South African Response to the SSG Request for Information

September 15, 2011

Contact details:
SKA South Africa Project Director
Dr. Bernie Fanaroff
bfanaroff@ska.ac.za
+27 11 442 2434

SKA South Africa Alternative Resource Liaison
Dr. Adrian Tiplady
atiplady@ska.ac.za
+27 11 442 2434
# Contents

## 1 Preface

1.1 Radio Astronomy in Africa ................................................. 2
  1.1.1 SKA South Africa Project Office ................................ 2
  1.1.2 The Establishment of the Karoo Radio Astronomy Reserve ....... 3
  1.1.3 The MeerKAT Radio Telescope ...................................... 5
  1.1.4 The Development of Human Capital ............................... 5
  1.1.5 VLBI in Africa .................................................. 6
  1.1.6 Partnerships ................................................... 7

1.2 The South African Proposal for the SKA ............................. 7
  1.2.1 Cost .......................................................... 7
  1.2.2 Implementation and Operation of the SKA and Associated Infrastructure .................................................. 8

1.3 Structure of Proposal ................................................... 8

## 2 Provision of Basic Infrastructure Components .................. 10

2.1 Introduction ............................................................. 10

2.2 Overview of Infrastructure Scenario ................................ 12
  2.2.1 Infrastructure for the SKA Model ................................ 12
  2.2.2 MeerKAT Basic Infrastructure - ‘SKA Ready’ ...................... 12

2.3 Road Infrastructure ..................................................... 14
  2.3.1 Road Technical Specification ................................... 16
  2.3.2 Road Infrastructure Plan ......................................... 16
  2.3.3 Operations and Maintenance ...................................... 18

2.4 Equipment and Office Buildings ...................................... 19
  2.4.1 Operations Centre near SKA Core Site: Astronomy Complex .... 19
  2.4.2 Bunkers for AA Stations ........................................ 21
  2.4.3 Remote Station Buildings ....................................... 21
  2.4.4 Off-site Buildings ............................................... 22

2.5 Accommodation and Construction Camps ............................ 22
  2.5.1 Construction Phase ............................................ 22
  2.5.2 Operations Phase ............................................... 23

2.6 Airstrips ................................................................. 25
  2.6.1 MeerKAT Air Strip ............................................ 25
  2.6.2 Carnarvon Air Field ........................................... 25

2.7 Water and Sanitation .................................................... 25

2.8 Dish Foundations ......................................................... 25
  2.8.1 Foundation Loads ............................................... 25
  2.8.2 Geotechnical Conditions ....................................... 26
  2.8.3 Dish Foundation Solutions ....................................... 26

2.9 Construction Methods and Materials ................................ 26

2.10 Relevant Regulations and Legislation .............................. 27
  2.10.1 Relevant Building Codes and Standards ......................... 27
  2.10.2 Health and Safety ............................................. 27
  2.10.3 Environmental ................................................ 27
3 Provision of Electrical Power
3.1 Introduction .................................................................................................................. 35
3.2 Electricity in South Africa ............................................................................................... 36
  3.2.1 Eskom – The National Electricity Utility .................................................................. 36
  3.2.2 NERSA – The National Electricity Regulator .......................................................... 36
  3.2.3 The Integrated Resource Plan 2010 ....................................................................... 38
  3.2.4 Renewable Energy in South Africa ........................................................................ 39
  3.2.5 Renewable Energy for the SKA ............................................................................. 39
3.3 Provision of Electrical Power to the SKA Core ............................................................... 40
  3.3.1 Overview of Design ............................................................................................... 40
  3.3.2 Location of the Super-Computer .......................................................................... 41
  3.3.3 Redundancy of the 132 kV Line ............................................................................ 42
  3.3.4 Backup Power Scenarios ....................................................................................... 42
3.4 Provision of Electrical Power to the Remote Stations .................................................... 44
  3.4.1 Remote Stations in South Africa ............................................................................ 44
  3.4.2 Remote Stations outside South Africa ................................................................... 45
3.5 RFI Mitigation ................................................................................................................ 45
  3.5.1 The Astronomy Complex 132 kV/33 kV Substation ............................................... 45
  3.5.2 132 kV Line .......................................................................................................... 45
  3.5.3 Medium Voltage, Low Voltage and Reticulation .................................................... 46
3.6 Existing ‘SKA Ready’ Infrastructure .............................................................................. 46
  3.6.1 Kronos Substation .................................................................................................. 46
  3.6.2 Existing KAT-7 and MeerKAT Infrastructure ......................................................... 47
3.7 Cost Summary ............................................................................................................... 49
  3.7.1 Capital Cost Summary ........................................................................................... 49
  3.7.2 Electricity Tariffs and their Effect on Operational Costs ......................................... 49
3.8 Amortisation of Capital Costs and the Resultant Operational Costs ............................. 51
3.9 Schedule of Power Provision Roll-Out ......................................................................... 51

4 Data Transport ................................................................................................................ 53
4.1 Overview of Proposed Data Transport Scenario ............................................................ 53
4.2 Local and International Data Network Industry ............................................................. 54
  4.2.1 De-Regulation and Competition .......................................................................... 54
  4.2.2 Existing Industry ................................................................................................... 58
4.3 Connectivity Plan: 0 - 180 km ....................................................................................... 59
  4.3.1 Existing Infrastructure .......................................................................................... 59
  4.3.2 Planned SKA Design ............................................................................................ 59
4.4 Connectivity Plan: South African SKA Remote Stations ................................................ 61
  4.4.1 Existing Infrastructure .......................................................................................... 61
  4.4.2 Planned SKA Design ............................................................................................ 61
  4.4.3 Operations and Management ............................................................................... 63
4.5 Connectivity Plan: African SKA Remote Stations ........................................................... 63
  4.5.1 Existing Infrastructure .......................................................................................... 64
  4.5.2 Planned SKA Design ............................................................................................ 64
  4.5.3 Operations and Management ............................................................................... 65
4.6 Connectivity Plan: Data Processor to Super-Computer ................................................... 65
  4.6.1 Existing Infrastructure .......................................................................................... 65
  4.6.2 Planned SKA Design ............................................................................................ 66
**Contents**

6 Radio Quiet Zone Protection ................................................. 95
   6.1 Executive Summary .................................................. 95
   6.2 Introduction ...................................................... 97
   6.3 Legislation (Item 3 of SSG-RFI-001) .............................. 98
      6.3.1 Astronomy Geographic Advantage Act (Act No. 21 of 2007) .. 98
      6.3.2 Features of the AGA Act .................................. 99
      6.3.3 AGA Act Declarations and Regulations and Timelines (Item 2 of SSG-RFI-001) ................................................. 100
      6.3.4 Communications Legislation in African SKA Partner Countries ............................................................. 102
      6.3.5 Operation, Management and Enforcement ....................... 102
   6.4 Technical Properties (Item 1 of SSG-RFI-001) ..................... 104
      6.4.1 South African Radio Astronomy Service (SARAS) Protection Levels ..................................................... 104
      6.4.2 Protected Astronomy Advantage Areas ......................... 104
      6.4.3 Protection Reference Location within the Protected Area .......... 105
      6.4.4 Exceptions .................................................... 105
   6.5 Spectrum Management (Item 4 in SSG-RFI-001) ...................... 107
      6.5.1 Organisation of Spectrum Management .......................... 107
      6.5.2 Empowerment of the SKA ..................................... 108
      6.5.3 Specific Measures of Radio Interference Protection ............. 108
      6.5.4 Remote Stations .............................................. 109
   6.6 Current and Future Spectrum Usage (Item 5 in SSG-RFI-001) ...... 110
      6.6.1 Current Usage and Future Improvements ....................... 110
      6.6.2 Expected New Services ....................................... 112
      6.6.3 Expected Termination of Services .............................. 112
   6.7 Relevant Activities (Item 6 in SSG-RFI-001) ....................... 113

5 Physical Characteristics of the Site ..................................... 72
   5.1 Executive Summary .................................................. 72
   5.2 Introduction ...................................................... 72
   5.3 SKA Core and Skirt Region .......................................... 74
      5.3.1 Meteorological Data .......................................... 74
      5.3.2 Geotechnical ................................................. 82
      5.3.3 Severe Weather Events ....................................... 87
   5.4 Variation Along Spiral Arms to 180km .................................. 87
      5.4.1 Environmental ............................................... 87
      5.4.2 Geotechnical ................................................. 91
      5.4.3 Severe Weather Events ....................................... 91
   5.5 Variation to Remote Stations ....................................... 92
      5.5.1 Environmental ............................................... 92
      5.5.2 Geotechnical ................................................. 94
      5.5.3 Severe Weather Events ....................................... 94

4 Connectivity Plan: Super-Computer to SKA Head Office and International Data Centres ................................. 67
   4.1 Executive Summary .................................................. 67
   4.2 Introduction ...................................................... 68
   4.3 Legislation (Item 3 of SSG-RFI-001) .................................. 98
      6.3.1 Astronomy Geographic Advantage Act (Act No. 21 of 2007) .. 98
      6.3.2 Features of the AGA Act .................................. 99
      6.3.3 AGA Act Declarations and Regulations and Timelines (Item 2 of SSG-RFI-001) ................................................. 100
      6.3.4 Communications Legislation in African SKA Partner Countries ............................................................. 102
      6.3.5 Operation, Management and Enforcement ....................... 102
   4.4 Technical Properties (Item 1 of SSG-RFI-001) ..................... 104
      6.4.1 South African Radio Astronomy Service (SARAS) Protection Levels ..................................................... 104
      6.4.2 Protected Astronomy Advantage Areas ......................... 104
      6.4.3 Protection Reference Location within the Protected Area .......... 105
      6.4.4 Exceptions .................................................... 105
   4.5 Spectrum Management (Item 4 in SSG-RFI-001) ...................... 107
      6.5.1 Organisation of Spectrum Management .......................... 107
      6.5.2 Empowerment of the SKA ..................................... 108
      6.5.3 Specific Measures of Radio Interference Protection ............. 108
      6.5.4 Remote Stations .............................................. 109
   4.6 Current and Future Spectrum Usage (Item 5 in SSG-RFI-001) ...... 110
      6.6.1 Current Usage and Future Improvements ....................... 110
      6.6.2 Expected New Services ....................................... 112
      6.6.3 Expected Termination of Services .............................. 112
   4.7 Connectivity Plan: Super-Computer to SKA Headquarters and International Data Centres ................................. 71
      4.7.1 Existing Infrastructure ........................................ 71
      4.7.2 Planned SKA Design .......................................... 71
      4.7.3 Operations and Management ................................... 71
   4.8 Regulatory Environment ............................................ 68
      4.8.1 South Africa .................................................. 68
      4.8.2 African SKA Partner Countries .................................. 69
   4.9 Costs ............................................................................. 69
      4.9.1 0 - 180 km ...................................................... 69
      4.9.2 Remote Stations ................................................. 70
      4.9.3 Data Processor to Super-Computer .................................. 70
      4.9.4 Super-Computer to SKA Headquarters and International Data Centres ..................................................... 71
      4.9.5 Summary ......................................................... 71
6.7.1 South African Ministry of Communications ........................................ 113
6.7.2 Independent Communications Authority of South Africa (ICASA) ........ 113
6.7.3 International Spectrum Management Bodies .................................... 113

7 Political, Socio-Economic and Financial Situations 115
7.1 JP Morgan Report ............................................................................. 116
7.2 International Metrics ....................................................................... 117
7.3 Other African Countries .................................................................... 117

8 Customs and Excise 120
8.1 Introduction .................................................................................... 120
8.2 Information Provided by the SA Revenue Service in Respect of the Republic of South Africa and Arrangements with Certain States in the Southern African Development Community (SADC) .... 121
8.2.1 Customs Duty ............................................................................ 121
8.2.2 Tariff Classification .................................................................... 121
8.2.3 Trade Agreements .................................................................... 121
8.2.4 Customs Duty Rebates ............................................................... 121
8.2.5 Prohibition and Restrictions ....................................................... 121
8.2.6 Value-Added Tax ..................................................................... 122
8.2.7 Income Taxation ....................................................................... 122
8.2.8 Trade Facilitation ..................................................................... 123
8.3 Other African Countries .................................................................... 123
8.4 Case Studies .................................................................................... 124
8.4.1 South Africa ............................................................................. 124
8.4.2 Other African Countries ............................................................. 124

9 Legal 125
9.1 Introduction .................................................................................... 125
9.2 Overview of Legal and Administrative Procedures .......................... 125
9.2.1 South Africa ............................................................................. 125
9.2.2 African SKA Partner Countries .................................................. 126
9.3 Acquisition of Legal Capacity .......................................................... 126
9.3.1 South Africa ............................................................................. 126
9.3.2 African SKA Partner Countries .................................................. 126
9.4 Formal Arrangements Amongst African SKA Partner Countries .......... 127
9.5 Ownership of Intellectual Property .................................................. 127
9.5.1 South Africa ............................................................................. 127
9.5.2 African SKA Partner Countries .................................................. 128
9.6 Rights of Land Ownership ............................................................... 128
9.6.1 South Africa ............................................................................. 128
9.6.2 African SKA Partner Countries .................................................. 128
9.7 Construction Licensing and Permits ............................................... 128
9.7.1 South Africa ............................................................................. 128
9.7.2 African SKA Partner Countries .................................................. 129
9.8 Environmental Issues ..................................................................... 129
9.8.1 South Africa ............................................................................. 129
9.8.2 African SKA Partner Countries .................................................. 130

10 Security 131
10.1 Introduction ................................................................................... 131
10.2 Security Risk Assessment .............................................................. 131
10.2.1 Threat Assessment .................................................................. 131
10.2.2 Case Studies ........................................................................... 131
10.3 Security Model .............................................................................. 132
10.3.1 Current MeerKAT Security ...................................................... 132
10.3.2 SKA Facility and Personnel ............................................................... 133
10.4 Insurance ......................................................................................... 134

11 Employment ..................................................................................... 136
11.1 Employment Legislation in South Africa ............................................. 136
11.2 Conditions of Employment ............................................................... 136
11.3 Trade Unions .................................................................................. 137
11.4 Health and Safety ........................................................................... 137
11.5 Social Security ................................................................................. 137
11.6 Deductions from Employees’ Pay ....................................................... 138
11.7 Work Permits and Visas ................................................................. 138
11.8 Spousal Employment ..................................................................... 139
11.9 Income Taxation of Employees ......................................................... 139
11.10 Availability and Cost of Skilled Labour .............................................. 140

12 Working and Support Environment .................................................... 141
12.1 Life in South Africa ........................................................................ 141
12.2 Towns and Cities of Residence ........................................................ 142
  12.2.1 Cape Town .............................................................................. 142
  12.2.2 Carnarvon ............................................................................. 143
  12.2.3 Kimberley ............................................................................ 143
12.3 Housing and Security ..................................................................... 143
12.4 Schools and Education ................................................................ 143
12.5 Leisure Facilities ........................................................................... 144
12.6 Healthcare, Pension and Life Cover ............................................... 144
12.7 Transport ....................................................................................... 145
12.8 Communication ............................................................................. 145

List of Annexures
A ................ South African Response to the SSG Request for Information (full report) /Annexure A/
B1 ............ African Union Heads of State Endorsement of the SKA 2010 /Annexure B/
B2 ............ Final Joint Statement by African SKA Partner Countries
B3 ............ African Ministerial Conference on Science and Technology 2010 (AMCOST IV)
B4 ............ Brochure - The SKA in Africa
B5 ............ White Paper on Science & Technology: 1996
B7 ............ DST Strategic Plan: 2011
B9 ............ Letter of Support: Premier of the Northern Cape province
B10 .......... Letter of Support: Premier of the Western Cape province
B11 .......... Letter of Support: Premier of the Free State province
B12 .......... Letter of Support: Vodacom
B13 .......... Letter of Support: PwC
B14 .......... Brochure - The Proposed South African SKA Site
B15 .......... Brochure - MeerKAT
B16 .......... Brochure - Human Capital Development Programme
B17 .......... Brochure - Industry Partnerships
B18 .......... Brochure - Institutional Partnerships
B19 .......... ALMA Operations
C1 ............ Drawings of Road Network Layout /Annexure C/
C2 ............ Drawings of Architectural and Building Layouts
C3 ............ Drawings of Construction Sites and Accommodation Units
C4.1 .......... Aurecon Report on Cost for SKA Infrastructure
C4.3 .......... Bill of Quantities - Operations Centre
C4.4 .......... Bill of Quantities - Dishes, Platforms and Remote Stations
C4.5 .......... Bill of Quantities - Construction Camps and Staff Accommodation
C4.6 .......... Bill of Quantities - Roads
C4.7 .......... Bill of Quantities - SKA Airfield
C4.8 .......... Bill of Quantities - Estimate Summary
C4.9 .......... Escalated Full Cost Model for SKA Infrastructure
C5.1 .......... MeerKAT Airstrip Layout
C5.2 .......... Road Technical Specifications
C5.3 .......... MeerKAT Airstrip Specifications
C5.4 .......... Carnarvon Airfield Specifications
C6.1 .......... SKA Antenna Foundation Design
C6.2 .......... Geotechnical Report for Dish Foundations at MeerKAT and SKA Core Site
C6.3 .......... Geotech Desktop Study for SKA Configuration
C6.4 .......... Analysis of Geotechnical Conditions at Remote Stations
C6.5 .......... Analysis of Geotechnical Conditions within 180 km
C6.6 .......... Geological Map
C6.7 .......... Landtype Map
C7.1 .......... Relevant Building Codes and Standards
C8.1 .......... CoDR Report 6 Stone Quarry Investigation
C8.2 .......... CRR24 Stone Quarries Studies
C8.3 .......... SKA Phase 2 Aggregate Investigation Report
C9.1 .......... Losberg Site Complex Layout and Plans
C9.2 .......... Losberg Site Complex Conceptual Drawings
C10.1 ......... Acquisition Differential Costing Report 2010
C10.2 ......... Acquisition Costing Report 2010
C11.1 ........ Aperture Array Bunker
C11.2 ........ Photographs of KAT-7 RFI Shielded Container
C12.1 ........ Presentation on Logistics Support Analysis - Data Modelling and Simulation
C12.2 ........ Memo on Logistics Support Analysis
C12.3 ........ Capability proposal for SLA from TFMC
C12.4 ........ Capability proposal for SLA from Crestwave
C13.1 ........ SKA Considerations for Health and Safety
C13.2 ........ Detailed summary of Environmental Legislation in South Africa
C13.3 ........ MeerKAT Environmental Impact Assessment
C13.4 - C13.14 Supporting Documentation for South African Environmental Legislation
C14.1 ........ Hourly Labour Rates
C14.2 ........ Unit Costs for Basic Infrastructure Components
C15.1 ........ TRH3 The Design and Construction of Surfacing Roads
C15.2 ......... TRH20 The Design Construction and Maintenance of Unpaved Roads
D1 ............ Response to Annex 2 of the SSG Request for Information /Annexure D/
D2 ............ SKA Power Cost Summary
D3 ............ Eskom’s Annual Report 2011
D4 ............ South African Department of Energy Integrated Resource Plan 2010
D5 ............ Eskom Design Report: SKA Africa Radio Telescope Grid Infrastructure Requirements
D6 ............ The Eskom Approach to the Wheeling of Energy
D7 ............ Eskom Design Report: Electromagnetic Compatibility Associated with the Power Supply of the SKA
D8 ............ Aurecon Design Report: Assistance for the SKA South Africa Site Bid Submission Revision 5; document number 107102-SKA-SSG-005
D9.1 ......... Drawing 107102-SSG-ELE-0001: Eskom Astronomy Substation 132kV/33kV (3 x 80MVA) Yard Layout
D9.2 ......... Drawing 107102-SSG-ELE-0002: Eskom Astronomy Complex Substation 132kV/33kV Single Line Diagram
D9.3 ......... Drawing 107102-SSG-ELE-0003: Astronomy Site Electrical Diagram Power Distribution Network
D9.4 ......... Drawing 107102-SSG-ELE-0004: Astronomy Complex Conceptual Electrical Reticulation Layout
D9.5 ......... Drawing 107102-SSG-ELE-0005: 33kV Monopole Structure Details
D9.7 ......... Drawing 107102-SSG-ELE-0007: Proposed Reticulation Layout for AA-Mid Stations
D9.8 ......... Drawing 107102-SSG-ELE-0008: Typical Distribution Network Components: Dish Antennas and AA-Low Stations
D9.9 ......... Drawing 107102-SSG-ELE-0009: Typical Distribution Network Components: AA-Mid Stations
D9.10 ....... Drawing 107102-SSG-ELE-0010: Transmission Network Diagram
D9.11 ....... Drawing 107102-SSG-ELE-0011: Typical Dish Construction Limits
D9.12 ....... Drawing 107102-SSG-ELE-0012: Carnarvon/Astronomy Complex/Core Site Relative Positions
D9.14 ....... Drawing 107102-SSG-ELE-0014 Sheet 1: Dish Reticulation Layout
D9.15 ....... Drawing 107102-SSG-ELE-0014 Sheet 2: AA-Low Station Reticulation Layout
D9.16 ....... Drawing 107102-SSG-ELE-0014 Sheet 3: AA-Mid Station Reticulation Layout
D9.17 ....... Drawing 107102-SSG-ELE-0014 Sheet 4: Reticulation: 180km
D9.18 ....... Drawing 107102-SSG-ELE-0014 Sheet 5: Reticulation: 100km
D9.19 ....... Drawing 107102-SSG-ELE-0014 Sheet 6: Reticulation: 35km
D9.20 ....... Drawing 107102-SSG-ARC-1002: Remote Site Conceptual Layout
D9.21 ....... Drawing 107102-SSG-ELE-0015: Proposed 33kV Overhead Line
D10 .......... Power Supply Costing from the City of Cape Town
D12 .......... Eskom Cost Estimate Letter from Eskom Group Customer Service Divisional Executive
D13 .......... Aurecon Report: Existing Eskom Infrastructure to be Utilized for Supply to RSA Remote, Outer and Skirt Zones
D14 ............ Aurecon Report: MeerKAT Electrical Systems Masterplan
D16 ............ Power Considerations for the Square Kilometre Array (SKA) Radio Telescope, URSI paper delivered by P. Hall
D17 ............ National Energy Regulator Act 40 of 2004
D18 ............ Gas Act of 2001
D19 ............ Petroleum Pipelines Act of 2003
D20 ............ Electricity Regulation Act No 4 of 2006
G1 ............ List of Legislation and Features for Electronic Communications, Telecommunications and Broadcasting in Participating African Countries
G1.1.1 ............ South Africa - Electronic Communications Act (No 36 of 2005, as amended)
G1.1.2 ............ South Africa - Independent Communications Authority of SA (ICASA) Act (No 13 of 2000 as amended)
G1.2.1 ............ Botswana - Telecommunications Act (No 15 of 1996 as amended)
G1.2.2 ............ Botswana - Telecommunications Regulations (1997)
G1.3.1 ............ Ghana - National Communications Authority Act (No 769 of 2008)
G1.3.2 ............ Ghana - Electronic Communications Act (No 775 of 2008)
G1.3.3 ............ Ghana - National Communications Regulations (2003)
G1.4.1 ............ Kenya - The Kenya Information and Communications Act (1998 as revised in 2009)
G1.5.1 ............ Madagascar - Decree No 97-1077 - Instituting the Office D’Etudes et de Regulation des Telecommunications (OMERT) (Malagasy Office of Telecommunications Studies and Regulation)
G1.5.2 ............ Madagascar - Act No 2005-023 revising Act No 96-034 on the Institutional Reform of the Telecommunications Sector (full French version)
G1.6.1 ............ Mauritius - Information and Communications Technologies Act (no 44 of 2001) and the Information and Communication Technologies (Amendment) Act (No 33 of 2002)
G1.7.1 ............ Mozambique - Law on Telecommunications (No 8 of 2004)
G1.8.1 ............ Namibia - Communications Act (No 8 of 2009)
G1.9.1 ............ Zambia - The Information and Communication Technologies Act (no 15 of 2009) and Amendment Act to the Information and Communication Technologies Act (No 3 of 2010)
G2 ............ Astronomy Geographic Advantage Act No. 21 of 2007
G3 ............ Analysys Mason-Fibre Availability Report
G4.1 ............ Analysys Mason SKA Fibre Availability presentation
G4.2 ............ Analysys Mason electronic mapset
G5 ............ Namibia Dataset Report Fibre Optic Infrastructure
G6 ............ Botswana Dataset Report Fibre Optic Infrastructure
G7 ............ Zambia Dataset Report Fibre Optic Infrastructure
G8 ............ Mozambique Dataset Report Fibre Optic Infrastructure
G9 ............ Madagascar Dataset Report Fibre Optic Infrastructure
G10 ............ Mauritius Dataset Report Fibre Optic Infrastructure
G11 ............ Ghana Dataset Report Fibre Optic Infrastructure
G12 ............ Kenya Dataset Report Fibre Optic Infrastructure
G13 ............ SIA Solutions Company Profile
G14 . . . . . . . . . . . . . . . . . . SIA Solutions SKA Core Fibre Network Proposal
G15 . . . . . . . . . . . . . . . . . . SKASA Project Costs
G16 . . . . . . . . . . . . . . . . . . Meraka Institute Scientific Research Council Act
G17 . . . . . . . . . . . . . . . . . . Meraka Institute ICASA PECN Exemption
G18 . . . . . . . . . . . . . . . . . . Meraka Institute CSIR Overview
G19 . . . . . . . . . . . . . . . . . . Broadband Infraco Indicative pricing for SKA long term data transport and connectivity requirements
G20 . . . . . . . . . . . . . . . . . . Broadband Infraco Company Profile
G21 . . . . . . . . . . . . . . . . . . Broadband Infraco ECNS Licence corrected
G22 . . . . . . . . . . . . . . . . . . Nokia Siemens Networks hIT 7300 Power Requirements
G23 . . . . . . . . . . . . . . . . . . Nokia Siemens Networks SKA Pricing Summary
G24 . . . . . . . . . . . . . . . . . . FibreCo SKA proposal
G25 . . . . . . . . . . . . . . . . . . SEACOM SKA Site Bid Proposal
G26 . . . . . . . . . . . . . . . . . . SEACOM 100Gbs Network Trial
G27 . . . . . . . . . . . . . . . . . . CISCO SKA Site Bid Project Proposal
G28 . . . . . . . . . . . . . . . . . . SKA Nexans Fibre Optic Enclosure Product Guide
G29.1 . . . . . . . . . . . . . . . . . . . EASSY / WIOCC SKA Proposal
G29.2 . . . . . . . . . . . . . . . . . . . EASSY / WIOCC SKA Service Legal Agreement
G30 . . . . . . . . . . . . . . . . . . . Muvoni Weltex SKA Proposal for Direct Burial/Trenching
G31 . . . . . . . . . . . . . . . . . . . Muvoni Weltex Long Haul Duct or Cable Laying Solutions
G32 . . . . . . . . . . . . . . . . . . . Muvoni Weltex Turnkey Project Services
G33 . . . . . . . . . . . . . . . . . . . African Partner Countries Data Transport Logical Network Drawings
G34 . . . . . . . . . . . . . . . . . . . MeerKAT Network
G35 . . . . . . . . . . . . . . . . . . . Telkom 2011 Tariffs for SpaceStream Products
F1.1 . . . . . . . . . . . . . . . . . . Chapter 5 of RSA 2005 Bid Submission (Climate at the SKA sites) /Annexure F/
F1.2 . . . . . . . . . . . . . . . . . . Annexure F1 of RSA 2005 Bid Submission (Analysis of Climate and Weather at the Core Site)
F1.3 . . . . . . . . . . . . . . . . . . Annexure G1 of RSA 2005 Bid Submission (Assessment of Geological and Geotech Constraints)
F1.4 . . . . . . . . . . . . . . . . . . Annexure G2 of RSA 2005 Bid Submission (Volume 1 of 3 - Geology and Hydrology)
F1.5 . . . . . . . . . . . . . . . . . . Annexure G3 of RSA 2005 Bid Submission (Volume 2 of 3 - Geotechnical)
F1.6 . . . . . . . . . . . . . . . . . . Annexure G4 of RSA 2005 Bid Submission (Volume 3 of 3 - Mineral Deposits)
F1.7 . . . . . . . . . . . . . . . . . . Annexure G5 of RSA 2005 Bid Submission (SKA Sites inundation mapping)
F2 . . . . . . . . . . . . . . . . . . . Phase Stability in Fibre Optic Cables
F3.1 . . . . . . . . . . . . . . . . . . HHK Soil resistivity survey for KAT 7 - Cover letter
F3.2 . . . . . . . . . . . . . . . . . . HHK Soil resistivity survey for KAT 7 - Telescope A results
F3.3 . . . . . . . . . . . . . . . . . . HHK Soil resistivity survey for KAT 7 - Telescope E results
F4.1 . . . . . . . . . . . . . . . . . . Detailed Geotechnical Report for MeerKAT and SKA Phase 1
F4.2 . . . . . . . . . . . . . . . . . . Summarised Results and Recommendations of Final Geotechnical Report for MeerKAT and SKA Phase 1
F4.3 . . . . . . . . . . . . . . . . . . MeerKAT CDR Report - WP1A
F4.4 . . . . . . . . . . . . . . . . . . Borehole Water Chemistry
F5 . . . . . . . . . . . . . . . . . . . MeerKAT Environmental Impact Assessment Report
F6.1 . . . . . . . . . . . . . . . . . . Raw Measurement Data from SKA Weather Station
F6.2          Temperature Statistics
F6.3          Relative Humidity Statistics
F6.4          Rainfall Statistics
F6.5          Dewpoint Statistics
F6.6          Wind Statistics
F6.7          Solar Radiation Statistics
F7           Aerosol Optical Thickness Report
F8.1          Number of days of Frost in Core and Skirt Region
F8.2          Wildfires and Burn Scars in Core and Skirt Region (2001 to 2010)
F8.3          Average Annual Solar Radiation Map of Africa
F8.4          Global Soil pH Map
F9.1          Physical Characteristics at SKA Remote Stations
F9.2          Annexure A to Physical Characteristics and SKA Remote Stations
F9.3          Annexure B to Physical Characteristics and SKA Remote Stations
F10          Repository of Monthly Wind Roses
F11          SKA Site Weather Parameters from AQUA Satellite Data
F12.1         Analysis of Geotechnical Conditions at SKA Remote Stations (Table 2)
F12.2         Analysis of Geotechnical Conditions at SKA Remote Stations (Table 1)
F12.3         Geological Map
F12.4         Landtype Map
F12.5         Analysis of Geotechnical Conditions at SKA Remote Stations
E1.0         Astronomy Geographic Advantage Act
E1.1         Proclamation to make the Astronomy Geographic Advantage Act operational
E1.2         Summary description of the features of the AGA Act
E1.3         Summary descriptions of the AGA Declarations and Regulations applicable to the SKA
E1.4         Declaration of the Northern Cape Province as an Astronomy Advantage Area
E1.5         Declaration of the MeerKAT and the SKA for the application of the AGA Act
E1.6.0        Regulations for the South African Radio Astronomy Service (SARAS) protection level standard
E1.6.1        Letter of Concurrence by ICASA on the SARAS protection level standard
E1.7.1        Declaration of the Karoo Core Astronomy Advantage Area for radio astronomy purposes
E1.7.2        Declaration of the Management Authority for the Karoo Core Astronomy Advantage Area
E1.7.3        Regulations for the protection of Core Astronomy Advantage Areas for radio astronomy
E1.7.4        Letter of Concurrence by ICASA on the protection of the Karoo Core Astronomy Advantage Area
E1.8.1        Declaration of the Karoo Central Astronomy Advantage Areas (1 to 3) for radio astronomy
E1.8.2        Regulations for Administrative Procedures to apply protection for radio astronomy in Central Astronomy Advantage Areas
E1.8.3        Regulations for the protection of the Karoo Central Astronomy Advantage Areas (1 to 3) for radio astronomy with respect to radio communications
E1.8.4 . . . . . . Regulations for the protection of the Karoo Central Astronomy Advantage Area 1 for radio astronomy with respect to electricity generation, transmission and distribution

E1.8.5 . . . . . . Regulations for the protection of the Karoo Central Astronomy Advantage Area 1 for radio astronomy with respect to exploration and mining

E1.9.1 . . . . . . Declaration of the Karoo Coordinated Astronomy Advantage Areas (1 and 2) for radio astronomy purposes

E1.9.2 . . . . . . Regulations for the protection of the Karoo Coordinated Astronomy Advantage Areas (1 and 2) for radio astronomy with respect to radio communications

E1.10 . . . . . . Management Authority Regulations

E2.0 . . . . . . List of legislation and features for electronic communications, telecommunications and broadcasting in participating African countries

E2.1.1 . . . . . . South African Broadcasting Act

E2.1.2 . . . . . . South African Electronic Communications Act

E2.1.3 . . . . . . Independent Communications Authority of South Africa Act

E2.1.4 . . . . . . South African Radio Frequency Spectrum Regulations

E2.2.1 . . . . . . Botswana Broadcasting Act

E2.2.2 . . . . . . Botswana Telecommunications Act

E2.2.3 . . . . . . Botswana Broadcasting Regulations

E2.2.4 . . . . . . Botswana Telecommunications Regulations

E2.3.1 . . . . . . Ghana National Communications Authority Act

E2.3.2 . . . . . . Ghana Electronic Communications Act

E2.3.3 . . . . . . Ghana National Communications Regulations

E2.4.1 . . . . . . Kenya Information and Communications Act

E2.4.2 . . . . . . Kenya Radio Communications and Frequency Spectrum Regulations

E2.5.1 . . . . . . Madagascar Decree No 97-1077 - Instituting the Malagasy Office of Telecommunications Studies and Regulations (French version and english translation of Article 1)

E2.5.2 . . . . . . Madagascar Act No 2005-023 Revision of Act No 96-034 on the Institutional Reform of the Telecommunications Sector (French version and english translation of Articles 18 and 19)

E2.5.3 . . . . . . Madagascar Decree No. 99-228 on the regulation and management of radioelectric frequencies and frequency bands (French version and english translation of all except Articles 32-36, 56-60 and 81-83)

E2.6.1 . . . . . . Mauritius Independent Broadcasting Authority Act

E2.6.2 . . . . . . Mauritius Information and Communication Technologies Act and Amendment Act

E2.7.1 . . . . . . Mozambique Telecommunications Act (English translated version - Original in Portuguese)

E2.7.2 . . . . . . Mozambique Decree No.36/2009 - Regulations for radio communications (English translation of all except Articles 29-33 and 35-40; plus full Portuguese version)

E2.8.1 . . . . . . Namibia Communications Act

E2.9.1 . . . . . . Zambia Independent Broadcasting Authority Act

E2.9.2 . . . . . . Zambia Information and Communications Technologies Act and Amendment Act

E3.1 . . . . . . Interim Regulations Advisory Committee Terms of Reference and membership

E3.2 . . . . . . Summary of Interaction Between the Department of Science and Technology, SASPO and ICASA
E3.3 . . . . . . . . . . National Research Foundation (NRF) Act
E5.0 . . . . . . . . . . Overview of Spectrum Management in the Participating African Countries
E5.1 . . . . . . . . . . Radio Frequency Spectrum Policy for South Africa
E5.2 . . . . . . . . . . Overview of Terrestrial Broadcasting Frequency Planning
E5.3.1 . . . . . . . . . . ITU Regional Agreements for the Planning of VHF Sound Broadcasting
E5.3.2 . . . . . . . . . . ITU Regional Agreements for Terrestrial Analogue Television Broadcasting
E5.3.3 . . . . . . . . . . ITU Regional Agreements for Digital Terrestrial Television Broadcasting
E5.4 . . . . . . . . . . ICASA Final Terrestrial Broadcasting Frequency Plan 2008
E5.4.1 . . . . . . . . . . Request to ICASA for the Amendment of the Final Terrestrial Broadcasting Frequency Plan 2008
E5.4.2 . . . . . . . . . . Official SABC Request to ICASA for migration of radio services and low power broadcasting transmissions
E5.4.3 . . . . . . . . . . Sentech broadcasting transmission study to comply with radio astronomy protection requirements
E5.4.4 . . . . . . . . . . Letter from ICASA indicating commitment to the amendment of the Terrestrial Frequency Broadcasting Plan
E5.6.0 . . . . . . . . . . South African Digital Migration Policy
E5.6.1 . . . . . . . . . . South African Digital Migration Regulations
E5.6.2 . . . . . . . . . . Draft Amendment to the South African Digital Migration Policy
E6.0 . . . . . . . . . . Agreement between the Department of Science and Technology and ICASA on cooperation with regards to the SKA Bid
E7.0 . . . . . . . . . . Report on Development of GSM Phased Antenna System
E7.1 . . . . . . . . . . Presentation on field measurements of GSM Phased Antenna System
E7.2 . . . . . . . . . . ICASA Trunking Frequency Licence
E7.3 . . . . . . . . . . ICASA PECN Licence Exemption
H1 . . . . . . . . . . . . Political Report on African Countries /Annexure H/
H2 . . . . . . . . . . . . Report by Price Waterhouse Coopers
H3 . . . . . . . . . . . . Report by JP Morgan
I1 . . . . . . . . . . . . Letters to and from Minister for Trade and Industry Aug 2011 /Annexure I/
I2 . . . . . . . . . . . . Aurecon SKA Customs and Excise Report
I3 . . . . . . . . . . . . SKA Project International Forwarding Services (Cape) (Pty) Ltd.
I4 . . . . . . . . . . . . African Union Decision to Support the SKA 201000727
I5 . . . . . . . . . . . . AMCOST Decision to Support the SKA /Annexure J/
J1.1.1 . . . . . . . . . . Overview of Legal System in South Africa
J1.1.2 - J1.1.7 . Supporting documentation for South Africa
J1.2.1 . . . . . . . . . . Overview of Legal System in Botswana
J1.2.2 - J1.2.7 . Supporting documentation for Botswana
J1.3.1 . . . . . . . . . . Overview of Legal System in Ghana
J1.3.2 - J1.3.3 . Supporting documentation for Ghana
J1.4.1 . . . . . . . . . . Overview of Legal System in Madagascar
J1.4.2 . . . . . . . . . . Supporting documentation for Madagascar
J1.5.1 . . . . . . . . . . Overview of Legal System in Mauritius
J1.5.2 - J1.5.3 . Supporting documentation for Mauritius
J1.6.1 . . . . . . . . . . Overview of Legal System in Mozambique
J1.6.2 . . . . . . . . . . Supporting documentation for Mozambique
Contents

J1.7.1 Overview of Legal System in Namibia
J1.7.2 - J1.7.6 Supporting documentation for Namibia
J1.8.1 Overview of Legal System in Zambia
J1.8.2 - J1.8.8 Supporting documentation for Zambia
J1.9.1 Overview of Legal System in Kenya
J1.9.2 - J1.9.7 Supporting documentation for Kenya
J2.1.1 Acquisition of Legal Capacity in South Africa
J2.1.2 Companies Act for South Africa
J2.1.3 Broad Based Black Economic Empowerment Act
J2.1.4 Codes of Good Practice on Broad Based Black Economic Empowerment
J2.2.1 Acquisition of Legal Capacity in Botswana
J2.2.2 Companies Act for Botswana
J2.2.3 Ownership and Operation of SKA in Botswana
J2.3.1 Acquisition of Legal Capacity in Ghana
J2.3.2 Companies Act for Ghana
J2.3.3 Ownership and Operation of SKA in Ghana
J2.4.1 Acquisition of Legal Capacity in Kenya
J2.4.2 Companies Act for Kenya
J2.4.3 Ownership and Operation of SKA in Kenya
J2.5.1 Acquisition of Legal Capacity in Mauritius
J2.5.2 Companies Act for Mauritius
J2.5.3 Ownership and Operation of SKA in Mauritius
J2.6.1 Acquisition of Legal Capacity in Namibia
J2.6.2 Companies Act for Namibia
J2.6.3 Ownership and Operation of SKA in Namibia
J2.7.1 Acquisition of Legal Capacity in Zambia
J2.7.2 Companies Act for Zambia
J2.7.3 Ownership and Operation of SKA in Zambia
J2.8.1 Acquisition of Legal Capacity in Madagascar
J2.8.2 - J2.8.4 Supporting documentation for Madagascar
J2.8.5 Ownership and Operation of SKA in Madagascar
J2.9.1 Acquisition of Legal Capacity in Mozambique
J2.9.2 - J2.9.3 Supporting documentation for Mozambique
J2.9.4 Ownership and Operation of SKA in Mozambique
J3.1 African Union Heads of State Endorsement of the SKA 2010
J3.2 Final Joint Statement by African SKA Partner Countries
J3.3.1 Letter of Commitment from Botswana 2010
J3.3.2 Letter of Commitment from Botswana 2011
J3.3.3 Memorandum of Understanding between Botswana and South Africa
J3.3.4 Non-Disclosure Agreement between Botswana and South Africa
J3.3.5 Scientific and Technological Agreement between Botswana and South Africa
J3.3.6 Letter of Commitment from University of Botswana
J3.4 Letter of Commitment from Ghana
| J3.5.1 | Letter of Commitment from Kenya |
| J3.5.2 | Scientific and Technological Agreement between Kenya and South Africa |
| J3.6.1 | Letter of Commitment from Mozambique |
| J3.6.2 | Scientific and Technological Agreement between Mozambique and South Africa |
| J3.7 | South African Democratic Community (SADC) 2009 Summit record |
| J3.8.1 | Scientific and Technological Agreement between Zambia and South Africa |
| J3.8.2 | Scientific and Technological Agreement between Zambia and South Africa - Plan of Action |
| J3.8.3 | Letter of Commitment from Zambia |
| J3.9 | Scientific and Technological Agreement between Namibia and South Africa |
| J3.10 | African Ministerial Conference on Science and Technology 2010 (AMCOST IV) |
| J4.1.1 | Summary of IPR Legislation in South Africa |
| J4.1.2 - J4.1.7 | Supporting documentation for South Africa |
| J4.2.1 | Summary of IPR Legislation in Botswana |
| J4.2.2 - J4.2.3 | Supporting documentation for Botswana |
| J4.3.1 | Summary of IPR Legislation in Ghana |
| J4.3.2 - J4.3.8 | Supporting documentation for Ghana |
| J4.4.1 | Summary of IPR Legislation in Kenya |
| J4.4.2 - J4.4.5 | Supporting documentation for Kenya |
| J4.5.1 | Summary of IPR Legislation in Madagascar |
| J4.5.2 - J4.5.6 | Supporting documentation for Madagascar |
| J4.6.1 | Summary of IPR Legislation in Mauritius |
| J4.6.2 - J4.6.6 | Supporting documentation for Mauritius |
| J4.7.1 | Summary of IPR Legislation in Mozambique |
| J4.7.2 - J4.7.4 | Supporting documentation for Mozambique |
| J4.8.1 | Summary of IPR Legislation in Namibia |
| J4.8.2 - J4.8.3 | Supporting documentation for Namibia |
| J4.9.1 | Summary of IPR Legislation in Zambia |
| J4.9.2 - J4.9.10 | Supporting documentation for Zambia |
| J5.1.1 | Property rights of the SKA in South Africa |
| J5.1.2 - J5.1.3 | Support documentation for South Africa |
| J5.2.1 | Property rights of the SKA in Botswana |
| J5.3.1 | Property rights of the SKA in Ghana |
| J5.4.1 | Property rights of the SKA in Kenya |
| J5.5.1 | Property rights of the SKA in Mozambique |
| J5.6.1 | Property rights of the SKA in Namibia |
| J5.7.1 | Property rights of the SKA in Zambia |
| J5.8.1 | Property rights of the SKA in Mauritius |
| J5.8.2 - J5.8.5 | Supporting documentation for Mauritius |
| J5.9.1 | Property rights of the SKA in Madagascar |
| J6.1.1 | Licensing and Permits in South Africa |
| J6.1.2 - J6.1.13 | Supporting documentation |
| J6.2.1 | Licensing and Permits in Botswana |
| J6.2.2 - J6.2.8 | Supporting documentation for Botswana |
J6.3.1 . . . . . . Licensing and Permits in Kenya
J6.3.2 - J6.3.7 . Supporting documentation for Kenya
J6.4.1 . . . . . . Licensing and Permits in Madagascar
J6.4.2 . . . . . . Supporting documentation for Madagascar
J6.5.1 . . . . . . Licensing and Permits in Mauritius
J6.5.2 - J6.5.6 . Supporting documentation for Mauritius
J6.6.1 . . . . . . Licensing and Permits in Namibia
J6.6.2 - J6.6.6 . Supporting documentation for Namibia
J6.7.1 . . . . . . Licensing and Permits in Zambia
J6.7.2 - J6.7.3 . Supporting documentation for Zambia
J6.8.1 . . . . . . Licensing and Permits in Ghana
J6.8.2 - J6.8.4 . Supporting documentation for Ghana
J6.9.1 . . . . . . Licensing and Permits in Mozambique
J6.9.2 - J6.9.5 . Supporting documentation for Mozambique
J7.1.1 . . . . . . Environmental law in South Africa
J7.1.2 - J7.1.14 Supporting documentation for South Africa
J7.2.1 . . . . . . Environmental law in Botswana
J7.2.2 - J7.2.5 . Supporting documentation for Botswana
J7.3.1 . . . . . . Environmental law in Ghana
J7.3.2 - J7.3.4 . Supporting documentation for Ghana
J7.4.1 . . . . . . Environmental law in Kenya
J7.4.2 - J7.4.4 . Supporting documentation for Kenya
J7.5.1 . . . . . . Environmental law in Madagascar
J7.5.2 - J7.5.4 . Supporting documentation for Madagascar
J7.6.1 . . . . . . Environmental law in Mauritius
J7.6.2 - J7.6.3 . Supporting documentation for Mauritius
J7.7.1 . . . . . . Environmental law in Namibia
J7.7.2 - J7.7.4 . Supporting documentation for Namibia
J7.8.1 . . . . . . Environmental law in Zambia
J7.9.1 . . . . . . Environmental law in Mozambique
J7.9.2 - J7.9.3 . Supporting documentation for Mozambique
J8 . . . . . . . . . . Listing of Annexures for African SKA Partner Countries

K1.1 . . . . . . Pasco Security Risk Assessment /Annexure K/
K1.2 . . . . . . Pasco Security Plan
K2 . . . . . . . . Alexander Forbes Insurance Cost Indication
K3 . . . . . . . . Aurecon Report on Infrastructure Costs
L1 . . . . . . . South African legislation relevant to the employment of professionals and others /Annexure L/
L2 . . . . . . . Basic Conditions of Employment Act
L3 . . . . . . . Occupational Health and Safety Act
L4 . . . . . . . Exposition of the Occupational Safety and Health Act
L5 . . . . . . . Income Tax Act 58 of 1962
L6 . . . . . . . Immigration Act 13 of 2002
L7 . . . . . . . Quota of exceptional skills
Contents

L8 ............. Large Accounts Unit of the Department of Home Affairs
L9.1 ........... Letter of Undertaking from Botswana
L9.2 ........... Letter of Undertaking from Zambia
L10 ............ Five-Year Rule Interpretation Note 4
L11 ............ Countries with which South Africa has concluded DTAs
L12 ............ Aurecon Report on Cost for SKA infrastructure
M1 .............. Results of the HSBC Expat Explorer Survey (2010) /Annexure M/
M2 .............. Ranked list of the 50 most expensive cities in the world (Mercer’s Worldwide Cost of Living Survey 2011)
M3 .............. OECD Tax Database for the 34 OECD Countries
M4 .............. Collection of photographs of South Africa
Chapter 1

Preface

Our commitment to the SKA is firm and steadfast. It is our hope that others will emulate this engagement.

This statement, made by South African Minister of Science & Technology, Naledi Pandor, at the 2011 SKA Public Forum in Banff, illustrates the level of support that the SKA instrument and science programme enjoy in Africa. The commitment to the SKA is part of a vision for the growth of astronomy in Africa, which has mobilized public enthusiasm and high-level government and industry support in South Africa and Africa and has led to very significant achievements in radio telescope development, radio astronomy and the development of a dynamic, vibrant, growing and world-class base of scientists and engineers in the SKA South Africa team, in universities in South Africa, and increasingly in other African countries.

The African proposal to host the SKA, with the majority of the receptors located in South Africa, is based on the principles of excellent and transformational science, low construction and operating costs, and the availability of skilled human resources. The Karoo Radio Astronomy Reserve is an ideal location for the core of the SKA, combining a low RFI environment, ready access to infrastructure, and a benign climate.

The Heads of State and Government of the African Union adopted a Declaration at their 2010 Assembly expressing the African Union’s unequivocal support for South Africa to lead the bid to locate the SKA in Africa (Annexure B1). This Declaration also committed Africa to participate in the global SKA project, and the SKA is recognized as a flagship project by the African Ministerial Council on Science and Technology. This vision for astronomy in Africa, which encompasses as a key and iconic flagship the SKA in Africa will show major benefits for Africa and for the world, both for science and for the importance to the world and to Africa of it reaching its potential as the next great business destination and the next great economic growth destination. Information sharing and coordination meetings with relevant government and academic representatives from the African partner countries started in 2004, and in April 2008 the SKA Africa Working Group was formally established to coordinate SKA-related activities in the continent (Figure 1.1). Formal declarations of support for the SKA in Africa by the African partner countries and the African Ministerial Conference on Science and Technology (AMCOST) are contained in Annexures B2 and B3. The brochure in Annexure B4 illustrates how Africa is ready for the SKA, and how the SKA has driven science and technology in Africa.

The development of astronomy in the region is part of a considered strategy that has its origins in a White Paper on Science & Technology drafted by the first democratic government of South Africa in 1996 (Annexure B5):

Scientific endeavour is not purely utilitarian in its objectives and has important associated cultural and social values. It is also important to maintain a basic competence in flagship sciences such as physics and astronomy for cultural reasons. Not to offer them would be to take a negative view of our future - the view that we are a second class nation, chained forever to the treadmill of feeding and clothing ourselves.

The essential elements of the White Paper were carried forward in the 2002 National Research Development Strategy (Annexure B6):

One way to achieve national excellence is to focus our basic science on areas where we are most likely to succeed because of important natural or knowledge advantages. In South Africa, such areas include astronomy, human palaeontology and indigenous knowledge.
Tangible early outcomes of the strategy have been the construction of SALT at the SAAO site, South African involvement in the HESS gamma ray facility in Namibia, and South Africa joining the SKA consortium at an early stage. This commitment is repeated in the following extract from the Department of Science and Technology’s (DST) Strategic Plan for the fiscal years 2011-2016 (Annexure B7):

*In growing its knowledge base, South Africa also needs to build on its niche strengths, especially those in which it has a geographic or natural advantage, such as astronomy, biodiversity, Antarctic research, minerals processing and palaeontology.*

and in these two Grand Challenge Outcomes in DST’s ten-year (2008-2018) plan (Annexure B8):

- Become the preferred destination for major astronomy projects and associated international investment in construction and operations.
- Will have constructed a powerful radio-astronomy telescope and used it for world-class projects.

Support for the SKA (and other radio astronomy activities) in South Africa and Africa is not limited to governmens and their agencies - civil society, commerce and industry have become fascinated by the scientific, engineering and educational aspects of the South African SKA project, and many local and multi-national organizations have endorsed the South African proposal to host the SKA. The South African SKA project, including the MeerKAT telescope, has been identified and supported as a flagship project of the LeadSA campaign run by a range of South African media groups. The SKA in Africa has also received active and enthusiastic support from the Johannesburg Stock Exchange and Business Leadership SA, and a range of South African and multi-national corporations, such as Intel, Nokia Siemens Networks, Price Waterhouse Coopers, Vodacom, and many others. Various letters of support for the SKA in Africa are contained in Annexures B9 to B13.

### 1.1 Radio Astronomy in Africa

The development of the astronomy Science Platform has become a keystone of science and technology strategy in South Africa, and significant resources are being channeled into astronomy facilities and associated scientific programmes. The significant achievements and developments in South African radio astronomy since 2003 are summarized below.

#### 1.1.1 SKA South Africa Project Office

The DST established the SKA South Africa Project Office as a business unit of the National Research Foundation (NRF) under the Directorship of Dr Bernie Fanaroff, supplementing the existing Hartebeesthoek Radio Astronomy...
Observatory (HartRAO). The Project Office reports to a high-level steering committee whose members include the Director-General of DST and the CEO of the NRF. To date the South African government have committed €210 million to the SKA South Africa project. The Project Office mandate includes:

- Manage all interactions with the international SKA project and partner institutions.
- Manage all aspects of the SKA site competition for South Africa and African partner countries.
- Establish the Karoo Radio Astronomy Reserve.
- Oversee the MeerKAT telescope project, including science and engineering aspects.
- Develop and manage the Human Capital Development programme.
- Manage cooperative projects and programmes with partner institutes and industries.
- Manage all interactions with the African partner countries, including the establishment of the African VLBI Network (AVN).

The Project Office has made significant financial, scientific and technical contributions to the international SKA project through membership of the SSEC (previously the ISSC) and its various sub-committees and working groups, participation in the site selection process, and involvement in associated activities such as SKADS and PREPSKA. The MeerKAT project has provided important technical and scientific inputs into the SKA-mid design process, with the MeerKAT project team members contributing significantly to design review processes.

The DST and NRF are currently driving the establishment of a South African National Radio Astronomy Facility. This entity will provide a long-term funding and management structure to host national facilities (including MeerKAT) and international projects (including the SKA, PAPER and C-BASS).

1.1.2 The Establishment of the Karoo Radio Astronomy Reserve

The Karoo Radio Astronomy Reserve was initially established to provide a suitable location for the SKA core region and the MeerKAT. Three candidate sites within South Africa were identified using a combination of desktop studies and physical site surveys. The Karoo site was selected over the other two because of these characteristics:

- Distance from RFI and EMI sources, but proximity to bulk infrastructure (roads and utility power grid) and small towns.
- Benign, dry climate and suitable physical characteristics.
- Flat-topped escarpment and hills providing natural RFI and EMI shielding.
- The core, spiral arms and most of the remote stations are at an elevation of 1000 m, or higher, thus reducing the atmospheric opacity.
- Low and diminishing economic activity in the area.

The South African Parliament has passed the Astronomy Geographic Advantage Act, which was drafted under the supervision of the DST and the SKA SA Project Office, in collaboration with stakeholders including the Independent Communications Authority of South Africa (ICASA), the Department of Communications, and major commercial operators. This wide-ranging and powerful legislation ensures the long-term viability of the Karoo Radio Astronomy Reserve by placing stringent thresholds on radio frequency interference in the Northern Cape province and protects the area from any other activities which might constitute threats to astronomy (such as mining activities). The extent of the protected reserve is illustrated in Figure 1.2.

The site has been provided with appropriate bulk infrastructure to support the MeerKAT and SKA Phase-1. The current buildings on site were designed to support KAT-7 construction and operation (Figure 1.2), and further buildings that will support MeerKAT have passed a Critical Design Review (CDR) and procurement procedures are about to commence. These infrastructure sectors are all SKA-ready.

The Karoo Reserve has attracted the attention of other radio telescope projects because of its excellent RFI characteristics, the availability of the installed infrastructure, engineering and technical assistance from on- and off-site staff, and the convenience of the location. The PAPER low-frequency epoch of re-ionization (EoR) array has been successfully deployed, commissioned and operated at the Karoo site, and the C-BASS antenna has been installed at the Karoo site. Figure 1.3 shows the installation of these two instruments, and Figure 1.4 illustrates the excellent quality of the PAPER wide-field, low-frequency images observed from the Karoo site. The brochure in Annexure B14 provides a brief overview of the advantages offered by the site.
Figure 1.2: Left: The location of the Karoo Radio Astronomy Reserve within the Northern Cape province of South Africa. The map illustrates the very low population density in this semi-arid region. Right: Existing buildings and infrastructure at the Losberg site complex, showing the access boom, dish fabrication shed, accommodation and sun shelter for shielded containers.

Figure 1.3: Deployment of the PAPER (left) and C-BASS (right) instruments in the Karoo Radio Astronomy Reserve, showing the use of on-site facilities and staff.
1.1.3 The MeerKAT Radio Telescope

South Africa is not only committed to hosting the SKA, but also to the development of technologies for the SKA (particularly SKA-mid). The MeerKAT project, an acknowledged SKA precursor, was initiated with full funding commitment from the South African government. The brochure in Annexure B15 provides a brief overview of the MeerKAT. A very competent, committed and enthusiastic engineering and science team has been established to execute this programme (Figure 1.5).

The MeerKAT has successfully passed its Concept Design Review (CoDR) and Preliminary Design Review (PDR) processes, confirming its status as an SKA precursor that provides a complete solution for the SKA mid-frequency dish array. Over 500 scientists participated in the call for MeerKAT Large Survey proposals, and ten of the twenty-one submissions were approved. These approved surveys align very closely with SKA mid-frequency science goals.

The MeerKAT development programme includes incremental prototypes, and information gained from these prototypes has been passed on the the SKA Project Development Office. The XDM prototype composite antenna was built and commissioned at HartRAO and is now being developed into an operational facility for pulsar timing and S/X-band VLBI observations. Innovative receiver systems have been developed in conjunction with EMSS (a local SMME specializing in antennas), and the MeerKAT digital processing team have become the dominant partner in the CASPER collaboration. The involvement of local industries in the MeerKAT programme has introduced them to radio astronomy and the exacting requirements of the SKA. These industries will be well-placed to develop and construct the SKA.

The KAT-7 precursor array has been constructed and commissioned on the Karoo site (Figure 1.5), and is in high demand from local and international scientists to test new back-end technologies and techniques, and perform test observations for the MeerKAT Large Surveys. The MeerKAT science processing (software) team and the KAT-7 commissioning team collaborate widely with their peers abroad, and an active staff exchange programme has developed. Figure 1.4 shows an early test image from KAT-7.

1.1.4 The Development of Human Capital

Radio astronomy in South Africa originated at Rhodes University in the 1960’s, with the development of small instruments to study Solar and Jovian radio emissions, and in parallel at the (then) National Institute for Telecommunications Research, using the 26 m NASA Deep Space Station antenna at Hartebeesthoek. The Hartebeesthoek
Radio Astronomy Observatory (HartRAO) was established in 1974, following the closure of the Deep Space Station. This accelerated the development of the field, and several other local universities became involved in radio astronomy research. HartRAO and these universities have provided a fertile environment for the training of a number of scientists who have attained international recognition.

A well-funded and focused Human Capital Development Programme (HCDP) was initiated in 2005, which has increased the number of scientists, engineers and technicians active in radio astronomy well beyond the threshold of critical mass and sustainability. This programme includes initiatives ranging from Research Chairs and Senior Fellowships through to internships for technicians. This programme has already seen the graduation of 25 PhD and 52 MSc students with thesis projects focused on MeerKAT and SKA science and engineering. The Research Chair initiative has attracted leading academics to five local universities, and increasing numbers of international scientists and engineers are spending significant time at local universities and in the MeerKAT office. Technicians in training have gained valuable experience working at HartRAO and at the Karoo site. Figure 1.3 shows some of these technicians installing the C-BASS and PAPER instruments.

The HCDP also includes individuals and institutions in the African partner countries. Forty-eight students from these partner countries have been supported to undertake postgraduate study in SKA-related science and engineering at South African universities. Appropriate science and engineering programmes are being initiated at universities within these countries, with Ghana, Kenya, Mozambique, Mauritius and Madagascar already having put programmes into place. Figure 1.1 shows the participants at a recent workshop on the development of radio astronomy at partner country universities. The brochure in Annexure B16 describes the various human capital development initiatives driven by the SKA South Africa Project Office.

1.1.5 VLBI in Africa

Hartebeesthoek was a participant in the first southern hemisphere intercontinental VLBI experiment in 1970, when the antenna was still a NASA DSN facility. HartRAO has been involved in VLBI experiments since that time, and is a member of all of the VLBI networks that have common sky coverage with the observatory. The observatory is a full member of the EVN, and routinely participates in eVLBI experiments via a data link provided by the South African National Research Network (SANReN). Figure 1.6 shows the full 1 Gb/s throughput to the EVN correlator at the Joint Institute for VLBI in Europe (JIVE, Netherlands).

A programme to convert redundant 30 m class telecommunications antennas throughout Africa into VLBI stations has been initiated to create an African VLBI Network. This initiative developed out of the extension of the human capital development programme into the African partner countries, and draws on VLBI expertise at HartRAO. Besides the intrinsic scientific value of this programme, it is establishing radio astronomy competence in African countries designated to host SKA stations. Figure 1.6 shows the antenna at Kuntunse in Ghana that is currently being refurbished for VLBI use.
1.1.6 Partnerships

The activities of the SKA South Africa Project Office have led to the establishment of a wide range of partnerships with local and multi-national industries, and local and international institutions. National facilities and organizations, such as the NRF, SAAO, HartRAO, SANReN and the Centre for High Performance Computing (CHPC) have all established programmes that focus on the needs of the SKA, MeerKAT and other radio telescopes on the Karoo site. Local industries, such as EMSS, Tellumat and MMS, have worked very closely with the MeerKAT team and have developed deep experience in the requirements of modern radio telescope. The resources of leading multi-national companies, such as IBM, Intel, Nokia Siemens Networks and BAE, have been tapped through the award of contracts or the signing of mutual-benefit agreements. Active collaborative partnerships have been developed with a large number of international institutions active in SKA science and technology development, largely as a result of the MeerKAT and the Human Capital Development Programme.

These partnerships have contributed to the SKA in that they have harnessed valuable expertise and know-how, and have extended the visibility of the SKA locally and internationally. The brochures in Annexures B17 and B18 provide examples of partnerships formed between the SKA South Africa project and various industries and astronomy institutes.

1.2 The South African Proposal for the SKA

The Request for Information is based on a scenario of a fully funded, and hence full-scope, SKA telescope. We consider that the responses to the RfI are important inputs in the evolution of the SKA to a realistic facility, via a defendable and rigorous system engineering process that balances scientific scope and realistic costs.

1.2.1 Cost

The total cost of ownership of the SKA, including both capital and operational components, must be understood with high fidelity for the project to achieve credibility with governments. This view was expressed by Minister Pandor at the Banff SKA Public Forum:

\[ \text{In this regard, I should emphasize that the SKA will only progress if cost is recognized as a critical criterion, to be fully and appropriately taken into account for all important decisions related to the further development of the project. To pretend otherwise in a global economic environment marked by} \]
austerity measures and concern regarding cost overruns at other large-scale infrastructures, will neither be a realistic, nor a responsible approach, for any funding partner.

Our response covers the full-scope SKA as prescribed in the RfI and its annexures. To assist with future system engineering work we have broken down costs for the various components of the SKA, and show how costs scale with scientific scope. Table 1.1 provides a summary of infrastructure costs for the SKA as proposed in this document. This table highlights the incremental costs associated with, for instance, the remote stations.

1.2.2 Implementation and Operation of the SKA and Associated Infrastructure

The preparation of this response to the RfI has required extensive engineering design, and consideration of logistic and operation aspects of the SKA. In the course of this work we have identified and evaluated project risks and alternative implementations, as one would expect in this phase of system engineering. In some instances we provide alternative implementation scenarios that deviate from the SKA model provided where these scenarios:

- are more cost effective or appropriate, or
- cover inadequacies in the SKA model provided, or
- take advantage of the unique opportunities provided by the our site.

Key preferred scenario options detailed in the later sections of this proposal are summarised below, together with a brief justification for the choice of scenario.

- The location of the high performance computing centre (including the non-imaging processor) adjacent to the power substation and array processor, 30 km from the core site. This has cost advantages, particularly because it negates the need for a huge data pipeline between the array processor and the computing facility (the cost of this link is dominated by transmission equipment, not the fibre). It is probably necessary for the non-imaging processing to be located close to the core site and this may share hardware with the computing facility (the SSG-RfI does not make reference to the requirements of the non-imaging processor). The topography of the region provides a natural RFI barrier between the power and data processing facility, and the core site.
- The use of existing infrastructure, particularly the regional road network and the bulk infrastructure installed for MeerKAT. The MeerKAT power and data networks are capable of supporting SKA Phase 1.
- The outsourcing of maintenance of remote stations under service level agreements (SLAs). This allows the use of commercial maintenance personnel already located near to the remote stations (e.g. technicians who maintain cell-phone base-stations) for front-line maintenance of SKA stations.
- The use of Indefeasible Right of Use (IRU) managed bandwidth for long-haul data connections. This is the most cost effective and risk averse way of providing connectivity to the remote stations, and is protected from inflationary cost increases.
- The use of a rotating shift system for skilled on-site staff, allowing senior staff to reside in the larger towns and cities. The Sistema de Turno has been shown to be effective for the operation of remote facilities in Chile, including ALMA (Annexure B19) and mining operations.
- Use of the utility grid to provide power to the core site. Utility grid power provides a cost-effective and high reliability solution, and also allows the use of the power transmission system to wheel power to the site from private power providers and green power sources.
- Various power backup and conditioning solutions have been provided because of the uncertainty in the power quality requirements of the various components of the SKA (e.g. receptor subsystems, array processor, high-performance computing).

1.3 Structure of Proposal

This proposal contains 11 chapters that deal individually with sections 3 to 13 of the SSG-RfI. All Annexures referred to in the proposal are listed in the Contents, and are available electronically. Annexure A contains the full text of the proposal, allowing access to the full document for those receiving individual chapters of the proposal and requiring cross-reference to the other chapters.
Table 1.1: A summary table of capital, operations and maintenance infrastructure costs for the SKA as defined in this proposal. The costs are broken down into line items that show the incremental costs associated with various components of the SKA.

<table>
<thead>
<tr>
<th>Description</th>
<th>Capital Cost</th>
<th>Annual Operations Cost</th>
<th>Annual Maintenance Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Infrastructure Components</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Roads</td>
<td>€ 58 410 000</td>
<td>€ 0</td>
<td>€ 841 694</td>
</tr>
<tr>
<td>- Main Access Road</td>
<td>€ 20 736 000</td>
<td>€ 0</td>
<td>€ 49 917</td>
</tr>
<tr>
<td>- Core, Inner and Skirt Region</td>
<td>€ 34 408 000</td>
<td>€ 0</td>
<td>€ 535 583</td>
</tr>
<tr>
<td>- Intermediate Roads (out to 180km)</td>
<td>€ 1 486 000</td>
<td>€ 0</td>
<td>€ 139 944</td>
</tr>
<tr>
<td>- Remote Stations in South Africa</td>
<td>€ 593 000</td>
<td>€ 0</td>
<td>€ 37 083</td>
</tr>
<tr>
<td>- Remote Stations outside South Africa</td>
<td>€ 1 237 000</td>
<td>€ 0</td>
<td>€ 79 167</td>
</tr>
<tr>
<td>Buildings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Astronomy Complex and Cape Town Headquarters</td>
<td>€ 31 354 000</td>
<td>€ 425 028</td>
<td>€ 561 194</td>
</tr>
<tr>
<td>- Core, Inner and Skirt Region</td>
<td>€ 0</td>
<td>€ 0</td>
<td>€ 0</td>
</tr>
<tr>
<td>- Intermediate (out to 180km)</td>
<td>€ 0</td>
<td>€ 0</td>
<td>€ 0</td>
</tr>
<tr>
<td>- Remote Stations in South Africa</td>
<td>€ 1 317 000</td>
<td>€ 0</td>
<td>€ 15 111</td>
</tr>
<tr>
<td>- Remote Stations outside South Africa</td>
<td>€ 2 099 000</td>
<td>€ 0</td>
<td>€ 22 083</td>
</tr>
<tr>
<td>- Dish Foundations &amp; Site Preparation</td>
<td>€ 179 311 000</td>
<td>€ 0</td>
<td>€ 2 267 500</td>
</tr>
<tr>
<td>- Core, Inner and Skirt Region</td>
<td>€ 107 187 000</td>
<td>€ 0</td>
<td>€ 1 438 194</td>
</tr>
<tr>
<td>- Intermediate (out to 180km)</td>
<td>€ 55 534 000</td>
<td>€ 0</td>
<td>€ 778 833</td>
</tr>
<tr>
<td>- Remote Stations in South Africa</td>
<td>€ 7 154 000</td>
<td>€ 0</td>
<td>€ 24 028</td>
</tr>
<tr>
<td>- Remote Stations outside South Africa</td>
<td>€ 9 436 000</td>
<td>€ 0</td>
<td>€ 26 444</td>
</tr>
<tr>
<td>- Other</td>
<td>€ 5 465 000</td>
<td>€ 449 000</td>
<td>€ 61 000</td>
</tr>
<tr>
<td>Power</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 13.8kV Bulk Power Supply</td>
<td>€ 29 501 000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Core reticulation (out to 35km)</td>
<td>€ 68 742 000</td>
<td>€ 46 721 556</td>
<td>€ 1 439 750</td>
</tr>
<tr>
<td>- Intermediate Reticulation (out to 180km)</td>
<td>€ 4 719 000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Remote Stations in South Africa</td>
<td>€ 3 671 000</td>
<td>€ 642 278</td>
<td>€ 61 194</td>
</tr>
<tr>
<td>- Remote Stations outside South Africa</td>
<td>€ 20 422 000</td>
<td>€ 592 861</td>
<td>€ 340 361</td>
</tr>
<tr>
<td>- Critical Backup Rotary UPS</td>
<td>€ 4 913 000</td>
<td>€ 0</td>
<td>€ 0</td>
</tr>
<tr>
<td>Data (20/50 Year IRU)</td>
<td>€ 331 020 000</td>
<td>€ 7 276 700</td>
<td>€ 0</td>
</tr>
<tr>
<td>- 13.8kV Bulk Power Supply</td>
<td>€ 88 842 000</td>
<td>€ 0</td>
<td>€ 0</td>
</tr>
<tr>
<td>- Core reticulation (out to 35km)</td>
<td>€ 28 106 000</td>
<td>€ 0</td>
<td>€ 0</td>
</tr>
<tr>
<td>- Intermediate Reticulation (out to 180km)</td>
<td>€ 91 494 000</td>
<td>€ 0</td>
<td>€ 0</td>
</tr>
<tr>
<td>- Remote Stations in South Africa</td>
<td>€ 108 218 000</td>
<td>€ 5 670 300</td>
<td>€ 0</td>
</tr>
<tr>
<td>- Remote Stations outside South Africa</td>
<td>€ 14 360 000</td>
<td>€ 718 000</td>
<td>€ 0</td>
</tr>
<tr>
<td>Subtotal</td>
<td>€ 740 944 000</td>
<td>€ 56 107 422</td>
<td>€ 5 609 889</td>
</tr>
<tr>
<td>Discounts</td>
<td>€ 17 234 000</td>
<td>€ 0</td>
<td>€ 0</td>
</tr>
<tr>
<td>Total</td>
<td>€ 723 710 000</td>
<td>€ 56 107 422</td>
<td>€ 5 609 889</td>
</tr>
</tbody>
</table>
Chapter 2

Provision of Basic Infrastructure Components

2.1 Introduction

Basic infrastructure requirements, as provided in the SSG-RfI, have been interrogated to develop an infrastructure solution that is appropriate, reliable and affordable for the SKA. Development of the solution was not performed in isolation, but took into consideration the provision of power infrastructure, data connectivity, and the opportunities provided by existing MeerKAT and national public infrastructure. As part of the process, cost-performance tradeoffs were undertaken across all areas of infrastructure provision: basic infrastructure, power infrastructure, and data connectivity. This enabled the development of an optimal infrastructure solution that not only meets the requirements of the SKA Model (Annex 1 of the SSG-RfI), but in many instances provides a significant improvement in the SKA basic infrastructure scenario. The high availability and reliability of the infrastructure solution has resulted in not only cost savings, but improvements in the operational and maintenance models, and hence operational availability, of the SKA.

The development of an infrastructure cost model has been part of an ongoing process. The South African SKA Project Office (SASPO) has engaged with Aurecon (formerly Africon) since 2005 in the development of cost models for infrastructure solutions to the SKA. Three separate infrastructure cost models have been developed: the South African Infrastructure Cost Model of 2005; an Acquisition Differential Cost Report in 2010 that considers international differences in costs for infrastructure components; and a full Acquisition Cost Report in 2010 for the African SKA configuration.

Aurecon South Africa were engaged to develop a cost model for an infrastructure solution in response to the SSG-RfI of 2011, in collaboration with the SASPO. The 2010 infrastructure cost reports referred to above were used as input, and are attached as Annexures C10.1 and C10.2. These reports contain information of relevance that has not specifically been addressed in the SSG-RfI. The full detailed response to the SSG-RfI on basic infrastructure components is attached as Annexure C4.1, with the costed model implemented as an Excel spreadsheet attached as Annexure C4.2. This model derives current rand values, and de-escalates the rand results to 2007 euro values. This detailed model is summarised in Annexure C4.8. Detailed cost breakdown structures for the different basic infrastructure components are provided in Annexures C4.3, C4.4, C4.5, C4.6 and C4.7. The cost model developed has an 85% level of confidence in infrastructure costs (assuming the SKA Model in Annex 1 of the SSG-RfI), and 75% level of confidence in maintenance and operations costs. Costs have been based on tendered prices for the MeerKAT project, quotations and industry estimates.

This report considers the cost of acquisition of roads, buildings and associated infrastructure, and dish foundations. Visual representations for each of the basic infrastructure components are referred to in the relevant sections. South Africa applies environmentally sustainable designs to infrastructure for the SKA in all respects, which is in line with modern international best practice.

All capital, operations and maintenance costs, including itemised discounts, labour rates and unit costs, are provided in Section 2.11. Maintenance costs have been split as a separate line item from operations costs. Maintenance refers to the upkeep of an infrastructure component to maintain full functionality, whereas operations refers to the use of the infrastructure component. Total cost of ownership of the basic infrastructure components, with
operations and maintenance for 36 years (6 years for SKA Phase 1, 30 years for SKA Phase 2), is summarised in Table 2.1. A more detailed summary of the total cost of ownership, including power and data infrastructure costs, is provided in Table 1.1 of the Preface. Operational costs are based on 2011 electricity tariffs, and a multi-year Indefeasible Rights of Use (IRU) upfront operations cost (with no further annual payments) for data connectivity. Tariff projections are discussed in more detail in the reports on Power and Data Infrastructure solutions in Annexure A.

Escalated costs of the basic infrastructure components and power infrastructure have also been summarised in Annexure C4.1, and have been based on economic projections for each of the African SKA Partner countries. The escalated costs indicate that the capital and maintenance costs will not increase over the construction and operation phase of the project, but will in fact decrease from €410.0 million to €391.5 million capital cost and from €202.0 to €129.2 million maintenance cost. This is as a result of the projected changes in the foreign exchange rate between the South African Rand and the Euro. The detailed escalated cost model is attached as Annexure C4.9.

Table 2.2 is a summary of the discounts, additional discounts that could benefit the SKA if MeerKAT ‘SKA-ready’ infrastructure is used, and design cost savings as a result of designing the SKA Model infrastructure solution to use existing infrastructure in Africa (these cost savings are not claimed as discounts). These costs are discussed in more detail in the report. There are further cost savings as a result of infrastructure solutions that we have proposed that are not site specific. These have been noted in the report.

Capital cost saving measures have been investigated as a method of releasing capital for construction of the SKA instrument. One of the most significant options is the amortisation of power capital costs (excluding the low voltage network) into the operational costs over a 20 year period. This would reduce the power capital cost from €131.968 million to an upfront connection fee of approximately €5.53 million, and increase the annual operations cost by €11.55 million. This operation cost would include maintenance of all power infrastructure, up to but not including the low voltage reticulated network.

Table 2.1: Total cost of ownership of the SKA basic infrastructure components, with operations and maintenance for 36 years.

<table>
<thead>
<tr>
<th>Description</th>
<th>Capital Cost</th>
<th>Lifetime Operations Cost (2020-2055)</th>
<th>Annual Operations Cost</th>
<th>Lifetime Maintenance Cost (2020-2055)</th>
<th>Annual Maintenance Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads</td>
<td>€38,409 M</td>
<td>€0</td>
<td>€0</td>
<td>€30,301 M</td>
<td>€842 M</td>
</tr>
<tr>
<td>Buildings</td>
<td>€34,771 M</td>
<td>€15,301 M</td>
<td>€4,250 M</td>
<td>€21,543 M</td>
<td>€596 M</td>
</tr>
<tr>
<td>Dish Foundations &amp; Site Preparation</td>
<td>€179,312 M</td>
<td>€0</td>
<td>€0</td>
<td>€81,631 M</td>
<td>€2,268 M</td>
</tr>
<tr>
<td>Other</td>
<td>€5,465 M</td>
<td>€16,156 M</td>
<td>€4,490 M</td>
<td>€2,186 M</td>
<td>€61 M</td>
</tr>
<tr>
<td>Subtotal</td>
<td>€277,957 M</td>
<td>€31,457 M</td>
<td>€8,740 M</td>
<td>€135,661 M</td>
<td>€3,769 M</td>
</tr>
<tr>
<td>Discounts</td>
<td>€17,234 M</td>
<td>€0</td>
<td>€0</td>
<td>€0</td>
<td>€0</td>
</tr>
<tr>
<td>Total</td>
<td>€260,723 M</td>
<td>€31,457 M</td>
<td>€8,740 M</td>
<td>€135,661 M</td>
<td>€3,769 M</td>
</tr>
</tbody>
</table>

Table 2.2: Cost advantages for the SKA in Africa. The Discount line item is the discount claimed as part of the total infrastructure cost solution. The Additional discount line item is the additional discount that could benefit the SKA if MeerKAT ‘SKA-ready’ infrastructure is used. This would require a re-analysis of the SKA Model requirements for infrastructure. The Design cost savings line item is the savings that have accrued as a result of designing the SKA Model infrastructure solution for existing infrastructure in Africa (these costs are not claimed as discounts).

<table>
<thead>
<tr>
<th>Description</th>
<th>Capital Cost</th>
<th>Lifetime Operations and Maintenance Cost (2020-2055)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discounts</td>
<td>€17,234 M</td>
<td>0</td>
</tr>
<tr>
<td>Additional discounts</td>
<td>€8,037 M</td>
<td>0</td>
</tr>
<tr>
<td>Design cost savings</td>
<td>€309,494 M</td>
<td>€47,793 M</td>
</tr>
</tbody>
</table>
2.2 Overview of Infrastructure Scenario

2.2.1 Infrastructure for the SKA Model

Most of the SKA infrastructure to meet the SKA Model requirements, as provided in the SSG-RfI, will be located within 100 km of the SKA Core. Figure 2.1 is a map of the local area surrounding the SKA Core, and includes the towns of Carnarvon and Van Wyksvlei, the Karoo Support Base at Klerefontein, the SKA Operations Centre (referred to as the Astronomy Complex), the on-site Losberg Site Complex, the upgraded main access road, a new 132 kV high voltage powerline and the SKA configuration for Africa. A 20 m resolution digital elevation model has been superimposed onto the map, indicating the topographical protection afforded to the SKA in the area.

Figure 2.1: Map of area around the South African SKA Core, including the following infrastructure: towns of Carnarvon and Van Wyksvlei, airfields, main access road, new high voltage powerline, Karoo Support Base, Astronomy Complex, Losberg Site Complex and SKA configuration. A 20 m resolution digital elevation model has been superimposed onto the map.

The different locations identified in this map are referred to throughout this report.

2.2.2 MeerKAT Basic Infrastructure - ‘SKA Ready’

The MeerKAT project, including the development of the KAT-7 radio telescope, has a major infrastructure construction program. This has resulted in the development of on-site (Losberg Site Complex) and off-site (Klerefontein Support Base) facilities, as well as bulk infrastructure. The design philosophy of this infrastructure has considered expansion to SKA Phase 1 and Phase 2. Excess capacity on MeerKAT infrastructure, due to be completed in 2013, ensures that a large portion of the required infrastructure for SKA Phase 1 will be available for use. This will result in substantial capital cost savings to the SKA.

Certain infrastructure components for MeerKAT have been discounted in this report because they can be used by the SKA. However, it is believed that key infrastructure components not considered in the SSG-RfI can be utilised following construction of the MeerKAT, which would result in further cost savings. A photo of the existing on-site Losberg Site Complex (see Figure 2.1) is shown in Figure 2.2, with identified infrastructure components.

MeerKAT infrastructure to be established is summarised as follows:
Expansion of Dish Assembly Shed and Pedestal Integration Building

Expansion of the existing Dish Assembly Shed is required for the manufacture of the MeerKAT 13.85 m x 15.5 m offset Gregorian dishes, which are aligned to the SKA dish reference design. This expansion will need to accommodate an area for two additional moulds, and an area for sub-reflector installation onto the dish. A chemical store will be constructed adjacent to the Dish Assembly Shed, to provide for on-site manufacture of dishes.

A new Pedestal Integration Building will be constructed for MeerKAT, where the integration of pedestal, yoke and dish electrical infrastructure will take place. This building will allow the dish contractor to execute this work in a controlled environment with cranes and platforms.

New Karoo Array Processor Building and Power Facility

The Losberg Site Complex will be extended with the construction of the Karoo Array Processor Building, which includes an RFI-shielded bunker, integration laboratory, conference room, control room and ancillaries. The bunker has a building footprint that accommodates 128 racks (50 racks for MeerKAT and additional space for the upgrade path to the SKA Phase 1).

A Power Facility bunker will be constructed, and has been designed such that electrical infrastructure can be added modularly to provide power for the SKA Phase 1. The maximum capacity of the Power Facility is 5 MVA. Rotary UPS will be provided for MeerKAT, and will allow for expansion to operate five Rotary UPS in an N+1 redundant configuration for SKA Phase 1.

Road Network

The main access road from Carnarvon to the Losberg Site Complex was upgraded, and is currently maintained, by the Northern Cape Provincial Department of Roads. The gravel road is designed to withstand heavy construction traffic, with a maximum travel speed of 80 km/hr. The Northern Cape province has committed to secure funding to seal the road with asphalt for MeerKAT and the SKA. Discussions are underway to de-proclaim the section of road between the ‘SKA Astronomy Complex’ (Operations Centre) and the SKA Core site for the purposes of the SKA. The MeerKAT road network will be constructed to access the MeerKAT and SKA Core site, and can be utilised for SKA purposes.
All-weather Landing Strip

A new all-weather landing strip will be constructed for MeerKAT, and can be used for SKA purposes. The strip will be constructed adjacent to the Meys Dam farmhouse, and allows for quick access to the SKA Core site. Further details on the landing strip are provided in Section 2.6.1 of this report.

Construction Camps

Two construction camps will be established for MeerKAT adjacent to the Meys Dam and Losberg farmhouses. The Losberg camp will accommodate up to 150 infrastructure contractor staff, and the Meys Dam construction camp will accommodate up to 80 dish contractor staff. Both farmhouses are being converted into office space for contractors. These camps would be available during the construction of the SKA.

Bulk Power

A new 33 kV utility grid power line has been constructed from the Karoo substation of the national grid (near Carnarvon) to the Losberg Site Complex. A specialised design was used to mitigate against spark-generated interference. Following the completion of the substation upgrade, a maximum demand of 5 MVA will be supplied to the MeerKAT site. The MeerKAT power requirement is currently 2.5 MVA, with a spare capacity of 2.5 MVA available for SKA Phase 1. As the grid power line passes the Operations Centre (known as the Astronomy Complex), it can provide a power source during construction of the complex.

Data Connectivity for Cape Town

A 10 Gbps data link from the Losberg site to Cape Town has been installed. A backup 10 Mbps data link is also available.

Expansion of Klerefontein Support Base

The existing Klerefontein Support Base, located 15 km from Carnarvon, will be upgraded with the construction of additional workshops and offices. This building will comprise a mechanical workshop, electronics workshop, cryogenic systems workshop, electrical workshop and offices for the MeerKAT technicians.

Visitors/Science Centre

A feasibility study is nearing completion for the establishment of a Visitors/Science Centre in Carnarvon. The Northern Cape Department of Tourism is in discussion with the National Department of Tourism to secure capital and operational funding for this centre.

Detailed site layouts for the expanded Losberg Site Complex, following the completion of the MeerKAT infrastructure program, are provided in Annexures C9.1 and C9.2. A concept drawing of the expanded Losberg Site Complex is provided in Figure 2.3.

Costs for the MeerKAT road network and main access road, all-weather landing strip and construction camps, totalling €17.234 million, have been discounted from the full infrastructure cost model and are summarised in Section 2.11. Were the dish assembly, pedestal integration, Karoo Array Processor and Power Facility buildings to be used for SKA Phase 1 and 2, an additional discount of €8.037 million would accrue.

2.3 Road Infrastructure

The provision of road infrastructure for the SKA considers both the technical requirements for the development of road specifications, as well as existing road infrastructure and how it may be incorporated into the SKA infrastructure plan. Annexure C1 contains a repository of drawings for the road network layout, indicating new and existing road infrastructure. An index of drawings is provided in Table 2.3.

The following assumptions were made for the road infrastructure design:
Figure 2.3: View of Losberg Site Complex, including new infrastructure for MeerKAT.

Table 2.3: Index of Road Network Drawings in Annexure C1.

<table>
<thead>
<tr>
<th>No.</th>
<th>File Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SSG-RDS-LOC-01</td>
<td>Africa Configuration</td>
</tr>
<tr>
<td>2</td>
<td>SSG-RDS-LOC-02</td>
<td>Northern Cape Road Network</td>
</tr>
<tr>
<td>3</td>
<td>SSG-RDS-L-01</td>
<td>Three Cores</td>
</tr>
<tr>
<td>4</td>
<td>SSG-RDS-L-02</td>
<td>Dish Core</td>
</tr>
<tr>
<td>5</td>
<td>SSG-RDS-L-03</td>
<td>Dense Aperture Array Core</td>
</tr>
<tr>
<td>6</td>
<td>SSG-RDS-L-04</td>
<td>Sparse Aperture Array Core</td>
</tr>
<tr>
<td>7</td>
<td>SSG-RDS-RL-01</td>
<td>Remote SKA Stations 1 - 6</td>
</tr>
<tr>
<td>8</td>
<td>SSG-RDS-RL-02</td>
<td>Remote SKA Stations 7 - 12</td>
</tr>
<tr>
<td>9</td>
<td>SSG-RDS-RL-03</td>
<td>Remote SKA Stations 13 - 18</td>
</tr>
<tr>
<td>10</td>
<td>SSG-RDS-RL-04</td>
<td>Remote SKA Stations 19 - 24</td>
</tr>
<tr>
<td>11</td>
<td>SSG-RDS-RL-05</td>
<td>Remote SKA Stations 25</td>
</tr>
</tbody>
</table>
All existing road infrastructure in South Africa and the African SKA Partner countries is maintained and will be maintained for the duration of the 36 years (six years for SKA Phase 1, 30 years for SKA Phase 2) of operation by the relevant government departments;

- No reconstruction of roads after the maintenance period is allowed for;
- Borrow pits for material will be sourced within 15 km of the construction site;
- Water is obtained from nearby licensed boreholes, and the yield is sufficient;
- Maintenance schedules are based on best practice cycles as proposed in this report, which should provide the user with an acceptable level of services for 36 years. The SKA has the option of downscaling maintenance according to the level of service they are willing to accept;
- Maintenance equipment will be hired on a contractual basis. Maintenance of all gravel roads in the road infrastructure plan is on an as-required basis, and it is recommended that this is contracted out.

2.3.1 Road Technical Specification

Three different road requirements have been provided in the SSG-RfI: the main access road; major roads to receptors; and minor roads to receptors. Vehicular volumes ranging between 1 million and 3.3 million E80’s (Equivalent Standard Axle loads) have been determined, as described in Section 2.1 of Annexure C4.1. Based on this analysis, and the road requirements provided in the SSG-RfI, detailed technical specifications have been derived for each type of road. The specifications can be reviewed in Annexure C5.2, and are based on an ES3 pavement design.

2.3.2 Road Infrastructure Plan

The various parts of the SKA facility requiring road infrastructure are dealt with in a sequential manner.

Main Access Road to Site

The main access road from Carnarvon to the Astronomy Complex, and on to the SKA Core site (see Figure 2.1), will handle the largest vehicular volume during the construction and operations phases. Traffic will range from large trucks carrying construction equipment and material from borrow pits, to regular movement of operations and maintenance vehicles. Degradation of the quality of road due to excessive use and subsequent increased requirements for constant maintenance, will have a direct impact on cost and timelines of the infrastructure and telescope construction program. It is therefore important to ensure that a sufficiently high technical specification is adopted to ensure continuous use in all weather conditions. The specifications provided in Annexure C5.2 represent the minimum technical specification that would meet the user specifications.

The length of the existing main access road is approximately 71.4 km (47.3 km - R63 to Astronomy Complex, 24.1 km - Astronomy Complex to SKA Core site), and connects to the main tarred road (R63) 11.5 km from the town of Carnarvon. The access road will be upgraded to have the same pavement layers as the major road network within the Skirt region. This upgrade will comprise in-situ rework and stabilising of the existing wearing course, construction of a new base course layer and construction of a surfacing seal. Due to the drainage and formation width of the existing access road, constructed as part of the MeerKAT infrastructure programme, only upgrading of the road is required. The existing road, together with the upgrade to be undertaken by the Northern Cape Provincial Department of Roads, represents a discount of €16.7 million to the SKA project. The provincial department will undertake subsequent maintenance of the 58.7 km section of the road between the Astronomy Complex and Carnarvon. As the MeerKAT project is in the process of having the section of road between the Astronomy Complex and the SKA Core site de-proclaimed as a Provincial road, the SKA will be responsible for the maintenance of this section.

Dish and Aperture Array Cores and Inner Zones

The SSG-RfI proposes a road specification providing for minor roads between dishes, and two 2 km diameter raised platforms for the Aperture Array (AA) cores. As a result of the density of dishes in the core, no road network could be formalised. For this reason, a 1.5 km diameter raised common platform is proposed at the dish core. Each dish beyond the raised platform has an individual 30 m diameter cleared area, with 20 m raised platform.
An investigation of the AA station configuration found that the two 2 km diameter raised platforms, as specified in the SSG-RfI, are not required. Minor roads can be constructed between stations instead, giving a capital cost design saving to the SKA project of approximately €9.9 million and a further €20.4 million in maintenance cost over the 36 year life cycle. Each of the AA stations consists of a 60 m or a 180 diameter levelled and raised gravel platform.

All raised gravel platforms consist of a 200 mm thick imported gravel layer. The proposed dish and AA cores and inner zones will consist of approximately 75 km of minor roads and one 1.5 km diameter raised platform.

Skirt Region (Extending to approximately 13.5km from Centre of Cores)

A map of the model major road infrastructure layout is provided as Figure 3 in Annex 1 of the SSG-RfI, with a total length of 180 km. A detailed examination of existing road infrastructure and the on-site road network enabled a reduction of the required total road length from 180 km to 109 km, excluding the 71.4 km main access road (see Figure 2.4). The proposed major road network still meets the maximum separation distance requirement of 2 km between a receptor and a major road. In addition, a 95 km minor road network has been designed to connect the major roads to individual receptors.

Figure 2.4: SKA Core and Skirt road layout. Blue lines indicate major roads, purple lines indicate minor roads, black lines indicate existing roads and red lines indicate the MeerKAT road network. 20 m contour lines have been provided in magenta, and farm borders have been indicated in white.

A road network of 28 km will be constructed as part of the MeerKAT project. Approximately 8 km of the MeerKAT road network will be used as part of the proposed SKA road network. This will result in an estimated discount of €130,000 in capital cost to the SKA.

Beyond the Skirt Region

Roads beyond the skirt region will meet the minor road specification as a minimum requirement. Existing road infrastructure in South Africa and its African partner countries is used to the maximum extent possible to determine the road network plan for the SKA. This has resulted in a dramatic reduction of 661 km in the required 750 km of road to be constructed, and hence a saving of €10.7 million capital cost and €43.4 million in maintenance cost.
for the SKA. The approximate total length of minor road to be constructed, taking into account existing road infrastructure, is summarised as follows:

- Beyond skirt region to 180 km (89 km)
- Remote stations in South Africa (37 km)
- Remote station in African partner countries (60.5 km)

The capital cost of these roads is expected to be €3.3 million, with a maintenance cost of €9.2 million over 36 years. Maps of the existing and proposed road infrastructure are provided in the index of drawings in Annexure C1.

2.3.3 Operations and Maintenance

Maintenance requirements for all roads and platforms are based on best practices in South Africa. The SSG-RfI requires maintenance of infrastructure to be calculated from completion of the infrastructure component to 30 years after the final completion of the SKA Phase 2 construction phase in 2025. This results in 36 years of maintenance requirement due to the early completion of SKA Phase 1.

1. Major Roads including Main Access Road

Maintenance of these roads is in accordance with the Technical Recommendation for Highways (TRH3): Design and Construction of Surfacing Seals, attached as Annexure C15.1. This specifies a reseal every 14 years. Further to the reseal, an allowance is made for patch and repair works to the road structure and some cleaning and repairing of drainage structures. Maintenance of the 58.7 km main access road from Carnarvon to the Astronomy Complex will be undertaken by the provincial government, and will not be to the cost of the SKA. This represents a saving of €4.4 million over the 36 year maintenance period.

2. Minor Roads

Maintenance of these roads is in accordance with the Technical Recommendation for Highways (TRH20): The Structural Design, Construction and Maintenance of Unpaved Roads, attached as Annexure C15.2. As this road is not a standard unpaved road, a farm road standard was derived from best practise and suggested maintenance methods from the TRH20. Re-grading of these roads was taken at five year intervals and re-grading and gravelling every ten years. This results in four re-grades and three re-grade and gravels over the maintenance period.

3. Platforms

Maintenance of platforms is in accordance with the TRH20. Re-grading of the platforms was taken at five year intervals and re-grading and graveling at ten year intervals, giving four re-grades and three re-grade and gravels over the maintenance period.

The sequence for re-seal of asphalt roads, and gravelling and re-grading of minor roads, is based on the specifications indicated above. This entails the following:

- An average of 10 km of gravel road is maintained per day, in contradiction with the 1.2 km indicated in the SKA Model of Maintenance;
- The approximately 360 km total of minor roads excluding platforms will take 18 working days to grade if two graders are used;
- Re-grading of the dish and AA platforms will take approximately 120 working days using two graders;

The model that has been adopted for the road maintenance cost calculation is based on work packages that would be put to tender for sub-contractors to do the road and platform maintenance. The SKA may wish to undertake maintenance of road networks itself, as indicated in the SKA Initial Model of Operations and Maintenance. This may result in minor cost savings. However, due to the inaccuracy of the operations and maintenance model that was provided in the SSG-RfI, and the gaps in the work breakdown structure, it is most accurate to cost this component as a tendered work package. This cost will include all direct and indirect costs not covered in the SKA Initial Model of Operations and Maintenance, and is based on tendered prices from other projects.
2.4 Equipment and Office Buildings

The proposed buildings for the SKA take into account requirements during the construction and operations phase, as well as existing infrastructure. Annexure C2 contains a comprehensive repository of architectural drawings for the buildings to be constructed at the Astronomy Complex and remote SKA stations. An index of architectural drawings in Annexure C2 is provided in Table 2.4.

Table 2.4: Index of Building Architectural Drawings in Annexure C2.

<table>
<thead>
<tr>
<th>No.</th>
<th>File Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>107102-SSG-ARC-1000</td>
<td>Astronomy Complex conceptual layout 1:1000</td>
</tr>
<tr>
<td>13</td>
<td>107102-SSG-ARC-1001</td>
<td>Astronomy Complex conceptual layout 1:500</td>
</tr>
<tr>
<td>14</td>
<td>107102-SSG-ARC-1002</td>
<td>Remote site conceptual layout</td>
</tr>
<tr>
<td>15</td>
<td>107102-SSG-ARC-3D01</td>
<td>Astronomy Complex conceptual 3D view 01</td>
</tr>
<tr>
<td>16</td>
<td>107102-SSG-ARC-3D02</td>
<td>Astronomy Complex conceptual 3D view 02</td>
</tr>
<tr>
<td>17</td>
<td>107102-SSG-ARC-3D03</td>
<td>Astronomy Complex conceptual 3D view 03</td>
</tr>
<tr>
<td>18</td>
<td>107102-SSG-ARC-3D01-RS</td>
<td>Remote site conceptual 3D view 01</td>
</tr>
<tr>
<td>19</td>
<td>107102-SSG-ARC-3D02-RS</td>
<td>Remote site conceptual 3D view 02</td>
</tr>
</tbody>
</table>

The construction of the MeerKAT Losberg Site Complex will be completed in 2013, prior to the initiation of the SKA infrastructure program. The Complex will have sufficient spare capacity to provide for the requirements of SKA Phase 1 if needed.

2.4.1 Operations Centre near SKA Core Site: Astronomy Complex

The Operations Centre near the SKA Core site (referred to as the Astronomy Complex), is located on the main access road, 24.1 km from the SKA Core site. The location of the Astronomy Complex is indicated in Figure 2.1, with a concept drawing of the Astronomy Complex shown in Figure 2.5. The electrical support facilities (transformer areas and control rooms) form part of the Astronomy Complex. The electrical substation, located next to the Astronomy Complex, is built, operated and maintained by the electricity generation and distribution utility Eskom. The substation has not been shown in Figure 2.5, but is included in the site layout drawings provided in Annexure C2.

Figure 2.5: View of Astronomy Complex.
The Astronomy Complex consists of four major buildings and a small accommodation compound, summarised in Table 2.5.

Table 2.5: Summary of buildings located at the Astronomy Complex, including total and sub-divided areas.

<table>
<thead>
<tr>
<th>Number</th>
<th>Building</th>
<th>Subdivision</th>
<th>Area [m²]</th>
<th>Total Area [m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Data Processor</td>
<td>Data storage</td>
<td>500</td>
<td>1600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Data interconnect</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Computer rooms</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>HVAC</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Power Building</td>
<td></td>
<td></td>
<td>768</td>
</tr>
<tr>
<td>3</td>
<td>Super Computer</td>
<td>Data storage</td>
<td>500</td>
<td>1600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Data interconnect</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Computer rooms</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>HVAC</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Office</td>
<td>General office space</td>
<td>600</td>
<td>1640</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hardware support staff work area</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Meeting rooms</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Canteen and storage</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recreational area for on-site staff</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical workshop</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electrical workshop</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parts store</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Staff Accommodation</td>
<td></td>
<td></td>
<td>30 people</td>
</tr>
</tbody>
</table>

A description of each of the buildings is provided below:

**Data Processor and Super-computer Buildings**

The data processor and super-computer buildings are co-located at the Astronomy Complex (the two buildings are linked, and share the same construction methods, materials and architectural language). This co-location is primarily due to the very high costs associated with the provision of the 400 Tbps data link between the data processor and super-computer over distances exceeding 80 km. Additional office space has been provided for the increased maintenance personnel, whilst remaining support staff are to be accommodated in the Head Office building, located in Cape Town. It is proposed that a centralised maintenance scenario will accommodate the maintenance requirements of both the data processor and super-computer.

Environmentally sensitive and functionally appropriate design and construction methodologies are used with strict environmental control, described in Section 2.2.1.1 of Annexure C4.1.

An alternative scenario has been costed, with the super-computer building located near the Head Office in Cape Town. This scenario results in an overall increase in capital expenditure of €1.265 million, including land, buildings and power, but excluding data transport. Further detail is located in Section 5.6 of Annexure C4.1. The Data Provision Report (see Annexure A) indicates a cost saving of €287.5 million in lifetime data connectivity costs (assuming a 50 year IRU managed bandwidth solution) by co-locating the data processor and super-computer.

**Power Building**

The Power building will house the uninterruptible power supply (UPS) equipment, and will adopt the same approach in design and construction methodologies as used for the data processor and super-computer buildings. The building will also require a degree of acoustic insulation, which will be determined in the detailed design phase of the project. Further detail is located in Section 5.6 of Annexure C4.1.
Offices and Equipment Buildings

Environmentally sensitive and functionally appropriate design and construction methodologies are used, with specific design features meant to improve the ‘human-friendly’ nature of the building.

Accommodation Compound

An accommodation compound consisting of 15 pre-fabricated sleeping units - each equipped with two bedrooms and a bathroom - will be constructed, with recreational and catering facilities housed in the offices and equipment building. These units will be arranged in clusters of five around a small landscaped courtyard and connected to the Astronomy Complex via paved footpaths. A landscaped ‘barrier’ will be constructed to ensure an appropriate degree of privacy for the occupants. The accommodation compound forms part of the total accommodation plan for the operations phase of the SKA, which is discussed in Section 2.5.

Heating, Ventilation and Air Conditioning

Heating, Ventilation and Air Conditioning (HVAC) in each of the buildings will be fit-for-purpose. The approach will be to design a building to operate in either natural ventilation mode or, if this is insufficient, forced ventilation and then to incorporate air conditioning. Due to the high demand of cooling for the super-computer and processor areas, chilled water will be generated on site. The cost benefit of using this facility for the rest of the buildings will be investigated.

- Office HVAC System
  Purpose designed systems using either split type air conditioners or chilled water fan coil and air handling systems to air condition the various areas.

- Super-computer and Data Processor HVAC System
  Due to power density in these buildings, dedicated water cooled rack cooling units will be supplied for cooling of computer equipment. To provide for redundancy, rack mounted air conditioning units will included. A number of air cooled chillers with pumps and piping distribution will provide the necessary cooling for the rack mounted air conditioning units in an N+1 redundant arrangement.

- Electrical substations, switch rooms and transformer rooms HVAC System
  Electrical substations will be designed to utilise natural ventilation where possible. When the power densities become too large, forced ventilation will be used. Active temperature control will only be used where essential.

External areas, civil works, including bulk earthworks, stormwater drainage and parking areas, fire protection, building electrical services and security systems are dealt with in detail in Section 2.2.1 of Annexure C4.1.

2.4.2 Bunkers for AA Stations

RFI shielded containers, as used for the KAT-7 radio telescope, will be used for the AA bunkers. The container has been specified to accommodate six racks, and is appropriate for use at the AA-mid stations. Photographs of one of the RFI shielded containers used by KAT-7 are located in Annexure C11.2. Larger containers, capable of accommodating ten racks, will be required for the AA-low stations. The container is positioned on a reinforced concrete slab 400 mm below ground level. Brick retaining walls run on the perimeter of the slab with stairs providing access into the RFI shielded container. Storm water drainage has been provided at the bottom of the stairs, which drains into a catchment tank. Refer to Annexure C11.1 for design layouts. The total cost of these container bunkers can be reduced by €4.9 million if the container and associated infrastructure is shielded from natural weather conditions. Bunkers have been costed as part of the dish foundations and site preparation component.

2.4.3 Remote Station Buildings

Remote station buildings are constructed 2 km from receptors to mitigate against self-generated electromagnetic interference. Any further requirements for mitigation will be determined in the detailed design phase. A typical remote station will consist of two distinct building components: storage shed (107 m²), and an electrical room and...
workshop (81 m²). The storage shed will consist of a steel-framed building, whilst the electrical room and workshop will be a precast concrete structure. Panels could either be manufactured off-site under controlled conditions, or on-site. Construction methods will be simple, to enable semi-skilled local labour to erect these structures, with an emphasis on pre-manufactured components to aid such principles. Annexure C2 contains architectural drawings for a typical remote station.

2.4.4 Off-site Buildings

A 3,500 m² Grade A double storey office building is planned to be built in Cape Town, for use as the SKA Head Office. This office space is sufficient for the estimated staff of 190 people. A reduction in this staff compliment of approximately 20-30 people is expected due to the co-location of the Data Processor and Super-computer buildings at the Astronomy Complex. It is possible that not all of the staff would be required at the Astronomy Complex, due to the overlap of scope of technical resources required between the data processor and super-computer.

2.5 Accommodation and Construction Camps

This section deals with the accommodation and construction camp requirements during the construction and operational phases. The accommodation provided for the operations phase considers the SKA Initial Model for Operations and Staffing (Reference 3 in Annex 1 of the SSG-RfI).

Annexure C3 is a repository of multi-layer site layouts for construction sites and camps. Table 2.6 is an index of this repository.

<table>
<thead>
<tr>
<th>No.</th>
<th>File Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>107102-SSG-CC-09</td>
<td>Construction Site Layout</td>
</tr>
<tr>
<td>21</td>
<td>107102-SSG-CC-10</td>
<td>Construction Camp Layout</td>
</tr>
<tr>
<td>22</td>
<td>SKA site accommodation units</td>
<td>Low cost 1 bedroom house</td>
</tr>
<tr>
<td>23</td>
<td>SKA site accommodation units</td>
<td>Low cost 2 bedroom house</td>
</tr>
<tr>
<td>24</td>
<td>SKA site accommodation units</td>
<td>Low cost 3 bedroom house</td>
</tr>
<tr>
<td>25</td>
<td>SKA site accommodation units</td>
<td>Low cost 4 bedroom house</td>
</tr>
</tbody>
</table>

2.5.1 Construction Phase

The SSG-RfI indicates that a total construction crew of 600 people will be required. A 35% to 50% local labour component was assumed in calculating the accommodation requirements for the construction site. Considering the phasing of construction, a construction camp for approximately 195 people would be required for the first four years and thereafter a camp catering for 300 people would be required for the remaining six years.

The construction camp will be located in Carnarvon, and hence power, water and sewer utilities would be supplied by the local municipality, resulting in cost savings of up to €10 million. Two options for accommodation were considered, with a park home (Porta-camp) being costed. The construction camp would comprise the following:

- Twenty-two × 16 sleeper units for labourers;
- Five × one bedroom units for supervisors;
- Four × two bedroom units for management and supervisors;
- Three × three bedroom units for management;
- Six ablution blocks,
- Kitchen, dining, recreation and laundry facilities;
- Dry store, cold and freezer rooms;
- Reception and administration building;
- Security guardhouse,
• Bulk site services, parking area, etc.

The quality of the one, two and three bedroom units is such that they may be used as an option for permanent accommodation after the construction phase, or may be handed over to the local municipality as an option for social investment.

The construction phase includes the provision of meals, and the daily transportation of construction crew in buses to the relevant construction sites, based on a 200 km round trip with 60 people per bus. Although the full 200 km distance has been costed, in reality this may be up to 30% less due to construction sites located at the Astronomy Complex. The travel time is not regarded as part of salary costs, as this is not normal practice in South Africa.

In addition to the construction camp accommodation in Carnarvon, six construction yards (laydown areas) around the SKA Core sites will be constructed for contractors to establish site offices, store yards etc. Two of these construction yards will be located at the farms Meys Dam and Losberg, re-utilising the sites to be established for the MeerKAT. This will result in a discount of €145,650 to the SKA. No dedicated construction yards of this magnitude are envisaged for any of the remote stations. It is assumed that four construction yards are required for the first construction phase, increasing to six in Phase 2.

Power will be supplied from existing infrastructure in the area or alternatively by generators.

2.5.2 Operations Phase

The accommodation compound at the Astronomy Complex will provide for overnight maintenance and operations staff plus a further ten personnel. Accommodation preparation and the provision of food services has been costed as part of the Astronomy Complex operations costs. However, the bulk of the accommodation solution for the operations phase is based on SKA permanent staff living in Carnarvon instead of building a new village complex near or at the Astronomy Complex. The compliment of total on-site staff (160 on SKA site, 100 at Astronomy Complex) for the cost calculation is assumed to comprise the following:

• 20 operations staff (full time on site)
• 10 maintenance staff (full time on site)
• 48 maintenance staff of 12 teams comprising 4 members per team for remote stations
• 26 administration staff
• 156 maintenance staff of 39 teams comprising 4 members per team for the Operation Centre, Core, Inner and Mid Zones (each team consists of a Supervisor/Leader, one skilled and two semi-skilled staff).
• An additional (15) super-computer hardware support staff will also be working on site if the super-computer building is to be built on site.

It is assumed that approximately 65 staff members (25%) of the total 260 complement will be local residents from Carnarvon and other towns near the remote stations. Taking into account the overnight accommodation available at the Astronomy Complex, housing (accommodation) for remaining Operation Centre staff is allowed and estimated for in Carnarvon, while staff for the remote stations will either reside in various towns closer to the remote station sites, or in a major city such as Cape Town or Kimberley. Operations costs for the Astronomy Complex include the cleaning and preparation of accommodation and provision of food services for the on-site complement of staff. Distributing staff in various towns, or setting up Service Level Agreements (SLAs) with local contractors in various towns, will result in significant improvement in the operational availability of remote stations due to the reduction in logistical delays. See Annexures C12.1 and C12.2 for further details. Accommodation for permanent staff will be built on vacant residential land owned by the municipality, and will comprise the following:

• Nineteen × one bedroom houses / units;
• Thirty-five × two bedroom houses / units;
• Seventeen × three bedroom houses / units;
• Three × 16 sleeper units;
• Ablution block for 16 sleeper units;
Provision of Basic Infrastructure Components

- Ninety-three covered parking units.

This mix, meeting accommodation requirements of 188 people, will meet the expected mix of short-term and longer-term accommodation requirements. Further accommodation is available in Carnarvon e.g. hotel, guesthouses, houses for rent and property for sale, which may reduce the amount of new accommodation to be built. The advantages of accommodating SKA staff in Carnarvon exceed the disadvantages for various social and economic reasons, including:

- Existing infrastructure and facilities in the town of Carnarvon (summarised in Section 5.5 of Annexure C4.1) will result in major capital cost savings for not having to build new recreation facilities and infrastructure bulk services;
- Although transportation to the various sites will have cost implications, this will be offset by savings in infrastructure maintenance and operations, job creation for the local community such as supplying bus services etc.
- Transportation from the Astronomy Complex to the SKA Core site will be required, irrespective of the location of staff accommodation. Hence, the ‘additional’ travelling distance for staff residing in Carnarvon will only be 57 km one way. The tarred main access road will allow for acceptable travel time durations - 30 mins to the Astronomy Complex, and a further 15 mins to the SKA Core site, based on a design speed of 100 km/hr;
- Economic injection into Carnarvon due to broader taxpayer basis for municipal services, enlarged buying public for shops, groceries etc;
- The environmental impact on resources, such as water from underground sources, near the Astronomy Complex will be eliminated. Large sewerage treatment plants, solid waste disposal etc. will not be required due to existing facilities and services already in Carnarvon.

A ‘turno’ system, based on the ALMA Operations Model and to be defined in more detail once an SKA operations and maintenance model is fully defined, would operate between Carnarvon, including the Astronomy Complex, and the major cities of Kimberley and Cape Town. Following the upgrade of the approximately 100 km gravel road between the towns of Carnarvon and Vosburg, the commute from Kimberley will take approximately 3.5 hours. The MeerKAT engineering team regularly flies from Cape Town to Carnarvon, which takes approximately 1.5 hours. SKA personnel have the option of permanently basing themselves and their families in either of these two locations. Options for accommodation, and detailed descriptions of the two cities, have been provided in the report responding to the SSG-RfI on Support and Working Environment.

The maintenance personnel responsible for remote stations (approximately 44 people) will probably be based in one of these two cities, resulting in a reduction in accommodation requirements in Carnarvon. Due to the distribution of towns in the Northern Cape Province, and Southern Africa, it may be more appropriate to enter into Service Level Agreements (SLAs) with local technicians, or even with a large-scale distributed infrastructure maintenance company (see Annexures C12.3 and C12.4 for more information on facility management proposals). This would not impact the costing presented in this report, but would probably result in a significant improvement in remote station operational availability.

The estimated 160 people working at the SKA Core site per day would probably be reduced to approximately 100. This is due to the approximately 60 personnel responsible for maintenance of receptors between 50 km and 180 km from the core being able to access these receptors via alternative roads, as indicated in drawings in Annexure C1.

Movement of Personnel and Equipment into African SKA Partner Countries

South African and multinational companies have operated efficiently in the African SKA partner countries for many years. The free movement of staff and equipment is facilitated through various free trade and other region-wide agreements, and at a minimum the SKA would be able to take advantage of this. As a scientific facility operating on a non-profit basis, the free movement of personnel and equipment will be further facilitated. See Section 4 of Annexure C4.1 for more details. Recent experience with the establishment of the first site of the Africa VLBI Network in Ghana indicates that the movements of people and equipment is quick and well facilitated by the appropriate officials.
Various commitments and bi-lateral agreements regarding the SKA have been put in place to ensure easy movement of personnel and equipment across international borders into the African SKA partner countries for maintenance purposes (see Legal Report), but it is envisioned that very limited cross-border movement of personnel would in any case be required for the SKA in Africa. It is recommended that, to improve Mean-Time-To-Repair statistics, and hence operational availability of remote stations, SLAs are put into place in each of the countries. These SLAs would concern infrastructure maintenance and first line maintenance of equipment, and their implementation would result in maintenance cost savings.

### 2.6 Airstrips

Two airstrips are available for use by the SKA. An airstrip is being constructed at the SKA Core site as part of the MeerKAT project. The strip will be used for transport of cargo and personnel, and provides for emergency evacuation. A registered aerodrome is located near Carnarvon and can accommodate larger aircraft. See Figure 2.1 for reference.

#### 2.6.1 MeerKAT Air Strip

An airstrip is being constructed as part of the MeerKAT project. The initial design was to accommodate a Pilatus PC-12 aircraft (Reference Code 1B according to the International Civil Aviation Organisation), requiring a 1,000 m long runway at the site specific elevation and temperature. To enable a wider range of aircraft to utilise it, the runway specifications were increased and meet the specifications as provided in Annexure C5.3. The layout of the MeerKAT airstrip is provided in Annexure C5.1. The construction of the MeerKAT airstrip will result in a cost saving of €271,880 to the SKA.

#### 2.6.2 Carnarvon Air Field

The Carnarvon airfield consists of three airstrips, large hangars and apron. Although no ground lighting currently exists, this will be installed as part of the MeerKAT infrastructure programme. Specifications and accompanying satellite image of the Carnarvon airfield are provided in Annexure C5.4.

### 2.7 Water and Sanitation

Water and sanitation plans have been drawn up for all phases of construction and operation.

During the construction phase, water will be supplied by means of boreholes. Detailed borehole studies have been undertaken at the SKA Core site. Information on availability and quality is provided in the Physical Characteristics Report in Annexure A. The results of these studies indicate sufficient yield for the construction and operation of MeerKAT and associated infrastructure. Further assessment will be required to determine adequacy for the SKA, but it is to be assumed that sufficient yield will be available for construction.

During the operations phase of SKA, water will be supplied by means of boreholes via water storage tanks, which will cater for the normal daily consumption of operational staff, as well as minimum irrigation requirements for landscape. Sewage will be drained to a package treatment plant (Lilliput or similar), where the sewage will be treated before it is discharged as runoff. Treated water could be used for irrigation purposes.

The water component cost at remote stations is for water-free ‘Enviroloo’ systems, which require minimal maintenance and no operational cost.

### 2.8 Dish Foundations

For detailed information on the design of dish foundations, refer to Annexure C4.1.

#### 2.8.1 Foundation Loads

Loading and performance requirements for the dish foundations were defined by the SSG-RfI, and later updated following queries. Two possible founding solutions were anticipated: pad foundations onto bedrock or competent
calcite, or piled foundations, where the competent material occurs at depths greater than 3 m. The impact of the different load conditions on the forces and moments on the foundations has been summarised in Table 2.7.

Table 2.7: Summary of forces and moments experienced under different load conditions.

<table>
<thead>
<tr>
<th></th>
<th>Static</th>
<th>Precision</th>
<th>Degraded</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind [m/s]</td>
<td>0</td>
<td>7</td>
<td>20</td>
<td>42</td>
</tr>
<tr>
<td>Overturn Moment [kNm]</td>
<td>36</td>
<td>80</td>
<td>483</td>
<td>1056</td>
</tr>
<tr>
<td>Maximum Overturning Deflection [arcsec]</td>
<td>N/A</td>
<td>3</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Down Force [kN]</td>
<td>212</td>
<td>220</td>
<td>238</td>
<td>388</td>
</tr>
<tr>
<td>Side Force [kN]</td>
<td>0</td>
<td>8</td>
<td>62</td>
<td>80</td>
</tr>
<tr>
<td>Azimuth Torque [kNm]</td>
<td>0</td>
<td>5.5</td>
<td>40</td>
<td>90</td>
</tr>
</tbody>
</table>

2.8.2 Geotechnical Conditions

Geotechnical conditions at the SKA Core site, spiral arms and remote stations have been analysed in detail through a series of commissioned surveys. An analysis of the geotechnical conditions is provided in Annexure C4.1, as well as Annexures C6.3, C6.4, C6.5, C6.6 and C6.7. Annexure C6.2 is a detailed report commissioned by the MeerKAT project on geotechnical conditions at the SKA Core site, and includes on-site measurements. These surveys were used to define a conservative ground profile that was considered representative of the site conditions. Detailed analyses, as described in Annexure C4.1, were conducted in order to derive a cost optimised piled solution.

For costing purposes, it is necessary to estimate the likely distribution of foundation solutions across the project, including along the spiral arms out to 180 km and at the remote stations. To perform this study, further information was sourced and analysed:

- Land Type Survey Staff. 1972 - 2006: Land types of South Africa from the Agricultural Research Council Institute for Soil, Climate and Water
- Google imagery of the sites
- 1:250,000 and 1:50,000 Scale Geological Topographical Series

2.8.3 Dish Foundation Solutions

The proposed design for the dish foundations is a piled foundation, where pile lengths are optimised for individual dish locations. This foundation design was based on the representative ground profile and strict loading and performance limits as supplied by the SSG-RfI. Table 2.8 summarises the proposed solution, which is driven by the precision operation conditions.

Table 2.8: Antenna dish foundation solutions.

<table>
<thead>
<tr>
<th>Depth of Competent Material</th>
<th>Pile Cap Size [mm]</th>
<th>No. of Piles</th>
<th>Pile Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 3m</td>
<td>4,200 x 4,200 x 1,000 Pile Cap</td>
<td>4</td>
<td>10 m</td>
</tr>
<tr>
<td>&lt; 3m</td>
<td>4,200 x 4,200 x 1,000 Pile Cap</td>
<td>4</td>
<td>5 m</td>
</tr>
</tbody>
</table>

Dish foundations will need to be tailored for the sub-surface geology at each location. The detailed dish foundation design is located in Annexure C6.1.

2.9 Construction Methods and Materials

The construction methods of the roads and platforms, buildings and dish foundations are based on the construction norms and specifications used in South Africa. These are a combination of international specifications and/or South African National Standards (SANS) developed specifically for local conditions and utilising available materials. All SANS specifications are developed by the SABS (South African Bureau of Standards) in accordance with international standards and practices. Whilst the SANS specifications are developed for South African conditions,
reference is made to international specifications in the SANS specification either in terms of quality requirements or test methods such as IEC, AASHTO, ASTM, BS, etc.

Designs are undertaken to meet the clients’ requirements (the SKA in this case) and are done in accordance with best practice industry standards and norms. Appropriate standards and specifications are utilised. An international specification will be used where no suitable local specification exists or where an international specification is required to meet the SKA’s design requirements.

Material will be sourced from borrow pits, quarries and commercial sources within 15 km of construction sites. The MeerKAT borrow pit investigation determined that sufficient material of sufficient quality (complying with the G7 requirement for aggregate specifications) for the wearing course of the minor roads and platforms could be sourced. The material used for the base layer and surfacing stone was assumed to be sourced from commercial sources within approximately 100 km radius of the construction site. Annexures C8.1, C8.2 and C8.3 provide further details on the MeerKAT and SKA quarry investigations. An unused approved stone quarry for concrete purposes exists in Carnarvon and is owned by the Municipality. It can be re-opened or sold on to an entrepreneur. More investigations will be undertaken during the MeerKAT project and the probability of finding suitable concrete aggregate much closer to the site is a good. The estimates here are based on the worst case scenario.

A transportation or haul cost at a rate of €0.44 per cubic metre per km was added to the normal cost of crushing the material in the cost model. This option will have no impact on environmental approval as the quarry is already registered and owned by the municipality.

The availability of local labour is high and has been used successfully in the construction of MeerKAT related infrastructure. A local labour component of 35% to 50% has been assumed in the design and costing of construction plans and facilities.

2.10 Relevant Regulations and Legislation

2.10.1 Relevant Building Codes and Standards

The relevant building codes and standards are too extensive to reproduce here, and are summarised in Annexure C7.1.

2.10.2 Health and Safety

All construction activities are bound by the Construction Regulations of 2003, published in terms of the Occupational Health and Safety Act. Under these regulations, the responsibility and liability to ensure health and safety will lie with the SKA. The contractors health and safety management programme will be certified in terms of ISO 18001.

An overview of the existing health and safety laws, by-laws, procedures, checklists and requirements as will be applicable to the construction and operation of the SKA is provided in Annexure C13.1, based on experience within the MeerKAT project.

2.10.3 Environmental

The SKA will comply with current South African legislation in terms of environmental management. An Environmental Impact Assessment (EIA) will be undertaken in terms of the National Environmental Management Act (NEMA). The MeerKAT has already been subjected to an EIA (attached as Annexure C13.3), which was approved by the Northern Cape Department of Environment and Conservation.

The Environmental Management Plan (EMP) for the MeerKAT will be form part of the relevant contract documentation and will be adhered to during the construction and operational phase of the project. Similarly, the EMP that will be developed for the SKA project will be submitted to the relevant environmental authority for approval and will be implemented during each phase of the SKA.

2.11 Cost

Cost estimates provided in this section for infrastructure components include planning, construction workforce and equipment to construct, supply and/or deliver the infrastructure in a fit-for-purpose state. The costs and unit rates for constructed elements exclude indirect costs, contingencies, local taxes and import duties or other statutory tariffs.

Operational cost estimates include all costs required and associated with the day-to-day operation of the SKA facilities, and include the workforce costs for operating the facilities but exclude the workforce costs for the SKA operation of the scientific programmes.

Maintenance cost calculations provide typical annual lifecycle maintenance costs for key elements and include plant, maintenance workforce for the facilities and power, equipment and material for planned and unplanned maintenance. Maintenance costs exclude the replacement of elements at end of life and exclude the SKA workforce for the maintenance of receivers, software, super-computer, data processor etc. Maintenance costs can therefore be viewed as tendered costs for sub-contracted maintenance work packages. This costing methodology was adopted due to the inaccuracies, gaps and over-specification of maintenance in the SKA Initial Model for Operations and Maintenance (Reference 3 in Annex 1 of the SSG-RfI). It is therefore more accurate to provide maintenance costs as tendered prices, which would be inclusive of all costs.

Cost calculations take into account all standards, legal requirements applicable and the region and location of the infrastructure. The total cost of ownership is based on a 10 year construction period (SKA Phase 1: 2016-2019, SKA Phase 2: 2020-2025) and 36 years of operations and maintenance (SKA Phase 1: 2020-2025, SKA Phase 2: 2026-2055), including land ownership or leasing.

Estimated costs are based on industry estimates, rates, quotation, data from previous projects (including the MeerKAT), and the MERKEL’S Builders’ Pricing and Management Manual. Detailed cost estimates, quotations, and other supporting documentation are part of the detailed report provided as Annexure C4.1, and is available on request. Preliminary and General (P&G) charges of the construction cost are between 13% to 18%, exclusive of the cost of the construction camps, accommodation, laydown yards, transport and meals as these have been costed as separate line items in the cost model. P&G charges are based on actual previous project tenders of these approximate values.

All costs are provided in January 2007 Euros, which required a de-escalation of present-day values. The methodology used is discussed in Section 5.1 of Annexure C4.1. Escalated costs of the basic infrastructure components and power infrastructure have also been summarised in Annexure C4.1, based on economic projections for South Africa and each of the African SKA partner countries. These escalated costs indicate that the capital and maintenance costs will not increase over the construction and operation phase of the project, but will in fact decrease from €410.0 million to €391.5 million capital cost and from €202.0 to €129.2 million maintenance cost. This is as a result of the projected changes in the foreign exchange rate between the South African Rand and the Euro. The detailed escalated cost model is attached as Annexure C4.9.

2.11.1 Capital Costs

Capital costs quoted in January 2007 euros are summarised in Tables 2.11.1 and 2.11.1, exclusive of discounts. Table 2.11.1 is a summary of the capital costs with discounts provided as a line item. Itemised discounts are summarised in Section 2.11.3.

2.11.2 Operations and Maintenance Costs

Maintenance costs in January 2007 Euros are summarised in Tables 2.11.2, 2.11.2 and 2.11.2. Operations and maintenance costs have been provided for the period 2020-2055 (36 years). This includes SKA Phase 1 operations and maintenance, from 2020 to 2025, and SKA Phase 2 operations and maintenance.

2.11.3 Discounts

Discounts that will be passed on to the SKA are summarised as Table 2.11.3. Subtotal 1 provides a discount subtotal, which is a result of MeerKAT infrastructure fully, or partially, meeting requirements of the SKA Model as described in Annex 1 of the SSG-RfI. Subtotal 2 provides a discount that is available to the SKA if part of the...
Table 2.9: Capital expenditure for Astronomy Complex, SKA Core site and Spiral Arms out to 180km, excluding power and data connectivity. Costs are provided in 1 January 2007 Euros.

<table>
<thead>
<tr>
<th>Description</th>
<th>SKA1 Capital costs</th>
<th>SKA2 Capital costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Astronomy Complex and Offsite Buildings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Cape Town Head Quarters and Offices</td>
<td>€ 3 858 000</td>
<td></td>
</tr>
<tr>
<td>2. Data Centre Processor Building</td>
<td>€ 4 701 000</td>
<td></td>
</tr>
<tr>
<td>3. Power Building (Rotary UPS)</td>
<td>€ 541 000</td>
<td></td>
</tr>
<tr>
<td>4. Workshops</td>
<td>€ 292 000</td>
<td></td>
</tr>
<tr>
<td>5. Offices, recreation, kitchen and canteen facilities</td>
<td>€ 1 513 000</td>
<td></td>
</tr>
<tr>
<td>6. On-site SKA operation and maintenance staff accommodation (15 × 2 bedroom units)</td>
<td>€ 213 000</td>
<td></td>
</tr>
<tr>
<td>7. Super-computer Building</td>
<td>€ 14 092 000</td>
<td></td>
</tr>
<tr>
<td>8. SKA permanent staff accommodation in Camaroon</td>
<td>€ 2 249 000</td>
<td></td>
</tr>
<tr>
<td>9. Construction camp in Camaroon (accommodation, kitchen, dining, laundry, store, recreation, etc. for 400 people)</td>
<td>€ 2 760 000</td>
<td></td>
</tr>
<tr>
<td>10. Transformer bays</td>
<td>€ 63 000</td>
<td></td>
</tr>
<tr>
<td>11. Control Rooms (5x3)</td>
<td>€ 1 062 000</td>
<td></td>
</tr>
<tr>
<td>12. Land</td>
<td>€ 12 000</td>
<td></td>
</tr>
<tr>
<td><strong>Roads</strong></td>
<td>€ 20 736 000</td>
<td></td>
</tr>
<tr>
<td>1. Tar Roads (Camaroon to Astronomy Complex, Astronomy Complex to SKA Core Site)</td>
<td>€ 20 736 000</td>
<td></td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>€ 1 676 000</td>
<td></td>
</tr>
<tr>
<td>1. Refuse dump</td>
<td>€ 15 000</td>
<td></td>
</tr>
<tr>
<td>2. Site works and bulk site services including parking, carparks, etc.</td>
<td>€ 1 059 000</td>
<td></td>
</tr>
<tr>
<td>3. Bulk water and sewer treatment plant to Operation Centre site</td>
<td>€ 213 000</td>
<td></td>
</tr>
<tr>
<td>4. Site Security</td>
<td>€ 390 000</td>
<td></td>
</tr>
<tr>
<td>5. Transportation and meals for construction crews (10 year period)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>€ 53 766 000</td>
<td></td>
</tr>
<tr>
<td><strong>Core and Inner Region</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Land</td>
<td>€ 934 000</td>
<td></td>
</tr>
<tr>
<td>2. Roads:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Tar Roads (major)</td>
<td>€ 13 620 000</td>
<td></td>
</tr>
<tr>
<td>2. Farm Roads (minor)</td>
<td>€ 1 537 000</td>
<td></td>
</tr>
<tr>
<td>3. Dish bases and station platforms</td>
<td>€ 7 470 000</td>
<td>€ 42 329 000</td>
</tr>
<tr>
<td>4. Air-strip (Ops and Maintenance by MeerKAT project)</td>
<td>€ 272 000</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>€ 23 833 000</td>
<td>€ 42 329 000</td>
</tr>
<tr>
<td><strong>Skirt Region</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Land</td>
<td>€ 1 262 000</td>
<td></td>
</tr>
<tr>
<td>2. Roads:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Tar Roads (major)</td>
<td>€ 18 035 000</td>
<td></td>
</tr>
<tr>
<td>2. Farm Roads (minor)</td>
<td>€ 1 216 000</td>
<td></td>
</tr>
<tr>
<td>3. Dish bases and station platforms</td>
<td>€ 2 869 000</td>
<td>€ 54 519 000</td>
</tr>
<tr>
<td><strong>Subtotals</strong></td>
<td>€ 23 382 000</td>
<td>€ 54 519 000</td>
</tr>
<tr>
<td><strong>Mid-Region (Spiral Arms)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Land</td>
<td>€ 340 000</td>
<td></td>
</tr>
<tr>
<td>2. Roads (minor)</td>
<td>€ 431 000</td>
<td>€ 1 005 000</td>
</tr>
<tr>
<td>3. Dish bases and station platforms</td>
<td>€ 4 443 000</td>
<td>€ 51 091 000</td>
</tr>
<tr>
<td><strong>Subtotals</strong></td>
<td>€ 5 213 000</td>
<td>€ 52 096 000</td>
</tr>
</tbody>
</table>
Table 2.10: Capital expenditure for SKA Remote stations, excluding power and data connectivity. Costs are provided in 1 January 2007 Euros.

<table>
<thead>
<tr>
<th>Description</th>
<th>SKA1 Capital costs</th>
<th>SKA2 Capital costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>South African Remote Stations (13)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€ 137 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€ 595 000</td>
<td></td>
</tr>
<tr>
<td>3 Dish and station bases and platforms</td>
<td>€ 7 154 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€ 1 317 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€ 19 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€ 300 000</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotals</strong></td>
<td>€ 9 521 000</td>
<td></td>
</tr>
<tr>
<td><strong>Botswana (3)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€ 16 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€ 884 000</td>
<td></td>
</tr>
<tr>
<td>3 Dish bases and platforms</td>
<td>€ 1 889 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€ 506 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€ 9 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€ 83 000</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotals</strong></td>
<td>€ 3 394 000</td>
<td></td>
</tr>
<tr>
<td><strong>Namibia (4)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€ 35 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€ 57 000</td>
<td></td>
</tr>
<tr>
<td>3 Dish bases and platforms</td>
<td>€ 2 421 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€ 446 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€ 8 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€ 101 000</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotals</strong></td>
<td>€ 3 067 000</td>
<td></td>
</tr>
<tr>
<td><strong>Mozambique (2)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€ 15 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€ 117 000</td>
<td></td>
</tr>
<tr>
<td>3 Dish bases and platforms</td>
<td>€ 1 650 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€ 506 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€ 5 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€ 73 000</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotals</strong></td>
<td>€ 2 369 000</td>
<td></td>
</tr>
<tr>
<td><strong>Madagascar (2)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€ 19 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€ 152 000</td>
<td></td>
</tr>
<tr>
<td>3 Dish bases and platforms</td>
<td>€ 2 641 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€ 486 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€ 9 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€ 111 000</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotals</strong></td>
<td>€ 3 417 000</td>
<td></td>
</tr>
<tr>
<td><strong>Zambia (1)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€ 8 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€ 27 000</td>
<td></td>
</tr>
<tr>
<td>3 Dish bases and platforms</td>
<td>€ 825 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€ 152 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€ 2 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€ 35 000</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotals</strong></td>
<td>€ 1 049 000</td>
<td></td>
</tr>
</tbody>
</table>
Table 2.11: Summary of capital expenditure, excluding power and data connectivity. Costs are provided in 1 January 2007 Euros.

<table>
<thead>
<tr>
<th>Description</th>
<th>Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astronomy complex and Offsite Buildings</td>
<td>€ 53 766 000</td>
</tr>
<tr>
<td>Core and Inner Zone</td>
<td>€ 66 162 000</td>
</tr>
<tr>
<td>Skirt Region</td>
<td>€ 77 902 000</td>
</tr>
<tr>
<td>Spiral Arms</td>
<td>€ 57 309 000</td>
</tr>
<tr>
<td>Remote Stations (South Africa)</td>
<td>€ 9 521 000</td>
</tr>
<tr>
<td>Remote Stations (Non-South African)</td>
<td>€ 13 296 000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>€ 277 956 000</strong></td>
</tr>
<tr>
<td><strong>Discounts</strong></td>
<td><strong>€ -1 723 000</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>€ 266 222 000</strong></td>
</tr>
</tbody>
</table>

power and data processing infrastructure is located at the Losberg Site Complex. The full SKA Phase 1 power and data processing infrastructure could probably be accommodated at the Losberg Site Complex.

### 2.11.4 Labour Rates

Labour rates have been provided by Aurecon, and are attached as Annexure C14.1. These labour categories are readily available throughout South Africa and the African SKA partner countries at the average hourly rates indicated. Hourly rates include leave, compulsory pension contributions, industry and trade allowances etc. Rates for construction labour, tradesmen and technical personnel (Items 1 to 3 in the table) are based on Government Grade 1 to 9 minimum wages. Items 4 to 8 are not regulated by Government and are based on private market remuneration packages. Secretarial rates are provided for senior (executive) secretaries, whilst rates for security provides for an all-inclusive 24/7 ‘manned’ presence i.e. the rate paid to a security company.

### 2.11.5 Unit Costs

Unit costs for the basic infrastructure components have been provided in Annexure C14.2. More detailed cost breakdown structures and unit costs are provided in Annexure C4.3 to C4.8.
Table 2.12: Operations and maintenance expenditure for the period 2020-2055 for the Astronomy Complex, SKA Core site and Spiral Arms out to 180 km, excluding power and data connectivity. Costs are provided in 1 January 2007 Euros.

<table>
<thead>
<tr>
<th>Description</th>
<th>SKA1 and SKA2 Operation (2020 - 2055)</th>
<th>SKA1 and SKA2 Maintenance (2020 - 2055)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Astronomy Complex and Offsite Buildings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buildings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Cape Town Head Quarters and Offices</td>
<td>€ 15 301 000</td>
<td>€ 20 203 000</td>
</tr>
<tr>
<td>2. Data - Processor Building</td>
<td>€ 122 000</td>
<td>€ 347 000</td>
</tr>
<tr>
<td>3. Power Building (Rotary UPS)</td>
<td>€ 58 000</td>
<td></td>
</tr>
<tr>
<td>4. Workshops</td>
<td>€ 32 000</td>
<td></td>
</tr>
<tr>
<td>5. Offices, recreation, kitchen and canteen facilities</td>
<td>€ 5 034 000</td>
<td>€ 163 000</td>
</tr>
<tr>
<td>6. On-site SKA operation and maintenance staff accommodation (15 x 2 bedroom units)</td>
<td>€ 15 000</td>
<td></td>
</tr>
<tr>
<td>7. Supercomputer Building</td>
<td>€ 14 205 000</td>
<td></td>
</tr>
<tr>
<td>8. SKA permanent staff accommodation in Carnarvon</td>
<td>€ 10 077 000</td>
<td>€ 182 000</td>
</tr>
<tr>
<td>9. Construction camp in Carnarvon (accom., ablutions, kitchen, dining, laundry, stores, recreation, etc. for 400 people)</td>
<td>€ 14 000</td>
<td>€ 362 000</td>
</tr>
<tr>
<td>10. Transformer bays</td>
<td>€ 8 000</td>
<td></td>
</tr>
<tr>
<td>11. Control Rooms (x3)</td>
<td>€ 115 000</td>
<td></td>
</tr>
<tr>
<td>12. Land</td>
<td>€ 54 000</td>
<td></td>
</tr>
<tr>
<td><strong>Roads</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Tar Roads (Carnarvon to Astronomy Complex, Astronomy Complex to SKA Core Site)</td>
<td>€ 1 797 000</td>
<td></td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Refuse dump</td>
<td>€ 7 312 000</td>
<td>€ 1 073 000</td>
</tr>
<tr>
<td>2. Siteworks and bulk site services including parking, carpots, etc.</td>
<td>€ 153 000</td>
<td>€ 153 000</td>
</tr>
<tr>
<td>3. Bulk water and sewer treatment plant to Operation Centre site</td>
<td>€ 703 000</td>
<td></td>
</tr>
<tr>
<td>4. Site Security</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Transportation and meals for construction crews (10 year period)</td>
<td>€ 7 159 000</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>€ 22 613 000</td>
<td>€ 23 073 000</td>
</tr>
<tr>
<td><strong>Core</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Land</td>
<td>€ 348 000</td>
<td></td>
</tr>
<tr>
<td>2. Roads</td>
<td>€ 9 724 000</td>
<td></td>
</tr>
<tr>
<td>2a. Tar Roads (major)</td>
<td>€ 15 428 000</td>
<td></td>
</tr>
<tr>
<td>2b. Farm Roads (minor)</td>
<td>€ 36 347 000</td>
<td></td>
</tr>
<tr>
<td>3. Other bases and station platforms</td>
<td>€ 48 100 000</td>
<td>€ 45 904 000</td>
</tr>
<tr>
<td><strong>Skirt Region</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Land</td>
<td>€ 48 100 000</td>
<td></td>
</tr>
<tr>
<td>2. Roads</td>
<td>€ 9 557 000</td>
<td></td>
</tr>
<tr>
<td>2a. Tar Roads (major)</td>
<td>€ 38 100 000</td>
<td></td>
</tr>
<tr>
<td>2b. Farm Roads (minor)</td>
<td>€ 45 904 000</td>
<td></td>
</tr>
<tr>
<td>3. Other bases and station platforms</td>
<td>€ 48 100 000</td>
<td>€ 45 904 000</td>
</tr>
<tr>
<td><strong>Mid-Region (Spiral Arms)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Land</td>
<td>€ 5 881 000</td>
<td></td>
</tr>
<tr>
<td>2. Roads</td>
<td>€ 5 038 000</td>
<td></td>
</tr>
<tr>
<td>3. Other bases and station platforms</td>
<td>€ 28 000</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotals</strong></td>
<td>€ 5 881 000</td>
<td>€ 33 076 000</td>
</tr>
</tbody>
</table>
Table 2.13: Operations and maintenance expenditure for the period 2020-2055 for SKA Remote stations, excluding power and data connectivity. Costs are provided in 1 January 2007 Euros.

<table>
<thead>
<tr>
<th>Description</th>
<th>SKA1 and SKA2 Operation (2020 - 2055)</th>
<th>SKA1 and SKA2 Maintenance (2020 - 2055)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South African Remote Stations (13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€1 980 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€1 335 000</td>
<td></td>
</tr>
<tr>
<td>3 Oven and station bases and platforms</td>
<td>€865 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€544 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€23 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€450 000</td>
<td></td>
</tr>
<tr>
<td>Subtotals</td>
<td>€1 980 000</td>
<td>€3 217 000</td>
</tr>
<tr>
<td>Botswana (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€27 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€1 989 000</td>
<td></td>
</tr>
<tr>
<td>3 Oven bases and platforms</td>
<td>€190 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€190 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€6 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€132 000</td>
<td></td>
</tr>
<tr>
<td>Subtotals</td>
<td>€27 000</td>
<td>€2 507 000</td>
</tr>
<tr>
<td>Namibia (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€58 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€185 000</td>
<td></td>
</tr>
<tr>
<td>3 Oven bases and platforms</td>
<td>€243 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€107 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€7 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€152 000</td>
<td></td>
</tr>
<tr>
<td>Subtotals</td>
<td>€58 000</td>
<td>€755 000</td>
</tr>
<tr>
<td>Mozambique (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€25 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€263 000</td>
<td></td>
</tr>
<tr>
<td>3 Oven bases and platforms</td>
<td>€186 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€191 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€3 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€117 000</td>
<td></td>
</tr>
<tr>
<td>Subtotals</td>
<td>€25 000</td>
<td>€740 000</td>
</tr>
<tr>
<td>Madagascar (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€32 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€353 000</td>
<td></td>
</tr>
<tr>
<td>3 Oven bases and platforms</td>
<td>€265 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€188 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€4 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€166 000</td>
<td></td>
</tr>
<tr>
<td>Subtotals</td>
<td>€32 000</td>
<td>€976 000</td>
</tr>
<tr>
<td>Zambia (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Land</td>
<td>€12 000</td>
<td></td>
</tr>
<tr>
<td>2 Roads</td>
<td>€60 000</td>
<td></td>
</tr>
<tr>
<td>3 Oven bases and platforms</td>
<td>€88 000</td>
<td></td>
</tr>
<tr>
<td>4 Buildings</td>
<td>€59 000</td>
<td></td>
</tr>
<tr>
<td>5 Water (Enviroloo)</td>
<td>€2 000</td>
<td></td>
</tr>
<tr>
<td>6 Security</td>
<td>€52 000</td>
<td></td>
</tr>
<tr>
<td>Subtotals</td>
<td>€12 000</td>
<td>€281 000</td>
</tr>
</tbody>
</table>
Table 2.14: Summary of operations and maintenance expenditure for the period 2020-2055, excluding power and data connectivity. Costs are provided in 1 January 2007 Euros.

<table>
<thead>
<tr>
<th>Description</th>
<th>Total Operational Cost (2020-2055)</th>
<th>Total Maintenance Cost (2020-2055)</th>
<th>Average Annual Operational Cost</th>
<th>Average Annual Maintenance Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astronomy complex and Offsite Buildings</td>
<td>€ 22 613 000</td>
<td>€ 23 073 000</td>
<td>€ 828 000</td>
<td>€ 848 000</td>
</tr>
<tr>
<td>Core</td>
<td>€ 348 000</td>
<td>€ 25 152 000</td>
<td>€ 10 000</td>
<td>€ 699 000</td>
</tr>
<tr>
<td>Skirt Region</td>
<td>€ 491 000</td>
<td>€ 45 904 000</td>
<td>€ 13 000</td>
<td>€ 1 275 000</td>
</tr>
<tr>
<td>Seral Arms</td>
<td>€ 5 581 000</td>
<td>€ 33 076 000</td>
<td>€ 153 000</td>
<td>€ 919 000</td>
</tr>
<tr>
<td>Remote Stations (South Africa)</td>
<td>€ 1 980 000</td>
<td>€ 3 217 000</td>
<td>€ 56 000</td>
<td>€ 89 000</td>
</tr>
<tr>
<td>Remote Stations (Non-South African)</td>
<td>€ 154 000</td>
<td>€ 5 239 000</td>
<td>€ 4 000</td>
<td>€ 146 000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>€ 31 457 000</strong></td>
<td><strong>€ 136 662 000</strong></td>
<td><strong>€ 874 000</strong></td>
<td><strong>€ 3 768 000</strong></td>
</tr>
</tbody>
</table>

Table 2.15: Discounts to the SKA. Costs are provided in 1 January 2007 Euros.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Roads</td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Road Network (existing road 48 km)</td>
<td>€ 130 000</td>
</tr>
<tr>
<td>1.2</td>
<td>Access Road (Camaron to Operational Centre - 47.3 km existing road to be upgraded and maintained by Provincial Government)</td>
<td>€ 13 737 000</td>
</tr>
<tr>
<td>1.3</td>
<td>Access Road (Operation Centre to Core - 24.1 km existing road, only upgrade and maintenance by SKA)</td>
<td>€ 2 951 000</td>
</tr>
<tr>
<td>2</td>
<td>Air-strip (existing air-strip and maintenance by MeerKAT project)</td>
<td>€ 272 000</td>
</tr>
<tr>
<td>3</td>
<td>Contractor construction yards (lay down areas) established during the MeerKAT project</td>
<td>€ 146 000</td>
</tr>
<tr>
<td><strong>Discounts</strong></td>
<td><strong>€ 17 234 000</strong></td>
<td></td>
</tr>
<tr>
<td><strong>MeerKAT site:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Karoo Array Processor Building (SKA phase 1)</td>
<td>€ 3 221 000</td>
</tr>
<tr>
<td>5</td>
<td>Power Facility Building (SKA phase 1)</td>
<td>€ 4 476 000</td>
</tr>
<tr>
<td>6</td>
<td>Building Maintenance System for SKA phase 1</td>
<td>€ 340 000</td>
</tr>
<tr>
<td><strong>MeerKAT Site Discount Option</strong></td>
<td><strong>€ 8 037 000</strong></td>
<td></td>
</tr>
</tbody>
</table>
Chapter 3

Provision of Electrical Power

This report is in response to the SSG Request for Information (SSG-RfI, dated 25 June 2011) on the provision of electrical power for the SKA, and addresses all items of concern listed in the request. Detailed answers to the questions asked in Annex 2 of the SSG-RfI can be found in Annexure D1. Details regarding the capital costs and lifetime operational and maintenance costs can be found in the spreadsheet in Annexure D2. This report outlines the proposed design solution and motivates the design decisions that were made in order to arrive at the most feasible, affordable and reliable power provision solution.

3.1 Introduction

The SSG-RfI provided the following model with respect to the required power loads for SKA:

| Receptors in central area out to 180 km | 55 MW |
| Central area buildings (including the data processor) | 10 MW |
| Super-computer | 40 MW |
| Remote stations (25 remote stations in total, 96 kW per station) | 2.4 MW |
| **Total** | **107.4 MW** |

From this model, two scenarios were identified:

1. Co-locating the data processor and super-computer near the core site, requiring a total of 105 MW on site,
2. Siting the super-computer in Cape Town, requiring a total of 65 MW on site.

Both options were investigated and it was concluded that the best option is to co-locate the data processor and super-computer near the core site at a site called the ‘Astronomy Complex’ (i.e. Option 1). The Astronomy Complex is approximately 30 km from the core site with topographical shielding providing sufficient RFI protection to comply with the RFI requirements of the telescope. The national electricity grid network (owned and operated by the national electricity utility Eskom) will be extended by means of a single 132 kV line up to the Astronomy Complex. The routing of this line takes into account the required EMI separation distance from the receptors. A new 132 kV/33 kV substation will be constructed at the Astronomy Complex, and from the Astronomy Complex five double-circuit 33kV feeder lines will provide the SKA Core with 55 MW.

Various factors led to the decision to co-locate the data processor and super-computer on the same site at the Astronomy Complex. Constructing a 400 Tbps data link over distances larger than 80 km is expensive. Long data links will require high levels of redundancy which increases costs dramatically. In this early design phase of the SKA, the lines between the data processor and super-computer are ill-defined. In all likelihood there will be a significant overlap between their functions. This has been the opinion of international peer review groups who reviewed the MeerKAT data processor and super-computer designs, and it is anticipated that the same conclusions will be
drawn for the SKA. By co-locating the data processor and the super-computer at the Astronomy Complex, data network costs are reduced and the redundancy requirement is severely relaxed without compromising performance and availability. The smaller data stream exiting the super-computer at the Astronomy Complex allows for the establishment of a fully redundant data connection to the SKA Head Office in Cape Town. It is also more expensive to site the super-computer in Cape Town, mainly because large portions of the electrical infrastructure must be duplicated. By siting the super-computer at the Astronomy Complex, only one substation has to be constructed, as opposed to two (one at the Astronomy Complex and one in Cape Town).

3.2 Electricity in South Africa

3.2.1 Eskom – The National Electricity Utility

Eskom is the national electricity utility of South Africa and is wholly owned by the South African Government. Eskom is one of the top 20 utilities in the world by generation capacity and generates approximately 95% of the electricity used in South Africa, and approximately 45% of the electricity used in Africa. Figure 3.1 shows Eskom’s generation and transmission footprint in South Africa.

Eskom has an extensive transmission network that covers most of South Africa. Figure 3.1 shows the proposed extension of the grid to provide 105 MW to the SKA Core. An existing 400 kV transmission station, Kronos (approximately 115 km north-east of the Astronomy Complex), will be upgraded to a 400 kV/132 kV substation. From Kronos it is proposed that a 132 kV line be constructed to the Astronomy Complex. Consequently the Astronomy Complex will be connected to a large and diverse ring network with excellent reliability and high availability (see Annexures D3 and D5 for more information regarding the network’s reliability and availability).

Eskom’s current new-build programme, which commenced in 2005 and is scheduled for completion in 2018, has already brought more than 5 000 MW of additional capacity online. The new-build programme includes two new coal-fired power stations, two ‘return-to-service’ coal-fired power stations, one pumped storage scheme (which will deliver 1 332 MW of hydro-power) and one wind farm of 100 MW (Annexure D3 contains more information on the status of these projects).

Figure 3.2 indicates the potential for growth of the energy network in Southern Africa. Some transmission networks already exist and will be extended and strengthened, which will allow the development of more of the regional energy sources and allow energy to be transported to South Africa, thereby increasing Eskom’s reserve capacity and introducing more renewables into the energy mix. Figure 3.2 together with Figure 3.1 indicates the ring configurations of the Eskom transmission network and highlights its robustness.

3.2.2 NERSA – The National Electricity Regulator

The National Energy Regulator of South Africa (NERSA) is an independent regulatory authority, established in terms of the National Energy Regulator Act of 2004, with the mandate to undertake the functions of the Gas Regulator as set out in the Gas Act of 2001, the Petroleum Pipelines Regulatory Authority as set out in the Petroleum Pipelines Act of 2003 and the National Electricity Regulator, as set out in the Electricity Regulation Act of 2006. (These Acts can be viewed in Annexures D17, D18, D19 and D20.)

NERSA has regulated the electricity industry over the past ten years and continues to do so. Utilities such as Eskom cannot increase their regulated rates or alter their conditions of service until NERSA approves the changes through a process of public consultation. To obtain approval, a utility must demonstrate that such a change is required and justified in its application to NERSA. NERSA’s mandate requires it to take into account the interests of all consumers before making determinations, especially poor and voiceless consumers.

Large industries and ‘special’ electricity consumers (such as the SKA) may apply for special electricity tariffs. The application process requires prior negotiation with the applicable utility (Eskom) for a Special Pricing Agreement (SPA). The South African SKA Project Office has already initiated discussions on an SPA for the SKA, and negotiations with various stakeholders are underway. An SPA must be authorised by NERSA, taking into account the best interests of all stakeholders (including other consumers).
Figure 3.1: Eskom National Generation and Transmission Network
3.2.3 The Integrated Resource Plan 2010

At the time of writing, Eskom had a total generation capacity of 41 194 GW for the 2010/2011 financial year. This includes power plants and utilities owned and operated by Eskom and additional electricity purchased by Eskom from Independent Power Producers (IPPs) or neighbouring countries. Currently 92.8% of this capacity is produced by coal-fired power stations, nuclear contributes 5.1% and the remainder is generated by renewable energy.

South Africa committed at COP 15 (in Copenhagen, December 2009) to take nationally appropriate mitigation action to enable a 34% reduction below the ‘business as usual’ emissions growth trajectory. This commitment was made despite the fact that, in terms of the Kyoto Protocol, South Africa has no obligation to reduce greenhouse gas emissions.

Partly in order to facilitate this mitigation strategy, the South African Department of Energy promulgated the Integrated Resource Plan (IRP) for Electricity (2010–2030) as the basis for South Africa’s power generation for the next 20 years. The full IRP can be viewed in Annexure D4.

The IRP outlines the path to be followed with regard to South Africa’s new-build generation fleet, with the emphasis on capping the allowable emissions level at 275 million tons per year from 2025. According to the IRP, approximately 42.6 GW of new capacity will be brought online during 2010–2030, of which approximately 42% will be renewable. Figure 3.3 illustrates how the diversification of the electricity generation mix will increase over the 20 year period. In 2010, 92.8% of South Africa’s electricity was generated by coal-fired power plants. By 2030, this will have dropped to 65% as other generation technologies come online. With the increase in renewable energies, the average CO$_2$ emission drops by 34% (as was committed at COP 15), from 912 g/kWh in 2010 to 600 g/kWh in 2030 (as shown in Figure 3.3).

The load shedding clause in the Eskom Cost Estimate letter (included in Annexure D12) indicates that the SKA must be in a position to shed load when requested by Eskom. However, this is only an issue while the national reserve capacity is under pressure. South Africa’s new-build programme, as laid out in the IRP, will increase the reserve capacity and remove the need to shed load. Eskom has also undertaken not to carry out load shedding but rather to buy back power from certain large customers and to implement other measures in order to eliminate load shedding over the period until its new capacity comes online in 2014. Eskom’s sole shareholder, the Minister for Public Enterprise, has instructed Eskom not to carry out load shedding. If required, the SKA can be declared a National Key Point, which will exempt the SKA from all risk of load shedding.
3.2.4 Renewable Energy in South Africa

In order to meet the targets as laid out in the Integrated Resource Plan, the Department of Energy initiated a renewable energy tender process inviting businesses in the renewable energy industry to submit applications to construct and operate renewable energy plants in South Africa. As per the IRP, the Department of Energy is required to procure 3 725 MW of renewable energy from private suppliers to stimulate the renewable energy industry in South Africa. To date the Department of Energy has received over 400 applications and more than 200 bidders have paid the required registration fees. The bulk of this renewable energy will be sourced from solar and wind, with the remainder being sourced from biomass, biogas and landfill gas.

The area in and around the South African SKA site has one of the highest solar irradiation fluxes in the world. The Clinton Climate Initiative has partnered with the South African Department of Energy to establish a solar park near Upington, with a generation capacity of at least 5 000 MW. Upington is approximately 250 km north of the SKA Core. The Upington Solar Park will serve as a concentrated zone of solar development and will comprise numerous solar power generation technologies offered by independent power producers (IPPs). Various IPPs, as well as Eskom, have submitted applications to the Department of Energy to construct and operate solar plants in the Upington Solar Park. Eskom intends to establish a 100 MW Concentrated Solar Thermal (CST) plant in the Upington Solar Park, funded largely by the World Bank. Annexure D3 contains more information regarding Eskom’s CSP project.

In addition, numerous IPPs have submitted applications to the Department of Energy to establish wind farms. As per the Department of Energy’s bidding process, it is expected that Power Purchase Agreements (PPAs) will be awarded from the end of 2011. Eskom will build a 100 MW wind farm at Sere on the west coast of South Africa, which will be largely funded by Development Finance Institutions (see Annexure D3 for more information related to the Sere wind farm project).

3.2.5 Renewable Energy for the SKA

Numerous renewable energy projects are, or soon will be, in operation in South Africa, making it feasible to power the SKA with renewable energy. Three options were investigated:
Option 1: Eskom Grid Electricity
In this option, the capital expenditure and project risk incurred by the SKA project is minimised. A 132 kV line from the nearest substation is to be constructed, with a new 132 kV/33 kV substation at the Astronomy Complex. From the Astronomy Complex substation five 33 kV feeder lines provide the 55 MW needed at the heart of the antenna core. The SKA is therefore already guaranteed a minimum of 2% renewable energy from the national grid, which will increase over the next 20 years to approximately 24%, in accordance with the Integrated Resource Plan. This will increase with the implementation of the West and East Coast Corridors, which will link the South African national grid to renewable energy generation (mainly hydro) in the region (see Figure 3.2). The SKA will qualify for Eskom’s ‘Megaflex’ tariff option, which is the lowest unbundled tariff option available to customers requiring 1 MVA or more. Eskom will obtain servitudes and maintain the high voltage network up to and including the Astronomy Complex substation. This is all included in the Megaflex tariff.

Option 2: Wheeling Renewable Energy from Independent Power Producers
As with Option 1, the Astronomy Complex substation and the 132 kV line will have to be constructed. This connects the SKA electricity network to the rest of the national network and allows energy from renewable energy sources to be wheeled to the SKA. The capital expenditure will, therefore, be the same as with Option 1. However, the monthly operational costs will be more than the standard Megaflex electricity tariff. A Single Buyer Office may purchase power produced by Eskom and IPPs and sell it at a blended tariff. Additional wheeling charges may also be charged. Should grid parity be reached early or should it be imperative that the SKA is powered with 100% renewable energy, a power purchase agreement can be concluded with an IPP with power wheeled to the SKA through the grid. Details on Eskom’s wheeling policy can be viewed in Annexure D6. Eskom will establish a 100 MW CST plant at Upington. This plant is scheduled to come online in 2016 and is ideally suited to powering the SKA.

Option 3: Dedicated Solar Power Plant
The option exists to build a dedicated solar plant for the SKA. It will most likely be a photovoltaic (PV) plant constructed at the Astronomy Complex site for RFI reasons. As noted previously, the solar irradiation in the area is excellent, making the siting of a solar plant at the Astronomy Complex viable. A PV plant delivering 105 MW would require between 170-200 hectares of land, which is readily available at the Astronomy Complex site. Sufficient water for the cleaning of panels is also available at the Astronomy Complex. In terms of storage, two options are available: (1) to construct a 132 kV line which connects the solar plant to the local Eskom transmission network, or (2) to provide storage via a large battery bank. Battery technology is developing rapidly but as yet there are no batteries available that can deliver energy in the gigawatt-hour range over a sustained period of time. By the time a decision is required, a lifetime cost analysis of both options will be conducted in order to identify the most cost effective solution.

3.3 Provision of Electrical Power to the SKA Core

3.3.1 Overview of Design
Figure 3.4 shows a schematic of the proposed electrical network design and indicates the new 132 kV overhead line from Kronos to the Astronomy Complex as well as the five double circuit 33 kV lines feeding the SKA Core. The remote stations are also indicated for completeness. Local reticulation at the Astronomy Complex provides power to the on-site data processor, the super-computer and other buildings. Annexure D9.1 indicates the 132 kV/33 kV substation yard layout and Annexures D9.2, D9.3, D9.7, D9.8, D9.9 and D9.10 contain detailed line diagrams. Details regarding the typical construction limits is available in Annexure D9.11. Annexure D9.4 depicts a conceptual layout of the whole Astronomy Complex. Annexures D9.14 to D9.19 shows the detail reticulation designs of the three cores and Annexure D9.12 and D9.21 shows the relative positions of the Astronomy Complex in relation to the SKA Core.
Note the following:

1. The single circuit 132 kV line runs along an existing road and is located inside an 11 km SKA electromagnetic interference (EMI) ‘exclusion zone’. No receptors are positioned within 11 km of any major road.
2. To reduce the risk of EMI, the 132 kV line is suspended on 400 kV steel structures for the last 20 km approaching the Astronomy Complex substation. Annexure D7 contains more detailed information regarding the 400 kV structures and designs to mitigate EMI.
3. The Astronomy Complex is topographically shielded from the SKA Core and is positioned approximately 30 km from the core. The switch gear and other equipment at the Astronomy Complex is shielded to mitigate against EMI. Annexure D7 contains more details regarding the shielding designs of the Astronomy Complex.
4. Five double circuit 33 kV lines (i.e. ten 33 kV lines) are suspended on galvanised steel structures. Annexure D9.5 contains details of the steel monopoles. Within 2 km from a receptor the 33 kV lines are buried underground to a miniature substation before the power is further distributed and reticulated to the various receivers via underground low voltage cables. The drawings in Annexures D9.8 and D9.9 show more details and indicate the point at which the overhead lines are buried underground.

Initial estimates based on MeerKAT designs suggest that 10 MW for the data processor may be low. The 132 kV line has a maximum carrying capacity of 120 MW, hence an unexpected increase in loads at the Astronomy Complex can easily be accommodated.

The most cost-effective, reliable design was established by conducting three trade-off studies. These trade-off studies are briefly discussed in the following paragraphs.

### 3.3.2 Location of the Super-Computer

A cost trade-off study between co-locating the super-computer with the data processor at the Astronomy Complex and locating the super-computer at the SKA Head Office in Cape Town was conducted. This entailed designing for a 105 MW firm supply at the Astronomy Complex versus providing 65 MW at the Astronomy Complex and...
40 MW in Cape Town for the super-computer. Excluding data transport considerations, co-location of the data processor and super-computer at the Astronomy Complex results in a cost saving of approximately €2.5 million. (Details of these calculations can be viewed in Annexure D2 and D10.) Consideration of the cost and risk trade-offs of the data connectivity requirements, including providing sufficient redundancy in the data connectivity solution, makes co-location at the Astronomy Complex financially, technically and scientifically the preferred solution.

3.3.3 Redundancy of the 132 kV Line

Eskom statistics indicate that the expected availability for a single 132 kV line in the Northern Cape Province is approximately 99.6%. This is because the Eskom network in the Northern Cape is a robust 400 kV ring network servicing few large customers, hence network outages rarely occur. Historical data from a nearby representative substation (called ‘Juno’) shows that since 1998 it has only experienced three outages with a combined outage time of just under 2 hours. Therefore it is expected that the performance and availability of a single 132 kV line connecting Kronos substation to the Astronomy Complex substation will be excellent. (Annexure D5 contains more discussions on the Eskom availability statistics.) The capital cost of constructing a 132 kV line from Kronos to the Astronomy Complex is €15 680 000. This includes the cost of a 48-pair OPGW fibre core incorporated into the earth wire, which creates an opportunity for a redundant optic fibre data link for the SKA.

Figure 3.5 indicates the voltage dip performance at an existing, representative substation (Hydra). From Figure 3.5 it is clear that the voltage dip performance is well within the allowable levels as specified in the national quality of supply standard NRS 048. It is anticipated that the voltage dip performance at the Astronomy Complex substation and the SKA Core will be similar because the Astronomy Complex substation is located in a similar geographic area and subject to similar loading conditions. (Annexure D5 contains more discussions on the voltage dip performance and the quality of supply standard NRS 048 can be viewed in Annexure D11.)

The option of constructing a second 132 kV line in order to improve the availability and the voltage dip performance was investigated. A second line improves the availability to approximately 99.8% and marginally improves the voltage dip performance. Should a second line be required, it is proposed that it be built on its own steel monopole structures so as to avoid a common mode of failure. If such a second circuit is to be considered, a standard earth wire will be used for lightning protection (i.e. no optical fibre).

Redundancy of the 132 kV line will cost an additional €15 million. Increasing the availability from 99.6% to 99.8% does not justify this additional expenditure.

3.3.4 Backup Power Scenarios

The requirements for the provision of backup power in the SSG-RfI are unclear, but it was deemed pragmatic to investigate the provision of backup power. Table 3.2 indicates various options that were investigated. In Table 3.2, Option 1 assumes that the requirement for power conditioning is a user specification on all electronic equipment. Options 2 to 5 provides for power conditioning and removes the requirement from the electronic equipment specifications.

The total load at the Astronomy Complex is 50 MVA. A critical load of 5 MVA was assumed, which is 10% of the full load. Option 1 in Table 3.2 shows costs for the provision of a rotary uninterruptible power supply (UPS) solution to provide backup power to the critical load of 5 MVA. This will be provided by four 1 250 kVA rotary UPS units. The line diagram in Annexure D9.3 indicates the reticulation of the rotary UPS units at the Astronomy Complex.

Options 2 and 3 in Table 3.2 are solutions to provide backup power to the full 50 MVA Astronomy Complex load. Note that the amount of backup time available is dependent on the amount of diesel stored on site.

Options 4 and 5 are different solutions to provide backup power to the 55 MVA SKA Core receiver load. The backup power for the SKA Core would be sited at the Astronomy Complex and transmitted to the core via the 33 kV overhead lines. As with Option 3, the amount of backup time indicated in Option 5 is dependent on the amount of diesel stored on site.

In the unlikely event of a catastrophic failure of one or more of the 33 kV lines, it may be necessary to provide emergency power to allow the dishes to safely stow in the birdbath position. To this extent it is proposed to site five 2 MVA backup generators on site at the core. One generator will be able to provide backup emergency power to the dishes along one arm. Emergency backup power will only be provided to the dishes because it is assumed that no vital equipment on the aperture arrays will require safe shutdown during emergency conditions. During emergency
Figure 3.5: Voltage dip scatter plot for a representative Northern Cape province 400 kV/132 kV substation for the period 2001 to 2010. (Depth % vs. Duration in milliseconds)
Table 3.2: Backup power options for the Astronomy Complex and the SKA Core. All costs in 2007 Euros.

<table>
<thead>
<tr>
<th>Option</th>
<th>Facility</th>
<th>Power Required</th>
<th>Backup Proposal</th>
<th>Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Astronomy Complex</td>
<td>50 MVA</td>
<td>5 MVA critical load backup (rotary UPS)</td>
<td>€4 913 004</td>
</tr>
<tr>
<td>2.</td>
<td>Astronomy Complex</td>
<td>50 MVA</td>
<td>5 MVA critical load backup (rotary UPS)</td>
<td>€4 913 004</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>45 MVA rotary UPS</td>
<td>€31 934 647</td>
</tr>
<tr>
<td>3.</td>
<td>Astronomy Complex</td>
<td>50 MVA</td>
<td>5 MVA critical load backup (rotary UPS)</td>
<td>€4 913 004</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>45 MVA static UPS with a backup time of 5 min</td>
<td>€10 213 515</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>45 MVA static UPS with a backup time of 15 min</td>
<td>€11 768 817</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>45 MVA static UPS with a backup time of 30 min</td>
<td>€17 118 945</td>
</tr>
<tr>
<td>4.</td>
<td>Astronomy Complex</td>
<td>55 MVA to the SKA Core</td>
<td>55 MVA rotary UPS</td>
<td>€42 920 739</td>
</tr>
<tr>
<td>5.</td>
<td>Astronomy Complex</td>
<td>55 MVA to the SKA Core</td>
<td>55 MVA static UPS with a backup time of 5 min</td>
<td>€14 939 481</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>55 MVA static UPS with a backup time of 15 min</td>
<td>€17 118 945</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>55 MVA static UPS with a backup time of 30 min</td>
<td>€21 063 508</td>
</tr>
<tr>
<td>6.</td>
<td>SKA Core</td>
<td>10 MVA to allow the dishes to safely stow</td>
<td>5 x 2 MVA generators</td>
<td>€2 699 626</td>
</tr>
</tbody>
</table>

conditions no scientific observations will be performed and consequently EMI generated by the generators will not be of concern. This implies that the generators do not have to be shielded.

The SSG-RfI did not identify any critical loads which require backup power. If provision for backup of 10% of the Astronomy Complex’s load is adequate, then Option 1 in Table 3.2 is appropriate and feasible. The availability of the 132 kV line is excellent, hence it is unnecessary to provide backup power for the full 50 MVA load at the Astronomy Complex. The 33 kV lines are all double circuit lines, i.e. there are redundant 33 kV lines providing power to the core. No catastrophic failure will result in the loss of all five double circuit 33 kV lines, hence it is not necessary to site five 2 MVA backup generators at the core. However, the additional capital expenditure to site these 2 MVA generators at the core is small in comparison to the rest of the expected capital cost, so it may be included if deemed essential. It is worth noting the expected capital cost of the various backup solutions shown in Table 3.2 and comparing it to the expected capital cost of other major components (as shown in Figure 3.4). It is cheaper to build a second, redundant 132 kV line to provide 105 MVA at the Astronomy Complex than to install UPS units to provide 105 MVA backup power.

3.4 Provision of Electrical Power to the Remote Stations

3.4.1 Remote Stations in South Africa

The thirteen remote stations within South Africa will be supplied from the existing national Eskom grid network. Power at these sites will be conditioned by means of in-line static UPS, which offer a standard battery autonomy backup time of between 5 minutes to 8 hours depending on the system load factor. Technical data sheets of the static UPS systems are in Annexure D13 for more information with regards to:

- the thirteen different Eskom proposed grid supply points,
- the distances from the identified stations to the grid power network,
- information with regards to the supply voltages (typically either 11 kV or 22 kV),
- reliability of the identified network specific feeder, and
3.4.2 Remote Stations outside South Africa

A site specific electrical infrastructure network study was conducted on all twelve sites in the African partner countries. Annexure D8 provides details of this study. From the study it was determined that four remote stations cannot be connected to local grid networks, either due to cost effectiveness or lack of services. The other eight remote stations will be connected to the local grid network of the particular country in a similar way that the remote stations in South Africa will be connected to the Eskom grid. Annexures D9.6 and D9.20 shows the reticulation designs.

A Request for Information was issued for the provision of off-grid power solutions for the four identified remote stations. Twenty responses were received and the designs were taken into consideration in the preparation of this proposal. The four remote stations will be supplied with the required 96 kW power load by using a hybrid system consisting of photovoltaic (PV) panels and batteries with a 250 kVA diesel generator as backup to provide the required 96 kW load per station. It is estimated that 99% of the operation time will be supplied from the battery system, which in turn is being charged by the local PV array. The estimated area needed for the array is in the region of 10,000 m$^2$. It is estimated that the generator will only generate power for 1% of the time. A two day battery autonomy is allowed for in the design. It is likely that the design and cost of these off-grid hybrid power units for the remote stations will be generic and independent of the location of the SKA.

The generator is equipped with a standard 350 litre self-storage fuel tank and will consume approximately 42 litres of diesel fuel per hour under a 75% load. It is estimated that a typical 250 kVA generator consuming diesel at a rate of 56 litres per hour will produce approximately 134 g/kWh CO$_2$.

Annexure D9.13 shows a schematic layout of the electrical reticulation of a remote site powered by this off-grid power solution. Annexures D8 and D15 provide more technical details.

Routine weekly site visits to the remote stations being powered by the off-grid systems will be conducted by personnel, trained by the SKA (but not necessarily employed by the SKA), from each of the nearest identified towns. The routine weekly site visits will require skilled technicians and will consist of some typical operation tasks, for example:

- verifying diesel levels
- verifying battery banks levels
- cleaning solar panels

These tasks will form part of the service level agreements in the operations and maintenance plans that will be entered into with the African partner countries. The Basic Infrastructure Report (in Annexure A) as well as Annexure D8 contain more details regarding these service level agreements.

3.5 RFI Mitigation

3.5.1 The Astronomy Complex 132 kV/33 kV Substation

The Astronomy Complex substation switch gear and protection equipment will be screened in order to minimise RFI. Due to the high summer temperatures in the Karoo region, it is not recommended to put the transformers inside the screened building. Instead it is recommended that the transformers be positioned on the eastern side of the building (away from the SKA Core) to offer additional shielding. The transformer areas will be shielded with an appropriate RFI mesh to allow for cooling and RFI mitigation. Annexure D7 contains all the details of the screening of the equipment and RFI mitigation designs.

3.5.2 132 kV Line

As mentioned previously, the 132 kV route was chosen such that it falls within an 11 km ‘EMI exclusion zone’. The last 20 km of the 132 kV line (before it terminates at the Astronomy Complex) will be suspended on 400 kV structures to mitigate the excitation noise levels, thereby mitigating unwanted EMI.
The two sources of radio interference on power lines at the 132 kV level and higher are corona and, very rarely, sparking. Corona is an inherent phenomenon on high voltage lines and is taken into account by the selection of the conductor diameter and phase geometry. The noise levels are highest in rainy conditions and lowest in dry conditions. Over a distance of 27 km, the combined effects of the free space attenuation and terrain attenuation by the hills and mountains along the path from the substation area to the core site will ensure that, even in wet conditions, the noise in the 70 MHz to 1 GHz band will not exceed the SKA limits. (This also applies to two 132 kV lines.)

Sparking is abnormal and is regarded as a ‘fault’. The frequency spectrum, in contrast to that of corona, can reach the GHz range and may saturate the SKA receivers. Such noise can be avoided altogether by good design, construction and maintenance. It is usually quite easily detected and remedied. Eskom has undertaken to provide a specialised radio noise investigation service as part of its routine maintenance. Tests done on the phenomenon of water droplet corona and micro sparking from the water droplet to the energised conductor have shown that the low levels of noise in the frequency band 70 MHz to 1 GHz are unlikely to exceed the SKA limits given the 20 dB of terrain shielding anticipated. Tests all indicated that water droplets on polymeric insulators energised at 145 kV do not generate measurable corona, and hence are not deemed to be an interference source.

A new self supporting monopole design will be utilised for the twin Kingbird conductor bundle. The monopole structure will be more RFI quiet than the lattice type structure. It is recommended that the new tower design caters for larger phase spacing. This larger phase spacing will help to reduce potential flashovers and faults, as well as reduce RFI risk due to lower field strengths. Corona rings will be fitted along the line to reduce potential higher electromagnetic fields and reduce the possibility of corona in severe weather conditions. Annexure D7 contains more in-depth discussions regarding the tests that were conducted and the design recommendations.

3.5.3 Medium Voltage, Low Voltage and Reticulation

The following has been implemented in the design of the medium- and low voltage portion of the SKA electrical network in order to mitigate EMI:

- overhead transmission lines at 33 kV (or lower) will be at a minimum of 2 km away from any receptor,
- 88 kV monopole galvanized steel structures will be used on all 33 kV (or lower) overhead lines to minimise the chance of sparking (this is the same design as implemented for MeerKAT),
- no miniature substations and distribution kiosks will contain any electronic (monitoring) equipment.

3.6 Existing ‘SKA Ready’ Infrastructure

3.6.1 Kronos Substation

Kronos substation is currently a 400 kV series compensation capacitor station. Eskom has identified the need to strengthen Kronos to support the local 132 kV network of Copperton and Prieska and other surrounding areas. The Eskom Kronos strengthening project was announced in March 2011 and includes:

- 1 x 250 MVA 400 kV/132 kV transformer
- 400 kV and 132 kV transformer bays
- 2 x 132 kV feeder bays to Cuprum substation

Eskom has scheduled the completion of this strengthening project by 2014. Should South Africa be awarded the SKA by mid 2012, requests for the following would be submitted timeously in order to meet SKA and Eskom timelines:

- additional space at Kronos for one or two SKA 132 kV feeder bays
- additional space for a second 250 MVA 400 kV/132 kV transformer

This strengthening project results in a cost saving of approximately €13 million to the SKA power solution. The Kronos–Cuprum 132 kV network is planning on picking up potential wind energy projects, solar PV projects and CSP trough generation projects, making the wheeling of renewable energy a realistic option.
3.6.2 Existing KAT-7 and MeerKAT Infrastructure

Figure 3.6 shows the current KAT-7 electrical infrastructure and the future upgrades to accommodate MeerKAT’s load. The modifications are scheduled to commence in September 2011 and will be complete by the end of 2012. Annexure D14 contains the modification and upgrade details and includes an overview of the project plan. Once the upgrades to the existing MeerKAT line are complete, the line will have 2.5 MVA spare capacity. This can be accessed at the Astronomy Complex for construction activities as well as for on site construction at the SKA Core. It will also be able to provide power for the initial operation of SKA1.

All the infrastructure in Figure 3.6 will be retained during the operation of SKA2. Note in Figure 3.6 that provision for SKA1 has been made.
Figure 3.6: KAT-7, MeerKAT and SKA₁ power infrastructure system diagram
3.7 Cost Summary

3.7.1 Capital Cost Summary

Table 3.3 shows a summary of the capital costs. Annexure D2 provides the details.

Table 3.3: Summary of capital costs. All costs are quoted in 2007 Euros.

<table>
<thead>
<tr>
<th>#</th>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Kronos 400 kV/132 kV transformer bay</td>
<td>€748 000</td>
</tr>
<tr>
<td>2.</td>
<td>Kronos-Astronomy 132 kV overhead line with OPGW</td>
<td>€15 680 000</td>
</tr>
<tr>
<td>3.</td>
<td>Astronomy substation with three 80 MVA transformers</td>
<td>€9 597 000</td>
</tr>
<tr>
<td>4.</td>
<td>Astronomy Complex switching station</td>
<td>€3 476 000</td>
</tr>
<tr>
<td>5.</td>
<td>SKA Core reticulation (out to 35 km)</td>
<td>€68 742 000</td>
</tr>
<tr>
<td>6.</td>
<td>Reticulation of spiral arms (out to 180 km)</td>
<td>€4 719 000</td>
</tr>
<tr>
<td>7.</td>
<td>Remote sites in South Africa: reticulation and Eskom grid connections (13 stations)</td>
<td>€3 671 000</td>
</tr>
<tr>
<td>8.</td>
<td>Remote sites outside South Africa: reticulation, grid connections and four off-grid solutions</td>
<td>€20 422 000</td>
</tr>
<tr>
<td>Sub-total</td>
<td></td>
<td>€127 055 000</td>
</tr>
<tr>
<td>9.</td>
<td>Rotary UPS backup of 5 MVA for critical loads</td>
<td>€4 913 000</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>€131 968 000</td>
</tr>
</tbody>
</table>

For comparative purposes, it is worth noting that powering all 12 remote stations outside South Africa with off-grid power systems amounts to €27 826 000.

3.7.2 Electricity Tariffs and their Effect on Operational Costs

The SKA Core area (out to 180 km) qualifies for Eskom’s Megaflex tariff. The remote stations in South Africa (which will be connected to local Eskom distribution infrastructure) will be billed according to Eskom’s Rural Landrate tariff, which is approximately 25% higher than Megaflex.

As requested by the SSG-RfI, all costs are 2011 costs backdated to 2007. Eskom’s 2011 tariffs were used to model the operational costs of the SKA Core (out to 180 km) and the remote stations connected to grid infrastructure. South Africa has embarked on a new-build programme (as per the Integrated Resource Plan discussed in Section 3.2.3) and it is expected that electricity tariffs will increase in order to recover some of the costs. Scenario modeling done in the IRP shows electricity tariffs increasing until 2014. Thereafter electricity tariffs are anticipated to stabilise. The worst-case scenario shown in Figure 3.7 stabilises in 2021/22 at a level of €0.108/kWh (R1.12/kWh). Annexure D4 has more information regarding this scenario modeling.

The projected increase in operational costs until 2014 was modeled and the results are summarized in Table 3.4. The detailed calculations of the tariff projections are in Annexure D2.

The memo Power Considerations for the Square Kilometre Array (SKA) Radio Telescope [Hall] (Annexure D16) mentions a target electricity tariff of €0.12/kWh for the lifetime of the SKA. The levelised energy cost was calculated using the 2011 tariffs and the 2014 projected tariffs. Table 3.5 shows the results of these calculations and shows that the lifetime costs of the SKA hosted in South Africa (which includes the capital cost, the lifetime

Footnote:
1 Levelised energy cost is defined as the price at which electricity must be generated from a specific source to break even. It is an economic assessment of the cost of the energy-generating system including all the costs over its lifetime, including the initial investment and lifetime operations and maintenance costs.
Table 3.4: Summary of Lifetime Operating Costs. Costs quoted in 2007 Euros.

<table>
<thead>
<tr>
<th>#</th>
<th>Item</th>
<th>Power</th>
<th>Energy Use</th>
<th>2011 Lifetime Operating Cost</th>
<th>2014 Projected Lifetime Operating Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>SKA1</td>
<td>35 MW</td>
<td>306.6 GWh p.a.</td>
<td>€107 076 000</td>
<td>€195 285 000</td>
</tr>
<tr>
<td>2.</td>
<td>SKA2</td>
<td>107.4 MW</td>
<td>940.824 GWh p.a.</td>
<td>€1 619 364 000</td>
<td>€2 985 277 000</td>
</tr>
<tr>
<td>Total (for full SKA)</td>
<td>107.4 MW</td>
<td>30 064 GWh (over lifetime)</td>
<td>€1 726 440 000</td>
<td>€3 180 562 000</td>
<td></td>
</tr>
</tbody>
</table>
operating cost and the lifetime maintenance cost) is below Hall’s hypothetical tariff of €0.12/kWh. Annexure D2 contains the detailed calculations.

Table 3.5: Levelised Energy Costs Comparisons. Costs are quoted in 2007 Euros.

<table>
<thead>
<tr>
<th>Item</th>
<th>Capacity</th>
<th>2011 Costs</th>
<th>2014 Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKA Capital Costs</td>
<td>107.4 MW</td>
<td>€131 968 000</td>
<td>€131 968 000</td>
</tr>
<tr>
<td>SKA (Lifetime) Operating Costs</td>
<td>107.4 MW</td>
<td>€1 726 440 000</td>
<td>€3 180 562 000</td>
</tr>
<tr>
<td>SKA (Lifetime) Maintenance Costs</td>
<td>107.4 MW</td>
<td>€66 288 000</td>
<td>€66 288 000</td>
</tr>
<tr>
<td>Levelised Energy Cost</td>
<td>107.4 MW</td>
<td>€0.064/kWh</td>
<td>€0.112/kWh</td>
</tr>
<tr>
<td>Levelised Energy Cost (out to 180 km only)</td>
<td>105 MW</td>
<td>€0.063/kWh</td>
<td>€0.111/kWh</td>
</tr>
</tbody>
</table>

3.8 Amortisation of Capital Costs and the Resultant Operational Costs

The possibility of amortising the capital cost of the power infrastructure over a period of time was investigated. In the past Eskom assisted its customers with funding the capital costs of power infrastructure. This option was investigated with Eskom as they have indicated that they are open to amortisation scenarios with the SKA.

In the studies conducted, Eskom indicated that the capital costs of all medium- and high voltage infrastructure can be amortised. Low voltage infrastructure (any infrastructure below 33 kV) would be for the customer’s account. The total capital cost of all medium- and high voltage infrastructure amounts to approximately €98 million. Eskom amortisation models show that an upfront investment of approximately €5.5 million would be required. The rest of the capital can then be amortised in any one of the options shown in Table 3.6.

Table 3.6: Eskom Amortisation Options.

<table>
<thead>
<tr>
<th>Loan Period</th>
<th>5 Years</th>
<th>10 Years</th>
<th>15 Years</th>
<th>20 Years</th>
<th>25 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable Monthly Interest Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monthly Installment</td>
<td>~€2.2 million</td>
<td>~€1.4 million</td>
<td>~€1.13 million</td>
<td>~€1 million</td>
<td>~€960 000</td>
</tr>
<tr>
<td>Total Charges Over the Term</td>
<td>~€132 million</td>
<td>~€168 million</td>
<td>~€203.4 million</td>
<td>~€240 million</td>
<td>~€288 million</td>
</tr>
<tr>
<td>Total Cost Paid at End of Term</td>
<td>~€138 million</td>
<td>~€174 million</td>
<td>~€209 million</td>
<td>~€246 million</td>
<td>~€294 million</td>
</tr>
</tbody>
</table>

It is worth noting that penalties are standard in Eskom amortisation agreements, and that the customer will be liable for a penalty of approximately €102 million should it terminate the agreement prematurely. The advantages of amortising the capital are that upfront capital costs for infrastructure are greatly reduced and that maintenance of all the infrastructure up to the miniature substations would be the responsibility of Eskom. This maintenance cost would be included in the monthly electricity tariff. Eskom is well aware of the sensitive RFI environment and would ensure that their maintenance plan is in line with the SKA requirements.

3.9 Schedule of Power Provision Roll-Out

Refer to Figure 3.6 on page 48. Currently a new and purpose-built 33 kV line runs past the proposed Astronomy Complex site to provide power to KAT-7 and MeerKAT. This 33 kV line is supplied from the Carnarvon 66 kV/33 kV substation (called ‘Karoo’ substation). Supply for the interim and construction phase of SKA1 can be made available from this existing supply.
Figure 3.8 shows two Gantt charts. The top Gantt chart shows the SKA project timeline. The bottom Gantt chart indicates the schedule for construction of the Astronomy Complex substation and the 132 kV line. Figure 3.8 shows that the timelines for the provision of power is tight, but that it fits within the SKA timelines. The 132 kV line construction and Astronomy Complex substation construction will be complete by 2016, which coincides well with the commencement of SKA₁ construction. Annexure D5 contains the details regarding the construction timelines and includes information related to conducting environmental impact assessments and obtaining the required construction permits.

Figure 3.8: SKA project timeline in comparison to the construction timeline of the 132 kV line and the Astronomy Complex substation.
Chapter 4

Data Transport

4.1 Overview of Proposed Data Transport Scenario

The data provision requirements posed in the SSG-RfI have been thoroughly interrogated to develop a data transport solution for the SKA that is reliable, practical and affordable.

The data transport design has been developed in parallel with the power and infrastructure components and the best utilisation of existing MeerKAT and public infrastructure to create an optimised SKA infrastructure solution. A major cost reduction has been realised by the proposal to co-locate the data processor and super-computer near the SKA Core. Two options were thoroughly investigated: the siting of the super-computer at the Astronomy Complex near the SKA Core site, or locating the super-computer in a major centre (Cape Town). It was concluded that the best option is to co-locate the data processor and super-computer at the Astronomy Complex. The Astronomy Complex is approximately 30 km from the core site, with topographical shielding providing sufficient RFI protection to comply with the RFI requirements of the telescope. The national electricity grid network (owned and operated by the national electricity utility Eskom) will be extended by means of a single 132 kV line up to the Astronomy Complex.

Various factors led to the decision to co-locate the data processor and super-computer on the same site at the Astronomy Complex. Constructing a 400 Tbit/s data link over distances larger than 80 km is expensive. Long data links will require high levels of redundancy, which increases costs dramatically. In this early design phase of the SKA, the lines between the data processor and super-computer are ill-defined. In all likelihood there will be a significant overlap between their functions. (This has been the opinion of international peer review groups who reviewed the MeerKAT data processor and super-computer designs, and it is anticipated that the same conclusions will be drawn for the SKA.) By co-locating the data processor and the super-computer at the Astronomy Complex, data network costs are minimised and the redundancy requirement is relaxed without compromising performance and availability. The smaller data stream exiting the super-computer at the Astronomy Complex allows for the establishment of a fully redundant data connection to the SKA Head Office in Cape Town. It is also more expensive to site the super-computer in Cape Town, mainly because large portions of the electrical infrastructure must be duplicated. By siting the super-computer at the Astronomy Complex, only one substation has to be constructed, as opposed to two (one at the Astronomy Complex and one in Cape Town). The data transport solution is therefore less complicated and less expensive, the cost of establishing power infrastructure is reduced, and skilled resources can be retained at a single site rather than being split across two geographically separate locations, so reducing the staff numbers required. The new power lines incorporate an OPGW fibre optic cable, providing a geographically diverse data transport route.

SKA South Africa has worked with a number of operators in the provision of alternative technology solutions and cost proposals to develop the optimal solution for the SKA. These individual proposals are included in Annexures G for reference, and the cost proposals from their various offers provide input to the Project Cost spreadsheets included in Annexure G15, where economic comparisons between the various options is made. IRU (Indefeasible Right of Use) solutions proposed by the operators are economically attractive, and provide a risk-free solution. The SKA will not be subject to annual cost inflation pressures, and the longer IRU periods provide stability in the relationships between the SKA and the Operators. This should lead to a lasting relationship, in turn benefiting the overall operation and performance of the SKA facility.
The Southern African and African telecommunications regulatory environment is vibrant, introducing a number of new operators eager for business, bringing innovative solutions to the market and doing business differently. This has afforded us the opportunity to work with a number of operators specialising in the various fields to put together a proposal that meets all SKA requirements in the most technically acceptable and economical manner. It is no longer a challenge to do business with diverse operators across different countries - the submarine cable operators do it routinely and successfully. The growth of submarine cable connectivity to African has initiated real competition and network growth, and prices will continue to drop because of competition and technological change. This is true for the SKA African partner countries, and can be seen in the competitive tariff structures introduced to the South African market. The incumbent operators are feeling the pressure from the new competition and are becoming more innovative in their product and pricing structures.

The optimal data transport solution selected for the SKA, is as follows. The Core area out to 180 km is proposed as a private network, to be owned and operated by the SKA. Connectivity to the 12 remote stations within South Africa will be provided by Broadband Infraico, a State Owned Enterprise. Broadband Infraico propose a managed bandwidth service, costed for both 20 year and 50 year IRUs (Indefeasible Right of Use), inclusive of maintenance and operations. SEACOM has been selected to provide the connectivity to the remote stations outside of Africa, being sites in Namibia, Botswana, Zambia, Mozambique and Madagascar. SEACOM have offered a single point-of-contact for the provision of these services, and have offered a twenty year IRU exclusive of operations and maintenance. Connectivity from the Astronomy Complex to Cape Town will be provided as a managed service by Broadband Infraico, also under a 50 Year IRU proposal inclusive of operations and maintenance. They have costed both options – the super-computer located at the Astronomy Complex, and the super-computer in Cape Town (requiring a 400 Tbit/s link). EASSY/WIOCC, the submarine cable operator, has been selected for the provision of the international connectivity from Cape Town to data centres in other parts of the world. EASSY have offered a 20 year IRU exclusive of operations and maintenance.

Table 4.1 provides a summary of the capital, operation and maintenance costs of the full data provision solution. The operations cost is in terms of a 20 year or 50 year IRU managed bandwidth solution, and is an up-front payment.

<table>
<thead>
<tr>
<th></th>
<th>Super Computer on SKA Core Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Fibre Implementation</td>
<td>Capital Cost (20/50 Year IRU)</td>
</tr>
<tr>
<td>Data Processor to Super Computer</td>
<td>€ 17 768 000</td>
</tr>
<tr>
<td>Super Computer to Main Office</td>
<td>€ 0</td>
</tr>
<tr>
<td>Remote Sites Within SA</td>
<td>€ 0</td>
</tr>
<tr>
<td>Remote Sites external to SA</td>
<td>€ 113 406 000</td>
</tr>
<tr>
<td>International Connectivity</td>
<td>€ 14 360 000</td>
</tr>
<tr>
<td>Total</td>
<td>€ 145 534 000</td>
</tr>
</tbody>
</table>

4.2 Local and International Data Network Industry

4.2.1 De-Regulation and Competition

The South African Telecommunications environment was de-regulated in 2005 with the promulgation of the Electronic Communications Act (Annexure G1.1.1), replacing the Telecommunications Act. The ECA was promulgated to promote convergence in the broadcasting, broadcasting signal distribution and telecommunications sectors, and to provide the legal framework for convergence of the sectors. The Act includes the licensing of ECS (Electronic Communications Services) and ECNS (Electronic Communications Network Services) operators, amongst others, to operate telecommunication services within South Africa.
There are currently about 350 ECS and ECNS licence holders that have been licensed under the new Act, many of these as a result of the conversion from the previous VANS (Value Added Network Services) licences to the new ECS and ECNS licence regime. Commercial competition is now the order of the day, and this is reducing the cost of telecommunications service provision in the country, both on a national and international basis. New competitors are entering the long distance fibre network market, offering a growing choice of operators on independent and diverse routes.

Broadband InfraCo is a state-owned enterprise (Annexure G20 for a company profile, and Annexure G21 for a copy of the relevant ECNS licence) that operates a national long distance fibre optic network, and is a Tier 1 shareholder in the WACS (West African Cable System) submarine system. This system connects South Africa to the United Kingdom and Europe, and a number of West African countries. Broadband InfraCo’s brief from the South African Government is to support Projects of National Importance - the SKA is designated as one of these. Fixed-line operator Neotel, and mobile operators Vodacom and MTN, are building national long distance fibre networks, in competition with the incumbent national telecommunications service provider, Telkom SA. A new market entry is FibreCo, which is implementing a national dark-fibre network, while sister company, Dark Fibre Africa, focuses on the provision of dark-fibre network services in the Metropolitan areas.

The Meraka Institute, a subsidiary of the CSIR (Council for Scientific and Industrial Research) and telecommunication implementation agency for the South African Department of Science and Technology, is strengthening and expanding the South African NReN (National Research Network) coverage, and has provided the initial 10 Gbit/s connectivity from the MeerKAT site in the Northern Cape to Cape Town, for onward connectivity to the international science community when required. The institute has been awarded a licence exemption for implementation of the SANReN network to support and interconnect national research institutions, projects, and tertiary institutions. The exemption allows for the self provisioning of telecommunications networks in support of research and education activities within South Africa, on a cost recovery basis. Spare network capacity may only be sold or leased with the express permission of the Independent Communication Authority of South Africa (ICASA). The SKA would be in a position to apply for similar licence exemption for the roll-out of the data transport network for interconnection of the antenna arrays to the data processor, and the data processor to the super-computer. Already, in terms of the Astronomy Geographic Advantage (AGA) Act, the Minister of Science and Technology may declare any existing or proposed scientific endeavour to be an astronomy device, inclusive of interconnected devices (Annexure G2). The SKA network could then be licensed as a private network, allowing the SKA to make the choice between self-provisioning or leasing services from competing operators. This augers well for choice and the future cost of implementation of the SKA data transport network. A copy of the Meraka Licence Exemption is included as Annexure G17, as well as the Scientific Research Act (Annexure G16).

Similar de-regulation of the telecommunications industry is taking place across Africa, with the subsequent increase in network offerings in the SKA African partner countries. The SKA African partner countries included in the evaluation configuration are Namibia, Botswana, Zambia, Mozambique and Madagascar. Major submarine cable operators, such as SEACOM and EASSY, are expanding their terrestrial footprint into these African countries in order to provide international connectivity to the subscriber base. Both organisations provide one-stop managed services on a point-to-point basis, and have offered support to the SKA Project.

During the past two years, international connectivity to Africa has increased significantly. This period has seen the commercial completion of the EASSY, SEACOM and WACS submarine cable systems, totalling approximately 11 Tbit/s of international connectivity. Planning for the ACE cable system to Europe (5.12 Tbit/s) is at an advanced stage, whilst the SAex cable system to Brazil (12.8 Tbit/s) will open up routes to gateways in the USA. These connections to Africa and the Indian Ocean islands have resulted in significant reduction in service costs. On timescales that are commensurate with the SKA implementation, it is expected that bandwidth will become a commodity resource and will significantly reduce the cost of connectivity to Africa. This will also benefit the African SKA additional sites of Mauritius, Ghana and Kenya. Figure 4.1 illustrates the expansion of submarine cables around Africa.

Large-scale investments in submarine cable systems around Africa are accelerating the establishment of terrestrial fibre connectivity, and hence is increasing the availability of low cost international bandwidth. Figure 4.2 indicates the level of fibre connectivity current on the African continent. This fibre network will be further strengthened by the establishment of new electricity transmission routes, which carry fibre cable, along the east and west power corridors through Southern Africa. These new routes are shown in Figure 4.3, and will expand existing fibre network capacities, strengthen the African fibre network backbone, and provide additional competition which will benefit both the SKA and NReN developments.
Figure 4.1: The African submarine cable network.
Figure 4.2: The African terrestrial optical fibre network.

Figure 4.3: The interconnected Power Network Development.
The European Union has agreed to fund the establishment of Africa Connect, the implementation of an African interconnected National Research Network (NReN). This has been made possible by the growth of a competitive telecommunications market, the development of high capacity data networks across (and surrounding) Africa, proximity to the NReN networks of Europe, and established NReN connectivity to the rest of the world. The South African Research Network (SANReN) recently provisioned a 10 Gbit/s fibre link to connect HartRAO (Hartebeesthoek Radio Astronomy Observatory) to the SANReN backbone link. This link currently operates at 1 Gbit/s, transporting real time e-VLBI data to the Jive Correlator in the Netherlands via the SANReN/Geant networks. This link is demonstrating excellent performance, equal to that from the other contributing countries in the international e-VLBI network. Much of this NReN development aligns with the SKA requirements for a seamlessly interconnected data solution, and will benefit the SKA organisation in making SKA science available to the world.

4.2.2 Existing Industry
The existing fibre optic and data connectivity industry is mature, and is growing due to significant local and international investment. The South African SKA Project Office (SASPO) has liaised with various representatives of this industry to provide data connectivity solutions for both MeerKAT and the SKA in Africa. Local and international competence and expertise is summarised below:

1. Short Distance / Private Fibre Networks
Various companies operate within South Africa, specialising in fibre optic infrastructure. SIA Solutions (company profile in Annexure G13) is a fibre optic company, part of the Tellumat group of companies, that specialises in high-tech fibre installations. Their core business revolves around the installation and maintenance of airport aviation fibre-based systems. Due to their expertise, SIA Solution were awarded the contract for the implementation of the KAT-7 fibre network, a complex requirement due to the analogue signal being transported across the fibre network. SIA Solutions performed well on this contract.

Optic-1 was contracted by SASPO to provide the fibre optic link from the SKA Core site (i.e. MeerKAT) to the town of Carnarvon, a distance of approximately 90 km. Similar companies, Optipower and Letacla, install long distance fibre networks on a national basis, in South Africa and internationally. Muvoni Weltex has been implementing Metro and Long Distance fibre networks for the national operators. They offer a turnkey solution employing a wide range of installation technologies, from road-surface cutting in the Metro areas to open-cut trenching and ploughing for L/D networks. They have a range of supplementary technologies available, enabling them to tackle all terrain types. Please see Annexure G32 for details of their turnkey offering. These Contractors are re-inforced by a number of horizontal directional cable drilling companies for establishing routes under roads or other road infrastructures and river crossings.

2. National Long Haul Fibre Networks
SASPO has established an excellent working relationship with Broadband Infraco, one of the national long distance operators. Other national operators are Telkom and Neotel, with Vodacom and MTN also establishing long distance networks. Broadband Infraco is a state-owned Enterprise, while Neotel is owned by Tata Holdings, Vodacom is part of Vodaphone, and MTN is the largest network operator in Africa. Telkom is the original South African Operator, partly owned by the South African Government, with many years of operational experience. SANReN (Meraka Institute) is a highly skilled organisation with the responsibility for the development and operation of the SANReN networks (Annexures G16, G17 and G18). The SANReN network currently operates a 10 Gbit/s national backbone, but this is due to be upgraded as more institutions are connected to the network.

3. International Fibre Networks
It is proposed that services external to South Africa will be provisioned and managed by SEACOM within the African SKA partner countries, utilising local operators. Many of these operators are the original country telecommunications operators, with many years of operational experience. EASSY can also provide a similar one-stop service. SEACOM and EASSY are both extending networks into the African partner countries, either on a stand-alone basis or in partnership with Government or private consortia. Orange (France Telecom) is establishing services in the French-speaking African countries, and Botswana, Madagascar and
Kenya. The power utilities are developing commercial offerings for access to dark fibre routes. The Analysys Mason report, attached as Annexure G3, provides a summary of the Operators in the partner countries. SEACOM have demonstrated their ability to operate world-class links within the African countries, including South Africa, by demonstrating the first 100 Gbit/s wavelength from the SEACOM Mtunzini cable landing station to the Teraco Data Centre outside Johannesburg (see Annexure G26), a distance of approximately 960 km. For this link, SEACOM leased long-distance dark fibres from Dark Fibre Africa, sister company to FibreCo. This demonstration was arranged to prove their ability to carry SKA services in the most economical manner.

A number of cable operators provide service from South Africa to the world, as can be seen from Figure 4.1. WACS (West African Cable System) and EASSY (East African Submarine Cable System) are owned and operated by consortiums. SEACOM is a privately-funded organisation. Other cable systems include SAFE (South Africa Far East) and SAT-3. In design and planning stages are the ACE and SAex cable systems.

4.3 Connectivity Plan: 0 - 180 km

4.3.1 Existing Infrastructure

The SKA Core site is co-located with MeerKAT and currently hosts the KAT-7 array, a seven dish prototype of the 64 dish MeerKAT array. The existing reticulated network comprises a pipe and chamber system, which is sized to accommodate the fibre optic cables from the KAT-7 and MeerKAT arrays to the data processor at the Losberg Site Complex, a distance of approximately 5 km. Further information on the existing infrastructure at the Losberg Site Complex is located in the report on Basic Infrastructure Components in Annexure A.

4.3.2 Planned SKA Design

Due to the number of SKA receptors, and the location of the Astronomy Complex approximately 30 km from the SKA Core site, it is envisaged that a green-field installation of the SKA Core fibre reticulation will be required. It is possible that the existing pipe and chamber system can be utilised in the network, but this will be determined during the detailed design phase. It is recommended, however, that the topology of the reticulated power network is adopted to ensure that common conduits are used. This will result in significant cost savings due to reduced trenching requirements.

The SKA configuration within 180 km of the SKA Core is illustrated in Figure 4.4. The optic fibre infrastructure providing the data connectivity requirements within this area will be a private optic fibre network (‘owner-operator’), to be built and maintained by the SKA. The data processor will be located at the Astronomy Complex approximately 30 km from the centre of the three SKA Cores (as per the SKA Model provided in Annex 1 of the SSG-RfI), behind a range of hills that provide additional topographical shielding of the SKA receptors from potential electromagnetic interference. This complex will host the data processor, super-computer, offices, workshops, accommodation and power facilities (132 kV electricity supply substation and switch area). Further detailed information on the Astronomy Complex is located in the report on Basic Infrastructure Components, located in Annexure A.

The SKA Model provided in Annex 1 of the SSG-RfI has been used as the basis for the costing model. Although there is no requirement for active components to be costed on this section of the network, we have worked with Nokia Siemens Networks (NSN) to design and cost an equipment solution on the five spiral arms (20 km to 180 km). This has been included for information purposes.

The fibre optic network out to 180 km from the SKA Core comprises a trench network solution. Although a requirement of eight fibres per core has been derived, South African cable suppliers generally utilise twelve fibre cores as a standard for the particular cable type used. Pricing for both eight and twelve fibres per tube has been provided in Annexure G14.

The fibre network will be implemented utilising heavy duty duct cabling, with G.652D fibre cores, drawn and/or blown into 40 mm silicone-coated Optex direct burial ducts. Although at this early stage there is no alignment between the independent power reticulation design and independent fibre network designs (optimisation tool developed by G. Grigorescu), this will be remedied at the time of implementation and trenches will be shared. For the purpose of this costing exercise, the full length of the fibre cable network as stated in Table 3 of Annex 1 to the SSG-RfI has been taken as the trench requirement, and the full trenching requirement costs included. It
is anticipated that the fibre network will share the cable trench system with the electrical reticulation network, and that this will be a shared cost. The power reticulation network designed for the African SKA configuration will extend to 30 km from the centre of the SKA Core, so a shared duct system is appropriate to this point (seen the Power Provision report in Annexure A for further details). Beyond this point, the power reticulation could be provided on overhead lines, but the fibre cable network will be buried throughout to accommodate the stability requirements of the centrally-fed timing/synchronisation services. The opportunity to implement lower-cost direct burial of the subduct system has been costed for the outer 150 km on each of the five spiral arms. Annexure G30 is a proposal from Muvoni Weltex for direct bury and/or ploughing solutions. Annexure G31 provides information on the Muvoni Weltex long haul duct cable laying solutions.

Nexan Nodes have been proposed for the fibre splice and/or through connection nodes (Annexure G28). These are metallic sealed enclosures, mounted atop a concrete plinth. Consideration has been given to the dusty conditions typical of the arid nature of the site, and the complexity of accessing these nodes for operational purposes. The establishment of the fibre nodes in purpose-built containers providing sufficient space for a technician plus test equipment was considered, however this proved too costly. The alternative proposal developed is to provide a self-standing sealed ‘gazebo-type’ tent that can be positioned over a standard enclosure and attached to a door opening of the technician’s vehicle. The required test equipment and/or splicing equipment is positioned inside the vehicle, as and when required. Positive air pressure could be applied within the gazebo to prevent the influx of dust during operations, prior to the sealed enclosure being opened. E2000 connectors, although the most expensive, have been specified due to their inherent dust-proofing capability, with in-built dust covers on both the connector and the midcoupler sections. FC/APC or SC/APC connectors have also been costed as an alternative. SIA Solutions, a specialist fibre network company (see Annexure G13 for a company profile), previously selected to do work at the KAT-7/MeerKAT site and therefore with insight into the site conditions, was approached for a pricing proposal. Their proposal is attached as Annexure G14, and summarised in Section 4.9.

Further thought was given to the implementation of metallic enclosures in a generally hot environment, and the effect on the stability of the timing and synchronisation services. This concern was discounted as both the go and return legs of the timing and synchronisation fibre network will follow the same route and be exposed to similar heat conditions, which will result in equal fibre effects on both the go and the return paths.
4.4 Connectivity Plan: South African SKA Remote Stations

The African SKA configuration includes 13 remote stations within South Africa, and 12 in African SKA partner countries. The connectivity plan to remote stations outside South Africa is discussed in Section 4.5.

4.4.1 Existing Infrastructure

A fibre optic link from the SKA Core site to Cape Town has been established for MeerKAT, currently operating a DWDM system idling at 10 Gbit/s. This infrastructure is ‘SKA Phase 1 ready’, capable of expansion to 1.6 Tbit/s at 10 Gbit/s wavelengths, or 3.2 Tbit/s at 40 Gbit/s wavelengths. The link from the Core site to Carnarvon, currently owned by the South African SKA Project, contains 48 G.652 fibre cores.

The capital cost of establishing this network is € and is considered as a discount to the SKA. See Annexure G34 for details of the MeerKAT network implementation. The existing MeerKAT network has been considered in the data connectivity plan and will be used to carry data from SKA remote stations, where appropriate.

4.4.2 Planned SKA Design

Data capacity requirements of 216 Gbit/s between SKA remote stations and the data processor are provided in the SKA Model in Annex 1 of the SSG-RfI. For the purposes of this submission, data capacity has been based on a unidirectional requirement of 220 Gbit/s (SKA remote station to data processor), and a bi-directional requirement of 10 Gbit/s for monitor and control, and timing and synchronisation.

Monitoring and Control Network

A 10 Gbit/s bidirectional link has been provisioned to each remote station for monitoring and control (M&C) purposes. It is assumed that M&C terminals are equipped with ethernet ports, allowing direct connection to the transmission equipment, hence no provision for any network switching equipment has been made. Required back-up of the M&C links can be decided when the actual design requirement is known and the site location is finalised. A simple solution for this back-up requirement is the implementation of stand-alone VSAT terminals, which are low-cost and are available with a number of service options. An excerpt of the Telkom tariffs for the Spacestream (VSAT) product is attached for information as Annexure G35; other operators have similar product offerings.

Timing and Synchronisation Service

The provision of a fibre solution for the timing and synchronisation service has been investigated. However, the requirement for an additional fibre pair from the data processor to each SKA remote station over distances of up to 3,000 km, as well as the provision and maintenance of stable optical amplifiers for each path every 80 km along the routes, results in this not being a preferred solution. Hydrogen masers have a high reliability and can be managed by the M&C systems at the SKA remote stations. They incorporate self-diagnostic features and have an expected lifetime of over twenty years.

Data

A number of options for the provision of data capacity have been investigated:

- Dark fibre solution;
- Leased dark fibre and associated repeater infrastructure, with full maintenance offering;
- Fixed Wavelength Service / Managed Bandwidth Solution

Proposals have been sought from two different service providers: Broadband Infraco, and FibreCo. Nokia Siemens Networks have provided equipment solutions with associated costs to match both of these networks. The results of the combination of the dark fibre network pricing and the associated equipment offering, have provided the key inputs into the development of the above solutions. The costs of these proposals are included in Annexure 15 - Data Transport tab.
1. Broadband Infraco

Broadband Infraco have provided the costs for a dark fibre solution, inclusive of a full maintenance offering, a fixed wavelength service solution and a managed bandwidth solution. The proposal includes the necessary capacities to extend the services from the hand-over points on the international borders between South Africa and the neighbouring states (Namibia, Botswana, and Mozambique), and Zambia, to the data processor. Zambia traffic will be routed via Botswana. A similar requirement has been included to extend the capacities from the SKA remote stations located in Madagascar from the cable landing station in Mtunzini to the data processor. Routing for the Broadband Infraco solution is illustrated in Figure 4.5.

![Figure 4.5: SKA remote stations overlaid on the Broadband Infraco fibre backbone network.](image)

The detailed Broadband Infraco proposal is included as Annexure G19, which includes both the terrestrial and international service offerings. Cisco offered a proposal for alien wavelengths to be considered on top of a long distance operator’s network as a Wavelength service, but this combination proved too costly. The Cisco equipment generally provides higher intelligence than is required to meet the SKA requirement. See Annexure G27 for the Cisco proposal, and Annexure G15 for the project costs.

2. FibreCo

FibreCo, a new entrant in the long distance dark and/or managed fibre optic network market, has provided the cost of a leased dark fibre solution with a full maintenance offering. Three options have been provided, which are dependent on the extent of their network build at the time the SKA services are required. FibreCo is offering free access to two fibre pairs on all existing fibre backbone networks as built at the time, with costing proposals for anticipated SKA build to supplement these backbone networks should they not be in place, as well as the cost of exclusive SKA fibre build to connect from the backbone networks to the SKA...
remote stations. The detailed FibreCo proposal is included as Annexure G24. Figure 4.6 shows the FibreCo backbone route in dark blue, with the Gauteng - Durban route to be obtained from other network providers shown in light blue. Planned backbone routes are shown in red, and SKA exclusive links are shown in magenta.

![Figure 4.6: FibreCo network showing SKA remote stations / connectivity to neighbouring states.](image)

To complement both of the above network proposals, we have worked with Nokia Siemens Networks (NSN) to develop the equipment requirement for both of the above networks. NSN have involved their International Research Department in developing a solution to address the requirement for a unidirectional service from the antenna arrays to the data processor in order to reduce costs. Although the final equipment layout and system design has not been fully developed, NSN have provided two costed equipment proposals that align with the Broadband Infraco and FibreCo networks. See Annexure G23 for further details.

### 4.4.3 Operations and Management

Services internal and external to South Africa would be monitored from central 24×7×365 Network Operations Centres (NOCs), with the possibility of a single NOC monitoring all SKA networks, providing a remote Management Terminal at the SKA Control Room with monitoring facilities for the SKA network services.

The managed bandwidth solutions proposed by Broadband Infraco and FibreCo provide the following information:

1. Broadband Infraco - offer a 97.0% Service Level Agreement on non-diverse links, and 99.5% on diverse links
2. FibreCo - offer a 2 hour response, 4 hour repair time for minor events and 12 hour target for major events on backbone components. Response times double for non-backbone components

### 4.5 Connectivity Plan: African SKA Remote Stations

The SKA African configuration includes 12 remote stations in the African SKA partner countries, summarised as follows:

- Namibia - 4 SKA remote stations
- Botswana - 3 SKA remote stations
- Zambia - 1 SKA remote station
- Mozambique - 2 SKA remote stations
- Madagascar - 2 SKA remote stations

Additional sites have been located in the following countries, but are not part of the site bid evaluation. These sites have been incorporated in the larger SKA configuration to provide greater east-west and north-south baselines than can be offered in the 3,000 km configuration:

- Ghana - 1 SKA remote station
- Kenya - 1 SKA remote station
- Mauritius - 1 SKA remote station

Costs for the international components for the additional sites have been provided in this submission in both of the SEACOM and EASSY/WIOCC proposals, but are not included in the final costed solution. Broadband Infraco have identified the terrestrial component for the additional sites in their submission as an option.

### 4.5.1 Existing Infrastructure

Analysys Mason, a UK-based telecommunications consulting company, was contracted to undertake an investigation and provide a report on the current and planned fibre-optic networks in African SKA partner countries. The Scope of Work included the identification of existing and planned fibre networks, as well as the current equipment base, available capacities, and service costs. These reports are attached as Annexures G3, G4.1 and G4.2. In collaboration with the African SKA partner countries, the fibre network availability was also sourced via their own resources; this information is included in Annexures G5 to G12, and concentrates on the availability of fibre in the immediate area of the SKA remote stations.

### 4.5.2 Planned SKA Design

The principles adopted for data capacity requirements between the SKA remote stations within South Africa and the data processor, discussed in Section 4.4.2, are adopted here.

To obtain a single point-of-contact pricing proposal, the South African SKA Project Office has worked with SEACOM, the submarine cable operator. SEACOM have established routes into a number of East African coastal countries, as well as some land-locked countries. They have also established operating agreements with a number of operators in these countries, utilising existing networks for network extensions where these are available and suitable. Some of these extensions align with SKA requirements, although an amount of new fibre build is required from existing fibre backbones to access the SKA remote stations. SEACOM have confirmed the information supplied by Analysys Mason with their own available network information, and have designed and costed new build routes incorporating latest generation fibre and infrastructure requirements. This includes DWDM (Dense Wave Division Multiplexing) equipment requirements to extend the specified bandwidth from the 12 remote stations to either hand-over points on the South African border (in the case of Namibia, Botswana, Mozambique and Zambia (via Botswana)), or for extension via submarine cable systems (SEACOM and/or LION submarine cable systems) to the cable landing station at Mtunzini on the South African east coast (in the case of Madagascar). The EASSY submarine cable system, with a total capacity of 4.7 Tbit/s, is also able to provide the required submarine route (see Annexure G29.1 and G29.2). It is noted that current submarine cable system capacities are designed on 10 Gbit/s wavelengths. With the advent of 40 Gbit/s wavelengths, the capacity of these systems can be at least doubled by upgrades at the terminal equipment. Most of the SEACOM partner country network information is provided under Non-Disclosure Agreements, and may not be disclosed in this submission.

A network design and costing has been done to provision the required bandwidths from the SKA remote stations to the international hand-over points on the South African borders. This costing has been done utilising existing fibre network infrastructure where this is available, and has estimated the provision of new build from existing infrastructure to the SKA remote stations. For SKA purposes this is largely irrelevant, as these networks will have changed significantly in both footprint and capability by the time that the SKA connectivity in these regions is required. Most of the existing national fibre networks are based on SDH (Synchronous Digital Hierarchy) 10 Gbit/s
capacities, and were not designed to meet capacities of 230 Gbit/s, or multiple services of 230 Gbit/s each. With the bandwidth explosion being brought about by the availability of low-cost international bandwidth, these networks will have been expanded and upgraded to the later generation high-capacity DWDM systems to meet the expanding user requirements by the time SKA requires service to these areas circa 2020. The cost to the SKA Data Transport will therefore reduce significantly. Annexure G33 provides logical network diagrams for the data connectivity plans in the African SKA partner countries.

Following de-regulation, the power utilities are installing fibre on their power networks for both utility and commercial purposes. These installations will offer additional options in the future. Annexure G33 provides an alternate proposal for data connectivity to the remote stations in Mozambique. It may be carried on the Cahora Bassa powerline, established by Eskom. Further investigation of this solution will be undertaken following the site bid decision.

4.5.3 Operations and Management

Services internal and external to South Africa would be monitored from a central 24×7×365 Network Operations Centre (NOC), with the possibility of providing a remote Management Terminal at the SKA Control Room with monitoring facilities of the SKA network services. SEACOM have proposed the establishment of a central NOC, establishing manageability of all their associated networks. They have offered this facility to monitor and operate all SKA networks, both internal and external to South Africa, although the South African operators have existing NOCs managing their individual networks. The benefits of such a proposal can be considered in the future by the SKA authority.

The proposal provides for the following service availabilities:

1. SEACOM terrestrial component - offer a Service Level Agreement of 99.5%, or 4 hour mean-time-to-repair, excluding force majeure
2. SEACOM submarine component - offer a Service Level Agreement 99.5%, excluding force majeure and wet segment cable breaks

SKA South Africa does not believe that it will be necessary for SKA personnel to travel to the African partner countries for data transport maintenance activities on a regular basis while the IRU is operational. Should the need arise, SKA personnel would be able to enter and leave these countries without issue, under similar arrangements as the multinational cellular operators with network operations in these countries, such as MTN and Vodacom. The SKA has been supported by the African Union, formalised by a document called African Union Heads of State Endorsement of the SKA 2010. A combination of bilateral Science and Technology agreements and letters of commitment for the SKA from the African partner countries are in place, facilitating ease of access of people for SKA purposes. Namibia, Botswana, and South Africa are members of the Southern African Custom Union. Many of the mobile operators high-level technical resources are located in South Africa, with agreements to enter the African Countries when required. Established processes are in place between South African and the African partner countries to provide for passage of goods and personnel, with letters of commitment from the African partner countries guaranteeing that SKA personnel and equipment can enter the countries with ease, and no project equipment will be liable for tax. It is not anticipated that there will be any difficulty for personnel or goods to be despatched across borders for the purposes of the SKA. These issues have been dealt with in the Basic Infrastructure, Customs and Excise, and Legal Issues reports. Annexure A contains detailed information regarding these issues.

4.6 Connectivity Plan: Data Processor to Super-Computer

4.6.1 Existing Infrastructure

The MeerKAT fibre optic link between Carnarvon and Cape Town has been outlined in Section 4.4.1, and can be used as part of the diversified network plan.
4.6.2 Planned SKA Design

The SSG-RfI identifies the requirement for a fibre optic system capable of carrying at least 400 Tbit/s between the data processor and the super-computer, located in a major town, requiring a high-availability design. This requirement for a high-reliability link, over redundant routes of approximately 900 km each, operating at this capacity, is a significant challenge. Only a totally diverse network solution can truly meet the reliability requirements. The South African solution offers a truly geographically redundant network providing the required levels of availability. Figure 4.7 indicates the logical connectivity for the diverse route from Astronomy Complex to Cape Town, while Figure 4.8 provides a geographical view.

![Figure 4.7: SKA Network Expansion: SANReN / Broadband Infraco Network.](image)

Figure 4.7: SKA Network Expansion: SANReN / Broadband Infraco Network.

The South African solution proposes that the data processor and the super-computer are located in adjacent buildings at the Astronomy Complex. There is then no requirement for the establishment of an extended fibre network to provide the 400 Tbit/s link identified above since connectivity between these two computers will be done by on-site fibre patch leads connecting the two computer installations. This eliminates the cost and ongoing maintenance requirement for a complex solution, proposing instead to provide a 1 Tbit/s diversified link from the super-computer to the SKA Head Office, located in Cape Town. The Power Provision Report, attached in Annexure A, notes that the proposed power solution is capable of providing for the full power load of the SKA in the Karoo. The proposed 132 kV electricity feed, carrying optic fibre infrastructure, will ensure geographically separated redundant data links are provided for a diversified solution. A reduction in the overall cost, the number of skilled personnel and the complexity required to maintain two geographically separated major computer installations is expected.

A 1 Tbit/s link is estimated to provide sufficient capacity for personnel located at the SKA Head Office to interact with the super-computer, and download large computational results for further study. This link will provide flexible capacity and will encapsulate a PVC (Permanent Virtual Circuit) to provide the required 100 Gbit/s from the super-computer to the SKA Head Office, to be extended to data centres in other parts of the world. This PVC can be established with a committed information rate of 100 Gbit/s, but can also be set up to allow traffic in the link to burst when other usage is low. Should this link capacity be deemed to be insufficient, the link capacity can be increased, but it will still remain a far more cost effective solution than the alternative 400 Tbit/s implementation, in system complexity, maintainability and cost.

For comparative purposes, a diverse 400 Tbit/s link from the Astronomy Complex to Cape Town has been costed. This provides challenges in both fibre network and equipment supply, and particularly in the cost of...
establishing large, costly, power-hungry repeater sites approximately every 80 to 100 km along the route. Taking the basis of 100 Gbit/s lambdas, and equipment system forecasts of system capacities of 9.6 Tbit/s (96 Channels × 100 Gbit/s per channel), this requires 42 parallel systems to meet the 400 Tbit/s requirement. Estimated equipment power consumption for the terminal station is 783 kW, and each repeater OLR (Optical Line Repeater) site 5.4 kW. Should 80 channel systems be implemented, the power consumption rises to 932 kW for the terminal equipment, and 6.5 kW for each OLR sites. This makes a significant contribution to overall operational costs. In comparison, a 1 Tbit/s system requires 2.5 kW for the terminal station and 129 W for each OLR equipment site. See Annexure G22 - NSN hIT7300 Power Requirements for further details.

Figure 4.8: Broadband Infraco Network showing diverse MeerKAT/SKA network.

4.6.3 Operations and Management

The proposed co-location solution at the Astronomy Complex in the Karoo requires a static on-site fibre interconnection arrangement between the two computer installations. This costing can only be done when the computer designs are known. Operations costs for this component would be negligible.

For comparative purposes, Broadband Infraco has provided IRU proposals for both a 400 Tbit/s link and a 1 Tbit/s link, which includes operations and maintenance costs, and offers a 99.5% Service Level Agreement based on the availability of a diverse link. Management would be provided for the diversified 1 Tbit/s via a central 24×7×365 NOC, in a similar arrangement for all SKA data links in South Africa.

4.7 Connectivity Plan: Super-Computer to SKA Head Office and International Data Centres

The South African proposal is to co-locate the super-computer and data processor at the Astronomy Complex, with the SKA Head Office located in Cape Town. The connectivity plan has been fully described in Section 4.6. The 100 Gbit/s capacity required for connectivity to the outside world from the super-computer will be contained within the 1 Tbit/s link from the super-computer to the SKA Head Office. No additional costs are foreseen.
4.7.1 Existing Infrastructure
A description of the existing MeerKAT data link between the SKA Core site (i.e. MeerKAT) and Cape Town has been provided in Section 4.4.1.

4.7.2 Planned SKA Design
The required international connectivity will extend from the SKA Head Office in Cape Town to the undersea cable network for transmission to other centres around the world. At this time, the link proposal is for 10 Gbit/s (2013), expanding to a 100 Gbit/s (2020) requirement, from Cape Town to either Europe or the United Kingdom. The terminal location in Europe has not been identified in the SSG-RfI, but it is anticipated to connect to the European GEANT NReN for connectivity to the international research network institutions in Europe and further afield. Most appropriate locations for this connectivity are believed to be either London or Amsterdam.

Proposals were received from three submarine cable operators, being Broadband Infraco, SEACOM and EASSY/WIOCC. A fourth proposal was received from FibreCo who included a proposal from Dimension Data (a subsidiary of Nippon Telecommunications Networks) within their shareholding of the WACS cable network. Broadband Infraco holds an 11.4% share in the WACS (West African Cable System - see Figure 4.1), an investment undertaken in support of the SKA and other projects of national importance. SKA has the highest capacity requirements of all identified national projects to date. Of all four proposals received, EASSY put forward the most economical solution with a 20 year IRU excluding annual Ops and Maintenance costs, which could be provided on either their East Coast system or on their shareholding in the WACS cable. This proposal has been included in the South African solution. It must be noted that a number of submarine cable systems provide diverse, high capacity bandwidth to Europe and the Americas along the African east coast. These operators hold either capacity or a shareholding in WACS, and are able to offer diverse routes should this be required. Capacity on the WACS cable will be extended from a Cape Town POP via the operator’s terrestrial network to the Yzerfontein Cable Landing Station.

4.7.3 Operations and Management
The solution for the super-computer to the SKA Head Office and international data centres comprises of two components:

1. Terrestrial section from the super-computer to the SKA Head Office, and
2. International component (submarine cable system) from the SKA Head Office to international data centres.

The operation and maintenance of the terrestrial section has been detailed in Section 4.6, where Broadband Infraco has proposed an IRU for the 1 Tbit/s link which includes operations and maintenance costs, and offers a 99.5% Service Level Agreement based on the availability of a diverse link. Management would be provided by a central 24×7×365 NOC.

EASSY have offered the international service managed by their NOC on a 24×7×365 basis. Service availability per month is offered as 99.95% minimum, with a rebate should actual levels fall below this. MTTR target times are 4 hours for terrestrial equipment failures, 12 hours for terrestrial cable cuts, and 21 calendar days for submarine cable cuts or faults. Annexure G29.1 contains the EASSY/WIOCC Service Level Agreement.

4.8 Regulatory Environment

4.8.1 South Africa
Telecommunication services are provided by operators licensed in terms of the South African Electronic Communications Act (ECA). The sector is regulated through the Independent Communications Authority of South Africa (ICASA). See Annexures G1.1.1 and G1.1.2 for the ECA and ICASA Acts. A detailed discussion of the regulatory environment in South Africa is provided in the report on Radio Quiet Zones in Annexure A. The SKA would be in a position to apply for a licence exemption, in terms of the ECA, for the roll-out of the data transport network to inter-connect antenna arrays. This would allow the SKA organisation to self-provision or lease services from competing operators.
In terms of Section 28 of the AGA Act (see Annexure G2), the Minister of Science and Technology will declare the SKA as an astronomy device, including all inter-connecting data link requirements. The MeerKAT, as a precursor telescope to the SKA, has already been declared as such an astronomy device. Hence, the data network required for the SKA would be classed as a ‘private network’ for astronomy research purposes, and is exempt from the requirement of the ECA in terms of Section 28 of the AGA Act.

4.8.2 African SKA Partner Countries

Telecommunication services are provided by an operator licensed to operate in all countries, with associated landing stations. SEACOM has agreements with licensed operator in these countries to extend terrestrial services. An alternative operator would be EASSY, with shareholders being the governments of the African SKA partner countries and/or operators. Annexure G1 is a list of legislation and features for electronic communications, telecommunications and broadcasting in the African SKA partner countries, inclusive of the various regulators appointments and reporting lines. Annexures G1.2.1 to G1.9.1 contain the telecommunication acts and regulations of the African SKA partner countries. All of the African partner countries have established regulatory frameworks and are ITU members. See Annexure G1 for a list of Legislation and Features for electronic Communications, Telecommunications and Broadcasting in the African partner countries, as well as Annexures G1.2.1 to G1.9.1 for the acts appropriate to each country. Further details on the regulatory environments in each of the African SKA partner countries is provided in the report on Radio Quiet Zones, in Annexure A.

4.9 Costs

Detailed costing for the various proposals have been provided in Annexure G15, with a summary of the data provision costs provided in Section 4.9.5, whilst costing assumptions have been outlined in the following sections.

4.9.1 0 - 180 km

1. Capital Costs

   A full capital cost for the supply and implementation of the fibre network solution is €[redacted] (including labour costs). Various assumptions have been made in the design and costing of the fibre optic network to 180 km.

   The SSG-RfI stipulates that the costs for trenching must be treated separately from the power reticulation. As specified we have costed on this basis, although this will not happen in practice.

   Costing includes the following top-end components:

   (a) Provision of heavy duty 8 fibre/tube duct fibre and sub-ducts in accordance with the proxy design
   (b) Provision of E2000 connectors (ceramic midcoupler) at both data computer and remote end
   (c) Provision of sealed Nexan fibre nodes in accordance with the proxy design

   Costs have also been provided for the following options for comparative purposes:

   (a) Provision of heavy duty 12 fibre/tube fibre cable : Additional €[redacted]
   (b) Provision of Nexan nodes equipped with FC-APC / SC-APC terminals : Less €[redacted]

   Although not required by the SSG-RfI, we have worked with NSN in developing the equipment requirement for the ‘clumped stations’ located along the five spirals to 180 km from the SKA Core. We have worked on the initial requirement for 41 Tbit/s per station for SKA Phase 1 (6 × ‘clump stations’ on 3 spirals out to a distance of 100 km from the Core), increasing to 61 Tbit/s per station for SKA Phase 2 (10 × ‘clump stations’ on each of 5 spirals extending out to 180 km from the Core). Equipment costs for SKA Phase 1 and Phase 2 are €[redacted] plus €[redacted] respectively. Further details are provided in Annexure G15.

2. Operations and Maintenance Costs

   The cost of maintaining the fibre network in the SKA Core is anticipated to be extremely low once the network is taken into operation. The network will run in a controlled environment, and damage to the fibre
cable network should seldom occur. Due to the dusty environment, it is preferable that the fibre network is generally accessed only under breakdown conditions. An annual integrity check of the fibre network is however recommended. There will be a number of electronic technicians on site for operations and maintenance of the total SKA facility. A recommendation for the purchase of fibre optic test equipment was received from SIA Solutions. All first line maintenance and operating procedures would be carried out as part of the technicians’ responsibility.

Costs for the continued operations of the fibre network, utilising SKA personnel, are as follows:

(a) Once-off cost of test equipment: €

(b) Annual cost of cleaning kits: €

(c) Annual staff costs have not been taken into account. This is the lowest cost option but it is difficult to provide a realistic estimate of the costs involved at this time.

For the purpose of the submission, and for comparative purposes, an out-sourced solution is proposed: Ongoing maintenance support provided by SIA solutions: € p.a. (Year 1)

Maintenance cost for 20 years is € (See SIA Solutions proposal in Annexures G14 and G15 - TAB ‘Core Fibre’).

4.9.2 Remote Stations

It has been difficult to obtain committed service quotations from operators for services anticipated to be required in 2016 and 2019. Operators have a roadmap of new equipment technologies and associated capacities due to be released to the commercial market over the next years, but have no experience of these technologies or compatibility with their management systems and external plant, and are therefore loathe to commit to final pricing, but have been willing to provide indicative pricing. The price of long distance network services will reduce from current price levels, both due to technology enhancements and growing industry competition.

The recommended solution is a managed bandwidth solution from Broadband Infraco within South Africa, and SEACOM in the African SKA partner countries.

The Broadband Infraco proposal utilises as a 50 year IRU, inclusive of all maintenance. This has been compared to the alternative solutions; with the 50 year IRU offer is similar to other 20 year lifetime costs. See Annexure G19 for details and assumptions, plus Annexure G15 for all solutions and cost details.

The SEACOM proposal is for a 20 year IRU (payable over 2 years), but excludes annual operations and maintenance charges. Further details are provided in Annexure G25.

A cost summary of the data provision to the SKA remote stations is provided in Table 4.2.

![Table 4.2: Costs for SKA remote stations.](image)

<table>
<thead>
<tr>
<th>Remote Sites Within SA</th>
<th>20 Year IRU Cost</th>
<th>Typical Annual Operations and Maintenance Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote Sites external to SA (Terrestrial)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remote Sites external to SA (Submarine component)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.9.3 Data Processor to Super-Computer

The South African SKA basic infrastructure and data provision solutions propose co-location of the data processor and super-computer at the Astronomy Complex. For comparative purposes, the scenario of the super-computer located at the Cape Town Head Office has also been costed.

The proposed solution is a managed bandwidth solution, based on a 50 year IRU inclusive of operations and maintenance costs. A cost summary is provided in Table 4.3.
Table 4.3: Costs for the data link between Carnarvon and Cape Town. The South African proposal co-locates the super-computer with the data processor, providing a 1 Tbit/s redundant data link to Cape Town. For comparative purposes, a scenario with the super-computer in Cape Town has been provided, requiring a 400 Tbit/s datalink.

<table>
<thead>
<tr>
<th>Data Link</th>
<th>Super Computer at SKA Core Site (South African Proposed Solution)</th>
<th>Super Computer in Cape Town (Comparative Purposes Only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carnarvon to Cape Town</td>
<td>50 Year IRU Cost (1 Tbit/s)</td>
<td>50 Year IRU Cost (400 Tbit/s)</td>
</tr>
</tbody>
</table>

### 4.9.4 Super-Computer to SKA Headquarters and International Data Centres

The South African proposal recommends a managed bandwidth solution, in the form of a 20 year IRU at a cost of €[redacted]. This cost is exclusive of operations and maintenance, which are typically €[redacted] per annum.

### 4.9.5 Summary

A high level cost summary is shown in Table 4.4. This summary table can be found in Annexure G15, along with spreadsheets that inform the summary. Two summaries are presented based on the options proposed for the data processor to super-computer link, namely the 400 Tbit/s and 1 Tbit/s link. These two options have a cost difference of €[redacted] while all other costs elements remain the same. The CAPEX costs include IRU purchases.

<table>
<thead>
<tr>
<th>Table 4.4: Summary of data provision costs in January 2007 Euros.</th>
</tr>
</thead>
</table>

Indicative costs have been given for a 20 year period, as this is generally the maximum period for proposals entertained by telecommunication operators. Broadband Infraco have provided both 20 year and 50 year IRU periods. The 50 year IRU proposals have been selected where available as there is little increase in cost, but it minimises risk and the possibility of a step-change in service charges between IRU contracts. Annexure G15 provides the spreadsheets detailing the various cost proposals received, and their CAPEX and Year 1 operations costs. These have been converted to 2007 Euros as per requirements, and the 'Summary' spreadsheet makes allowance for entering the number of years of operation for an indicative lifetime system cost, inclusive of initial capex and/or IRU value.
Chapter 5

Physical Characteristics of the Site

5.1 Executive Summary

The analysis of geophysical characteristics at the South African SKA Core and Skirt region, spiral arms out to 180 km, and the remote stations shows that the benign weather conditions and geotechnical conditions are suitable for hosting the SKA. No extreme weather conditions exist, such as very high temperatures or excessive flooding, which will have significant cost implications on the design of the telescope and supporting infrastructure.

5.2 Introduction

In preparation for the South African SKA 2005 bid proposal to host the Square Kilometre Array (SKA), the South African SKA Project Office (SASPO) considered a number of potential sites for the SKA in South Africa in terms of physical characteristics. The SKA Core site was selected primarily due to its proximity to infrastructure, resulting in significant cost savings on capital expenditure, and the topographical shielding to the south, which provides excellent long term protection from potential sources of radio frequency interference. Figure 5.1 illustrates the site with relevant geophysical features.

SASPO undertook a series of wide ranging analyses on the physical and meteorological characteristics of the final selected SKA Core site, as well as all of the proposed remote stations. These included both geotechnical and geohydrological surveys conducted by the South African Council for GeoScience at all sites, as well as a meteorological analysis of long term weather data by the South African Weather Service. Some of these data extended over 100 years. Annexures F1.1 and F1.2 are the relevant section on climate and corresponding annexure as submitted to the International SKA Project Office (ISPO) in 2005 for consideration.

Since 2005, SASPO has operated a weather station at the South African SKA Core site. It has captured data at 10 minute intervals for a variety of meteorological parameters since its installation, with only minor interruptions. A complete summary of the measured data is provided in Figures 5.2 and 5.3. Raw measurement data for the weather station is attached as Annexure F6.1. A second weather station has recently been installed for monitoring at the KAT-7 facility and is available in real time, whilst detailed geotechnical analyses have been undertaken in preparation for the establishment of both KAT-7 and MeerKAT.

Comparison of the statistical analysis of the weather station data with existing long-term weather data presented in 2005 indicates that the two datasets are consistent, except for measured absolute maximum rainfall. Higher maximum daily rainfall statistics have been recorded at Van Wyksvlei historically as a result of longer term datasets. However, short term (30 minute) timescales are not available for detailed flooding analysis based on these data.

Since 2008, SASPO have had a permanent presence at the SKA Core site in the form of an SKA Site Manager. This person has been able to provide first hand observer accounts of weather conditions, and other physical characteristics, which are referred to in this report.

Datasets from appropriate weather stations operated by the Agricultural Research Council Institute for Soil, Climate and Water (ARC-ISCW), as well as the South African Weather Service (SAWS), have been used to analyse the environmental conditions along the spiral arms and remote sites of the African SKA configuration. Satellite datasets and modelled datasets have been used to complement weather station data where it is insufficient, or not available, and to ensure uniformity across the measurement sets. Two weather prediction models have been used
Figure 5.1: Map of the South African SKA Core site, with 20 m contour lines overlaid showing the RFI shielding topography to the south of the site.

Figure 5.2: Summary of measured data (temperature in celcius, relative humidity and rainfall rate), collected in the period 01/01/2005 to 31/03/2011.
Figure 5.3: Summary of measured data (windspeed, wind direction and maximum wind gusts), collected in the period 01/01/2005 to 31/03/2011.

- the Global Forecast System, and the Weather, Research and Forecasting (WRF) model. The WRF model was developed through a partnership including the National Oceanic and Atmospheric Administration (NOAA), the National Center for Atmospheric Research (NCAR), and more than 150 other organizations and universities in the United States and abroad. The results of the model have been verified against ground station weather data in South Africa (see Annexure F9.2).

Datasets from existing geotechnical, LIDAR (Light Detection and Ranging) and other surveys, as well as from internationally operated satellites, are used to provide information on geotechnical aspects beyond the SKA Core and Skirt region.

The information presented in this report more than adequately addresses the requested information as it is interpreted, and provides a detailed understanding of the physical characteristics over the extent of the African SKA configuration. Section 5.3 considers the physical characteristics of the SKA Core and Skirt region together, as there is no significant variation in physical characteristics across the two regions. Sections 5.4 and 5.5 consider the variation of physical characteristics across the spiral arms out to 180 km, and remote stations. Detailed analysis of physical characteristics in these two regions can be found in Annexures F9.1, F9.2 and F9.3.

5.3 SKA Core and Skirt Region

5.3.1 Meteorological Data

High time resolution measurement data recorded at 10 minute intervals by the onsite weather station have been analysed. Results of this analysis are provided in this section. Numerical results have been attached in relevant annexures.

Air Temperature

Results from the statistical analysis of temperature data are shown in Figure 5.4, and attached as Annexure F6.2. The following statistical parameters for temperature are provided for each month of the year: mean, range (average of maximum - minimum daily temperature), average maximum and minimum over the days of the month, absolute maximum and minimum over the days of the month, and average and maximum rate of variation over one hour timescales.
Air temperature is benign, with maximum temperatures not exceeding 40 celcius. Large temperature variations only occur as a result of sudden rainfall.

![Temperature Data](image)

Figure 5.4: Statistics for temperature data, collected in the period 01/01/2005 to 31/03/2011, indicating the following: mean, range (average of maximum - minimum daily temperature), average maximum and minimum over the days of the month, absolute maximum and minimum over the days of the month, and average and maximum rate of variation over one hour timescales.

### Relative Humidity

Results from the statistical analysis of relative humidity data are shown in Figure 5.5, and attached as Annexure F6.3. The following statistical parameters for relative humidity are provided for each month of the year: mean, range (average of maximum - minimum daily relative humidity), average maximum and minimum over the days of the month, and absolute maximum and minimum over the days of the month.

### Rainfall

Results from the statistical analysis of rainfall data are shown in Figure 5.6, and attached as Annexure F6.4. The following statistical parameters for rainfall are provided for each month of the year: mean per day, absolute maximum daily rainfall over the days of the month, and absolute maximum rainfall in a 30 minute burst in that month. The very low mean daily rainfall is indicative of the arid conditions in the Karoo.

### Derived Dewpoint

Dewpoint temperature has been derived from the measurement data according to the formula $T_{dp} = \frac{\beta \gamma + \ln \frac{RH_{avg}}{100}}{\alpha - \gamma}$, where $\gamma = \frac{\alpha T_{avg}}{\beta + T_{avg}} + \ln \frac{RH_{avg}}{100}$ with $\alpha = 17.271$, $\beta = 237.7$ and average relative humidity and temperature $RH_{avg}$ and $T_{avg}$ respectively. Results from the statistical analysis of derived dewpoint data are shown in Figure 5.7, and attached as Annexure F6.5. The following statistical parameters for derived dewpoint are provided for each month of the year: mean, range (average of maximum - minimum daily derived dewpoint), average maximum and minimum over the days of the month, and absolute maximum and minimum over the days of the month.

The absolute maximum value measured in the month of September appears to be anomalous and is inconsistent with other absolute maximum values. It should therefore be treated as unconfirmed, as it is highly unlikely that dew point temperatures would exceed 21 celcius in the Karoo. Alternative weather station data used to analyse...
Figure 5.5: Statistics for humidity data, collected in the period 01/01/2005 to 31/03/2011, indicating the following: mean, range (average of maximum - minimum daily relative humidity), average maximum and minimum over the days of the month, and absolute maximum and minimum over the days of the month.

Figure 5.6: Statistics for rainfall data, collected in the period 01/01/2005 to 31/03/2011, indicating the following: mean per day, absolute maximum daily rainfall over the days of the month, and absolute maximum rainfall in a 30 minute burst in that month.
meteorological conditions along the spiral arms has been considered (see Annexure F9.1 and Section 5.4), indicating an absolute maximum dew point temperature of 10.4 celcius in the month of September. This is in line with the expected trend.

Figure 5.7: Statistics for derived dewpoint data, collected in the period 01/01/2005 to 31/03/2011, indicating the following: mean, range (average of maximum - minimum daily derived dewpoint), average maximum and minimum over the days of the month, and absolute maximum and minimum over the days of the month.

Occurrence of Ice Formation, Hailing and Pooling of Water

The SKA configuration within the 180 km intermediate region, including the five spiral arms, core and skirt regions, has been optimised taking into consideration areas that are subject to inundation. Therefore, the risk of occurrence of the pooling of water is very low, as indicated in Figure 5.8.

Annexure F8.1 indicates that the average number of days per year where frost is recorded in the SKA Core and Skirt region is 33. This is typically early morning frost that does not persist during the course of the day. To determine the risk of formation of ice that could potentially damage infrastructure or equipment, the following data are interrogated: temperature, precipitation and the pooling of water. This interrogation indicated that a very low risk of significant ice formation exists. This is supported by first-hand observer accounts at the site.

The subject of hail is considered in Section 5.3.3.

Cloud Cover

An analysis of cloud cover was undertaken in preparation for the South African 2005 SKA Bid Submission, located in Annexures F1.1 and F1.2. Results of the analysis are summarised here.

Ten year datasets from weather stations located at the towns of Van Wyksvlei (58 km from the site) and Fraserburg (140 km from the site) have been used to analyse cloud conditions near the SKA Core site. Figures 5.9 and 5.10 indicate the monthly mean cloud cover at the towns of Van Wyksvlei and Fraserburg respectively. Measurements are in units of Octas, where one Octa corresponds to 12.5% of the visible sky.

Figure 5.11 indicates the percentage of time during the year for which no clouds are visible in the sky, and for which no cumulus-type clouds are visible. The analysis includes the town of Brandvlei, approximately 96 km from the SKA Core site, in the place of Fraserburg. This cloud analysis is supported by an analysis of AQUA satellite data, attached as Annexure F11, which indicates an average annual fractional cloud coverage of 23%.
Figure 5.8: Inundation layer from South African 1:250,000 topographic series. This layer indicates areas that are subject to saturation, and hence pooling of water.

Figure 5.9: Cloud cover for Van Wyksvlei

Figure 5.10: Cloud cover for Fraserburg
Physical Characteristics of the Site

Van Wyksvlei

Brandvlei

0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Percentage of year [%]
Cloud Presence − 1995 to 2004
No clouds
No cumulus

Figure 5.11: Clear skies analysis for VanWyksvlei and Brandvlei, 58 km and 96 km from the SKA Core site respectively).

Wind

Results from the statistical analysis of wind speed data are shown in Figure 5.12, and attached as Annexure F6.6. The following statistical parameters for wind are provided for each month of the year: average wind over the month, absolute and average maximum over the month and absolute peak gust (<10 seconds) over the month.

A wind rose for the period 01/01/2005 to 31/03/2011, providing a direction and speed histogram for all measured wind speed data, is shown in Figure 5.13. Monthly wind roses are provided in Annexure F10.
Physical Characteristics of the Site

Solar Radiation

Results from the statistical analysis of solar radiation data are shown in Figure 5.14, and attached as Annexure F6.7, using hourly data obtained from the ARC-ICSW weather station in Van Wyksvlei. Data are measured in units of kilowatts per square metre, which is averaged per hour and converted to megajoules per square metre per day. The following statistical parameters for solar radiation are provided for each month of the year: mean, average maximum and average minimum.

Airborne Particles and Chemicals

The satellite measurement of aerosol optical thickness (AOT) provides an accurate measure of the amount of chemical and particulate matter in the atmosphere, and is commonly used as a measure of air quality, the monitoring of the presence of aerosols, emissions from volcanic eruptions, water soluble sea salt, dust, urban pollutants and forest fires. Daily AOT maps are available at 550 nm from GlobAEROSOL, which is a European Space Agency funded project that derives AOT measurements from three satellites. Further information can be located in the report on aerosol optical thickness in Annexure F7.

Figure 5.15 presents the 2007 monthly mean AOT (measured between 0 and 1) at the SKA Core and Skirt region, spiral arms and remote stations. The global mean has been provided for comparative purposes. The data indicates that the air quality at the South African site is significantly better than the global mean.

Wildlife

The predominant wildlife identified in the SKA Core and Skirt region that warrants consideration is the ‘sociable weaver’. These birds are known to construct large nests, housing at times many hundreds of birds. The South African SKA Project mitigates the potential risk of these large nests by fixing perches onto powerline support structures. This has proved to be very effective, and is a technique commonly used in the area. Standard maintenance procedures can include checks, and removal of any potential nests in dish structures. However, experience thus far with the KAT-7 antennas indicates that this may not be necessary.
Figure 5.14: Statistics for solar radiation data in units of MJ per square metre per day, collected in the period 15/10/2004 to 05/07/2011, indicating the following: mean, average maximum and average minimum.

Figure 5.15: Aerosol Optical Thickness (AOT), as measured in summer and winter at the SKA Core and Skirt region in 2007. The global mean is provided for comparative purposes.
Land Restrictions

The land upon which the SKA Core and Skirt region is located is not subject to any land restrictions. The two farms, Losberg and Meys Dam (totalling 14,000 hectares), are currently owned by the National Research Foundation. Further land to accommodate the full SKA Core and Skirt region is currently privately owned, and would need to be acquired through purchase, way-leave or lease agreements. The Astronomy Geographic Advantage (AGA) Act provides for rights of expropriation and servitudes to assist in the process of land acquisition.

The MeerKAT Environmental Impact Assessment (EIA) Report has been attached as Annexure F5. The EIA covers a large part of the SKA Core and Skirt region. The report concludes that no significant ecological reasons exist as to why the development of a radio astronomy facility cannot proceed at the site. Although a few sites of heritage importance were identified in the report, these sites may be destroyed following the implementation of the necessary mitigation measures as indicated by the South African Heritage Resources Agency. Timescales associated with the implementation of such measures are not significant, and would not have a major impact on the project. No legislated protection currently exists for any flora and fauna identified at the site.

Wild Fires

The MODIS (Moderate Resolution Imaging Spectroradiometer) Active Fire and Burnt Areas global satellite dataset is produced on an annual basis, with four transits of the satellite per day, and 10 years worth of data have been interrogated for the area around the SKA Core and Skirt region. No active fires, or burn scars, have been identified in the period 01/01/2001 to 31/12/2010, as shown in Annexure F8.2.

Seismic Stability

The observed seismicity in the Karoo area is typical of intra-plate regions. These regions are characterised by low-level activity with earthquakes randomly distributed in space and time. The area therefore has very low risk of significant seismic activity. Historical data support this position.

Seismic events recorded between 1973 and 2003 at the National Earthquake Information Centre, operated by the US Geological Survey, are shown in Figure 5.16. Only one event over this period has been recorded approximately 100 km from the SKA Core site. Metadata for this event indicates that the event took place at a depth of 5 km below ground level, with a magnitude of 4.5. However, almost all seismic activity in South Africa is as a result of deep level mining, and no active deep mines are located within several hundred of the SKA Core and Skirt region. This event should therefore be treated as unconfirmed.

5.3.2 Geotechnical

The South African Council for GeoScience was commissioned in 2005 to undertake a comprehensive geotechnical survey, in preparation for the South African 2005 SKA Bid Proposal. This survey resulted in a number of volumes, and included the following: geological and geotechnical constraints, hydrology, mineral deposits and inundation mapping. These reports can be located in Annexures F1.3, F1.4, F1.5, F1.6 and F1.7.

Since the initiation of MeerKAT, a wide variety of geotechnical studies have been commissioned. The results presented in this section are derived mainly from these studies. The results of many of these studies are located in the MeerKAT Critical Design Review in Annexure F4.3, and the Detailed MeerKAT Geotechnical Report in Annexure F4.1. A summary of this report is located in Annexure F4.2.

Sub-surface Strata

The SKA Core and Skirt region is part of the Karoo Supergroup, intruded by dolerite sills and dykes. A map of the region, indicating lithographic classes, is shown in Figure 5.17.

Annexure F4.1 is a comprehensive report on the geotechnical investigation for dish foundation studies undertaken for the MeerKAT and SKA Core site, which included borehole drilling of 44 sites, soil profiling, laboratory testing, CSW (continuous surface wave) and plate bearing tests. The investigation revealed that the soil profile across the site is relatively similar, with slight variability. This has resulted in the consideration of two foundation solutions (pad and piled) for MeerKAT, to be investigated further in a cost-benefit analysis that is currently underway.

1The South African SKA Project Office is a Business Unit of the National Research Foundation.
Figure 5.16: Seismic events, as recorded between 1973 and 2003 at the National Earthquake Information Centre, operated by the US Geological Survey.

Figure 5.17: Geological survey map, indicating lithographic classes of rock structure.
The following horizons were identified in the geotechnical investigation:

- Hillwash
  - Transported hillwash horizon - slightly moist, silty sand, occasionally containing plant roots, fine gravel or traces of calcareous concretions. Occurs over most of the site at a layer depth of 1 m;
  - Aeolian hillwash horizon - silty sand with traces of fine mudstone gravel. Forms shallow dunes in many parts of the site. Thickness varies between 1 m to 2 m, with an average thickness of 1.2 m;

- Alluvial streambed deposits
  - Loose alluvium - loose to medium dense silty sand, with occasional thin bands and lenses (100 mm) of minor to abundant medium sub-rounded platy mudstone and sandstone gravel. Encountered in 12 of the boreholes investigated, and typically extends from ground level to 2 m depth;
  - Cemented or Calcareous alluvium - fine and medium sub-rounded platy mudstone and sandstone gravel, with minor to abundant brown and white calcrete. Encountered in 32 of the boreholes investigated at an average thickness of 3.4 m, but varying from a minimum of 1 m to a maximum of 9 m;

- Calcrete - A calcrete horizon was found in 10 of the borehole investigations, as a transitional layer between alluvial and mudrock horizons. Layer thickness varies between a 1 m and 7 m;

- Residual soils - Only present at two of the borehole investigations. Encountered from 5 m deep with an average thickness of 3 m;

- Mudrock/Shale - Slightly weathered mudstone horizon encountered at 39 of the borehole investigations, from a minimum depth of 0.5 m to 10 m (the maximum depth of the borehole drill sites).

The depths at which each horizon was encountered for all borehole sites are provided in the details of Annexure F4.1. Following laboratory tests, and onsite field measurements, geotechnical parameters have been assigned to the various horizons. These are indicated in Table 5.1.

<table>
<thead>
<tr>
<th>Horizon Description</th>
<th>Comment</th>
<th>High Strain Stiffness E [MPa]</th>
<th>High Strain Stiffness G [MPa]</th>
<th>Small Strain Stiffness E0 [MPa]</th>
<th>Small Strain Stiffness G0 [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper sandy horizon. Aeolian, hillwash and alluvium.</td>
<td>Proved to be incompetent as a founding horizon</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Low strength gravel/calcrete horizon</td>
<td>Significant reduction in strength when saturated. Not considered as good founding horizon for this reason</td>
<td>70</td>
<td>25</td>
<td>150</td>
<td>60</td>
</tr>
<tr>
<td>Gravel and calcrete with interlayered sand.</td>
<td>Some reduction in strength with saturation.</td>
<td>140</td>
<td>55</td>
<td>450</td>
<td>175</td>
</tr>
<tr>
<td>Thick, high strength, solid calcrete</td>
<td>CSW testing in all cases indicates this is a conservative set of design values.</td>
<td>250</td>
<td>100</td>
<td>475</td>
<td>190</td>
</tr>
</tbody>
</table>

Some groundwater seepage was encountered to a limited extent in the area at depths between 6 m and 9 m. These depths will fluctuate with seasonal change. It is clear from the investigations that the sandy soils, which occur at the top of the profile, are low density and highly compressible in nature. Dramatic improvements occur in general at depths of between 2 m and 3 m below the surface.

Figure 5.18 is a subsurface pH map, as a proxy for corrosive minerals, derived from a regression analysis of 5,496 measurement points across South Africa obtained by the ARC-ICSW. An average pH value of 8.4 is recorded across the SKA Core and Skirt region. The map indicates no serious risk of corrosive minerals on the site.
Figure 5.18: Subsurface pH map for the Core site, which can be used as a proxy for corrosive minerals. An average pH value of 8.4 is recorded across the Core and Skirt region.

Water Table

A series of borehole investigations have taken place on the MeerKAT and SKA Core sites. The pertinent information as required by the SSG-RFI on water table depth and flow rates is shown in Table 5.2. Based on the sustainable yields indicated, there will not be a shortfall of water for MeerKAT construction purposes. Further analysis on the full water requirements for the SKA will be necessary in order to determine adequacy.

Table 5.2: Results of borehole investigation (mbgl = metres below ground level; RWL = Recoverable Water Level).

<table>
<thead>
<tr>
<th>Borehole No</th>
<th>Coordinates</th>
<th>Depth [mbgl]</th>
<th>RWL [mbgl]</th>
<th>Sustainable yield [m³/d]</th>
<th>Recovery [l/s@24h/d]</th>
<th>Pump Intake [mbgl]</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA BH01</td>
<td>-30.7548</td>
<td>21.4301</td>
<td>121.08</td>
<td>16.36</td>
<td>8.64</td>
<td>0.10</td>
</tr>
<tr>
<td>WA BH02</td>
<td>-30.7567</td>
<td>21.4301</td>
<td>106.74</td>
<td>14.10</td>
<td>8.64</td>
<td>0.10</td>
</tr>
<tr>
<td>WA BH03</td>
<td>-30.7579</td>
<td>21.4244</td>
<td>120.14</td>
<td>15.12</td>
<td>4.32</td>
<td>0.05</td>
</tr>
<tr>
<td>WA BH04</td>
<td>-30.7101</td>
<td>21.3957</td>
<td>100.31</td>
<td>6.84</td>
<td>12.96</td>
<td>0.15</td>
</tr>
<tr>
<td>WA BH07</td>
<td>-30.7138</td>
<td>21.3961</td>
<td>39.16</td>
<td>7.22</td>
<td>43.2</td>
<td>0.50</td>
</tr>
<tr>
<td>WA BH08</td>
<td>-30.7144</td>
<td>21.3955</td>
<td>100.98</td>
<td>7.26</td>
<td>56.16</td>
<td>0.65</td>
</tr>
<tr>
<td>WA BH11</td>
<td>-30.7161</td>
<td>21.3941</td>
<td>29.40</td>
<td>7.82</td>
<td>8.64</td>
<td>0.10</td>
</tr>
<tr>
<td>WA BH05</td>
<td>-30.7095</td>
<td>21.3951</td>
<td>116.32</td>
<td>7.43</td>
<td>8.64</td>
<td>0.10</td>
</tr>
<tr>
<td>WA BH06</td>
<td>-30.7092</td>
<td>21.3954</td>
<td>115.00</td>
<td>9.12</td>
<td>8.64</td>
<td>0.10</td>
</tr>
<tr>
<td>WA BH09</td>
<td>-30.7121</td>
<td>21.3907</td>
<td>115.30</td>
<td>7.35</td>
<td>4.32</td>
<td>0.05</td>
</tr>
<tr>
<td>WA BH10</td>
<td>-30.7099</td>
<td>21.3919</td>
<td>56.72</td>
<td>11.32</td>
<td>4.32</td>
<td>0.05</td>
</tr>
<tr>
<td>WA BH12</td>
<td>-30.7186</td>
<td>21.4084</td>
<td>112.30</td>
<td>9.81</td>
<td>3.46</td>
<td>0.04</td>
</tr>
<tr>
<td>SKAE5</td>
<td>-30.7170</td>
<td>21.4749</td>
<td>40.81</td>
<td>6.32</td>
<td>86.4</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Detailed water quality information is located in Annexure F4.4. Chemical tests indicate that water treatment would be required for human drinking usage.
Sub-surface Conductivity

Subsurface conductivity of the Core site has been investigated through a series of commissioned surveys for the KAT-7 telescope. Detailed results of soil resistivity measurements (resistivity = 1/conductivity) at various depths are provided in Annexures F3.1, F3.2 and F3.3.

Results of the measurements indicate that soil conductivity, shown in Table 5.3, reduces to a depth of 4.5 m, and then rises to 12 m.

<table>
<thead>
<tr>
<th>Conductivity [mS per metre]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth: 1.5m 3m 4.5m 6m 7.5m 9m 10.5m 12m</td>
</tr>
<tr>
<td>Site A: 5.34 3.52 3.30 3.99 5.66 – 6.89 8.88</td>
</tr>
<tr>
<td>Site B: 4.76 3.28 2.99 3.91 5.34 – 7.73 10.58</td>
</tr>
</tbody>
</table>

Surface and Sub-surface Thermal Profiles

Surface and sub-surface thermal profiles have been measured and modelled in detail, described in Annexure F2. An estimate of the variation in temperature as a function of soil depth is expressed as $dT = dT_{env}e^{-d/D}$, where $dT_{env}$ is the environmental temperature variation and $d$ is the soil depth. $D$ is the scale depth of the soil, expressed as $D = \sqrt{\frac{\eta P}{\rho}}$, where $\eta$ is the soil’s thermal diffusivity, and $P$ the period over which the temperature change takes place.

Using the measured data presented in Annexure F2, and the theoretical model described above, the soil’s thermal diffusivity $\eta$ is calculated as $3.5 \times 10^{-7}$ m$^2$s$^{-1}$, with a scale depth of 0.098 m over a 24 hour period. As the measurement resolution exceeded the temperature variation at depths below 0.5 m, only data at depths of less than 0.5 m were used for fitting of the soil thermal profile model. The expected scaling of diurnal temperature variations, as a function of soil depth, is provided in Figure 5.19.
5.3.3 Severe Weather Events

To correctly analyse the occurrence of severe weather events, which have a long return period, long term datasets are required for interrogation. This was reported on in detail in the South African 2005 SKA Bid Submission, attached in Annexures F1.1 and F1.2. Weather stations with long term datasets that are appropriate for use in this analysis are located in the towns of Van Wyksvlei and Fraserburg.

Table 5.4 summarises the annual occurrence of significant weather events, averaged over data measured between 1995 and 2004. The significant weather events under consideration include lightning, thunderstorms and hail events. Although no size definition is provided for hailstones, first hand observer accounts indicate that hailstones very rarely exceed 5 mm in diameter. The relevant section in Annexure F9.1 provides an average lightning ground flash density per year across South Africa, developed by the South Africa Weather Service. The SKA Core and Skirt region is located in an area that has one to two lightning ground flashes per square kilometre per year.

<table>
<thead>
<tr>
<th>Town</th>
<th>Hail</th>
<th>Thunderstorms/Lightning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Van Wyksvlei</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Fraserburg</td>
<td>4</td>
<td>37</td>
</tr>
</tbody>
</table>

The broader definition of storms includes minor occurrences such as ‘dust devils’. These do not pose any risk of damage, or interruption of standard operational procedures at the SKA Core site. Therefore, only storms and other severe weather events that cause infrastructural damage have been considered. Table 5.5 summarises the total occurrence of severe weather events in the period 1961 to 2004.

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Van Wyksvlei</th>
<th>Fraserburg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding and Flash Floods</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Wind Storms (Dust Storms)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cyclones and Hurricanes</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

An extensive analysis of the risk of flooding, and flash floods, in the Northern Cape province of South Africa is provided in Annexure F1.7.

First hand observer accounts indicate that heavy rainfall on the site may result in some water run-off and subsequent erosion. However, this has been mitigated through maintenance measures, such as the grading of roads where usage is high, the layering of additional material where erosion does occur, and the construction of appropriate water drainage channels at culverts. Approximately 25 mm of rainfall in half an hour is required to observe partial water runoff, such as next to roads that do not have appropriate culverts and drainage systems. Approximately 45 mm of rainfall in half an hour would be required in order to observe heavy runoff. The rainfall statistics provided in this report indicate that this occurs rarely.

The measured wind data (averaged over 10 minute measurement intervals) obtained from the onsite weather station are used to analyse the occurrence of strong winds greater than 50 km/hr. The probability distribution of the measured wind data is provided in Figure 5.20. The dip in distribution near 0.5 m/s is as a result of inertia in the anemometer. Winds greater than 13.9 m/s (50 km/hr) occur less than 0.0016% of the time.

5.4 Variation Along Spiral Arms to 180km

5.4.1 Environmental

Environmental conditions along the five spiral arms of the SKA configuration were characterised by the five nearest ARC-ISCW weather stations, shown in Figure 5.21.

Data have been recorded at these weather stations, and the necessary weather statistics produced, to characterise the spiral arms as follows:
Figure 5.20: Probability distribution of measured wind data, collected in the period 01/01/2005 to 31/03/2011.

Figure 5.21: Nearest ARC-ICSW weather stations to spiral arms of the SKA configuration. A 10 km buffer has been placed on each spiral arm.
A description of the variation in environmental parameters compared to the SKA Core and Skirt region is provided here, with detailed statistics located in Annexure F9.1.

**Temperature**

Analysis indicates that temperature statistics along the spiral arms are consistent with those experienced at the SKA Core and Skirt on a monthly basis. A two to three degree increase in average temperature range is measured along Spiral Arms 3, 4 and 5, and a one to two degree increase along Spiral Arms 1 and 2, compared to the SKA Core and Skirt region. A one to two degree decrease in the minimum, maximum and average temperature is expected along Spiral Arm 2.

**Relative Humidity**

Analysis indicates that relative humidity statistics along the spiral arms are consistent with those experienced at the SKA Core and Skirt on a monthly basis. Although no variation is expected along Spiral Arm 4, a slight increase of 5% in the average and average maximum relative humidity compared to the SKA Core and Skirt region is measured across Spiral Arms 2, 3 and 5, and a slight increase in the average maximum experienced in the winter months across Spiral Arm 1.

**Rainfall**

Rainfall measurement data are measured on an hourly basis. The maximum rainfall burst is on timescales similar, but not directly comparable to that determined for the SKA Core and Skirt region. Analysis indicates that rainfall statistics along all spiral arms are consistent with the SKA Core and Skirt region.

**Dew Point**

Analysis indicates that dew point statistics along the spiral arms follow the same trends as in the SKA Core and Skirt region on a monthly basis. A three to four degree increase in the average and maximum dew point during summer is expected across all spiral arms, with a three to four celsius increase in the average minimum of Spiral Arms 4 and 5.

**Occurrence of Ice Formation, Hailing and Pooling of Water**

Conditions along the spiral arms are consistent with those experienced in the SKA Core and Skirt region. The relevant section in Annexure F9.1 provides an indication of the number of days that frost is experienced across South Africa. This is typically early morning frost that does not persist during the course of the day, with no occurrence of significant ice formation along the spiral arms.

Annual hail occurrence typically increases moving from west to east across South Africa, as illustrated in the relevant section in Annexure F9.1. The SKA spiral arms are located in an area with very low annual occurrence of hail. These range from zero days per year along spirals west of the SKA Core and Skirt region, to two days per year in the east. First hand observer accounts indicate that the occurrence of hail is very short-lived, with the size of hailstones rarely exceeding 5 mm. Thus, no structural damage is expected from hail.

The pooling of water out to 180 km has been addressed in Section 5.3.1.
Cloud Cover

The Global Climate Database was used to interrogate cloud cover conditions across a broader area in Southern Africa. The database contains a number of bright sunshine hours data product, which has been reproduced on a monthly basis for the entire Southern African region in Annexure F9.1. This data product was verified against AQUA satellite data and calibrated against ground-based measurement stations near the SKA Core for comparative purposes.

The SKA Core and Skirt region, together with most of the spiral arms, lies in an area with extremely high annual percentage of bright sunshine hours (79% - 92%) per annum. A 10% decrease in the number of bright sunshine hours is expected at the southern extremities of Spiral Arms 1 and 5.

Wind

Although weather station data is available, the increased sensitivity of wind characteristics to local micro-climates and conditions resulted in the use of modelled data at exact SKA positions, as opposed to extrapolation from weather station data from nearby positions. Synoptic patterns, frontal weather and local conditions have been taken into account in the modelled data, which are based on 12 hour averages over 50 km resolution grids.

In general, Spirals Arms 1, 2 and 4 are consistent with wind in the Core and Skirt region. Average maximum wind reaches between 5 m/s and 6 m/s, with absolute maximum wind speeds reaching between 11 m/s and 14 m/s. Spiral Arms 3 and 5 have a slight increase (5% - 10%) compared to the core across all wind statistics. Wind speeds reach a peak in summer across all spiral arms.

Solar Radiation

Solar radiation does not vary significantly from the SKA Core and Skirt regions.

Airborne Particles and Chemicals

Airborne particles and chemical along the spiral arms and remote stations have been addressed in Section 5.3.1 and Figure 5.15. Aerosol optical thickness is shown to increase slightly in the winter months of June and July at the SKA spiral arms and remote stations, but remains below the global mean. This is most probably as a result of controlled bush and grass burns.

Wildlife

As per the SKA Core and Skirt region, preventative measures may need to be taken to prevent the nesting of sociable weavers in telescope structures along the spiral arms.

Land Restrictions

No restrictions on land due to indigenous use exist at any of the sites in the spiral arms. However, all relevant land is currently privately owned and would need to be acquired for use by the SKA. Processes followed for the acquisition of land for the SKA Core and Skirt region would apply for the spiral arms.

Data from the ‘Succulent Karoo Ecosystem Program’ (SKEP) were used to determine what restrictions as a result of fauna and flora would be required. Although parts of the southern SKA spiral arms intersect with the habitat of the ‘Riverine Rabbit’, this would not impact the construction of SKA stations along the spiral arms. However, some precautionary measures may need to be taken. These would be identified in the relevant Environmental Impact Assessment.

Wild Fires

Using the MODIS Active Fires and Burn Scars dataset to analyse the occurrence of fires and burn scars within 10 km of each of the spiral arms, uncontrolled fires do not pose a risk to any of the stations along the spiral arms.
Physical Characteristics of the Site

Seismic Stability
The seismic activity profile along the spiral arms is consistent with that for SKA Core and Skirt region. One event in 30 years has been detected on Spiral Arm 2, with an indicated magnitude of 4.5. However, as almost all seismic activity in South Africa is a result of deep level mining, and no active mines are located within 180 km of the SKA Core and Skirt region, this event should be treated as unconfirmed at this stage.

5.4.2 Geotechnical

Sub-surface Strata
Sub-surface strata and geotechnical conditions along the spiral arms have been studied in detail, and are not expected to vary significantly from the geotechnical parameters derived for the SKA Core and Skirt region. Detailed results are located in Annexures F12.1 to F12.5. The impact on dish foundations has been quantified in the report on basic infrastructure.

The map of sub-surface pH levels across South Africa, shown in Annexure F9.1, indicate that levels are highest in the SKA Core and Skirt region at an average level of 8.4. This level is expected to decrease by between 5% and 10% across the SKA spiral arms.

Water Table
Water table data, collected from boreholes by the South African Department of Water Affairs, have been considered. Water table levels are consistent with borehole data from the SKA Core and Skirt region. Although flow rates have been provided for very few of the boreholes near the spiral arms, flow rates for boreholes nearest Spiral Arm 1 are significantly higher than measured at the SKA Core site. This indicates adequate ground water supply will be available for construction and operation purposes. The water quality is not expected to be significantly different from the SKA Core and Skirt region.

Sub-surface Conductivity
Conductivity maps for Africa have been used to determine effective ground conductivity in mS/m in Annexure F9.1. VLF band maps, limited in frequencies up to 30 kHz, and MF maps, standardised to 1 MHz, indicate that an average ground conductivity of between 8 to 10 mS/m can be assumed across the SKA spiral arms. The maps contain no allowance for seasonal variation, and have been calculated from geological data used to define boundaries, together with actual conductivity data derived from measurements. Recorded data indicate that at frequencies as high as 1 MHz, seasonal variations will have a negligible influence on conductivity.

Surface and Sub-surface Thermal Profiles
As soil conditions do not vary significantly across the SKA spiral arms, it is likely that surface and sub-surface thermal profiles will be consistent with measurement data in the SKA Core and Skirt region. Detailed on-site fieldwork will be required for confirmation.

5.4.3 Severe Weather Events
Thunderstorm induced lightning activity across the spiral arms increases from one to two lightning ground flashes per kilometre per year to the west of the SKA Core and Skirt region, to two to three ground flashes in the east. As there is a strong correlation between lightning and thunderstorms, it is not expected that thunderstorm activity will deviate significantly from conditions experienced in the SKA Core and Skirt region. Similarly, only limited hail events are to be expected, in line with conditions experienced in the SKA Core and Skirt region. Dust storms are not expected near the spiral arms, as this is extremely rare in South Africa.

The SKA configuration was optimised, taking into account potential floodplains and areas subject to inundation. Considering the rainfall statistics as provided for the SKA Core and Skirt region, there is no significant risk of flooding near the spiral arms. Water runoff plays a strong role in the occurrence of flash floods. A map of South Africa, providing water runoff information, is provided in Annexure F9.1. This map indicates that the SKA Spiral Arms, similarly to the SKA Core and Skirt region, will not be at significant risk for the occurrence of flash floods.
5.5 Variation to Remote Stations

Analysis of the environmental conditions at all remote stations has been provided in Annexure F9.1 and F9.2. Data from ARC-ICSW weather stations is used to characterise environmental conditions at SKA remote stations within South Africa. A combination of modelled and satellite data has been used for analysis of SKA remote stations outside of South Africa (referred to as African SKA remote stations) to ensure uniformity in measurement protocols. The Weather, Research and Forecasting (WRF) model is used for wind modelling, developed through a partnership including the National Oceanic and Atmospheric Administration (NOAA), the National Center for Atmospheric Research (NCAR), and more than 150 other organizations and universities in the United States and abroad. The results of the model have been verified against ground station weather data in South Africa (see Annexure F9.2). The Global Forecast System (GFS) model is used for other meteorological statistics, where appropriate.

Brief mention of the variation of relevant parameters to the SKA Core and Skirt region is made here.

5.5.1 Environmental

Air Temperature

The standard deviation in the monthly difference in average temperature between each South African SKA remote station and the SKA Core and Skirt region has been determined. The standard deviation increases from 0.5 celcius to 2.2 celcius with an increase in baseline distance to the core. Temperature statistics for African SKA remote stations indicate a general increase in average temperature during winter, with a more equatorial climate.

Relative Humidity

The standard deviation in the monthly difference in relative humidity between each South African SKA remote station and the SKA Core and Skirt region has been determined. The standard deviation increases from 2% to 11.7% with an increase in baseline distance to the core. Relative humidity statistics for African SKA remote stations indicate a general increase in the average relative humidity. The highest mean relative humidity will be experienced in Mozambique and Madagascar.

Rainfall

The standard deviation in the monthly difference in mean daily rainfall between each South African SKA remote station and the SKA Core and Skirt region has been determined. The standard deviation increases from 0.31% to 2.18% with an increase in baseline distance to the core. Rainfall statistics for African SKA remote stations indicate a general increase in the average rainfall.

Derived Dewpoint

The standard deviation in the monthly difference in average derived dewpoint between each South African SKA remote station and the SKA Core and Skirt region has been determined. The standard deviation increases from 1.3 celcius to 3.2 celcius with an increase in baseline distance to the core. Modeled dewpoint data are provided in Annexure F9.2 for the African SKA remote stations.

Occurrence of Ice Formation, Hailing and Pooling of Water

The susceptibility of the SKA remote stations to ice formation, hailing and pooling of water is illustrated in Annexure F9.1. In general, the risk of ice formation is very low at almost all SKA remote stations. The pooling of water will require more detailed geohydrological surveys at each site.

Cloud Cover

Analysis of the Global Climate Database indicates a general decrease in the number of sunshine hours at the South African SKA remote stations, with increasing baseline to the SKA Core, compared to the SKA Core and Skirt region. The decrease is approximately 10% to 14% for most of the remote stations, with a further 10% to 14% drop at two remote stations. This trend is expected at the African SKA remote stations, compared to the SKA...
Core and Skirt region. On average, the African SKA remote stations are located in areas that have between 69% and 78%, or 57% to 68%, of bright sunshine hours in the year.

Wind

The WRF model has been used to analyse wind conditions at the South African and African SKA remote stations, and detailed wind statistics can be located in Annexure F9.2. Wind statistics are based on 12 hour averages over 50 km resolution grids. Mean wind speeds at remote stations rarely exceed 4 m/s, and no SKA remote station has a mean wind speed that exceeds 5 m/s. In general, average maximum wind speeds are 1 m/s to 2 m/s higher than the mean wind speed and absolute maximum wind speeds reaching between 8 m/s and 11 m/s for a majority of the remote stations.

The nature of the model statistics is such that peak gusts may not be sufficiently interrogated. Although it is believed that peak gusts at most of the remote stations will not require further analysis at this stage, the remote stations in Madagascar have been selected for such an analysis due to the potential for season tropical storms. Further information is provided in Section 5.5.3.

Solar Radiation

The standard deviation in the monthly difference in mean daily solar radiation between each South African SKA remote station and the SKA Core and Skirt region has been determined. The standard deviation decreases from 3.9 MJ per day per square metre to 1.5 MJ per day per square metre with an increase in baseline distance to core. Solar radiation at the African SKA remote stations is not expected to vary by more than 10% from measurements at the SKA Core and Skirt region, with a general decrease moving from the west of Africa to the east as shown in Annexure F8.3.

Airborne Particles and Chemicals

Airborne particles and chemicals have been addressed in Section 5.3.1.

Wildlife

No SKA remote stations will require special protection measures from wildlife beyond what has been provided in the security plan.

Land Restrictions

No SKA remote stations are located on land that is restricted due to indigenous or other use. All SKA remote stations in South Africa and the African partner countries are currently located on privately owned land, or state land, and would need to be acquired for use by the SKA. Various commitments have been put in place by the African SKA Partner countries regarding the provision of the necessary land for the SKA remote stations.

Wild Fires

Analysis of wild fires near SKA remote stations is provided in Annexure F9.1. 10 km radius zones have been analysed around each SKA remote station. Results indicate that six remote stations have had more than 10 fire signatures within 10 km during the year 2010. It must be noted that in almost all cases, these were controlled burns that happen during the winter months for both the creation of fire breaks and burning off of cultivated land.

Seismic Stability

No significant increase in seismic activity can be identified near the SKA remote stations in South Africa and the African partner countries compared to the SKA Core and Skirt region.
5.5.2 Geotechnical

Sub-surface Strata

The geotechnical conditions for each South African, and African SKA remote station was evaluated in a desktop analysis, and is attached as Annexure F12.5 with supporting Annexures F12.1 to F12.4.

The pH map for South Africa has been used as a proxy for potential corrosive minerals, and is shown in Annexure F9.1. There does not appear to be any significant risk of corrosion at the South Africa SKA remote stations. Analysis of the global soil pH data from the ‘Harmonized World Soil Database’, attached as Annexure F8.4, indicates slightly more alkali conditions expected in Botswana and Namibia, and slightly more acidic levels in Madagascar, compared to the SKA Core and Skirt region.

Water Table

Water table levels have been summarised for each of the South African SKA remote stations in Annexure F9.1. Water table depths, water quality and flow rates have been provided for boreholes nearest the relevant remote station. In some cases, test sites were in excess of 100 km and so should be treated with caution. Accurate water table levels and flow rates at the African SKA remote stations will require detailed borehole investigation.

Sub-surface Conductivity

Ground conductivity maps have been provided in Annexure F9.1, covering all regions that host SKA remote stations. Ground conductivity ranges between 1 mS/m to 10 mS/m.

Surface and Sub-surface Thermal Profiles

No surface or sub-surface thermal profiles have been measured, and would require on-site geotechnical studies for accurate modelling.

5.5.3 Severe Weather Events

Lightning ground flash densities per annum generally increase as one moves towards the North-Eastern interior of South Africa, an area referred to as the ‘highveld’. Lightning activity is typically highest in this region, occurring mostly during summer and associated with summer thunderstorms. The lightning ground flash density per annum map in Annexure F9.1 indicates that no South African SKA remote stations are located near the highest densities experienced in the ‘highveld’, with a maximum density of between five and ten lightning ground flash events per square kilometre per annum experienced at five of the remote stations.

In general, weather conditions across South Africa are benign, and the occurrence of severe weather events will typically not be significantly different from the SKA Core and Skirt region. Storm tracks have been provided for the entire region in Annexure F9.1, providing a comparison with global storm weather conditions. The occurrence of storm cells in the Southern African region is typically well below other regions in the world.

Tropical storms data for the Southern Hemisphere is compiled from the Australian Severe Weather database (http://www.australiansevereweather.com, [Online, August 2011]). A map of tropical storms tracked in the Southern Hemisphere in the 1998 - 1999 storm season is provided as a typical example in Section 6.1 of Annexure F9.1. Tropical storm data, providing tracks and 10 min averaged wind speeds, over Madagascar in the period 1999 to 2011 have been interrogated. The data indicates that, although high wind speeds are measured off-shore, the highest wind speeds measured within 60 km of each of the two remote stations in Madagascar do not exceed 74 km/hr.

Analysis of water bodies indicates that the risk of flooding at any of the SKA remote stations is low. However, more thorough detailed geotechnical and geohydrology surveys will be required in the detailed design phase. Water runoff for South Africa has been provided in Annexure F9.1, and indicates that there is a low risk of the occurrence of flash floods at a majority of the South African SKA remote stations.
Chapter 6

Radio Quiet Zone Protection

This report is in response to the SSG Request for Information (SSG-RFI-001, dated 25 June 2011) on radio quiet zone protection in South Africa, and addresses all items of concern that are listed in the request.

6.1 Executive Summary

During the course of 2005 and 2010, South Africa undertook a radio frequency measurement campaign in collaboration with the International SKA Project Development Office (later the Square Kilometre Array Project Development Office). The results of these measurement campaigns confirmed the South African SKA site as one of the best sites in the world for establishing a radio astronomy facility.

The South African Square Kilometre Array Project Office (SASPO) has been engaged with the telecommunications industry, including the private, public and government sectors, since October 2003. During this period, it has established an excellent working relationship with all relevant stakeholders and received growing support for its initiatives from industry and to the highest levels of government. These initiatives centred around the establishment of a scheme that would not only ensure the protection of radio astronomy observations by the Square Kilometre Array (SKA) in South Africa, but also dramatically improve the existing radio frequency environment at the SKA site. As a result, SASPO has achieved a number of successes that will result in the best protected radio frequency environment in the world for the SKA. These are highlighted below:

1. **Astronomy Geographic Advantage Act (Act No. 21 of 2007)**: The promulgation of the Astronomy Geographic Advantage (AGA) Act has resulted in the most forward-looking and comprehensive piece of legislation in the world that has as its main objective the protection of astronomy. The legislation not only provides power to the Minister of Science and Technology to prohibit any further activities and new infrastructure that could result in detrimental interference to astronomy facilities, but also to require amendment or discontinuation of existing activities and infrastructure to bring about the improvement of the radio- or optical- astronomy environment. These legislative requirements cover both licensed and exempted (type approved) transmitting equipment, as well as any activities and infrastructure making use of equipment that may generate radio frequency interference.

2. **Interim Regulations Advisory Committee (IRAC)**: The establishment of the IRAC ensured buy-in and support from all relevant stakeholders in the telecommunications industry during the drafting of declarations and regulations. From within the IRAC were established informal Stakeholder Groups to determine engineering solutions for the mitigation of existing radio frequency interference at the SKA Core Site.

3. **Stakeholder Groups for RFI Mitigation**: The establishment of smaller stakeholder groups allowed for the development of engineering solutions for the mitigation of radio frequency interference, and the improvement of the existing radio frequency environment for radio astronomy. This improvement will be enforceable by law as a result of the AGA Act. These stakeholder groups include the following:

---

1 For the purposes of this report, radio frequency interference includes both the interference generated from radio transmitting equipment and the electromagnetic interference generated from electrical equipment, unless stated otherwise.
• Mobile and Fixed Line Operators: including GSM operators Vodacom (owned by Vodafone) and MTN, as well as the former state telecommunications company Telkom and the second national operator Neotel;

• Broadcasting: including the National Association of Broadcasters (NAB), the South African Broadcasting Corporation (SABC), Sentech (signal distributor), Orbicom/Multichoice, the Independent Communications Authority of South Africa (ICASA), and the Department of Communications (DOC);

• State Utilities: including Transnet (state railway utility) and Eskom (state electricity generation and distribution company);

• Aviation: including the Civil Aviation Authority (CAA) and the Air Traffic Navigation System (ATNS) company.

SASPO meets with these groups approximately three to four times per year on an individual basis, depending on the need.

4. Phased GSM Antenna System: The existing signal coverage for access to GSM-based mobile telecommunications services in the Northern Cape Province is very sparse. In order to further reduce the impact of GSM signals in the area around the SKA, which have been measured as having the highest signal power levels at the SKA Core Site (this signal level is still too weak to provide access to a telecommunications service), Vodacom (a major GSM operator in South Africa, majority owned by Vodafone) established a research program within their company to design and develop a phased antenna system for use by GSM mobile operators. Use of this antenna enables nulls of up to 40 dB to be pointed in the direction of an SKA station, and will result in significantly lower GSM signal levels at the SKA Core Site. This program was established to ensure compliance with regulations promulgated in terms of the AGA Act. In support of the SKA, Vodacom has made the antenna design available to all GSM mobile operators in the area at no cost.

5. Low Power Digital Broadcasting Plan: The migration of terrestrial television from analogue to digital transmission in South Africa enabled SASPO and the Department of Science and Technology, together with the Broadcasting Stakeholder Group (BSG), to develop a broadcasting plan for the Northern Cape Province in South Africa that would result in dramatic improvements in the radio frequency environment at the SKA location. Implementation of this plan will result in the following in the protected areas around the SKA Core Site:

- VHF-FM Radio (87.5 to 108 MHz): Migration of existing radio services between 100 MHz and 108 MHz to below 100 MHz leaving the spectrum above 100 MHz unused
- VHF-TV (174 to 254 MHz): Discontinuation of the use of this band for broadcasting following digital migration
- UHF-TV (470 to 862 MHz): Discontinuation of the use of this band for broadcasting, except for two approved 8 MHz wide channels for low power digital broadcasting. All low powered broadcasting sites in the protected areas would have two co-channel allocations for improved spectrum efficiency. Studies by Sentech indicate that the received spectral power flux density in the two approved channels would not exceed the required protection threshold levels for radio astronomy at the SKA Core Site. Access to television broadcasting services in outlying areas would be via digital direct-to-home satellite transmissions.

An alternative scenario that has been proposed by the Department of Communications sees the complete removal of all terrestrial broadcasting transmitters in the protected areas, with access to television broadcasting services in both rural and urban areas provided by existing direct-to-home satellite transmissions. In both scenarios, the migration to satellite reception will be facilitated through a Department of Communications policy decision to provide access to subsidy funding through the Universal Service and Access Fund (see paragraph 2.1.4 in Annexure E5.6.2 for the Draft Policy Amendment, to be accepted by the South African Cabinet in August 2011) as a result of the SKA protection requirements.

6. High Level Support: The establishment of a protected area for the purposes of radio astronomy could not be fully realised without the support of key governmental stakeholders within the telecommunications industry. In particular, this support has allowed for the development and approval of plans to establish either one of the two broadcasting solutions described in the item above, as well as the policy decision to provide access to subsidy funding for migration to satellite reception as a result of the SKA protection requirements.
7. **Transnet Ltd**: Transnet Ltd is the incumbent state railway utility, and operates a railway line between Sishen iron ore mine, and the Port of Saldanha. Part of this line intersects with the protected area, approximately 150 km north of the SKA Core site. At Transnet’s own cost, one million euros have been spent on the upgrade of their radio communication system to reduce potential radio frequency interference at the SKA Core site. This upgrade includes lowering of antenna mast heights, replacement of omni-directional antennas with directional antennas, and reduction of transmit power in the direction of the SKA.

8. **Establishment of Alternative Mobile Communications Network**: SASPO has committed to establishing a trunked mobile communications network in the band 66 MHz to 88 MHz. This system would serve as a consolidated platform for existing mobile communication network requirements, including government, private and public sector, that operate in a variety of bands such as the GSM band. This would reduce spectrum use by mobile telecommunication service providers across the operating frequency range of the SKA due to increased spectrum efficiency and the use of a common mobile communications platform. The first phase of this network is in place, providing emergency communication services.

9. **New Facilities**: The creation of a protected, pristine area for radio astronomy observations has been significant in attracting new international radio astronomy facilities to the area. These include:

   - **Precision Array for Probing the Epoch of Re-ionisation (PAPER)** - The successful commissioning of the PAPER telescope in the protected area, operating between 100 MHz and 200 MHz, has supported the positioning of the South African SKA Core site as an outstanding low frequency radio astronomy site.
   - **C-Band All Sky Survey (C-BASS)** - The international C-BASS project will operate in the 4.5 GHz to 5.5 GHz band near the SKA Core site. Only a radio frequency environment that can support next generation radio astronomy facilities will provide the required scientific integrity to produce the necessary data results.

The South African protection scheme is more comprehensive, and covers a broader spectrum of requirements, than any other comparable existing or proposed protection schemes for new radio astronomy facilities. The factors that result in this overwhelming advantage are:

1. **Creation of protected areas**: The South African frequency dependant protected areas are larger than any other existing or proposed protected areas worldwide;

2. **Protection levels**: The South African radio astronomy protection threshold levels are an order of magnitude more sensitive than any other existing protection schemes for other potential SKA sites;

3. **Methodology to protect allocated spectrum**: The South African methodology of protection is stronger and provides for more variation than any existing or proposed protection schemes. This is necessary to address the wide variety of potential sources of interference, from electricity generation and transmission infrastructure to television broadcasting transmitters;

4. **Provisions to deal with existing services**: The South African provisions would apply to both existing and new transmissions, resulting in amendment requirements to existing transmissions that are enforceable by law;

SASPO is supported in all engagements by the South African Department of Science and Technology.

### 6.2 Introduction

The Southern African protection philosophy for the SKA is based on a multi-pronged approach. It relies on specialised and dedicated legislation and regulatory regimes in South Africa where the SKA Core, Intermediate and some Remote stations are planned. Within the African SKA Partner Countries, where the remainder of the Remote stations are located, reliance will be on local legislation and regulatory regimes.

As legislation forms the core of the protection scheme for the SKA, it is dealt with first in this report.
6.3 Legislation (Item 3 of SSG-RFI-001)

South Africa recognised in October 2003 the necessity to protect radio astronomy observations by the SKA. A study was carried out of the International Telecommunication Union recommendations in respect of radio astronomy, of the local broadcasting and telecommunications regulatory regime, and of improvements required for the SKA. It was concluded that long term robust support by means of legislation or policy direction was required, together with the amendment of broadcasting and radio communications policy, to provide for the SKA. The decision was made to adopt the legislative route, and to promulgate specialised legislation for all forms of astronomy. South Africa also participated in the SKA Task Force on Regulatory Issues and contributed to SKA Memo 73 on Spectrum Protection Criteria for the SKA.

6.3.1 Astronomy Geographic Advantage Act (Act No. 21 of 2007)

The Astronomy Geographic Advantage (AGA) Act was adopted in 2007 as a comprehensive long term instrument to protect astronomy in all its forms in South Africa, in particular but not limited to the Northern Cape Province, which exhibits outstanding natural advantages for astronomy.

When the AGA Act (Bill) was drafted, an extensive consultation process was embarked on. All major public and private stakeholders in the electronic communications sector and government departments were approached and requested to submit comments on the draft Bill. This was followed by a personal approach to the key stakeholders. Finally, the Department of Science and Technology (DST) convened an Interim Regulations Advisory Committee (IRAC) with 25 delegates representing the stakeholders. A copy of the terms of reference for the IRAC, and its membership, is included as Annexure E3.1.

A series of six meetings was held during 2008. Initially the IRAC made input into the draft Bill, but later worked on drafting regulations to be made to implement the provisions in the AGA Act. The AGA Bill was published for public comment by the Department of Science and Technology. The Parliamentary Portfolio Committee on Science and Technology and the National Council of Provinces held public hearings before deliberating and finalising the Bill for adoption by the National Assembly.

A copy of the AGA Act, as published in the Government Gazette, is attached in Annexure E1.0. The Act was made operational by the South African President on 24 April 2009. The proclamation making the AGA Act operational is attached in Annexure E1.1.

The AGA Act is an all-encompassing Act, and addresses a wide range of issues that concern the development of astronomy in South Africa. These are highlighted in the Objects of the AGA Act, summarised as follows:

1. Provide measures to advance astronomy and related scientific endeavours;
2. Develop skills, capabilities and expertise;
3. Identify and protect areas in which astronomy projects can be undertaken;
4. Provide a framework for the establishment, protection, preservation and maintenance of a national system of Astronomy Advantage Areas highly suitable for astronomy;
5. Regulate activities which cause or could cause interference;
6. Provide for the declaration and management of Astronomy Advantage Areas;
7. Enable the Minister to participate in efforts to preserve the South African astronomy advantage and coordinate astronomy in the area.

In the implementation of the AGA Act and its regulations, issues of coexistence and participation within the South African telecommunications environment are relevant, and are discussed below.

1. Co-existence

(a) Conflicts with other legislation

The AGA Act provides for possible conflict with other legislation, in that it states that the AGA Act will prevail if the conflict with other national legislation specifically concerns the management or development of the relevant area, or the protection of such an area from radio frequency interference or any other matter lawfully restricted within the area.
(b) Electronic Communications Act (ECA) and the Independent Communications Authority of South Africa (ICASA) Act

Electronic communications in South Africa are regulated by the ECA and the ICASA Act. Copies of the ECA and of the ICASA Act are attached as Annexures E2.1.2 and E2.1.3 respectively. The ECA is an enabling act that maximises the use of electronic communications. It is therefore in conflict with the AGA Act, which restricts electronic radio communications to gain the necessary protection and will prevail where the required conditions exist as per the preceding item.

The AGA Act provides for interaction with ICASA by imposing certain obligations, and requires that concurrence is obtained from ICASA on matters related to broadcasting. For example, the AGA Act requires that ICASA must not issue any broadcasting service licence or radio frequency spectrum licence where it would cause interference within a Core or Central Astronomy Advantage Area, unless protection conditions are set out in the licences. Special arrangements between the SASPO, Department of Science and Technology, and ICASA make it possible to ensure active coordination on matters concerning the SKA. See Section 6.7.2 for further details.

(c) Radio telecommunication services

The SKA Core site has been placed in a sparsely population region in South Africa, where demand for radio telecommunication services is very low. South African radio network operators recognise the value of the SKA and willingly contribute to the creation of the best possible radio frequency protected area for radio astronomy. This support has enabled the optimisation of the radio frequency environment for radio astronomy at the SKA Core site. This is achieved through the use of appropriate technology and engineering for telecommunication services where they are required in localised settlements.

2. Participation in ICASA inquiries

ICASA conducts public enquiries from time to time on various matters, including the national radio frequency plan, the terrestrial broadcasting frequency plan and the digital terrestrial television regulations. The DST and the SASPO have participated actively by responding to the enquiries, submitting written representations and making oral representations to state the requirements for the protection of the SKA, and propose methods of coordination. A summary of the DST and SASPO interaction with ICASA is attached as Annexure E3.2.

6.3.2 Features of the AGA Act

The AGA Act provides for a wide range of requirements for the advancement and protection of astronomy. These provisions are discussed in a summary description of the features of the AGA Act in Annexure E1.2, and are further summarised into focus areas as follows:

1. Protection scheme with tiered structure of Astronomy Advantage Areas (AAAs) - A progression of three classes of protected areas is declared. The Core AAA is declared around the immediate vicinity of the astronomy facility, and may be surrounded by one or more Central AAAs followed by one or more Coordinated AAAs. This scheme is designed to provide the highest level of protection in the Core AAA, with a gradual lessening of the restrictions on potential sources of interference in the other two categories of protected AAAs.

2. Astronomy Management Authority - The establishment of a management authority to whom the declared AAAs are assigned, with specified duties to ensure the prescribed protection of the AAAs. The National Research Foundation is obliged to monitor and report on the status of AAAs and protection thereof.

3. Empowerment of Minister of Science and Technology - The Minister is empowered to make regulations on a broad range of matters affecting radio astronomy. These include a wide range of protection measures such as:

   (a) Regulations that provide for the protection of the radio frequency spectrum for radio astronomy purposes within the declared Core and Central AAAs. This protection is provided against all licensed transmitting equipment, as well as unlicensed equipment that may produce electromagnetic interference, such as power generation and transmission infrastructure, as well as mining and exploration activities.

---

2The South African protection scheme does not use the terminology ‘radio quiet zone’ but rather uses that of an ‘Astronomy Advantage Area’ (AAA). The concept of an AAA and the tiered structure of the AAAs are fully explained in this report.
(b) Regulations that restrict any activities within Core and Central AAAs that may be harmful to radio astronomy observations totally or subject them to prescribed standards and conditions.

(c) Regulations that apply prescribed standards or conditions to notified activities within Coordinated AAAs that may be harmful to radio astronomy, in particular radio frequency interference from fixed sources.

(d) Regulations that restrict over-flights of aircraft in the Core and Central AAAs.

(e) Regulations that define national standards for the protection of radio astronomy observations.

The AGA Act provides for further measures not directly linked to radio frequency protection that support and facilitate the establishment of radio astronomy facilities in AAAs. These include rights to land acquisition, rights of way, permit applications for construction of infrastructure and other such general measures. As an example, the designation of a facility, including the associated infrastructure such as fibre optic networks, as an astronomy device makes it exempt from the requirements of the ECA with respect to licenses for the construction and operation of a wide area fibre optic data network.

6.3.3 AGA Act Declarations and Regulations and Timelines (Item 2 of SSG-RFI-001)

The protection scheme for a radio astronomy facility is established through the promulgation of appropriate declarations and regulations made in terms of the AGA Act. The specific geographical areas to be protected are determined in declarations, and the protection measures and procedures to be applied within the declared areas are prescribed in regulations.

Declarations and regulations for the protection of the SKA, and its pre-cursor instrument MeerKAT, are listed in Table 6.1 in chronological order with relevant annexure references. The current status of the making of the listed declarations and regulations is provided in the last column of the table, while summary descriptions are provided in Annexure E1.3.

The required letters of concurrence from ICASA on the SARAS protection level standard and the Karoo Core Astronomy Advantage Area regulations are provided in Annexures E1.6.1 and E1.7.4 respectively. The technical features of the declared AAAs, and the required protection levels, are discussed further in Section 6.4.

Following the promulgation of the declarations and regulations described in Table 6.1, the required protection within the declared AAAs is implemented by the Astronomy Management Authority in a two-stage process. The first stage of implementation involves a review of all existing infrastructure and activities for which regulations have been promulgated. This includes:

- radio telecommunication infrastructure;
- power generation and transmission infrastructure;
- transport infrastructure;
- mining and exploration activities;
- heavy industry;

and any other activities that may result in the generation of radio frequency interference.

This review will result in the issue of compliance certificates where the radio communication, or other infrastructure or activity, meets the protection requirements of the SKA; or in requests for exemption of the radio communication, or other infrastructure or activity, to comply with the protection requirements. Operators of the infrastructure or activity are required by law to carry out the modifications required to comply.

In reality, the SKA configuration has been optimised to minimise the potential radio frequency interference risk associated with transport infrastructure, towns and dwellings, and power generation and transmission infrastructure. Therefore, existing infrastructure is considered to be SKA compliant on aspects excluding radio communications. However, the various operators of radio communication infrastructure will, where required, need to modify the transmission characteristics of existing transmitters. The various improvements that have taken place thus far in the process, including the development of a phased antenna system for GSM radio communication...
Table 6.1: List of AGA Declarations and Regulations with Timelines

<table>
<thead>
<tr>
<th>Category (Annexure)</th>
<th>Name and Purpose of Declaration or Regulation</th>
<th>Date Promulgated or Published</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declaration (E1.4)</td>
<td>Northern Cape Province to be an Astronomy Advantage Area in terms of Section 5 of the AGA Act</td>
<td>Done on 19 February 2010</td>
</tr>
<tr>
<td>Declaration (E1.7.1)</td>
<td>Karoo Core Astronomy Advantage Area</td>
<td>Done on 20 August 2010</td>
</tr>
<tr>
<td>Declaration (E1.5)</td>
<td>MeerKAT and SKA to be astronomy and related scientific endeavours in terms of the AGA Act</td>
<td>Done on 15 October 2010</td>
</tr>
<tr>
<td>Declaration (E1.7.2)</td>
<td>DST as the Management Authority for the Karoo Core Astronomy Advantage Area</td>
<td>Done on 3 December 2010</td>
</tr>
<tr>
<td>Regulations (E1.6.0)</td>
<td>South African Radio Astronomy Service (SARAS) Protection Level Standard (Draft for public comment)</td>
<td>Due in July 2011</td>
</tr>
<tr>
<td>Regulations (E1.7.3)</td>
<td>Core AAA regulations for protection w.r.t. frequency spectrum use and harmful activities (Draft for public comment)</td>
<td>Due in July 2011</td>
</tr>
<tr>
<td>Declaration (E1.8.1)</td>
<td>Karoo Central Astronomy Advantage Areas (1 to 3) (Draft for public comment)</td>
<td>Due in July 2011</td>
</tr>
<tr>
<td>Regulations (E1.8.2)</td>
<td>Radio Astronomy Administrative Procedures Regulations for central AAAs</td>
<td>Due in August 2011</td>
</tr>
<tr>
<td>Regulations (E1.8.3)</td>
<td>Karoo Central AAAs Regulations with respect to radio communications</td>
<td>Due in August 2011</td>
</tr>
<tr>
<td>Regulations (E1.8.4)</td>
<td>Karoo Central AAA Regulations with respect to electricity generation, transmission and distribution</td>
<td>Due in August 2011</td>
</tr>
<tr>
<td>Regulations (E1.8.5)</td>
<td>Karoo Central AAA Regulations with respect to prospecting and mining</td>
<td>Due in August 2011</td>
</tr>
<tr>
<td>Declaration (E1.9.1)</td>
<td>Karoo Coordinated AAAs (1 and 2)</td>
<td>Due in November 2011</td>
</tr>
<tr>
<td>Regulations (E1.9.2)</td>
<td>Karoo Coordinated AAA regulations for high power radio communications</td>
<td>Due in December 2011</td>
</tr>
<tr>
<td>Regulations (E1.10)</td>
<td>Astronomy Management Authority Regulations</td>
<td>Due in July 2011</td>
</tr>
</tbody>
</table>
services and the planning for a low power terrestrial television broadcasting solution, have been preemptive of the process to ensure compliance when reviewed. Further discussion of this aspect is provided later in this report. The implementation of improvements will occur over a period of time following the review, but the objective is that it will be completed in time for the relevant observations to commence.

Following the review process, the second stage will be where the AAAs will be managed on an on-going basis in accordance with the relevant regulations, where all new radio telecommunication and other infrastructure and activities will be subject to the protection requirements of the SKA and will be subject to compliance certification by the Astronomy Management Authority before the activity commences.

6.3.4 Communications Legislation in African SKA Partner Countries

All legislation with respect to electronic communications, telecommunications, information technology and broadcasting in the African SKA partner countries is listed with its key features in Annexure E2.0. The legislation provides the full legislative and regulatory powers required to efficiently manage spectrum in each of the African SKA partner countries, and to establish the necessary protection scheme for each of the SKA remote stations when constructed. Further discussion on the protection scheme is provided in Section 6.5.4.

The relevant pieces of legislation for each of the African SKA partner countries are attached in annexures as listed in Table 6.2.

6.3.5 Operation, Management and Enforcement

The operation of astronomy facilities, insofar as the government has a responsibility, will be the responsibility of the National Research Foundation (NRF), which operates in terms of the National Research Foundation Act (Act No. 23 of 1998). A copy of the NRF Act is attached as Annexure E3.3. Duties of the NRF in terms of the AGA Act are prescribed in Section 47 of the AGA Act.

The AAAs for the SKA will be managed by the Astronomy Management Authority, although the AGA Act allows for more than one management authority to be established if it is required for different declared AAAs. The Astronomy Management Authority is located in the Department of Science and Technology under the control of the Chief Director: Radio Astronomy Advances. The Astronomy Management Authority will operate in terms of the AGA Act and the Management Authority Regulations. The draft regulations are attached as Annexure E1.10. Functions ascribed to the Minister in the AGA Act may be delegated to the Astronomy Management Authority where the AGA Act permits.

The AGA Act makes provision in Section 18 that the Management Authority of a Core or Central AAA may enter into a co-management agreement with another entity to co-manage the area, and regulate human activities that affect astronomy. The co-management agreement may provide for occupation of the area or portions thereof, and prohibitions or restrictions on the use of any interference source. These may include mobile radio interference sources, short range devices and equipment or instruments that may cause radio frequency interference or have other detrimental impacts.

Enforcement of the AGA Act is substantially provided for in the Act and promulgated regulations. Enforcement would be carried out by the Astronomy Management Authority or Authorities, by the NRF where monitoring is involved, and by the National Prosecuting Authority where offences are involved. A description of the enforcement structure is provided in Sections 13, 14 and 16 of Annexure E1.2. The communications laws for the other participating African countries all make provision for enforcement of the provisions of their legislation as referred to in Annexure E2.0.

The AGA Act can only be repealed or amended by the National Assembly (Parliament) of South Africa but such a process will also be governed by the South African Constitution in terms of any vested rights and by other legislation such as the Promotion of Administrative Justice Act (Act No. 3 of 2002). The declarations made in terms of the AGA Act can be withdrawn or a part of a declared area can be excluded by the Minister as prescribed in the AGA Act Sections 8, 10 and 12 where the purpose of the declaration is no longer necessary. Regulations may also be repealed or amended by the Minister. The declaration of AAAs or the making of regulations by the Minister cannot be delegated.
### Table 6.2: List of Legislation for the African SKA Partner Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Annexure</th>
<th>Legislation or Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Africa</td>
<td>E2.1.1</td>
<td>Broadcasting Act</td>
</tr>
<tr>
<td>South Africa</td>
<td>E2.1.2</td>
<td>Electronic Communications Act</td>
</tr>
<tr>
<td>South Africa</td>
<td>E2.1.3</td>
<td>Independent Communications Authority of South Africa Act</td>
</tr>
<tr>
<td>South Africa</td>
<td>E2.1.4</td>
<td>Radio Frequency Spectrum Regulations</td>
</tr>
<tr>
<td>Botswana</td>
<td>E2.2.1</td>
<td>Broadcasting Act</td>
</tr>
<tr>
<td>Botswana</td>
<td>E2.2.2</td>
<td>Telecommunications Act</td>
</tr>
<tr>
<td>Botswana</td>
<td>E2.2.3</td>
<td>Broadcasting Regulations</td>
</tr>
<tr>
<td>Botswana</td>
<td>E2.2.4</td>
<td>Telecommunications Regulations</td>
</tr>
<tr>
<td>Ghana</td>
<td>E2.3.1</td>
<td>National Communications Authority Act</td>
</tr>
<tr>
<td>Ghana</td>
<td>E2.3.2</td>
<td>Electronic Communications Act</td>
</tr>
<tr>
<td>Ghana</td>
<td>E2.3.3</td>
<td>National Communications Regulations</td>
</tr>
<tr>
<td>Kenya</td>
<td>E2.4.1</td>
<td>Information and Communications Act</td>
</tr>
<tr>
<td>Kenya</td>
<td>E2.4.2</td>
<td>Radio Communications and Frequency Spectrum Regulations</td>
</tr>
<tr>
<td>Madagascar</td>
<td>E2.5.1</td>
<td>Decree No 97-1077 - Malagasy Office of Telecommunications Studies and Regulation (French version and English translation of Article 1)</td>
</tr>
<tr>
<td>Madagascar</td>
<td>E2.5.2</td>
<td>Act No. 2005-023 of 17 October 2005 revising Act No. 96-034 of 27 January 1997 on the institutional reform of the Telecommunications sector (French version and English translation of Articles 18 and 19)</td>
</tr>
<tr>
<td>Madagascar</td>
<td>E2.5.3</td>
<td>Decree No. 99-228 on the regulation and management of radioelectric frequencies and frequency bands (French version and English translation of all except Articles 32-36, 56-60 and 81-83)</td>
</tr>
<tr>
<td>Mauritius</td>
<td>E2.6.1</td>
<td>Independent Broadcasting Authority Act</td>
</tr>
<tr>
<td>Mauritius</td>
<td>E2.6.2</td>
<td>Information &amp; Communication Technologies Act and Amendment Act</td>
</tr>
<tr>
<td>Mozambique</td>
<td>E2.7.1</td>
<td>Telecommunications Act (Translated version in English Original in Portuguese)</td>
</tr>
<tr>
<td>Mozambique</td>
<td>E2.7.2</td>
<td>Decree No.36/2009 Regulations for radio communications (English translation of all except Articles 29-33 and 35-40; plus full Portuguese version)</td>
</tr>
<tr>
<td>Namibia</td>
<td>E2.8.1</td>
<td>Communications Act</td>
</tr>
<tr>
<td>Zambia</td>
<td>E2.9.1</td>
<td>Independent Broadcasting Authority Act</td>
</tr>
<tr>
<td>Zambia</td>
<td>E2.9.2</td>
<td>Information and Communications Technologies Act and Amendment Act</td>
</tr>
</tbody>
</table>
6.4 Technical Properties (Item 1 of SSG-RFI-001)

6.4.1 South African Radio Astronomy Service (SARAS) Protection Levels

A national standard specifying the protection levels for radio astronomy observations has been developed in South Africa for the frequency spectrum between 70 MHz and 25.5 GHz. The protection levels are derived using the methodology approved in Recommendation ITU-R RA.769-2, while interpolating system and receiver temperatures and assuming a 1% receiver bandwidths in order to derive a continuous function for threshold levels across the entire band. A piecewise linear function is used to describe the SARAS standard, shown in Figure 6.1, using a best-fit algorithm of the derived levels.

![South African RAS Protection Levels](image)

**Figure 6.1:** South African Radio Astronomy Service standard, derived from the methodology outlined in Recommendation ITU-R RA.769-2.

The standard will be promulgated in accordance with Section 37 of the AGA Act. A copy of the draft regulation is provided in Annexure E1.6.0, with the required concurrence from ICASA on the SARAS regulation provided in Annexure E1.6.1. In order to limit the level of radio frequency interference over a greater geographical area, limits on emissions are included in the regulations governing the protection in the Karoo Core and Central AAAs, as described respectively in items 5 and 6 in Annexure E1.3.

6.4.2 Protected Astronomy Advantage Areas

The Northern Cape Province has been proclaimed as an Astronomy Advantage Area, in terms of Section 5 of the AGA Act (see Annexure E1.4). The farms Losberg and Meys Dam, totalling 14,000 hectares in area, have been proclaimed as the Karoo Core Astronomy Advantage Area. The MeerKAT and SKA Cores are located on these two farms.

Three frequency dependent Karoo Central Astronomy Advantage Areas (KCAAs) are to be declared according to the schedule in Table 6.1, and are illustrated in Figure 6.2. Regulations for the KCAAA1, KCAAA2 and KCAAA3 apply to the frequency bands 70 MHz - 1710 MHz, 1710 MHz - 6000 MHz, and 6000 MHz - 25500 MHz respectively. The size and shape of the KCAAs have been determined taking into consideration local topography, which has a significant attenuating effect on radio propagation (especially at high frequencies). The total protected area for the KCAAA1, KCAAA2 and KCAAA3 are 123,456 km$^2$, 79,963 km$^2$ and 44,602 km$^2$ respectively.

Figures 6.3 and 6.4 indicate the Karoo Coordinated Astronomy Advantage Areas 1 and 2, which surround the KCAAA1 and KCAAA2 respectively. The total protected area for the KCoAAA1 and KCoAAA2 are 372,889...
Figure 6.2: Karoo Central Astronomy Advantage Areas 1, 2 and 3 for radio astronomy.

km² and 43,493 km² respectively.

6.4.3 Protection Reference Location within the Protected Area

All reviews and assessments are performed with respect to the protection levels described in Section 6.4.1 at pre-defined reference locations located within the particular Core AAA. In the case of the SKA, this is the Karoo Core AAA where the SKA Core will be located. The protection reference point is referred to as the Karoo Core Centre (21.3880 degrees East and 30.7148 degrees South) at a height of 10 metres.

Regulations that protect the SKA from broadband electromagnetic interference, in particular from power generation and transmission infrastructure (Annexure E1.8.4), and from mining and prospecting activities (Annexure E1.8.5), use SKA stations within the KCAAA1 as reference locations and define required separation distances from each station.

Finally, all stations within the KCAAA1 will be protected reference locations for signals that may cause saturation (see Section 6.4.4).

6.4.4 Exceptions

Exceptions in the application of the protection levels will be made where all options to reduce radio frequency interference have been exhausted. This process is defined in the regulations, and only applies to essential and/or safety-of-life radio communication services. In no cases will it be permitted that the approved radio frequency interference level exceeds the saturation level at any SKA station, defined in regulations as -120 dBm/Hz.
Figure 6.3: Karoo Coordinated Astronomy Advantage Area 1 for radio astronomy.

Figure 6.4: Karoo Coordinated Astronomy Advantage Area 2 for radio astronomy.
6.5 Spectrum Management (Item 4 in SSG-RFI-001)

6.5.1 Organisation of Spectrum Management

Information is provided on four separate areas of spectrum management: government spectrum policy in South Africa; information on the provisions for spectrum management in legislation in the participating African countries; spectrum management for broadcasting that has a substantial impact on the RFI environment; and lastly provisions in the AGA Act in South Africa on the use of the frequency spectrum.

1. Radio Frequency Spectrum Policy for South Africa

The National Radio Frequency Spectrum Policy for South Africa was promulgated by the Minister of Communications by notice in the Government Gazette on 16 April 2010. Key policy statements on scientific research and on radio astronomy cover the need to provide and protect frequency spectrum for this purpose. The references and summaries of the policy statements are provided in Section 2 of Annexure E5.0, with a copy of the published policy included as Annexure E5.1.


Provisions for spectrum management in legislation and promulgated regulations for the African SKA Partner Countries are listed in Section 3 of Annexure E5.0, together with references to the key provisions. A descriptive summary of the regulatory measures in the legislations for radio frequency spectrum management is also provided in the annexure.

In South Africa, the ICASA Special SKA Committee has agreed that new or renewed (annually) frequency spectrum licences will include a provision to state the requirement to comply with the AGA Act in the Northern Cape Province.

3. Terrestrial Broadcasting Frequency Plans

The terrestrial broadcasting frequency plan for South Africa, published by ICASA in 2009 (see Annexure E5.4), was compiled using a common approach for the whole country. As such, it includes frequency assignments for the Northern Cape Province, only some of which are operational, that are incompatible with protection requirements for radio astronomy in this area. The plan makes key statements on pages 8, 31 and 32 regarding the SKA -

all existing and new assignments/allotments in the frequency bands depicted in Table 1 (all terrestrial broadcasting Bands) for the Northern Cape Province will be subjected to the restrictions prescribed by the Astronomy Geographic Advantage Act.

In order to ensure compliance with the declarations and regulations made, or to be made, the ICASA Special SKA Committee together with the Department of Communications, National Association of Broadcasters, the national signal distributor Sentech, South African Broadcasting Corporation and SASPO, undertook studies to determine the required mitigation for protection of radio astronomy in the following broadcasting bands: VHF-FM (87.5 MHz to 108 MHz), VHF-TV (174-254 MHz) and UHF-TV (470 MHz to 862 MHz) (see Section 6.6.1 for further discussion on future improvements in the broadcasting band). The mitigation measures have been incorporated in the draft AGA regulations, and would be required as a result of the first stage review process following the promulgation of the declarations and regulations as listed in Table 6.1.

ICASA has been formally requested, as a pre-emptive action, to amend the terrestrial broadcasting frequency plan (see Annexure E5.4.1), following discussions with ICASA and the Department of Communications. Annexure E5.4.4 is a letter from ICASA, confirming that the required amendments would be undertaken.

An overview of broadcasting frequency assignments and the amendments requested from ICASA is provided in Annexure E5.2, as well as the relevant ITU Regional Agreements for VHF-FM, analogue television and digital television broadcasting in Annexures E5.3.1, E5.3.2 and E5.3.3 respectively.

4. Provisions in the AGA Act and Regulations

The AGA Act addresses the use of the radio frequency spectrum in AAAs specifically in Section 22, and requires the protection of the radio frequency spectrum for radio astronomy observations within Core and
Central AAAs. A summary of the measures that may be applied is provided in Annexure E1.2. The specific measures are prescribed in the draft regulations for the Core and the Karoo Central AAAs contained in Annexures E1.7.3 and E1.8.3.

The provisions in Section 25 of the AGA Act for the authorisation of identified activities, and the prescription of standards and conditions for activities within Coordinated AAAs, will contribute to spectrum management and preservation of the spectrum for the benefit of SKA observations. The detailed measures are prescribed in regulations for the Karoo Coordinated AAAs in Annexure E1.9.2.

6.5.2 Empowerment of the SKA

Empowerment of the SKA organisation to manage the quality of the AAAs in case of violations, or if there is pressure from other parties to compromise that quality in any way, is derived from the following:

1. Declaration, in terms of Section 28(1) of the AGA Act, for the establishment and operation of the SKA to be an astronomy and related scientific endeavour. This makes the provisions in the AGA Act and the regulations applicable to the SKA.

2. Reliance on the AGA Act in terms of its Objects and provisions to deal with the protection of radio astronomy observations within declared AAAs in a prescribed manner.

3. Reliance on the regulations made, and standards adopted, in terms of the AGA Act that provide specific protection criteria, methodology and procedures.

4. Reliance on the powers and duties of the NRF as prescribed in the AGA Act to monitor the status of the declared areas, and to provide assistance to the Minister in the performance of the duties and exercise of powers granted to the Minister in terms of the AGA Act.

5. Reliance on the responsibilities and duties of the designated management authority as prescribed in the AGA Act and in regulations.

6. The establishment and agreement between the Astronomy Management Authority and the SKA organisation in making the SKA organisation a co-management entity in terms of Section 18 of the AGA Act, so as to be involved in the protection of the declared areas as provided for in the applicable regulations.

To illustrate the existing empowerment of the SKA project in South Africa, the SASPO is represented by Dr. Adrian Tiplady on the recently established inter-departmental task team to look at the potential environmental impact of hydraulic fracturing (commonly referred to as 'fracking'). This task team was established following the application for exploration rights by various companies (and subsequent moratorium on the issuing of such exploration rights), and will consider the protection requirements of the SKA as a key requirement to be fulfilled by any licence applicant.

6.5.3 Specific Measures of Radio Interference Protection

Specific measures of radio frequency interference protection that have been, or will be, established have been covered in detail in the preceding sections. However, to respond to this topic in a direct and concise manner, a brief summary is provided below:

1. The Objects of the AGA Act include the protection of the declared areas in which astronomy projects of national importance can be undertaken; that geographic areas highly suitable for radio astronomy due to minimal radio frequency interference are protected, preserved and properly maintained; that activities that causes or could cause radio interference will be regulated; and that the Minister will be enabled to participate in efforts to preserve the astronomy advantage of Southern Africa.

2. Section 22 of the AGA Act is dedicated to protect the use of the radio frequency spectrum within declared core or central astronomy advantage areas by prohibiting completely or restricting the use of parts of the spectrum, or requiring the migration to frequencies or alternative technologies that more effectively protects radio astronomy observations and exempting entities who have agreed to mitigate their impact on the spectrum.
3. Subsection 22(6) of the AGA Act requires that ICASA must not issue radio frequency licences where it is likely that interference would be caused in core or central advantage areas.

4. Section 23 of the AGA Act provides for the prohibition of activities that may detrimentally impact on radio astronomy in Core and Central AAAs, or alternatively require that these activities comply with prescribed standards or conditions. This includes activities involving the construction, expansion or operation of fixed radio frequency interference sources, and activities capable of causing radio frequency interference including bringing into the areas, or operating in such areas, any interference source, mobile interference source or short range device. It is further provided that all such activities that were previously legally conducted must be reviewed and can be required to cease or comply with prescribed conditions to reduce or eliminate the interference.

5. Sections 24 and 25 of the AGA Act provides that standards and conditions may be prescribed for the construction, expansion and operation of any fixed radio frequency interference source located within Coordinated AAAs. Section 27 of the AGA Act provides that any specified activities that were previously lawfully conducted may be reviewed and conditions prescribed under which the activities may continue.

6. The draft regulations for the Karoo Core AAA, where the core and central zones of the SKA are to be located. The construction, expansion or operation of any fixed radio frequency interference source and activities capable of causing radio frequency interference in the radio frequency spectrum 9 kHz to 3 000 GHz are prohibited within the Karoo Core AAA. This prohibition is exempted if the fixed radio frequency interference source or activity is required for the purposes of radio astronomy and related scientific endeavours, and authorised by the relevant management authority or party with whom the management authority has entered into a co-management agreement.

7. The draft regulations for the Karoo Central AAAs, where the outer zone and some of the remote zone of the SKA are to be located. The use of the frequency spectrum 70 MHz to 25.5 GHz will be restricted except in accordance with exemptions granted, and activities causing radio frequency interference are prohibited unless they are authorised and comply with standards and conditions prescribed in these regulations as determined by the management authority or co-management entity.

8. The draft regulations for the Karoo Coordinated AAAs where measures will be applied to enhance the protection of the Karoo Core and Central AAAs within the frequency spectrum from 70 MHz to 6 GHz and prohibit transmissions into the respective Karoo Central AAA with an effective radiated power level in excess of 60 dBm.

### 6.5.4 Remote Stations

Remote stations in the different participating countries will be the subject of protection schemes based on the local conditions and legislation as and when required, but the guidelines for protection are based on a common approach for all of them and are as follows:

1. The remote stations located within the Karoo Central or Coordinated AAAs will be subject to the protection conditions in force within these areas. However, in general, the protection level will decrease as the distance from the Karoo Core Centre increases. It would therefore be necessary to apply other protection techniques as for the remote stations in the other parts of South Africa or in the other participating African countries.

2. The remote stations are located to seek the maximum possible isolation and minimum impact from existing RFI sources.

3. The operating frequency spectrum for the remote stations to be protected is the range from 300 MHz to 10 GHz.

4. The preferred protected zone will be an area with a radius of 50 km within which no new radio communication transmissions or the use of radio apparatus is to be established, or the use of existing transmissions or radio apparatus extended or increased in any form. The separation distance requirement can be amended depending on the nature of the transmitter, and the characteristics of the local topography.
5. In South Africa the protection of the remote stations will be provided in terms of the AGA Act. The Act provides in Section 5 that any other area in the Republic of South Africa may also be designated and declared as an AAA, subject to the area not being within the boundaries of a Category A municipality, and that the different tiers of government are consulted. Within these areas, Core and Central AAAs may be declared subject to public consultation. The Core AAA would include the area to be used to accommodate the remote station and the Central AAA would constitute the protected area of 50 km radius, or otherwise depending on the nature of the local topography, around the core.

6. In the other African participating countries an arrangement based on local communications, broadcasting and/or telecommunications law (as reflected in the analysis of the existing laws and regulations in these countries in Annexure E2.0) would be made with the local government and regulator as and when required. The protection sought will be the same as that stated above.

6.6 Current and Future Spectrum Usage (Item 5 in SSG-RFI-001)

The information provided below applies only to South Africa and mostly to the Northern Cape Province. With the very low level of economic activity in the Northern Cape, frequency spectrum use is also at a relatively low level in the most popular parts of the frequency spectrum. The analysis that follows will attend to these popular frequency bands. Use in the other parts of the frequency spectrum is sporadic, and will be attended to in implementing the regulations for the Karoo Central AAAs.

6.6.1 Current Usage and Future Improvements

1. Broadcasting : VHF-FM (87.5 MHz to 108 MHz)

   Currently, four radio broadcast services are available in the KCAAA1. Due to the nature of low frequency radio propagation, it is very difficult to reduce all VHF-FM radio signal power levels to below the required protection levels for radio astronomy. These signals are measurable at both the South African and Australian SKA Core sites. However, the improvements to be adopted by the Broadcast Stakeholder Group (BSG) are through the consideration of spectrum efficiency. Due to the low demand in services, all radio services will be migrated to the lowest part of the VHF-FM bands. These migrations will be performed in a staged process, prioritised by RFI impact on the SKA Core site. Annexure E5.4.2 is a copy of the official request sent to ICASA, by the SABC, to migrate the first of these services. This request also deals with the establishment of low powered analogue transmission sites to replace the high powered site in Carnarvon (nearest transmitter to the core site). This is an interim measure prior to digital migration.

2. Broadcasting : VHF-TV (174 MHz to 254 MHz) and UHF-TV (470 MHz to 862 MHz)

   Migration to digital television in South Africa is guided by the policy directive issued by the Minister of Communications in Annexure E5.6.0, and regulations made by ICASA in Annexure E5.6.1, which stipulates that digital migration will be completed by the end of 2013. The draft policy amendment, in Annexure E5.6.2, will be approved by the South African Cabinet in August. It includes an important clause that considers the subsidisation of affected communities within the Karoo AAAs to migrate to satellite reception of television broadcasting services through the Universal Service and Access Fund (see paragraph 2.1.4 in Annexure E5.6.2).

   To this effect, the BSG together with SASPO have developed a broadcasting plan that takes into account the protection requirements of the SKA in the Northern Cape Province. Details of this plan are located within the official amendment request to ICASA (see Annexure E5.4.1), as well as the first stage implementation proposal from Sentech to ICASA attached as Annexure E5.4.3. The ICASA Special SKA Committee have already seen and given its full support to the amendment request (see Annexure E5.4.4).

   The new, low powered broadcasting plan would result in the following changes to the radio frequency environment in the Karoo Core and Central AAAs

   (a) Discontinuation of use of the VHF-TV band for broadcasting. Although this band may be the subject of applications for other services in other parts of South Africa following digital migration, no future applications in this band will be approved if they present a risk of RFI at the Core and Central AAAs.
(b) Discontinuation of use of the UHF-TV band for broadcasting, except for two specific 8 MHz channels for digital transmissions. These digital transmissions will be carried by low powered transmitters in the urban centres within the Central AAA. Due to their low power, and distances between towns, these transmitters will have a co-channel allocations. Whilst there may be a very low risk of low level interference measured at the SKA Core site in these two channels, planning studies indicate that no further interference will be measured in any other parts of the UHF-TV band, even from transmitters outside of the Central AAA.

The letters also point to the investigation of an alternative solution that would result in the complete removal of all terrestrial broadcasting transmitters in the Central AAA, with broadcasting services delivered through direct-to-home satellite solutions.

3. **GSM Mobile Cellular Communications (880 MHz to 915 MHz, 925 MHz to 960 MHz)**

   The 1.8 GHz and 2.1 GHz mobile communication bands are not used in the Northern Cape Province except in Kimberley. Base stations within the Karoo Central AAA will restrict their radiation in the direction of the Karoo Core AAA by the establishment of phased GSM antenna systems in the relevant base stations. The design of this antenna system has been funded by the relevant GSM operator concerned, and has been made available at no cost to any other GSM operators in the protection area. See Annexures E7.0 and E7.1 for a design report, as well as measurement report of the system.

4. **Private radio communications (146 MHz to 174 MHz, 406 MHz to 470 MHz)**

   Private radio communication systems used by local government, health services, police, farmers, service providers etc. are scattered in the various frequency bands allocated for two-way radio communication. The strategy to be employed is to migrate these users in the Karoo Central AAA to the spectrum 66 to 88 MHz. SASPO has obtained a licence to operate a trunked radio network within this band (See Annexure E7.2 and E7.3), and is developing a scheme in cooperation with the Northern Cape Agricultural Union Cooperatives to operate and use this system. In this way, the use of the 146-174 MHz and 406-470 MHz bands would be minimised.

5. **Public trunked radio communications (254 MHz to 259.4 MHz, 262 MHz to 267.4 MHz)**

   Although the network planning is extensive there has been little implementation only along the main national roads. The technology is obsolete and is destined to be phased out. In practice users have migrated to use the GSM mobile networks.

6. **Transnet Ltd**

   Transnet Ltd operates a single railway line running through the Karoo Central AAA, carrying iron ore to be exported to the Saldanha and Coega harbours. Modern ore-carrying trains are dependent on radio communication to operate within a train and with its control centre. Although progressively more use is being made of the GSM mobile system, specialised radio communications are used that operate at 160 MHz (unique use limited to immediate train environment) and portions of the 440 MHz to 466 MHz bands. Transnet has made a commitment to support the SKA and has recently replaced and upgraded their radio communication systems, at their own cost, for one million euros (covered). They have adopted a new design approach in which transmissions are focused on the railway line and minimised in the direction of the KCC by using lower sites, directional antennas and the minimum power level required to produce the quality of service required. An improvement has been observed in the RFI measurements carried out in 2010 against that in 2005.

7. **Aviation**

   The aeronautical radio communications and navigation services are provided by ATNS (a state owned entity) and include voice communications in the frequency band 108 to 137 MHz, secondary surveillance radar on 1030/1090 MHz and distance measuring equipment (DME) on 1019/1201 MHz. Small private aircraft are used by various entities mostly for non-scheduled flights. They mostly use voice communications in the frequency band 108 to 137 MHz band and the DME system for navigation. In terms of Section 21 in the AGA Act over flight restrictions can be imposed in concurrence with the Civil Aviation Authority of South Africa. The intention is impose an over flight restriction over at least the Karoo Core AAA.
6.6.2 Expected New Services

The expectation on new services is in an on-going growth of the volume of radio communications and thus in the use of the frequency spectrum that is mostly focused in two key areas.

1. The on-going world-wide trend in the development and growth of personal communications is radio based and has spread beyond voice and SMS communications to internet access with a growing multitude of applications. The increase in traffic volume is predominantly in the metropolitan areas, where a high level of economic activity exists and grows. The growth tempo in the rural areas is much lower, due to the low population density, low income levels and low levels of economic activity.

   In this context, the growth in frequency spectrum use varies with population density and economic activity. In the high density areas, the use of the allocated 900 and 1800 MHz spectrum has reached saturation and growth is now focused on the 2.1, 2.6 and 3.4 GHz frequency bands. In the low density areas, such as the Northern Cape, the use of the 900 MHz spectrum has not reached saturation level. The implementation of AGA regulations ensures the restriction of GSM in the area concerned, whilst the demand is kept to a minimum due to ongoing de-population in the Northern Cape province.

   The digital dividend arising from the migration of terrestrial analogue television transmissions to digital technology will free up at least the spectrum between 790 and 862 MHz. The electronic communications operators already have high expectations to access this spectrum, in particular because of the economic benefit to operate at lower frequencies. However, demand in the Northern Cape Province (although very low) will be superseded by the requirements of the AGA Act.

2. The second key area for growth in radio communications relates to the rural areas and the replacement of obsolete and uneconomical open wire telephone systems with radio communications. This has already occurred to a fair extent but is limited by the economics involved and consequently the lack of coverage in substantial parts of the very sparsely populated areas. For this reason there is consideration to use even lower frequency spectrum around 380 MHz. The volume of demand in this area is very low, but it still means that the use of some spectrum will be in demand.

6.6.3 Expected Termination of Services

The possible termination of services expected are summarised below:

1. The VHF-FM Sound broadcasting transmissions in the spectrum from 100 MHz to 108 MHz in the Karoo region of the Northern Cape Province. This is due to the low number of transmissions in this Province that can all be comfortably fitted into the spectrum from 87.5 MHz to 100 MHz with some room for expansion.

2. The analogue VHF-TV broadcasting transmissions in the spectrum from 174 MHz to 254 MHz in South Africa that will not be used for digital terrestrial television broadcasting and will become free when the migration to digital takes place.

3. The analogue UHF-TV broadcasting transmissions in the spectrum from 470 MHz to 790 MHz in the Northern Cape Province that can be freed when the migration to digital takes places. Existing and additional services can be fitted into only 2 spectrum blocks of 8 MHz each for two digital multiplexes within the 470 MHz to 854 MHz spectrum. Co-channel low power transmissions can be used at the different locations which are sufficiently separated. The restriction in spectrum use in this band will only apply in cases where the RFI level may exceed the protection level.

4. Analogue public trunked radio communications (MPT 1327 standard) in the frequency bands from 254 MHz to 259.4 MHz and 262 MHz to 267.4 MHz that will be phased out due to obsolescence. Although there was substantial network planning in the Northern Cape Province it was only rolled out at the largest towns for road transport.

5. The better use of the frequency spectrum with the objective to free up larger chunks of spectrum for radio astronomy observations can also be considered as a form of termination of services expected. The density of radio communications in the Northern Cape Province is very low, but at present it occurs sporadically within the various allocated frequency bands. The objective is that in the process to review existing radio
transmissions, the number of allocated frequency bands would firstly be minimised and secondly, the necessary transmissions would to the maximum extent possible be concentrated in one part of the bands that can be used.

6. The use of microwave radio communication links is being phased out and is being replaced by the use of fibre optic links. The microwave systems operate in the 4, 6, 7, 8, 10 and 22/23 GHz bands.

6.7 Relevant Activities (Item 6 in SSG-RFI-001)

6.7.1 South African Ministry of Communications

The Ministry includes the Office of the Minister of Communications and the Department of Communications that determines government policy in the electronic communications sector by means of legislation (Electronic Communications Act), compliance with the provisions in the legislation, policy directives in accordance with the legislation and provides governance to the state owned entities in their portfolio. The portfolio entities include the South African Post Office (SAPO), South African Broadcasting Corporation (SABC), Sentech (signal distributor), National Electronic Media Institute of South Africa (NEMISA), Universal Service and Access Agency of South Africa (USAASA), Domain Name Authority (.zaDNA) and the Independent Communications Authority of South Africa (ICASA).

The Ministry of Science and Technology governs development with respect to the MeerKAT and the SKA projects and interacts with the Ministry of Communications on matters of common interest and to ensure the harmonious development of these projects.

A committee of delegates from the Departments of Communications and of Science and Technology, SASPO, ICASA, SABC, Sentech and the National Association of Broadcasters in Southern Africa exists to meet from time to time to discuss matters concerning broadcasting and the protection of radio astronomy.

6.7.2 Independent Communications Authority of South Africa (ICASA)

The relationship and interaction with ICASA are vested on three pillars:

1. An agreement between the Department of Science and Technology (DST) and the Independent Communications Authority of South Africa (ICASA) on Cooperation with regards to the South African SKA Bid Proposal, entered into on 2 November 2004. A copy of the agreement is included in Annexure E6.0.

2. The ICASA Special Committee for SKA Matters, established in terms of Section 17 of the ICASA Act and in which the DST and SASPO participates.

3. The participation in ICASA public enquiries and other forms of interaction as described in detail in Annexure E3.2 containing the summary of DST and SASPO interaction with ICASA.

6.7.3 International Spectrum Management Bodies

1. South African WRC Preparatory Meetings

SASPO is represented within South African WRC-12 preparatory meetings, with Dr. Adrian Tiplady (SASPO) acting as the official South African rapporteur for Agenda Item 1.6. Due to long standing relationships with the various stakeholders in the telecommunications sector in South Africa, all South African rapporteurs are cogniscent of the requirements of radio astronomy, and consider inputs from SASPO, CRAF and IUCAF in their deliberations.

2. International Telecommunication Union Working Party 7D (ITU WP7D)

SASPO is represented within ITU-WP7D meetings by Dr. Adrian Tiplady (SASPO), and forms part of the drafting group responsible for the development of an ITU report on radio quiet zones.

3. Committee for Radio Astronomy Frequencies (CRAF)

SASPO is represented on the European Science Foundation expert Committee on Radio Astronomy Frequencies (CRAF) by Dr. Adrian Tiplady.
4. Scientific Committee on the Allocation of Frequencies for Radio Astronomy and Space Science (IUCAF)
   Dr. Adrian Tiplady (SASPO) represents CRAF on IUCAF.

5. Independent Communications Authority of South Africa
   Dr. Adrian Tiplady (SASPO) is an authorised ICASA Inspector, and represents SASPO on the ICASA Special SKA Committee.

6. Inter-departmental Task Team
   Dr. Adrian Tiplady (SASPO) represents SKA interests on the inter-departmental task team to look at the potential environmental impact of hydraulic fracturing (commonly known as ‘fracking’), a method to extract shale gas. This task team was established due to recent exploration applications by various companies. Part of the recommendations will be to ensure that SKA interests are protected and not compromised in any way.
Chapter 7
Political, Socio-Economic and Financial Situations

This report shows that a major investment in the SKA in Africa would be efficiently handled and low risk in the short and long term. The report demonstrates that it is easy to do business in the countries party to the African SKA site bid and in South Africa in particular, which is where any SKA company would presumably be incorporated and where the assets of the SKA would be owned. South Africa’s financial and banking system will facilitate and safeguard transactions. South Africa’s construction, engineering, ICT and high tech industries have a world-class track record and operate globally. Governance and policy are stable and predictable. There is a clear rule of law with an independent and highly-rated judiciary and courts. Access by the SKA to legal process would be easy and fairly quick. The South African Constitution is the supreme law and is backed by a highly respected and independent Constitutional Court. It guarantees freedom of speech, freedom of association, freedom from discrimination, fair, transparent and accountable administrative action, extensive access to information and socio-economic rights. Strong and active civil society organisations play a significant role in holding the state accountable and in exposing maladministration.

The telecommunications and transport markets have been deregulated and the power market is in the process of being deregulated, especially for renewable energy. The regulators in these markets are independent and competent. South Africa’s economy has been tightly managed since 1994 - the budget deficit is projected to be 3.8% of GDP by 2013 and the national debt has been reduced to 30% of GDP. The currency (the Rand) has held up well, indicating confidence by external investors. Inflation has remained benign.

The reports from JP Morgan (Annexure H3), PwC (Annexure H2) and Eusebius Mackaiser (Annexure H1), a respected political commentator, and extracts from the print media show that:

1. Africa is a continent of opportunity that is already showing economic growth rates above those of most other regions and is likely to become an economic power house.
2. Improved governance and rapidly increasing revenue from mining, oil and gas are leading to the development of a rapidly growing middle class in many African countries and major investment programmes for economic and social infrastructure. This middle class is well-informed because of the very rapid uptake of broadband in Africa, where it is growing faster than other regions of the world.
3. It is expected that Africa’s population will reach 1.2 billion by 2030, with a very large proportion of young people and growing discretionary income. It is thus likely to emerge quite rapidly as a very significant consumer market. The rapid economic growth, according to McKinsey, is and will became more diverse and not limited to resource extraction.
4. Telecommunications infrastructure has developed rapidly, with huge increases in both marine and terrestrial bandwidth on optical fibre networks coming on stream as markets have been deregulated. Access to broadband has grown faster than other regions. The planned investments in electrical power (including major hydropower projects) and in road, rail, and port and airport infrastructure will significantly increase intra-regional as well as international trade.
5. The eight countries in Africa with which the RSA has partnered in the SKA site proposal show increasing deregulation of markets; stable governance and stable and predictable policy environments; stable, transparent
and predictable regulatory regimes in respect of financial, banking and telecommunications markets; stable and modern financial and banking sectors; efficient and competitive insurance industries; effective rule of law and a rapid decrease in arbitrary administrative actions; effective and independent judiciary and courts and increasing recognition of the importance of science and technology in their development.

6. South African and multi-national companies in a wide range of consumer and other industries operate effectively in all of the countries that have partnered with South Africa in the SKA site proposal.

7. South Africa, in particular, has a modern and efficient economy and financial system capable of delivering very large projects on time and to budget. (The 2010 Football World Cup is an example.) The Johannesburg Stock Exchange and South African corporate governance and auditing industries are rated best in the world. Effective bank regulation meant that South Africa’s banks were not seriously affected by the global financial crisis. This was true of banks in Africa in general. South Africa’s banks are amongst the most modern in the world and have extensive operations in Africa.

8. South Africa has embarked on a huge infrastructure investment programme in electrical power, rail, harbours, airports, roads and telecommunications. This is expected to be well over R1 trillion (US$143 billion). South Africa is also increasingly committed to investing in infrastructure to improve regional telecommunications, power and transport networks.

9. South African management in general is rated world-class.

10. South Africa rates very well in the HSBC surveys of the countries in which expatriates integrate most easily and have the best lifestyle. Surveys such as those by the Economist Intelligence Unit and Mercer also show that Johannesburg and Cape Town have significantly lower costs for business and expatriates than comparable world cities.

11. With its modern infrastructure, excellent financial and legal systems, skilled workforce, modern industry and excellent expatriate lifestyle, more and more global corporations are seeing South Africa as the gateway into the increasingly lucrative African market.

12. South Africa has an excellent relationship with its neighbours in Africa and, in particularly, with its eight partners in the SKA site proposal.

13. The commitment of South Africa and Africa to the bid are shown by:

   - South Africa’s huge investment in establishing and regulating by legislation a greenfield site for the SKA and providing SKA-ready infrastructure.
   - The huge investment in the MeerKAT telescope array.
   - The establishment of an Inter-Ministerial committee on the SKA by the Cabinet.
   - The excellent cooperation received by the Department of Science and Technology from the broadcasting, telecommunications and other industries to strengthen the bid.
   - The unanimous resolution of support from the General Assembly of the Heads of State of the African Union, together with commitments from the African Ministers Committee on Science and Technology and individual governments.

7.1 JP Morgan Report

Eskom Holdings SOC Ltd, the national electricity utility, has recently completed a very successful bond issue and used information from JP Morgan, which sums up the economic picture for South Africa as follows (See Annexure H3):

South Africa, part of the BRICS countries, has a stable political landscape, attractive economic outlook and sound regulatory framework. South Africa provides the best of both worlds: long-term growth profile of emerging markets, political stability, legal framework and ‘doing-business’ environment of developed countries. The country’s political and economic influence over the African continent has grown considerably over the last 10 years, making South Africa the preferred economic platform to invest in the African continent.

- Background: South Africa is a US$ 280 billion open economy with a per capita GNI of about US$10 000. It is the largest economy in the African continent and serves as a gate way for investment in sub-Saharan Africa.
Politics: A constitutional multi-party democracy with an independent judiciary system, with a free and vibrant media whose role and rights are guaranteed in the constitution.

Fiscal Policy: The budget process is considered as the most transparent in the world. The country has an established record of prudent fiscal policy, with the current budget deficit projected to moderate to 3.8% by 2013.

Monetary Policy: An independent Reserve Bank with a mandate to protect the value of the South African Rand and enable faster economic growth. An explicit inflation targeting regime exists, with an established target of CPI at between 3% to 6%. Government has expectations of inflation of 5.2% and 5.5% for 2012 and 2013 respectively.

Well-developed Financial Markets: The JSE Securities Exchange is the 20th largest equities exchange in the world, with a total market capitalization of ZAR 5 trillion (US$715 billion), which facilitates capital mobility. South Africa enjoys one of the largest financial sectors of the emerging markets with well-developed and well regulated capital markets that support an efficient deployment of local and global savings. Local debt and equity markets can provide a stable source of local funding for African projects of foreign companies. A robust banking sector exists that supports the real economy and the financial markets. Non-prohibitive foreign exchange controls exist.

Efficient Regulatory Environment: A sophisticated and robust regulatory framework in the various economic spheres including, consumer rights protection, credit regulation, competition commission, broadcasting, banking, public protector and energy regulator amongst others. Much of South African regulation is based on the best practice in the UK, Europe and the US. There are few restrictions on investment. Income from an investment may be paid to a foreign investor, and the proceeds of any sale of assets in South Africa may be transferred abroad by a non-resident seller.

Infrastructure: A well developed and interconnecting National Roads System; a functioning sea and airport system; a sound communication network; and a world class revenue collecting agency.

‘Investor-friendly’ economic environment: South Africa has the 26th biggest economy in the world, with a GDP of US$ 357 billion (2010). Well-established road, railway and ports network make distribution reliable. Macroeconomic stabilization has had a positive impact on the South African economy, contributing to lower inflation, reduced interest rate volatility and stronger domestic demand. Presence of multinationals in all spheres of the market highlights ease of doing business for international investors.

Exchange rate: Over the short-to-medium term, the Rand will stay overvalued. However, over the longer term, the Rand is expected to continue to depreciate in line with inflation differentials with South Africa’s major trading partners.

The country’s fiscal position remains strong, where prudent fiscal policies have allowed for counter-cyclical spending. Expanding reserves have strengthened South Africa’s fiscal position. The South African Reserve Bank has demonstrated consistent and effective inflation management. Banks remain a pillar of the South African economy. External vulnerability has fallen over the past decade and is expected to decrease further. The medium term outlook remains robust, with prudent monetary and fiscal policy, sustainable macroeconomic policy and reforms, low foreign debt, a well regulated and capitalised banking system.

7.2 International Metrics

South Africa compares favourably to other countries on a number of key metrics on foreign investment. These metrics are shown in Annexure H3 and H2, and some are re-produced in Figures 7.1, 7.2, 7.3 and 7.4.

7.3 Other African Countries

Details relating to their political and economic environment are contained in the reports by PwC and McKaiser in Annexures H2 and H1. These reports show that the SKA investments in these countries will be secure and that the SKA can easily do business in these countries.
Figure 7.1: Political and financial environments are secure and effective.

Figure 7.2: Corporate South Africa is generally well-managed.
Figure 7.3: South Africa’s legal system is recognised as one of its greatest assets.

Figure 7.4: South African banks remain a pillar of the economy.
Chapter 8

Customs and Excise

8.1 Introduction

This report deals with the questions regarding customs and excise and the taxation status of the SKA company and employees, as set out in the SSG-RfI. Besides providing information on duties, tax and procedures, this report also provides case studies regarding the import and export of goods into and from the African countries which are partnering with South Africa in the SKA site bid.

The information on import duties and procedures for South Africa and the tax status of the company and employees was provided by the South African Revenue Service (SARS). They have also indicated where information can be found on the SARS website. SARS indicated that a special dispensation will probably be possible for the SKA and this is supported by the attached letter (Annexure I1) from the Minister for Trade and Industry to the Minister for Science and Technology regarding discussions with the International Trade Administration Commission (ITAC). The Minister states:

I have been advised by ITAC that the majority of the equipment used for the construction and operation of the Square Kilometre Array (SKA) radio telescope is classifiable as free of duty under a range of tariff headings and subheadings of the customs description and coding system administered by the South African Revenue Service (SARS). Smaller components, not specifically identifiable as components for radio telescopes, such as switches, etc. may be dutiable.

The Commission further advised that the introduction of a rebate of duty provision under Schedule No. 4 of the Customs and Excise Act, specifically formulated to be used for the construction and operation of the SKA project would be a workable solution.

At the time of writing, SARS had begun work with the ITAC on a special provision for the SKA.

Information on the customs duties and procedures of the other African countries which have partnered with South Africa in the SKA site bid has been provided by Aurecon (Annexure I2). A number of agreements are in place to support an extended organisation operating in Africa. The African Union has adopted a resolution to support the bid to host the SKA in Africa, with support from all participating Governments (see Annexure I4). The African Ministerial Conference on Science and Technology (AMCOST) passed a resolution in support of the SKA at their meeting on 10 March 2010 in Cairo (See Annexure I5). There are Bilateral Agreements for Science and Research between South Africa and the African partner countries which provide for the exchange of researchers and equipment, with additional Letters of Commitment stating government commitments to facilitate the free flow of SKA personnel and equipment across their international borders. A number of the countries are member of the Southern African Development Community, with mutual co-operation agreements in place.

It is assumed that all or almost all SKA employees, especially expatriate staff, will be employed and be resident in South Africa, with the exception of a small number of first-line maintenance employees at the remote stations outside South Africa. Their individual tax status would therefore be as described below by SARS. Local staff will be expected to handle the day-to-day operations of the Remote Sites outside South Africa, with specialist support provided from the SKA South African office.
8.2 Information Provided by the SA Revenue Service in Respect of the Republic of South Africa and Arrangements with Certain States in the Southern African Development Community (SADC)

8.2.1 Customs Duty

Section 47 of the Customs and Excise Act, 1964, (the C & E Act) provides that duty shall be paid in accordance with the rate specified in Schedule No. 1 of the C & E Act on all imported goods at the time of entry for home consumption. The rate of duty in Schedule No. 1 is specified according to the tariff classification and trade agreements.

8.2.2 Tariff Classification

From the information that has been provided, the majority of the goods that will be imported into South Africa for the SKA project are free of duty in terms of Schedule 1 of the C & E Act. The Southern African Customs Union shares an external tariff. The import tariffs in the member states (South Africa, Botswana, Namibia, Lesotho, and Swaziland) are, therefore, the same.

8.2.3 Trade Agreements

The Trade, Development and Cooperation Agreement with the European Commission, the Southern African Development Community Agreement and the Southern African Customs Union Agreement with the European Free Trade Association provide for preferential rates of duties on imported goods originating in those jurisdictions.

In order to utilise the preferential trade agreements documentary requirements for the eligibility for preferential treatment, such as a certificate of origin, invoice declaration, etc. are required. The various Trade Protocols are available on the SARS website at http://www.sars.gov.za/home.asp?pid=912.

8.2.4 Customs Duty Rebates

Section 75 provides that any imported goods described in Schedule No. 4 of the C & E Act shall be admitted under rebate of any customs duties applicable in respect of such goods at the time of entry for home consumption thereof.

As regards the construction of the SKA, rebate item 490.40 of Schedule 4 of the C & E Act provides for a full rebate of duty on the temporary importation of machinery or plant (excluding tower cranes) for use on contract in civil engineering or construction work, subject to certain conditions.

In respect of the employees of the SKA or its construction contractors, rebate item 407.06 of Schedule No. 4 of the C & E Act provides for a full rebate of duty for inter alia household furniture, other household effects and equipment necessary for the exercise of the calling, trade or profession of a person being the bona fide property of a natural person and members of his or her family, imported for own use on change of his or her residence to South Africa. This will cover both employees who move to South Africa permanently and expatriate employees moving to South Africa temporarily.

In order to simplify administration and further facilitate the SKA, Government has begun a consultative process to investigate the creation of a special rebate facility in Schedule 4 of the C & E Act to provide for a full rebate of duty for all goods imported by the SKA project, including those goods not covered by the specific rebate items described above.

8.2.5 Prohibition and Restrictions

From the information that has been provided, there will be no import or export restrictions that will apply during the construction and operation of the SKA except in respect of those goods having dual purpose capabilities as provided for in the Non Proliferation of Weapons of Mass Destruction Act, 1993.
8.2.6 Value-Added Tax

Value-Added Tax Treatment of the Non-Profit Company Operating SKA

In as far as the overall VAT treatment of the non-profit company operating the SKA is concerned, the scale of the operations it will undertake mean that the company will have to register for VAT in terms of the Value-Added Tax Act, 1991, (the VAT Act). This means that the company will have to levy VAT on the funds it receives but will be able to claim back the VAT that it pays, within the framework provided by the VAT Act. A critical point impacting on the rate at which VAT is levied on the funds received by the company is the funding mechanism used by the company. Depending on the mechanism used, it may be possible to levy VAT at the rate of 0% on the funds linked to the provision of research data for the use of persons and entities outside South Africa. In other cases VAT must be levied at the standard rate of 14%.

Value-Added Tax on Imported Goods

Goods imported into South Africa are subject to VAT at the standard rate unless a specific exemption is provided for in Schedule 1 of the VAT Act.

Item no. 490.40 in Schedule 1 of the VAT Act provides an exemption from the payment of VAT on the temporary importation of machinery or plant (excluding tower cranes) for use on contract in civil engineering or construction work, subject to certain conditions.

Item no. 407.06 in Schedule 1 of the VAT Act in provides an exemption from the payment of VAT on inter alia household furniture, other household effects and equipment necessary for the exercise of the calling, trade or profession of a person being the bona fide property of a natural person and members of his or her family, imported for own use on change of his or her residence to South Africa.

No overall exemption in respect of goods imported for the SKA project is contemplated at present but the National Treasury may be approached to consider such an exemption in view of the significance of the SKA project.

In the absence of an overall exemption the VAT paid on import by the SKA project may be claimed back as described above.

8.2.7 Income Taxation

Income Taxation of Non-Profit Company Operating SKA

Section 10(1)(cN) of the Income Tax Act, 1962, (the IT Act) provides for a comprehensive income tax exemption for the non-business/non-trading income and a limited exemption for the business/trading income of a “public benefit organisation” approved by SARS in terms of section 30 of the IT Act.

Section 30 provides for the requirements that must be fulfilled for approval to be granted. These requirements are directed at ensuring that the public benefit organisation focuses its activities on the public benefit activity for which it was established, is not profit driven, does not distribute income either directly or indirectly and is of a public character. Section 30 caters for the approval of a branch of an offshore entity, provided the entity is exempt from income tax in its home jurisdiction, and a domestic non-profit company established under the Companies Act, 2008.

Public benefit activities are listed in the Part I of the Ninth Schedule to the IT Act and the relevant activity in this case is ‘8(a) Research including agricultural, economic, educational, industrial, medical, political, social, scientific and technological research.’

An entity that has been approved in terms of section 30 also enjoys benefits in respect of other taxes. Donations made to it are exempt from donations tax, bequests to it are not subject to estate duty, its acquisitions of property for use in a public benefit activity are exempt from transfer duty and transfers to it of securities are exempt from securities transfer tax.

SARS’s Guide for Public Benefit Organisations of October 2007 is available at http://www.sars.gov.za/Tools/Documents/DocumentDownload.asp?FileID=45625 but is in the process of being revised. While it provides a useful overview, several specifics are outdated. As an example, the requirement that an entity conducts 85% or more of its domestically funded activities in South Africa, unless the Minister of Finance approves otherwise, no longer applies.
Income Taxation of Employees

Employees will be subject to income tax in respect of the remuneration for the services they render in South Africa. The following points should, however, be borne in mind.

Although South Africa taxes its resident on their worldwide income, expatriate employees who are present in South Africa for five years or less will only be subject to income tax on their South African source income. This concession does not apply to employees who move to South Africa with the intention of making it their home. A detailed explanation of the five year rule is to be found in Interpretation Note 4 at http://www.sars.gov.za/home.asp?pid=54958.

Employees who are present in South Africa for 183 days or less in any twelve month period and are not remunerated by a domestic employer or domestic branch of a foreign employer will generally be exempt from income tax in South Africa, if South Africa has concluded a double taxation agreement (DTA) with the employees’ jurisdiction of residence. The terms of the exemption will depend on the specific DTAs.

To the extent that employees are taxed on their remuneration both in South Africa and in their jurisdiction of residence, relief from double taxation will be available in the jurisdiction of residence if South Africa has concluded a DTA with the jurisdiction. The terms of this relief will depend on the specific DTAs. The jurisdiction of residence may also offer unilateral relief outside a DTA.

South Africa has concluded DTAs with a wide range of countries. A list of the countries and links to the relevant DTAs are available at http://www.sars.gov.za/home.asp?pid=3919.

8.2.8 Trade Facilitation

Electronic Data Interchange

The C & E Act provides for inter alia the electronic submission of customs declarations. The electronic submission of declarations reduces costs for the importer and expedites the release of goods.

Pre-clearance

Customs declarations of goods can be made before arrival in terms of Section 38 of the C & E Act. Clearing goods in advance will assist in accelerating the facilitation process. Should the goods require inspection before release; a pre-booking can also be done in advance.

Duty Rebate

The special rebate facility described in Item 2 above would also facilitate customs clearances at the actual ports of entry to minimize delays and detentions, as the shipments in question can be identified as being for the SKA project.

All the legislation mentioned above is available at http://www.sars.gov.za/LNB/MyLNB.asp.

8.3 Other African Countries

Aurecon is a large multinational consulting and project management firm, undertaking successful contracts in many parts of Africa. Their report, Annexure I2, indicates that there are processes in each of the countries. All of the countries are members of the World Customs Union (WCU) and the World Trade Organisation (WTO). They are standardizing or have standardized processes, based on WCU standards. If the correct processes are followed by competent handling agencies, the expected clearing times are from 24 hours to 72 hours, depending on the items being shipped. We have also received a report from International Forwarding Services (Cape)(Pty) Ltd (IFS) identifying the typical services offered to ship scientific equipment to other countries (Annexure I3). IFS has handled shipping on behalf of the South African SKA Project Office, as well as the high-spec optical mirrors for the South African Large Telescope in Sutherland.

Note that a Free Trade Area between the Common Market for East and Southern Africa, COMESA, the East African Community (EAC) and the SADC is planned for 2014.
8.4 Case Studies

8.4.1 South Africa

The import of components and equipment required for the KAT-7 and MeerKAT telescopes in South Africa has been straightforward. Permission to submit forex payments outside the RSA is required from the South African Reserve Bank (SARB). The SARB has indicated that it is open to a special facility for the MeerKAT and for the SKA and work is proceeding on this arrangement between the SARB, the National Research Foundation (NRF), the SKA South Africa Project Office (SASPO) and ABSA bank (where the NRF and the SKA South Africa hold their accounts).

A number of major projects in South Africa have been accorded special status with regard to both personnel and customs and excise duties. The recently completed Gautrain project (for which the lead contractor was a consortium including the French company Bouygues) is an example. Special arrangements were also put in place to facilitate both goods and visitors entering the country for South Africa’s successful hosting of the FIFA World Cup in 2010.

8.4.2 Other African Countries

Two of the major South African cellular operators, Vodacom and MTN, have successful international divisions operating in a number of African countries. The French cellular operator, Orange, has similar operations in Africa and Madagascar. These organisations have similar requirements to the SKA, in that they have high-tech electronic equipment operating in these countries, with the need for continued maintenance and specialist intervention as and when required. In these businesses any system downtime results in a direct loss of income and possible loss of customer base. Necessary agreements are in place with the host Governments to facilitate the movement of personnel and equipment at short notice. The SKA will be able to make similar arrangements, which will be facilitated where necessary by the Government of South Africa, which leads the African SKA site bid.

South Africa is collaborating with the Ghanaian government to convert a 32m satellite dish handed over by Vodafone in Ghana. The SKA South Africa project manager is an Indian national. His visits to Ghana with South African technical staff and a large quantity of sophisticated test equipment have been approved within days and no delays have been experienced at the ports of entry. The accompanying equipment was not subject to duties or taxes. Technical teams visiting Mozambique, Namibia and Botswana have had similar experiences.

With escalating business opportunities opening up in Africa, large numbers of companies are doing business across international borders. To expedite and facilitate the growing requirement for necessary travel permissions, the various countries are developing efficient solutions, enabled by growing access to electronic communications.
9.1 Introduction

Documentation to address the legal issues relevant to the construction and operation of the SKA facility in South Africa and its African SKA partner countries has been compiled. As most relevant legal issues for the SKA will be located within South African jurisdiction, these have been dealt with in more detail in this report. Detailed examination of the relevant legal issues in the African SKA partner countries for each of the required responses to the SSG-RfI is provided in annexures. A full listing of the annexures that deal with the African SKA Partner Countries is provided in Annexure J8, and has been categorised on a country by country basis.

9.2 Overview of Legal and Administrative Procedures

9.2.1 South Africa

The structure of the judicial system in South Africa, the commercial arbitration facilities, and the structure of other judicial and quasi-judicial fora that may be relevant to the SKA are in line with international best practice. The judiciary is independent of Parliament and the Executive, meaning that it has distinct powers, roles and duties. The high international standing of the South African judiciary has resulted in key international appointments, such as Richard Goldstone as Chief UN Prosecutor of the International Criminal Tribunal for the Former Yugoslavia.

The structure of the South African courts, dealt with in more detail in Annexures J1.1.1 and J1.1.4, are summarised as follows (in order of jurisdiction): Magistrates (Lower) Courts; High (Superior) Courts; Supreme Court of Appeal; and the Constitutional Court. The Supreme Court of Appeal is the highest court in South Africa for non-constitutional matters. The Constitutional Court has jurisdiction throughout South Africa as a court of final instance over all matters relating to the interpretation, protection and enforcement of the provisions of the Constitution.

Key Constitutional Rights include:

1. The right to fair administrative action, which is effected through the Promotion of Administrative Justice Act and ensures that everyone has the right to administrative action that is lawful, reasonable and procedurally fair. The intended outcome of the Act is the promotion of an efficient administration and good governance, and the creation of a culture of accountability, openness and transparency in the public administration or the performance of a public function;

2. The right to information, which is effected through the Promotion of Access to Information Act and fosters a culture of transparency and accountability in public and private bodies;

3. The right to property;

4. The right to freedom of speech, association and movement.

The Rules of the High Court provide for execution against property, whether movable or immovable, in satisfaction of judgement. Foreign judgements are enforced in South Africa by way of provisional sentence proceedings, and will be enforced by the courts provided that the court which pronounced the judgement had jurisdiction to entertain
Arbitration is commonly used for the resolution of commercial disputes in South Africa. It is usually quicker and less expensive than litigation, and enables parties to agree on the arbitrator(s) to hear and determine the dispute. An arbitration agreement, defined in the Arbitration Act attached as Annexure J1.1.3, will usually provide for the submission of the dispute to arbitration in accordance with the rules of a specified arbitration organisation, such as the International Court of Arbitration of the International Chamber of Commerce, or the Arbitration Foundation of Southern Africa (‘AFSA’ - www.arbitration.co.za). AFSA is a highly regarded domestic arbitration organisation, and recently has been involved in the establishment of the Africa ADR (a dispute resolution body for African commercial disputes - see Annexure J1.1.2). South African courts generally give effect to arbitration agreements. They uphold the principle of party autonomy in arbitration proceedings, and show a high degree of deference to arbitration awards. Where the award complies with the requirements of the Arbitration Act, the successful party may apply to court to have the award made an order of the court, which is enforced in the same way as a judgement of the court.

9.2.2 African SKA Partner Countries
Annexure J8 provides a listing of annexures that deal with the overview of the legal system in each African SKA partner country.

9.3 Acquisition of Legal Capacity

9.3.1 South Africa
Detailed consideration of the acquisition of legal capacity by the SKA Organisation under the laws of South Africa is presented in Annexure J2.1.1.

Two scenarios have been considered: firstly, the options available to an external company to acquire legal capacity (if the SKA Organisation were to be established in the UK as a company limited by guarantee); and secondly, the consideration of the legal position of a non-profit company formed within the jurisdiction of South Africa.

A foreign company that wishes to acquire legal capacity in South Africa has three options under the Companies Act (Annexure J2.1.2), although the most appropriate for the SKA would be to register as an external company doing business (or non-profit activities) in South Africa. The SKA Organisation would have 20 working days upon commencement of activities to register with the Companies and Intellectual Property Commission. The Companies Act prescribes various requirements that a foreign company must comply with in order to be recognised as a foreign company conducting business (or non-profit activities) in South Africa.

A non-profit company formed within the jurisdiction of South Africa under the Companies Act may be incorporated by an organ of state, a juristic person or three or more persons acting in concert, subject to their compliance with the various procedures outlined in the Act. The provisions regulating non-profit companies and particularly, the provisions relating to the required objects and policies of non profit companies, are detailed in Schedule 1 of the Companies Act.

Following the acquisition of legal capacity, there are no laws in South Africa that prevent foreign ownership and/or operation of a radio telescope. Compliance with the requirements of the Broad-Based Black Economic Empowerment Act will be required in the event that the SKA organisation conducts any direct or indirect business with any state organ or public entity. That Act is attached as Annexure J2.1.3. The Codes of Good Practice on Black Economic Empowerment is provided in Annexure J2.1.4.

9.3.2 African SKA Partner Countries
Annexure J8 provides a listing of annexures that deal with the acquisition of legal capacity by the SKA Organisation in each African SKA partner country. The acquisition of legal capacity ensures that the SKA may own and/or operate a radio telescope in all African SKA partner countries. This is dealt with in more detail in the relevant annexures listed in Annexure J8.
9.4 Formal Arrangements Amongst African SKA Partner Countries

South Africa has engaged with its African SKA partner countries since 2003. The SKA is supported at the highest level in the partner countries and across the continent. Annexure J3.1 is an official endorsement of the SKA by the African Union Heads of State. Annexure J3.10 (clause 2.3.7) is the official endorsement of the bid to host the SKA taken at the African Ministerial Conference on Science and Technology 2010 (AMCOST IV). Annexure J3.2 is a copy of the official joint declaration by the Ministers responsible for Science, Technology and Innovation from the African SKA partner countries, re-affirming their commitment to participation in the SKA. The joint declaration also commits to the establishment of site readiness teams in each country to facilitate and optimise the various processes with respect to land acquisition, and the movement of SKA equipment and personnel.

Examples of various Memoranda of Agreement and Understanding, Letters of Commitment, and Science and Technology Cooperation Agreements between South Africa and the African SKA partner countries have been provided in Annexures J3.3.1 to J3.3.6, J3.4, J3.5.1, J3.5.2, J3.6.1, J3.6.2, J3.7, J3.8.1 to J3.8.3 and J3.9. Commitments include the acquisition of land, optimisation of customs and excise and immigration processes for equipment and personnel, the waiving of duties, the facilitation of all environmental impact assessments and other issues that are relevant to the SKA. South Africa has led the African SKA bid on behalf of the African SKA partner countries, and will continue in that facilitation role to ensure optimal logistical, administrative and legal processes are used in the construction and operations phase in each of the African SKA partner countries. Recent experience with the establishment of the first site of the Africa VLBI Network in Ghana indicates that the movement of people and equipment is unhindered, quick and well facilitated by the appropriate officials.

9.5 Ownership of Intellectual Property

9.5.1 South Africa


IP law in South Africa is contained in various pieces of legislation. These are listed below, but only legislation that would be pertinent to the SKA Organisation is expanded upon.

1. Copyright Act (Annexure J4.1.2);
2. Counterfeit Goods Act (Annexure J4.1.3);
3. Designs Act (Annexure J4.1.4);
4. Patents Act (Annexure J4.1.5): An invention that is capable of being used or applied in trade, industry or agriculture is patentable in terms of the Patents Act. South Africa is a member of the Patent Co-operation Treaty. This allows an applicant to file one application in which the applicant can designate countries of interest in which it seeks patent protection. Following designation, the applicant must file individual applications in each country where it seeks protection.
5. Trademarks Act (Annexure J4.1.6)
6. Intellectual Property Rights from Publicly Financed Research and Development (IPR) Act (Annexure J4.1.7): Deals with intellectual property emanating from publicly financed research and development. Its primary objective is to ensure that intellectual property created with public funds is identified, protected, utilised and commercialised for the benefit of South Africa. The IPR Act does not apply to research and development undertaken at an institution and funded by a private entity or organisation on a full cost basis. The IPR Act establishes the National Intellectual Property Management Office (‘NIPMO’) to promote the objectives of the Act, which include the statutory protection, management and commercialisation of intellectual property.

The South African Department of Trade and Industry is mandated to oversee policy formation in respect of IP rights in South Africa. The Companies and Intellectual Property Commission maintains registers of registered
IP rights. It also works closely with the South African Revenue Services and the South African Police Service in ensuring efficient enforcement of IPR legislation. NIPMO is tasked with monitoring, evaluating and reviewing obligations of recipients in terms of the IPR Act.

9.5.2 African SKA Partner Countries

Annexure J8 provides a listing of annexures that deal with the principles of ownership of intellectual property in each African SKA partner country.

9.6 Rights of Land Ownership

9.6.1 South Africa

Detailed consideration of the rights of the SKA Organisation in respect of land, rights of access, and other relevant information is provided in Annexure J5.1.1, with supporting documentation in Annexures J5.1.2 and J5.1.3. A summary is provided below.

1. Ownership of Land: The ownership of land or property in South Africa is a constitutional right. Property cannot be arbitrarily confiscated except by expropriation in terms of the relevant legislation. This process includes a right to appeal. The property sector in South Africa relies on a secure and well-regulated system. Ownership of property in South Africa either vests in the State or private entities, who must register their properties in a Deeds Registry in the name of a natural person or corporate entity. A foreign company must first register as an external company in South Africa before it may take transfer of property.

2. Leasing of Land and Fixed Property: Any natural person or company may enter into a lease agreement to lease land or fixed property. A foreign company may enter into such a lease agreement. Rights over property in favour of persons other than the owner of that property may be registered in the form of servitudes.

3. Provision in the Astronomy Geographic Advantage Act (Annexure J6.1.7) concerning Land Acquisition: The Minister of Science and Technology is empowered to acquire land or property, or any right in or to land or property, which has been declared as an Astronomy Advantage Area. This can be exercised through purchase, exchange or expropriation if no agreement is reached with the owner of the land or right. Thus if the SKA Organisation needs to acquire land or property, or any right in or to land or property, it could approach the Minister to exercise his/her powers, and the SKA Organisation could then enter into a lease or other appropriate agreement with the Minister as regards the land or property, or any right in or to land or property required by the SKA Organisation. The Northern Cape Province, in which the bulk of the SKA configuration is located, has already been declared an Astronomy Advantage Area.

9.6.2 African SKA Partner Countries

Annexure J8 provides a listing of annexures that deal with the rights to land and access in each African SKA partner country.

9.7 Construction Licensing and Permits

9.7.1 South Africa

Detailed analysis of the permit and licence requirements for construction and operation of the SKA in South Africa is provided in Annexure J6.1.1, with supporting documentation attached in Annexure J6.1.2 to J6.1.13.

Permit and licence requirements for the construction of the SKA infrastructure is summarised as below:

1. Building: The National Building Regulation and Standards Act regulates the construction of buildings in South Africa. No person may erect any building without prior approval from the local authority, to which plans and specifications of the buildings in question should be submitted;
2. Water: The National Water Act requires application for a ‘water use’ licence, subject to certain conditions. The construction and operation activities associated with the SKA will require a water use licence. The existing MeerKAT water licence can be extended to include the SKA;

3. Waste Management: The National Environmental Management Waste Act requires application to the relevant licensing authority for a waste management licence. This is required for the construction of facilities and associated structures and infrastructure in relation to each waste management activity undertaken. The MeerKAT waste management licence may be extended for the purposes of the SKA;

4. Roads: To the extent that any road built by the SKA impedes or diverts the flow of water in a water course, alters the bed, banks, course or characteristics of a watercourse, a water use licence is required. The construction of roads must also comply with the National Heritage Act, referred to in the environmental section of this report. Any abnormal loads to be transported on public roads will require the relevant authorisation from the provincial roads authority. The construction of private roads joining public roads will require the relevant authorisation from the provincial roads authority;

5. Bulk Material: The Mineral and Petroleum Resources Development Act requires that, due to the large quantities of materials required from borrow pits and stone quarries for the construction of road networks, a mining right would ordinarily be required. However, the Minister of Minerals and Energy may exempt any organ of state from the requirement in respect of any activity to remove any mineral for road construction, buildings of dams or other purposes. As the South African SKA project is a Business Unit of the National Research Foundation, it constitutes an organ of state and would qualify for exemption. The South African SKA project has applied for this exemption for MeerKAT;

6. Electricity Supply: After the construction of a building, an electrical installation inspection is required to ensure compliance with the provisions of all applicable laws in terms of the National Building Regulation and Standards Act;

7. Land: Construction may only take place on land that has been appropriately zoned for the intended use. If not, the SKA will need to submit a re-zoning application to the relevant municipality in accordance with the applicable town planning laws;

8. Airstrips: An airstrip is required to be licensed by the Civil Aviation authority if it is used for commercial air transport operations, or where the aeroplane use the airstrip exceeds the maximum certified mass of 5,700 kg.

The Astronomy Geographic Advantage Act (Annexure J6.1.7) provides wide ranging powers to the Minister of Science and Technology, and the Astronomy Management Authority in South Africa, that will facilitate the construction and operation of the SKA. This includes access to land and servitudes. SKA is accordingly exempt from the requirement to apply for permits relating to the construction of optic fibre data networks linking all receivers to the core site. In the event of a conflict between a provision of the AGA Act, and any national or provincial legislation, or a municipal by law, the provisions of the Act will prevail.

Ordinarily the Electronic Communications Act (ECA) would require an entity to hold certain licences in order to construct and operate an optic fibre data network over the extent required for the SKA. However, the AGA Act specifically exempts any astronomy device, that is declared as such by the Minister of Science and Technology, from any licensing or other requirements of the ECA.

9.7.2 African SKA Partner Countries

Annexure J8 provides a listing of annexures that deal with the licensing and permit requirements for the construction and operation of the SKA in each African SKA partner country.

9.8 Environmental Issues

9.8.1 South Africa

A detailed summary of environmental issues and legislation in South Africa is provided as Annexure J7.1.1.

South Africa is a signatory to numerous international environmental conventions, agreements and protocols, including the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change,
the Montreal Protocol on Substances that Deplete the Ozone Layer, and the Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention).

The protection of the environment is a constitutional right in South Africa, and is implemented primarily through the following legislation:

1. National Environmental Management Act (NEMA) (Annexure J7.1.10) : South Africa’s main environmental statute. NEMA requires the cumulative impact of a proposed development on the environmental, socio-economic conditions and cultural heritage to be assessed within a regulated system of assessment. Environmental authorisation is required from the respective authority prior to the commencement of any activity for which the assessment was conducted. The environmental impact assessment (EIA) regulations have been attached as Annexure J7.1.4 - J7.1.9, and a detailed analysis of the EIA process in South Africa is provided in Annexure J7.1.13. NEMA provides for strict criminal liability for environmental harm. NEMA imposes a duty of care on every person who causes significant pollution or degradation to the environment. The MeerKAT Environmental Impact Assessment Report, which encompasses the construction of a radio astronomy facility on the farms Losberg and Meys Dam in the Karoo, is provided as Annexure J7.1.2. The bulk of the SKA Core region (include dishes, aperture array high and aperture array low) will be located on these two farms;

2. National Water Act (Annexure J7.1.12) : The Act regulates the manner in which a person obtains the right to use water, and provides for just and equitable use of water resources. The purpose of the National Water Act is to ensure that the nation’s water resources are protected, used, developed, conserved, managed and controlled in ways that take into account basic human needs. Issues covered include the needs of present and future generations, production and prevention of pollution, and the degradation of water resources, as well as promotion of the efficient, sustainable and beneficial use of water in the public interest. Water use requires a licence under the Act, unless that water use is permissible in terms of a general authorisation issued under the Act. The MeerKAT project has obtained a water use licence, which can be extended for the SKA;

3. National Environmental Management Air Quality Act (Annexure J7.1.3) : The Act regulates air quality in line with the Constitution and NEMA;

4. National Environmental Management Waste Act (Annexure J7.1.11) : The Act create a general duty in respect of waste management, and prescribes activities for which a waste licence would be required. Waste must be avoided/minimised, and where it cannot be altogether avoided, should be re-used, recycled or disposed of in an environmentally sound manner;

5. National Environmental Management Biodiversity Act (Annexure J7.1.14) : The Act seeks to provide for the management and conservation of biological diversity and its components. It provides for the protection of species and eco-systems that are threatened or are in need of protection.

The conservation and protection of heritage resources is provided for in the National Heritage Resources Act. This Act has significant implications for the development of infrastructure, such as the construction of a road, wall, powerline, pipeline, canal or other similar form of linear development or barrier exceeding 300 m in length, the construction of a bridge or similar structure exceeding 50 m in length, or any development or other activity which will change the character of a heritage site.

Any person engaging in such activities must, at the very earliest stages of the development, notify the responsible heritage resources authority and furnish the authority with certain details regarding the development. The South African Heritage Resources Authority will make a decision regarding whether or not the development may proceed and, if so, conditions may be introduced in order to fulfill the obligations of the Heritage Resources Act. The Environmental Impact Assessment, to be conducted during the detailed design process, will identify specific heritage issues to be dealt with. No heritage issues that would cause significant delay in the construction program are expected.

9.8.2 African SKA Partner Countries

Annexure J8 provides a listing of annexures that deal with environmental legislation in each African SKA partner country.
Chapter 10
Security

10.1 Introduction
A detailed security risk assessment has been compiled by Pasco Risk Management, a multinational company providing security risk assessment worldwide. This assessment is attached as Annexure K1.1. The risk assessment was conducted for all locations that will host SKA infrastructure and personnel as per the SKA scenario used for costing purposes. Therefore, Kenya, Mauritius and Ghana have not been considered at this stage, as these sites are considered additional sites to the SKA Model scenario.

The risk assessment, existing security plans at the MeerKAT site (co-located with the SKA Core Site) and advice based on construction experience in Africa from Aurecon was used to develop appropriate security models for the SKA facility. As recommended in the risk assessment report, the model adopted is a low security profile model due to the low to negligible risk of any threat to the SKA facility and its personnel. A comprehensive safety and security plan developed by Pasco has been attached as Annexure K1.2, and provides general recommendations on policies, organisation, risk assessment and management.

10.2 Security Risk Assessment

10.2.1 Threat Assessment
A summary of the threat assessment across all components of the SKA project is provided as follows:

1. Terrorism: There is a negligible threat from domestic or international terrorism in the region where the SKA sites are located;
2. Political Stability: The threat of political instability to the SKA project in the Southern African Development Community states is negligible;
3. Regulatory/Legal: Legal and regulatory threats have been determined as negligible;
4. Social Unrest: Labour disputes are common in South Africa. The physical threat to the SKA as a result of social unrest has been determined as negligible in the locations where the SKA is to be located;
5. Criminality: There is a low to negligible threat of organised crime against SKA assets and personnel, and a low threat of theft or violent crime against the SKA assets and personnel in the areas where the SKA sites will be located, or where SKA staff will live or travel.

10.2.2 Case Studies
The risk assessment included case studies that were undertaken at various sites, including SKA station locations, existing astronomy sites (South African Astronomical Observatory - SAAO; Hartebeesthoek Radio Astronomy Observatory - HartRao; and the MeerKAT site and Support Base near Carnarvon in the Karoo), and remote construction and telecommunication sites. The SAAO operates a site near the town of Sutherland (approximately 400 km from the SKA Core) that hosts the Southern African Large Telescope (SALT), as well as a number of...
other international instruments. Its head office is located in Cape Town. HartRAO operates a 26 m radio telescope 70 km from Johannesburg. With minimum security in place, these locations have no significant security concerns. This is partly as a result of being located in remote and isolated areas.

10.3 Security Model

As a result of the risk assessment, which indicated that the risk of crime and other threats was low at all SKA locations, a security model was developed that would ensure the necessary level of protection whilst being compatible with the operations of a radio astronomy facility. This model, and various security requirements at each location, are covered in Annexure K1.

The MeerKAT security plan is discussed in Section 10.3.1 prior to discussion of the SKA security measures in Section 10.3.2, as the SKA and MeerKAT telescopes and support infrastructure will be co-located.

10.3.1 Current MeerKAT Security

The South African SKA’s MeerKAT project currently operates at three locations: the MeerKAT Science and Engineering Office in Pinelands, Cape Town; the Klerefontein Karoo Support Base, 14 km outside the town of Carnarvon, includes offices, accommodation and mechanical workshops, and the C-BASS telescope; and the Losberg Site Complex, 80 km outside of Carnarvon, which includes the KAT-7 telescope, the PAPER telescope, and support infrastructure.

The Losberg Site Complex has access control on the gravel road, manned at all times by one security guard who is in contact with the Klerefontein Karoo Support Base. Farm fencing surrounding the Losberg and Meys Dam farms exists for vermin (jackals) control. No new fencing exists, as it was deemed unnecessary. No additional security measures are in place. A photograph of the Losberg Site Complex, indicating the access control to the site, is shown in Figure 10.1.

![Figure 10.1: Photo of the Losberg Site Complex, with the security guardhouse and boom indicated. The guardhouse is manned by one person, who can communicate with the Klerefontein Karoo Support Base.](image)

No additional security measures have been put in place around the KAT-7 telescope. Although webcams offer live viewing from Cape Town, this is for operational purposes only and does not form part of any security plan. No criminal activities have been reported at this site since its establishment in 2008.

The Klerefontein Karoo Support Base has access control, manned by one security guard at all times. The site is fenced with a very light fence, mostly for animal control. No criminal activities have been reported at this site since its establishment in 2008.

The MeerKAT Science and Engineering Office in Pinelands, Cape Town, is located in a large office building. Security measures for the building include palisade fencing, access control manned by a security guard, visitors and staff authentication procedures and CCTV.
10.3.2 SKA Facility and Personnel

Continuing risk assessment during the course of construction and operation will inform the security model, which will be adapted accordingly. Initial security measures for the SKA facility are summarised below.

1. SKA Head Office

The SKA Head Office, located in Cape Town, would employ similar security measures to those taken for the MeerKAT Office. This would include basic palisade or wire mesh fencing around the office complex; interior and exterior CCTV (Closed Circuit Television) at key points; manned vehicle access control and security checkpoints; alarm systems; area designations (restricted areas, controlled area, unrestricted areas); identification, admission and interior movement control; employee entry and monitoring; and visitor identification accountability systems.

2. Astronomy Complex (Operations Centre)

The Astronomy Complex is located on the main access road to the SKA Core site. A detailed description of the Astronomy Complex is provided in the Basic Infrastructure Report in Annexure A. The security measures undertaken for the SKA Head Office would apply to the Astronomy Complex. The main access road will be de-proclaimed from the entrance of the Astronomy Complex to the SKA Core site. This will provide control of traffic volumes on the road, and hence of the number of potential sources of electromagnetic interference (EMI). This de-proclamation will include access control on the main road, introducing a further security measure.

3. SKA Core Site

Farm fencing (three strand, 4 ft high) has been considered as a method of vermin (jackals) control. No security fencing is deemed to be necessary. CCTV at various strategic locations would provide an adequate level of monitoring, with regular foot patrols by security personnel to gather information on potential threats from wild animals or trespassers. The main vehicle access point would be via the Losberg Site Complex, which has existing manned access control. CCTV at various strategic locations in the complex would aid in general site management e.g. ensuring safe movement of vehicles and persons, as well as recording of work related incidents.

4. SKA Remote Stations

A perimeter palisade or wire mesh fencing will surround each remote station. This will act as a deterrent to would-be trespassers, and ensure proper vermin control. Vehicle access control will be implemented with manual slide gates. Fixed cameras will be installed at all building doors and vehicle gates for entry and exit verification. Magnetic strip card readers for access control will be installed for buildings doors, whilst other rooms and buildings will be manually locked. All CCTV surveillance will be recorded at high resolution and it will be possible to control the system and view the video from remote locations through the SKA Intranet.

5. Construction Site

Security measures include palisade or wire mesh fencing, CCTV at strategic points, security lighting, manned security checkpoint at entrance and vehicle access control. Alarms will be installed on priority buildings.

Initial security measures for SKA personnel are summarised below.

1. SKA Head Office Personnel

Transient and permanent personnel located at the SKA Head Office in Cape Town will either be accommodated in hotels and/or bed and breakfast establishments (short period visits), or in residential properties. Standard security measures at hotels in and around Cape Town have been determined to be adequate for SKA personnel being accommodated in such establishments. Security measures required to secure an typical house in an typical suburb in Cape Town were assessed. These include intruder alarm systems and security gates. It is unlikely that additional security measures would need to be considered. It is presumed that staff would be responsible for their own accommodation. A photograph of an typical house located in the suburb of Pinelands, where the current MeerKAT Project Office is located, is provided in Figure 10.2.

2. Astronomy Complex On-site and Off-site Personnel
Security measures at the Astronomy Complex will ensure an adequate level of security for staff at the site. The security threat level for off-site personnel accommodated in Carnarvon is very low. Basic security measures include intruder alarm systems for accommodation facilities. Cooperation with the South African Police Service and basic security awareness on the part of SKA personnel will mitigate most security risks. Operational security plans should include monthly interactions with the South African Police Service and Community Policing Forums based in Carnarvon.

3. Construction Camp

The influx of labourers for the KAT-7 project did not result in any changes in the crime profile for the town of Carnarvon. Assessment for the SKA indicated that the risks to SKA personnel and construction workers will remain low. Only light security measures need to be implemented at the construction camp. These include wire mesh fencing, security checkpoint and vehicle access control, security lighting, intruder alarm systems on certain buildings, incident reporting procedures and regular foot patrols by security guards. Security would be the responsibility of the relevant contractors, and would be included in the Preliminary and General charges. Cooperation with the South African Police Service and basic security awareness on the part of construction personnel will mitigate most security risks. Operational security plans should include monthly interactions with the South African Police Service and Community Policing Forums based in Carnarvon.

The cost to the SKA project for the various security measures outlined is estimated at €1.03 million capital cost, and €323,000 annual operational and maintenance cost, for all locations.

10.4 Insurance

Alexander Forbes Risk Service are currently the brokers to a number of scientific institutions and 97% of tertiary education institutions in South Africa, including the SALT telescope, the National Research Foundation (NRF) and the Council for Scientific and Industrial Research (CSIR). The company was approached to consider insurance costs for the SKA facility and personnel. A detail analysis of the insurance costs for the construction and operational phases of the SKA is included as Annexure K2. Insurance costs for the entire construction phase are estimated over 10 years. Insurance costs for the operational phase are based on an annual policy, renewable every 12 months. Cost indications may change once the Operational Phase has commenced due to a number of factors, such as a change in the current understanding of the risk profile, state of insurance market, claims history, value of the assets etc.

Indicative insurance costs have been converted to 2007 Euros, as per the methodology outlined in Section 5.8 of Annexure K3. A summary of indicative insurances costs is provided in Table 10.1.
Table 10.1: Indicative insurance costs in January 2007 Euros.

<table>
<thead>
<tr>
<th>Description</th>
<th>Annual Premium Rate</th>
<th>Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property Damage (Assets All Risk) - Operational Phase</td>
<td>0.035% to 0.05%</td>
<td>€1,456,500,000</td>
</tr>
<tr>
<td>Public Liability - Operational Phase</td>
<td>€29,130</td>
<td></td>
</tr>
<tr>
<td>Motor Fleet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Motor vehicles</td>
<td>3.50%</td>
<td>Based on 30 vehicles at value of €728,250</td>
</tr>
<tr>
<td>ii. Cranes</td>
<td>1%</td>
<td>Based on 20 cranes at value of €5,826,000</td>
</tr>
<tr>
<td>iii. Cherry Pickers</td>
<td>1%</td>
<td>Based on 20 cherry pickers at value of €1,942,000</td>
</tr>
<tr>
<td>Group Personal Accident</td>
<td>€135.94 per person</td>
<td>Accidental death benefit of €97,100 for 300 insured persons</td>
</tr>
<tr>
<td>Travel</td>
<td>€3.50 per travel day per person</td>
<td>Emergency medical expenses cover of €8,739,000</td>
</tr>
<tr>
<td>Contract Works and Liability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Contract Works (10 year Construction Phase)</td>
<td>0.22%</td>
<td>€1,667,741,050</td>
</tr>
<tr>
<td>ii. Contract Works Liability (10 year Construction Phase)</td>
<td>0.02%</td>
<td>€1,667,741,050</td>
</tr>
<tr>
<td>Contract Contingency (Operational Phase)</td>
<td>0.25%</td>
<td>€1,942,000</td>
</tr>
<tr>
<td>SASRIA (Riot and Strike) - Construction Phase</td>
<td>0.0072%</td>
<td>€1,667,838,150</td>
</tr>
<tr>
<td>SASRIA (Riot and Strike) - Operational Phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Property Damage</td>
<td>0.00478%</td>
<td>€1,456,500,000</td>
</tr>
<tr>
<td>ii. Motor Fleet</td>
<td>0.036%</td>
<td>€3.88 per vehicle per annum</td>
</tr>
<tr>
<td>COID (Workman’s Compensation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Category I (construction/manual labourers)</td>
<td>4.63%</td>
<td>Based on annual earnings</td>
</tr>
<tr>
<td>ii. Category II (admin staff)</td>
<td>0.33%</td>
<td>Based on annual earnings</td>
</tr>
<tr>
<td>Group Life Benefits</td>
<td>1.43%</td>
<td>Based on annual pensionable earnings</td>
</tr>
</tbody>
</table>
Chapter 11

Employment

11.1 Employment Legislation in South Africa

South Africa has comprehensive legislation dealing with working conditions and the rights of employees and employers. The legislation relevant to the employment of professionals and others by the SKA in South Africa is set out in Annexure L1. The legislation creates a framework for the establishment of minimum conditions, collective bargaining, the protection of the rights of employees and employers and other matters.

South African labour legislation does not discriminate between South African citizens and expatriates. Rights and entitlements apply not only to South African citizens, but also to any person who falls within the definition of an employee in South African employment legislation and who is employed in South Africa. Persons who do not have permanent residence in the RSA can only work when they hold a work permit.

Employees of SKA will work in South Africa in terms of the South African legislation and will enjoy all the rights accorded therein. Employees who travel to other countries for work will continue to enjoy these rights and benefits. We propose that all employees be based in South Africa and travel to remote stations outside the country as and when required, excluding a small number of employees, such as site security, who will be employed from the local population.

There are in general no restrictions on the availability of rights under South African employment legislation to any class of employees, including senior managerial or executive level employees. However, employees earning in excess of a promulgated threshold, currently set at R172 000 per annum, are not subject to the restrictions on maximum hours of work. The rights of employees in terms of South African employment statutes also apply to applicants for employment.

11.2 Conditions of Employment

Working conditions and conditions of employment may be set in any of the following ways:

1. Minimum conditions are established by legislation.

2. Conditions which are in general, better than the minimum may be set through individual contracts of employment, by agreement between the employee and employer.

3. Conditions which are in general better than the minimum may be set in collective bargaining agreements negotiated in industry-level Bargaining Councils between employees, represented by trade unions, and employers, represented by employer associations. Such agreements may cover any matters agreed between the parties. Provided the parties to the agreement are sufficiently representative of the employees and employers in the industry, the Minister of Labour may make the agreement binding on all employers and employees in the industry.

4. Conditions which are in general better than the minimum may be set in collective bargaining agreements at workplace or company level between employees, represented by trade unions, and the employer. Such agreements may cover any matters agreed between the parties.
Collective bargaining agreements are normally for a period of a year, but often cover a longer period. Employees in managerial and/or professional positions are generally not included in collective bargaining or covered by collective bargaining agreements. Their conditions of employment are normally set in their individual employment contracts.

As an example, the National Research Foundation of South Africa (NRF) is not covered by an industry-level Bargaining Council, but negotiates annually with the unions which have sufficient representation in the NRF. Although the managerial grades are not directly represented, the negotiated across-the-board increases in remuneration are generally implemented for them. The conditions of employment of the NRF are better than the minimum conditions set in the legislation.

The Basic Conditions of Employment Act (BCEA) (Annexure L2) covers such things as minimum standards for hours of work, payment of overtime and work on Sundays and holidays, payment when employees work continuous shift systems, minimum leave days, payment for leave, holidays, sick leave, rest periods including lunch and tea times, maternity leave and other matters. The Act also empowers the Minister for Labour to establish minimum wages in an industry where there is no Industry Bargaining Council.

11.3 Trade Unions
All employees have the right to join a trade union. If a union is sufficiently representative, it acquires certain rights to represent its members at a workplace or in an industry, both in collective bargaining and in individual disputes (such as dismissals). Employees (other than those in essential services) have a right to strike legally, provided they have exhausted the prescribed dispute resolution procedures and have given notice of their intention to strike. Employers have a corresponding right to lock employees out. The dispute resolution mechanisms are set out in the Labour Relations Act and include the Commission for Conciliation, Mediation and Arbitration and the Labour Appeal Court. Arbitration is commonly used to resolve disputes.

An employer may not unilaterally change conditions of employment. Consultation or negotiation with the affected employees is required. If there is no agreement, either side may declare a dispute and move through mediation or arbitration. If there is no resolution, the employer may implement the new conditions.

The Constitution, which is the supreme law (i.e. all legislations must be consistent with the Constitution), guarantees all employees and employers the right to fair labour practices and the right of association. The Constitution also guarantees the right not to be discriminated against on the grounds of race, gender, ethnicity, religion, sexual preference or disability. These guarantees are given effect in the Labour Relations Act and the Employment Equity Act. The right not to be discriminated against also applies to applicants for employment.

11.4 Health and Safety
Employees are guaranteed the right to a safe workplace. Employers have the obligation to ensure that workplaces are safe for the employees and people in the surrounding area and that potential dangers are removed or mitigated. Employees have a duty to ensure that they identify and report unsafe acts and conditions to the employer. These rights and duties are set out in the Occupational Health and Safety Act (Annexure L3), with additional requirements contained in the BCEA and in municipal bye-laws. Specific measures required to implement the legislation are contained in regulations published from time to time by the Minister of Labour in terms of the Act. A detailed exposition of the Act and its application is attached as Annexure L4.

11.5 Social Security
All employees are covered by the Compensation for Occupational Diseases and Injuries Act and the Workmen’s Compensation Fund. Employers contribute to the fund and are assessed for contributions taking into account their lost-time accident record. Many employers provide additional life and disability insurance schemes, to which the employer and employees may or may not be required to contribute. The National Research Foundation offers such group schemes to its employees - both employer and employees contribute.

All employees who work for more than 24 hours per month must contribute to the Unemployment Insurance Fund. It is illegal for employers not to make such deduction from earnings. Both the employers and employees contribute 1% of the employee’s remuneration. The UIF also covers illness and maternity leave.
Certain practices have been established through case law as fair labour practices. For instance, all employees (at whatever level) who are made redundant are entitled to a payment from the employer in addition to the normal notice period. This would normally be at least one week’s salary per year of service with the employer.

11.6 Deductions from Employees’ Pay

In terms of the Income Tax Act, 58 of 1962 (Annexure L5), employers act as representative taxpayers and must deduct Pay As You Earn (“PAYE”) from remuneration payable to each employee. PAYE is based on the employee’s rate of pay.

Employers must register with and pay contributions to the Unemployment Insurance Fund in terms of the UICA. The contributions payable to the Unemployment Insurance Fund are made up of a deduction from the employee’s remuneration and an equal payment made by the employer.

Other than the above statutory deductions, the BCEA provides that no deduction can be made from an employee’s salary unless the specific amount is agreed to in writing by the employee. Union subscriptions may be deducted directly from employees’ salaries.

There is presently no requirement under South African employment legislation for compulsory contributions to any national or private medical benefit scheme and retirement benefit scheme. Government appointed committees are examining these issues.

Private retirement schemes are subject to separate regulation by the Financial Services Board, under the Pension Funds Act, 24 of 1956.

Total employer deductions for pension, provident and medical schemes are limited to a maximum prescribed percentage of the employee’s remuneration. Contributions to a pension fund are usually paid by employers as salary deductions, entitling employees to a limited deduction for income tax purposes. However, this limited deduction does not apply in respect of contributions to a provident fund. Where an employer makes a contribution to a retirement annuity fund as part of the income of the employee as a taxable benefit, the employee will be entitled to a deduction for income tax purposes.

Contributions paid by employers towards employees’ medical aid are taxable as fringe benefits in the hands of the employees, but deductible as part of the employer’s salary cost. The employee may deduct medical aid contributions from tax, subject to certain limits.

11.7 Work Permits and Visas

The Immigration Act 13 of 2002 (“the Immigration Act”) deals with the status of foreigners in South Africa. The Immigration Act is attached as Annexure L6.

No employer may employ a person to work in South Africa unless that person is either a South African citizen (in which case he/she automatically has the right to work) or that person has a work permit. The Immigration Act allows for a variety of work permits to be issued.

The first is a treaty permit, in terms of which foreigners can be authorised to conduct activities in South Africa in terms of an international agreement to which South Africa is a party. Treaty permits may be issued by either the Department of Home Affairs (DHA), the Department of International Relations & Cooperation, or any other organ of state responsible for the implementation of the international agreement.

The second is a corporate permit, which may be issued to corporate applicants to employ foreigners to conduct work for that specific applicant. A corporate permit allows a number of foreigners to be employed by a corporate applicant, and may be modified on good and reasonable cause. The SKA could therefore apply for such a permit to enable foreigners to work on the SKA in South Africa.

The third is an intra-company transfer permit, which may be issued to allow employees of foreign companies to perform services for branch or affiliated companies in South Africa. The SKA could therefore apply for such a permit to transfer foreign employees to branch companies to work on the SKA in South Africa.

Fourth, individual employees could apply for an exceptional skills permit, quota work permit, or a general work permit. A wide range of occupations are covered in the list of exceptional skills, including astronomers and astrophysicists (see Annexure L7). These and other occupations were specifically included in order to support South Africa’s proposal to host the SKA, the construction of the MeerKAT telescope and the SKA South Africa’s Human Capital Development Programme. The list includes all of the categories of skills which are likely to be
required in the construction and operation of the SKA. The experience of the South African SKA Project Office (SASPO) has been that, provided the specified procedures are followed, it has been straightforward to obtain permits for people coming to work for the project or the universities, and also to extend those permits when they expire.

The timing of the work permit application process varies, depending on the type of permit applied for. The DHA has made a commitment to improve service delivery and turnaround times, which has been the result of a major revamp of the department. It is being driven by the Minister for Home Affairs, who is a very senior minister. Note that all Ministers have been required to sign performance contracts with the President, committing them to specific measures to improve service delivery.

Special dispensations are also possible.

- A Large Accounts Unit has been created by the DHA (see Annexure L8). This provides a special channel for certain corporations to use, making applications easier and quicker. For example, Eskom has registered with the Large Account Unit and obtains batches of permits for specified disciplines for five years at a time. Eskom reports that they have no problems in obtaining further permits when required. The responsible officials in the DHA have indicated that the SKA would be able to apply to register with the Large Accounts Unit.
- The Director General of Home Affairs, the civil service head of the department (the Minister is the political head), is empowered to grant exemptions from the requirements for work permits. This was done for instance for the preparatory work carried out for the hosting of the 2010 Football World Cup in South Africa and for the period of the World Cup itself. The Director General of Home Affairs has informed the Director General of the Department of Science and Technology that an application for exemption from the SKA is likely to be viewed favourably.

Other than in respect of treaty permits, the DHA is the regulatory authority in respect of the issue of work permits and the status of foreigners.

Any visitors to South Africa, including family members and dependants of foreigners legally working in South Africa, may apply for a non-working visitors visa to enter South Africa to accompany the foreign worker. Study permits may also be granted to allow family members and dependants of foreigners legally working in South Africa to study in South Africa.

SASPO has received many international visitors and has encountered no delays or problems with their entry. A substantial number of non-South African nationals have taken up full or part time positions with SASPO and the universities working with the project. No problems have been encountered with visas or work permits for them. Staff seconded from the NRAO have not encountered problems in obtaining permits.

Undertakings have been received from all of the African countries in which SKA stations will be located to facilitate the issue of visas and work permits (see examples of letters of undertakings in Annexures L9.1 and L9.2). SASPO has sent personnel to Namibia, Botswana and Mozambique to carry out RFI measurements and to Ghana to work on the conversion of a 32 m satellite communication dish for the African VLBI Network. SASPO representatives have also regularly traveled to all of the African countries partnering in the South African SKA site proposal for various meetings and studies. No problems or delays have been encountered. Two of those traveling have been non-South African nationals. No problems have been encountered in the issue of permits and visas for them, nor have they encountered problems at the ports of entry.

11.8 Spousal Employment

Spouses of foreign workers legally working in South Africa can apply for a visitor’s visa to enter South Africa to accompany the foreign employee. The visitor’s visas, on application to the DHA, may authorize the spouse to perform work in South Africa. Spouses of foreign workers may also, in their own right, apply for entry into South Africa under an applicable work permit.

11.9 Income Taxation of Employees

The SA Revenue Service provided the following explanation for potential employees of the SKA in South Africa.

Employees will be subject to income tax in respect of the remuneration for the services they render in South Africa. The following points should, however, be borne in mind.
Although South Africa taxes its residents on their worldwide income, expatriate employees who are present in South Africa for five years or less will only be subject to income tax on their South African source income. This concession does not apply to employees who move to South Africa with the intention of making it their home. A detailed explanation of the five year rule is to be found in Interpretation Note 4 at http://www.sars.gov.za/home.asp?pid=54958 (Annexure L10).

Employees who are present in South Africa for 183 days or less, in any twelve month period, and are not remunerated by a domestic employer or domestic branch of a foreign employer will generally be exempt from income tax in South Africa, if South Africa has concluded a double taxation agreement (DTA) with the employees’ jurisdiction of residence. The terms of the exemption will depend on the specific DTAs.

To the extent that employees are taxed on their remuneration both in South Africa and in their jurisdiction of residence, relief from double taxation will be available in the jurisdiction of residence if South Africa has concluded a DTA with the jurisdiction. The terms of this relief will depend on the specific DTAs. The jurisdiction of residence may also offer unilateral relief outside a DTA.

South Africa has concluded DTAs with a wide range of countries. A list of the countries and links to the relevant DTAs are available at http://www.sars.gov.za/home.asp?pid=3919 (Annexure L11).

11.10 Availability and Cost of Skilled Labour


<table>
<thead>
<tr>
<th>Occupation</th>
<th>Number</th>
<th>Hourly rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site managers</td>
<td>50 425</td>
<td>€18-29</td>
</tr>
<tr>
<td>Plant operators</td>
<td>334 025</td>
<td>€2.66</td>
</tr>
<tr>
<td>Construction labourers &amp; tradesmen</td>
<td>1 241 413</td>
<td>€1.38-2.66</td>
</tr>
<tr>
<td><strong>Professional engineers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Civil engineers</td>
<td>27 821</td>
<td>€29-37</td>
</tr>
<tr>
<td>Electrical engineers</td>
<td>34 771</td>
<td></td>
</tr>
<tr>
<td>Electronics and telecommunications engineers</td>
<td>2 579</td>
<td></td>
</tr>
<tr>
<td>Mechanical engineers</td>
<td>9 308</td>
<td></td>
</tr>
<tr>
<td><strong>Architects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land surveyors</td>
<td>12 022</td>
<td>€29-37</td>
</tr>
<tr>
<td>Architects, town and traffic planners</td>
<td>17 585</td>
<td>€29-37</td>
</tr>
<tr>
<td>Draughtspeople</td>
<td>11 179</td>
<td>€10-20</td>
</tr>
<tr>
<td><strong>Technical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Civil engineering technicians</td>
<td>5 768</td>
<td>€15</td>
</tr>
<tr>
<td>Electrical engineering technicians</td>
<td>34 512</td>
<td></td>
</tr>
<tr>
<td>Electronics and telecommunications engineering technicians</td>
<td>75 861</td>
<td></td>
</tr>
<tr>
<td>Mechanical engineering technicians</td>
<td>49 010</td>
<td></td>
</tr>
<tr>
<td><strong>Trades</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal moulders, welders, sheet-metal workers, structural metal preparers and related trades workers</td>
<td>198 132</td>
<td>€15</td>
</tr>
<tr>
<td>Blacksmiths, tool-makers and related trades workers</td>
<td>63 266</td>
<td></td>
</tr>
<tr>
<td>Machinery mechanics and fitters</td>
<td>228 307</td>
<td></td>
</tr>
<tr>
<td>Electrical and electronic equipment mechanics and fitters</td>
<td>56 782</td>
<td></td>
</tr>
<tr>
<td><strong>Secretarial</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administrative secretaries</td>
<td>10 827</td>
<td>€10.16</td>
</tr>
<tr>
<td>Secretaries and keyboard-operating clerks</td>
<td>159 759</td>
<td>€6.25</td>
</tr>
<tr>
<td><strong>Medical and security</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paramedics</td>
<td>590 423</td>
<td>€14.36</td>
</tr>
<tr>
<td>Security guards (contract cost, i.e. not a wage cost)</td>
<td>509 423</td>
<td>€6.06</td>
</tr>
</tbody>
</table>
Chapter 12

Working and Support Environment

12.1 Life in South Africa

In 1994 South Africa transformed from an apartheid system of discrimination and inequality to a fully democratic and highly progressive society. The entire nation has embraced this change positively and icons, such as the former President Nelson Mandela, have led the way for a peaceful and exciting transformation. In the 2005 Gallup International Poll on attitudes about the future, South Africans turned out to be the 8th most optimistic people in the world.

South Africa’s Constitution is widely regarded as the most progressive constitution in the world and is the supreme law of the country. The rule of law requires the government to exercise its power in accordance with the constitution and ensures the prohibition of arbitrary acts by the state and any of its agencies. Human rights are given clear prominence in the Constitution. Prohibition of discrimination on the grounds of race, religion, sexual preference and political views is regarded very seriously. The citizens of South Africa are even guaranteed the right to an efficient administration.

The HSBC Expat Explorer survey (HSBC, 2010) is the largest independent survey of expatriates providing insights about their experiences (survey results tabulated in Annexure M1). According to the survey, South Africa is the easiest country to relocate to, in terms of organising and setting up. It scores extremely well in finding accommodation, healthcare, getting used to local food, adapting to the local weather and adjusting to the work culture, among others. In terms of the ease of integrating into society, South Africa-based expatriates respond positively, noting that they enjoy the local food and make local friends easily. South Africa also scores very well in quality of life, ranked third, and is rated highly in the quality of accommodation, opportunities for sports and overall work-life balance with a better working environment, active social life and healthier diets.

South Africa-based expatriates tend to own more luxury items than other expatriates. More than 60 per cent of respondents in South Africa affirmed that they had nicer or bigger properties, domestic staff, swimming pools, more luxurious holidays and healthcare. This reflects the affordability of living in South Africa.

Astronomers from other countries who have relocated to South Africa affirm the findings of the HSBC Expat Explorer survey, with comments such as:

- “On the whole, South Africans are a very friendly and curious lot, and are very welcoming to foreigners.”
- “South Africa is a great place to live for foreign expats. While the country certainly has its challenges, there are endless opportunities for well-trained specialists. Nature has favoured South Africa in many unique ways and the country has a modern infrastructure without having lost its traditional roots. South Africans are friendly and, despite a tough 20th century, are optimistic about their future in the 21st and willing to work for it.”
- “Great weather, lots of nature, beautiful beaches, fantastic restaurants”
- “On astronomy: lively community, though fairly small, however, that enables anyone who wants to, to play a large role in that community.”

According to Mercer’s “Worldwide Cost of Living Survey 2011” of the world’s most expensive cities, Johannesburg and Cape Town are ranked 131 and 158 respectively out of 214 cities (Annexure M2 is a ranked list of the 50 most
expensive cities in the world). It is the world’s most comprehensive cost of living survey, measuring the comparative cost of over 200 items, including housing, transport, food, clothing, household goods and entertainment. New York is used as the base city against which all other cities are compared. The cost of housing, often the biggest expense, plays an important part in determining where cities are ranked. In South Africa the cost of housing is much lower than in many other big cities in the world. In addition to the low prices, South African homes are generally larger, and have large gardens.

In South Africa the top statutory personal income-tax is 40%. For comparison, Annexure M3 contains the OECD tax database for the 34 OECD member countries. Personal taxation is covered under the Customs and Excise, and Employment reports (Annexure A).

12.2 Towns and Cities of Residence

The proposed location, accommodation and movements (within South Africa and to the African partner countries) of various levels of SKA staff are described in some detail in Chapter 2 (Provision of Basic Infrastructure Components) of the full response (Annexure A). Three towns and cities are identified as possible places of permanent accommodation for various SKA staff categories.

- **Cape Town:** International staff, scientists, engineers and senior technicians would probably reside in Cape Town, the location of the SKA Head Office. Some of these staff will commute to and from Carnarvon on a rotating shift system (similar to the ALMA Sistema de Turno).

- **Carnarvon:** This is the closest town to the SKA Core site, and will be where local maintenance staff (and their families) will be based. Cape Town resident staff working on a Turno rotating shift will be housed in Carnarvon in accommodation provided by the project.

- **Kimberley:** This is the closest city to the core site. Local maintenance staff (and their families) associated with the core site and the remote SKA stations could reside here.

No international SKA staff will reside permanently or for long periods in the African partner countries.

12.2.1 Cape Town

Cape Town is the ideal city for SKA staff to live in, especially well-educated, high level scientists and engineers who thrive in research-intensive environments with access to modern infrastructure, universities and appropriate industries. Work on the MeerKAT has laid the basis for the SKA with respect to the establishment of an operating Control, Science and Engineering Centre, access to fast data connectivity and proven travel logistics to and from the site.

Cape Town is a world class, cosmopolitan city that attracts many people to visit and live there because of its extraordinary natural beauty and world-class infrastructure, industry and business. Cape Town has been ranked as the world’s top tourist destination in 2011 (http://www.tripadvisor.com/TravelersChoice-Destinations-cTop25-g1). It is famous for its harbour as well as its natural setting in the Cape floral kingdom, including such well-known landmarks as Table Mountain, Cape Point and Robben Island, and its beaches. Commercially Cape Town offers everything any other top-ranking city in the world would offer, all major brands and franchises are represented, as are major financial, insurance and health corporations. Industry is diverse and the business sector, especially in ICT, is thriving.

Cape Town has a Mediterranean Climate: winters are mild with some rain and the average daytime temperature is 17.5 C. Summers are hot with low humidity and the average daytime temperature is 26.5 C.

It has become widely recognised by the South African astronomical community and the South African science administration, that Cape Town is the centre of astronomy activities. The MeerKAT radio telescope will be operated remotely from the MeerKAT Cape Town Control, Science and Engineering (CSE) Centre via a recently installed 10 Gigabit/second optic fibre link from the Karoo to Cape Town. The office is based in Pinelands, a suburb of Cape Town, and all the project’s scientists and engineers are based at this office. The office is conveniently located close to Cape Town International Airport, as well as to hotels and the CBD of Cape Town. The South African National Research Foundation has requested that the MeerKAT CSE Centre form the nucleus for a campus which can be expanded to form the Head Office of the National Radio Astronomy Facility and eventually of an Institute of Astronomy. In the event that Africa wins the SKA site bid, it is possible that the MeerKAT CSE Centre could
be the nucleus for the SKA CSE Centre and the planning and design of the MeerKAT CSE Centre has taken into consideration the SKA requirements.

12.2.2 Carnarvon

Since 2005 the South African SKA team has spent significant time in Carnarvon, and many of the site staff are permanently resident there. They rely on the town’s services for accommodation, banking, daily provisions and medical services, all of which are readily available. The team has also had the opportunity to meet the residents of the town and the farmers in the area and the SKA is now well known and supported by the community. Through our experience with the construction of MeerKAT we have found that some staff enjoy the small town atmosphere and community in Carnarvon. The average, daily maximum temperatures for Carnarvon range from 15 C in June, to 30 C in January. The region is coldest during July, when temperatures drop to approximately 0.5 C during the night. Temperatures occasionally reach 40+ C during the day, but because of low humidity there is no significant impact on work efficiency.

12.2.3 Kimberley

Kimberley is the capital of the Northern Cape province and has a population of approximately 167 000 people. This small city has considerable historical significance due its diamond mining past and siege during the Second Boer War. Economically, the town is self-sufficient and although Kimberley is small, the type of services and amenities available are comparable with those found in big cities such as Johannesburg and Cape Town. Kimberley offers all major retailers, banks, motor dealerships, finance service providers, insurance and medical groups as well as a large and diverse engineering and construction industry, and a large number of hotels and guesthouses. Kimberley has an airport that is serviced by a number of commercial airlines with regular scheduled flights to Cape Town (one per day) and Johannesburg (five per day).

12.3 Housing and Security

International and senior SKA staff will probably be housed in Cape Town. Due to its popularity, property prices in Cape Town are slightly higher than other cities in South Africa, but still substantially lower than most comparable cities in the world. Cape Town offers a variety of accommodation types, from small apartments to townhouses and free-standing residences, and therefore caters for all residential requirements. Property prices vary from suburb to suburb, with a large family home (three bedrooms, two bathrooms and large living areas and a large garden) in a comfortable suburb costing about R3 300 000 (€320 000). The cost of houses in Carnarvon ranges from R300 000 (€29 000) to approximately R650 000 (€63 000) for a four- bedroom, two-bathroom house. Property prices and availability in Kimberley depend on the suburb of choice and the type of house required. There is a large variety of real estate available from small apartments to family homes, and prices vary accordingly. The cost of a family home consisting of three bedrooms and three bathrooms with a large garden is approximately R1 500 000 (€145 650).

All three of these towns/cities provide a secure and safe living environment, with no need for special security arrangements beyond normal “common sense” security measures. Many South Africans resident in cities contract private security companies to provide an appropriate level of protection of their properties, and both physical and electronic barriers are commonly deployed to protect property perimeters. Minimal physical security measures are deployed in smaller towns, such as Carnarvon.

12.4 Schools and Education

Many of the South Africa’s best schools are found in Cape Town. There are many public schools and thirty-seven private schools, offering many different curricula. The International School of Cape Town and the Deutsche Internationale Schule Kapstadt offer more than the standard twelve years of education. The International School of Cape Town opened in 1998 to serve the needs of the international community based in Cape Town. All nationalities and religions are accommodated in any of the levels from pre-school to post-secondary school. The school’s curriculum incorporates both an international programme as well as the local one so that South Africans may also benefit. A levels, the SAT and IGCSE curricula are offered. Tuition ranges from R23 245 - R60 589 per
annum (€2 257 to €5 883) depending on the level of study. The Helderberg IES International School offers the International Baccalaureate and five additional schools, three of which are international, offer the British A levels. Recently ranked 107th in the Times Higher Education Survey, the University of Cape Town (UCT) is the top tertiary institution in Africa. The University caters for approximately 20 000 students from across the country, the continent and the world. Astronomy and Engineering at UCT have strong ties with the South African SKA Project and have attracted 94 SKA bursaries and grants since 2005. UCT has recently been awarded one of the SKA Research Chairs (the South African SKA Project has awarded research chair positions to five South African universities. Each chair is awarded for a period of 15 years at a total cost of R45 000 000 (€4 370 000) each.)

Stellenbosch University is also an excellent tertiary institution. In particular their department of electronic engineering has a strong research group with significant research capacity in electromagnetic modeling, EM compatibility and radio frequency interference mitigation modeling. Thirty-six research grants and bursaries have been awarded to the department’s staff and students since 2005 and the department has also been awarded one of the SKA Research Chairs, which has been filled by Prof. David Davidson.

The University of the Western Cape is based in the greater Cape Town area and the SKA SA Project has provided significant support to the University to develop astronomy and astrophysics, including 25 grants and bursaries and an SKA Research Chair. The chair has been filled by Prof. Roy Maartens, a South African who has returned to the country to focus his research on exploiting MeerKAT and SALT data to answer fundamental questions in cosmology.

12.5 Leisure Facilities

The climate and geography of South Africa naturally lead to an outdoor lifestyle, with sport and enjoyment of the natural beauty of the country being primary leisure activities. The 10 million tourists visiting South Africa every year attest to the popularity of the country as a premier leisure and sporting destination.

South Africa has a rich natural heritage, ranging from the Kalahari Desert to the Drakensberg Mountain Range and the coastal Garden Route. It is home to eight World Heritage Sites. South Africa has the most diverse and intensely populated floral kingdom in the world (Table Mountain National Park has more plant species in its 22 000 hectares than the British Isles or New Zealand), and many species of wildlife, including 299 mammal species such as whales, lions, leopards and elephants, as well as 900 species of birds.

Team and individual sports are extremely popular in South Africa, both in terms of participation and support. All towns and cities are well provided with sports facilities, ranging from high-class golf clubs and well-equipped gyms to modest soccer pitches. Many people make use of the natural environment for their exercise needs, and distance running and hiking are very popular pursuits.

12.6 Healthcare, Pension and Life Cover

Health care ranges from the most basic primary health care to highly specialised hi-tech services. The health system consists of a state-provided public sector, which is free, and a private sector. Most middle-class South Africans make use of the world-leading private sector, and it is expected that SKA staff will do the same. Service is of a high standard, and there is no waiting period in the private sector for consultation with doctors and specialists or for treatment. It is expected that SKA staff will subscribe to one of the available private medical aid (insurance) options, which will afford them access to the private health sector. There are more than eight medical aid companies in South Africa and monthly medical aid premiums can either be paid by the employer or by the employee. All medical aid companies offer their members a similar range of options. These options vary according to what a member can afford and a member’s health care requirements. Discovery Health is the largest medical aid company in South Africa. Discovery offers a number of plan options, ranging from a hospital plan, which provides the member with unlimited hospital cover but no cover on out-of-hospital expenses (monthly cost is approximately R500 / €48), to a fully comprehensive plan which provides unlimited hospital cover and almost unlimited out-of-hospital cover, including cover for chronic medication and conditions (monthly cost is approximately R2 500 / €242). Family members / dependents of the main member can be covered by the same plan at a reduced premium. In addition, most of the Discovery Health plans cover emergency air evacuations inside and outside of South Africa.

The standard of health care in the Western Cape is particularly high. Cape Town attracts some of the country’s best doctors, and is generally the preferred choice of post for newly qualified health professionals. Groote Schuur
Hospital, based in Cape Town, is a public hospital that is famous for the world’s first human heart transplant, performed there in 1967 by Dr Christiaan Barnard.

Carnarvon has a community health centre as well as a small hospital and one pharmacy. For emergency services many Carnarvon residents make use of the added benefit of their private medical aid schemes, which provide emergency airlift to Kimberley, Johannesburg or Cape Town.

Kimberley is very well equipped with medical services in the public and private sectors. There are 21 medical facilities, including three private hospitals and seven municipal clinics, as well as Netcare 911 and ER24 emergency response services.

Most professionals subscribe to private pension schemes either as part of a group scheme (through the employer), or privately, or both. Group cover generally works out cheaper than subscribing to a scheme privately. However, rates for pension schemes in South Africa are very competitive. Most are defined contribution schemes. Generally professionals take care of their life cover and disability insurance. However, many companies in South Africa (including the NRF) also make it compulsory for all employees to contribute to a group life scheme, which will usually pay out the equivalent of three years’ remuneration on death, or disability. Many companies compete for business in the South African insurance and investment markets, making insurance and investment affordable and competitive.

12.7 Transport

South Africa has an excellent infrastructure of airports, with airports in all of the major cities. The three main international airports are OR Tambo International Airport in Johannesburg, Cape Town International Airport and Durban International Airport. OR Tambo International Airport is the major gateway to South Africa, offering international arrivals and departures, domestic flights and connections to the rest of Africa. Table 12.1 summarizes the number of direct international flights into Johannesburg and Cape Town.

Kimberley has a domestic airport servicing daily scheduled flights to and from Cape Town and Johannesburg international airports. Chartered flights connect the Carnarvon airfield with Cape Town international and Lanseria (Johannesburg) domestic airport. The South African SKA Porject Office has contracted a charter company to provide “on-demand” flights on these routes.

12.8 Communication

Communication systems in South Africa and the African partner countries are world-class and ubiquitous. In South Africa mobile services are provided by Vodacom, MTN, Cell C, Virgin Mobile and 8ta (all with 3G coverage). These mobile operators cover all towns, cities and transport routes in South Africa. Land-line providers, such as Telkom and Neotel, cover all towns and cities and most rural areas. There are many Internet service providers offering broadband through ADSL, 3G and wireless at competitive rates. Wi-Fi hot-spots are ubiquitous in restaurants, airports and business hubs, and there is an abundance of Internet Cafes.

Annexure M4 contains a collection of photographs of various aspects of South African life.
This page is intentionally blank.