




# The Square Kilometre Array

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## The SKA Concept

A large radio telescope for transformational science:

- up to 1 million m<sup>2</sup> antenna collecting area distributed over a distance of 3000+ km
- operating at frequencies from 70 MHz (wavelength = 4+ m) to 10 GHz (~3 cm) with two or more detector technologies
- connected to a signal processor and high performance computing system by an optical fibre network

Providing

- 50 x sensitivity of current world's best radio interferometers, and
- up to 1 million x survey speed

A global collaboration with 70 institutes in 20 countries participating

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## Great Observatories for the coming decades







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## 1: Probing the dark ages – the first black holes and stars

- What happened after the Big Bang and before the first stars and galaxies formed?
- Which came first - stars or galaxies?
- Investigating the epoch of reionisation.



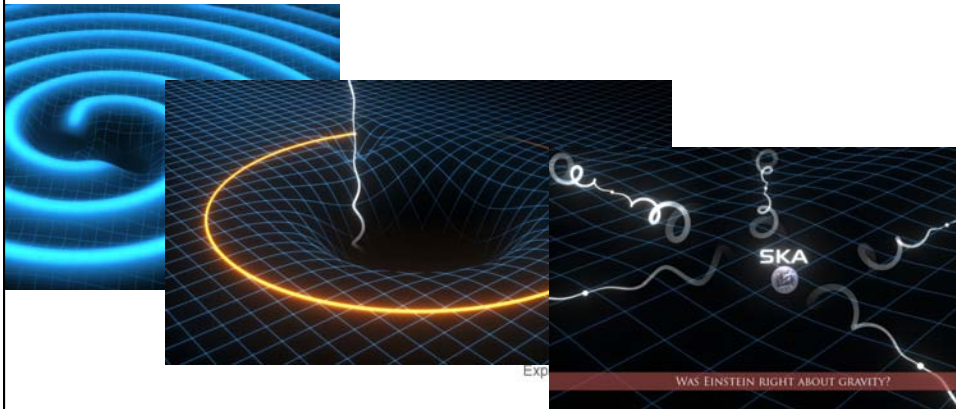


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## 2: Strong-field tests of gravity using pulsars and black holes



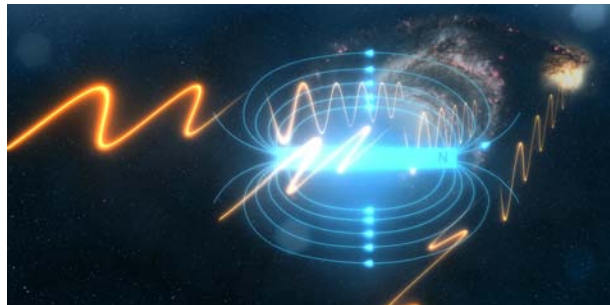
- Monitoring pulsars to search for gravitational waves.
- Using pulsars to test general relativity in extreme conditions, for example close to black holes.



## 3: Investigating the origin and evolution of cosmic magnetism



- What generates the giant magnetic fields in space?
- The SKA will create three-dimensional maps of cosmic magnets to understand how they stabilise galaxies, influence the formation of stars and planets, and regulate solar and stellar activity.



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## 4: Galaxy evolution, cosmology and dark energy



- How do galaxies evolve and what is dark energy?
- The acceleration in the expansion of the Universe has been attributed to dark energy. The SKA will track young galaxies and help identify the nature of dark energy by mapping the cosmic distribution of hydrogen.

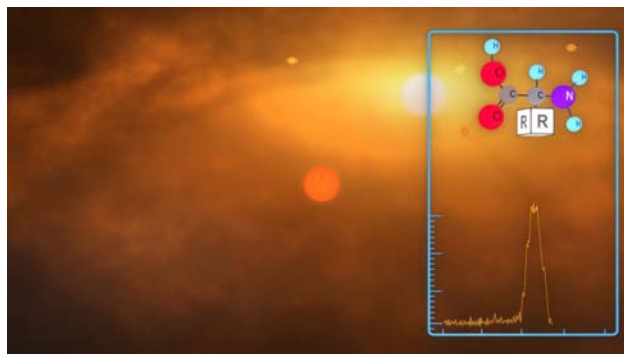


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## 5: The cradle of life – searching for life and planets



- The SKA will be able to detect very weak extra-terrestrial signals and will search for extra solar planets and could detect complex organic molecules, the building blocks of life, in space.



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## Phased Construction



Construction will proceed in two phases (SKA1 & SKA2).

- SKA1 will be a subset (~10%) of SKA2.
- Major science observations already possible with SKA1.
  - Understanding the history and role of neutral hydrogen in the Universe from the Dark Ages to the present-day (part of Science Case 1 & 4)
  - Detecting and timing binary pulsars and spin-stable millisecond pulsars in order to test theories of gravity (including General Relativity and quantum gravity), to discover gravitational waves from cosmological sources, and to determine the equation of state of nuclear matter (part Science Case 2)
- Phased construction => parallel technology development for SKA2.

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## Antenna Types



Artist renditions from Swinburne Astronomy Productions

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## SKA Phase 1 Dual Site Implementation



SKA1\_Mid



SKA1\_Low



SKA1\_AIP\_Survey

	SKA Element	Location	Indicative Number
Dish Array	SKA1_Mid	RSA	190 + 64 MeerKAT
Low Frequency Aperture Array	SKA1_Low	ANZ	50 stations
Survey Instrument	SKA1_AIP_Survey	ANZ	60 + 36 ASKAP

## SKA Phase 2 Dual Site Implementation



SKA2\_Mid\_Dish



SKA2\_AIP\_AA



SKA2\_Low

	SKA Element	Location	Indicative Number
Low Frequency Aperture Array	SKA2_Low	ANZ	250 stations
Mid Frequency Dish Array	SKA2_Mid_Dish	RSA	3000 dishes
Mid Frequency Aperture Array	SKA2_Mid_AA	RSA	250 stations

## Timeline




1995-2000	Preliminary R&D
2000-2007	Initial Concept Phase
<b>2008-2012</b>	<b>Preparatory Phase: Telescope system design and cost</b>
2013-2015	Detailed design in the pre-construction phase
2016-2019	Phase 1 construction
2016	Advanced Instrumentation Program decision
2020→	Full science operations with Phase 1
2020-2023	Phase 2 construction
2024→	Full science operations with Phase 2

**Major decisions**

2011	Funding for pre-construction phase Establish SKA Organisation as a legal entity Select location for SKA Project Office
<b>2012</b>	<b>Site selection</b>
2014	Approve construction funding for Phase 1

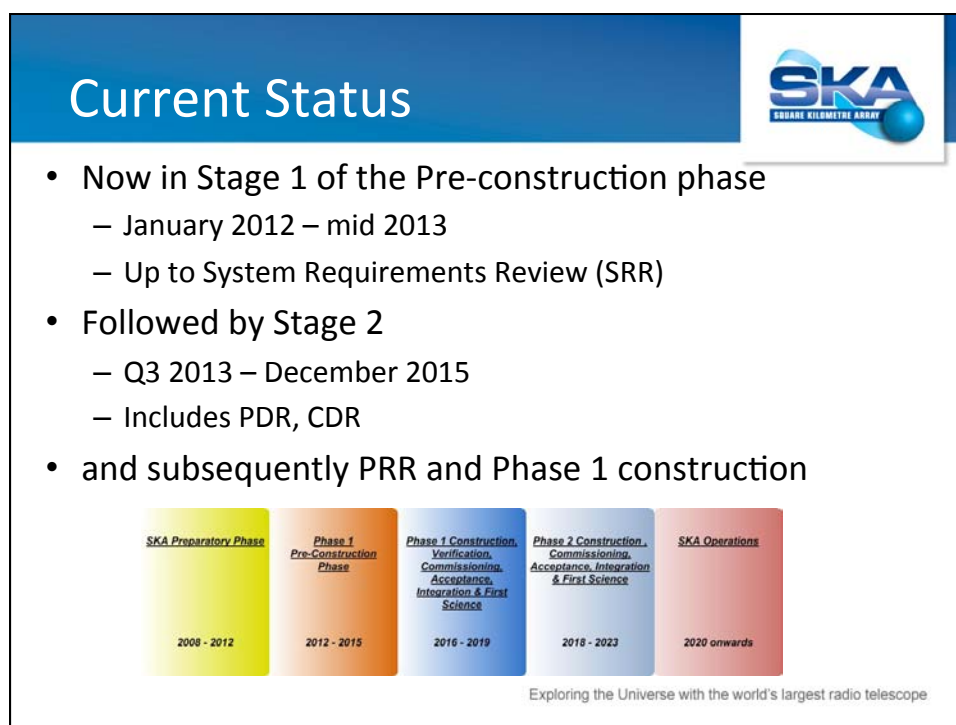
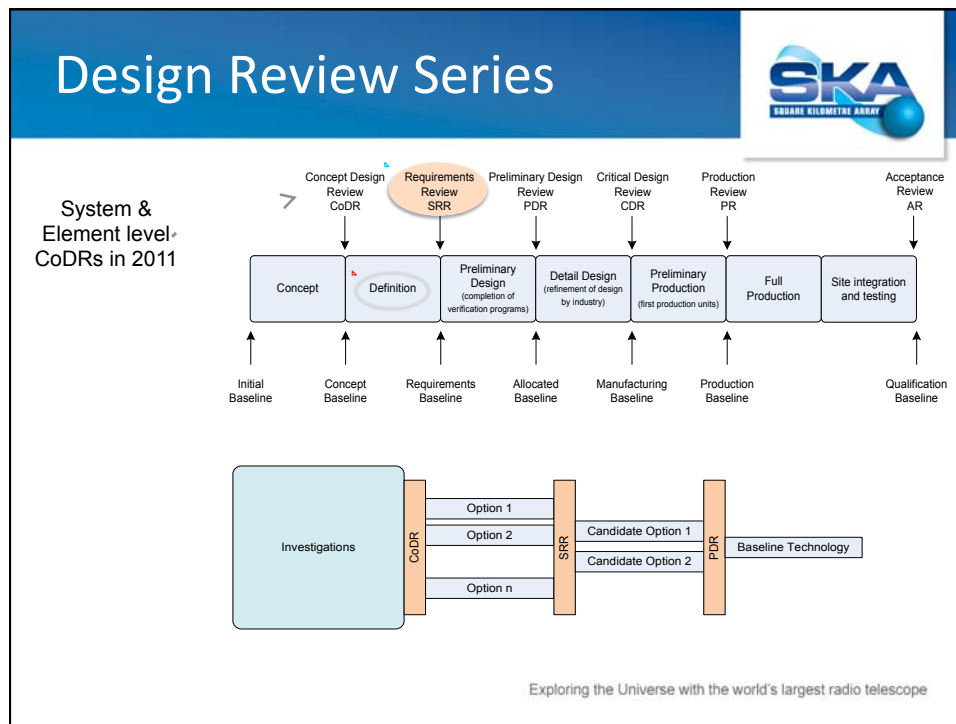
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## Conceptual Design Reviews 2011/12



- **23-25 Feb 2011** System delta-CoDR on SKA1
- **14-15 Apr** Signal Processing
- **19-20 Apr** Aperture Arrays
- **28-30 Jun** Signal Transport & Networks
- **13-15 July** Dish and Dish Arrays
- **9-11 Nov** Monitor & Control
- **27-28 Nov** AA-mid (delta)
- **15-16 Feb 2012** Software & Computing

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## The SKA Organisation



- SKA Organisation set up as “Company Limited by Guarantee” 14 December 2011
- Founding (Full) Members: Australia, China, Italy, Netherlands, New Zealand, South Africa and United Kingdom
- Joined by Canada (F) in March, India (A) in April, more expected
- Governed by a Board of Directors.
- General meeting of the Members has ultimate authority.

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## Aims of the SKA Organisation



1. Progress the SKA design and prototyping through the pre-construction phase to the point that production readiness reviews have been successfully completed and related data packs prepared ;
2. Establish industry participation strategies, procurement processes, and the protocols governing the selection of work package consortia, ready for use in accordance with the PEP timeline;
3. Work towards identifying funding commitments for SKA Phase 1 (SKA1) construction and operations on a timescale commensurate with the planned start of construction;
4. Prepare the long term SKA organisational structure and arrangements for the construction, verification and operation of the SKA;
5. Build relationships with relevant national and international astronomy organisations to leverage skills and ensure SKA 1 science and opportunities are fully integrated into a global astronomy perspective.

(Source: SKA Business Plan)

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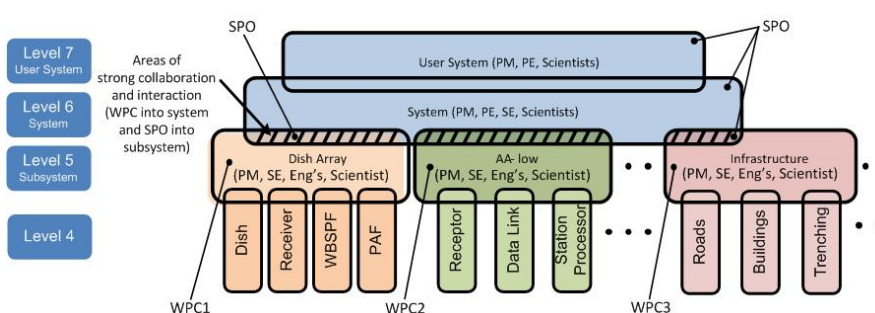
## Office of the SKA Organisation



- Activities to be led by a stronger Office of the SKA Organisation
  - Led by a Director General, staff transferred from SPDO (Univ. Manchester)
- Building up the SKA Organisation in 2012
  - Recruitment of personnel (~30 by end of 2012; 45-50 ultimately)
- Formalisation of procedures
  - Work being carried out in parallel in many locations
  - Working towards common goals
  - Documentation, reporting, reviewing to be improved
  - Deliverables must be produced
  - Communication (!)
- Formation of Work Package Consortia
  - Composed of Research Organisations, Universities and Industry
  - Rules of engagement must be defined
  - Industry Engagement Policy, IP Policy, Procurement Policy
- Funding for 2012-2015 approved

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## SKA Project Structure



Note: SPO now Office of the SKA Organisation

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## Work Packages



- Led by SKA Office
  - Management
  - Science
  - System Design and system engineering
  - Maintenance & Support and Operations
- Carried out by Work Package Consortia
  - Site and Infrastructure (originally Site Engineering)
  - Dish Array
  - Aperture Arrays
  - Signal and Data Transport (originally Signal Transport & Networks)
  - Clock and Timing Distribution (originally Signal Transport & Networks)
  - Central Signal Process
  - Science Data Processor (originally Software & Computing)
  - Telescope Manager (originally led by SKA Office)
  - Power
- Advanced Instrumentation Programmes (to be integrated with Dish & AA WPs)
  - Mid Frequency Aperture Array
  - Phased Array Feeds
  - Wide Band Single Pixel Feeds

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## WBS – Phase 1, Stage 1



MGT-001.005.030-WBS-001  
Revision 1.0

### 5 Work Breakdown Structure

- 1 SKA – Square Kilometre Array
  - 2 SKA MGT – SKA Management
    - 3 SKA MGT BMD – SKA Board
    - 3 SKA MGT ACD – Advisory Committees
    - 3 SKA MGT SKAD – SKA Office Senior Management\*
    - 3 SKA MGT OUT – SKA Outreach
    - 3 SKA MGT MA – SKA Mission Assurance
  - 2 SKA TEL – SKA Telescope
    - 3 SKA TEL SCI – SKA Telescope Science
      - 4 SKA TEL SCI PRGJ – Project Level Interactions
      - 4 SKA TEL SCI SRR – System Requirements Review
      - 4 SKA TEL SCI SYD – System Design Studies
      - 4 SKA TEL SCI OPS – Concept of Operations
      - 4 SKA TEL SCI EXT – Extensibility Studies
      - 4 SKA TEL SCI WBS – Stage 2 Work Breakdown Structure
      - 4 SKA TEL SCI PCJ – Project and Community Interactions
      - 5 SKA TEL SCI PCJ EOMT – Community Engagement
      - 5 SKA TEL SCI PCJ SAC – Science Advisory Committee
    - 4 SKA TEL SCI EISA – Element Level Science Analysis
      - 5 SKA TEL SCI EISA MGT – Management
      - 5 SKA TEL SCI EISA TTS – Technology Trade Studies
      - 5 SKA TEL SCI EISA TVP – Technology Verification Plans
      - 5 SKA TEL SCI EISA AV – Advanced Instrumentation
    - 3 SKA TEL MGT – SKA Telescope Project Management
      - 4 SKA TEL MGT APP – Project Management Approach
      - 4 SKA TEL MGT SLA – Stage 1 Agreements
      - 4 SKA TEL MGT SZP – Stage 2 Preparation
      - 4 SKA TEL MGT EMFT – Enterprise Management and Tools
      - 4 SKA TEL MGT MFG – Meetings
      - 4 SKA TEL MGT TPR – Technical Peer Reviews
      - 4 SKA TEL MGT SCH – Project Scheduling
      - 4 SKA TEL MGT RES – Resource Planning and Management
      - 4 SKA TEL MGT CCM – Configuration/Change Management
      - 4 SKA TEL MGT RMT – Risk Management
      - 4 SKA TEL MGT DMF – Documentation Management
      - 4 SKA TEL MGT QA – Quality Assurance
      - 4 SKA TEL MGT GAP – Gap analysis
      - 4 SKA TEL MGT CST – Costing
      - 4 SKA TEL MGT COMM – Communications
      - 4 SKA TEL MGT SGS – Specialist Groups (Domain Groups)
      - 4 SKA TEL MGT TTT – Integrated Task Teams
      - 4 SKA TEL MGT SORA – Site Documentation Review and Analysis
      - 4 SKA TEL MGT AUD – Site Audit
      - 4 SKA TEL MGT SSLA – Site Specific Stage 1 Agreements
      - 4 SKA TEL MGT SAMP – Site Management Plan
      - 4 SKA TEL MGT IND – Industry Involvement
      - 4 SKA TEL MGT TVA – Travel

2012-04-04

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### 6.6.3 SKA.TEL.DSH.SE-VSYS - System Engineering for Verification Systems

<b>WBS element identification</b>	4 SKA.TEL.DSH.SE-VSYS - System Engineering for Verification Systems
<b>WBS element description</b>	This WBS element provides System Engineering underpinnings for Verification Systems development and the necessary links to SKA development.
<b>Inputs</b>	<ul style="list-style-type: none"> <li>• SKA System Engineering Management Plan (SEMP), WP2-005.010.030-MP-001,</li> <li>• SKA Project Execution Plan (PEP): MGT-001.005.005-MP-001</li> <li>• Requirements Look Ahead documents (to be generated – see <i>Element.SE-SRR.REN</i>)</li> <li>• SKA1 System Requirement Specification: WP2-005.030.000-SRS-002</li> <li>• Element Requirements Specifications (to be generated – see <i>Element.SE-SRR.REN</i>)</li> <li>• Element Requirements Analyses (to be generated – see <i>Element.SE-SRR.REN</i>)</li> <li>• Subsystem Requirements specifications (to be generated – see <i>Element.SE-SRR.REN</i>)</li> <li>• Verification Systems documents (TBD)</li> </ul>
<b>Tasks</b>	<ul style="list-style-type: none"> <li>• Identify and analyse the Requirements for which the necessary design features/technologies are being developed, including any initial assumptions.</li> <li>• Develop a plan, tied to the availability of the analysis of allocated SKA requirements, to replace assumptions as design drivers for verification systems.</li> <li>• Identify and elaborate the design options that are being examined/demonstrated</li> <li>• Describe the verification systems, including those parts which are not being verified and those design features that must be incorporated in order that two or more design options may be demonstrated/verified at minimum cost</li> <li>• Identify the models to be validated by the programme (from <i>Element.SE-SRR.MOD</i> – Modelling)</li> <li>• Identify the tests and measurements that will be carried out to validate models.</li> <li>• Identify the limitations and constraints that exist solely for this development activity which will not apply for SKA</li> <li>• Devise and document the approach to be taken in quantifying and eliminating the effects of the non representativity of the verification programme designs, environments and tests.</li> <li>• Develop a plan which shows how design decisions for second and subsequent verification systems will be arrived at.</li> <li>• Develop a schedule showing the milestones by which designs will be verified as being compliant with requirements. Examples of such milestones are the SKA PDR or CDR.</li> </ul>
<b>Outputs/deliverables</b>	<ul style="list-style-type: none"> <li>• A Verification System Development Plan</li> </ul>

## Stage 1 WPC Assignment (1)



- Step 1 : Expressions of Interest
  - Goal 1: Provide a snapshot of interest in Stage 1 WBS
  - Goal 2: Facilitate formation of Work Package Consortia
  - Simple process requesting minimal information
  - Commitment follows at Step 2
  - Responses from 133 organisations, industry and (preliminary) consortia
  - Information gathered now available

3 SKA.TEL.CSP - Central Signal Processor (CSP)	Lead:
4 SKA.TEL.CSP.MGT - CSP Project Management	⬇
The CSP project management covers the overall project management work to be performed at the CSP element level during Stage 1 of the SKA Preconstruction Phase. The project management principles and process will be applicable throughout all the levels of the element. The project management tasks include the development and roll out of the Project Management Approach, management and maintenance of the Stage 1 Agreements, Stage 2 Preparation, selection and roll out of Enterprise Management and Tools, managing and conducting Meetings, managing and conducting Technical/Peer Reviews, Project Scheduling, Resource Planning and Management, Configuration/Change Management, Risk Management, Documentation Management, Quality Assurance, Gap analysis, Costing, Communications, management and participation in of Domain Groups and Integrated Task Teams, Industry liaison and Travel budgeting and management.	
4 SKA.TEL.CSP.SE-SRR - CSP SE to Requirements Review	⬇
This WBS element provides for all the system engineering tasks of the CSP Element to bring the Element to a readiness which will allow the successful conduct of Requirements Reviews as defined in the SEMP (SKA System Engineering Management Plan, WP2-005.010.030-MP-001). The system engineering tasks will include Technical/Peer Reviews, Requirements Engineering, Verification Planning, Modelling, Architecture development, Interface Definition, Design Specification development, Road Mapping & Obsolescence analysis, Engineering Resource Allocation, Operations, Sustaining Engineering, Software Development Environment, Standardisation Activities, System Engineering Approach, Stage 2 preparation, SE Management and Tools, Enterprise Management and Tools, Configuration Management/Change Control, Risk Management, Product Assurance, participation in Integrated Task Teams and Domain Groups.	
4 SKA.TEL.CSP.SE-VSYS - System Engineering for Verification Systems	⬇
This WBS element provides the System Engineering underpinnings for Verification Systems development and the necessary links to SKA development.	

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## Stage 1 WPC Assignment (2)



- Step 2 : Requests for Proposals
  - RfP to be issued: Summer 2012\*
  - Bids/Proposals due: ....
  - Followed by evaluation, Board Approval, Signing of MLA
  - Process complete by end of 2012 (t.b.c.)
  - Uncertainty in timing resulting from Site Selection decision
- Documentation to be provided
  - Main Document (includes Instructions for bid preparation, guidance on how bids will be evaluated, guidance on possible work packages, high level project schedule)
  - Stage 1 WBS/SOW (possible further revisions resulting from Site Selection may follow)
  - Template agreements for Consortia and Multi Lateral Agreements
    - To include Draft Intellectual Property Policy
  - Updated System Engineering Management Plan
  - SKA Stage 1 draft Project Management Plan
  - Exact date for RFP delivery and subsequent milestones
  - Templates for major technical documents such as Requirement Specifications (SRS), Architectural Design Documents (ADD), Procurement Specifications, Development Specifications.

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## SKA is driving development of new science & technical solutions



- Dishes, feeds, receivers (N=3000)
- Low and mid aperture arrays (N=250)
- Signal transport (10 petabit/s)
- Signal processing (exa-MACs)
- Software engineering and algorithm development
- High performance computing (exa-flop capability)
- Data storage (exa-byte capacity)
- (Distributed) power requirements (50 -100 MW)

**INDUSTRY ENGAGEMENT IS CENTRAL TO THE SKA**

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## Potential Large Contracts for Industry



- Site studies and infrastructure engineering.
- Scheduling, operations and maintenance models.
- Low-cost, mass manufacturing of small to medium diameter dishes.
- Wide bandwidth feed antennas for dishes.
- Broadband, phased arrays for aperture and focal plane applications.
- Low-noise, highly integrated, receivers for both cryogenic and uncooled applications.
- High-speed (terabits/s) digital fibre optic links for distance regimes extending from 100 m to >3 000 km.
- Low-cost, high-speed (GS/s) analogue to digital converters.
- High-speed digital signal processing engines (petabyte/s) and ultra-fast super computing (at exaflop rates).

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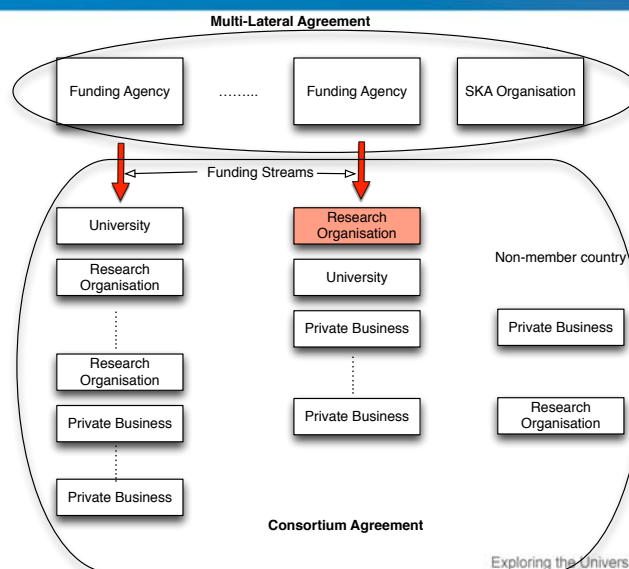
## Further roles for industry



- Cost control
- Contract management & consultancy
- Assisting with documentation management
- (Preparing for) Procurement
- (System) Engineering support
- Planning for operations
- Design for manufacture
- Detailed design work
- Construction of verification programme components
- Assisting with the assembly of production data-packs

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## Organisation of Work Package Consortia



SKA Board enforces delivery in case of conflicts

SKA Members will sign Multi-Lateral Agreements with the SKA Organisation to commit funding of the consortia to carry out the work

Work Package Consortia will be funded by local sources and will operate under Consortium Agreements

Consortia take responsibility for delivery of work by organisations from non-member countries

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