SKACH

Square Kilometer Array Swiss project (SKACH)
2022-10-03 Instrumentation program overview
@Swiss SKA days Lugano

Hes·so
Haute Ecole Spécialisée de Suisse occidentale
Fachhochschule Westschweiz
University of Applied Sciences Western Switzerland

HEIG VD
SCHOOL OF ENGINEERING AND MANAGEMENT

Dominique Bovey

Instrumentation program overview

- Mid-band 6 Instrument specifications and science
- SKACH instrumentation project context
- Mid-band 5 instrument block diagrams
- Breadboarding??
- Work breakdown on the instrument
- Schedule
- Features of the various instrument models
- Project status
- Project management
- Industrial partnerships

SKA instrumentation program

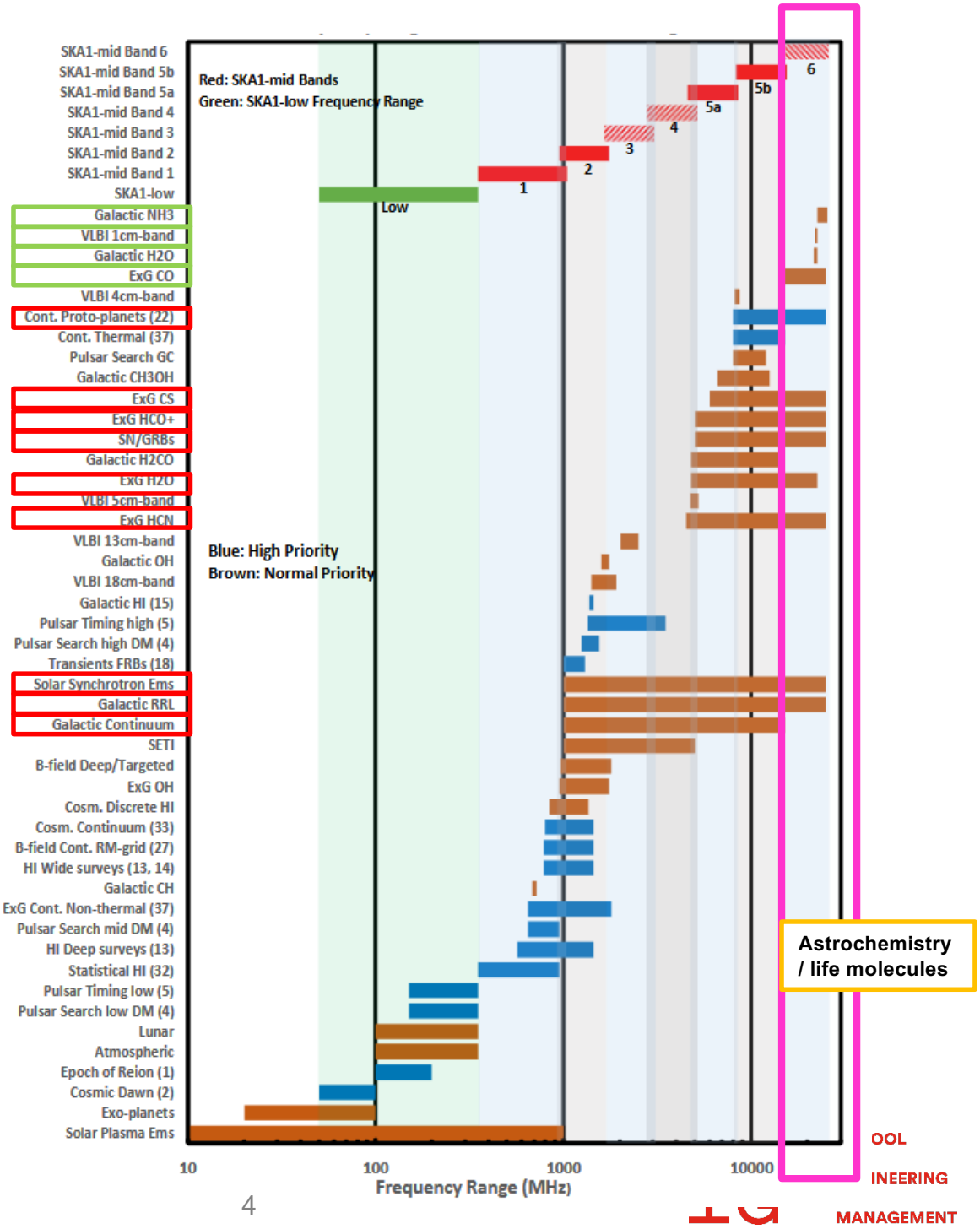
- **The instrument… a receiver <u>system</u>**
  - Feed to correlator interface
  - MID-band 6 (~15 to 24GHz)
  - Developed to be ultimately deployed on 200+ antennas
  - State of the art performance
  - Multi-Gigasample/s “digitizer”
  - Band6+ (>30GHz ultimately foreseen)
  - Cryogenic front-end
  - Not disturbing RA operation (EMC, noise)
  - And … ultimately multi-band: bands 3,4,5,6
  - Deployment sought on other RA projects (EVN…)
  - European technological collaboration
  - An Elegant Bread Board (EBB)
- **… anything else?**
  - To be determined…

Why MID-band 6? SKA science objectives

MID band 6+overlap with other band

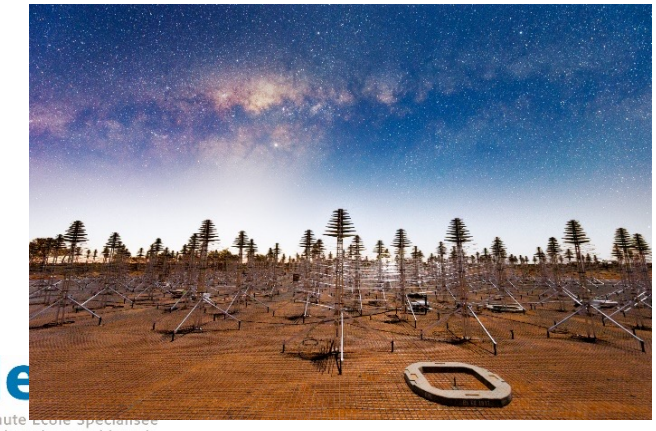
Entirely in MID band 6

Conclusion: a wider operation bandwidth capable receiver is a plus!



SKA observatory

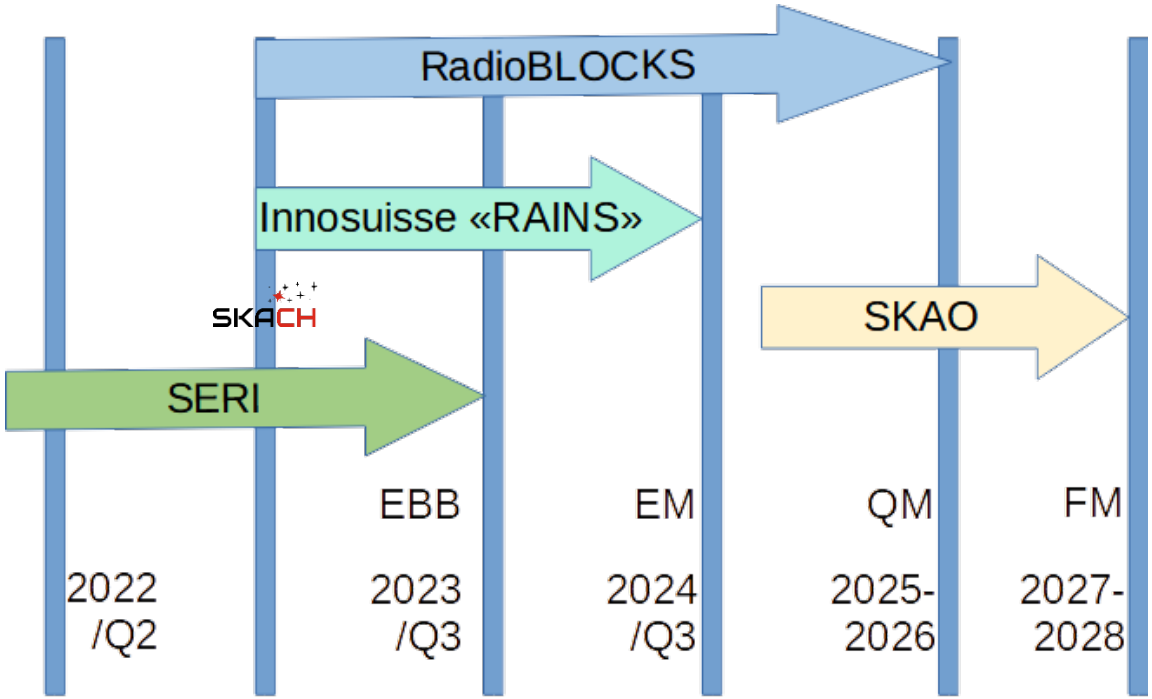
- **SKA-MID**
  - Karoo Desert, Republic of South Africa
  - Currently: 64 round dishes (“Meerkat”) in 20km zone (made in SA!)
  - Phase 1: +130 “Gregorian” dishes in 150km zone
  - Phase2: >2000 TBD dishes across 3500km (SA to Mauritius)
  - Only band 1 and 2 implemented on 64 Meerkat antennas in 2022
- **SKA-LOW**
  - Murchison desert, Western Australia
  - 50-350MHz



Band	Frequency Range	Bandwidth
Low	50 – 350 MHz	300 MHz
Mid Band 1	0.35 – 1.05 GHz	700 MHz
Mid Band 2	0.95 – 1.76 GHz	810 MHz
Mid Band 3	1.65 – 3.05 GHz	1.4 GHz
Mid Band 4	2.80 – 5.18 GHz	2.4 GHz
Mid Band 5a	4.6 – 8.5 GHz	3.9 GHz
Mid Band 5b	8.3 – 15.3 GHz	2 x 2.5 GHz
Mid band 6	15-25GHz	TBD

MB(6)RX financing

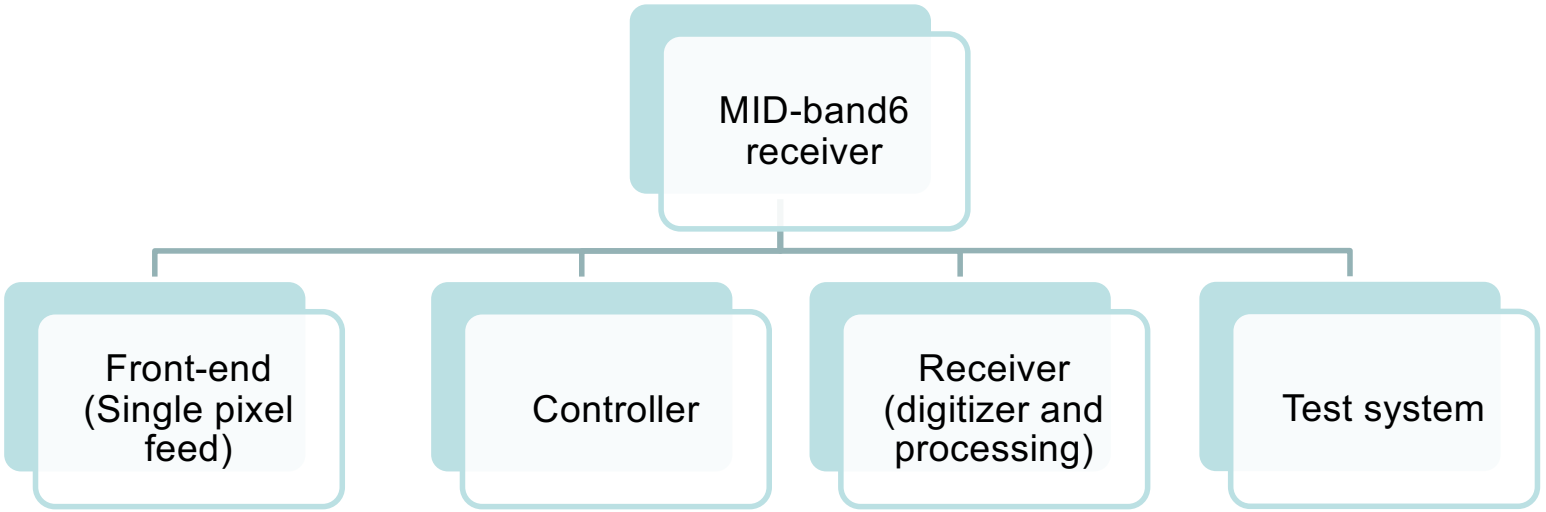
- Several sources of financing



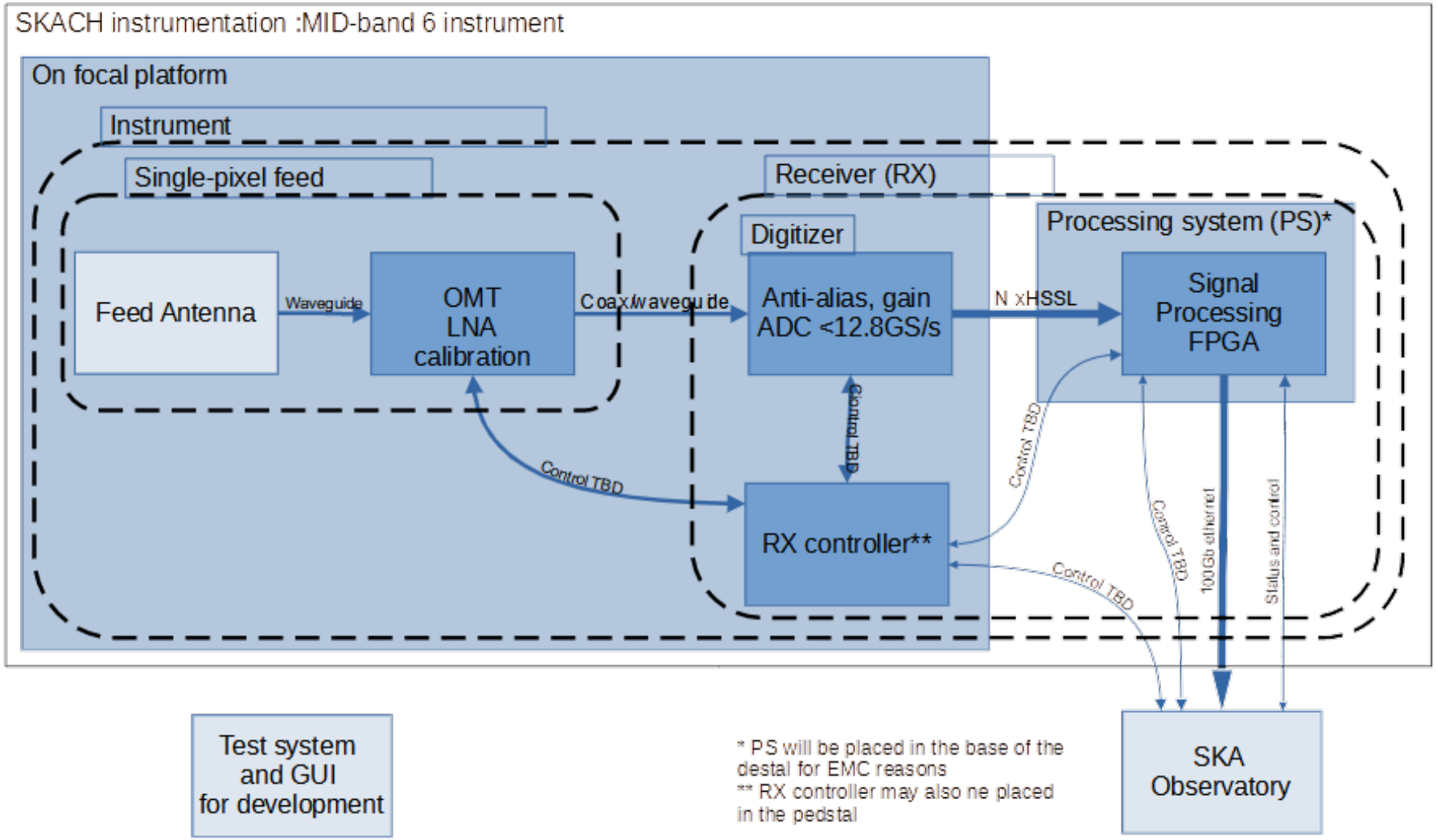
- SERI: CH “seed” funding, currently in use
- Innosuisse: co-financing requested by SERI
  - RA innovations in Switzerland: filtering, cryo, faster processing
  - Submission 2022-09
- EU RadioBLOCKS:
  - HES-SO is partner, awarded 2022-08
  - Adaptation of receiver to European VLBI Network (EVN)

MB6 receiver EBB top-level product tree

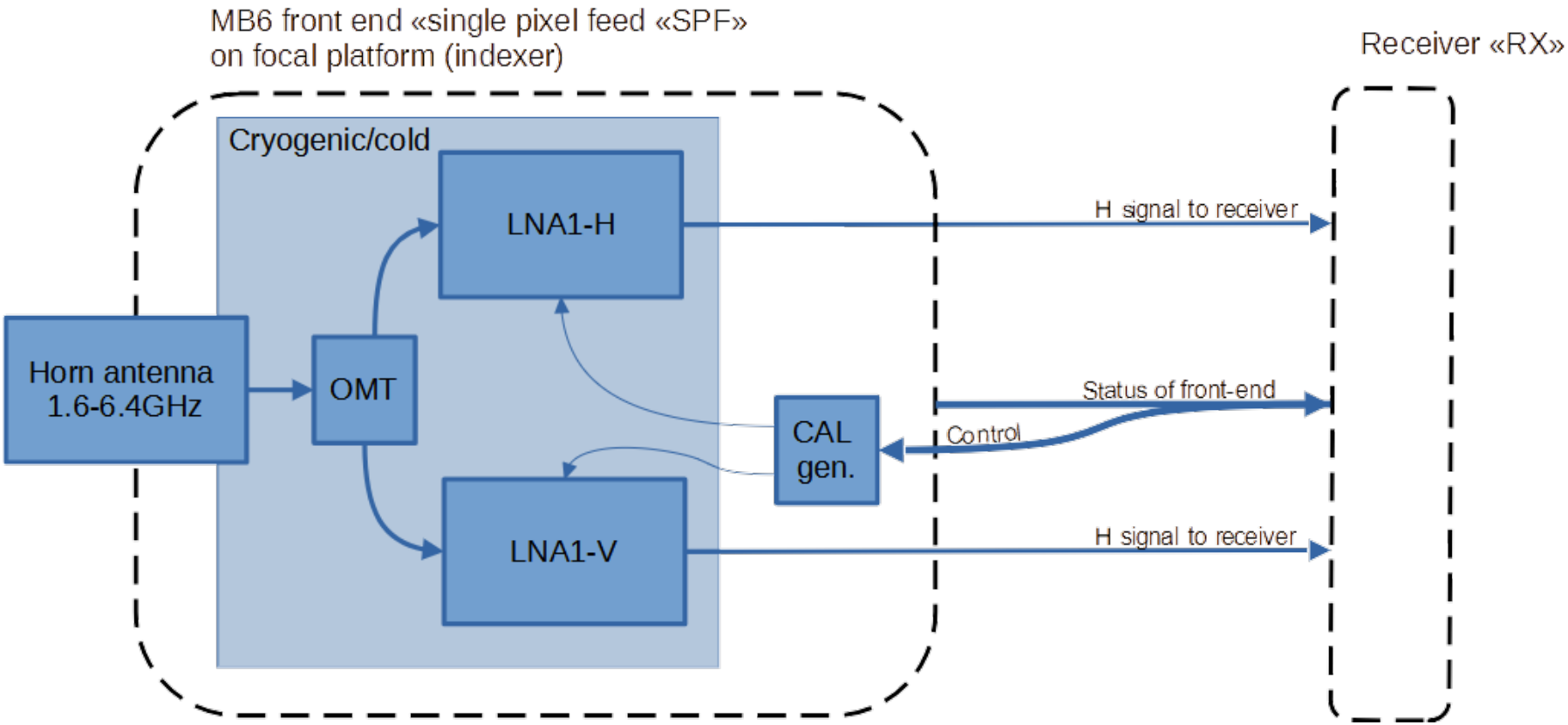
EBB: Elegant BreadBoard



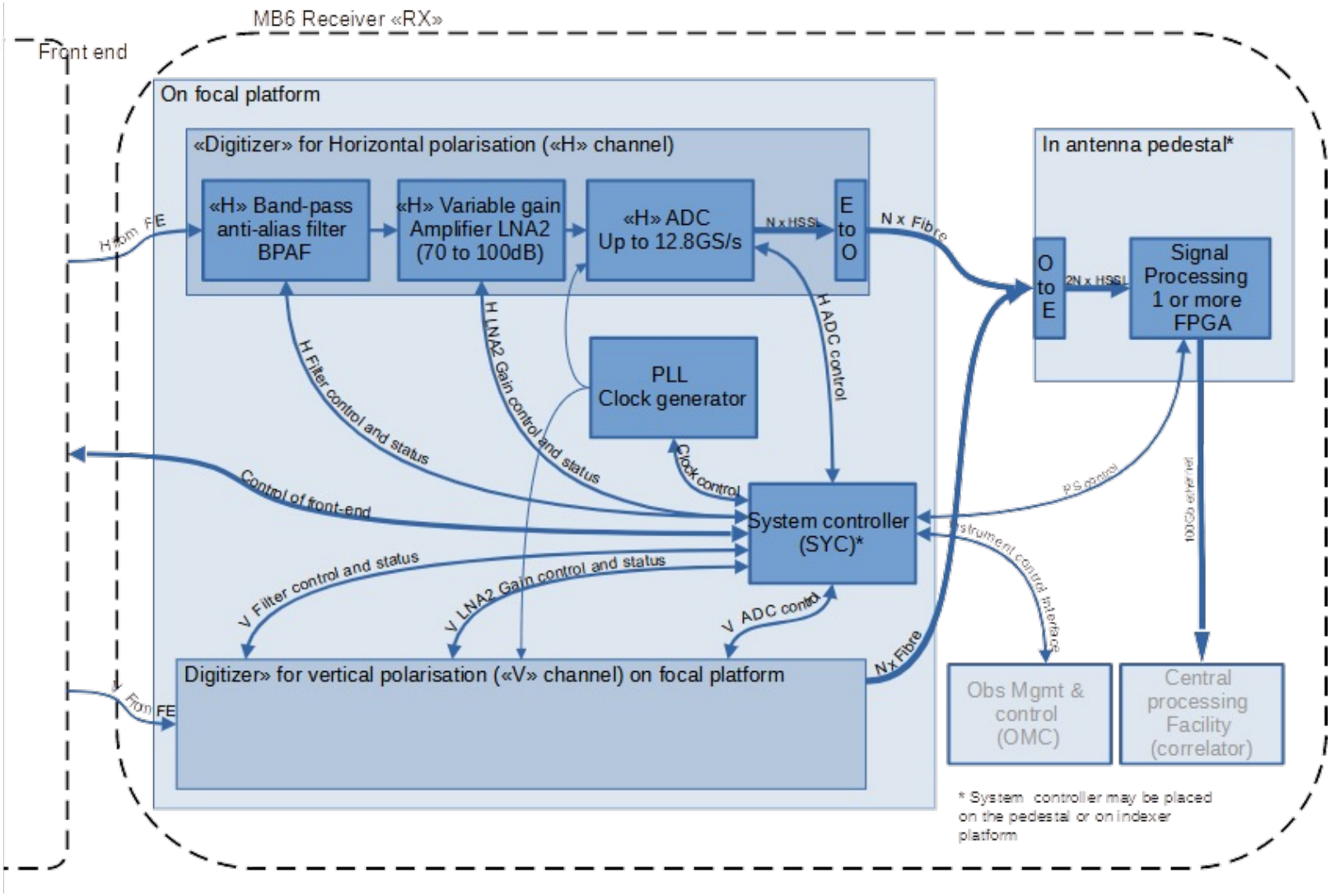
MB6 instrument Block diagram: top



MB6 instrument Block diagram: front-end



MB6 instrument Block diagram: receiver



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Breadboards??

- Why is this guy talking about bread boards?
- A bit of vintage electronics (1930-1960s)

- …

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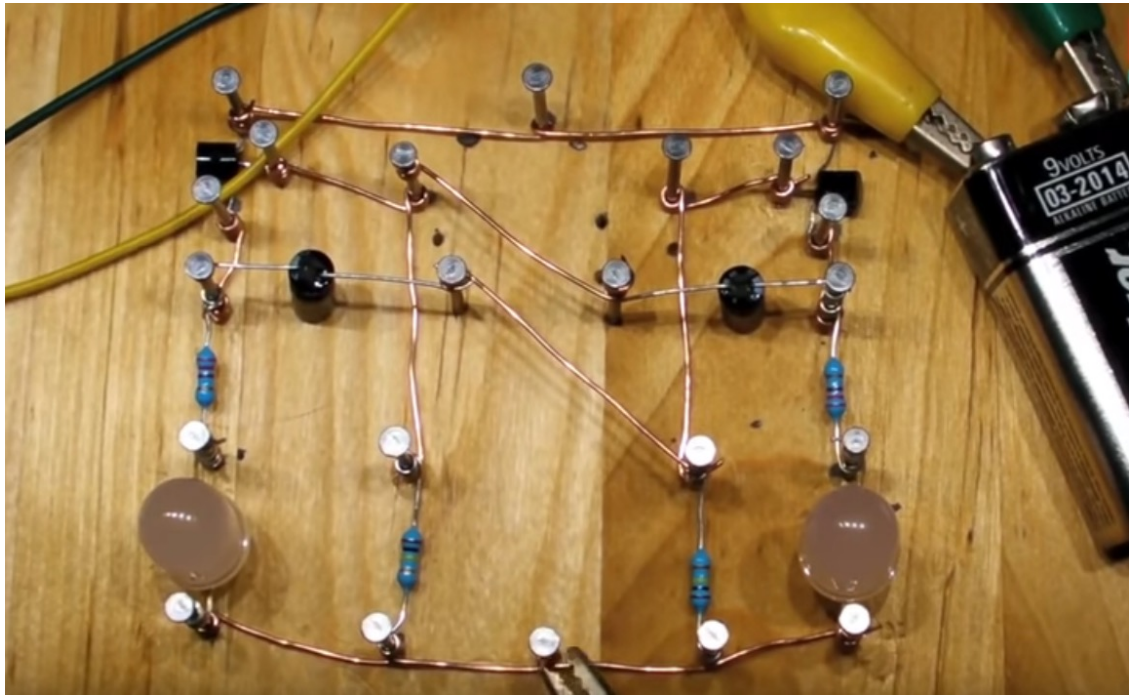

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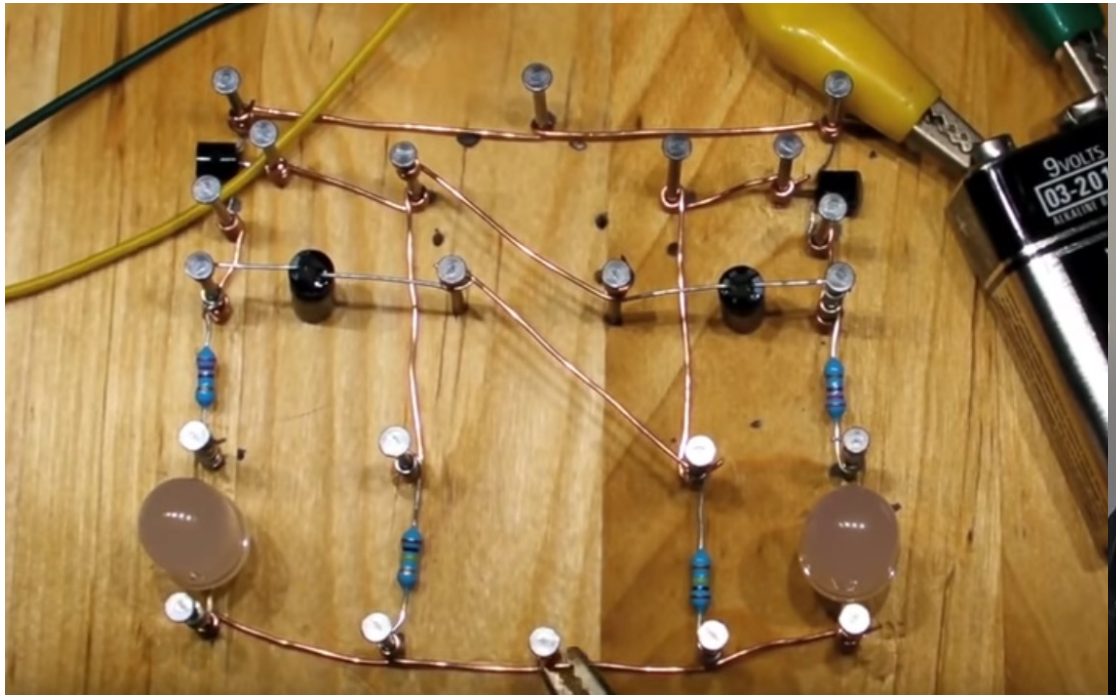

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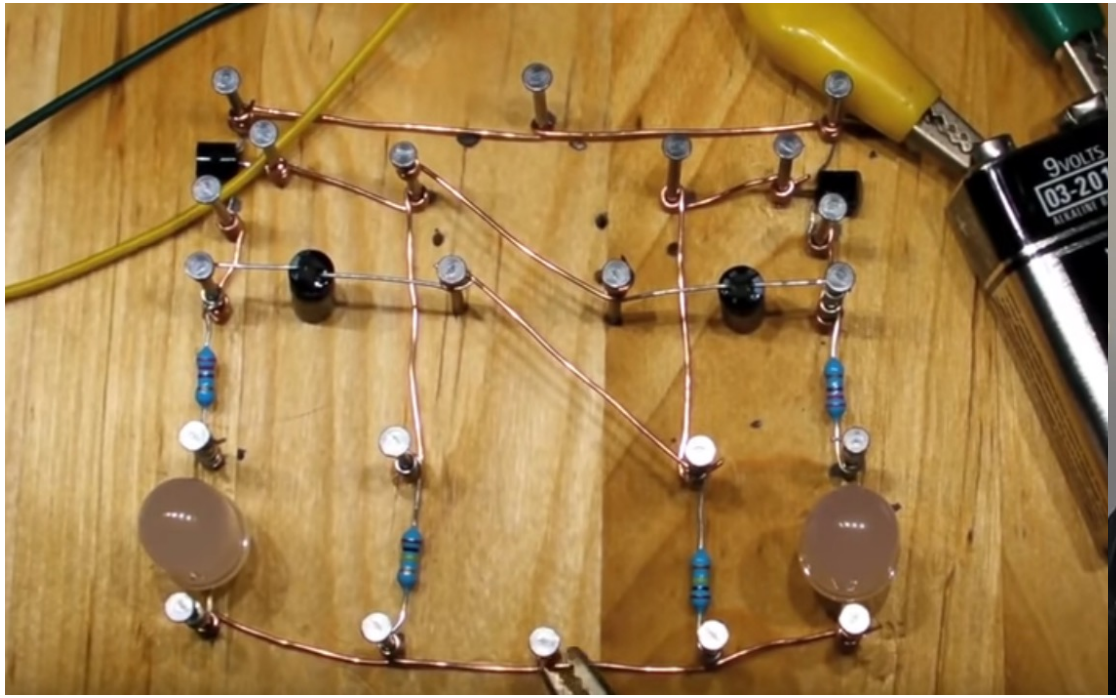
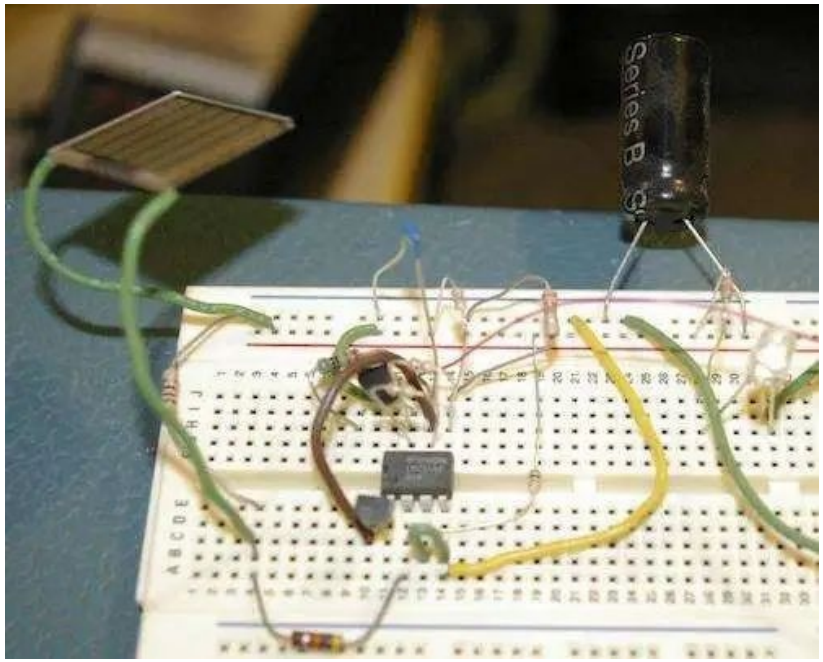


- … does not work above 0.001GHz…

https://hackaday.com/2011/04/06/circuit-building-with-a-hammer-and-nails/

Breadboards, evolution

- **This is what of today's current electronics engineers think:**

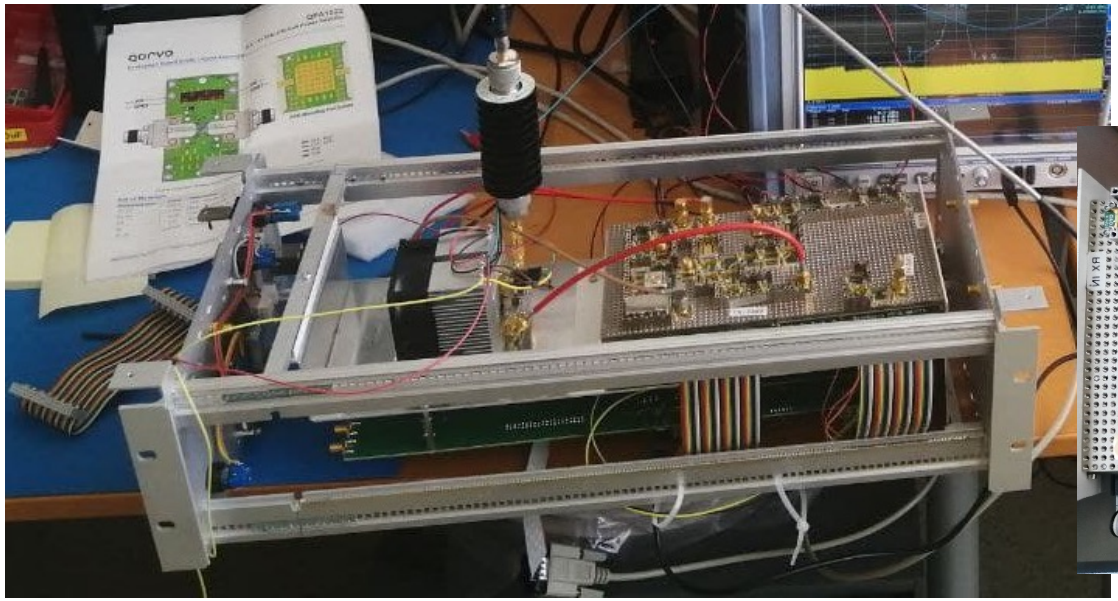


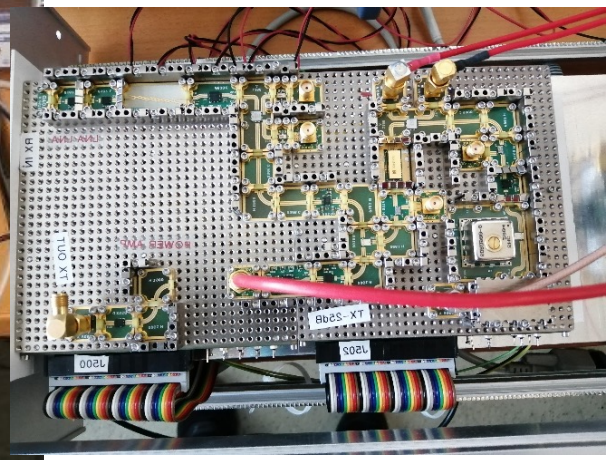
- **… does not work above 0.003GHz…**

https://www.edn.com/prototyping-methods/

The SKC-I elegant breadboard (EBB)

- **This is what the result of the SKACH instrumentation program will look like:**

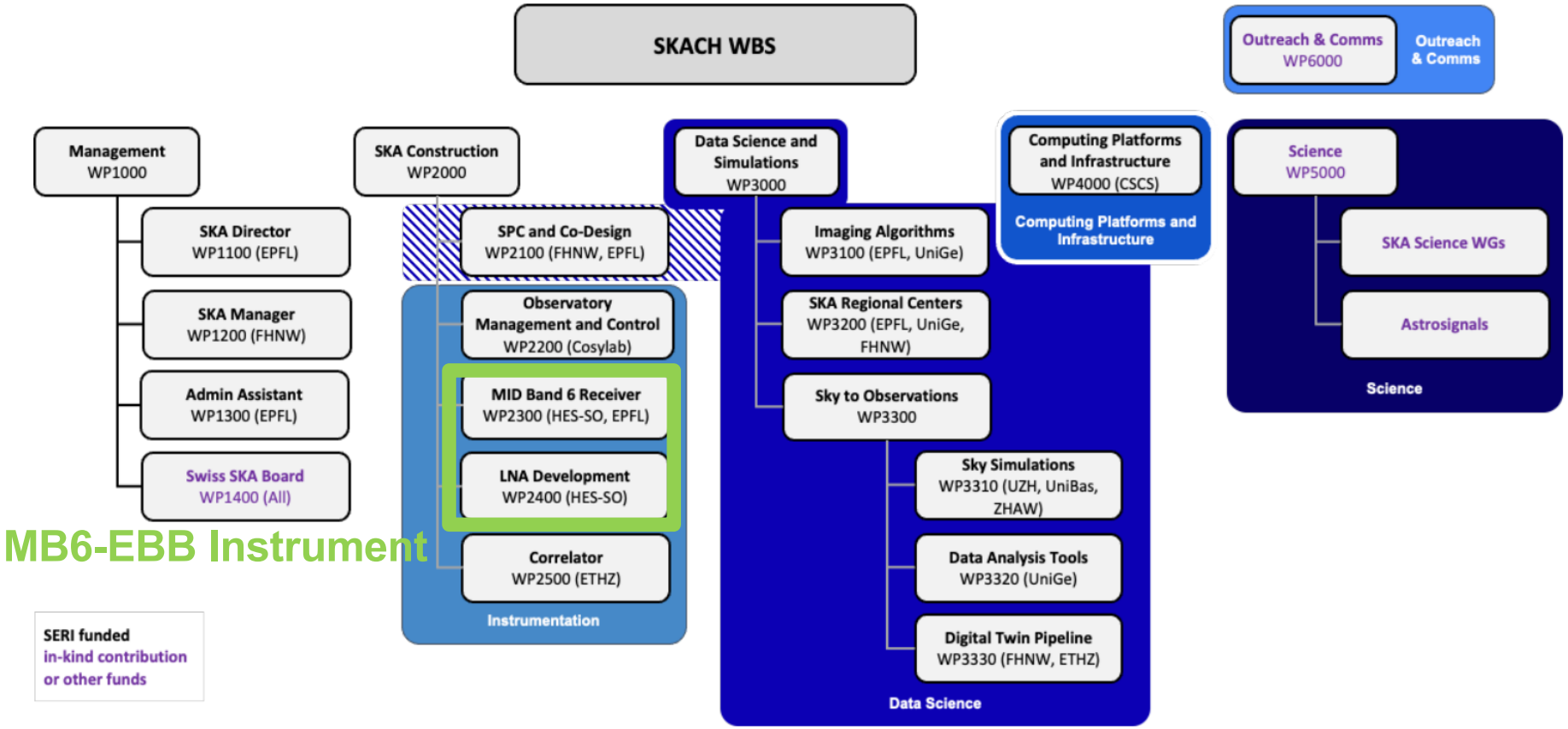




- **… will work up to 25GHz!** **(and more)**

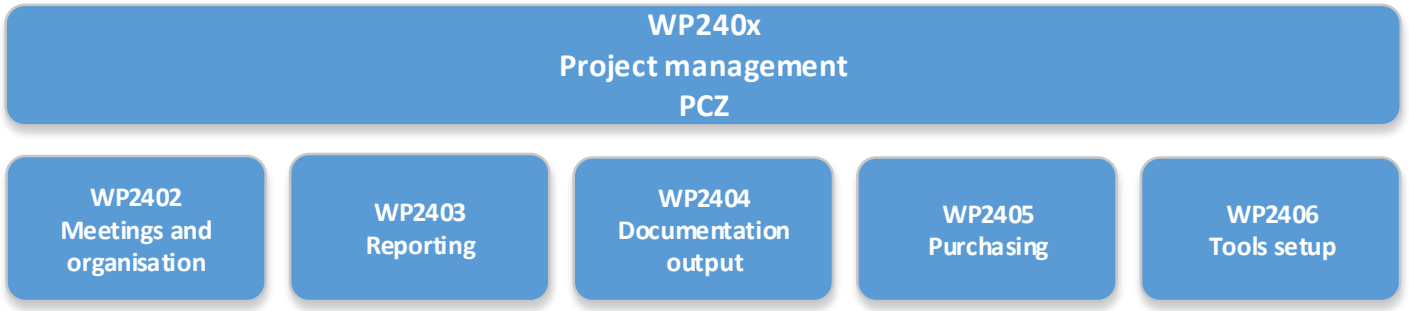
- **For the lab environment and beyond, transportable**

Work breakdown: overall



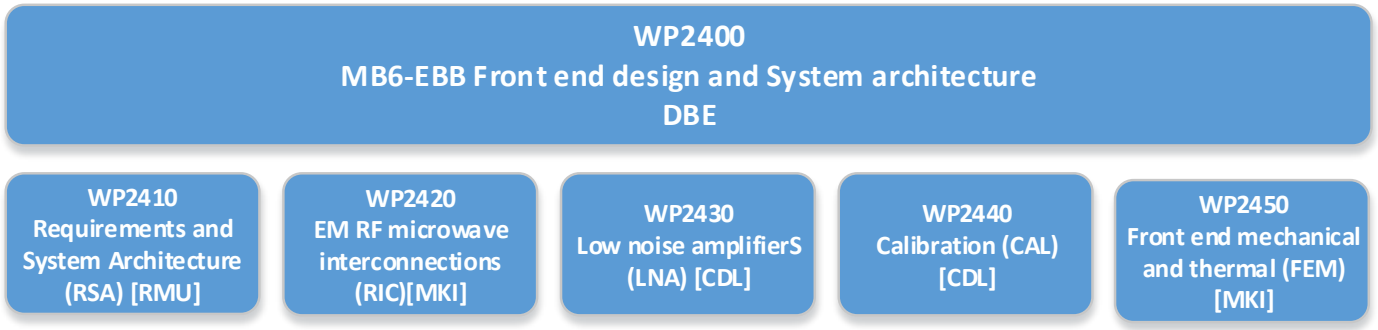
- **WP2400 LNA development ➔ MB6-EBB front-end**, as it contains much more than an LNA, but functionally the signal chain ends at the output of the LNA. As its cost is lower than the receiver itself, the WP2400 includes Project management and System architecture.
- **WP2300 MID-band 6 receiver ➔ MB6-EBB receiver**; WP2300 includes the system controller and test system.

EBB Work breakdown: WP240x PM



- **WP2404:** Documentation: PM plan, design&development plan (DDP), Master test plan (MTP), risk analysis, EMC control plan
- **WP2405**: purchasing is a critical activity in the current times of shortage of electronic components
- **WP2406**: setting up and maintaining Cameo and git

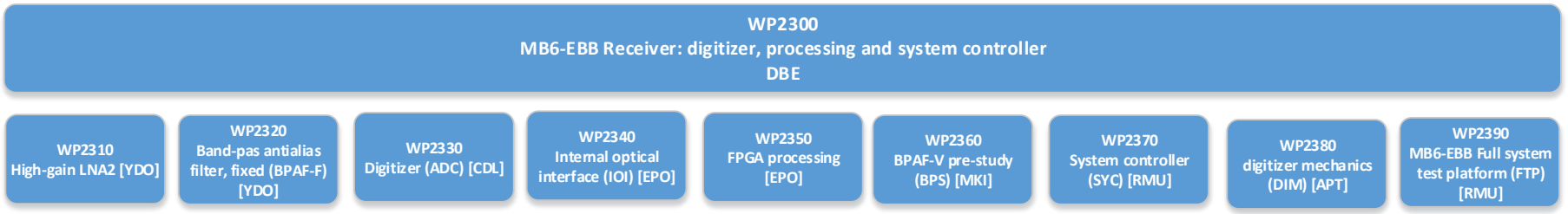
EBB Work breakdown: WP2400 front-end



- **WP2410:** functional, interface and science **requirements** are analysed. **System architecture** design and input requirements are produced for the **detailed design** of the instrument.
- **WP2420**: the **interconnections** in the front end transport very weak microwave signals and must shield them from external noise with absolutely minimal loss
- **WP2430**: the first **low noise amplifier** sets the noise performance of the whole instrument.
- **WP2440**: A **calibration** source must be switched in and out
- **WP2450**: **thermo-mechanical** issues which also have an impact on the noise performance are handled in this WP

Possible partnership with a UK university!

EBB Work breakdown: receiver



- **WP2310**: **amplify** LNA1 (output of FE) to the full-scale level of the ADC
- **WP2320**: band pass **anti-alias** filter for and selecting the frequency band. This is a fixed-frequency analog component in the EBB
- **WP2330**: analog to digital converter (**ADC**) (**digitizer**). Sampling rate of a dozen gigasamples per second, and a bandwidth of several times the sampling rate. Digital output on high speed serial lines.
- **WP2340**: **optical digital interface** to place the FPGA away from the front-end. Digital to optical fibre to digital interface
- **WP2350**: The digital data are **processed** by very high performance FPGA to provide the correctly formatted information in a protocol acceptable to the correlator of the SKA.
- **WP2360**: this WP is a pre-study to explore **how to make a bandpass filter variable** by changing its dimensions by micro-actuators.
- **WP2370**: the **system controller** receives commands from the OMC to set the instrument operational parameters, and sends instrument status data to the OMC.
- **WP2380**: mechanics
- **WP2390**: test system allowing automated test of the whole instrument during development

Schedule

Phases:

- Phase 1a EBB System architecture and early design
  - Aug to dec 2022
  - WP2410 System requirements ➔ design input requirements for engineering
  - ➔ SRR System requirements Review jan 2023
  - Work on WP2404 (basic doc) WP 2430 (LNA1 design), WP2320 (BPAF-F), WP2330 (ADC/digitizer), TBC WP2310 (LNA2),
- Phase 1b Implementation of EBB Jan to Dec 2023
  - Work on design of HW blocks: WP2440 (CAL), WP2450 (FE-MEC), 2340 (IODI), 2350 (PROC)
  - ➔PDR/MRR June 2023: decide whether ready do manufacture ph1b blocks
  - Aug-Dec 2023: integration and tests (including on the field)
  - ➔Dec 2023: EBB delivery review board (EBB-DRB), end of SKACH part

EBB-EM-FM feature evolution

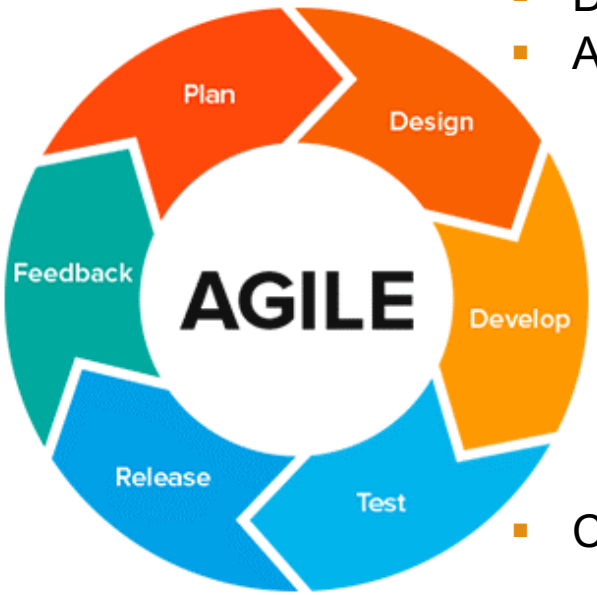
Functional group	EBB	EM and EQM	FM
Start-end TRL	**2-4**	**4-5 or 4-6**	**7**
Feed antenna	Horn or similar (COTS)	Custom	Same
OMT	Custom, ambient or LN2 (77K) temp	GHe temperature (15-20K)	Same
LNA1	InP, ambient temp or LN2 (77K) temp	GHe temperature (15-20K)	Same
Bandpass anti-aliasing filter	Bank of fixed bandpass BPAF-F, amb temp, 15-22GHz (TBC), 2.5GHz bands	Tunable Bandpass, amb. Temp, 15-30GHz (TBC) (Innosuisse)	Same
LNA2	Diramics InP, multistage, amb.temp	Diramics InP, multistage, 85K (GLN2)	Same
Digitizer	Teledyne ADC, custom board, up to 12.8GS/s, up to 40GHz passband	Same	Same
Link to FPGA	Optical, 22 fibre links	Same	Same
FPGA	Altera or Xilinx Evaluation boards	Custom design, with Nanoxplore MIL-spec FPGA (TBC)	Same
Output interface	1x10GbEth	N x 10GbEth (TBC)	same

- Operating temperatures
  - LN2=liquid nitrogen @-196°C
  - Ghe: gaseous helium @-253°C
  - GLN2: gaseous nitrogen @-188° to -183°C
  - Ambient for EBB electronics: 5-30°C (TBC)
  - Ambient for EM electronics: -10 to + 50°C (TBC)
- Acronyms
  - EBB: Elegant Bread Board (functional spec)
  - EM: engineering model (+size and fit)
  - EQM: engineering and qualification model (qualified)
  - FM: Field model (full spec

Project status MB6-EBB

- WP2404 documentation
  - ☑ Project management plan PMP, Design development plan DDP. Product assurance plan PAP
  - ⚠ Master test plan, Risk Register, Glossary, EMC control plan
- ☑ WP2406 project tools: git and cameo setup
- WP2430 LNA1:
  - ☑ WP spec done
  - ⚠ noise modeling started
- WP2420 fixed anti-alias filter BPAF-F
  - ☑ WP spec done
- WP2330 ADC: work in partnership with chip manufacturer Teledyne
  - ☑ WP spec done
  - ☑ top-level design and schematics of custom ADC board for MB6
  - ⚠ PCB of MB6 ADC base board
- WP2360 BPAF-V: analysis started
  - ☑ WP spec done
- 🕘 WP2410: Waiting for 1st elements of SKA specifications
- Other WP: 🕘

Project management



- Described in PMP, PLN-001, and DDP, PLN-003
- Agile workflow:
  - a “story” document for each tier-2 WP (2410, 2420…)
    - Dedicated teams by story
    - Tier-3 WP in 1-month sprints (WP2411, 2412, …)
    - Monthly Scrum sprints
    - Monthly objectives, readapted
    - Story also used also as tracking documentation of work performed
  - Weekly meetings with whole team (all WP)
    - Allows discussing issues across teams
  - Sprints have final milestones
- Configuration management on Git
  - SW code and FPGA HDL: full use
  - HW design files: commented commit only
  - All other doc and reports commented commit only
  - Deliverables will be TAGged (=snapshot of all files)
  - WBS of proposal is base of project structure
  - Issue management (“tickets”)
- “SKA lab”: a place dedicated to the project
  - Schedules and basic documents displayed
  - Meeting table
  - Integration+test laboratory benches

https://medium.com/moodah-pos/agile-development-95cad3573abf

Project partnerships with industry 1/2

- Diramics (Switzerland), manufacturer of LNAs
  - Foreseen from the start in SKACH
  - Indium Phosphide, very low noise
  - Only one other manufacturer worldwide for LNAs (Low Noise Factory)
- Manufacturer of ADC (France):
  - “heart” of the instrument
  - Only (soon) available ADC chip with this level of performance
  - Non-ITAR (strategic)
  - Design partnership
    - on the digitizer main board (no FPGA on board)
    - (in discussion) on the sampling clock generator
  - Access to
    - Advance/”insider” data on the ADC device
    - Debug information
  - Speeds up the design
  - De-risks the future design

Project partnerships with industry 2/2

- Partner for micro-mechanical device: to be defined
  - Not SKACH, but Innosuisse (1Q23) ➔ Swiss partner
  - BPAF-V variable band pass filter
  - Varying mechanical dimensions of microwave filter
  - Actuator track length: few mm, high accuracy
- FPGA: European manufacturer
  - Goal: Use “made in Europe” high-grade long availability FPGA (MIL)
  - Non-ITAR (strategic) alternative to big players (Altera, Xilinx)
  - Only for EM (>2023/4)
  - Goal: future design partnership similar to the one of ADC?
  - Technically, yet to be discussed between technical project partners
- Partners for manufacturing and assembly: to be defined
  - Not SKACH, but future “fair work return” scheme for SKACH (>2025?)
  - For EM
  - Swiss and/or international
  - Electronics boards:
    - High precision PCB manufacturing
    - High-precision assembly
  - Electromagnetic parts:
    - OMT, feed antenna
  - Instrument assembly
    - Vacuum, cryo

Contacts

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