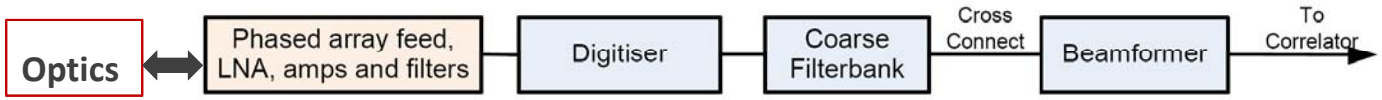
WP2.2 CoDR
PAF Concept
Summary, costs & next phase

Carole Jackson
CSIRO / PAFSKA
WP2.2.3

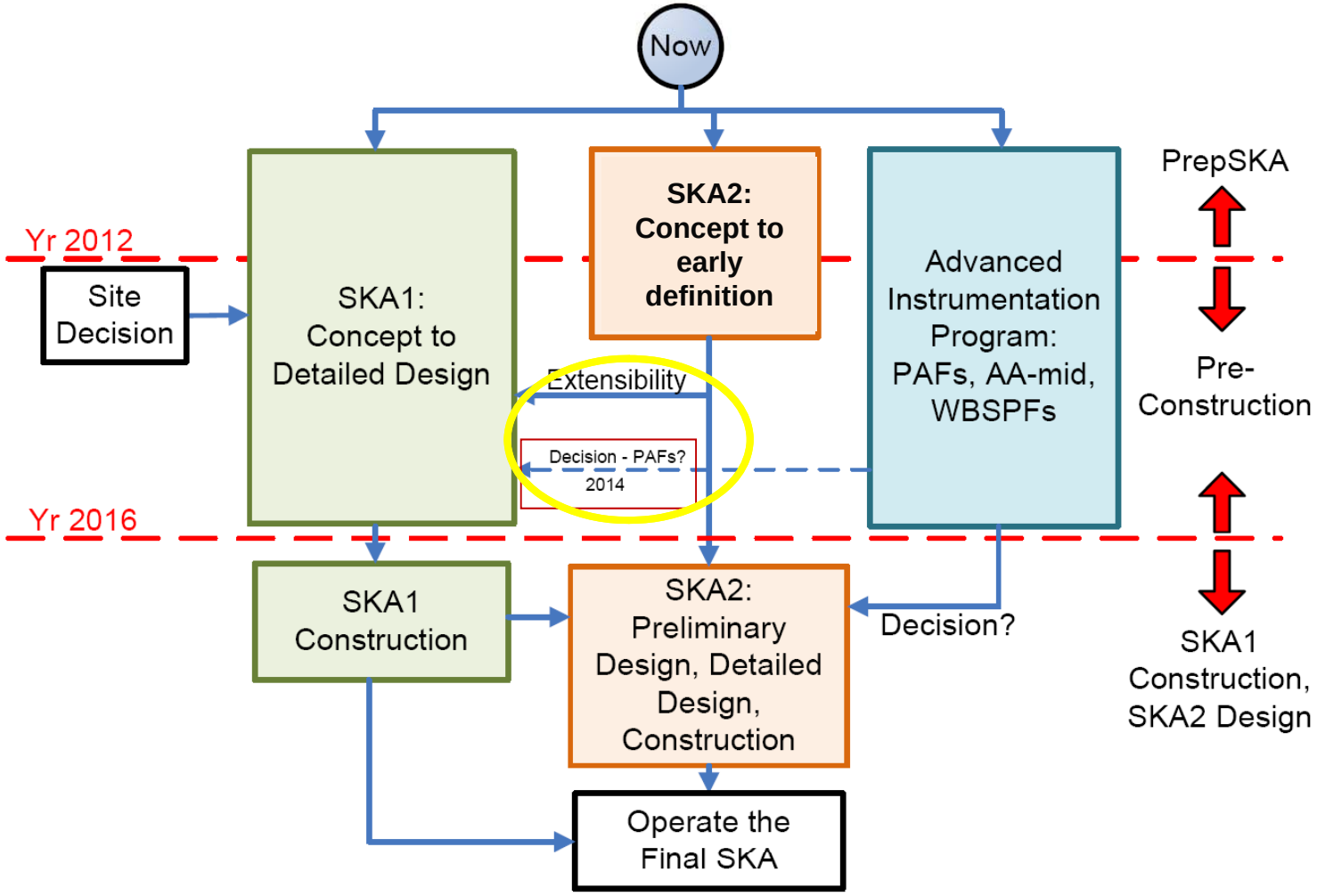
PAF sub-system overview

PAF presentations at CoDR



PAF SKA Context, addressing SKA requirements	Carole
PAF concept – PAF design (optics) feeds & LNA	Stuart
PAF Concept PAF Receiver systems	Russell, Gary, Grant
PAF requirements, risks and logistics at the SKA scale	Mark
PAF Costs & plans for next phase	this presentation

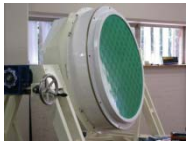
SKA development steps



PAF development 2011+

ASTRON

CSIRO



PAFSKA

BYU

NRAO

Cornell University

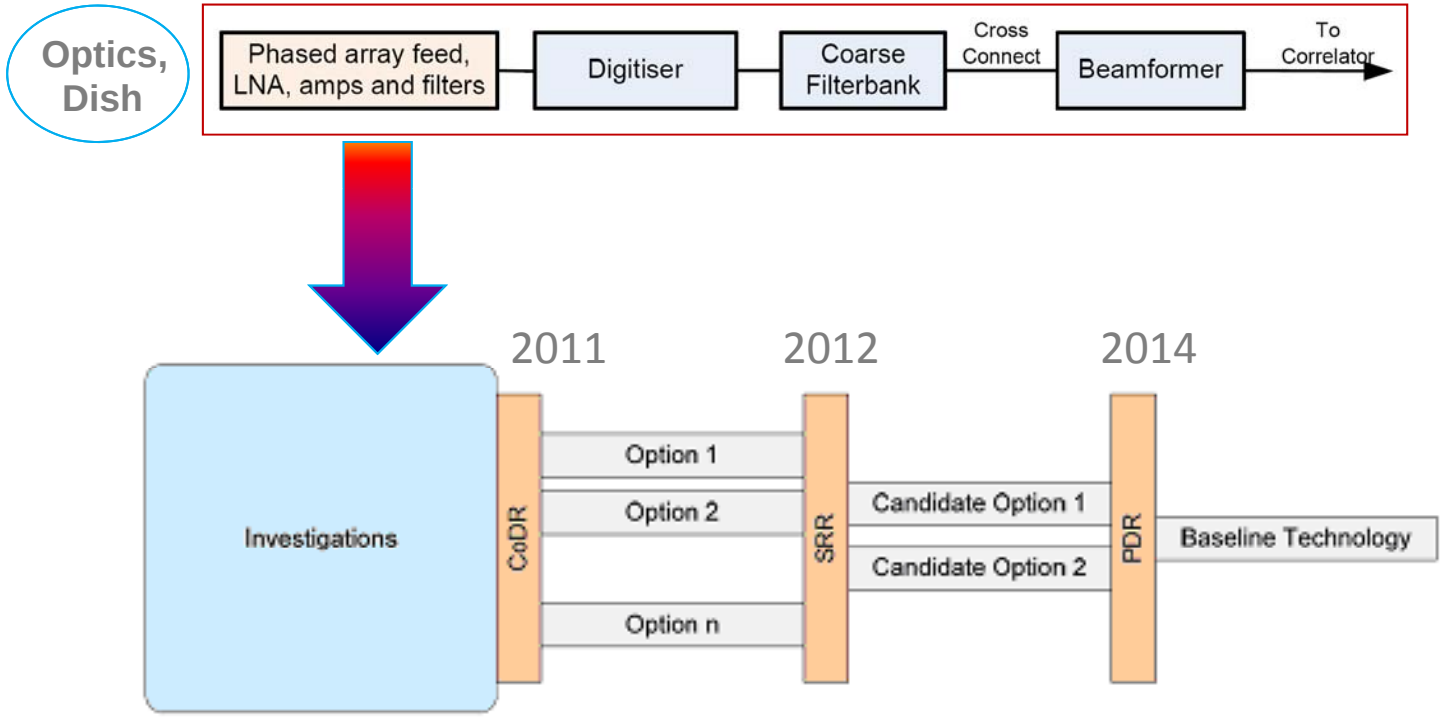
National Astronomy and Ionosphere Center

Radio Station de astronomie de Nançay

SKA PEP WP5
Dish Array EUR 15.3M
Dish EUR 3.4 M
OBSPF EUR 1.4 M
PAF EUR 7.9 M
WBSPF EUR 0.9 M

Critical aspect is for the PAF to be *manufacturable* and *maintainable*; ….a new challenge for the community and applicable to all components of SKA

PAF sub-system overview

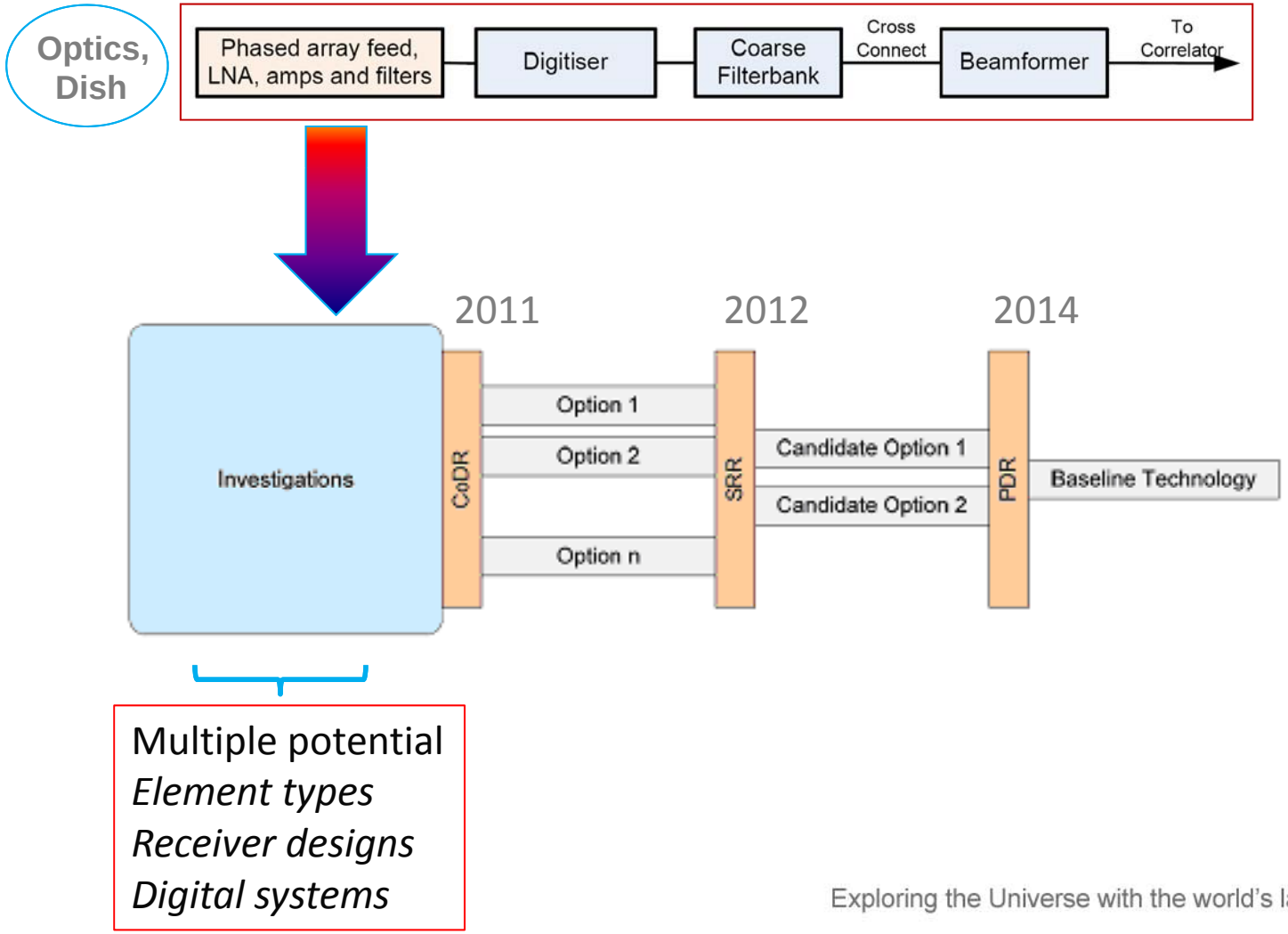


Narrowing of options during development of SKA

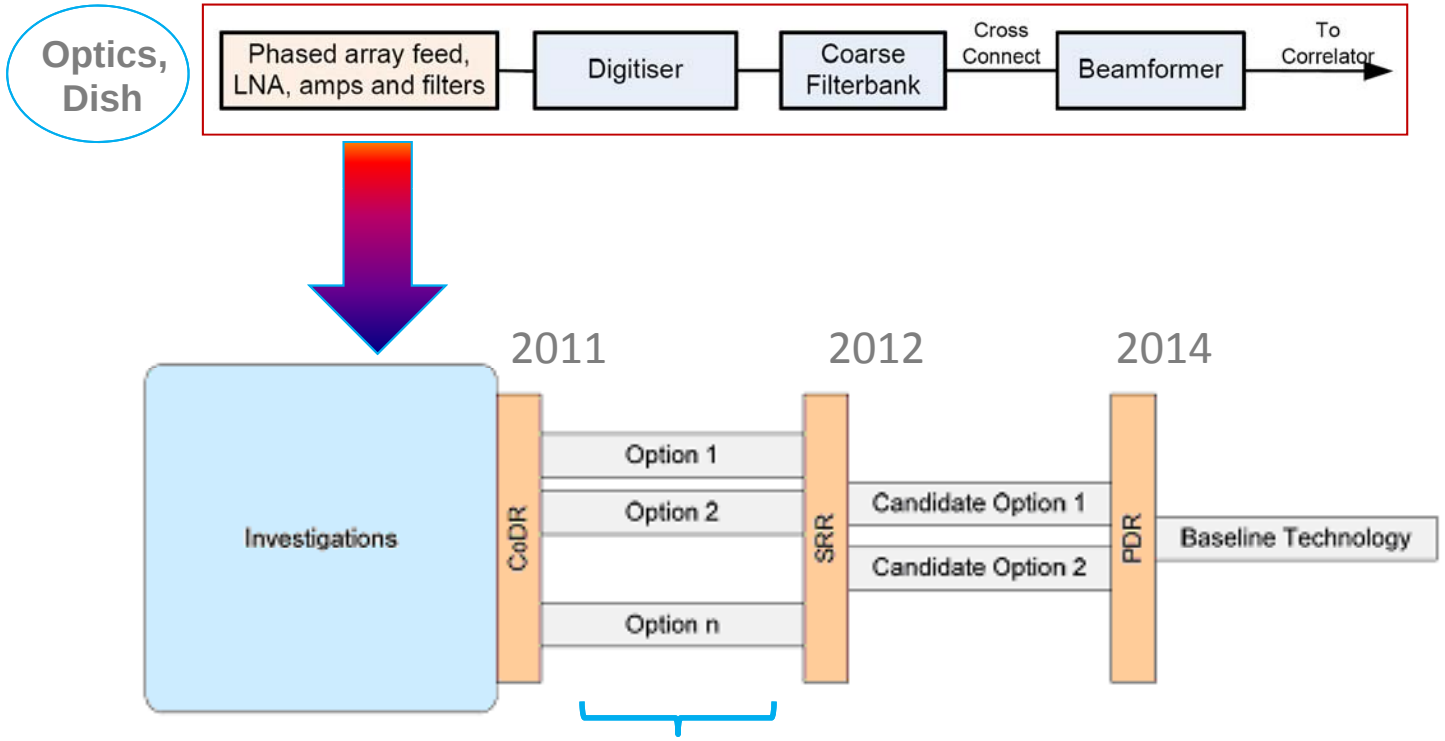
SKA1 ready

SKA2 ready

PAF sub-system overview

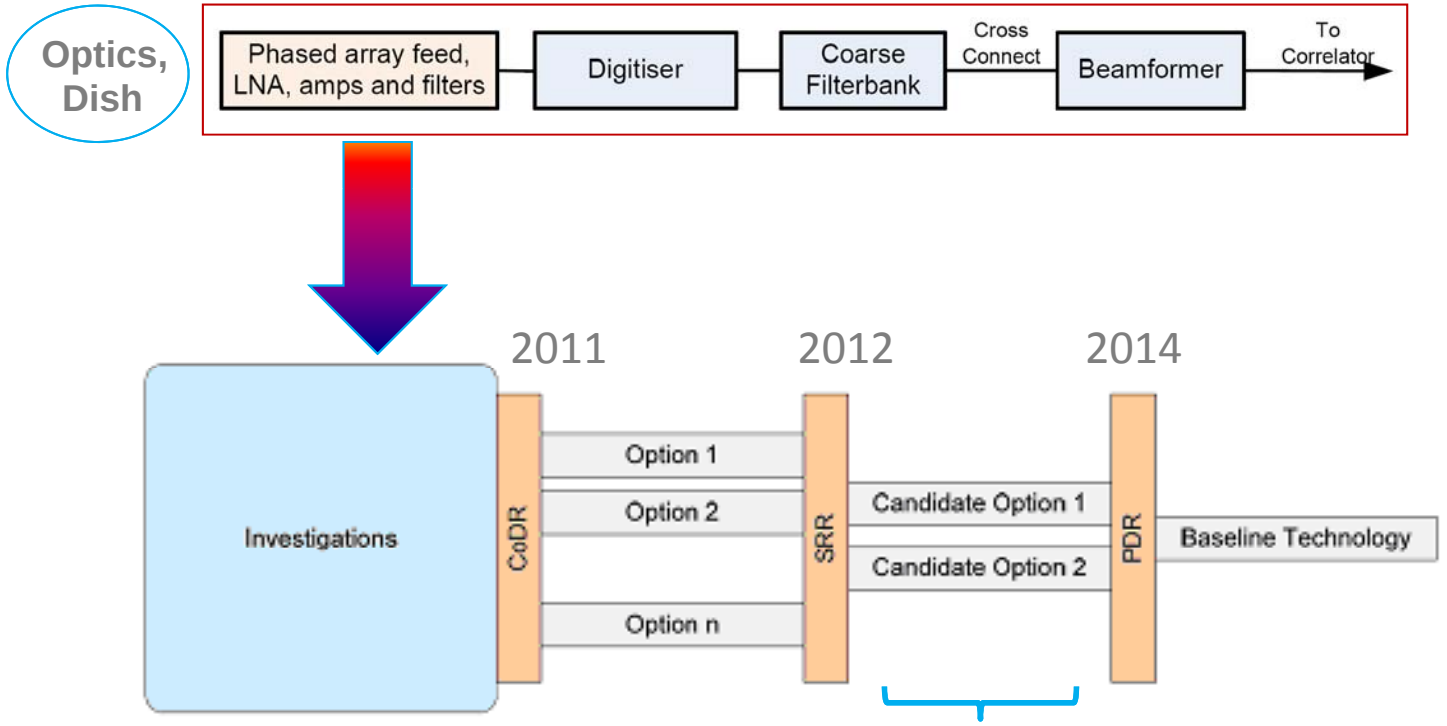


PAF sub-system overview



Analyse element type performance
Feed design & integration
SKA1: Receiver development – RFoF/I-Q
SKA2: Receiver development – Direct sampling

PAF sub-system overview



Element type selection
Feed design & integration prototype
SKA1: Receiver development – RFoF/I-Q
SKA2: Receiver development – Direct sampling

PAF Development Plan

PAF sub-system Strategy & Plans for Next Phase 2012-2015: (PEP WP5)

Develop one or more SKA1-ready PAF sub-systems; either

A single 'L-band' PAF (e.g. covering the frequency range 600 MHz – 1.5 GHz)

- Or -

2 PAF systems aligned to, or exceeding, the dish-array frequency bands as defined in SKA Memo 130 (e.g. 450 MHz – 1 GHz and 1 – 2 GHz)

To be determined before the Dish Array SRR Q3 2012.

PAF Development Plan

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Some thoughts:

- The SKA would be well served by the '2 PAF' option.
- The entire Dish Array must be optimized as a single system
  - i.e. dish size/design/cost future-proofed for potential feed options, including multiple PAFs.
- Integrate with "DVA"; defined feed/dish performance testing.

+ Advance definition of PAF systems for SKA2

PAF Development Plan

Test and document the SKA1 PAF system -

- Test at a well-calibrated radio telescope (location to be specified)
- Understand the complexities of PAFs at SKA1 scales (and SKA2 scales),
  - e.g. PAF systems across 100-200 dishes and 100 km baselines,
- Performance comparisons with alternative receiver systems ($/science return)

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Fully cost the prototype system(s), including

- Build costs at quantity, including defining all integration and interface issues (costs),
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- MTBF, environmental analyses, Power and other resourcing requirements.

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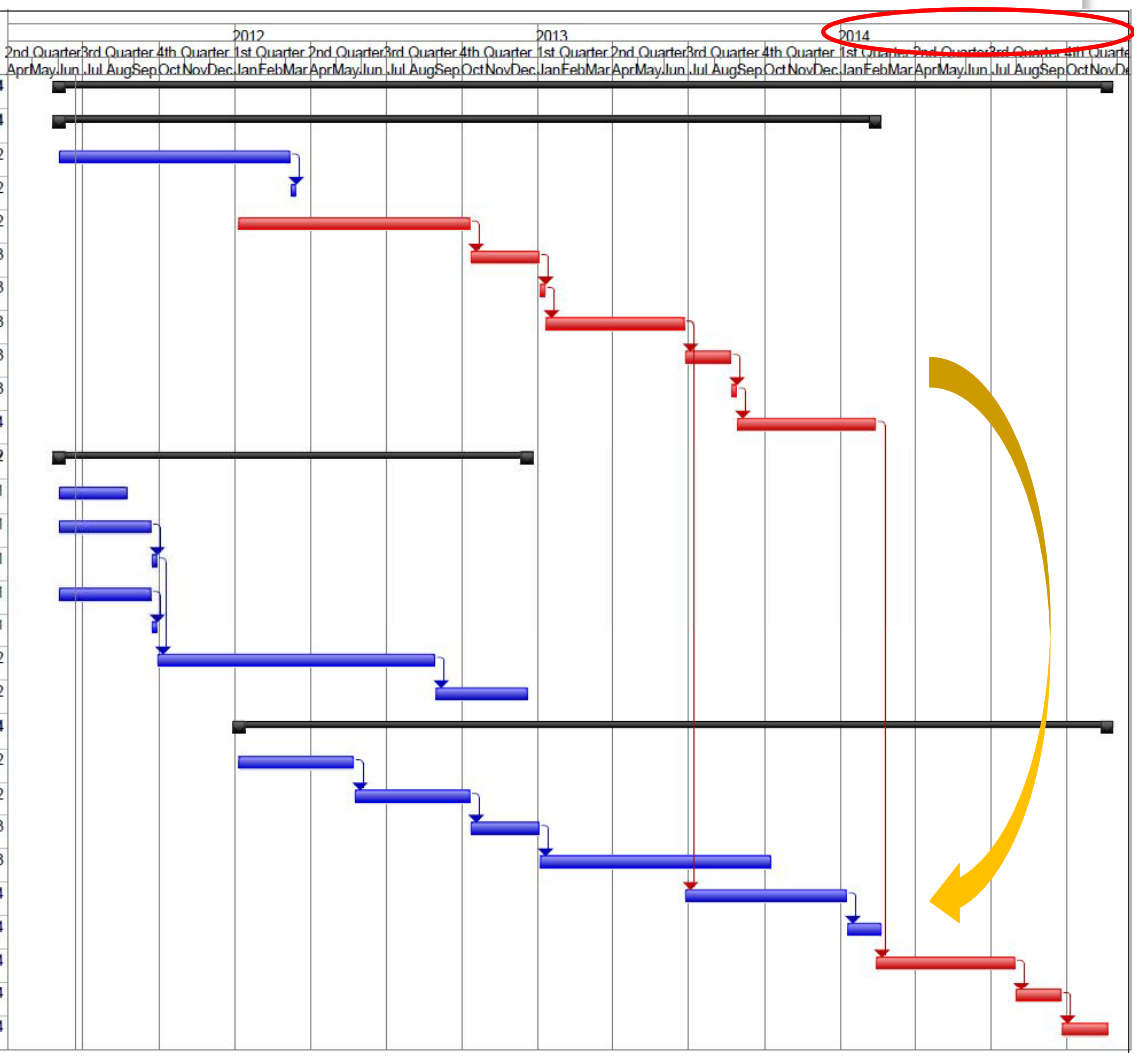
Risk Mitigation/Recommendations

Early in the PEP development phase (i.e. during 2012) there must be a

- detailed analyses of the proposed SKA dish array system (close integration)
- including PAF system(s) and other feeds,
- define the performance metrics, cost-performance trade-offs and options.

PAFs – PEP phase plan

Task Name	Duration	Start	Finish
SKA PEP WP5 activities	**905 days**	**Mon 6/06/11**	**Fri 21/11/14**
SKA PAF development	**705 days**	**Mon 6/06/11**	**Fri 14/02/14**
Critically assess best PAF system design for SKA	200 days	Mon 6/06/11	Fri 9/03/12
Signoff PAF parameters/basic architecture between SKA/PAF partne	5 days	Mon 12/03/12	Fri 16/03/12
Design-for-SKA manufacture study I	200 days	Mon 9/01/12	Fri 12/10/12
Prepare for CDR for SKA1 PAF(s) systems	60 days	Mon 15/10/12	Fri 4/01/13
CDR for SKA1 PAF(s) systems	5 days	Mon 7/01/13	Fri 11/01/13
Build SKA1 PAF(s) systems prototypes (feed, receiver, digital, data t	120 days	Mon 14/01/13	Fri 28/06/13
Design-for-SKA manufacture study 2	40 days	Mon 1/07/13	Fri 23/08/13
2nd CDR for SKA1 PAF(s) systems	5 days	Mon 26/08/13	Fri 30/08/13
Build final SKA1 PAF(s) systems prototypes (feed, receiver, digital)	120 days	Mon 2/09/13	Fri 14/02/14
SKA Dish prototyping	**405 days**	**Mon 6/06/11**	**Fri 21/12/12**
Define dish design parameter, traceability matrix etc	60 days	Mon 6/06/11	Fri 26/08/11
Dish design 1	80 days	Mon 6/06/11	Fri 23/09/11
Dish design 1 CDR/PDR	5 days	Mon 26/09/11	Fri 30/09/11
Dish design 2	80 days	Mon 6/06/11	Fri 23/09/11
Dish design 2 CDR/PDR	5 days	Mon 26/09/11	Fri 30/09/11
DVA-1 contract; manufacture; FAT	240 days	Mon 3/10/11	Fri 31/08/12
DVA-1 install at test site; integration, SAT	80 days	Mon 3/09/12	Fri 21/12/12
SKA Dish Array system integration	**750 days**	**Mon 9/01/12**	**Fri 21/11/14**
OBSPF design study, analysis	100 days	Mon 9/01/12	Fri 25/05/12
OBSPF contract; manufacture	100 days	Mon 28/05/12	Fri 12/10/12
OBSPF calibration & test at test site	60 days	Mon 15/10/12	Fri 4/01/13
Undefined task for WBSPF test & integrate at test site	200 days	Mon 7/01/13	Fri 11/10/13
Integrate & test prototype 1 SKA1 PAF(s)	140 days	Mon 1/07/13	Fri 10/01/14
Review prototype 1 performance	30 days	Mon 13/01/14	Fri 21/02/14
Integrate & test prototype 1 SKA1 PAF(s)	120 days	Mon 17/02/14	Fri 1/08/14
Review final prototype PAF performance; submit to SKA1 build plan	40 days	Mon 4/08/14	Fri 26/09/14
SKA1 PAF manufacturing plan; ready for build	40 days	Mon 29/09/14	Fri 21/11/14



PAFs – cost estimates (SKA1)

PAF sub-system based on RF-over-Fibre with multi-band direct sampling.

Start with established PAF build costs (2009 designs)
- small N systems; non-optimised; RF over coax; from PAFSKA

3 steps to a 2014-build PAF cost estimate:

Step A. Estimate the cost for PAF RFoF today (2011),

Step B. Review the feed payload design optimisations, move from 'proof of concept' feed array to smart design-for-build (first-level cost reduction),

Step C. Consider further refinements and component cost reductions expected by 2014 (refine cost-per-build)

Baseline for costing: assuming a 0.6-1.5 GHz PAF (scalable)
200 elements (dual-pol, any element type),
400 MHz bandwidth, 36 beams

PAFs – cost estimates (SKA1)

Step A. PAF RFoF - components as available to ASKAP now (2011)

Component	Cost each (EUR)/ 2011	Number Per PAF	Total cost EUR
Mechanical, structure	21,000	1	52,500
Feed element, LNA, filters and amplifiers	300	200	60,000
RFoF links	206	200	41,250
ADC & signal condition	173	200	24,000
Coarse filterbank	600	12	7,200
ADC/filterbank boards	1,500	12	18,000
Cross Connect	12	450	5,400
Beamformer (boards & FPGAs)	8,250	8	66,000
Other infrastructure	7,500	1	7,500
Total			**EUR 292,350**
Contingency (15%)			EUR 43,850
TOTAL			**EUR 336,200**

PAFs – cost estimates (SKA1)

Step B: PAF feed payload design optimisations

- Medium-level component integration,
- Smart design (optimise dish mechanics etc),
- Reduction in RFoF COTS component prices, and
- Initial 'design for manufacture'.

We estimate that PAF costs would reduce to (in 2014):

Mechanical structure from EUR 52,500 to EUR 21,000
Feed elements, LNAs, filters and amplifiers from EUR 300 each to EUR 248 each
RF over fibre link component costs from EUR 206 each to EUR 113 each

PAFs – cost estimates (SKA1)

Step C: Anticipate market component costs & capacities in 2014

Incorporate some significant digital system component reductions, based on our experience in adopting new FPGA technologies, e.g.

- The coarse filterbank reduces from 12 off of EUR 600 systems to 5 off system at EUR 600
- The ADC and filterbank boards reduce from 12 off EUR 1,500 systems to 5 off at EUR 750
- The beamformer reduces from 8 off systems at EUR 8,250 each to 4 off at EUR 9,000 each

PAFs – cost estimates (SKA1)

PAF cost estimate for 2014:

Component	Cost each (EUR)/ 2014	Number Per PAF	Total cost EUR
Mechanical, structure	21,000	1	21,000
Feed element, LNA, filters and amplifiers	248	200	49,500
RFoF links	113	200	22,500
ADC & signal condition	143	200	28,500
Coarse filterbank	600	5	3,000
ADC/filterbank boards	750	5	3,750
Cross Connect	24	200	4,800
Beamformer (boards & FPGAs)	9,000	4	36,000
Other infrastructure	7,500	1	7,500
Total			EUR 176,550
Contingency			EUR 26,400
TOTAL			**EUR 202,950**

Same design; 100 element PAF EUR 106,000

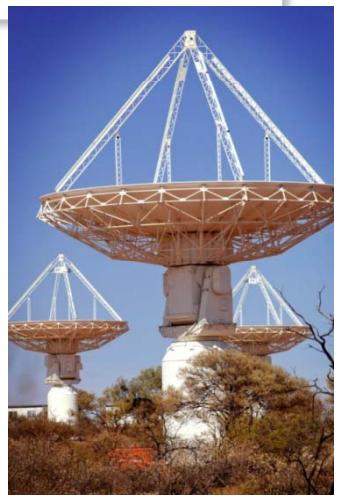
PAFs – costs > 2014

PAF Cost estimates (SKA2) 2016+

PAF sub-system with the ADC as part of the feed payload (direct sampling).
Aim to be ready for a proof-of-concept build for SKA2.

PAFs in development 2011+

PAFs and Dish Design options



ASKAP PAF on 12-m axi-symmetric dish
APERTIF on 25m WRST equatorial symmetric dish

APERTIF & ASKAP are SKA pathfinders…. Plus PAFSKA
Providing critical lessons for SKA:

1. Need to optimise dish-feed design, and not build-out flexibility re feeds
2. Optimised for survey speed – demonstrate PAF flexibility (DR, FoV etc)
3. Advantages of a sky-mount axis (DR, ….for any feed type?)
4. Full system builds (far better than single prototypes or paper-based design concepts)
5. Develop & test calibration, imaging, etc schemes – to be well understood

in time for SKA

5. Astronomers will learn to expect PAF performance & flexibility on the SKA –

Wide FoV is not a mosaic; it is a singly-imaged flat field.

Conclusions: PAF sub-system

1. Powerful and flexible feed option for SKA

2. PAF enables wide-field surveys on viable timescales;
-> also capable of meeting SKA dynamic range & polarisation purity spec etc.

3. Established technology; identified the key refinements during PEP phase
(next phase planning is well progressed; expertise available)

4. Ready for SKA1; PAFs for high frequency for SKA2

5. Array test-bed(s) available now, ahead of the PEP.

6. Major institutional commitment to demonstrate astronomy-ready PAF arrays
(ASTRON & CSIRO)

7. PAFSKA continues as collaborative pool of international expertise
(extending beyond PEP participants)

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