Retrofitted Digital Optical Modules for Radio Detection of Neutrinos in Ice

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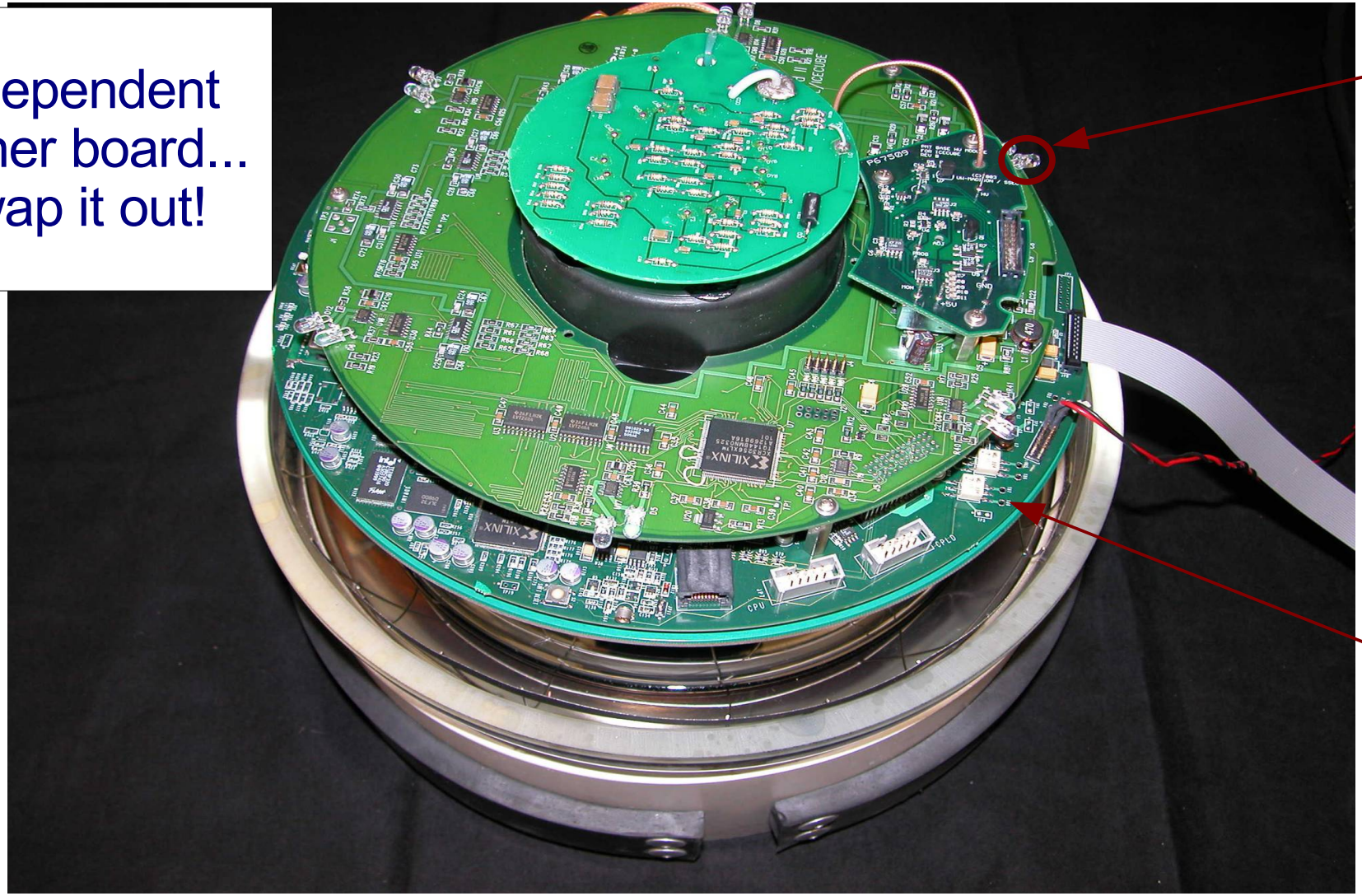
Radio Deployment in 2006/7

- Take advantage of unused breakout on IceCube cable
- Instead of IceCube DOM, deploy a Digital Radio Module (DRM)
  - Photomultiplier -----> radio antenna
  - Digitize and trigger in ice
    - Use ANITA digitizer rather than IceCube ATWD
- Minimal impact on IceCube deployment

Interior of a DOM

Independent flasher board... swap it out!



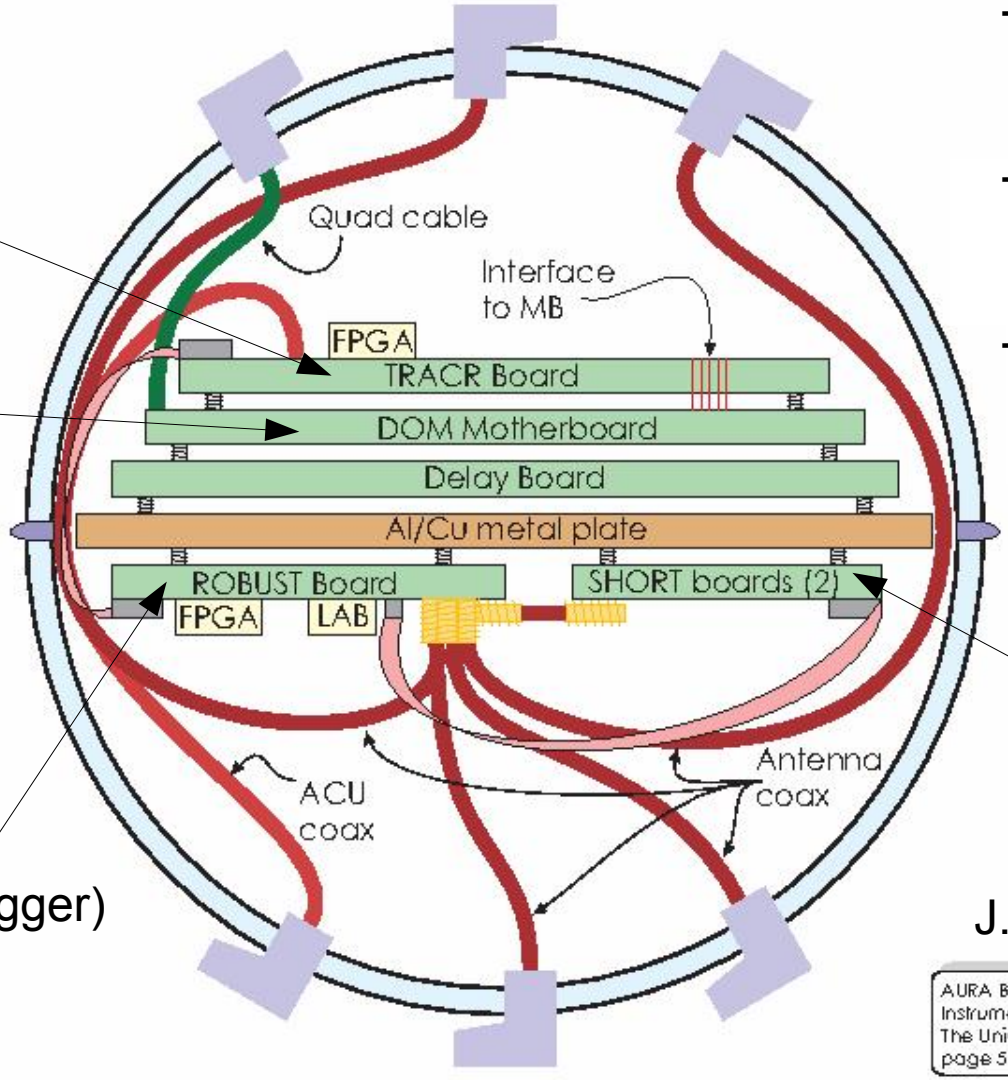
K. Hansen

Digital Radio Module Concept

TRACR (trigger/data storage)

IceCube Mainboard

ROBUST (digitizer/L1/L2 trigger)



SHORT (L0 trigger)

- **SHORT**
  - **S**urf **H**igh **O**ccupancy **R**F **T**rigger
- **ROBUST**
  - **R**ead**O**ut **B**oard, **U**HF **S**ampling and **T**rigger
- **TRACR**
  - **T**rigger **R**eduction **A**nd **C**ommunications for **R**adio

J.Ledford

AURA Block Diagrams
Instrumentation Design Lab
The University of Kansas
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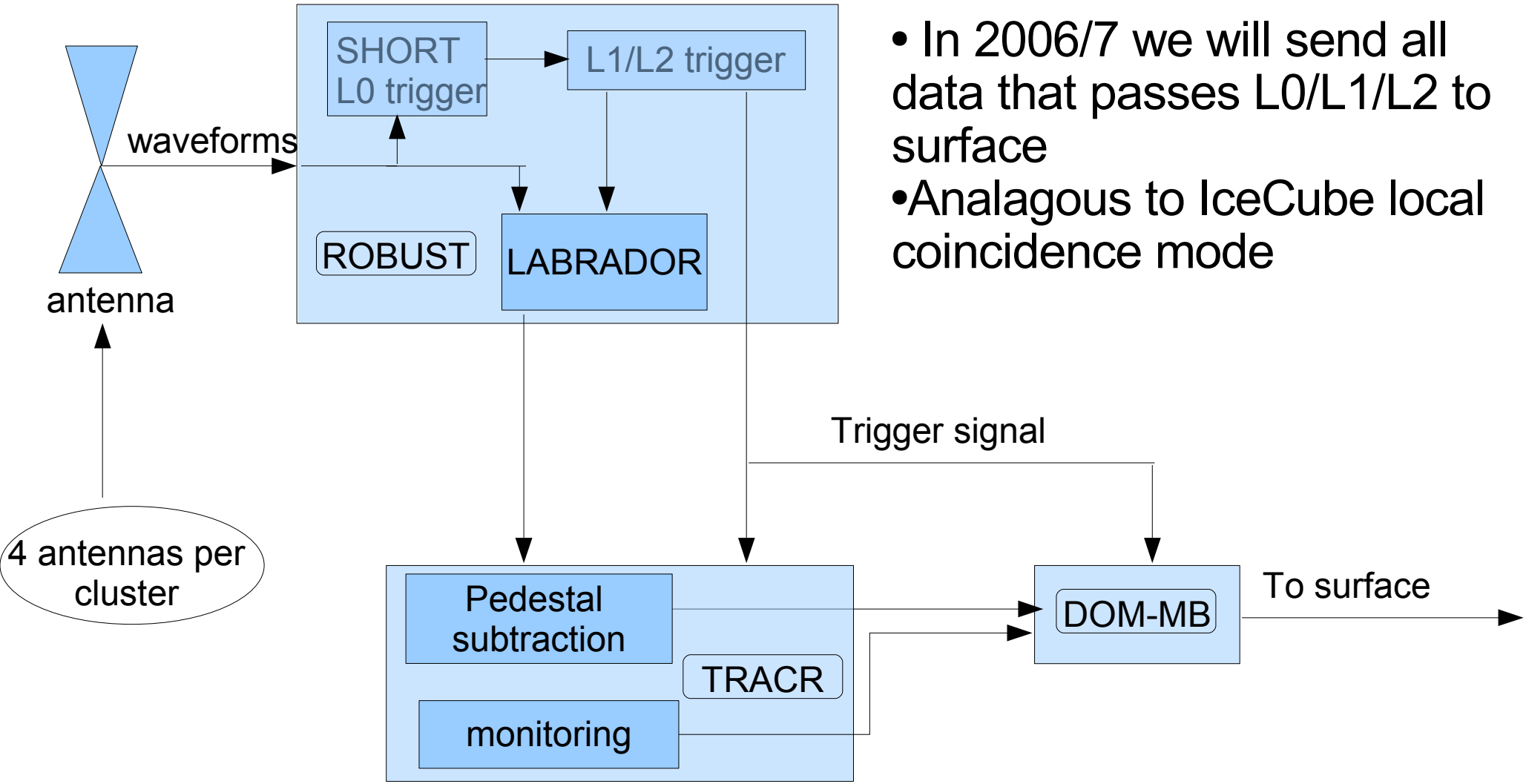
DRM Data Flow



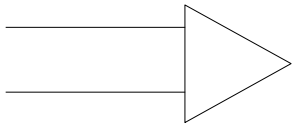
- In 2006/7 we will send all data that passes L0/L1/L2 to surface
- Analagous to IceCube local coincidence mode

L0, L1 and L2 trigger

Bandpass filter

4 bands per antenna

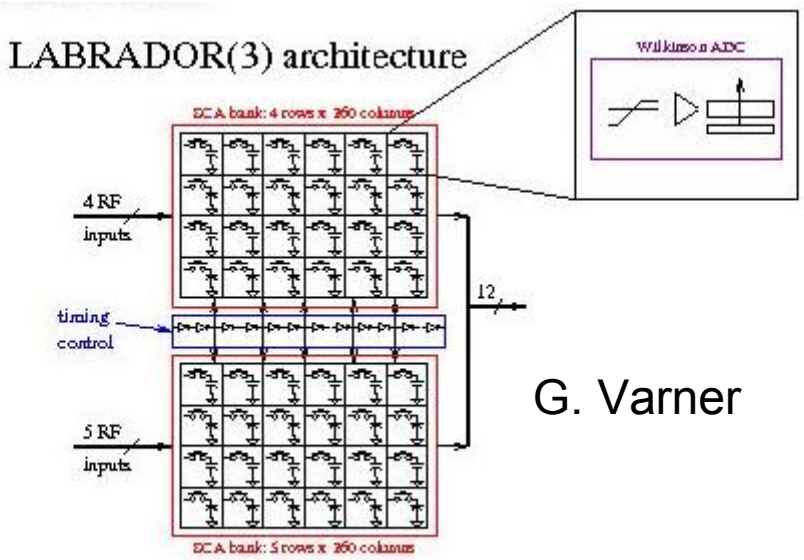
Tunnel diode



discriminator

- High level monitor vetoes on very large RFI signals
- L0 trigger: one antenna crosses discriminator threshold
- L1 trigger: majority trigger of 4 bands in one antenna
- L2 trigger: majority trigger of 4 antennas in the cluster
- Thresholds and multiplicity conditions controlled by the ROBUST FPGA, and will be adjusted in real time so that the final trigger rate is what we want it to be.
- Will also have prescaled data

LABRADOR (3)



G. Varner

- Bandwidth 1.3 GHz
- Triggered digitization
- 2 GSamples/s
- ~120 μs digitization time
- Over 99% livetime at 25 Hz!

- Developed for ANITA/SALSA
- 9 channels
  - 2 per antenna plus timing
- 260 samples/channel
- 12 bits/samples
- Total waveform size 3.5 kB
- Bandwidth on IceCube cable is 90 kB/s
- Trigger rate can be no more than 25 Hz
- Waveform packet will also have timestamps, other info.

TRACR

- 2006/7
  - Waveform transfer to DOM-MB
    - 32 MB buffer = 6 minutes of data
  - Monitoring
    - Singles rates
    - Livetimes
    - Veto rates
    - Pedestals
    - Temperatures
  - Passes provisioning info to ROBUST from DOM-MB
    - Set prescale level, ultrahigh veto level, L0 discriminator levels, L1/L2 coincidence levels

TRACR in the future

- More complex algorithms?
  - TRACR contains Xilinx Virtex2Pro w/ 2 CPU cores
  - One CPU core for data transfer, one for trigger reduction
  - Possible trigger reduction
    - Direction/vertex checking beyond the banding algorithm of L1
    - Use of hardware-accelerated FFT to eliminate narrow-band RFI signals
    - Send waveform data only on request from surface trigger?

The DOM Mainboard

- Mainboard contains Altera Excalibur FPGA
  - "domapp" code runs on Excalibur's CPU core
  - Modify domapp to talk to TRACR across flasherboard interface
    - Transmit information to and from TRACR
    - DOM-MB clock also controls TRACR
      - Calculate timestamp offset
      - Use offset to correlate a given trigger signal with a given TRACR-timestamped waveform packet

DOM Mainboard

- ROBUST trigger signal plugged into PMT input
- Mainboard contains 4 ATWD channels
  - Bin size is 3 ns
  - Normally used to digitize PMT signal with various gains
  - We will use one to digitize the ROBUST trigger
  - DOM-MB timestamp is only to within 25 ns
  - Calculate digitized trigger signal crossing time offline to get a finer timestamp

Iceboot

- DOM mainboard bootloader software environment
- Forth language
- Command line interface (python scripts)
- Runs programs stored in flash memory
- Already used by IceCube for simple DAQ tasks such as collecting monitoring data
- Will probably be used for first year radio DAQ

Radio "Hub"

- Each IceCube string connects to a "DOMHub"
  - One string to one DOMHub
  - PC running Linux in the IceCube counting house
  - Runs "domhubapp" software which communicates with the DOMs
  - Different DAQ modes supported, including Iceboot based DAQ
  - IceCube routinely switches daq modes in real time
    - New FPGA code can be sent from north through hub
- All DRMS will connect to one radio hub in 2006/7
- Further lossless compression and multi-string majority trigger applied on the hub

Conclusions

- Taking advantage of the IceCube model and infrastructure
  - Digitizing in ice
  - FPGA-based trigger system: can be reprogrammed and upgraded as needed, from the north
  - Multi-tiered triggering
  - 99% livetime
- Also taking advantage of ANITA R&D
- Straightforward codeployment with IceCube