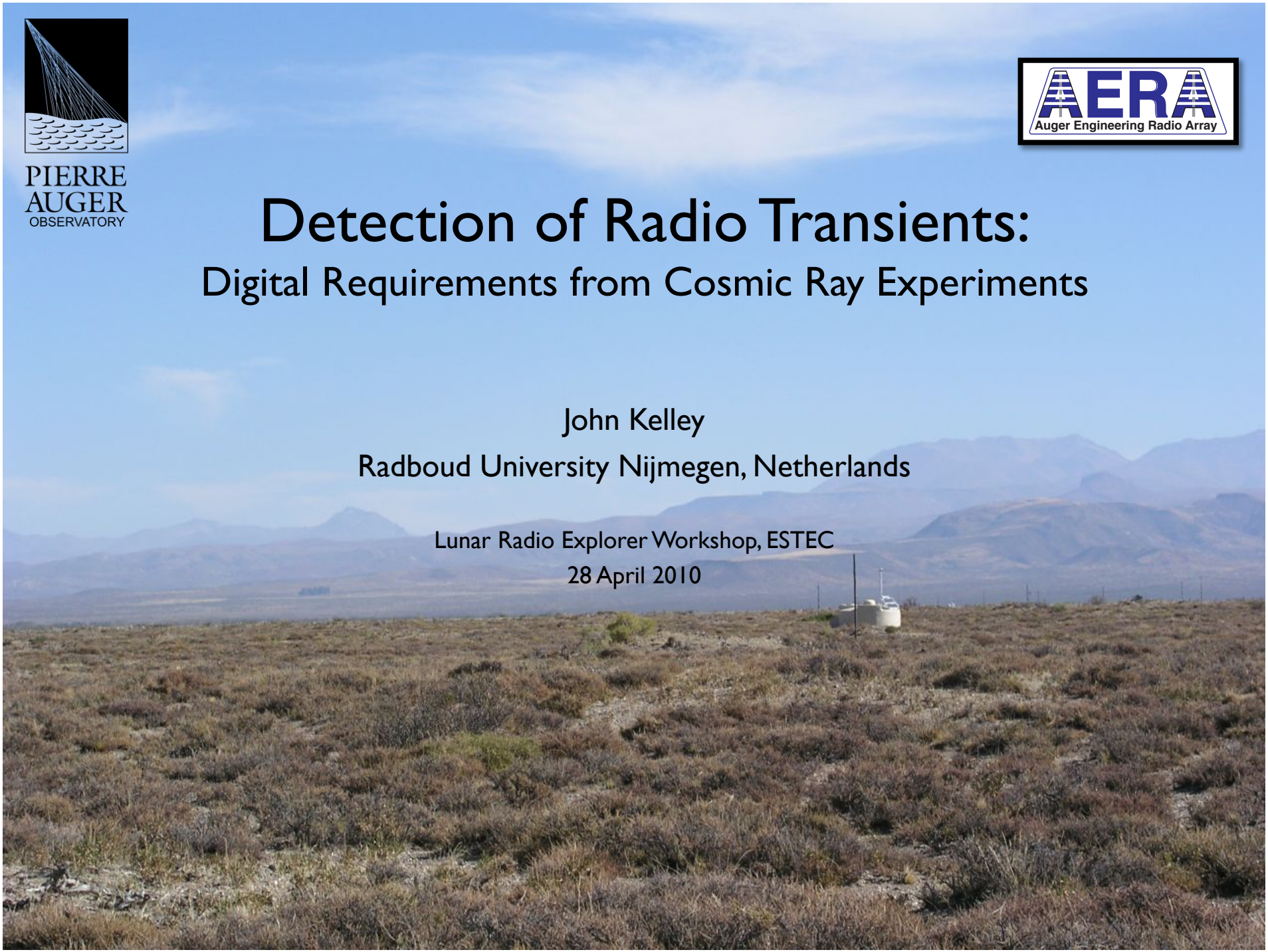

Detection of Radio Transients:

Digital Requirements from Cosmic Ray Experiments

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Lunar Radio Explorer Workshop, ESTEC

28 April 2010

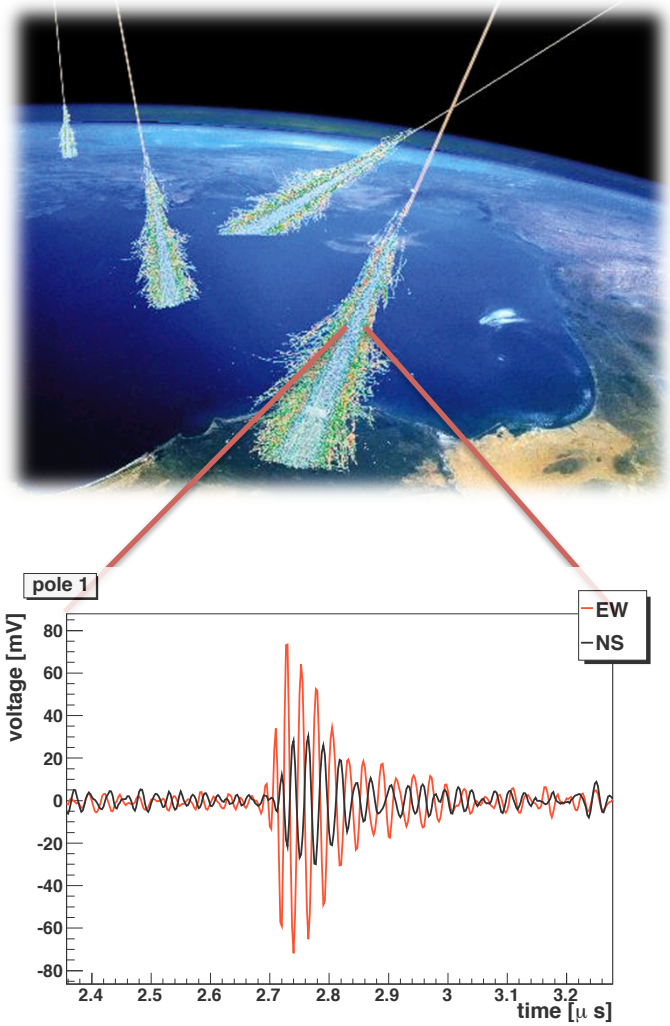
Introduction

- Goal: impulsive radio transients on the moon
  - cosmic ray emission in regolith (Askaryan effect)
  - other sources? (talk by O. Scholten)

- Radio cosmic ray detection on Earth
  - emission mechanism different, but pulses similar
  - experience with triggering, background rejection
  - modest power budget

Radio Emission from Cosmic Ray Air Showers

- Primary cosmic ray interacts and causes cascade of particles in atmosphere (or in the moon)
- Broadband radio pulse
  - width ~50 ns
  - due to interaction with Earth's magnetic field
- Emission is coherent up to 100 MHz
  - RF power scales as (energy)^2
- Trigger on bandwidth-limited pulse

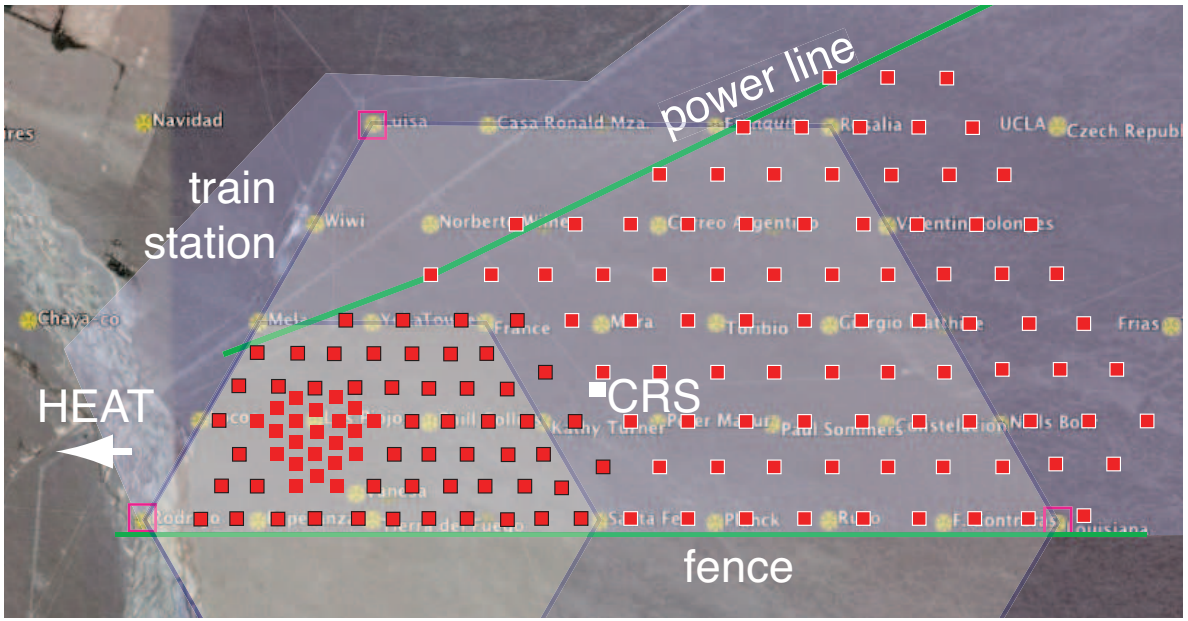


Radio Detection Station

- Prototype array in Argentina
  - at the Pierre Auger Cosmic Ray Observatory
- Autonomous, solar power
- LPDA antenna
  - two polarizations
  - to 30-80 MHz bandpass filter
- Local digitizer and trigger
  - four channels
- Multi-station coincidence via central DAQ

Auger Engineering Radio Array

- AERA: Auger Engineering Radio Array
- 20 km^2 extension to southern Auger site
- Phase I: 20 stations, June 2010 (total: 150)

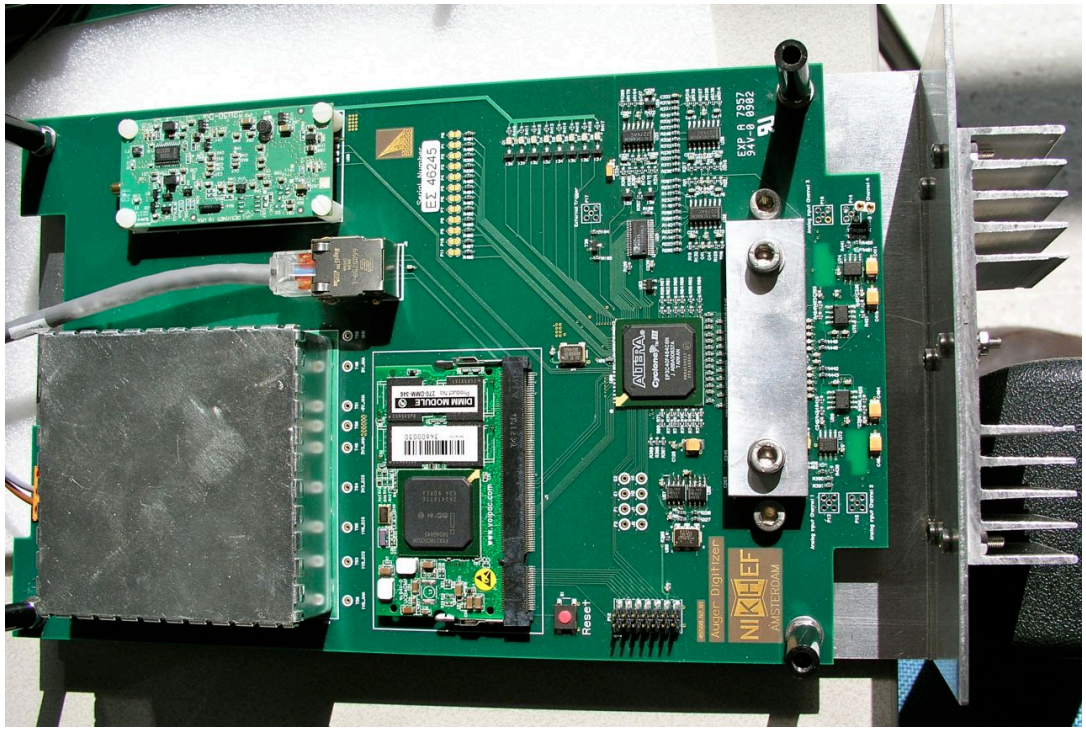


Digital Electronics (NIKHEF and RU)

GPS receiver (timestamping)

Cyclone III FPGA (triggering & readout)

Ethernet



4 channel, 200 MHz 12b ADCs

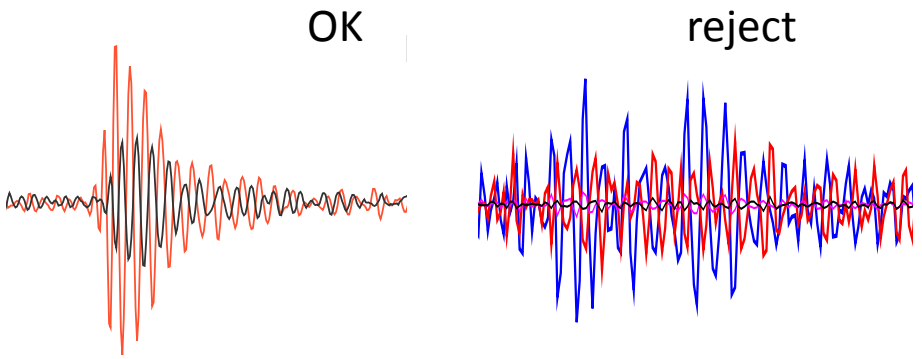
DC/DC conv. (shielded)

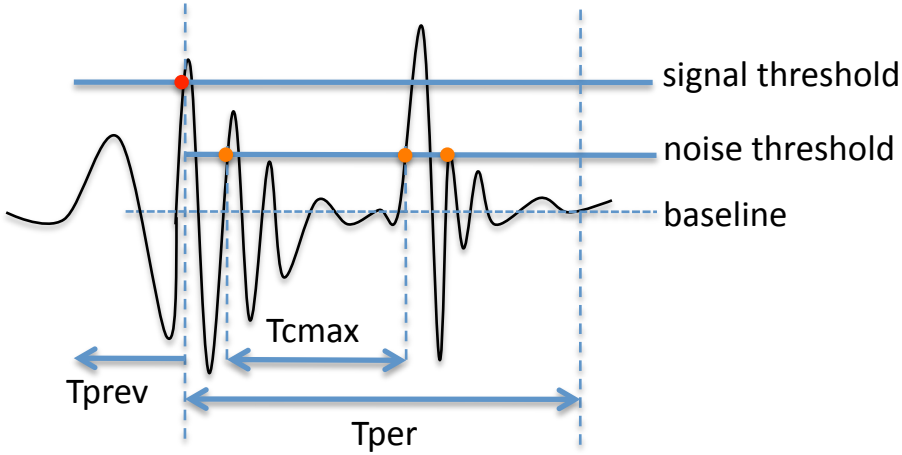
XScale-based PC card (buffering, comms)

serial interface

Triggering in FPGA

- Main challenge: impulsive RFI
- Time-domain pulse analysis
- Basics
  - threshold trigger
  - baseline integration / subtraction
- Enhancements
  - (max, min) number of threshold crossings
  - time between crossings
  - veto period before pulse
  - pulse height vs. number of crossings
  - dynamic noise levels
  - …
- Complexity: 3K logic gates / channel
- Optional(?) narrowband rejection
  - FFT ➔ filter ➔ iFFT
  - digital notch filters (e.g. LOFAR)





Comparison with Lunar Requirements

	AERA	Moon	Notes
Trigger rate	>100 Hz	30 Hz	OK; can also relax trigger
Frequency range	30-80 MHz	10-200 MHz	Faster sampling: see below
Background	Man-made RFI	?	With self-shielding, OK?
Power	9W 35% ADCs 15% FPGA 15% CPU etc.	1-2 W?	CPU hard or soft core (buffering, comms, compression?) Low-power digitizer (e.g. ATWD / Labrador): switching cap. array, > 1Gs/s, O(10 mW) / channel