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SKAO

SKA-Low
The INAF contribution

Speaker & Author: Jader Monari

Co-author: Monica Alderighi, Carlo Baffa, Carolina Belli, Gianni Bernardi, Pietro Bolli, Letizia Caito, Federica Caputo, Alessandro Cattani, Simone Chiarucci, Giovanni Comoretto, Sergio D'Angelo, Paola Di Ninni, Davide Fierro, Elisabetta Giani, Giulia Macario, Andrea Mattana, Giovanni Naldi, Federico Perini, Marco Poloni, Giuseppe Pupillo, Simone Rusticelli, Marco Schiaffino, Francesco Schilliro', Alice Tabellini

jader.monari@inaf.it

History of INAF participation to SKA

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LFAA CDR | SCDR | PRR | Construction

Dawn project | BEST era | Middle age | Renaissance

2002
First SKA meeting

2004
Preparation requests UE – FP6-SKADS

2005–2009
SKADS

2010–2015
AAVP

2015-2018
AADC-RT

2018-2022
Bridging phases
Pre-procurement

2018-2022
Bridging phases 1-2-3
Pre-procurement

2023-2028
AA0.5-AA3*

SKA SQUARE KILOMETRE ARRAY

PrepSKA SQUARE KILOMETRE ARRAY

SKADS

Sixth Framework Programme

MARIE CURIE ACTIONS

SKA-AAVP

SKA SQUARE KILOMETRE ARRAY

LOW-FREQUENCY APERTURE ARRAY

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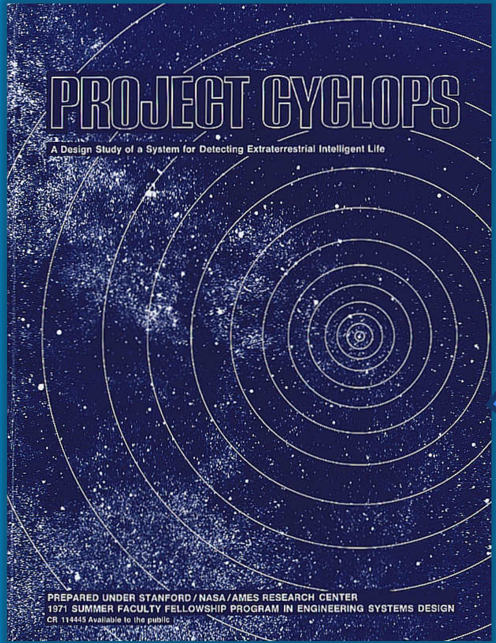

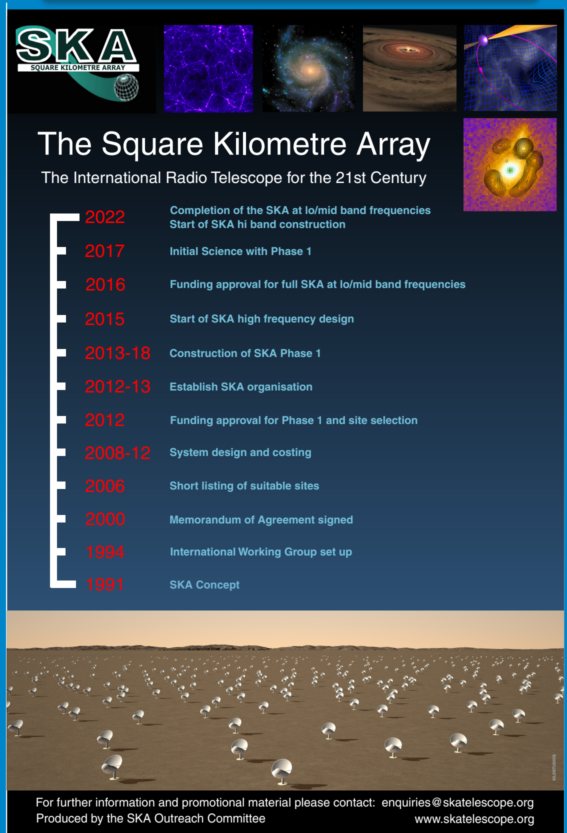

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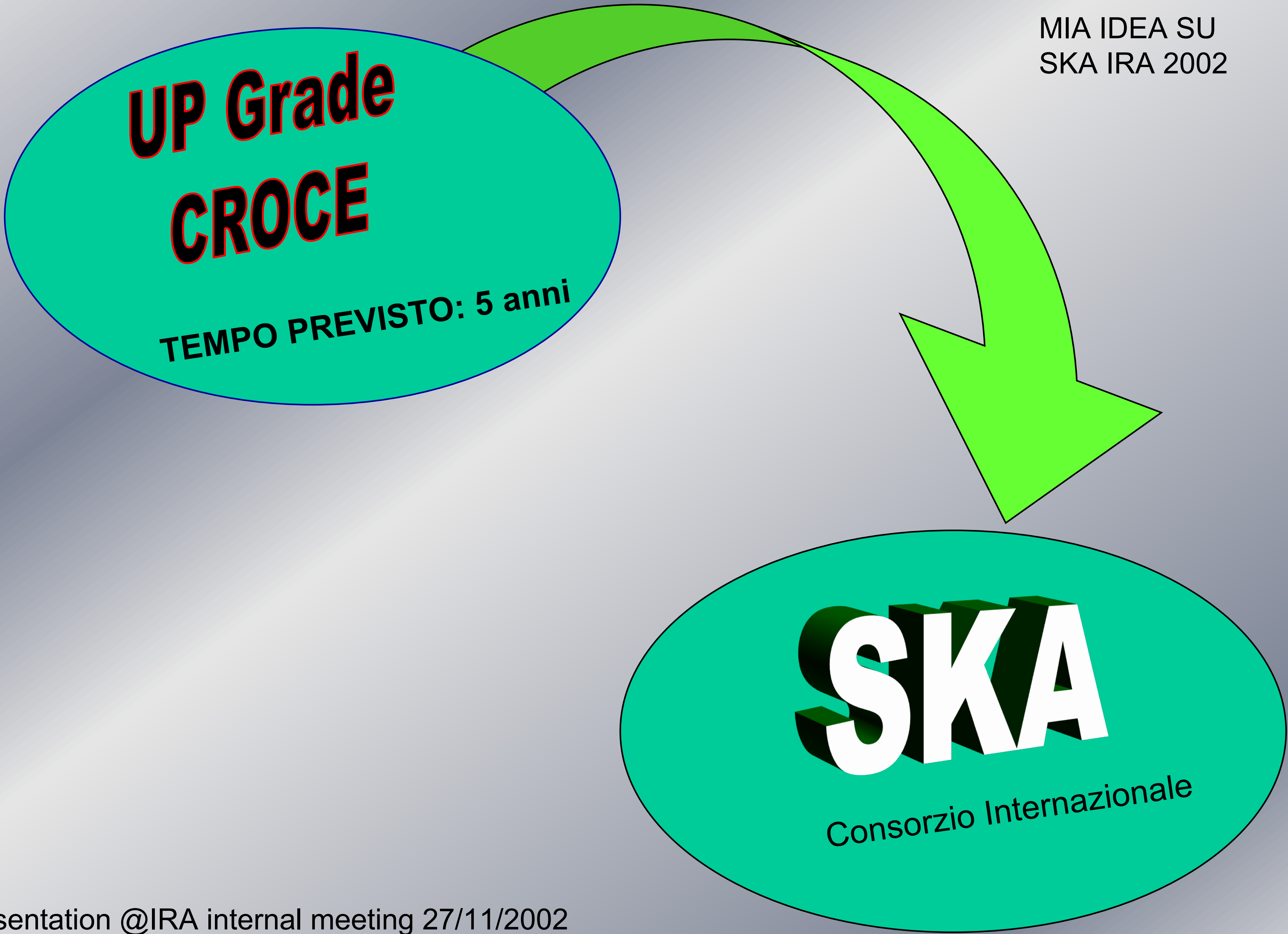
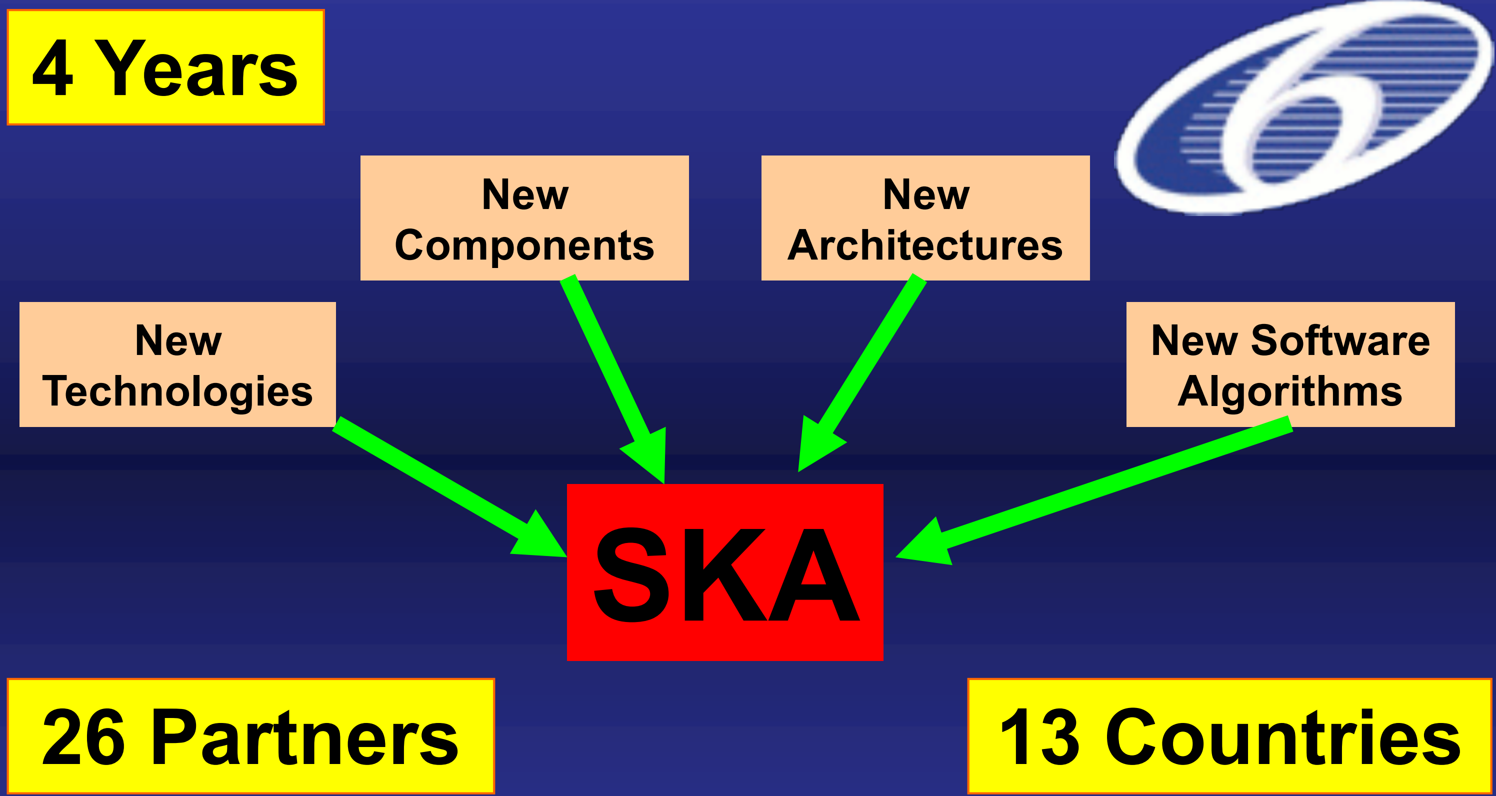
MIA IDEA SU
SKA IRA 2002



SM Presentation @IRA internal meeting 27/11/2002

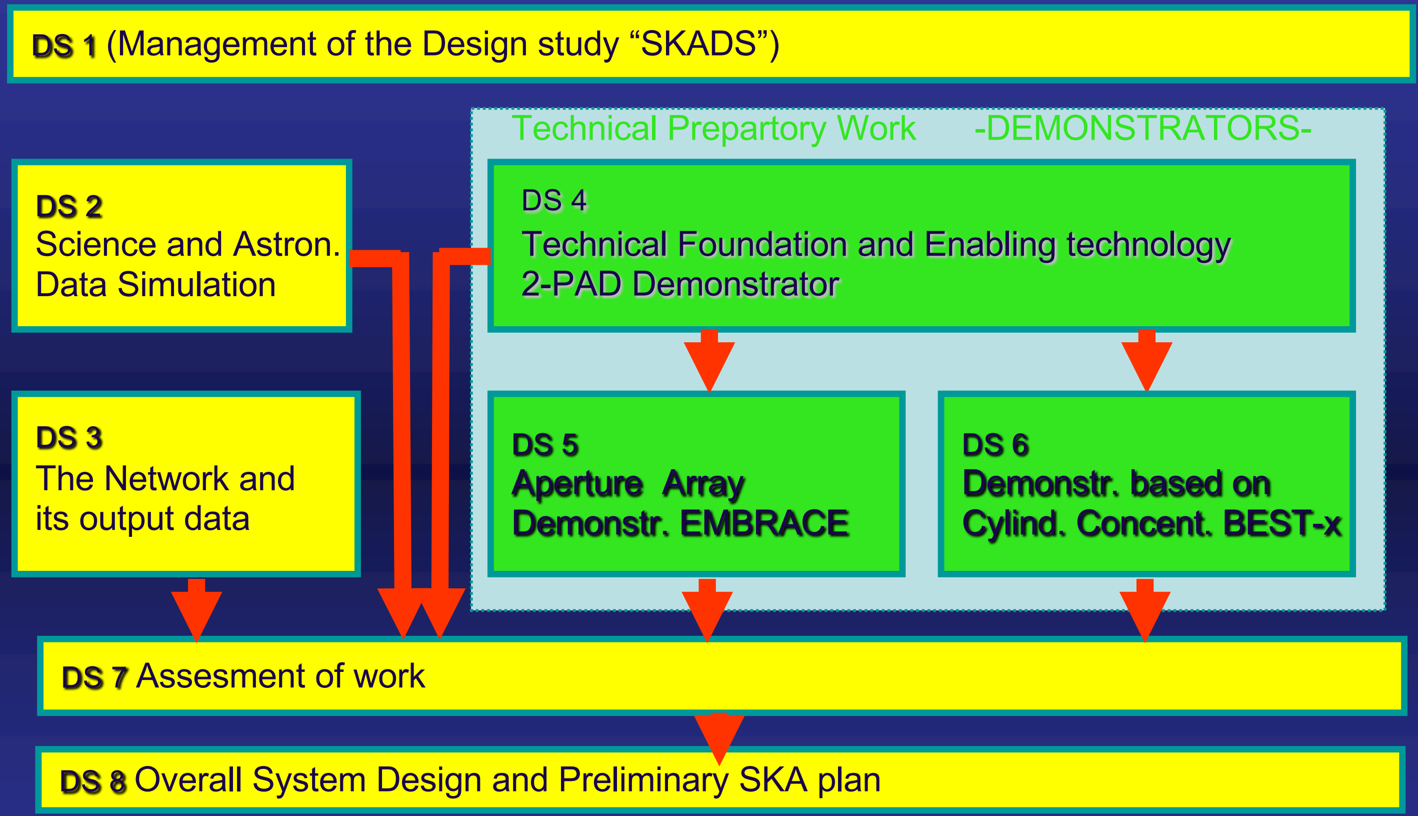
SKADS


4 Years
New Components
New Architectures
New Technologies
New Software Algorithms
SKA
26 Partners
13 Countries

MARIE CURIE ACTIONS

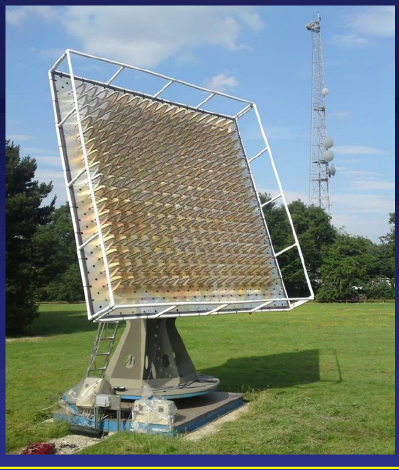
INAF

Organizational structure



SKADS demonstrators

2-PAD	EMBRACE	BEST
2 Polarisation All Digital tile	Electronic Multi Beam Radio Astronomy ConcEpt	Basic Element for SKA Training



BEST-2 test bed: Radio over Fiber experiences

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

Presented by Monari Jader
IRA-INAF Radiotelescopio Croce del Nord Villafontana (BO) ITALY
Email : j.monari@ira.inaf.it

Coaxials vs Fibers

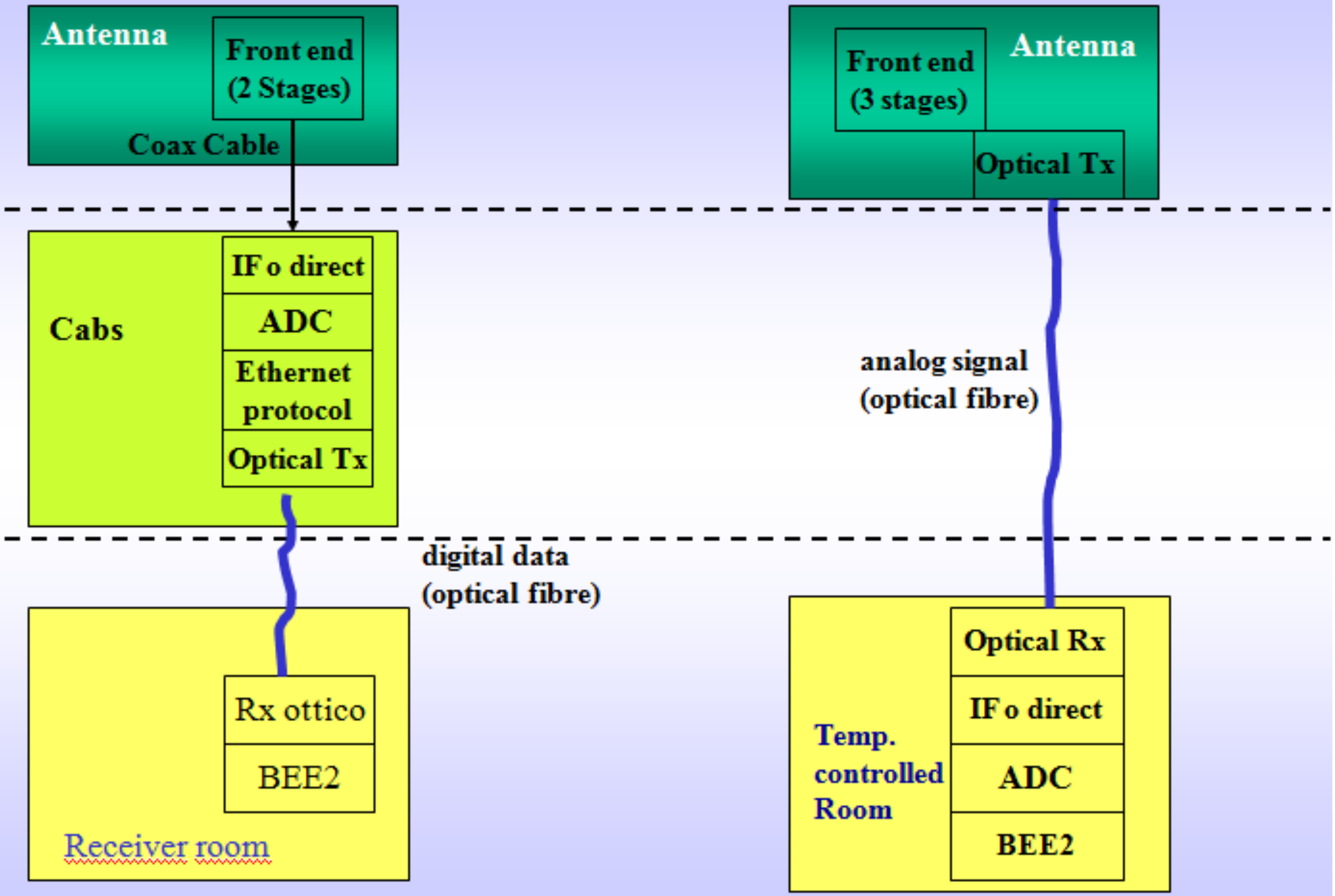
Coaxial cables to external cabins where signals can be digitized and sent via Fast Ethernet links to the processing room

Analogue Optical Links directly from Focal Lines to the Processing Room

The costs of both of them are very similar (hardware and manpower)

Which solutions?

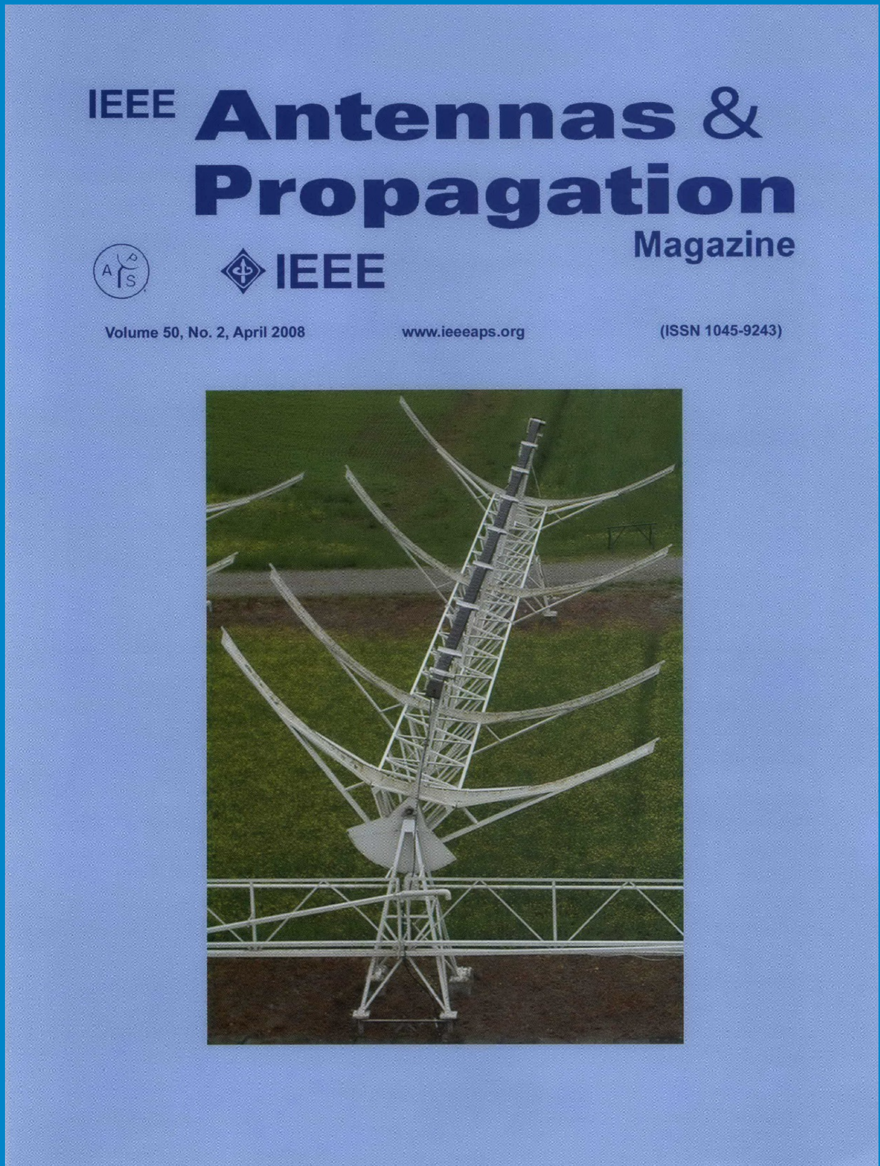
…the reliability is improved with the use if analog optical link data transport….



RF Analog Optical Link Vs digital link….

Big efforts are spent to design low cost analog links because they offer several benefits:

1) The electronic move from the outside cabins to the processing room in the central building.
2) More Reliable, less risks and easier maintenance.
3) No Sync, LO and PPS distribution from the main building to cabins.
4) Fibers are cheaper, lighter and more flexible than coaxial cables.
5) Fibers have more phase stability vs temperature and amplitude equalization in wide bandwidth than coaxial.

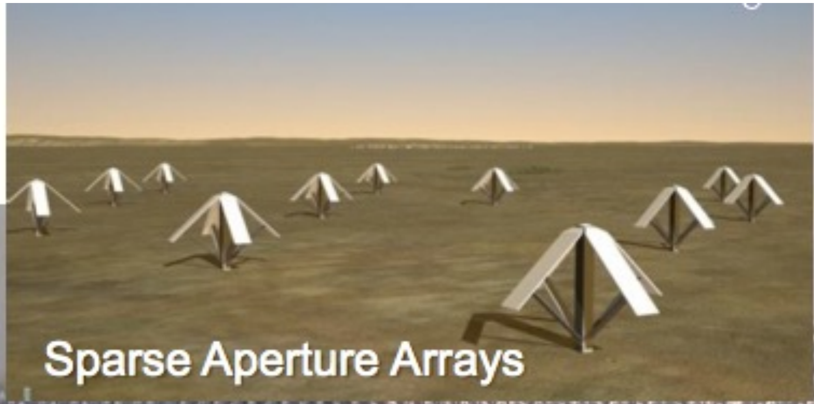


Basic Element for Square Kilometer Array Training (BEST): Evaluation of the Antenna Noise Temperature

P. Bolli[1], F. Perini[2], S. Montebugnoli[2], G. Pelosi[3], S. Poppi[1]

2008

SKA-AAVP



Aperture Array Verification Programme: Toward the SKA

Project size:

~18-20M€

100+ FTE

42 month

15 institutes

9 European countries

+ Australia & SA

www.SKA-AAVP.eu

secretary@SKA-AAVP.eu

www.ska-aavp.eu/aavpwiki

SKA-AAVP

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ASTRON · ICRAR · PS · HF

FUNDING & RESOURCE PROVIDED BY COOPERATING INSTITUTION

Proposed Effective Date: July 2013

Stage 1 / Stage 2

	K€	Source	FTE[1]	K€	Source	FTE
Staff:	495K€	INAF-CNR/IEIIT-CNR/IMEM-UNIBO-POLITO	7,5	633,6K€	INAF-CNR/IEIIT-CNR/IMEM-UNIBO-POLITO	9,6
Equipment:	70K€ (MAD) 150K€ (SAD) 50K€ (Labs) 10K€ (CCL payment)	INAF -RAS		250K€ (AAVS1) 270K€ (SAD) 70K€ (Labs) 50K€ (RE development)	INAF - RAS	
Industrial:	96K€	INAF		132K€	INAF	
Travel :	50K€	INAF		100K€	INAF	
Total:	921K€			1505,6K€		

CONSORTIUM LEAD ORGANISATION

ASTRON
Name of Institution

Signature of Authorized Official

Prof. M.A. Garrett
General Director
Name & Title of Authorized Official

4-6-2013
Date

CONSORTIUM MEMBER

INAF
Name of Institution

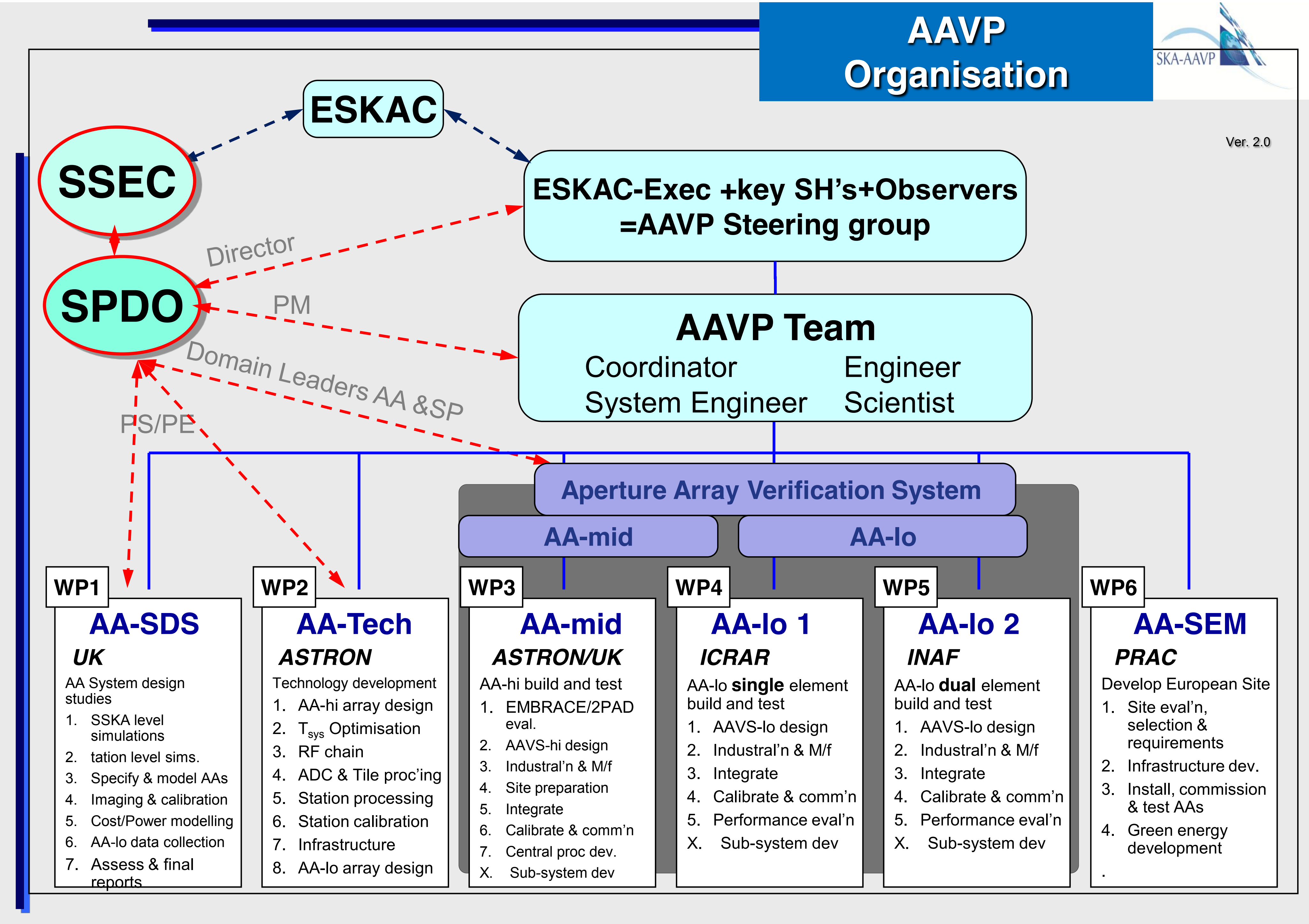
Signature of Authorized Official

Giovanni F. Bignami
INAF Presidente
Name & Title of Authorized Official

Date

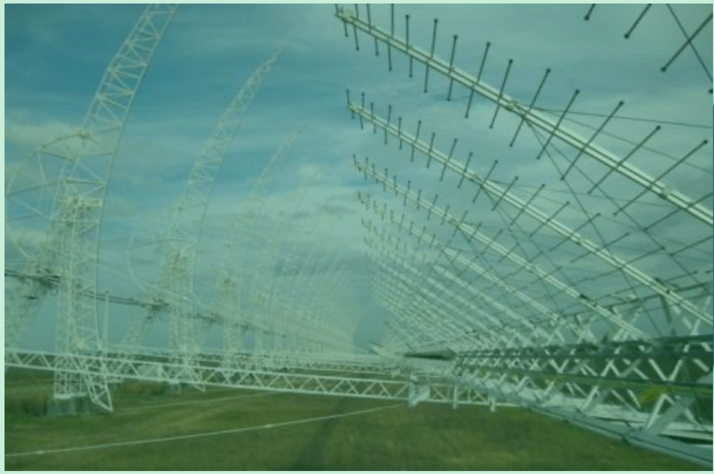
Provisional Acceptance, parts that contribute to the SAD project are not considered to contribute to LFAA work

[1] 1 FTE=12MM=66K€ (+ taxes)


AAVP Organisation
SKA-AAVP
Ver. 2.0
ESKAC
SSEC
SPDO
ESKAC-Exec +key SH's+Observers =AAVP Steering group
Director
PM
Domain Leaders AA &SP
PS/PE
AAVP Team
Coordinator
Engineer
System Engineer
Scientist
Aperture Array Verification System
AA-mid
AA-lo
WP1
AA-SDS
UK
AA System design studies
1. SSKA level simulations
2. tation level sims.
3. Specify & model AAs
4. Imaging & calibration
5. Cost/Power modelling
6. AA-lo data collection
7. Assess & final reports
WP2
AA-Tech
ASTRON
Technology development
1. AA-hi array design
2. T_{sys} Optimisation
3. RF chain
4. ADC & Tile proc'ing
5. Station processing
6. Station calibration
7. Infrastructure
8. AA-lo array design
WP3
AA-mid
ASTRON/UK
AA-hi build and test
1. EMBRACE/2PAD eval.
2. AAVS-hi design
3. Industral'n & M/f
4. Site preparation
5. Integrate
6. Calibrate & comm'n
7. Central proc dev.
X. Sub-system dev
WP4
AA-lo 1
ICRAR
AA-lo single element build and test
1. AAVS-lo design
2. Industral'n & M/f
3. Integrate
4. Calibrate & comm'n
5. Performance eval'n
X. Sub-system dev
WP5
AA-lo 2
INAF
AA-lo dual element build and test
1. AAVS-lo design
2. Industral'n & M/f
3. Integrate
4. Calibrate & comm'n
5. Performance eval'n
X. Sub-system dev
WP6
AA-SEM
PRAC
Develop European Site
1. Site eval'n, selection & requirements
2. Infrastructure dev.
3. Install, commission & test AAs
4. Green energy development

SKADS – (IRA-INAF) → AAVP WP5 AA-lo

Experience from SKADS-BEST (UHF) (1400 sqm)

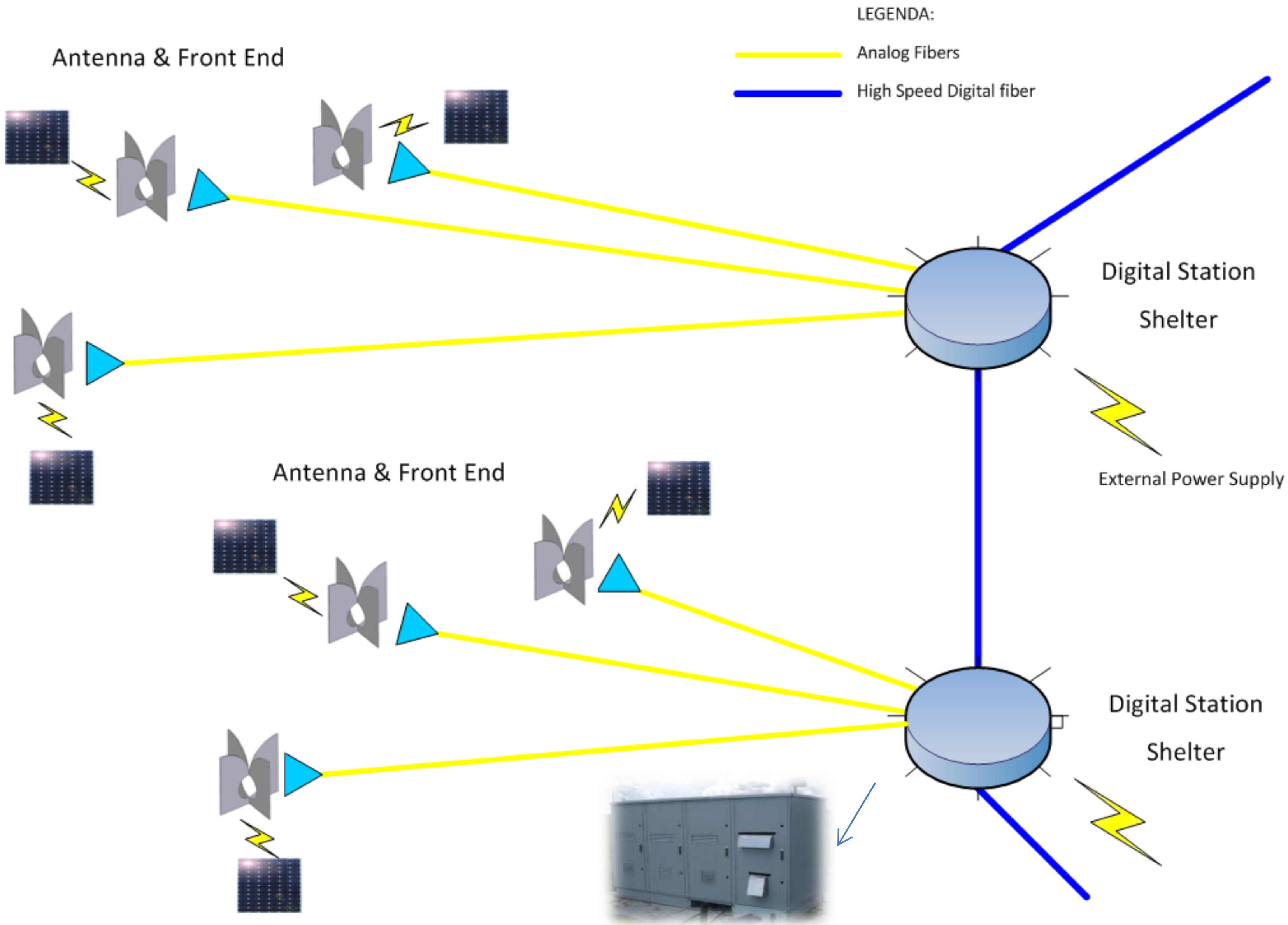


Experience from a VHF prototype. (800 sqm)

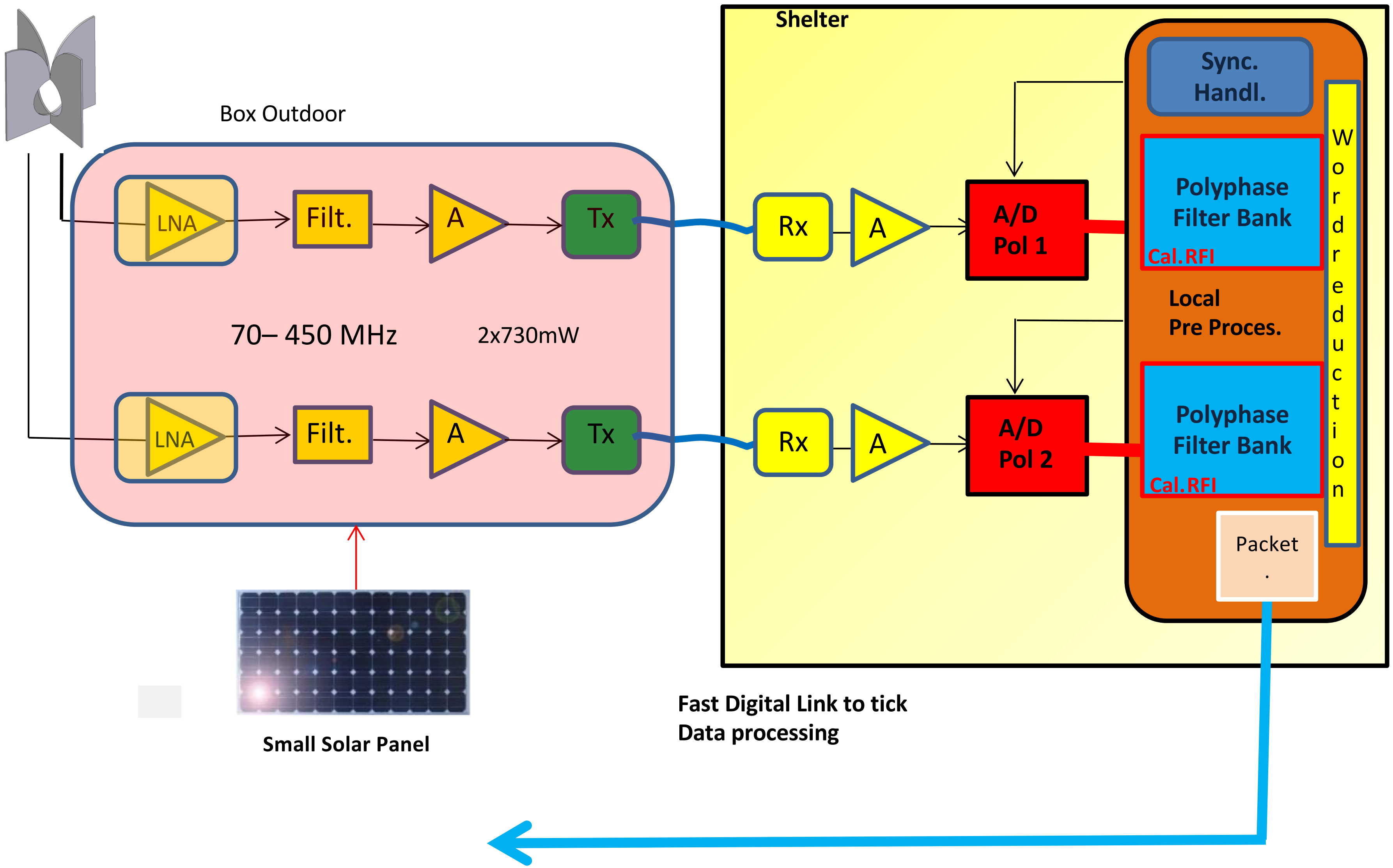
AAVP (AA-lo2)

This is the point we start from....

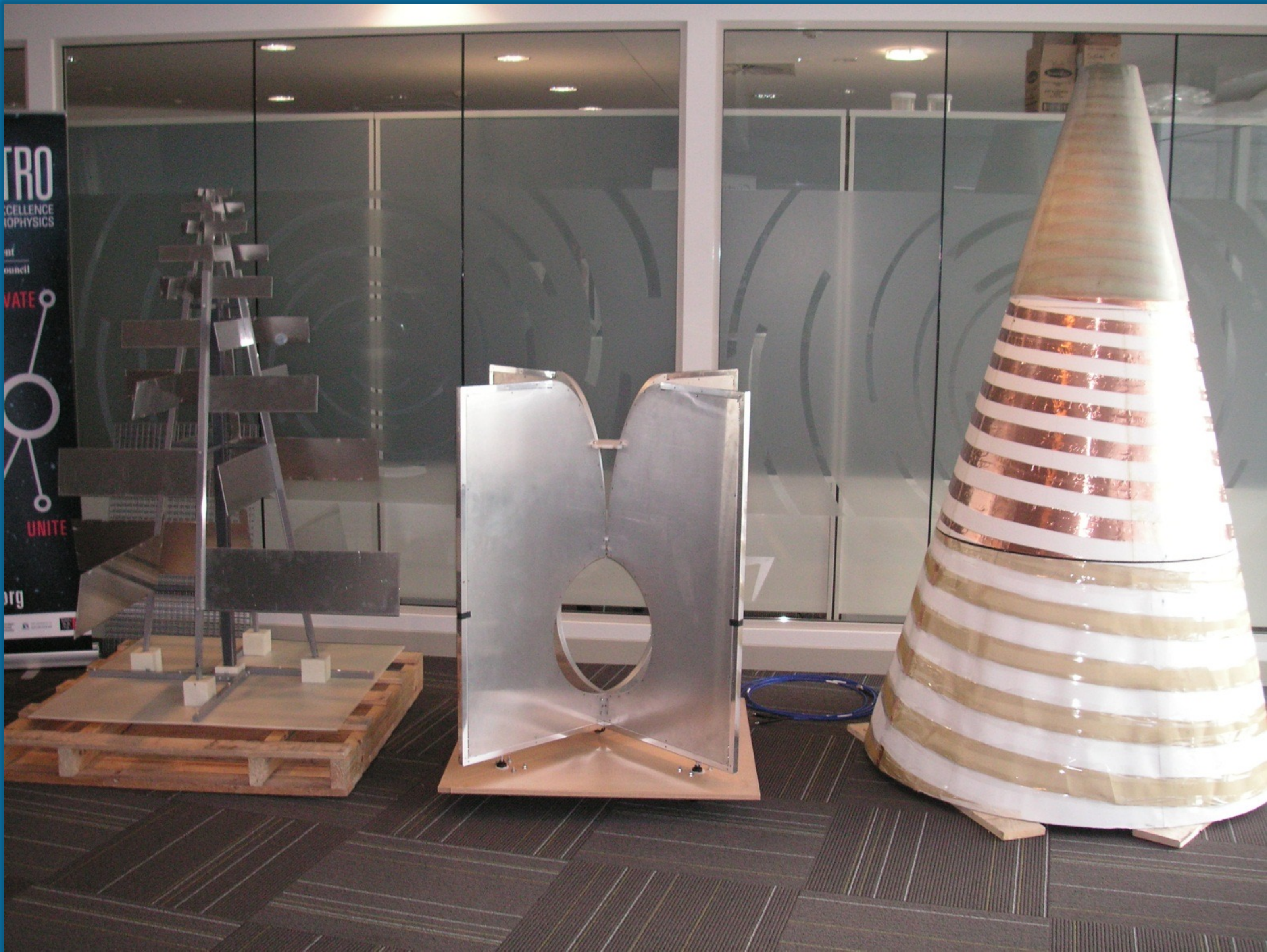
AAVP WP5 AAlo



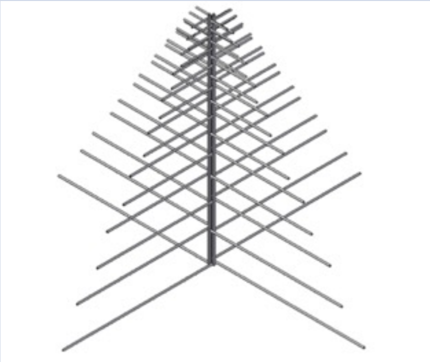
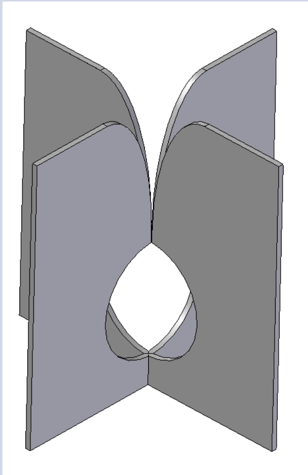
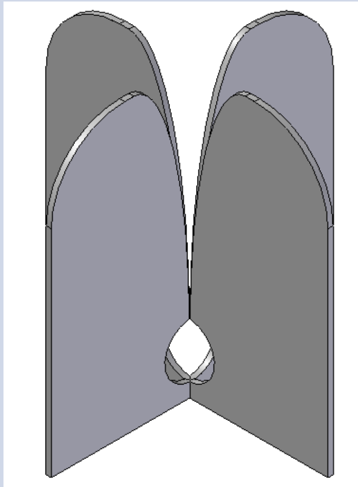
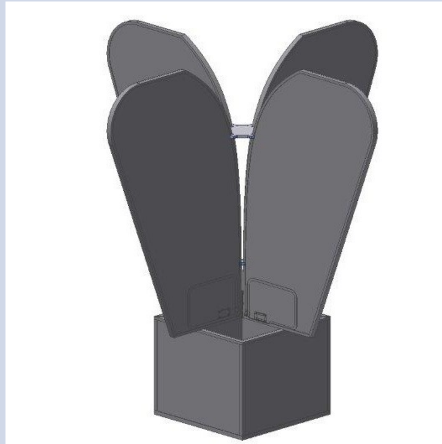
AAlo basic block diagram



AAVP Antennas



Picture took in Perth September 2011

Dual-Pol Log-periodic	**Dual-Pol Vivaldi version 1**	**Dual-Pol Vivaldi version 2**	**Dual-Pol Vivaldi version 3.1**
			
Pro - Well-known design - Simple manufacturing - Low-cost	Pro - Good reflection coefficient (50 Ohm) - High isolation between polarizations	Pro - Acceptable refl. Coeff. (50 Ohm) - High isolation between polarizations - Lower back lobe - Higher directivity at 45°	Pro - Very High directivity in the required sky coverage - Very Low back lobe - High isolation between polarizations
Cons - poor cross polarization performance	Cons - High back lobe	Cons - Refl. Coeff is -4 dB at 120 MHz	Cons - Lower directivity at 45°


DESIGNING THE
Square Kilometre Array
Telescope Manager
Assembly, Integration and Verification
Central Signal Processor
CSP
Pulsar Search
Pulsar Timing
Mid Correlator Beam-Former
Low Correlator Beam-Former
SKA
SQUARE KILOMETRE ARRAY
Dish
Signal and Data Transport
Science Data Processor
SDP
Low-Frequency Aperture Array
Infrastructure South Africa
Infrastructure Australia
Progress
Completed

Aperture Array Design & Construction Consortium

The Low Frequency Aperture Array

Jan Geralt Bij de Vaate

ASTRON

ICRAR International Centre for Radio Astronomy Research

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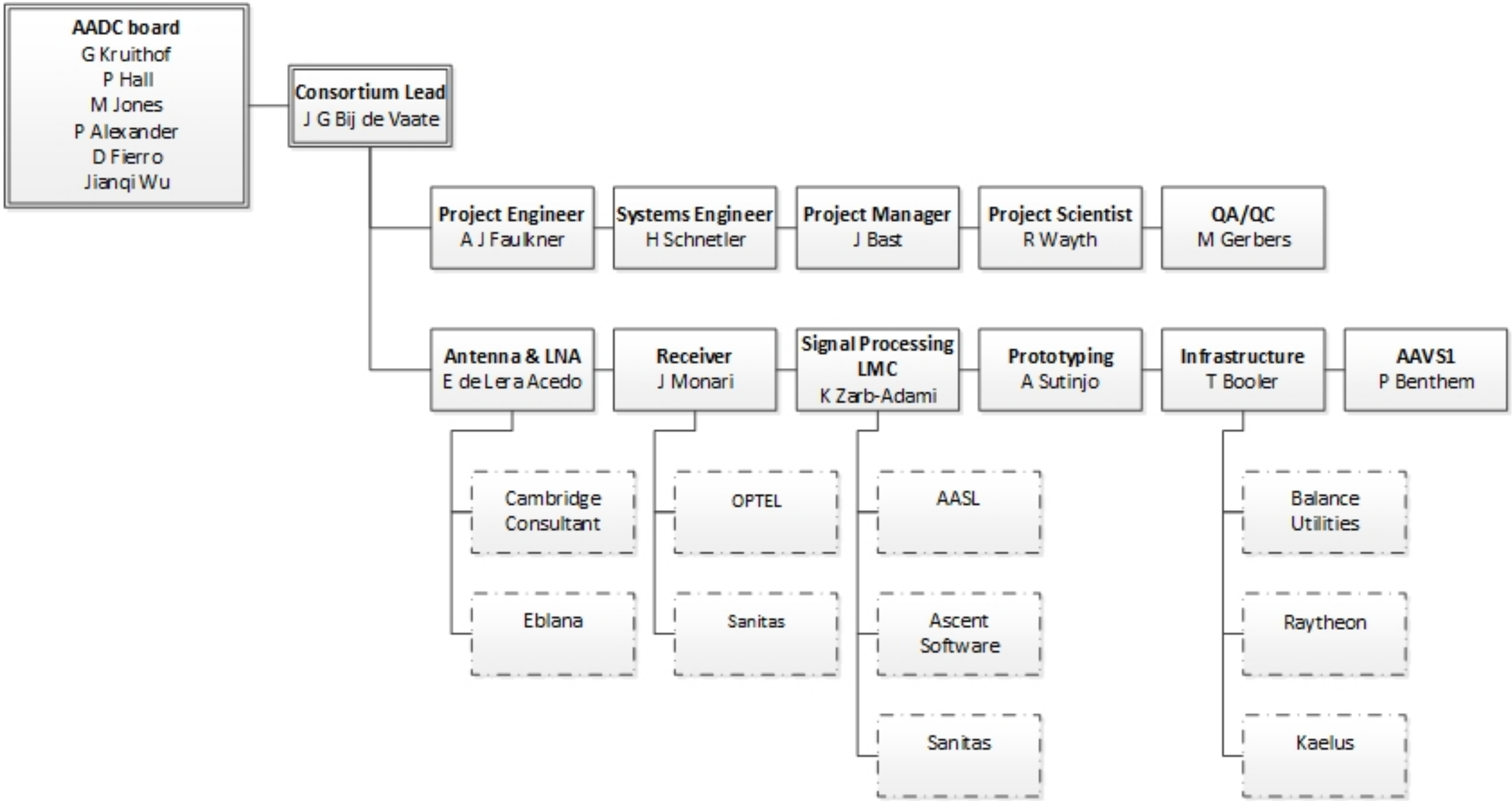
KLAASA Key Lab of Aperture Array and Space Application

Science & Technology Facilities Council

UNIVERSITY OF CAMBRIDGE

UNIVERSITY OF OXFORD

Consortium Organisation



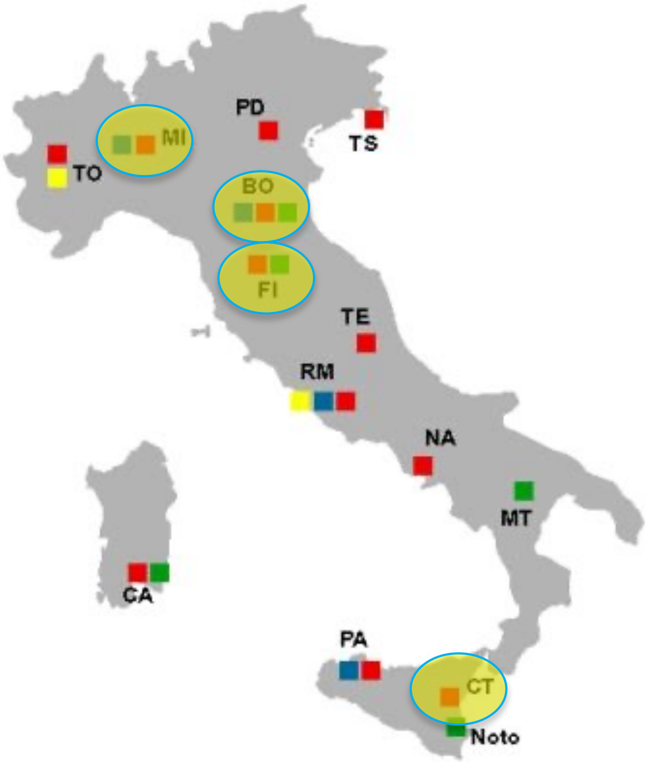
INAF Team (2016)

AADC board member: Davide Fierro
Coordination & RX WP leader : Jader Monari
Antenna & Calibration: Pietro Bolli, Giuseppe Pupillo , Salvatore Pluchino
Receiver Chain: Federico Perini, Simone Rusticelli, Marco Poloni
Mechanics: Marco Schiaffino
Signal Processing: Francesco Schillirò, Monica Alderighi, Giovanni Naldi, Andrea Mattana
Firmware: Gianni Comoretto, Carolina Belli, Simone Chiarucci
Admistration: Alice Tabellini

INAF - LFAA technical group (internal organigram -2016)

IRA — **Jader Monari**, PM

- **Pietro Bolli** — Antenna & LNA — OAA
- **Federico Perini** — Receiver — IRA
- **Francesco Schillirò**, **Monica Alderighi** — Acquisition System — OACT, IASF-Mi
- **Gianni Comoretto** — FW beamforming — OAA
- **Marco Schiaffino** — Mechanics — IRA
- **Gianni Bernardi** — Observation — IRA



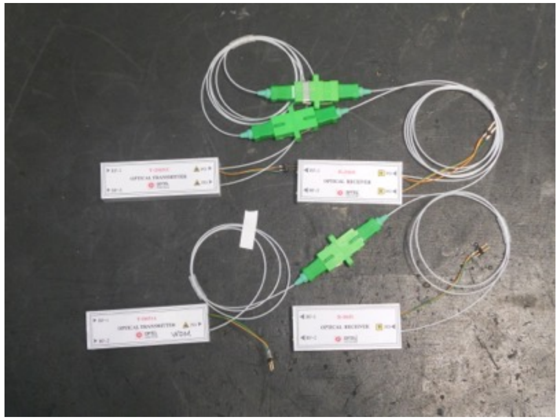
Research Contracts

- CNR-IEIIT & POLITO (WP-AL)
- UNIBO (WP-RX)
- UNIFI (WP-AL/RX/SP)

UniBO	Analogue Optical fibre
CNR-IEIIT	Antenna & Calibration
POLITO	Flying measure facility
UniFi	Reliability

Main Past/Current Activities

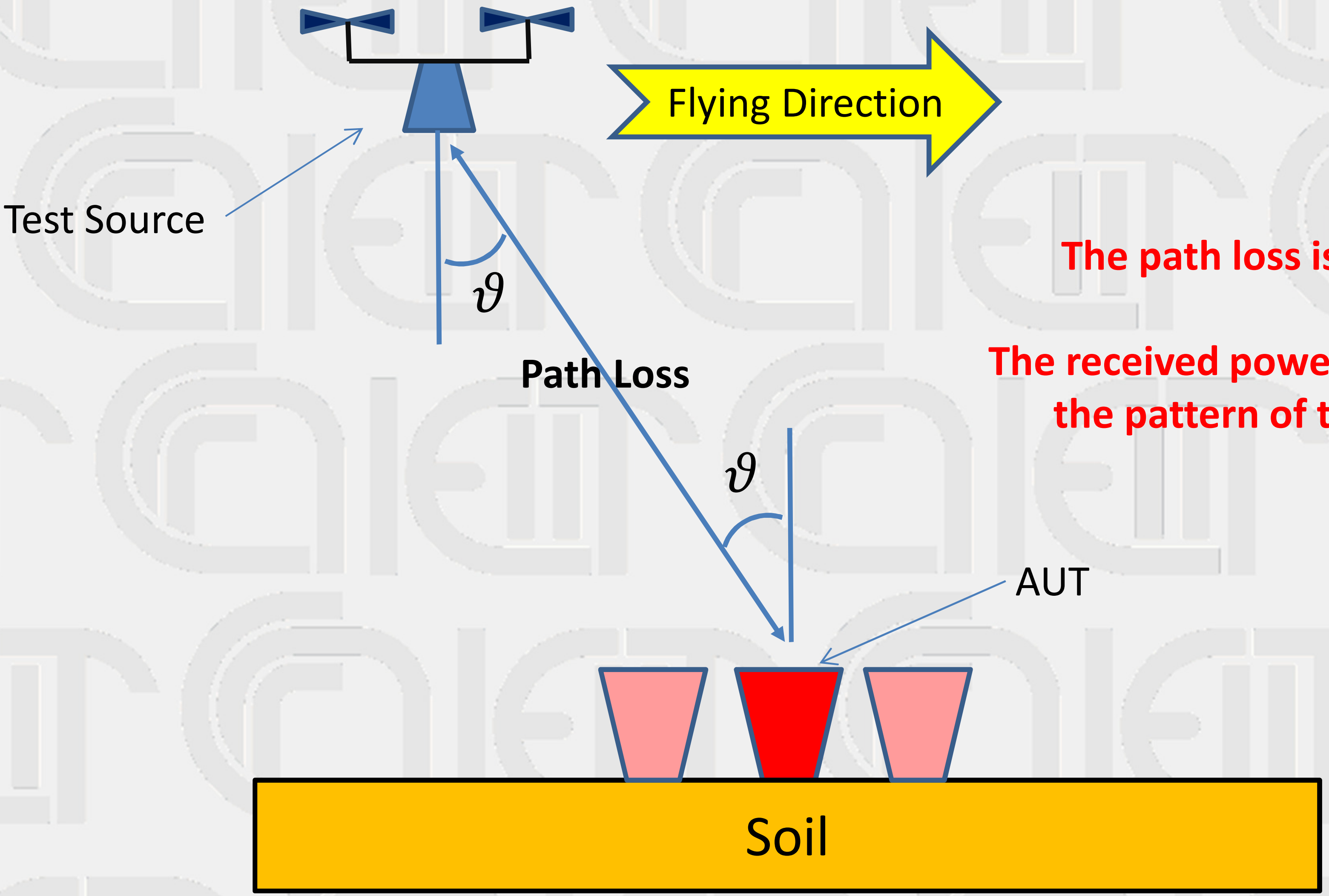
- Vivaldi design
- Hexacopter test bench
- RFoF technology (standard, WDM, VCSEL, POF)
- Pattern measurement/Calibration for Vivaldi/SKALA, Mini MAD, MAD-1,2,3
- iTPM assembly (PREADU PRE-analogue board and ADU (Analogue Digital Unit)



Hexacopter for RF measurements

The UAV is equipped with a transmitter emitting a CW linear polarized signal with a power of about 3 mW, tunable in frequency from 35 MHz to 1.1 GHz

Quasi-rectilinear flying paths above the AUT (2D representation)

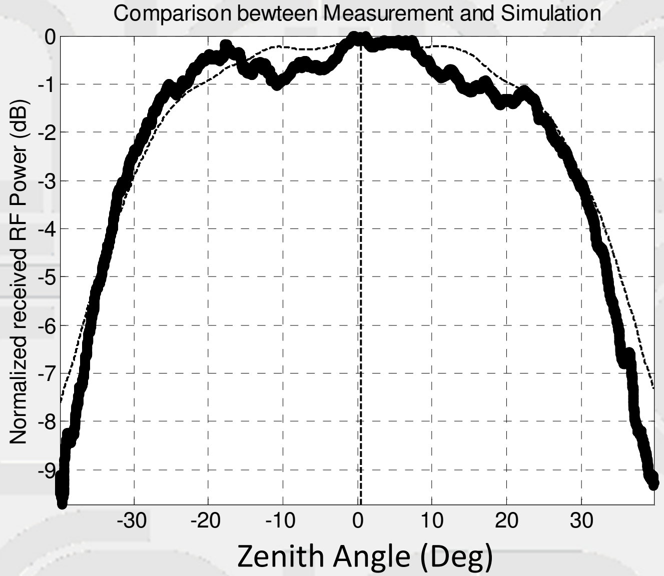


The path loss is not constant

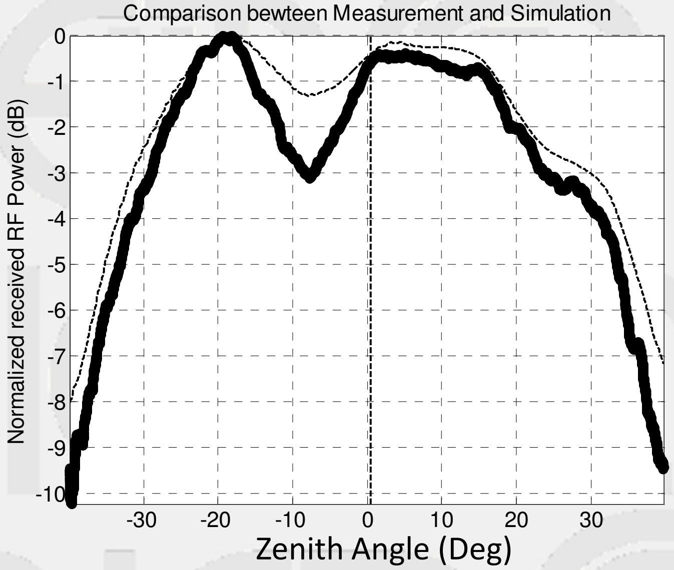
The received power also depends on the pattern of the test source

1-4 Embedded Element Patterns

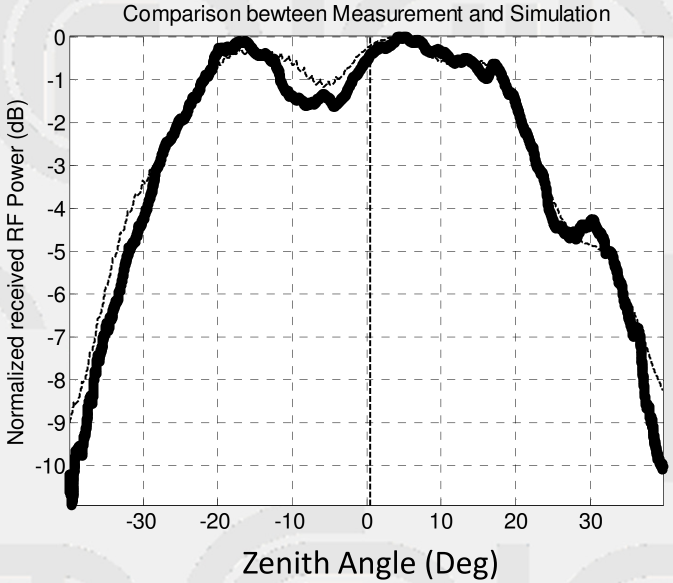
V1



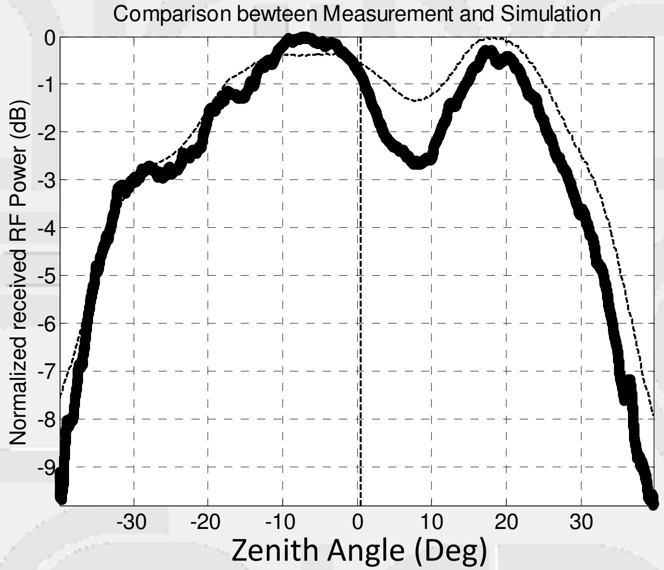
V2



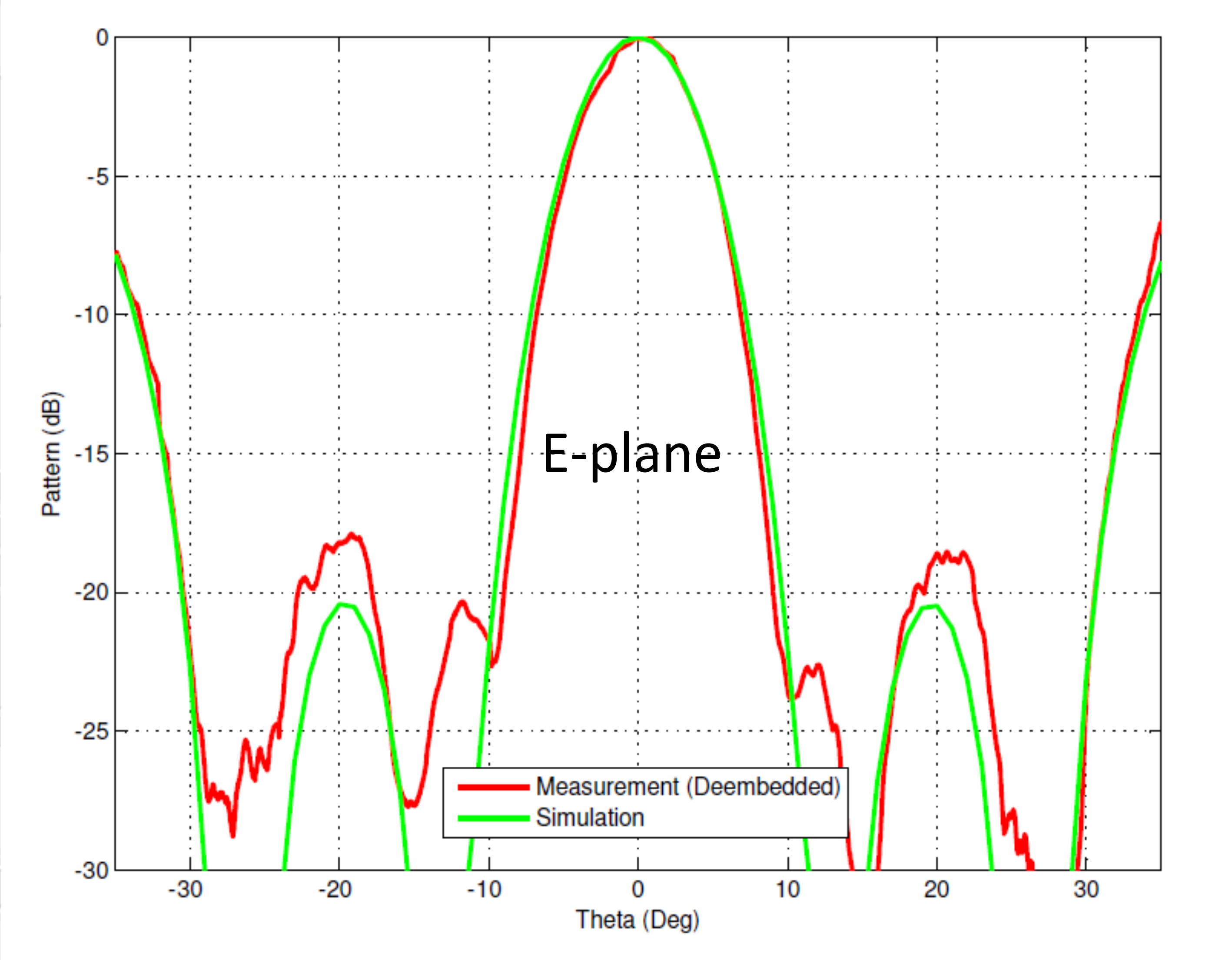
V3



V4



MAD Array Radiation Pattern



G. Pupillo, et al. "**Calibration of aperture array receivers based on unmanned aerial vehicle**", *2nd ERATEC Workshop on Calibration of multi-beam receivers*, Bologna, 28-29 October 2013

A PROJECT WITHIN A PROJECT (AAVS1)

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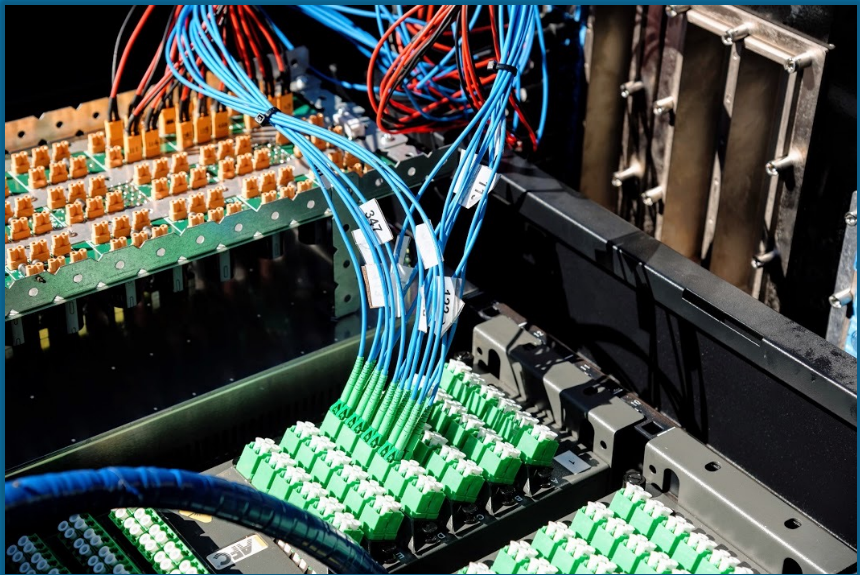
Antenna deploy

On-field cabling and testing



Correlator room - Acquisition system

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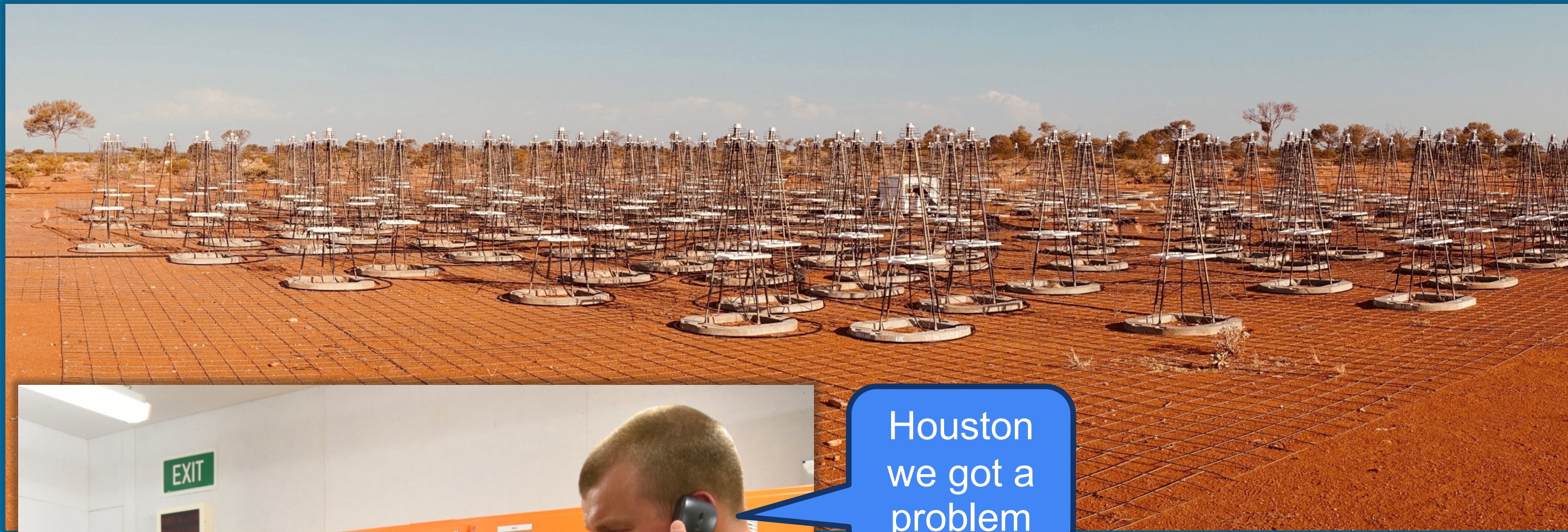
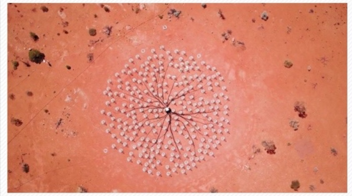
Aperture Array Verification System 1



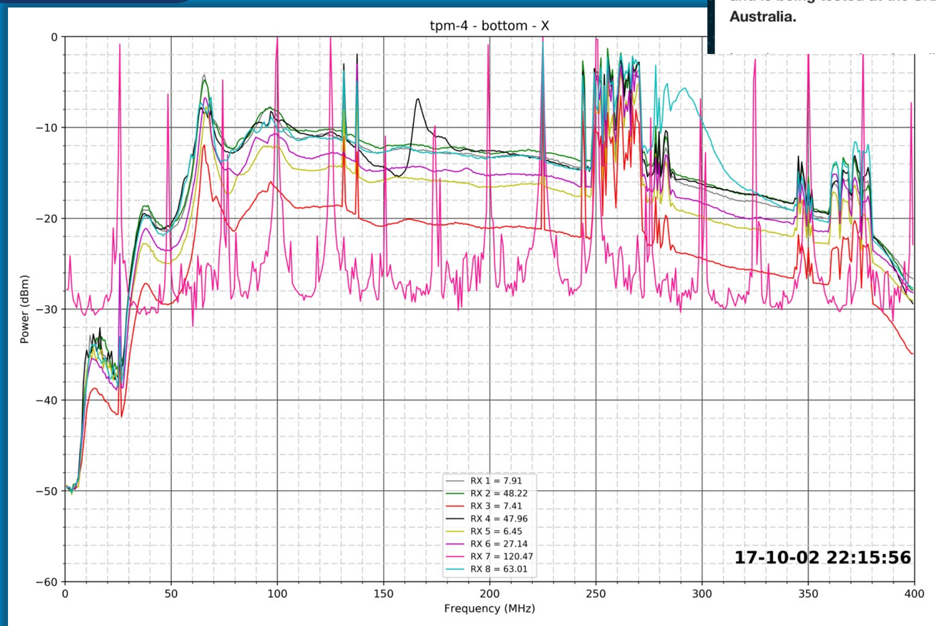


First SKA-Low Prototype Station Completed On Site

A full station of 256 antennas at CSIRO's Murchison Radio-astronomy Observatory in outback Western Australia. The demonstrator is used to help test and finalise the design of the low frequency antennas for the SKA. Credit: ICRAR/Curtin University

Perth, Western Australia, Thursday 24 May – A complete prototype station of antennas for the future SKA-low telescope has been completed and is being tested at the SKA site in Western Australia.

Houston we got a problem



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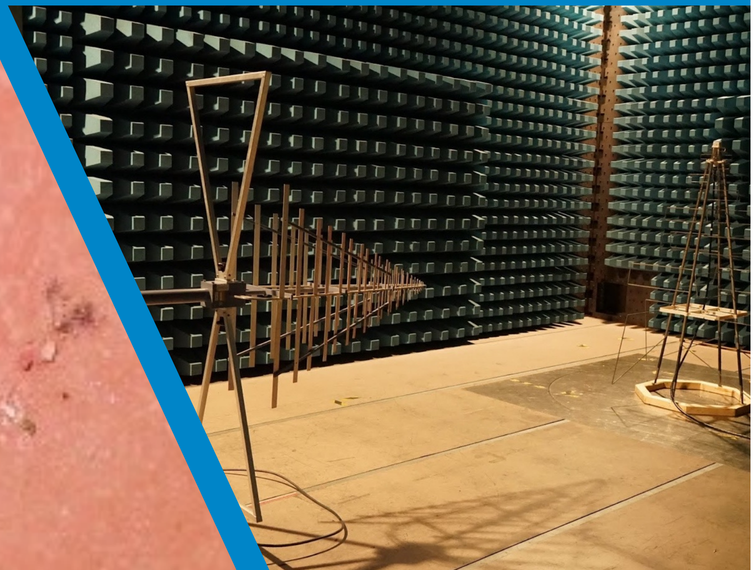

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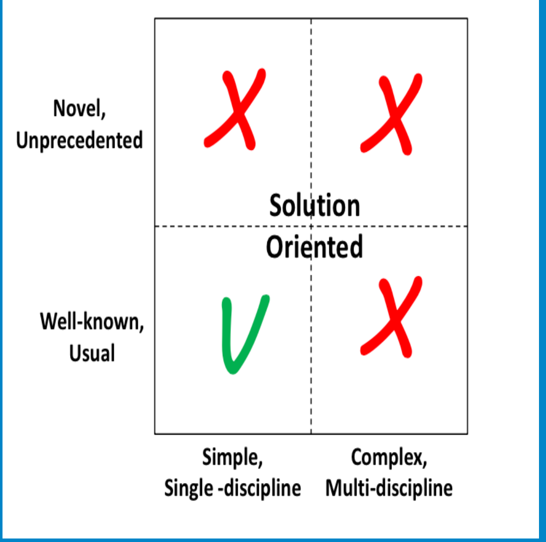
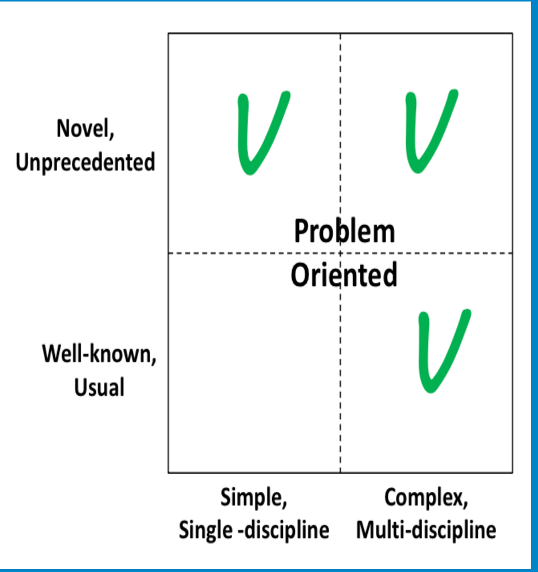
No vision about the integrated system

...design approach

Solution-oriented approach: an ***initial solution*** is proposed, analysed and then ***repeatedly modified*** as the design space and requirements are explored together.



Problem-oriented approach: the emphasis is placed upon ***abstraction*** and ***thorough analysis of the problem*** structure ***before*** generating a ***range of possible solutions***.



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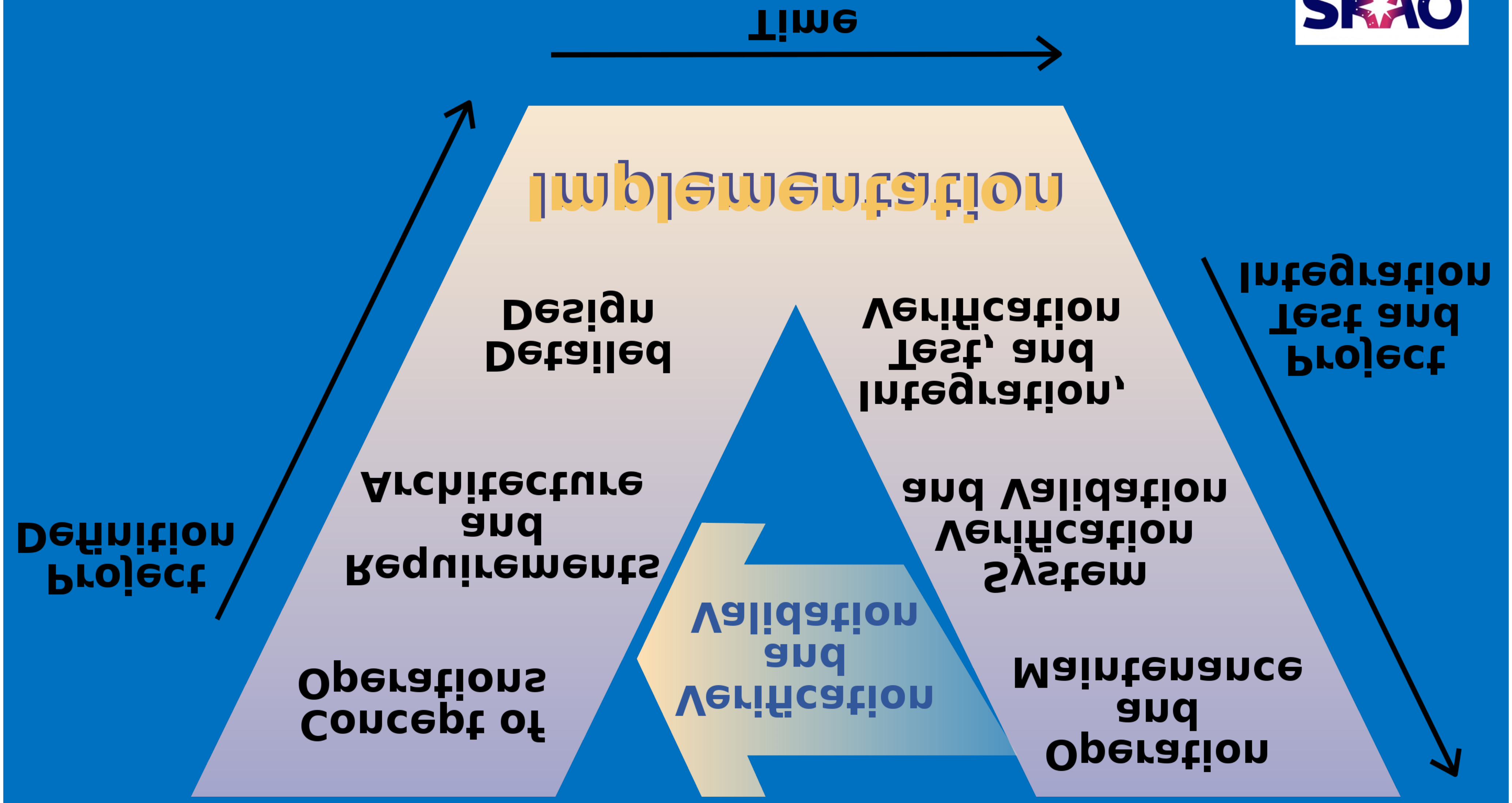

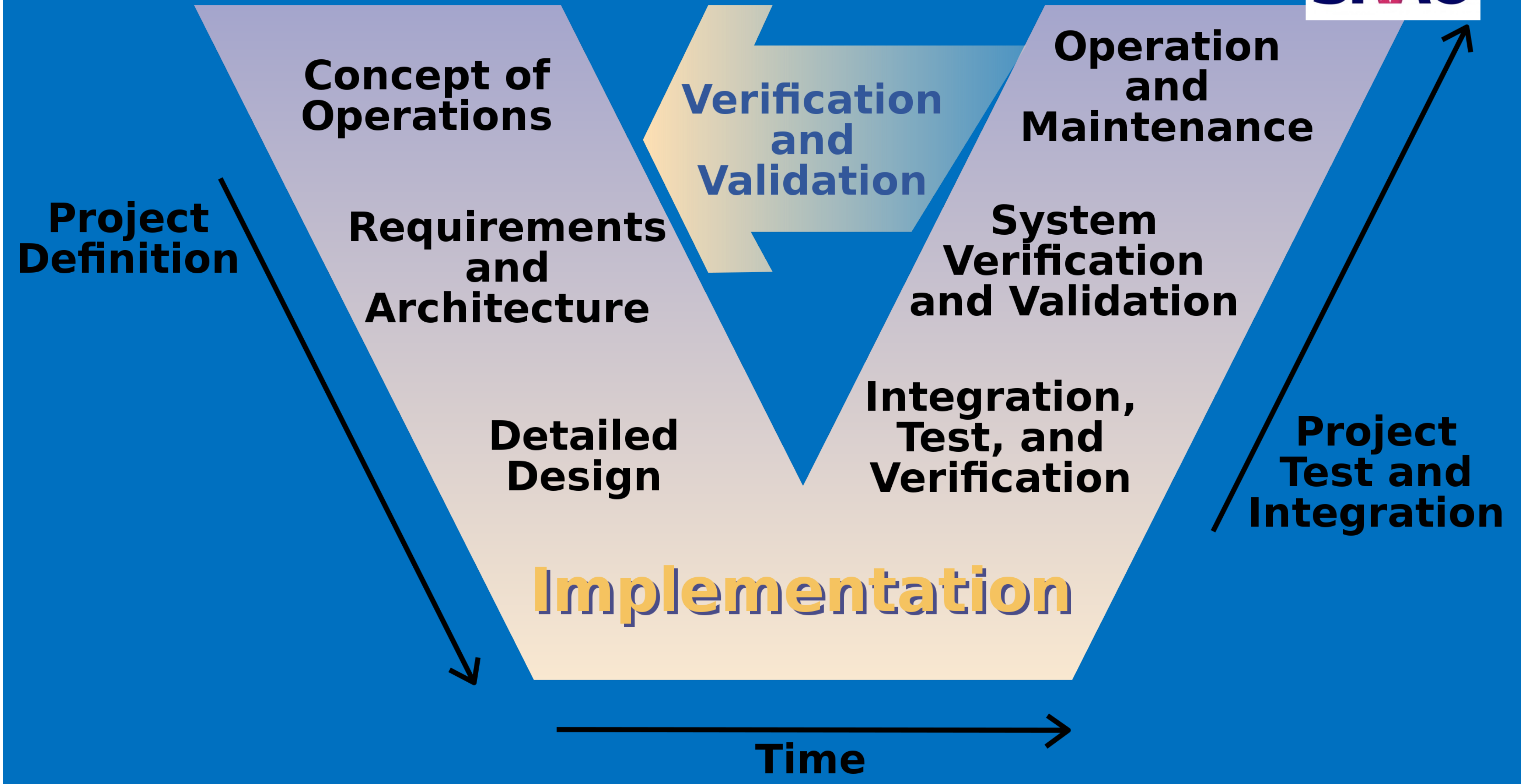
Concept of Operations
Requirements and Architecture
Detailed Design
Verification and Validation
Operation and Maintenance
System Verification and Validation
Integration, Test, and Verification
Implementation
Project Definition
Project Test and Integration
Time

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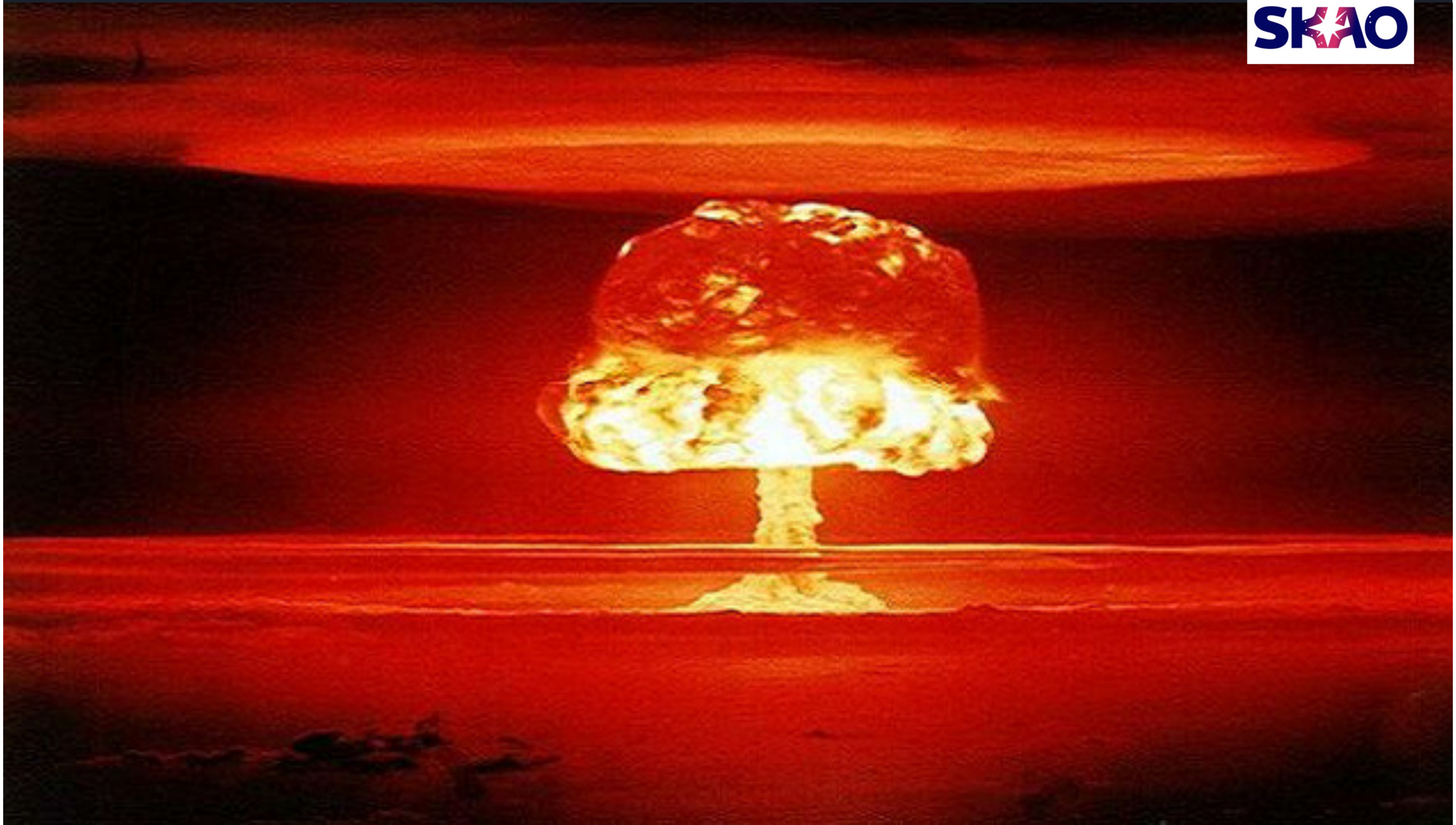


CRISIS
OPPORTUNITY

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SKALA4.1AL Antenna

IEEE Open Journal of
Antennas and Propagation

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Test-Driven Design of an Active Dual-Polarized Log-Periodic Antenna for the Square Kilometre Array

PIETRO BOLLI[1], LORENZO MEZZADRELLI[2], JADER MONARI[3], FEDERICO PERINI[3], ALBERTO TIBALDI[4,5] (Member, IEEE), GIUSEPPE VIRONE[5] (Member, IEEE), MIRKO BERCIGLI[6], LORENZO CIORBA[4,5], PAOLA DI NINNI[1], MARIA GRAZIA LABATE[7], VITTORIO GIUSEPPE LOI[2], ANDREA MATTANA[3], FABIO PAONESSA[5] (Member, IEEE), SIMONE RUSTICELLI[3], AND MARCO SCHIAFFINO[3]

[1]Astrophysical Observatory of Florence, INAF, 50125 Florence, Italy

[2]Department of Research and Development, Sirio Antenne, 46049 Volta Mantovana, Italy

[3]Institute of Radioastronomy, INAF, 40129 Bologna, Italy

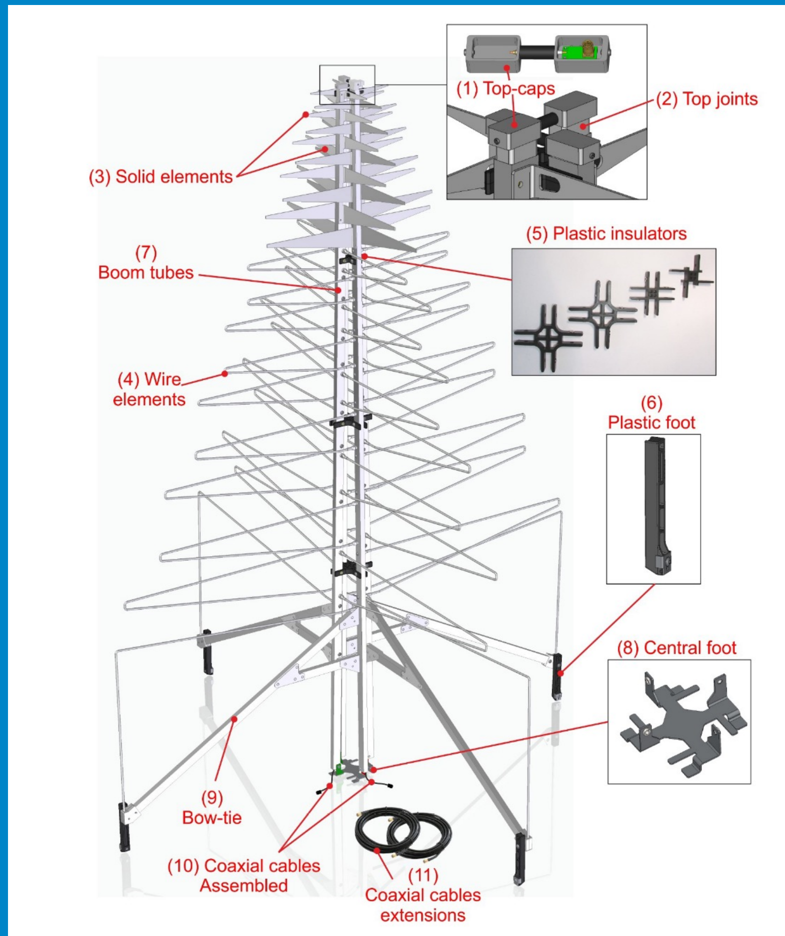
[4]Department of Electronics and Telecommunications, Politecnico di Torino, 10129 Turin, Italy

[5]Institute of Electronics, Computer and Telecommunication Engineering, CNR, 10129 Turin, Italy

[6]Department of Computational Electromagnetic Engineering, Ingegneria dei Sistemi, 56121 Pisa, Italy

[7]Department of Project Engineering, Square Kilometre Array Organization, Lower Withington SK11 9FT, U.K.

CORRESPONDING AUTHOR: P. BOLLI (e-mail: pbolli@arcetri.inaf.it)



- Dual-polarized LPDA.
- 20 dipoles: 19 triangular-tooth plus 1 bow-tie at the bottom of the antenna.
- Solid dipoles on the high-frequency elements and wire dipoles on the low-frequency ones.
- 1-degree tilted boom.
- Aluminium-made.
- Electrical connection of the antenna to the ground plane.
- Antenna matched to a single-ended 50-ohm LNA.
- LNA encapsulated in the top-cap of the antenna and connected to a coaxial cable embedded in the antenna booms.

The pre-EPA bridging project for SKA_low

Steven Tingay (Curtin University), Jader Monari (INAF), Ant Schinckel (CSIRO), André van Es (SKAO), and Luca Stringhetti (SKAO).

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SKA
SQUARE KILOMETRE ARRAY

SKA Organisation
Jodrell Bank Observatory
Lower Withington
Macclesfield
Cheshire, SK11 9DL
United Kingdom

October 16th, 2018

Dear Steven,

We wanted to document that the SKAO enthusiastically endorses the proposal "The pre-EPA Bridging Project for SKA LOW" with authors: Steven Tingay (Curtin University), Jader Monari (INAF), Ant Schinckel (CSIRO), Andre van Es and Luca Stringhetti (SKAO).

SKAO welcomes the initiative to establish a reference design compliant Low station architecture for addressing the major risk of calibration for the Low telescope and as a platform for further risk mitigation. The outlined work directly addresses the vital bridging task for "LOW Station Calibration Risk", providing a detailed path to resolution. Although bridging tasks are normally begun only following a successful CDR, the LFAA CDR will take place with an existing uncertainty in this design area which must be addressed rapidly for incorporation into the system level design. The very rapid start up and execution of the relevant tasks is essential to understand and resolve these issues on the timeline required for the design adoption process. We will be working directly with all of the participating institutes to complete the activity and this will be formally included into the bridging SOWs as appropriate. After addressing the highest risks, the platform will be made available for further testing of alternative compliant technologies for SKA-Low; these initiatives can be submitted to and approved by the management team for this bridging activity.

Thanks for the initiative and drive from all involved.

Best Regards,

J P McMullin

SKA Programme Director
SKA Organisation
United Kingdom
Tel: +44 161 306 9600
Mob: + 44 7384 219024

SKA Organisation
tel: +44 (0)161 306 9600
Registered in England & Wales, Company number 07881918
www.skatelescope.org

Bridging phases - preconstruction epoch

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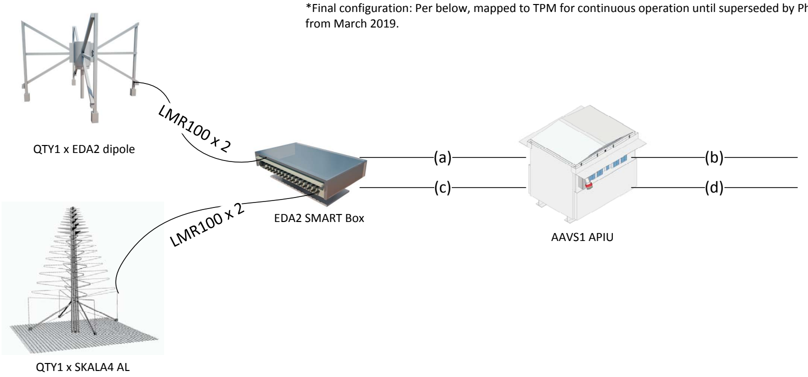
Instrument: Phase 0
Target Date: November 2018

* To be deployed week commencing 26 November 2019

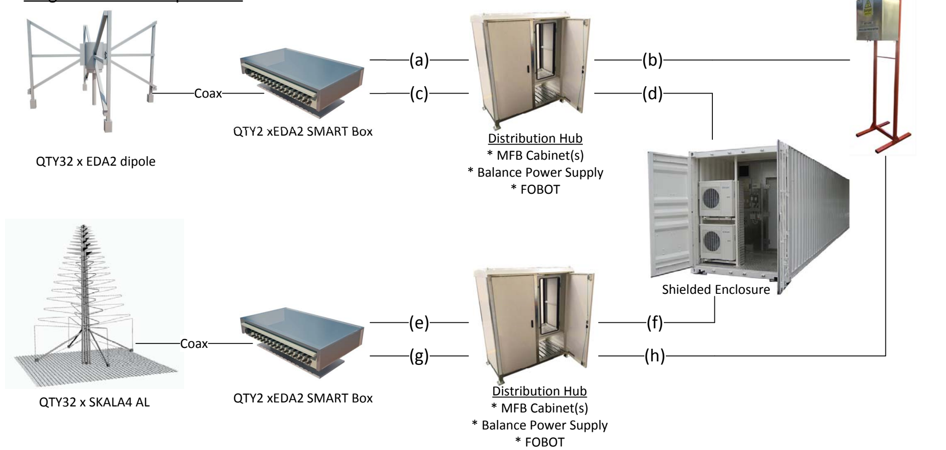
* Preliminary activity: 24-hour scan with single pol from both antennas, via coax (ex. SMART), to two spectrum analysers housed inside the APIU. Require two identical SpecAn (Agilent N9344C?).

*Final configuration: Per below, mapped to TPM for continuous operation until superseded by Phase-1 from March 2019.



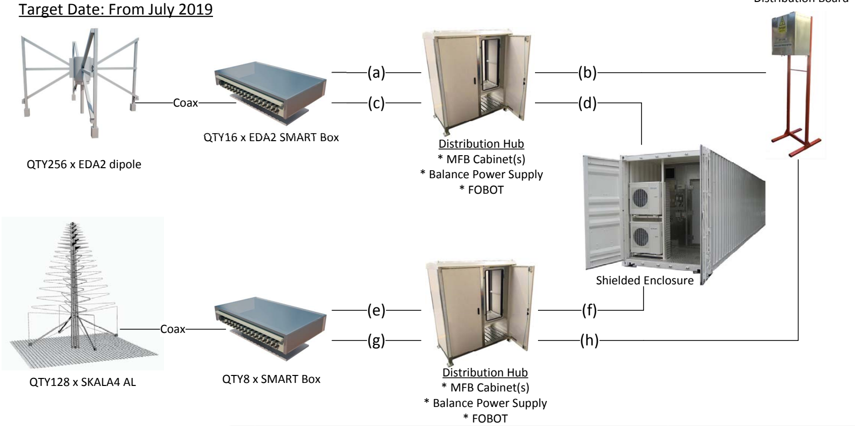
ID	Element	Proposed
(a)	Fibre optic cable	Use cable procured for EDA2
(b)	Fibre optic cable	Existing AAVS cable 192-core
(c)	Power cable	Procure specific for purpose cable (XT30 on APIU end)
(d)	Power cable	Existing AAVS supply cable

Instrument: Phase 1
Target Date: from April 2019



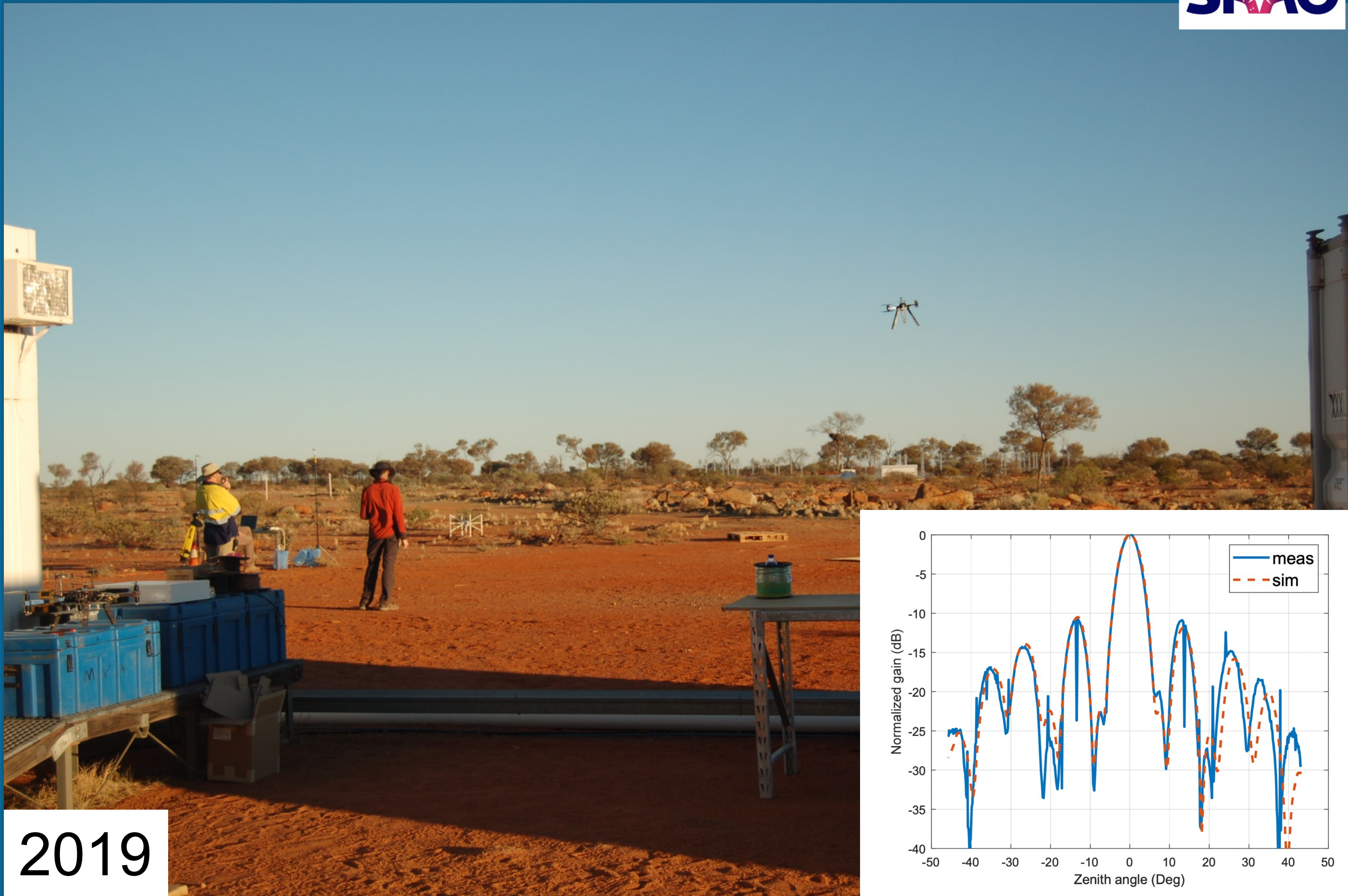
ID	Element	Proposed
(a)	Power: 48V from array power supply in Distribution Hub to SMART box(es)	EDA2 spec – ordered (Balance)
(b)	Power: 230V from site distribution board to array power supply in Distribution Hub	Existing from AAVS inventory
(c)	Fibre: 20-core (?) jacketed F/O cable from SMART box to FOBOT in Distribution Hub	EDA2 spec – in hand
(d)	Fibre: ≥ 260-core jacketed F/O cable from Distribution Hub to Shielded Enclosure	To be spec'd – to be ordered
(e)	Fibre: 20-core (?) jacketed F/O cable from SMART box to FOBOT in Distribution Hub	EDA2 spec – to be ordered
(f)	Fibre: ≥ 260-core jacketed F/O cable from Distribution Hub to Shielded Enclosure	To be spec'd – to be ordered
(g)	Power: 48V from array power supply in MFB cabinet to SMART box(es)	EDA2 spec – to be ordered (Balance)
(h)	Power: 230V from site distribution board to array power supply in MFB cabinet	Existing from AAVS inventory

Instrument: Phase 2
Target Date: From July 2019



ID	Element	Proposed
(a)	Power: 48V from array power supply in Distribution Hub to SMART box(es)	EDA2 spec – ordered (Balance)
(b)	Power: 230V from site distribution board to array power supply in Distribution Hub	Existing from AAVS inventory
(c)	Fibre: 20-core (?) jacketed F/O cable from SMART box to FOBOT in Distribution Hub	EDA2 spec – in hand
(d)	Fibre: ≥ 260-core jacketed F/O cable from Distribution Hub to Shielded Enclosure	To be spec'd – to be ordered
(e)	Fibre: 20-core (?) jacketed F/O cable from SMART box to FOBOT in Distribution Hub	EDA2 spec – to be ordered
(f)	Fibre: ≥ 260-core jacketed F/O cable from Distribution Hub to Shielded Enclosure	To be spec'd – to be ordered
(g)	Power: 48V from array power supply in MFB cabinet to SMART box(es)	EDA2 spec – to be ordered (Balance)
(h)	Power: 230V from site distribution board to array power supply in MFB cabinet	Existing from AAVS inventory

UAV mission- AAVS1.5



2019

EDA2 and AAVS2

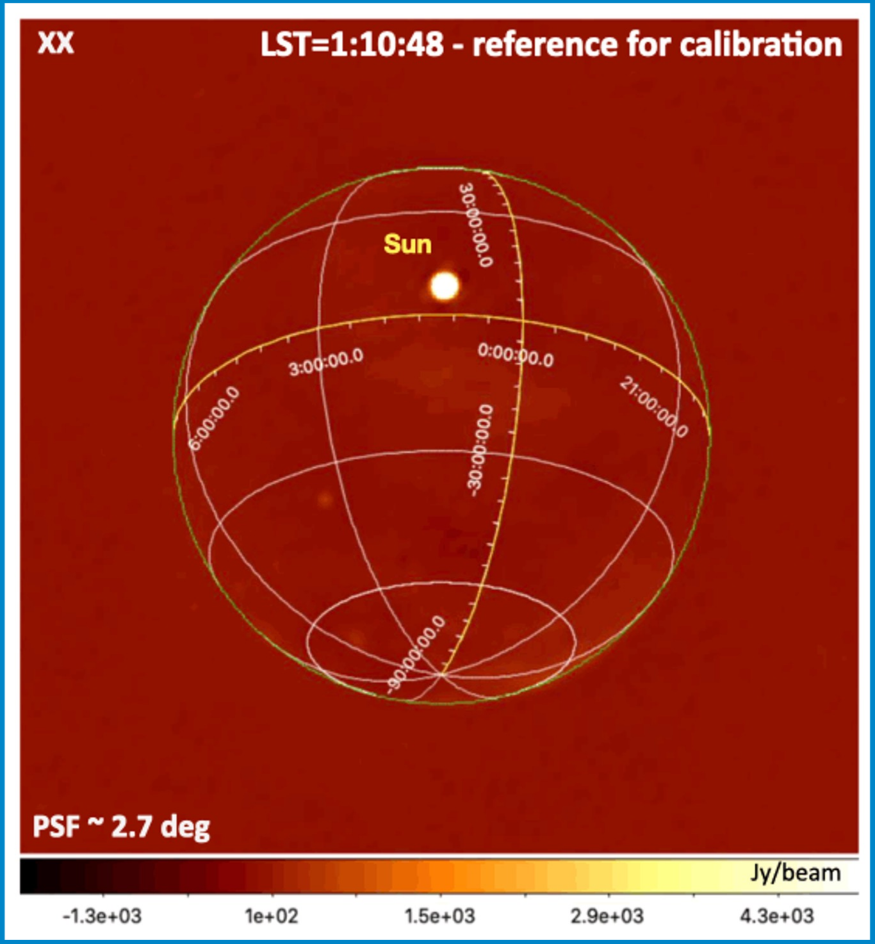
2 demonstrators built at MRO site to verify SKA1-low system before construction

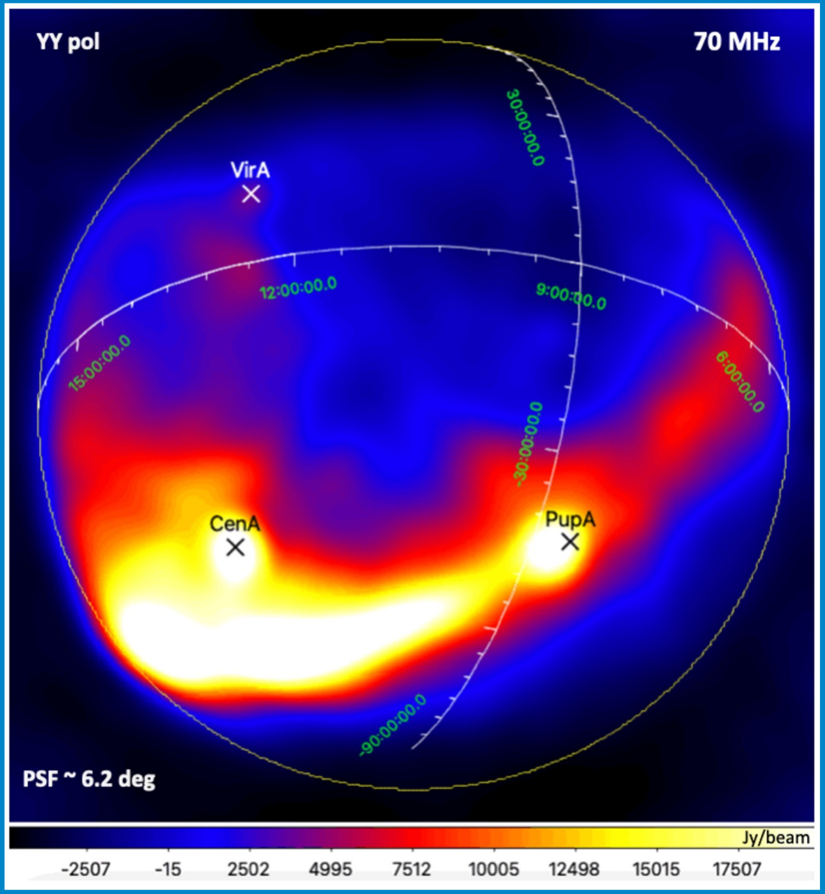
EDA2 (2019)
256 **MWA dipoles**
LNA modified for
50-350 MHz
35 m diameter

AAVS2 (end of 2019)
256 **SKALA 4.1** log-periodic
LNA optimized for
full **50-350 MHz**
38 m diameter

Aerial view of EDA2 and AAVS2 - Credits: Icrar/Curtin

AAVS2: first light





See Giulia Macario's talk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Receiver chain:
technology made in Italy

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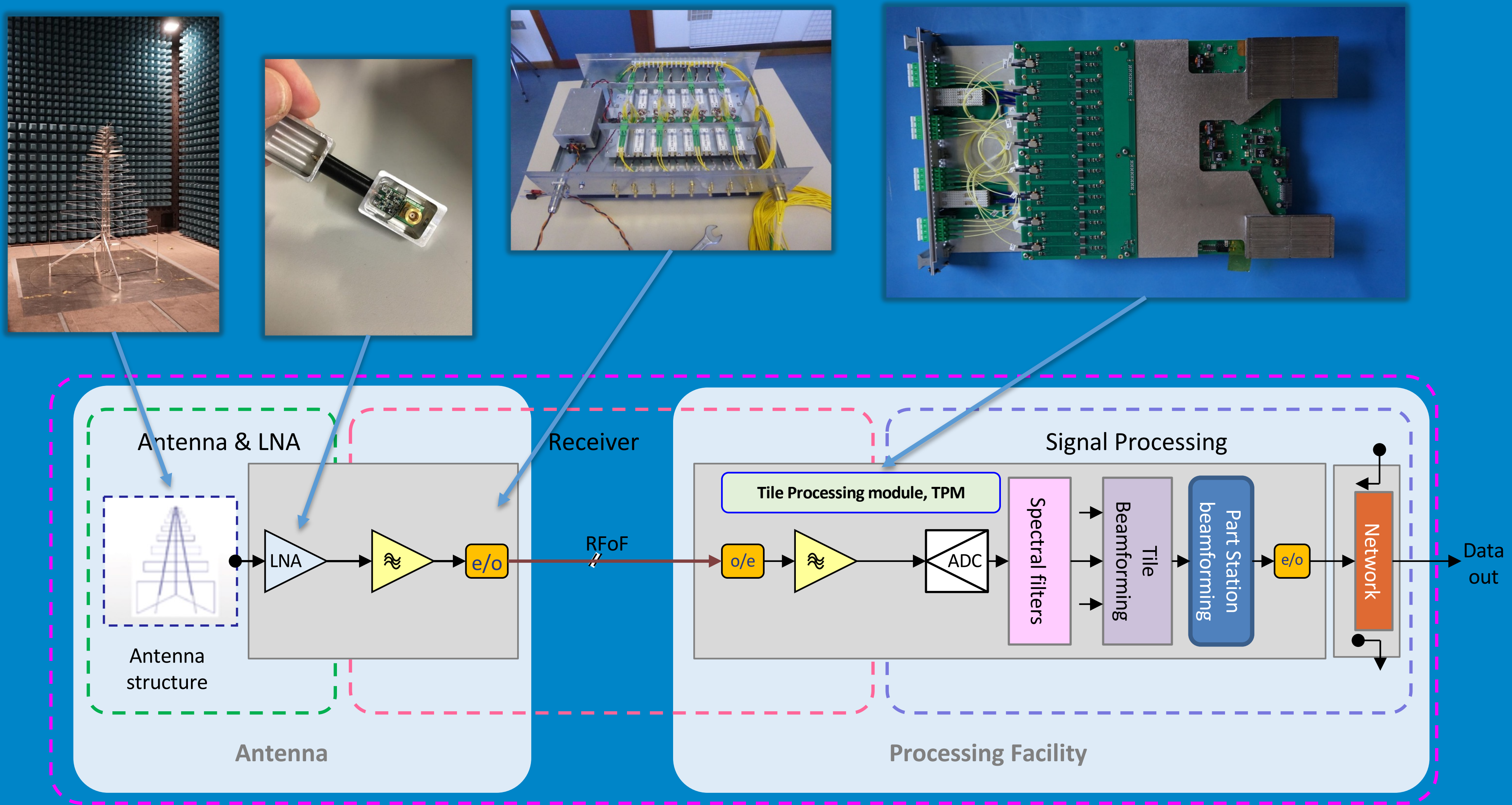

Industrial Contracts (2017-2023)

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OPTEL OPTOELETTRONICA TELECOMUNICAZIONI

MFC

PROTECH ENGINEERING

DIAMOND the fiber meeting

Sanitas EG DIGITAL SYSTEMS, RESEARCH AND INNOVATION

FINMECCANICA

CAMPERA electronic systems

SIRIO antenne

AAVID THERMAL DIVISION OF BOYD

Italdron

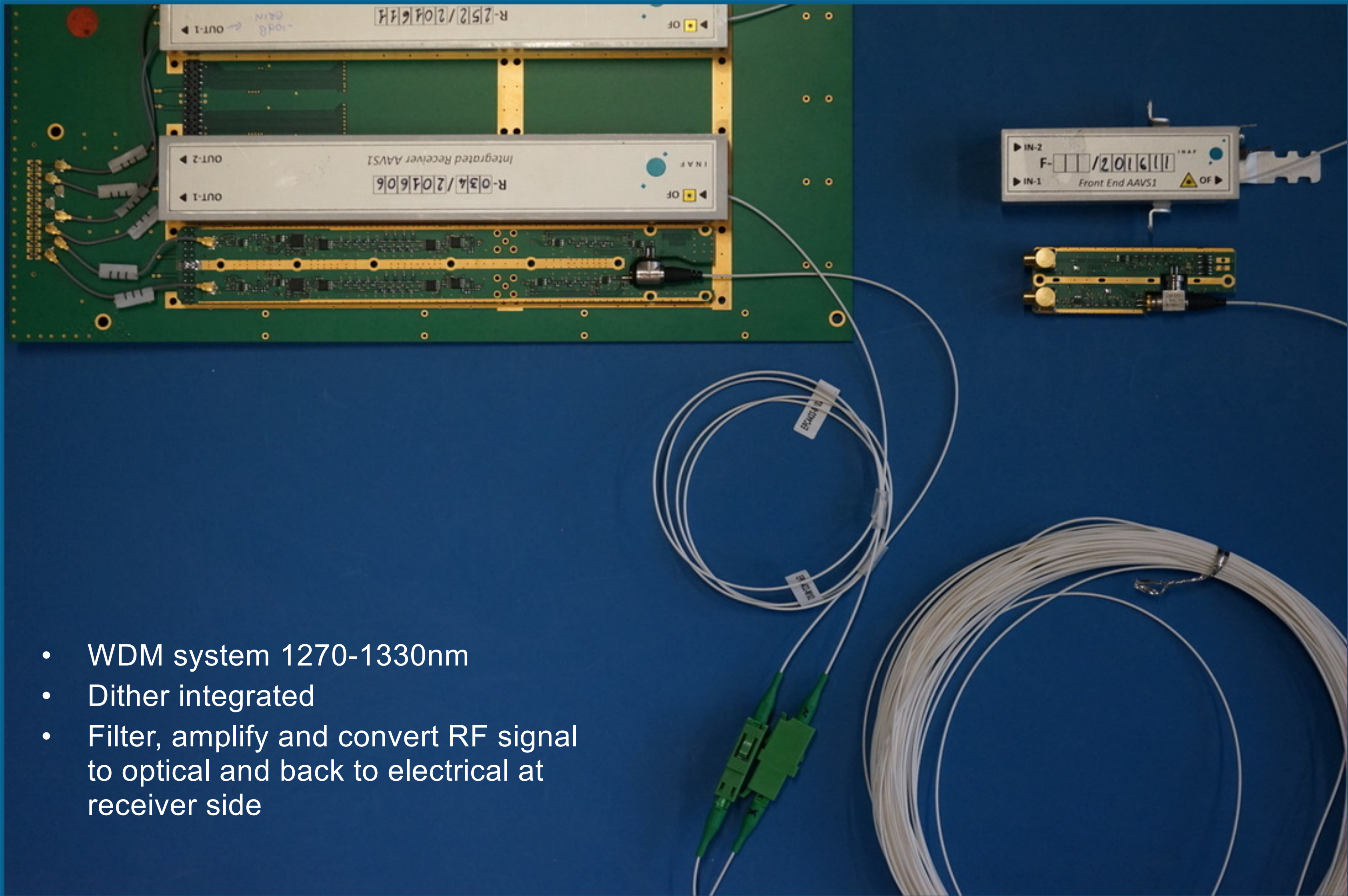
LighTech Fiber Optics Components and Accessories

RGM PARTNER OF LEADERS

IDS INGEGNERIA DEI SISTEMI

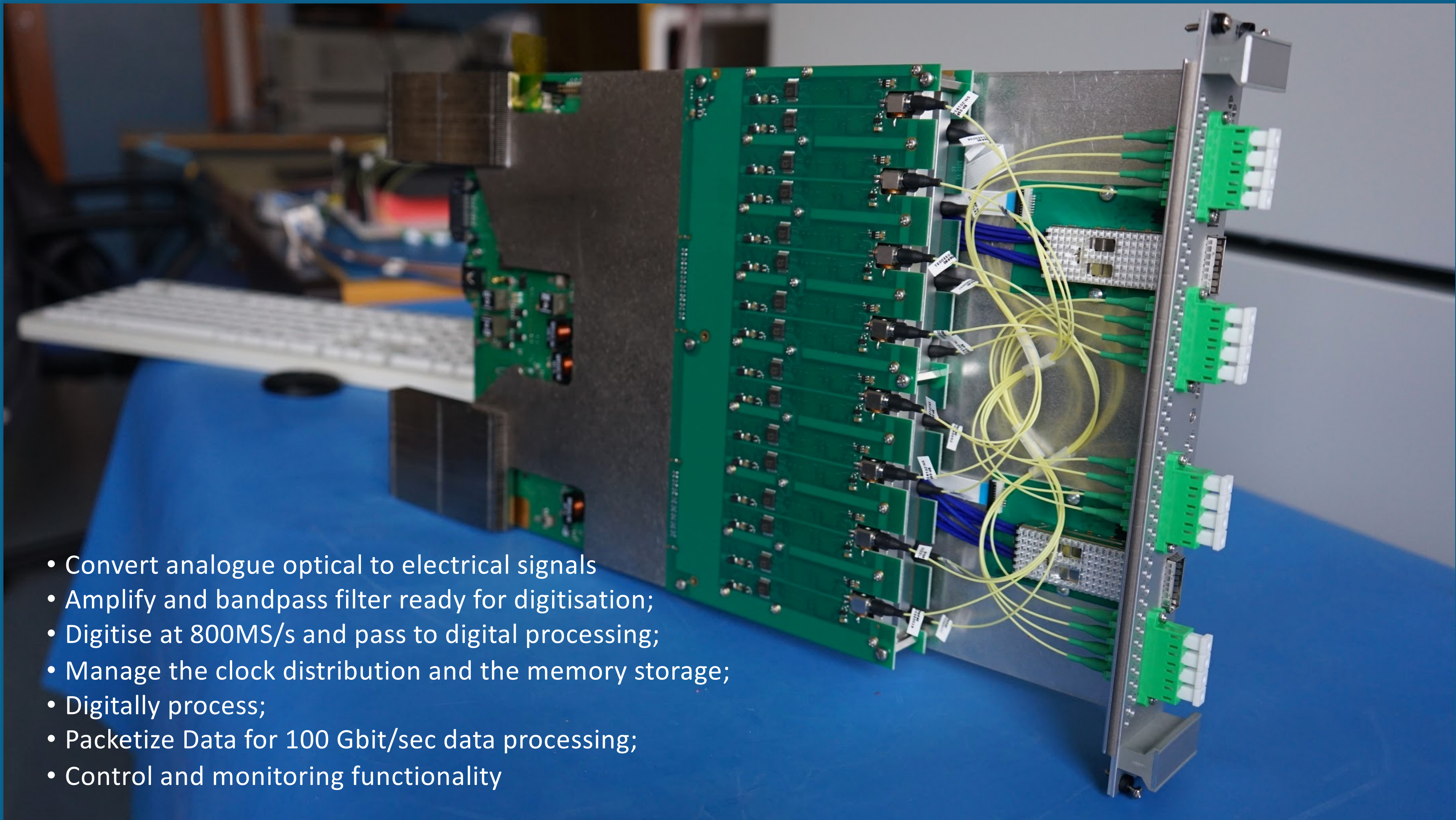
ELEMASTER

Analogue RFoF link



- WDM system 1270-1330nm
- Dither integrated
- Filter, amplify and convert RF signal to optical and back to electrical at receiver side

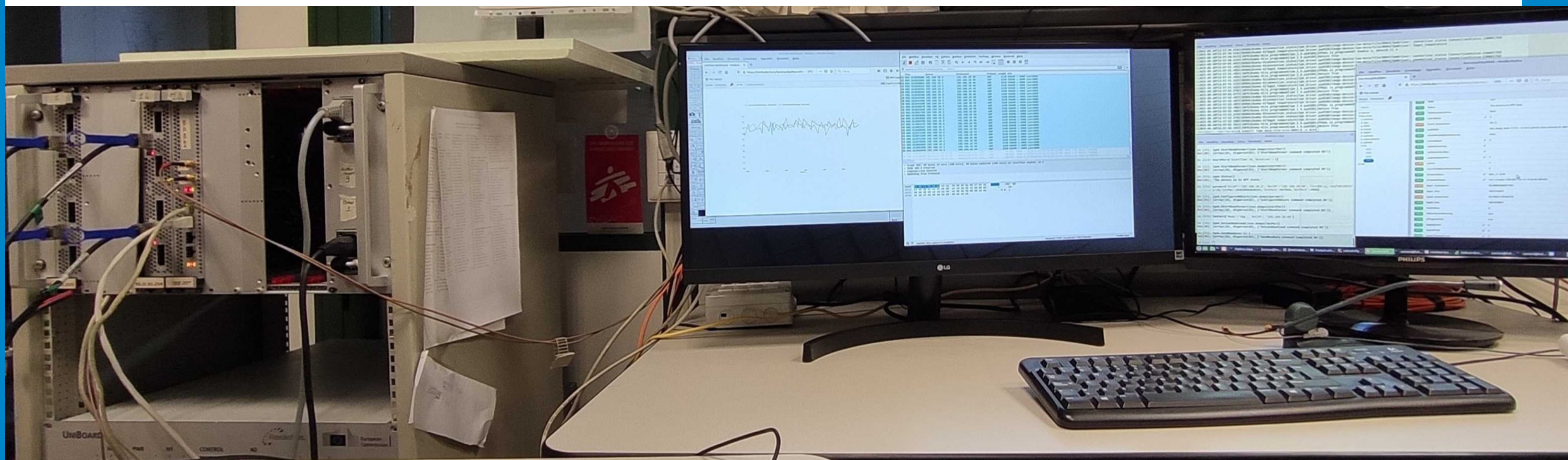
Tile Processing Module



- Convert analogue optical to electrical signals
- Amplify and bandpass filter ready for digitisation;
- Digitise at 800MS/s and pass to digital processing;
- Manage the clock distribution and the memory storage;
- Digitally process;
- Packetize Data for 100 Gbit/sec data processing;
- Control and monitoring functionality

Firmware

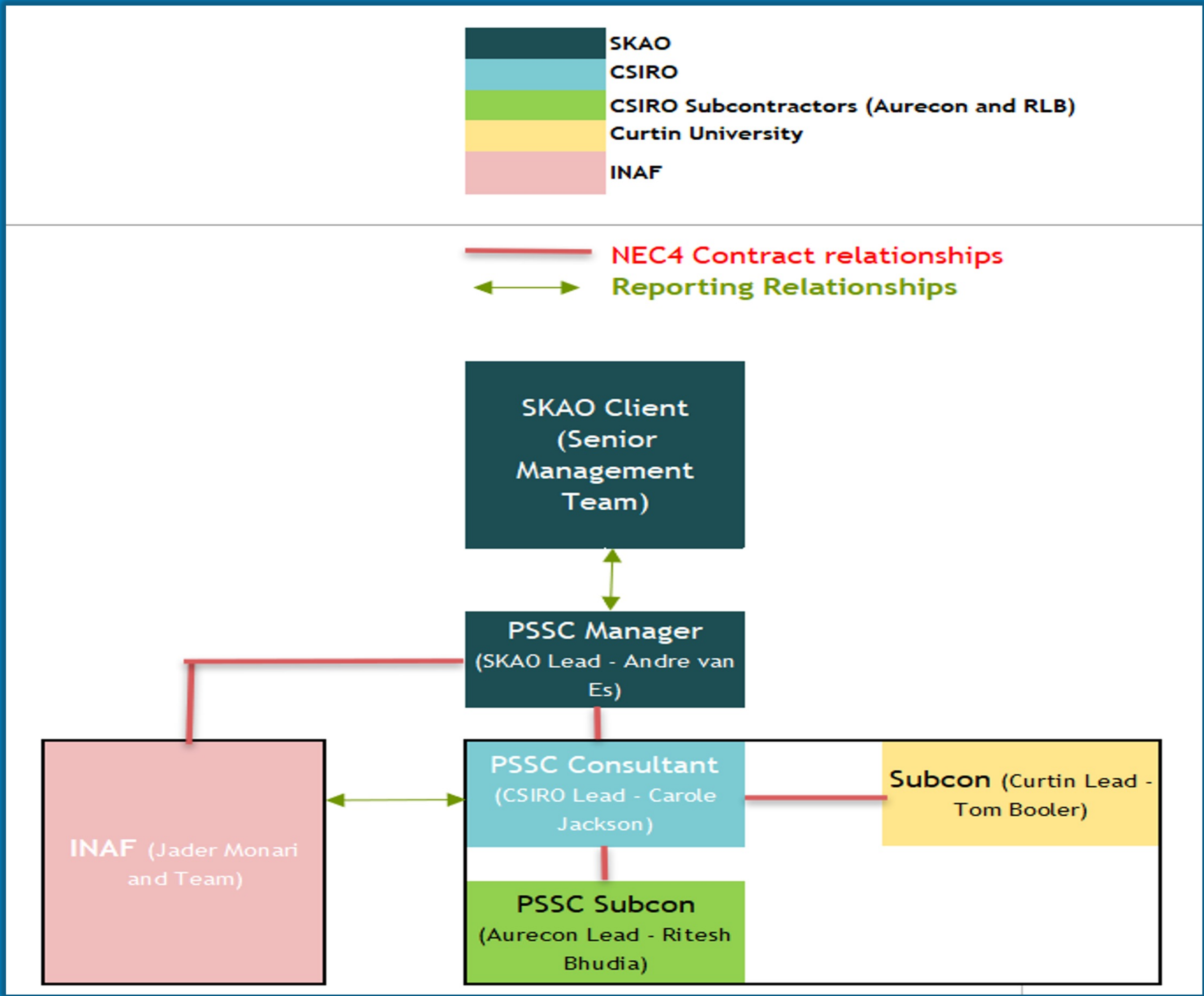
- LFAA firmware used in the iTPM board to
  - Channelize, calibrate and align antenna signals
  - Combine 256 antennas in up to 48 beams
  - Format and transmit beamformed signals to correlator
  - Format and transmit selected signals to calibration server
- Prototype firmware used in AAVS array
- Significant work required for industrial grade final system
- People: 3 persons (1 FTE) INAF, 4 persons (3 FTE) UK



Software

- Low level control software
  - Hardware drivers: developed together with firmware blocks
  - General standalone software, used at AAVS array
  - Control of cabinet and subrack electronics (power management, temperature, cooling)
- Integration of hardware in SKA Low LMC
  - Device software in the Tango Control environment
  - Hardware related problems: antenna pointing, beam management, obsrvation management, calibration strategies
  - Interface with other systems (correlator, telescope manager)
  - Network design and management (SKA as a network defined instrument)

Where do we are today?



INAF - SKAlow team today

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AL Specialists (Pietro Bolli, Paola di Ninni, CNR-IEIIT)

SPS Specialists (Gianni Comoretto, Andrea Mattana, Federico Perini)

RX Analogue Chain (Federico Perini, Federica Caputo, UNIBO)

R&D ACTIVITY and PRODUCTION FOLLOW UP

FW/SW developers Specialists (Gianni Comoretto, Simone Chiarucci, Carlo Baffa)

FW-SW

Station deployment / Integration / Debug

Federico Perini, Andrea Mattana, Marco Schiaffino

Station verification

Giulia Macario, Giuseppe Pupillo, Gianni Bernardi, CNR-IEIIT

Management IT team

Jader Monari, Carolina Belli, Letizia Caito

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Summary of the efforts spent

	FTE	FTE partner	Total FTE	Industry	Development	Travel	Total per year
2012-2013	7,64	1,38	9,02	- €	185.000 €	20.000 €	800.000 €
2013-2014	7,91	1,42	9,33	100.000 €	256.000 €	20.000 €	992.000 €
2014-2015	8,00	1,48	9,48	- €	165.000 €	49.800 €	840.800 €
2015-2016	9,91	1,33	11,24	589.300 €	212.200 €	41.000 €	1.584.500 €
2016-2017	11,64	1,30	12,94	227.000 €	153.000 €	50.000 €	1.284.000 €
2017-2018	11,64	1,30	12,94	188.000 €	61.000 €	60.400 €	1.163.400 €
2018-2019 (P2 ext)	11,18	1,59	12,77	198.000 €	56.000 €	60.400 €	1.157.400 €
2019-2020 (low B)	11,27	1,52	12,79	937.000 €	95.200 €	100.000 €	1.976.200 €
2020-2021	10,19	1,15	11,34	626.000 €	79.000 €	- €	1.453.660 €
2021-2022	9,29	1,15	10,44	55.000 €	61.000 €	150.000 €	955.200 €
TOTAL	98,66	13,64	112,30	2.920.300 €	1.323.400 €	551.600 €	**12.207.160 €**

Contratto In-Kind 1 (2021)	≃1.000.000
Contratto Extra In-Kind 2 (2023)	≃1.380.000
Contratto Cash*	700K€x3≃2.100.000
Totale	≃**4.400.000€**
Industrial Geo return – Allocated- - Real	**67.000.000€** **80 / 90.000.000€**

* Spese dirette future non sono calcolate in quanto fatturate a SKAO
** Nelle spese «development» sono incluse costi di strumentazione per laboratori INAF
*** Spese del personale in termini FTE, non sono calcolati nel computo complessivo (flat rate di 66K€xFTE)

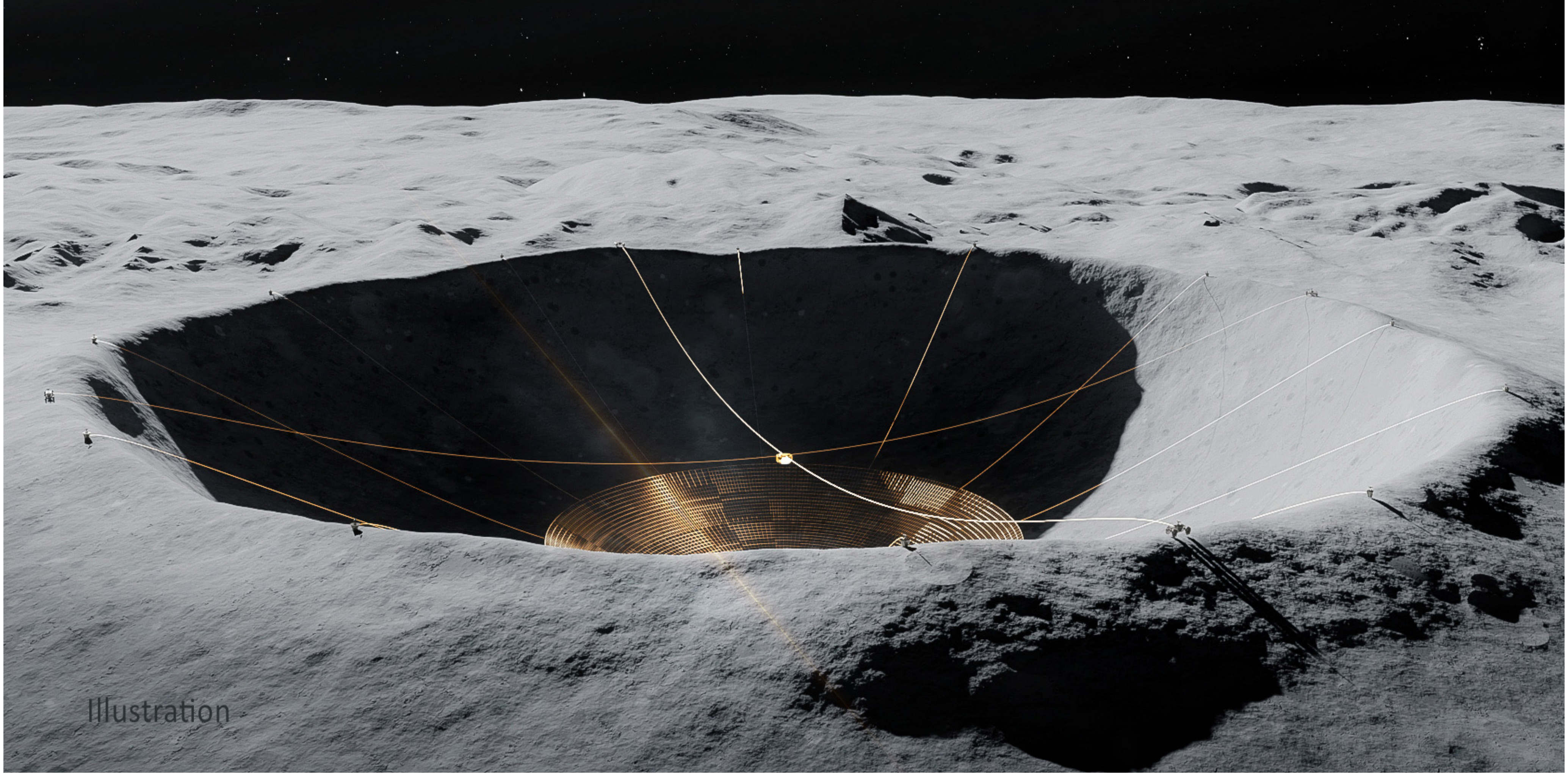
…. INAF and the future …

cit. Yoda <<Difficult to see. Always in motion is the future.>>

- **Increase resources and efforts for the commissioning and early science phases.**
- **Finalize the technology/experience handover to SKAO and to Italian industries (now at 95%).**
- **Facilitate communication for the coordination of production between SKAO and Italian industrial companies.**
- **Continue support for the fine tuning of designs and ECP based on the feedback received from the first productions.**
- **Support the debugging and contribution to the "problem solving" process for any issues that may arise.**
- **At a prototype level, continue the development of some critical elements to improve efficiency in integration/installation, maintenance, reliability and where there are still margins, improve performances.**
- **Contribution to the development of a new generation of systems / subsystems in anticipation of a phase 2 after AA*.**

Conclusions

The experience and capabilities exploited by INAF researchers in the field of SKALow radio technologies is today recognized internationally thanks to the promotion and efforts and development of the last 20 year. This allows our young technological researchers to be able to enter even more challenging and ambitious projects with a layer of state-of-the-art knowledge.



Thank you team for the incredible job!

Grazie per l'attenzione

Jader Monari: jader.monari@inaf.it