Technical consideration of the “Report and Recommendation of the SKA Site Advisory Committee (SSAC)”.

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Introduction

We present below our examination of the SSAC report (the Report) and outline our areas of technical concern with the Report. We also describe the potential impact on the site evaluation. Further information is provided in the Appendices.

1. RFI Assessment (see also Appendix 1)

We note that the SSAC and the Expert Panel on RFI did not have access to the raw data that would have enabled them to discriminate better between the two core sites. For the remote sites, the SSAC evaluation of the relative RFI environments was based primarily on analysis of two modelled data sets that the Expert Panel advised were inadequate for the purpose[1]. Moreover, observational evidence from measured RFI of the remote sites presented in the Expert Panel report is inconsistent with the conclusion in the Report.

1.1 Core site

Although the SPDO conducted an extensive RFI measurement campaign at both core sites, the SSAC and Expert Panel did not have access to this full data set for site evaluation. There was no analysis of the RFI monitoring data against agreed, scientifically-driven Figures of Merit provided to the SSAC[2], nor were the Expert Panel provided with the raw data from the RFI measurement campaign. With the information provided to it, the Expert Panel was unable to draw a conclusion on the relative merit of the sites[3]. However, they noted that the Australian core site appeared to be more radio-quiet for one FoM, albeit at a low level of significance given the data quality[4].

CSIRO received two (7200sec) raw data sets (one from each site) from the SPDO. An analysis of these data sets by the ANZ RFI monitoring team indicates the Australian core site as more radio-quiet based on spectral occupancy and RFI noise power levels (see Appendix 1) for this limited data. This indicates the value of conducting a proper analysis of the raw data, using agreed science-driven Figure-of-Merit (FoM), to explore any important differentiation between the core sites.

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[1] RFI Expert Panel report, Addendum
[2] RFI Expert Panel report, Section 3.1.1
[3] RFI Expert Panel report, Section 3.2.3
[4] RFI Expert Panel Report 3.4.1

1.2 Remote sites

Given the lack of discrimination possible between the core sites, the relative radio-quietness of the remote sites became the dominant factor affecting the SSAC's score for RFI[5]. However, the conclusions drawn in the Report in this area do not appear to match the evidence or advice of the Expert Panel. According to the Expert Panel, the *measured* RFI showed that the A-NZ remote sites that were monitored were *more* radio-quiet than the southern African sites[6]. The Expert Panel further advised in an addendum to their report that an analysis based on transmitter databases *could not* be used to robustly compare the expected RFI from the sites. The databases do not reflect emitted RFI and are of different completeness levels between the sites (see Appendix 1).

We note that the final report from the Expert Panel containing this advice is dated *after* the interviews with sites and the SSAC's initial voting on this parameter. This may not have given the SSAC adequate time to consider the implications of the report.

2. Array Configuration (see also Appendix 2)

The overall ranking of the array configuration for the sites was largely determined by performance against FoMs for which the ANZ array had not been optimised. Moreover, we contend that the observational scenarios on which the FoMs were based do not necessarily reflect the likely scientific use of the SKA. Further, we believe the impact of the EMI-risk may have been significantly underestimated in the southern African configuration. A more complete assessment of EMI risk could provide greater discrimination between the array configurations within the inner 180km. Based on the SKA Design Reference Missions, approximately 80% of the SKA science will be conducted within the inner 180km.

2.1 Configuration optimisation process.

The SPDO process for configuration *eva*luation[7] specified a meeting with each site to define an initial configuration, and subsequent optimisation of the configuration once the selection criteria weights and the Figures of Merit were set. The agreed process, where optimisation would occur in collaboration with SPDO, has not yet taken place. Furthermore, in response to a question raised by the SSAC, the ANZ team proposed the inclusion of a New Zealand station in the configuration at the December interview, increasing both the N-S and E-W baselines. This configuration was not analysed or subsequently acknowledged in the Report.

The ANZ configuration put significant emphasis on stringently meeting RFI and EMI mask requirements at each site, on ensuring proximity to infrastructure and taking into account tropospheric considerations, thus avoiding tropical regions. The ANZ site bid team were unaware of the finally selected FoM until the Report was released. There is no evidence in the Report that the SSAC was informed that the ANZ configuration was, as yet, not optimised for the finally selected FoMs.

The assessment process conducted by SSAC thus amounts to a comparison of two possible designs for the SKA rather than a comparison assessing intrinsic site attributes (see Appendix 2).

[5] The Report, p82
[6] RFI Expert Panel report, Section 4
[7] Array configuration for the SKA, SPDO, 2 July 2010 v0.6 communicated to sites on 3 July 2010

A fuller consideration of geophysical, EMI and RFI masks for the two sites and the availability of essential infrastructure would help to determine the ability of each site to configure the SKA.

We believe that Australia and New Zealand offer sufficient flexibility in these parameters to allow any SKA configuration to be optimised straightforwardly for any appropriate FoM.

2.2 Array Configuration: Long Baselines.
The SSAC score in the area of array configuration primarily reflects a difference in the array performance at long baselines. The SSAC concluded that the array configurations within 180km (ie the short baselines) were largely equivalent between the sites. We note that in the SKA Science Design Reference Mission, approximately 80% of the science will use short baselines.

The UVGAP parameter is a useful FoM for high image dynamic range performance. However, the long-baseline observing mode required to deliver high dynamic range considered in the UVGAP calculation (less than 10% relative bandwidth, short tracks over a limited hour angle range) would be very rarely used in practice. A UVGAP FoM determined for a more realistic observing mode required to deliver high dynamic range at long baselines (25% relative bandwidth, observations distributed over hour angles of 8 hours or greater) demonstrates that even the current non-optimised ANZ array is very competitive with the current southern African array.

2.3 Array Configuration: Short Baselines.
At shorter baselines the SSAC considered the EMI-risk from farmsteads in the southern African configurations to have minimal impact on survey speed[8].

However the FoM defined by the SPDO to quantify the EMI-risk assumes an isolated or 'VLBI'-setting in which the EMI signal from farmsteads is uncorrelated ie the receptors each 'see' different RFI from different farmsteads.

At some locations less than 180km from the southern African core, individual groups of receptors are separated by distances less than the farmstead buffer zone diameter. This does not represent an isolated setting. The EMI signals will produce a correlated response in the recorded visibilities for all the receptors within the buffer zone of the same farmstead. In this case, the EMI science impact on visibility data is underestimated by the SPDO-defined risk factor by a factor of up to 10,000.

Any transient EMI that is seen over several groups of receptors will also have a substantial impact for SKA science drivers such as pulsar and other time-domain-critical science. These science drivers are not accounted for in the SPDO-derived EMI FoM.

Given the very significant difference in farming density between the Australian and RSA sites, a more comprehensive assessment of the scientific impact of the EMI risk may have led to a different evaluation of the relative science performance/risk of the configurations at these baselines.

[8] SSAC Report, p94

3 Implementation and Cost Factors (see also Appendix 3)

The SKA Model was not tightly defined enough to ensure that cost and implementation comparisons were of intrinsic site attributes as was intended, rather than simple design considerations.

In particular, our analysis indicates that the large difference in power costs (both capital and operating) is largely a result of different design and operating assumptions, rather than intrinsic site characteristics.

In the SSAC's consideration of data communications, we are concerned at the relative ranking of low risk to the cost, timescale & access details for the SKA to a critical piece of infrastructure:

"Not all details about the connectivity situation between the DP [data processor] and the partner countries outside South Africa are clear. The SSAC interprets this as a low level weakness, as the telecom situation is bound to improve." [9]

and a medium-to-high risk associated with a design choice:

"If collocation and integration of the DP [data processor] and the SC [super computer] are feasible and affordable in RSA and not in ANZ, we judge this to be a medium to high level weakness for ANZ." [10]

We note that the SC and DP can be collocated and integrated in the Australian and New Zealand implementation of the SKA.

[9] SSAC Report p136
[10] SSAC Report, p136

Appendix 1. Analysis of RFI Measurement Section.

RFI measurements at the core

Information made available to the SSAC and the Expert Panel on RFI measurements

The radio-quietness of the SKA core has been identified as a high priority criterion for site selection. However, the Expert Panel was not provided with an analysis of the RFI monitoring data for both sites against scientifically motivated FoM[11], or with the raw datasets from the RFI measurement campaign, which may have enabled the Panel to conduct their own analysis. Initially the Panel were provided with plots of the data and subsequently with MATLAB files and, from this, have done some reanalysis of the averaged/integrated points[12].

The Expert Panel was unable to draw a conclusion on the relative merit of the sites with the information provided, although they noted that the Australian core site appeared to be more radio-quiet on one criterion, albeit at a low level of significance, given the data quality[13].

A simple "counting spikes" exercise conducted by the SSAC (Table A4.2-1) indicated a larger number of interfering signals in the RSA data than in the Australian data (93 vs 84).

Analysis of Raw Datasets from Core sites

Two raw datasets, one from each site, (comprising 7,200 seconds of data) in the frequency range 50 – 2050 MHz are currently available to both prospective host nations. A detailed comparison of these data was made by CSIRO in February 2011. The results are presented below. We emphasise that the results presented below are a preliminary internal analysis of only two datasets. However, they clearly demonstrate the potential value of conducting an analysis with the raw datasets available.

In the comparison of data from the RSA and AUS sites, three major measures of RFI were used. The first was *spectral occupancy*, which measures the fraction of spectral channels that contain RFI. A more sophisticated figure is the *bandwidth-time occupancy*, given by the fraction of measurement points that contain a signal (presumed to be RFI) more than 6 times above the mean noise. The third and perhaps the most useful measure of RFI is the *RFI noise power ratio*. This is the ratio of total measured RFI power to total noise power expected from the receiver which captures all 3 RFI parameters; frequency, duration and power.

Table 1 below shows a comparison of the RFI spectral occupancy, bandwidth-time occupancy and RFI-to-noise power ratio at the RSA and AUS sites as derived from the common datasets provided. This is split into three frequency bands, to illustrate the relative impact of RFI on the various SKA science themes.

[11] Expert Panel report, Section 3.1.1
[12] Expert Panel report ,Section 3.2,
[13] Section 4, Expert Panel report

	The first stars and galaxies 50 – 200 MHz			Early Universe Science 300 – 900 MHz			Our Galaxy and the Local Universe 900 – 1400 MHz		
	SO%	BTO%	RFI/N	SO%	BTO%	RFI/N	SO%	BTO%	RFI/N
RSA	9.2	3.3	0.23	1.55	0.52	0.12	5.6	1.4	2.5
AUS	6.0	1.6	0.02	1.61	0.47	0.02	3.5	0.4	0.008
RSA/AUS	1.5	2.1	12	1.0	1.1	6.0	1.6	3.5	310

Table 1: *Spectral occupancy (SO) in percent, bandwidth-time occupancy (BTO) in percent and the RFI/noise power ratio (RFI/N) for the RSA and AUS sites in three SKA science bands. The bottom row shows the ratio of these values at the RSA and AUS sites. Worst case errors are about 10% of the stated values in the Table above.*

The spectra from the two datasets available are shown in the Figure below together with the ratio of the mean power integrated over 100 MHz bins at the two sites. At the Australian site, the RFI-to-noise power ratio is in all cases a very small fraction of the receiver noise. This would allow the SKA project to build high performance and lower cost radio receivers with minimal complexity. Higher RFI-to-noise ratio would carry increased design risk for the SKA.

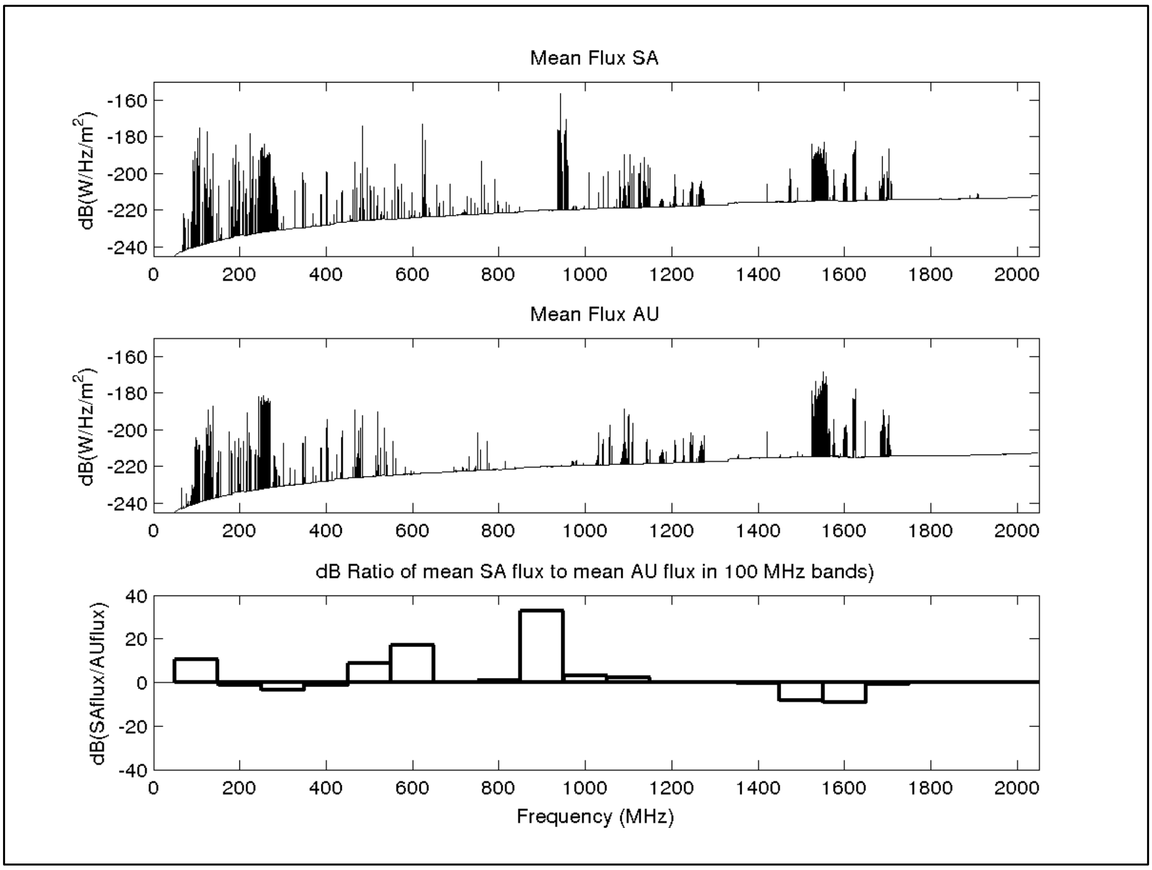

Figure A1.1. *Spectra from RSA (upper plot) core site and Australian (middle plot) core sites, and ratio (in dB) of the mean power integrated over 100 MHz bins between the South African and Australian site. Positive values indicate more RFI power at the South African* *site. 10dB, 20dB and 30dB reflect power ratios of 10, 100 and 1000 respectively.*

GSM

The SSAC report notes the RSA statement that they have arranged with GSM providers to use directional antennas with a level suppressed by 40dB in the direction of the core. Note that this is not required in the Australian case. We identify a number of potential technical difficulties with the effective implementation of such a solution. For example:

- The 180km radius intermediate zone may cover a wide angular extent from nearby GSM transmitters. Protection of the whole intermediate zone array-stations from damaging GSM transmissions from the towers, as would be required, could have a negative effect on service provision to a large population. Similarly, at the remote sites, nulls in the antenna pattern would preclude service to subscribers between the mobile base station site and the telescope location.
- Typically, as a mobile phone GSM user moves into a region of weak transmitter signal, the transmission strength from the phone unit itself increases to compensate. The signal from typical phone units can be enough to significantly impact on an array-station nearby.
- In a region with a significant number of mountain range edges and buildings, reflections can be important and can significantly reduce the effectiveness of directional nulling.
- From the RFI monitoring data that has been provided to us by the SPDO, we note that the GSM signal in the RSA core is 50dB above the base line. Therefore, suppression of 40dB is insufficient to satisfy the radio-quiet standards of the SKA.

For these reasons, we suggest that the SSAC cannot assume that the RFI risk from GSM signals can be effectively mitigated in South Africa until a full analysis has been conducted.

RFI measurements at the remote sites

The Expert Panel report indicates that, using the data given, at the current time the selected remote sites in Australia were more radio-quiet than the selected remote sites in southern Africa[14].

These measurements were not highlighted in the SSAC report and the overall conclusion on the “RFI measurements” factor appears to have been determined primarily by the modeling of transmitter databases at the remote sites. [15]

However, in respect of the transmitter databases the Expert Panel resolved: “The panel can make no meaningful conclusions about the relative suitability of the set of remote sites for the two candidate sites based on the RFI prediction studies [16]

This is primarily because the databases used are not comparable. The RSA modeling[17] for sites outside South Africa used only the data for television and radio broadcasting. Within

[14] Expert Panel report, Section 4, page 20
[15] SSAC report p82
[16] Expert Panel on RFI-final-report-with-addendum, p32
[17] Rfi-impact-at-candidate-remote-station-sites-sa-1.0.pdf, p9

South Africa, it is stated in the SPDO report[18] that the data for modelling came from a set of separate databases including a subset of the GSM operators. Given the comparison of measurements to modelling, which indicates that for at least 3 of the 4 remote stations in southern Africa there are more measured signals than appear in the database modelling, it appears that the databases do not represent the full spectrum environment[19].

The ANZ modelling used the Australian Communications and Media Authority database including mobile telephony, fixed links, private mobile radio, aeronautical communications, earth stations, CB repeaters, and others. The ACMA database lists the maximum licensed transmission, not the actual transmitter strength deployed, and may contain listings for licenses for transmitters that have been removed. It represents a theoretical worst case.

The SSAC used the 'peak signal' across the frequency range[20] in the database as a FoM, which is neither a reliable indicator of the overall radio-quietness of a site nor, indeed the actual peak transmission present.

The Report claims that a similar 'peak signal' statistic from the measurements of remote sites RFI[21] corroborates the findings from the transmitter database comparison ie the southern African sites are more radio-quiet than the Australian remote sites. However, this conclusion is inconsistent with the observationally-based evidence from the Expert Panel report which indicates that the measured indicative Australian remote sites are more radio-quiet than the measured indicative African remote sites.

In summary, it is our view that the principal criterion used by the Report to determine relative interference levels for remote stations does not justify the conclusion that the RSA site has superior radio-quiet in the remote stations.

Long term RFI Environment

The consultant's report "Study of the long-term RFI environment for the SKA radio telescope" looks at national trends, but does not consider the situation specific to each site. While the report mentions the much larger rural population density in RSA (38% of the total population in RSA, 11% of the population in Australia,[22]), and the high and increasing use of mobile devices in both countries, the report does not consider the long-term RFI environment of the actual sites, where the population density of the Australian site is much lower than the RSA site. The report is, therefore, of very limited use in addressing the question of any difference in long-term RFI for the two candidate sites.

The statement made in the Report that the RFI-tolerance of remote stations will mitigate the risk of any problems with enforcement of RFI regulations in African countries[23]does not appear to be well justified, given results presented that the remote sites do experience RFI above the relevant VLBI thresholds, and protection measures would therefore be required.

[18] RFI Impact at candidate SKA remote sites (p11)
[19] RFI Expert Panel report Addendum
[20] SSAC Report, p 81
[21] SSAC Report, p79,82
[22] Consultant's report pp 44, 55
[23] SSAC Report p86, 87

The population density of the ANZ core site is sufficiently low that mobile phone service is not provided anywhere in the vicinity. The SSAC report [24] makes broad statements that both countries will experience increased RFI produced by cellular devices, but the specific and very different implications for the core sites in each country are not explored.

We suggest that examination of the EMI mask documents for both sites, or the receiver threshold mask documents would have assisted the Expert Consultant with the assessment of local trends.

Finally, the Report concludes that the long-term RFI environment is comparable and acceptable in both ANZ and RSA. However, the numerical vote on this factor is weighted in favour of RSA (9.3 – 10.7).

[24] SSAC Report, p87

Appendix 2. Analysis of Array science performance section

The ANZ array configuration was not optimised for the particular UVGAP figure of merit used in the evaluation

The ANZ configuration has not undergone any optimisation for the UVGAP figure of merit.

The SPDO process for configuration evaluation[25]specified a meeting with *each sit*e to define an initial configuration, and subsequent optimisation of the configuration in collaboration with SPDO and a Tiger Team once the selection criteria weights and the Figures of Merit were set. This has not yet occurred. The ANZ array in the response to the request for information represents one possible instantiation of SKA that attempts to balance cost, extremely low-risk RFI/EMI environment, tropospheric stability and availability of roads, fibre and power. It appears that the SSAC were not provided with the information that the ANZ configuration had not undergone the collaborative optimisation process with SPDO.

The ANZ array is widely configurable

In fact, Australia and New Zealand offer the project a large number of options within the maximum 5100 km east-west baseline and a 3000 km north-south baseline. The ANZ team offered at interview to provide an analysis of a configuration that increased N-S and E-W baselines, but the team was informed that this was not necessary. It appears from the figure of merit selected that it would have provided very useful information on ANZ configurability had the ANZ team had the opportunity to provide such information.

The extremely low population density in many large areas of Australia affords the SKA remote array stations a high degree of configurability.

In rigidly applying the UVGAP figure of merit to a single 'example' array prior to optimisation, the assessment process amounts to a comparison of two possible *designs* for the SKA, rather than a comparison of the intrinsic site qualities.

The UVGAP analysis assumes unrealistic observational scenarios

The UVGAP parameter is correctly identified in the SSAC report as being important for achieving high image dynamic range. However, image dynamic range limitations are only encountered in practise in long duration continuum observations employing significant relative bandwidth. None of the eighteen observational scenarios that are assessed against the UVGAP figure of merit in the SPDO analysis (listed in their Table 7) [26] exceed four hours duration or 10 percent relative bandwidth and half of these scenarios are of negligible bandwidth. This is in contrast to the recommendations of the Configuration Simulations Task Force (SKA array configuration studies – a guide for SKA site proposers, January 2005) who recommend assessment of eight-hour tracks with 25% relative bandwidth. It is specifically such long duration, high relative bandwidth observations that can be usefully compared with the UVGAP figure of merit. Such a comparative analysis has not yet been done.

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[25] Array configuration for the SKA, SPDO, 2 July 2010 v0.6 communicated to sites on 3 July 2010

[26] Array Configurations for Candidate SKA Sites: Design and Analysis, Millenaar, Bolton & Lazio, 4-11-2011.

The core participates in all SKA science but long baselines are required for a small number of key science projects.

Approximately 80% of SKA science uses the 180km radius central region, according to the SKA Design Reference Mission.   The SSAC score of 6:14 in favour of the South African configuration primarily reflects the perceived difference in the array performance at long baselines, in contrast to the greater scientific importance of the short baselines.

The EMI analysis is incomplete

The SPDO report states that, when EMI masks are taken into consideration, the Australian array layout is highly configurable within the inner 180 km region, whereas the southern African array is not.

Unlike the positions of remote stations, which can be arranged in a large number of different ways, EMI risk near the core is an intrinsic attribute of the southern African candidate site. The EMI risk of the ANZ configuration is formally zero, even prior to the relaxing of the rules governing farmstead mask radius that occurred during the process.

The SPDO assessment of EMI-risk is based on the projected interference levels that would increase the system temperatures of antennas in an *isolated* setting. By this definition, 72% of all SA stations within the 2.5-180 km zone have a non-zero EMI-risk.

It is apparent from Figure 44 of WP3-050.020.010-TR-001 (see Figure below) that the SA configuration is immersed within more than 1000 active farmsteads (compared to 90 in ANZ) on intermediate baseline scales where individual receptors are separated by only kilometres. This does not represent an isolated setting. The EMI-risk figure of merit only addresses *system temperature* impacts on performance and does not begin to capture the much more serious consequences to scientific performance of EMI signals that produce a correlated response in the recorded visibilities within every pair of antennas that is visible to the same farmstead or farm activity (see Figure below). The EMI-risk metric treats the SKA as a collection of independent receptors. However the strength of a telescope like SKA comes from using the receptors in unison, measuring the correlations in the signals received at the antennas from celestial sources. A typical SKA visibility fluctuation for a continuum observation is only 1/10,000 of the system temperature. The EMI science impact on interferometer data is therefore potentially underestimated by the SPDO-defined risk factor by a large factor. For similar reasons, the farmhouse emissions are also damaging when using the SKA to search for transient or time-variable celestial objects, which involve baselines out to a few hundred km.

The science impacts of such correlated EMI have not yet been quantified, but they may well be substantial. This is particularly relevant for spectral line and time-domain science, which are the two top priority projects for SKA Phase 1 (SKA Memo 125, Garrett et al. 2010) and make up a large proportion of the SKA Phase 2 science case. It would appear that the EMI from farmsteads, and also from farm activity, poses a significant risk to the performance of SKA if sited in RSA; a risk that may not have been fully appreciated in the SSAC Report, where it was resolved to be “negligible”.

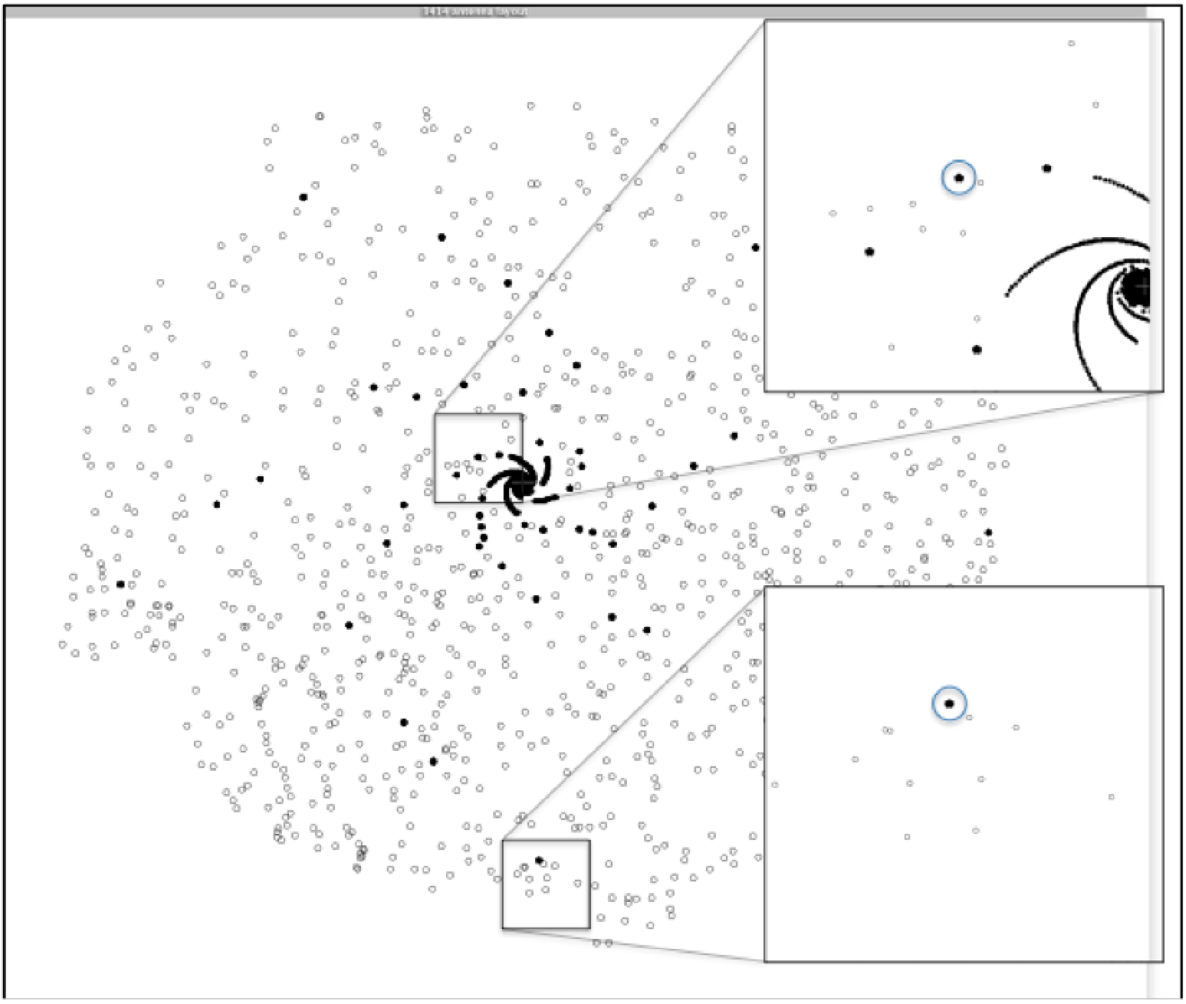

Figure A2.1. This Figure is a reproduction of Figure 44 in the SPDO report "Array configurations for candidate SKA sites; design and analysis". It is a diagram showing RSA dish positions (black) and the inhabited farmstead locations (open black circles). The two regions highlighted are the positions most seriously affected by the farms in the EMI risk figure calculation. 72% of the dishes within the 2.5-180km region have non-zero EMI risk values. There are 90 homesteads within 180km of the ANZ core site, in contrast to 1000 for the RSA case.

Appendix 3. Relative power costs

Both capital and operating costs for the provision of power differ substantially between the southern African and Australian/New Zealand responses. We contend that the difference is based largely on varying design assumptions and is *not* fundamental to the candidate sites.

Capital costs

Summary

The Report conclusion[27] that RSA's lower capital cost reflects their ability to use the grid more readily is not supported by a cost analysis. Rather, the Parsons Brinckerhoff reports (PB) show that the main cost difference between sites is the in the on-site power distribution system, most likely the result of differing design assumptions made in the preparation of the responses.

Analysis

We use a breakdown of capital costs provided in the PB reports to separate infrastructure that should truly be site-dependent in cost from that which should be largely site-independent (i.e., design dependent)

Category (PB report)	**Cost – ANZ (M€)**	**Cost – RSA (M€)**
HV transmission	(Note 1)	34.9
MV/LV distribution & transformers	214.4	59.6
LV distribution	28.4	29.4
Generation	54.0	17.0
Other	14.0	-
Total	**310.8**	**140.8**
SSAC report total (Note 2)	331.5	132.0

Table 1: comparison between RSA and ANZ capital costs.

Notes: 1. Capital cost (68.9 M€) for the new transmission line to the ANZ site is amortised in the operating costs. 2. The PB breakdown is used here as the preparers had access to all the data from the responses to the RfI. We note that the PB final totals differ at the 6% level from those used by the SSAC but conclude that the broad conclusion from the PB analysis stands.

The site-specific factors are primarily the distance from the existing grid (a cost difference of €34 M)[28] and the degree to which generator power would be needed (cost difference €37 M).

By contrast, the difference in the costs of the on-site power distribution system (€154 M) accounts for the majority of the capital cost difference between the two sites. This system should be largely **site-independent** as the core infrastructure supported is to be identical, and in similar configurations. PB note that there is insufficient detail in this aspect of the RSA proposal to evaluate their proposal.

[27] SSAC Report, p137ff

[28] For this purpose the capital cost is compared directly, i.e. assuming that the ANZ line would **not** be amortized in electricity rates.

Our analysis indicates that the cost of given power infrastructure should be similar in RSA and ANZ, as much of cost is for material procured in an international market. This implies that the comparison made in the Report is more between *different designs* than between *intrinsic site attributes*, i.e., is an artefact of the scoping process.

For example, the ANZ solution proposed gives considerable weight to RFI mitigation and reliability in the infrastructure. However, it is recognised in the SSAC report that the RSA design breaches the RfI requirements for RFI control by the use of overhead power lines. The cost to mitigate this, i.e. by burying the cables, is however not included in the SSAC's overall comparison of costs.

Site-specific cost factors alone are therefore not sufficient to explain the large difference in costs between the bids. The major part of the capital cost difference is unlikely to be a core site attribute and is likely to reflect a design difference.

Operating costs

Summary

The cost of grid versus off-grid (generated) power is not a significant operating cost differentiator. The main difference stems from the use of 2011 electricity tariffs in South Africa and Australia and an implicit assumption that these will remain the same relative to each other for the lifetime of the SKA. This ignores actual known tariff changes as indicated in the expert consultant's reports and the uncertainty of future tariffs.

Analysis

The SSAC used an operating cost for RSA of €50M and for ANZ €124M per annum. The Parsons Brinckerhoff (PB) reports provide a broadly consistent breakdown that shows that the dominant operating cost is the wholesale cost of grid electricity:

	RSA (€M)	ANZ (€M)
Electricity cost (grid) including supercomputer, based on 2011 tariffs	43.2	78.0
Additional amortised infrastructure cost foreshadowed in tariff (132kV supply)	0	26.6
Operations and maintenance (including diesel for ANZ)	12.5	19.7
Total	55.7	124.3

Table 2 Relative Operating Costs

The cost of grid versus off-grid (generated) power is not a significant factor. This difference is included in the operations and maintenance line. The factor is small since most ANZ power would be provided from the grid.

As requested, the candidate sites used 2011 tariffs in their calculations. The main difference between RSA and ANZ operating costs arises from the tariff assumed and these numbers projected 30 years into the future are hugely uncertain.

For example, PB show that if the RSA tariff for 2014 is assumed rather than the 2011 number used in their submission, the RSA electricity cost approximately doubles from €43.3M to €88.9M per annum.

We believe that these large uncertainties in both design issues and operating costs serve to reduce the significance of the differentiation between the sites found in the SSAC report.