Topics to be considered

1. Progress on project tasks

2. Development of data centre test facility
   - Overall aims
   - Main features
   - Options for air flow management
   - Equipment needed
   - Instrumentation and sensors
   - Evaluation of recovered heat

3. Planned experiments for data centre test facility

4. Future work
<table>
<thead>
<tr>
<th>Task</th>
<th>Duration</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with Robert Tozer to finalise roadmap report</td>
<td>May-June 2015</td>
<td>New section on use of heat pumps for upgrading waste heat incorporated. RT is applying alternative method for classifying cooling technologies</td>
</tr>
<tr>
<td>Publish journal paper on waste heat recovery from data centres</td>
<td>May-June 2015</td>
<td>Paper submitted to ATE. Reviewers comments currently being addressed.</td>
</tr>
<tr>
<td>Design and construction of data centre test facility</td>
<td>May-Dec 2015</td>
<td>Currently underway. Progress to be reported below.</td>
</tr>
</tbody>
</table>
Development of data centre test facility

Overall aims:

1. Construct a test facility to simulate a conventional server rack producing 5-10 kW of heat
2. Apply a range of thermal management approaches i.e. cooling methods and waste heat recovery approaches
3. Evaluate the quantity and quality of waste heat recovered in each case
4. Estimate the potential energy, carbon and cost savings available

Schematic of remote air cooled data centre with waste heat recovery
Typical conventional data centre – main features

1. 42U racks – dimensions 0.6 m (w) x 1.07 m (d) x 2.0 m (h)
2. 42 x 1U servers or a combination of 1U up to 7U servers
3. Remote air cooling using CRAC/DX or CRAH/chilled water system
4. Reject waste heat directly to air or via chilled water to air
5. Hot aisle/cold aisle arrangement
6. Raised floor/plenum for delivery of cold air
7. May use cold air or hot air containment
8. CRAC condenser may be inside or outside data centre room
Planned LSBU test facility:

1. Single 42U (42 x 1U) IT server rack in a room of dimensions 3.8 x 6.4 x 2.7 m
2. Remote air cooled using CRAC/DX system
3. Waste heat recovery system using water cooled CRAC condenser to collect rejected heat
4. Upgrade of waste heat removed by CRAC to produce water at 70°C
5. Cold air or hot air containment
Options for air flow management

- Underfloor (plenum) cold air supply
- Cold air containment (using 2\textsuperscript{nd} plenum)
- Cold air supply above floor
- Cold air containment using duct and plenum
• Cold air supply above floor

• Cold air containment using expanding duct

• Cold air supply above floor (uncontained)

• Hot air containment using plenum and duct
Details of CRAC/heat recovery unit

- Typical hot air return temperature 30-35°C
- Server supply air temperature 20-25°C
- CRAC/heat pump will be used to boost temperatures to 85°C and then transfer to water
- Water supply/return temperatures 60/70°C or 50/70°C
- Use R134a
- Suitable components identified
Overall design for test facility

- Water will be pumped to a dry cooler outside the laboratory
- Heat will be rejected to ambient air
- However, heat carried in water could be reused
- Heat flow meter will be used to quantify the recovered heat

(Note: initially cold air containment will be used in data centre room)
## Data centre test facility – equipment needed

<table>
<thead>
<tr>
<th>Equipment needed</th>
<th>Source identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data centre room (minimum height 2.7 m)</td>
<td>LSBU environmental chamber</td>
</tr>
<tr>
<td>42U IT server</td>
<td>Recycled server(s) from co-location operator</td>
</tr>
<tr>
<td>CRAC compressor</td>
<td>Bitzer</td>
</tr>
<tr>
<td>CRAC water cooled condenser</td>
<td>Swep</td>
</tr>
<tr>
<td>CRAC evaporator</td>
<td>Lu-ve</td>
</tr>
<tr>
<td>Control instrumentation</td>
<td>TBC</td>
</tr>
<tr>
<td>Water pump</td>
<td>TBC</td>
</tr>
<tr>
<td>Dry cooler</td>
<td>TBC</td>
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</tbody>
</table>
Sensor locations:
1. Temperatures of air at inlet, outlet and inside of server rack for top, middle and bottom servers
2. Humidity measurement at inlet to IT server rack and within data centre room
3. Air off temperature for evaporator and hot air return temperature at inlet to CRAC
4. Air temperatures at a range of locations within data centre room
5. Temperature of water at inlet and outlet of heat pump condenser
6. Ultrasonic heat flow meter used to measure heat flow out of heat recovery condenser and heat flow into condenser (difference = heat recovered)
7. Electricity power meter used to monitor power draw by IT servers (IT load)
8. Electricity use by CRAC compressor, evaporator fan and water pump also monitored
9. Pressure sensors used to determine pressure in cold air duct and in room
Evaluation of recovered heat

- The effectiveness of energy recovery from the data centre may be characterised as:

Energy Reuse Effectiveness (ERE):

\[
ERE = \frac{\text{Total energy (CRAC/Heatpump + Fans + Water pump + IT server input - Reused (recovered) heat)}}{\text{IT server input energy}}
\]

or Energy Reuse Factor (ERF):

\[
ERF = \frac{\text{Reused (recovered) heat energy}}{\text{Total energy}}
\]

- The overall power usage effectiveness of the data centre (PUE) may be determined as:

\[
PUE = \frac{\text{Total energy (CRAC/Heatpump + Fans + Water pump + IT server input))}}{\text{IT server input energy}}
\]

- Other measurements of temperatures, humidity, heat energy and flow rates will provide further characterisation of the system
It is proposed that the test rig will be used to evaluate:

1. IT input loads e.g. 5% of maximum power capacity, up to 100%

2. CRAC cold air temperatures (and flow rates) and hence IT server rack inlet temperatures e.g. 15 to 27°C

3. Duct fan speed and hot air return temperature

4. CRAC evaporator temperature e.g. 5-17°C

5. CRAC condenser temperature e.g. 60-90°C

6. CRAC condenser water inlet/outlet temperature and flow rate (i.e. heat recovery conditions) – to be determined.
## Future work

<table>
<thead>
<tr>
<th>Activities</th>
<th>Duration</th>
<th>Deliverables</th>
<th>Due date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Publish roadmap report</td>
<td>May- June 2015</td>
<td>Roadmap report</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Aug 2015</td>
</tr>
<tr>
<td>Design data centre/heat recovery test facility</td>
<td>May-July 2015</td>
<td>Completed plan</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Aug 2015</td>
</tr>
<tr>
<td>Assemble equipment and install/ connect</td>
<td>Aug-Sep 2015</td>
<td>Completed facility</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Oct 2015</td>
</tr>
<tr>
<td>Install monitoring instrumentation and sensors</td>
<td>Oct 2015</td>
<td>Completed monitoring system</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Nov 2015</td>
</tr>
<tr>
<td>Commission and test</td>
<td>Nov-Dec 2015</td>
<td>Operational facility Report on test facility construction</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Dec 2015</td>
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<td></td>
<td></td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Feb 2016</td>
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