1) Motivations for a TRT HWI
2) Overview of the HWI system
3) Comparator Board operation
4) Current installation status
5) Future Logic Box in USA 15
Why have a HWI?

DCS monitoring failed to act during cooling failures in SR1

- 2004: during a beam test
- 2006: In April the detector electronics were allowed to reach 100° for about 12 hours

Review held in July 2006

- Decided the TRT should study/implement a secondary HWI system

Design of HWI starts in July 2006

- Indiana begins working on project in September 2006
- Design reviewed by TRT group in Nov. 2006 and Jan. 2007

TRT Risk Analysis group in February 2007

- HWI is a necessary component to the TRT safety system
- Recommend installation to HWI for TRT commissioning
- A comparator board monitors NTC signals from 1/32 of barrel and endcap on side A or C
- CB can be connected to LV PP2 boards with LEMO cable to locally kill system
  *This is the setup used for commissioning*
- Logic Box in USA15 monitors all CB and can directly kill MARATON supplies
- Zero programmable logic (thresholds set by socketed resistors, trip delay with RC circuit)
Comparator Board Layout

- Barrel NTC connector
- Endcap NTC connector
- Barrel/Endcap NTC trip threshold resistors
- NTC Grounding Modification
- Ethernet cable output to Logic Box
- Power input from PP2 box
- Voltage Regulator
- Local kill LEMO outputs
- Local operation set resistors
- 1st Level Comparators
- 2nd Level Comparators
- Local kill threshold resistors
- Channel Trip LEDs
- Channel Disable switches
Comparator Board Operation

- Comparator board constantly monitors 28 NTC temperatures (8 from barrel, 20 from endcap)
- Hot NTCs go over adjustable threshold (changed with socketed resistor)
- The total number of overthreshold NTCs is summed for the Barrel and Endcap

2 operational modes
- Local: #NTCs overthreshold (adjustable) trip board and kill sent directly to LV PP2 board
- With logic box: #NTCs overthreshold for Barrel/Endcap sent via ethernet cable to logic box
- 80 Comparator boards produced at IU in March 2007 (64 needed + 16 spares) and arrive at CERN on April 18th 2007

- April 20th, power up comparator boards and find large (2V) voltage regulator oscillations. Discover LHC4913 regulator needs extra 22μF at input.

- April 24th, 6 comparator boards tested at PP2 Loc 5&6 A and fail to kill system. Miscommunication led to NTC input cable at CB to be wired wrong. NTC cables are easily modified to fix this.

- May 5th, Second test at PP2 Loc 5&6 and 80% of LV boards killed. Grounding problems are discovered between PP2 and CB.

- End of May, NTC ground is isolated from CB power ground fixing problem.

- June 7th, CERN modified comparator boards tested at PP2 Loc 5&6 A/C side. Test successful and remaining boards sent to IU for modification.

- CB continuously run in PP2 Loc 5&6 A/C, no problems observed

https://twiki.cern.ch/twiki/bin/view/Atlas/TrtHardwareInterlock
So where exactly are these boards?

Each PP2 box has one CB to monitor 8 Barrel NTCs and 20 Endcap NTCs

<table>
<thead>
<tr>
<th>Loc</th>
<th>PP2 Boxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>
Comparator Board Installation

ID Week, July 2nd 2007: TRT HWI
Penwell 9

PP2 box orientation (CB box in red)

- Boards are mounted in aluminum boxes with space for 6 or 8 boards
- Boxes will be labeled like the one shown
- CB box will be screwed onto PP2 box
- Extra cable ties will be wrapped around CB box as extra security to hold boards in

Loc 1A/4C (1C/4A mirror)
Loc 2A (2C mirror)
Loc 3A (3C mirror)
Loc 5&6

Loc 1 = Sector 1
Loc 2 = Sector 3
Loc 3 = Sector 7
Loc 4 = Sector 9
Loc 5&6 = Sector 13
How it really looks

Loc 2
A side

Loc 3
C side

Loc 1
C side

Loc 1
A side

Loc 5&6
A side
1) 12 boards installed in locations 5&6 (both sides)
   - Available for barrel commissioning
   - Currently set to trip at 45°, needs to be changed
   - Running nonstop for 3 weeks, no problems

2) Locations 1,2,3,4 on the A side will be equipped this week (26 boards)

3) Boards will be running in local kill mode
   - Have 32 LEMO cables (12 already in use)
   - Still need 32 cables, 32 T connectors, 32 jumpers

4) Need 10 more boards from Indiana to equip the C side (Shipping to CERN ~ 1 week)

Current Inventory
- Installed 12
- At CERN 42
- At Indiana 25

Planned NTC threshold settings
- Barrel - 52° (1.8 kΩ)
- Endcap - 65° (1.1 kΩ)
Logic Box Overview

Composed of 3 boards that will be mounted as one unit in USA15 by TRT power supplies

- **2 Receiver boards** (A side / C side)
  - Read out number of NTCs over threshold from each CB, determine number of tripped CB

- **Alarm board**
  - Responsible for monitoring number of tripped CB and 8 aux inputs.
  - Also responsible for setting global thresholds for receiver boards.
  - Issues a kill signal if an alarm has been raised longer than a preset delay.

**Requirement for Logic Box to kill power racks**

- The NTCs go above the DCS kill temperature, and the DCS system does not act
- N comparator boards are tripped for X time (where N ~ 1-3 boards, X ~ 15s)
  - The short delay is added to provide immunity to external electronics noise
- Or a signal is sent to one of the Aux inputs (ie. DCS watchdog)
- When issued, the kill signal latches a relay to shut off HV/LV racks (latch reset by pushbutton)
The Comparator Tree
(or where the heck do all these thresholds come from)

Threshold for individual NTCs going over temperature
Individually adjustable for each board

Comparator Board (1)
<table>
<thead>
<tr>
<th>Barrel NTCs</th>
<th>Endcap NTCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>x8</td>
<td>x20</td>
</tr>
</tbody>
</table>

Comparator Board (2)
<table>
<thead>
<tr>
<th>Barrel NTCs</th>
<th>Endcap NTCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>x8</td>
<td>x20</td>
</tr>
</tbody>
</table>

Comparator Board (64)
<table>
<thead>
<tr>
<th>Barrel NTCs</th>
<th>Endcap NTCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>x8</td>
<td>x20</td>
</tr>
</tbody>
</table>

Thresholds for NTCs on CB overthreshold for CB to trip
Global Threshold

Receiver Board (A side)
<table>
<thead>
<tr>
<th>BR_NT_C_THRESH (1)</th>
<th>EC_NT_C_THRESH (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>x8</td>
<td>x8</td>
</tr>
</tbody>
</table>

Receiver Board (C side)
<table>
<thead>
<tr>
<th>BR_NT_C_THRESH (64)</th>
<th>EC_NT_C_THRESH (64)</th>
</tr>
</thead>
<tbody>
<tr>
<td>x8</td>
<td>x8</td>
</tr>
</tbody>
</table>

Alarm Board
<table>
<thead>
<tr>
<th>KILL</th>
</tr>
</thead>
</table>

Threshold for #CB tripped and #AUX signals

Via Ethernet Cables
Disabling the Interlock

Sometimes is a good idea to have a system disable
- Interlock is designed to run constantly as a backup to DCS
- If any connection fails it will be interpreted as a trip
  Bad NTC channel = overthreshold, Disconnected CB = tripped board
- While running we might not be able to easily fix a broken connection/component

Comparator Boards
- Individual NTC channels can be disabled with a DIP switch, already looking out for broken NTCs
- Once installed and running, limited access to switches

Receiver Boards
- Toggle switches allow the Barrel and Endcap sum signals from a CB to be independently disabled
- Necessary if connection to CB gets broken, or a group of NTCs fail while ATLAS is running

Alarm Board
- Set of DIP switches allows AUX inputs to be independently disabled
- Toggle switches allow AUX_sum, BR_sum, and EC_sum to be disabled from issuing an ALARM
- Pushbutton disables ENTIRE interlock for an adjustable amount of time (~5 min) during situations like HV/LV powerup. There’s also a hidden toggle switch on the alarm board if the interlock needs to be shut down for an extended period of time.
Comparator Boards
- Each board has 28 LEDs, one light up when a NTC channel goes over threshold
- In local mode, 2 LEDs show if Barrel or Endcap has been tripped

Receiver Board
- Each channel has a stack of three LEDs displaying channel status

Alarm Board

On front of board
- 8 Aux inputs have single LED (active/inactive)
- 3 sum signals have sets of 3 LEDs like receiver board
- Blinking red LEDs when an alarm is raised, alarm over delay, and kill

External
- Yellow if system disabled,
- Flashing Red + Buzz 1 if Alarm
- Flashing Red + Buzz 2 if Kill

Easy to check and hard to miss!
There are 5 ELMB boards in the logic box
- 2 ELMBs on the two receiver boards, and one on the alarm board
- Internally daisy chained together and connected to a CAN DB9 connector in black panel
- Power interrupt button for ELMBs to reset them if they get into an unrecoverable state

Signals monitored on Receiver Board
- 1 ELMB monitors the 64 channels of Barrel/Endcap data from the 32 CB
- 1 ELMB monitors the status of the 64 enable/disable switches

Signals Monitored on Alarm Board
- Status of the disable switches (BR_enable, EC_enable, AUX_enable, Disable)
- All the thresholds for the Receiver and Alarm board
- System status (BR_sum, EC_sum, AUX_sum, Alarm, Kill, Delay)
- 8 LEMO inputs optically isolated to avoid potential grounding problems
  
  PC3Q510NIP0F contains a IRED optically coupled to a phototransistor

- Use standard TTC logic, inputs triggered when pulled low

- Useful if we want to trip the HV/LV supplies with an external signal (DCS watchdog)
Acknowledgments

Indiana HWI gang
- Peter Cwetanski
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- Paul Smith

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- Jack Fowler

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- Zbyszek Hajduk - Elzbieta Banas - Peter Lichard
- Jolanta Olszowska - Bartek Kisielewski - Anatoli Romaniouk
Alarm Board Schematic
Receiver Board Schematic
Comparator Board Schematic
Original Grounding Scheme (pre modification)
Photos of Ground Modification on CB
J?\n\nRJ45

UNPLUG_THRESH

BR_CHAN

CHANNEL

VIN+
VIN-
UNPLUG_THRESH
MULT_THRESH
VRCV
ENABLE
SUM
BR_VRCV
BR_ENABLE
BR_SUM

EC_CHAN

CHANNEL

VIN+
VIN-
UNPLUG_THRESH
MULT_THRESH
VRCV
ENABLE
SUM
EC_VRCV
EC_ENABLE
EC_SUM

BR_MULT_THRESH

EC_MULT_THRESH

Indiana University
Physics Department
ATLAS TRT Hardware Interlock
Logic Box
Compare Board Receiver
Paul Smith  June, 2007
ptsmith@indiana.edu
Original Grounding Scheme (pre CB modification)

Cable color key:
- Red: Supply Power
- Brown: Supply Ground
- Green: Supply Power/Ground daisy chain
- Blue: Signal cable with ground connection

Comparator board ties all grounds together

PP2 panel daisy chain (high voltage drop across)

Other Grounds in the system but not involved:
- LV bulk power has its own ground which is kept separate from the PP2 panel ground on the LV board.
- The TTC has a digital ground which is kept separate from the PP2 panel ground on the TTC board.

NTC data:
- Using 0.33mm diameter ribbon cable
- 600-700 mOhm resistance

Comparador board daisy chain

LV Kill signals:
- Using LEMO cable
Ground mod to CB

Two ground vias drilled out
NTC ground from TTC isolated from CB power ground

NTC threshold resistors connected to isolated NTC ground

Boards moded at IU drilled out ground plane around this socket