14 RPT ACQ-PRO

Towards the propagation of AC Quantum Voltage Standards

Status of ACJVS in metrology:

- used only in a **small** number of NMI,
- traceability to AC quantum standards maintained by a
- small number of NMI,
- **limited research** and transfer to industry.

Project goal:

To increase ACJVS dissemination and research capability.

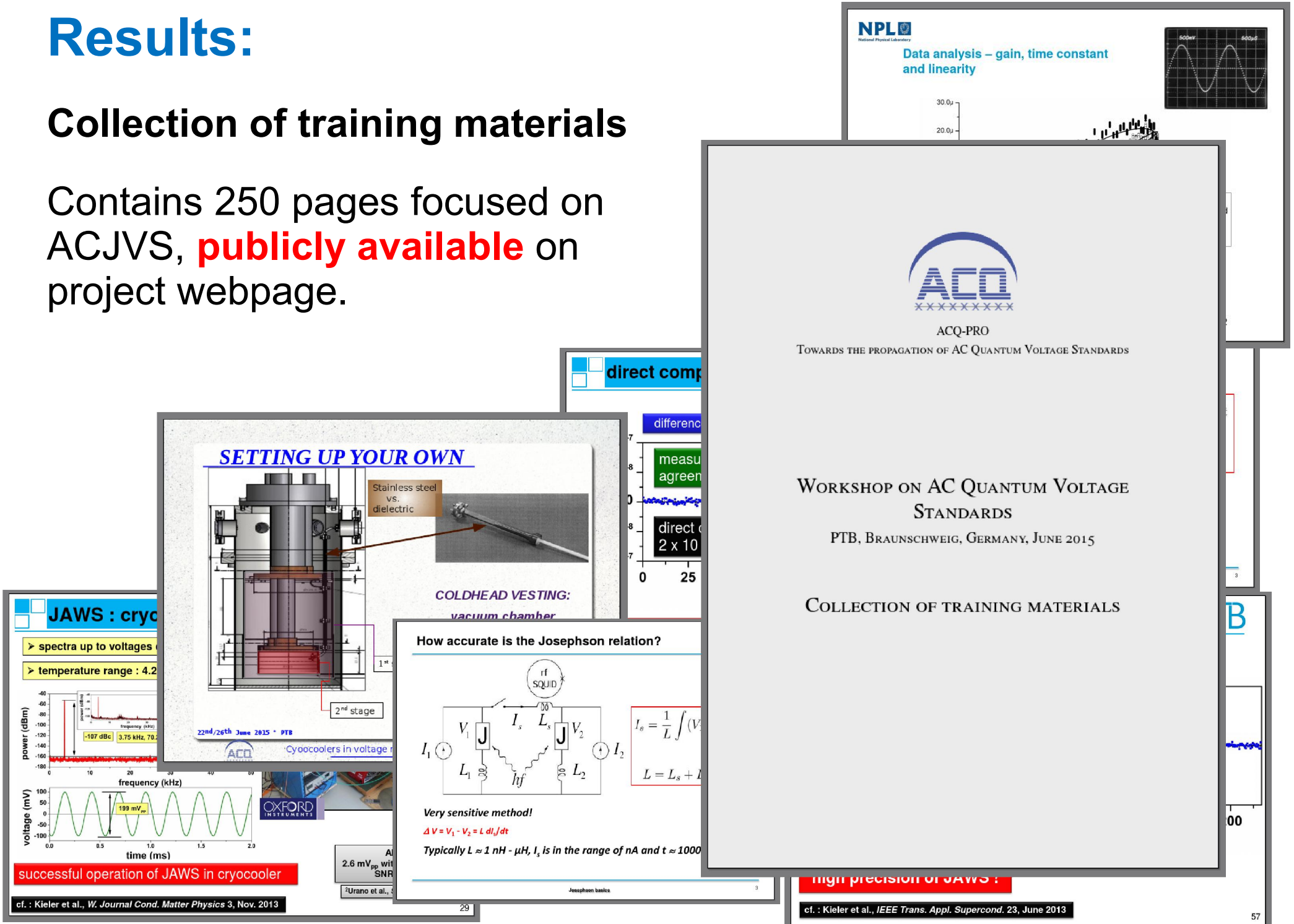
Objectives:

- **Transfer** experience and expertise
- **Design** a new practical ACJVS
- Good Practice **Guide** on the use of ACJVS
- Establish future **collaboration** between metrological institutes working on ACJVS
- Create individual **strategy** for NMI development in ACJVS metrology

Results:

Collection of training materials

Contains 250 pages focused on ACJVS, **publicly available** on project webpage.



Results:

Transfer of experience:

110 Research visits

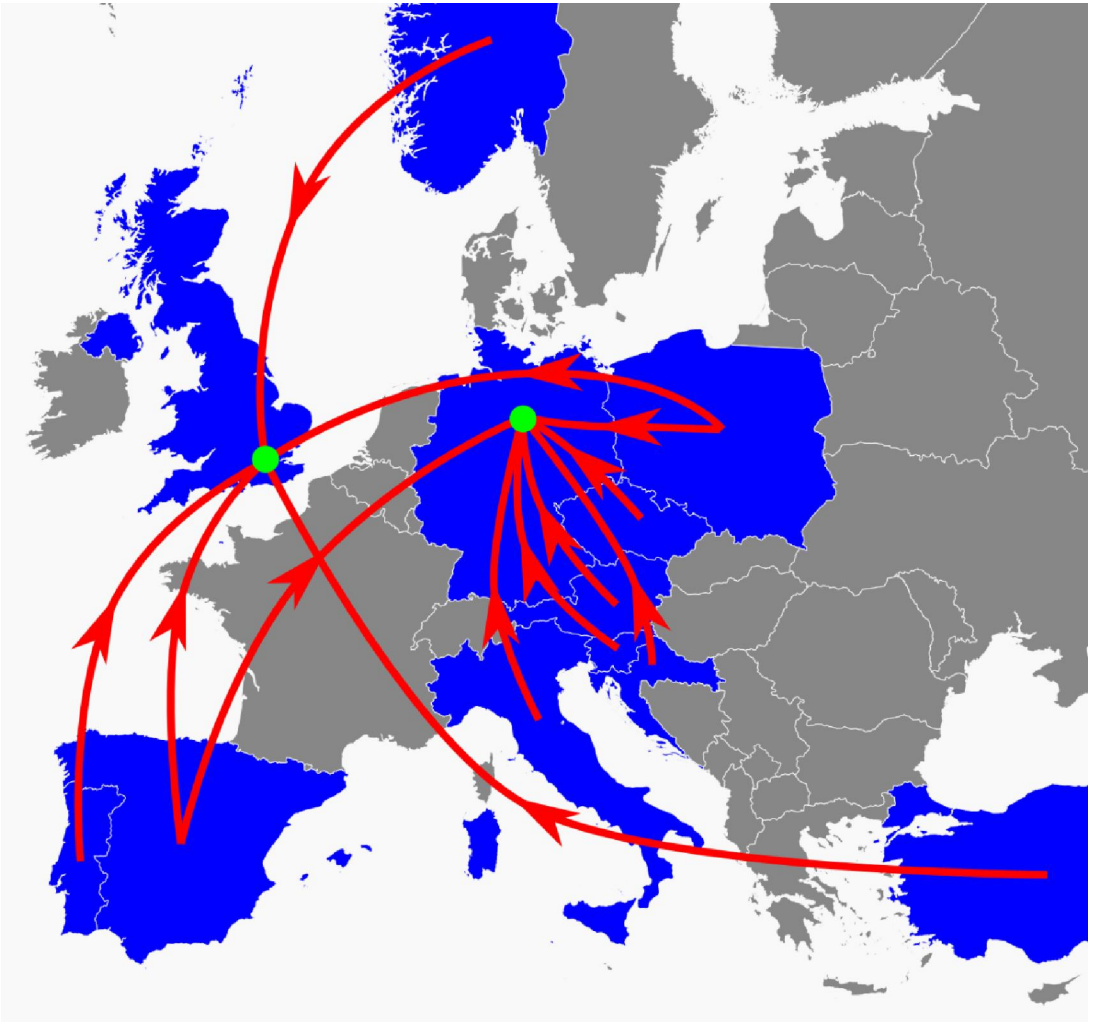
1 Research Mobility Grant

NPL:

- Adam Tatar(GUM)
- Recep Orhan (TÜBİTAK)
- Vitor Cabral (IPQ)
- Helge Malmbekk (JV)
- Javier Díaz de Aguilar (CEM)

PTB:

- Martin Šíra (CMI)
- Damir Illic (FER)
- Raúl Caballero Santos (CEM)
- Vitor Cabral (IPQ)
- Bostjan Voljc (SIQ)
- Josef Pribil (BEV)
- Adam Tatar (GUM)
- Paolo Durandetto (INRIM)



Results:

Research topics of visits:

- Calibration of **ADC** by a specific waveform generated by JAWS
- Direct calibration of **AC source** using AC Quantum Voltmeter
- Calibration of **voltmeter** using PJVS and transfer standard based on DAC
- Frequency response and stability of **ADC** using both JAWS and PJVS

Results:

Research Mobility Grant (4RPT01-RMG1)

PTB – 2017 May 1 - July 31

Paolo Durandetto (INRIM)

Aim:

•refinement of ACJVS based on programmable and pulse-driven Josephson arrays for simplifying system management in dissemination-oriented laboratories

•facilitating knowledge transfer in the field of quantum standards for time-dependent voltages.

Outcome:

Experiment transfer knowledge to the INRIM and the consortium

Results:

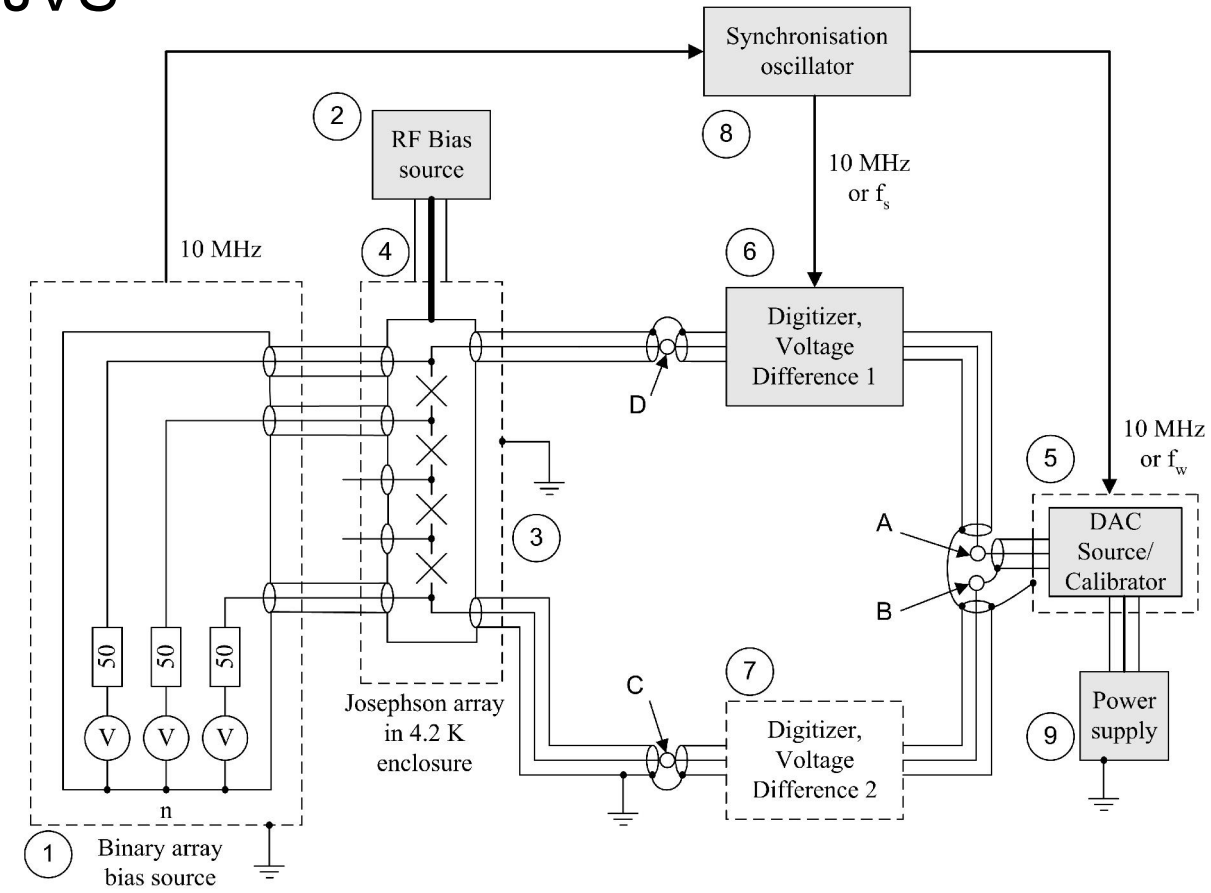
Preparation of a new ACJVS design

- Quantum traceable waveform generator

- Based on combination
  of ultrastable DAC and PJVS

- DAC directly
  corrected by PJVS

- DualDAC 2
  VTT/MIKES – Aivon



Results:

ACQ standards intercomparison

- A pioneering intercomparison will take place in 2017

BIPM ↔ NPL ↔ PTB

- The comparison will be used to validate the new AC quantum design.

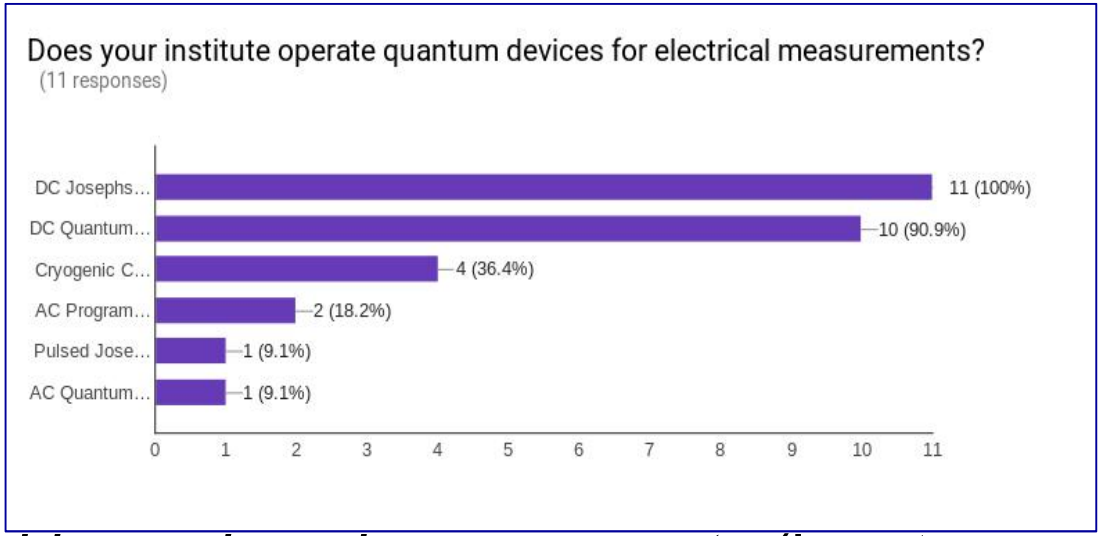
- This will serve as a basis for future worldwide bilateral and pilot comparisons of ACQ standards.

Results:

Startup Survey

A questionnaire to collect info on participants plans/aims
13/14 replies from Participating Institutes and BIPM

Questions on:
- Motivations
- Measurement capabilities
- Cooling techniques
- Cooperation setup
- Expectations from ACQ-PRO



Outcome:
Participants interest on *practical know-how improvements* (input for Best Practice Guide) but *not only aimed at calibrations*.

Willing to tightly cooperate, possibly sharing systems.

Results:

Good Practice Guide on the use of AC quantum voltage standards (in development).

Instruments, configuration, cryogenics, how to use.

Best practice guide – outline

Content unique to binary-divided arrays, NPL

1. Cryoprobe and microwave source
   - 1.1. Synthesizers 20 GHz, 70 GHz, Gunn diodes, frequency counters, power amplifiers
   - 1.2. Array bias lines; twisted pairs, coaxial lines, types and suppliers
   - 1.3. RF waveguides; coaxial, circular, launchers
   - 1.4. Array mounting, cable termination, heater for removing trapped flux
2. Binary bias source
   - 2.1. Electrical characteristics: output voltage, impedance, rise time, stability/drift
   - 2.2. Number of channels, data memory, time resolution, channel skew, triggering, frequency locking
   - 2.3. Computer interface, power, electrical isolation, interface software
3. Binary array
   - 3.1. Junction technology, critical current, rf operating frequency, Shapiro step width as a function of microwave power
   - 3.2. Output voltage, number of junctions, binary division, minimum voltage resolution

Content unique to pulse-driven arrays, PTB

4. Cryoprobe and microwave source
   - 4.1. PPGs, power amplifiers, including specifications
   - 4.2. IV-box, low frequency synthesizers
   - 4.3. Array bias lines; twisted pairs, coaxial lines, types and suppliers
   - 4.4. RF waveguides; coaxial, launchers, DC-blocks
   - 4.5. Array mounting, cable termination, heater for removing trapped flux
5. Pulse driven array
   - 5.1. Junction technology, critical current, operating frequency, Shapiro step width as a function of microwave power and pulse repetition frequency, on-chip filters
   - 5.2. Output voltage, number of junctions (mostly now with termination)
   - 5.3. Output cable correction at high frequencies
   - 5.4. Sigma-Delta simulation, quality of codes, SNR, quantisation noise

Content common to both approaches

6. Low frequency synthesizer, PTB, CEM, NPL
   - 6.1. Output voltage, resolution and output impedance
   - 6.2. Synthesis method: analogue or digital
   - 6.3. Amplitude stability
   - 6.4. Harmonic distortion (amplitudes, frequencies)
   - 6.5. Frequency/phase stability, frequency locking facilities
7. Null detector, CMI
   - 7.1. Voltage and current noise, dynamic range, maximum voltage
   - 7.2. Common-mode rejection, electrical isolation (resistance, capacitance), input impedance
   - 7.3. Sampling rate, sampling aperture, digital filter (sampling ADC / delta-sigma converter)
   - 7.4. Bandwidth, step-recovery time (rise-time), gain stability, linearity, hysteresis, recovery from overload, phase error/time delay
   - 7.5. Characterisation methods for null detectors, refer to IEEE standards 1241-2000, 1057-2007
   - 7.6. Overall uncertainty contribution of the null detector
8. Measurement system
   - 8.1. Cables and interconnections, screening, current equalisation, mutual inductance (including in the cryoprobe), current and voltage paths, cross-talk
   - 8.2. Laboratory safety ground connections
9. Software, CMI and others
   - 9.1. Array characterisation and optimisation
   - 9.2. Waveform synthesis
   - 9.3. Spectral measurements
   - 9.4. Null detector data collection and processing
   - 9.5. Synthesizer control
   - 9.6. System control, automated measurements and calibrations
   - 9.7. Interoperability of software components
   - 9.8. Data storage: content and format
   - 9.9. Uncertainty attributed to data processing algorithms
   - 9.10. Data analysis, measurement parameters, measurement uncertainty
10. Cryocoolers
11. Measurement procedure
    - 11.1. Definition of Device Under Test (DUT), including connections, loading, interaction between DUT and measurement system
    - 11.2. Definition of measurement parameters (rms voltage, ac/dc, harmonic content…)
    - 11.3. Choice of measurement frequencies, voltages, sampling rates
    - 11.4. Measurement time/sequence to achieve required measurement uncertainty (especially ac/dc transfer)
    - 11.5. Application of Josephson ac waveform systems to other measurements, eg impedance ratio
    - 11.6. Protocol asks for:
      - 11.6.1. Calibration of thermal converters, voltmeters and AC sources (Tubitak, GUM, JV, SIQ, BEV)
      - 11.6.2. Characterisation of ADC (CMI, CEM, FER, IPQ, FCT)
      - 11.6.3. Impedance ratio (PTB, CEM, FER, IPQ, FCT)
      - 11.6.4. Power and power quality (CEM, CMI, FER, IPQ, FCT)

Results:

Establishing working group on ACJVs Cryogenics

- Aimed at the development of an European research network on JVS cryogenics, and application of cryocoolers to JVS.
- Sharing experiences, tricks, know-how.
- Special chapter on Good practice guide: FCT, INRIM, IPQ

Ongoing: **Establishment of working group** on ACJVS

- Aim: “...future cooperation between European NMIs working on AC quantum voltage standards”
- will include project partners, potential collaborators, experts (including non-Eu)
- will work in close collaboration with the relevant existent TC & groups (EURAMET TC-EM “DC &
- Quantum Metrology”, “Low Frequency” and “Power and Energy”..)
- Terms of Reference preparation at draft stage 2

Everyone is welcome to collaborate

Project timeline: 2015 – 2018

Partners: CEM, BEV, CMI, FER, GUM, INRIM, IPQ, JV, NPL, PTB, SIQ, TUBITAK

Collaborators: BIPM, SUPRACON

Project coordinator: **Javier Díaz de Aguilar**
jdiaz@cem.minetur.es

Website: **http://acqpro.cmi.cz/**

Everyone is welcome to collaborate:

suggestions for the best practice guide, participate on the creation of working group, comment the comparison, ...