PrepSKA WP2

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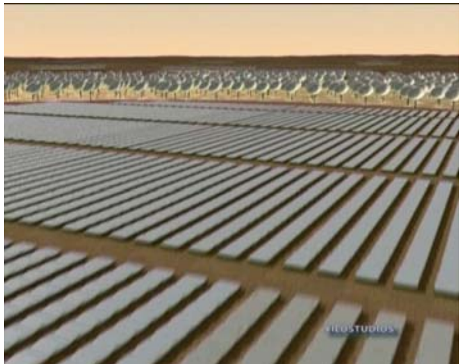
Manchester, Sept 27, 2007

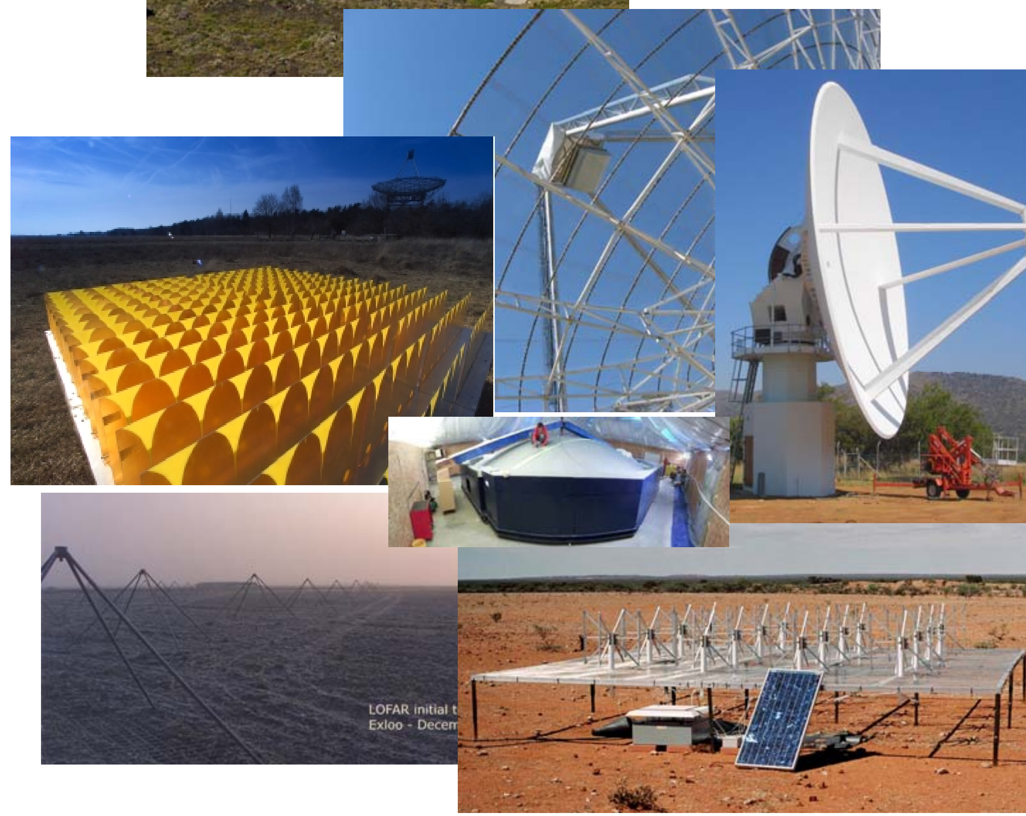
www.skatelescope.org



SKA development approach

- **Astronomy & engineering iteration**
  - Initial specs early 2008
- **International system design effort**
  - Recent: Memo 91
  - Intensifying in PrepSKA
- **Strong emphasis on technology <u>demonstration</u>**
  - Retire risk as early as possible
  - **Regional pathfinders are crucial**
    - » > €200M investment
- **Focus on:**
  - Aggressive cost reduction strategies
  - Industry engagement
    - » To deliver SKA on required timescales

Reference Design technologies



1% (pathfinders) → 10% (SKA Phase 1) → 100% (SKA)

SKA antenna applications

	Frequency range (GHz)	Sparse Aperture Array	Dense Aperture Array	Dish + Phased Array Feed	Dish + Single-Pixel Feed
Low-band "EoR" array	0.1-0.3	✓			
All-sky monitor	0.3-1	?	✓		
Imaging mid-band array	0.3-3	? (to ~0.5 GHz)	? (to ~1 GHz)	?	?
High-band array	3-25				✓
Pathfinders or Design Studies		LOFAR, MWA, LWA	SKADS	ASKAP, APERTIF	ATA, TDP, meerKAT

Mid-band SKA is the focus of intense Pathfinder activity

Technology Readiness Level (TRL)

Generate Knowledge (Research)

Basic Technology Research	Level 1	Basic principles observed and reported
Research to Prove Feasibility	Level 2	Technology concept and/or application formulated
	Level 3	Analytical and experimental critical functions and/or characteristic proof-of-concept
Technology Development	Level 4	Component and/or breadboard validation in laboratory environment
Technology Demonstration	Level 5	Component and/or breadboard validation in relevant environment
	Level 6	System/subsystem model or prototype demonstration in a relevant environment
System/Subsystem Development	Level 7	System prototype demonstration in an operational environment
System Test and Operation	Level 8	Actual system completed and qualified through test and demonstration
	Level 9	Actual system proven through successful mission operations

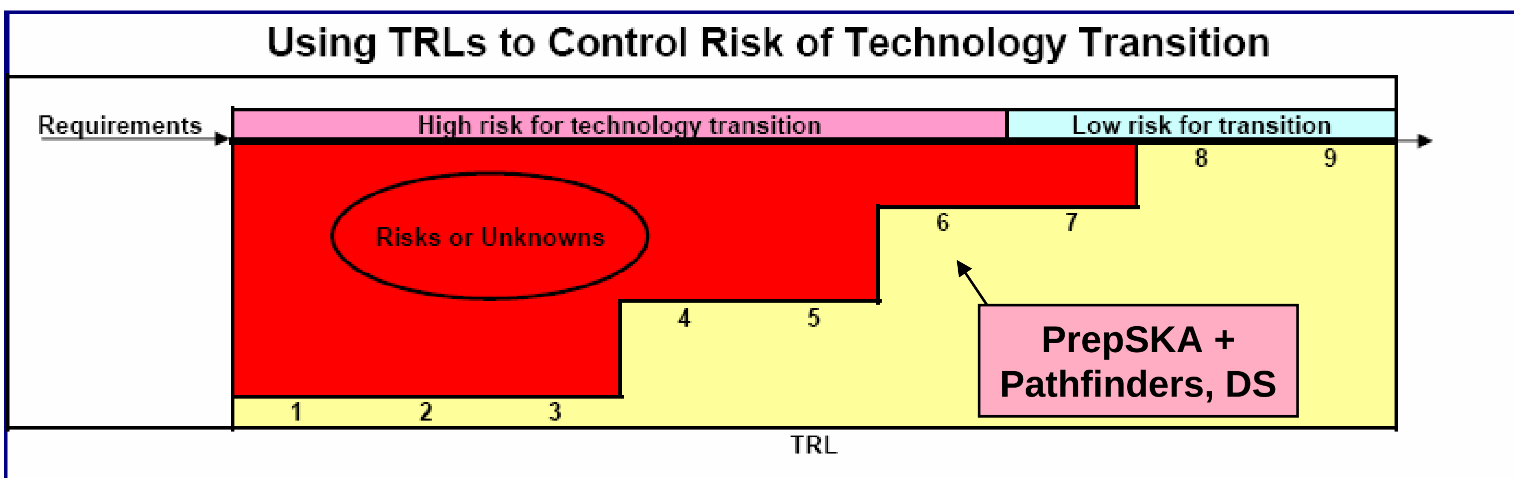
Produce Products and Capabilities (Development)

Generate Knowledge (Research)

Description: DoD 5000.2-R, Appendix 6, April 5, 2002

TRL 1	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
TRL 2	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
TRL 3	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
TRL 4	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
TRL 5	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
TRL 6	Representative model or prototype system, which is well beyond that of TRL5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
TRL 7	Prototype near or at planned operational system. Represents a major step up from TRL6, requiring demonstration of an actual system prototype in an operational environment, such as in aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
TRL 8	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
TRL 9	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Produce Products and Capabilities (Development)



NASA/DoD

Main Menu | TRL Calculator | TRL Definitions

Manufacturing Readiness Level Definitions

Generate Knowledge (Research)	
TRL	**MRL**
1	N/A
2	N/A
3	**Manufacturing Concepts Identified.** Assessment of current manufacturability concepts or producibility needs for key breadboard components.
4	**Laboratory Manufacturing Process Demonstration.** Key processes identified and assessed in lab. Mitigation strategies identified to address manufacturing/producibility shortfalls. Cost as an independent variable (CAIV) targets set and initial cost drivers identified.
5	**Manufacturing Process Development.** Trade studies and lab experiments define key manufacturing processes and sigma levels needed to satisfy CAIV targets. Initial assessment of assembly needs conducted. Process, tooling, inspection, and test equipment in development. Significant engineering and design changes. Quality and reliability levels not yet established. Tooling and machines demonstrated in lab. Physical and functional interfaces have not been completely defined.
6	**Critical Manufacturing Processes Prototyped.** Critical manufacturing processes prototyped, targets for improved yield established. Process and tooling mature. Frequent design changes still occur. Investments in machining and tooling identified. Quality and reliability levels identified. Design to cost goals identified.
7	**Prototype Manufacturing System.** Prototype system built on soft tooling, initial sigma levels established. Ready for low rate initial production (LRIP). Design changes decrease significantly. Process tooling and inspection and test equipment demonstrated in production environment. Manufacturing processes generally well understood. Machines and tooling proven. Materials initially demonstrated in production and manufacturing process and procedures initially demonstrated. Design to cost goals validated.
8	**Manufacturing Process Maturity Demonstration.** Manufacturing processes demonstrate acceptable yield and producibility levels for pilot line, LRIP, or similar item production. All design requirements satisfied. Manufacturing process well understood and controlled to 4-sigma or appropriate quality level. Minimal investment in machine and tooling - machines and tooling should have completed demonstration in production environment. All materials are in production and readily available. Cost estimates <125% cost goals (e.g., design to cost goals met for LRIP).
9	**Manufacturing Processes Proven.** Manufacturing line operating at desired initial sigma level. Stable production. Design stable, few or no design changes. All manufacturing processes controlled to six-sigma or appropriate quality level. Affordability issues built into initial production and evolutionary acquisition milestones. Cost estimates <110% cost goals or meet cost goals (e.g., design to cost goals met).
Produce Products and Capabilities (Development)	

Manufacturing Readiness Level (MRL)

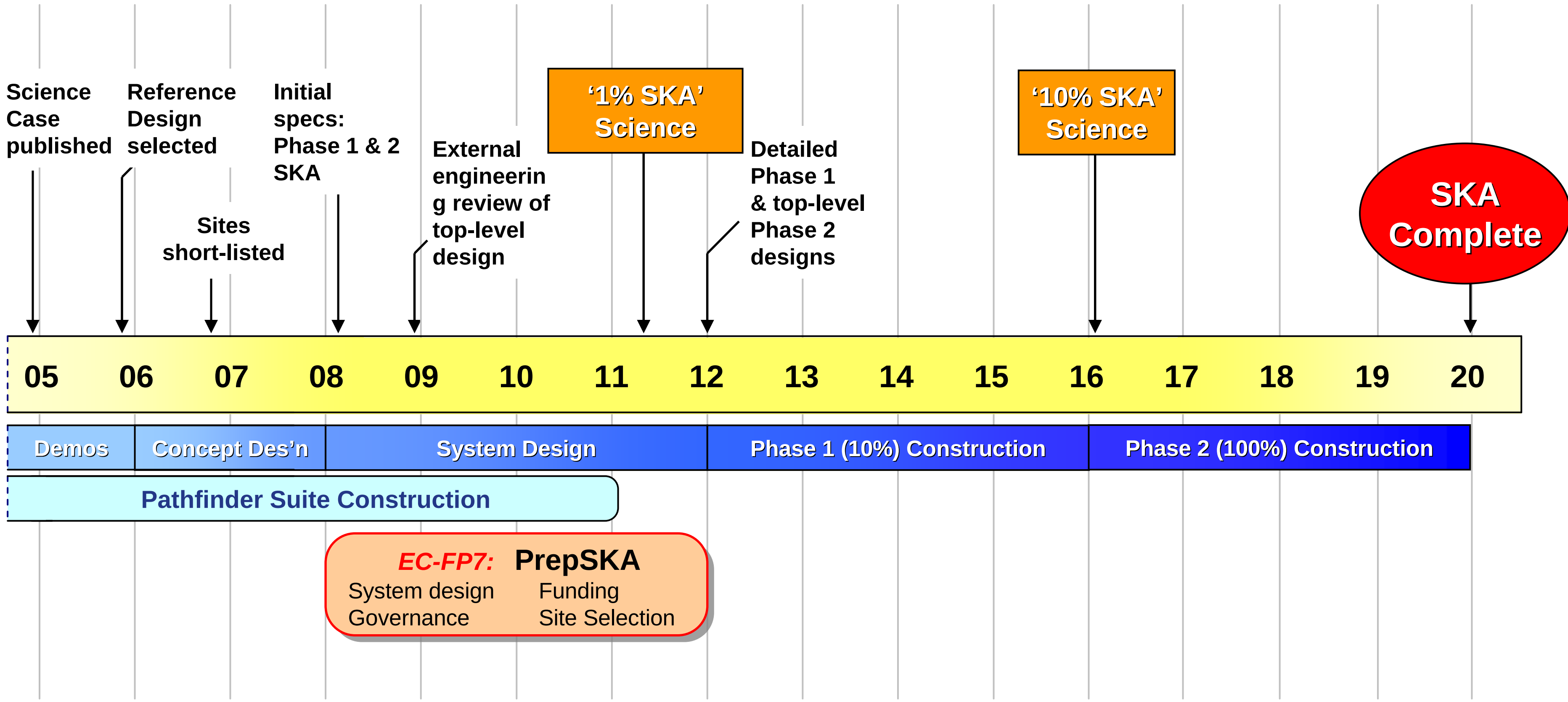
TRL alone does not measure whether a product can actually be affordably produced.

Caution: TRL measures maturity only on single axis of demonstrated technology capability
- not ease of progress to higher level
- not risk (MRL helps here)

MRL addresses producibility from early development phase.

https://acc.dau.mil/CommunityBrowser.aspx?id=25811

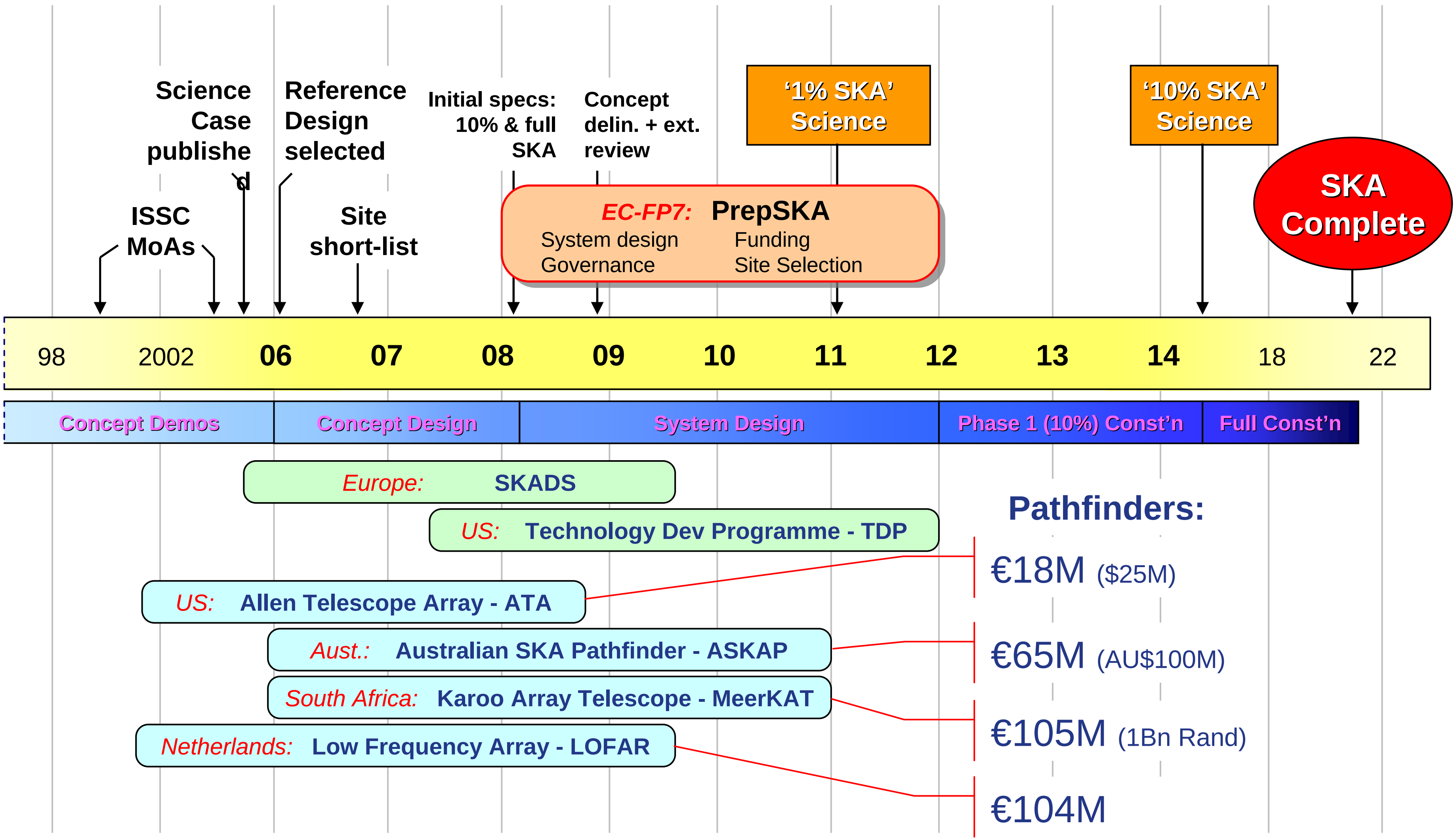
SKA timeline



Courtesy Andy Faulkner

ISPO

SKA timeline



Courtesy Andy Faulkner

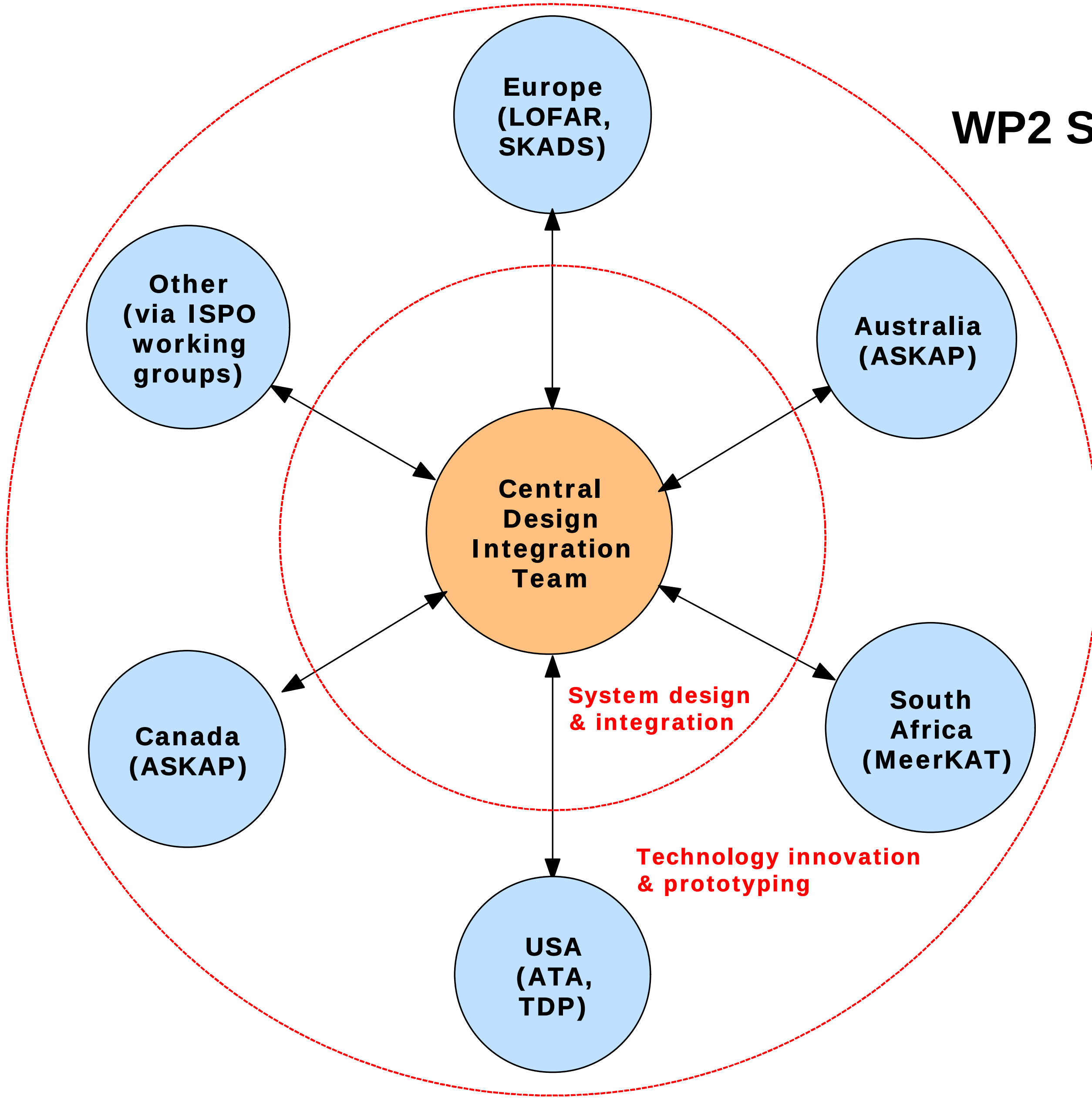
PJ Hall, Sept 2007

SKA preparatory phase: PrepSKA (2008 – 2011)

- **WP1: PrepSKA management**
- **WP2: SKA system design**
  - Overlaps completely the central design task recommended by the EWG
  - Establishes ISPO Central Design Integration Team (CDIT)
    - 15 engineers
    - Located Manchester, UK
  - Includes Initial Verification System
- **WP3: Continuing site selection process**
  - Regional, international, joint projects
- **WP4: Governance**
- **WP5: Industry and procurement policy**
- **WP6: Funding model**
- **WP7: Implementation strategy**

€ 22M European program with strong international collaboration (including US Technology Development Project)

WP2 SKA design



WP2: SKA design

- **Recognizes primary role of Pathfinders & Design Studies in technology development**
- **Adds to current programs by generating coherent SKA design**
  - Brings the best technologies together into complete program
  - Emphasizes “fit for manufacture” design
- **Delivers**
  - Overall SKA concept design, with costing
  - Detailed SKA Phase 1 design
  - Initial Verification System for SKA Phase 1 design
- **Demonstrates functional central team, plus strong working links to regional engineering**
- **~180 p*yr effort**
- **Many shared central and regional projects**

FP7 Preparatory Phase: Elements of Work Package 2 (WP2)										
		T1	**T2**	**T3**	**T4**	**T 5**	**T 6**	**T 7**	**T 8**	**T 9**
P1	***SKA design***	SKA concept delineation *CDIT*	SKA specification *CDIT*	SKA life-cycle study *KAT*	SKA operations plan *ASTRON*	SKA support plan *CDIT*	SKA cost opt'n *CDIT*	SKA manu-facturing studies *UK:man*	SKA technical doc. *CDIT*	SKA system design *CDIT*
P2	***SKA-P1 sub-system spec & evaluation***	SKA-P1 sub-systems spec. & evaluation *CDIT*								
P3	***Initial Verification System***	IVS specification *CDIT*	IVS construction *UK*	IVS integration & test *CDIT*						
P4	***Dish design & optimization***	Dish design 1 (basic metal) *CSIRO*	Dish design 2 (composite) *KAT*	Dish design 3 (carbon fibre) *DRAO*	Dish design 4 (hi perf. metal) *TDP*					
P5	***Feed prototyping***	Wideband single-pixel feeds *TDP*	WFoV – Aperture array tiles *UK:man*	WFoV - Phased array feeds *CSIRO*	WFoV – Multiple-feed clusters *KAT*					
P6	***Receiver prototyping***	Low-noise amplifiers *ASTRON*	Integrated receivers *CSIRO*	New-gen. cryo solutions *TDP*						
P7	***Signal transport prototyping***	Intra-antenna data links *CSIRO*	Intra-station data links *UK:man*	Station-core data links *UK:man*	LO and timing *UK:man*	Monitor & control *UK:cam*				
P8	***Signal processing prototyping***	Station DSP *UK:oxf*	Correlator *DRAO*	RF interference mitigation *ASTRON*	Non-imaging processors *UK:man*					
P9	***Computing specification & prototyping***	SKA computing & software spec. *CDIT*	Computing hardware *CDIT*	Software engineering *ASTRON*	Data products & VO plan *UK:cam*	Calibration *ASTRON*	Science post – proc. *CSIRO*			
P10	***WP2 design study management***	CDIT project management *CDIT*								

WP2: General approach

- **Adopt "base" SKA design: D+SPF**
  - Consistent with current technology maturity
  - Lowest (relative) risk; viable scientifically
  - Allows system and sub-system design to begin
- **Add extensions to base design e.g. WFoV**
  - Identify expanded requirements in sub-systems, …
- **Incorporate strong formal links to regional programs**
  - Continuous inclusion of WFoV and other program results
- **Evaluate maturity of WFoV receptors in terms of suitability for SKA-P1**
- **Choose SKA-P1 receptors and desired path to SKA**

WP2: First tasks

- **SKA concept delineation**
  – Report end of Aug 2008
- **Draft SKA engineering specs**
  – SKA Phase 1 specs + SKA performance goals
  – Includes performance boundaries for system + sub-systems
  – Draft specs report end Nov 2008

Need 2007 initial SKA specs

- **International Engineering Advisory Committee review**
  – Report end Dec 2008
  – Working engineering specs set early 2009 (ISSC)
- **Other tasks begin mid-2008, e.g.**
  – Life cycle study
  – Operations plan
  – Support model
  – Performance – cost optimization
  – Manufacturing studies
  – Technical documentation

SKA initial (draft) specifications – a big engineering impact

- **SKA-P2 upper frequency limit ~8 GHz**
  - More certainty in antennas, data transport, processing, …
- **Lower frequency limit ~ 0.07 GHz**
  - But should 0.07 – 0.3 GHz array should stay as part of SKA?
- **Survey science emphasis**
  - Survey speed as primary spec, minimum A/T stated
  - Allows engineers to "unroll" the A/T & FoV product
- **More types of receptor ("open telescope" model)**
  - Sharper performance-to-cost peaks
  - Greater role for sparse aperture arrays < 0.6 GHz
- **Wide-field (~30 deg^2) synthesis imaging limited to baselines < 5 km**
  - Mitigates huge DSP + computing burden
- **BUT lots of PreSKA work to produce engineering specifications**

SKA: engineering retrospective

- **SKA2000 (Jodrell Bank), IEMT conceived**
- **2002-3, "Concept" white papers + IEMT reviews**
  - Birth of common system approach
- **2003, IEMT morphs into EWG**
  - Wide FoV technologies → SKA survey potential
  - Intense regional technical feasibility programs (various scales)
- **2004, modular system approach**
  - Birth of performance-cost tools
  - Attempts to roll together the best from all concepts (incl. "hybrids")
- **2005, site RFI tests, engineering book, industry links, …**
- **2006, Reference Design, site shortlist, Paris + strawman, system white papers, …**
- **2007, PrepSKA, performance-cost modelling, specifications, infrastructure, …**

- **2008-11, CDIT era, large-scale Pathfinders & Design Studies.**
  - Central + regional effort → SKA