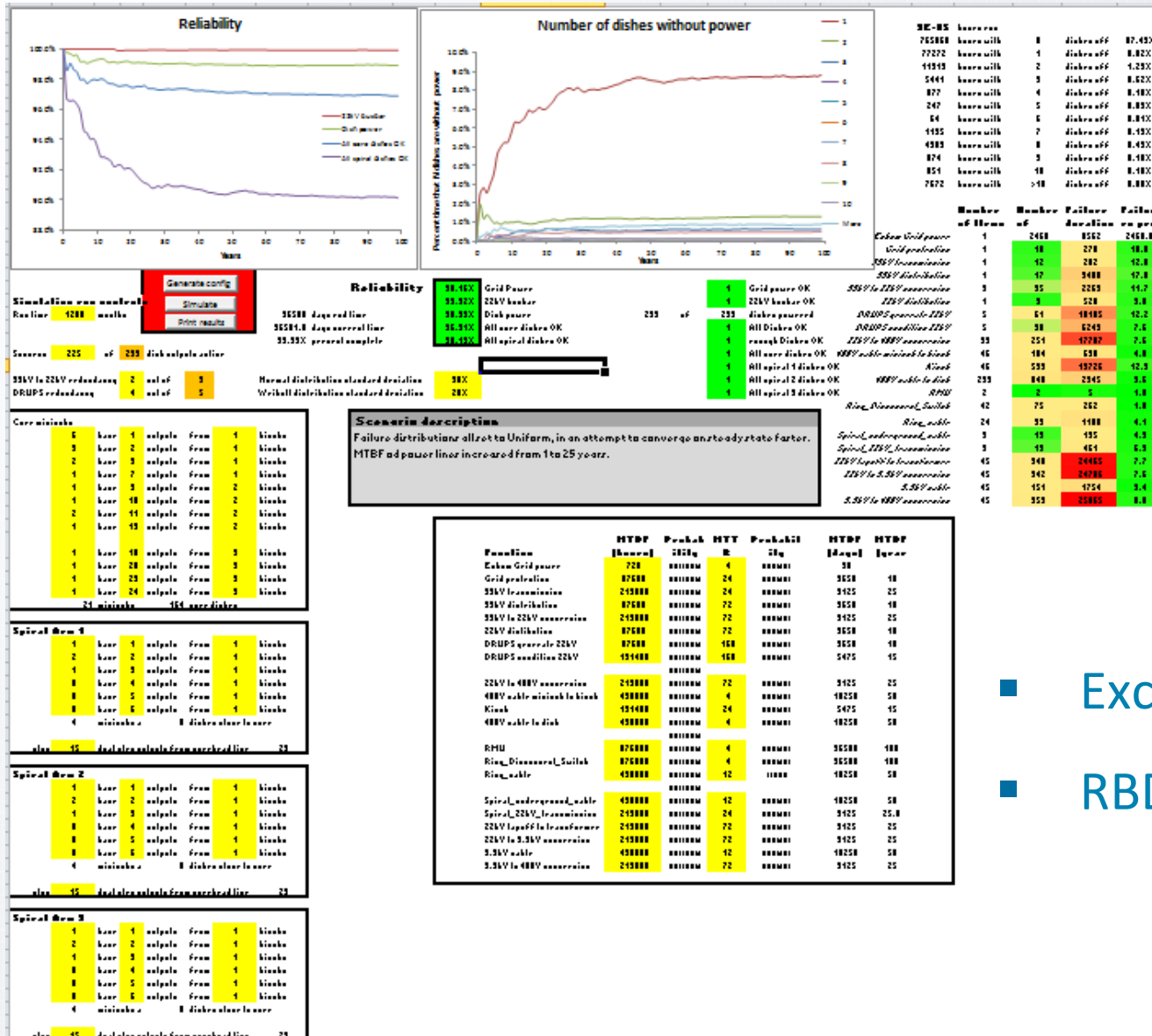
- Number of mini-subs
- Number of kiosks per mini-sub
- Number of receptors fed per individual kiosk

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

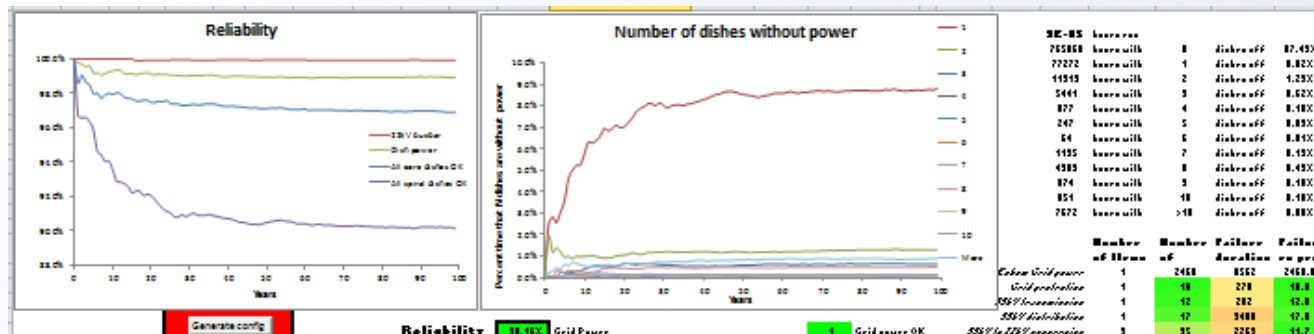


Simulation Model

- 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



Simulation run controls

Run time **600** months

Success **189** of **197** dish outputs active

33kV to 22kV redundancy **2** out of **3**

DRUPS redundancy **4** out of **5**

Reliability **97.94%** Grid Power

100.00% Grid power OK

98.95% Dish power

98.40% All core dishes OK

91.58% All spiral dishes OK

Availability

18250 days end time

18258.8 days current time

99.99% percent complete

Lognormal distribution standard deviation **30%**

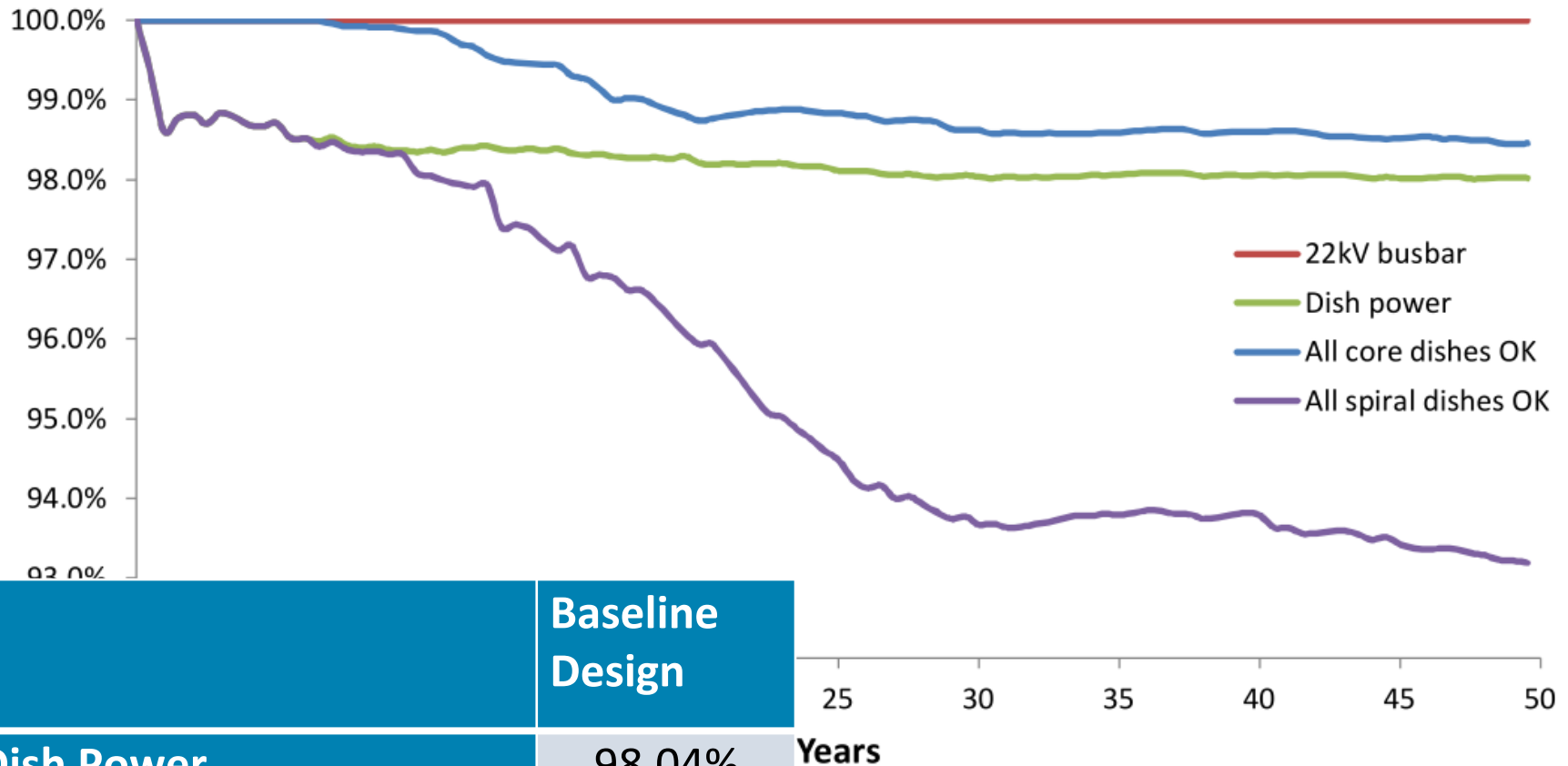
Weibull shape parameter **5.0**

SE-MS	hours run	hours with	dishes off	hours off
76268	hours with	1	dishes off	87.43X
77272	hours with	1	dishes off	8.82X
11515	hours with	2	dishes off	4.23X
5461	hours with	3	dishes off	0.62X
827	hours with	4	dishes off	0.18X
247	hours with	5	dishes off	0.08X
14	hours with	6	dishes off	0.04X
1185	hours with	7	dishes off	0.13X
4583	hours with	8	dishes off	0.45X
874	hours with	9	dishes off	0.18X
851	hours with	10	dishes off	0.18X
7672	hours with	>10	dishes off	0.08X

Category	Number of items	Number of failures	Failure rate per year
22kV busbar	1	18	27.8
Dish power	1	12	282
All core dishes OK	1	17	3408
All spiral dishes OK	8	35	2259

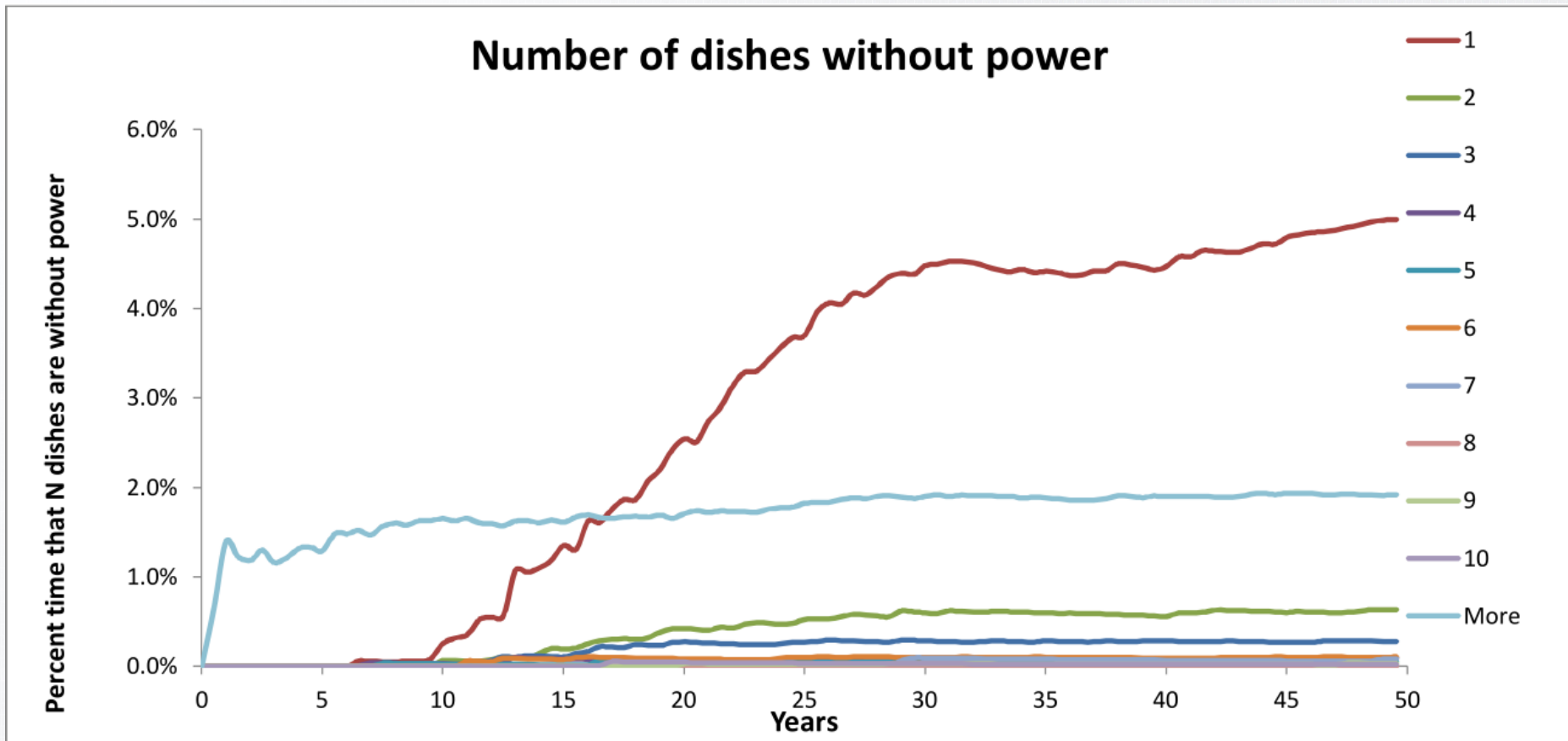
Baseline Design

Availability



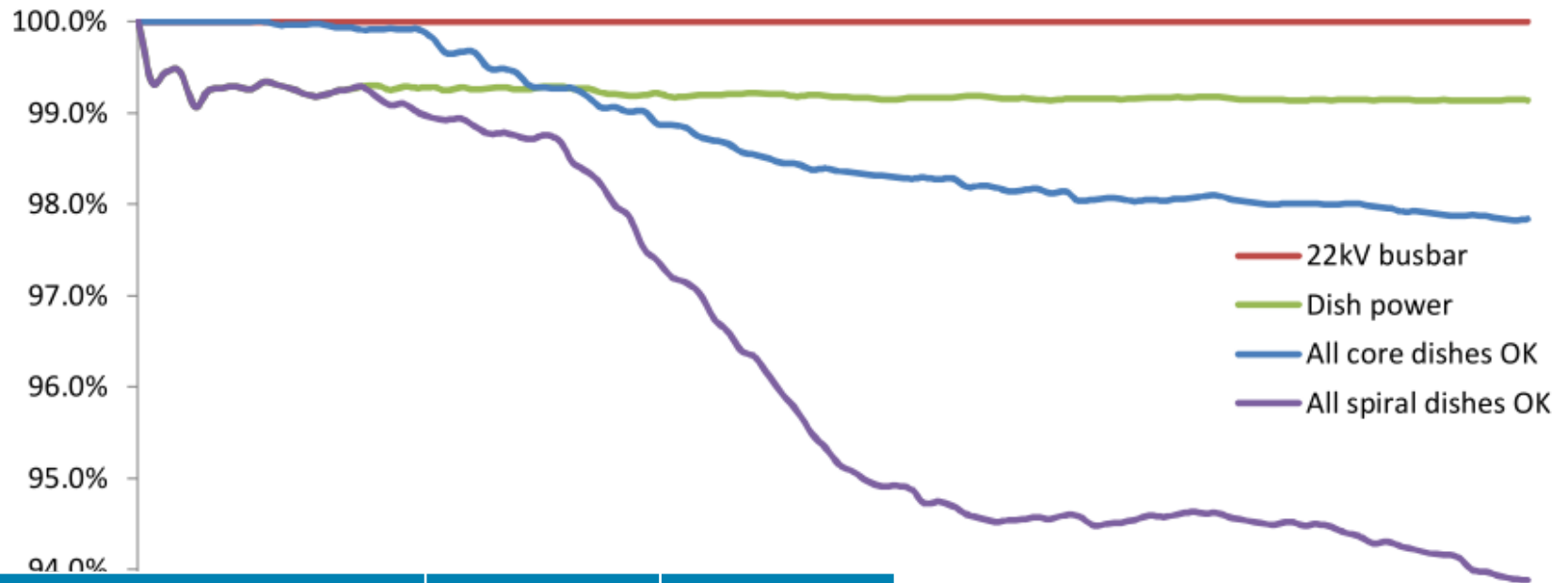
	Baseline Design
Dish Power	98.04%
All core dishes OK	98.02%
All spiral arm dishes OK	93.18%

Baseline Design



One kiosk per mini-sub, better 22kV overhead

Availability

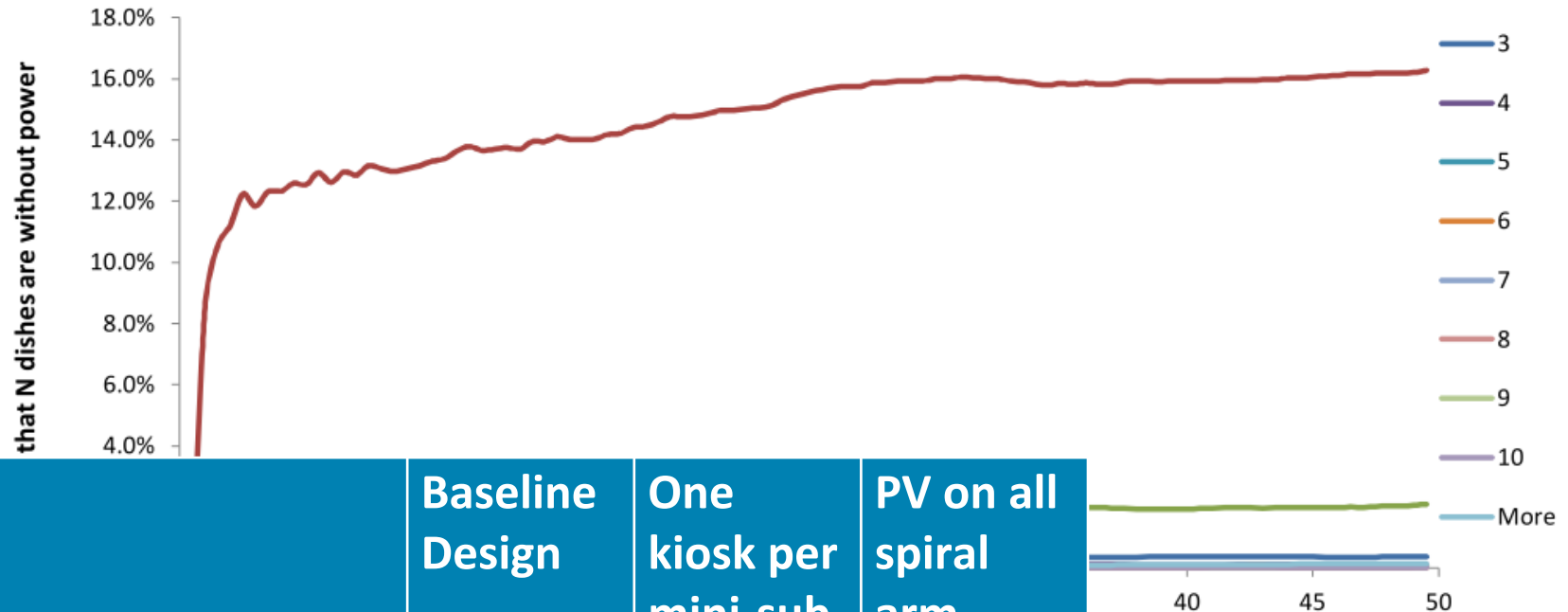


	Baseline Design	One kiosk per mini-sub
Dish Power	98.04%	-----
All core dishes OK	98.02%	97.83%
All spiral arm dishes OK	93.18%	93.82%

PV on outer spiral arm receptors

Availability

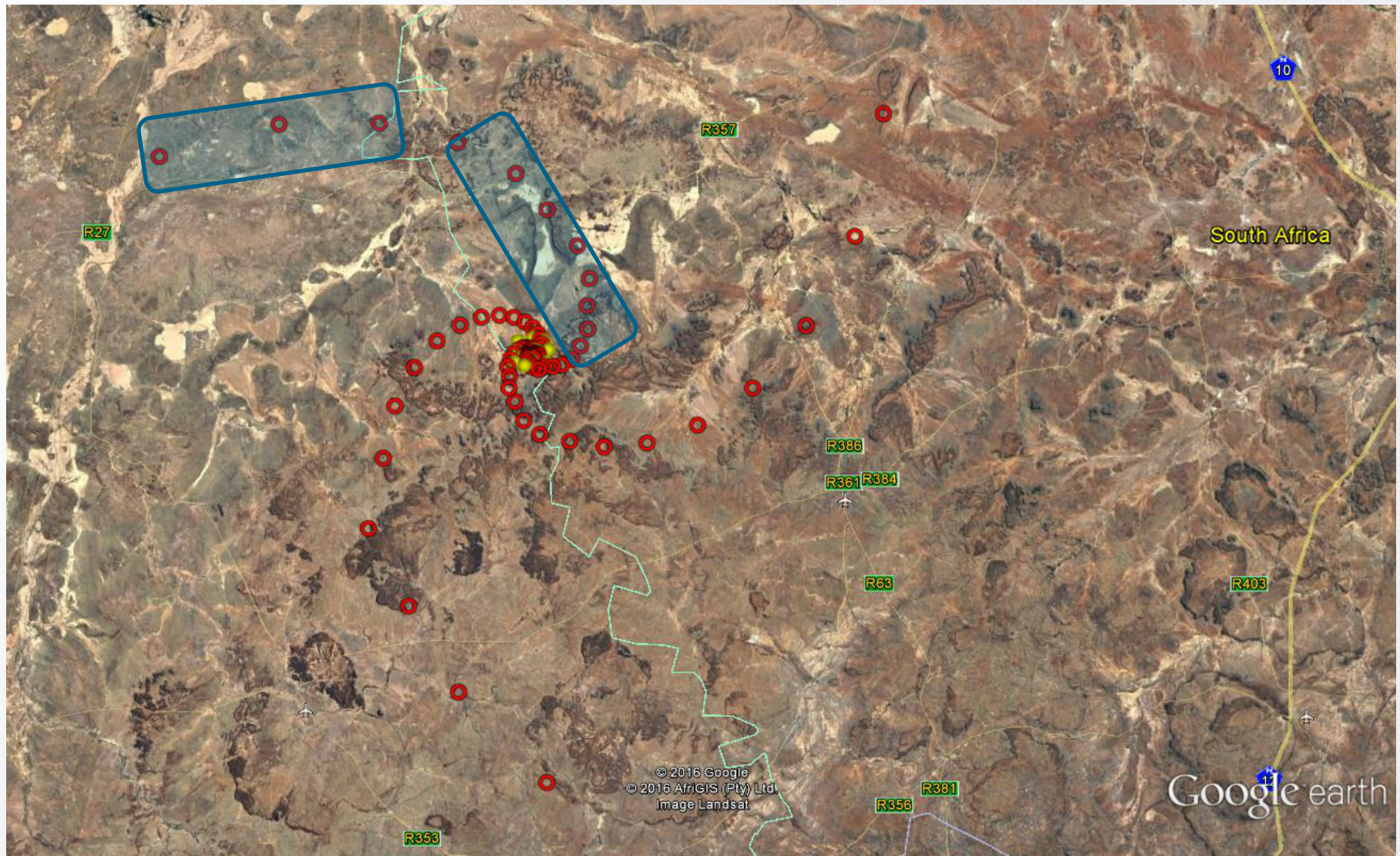
Number of dishes without power



	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%

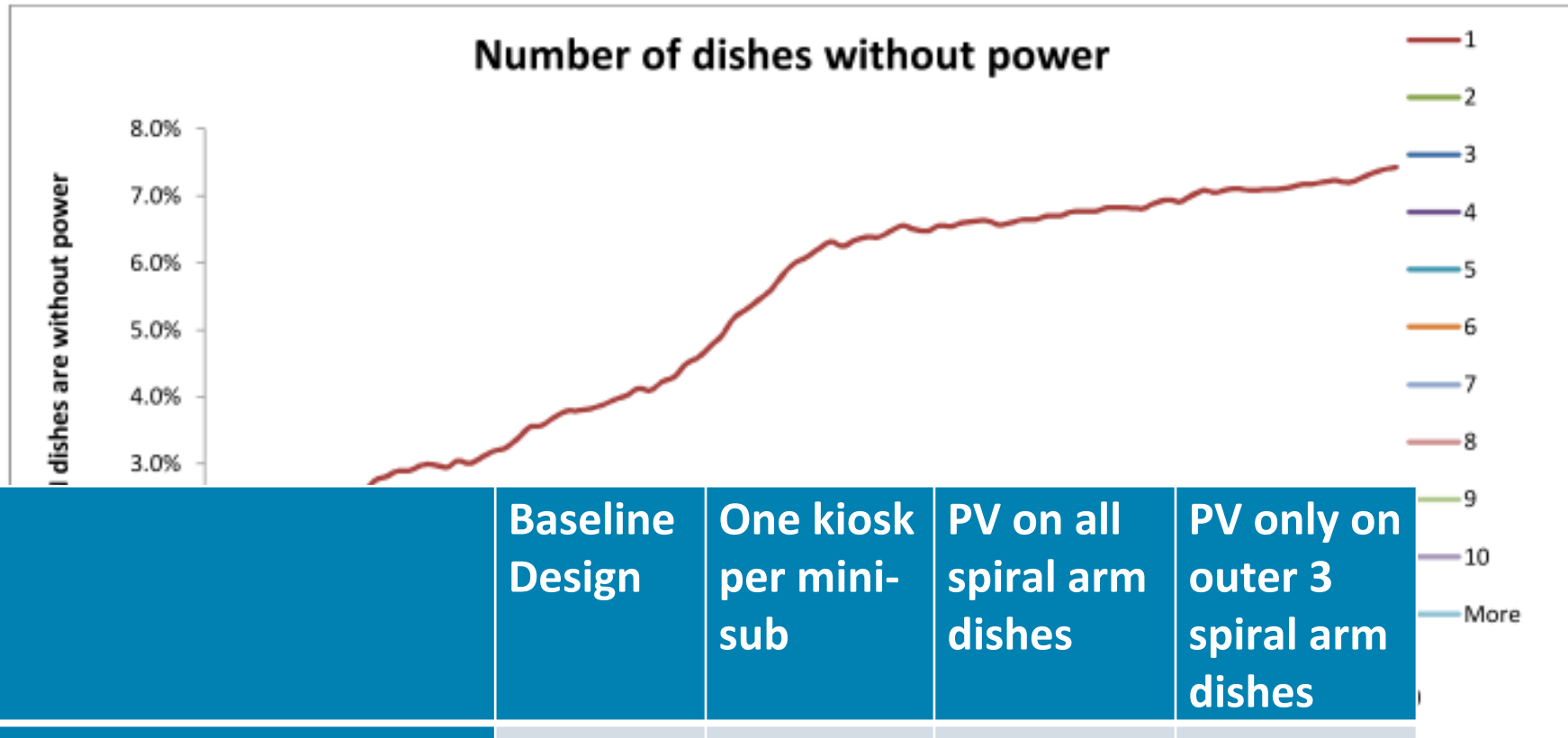


PV on last three spiral arm receptors



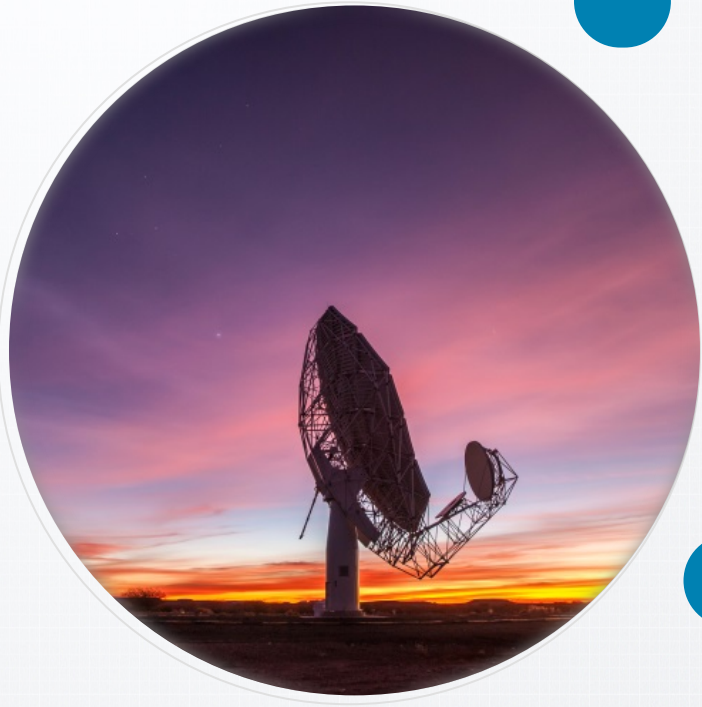
PV on last three spiral arm receptors

Availability



	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



NRF

National
Research
Foundation



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



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