Re-examining the Suitability of the Raised Floor for Data Center Applications

White Paper 19

Revision 2

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> Executive summary

The circumstances that gave rise to the development and use of the raised floor in the data center environment are examined. Many of the reasons for the raised floor no longer exist, and the problems associated with raised floors suggest that their widespread use is no longer justified or desirable for many applications.

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Introduction

The raised floor is a ubiquitous feature of data centers. In fact, one common definition of a data center is that it is a computing space with a raised floor.

The basic science and engineering of the raised floor was fully developed in the 1960s and was described in detail in the 1983 Federal Information Processing Standard 94. The basic design of raised floors has remained relatively unchanged for 40 years.

In the telecommunications business the raised floor has never been common. The convergence of telecommunications and IT systems has raised the question of how to decide which approach to use. Recently, more and more IT data centers are being constructed without the use of the raised floor. A review of the history of the raised floor offers insight into this trend.

Elements of the raised floor

The raised floor was developed and implemented as a system intended to provide the following functions:

- A cold air distribution system for cooling IT equipment
- Tracks, conduits, or supports for data cabling
- Conduits for power cabling
- A copper ground grid for grounding of equipment
- A location to run chilled water or other utility piping

To understand the evolution of the raised floor, it is important to examine each of these functions and what original requirement caused the raised floor to be the appropriate solution. In addition, it is useful to see how the original requirement has changed over time. In the following sections, the original and current requirements relating to the above functions are contrasted.

A cold air distribution system for cooling IT equipment

Table 1

Cool air distribution requirement

Original requirement	Current requirement
Cool air required near equipment air inlets. Cooling requirement does not change significantly during the lifetime of the data center. Multiple A/C units can feed the system in order to provide fault tolerance.	Cool air required near equipment air inlets. New IT equipment can operate at 25kW or more per rack requiring 4x the airflow that typical raised floors are designed for; unobstructed underfloor height of 1m is required to attain high density. Cooling requirement changes many times during the lifetime of the data center as equipment moves in and out. Multiple A/C units can feed the system in order to provide fault tolerance. Newer high density, high efficiency air conditioners are closely coupled to the IT cabinets and do not use the raised floor for cool air supply.

The raised floor concept meets the original requirement and, due to the ability to change and move vented tiles, it also is well suited for the current requirement. However, the heights of traditional raised floors are inadequate, and many new air conditioner designs simply don't use the floor for the cool air supply.

Tracks, conduits, or supports for data cabling

Table 2

Data cabling requirement

Original requirement	Current requirement
Bulky multi-conductor copper data cables connect between cabinets. Cables must be as short as possible to ensure correct operation. Cables need to be hidden from view. Cables are not changed during data center life.	Thin fiber and copper network cables. Cables are changed many times during data center life. Easy access to cables required.

The raised floor was the only practical way to meet the original requirement, but is no longer necessary and is poorly suited to the current requirement due to the difficulty of data cable access. For this reason, most data centers today that use raised floor have some or all data cabling overhead.

Conduits for power cabling

Table 3

Power cabling requirement

Original requirement	Current requirement
IT equipment is hard-wired with dedicated circuits. Circuit does not change over lifetime of data center.	IT equipment plugs into standard receptacles. Much higher number of distinct IT equipment per sq. ft. IT Equipment subject to change every 2 years. Branch circuits subject to change multiple times over lifetime of data center.

The raised floor meets the original and current requirements but has a disadvantage related to access for wiring changes. Overhead power distribution has historically not had any advantages. Power distribution remains a key reason why raised floor is deployed.

A copper ground grid for grounding of equipment

Table 4

Grounding requirement

Original requirement	Current requirement
Direct coupled data signal integrity requires interconnected equipment be hard-grounded together to less than 0.1V differential to preserve correct operation and prevent damage.	Copper network cabling is galvanically transformer isolated and not subject to interference from ground shift up to 1000V and routinely interconnects distances over 50m (160ft). Fiber network cabling is totally immune to ground shift.

The need for a copper ground grid has been virtually eliminated. The ground connection between racks and to the branch circuit panels meets the current requirement.

A location to run chilled water or other utility piping

Table 5

Chilled water requirement

Original requirement	Current requirement
Some IT equipment requires direct cold water piping for cooling.	IT equipment does not require direct cold water piping for cooling. However, newer row-oriented and rack-oriented air conditioning systems do require water or refrigerant piping. This piping must either be under the floor, or, in some designs may be overhead.

The raised floor was the only practical way to meet the requirement to deliver water piping to IT equipment. The new requirement for refrigerant or water piping does require either underfloor or overhead installation. If underfloor piping is selected, then a raised floor is required but it only needs to have a height of 16 inches (0.4m) or less. New joint-less overhead piping technology is an alternative that eliminates the need for a raised floor.

The problems of using a raised floor

The examination above indicates that the raised floor was a very effective and practical way to meet the original requirements of early data centers. It is also apparent that many of the original requirements that dictate the use of the raised floor no longer exist. In fact, data center requirements have evolved and changed significantly. It is important to review problems that are actually created by the raised floor.

Earthquake

The raised floor greatly increases the difficulty of assuring or determining a seismic rating for a data center. Supporting equipment above the floor on a grid greatly compromises the ability to anchor equipment. Because each installation is different, it is almost impossible to test or validate the seismic rating of an installation. This is a very serious problem in cases where a seismic withstand capability is specified.

In and around Kobe Japan, during the great earthquake of 1995, data centers experienced an extraordinary range of earthquake damage. Many data centers which should have been operational within hours or days were down for more than a month when a large number of supposedly earthquake-rated raised floor systems buckled, sending IT equipment crashing through the floor. Damaged equipment needed to be fished out and repaired or replaced in complex and time consuming operations.

During the World Trade Center collapse of 2001, nearby data centers which should have survived the tragedy were seriously damaged and experienced extended down time when impacts to the buildings caused raised floor systems to buckle and collapse.

A down time of 5 weeks as was typical near Kobe, corresponds to 50,000 minutes as compared with the 5 minutes per year of downtime required to achieve 5-nines reliability. This is 10,000 times worse than the 5-nines design value. If earthquake downtime is considered 10% of the availability budget, then the data centers near Kobe could not achieve 5-nines reliability unless an earthquake of that magnitude were to occur only once every 100,000 years, which would not be a realistic assumption.

In areas which are subject to any earthquake activity it is unreasonable to expect 5-nines availability using a raised floor. Even an attempt to do so would be effectively unverifiable. This is one of the reasons why telephone central office facilities do not use raised floors. This is the single most compelling reason why raised floors are no longer desirable for high availability data centers.

Access

The fact that equipment turnover in a modern data center is around two years gives rise to the situation where data and power cabling is subject to nearly continuous change. The difficulty of access to this cabling when it is under the raised floor results in delay and costs associated with changing needs.

Floor loading

Typical equipment racks can reach 2000 lbs (907 kg) in weight capacity, and may need to be rolled to be relocated. In addition, the equipment used to move and locate equipment needs data center access. Special reinforcement may be required in a raised floor environment, and in some cases this capability is restricted to certain aisles. Ensuring floor loading requirements are not exceeded requires significant cost and planning.

The full load capability of a raised floor is only realized when all of the tiles are in place. The buckling (lateral) strength of the floor depends on the presence of the tiles. However, tiles and even rows of tiles are seen routinely pulled in a data center when frequently required cabling changes or maintenance is performed. This situation can give rise to unexpected catastrophic collapse of the raised floor.

Headroom

In some potential data center locations the loss of headroom resulting from a raised floor is not acceptable. This can limit the options for locating a data center. In Japan, it is common for the floor of the next overhead level of the building to be cut out to create the headroom required.

Conduit

When cabling is run under a raised floor it becomes subject to special fire regulations. The raised floor is considered under the codes to be an “air plenum”. Due to the moving and distributed air the fire codes consider a fire in an air plenum to be a special risk. Therefore, cabling under the raised floor is required to be enclosed in fire-rated conduit, which may be metal or a special fire rated polymer. The result is considerable cost and complexity to install this conduit, and a particularly difficult problem when conduit changes are required in an operating data center.

Security

The raised floor is a space where people or devices may be concealed. In the case of data centers which are partitioned with cages, such as co-location facilities, the raised floor represents a potential way to enter and access caged areas. This is a reason why many co-location facilities do not use raised floor systems.

Power distribution

The number of branch circuits per square foot in the modern data center is much greater than it was at the time when the raised floor architecture was developed. During the mainframe era, a single hardwired high amperage branch circuit could service a cabinet using 6 floor tiles or 24 square feet (2.2 square meters). Today, this same area could contain two racks, each of which could require 12 kW of 120V circuits with an A and B feed, for a total of 12 branch circuits. The density of the resulting conduits associated with this dramatic increase in branch circuits represents a serious obstacle to underfloor air flow. This can require a raised floor height of 4 feet (1.2 meters) to ensure the needed airflow. Increasing the height of the raised floor compromises the structural integrity and compounds cost, floor loading, and earthquake issues.

Cleaning

The raised floor is an area which is not convenient to clean. Dust, grit, and various items normally accumulate under the raised floor and are typically abandoned there since the difficulty and accident risk associated with cleaning this area are considered to be serious obstacles. The act of removing a floor tile may cause dramatic shifts in the air motion under the floor, which can and has caused grit or even objects to be blown out into equipment or the eyes of personnel.

Safety

A tile left open poses a severe and unexpected risk to operators and visitors moving in the data center. In data centers with 4 foot (1.2 meters) or higher raised floors the risk of death resulting from a fall into an open tile location increases greatly. Equipment is frequently moved over the course of the lifetime of today's data centers; this creates the risk that the floor loading will be exceeded leading to a floor collapse.

Cost

The raised floor represents a significant cost. The typical cost of raised floor including engineering, material cost, fabrication, installation, and inspection is on the order of $20 per square foot ($215 per square meter). Furthermore, the maximum space that might be ultimately utilized by the data center is normally built-out with a raised floor whether or not the current, near term, or even the actual ultimate requirement requires the use of this space. The cost of $20 per square foot ($215 per square meter) does not include the extra costs associated with power and data cabling. This is a considerable cost, which should only be incurred if it is actually required.

The barriers to eliminating the raised floor

Although more and more installations have eliminated the raised floor, and the benefits of eliminating the raised floor are substantial, some data centers are still designed using a raised floor. Interviews with users of raised floors conducted by APC by Schneider Electric have identified the following barriers.

Perception

The raised floor is an icon symbolizing the high availability enterprise data center. For many companies the presentation of their data center is an important part of facility tours for key customers. Data centers that do not have a raised floor are perceived as incomplete or deficient or less than the highest quality. The result is that raised floor is installed as part of creating an image. In some cases, raised floors have been installed that are not used for cooling, wiring and, in fact, have no function at all other than to create the desired image. This issue is by far the largest barrier to the elimination of the raised floor.

Cooling design

Data center designers and operators value the flexibility that is provided by raised floor cooling designs. The raised floor provides some opportunity to move air vent tiles around in order to achieve a desired temperature profile. This is more difficult in a ducted system using overhead air pipes. In addition, there is much more experience in the design of raised floor air distribution design and designers are therefore better able to predict system performance. However, newer high density, high efficiency air conditioning systems are closely coupled to the IT racks and no longer use the raised floor as a cool air supply, which eliminates this barrier for new designs.

Power distribution

Due to the shift from a smaller number of larger IT devices to a relatively much larger number of smaller IT devices, the number of branch circuits per square foot in the modern data center is much greater than it was at the time when the raised floor architecture was developed. A location for running these branch circuits is needed. If a raised floor is not used, these circuits must be provided using overhead distribution. Installing and maintaining ceiling mounted branch circuits is perceived to be more difficult than managing underfloor branch circuits. However, in most typical data centers, access above the racks is much easier than access under the raised floor.

Designing without a raised floor

The costs and problems associated with a raised floor can be eliminated only if a practical and available alternative exists. Fortunately, a number of design options allow some flexibility. A complete discussion of these alternatives is beyond the scope of this white paper. In general, the methods for cooling without a raised floor fall into the three categories summarized in the following table.

Table 6

Cooling methods without a raised floor

Original requirement	Current requirement
Small Data Centers / Data Rooms (<1000 sq ft) (<93 sq m)	Rack, wall, or ceiling mounted air conditioning units operating without ductwork.
Medium Data Centers (1000 – 5000 sq ft) (93 – 465 sq m)	Traditional design: Floor standing CRAC units with ductless distribution and with dropped ceiling return plenum. Newer high density, high efficiency design: Row-oriented or rack-oriented cooling systems with overhead joint-less water or refrigerant piping
Large Data Centers (>5000 sq ft) (>465 sq m)	Traditional design: Floor standing CRAC or roof mount units with ducted overhead cold air distribution combined with open ceiling or dropped ceiling air return. Newer high density, high efficiency design: Row-oriented or rack-oriented cooling systems with overhead jointless water or refrigerant piping

These methods have all been used, but the equipment and the design guidelines for these types of installations are less mature when compared with that of raised floor designs. Therefore many systems of traditional design that operate without a raised floor are unique. Engineering firms and suppliers must add to the product base and the knowledge base before these types of installations can be implemented with the predictability offered by the raised floor approach. In general, the traditional methods of implementing cooling in environments without a raised floor exhibit performance that is difficult to predict.

The pressures to solve the problems of high density, high efficiency, and predictability have given rise to new air conditioning technologies based on row-oriented and rack-oriented methods. These new air conditioning systems are tightly coupled to the IT loads and integrate into rack cabinets or may be located overhead. Because of the ability of these systems to simultaneously achieve high density, high efficiency, and predictability, their adoption is increasing. One important consequence of these new cooling technologies is that they do not require a raised floor. These technologies are described in more detail in APC White Paper 130, *The Advantages of Row and Rack-Oriented Cooling Architectures for Data Centers*.

Link to resource
APC White Paper 130
The Advantages of Row and Rack-Oriented Cooling Architectures for Data Centers

Recent innovations in overhead rack power distribution have provided a lower cost option when compared with under-floor power distribution. When combined with the emerging overhead cooling methods, it becomes practical to consider eliminating the raised floor, particularly in small and medium sized data centers.

Conclusion

Many of the reasons that led to the application of the raised floor no longer exist. The absence of a compelling requirement combined with the problems associated with raised floors suggest that their widespread use is no longer economically or technically justified in most applications, particularly in small and medium sized data centers. Recently introduced solutions have solved the technical barriers to the elimination of the raised floor. In fact, the highest density and highest efficiency data center power and cooling technologies specifically do not require a raised floor. Nevertheless, data centers are likely to use raised floors for some time due to large base of experience with raised floor design, traditions of locating piping and wiring under the floor, and the intangible issues of perception and image.

About the author

Neil Rasmussen is the Senior VP of Innovation for APC, which is the IT Business Unit of Schneider Electric. He establishes the technology direction for the world's largest R&D budget devoted to power, cooling, and rack infrastructure for critical networks.

Neil holds 14 patents related to high efficiency and high density data center power and cooling infrastructure, and has published over 50 white papers related to power and cooling systems, many published in more than 10 languages, most recently with a focus on the improvement of energy efficiency. He is an internationally recognized keynote speaker on the subject of high efficiency data centers. Neil is currently working to advance the science of high-efficiency, high-density, scalable data center infrastructure solutions and is a principal architect of the APC InfraStruXure system.

Prior to founding APC in 1981, Neil received his bachelors and masters degrees from MIT in electrical engineering, where he did his thesis on the analysis of a 200MW power supply for a tokamak fusion reactor. From 1979 to 1981 he worked at MIT Lincoln Laboratories on flywheel energy storage systems and solar electric power systems.

Resources

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The Advantages of Row and Rack-Oriented Cooling Architectures for Data Centers
APC White Paper 130

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