Workspace
Technology Limited

Technology Paper 001

Server Room Cooling Issues & Solutions Explained

Workspace Technology Limited
Technology House, PO BOX 11578, Sutton Coldfield West Midlands B72 1ZB
Telephone: 0121 354 4894 Facsimile: 0121 354 6447
www.workspace-technology.com **email: sales@workspace-technology.com**

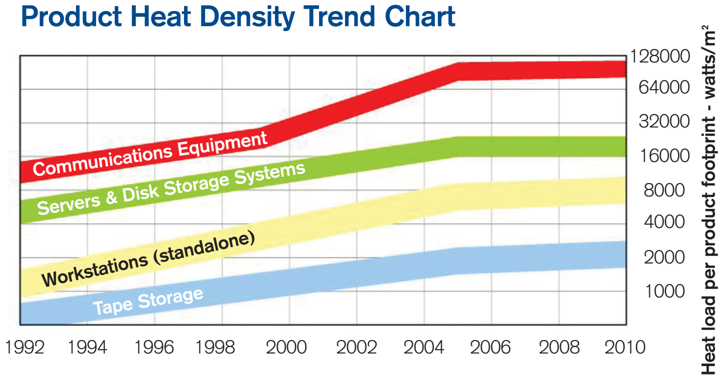
Published in March 2007

Rising Server Room Temperatures

Blade servers, communications switches and other electronics are being packed into tighter and tighter spaces. Computing capacity that once filled an entire room is now contained in a single rack creating extreme power and heat densities.

This technology paper is intended to provide a summary of the current issues and provides an overview of the various methods that can be employed to provide effective solutions for data centre and server room cooling.

Product Heat Density Trend Chart



Server Room Trends

Over the past 40 years, the Information Technology industry has seen a geometric decrease in the floor space required to achieve a constant quantity of computing and storage capability. While the floor space required for a fixed level of computing work has shrunk (technology compaction), the energy efficiency of equipment has not dropped at the same rate. As a result the density of power consumed and the heat dissipated within the footprint of communication and computer hardware products has increased significantly. Another trend is the cost of the computing hardware to accomplish a task has been dropping over the same forty year period while the power consumed by the hardware in the same products footprint has climbed continuously. The result is the watts of imbedded power consumed per £1000 of I.T hardware spending has risen steadily. This means for a constant level of annual IT spending, power consumption in the same product footprint will go up and density will rise.

A common misconception among IT users is that technology compaction is making power consumption and cooling issues almost irrelevant, because new generations of products will continue to require less space. This view, however assumes a constant level of processing activity. However the total amount of processing and storage capability being sold is rising rapidly, mostly because falling prices make new software applications feasible in situations where previously they were not economically viable.

If this voracious growth in applications were not occurring, computer manufacturers would now be experiencing a decline in product volume and related sales revenue.

IT users have realized that servers can be vertically racked (dense packing) to conserve floor space. The resulting power consumption and heat densities that can be created are almost unimaginable. Trends are moving “cabinet footprint” heat densities from 3Kw to 10Kw and even 30-50Kw within a single cabinet footprint.

Using existing methods to provide sufficient cooling to supply one such rack is not particularly difficult, but supplying reliable cooling to multiple racks in a densely packed area requires a totally different approach. As density increases, cooling systems which historically have been “loosely coupled” in the sense that malfunctions and failures could occur without affecting IT performance will become “tightly coupled” and require uninterruptible cooling.

This technology paper further reviews options that can be deployed to assist in cooling of high density server technology.

Comparison Table

	Required Attributes	Mission Critical Air Conditioning Systems	Typical Comfort Air Conditioning Systems
Design Considerations for any Computer Room Environment	High sensible heat ratio to provide high cooling capacity/ minimum dehumidification	Computer environments produce high heat and no humidification	People produce an equal amount of heat and humidity
	High efficiency air filtration	Typical MERV rating of 5	Minimum MERV rating of 8
	Humidity Control	Integral with control systems	Typically an add on system with separate controls
	Year Round Operation	Positive operation with outside temperatures as low as -10°C	Typically used May to October
Additional Design Considerations required for high density environments	High density loads require more room air changes	1 to 2 per minute at 1Kw/m^2	3-4 per hour
	More tons of cooling per m^2	One ton of cooling per 1 to 6 m^2	One ton of cooling per 20 to 40 m^2
	Control staging	Fast acting, multiple cooling stages maintain tight control	Slow response systems, typically only on/off control

Mission Critical Cooling vs. Comfort Cooling

One area of importance to highlight before we explore what critical cooling solutions are available is the difference between, comfort and critical cooling systems.

Ordinary building air conditioning and heating systems are designed to keep people comfortable. In most cases, this is done 8-12 hours each day, five days a week and only during the warmest summer months. These units are simply not built to handle the 24 hour a day operation associated with computer rooms and communications equipment.

Mission critical cooling systems are designed to run the same hours as your network – continuously, year in year out, 24 hours a day. Computers and other sensitive electronics require a system that provides stringent humidity control to meet equipment specifications and air filtration designed to keep airborne particles from causing problems.

The biggest problem with ordinary air conditioning systems is they are designed for the comfort of people and not the protection of computer based electronic equipment. Unlike people, computers generate dry or sensible heat, but not humidity.

With a large percentage of there total capacity devoted to the removal of moisture, comfort systems can lower room humidity far below acceptable standards for electronic equipment and they have no provision for adding moisture. To correct this situation, precision air conditioning systems typically have a high ratio of sensible to total cooling capacity to remove heat from the air. This allows for a much lower operating cost since the type of cooling is matched to the load. These units also use integrated humidification systems to provide the necessary level of moisture control.

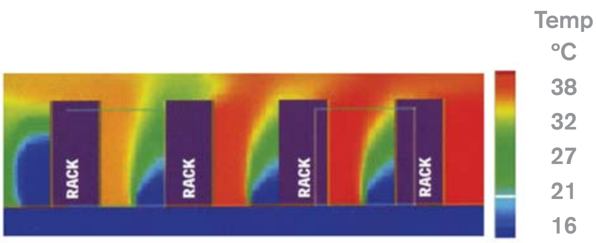
Very often comfort cooling is deployed within the critical space as the initial capitol costs are cheaper, or there is limited or no understanding of technology differences.

Whilst comfort cooling systems may be adequate for small wiring closets and small communications and server rooms, they are a false ecnonomy for medium to large server rooms. The system will not only be inefficient leading to increased energy and carbon emissions but will prove to be unreliable and will not cope with increasing cooling demands of new technology.

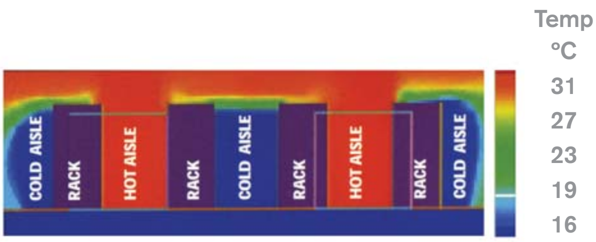
Hot Spots

Compounding the problem, higher heat loads may not be evenly distributed throughout the rooms. Sometimes, power densities can grow to thousands of Watts per square metre, creating localised "hot spots" of extreme heat. These hot spots are generated from a congregation of high density equipment.

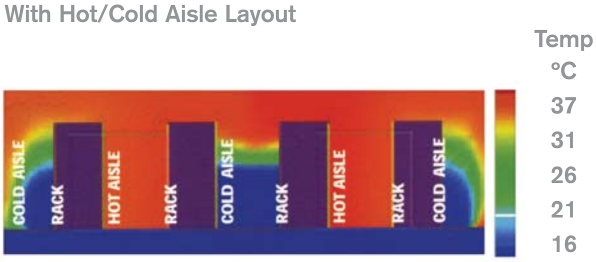
Hot spots can be mitigated by using a number of low cost techniques. Distribution of high density equipment dissipates the load throughout the room. Load sharing is another method to mitigate the effect of hot spots. Installing high density equipment between low density cabinets enables the high density servers to share some of the cooling capacity from neighbouring cabinets. Distribution and load sharing techniques will work where there are a limited number of high density loads. However as the volume of these loads increases supplemental cooling will be required.



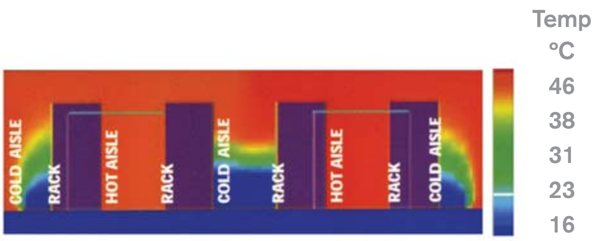
Heat Load = 3 k W Per Rack
Without Hot/Cold Aisle Layout



Heat Load = 3 k W Per Rack
With Hot/Cold Aisle Layout



Heat Load = 6 k W Per Rack
With Hot/Cold Aisle Layout



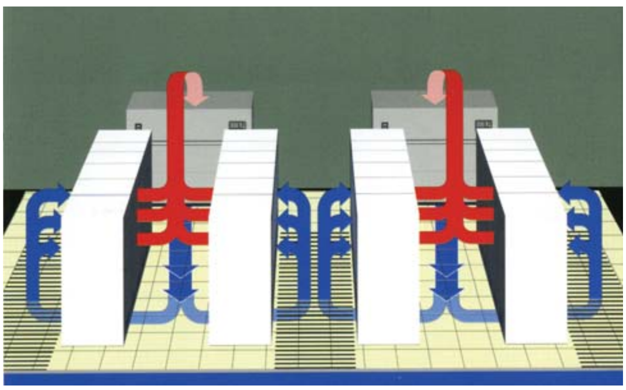
Heat Load = 10 k W Per Rack
With Hot/Cold Aisle Layout

Hot & Cold Aisle Configuration Limitations

A common way to improve performance of existing raised floor cooling applications has been the "hot aisle / cold aisle" approach. In this configuration, rows of equipment racks are arranged in alternating "hot" and "cold" aisles. Only cold aisles have perforated floor tiles that allow cool air to come up from under the raised floor.

As can be seen from computational fluid dynamics profiles the implementation of a hot and cold aisle arrangement improves airflow over the none hot and cold aisles arrangement shown at the top.

However as the heat density increases the effectiveness of the solution decreases preventing effective cooling for servers and equipment at the top of the server rack. The use of the hot and cold aisle approach alone will only support average loads of up to 3Kw per cabinet. After this level additional point cooling will be required to support higher heat loads within server cabinets.



▲ Typical Hot & Cold Aisle arrangement

Cooling Solutions Explained

Business continuity professionals are demanding an integrated solution, one that considers both room level and rack level problems.

Summary Table

Cooling Method	Air Flow		Floor		Max Pwr per rack
	Open	Closed	Raised	Solid	
Base Cooling					
Down Flow		✔	✔		3Kw
Localized Cooling					
Overhead	✔		✔	✔	10Kw
Vertical Top	✔		✔	✔	10Kw
In Row Cooling	✔	✔	✔	✔	10/15Kw
Enclosed Rack		✔	✔	✔	<15kW
Supplemental					
Hot Aisle Containment		✔	✔	✔	30Kw*
Air Removal Units	✔	✔	✔	✔	7Kw
Air Distribution Units	✔	✔	✔		3Kw
Cabinet Blanking Panels	✔	✔	✔	✔	N/A

* When used with In Row Systems

Base Cooling

Base systems provide room level cooling, humidification and air filtration control. This solution alone is suitable for average heat loads of 540 to 1080 Watts per m^2 (average 3Kw per rack).

Localised Supplemental Cooling

Trying to lower the temperature of hot spots by increasing the overall base air conditioning is not an effective use of energy. Indeed the conventional approaches may simply take up too much floor space to be practical.

The closer the source of cold air to the hot spot the more efficient the system. Localised rack level cooling provides an adaptive architecture for providing direct precision cooling for area's of high density power or hot spots within a server room or data centre environment.

Air Flow Control Measures

The greater the differential of output cold and input hot air, the more efficient a cooling system will be. Improving the flow of air and taking measures for preventing the mixing of hot and cold air are an important part of any overall room cooling strategy.

In addition to base level airflow measures i.e. raised floor and return air duct systems, there are a number of additional flow control technologies which can further improve the overall efficiency of the system.

The following details technology solutions that can be applied with a server room environment.

Base Cooling

Down flow Solutions

This is a traditional approach for Data Centre and Server Room air conditioning systems. The raised floor acts as a plenum or open duct for the delivery of cold air with an open ducted or closed overhead hot air return path to the air conditioning unit. This is an efficient method of cooling and is appropriate for low to medium density equipment cabinet footprints i.e. 3Kw to 5 Kw maximum per cabinet.

These systems work by drawing air into the top of the HVAC unit, either from the room or from the return plenum (return air), where it is cleaned by air filters banks, and passed over a cooling coil.

These systems will generally take up floor space adjacent to walls within the server room. Typically a 650mm deep x 1200mm wide unit will support 20Kw of cooling. Units are distributed throughout the room to provide an even flow of air.

These system work best with adjustable vented floor grill tiles (with at least 50% open space) where air flow can be controlled depending on how far away the tile is from the air source. A typical grill tile may allow up to 330Lts of air flow which is approx 3.6Kw of cooling. From a practical point of view it is generally only possible to install one grill tile per cabinet, thus this will become the restrictive bottle neck on cooling performance. The quantity of tiles must be balanced against the volume of air produced by the air handling unit to ensure a positive pressure balance is maintained within the raised floor plenum.

Localised Supplemental Cooling

Overhead Cooling

There are a number of systems that provide precision cooling based an over head cooling solution. These provide direct mission critical cooling to address area's of high density tightly packed electronic rack enclosures.

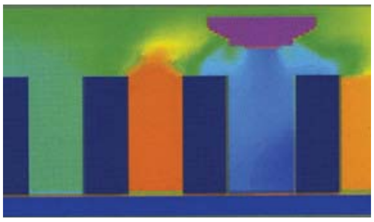
The example shown sits above the cold aisle discharging cold air to the front of server cabinets. Hot air is drawing through side vents from both hot aisles. These units are ceiling mounted therefore do not directly take any floor space within the server room.

As can be seen on the fluid dynamic drawings airflow is efficiently controlled with effective cooling at both the top and bottom of the equipment cabinets.

Overhead cooling systems work on low pressure pumped refrigerant which typically is a gas at room temperatures. These units provide 100% sensible capacity. They rely on humidification from room base systems.

These systems will require either a self contained refrigerant chiller system which will support multiple overhead units or a pumping unit which will interface between a building chilled water system and the overhead cooling units.

▲ Example of overhead cooling



▲ Overhead cooling CDP profile

Cabinet Vertical Cooling

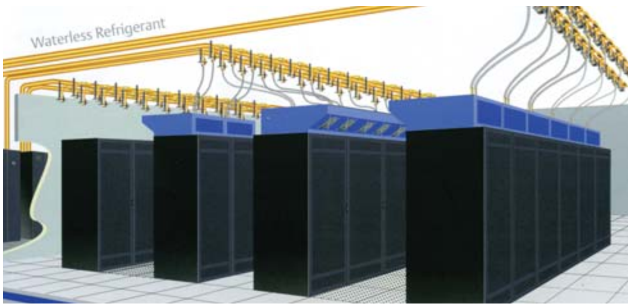
This approach is very similar to overhead cooling and is based on cooling units which sit directly on the top of existing equipment cabinets. These units will draw hot air from the top of the server cabinet or from the hot aisle and via heat exchange technology will discharge cool air to the front of the server cabinet.

Again this type of solution does not directly take any floor space within the server room.

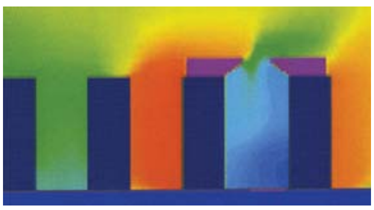
As can be seen on the fluid dynamic drawings airflow is efficiently controlled with effective cooling at both the top and bottom of the equipment cabinets.

As with overhead systems cabinet vertical cooling systems work on low pressure pumped refrigerant. These units provide 100% sensible capacity and rely on humidification from room base systems.

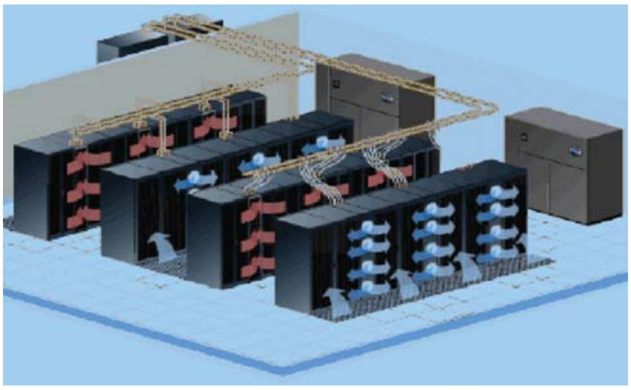
Vertical systems will require either a self contained refrigerant chiller system which will support multiple units or a pumping unit which will interface with the building chilled water system.



▲ Example of vertical cooling

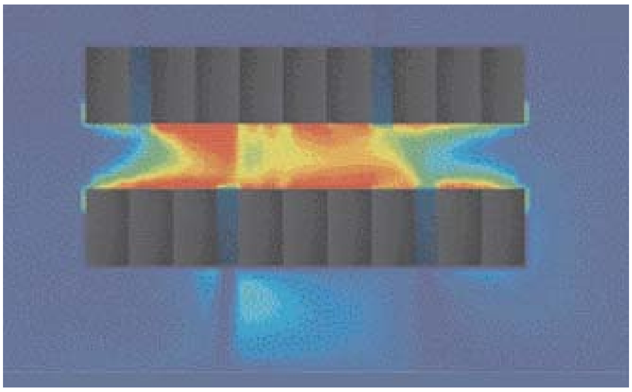


▲ Vertical cooling CDP profile



▲ In row cooling configuration with base cooling

▲ APC hot aisle containment system



▲ Hot aisle containment CDP profile

In-Row Cooling

Again based on the principle of moving the cooling unit closer to the source of heat generation, In Row cooling technology provides a third option for point cooling. This design helps eliminate air mixing and provides a predictable cooling architecture.

The In Row system is placed in line with server equipment racks and air is drawn in through the rear of the unit, cooled, and discharged into the cold aisle where electronic equipment air inlets are located.

These units typically take up 300mm width of rack floor space. Cooling capacities can be as much as 30Kw so these are ideal to position in hotspot area's.

Again as with both over head and vertical cabinet cooling systems are connected to either pumping or self contained chiller units via low pressure pipework systems.

Some In Row systems have built in chiller or direct exchange cooling technology to provide self contained cooling.

Self Contained Closed Architecture Cabinet Cooling

Where extreme heat densities are present an enclosed rack complete with in build closed air circulation can be deployed. Server heat load is dissipated into the process system heat exchanger contained within the rack. Internal fans drive closed loop circulation within the rack interior, while servers are supplied with cold air to the front of the rack. Typically both air and water cooled systems are available offering internal or external heat dissipation options.

Air Flow Controlling Measures

Hot Aisle Containment

Air containment systems increase cooling predictability in extreme high density environments within rack level solutions that neutralize the hot exhaust air at the rack or row level.

With this solution, high density technology clustered together in two rows of cabinets within the general data centre floor space. These systems are deployed with In Row cooling units which will provide cold air to the front of the equipment cabinets. A containment system is used to enclosed and prevent the escape of hot cabinet exhaust air into the general data centre environment. The In Row cooling units will then draw the hot air back and re-circulate as cold air to the front of the cabinets.

This approach effectively eliminates mixing of cold and hot air maximising system efficiency. There is a neutral impact on the overall server room environment.

Space planning is important in the deployment of such systems as typically there will be a requirement for a least 8 cabinet footprints distributed over two rows. These may sit within a self contained room or be part of a general data centre floor space.

Air Removal Units

These units will provide enhanced air flow and are designed to assist base and supplemental cooling systems. Rack Air Removal Units are designed to improve the airflow within a high density server cabinet. Very often the internal server fans are not adequate to force the cold air through the system.

Typically a Rack Air Removal Unit will be fixed to or form part of the rear door assembly of a server cabinet. A row of vertical fans will assist in removing the hot air from the equipment cabinet. Options may include ducting where enclosed hot air plenum returns are installed. The use of variable speed fans help improve performance and power consumption.

Typically a Rack Air Removal Unit will improve cooling performance by up to 7Kw.

More sophisticated systems will have built in heat exchange systems so will also provide cooling to help reduce the exhaust heat load. These types of units expel air from the back of the cabinet, chilled to the point where impact on the room is close to neutral.

◀ APC rack mounted Fully Ducted air return unit

Air Distribution Units

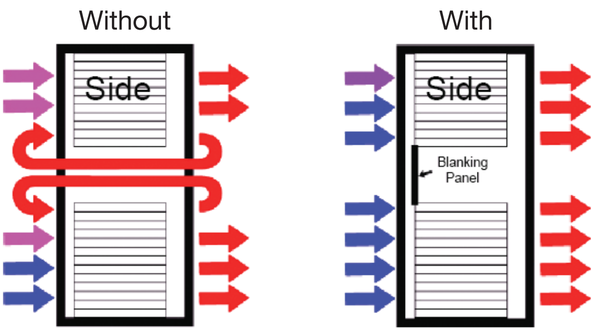
As with Air Removal Units, these units will provide enhanced air flow and are designed to assist base and supplemental cooling. Typically this unit will fit at the bottom of a server cabinet. It is designed to draw air from the raised floor plenum and force the air to the font of the equipment cabinet. This product will assist performance load sharing techniques improving rate of flow to the target cabinet. This may improve effective cooling by up to 3Kw.

▲ APC rack mounted air distribution unit

Cabinet Blanking Panels

One of the most fundamental mistakes made within a server room is allowing exhaust air to re circulate back through an equipment cabinet which creates an over heating problem. Reducing the bulk air supply temperature to over come this will reduce the efficiency of the air conditioning system and create the need for supplemental humidification.

The cabinet recirculation issues can simply be prevented by the installation of blanking panels on all empty cabinet space.



▲ Rack airflow showing effect of blanking panels

Conversion Tables

Conversion Tables

In general cooling is discussed in terms of Kilowatts, there is however a tendency for manufactures to use legacy units of measurement. Hence cooling related units of measurement are often a source of confusion for IT personnel when assessing cooling needs. Useful Imperial to Metric and Metric to Imperial conversion factors and formulas are provided below.

Imperial to Metric Table

Quantity	From Metric Units	To English Units	Multiply By
Cooling	Ton (refrigeration)	Kilowatts	3.517
	BTU/Second	Kilowatts	1.054
	BTU/Hour	Kilowatts	0.000293
Length	Foot	Meter	0.3048
Room Area	Square Foot	Square Metre	0.3048
Mass	Pound	Kilogram	0.4536
Floor Loading	Pound / $Foot^2$	Kilograms / $Metre^2$	4.882
Volume	Cubit Feet	Cubic Metre	0.02832
	Gallon	Litre	3.785
Pipe Flow Rate	Gallons / Minute	Litres / Second	0.06364
Air Flow Rate	Cubic Feet / Minute	Cubic Meters / Second	0.000471
Air Flow Velocity	Feet / Second	Metres / Second	0.3048

Metric to Imperial Table

Quantity	From Metric Units	To English Units	Multiply By
Cooling	Kilowatts	Ton (refrigeration)	0.2843
	Kilowatts	BTU/Second	0.9488
	Kilowatts	BTU/Hour	3413
Length	Meter	Foot	3.281
Room Area	Square Metre	Square Foot	10.764
Mass	Kilogram	Pound	2.2046
Floor Loading	Kilograms / $Metre^2$	Pound / $Foot^2$	0.2048
Volume	Cubic Metre	Cubit Feet	35.311
	Litre	Gallon	0.2642
Pipe Flow Rate	Litres / Second	Gallons / Minute	0.06364
Air Flow Rate	Cubic Meters / Second	Cubic Feet / Minute	15.713
Air Flow Velocity	Metres / Second	Feet / Second	3.281

1Kw = 3,412BTUs/hr = 0.29 Ton

100 Litres Air Flow per Second = approx 1Kw of cooling

Conclusions

Conclusions

The deployment of a successful server room cooling system requires detailed, space planning, current and future load analysis, and appropriate technology selection.

The design of the solution will have a significant effect on the overall system performance, and also greatly affects the uniformity of temperature within the data centre. The adoption of simple, standardised, and modular air distribution system architecture will allow the flexibility of any solution to evolve and adapt over the lifetime of the facility.

About Workspace Technology

Workspace Technology provides a range of services for Network Critical Physical Infrastructure (NCPI) facilities which include Communications, Server and Data Centre facilities.

The design and implementation of cooling solutions forms part of Workspace Technology's overall strategy for providing clients with a complete turnkey approach to the design and build of server room solutions.

Workspace Technology's expertise and services incorporates consultancy, upgrades, expansion, re-locations, turnkey design & build, planned maintenance, support and remote monitoring services.

A copy of Workspace Technology's "Environment" Server Room Solutions and Services can be downloaded from **www.workspace-technology.com**.

Workspace Technology are approved Integration Partners for a number leading manufacturers of critical cooling systems and are APC Silver Partners, and specialists in the design and implemtation of APC's InfraStruXure range of technology.

Workspace Technology Limited

Workspace Technology Limited
Technology House, 5 Emmanuel Court,
Reddicroft, Sutton Coldfield
West Midlands B72 1TJ
Telephone: 0121 354 4894
Facsimile: 0121 354 6447
www.workspace-technology.com
email: sales@workspace-technology.com

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