AA-MID SYSTEM REQUIREMENTS SPECIFICATION

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Revision ................................................................................................. D
Author .................................................................................................. See below
Date ...................................................................................................... 2011-11-14
Status ................................................................................................. FINAL

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<th>Affiliation</th>
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<tbody>
<tr>
<td>A. W. Gunst</td>
<td>AA domain specialist</td>
<td>SPDO</td>
<td>2011-11-15</td>
<td></td>
</tr>
<tr>
<td>A. Faulkner</td>
<td>System engineer</td>
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<td>2011-11-15</td>
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Approved for release as part of SKA AA dCoDR documents:

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<tr>
<td>K. Cloete</td>
<td>Project Manager</td>
<td>SPDO</td>
<td>2011-11-15</td>
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**DOCUMENT HISTORY**

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<td>-</td>
<td>First draft release for internal review</td>
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<td>B</td>
<td>2011-10-21</td>
<td>-</td>
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**DOCUMENT SOFTWARE**

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**ORGANISATION DETAILS**

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<tr>
<th>Name</th>
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<tr>
<td>Physical/Postal Address</td>
<td>ASTRON</td>
</tr>
<tr>
<td></td>
<td>Oude Hoogeveensedijk 4</td>
</tr>
<tr>
<td></td>
<td>P.O. Box 2</td>
</tr>
<tr>
<td></td>
<td>7990 AA Dwingeloo</td>
</tr>
<tr>
<td></td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Fax.</td>
<td>+31 (0) 521 59 51 44</td>
</tr>
<tr>
<td>Website</td>
<td><a href="http://www.skatelescope.org">www.skatelescope.org</a></td>
</tr>
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## LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>AA-Mid</td>
<td>Aperture Array for mid-frequencies</td>
</tr>
<tr>
<td>AC</td>
<td>Alternating Current</td>
</tr>
<tr>
<td>ADC</td>
<td>Analogue to Digital Converter</td>
</tr>
<tr>
<td>ADD</td>
<td>Architectural Design Document</td>
</tr>
<tr>
<td>CI</td>
<td>Configuration Item</td>
</tr>
<tr>
<td>CMS</td>
<td>Configuration Management System</td>
</tr>
<tr>
<td>COAR</td>
<td>Consolidated Observation Action Register</td>
</tr>
<tr>
<td>CoDR</td>
<td>Concept Design Review</td>
</tr>
<tr>
<td>dB</td>
<td>Decibel</td>
</tr>
<tr>
<td>deg</td>
<td>degree</td>
</tr>
<tr>
<td>DRM</td>
<td>Design Reference Mission</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>EM</td>
<td>Electro Magnetic</td>
</tr>
<tr>
<td>EMC</td>
<td>Electromagnetic Compatibility</td>
</tr>
<tr>
<td>EMI</td>
<td>Electromagnetic Interference</td>
</tr>
<tr>
<td>FAT</td>
<td>Factory Acceptance Test</td>
</tr>
<tr>
<td>FCA</td>
<td>Functional Configuration Audit</td>
</tr>
<tr>
<td>FMECA</td>
<td>Failure Modes, Effects and Critically Analysis</td>
</tr>
<tr>
<td>FOV</td>
<td>Field of View in squared degrees</td>
</tr>
<tr>
<td>GHz</td>
<td>Giga Hertz</td>
</tr>
<tr>
<td>Hz</td>
<td>Hertz</td>
</tr>
<tr>
<td>HFE</td>
<td>Human Factors Engineering</td>
</tr>
<tr>
<td>HPBW</td>
<td>Half Power Beam Width</td>
</tr>
<tr>
<td>HPC</td>
<td>High Performance Computing</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunications Union</td>
</tr>
<tr>
<td>ICD</td>
<td>Interface Control Document</td>
</tr>
<tr>
<td>INCOSE</td>
<td>International Council on Systems Engineering</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standards Organisation</td>
</tr>
<tr>
<td>Jy</td>
<td>Jansky</td>
</tr>
<tr>
<td>Kg</td>
<td>kilogram</td>
</tr>
<tr>
<td>km</td>
<td>kilometre</td>
</tr>
<tr>
<td>LEMP</td>
<td>Logistic Engineering Management Plan</td>
</tr>
<tr>
<td>LO</td>
<td>Local Oscillator</td>
</tr>
<tr>
<td>LOFAR</td>
<td>Low Frequency Array</td>
</tr>
<tr>
<td>m</td>
<td>metre</td>
</tr>
<tr>
<td>M&amp;C</td>
<td>Monitoring and Control</td>
</tr>
<tr>
<td>MHz</td>
<td>Mega Hertz</td>
</tr>
<tr>
<td>MIL-STD</td>
<td>Military Standard</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failures</td>
</tr>
<tr>
<td>MTTR</td>
<td>Mean Time To Repair</td>
</tr>
<tr>
<td>OAR</td>
<td>Observation Action Register</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>OICD</td>
<td>Operator Interface Control Document</td>
</tr>
<tr>
<td>PAF</td>
<td>Phased Array Feed</td>
</tr>
<tr>
<td>PCA</td>
<td>Physical Configuration Audit</td>
</tr>
<tr>
<td>PDR</td>
<td>Preliminary Design Review</td>
</tr>
<tr>
<td>PPR</td>
<td>Pre-production Review</td>
</tr>
<tr>
<td>PrepSKA</td>
<td>Preparatory phase for the SKA</td>
</tr>
<tr>
<td>RAM</td>
<td>Reliability, Availability and Maintainability</td>
</tr>
<tr>
<td>RAS</td>
<td>Radio Astronomy Service</td>
</tr>
<tr>
<td>RFI</td>
<td>Radio Frequency Interference</td>
</tr>
<tr>
<td>RMS</td>
<td>Root Mean Square</td>
</tr>
<tr>
<td>RQZ</td>
<td>Radio Quiet Zones</td>
</tr>
<tr>
<td>SAT</td>
<td>Site Acceptance Test</td>
</tr>
<tr>
<td>SEMP</td>
<td>System Engineering Management Plan</td>
</tr>
<tr>
<td>SI</td>
<td>Système International d'unités</td>
</tr>
<tr>
<td>SKA</td>
<td>Square Kilometre Array</td>
</tr>
<tr>
<td>SKADS</td>
<td>SKA Design Studies</td>
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<td>SKA Program Development Office</td>
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<td>SRR</td>
<td>(Sub)System Requirements Review</td>
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<td>SRS</td>
<td>System Requirements Specification</td>
</tr>
<tr>
<td>SS</td>
<td>Survey Speed</td>
</tr>
<tr>
<td>SSEC</td>
<td>SKA Science and Engineering Committee</td>
</tr>
<tr>
<td>STaN</td>
<td>Signal Transport and Networks</td>
</tr>
<tr>
<td>TBC</td>
<td>To Be Confirmed</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Determined</td>
</tr>
<tr>
<td>TBV</td>
<td>To Be Verified</td>
</tr>
<tr>
<td>TRR</td>
<td>Test Readiness Review</td>
</tr>
<tr>
<td>V</td>
<td>Volt</td>
</tr>
<tr>
<td>WBS</td>
<td>Work Breakdown Structure</td>
</tr>
<tr>
<td>WP</td>
<td>PrepSKA Work package</td>
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</table>
1 Introduction

This document covers the System requirements for the mid frequency Aperture Array for the SKA Phase 2, SKA2. It is part of the systems engineering document set for the delta concept design review for SKA AA-mid.

The requirement sources are from the SKA2 DRM [5] and the technical evaluations taking place.

Notes:

1. Comments are in red italics
2. TBDs etc are just in red
3. I have created the need for a “Technical Requirements” document that derives details of the system requirements for AAs given the parameters from the science and other requirements docs....
4. There needs to an Operations document to reference.
5. Some of the requirements will need to be fed back up to the System SRS
6. There is very little use of standards in the requirements – this needs to be fixed
7. Really this should be operating under ISO9001 quality standards
8. The references are now using Word’s structure for them.
2 References


3 Functional and performance requirements

These requirements cover AA-mid for SKA Phase 2. These requirements are specific to AA-mid and flow down from the science cases in the SKA DRM 1.0 [5].

3.1 Functional overview

The top level context diagram for the AA-mid Reception is shown in Figure 1, these are the same for all AAs in the SKA. This is part of the second level of the SKA context diagram as presented in [2]. From this figure it is clear that the AA-mid requirements are directly influenced by the following external aspects (blue arrows):

- RF Signal: the signal of interest received by the AA
- RF Interference: any human made disturbing signal which is also received by the AA and for which the system should be made robust
- Maintenance: the design of the AA reception system should take into account the affect it has on maintenance since the total amount of electronics in the field will be significant. Hence maintenance should be minimized and any extra investment to achieve that must be balanced against the reduction in maintenance cost.
- Environment: the environment of the AA poses extra requirements on primarily the mechanical design of the antenna element and receiver systems, installation of cables and bunkers necessary for the AA system. Examples of environmental influences are dust,
temperature (and its variation), humidity and soil composition. The soil composition has mechanical implications and a strong influence on the electrical grounding of the antennas.

- Re-cycling: since the SKA has a limited lifetime the usage of materials which can be re-cycled may be of relevance.

- Weather: the AA reception systems should be designed to withstand rain, lightning, earthquakes, hail, snow etc. dependent on the weather profile of the site.

![Diagram of SKA interfaces]

In Figure 1 the internal SKA interfaces are shown in black. These interfaces are required for AA reception to work properly. The following internal interfaces are defined:

- Networking: via this interface the data from the AA reception system is transported to the central systems to be further processed.

- Monitor & Control: via this interface monitor information like status reports from all the subsystems in the AA reception system are communicated in one direction, while the control of the AA reception system is done in the other direction. Control of the AA reception system is necessary since there are many settings: beam steering, selecting the frequency bands, etc.

- Sync & Timing: via this interface the synchronization, timing and eventually LO signals are retrieved from a central system. For radio astronomical systems one of the most important aspects is to synchronize all AA reception systems with each other since the phase relation...
between the AA stations is a primary parameter which should be retrieved. Typical signals required by the AA reception system are: clock signal to sample the analogue signal and a synchronisation signal e.g. a pulse per second signal to align all AA reception systems.

- AA Receptor Cooling: cooling is necessary primarily because the amount of signal processing required in the AA reception systems is significant and the environmental conditions are likely to be hot.

- AA Receptor Power: This interface is defined to power all the electronics in the AA Reception system.

![Figure 1 Context diagram of the AA Reception system (level 2)](image)
Considering in more detail the AA-mid Reception context diagram of Figure 1 results in the third level context diagram presented in Figure 2.
As shown in Figure 2 the primary functions of the SKA$_1$ AA-mid reception system are:

1) **EM waves reception**: the electromagnetic radiation is converted into the electrical domain.

2) **Amplification**: this boosts the signal for digitisation and reduces the noise contribution of later stages.

3) **Beamforming & Filtering**: adds optionally multiple antenna elements with an analog beamformer and filters out the frequencies outside the AA-mid specification. In practice multiple amplifier and filtering stages will be implemented.

4) **Digitizing**: the analogue signal is sampled and quantized.

5) **Beamforming & Correlation**: in the beamforming phase the signals of multiple receptors are combined in order to make beams on the sky. A correlation function is required to calibrate all the individual receiver chains with each other to compensate for gain and phase variations between them as a function of time.

6) **AA Calibration**: calculates the gain and phase differences between receiver chains and uses the output of the correlation functionality as an input.

7) **AA Monitor & Control**: translates high level system control information to specific commands for the AA hardware and software. The monitor information from the software and hardware is transmitted to the SKA Monitor & Control system. This system also enables local control of the AA station for maintenance and troubleshooting activities.

8) **AA Reception Power Generation**: power is generated or retrieved from a central node.
9) **AA Reception Cooling**: maintains the temperature of all parts of the AA-mid station within specification limits.

### 3.2 AA-mid spectral characteristics

The spectrum to be observed with SKA\textsubscript{1} AA-mid is specified.

#### 3.2.1 Operating Frequency

<table>
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<tr>
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<th>Requirement</th>
<th>Applicability</th>
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<tr>
<td>AAM_REQ_1110</td>
<td><strong>Electromagnetic frequency range.</strong> AA-mid shall be able to measure electromagnetic radiation in a frequency range from:</td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>400 MHz to 1450 MHz</td>
<td></td>
<td></td>
<td></td>
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The higher boundary is from Section 12.4.1 [5], 1450 MHz is taken since neutral hydrogen is at 1421 MHz.

#### 3.2.2 Instantaneous Bandwidth

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<td>AAM_REQ_1120</td>
<td><strong>Instantaneous bandwidth.</strong> AA-mid shall have a minimum instantaneous bandwidth of:**</td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>1000 MHz</td>
<td></td>
<td></td>
<td></td>
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[5] Section 1.4, fractional bandwidth ~ 1

#### 3.2.3 Spectral Flatness

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<th>Parent</th>
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<tr>
<td>AAM_REQ_1130</td>
<td><strong>Spectral ripple.</strong> The passband ripple over the band, after calibration:**</td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>Maximum +/- 1 % (TBD). <strong>Note that this is not the analogue system, but after digitisation and processing. The only characteristics</strong></td>
<td></td>
<td></td>
<td>[2] SYS_REQ_1190, The parent is not very specific.</td>
</tr>
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</table>
the analogue chain requires is to deliver a signal within bounds to the ADC, stability and be capable of measurement for calibration.

### 3.2.4 Spectral Passband Slope

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<th>Requirement</th>
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<th>Parent</th>
<th>Verification/Comments</th>
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<td>AAM_REQ_1135</td>
<td>Spectral passband slope.</td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>The passband slope over the band should be:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximum x dB (TBD).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Note that this is the analogue system, prior to digitisation. This can be calibrated out but decreases the Signal to Noise Ratio.</td>
<td></td>
<td></td>
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### 3.2.5 Spectral Resolution

The following requirements are for the AA-mid station only. This is when using frequency domain beamforming and is necessary to meet the size and spacing of the elements. The spectral filter must also transmit the data such that the correlator may further subdivide the data into much narrower bands required for correlation. The final required SKA spectral resolution should be made by the central systems.

<table>
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<tr>
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<td>Spectral resolution.</td>
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<td>Test</td>
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<td></td>
<td>The AA-mid station shall have a minimal spectral resolution over the full instantaneous bandwidth (TBV):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1MHz (TBD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[5] Table 12.2 requires resolution before correlation of 3 kHz</td>
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### 3.2.6 Spectral Dynamic Range

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<tr>
<td>AAM_REQ_1150</td>
<td>Spectral dynamic range.</td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>SKA shall have a minimum spectral dynamic range at the output of the correlator of:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>62 dB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[1] Paragraph 3.3.5, changed 1400 to</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2.7 Clipping

The dynamic range of the element (or Tile) up to digitisation is partly set by the effective number of bits, ENOB, of the digitiser. This is a measure of the ability to cope with interference and large astronomical signals; it is not a measure of the dynamic range of the array itself or the images that get produced after processing.

It is not practical to expect to precisely digitise every possible interference signal, however, statistically the amount of observing time lost due to clipping can be determined.

<table>
<thead>
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<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1160</td>
<td>Clipping</td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>The dynamic range of the ADC’s shall be such that no clipping will occur for 95% (TBC) of the time.</td>
<td></td>
<td>[2] SYS REQ 5430</td>
<td>The parent requirement needs some changes since it specifies no clipping</td>
</tr>
<tr>
<td>AAM_REQ_1165</td>
<td>Clipping data should be marked in the data stream</td>
<td>Essential</td>
<td></td>
<td>[2] SYS REQ 5430</td>
</tr>
</tbody>
</table>

3.3 AA sensitivity, FOV and survey speed

3.3.1 Sensitivity

<table>
<thead>
<tr>
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<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
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</thead>
<tbody>
<tr>
<td>AAM_REQ_1210</td>
<td>Sensitivity (\frac{A_{eff}}{T_{sys}}). The AA receptor system shall have a minimum sensitivity for scan angles of maximal 45 degrees (TBD) of:</td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>10,000 (m^2/K) expressed in Stokes I. This is equivalent with the sensitivity which is required for one polarisation.</td>
<td></td>
<td>[5] Section 18, Table 18.2 (DRM Chapters 6, 7, 8, 15 and 17)</td>
<td></td>
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</tbody>
</table>
3.3.2 Instantaneous Field of View

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1220</td>
<td><strong>Instantaneous field of view.</strong> The SKA shall achieve a minimum total FOV (that can be synthesized from multiple beams) of:</td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>100 square degrees</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The field of view is derived from the survey speed and sensitivity.

3.3.3 Survey Speed

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1230</td>
<td><strong>Survey speed.</strong> AA-mid shall have a survey speed ($m^4K^{-2}deg^2$):</td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>$10^{10}$ $m^4K^{-2}deg^2$</td>
<td></td>
<td></td>
<td>[5] Section 12.4.2</td>
</tr>
</tbody>
</table>

3.4 Spatial Characteristics

3.4.1 Baseline Requirements

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1310</td>
<td><strong>Baseline.</strong> The maximum baseline is:</td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>180 km (TBD)</td>
<td></td>
<td></td>
<td>[4]</td>
</tr>
</tbody>
</table>

3.4.2 Sky Coverage

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1320</td>
<td><strong>Sky coverage.</strong></td>
<td>Desirable</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>6000$deg^2$ (TBD)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.4.3 Scan Angle

This requirement is derived from the sky coverage.
### 3.4.4 Core filling factor

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1340</td>
<td><strong>Core filling factor.</strong>&lt;br&gt;The filling factor of the core should be at least:</td>
<td>Essential</td>
<td></td>
<td>Analysis</td>
</tr>
<tr>
<td></td>
<td>? %</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.4.5 Station Side Lobes

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1350</td>
<td><strong>Station side lobes.</strong>&lt;br&gt;The integral of all station side lobes should be smaller than</td>
<td>Essential</td>
<td></td>
<td>Analysis</td>
</tr>
<tr>
<td></td>
<td>? dB compared with the main lobe.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.5 Systematic Errors

#### 3.5.1 Coherence Loss

Any coherence loss in the system introduced should be below the value specified below. An example of a coherence loss effect is the beam squint which is caused by a beamformer using phase shift. Since only one phase shift setting per sub-band or channel can be set an error arises at the edges of the sub-band or channel. The error causes coherence loss in the beamformer and should stay below the specified value.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1410</td>
<td><strong>Coherence loss.</strong></td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
</tbody>
</table>
### 3.5.2 Positioning Error

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_1420   | **Position error.**  
The position error of the all antenna elements from the specified position should be smaller than: | Essential |       | Test         |
| TBD            | Note that this will depend on the array configuration used e.g. random may be very tolerant of errors – calibrate out. | LOFAR uses $\lambda/40$ |        |              |

### 3.5.3 Orientation Error

The orientation of the elements is considered within one array. Array to array orientation is the subject of the System SRS (2). It is necessary to orientate the elements for consistency of polarisation, however, it may be easier to calibrate out detailed errors.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_1430   | **Orientation error.**  
The orientation error of the antenna elements from the specified orientation should be smaller than: | Essential |       | Test         |
| TBD            | This will depend on the ability to calibrate individual elements | LOFAR uses 1 degree |        |              |

### 3.6 Temporal Characteristics

The stability of the analogue systems directly impacts the calibration requirements and their regularity. They need to be traded off together.
### 3.6.1 Gain Stability

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1510</td>
<td><strong>Gain stability.</strong> The gain stability of each SKA receiver chain which is digitized should be smaller than:</td>
<td>Essential</td>
<td>Should be derived from a calibration requirement if possible.</td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>Stability per °C: 0.5% (TBD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>over 24 hours: 0.5% (TBD) RMS at a constant temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.6.2 Phase Stability

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1520</td>
<td><strong>Phase stability.</strong> The phase stability of each SKA receiver chain which is digitized should be smaller than:</td>
<td>Essential</td>
<td>Should be derived from a calibration requirement if possible.</td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>Degree per °C: 0.5 deg (TBD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>over 24 hours: 0.5 deg (TBD) RMS at a constant temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.6.3 Beam Stability

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1530</td>
<td><strong>Beam stability.</strong> The SKA shall have a maximal RMS stability in the HPBW of:</td>
<td>Essential</td>
<td>Should be derived from a calibration requirement if possible.</td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>over 24 hours: TBD % RMS with a zenith pointing direction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TBD % RMS (TBD) with a zenith pointing direction if one receiver chain is failing in the full band for SKA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 3.6.4 Smoothness

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1530</td>
<td><strong>Smoothness.</strong>&lt;br&gt;Any variation in the SKA system shall be smoother than:</td>
<td>Essential</td>
<td>Should be derived from a calibration requirement if possible.</td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.01% per second (TBD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.1%/Hz (TBD) over the instantaneous bandwidth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>This needs much more thought......</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.6.5 Tracking Accuracy

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1540</td>
<td><strong>Tracking accuracy.</strong>&lt;br&gt;The beam pointing accuracy should be such that:</td>
<td>Essential</td>
<td>(2) SYS_REQ_1980</td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A point source remains within TBD% of the HPBW of the beam.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Presumably this requirement is due to the frequency dependant nature. Even so, it may well be that a figure in degrees for the AA-mid is better.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.6.6 Beam Switching Agility

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1550</td>
<td><strong>Beam switching agility.</strong>&lt;br&gt;The beam switching time includes the distribution of the command from the control centre. A beam should be re-pointed to a predefined position in:</td>
<td>Essential</td>
<td>TBD</td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TBD secs.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 3.6.7 Maximal Observation Period

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1560</td>
<td><strong>Maximal Observation Period.</strong></td>
<td>Essential</td>
<td>(2) SYS_REQ_1430</td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>The AA subsystem shall be designed so that a deep field observed. The requirement is maintain noise limited sensitivity.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capable of 1000 hr integration time</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.6.8 Temporal Resolution

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1560</td>
<td><strong>Temporal resolution.</strong></td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>The AA subsystem shall have an attainable time resolution of at least:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50 µs</td>
<td></td>
<td>[5] Paragraph 16.4.4</td>
<td></td>
</tr>
</tbody>
</table>

### 3.7 Polarisation Characteristics

#### 3.7.1 Beam Polarization Stability

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1610</td>
<td><strong>Beam polarization stability.</strong></td>
<td>Essential</td>
<td>(2) SYS_REQ_1710</td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>The polarisation properties of the beams shall be stable enough to enable their calibration to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;0.5 % (TBD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>This needs to be better specified in dB, which will be the scientific requirement. It needs to be derived into something that can be built and tested.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 3.7.2 Beam Polarization Purity
3.8 Imaging Characteristics

3.8.1 UV Coverage

<table>
<thead>
<tr>
<th>Ident</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1710</td>
<td><strong>UV coverage.</strong> SKA shall have a:</td>
<td>Essential</td>
<td>UV coverage is not defined good at the moment</td>
<td>Analysis</td>
</tr>
</tbody>
</table>

3.8.2 Imaging Dynamic Range

STATION DYNAMIC RANGE This has to be translated into AA station requirements. The imaging is a system wide requirement dominated by the post processing – the tech requirements of the AA station is determined here.

<table>
<thead>
<tr>
<th>Ident</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1720</td>
<td><strong>Imaging dynamic range.</strong> SKA shall be able to provide an imaging dynamic range for continuum imaging (thermal noise imaging to classical (micro Jansky (Jy)) confusion limits) of at least:</td>
<td>Essential</td>
<td></td>
<td>Test</td>
</tr>
</tbody>
</table>

3.9 Monitoring and Control

Monitoring and Control is a central system responsible for acquiring and monitoring data and for control of the SKA systems. The requirements in this section reflect the consequent requirements for the AA reception subsystems.
3.9.1 M&C Monitoring Data

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2110</td>
<td><strong>M&amp;C monitoring data.</strong> AA subsystems shall provide monitoring data to the monitoring and control function (for performance monitoring and closed-loop control functions) <strong>This will need substantial expansion.</strong></td>
<td>Essential</td>
<td>(2) SYS_REQ_2220</td>
<td>Demo</td>
</tr>
</tbody>
</table>

3.9.2 M&C Calibration Information

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2120</td>
<td><strong>M&amp;C calibration information.</strong> Individual AA subsystem calibration information shall be available to the measurement function. <strong>This will need substantial expansion.</strong></td>
<td>Essential</td>
<td>(2) SYS_REQ_2250</td>
<td>Demo</td>
</tr>
</tbody>
</table>

3.9.3 Subsystem M&C Action

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2130</td>
<td><strong>Subsystem M&amp;C action.</strong> AAs shall report completion of actions to M&amp;C</td>
<td>Essential</td>
<td>(2) SYS_REQ_2420</td>
<td>Demo</td>
</tr>
</tbody>
</table>

3.9.4 Autonomous Control

This is to provide maintenance and troubleshooting capabilities. All the functions available centrally will be available at a local station interface e.g. power up and down, parameter setting and reporting and other diagnostic tools.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2140</td>
<td><strong>Autonomous Control.</strong> The AA station shall be capable of coming under local control and not interacting with the overall SKA.</td>
<td>Essential</td>
<td>(2) SYS_REQ_3620</td>
<td>Demo</td>
</tr>
</tbody>
</table>
3.9.5 Calibration

The calibration of the AAs is important to their operation. The details of the scheme used needs to be defined: they could be calibrated using external sources; astronomically while not observing or during observations using a separate beam.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_1620</td>
<td><strong>Calibration update rate.</strong></td>
<td>Essential</td>
<td>(2) SYS_REQ_1720</td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>External Calibration measurements shall be necessary at a rate of:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;1 hour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>For AAs this would mean using artificial sources. Maybe this should be showing observation time lost from recalibration...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAM_REQ_1630</td>
<td><strong>Real-time calibration.</strong></td>
<td>Essential</td>
<td>(2) SYS_REQ_2760</td>
<td>Demo</td>
</tr>
<tr>
<td></td>
<td>The AA reception system shall provide instrumental real-time calibration functions.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.10 Observational modes

3.10.1 Beam Forming Mode

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2210</td>
<td><strong>Beam forming mode.</strong></td>
<td>Essential</td>
<td>(2) SYS_REQ_2710 – SYS_REQ_2740</td>
<td>Demo</td>
</tr>
<tr>
<td></td>
<td>The AA reception system shall provide a beam forming mode</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.10.2 Aggregate Mode

The AA performance is defined by the data rate that is transmitted to the correlator. The concept of maximum bandwidth beams is useful for explaining the capability of the AAs. However, considerable scientific benefit is available by adjusting the number of beams as a function of frequency such that a large amount of sky can be observed over a narrow bandwidth or less sky over a wide bandwidth. The total data rate from the array is the limiting factor. Further, the data rate could be used differently by adjusting the number of bits per sample. This exchange of bandwidth and beams is called “Aggregate Mode”.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
### 3.11 Data Products

#### 3.11.1 Total output data rate

The output data rate, station to correlator, defines the survey capabilities of the array. It also determines the requirements of the correlator and post processor. The aggregate data rate for all the AA-mid stations is constant for a given sensitivity and survey speed, however many stations are used.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2305</td>
<td>Data rate.</td>
<td>Essential</td>
<td>TBD</td>
<td>Demo</td>
</tr>
<tr>
<td></td>
<td>The aggregate data rate of all AA-mid stations should be:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total data rate: TBD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>This is a function of sensitivity and survey speed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 3.11.2 Beam Products

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2310</td>
<td>Beam products.</td>
<td>Essential</td>
<td>(4) Paragraph 5.4.6</td>
<td>Demo</td>
</tr>
<tr>
<td></td>
<td>AA-mid shall be capable of communicating the beam products as a voltage time series over the observed FoV.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 3.11.3 Data Product Types

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>

2011-11-14
4   Operational requirements

4.1   General

4.1.1   Up-time

<table>
<thead>
<tr>
<th>Ident</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2410</td>
<td>Up-time.</td>
<td>Essential</td>
<td>(2) SYS_REQ_3110</td>
<td>Demo</td>
</tr>
<tr>
<td></td>
<td>AA-mid shall be designed to be operated continuously, other than for regular maintenance.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>This needs qualification – what about maintenance?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.1.2   Reconfiguration Time

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2420</td>
<td>Reconfiguration time.</td>
<td>Essential</td>
<td>(2) SYS_REQ_3150</td>
<td>Demo</td>
</tr>
<tr>
<td></td>
<td>Reconfiguration time for AA-mid from one observational mode to another:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;5 minutes (TBC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assumes all software applications are present at their designated location</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2   Start-up and Shut-down

4.2.1   Start-up Sequence

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
AAM_REQ_2430 | **Start-up sequence.**  
The start-up of AA-mid functions shall follow a pre-defined sequence taking not longer than:  
<table>
<thead>
<tr>
<th>Essential</th>
<th>(2) SYS_REQ_3170</th>
<th>Test</th>
</tr>
</thead>
</table>
| Hot start: | 10 minutes  
This is a restart |
| Cold start: | 24 hours  
A cold start is defined as requiring..... |

### 4.2.2 Shut-down Sequence

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_2430 | **Shut-down sequence.**  
The AA stations will use a controlled shut down process. |
| Essential | (2) SYS_REQ_3190 | Test |

### 4.2.3 AA-mid Autonomous Shut-down

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_2440 | **AA autonomous shut down.**  
An AA-mid station shall be capable of autonomously detecting conditions requiring station shut down e.g. power anomalies, over temperature, cooling failure etc and then shutting down and reporting the condition to the central M&C systems.  
This implies a separately powered M&C system that is kept alive – what if that needs powering down? |
| Essential | (2) SYS_REQ_3190 | Test |

### 4.2.4 Start-up and Shut-down Individual Antenna Systems

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_2440 | **Start-up and shut-down individual AA-mid stations.**  
It shall be possible to start-up or shutdown individual AA-mid stations and communicate status to the M&C systems. |
| Essential | (2) SYS_REQ_3180 | Test |
### 4.2.5 Start-up and Shut-down Dependencies

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2450</td>
<td><strong>Start-up and shut-down dependencies.</strong>&lt;br&gt;Any dependencies in the start-up and shutdown sequences shall be automatically verified (so they do not depend on operator intervention).</td>
<td>Essential</td>
<td>(2) SYS_REQ_3220</td>
<td>Inspection</td>
</tr>
</tbody>
</table>

### 4.2.6 Subsystem Shut-down

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2460</td>
<td><strong>Start-up and shut-down dependencies.</strong>&lt;br&gt;The shutdown of pre-defined parts of AA-mid stations shall have no (TBC) impact on SKA₁ operations after appropriate re-calibration performed automatically.&lt;br&gt;This cannot be completely true – e.g. sensitivity will be lost or gained – just qualify with “significantly”?</td>
<td>Essential</td>
<td>(2) SYS_REQ_3230</td>
<td>Test</td>
</tr>
</tbody>
</table>

### 4.2.7 Initial Check-out

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2470</td>
<td><strong>Initial check-out.</strong>&lt;br&gt;AA-mid shall be designed to enable an operational readiness check, including redundancies, prior to commencement of any SKA₁ operations (initial check-out).</td>
<td>Essential</td>
<td>(2) SYS_REQ_3240</td>
<td>Test</td>
</tr>
</tbody>
</table>

### 4.2.8 Operational Readiness Check

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2480</td>
<td><strong>Operational readiness check.</strong>&lt;br&gt;The AA-mid operational readiness check shall take:</td>
<td>Essential</td>
<td>(2) SYS_REQ_3250</td>
<td>Test</td>
</tr>
<tr>
<td></td>
<td>&gt;5 minutes.</td>
<td></td>
<td></td>
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</tbody>
</table>
## 4.3 Failure Management

### 4.3.1 General

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
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<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3310</td>
<td><strong>Personnel safety.</strong></td>
<td></td>
<td>(2) SYS_REQ_3310</td>
<td></td>
</tr>
<tr>
<td></td>
<td>As far as possible, no single failure in AA-mid shall lead to personnel safety hazards.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>This seems very mild – surely it should cope with some level of anticipated further failure modes. Suggestion: take single out and change to: “as far as reasonable, no failures...”</em></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3320</td>
<td><strong>Failure propagation.</strong></td>
<td></td>
<td>(2) SYS_REQ_3320</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Failures in the AA-mid subsystems shall not lead to failures in other AA subsystems or other SKA systems.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3330</td>
<td><strong>Operator command safety.</strong></td>
<td></td>
<td>(2) SYS_REQ_3330</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No single operator command for AA-mid shall cause catastrophic, serious, or major consequences.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3340</td>
<td><strong>Voltage transient consequences.</strong></td>
<td></td>
<td>(2) SYS_REQ_3340</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No voltage-transients or &quot;cut-off&quot; of electrical power shall lead to catastrophic or serious consequences in AA-mid. <em>This includes voltage transients applied to the input of the receivers.</em></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3350</td>
<td><strong>Operator command absence.</strong></td>
<td></td>
<td>(2) SYS_REQ_3350</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The absence of operator commands shall not cause catastrophic or</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
serious consequences.

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3360</td>
<td>Single-point failures.</td>
<td>· Single-point-failures in the AA-mid shall be listed in the design and operational documentation.</td>
<td>(2) SYS_REQ_3360</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3370</td>
<td>Single-point failure justification.</td>
<td>· Each single-point failure listed for the AA-mid shall be justified, and assessed against alternative design(s) where this single-point-failure would not occur, if possible.</td>
<td>(2) SYS_REQ_3370</td>
<td></td>
</tr>
</tbody>
</table>

### 4.3.2 Detection and Reporting

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3520</td>
<td>Status report availability time.</td>
<td>· The availability of a status report of the functioning of AA-mid shall be in:</td>
<td>(2) SYS_REQ_3520</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>· ≤5 seconds</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>· This is too generic a request, how much status, in what detail etc?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Applicability</th>
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<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3530</td>
<td>Status report request.</td>
<td>· The status report of a subsystem shall show the functioning of the subsystem at or after the operator request has been submitted to the system.</td>
<td>(2) SYS_REQ_3530</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3540</td>
<td>Status report scope.</td>
<td>· The status report shall display the status of a sub-system, together with the system time the status was determined.</td>
<td>(2) SYS_REQ_3540</td>
<td></td>
</tr>
</tbody>
</table>
### 4.3.3 Diagnosis and Recovery

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_3610   | **System interrogation reply.**  
Each AA-mid station shall have the capability to answer an operator interrogation.  
*Is this what is meant or is it subsystem?* | | (2) SYS_REQ_3610 | |

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_3670   | **Autonomous recovery.**  
AA-mid shall be able to recover autonomously in case of failures that are classified as minor or negligible.  
*Where the classification of failures and what is meant by recovery?* | | (2) SYS_REQ_3670 | |

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_3680   | **Effect of disabled units.**  
The AA-mid design shall ensure that disabled units do not corrupt the observational data in the remaining system. | | (2) SYS_REQ_3680 | |

### 4.3.4 Lifetime

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_3710   | **Continuous operation period.**  
AA-mid shall be designed for a continuous operational periods of:  
6 months  
After this time maintenance may be necessary, e.g. exchange/cleaning of air-conditioning filters. | | (2) SYS_REQ_3710 | |

<table>
<thead>
<tr>
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<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_3720   | **Minimum life time.**  
The AA subsystem shall be designed | | (2) SYS_REQ_3720 | |
for a minimum life time (including initial installation, testing and commissioning period) of:

TBD years

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_3725   | **Support equipment life-time.**  
AA-mid support equipment shall be designed to maintain SKA₁ for:  
12 (TBC) years. | (2) SYS_REQ_7960 |        |              |

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_3730   | **Availability.**  
The average availability of all AA-mid subsystems during the operational period shall be:  
> 90% (TBC).  
Availability is defined here as being available for scheduled observations in at least one of the supported operational modes.  
*This is far too loose. What level of subsystem? Board – the array would never be in use. The station? This would take into account redundancy of elements* | (2) SYS_REQ_3730 |        |              |

<table>
<thead>
<tr>
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<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_3740   | **Upgradeability**  
AA-mid shall be upgradable.  
*This is again far too vague. Anything is upgradeable to a trivial extent. This should be defined...* | (2) SYS_REQ_3740 |        |              |

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_3750   | **Life-time extension.**  
Large scale maintenance and/or an upgrade shall give the possibility to reach a life time of:  
50 years (TBC).  
*The level of maintenance needs to be* | (2) SYS_REQ_3750 |        |              |
4.3.5 Reliability

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7420</td>
<td>Field return rate.</td>
<td></td>
<td>(2) SYS_REQ_7420</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The field return rate of equipment, during installation and the first year full usage, shall be:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;0.5% (TBC).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Where did this figure come from?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5% of what? All like equipment?</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

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<tr>
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<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7810</td>
<td>Equipment reliability.</td>
<td></td>
<td>(2) SYS_REQ_7810</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The reliability of AA-mid equipment to meet its performance requirements over a period of 10 years shall be:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;99.4 % (TBC).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>This is a very confusing specification. Does it mean &lt;6 boards out of a thousand work for 10 years (an MTBF of &gt;1000years)? Or is it the overall</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 4.4 Maintenance

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3840</td>
<td>Data-loss due to power outage</td>
<td></td>
<td>(2) SYS_REQ_3840</td>
<td>This requirement needs to be rewritten in order to be feasible for the AA subsystems</td>
</tr>
<tr>
<td></td>
<td>This spec does not apply to AA-mid – it is a system parameter, there is no significant data stored locally.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The AA subsystem shall not lose more than 4 hours of acquired or processed measurement data (not yet permanently stored) as a result of an outage in the external power supply.</td>
<td></td>
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<th>Applicability</th>
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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3850</td>
<td>Autonomous restart after power outage.</td>
<td></td>
<td>(2) SYS_REQ_3850</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid shall have the capability to restart autonomously and without failures, after an outage in external power supply.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>How does this vary from AAM_REQ_3670?</em></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3860</td>
<td>System availability after restart.</td>
<td></td>
<td>(2) SYS_REQ_3860</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid shall be available within 5 minutes (TBC) after restart.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>How does this vary from AAM_REQ_2480?</em></td>
<td></td>
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</table>

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_3870</td>
<td>Software/firmware re-installation.</td>
<td></td>
<td>(2) SYS_REQ_3870</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All software / firmware in AA-mid shall be capable of being re-installed.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Identification | Requirement | Applicability | Parent | Verification
--- | --- | --- | --- | ---
**AAM_REQ_3880** | **Software/firmware upgrades.**
It shall be possible to replace all software / firmware configuration items in AA-mid through software-upgrades. | | (2) SYS_REQ_3880 |  
**AAM_REQ_3890** | **Software code identification.**
Software configuration items shall provide unambiguous identification to allow the maintenance of a configuration management database. | | (2) SYS_REQ_3890 |  
**AAM_REQ_3910** | **Software code identification response time.**
The software identification requests shall be available to the operator within:

10 seconds (TBC)

*Why the urgency?*

**AAM_REQ_3920** | **AA maintenance functions.**
The AA-mid shall include functions that allow maintenance of hardware and software.

*This is far too wholly! What maintenance etc.*

**AAM_REQ_7820** | **Tools and test equipment.**
The AA-mid design shall require and specify a minimum number of special tools and test equipment to perform assembly, integration and repair and maintenance activities.

(2) SYS_REQ_7820
(2) SYS_REQ_9110
### Identification | Requirement | Applicability | Parent | Verification
--- | --- | --- | --- | ---
AAM_REQ_7830 | **Inaccessible hardware maintenance.**  
Inaccessible hardware or structures shall require no maintenance during operation and should have built in test capability when applicable. | | (2) SYS_REQ_7830 |  
AAM_REQ_7840 | **Test and repair instructions.**  
Test and repair instructions shall be written for fault detection and maintenance of the AA-mid equipment. | | (2) SYS_REQ_7840 |  
AAM_REQ_7850 | **Maintenance team size.**  
It should be possible to execute regular maintenance jobs with not more than two (2) people per job. | | (2) SYS_REQ_7850 |  

#### 4.5 Disposal Phase

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
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<th>Verification</th>
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</thead>
</table>
AAM_REQ_4110 | **Environmental rule compliancy.**  
The AA-mid design shall be fully compliant to all environmental rules applicable to the SKA site.  

*This requirement should be much more specific* | | (2) SYS_REQ_4110 |  
AAM_REQ_4120 | **Lasting environmental effects.**  
AA-mid shall be designed to have no lasting adverse environmental effects on the facility and site.  

*This requirement should be much more specific* | | (2) SYS_REQ_4120 |
5 Engineering Design Constraints

This chapter specifies the design constraining requirements for engineering.

5.1 Materials and Processes

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7110</td>
<td><strong>Materials, Parts and Processes lists.</strong></td>
<td></td>
<td>(2) SYS_REQ_7110</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Each subsystem supplier of AA-mid shall establish, collect, review and</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>deliver materials, parts and processes lists including all the Materials,</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Parts and Processes intended for use in the SKA by his suppliers and himself.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>They shall reflect the current design at the time of issue.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td><em>This all reads very muddled – should be part of a quality system</em></td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7130</td>
<td><strong>Parts availability.</strong></td>
<td></td>
<td>(2) SYS_REQ_7130</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The estimated availability of the parts and products obtained from materials and processes used shall be compatible with the final system's life cycle (tests, storage, mission).</td>
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</tbody>
</table>

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<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7140</td>
<td><strong>Product manufacturing.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Products should be manufactured as much as possible in a factory.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7150</td>
<td><strong>Product assembly.</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Products which needs to be assembled at the site should be constructed as simple as possible to minimize the construction time.</td>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7160</td>
<td><strong>Product testing.</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Products should be tested as much as</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
possibly in the factory instead of testing at site.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_7170   | **Product sealing.**
                 | Products exposed directly to the environment (like antenna elements) should be fully sealed before shipping to the site. |        |              |              |

### 5.2 Marking

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_7210   | **Part identification.**
                 | Each part, material or product shall be identified with a unique and permanent part or type number. Needs to be more specific how far down the hierarchy the identification is necessary (board level, cables, connectors, ...). |        | (2) SYS_REQ_7210 |

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_7220   | **Marking method.**
                 | Method of marking shall be compatible with the nature of the item and its use. |        | (2) SYS_REQ_7220 |

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_7230   | **Documentation marking.**
                 | Identification numbers shall be marked on documentation and, where possible, on all items. |        | (2) SYS_REQ_7230 |

### 5.3 Power and other utilities

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
</table>
| AAM_REQ_7330   | **Limiting excessive currents.**
                 | AA-mid equipment circuitry shall be protected against excessive currents by a current limiting device, which |        | (2) SYS_REQ_8160 |
shall not itself produce excessive currents.

*What is this? Is this on the interfaces against lightning or other problems – if so, say so.*

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7340</td>
<td><strong>Power surge protection.</strong></td>
<td></td>
<td>(2) SYS_REQ_8170</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid subsystems shall be protected against power transients and surges.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7350</td>
<td><strong>Polarity mis-connection protection.</strong></td>
<td></td>
<td>(2) SYS_REQ_8180</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid equipment circuitry shall be protected against the effects of inadvertent wrong polarity connections. <em>(TBC)</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>This needs to be specified at what level and if it really needs to be done. This could use substantially more power due to diode drops etc.</em></td>
<td></td>
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</tr>
</tbody>
</table>

### 5.4 Accessibility and testability

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<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7880</td>
<td><strong>Self-test capability.</strong></td>
<td></td>
<td>(2) SYS_REQ_7880</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The AA-mid subsystem design for both hardware and software shall provide self-test capabilities.</td>
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</table>

<table>
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<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7890</td>
<td><strong>Servicing point making.</strong></td>
<td></td>
<td>(2) SYS_REQ_7890</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All servicing and test points shall be clearly marked using TBD labelling standards.</td>
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</tr>
</tbody>
</table>

### 5.5 Transportability and storage
### Handling heavy equipment.

AA-mid parts, test equipment or supporting equipment with a mass exceeding 25 kg shall be provided with provisions for handling and transportation.

**Warnings?**

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7910</td>
<td>Handling heavy equipment.</td>
<td></td>
<td>(2) SYS_REQ_7910</td>
<td></td>
</tr>
</tbody>
</table>

#### Disassembly for transport.

It shall be possible to disassemble AA-mid equipment for transportation or storage as necessary.

<table>
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<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7920</td>
<td>Disassembly for transport.</td>
<td></td>
<td>(2) SYS_REQ_7920</td>
<td></td>
</tr>
</tbody>
</table>

#### Long term storage.

It shall be possible to store AA-mid equipment (spare parts) for 10 years without any degradation of its function or performance.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7930</td>
<td>Long term storage.</td>
<td></td>
<td>(2) SYS_REQ_7930</td>
<td></td>
</tr>
</tbody>
</table>

#### Special storage.

If special storage facilities are needed they shall be supplied as part of the spares procurement.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7935</td>
<td>Special storage.</td>
<td></td>
<td>(2) SYS_REQ_7935</td>
<td></td>
</tr>
</tbody>
</table>

#### Packing density.

Packing density for transportation should be designed as an optimised cost/performance requirement.

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7940</td>
<td>Packing density.</td>
<td></td>
<td></td>
<td>TBD</td>
</tr>
<tr>
<td>Ident</td>
<td>Requirement</td>
<td>Applicability</td>
<td>Parent</td>
<td>Verification</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------------</td>
<td>--------</td>
<td>--------------</td>
</tr>
<tr>
<td>AAM_REQ_7950</td>
<td><strong>Packing method.</strong>&lt;br&gt; All products should be packed prior to transportation such that it can withstand (1) rigorous transportation, (2) transport vibration and (3) movement. Perhaps this should be specified more quantitatively in G’s for example.</td>
<td></td>
<td></td>
<td>TBD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ident</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7960</td>
<td><strong>Large equipment size.</strong>&lt;br&gt; The volume of large equipment which cannot be disassembled should be driven by standard shipping container guidelines.</td>
<td></td>
<td></td>
<td>TBD</td>
</tr>
</tbody>
</table>

### 5.6 Array Deployment

<table>
<thead>
<tr>
<th>Ident</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_8000</td>
<td><strong>Antenna element deployment time.</strong>&lt;br&gt; The time to assemble and deploy the antenna elements should be minimized to ? minutes per antenna element.</td>
<td></td>
<td></td>
<td>TBD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ident</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_8010</td>
<td><strong>Antenna element deployment.</strong>&lt;br&gt; The AA array design and deployment should be able for installation on a site with a local flatness tolerance of ? cm over ? m.</td>
<td></td>
<td></td>
<td>TBD</td>
</tr>
<tr>
<td>Ident</td>
<td>Requirement</td>
<td>Applicability</td>
<td>Parent</td>
<td>Verification</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------------------------------</td>
<td>---------------</td>
<td>--------</td>
<td>--------------</td>
</tr>
<tr>
<td>AAM_REQ_8020</td>
<td><strong>Antenna positions.</strong> Each individual antenna position should be measured and known within ? mm in three dimensions in the ITRF coordinate system.</td>
<td>TBD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAM_REQ_8030</td>
<td><strong>Antenna orientation.</strong> Antenna elements should be designed such that they can be rotated quick and simple.</td>
<td>TBD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAM_REQ_8040</td>
<td><strong>Antenna fixation.</strong> Antenna elements should be designed such that they can be simple and effectively fixed to the ground.</td>
<td>TBD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAM_REQ_8050</td>
<td><strong>Housing heights.</strong> Any housing near the antenna field should not be in the line of sight of $\theta = x$ degrees above horizon. The following relation should hold: $h &lt; d \cdot \tan(\theta)$, wherein $h$ is the height and $d$ is the distance of the housing to the nearest antenna.</td>
<td>TBD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAM_REQ_8060</td>
<td><strong>Burying cables and fibres.</strong> If possible cable and fibre burying should be avoided as much as possible. Does not seem a good requirement I think.</td>
<td>TBD</td>
<td></td>
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</table>


5.7 Electronic Design Requirements

<table>
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<tr>
<th>Ident</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_8100</td>
<td><strong>Device junction temperature.</strong>&lt;br&gt;The device junction temperature of the main devices should be kept below x degrees Celsius to increase lifetime.</td>
<td></td>
<td></td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td>Should follow from the RAMS analysis. Don’t know if you should put this as a requirement.</td>
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</table>

<table>
<thead>
<tr>
<th>Ident</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_8110</td>
<td><strong>Design for upgradability.</strong>&lt;br&gt;The AA low design should be made such that future upgrades are able to process the full bandwidth of each antenna element, assuming the cost impact is small.</td>
<td></td>
<td></td>
<td>TBD</td>
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</tbody>
</table>

6 External Interface Requirements

External Interfaces are defined as interactions or communications with the world outside an AA-mid station. These are represented as blue arrows in
6.1 RF Signal

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_8300</td>
<td><strong>RF signal.</strong> The input signal of each AA-mid station has the following characteristics in the band 70-450MHz:</td>
<td><strong>The input for this requirement is the spectrum measured at the selected site.</strong></td>
<td></td>
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<tr>
<td></td>
<td><strong>TBD dBm:</strong> 24 hours average power</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>TBD dBm:</strong> Peak power</td>
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</table>

6.2 RF Interference

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_8400</td>
<td><strong>Damaging interference levels.</strong> The AA-mid subsystem shall not be damaged by RFI signals of less than:</td>
<td></td>
<td>(2) SYS_REQ_5410</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>TBD V/m</strong></td>
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</tbody>
</table>
6.3 Maintenance

The requirements for maintenance are listed in the operational requirements section (Section 4.4).

6.4 Re-Cycling

Currently no re-cycling requirements are formulated.

6.5 Environment

6.5.1 General

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5120</td>
<td>Compliancy with local environment.</td>
<td></td>
<td>(2) SYS_REQ_5120</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The design of the AA-mid shall be</td>
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<tr>
<td></td>
<td>appropriate (TBD) for operation in</td>
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<tr>
<td></td>
<td>the natural environment for the</td>
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<tr>
<td></td>
<td>geographical deployment location</td>
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<tr>
<td></td>
<td>of the SKA.</td>
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<tr>
<td></td>
<td>This requirement should be made</td>
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<tr>
<td></td>
<td>more specific</td>
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</table>

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5130</td>
<td>Transportation conditions.</td>
<td></td>
<td>(2) SYS_REQ_5130</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid equipment shall be</td>
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<tr>
<td></td>
<td>designed for the the mode of</td>
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<tr>
<td></td>
<td>transport being used (road, air,</td>
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</tr>
<tr>
<td></td>
<td>sea, etc.) between place of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>manufacturing and final</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>installation on the SKA site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(including packaging requirements)</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>This requirement should be made</td>
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<tr>
<td></td>
<td>more specific e.g. use proper</td>
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<tr>
<td></td>
<td>standards etc</td>
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</tbody>
</table>

6.5.2 Site and infrastructure requirements

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<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5220</td>
<td>Facilities and equipment</td>
<td></td>
<td>(2) SYS_REQ_5220</td>
<td></td>
</tr>
<tr>
<td></td>
<td>intrusion.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>This is a system wide</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>requirement and not specifically</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid: delete it</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.5.3 Contamination and precipitation

<table>
<thead>
<tr>
<th>Identification</th>
<th>Requirement</th>
<th>Applicability</th>
<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5230</td>
<td><strong>Precipitation.</strong> AA-mid shall be able to operate with maximal 1% (TBD) degradation of the performance during any type of precipitation (TBD). The original requirement is too stringent. Precipitation like snow will always have some influence. Need to determine reasonable acceptable degradation and define it. Shouldn't this be with 6.6 Weather?</td>
<td></td>
<td>(2) SYS_REQ_5230</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5240</td>
<td><strong>Pollution and contamination protection.</strong> AA-mid shall be adequately protected against performance degradation caused by contaminating particles (dust, sand etc), polluted air or any precipitation. This requirement should be made more specific</td>
<td></td>
<td>(2) SYS_REQ_5240</td>
<td></td>
</tr>
</tbody>
</table>

6.5.4 Electro Magnetic Compatibility

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5420</td>
<td><strong>EM immunity.</strong> AA-mid shall not be susceptible to RFI signals, in-band or out-band, other than via the receptors. (What does this mean??) This requirement should be made more specific with numerical values</td>
<td></td>
<td>(2) SYS_REQ_5420</td>
<td></td>
</tr>
</tbody>
</table>
otherwise this lead to an overdesign by putting all equipment in a Faraday cage.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5610</td>
<td><strong>EMC safety margin.</strong></td>
<td></td>
<td></td>
<td>(2) SYS_REQ_5610</td>
</tr>
<tr>
<td></td>
<td>The EMC safety margin, which is defined as the ratio between susceptibility threshold and the interference at any point within the system, shall be greater than TBD dB.</td>
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</table>

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<tr>
<th>Identification</th>
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<th>Applicability</th>
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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5620</td>
<td><strong>EMC compatibility marking.</strong></td>
<td></td>
<td></td>
<td>(2) SYS_REQ_5620</td>
</tr>
<tr>
<td></td>
<td>All &quot;off-the-shelf&quot; equipment applied within the AA-mid subsystem shall posses as a minimum the host country EMC marking, including electrical and electronic supporting and infrastructural equipment. Needs to be more specific when the site is selected.</td>
<td></td>
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</table>

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<thead>
<tr>
<th>Identification</th>
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<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5630</td>
<td><strong>Grounding concept.</strong></td>
<td></td>
<td></td>
<td>(2) SYS_REQ_5630</td>
</tr>
<tr>
<td></td>
<td>A hybrid grounding concept as shown in figures TBD shall be used for EMC purposes. Ground loops involving DC, and low frequency AC, currents shall be avoided inside the system. Intentional currents through structure are not permitted. (to be elaborated)</td>
<td></td>
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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5640</td>
<td><strong>EMC design efforts.</strong></td>
<td></td>
<td></td>
<td>(2) SYS_REQ_5640</td>
</tr>
<tr>
<td></td>
<td>Maximum effort (to be detailed) shall be put into designing signal interfaces to withstand noisy environments and to minimize the generation of excessive noise. This needs to be properly fleshed out.</td>
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</tbody>
</table>
### 6.5.5 Self-generated RFI environment

<table>
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<tr>
<th>Identification</th>
<th>Requirement</th>
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<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_2910</td>
<td><strong>Self-generated RFI susceptibility.</strong> Interference due to self-generated RFI shall not degrade the performance of the instrument by greater than 1% by any measure (TBC). <em>This is a wild guess....</em></td>
<td></td>
<td>(2) SYS_REQ_2910</td>
<td></td>
</tr>
</tbody>
</table>

### 6.5.6 Grounding

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5810</td>
<td><strong>Safety ground.</strong> Electrical safety ground shall be designed according to the regulations imposed by the local government. <em>This should be made more specific as soon the site is selected.</em></td>
<td></td>
<td>(2) SYS_REQ_5810</td>
<td></td>
</tr>
</tbody>
</table>

### 6.5.7 Corrosion

<table>
<thead>
<tr>
<th>Identification</th>
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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5820</td>
<td><strong>Corrosion protection.</strong> AA-mid equipment and buildings shall be protected against corrosion. <em>Specify the standard...</em></td>
<td></td>
<td>(2) SYS_REQ_5820</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5830</td>
<td><strong>Corrosion protection in air flows.</strong> AA-mid electronics and connectors in areas with a higher air flow (for cooling) or outdoor environment shall be additionally protected against corrosion. <em>Specify the standard...</em></td>
<td></td>
<td>(2) SYS_REQ_5830</td>
<td></td>
</tr>
</tbody>
</table>
### 6.6 Weather

#### 6.6.1 Climatic Requirements

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5310</td>
<td><strong>Humidity.</strong></td>
<td></td>
<td>(2) SYS_REQ_5310</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid equipment shall be able to withstand moisture and humidity levels up to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 % RH.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>For how long? Operating?</em></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5320</td>
<td><strong>Allowable air temperature range.</strong></td>
<td></td>
<td>(2) SYS_REQ_5320</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid equipment shall be able to withstand (non-operating if necessary) an outside air temperature within the range of:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-15 °C (TBC) to +60 °C (TBC).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>For how long...?</em></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Identification</th>
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<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5330</td>
<td><strong>Air temperature operation range.</strong></td>
<td></td>
<td>(2) SYS_REQ_5330</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid equipment shall be able to operate within specification if the outside air temperature is within the range of:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-5 °C (TBC) to +50 °C (TBC).</td>
<td></td>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5340</td>
<td><strong>Wind velocities.</strong></td>
<td></td>
<td>(2) SYS_REQ_5340</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid shall be able tolerate wind velocities up to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Survival: 160 km/hr (TBC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Normal operation: 40 km/hr (TBC).</td>
<td></td>
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</tbody>
</table>
6.6.2 Lightning

<table>
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<tr>
<th>Identification</th>
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<th>Verification</th>
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</thead>
<tbody>
<tr>
<td>AAM_REQ_5710</td>
<td>Lightning discharge susceptibility.</td>
<td></td>
<td>(2) SYS_REQ_5710</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid shall be able to withstand the electromagnetic field impact defined in TBD during operation or in any other mode without any damage or characteristics degradation because of a lightning discharge.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>This needs considerable study, there may be elements of the array destroyed and still carry on.</em></td>
<td></td>
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<tr>
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<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5720</td>
<td>Lightning protection.</td>
<td></td>
<td>(2) SYS_REQ_5720</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid dedicated buildings and equipment located on sites shall be protected to minimize the effects of a direct lightning strike using certified methods (e.g. as described in NEN 1014).</td>
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</table>

6.6.3 Seismicity

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<tr>
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<th>Parent</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_5910</td>
<td>Earthquakes.</td>
<td></td>
<td>(2) SYS_REQ_5910</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA-mid equipment and buildings shall be protected against earthquakes with a magnitude up to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Richter 3.8 (TBC).</td>
<td></td>
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</table>

7 Internal Interface Requirements

Internal interfaces are defined as interactions or communications with the SKA system outside the AA-mid subsystems. These are represented as black arrows in
7.1 AA Receptor Power

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>AAM_REQ_8110</td>
<td>Supply power. The power supplied to AA-mid shall have the following characteristics (TBC):</td>
<td></td>
<td>(2) SYS_REQ_8110</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Voltage: 380 V +/- 10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phases: Three</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Frequency: 50 Hz +/- 1 Hz</td>
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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_7320</td>
<td>Power consumption. The power consumption of all equipment at an AA-mid station shall be:</td>
<td></td>
<td>(2) SYS_REQ_7320</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;TBD kVA. A biggy ....</td>
<td></td>
<td></td>
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</tbody>
</table>
## 7.2 Sync and Timing

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<th>Verification</th>
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</thead>
<tbody>
<tr>
<td>AAM_REQ_8140</td>
<td><strong>Subsystem time standard.</strong> Each AA-mid station shall maintain an internal time standard with an accuracy of:</td>
<td>(2) SYS_REQ_8140</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TBD nanoseconds. Needs to discuss “stand-alone” and drift rate etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAM_REQ_8150</td>
<td><strong>Central time standard.</strong> All AA-mid stations shall synchronize their internal time standards to the central timing standard with an accuracy of</td>
<td>(2) SYS_REQ_8150</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TBD nanoseconds.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAM_REQ_8160</td>
<td><strong>Synchronisation signal.</strong> A synchronisation signal (tick or pulse) is distributed to each AA station and has the following characteristics:</td>
<td>This will be derived from the Signal Transport and Networks domain.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Voltage: TBD V. Needs to discuss “stand-alone” and optical signal over fibre.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rise time: TBD ps. It will probably not be done this way</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TBD s pulse with a width of TBD s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAM_REQ_8170</td>
<td><strong>Clock signal.</strong> This looks wrong – surely it will be a locally generated signal that is synchronised with the above The central clock is distributed to each AA-mid station and has the</td>
<td>This will be derived from the Signal Transport and Networks domain.</td>
<td></td>
<td></td>
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</tbody>
</table>
following characteristics:

<table>
<thead>
<tr>
<th>Voltage of TBD V</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Frequency of TBD MHz</td>
<td></td>
</tr>
<tr>
<td>Jitter of TBD ns</td>
<td></td>
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<tr>
<td>Long term stability of TBD</td>
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</tbody>
</table>

7.3 Network

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<tr>
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</thead>
<tbody>
<tr>
<td>AAM_REQ_8200</td>
<td>Data time-tagging. All aperture arrays shall time-tag received and processed data with the accuracy of their internal time standard.</td>
<td>[1] SYS_REQ_8210</td>
<td></td>
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</tbody>
</table>

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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_8210</td>
<td>Data packetizing. All AA-mid observation data shall be packetized according to the SKA standard written in [TBD].</td>
<td>TBD</td>
<td></td>
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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_8220</td>
<td>Data interface. The data interface of AA-mid to the central processing has the following characteristics:</td>
<td>This will follow from the Signal Transport and Network domain.</td>
<td></td>
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</tr>
</thead>
<tbody>
<tr>
<td>AAM_REQ_8500</td>
<td>M&amp;C protocol. The M&amp;C protocol used to interface with the AA-mid is TBD</td>
<td>This is driven by the M&amp;C domain.</td>
<td></td>
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</tr>
</tbody>
</table>

7.4 Monitor and Control
### 7.5 AA Receptor Cooling

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<tr>
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</thead>
<tbody>
<tr>
<td>AAM_REQ_8600</td>
<td><strong>Cooling capacity.</strong></td>
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<tr>
<td></td>
<td>The required cooling capacity for each AA-mid station requires:</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>TBD kW</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>TBD</td>
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<td></td>
<td>TBD</td>
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<td></td>
<td>TBD</td>
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