63U ATCA rack – cooling capabilities

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Rack configuration

- 3x 2U heat exchangers with max. cooling capacity of **7.9 kW** each
- 3x ATCA shelves – 2x CERN standard Schroff unit + 1x ASIS
- Water chiller: max. cooling capacity **25 kW**

- 3x different set of load blades (LB):
  - 14x ASIS LB, max power dissipation: **600W** only front
  - 14x New type Comtel LB, max power dissipation: **800W** only front
  - 14x Old type Comtel LB, max power dissipation: **50W** RTM+ **300W** front

**Important note:** The power dissipation on the load blades is spread equally on the whole board

Water piping are insulated for cold water tests
Hardware used and cooling principal

• 2x **CERN standard Schroff ATCA crate** – each equipped with 2 fan trays (1 top and 1 bottom)

• 1x **NOT CERN standard ASIS ATCA crate** – equipped with 3 fan trays on the top and one on the bottom

• Different LB sets => different cooling efficiency:
  - **ASIS LB** = a lot of heat sinks => higher air resistance => **better cooling efficiency**
  - **Old Comtel LB** = no heat sinks => low air resistance => **high temperature peaks on axis of the fans**
  - **New Comtel LB** = not equipped with any sensors => **no readout**

**Important note:** To prolong the life time of the electrical equipment installed in the ATCA shelves, maximum target temperature on boards is **50°C**.
Noise reduction: soundproofing and impact on cooling

ATCA fans working at max speed → Over 100 [dB(A)]! -> needs soundproofing

Soundproofing material installed in the air corridors reduces its width from 65 [mm] to 37 [mm] – **impact on cooling?**

<table>
<thead>
<tr>
<th>Noise values (52U)</th>
<th>Pos. 1 Door open [dB(A)]</th>
<th>Pos. 1 Door closed [dB(A)]</th>
<th>Pos. 2 [dB(A)]</th>
<th>Av. max T ASIS [°C]</th>
<th>Av. max T Comtel [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without insulation</td>
<td>102.8</td>
<td>90</td>
<td>87.5</td>
<td>49.2</td>
<td>53.1</td>
</tr>
<tr>
<td>With insulation</td>
<td>86.3</td>
<td>84</td>
<td>51.8</td>
<td>49.4</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-3.7</td>
<td>-3.5</td>
<td>2.6</td>
<td>-3.7</td>
<td></td>
</tr>
</tbody>
</table>

The av. max. T is increased by 2.6K, which is not a big price to pay for reducing the noise by 3.7 [dB(A)] on the level of the rack.

**Important note:** All the results showed for 63U rack are taken from the tests carried out in **soundproofed** rack.
Environmental conditions and chiller operations – SR1 Laser Room

Parameters measured and calculated during the tests:

- \(\Delta T\) – temperature difference between water inlet and outlet
- \(Q_r\) – heat removed from the rack
- \(P\) – % of total power removed

Controlled ambient temperature 19C.

\(T_{\text{water}} < 15.5-16^\circ\text{C}\) Mixed water T in USA15

Starting of the setup
Temperatures in the old Comtel are less homogeneous in push-pull configuration but average T decreasing in only pull configuration.

**Test results with 400W/blade**

### With Bottom fans

- **14x450W New Comtel LB (ASIS)**
- **14x(300+50)W Old Comtel LB (Schroff)**
- **14x400W ASIS LB (Schroff)**

#### Flow
- Flow: 2.4 m³/h
- $\Delta T = 7^\circ C$
- $Q_r = 19.5$ kW
- $P = 83%$

#### Average max T

<table>
<thead>
<tr>
<th></th>
<th>ASIS [°C]</th>
<th>Comtel [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>54.8</td>
<td>58.6</td>
</tr>
</tbody>
</table>

#### Total power in the rack
- 23.4 kW

### Without Bottom fans

- **14x450W New Comtel LB (ASIS)**
- **14x(300+50)W Old Comtel LB (Schroff)**
- **14x400W ASIS LB (Schroff)**

#### Flow
- Flow: 2.4 m³/h
- $\Delta T = 6^\circ C$
- $Q_r = 16.7$ kW
- $P = 81%$

#### Average max T

<table>
<thead>
<tr>
<th></th>
<th>ASIS [°C]</th>
<th>Comtel [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>59.7</td>
<td>56.8</td>
</tr>
</tbody>
</table>

#### Total power in the rack
- 20.6 kW
Test results with 350W/blade

**With Bottom fans**
- 14x350W New Comtel LB (ASIS)
- 14x(300+50)W Old Comtel LB (Schroff)
- 14x350W ASIS LB (Schroff)

**Without Bottom fans**
- 14x350W New Comtel LB (ASIS)
- 14x(300+50)W Old Comtel LB (Schroff)
- 14x350W ASIS LB (Schroff)

**Total power in the rack**
- With Bottom fans: 21.3 kW
- Without Bottom fans: 18.4 kW

**Average max T**

<table>
<thead>
<tr>
<th></th>
<th>ASIS [°C]</th>
<th>Comtel [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>With fans</td>
<td>50.5</td>
<td>57.6</td>
</tr>
<tr>
<td>Without fans</td>
<td>53.6</td>
<td>54.9</td>
</tr>
</tbody>
</table>

**Flow**
- Flow 2.4 m³/h
- \( \Delta T = 6.4^\circ C \)
- \( Q_r = 17.9\) kW
- \( P = 84\% \)

**Total power in the rack**
- With Bottom fans: 21.3 kW
- Without Bottom fans: 18.4 kW

**Flow**
- Flow 2.4 m³/h
- \( \Delta T = 5.4^\circ C \)
- \( Q_r = 15.1\) kW
- \( P = 82\% \)

In push-pull configuration the ASIS blades can stay within the target of 50°C.
With RTM vs without RTM

**With Bottom fans**
14x350W ASIS LB (Schroff)
14x(300+50)W Old Comtel LB (Schroff)
14x350W New Comtel LB (ASIS)

**With Bottom fans**
14x350W ASIS LB (Schroff)
14x(300+0)W Old Comtel LB (Schroff)
14x350W New Comtel LB (ASIS)

<table>
<thead>
<tr>
<th></th>
<th>ASIS °C</th>
<th>Comtel °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average max T</td>
<td>49.6</td>
<td>58.9</td>
</tr>
</tbody>
</table>

**Total power in the rack**
21.2 kW

Flow 2.4 m³/h
ΔT = 6.4°C
Q_r = 17.8 kW
P = 84%

**Total power in the rack**
20.5 kW

Flow 2.4 m³/h
ΔT = 6.1°C
Q_r = 17 kW
P = 83%

The additional 50W on the RTM has negligible influence on cooling performance of the front of the board.
ASIS shelf vs Schroff shelf

All the tests carried out with top and bottom fans at max. speed

Total power in the rack
23.4 kW

Flow 2.4 m³/h
\[ \Delta T = 7^\circ C \]
\[ Q_r = 19.5 \text{ kW} \]
\[ P = 83\% \]

The overall cooling efficiency stays the same.
In the same power configuration changing the type of crate from Schroff to ASIS, reduce the av. max T on the concerned blades by ~1.5°C for higher air resistive blades and by ~5.1°C for less resistive ones.
Test setup availability

• The ATCA test setup is available for testing the real boards prototypes
• To minimalize the impact of different air resistance between the real boards and the load blades it is advised to test the batches of minimum 3 pieces.

New Comtel LB 13x200W+Real board up to ~23W per FPGA

Thiago Costa de Paiva from University of Massachusetts Amherst results.
ATCA cooling - tests conclusions

- Design target for boards in 63U ATCA crate is a maximum of 350W + 50W on RTM, during the design necessary margins should be taken into account

- Since the air resistance and proper heat removal management (heat sinks) has a very big impact on the cooling performance of the ATCA boards— it is **mandatory** to test prototypes at the ATLAS SR1 test facility (for those who foresee to come close to 350W+50W requirement)

- The heat removed from the rack, via the water cooling was measured to be at 80-85% of the total measured power delivered, the rest goes into the environment and has to be handled by the air conditioning (HVAC) (!)

- The test system is ready for prototypes tests
ATCA cooling – future development

• Pentair, the company that supplies CERN with Schroff shelves and heat exchangers, was asked to investigate possibility of integrating microchannel HX into the 63U ATCA rack to improve the rack cooling efficiency.

• Looking into possibility of adding the 4th heat exchanger in the test facility

• ASIS shelves showed better cooling performance than the Schroff ones – to be reconsidered for the long term? More tests to be carried out soon.

• Due to the fact that the amount of noise generated by the ATCA shelves is extremely high, the soundproofing on the level of the rack is necessary to reduce the noise as much as possible – there is also consideration of separating the part of the counting rooms with the ATCA racks by the sound insulating wall.
VME + ATCA tests

To evaluate a possibility of mixing two different architectures – VME and ATCA, test campaign has been launched focusing on assessment of possible aftermath of such configuration.

<table>
<thead>
<tr>
<th>Fan Model</th>
<th>Crate</th>
<th>Number of fans per crate</th>
<th>Max. Power per fan [W]</th>
<th>Max. RPM per fan [min⁻¹]</th>
<th>Max. Air Flow total [m³/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>9HV124891G001</td>
<td>ASIS</td>
<td>15</td>
<td>145</td>
<td>11500</td>
<td>4482</td>
</tr>
<tr>
<td>UEL6020 EX</td>
<td>VME</td>
<td>3</td>
<td>8</td>
<td>3600</td>
<td>540</td>
</tr>
<tr>
<td>4114N/2H8P</td>
<td>Schroff</td>
<td>12</td>
<td>120</td>
<td>11000</td>
<td>3420</td>
</tr>
</tbody>
</table>

Velocity sensors are installed above the VME crate and below the ATCA crate.

Power Configuration:
Top: 14x Old Comtel LB – 350[W] (ASIS)
Middle: 14x ASIS LB – 400[W] (Schroff)
Bottom: 13x VME board – 0[W] (VME)

Tests were carried out with 3 different speeds of VME Fans:
- 1200RPM
- 2400RPM
- 3600RPM
Test results – Top position – 3600RPM

Total power in the rack: 12.5 kW

Flow: 3.0 m³/h
ΔT water = 3.1 °C
\( Q_r = 10.9 \text{ kW} \)
Cooling efficiency = 87%

Average max T

<table>
<thead>
<tr>
<th>ASIS [°C]</th>
<th>Comtel [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>48.6</td>
<td>48.4</td>
</tr>
</tbody>
</table>
Test results – Top position – 2400RPM

No significant impact on the blades temperatures with lower VME fans speed

Average max T

- ASIS [°C] 48.5
- Comtel [°C] 48.8
Velocity sensors – New location - Test results

Velocity sensors installed between ATCA shelves didn’t show any significant variation changing the speed of VME fans

VME fans on 3600 rpm + turbine unit airflow = ~0.6 m/s
VME+ATCA conclusions

• The VME crate has negligible impact on the overall rack airflow and cooling efficiency – yet this solution must be treated as an exception.

• As the VME fans can provide up to 0.6 m/s, running them in almost 10 times higher airflow can damage them

• Long term impact of the VME crate on the ATCA fans life span is unknown, as from the ATCA crate point of view the VME is additional air resistance that has to be coped with
Backup slides
High power test results 416W/blade

**With Bottom fans**
- 14x450W New Comtel LB (ASIS)
- 14x(300+50)W Old Comtel LB (Schroff)
- 14x450W ASIS LB (Schroff)

**Without Bottom fans**
- 14x450W New Comtel LB (ASIS)
- 14x(300+50)W Old Comtel LB (Schroff)
- 14x450W ASIS LB (Schroff)

**Average max T**

<table>
<thead>
<tr>
<th></th>
<th>ASIS [°C]</th>
<th>Comtel [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Bottom</td>
<td>57.8</td>
<td>59.9</td>
</tr>
<tr>
<td>Without Bottom</td>
<td>64.3</td>
<td>57.4</td>
</tr>
</tbody>
</table>

**Total power in the rack**

- **With Bottom fans**: 24.3 kW
- **Without Bottom fans**: 21.4 kW

**Flow**

- 2.4 m³/h

**ΔT**

- With Bottom: 7.1°C
- Without Bottom: 6.2°C

**Q_r**

- With Bottom: 19.8 kW
- Without Bottom: 17.3 kW

**P**

- With Bottom: 82%
- Without Bottom: 81%

Max average power available 416W, due to the old Comtel LB limitation of 350W per blade.
52U vs 63U

The test was carried out in following power configuration:

**52U (not soundproofed):**
- 14x350 [W] on old type Comtel LB (top)
- 14x400 [W] on ASIS LB (bot)

**63U (soundproofed):**
- 14x350 [W] on old type Comtel LB (top)
- 14x400 [W] on new type Comtel LB (mid)
- 14x400 [W] on ASIS LB (bot)

Comparison of the temperatures on the same set of blades installed in the same crate (ASIS).

Soundproofed vs not soundproofed – why? The 63U rack was soundproofed from the beginning.
With RTM vs without RTM

**With Bottom fans**
- 14x350W ASIS LB (Schroff)
- 14x(250+50)W Old Comtel LB (Schroff)
- 14x350W New Comtel LB (ASIS)

**Average max T**

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<thead>
<tr>
<th></th>
<th>ASIS [°C]</th>
<th>Comtel [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>s13</td>
<td>49.6</td>
<td>54.5</td>
</tr>
<tr>
<td>s11</td>
<td>49.5</td>
<td>54.2</td>
</tr>
<tr>
<td>s9</td>
<td>49.7</td>
<td>54.3</td>
</tr>
<tr>
<td>s7</td>
<td>49.8</td>
<td>54.4</td>
</tr>
<tr>
<td>s5</td>
<td>49.9</td>
<td>54.5</td>
</tr>
<tr>
<td>s3</td>
<td>50.0</td>
<td>54.6</td>
</tr>
<tr>
<td>s1</td>
<td>50.1</td>
<td>54.7</td>
</tr>
<tr>
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<td>49.7</td>
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<tr>
<td>s13</td>
<td>49.6</td>
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</tr>
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</table>

- Old Comtel
- ASIS LB
- 50°C - Target maximum temperature

**Total power the rack**
- 20.5 kW

**Total power in the rack**
- 19.8 kW

**Flow 2.4 m³/h**
- $\Delta T = 6.2°C$
- $Q_r = 17.3\ kW$
- $P = 84\%$

**Flow 2.4 m³/h**
- $\Delta T = 6°C$
- $Q_r = 16.7\ kW$
- $P = 84\%$

Additional 50W on RTM has negligible impact on other shelves cooling