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Society of Cable Telecommunications Engineers
International Society of Broadband Experts

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ENERGY MANAGEMENT

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From the Editors

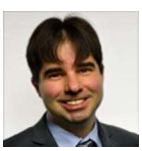
The opening issue of the 2018 Journal of Energy Management has three articles for your review. First is a follow-up from a presentation by Comcast's Ben Strunk presenting the concept of infrastructure headway. Headway is the extra capacity that is "baked into" the critical facility to accommodate future growth and demand. Critical power at the facility transformer and power distribution levels can often be costly to upgrade when service demands rapidly expand. Ben's paper looks at finding ways to address the prep and preservation of the critical space headroom. Next, the Villanova University RISE Forum team presents their research findings regarding causes of critical facility outages. One consistent theme in their findings is lack of power. Read more to uncover their conclusions. Finally, the Climate Technology Optimization working group chaired by Rogers' John Dolan presents a follow-up to their *letter to the editor* in our previous issue, on a study about using computational fluid dynamic modeling to assess cooling in the critical facility. As mentioned in prior papers, cooling can account for 30% of energy costs at a critical facility. Ensuring you have enough cooling and the proper airflow can lead to better uptime and lower bills

If you have feedback on this issue, have a new idea, or would like to share a success story please reach out to journals@scte.org for consideration in an upcoming issue.

SCTE/ISBE Journal of Energy Management Senior Editors,

Simpson Cumba

SCTE Energy Management Subcommittee Chair



Derek DiGiacomo

Senior Director, Energy Management Programs and Business Continuity

The Tech Refresh and the Nega-Watt: Common Sense Powering at Comcast

A Technical Paper prepared for SCTE•ISBE by

Benjamin Strunk, Power and Facility Infrastructure, Comcast Cable, SCTE•ISBE Member

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1. Introduction

From CCAP devices to node splits, and from distributed access architectures (DAA) to remote-PHY, job number one for any network engineer is to persistently build enough bandwidth to stay reasonably ahead of bandwidth consumption -- which doubles approximately every four years. Yet this perpetual pursuit of network capacity often comes with a foregone conclusion: that to continuously improve our networks and infrastructure is to continuously use more electricity.

The engineering leadership in Comcast's Northeast Division, which serves 12 million customers in 14 states, reasoned that the conclusion stated above was anything but "foregone." We decided to launch a pilot metering program to capture true consumption data. The pilot consisted of deploying professional metering equipment at a sampling of sites in the Western New England Region. The sites were selected so we could form peering relationships for technology, physical sizing and facilities purposes. If Comcast's Northeast Division could counter the accepted theory -- that growth equals additional power consumption -- a windfall of efficiency improvements could result that would encourage advancement, while deferring capital investments.

With the metering pilot fully implemented, data feedback showed how the overall Comcast Northeast Division could strategically and systematically remove old legacy equipment, replace outdated HVAC units, and improve airflow. The Northeast Division ultimately reclaimed 2.7 "Nega-watts" of power over a 15 month period. (The "Nega-watt" is defined[1] as a Megawatt of power saved, either by increasing efficiency, or reducing consumption.) To put that into context, 2.7 Nega-watts is the powering equivalent of:

- 250 CCAP devices; or
- 3,921 virtual CMTS servers; or
- 241,545 small-form, pluggable lasers, used in HFC nodes.

It is an important metric, because every "un-spent" Megawatt can be immediately and directly applied to energize next-generation platforms and technologies. And of course, reducing usage is both beneficial to the environment and helpful in reducing energy costs.

2. The Capacity Balance Scale

Capacity is the lifeblood of our industry. This paper will focus on the power capacity needs for facilities, which can be difficult to manage. Increasing power capacity within a facility -- such as a headend or data center -- can be the largest investment within an operator's budget. Just to turn up 40 kilowatts of facility energy can cost millions of dollars. The time to market for that availability can take years.

This concept can be illustrated in terms of a Capacity Balance Scale (Figure 1). Solving for capacity growth simultaneously requires powering "headroom," because without it, costs start to accrue to power the equipment supporting that growth. In a sense, it's like preparing a ship for distribution: if the ship is already full, bringing on an additional ton of cargo means removing a ton, or it won't float. So, if we couple common sense measures -- like removing unnecessary, power-hungry components -- we get both powering "headroom," and improved efficiencies.

[1] The "Nega-watt" was coined by physicist Amory Lovins in 1989.

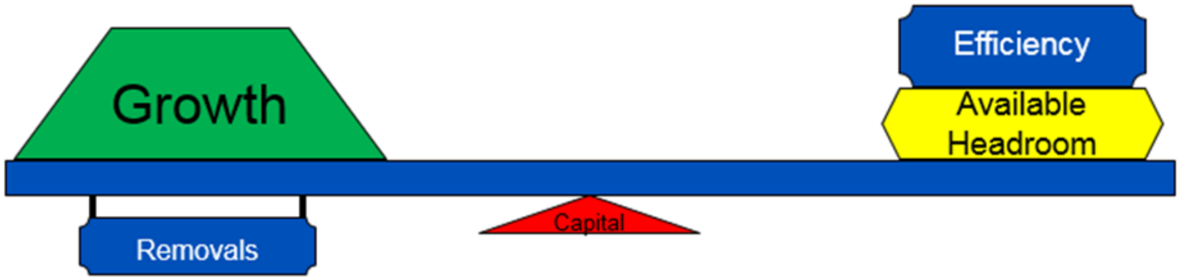

Figure 1 - The Capacity Balance Scale

Reclaiming capacity by making facilities more efficient triggers at least three success stories from the same action. First, more efficient facilities require less operational expense. Second, a higher level of efficiency also ensures the ongoing usefulness of existing facility capacities. And finally, producing more capacity with less power reduces our overall environmental footprint. Facilities that are performing in an operational capacity of 30% to mid-40% efficiency are contributing to intangible waste. It is likely that the sum of all facility waste, within the MSO community, can be calculated in Megawatts.

3. Facility Optimization Basics

The basic considerations for any capacity augmentation plan, as it relates to facilities, are three-fold: 1) is space available? 2) how much power is available? and 3) can the new platform be cooled? The cost to build out facility capacity can be expensive -- but, again, capacity can be found, not built! Comcast's Northeast Division pilot proved that it can be less expensive to reclaim facility capacity than it is to build it. Let's run through an example. To deploy a new chassis with a load rating of 1,000 watts, the facility capacity build costs will be approximately $10,000. To remove 1,000 watts of old gear, the cost is approximately $1,200. Consider the capital savings if the same amount of watts reclaimed by decommissioning old equipment, equaled the amount watts needed to launch the new, capacity-expanding platform. The capital savings are considerable! Put another way, by striving to remove something old, before something new is needed, you just saved about 88% of your project costs.

Facility efficiency is also a vital indicator of available, low-cost power capacity for new equipment deployments, especially for data centers and master headends. Efficiency matters to the bottom line. Carving out a three percent efficiency improvement from a facility already operating at a high level of efficiency (upwards of 90%) is capital-intensive. On the other hand, gaining 40% efficiency from a facility operating at 30% efficiency qualifies as "low hanging fruit" and is comparatively inexpensive. Two test sites in Comcast's Northeast Division pilot proved this. We scrubbed and removed non-essential equipment. We replaced all old and un-reliable components with highly reliable, highly efficient replacements, and fixed the size and style of cooling for the remaining equipment. Hence the facility efficiency rose from 23% to 70%. This "claw-back" of available service energy eliminated the need for a service upgrade.

An example of energy claw-back relates to airflow improvements, which is generally not an area of focus during technology platform refreshes. Communication networks are in a perpetual cycle of technology refreshes at the "edge." Network edge buildings are often small in size and inefficiently cooled.

The placement of gear within the network edge facility typically starts with an "open space evaluation." As network edge facilities begin to house smaller, more dense gear, an opportunity exists to correct suboptimal airflow while supporting the placement of new network components. Because new edge gear is typically smaller and denser, the HVAC systems need to be adapted accordingly.

Happily, there are multiple ways in which airflow improvements can be made. The most widely accepted means of improving airflow is to make sure aisles are configured in a "Hot Aisle/Cold Aisle" arrangement. While this is important, it's even better, in terms of potential efficiencies, when coupled with an optimized HVAC architecture. Any network edge facility refresh that includes HVAC should also include an examination of HVAC placement to ensure such placement is optimal relative to the other changes in the facility. New technologies in hot and cold aisle containment, coupled with rack level cooling, may, in some cases, afford the luxury of leaving equipment in its legacy orientation.

It is worth mentioning that HVAC refreshes are also big contributors to energy savings. An older HVAC unit can consume as much as 725,000 kilowatts in a year, while a newer, more efficient unit can cut that consumption by as much as two-thirds.

Adding or removing ductwork can also contribute to facility powering efficiencies. Likewise, for simply relocating the existing HVAC systems to what is the optimal location for the new equipment. Most small, edge site HVAC units are still situated where they were placed three technology refreshes ago. The "Cool the Box" practices of yesterday are less and less valid, and more and more expensive.

4. How to Create "Nega-watts"

Another efficiency lever that can be pulled, in order to create more powering headroom in facilities and to help support the financial basis for overall network capacity increases, is a heavy dose of "Spring Cleaning." "Nega-watts" are created in three ways:

1. Turn equipment off;
2. Get rid of legacy gear; and/or
3. Upgrade or make equipment more efficient.

Things that can be removed include inefficient rectifiers, network gear, and low utilization UPSs. Things that can be improved include the utility grid power factor, HVAC units and related "economizers," HVAC airflow, and high return air temperature deltas. Specifically, HVAC units run best when large temperature differences exist. For instance, if the HVAC refrigerant is 50 degrees, trying to cool air that is already 60 degrees is highly inefficient, but cooling 100-degree air is highly efficient.

5. The Goals of the Northeast Division "Nega-watt" Pilot

Comcast's Northeast Division's efforts to create powering "headroom" for headends was funded to add metering equipment, remove old gear, eliminate related preventative maintenance headaches, and improve airflow. Ultimately, Comcast gained back 30 kW of free power capacity, per facility, to enable the improvement of the network without spending capacity increasing capital.

The pilot proved that at a time when the going assumption is that the demand for power is growing exponentially, actual consumption can actually decrease as much as 10% year over year. Figure 2, plots energy efficiency versus consumption data at one Comcast facility. This data collected over a nearly 3-year period from March 1, 2015 to December 11, 2017.

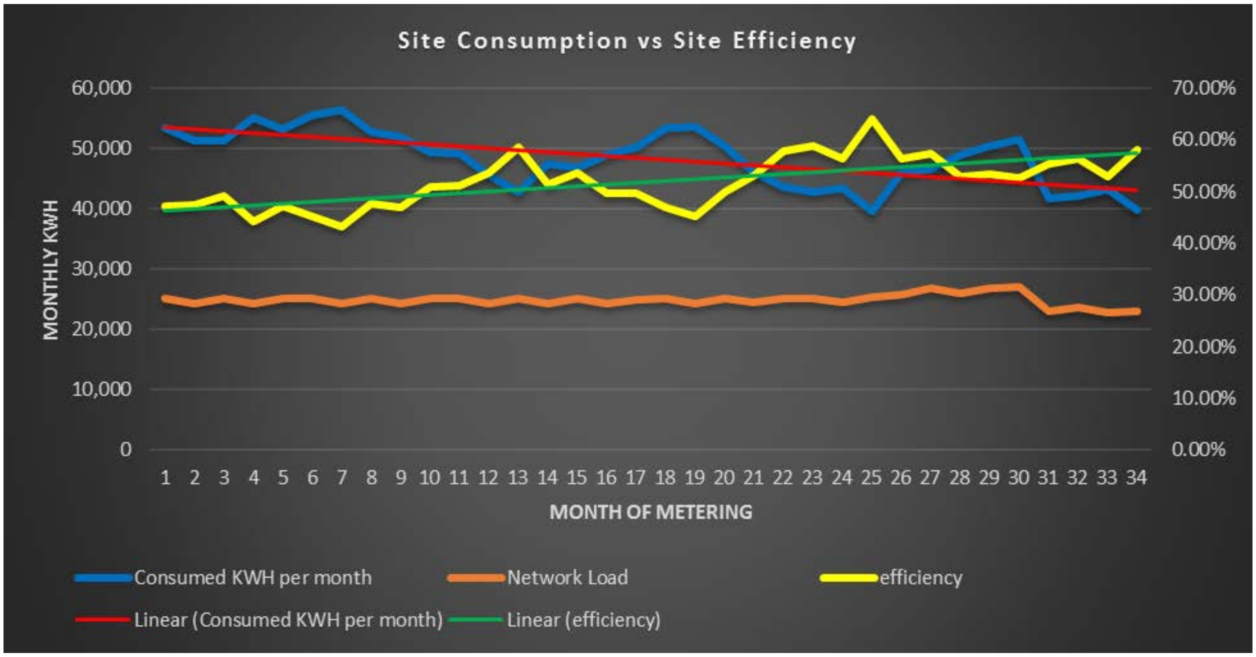

Figure 2 - A Chart of Energy Consumption Vs. Efficiency in a Comcast HE in the Northeast Division

In the graph, the yellow line depicts overall efficiency, and the blue line indicates actual consumption. Look in particular at what happens at around month 21. Over the course of all metered data, efficiency is trending upward, while load remains the same, and actual energy consumption goes down.

6. Conclusion

Everyone wants to be part of doing and building something new. As power engineers, we need to take pride in being able to support the new gear while spending limited funds or eliminating new build costs. The key is to make what we have perform better, to work within the capacity guardrails of not having too much nor too little, and to focus our efforts on what equipment can be removed before new equipment is added.

7. Abbreviations

CCAP	converged cable access platform
DAA	distributed access architectures
HVAC	heating, ventilation, and air conditioning
HFC	hybrid fiber-coax
HD	high definition
Hz	hertz
MSO	multiple-system operator
ISBE	International Society of Broadband Experts
SCTE	Society of Cable Telecommunications Engineers

Assessing Network Reliability in Cable Facilities: Current State, Trends, and Opportunities

A Technical Paper prepared for SCTE•ISBE by

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1. Executive Summary

Reliable systems are the backbone of society. In any kind of network, the reliable delivery of services or products is the core purpose of a healthy, high-performance system. Through Villanova University's industry consortium to promote sustainability in business, graduate engineering students collaborated with the Society of Cable Telecommunications Engineers ("SCTE") to assess network reliability in cable facilities, particularly hubs and headends. As part of the research, the project team investigated the current state of the industry, trends in sample outage data, wildcard industries, and opportunities for improvement using a whole-systems perspective.

The team found that significant opportunities exist. At the highest level, reliability is clearly not limited to technological issues and solutions. Analyzed data show that facilities can benefit from human-centric improvements, such as training programs and accident-proofing physical layouts. Monitoring and analyzing outage data also enable targeted and prioritized action to be taken toward contractors, staff, and equipment.

Recognition that people are inherently involved with the management, operations, and maintenance of cable facilities is important to understand the multi-faceted drivers of reliability. These drivers are: people management; equipment and systems; planning and coordination; maintenance, and infrastructure. This project proposes a simple, straightforward cable facility rating system for reliability that defines individual actions categorized by these five drivers. This rating system would provide decision-makers with a tool to benchmark, manage, and improve the reliability of their cable facilities.

Further work on this project will refine the rating system, engage additional stakeholders, pilot the rating system on select facilities, and finally result in a deployable rating system for the industry to use.

2. Project Background

Reliable systems are the backbone of society. In any kind of network, the reliable delivery of services or products is the core purpose of a healthy, high-performance system. Through Villanova University's industry consortium to promote sustainability in business, graduate engineering students collaborated with the Society of Cable Telecommunications Engineers ("SCTE") to assess network reliability in cable facilities, particularly hubs and headends.

SCTE has identified that these smaller cable facilities hold opportunities in boosting reliability performance and consequently improving operational sustainability. Because large investments in security, manpower, and infrastructure may not be as practical for these smaller facilities as in data centers, there is ample room for creative approaches and further investigation.

This paper presents findings and trends from research into the current state of the industry, reliability theory, wildcard industries, and data center reliability.

3. Methodology

The team approached the project by establishing four main areas of research to conduct: the current state of the industry, reliability theory, wildcard industries, and data center reliability. To understand the current state of the industry, the team:

- Interviewed engineers from SCTE and a cable operator,
- Reviewed relevant SCTE standards,
- Conducted a site visit to a cable hub, and
- Analyzed outage dataset for trends and insights.

Reliability theory was chosen as an area for investigation to help frame the analysis and findings from an abstract, conceptual viewpoint. The team conducted literature reviews in reliability theory for this effort. Wildcard industries were also investigated to examine outside perspectives and potentially uncover innovative practices. Data center reliability was researched by reviewing services and products offered by the data center consulting firm Uptime Institute.

Finally, the research informed the team and allowed for the development of a cable rating system. For this effort, the team identified the major drivers of reliability and constructed a rating system proposed as a tool to evaluate and guide cable facilities toward specific actions that contribute to reliability.

4. Research Findings

Research into reliability covered the following four major areas: current state of the cable facility industry; reliability engineering; wildcard industries, and the Uptime Institute. Key metrics, performance indicators, and issues have been assessed. Observations and data are presented to characterize reliability.

4.1. Current State of the Industry

The research team sought to understand how the industry currently manages reliability in cable facilities, particularly hubs and headends.

As relayed by SCTE to the research team, reliability in cable facilities is supported by four pillars: electric power; heating, ventilation, and air conditioning ("HVAC"); building infrastructure, and information technology ("IT") systems. Vulnerability in any of these can increase the likelihood of failures. For electric power, a combination of backup diesel generators and battery energy storage systems maintain both power quality, and security of power in the event of grid outages.

Power is at the heart of reliability concerns; system growth, such as to support a growing customer base or operational consolidations, requires first and foremost proper management of electrical power capacity and adequacy. Second, the proper design, operation, and maintenance of HVAC systems are critical as well to maintain device temperatures cool enough and prevent destructive thermal runaway. SCTE estimates that an HVAC failure can lead to device failure within minutes. Third, the building infrastructure provides physical shelter from the environment and general public. Upkeep of facilities is thus important to maintain this foundation. Lastly, the IT systems are critical because they are delivering the actual cable services to customers. For the industry, the main concerns are grounded in physical damage to the systems, such as fiber and cable, rather than network congestion or cybersecurity, which are already adequately protected against.

To ensure reliability is integrated into these cable facilities, SCTE provides standards to guide member companies with design, operations, and maintenance (download SCTE standards). Because SCTE standards are generally intended to serve as a baseline requirement, some member companies, use their own proprietary standards instead.

According to SCTE, a combination of in-house staff and contractors maintain facilities. For smaller facilities, teams often maintain several facilities at once, often with the help of remote monitoring. This allows staffing to be spread over several geographically-diverse facilities. Larger facilities may have more dedicated staffing with more shifts. Relative to data centers, smaller cable facilities such as hubs and headends may not have as rigorous performance, staffing, or security measures in place. Consequently, there is a need for creativity in addressing this gap affordably and efficiently.

Data on outages and equipment failures can be a valuable asset and useful tool to drive improvements in reliability. A cable partner provided the team with data on equipment outages and failures in some cable facilities, and the analysis provides a window into the larger trends and drivers behind reliability issues. Although the analysis is based on a large sample size of 232 data entries over four years, it must be noted that this may not be representative of the operator or the cable industry as a whole. Figure 1 is a criticality grid of top failures based on the data set, plotting the type of failure by their impact, measured by the duration of outage, and frequency of failure over the four-year time period of the data set. This figure, along with others shown in Appendix A, revealed insights into the larger trends and drivers of reliability, and its impediments in cable facilities.

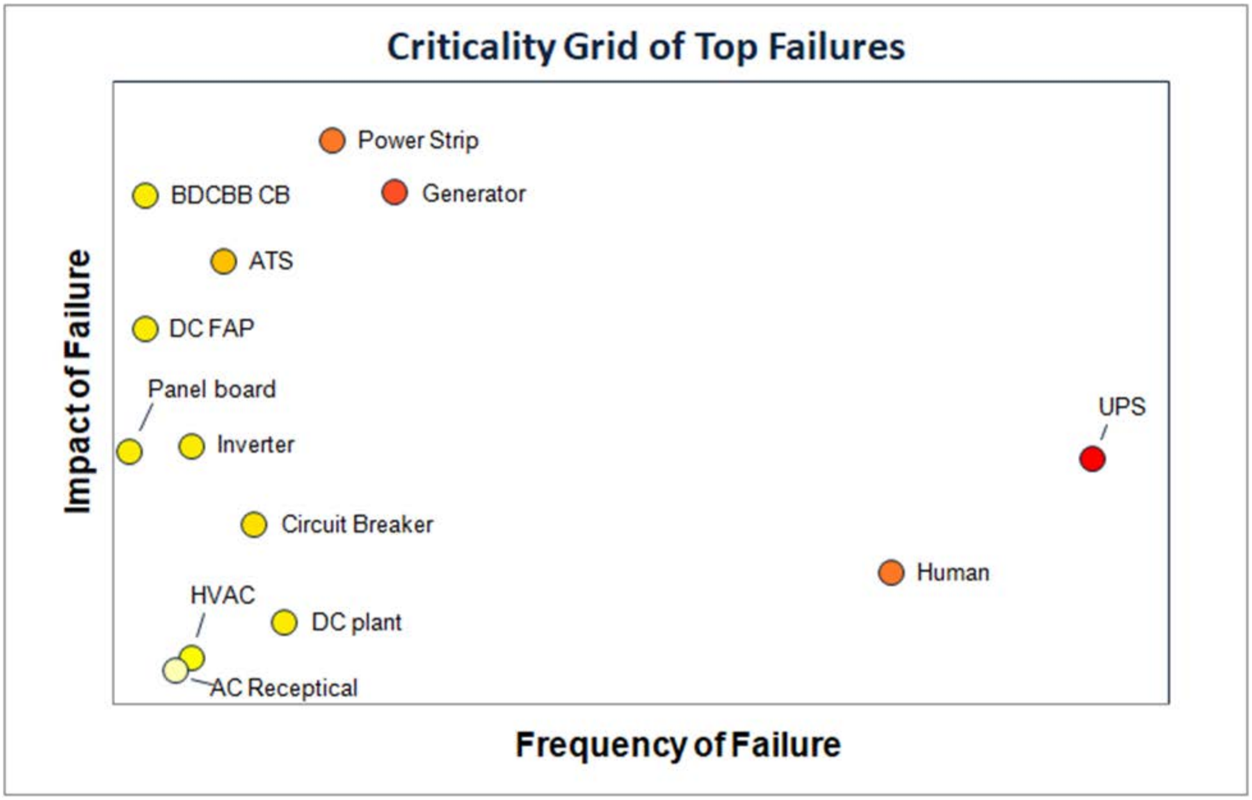

Figure 1 - Criticality Grid of Top Failures from the Data Set

Key insights from the data analysis are:

1. **Human-Centric Improvements:** There are significant opportunities in human-centered improvements, such as designing physical layouts to reduce human-caused accidents, additional and focused training to improve practices and behaviors, or highlighting vendors that show clear track records of performance and quality.
2. **Prioritizing Action with Contractors and Staff:** Data can reveal which contractors or staff have the highest rate of incidence and the highest impact on reliability. Analysis would enable prioritized actions, such as through targeted training programs, or preferential contracting policies.
3. **Prioritizing Action with Equipment:** The data analysis highlighted the most problematic equipment in terms of both frequency and duration of outages. In particular, Uninterruptible Power Supply ("UPS") systems were by far the most frequent source of outages. Higher impact, but more infrequent outages were due to failures of power strips and generators. Although this project did not attempt to determine the particular solutions for these devices, such data can help decision makers improve processes geared toward these specific devices, such as testing procedures, maintenance scheduling, or procurement policies. Additional analysis can further identify where existing efforts are disproportionate to the impact caused by a component.

Research found that elements essential to the value of data include: a classification scheme for incidents; tagging incidents with characteristics, such as those relevant to understanding impact; time of occurrence; duration of impact (or better, timestamps of both failure and repair); location; root causes, and ultimate responsibilities for failure and repair. In this data set, root causes were incident-specific comments that are likely valuable to understanding individual events, but consequently not very amenable to extracting trend-level insights. Additional considerations for a data acquisition and management process include: ease and ubiquity of data capture and system maintenance; genuine understanding of the systems and processes in cable facilities by the analytics team; extracting clear insights regularly from the data, and consistent, standardized values to maximize data quality. One example of this last consideration would be ensuring consistent capitalization in the words “Power Strip” for all data entries.

Appendix A includes additional analysis for the referenced data set to illustrate the value of reliability data and showcase potential use cases.

4.2. Reliability Theory

Reliability theory offers some high-level concepts that are worth highlighting here. As a precise definition, reliability is “the probability that a system (part or component) can perform its intended task under specified conditions and time interval" (Gunawan). This view of reliability assumes that failure can be predicted with well-defined, meaningful probabilities for components and processes within the system. For many systems, this may be the case due to systemic patterns. For others, such a statistical analysis may be useless, and an actual impediment to real improvements due to the various possible random factors that may trigger a failure (Barnard).

Another important concept is the idea of redundancy, and with it comes complexity. Redundancy is important to design into reliable systems, but adding such redundancy brings in added costs and complexity, which may itself become a new source of critical accidents (Bush). Thus, the process of designing reliability into a system is a constant optimization to balance the costs and complexity of redundancy with non-redundant components. Lastly, this research does not address resilience of cable facilities. Whereas reliability is concerned with normal, more regular accidents, resilience is the ability of a system to withstand and recover from rare, catastrophic accidents, such as an earthquake or hurricane (Sagan). As such, the root causes and nature of solutions are entirely different, and thus the team focused on reliability rather than the resilience of cable facilities.

4.3. Wildcard Industries

Industries outside the cable sector, in particular bulk power systems and banking services, termed “wildcard industries,” have been included in order to glean further insights into reliability. Relevant metrics have been included for comparative purposes.

4.3.1. Bulk Power Systems

The North American Electric Reliability Corporation (“NERC”) is an independent, third-party organization that designs and enforces standards for reliable planning and operations of the bulk electric power system in North America. According to NERC, a reliable bulk power system is “one that is able to meet the electricity needs of end-use customers even when unexpected equipment failures or other factors reduce the amount of available electricity” (NERC). The operation of the electric system is managed by Balancing Authorities, which can be electric utility companies, regional transmission organizations (RTOs), or independent system operators (ISOs). This interconnected structure helps maintain reliability by providing multiple routes for power to flow, which prevents failures from interrupting service.

Reliability is primarily enforced in the bulk power system through organized markets, which are often designed, maintained, and operated by Balancing Authorities. These organized markets are manifested in time-varying, locational prices, which were developed to provide market signals to electric power producers and consumers. This model aims to ensure reliability at the lowest overall cost to society by internalizing market forces. Failure to produce the committed amount of power also results in heavy financial penalties, negotiated beforehand through contracts. Last, reliability planning is incentivized through a competitive proposal process. When reliability violations are discovered in the system model, Balancing Authorities, such as PJM Interconnection, hold competitive proposal windows in which various entities can submit proposals for new transmission projects. The projects are evaluated and the best one is chosen for construction as a means to reward the least cost solution regardless of territorial monopolies.

4.3.2. Banking Services

Banking services were investigated for their high reputation of reliability. The best ATMs have an availability of at least 98.25 percent (NCR). A boost of one percent in availability can have an impact greater than $1 million (NCR). The range of ATMs in the banking industry furnishes a wide array of unique fault data with myriad error codes. Codes can be automatically processed and prioritized by a decisioning system to reduce analysis. Transactions are tracked and monitored in real-time. ATMs have an "…average hardware uptime between 98 and 99 percent" (Johnston and Gorkoff).

One metric to assess reliability of ATMs is to track the number of failed customer interactions ("FCI") for the total number of transactions. The target FCI "…should be between 2-5 percent" or less (Kramer). Analyzing data for patterns permits the resolution of issues to increase reliability. In analyzing the data, special attention is paid to peak hours and dates of usage. A key performance indicator ("KPI") metric is unserved customers, which are those customers that were inconvenienced by unavailable units (Johnston and Gorkoff).

Reliability of online banking services depends heavily on security and privacy (Sikdar). Slow or failed transactions can point to service performance issues, infrastructure problems impacting networks, and unsuccessful handoffs (Johnston and Gorkoff). The mobile services financial index presented the following benchmark data for the week of August 6, 2017: response time of 7.07 seconds; 99.51 percent success rate, and an indexed score of 613 (Dynatrace). The Keynote Banking Performance Index for the week of October 15, 2017 was reported as follows: response time of 10.98 seconds, 99.93 percent success rate, no outage hours, and 6.68 seconds of total time to reach an interactive page (Dynatrace).

4.4. Uptime Institute

The Uptime institute was selected for review because it has become a reputable organization serving organizations similar to members of SCTE. The Uptime Institute provides a connection point for peer organizations and operations with data center assets to come together to discuss challenges and solutions, and encourages collaborations and performance improvements in the operation and design of highly reliable data centers.

Of immediate interest is the Tier System Certification program ("Tier System") used by the Uptime Institute to evaluate the functional and physical reliability of the facility, supporting staff, and processes in place. The Tier System is a ranked classification scheme, ranging from Tier 1 at the lowest level of achievement to Tier 4 as the high level achievement, shown below in Table 1. Each level of certification represents a level of achievement against standards developed for facility design, facility construction, operational sustainability, and modular design.

Table 1 - Uptime Institute's Tier System Classification Scheme

Tier 1	Tier 2	Tier 3	Tier 4
99.671% uptime	99.947% uptime	99.982% uptime	99.995% uptime
No built-in redundancy	Partial redundancy in power and cooling	N+1 Fault tolerance providing 72 hours of power	2N+1 fully redundant infrastructure and 96 hours of power outage protection
28.8 hours annual downtime	22 hours annual downtime	1.6 hours annual downtime	26.3 minutes annual downtime

The primary focus of the Uptime Institute is data centers that host significant volumes in storage devices and their secure connections to the environment. Though there are some fundamental differences in the operations evaluated by Uptime Institute and those considered in this report, there are also many applicable features from which we can learn. After reviewing this approach, and comparing to other research, the team decided to consider a similar approach that could be adopted by SCTE but using characteristics that are more applicable to hub and headend facilities.

5. Cable Rating System

5.1. Proposed Rating System

From the research conducted and a more detailed evaluation of the Tier Certification developed by Uptime Institute, this project proposes that SCTE develops and adopts a rating system that can be utilized by its members to assess their own facilities and processes for reliability. The proposed system is intended to be simple to use and readily applied to different goals of performance that each manager may have.

The purpose of the rating system will initially be to make crude assessments on the overall performance of the facilities and make it easy to identify areas for improvement or further investigation. This should allow operators to understand where their facilities are performing relative to their peers and where their facilities may be at risk. It can also be useful to other stakeholders that may want to compare the performance of their assets within a portfolio.

Figure 2 is a mockup of a possible scorecard used to assess each facility against a set of defined behaviors in categories believed to be the main drivers of reliability: people management, equipment & systems; planning and coordination; maintenance, and infrastructure. The proposed detailed list of behaviors by category is shown in Appendix B. These specific behaviors and categories should be refined further with input from SCTE and additional stakeholders in the cable industry to develop the most relevant and valuable rating system possible.

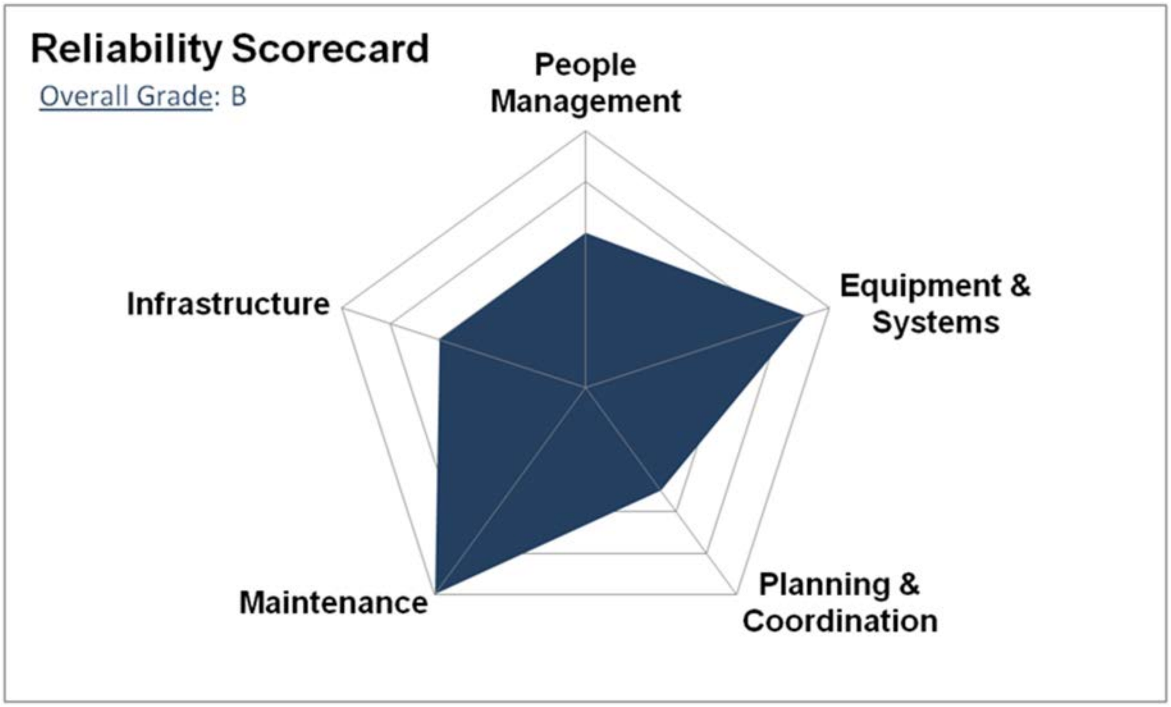

Figure 2 - Mockup of Reliability Scorecard for Cable Rating System

5.2. Benefits of a Rating System

The proposed rating system can provide many benefits for the cable industry. First and foremost, the rating system would provide simple metrics derived from individual behaviors. To examine those individual behaviors, it presents an easy-to-use checklist. Correspondingly, it offers a point system to quantify performance by awarding behaviors with various levels of points. The rating system can also act as a set of guidelines to help drive actionable improvements. As an additional bonus, it can enable competition between managers or sites, potentially driving further improvements. Furthermore, the proposed rating system would create brand value by acting as a badge of excellence for customers and investors.

5.3. Challenges of a Rating System

Potential challenges of implementing the proposed rating system have also been identified. Notably, a certification authority would be needed to assign and validate the ratings as proposed. Therefore, there would be staffing and resources needed for maintaining the rating system. Additional resources, such as labor, costs, and administrative overhead, would also be needed to support this effort. The establishment of a certification authority could also create another layer of burden with respect to current processes, systems, and bureaucracy. Finally, a new source of contention may arise from poorly rated facilities, and managers may be hesitant to adopt the system with such risks.

6. Conclusion

This research examined various aspects of reliability as they pertain to cable facilities, including: the current state of the industry; sample outage data from an SCTE member company; key concepts from reliability theory; how two other leading industries maintained high degrees of reliability, and the Uptime Institute's approach to data center reliability. Finally, the team proposed a cable facility rating system as a potential tool to drive improvements to reliability.

Recognition that people are inherently involved with the management, operations, and maintenance of cable facilities is important to understand the multi-faceted drivers of reliability. These drivers are: people management; equipment and systems; planning and coordination; maintenance, and infrastructure. This project proposed a simple, straightforward cable facility rating system for reliability that defines individual actions categorized by these five drivers. This rating system would provide decision-makers with a tool to benchmark, manage, and improve the reliability of their cable facilities.

Further work on this project will refine the rating system, engage additional stakeholders, pilot the rating system on select facilities, and finally result in a deployable rating system for the industry to use.

Appendix A: Analysis of Outage Tracking Data

This section is meant to illustrate the value of tracking and analyzing outage data in providing insights for any decision maker.

The analysis of outage tracking data was based on data obtained from an SCTE member company. The sample size comprises 232 data entries for a single manager within the SCTE member company. Consequently, the data may not be representative of the industry or even the particular company at large.

Data overall suggests significant opportunities in human-focused improvements, such as physical layouts, training, or vendor-preference. As an illustration, Figure 3 shows equipment-related versus human-related outages by year.

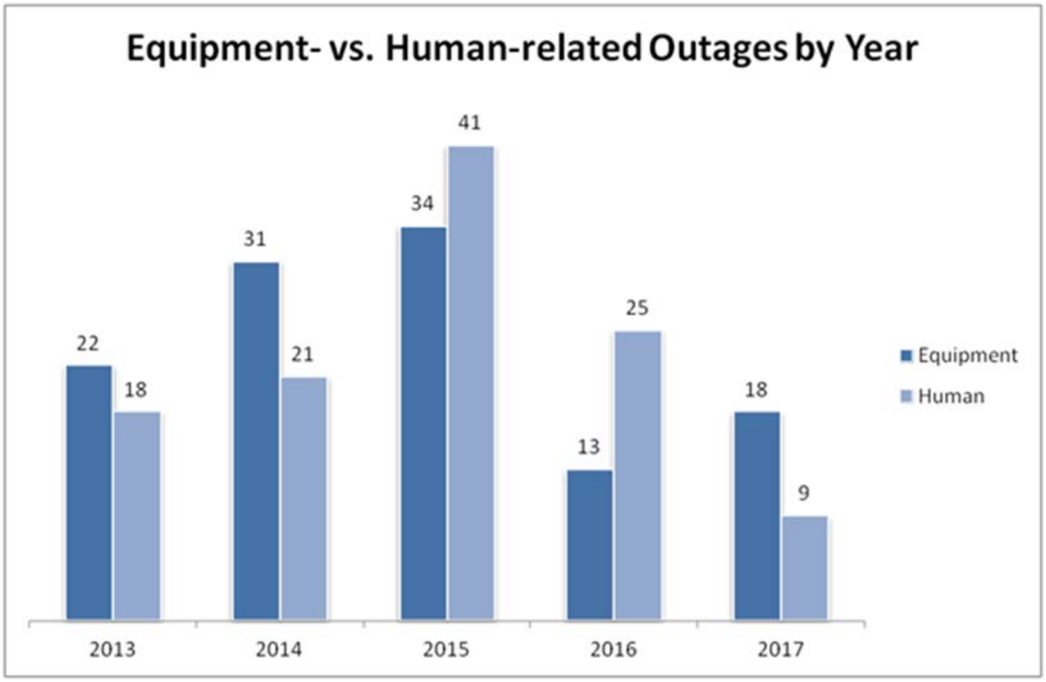

Figure 3 - Equipment-Related vs. Human-Related Outages by Year

For human-related outages, six out of 23 vendors are responsible for 86 percent of total outage minutes. This is shown in Figure 4. Note that vendor names are anonymized with three-letter code names.

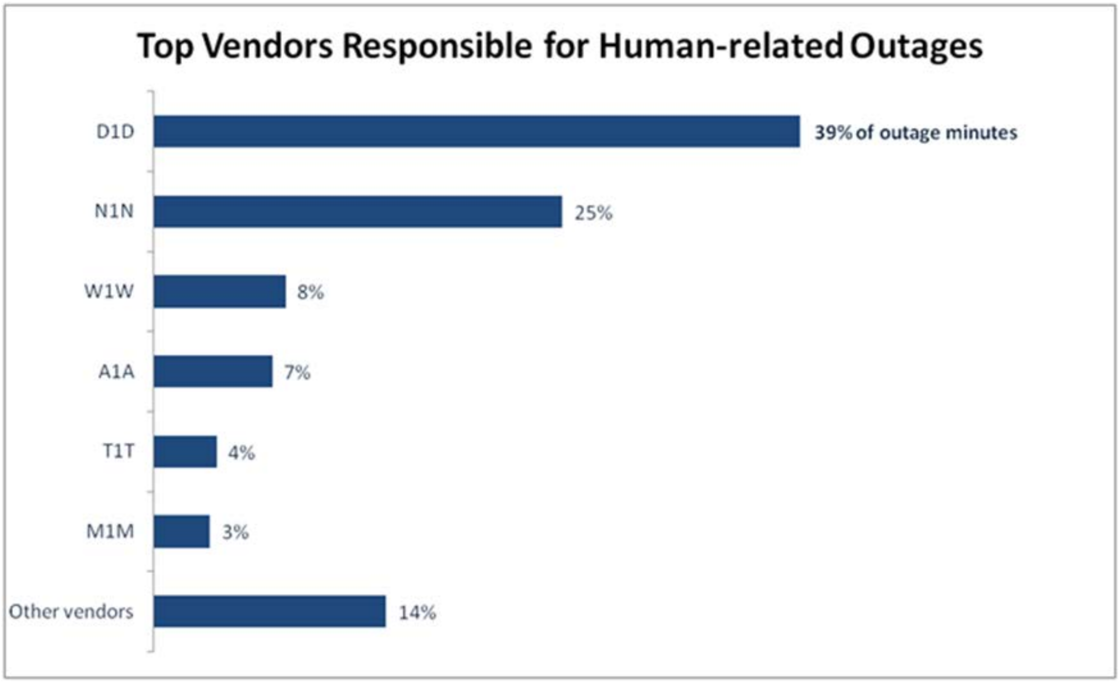

Figure 4 - Top Vendors Responsible for Human-Related Outages

Figure 5 illustrates the longest restoration times by vendor, excluding vendors with less than 5 total outages. Corrective actions can be directed toward these vendors to understand how to improve their average repair times.

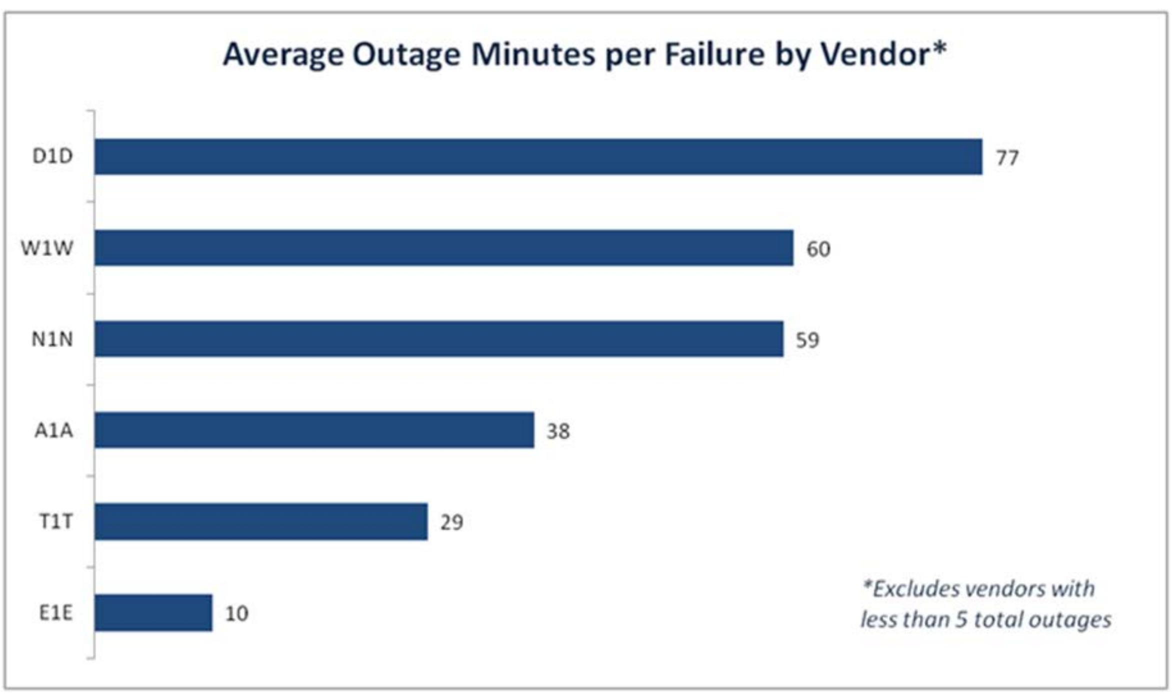

Figure 5 - Average Outage Minutes per Failure by Vendor

Similarly, Figure 6 shows the longest average restoration times by equipment for the top 12 offenders. Targeted and prioritized improvements to how these individual devices are repaired may significantly enhance reliability.

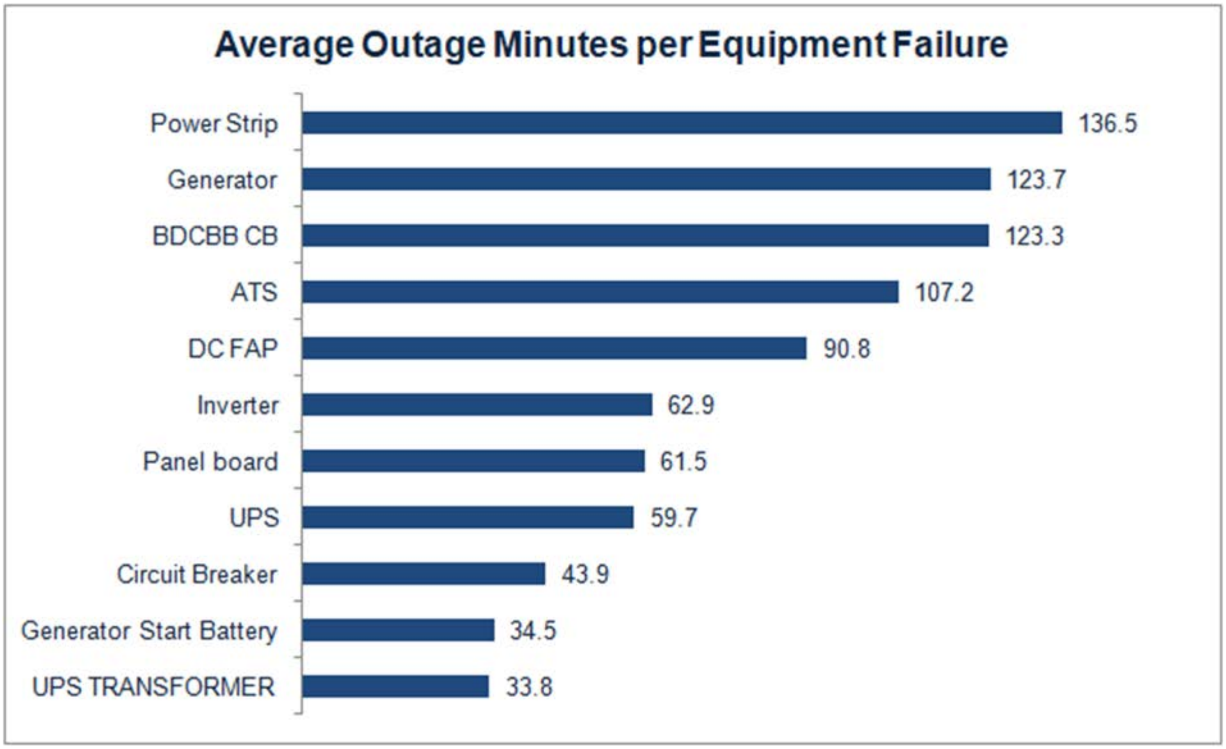

Figure 6 - Average Outage Minutes per Equipment Failure

Lastly, the research team looked at the UPS in particular, due to its high frequency of failure, and how its contribution to outages has changed over the period 2013 to 2017, shown in Figure 7. The figure depicts that both the UPS share of outages and duration have reduced significantly over the years. Thus, significant action may have already been taken toward addressing UPS reliability, and decision makers should focus on the next priorities in reliability.

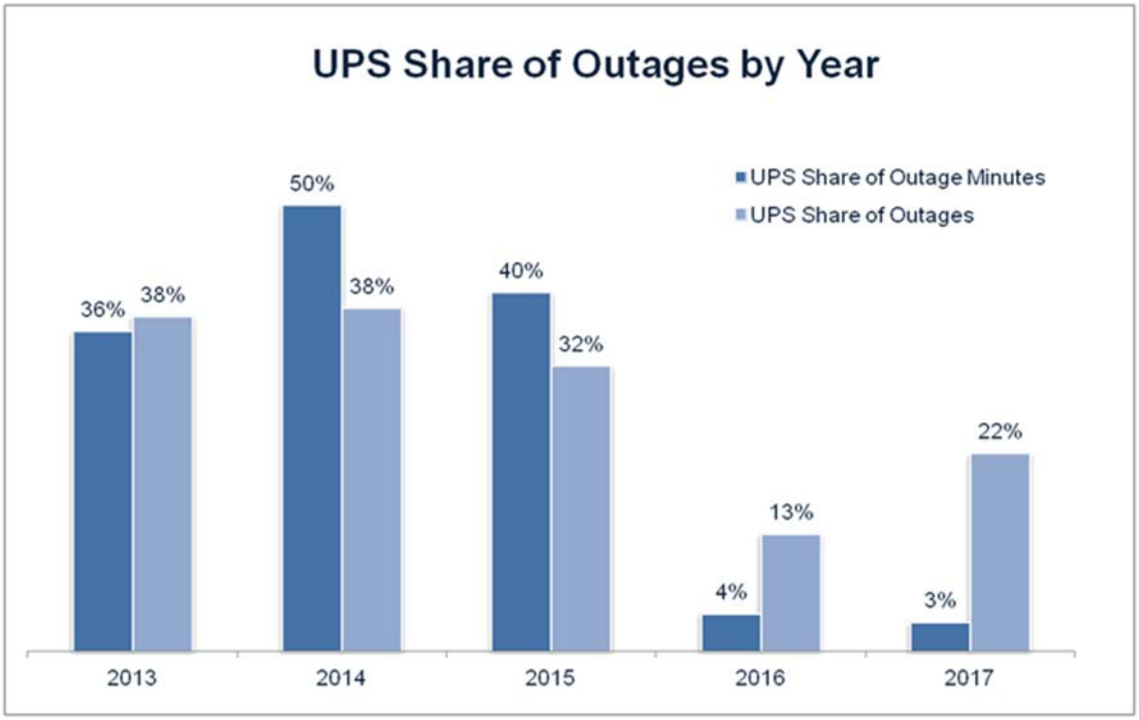

Figure 7 - UPS Share of Outages by Year

Appendix B: Cable Rating System - List of Behaviors

A proposed cable rating system is presented here. The rating system comprises tables of behaviors, broken out into five categories that drive reliability in cable facilities.

Table 2 - List of Behaviors for Cable Rating System

Category	Behavior	Points
Equipment & Systems	Process to ensure load capacity is never exceeded	3
Equipment & Systems	Operating set points for HVAC established based on both reliability and energy efficiency	3
Equipment & Systems	Process for rotating usage of redundant infrastructure equipment	3
Equipment & Systems	Factory acceptance testing of critical infrastructure equipment	3
Equipment & Systems	Pre-functional testing of critical infrastructure equipment	3
Equipment & Systems	System startup testing, including tests per OEM specifications	3
Equipment & Systems	System functional testing of critical infrastructure	3
Equipment & Systems	Integrated systems operational test	2
People Management	Part-time or full-time supervisor to oversee operations	4
People Management	Organization chart with reporting chain and appropriate interfaces between teams	4
People Management	On-the-job training (OJT) for all new employees for their responsible system(s)	4
People Management	List of required training before vendor is allowed to work in facility	4
People Management	Full-time supervisor to oversee operations	3
People Management	Designations for specific staff and vendor support for each critical system and equipment	3
People Management	Staff training via formal classroom, demonstrations, and/or drills	2
People Management	Staff training programs with training schedule, required reference materials, and records of attendance	2
People Management	Formal specific training for vendors	2
People Management	Facility manned with on-site staff at all hours of the day, seven days a week (24/7)	1
Infrastructure	Controlled access	4
Infrastructure	Space available for power, cooling, or equipment upgrades	4
Infrastructure	Adequate space available as workshop	3
Infrastructure	Fully labeled and standardized sizes used	3
Infrastructure	Equipment installed for ease of access and operation	3
Infrastructure	Layout designed to avoid thermal buildup and facilitate optimal ventilation for IT equipment	3

Category	Behavior	Points
Infrastructure	Adequate space available for storage and staging	2
Planning & Coordination	Process ensuring capital funds are sufficient and available to support business objectives	4
Planning & Coordination	Documentation for as-built drawings, operations and maintenance procedures, studies, commissioning reports, and warranty documentations	4
Planning & Coordination	Process for managing installation and removal of IT equipment	4
Planning & Coordination	Documented procedures for site configuration, standard operations, emergency operations, change management, and plans for site risks	3
Planning & Coordination	Regularly updated floor plans with clear indication of major functional areas and critical equipment	3
Planning & Coordination	Separately managed operating and capital budgets	2
Planning & Coordination	Process ensuring documentation is maintained current and copies are available to all relevant parties	2
Planning & Coordination	Process to manage and maintain effective airflow management regularly	2
Maintenance	Preventive maintenance program that includes: a prescribed list of maintenance tasks, assigned personnel, completion dates, and records	4
Maintenance	Floors in areas with server equipment are free of dust, dirt, and debris	4
Maintenance	Paper or electronic maintenance management system for tracking, assigning, and recording maintenance work orders	4
Maintenance	List of vendors qualified to work on systems during routine operations, and in case of emergencies	4
Maintenance	Preventive maintenance program incorporates maintenance procedures as directed by OEM	3
Maintenance	Server areas free of loose boxes, cleaning equipment, combustibles, and beverages	3
Maintenance	Keep detailed list of equipment and characteristics, such as warranties and year of installation.	3
Infrastructure	Layout designed to avoid thermal buildup and facilitate optimal ventilation for IT equipment	3
Infrastructure	Adequate space available for storage and staging	2
Planning & Coordination	Process ensuring capital funds are sufficient and available to support business objectives	4
Planning & Coordination	Documentation for as-built drawings, operations and maintance procedures, studies, commissioning reports, and warranty documentations	4
Planning & Coordination	Process for managing installation and removal of IT equipment	4
Planning & Coordination	Documented procedures for site configuration, standard operations, emergency operations, change management, and plans for site risks	3
Planning & Coordination	Regularly updated floor plans with clear indication of major functional areas and critical equipment	3
Planning & Coordination	Separately managed operating and capital budgets	2
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Category	Behavior	Points
Maintenance	Preventive maintenance program that includes: a prescribed list of maintenance tasks, assigned personnel, completion dates, and records	4
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Maintenance	Preventive maintenance program incorporates maintenance procedures as directed by OEM	3
Maintenance	Server areas free of loose boxes, cleaning equipment, combustibles, and beverages	3
Maintenance	Keep detailed list of equipment and characteristics, such as warranties and year of installation.	3
Maintenance	Employ service level agreements (SLAs) for all systems deemed critical	3
Maintenance	Fully document and characterize downtime incidents	3
Maintenance	Effective process for planning, scheduling, and funding the life-cycle replacement of major infrastructure components	3
Maintenance	Procedures with detailed steps for taking redundant equipment offline, and switching to another system in order to maintain uptime	2
Maintenance	Detailed preventive maintenance tasks that include formalized, step-by-step procedures, along with a method of documenting completion	2
Maintenance	Quality checks to ensure preventive maintenance is being properly performed; process for refining or improving preventative maintenance tasks	2
Maintenance	Documented and enforced housekeeping policies	2
Maintenance	Special tools and equipment necessary for performing maintenance are listed on work orders	2
Maintenance	Track, monitor, report, and analyze outage data with enough detail to determine equipment involved, downtime, time of failure, and other relevant factors for trending and root cause analysis	2
Maintenance	Preventive maintenance program incorporates calibration requirements per OEM or better	2
Maintenance	Monitor critical spares in stock, and advise when there is a need to procure more	2
Maintenance	Keep a list of vendors to contact for remote support by phone, and a list of technicians that are pre-approved and qualified	2
Maintenance	Monitor and report out progress toward completion of preventive maintenance tasks on at least a monthly basis	2
Maintenance	Perform deferred maintenance during scheduled downtimes	2
Maintenance	Predictive maintenance program to anticipate potential equipment failures before they occur	1
Maintenance	Perform systematic root cause analyses to understand failures and underlying issues	1

7. Abbreviations and Definitions

7.1. Abbreviations

ATM	automatic teller machine
FCI	failed customer interactions
HVAC	heating, ventilation, and air conditioning
ISOs	independent system operators
IT	information technology
KPI	key performance indicators
NERC	North American Electric Reliability Corporation
OEM	original equipment manufacturer
OJT	on the job training
RTO	regional transmission organizations
SCTE•ISBE	Society of Cable Telecommunications Engineers International Society of Broadband Experts
SLA	service level agreement
UPS	uninterruptable power supply

7.2. Definitions

Reliability	The probability that a system (part or component) can perform its intended task under specified conditions and time interval.
Resiliency	The ability of a system to withstand and recover from rare, catastrophic accidents, such as an earthquake or hurricane.

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Computational Fluid Dynamics (CFD) – Is It The Right Tool To Improve Cooling In Your Facilities?

A Technical Paper Prepared for SCTE/ISBE by

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1. Introduction

Edge Facilities (Class D as defined by SCTE 226) significantly outnumber data centers and regional head ends. On an individual basis energy use is quite low however when taken as a total they are the largest contributor to an MSO's energy consumption.

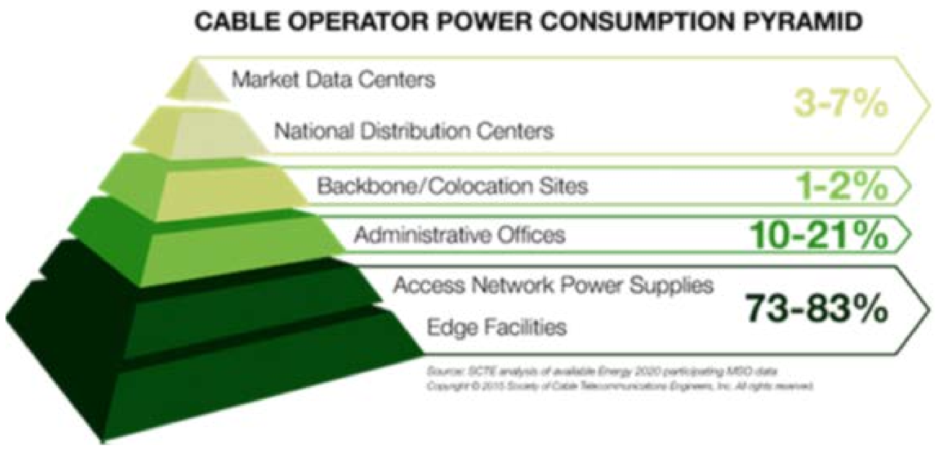


Figure 1 - Cable Power Pyramid

Because of low heat loads and random air flow designs of IT (Information Technology) equipment most legacy facilities are subject to poor airflow management. Flooding the room with cool air without AFO (air flow optimization) was the standard approach which required excess cooling capacity and cost.

As the power density in facilities increases providing adequate cooling in an efficient manner becomes more complex. As MSOs (multiple system operator) focus on reducing facility operating costs, development of effective and efficient cooling methods becomes necessary to counter large increases in cooling cost. Hot aisle and cold aisle rack layouts and IT equipment with clear front to back air flow designs are being driven by the requirements to develop better cooling strategies. A cooling strategy that relies solely on flooding the room with cool air without addressing rack air flow optimization through some form of containment, for example, has proven to be both ineffective and expensive.

Many factors beyond IT heat load need to be taken into consideration to develop an effective cooling strategy. Managing air flow is the first step in developing that strategy. The key focus while developing a good AFO strategy is to ensure a clear separation exists between cool supply air and warm return air. Air flow is difficult to measure and is influenced by the many factors.

A software-based tool called computational fluid dynamics (CFD) has been adapted to conduct air flow modeling of data centers, head ends and edge facilities. CFD is a numerical approach to simulate environments, changes, and impacts from variables. It is a predictive tool with the capacity to test scenarios prior to deploying costly and potentially ineffective solutions. It has been used for many years in a range of industries including aerospace/aeronautics, automotive, building HVAC (heating, ventilation, and air conditioning), energy/power generation, and process engineering.

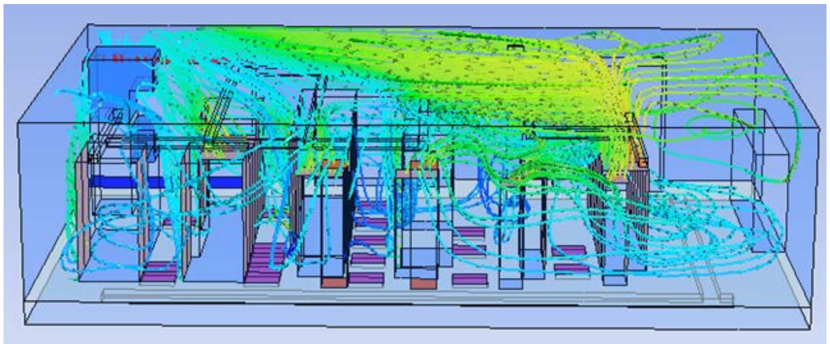


Figure 2 - CFD Air Flow Modeling Example

Higher heat density racks need proportionally more air flow than low heat density racks. Obstructions in the supply plenum, height of room, return plenum and the layout of racks are some of the elements that impact how air moves around the room and how effective it is in providing adequate cooling. To develop a plan for improving air flow management a software-based computational fluid dynamics (CFD) tool can be useful to develop a model of the facility replicating air flow patterns and associated temperature profiles, identify air bypass and recirculation, air mixing and wasted cooling capacity. CFD modeling has become a common tool to identify air flow issues and determine what action to take to improve cooling effectiveness without incurring substantial costs implementing ineffective solutions that may worsen the situation.

This article will provide guidance in the use of CFD as a tool to assist in improving air flow management, when it is applicable and when it is not, to identify the types of facilities and conditions where it is most effective. Reference to facility types follows the nomenclature defined in ANSI/SCTE 226 – 2015.

Background reference material on CFD to help the reader understand CFD is provided in the Bibliography and Reference Section.

The paper was a team effort not only from the 6 principle authors but I would like to recognize the significant contributions from the following people:

Ken Nickel, Quest Controls, **Dave Smargon**, AIRSYS North America, **Mike Glaser**, Cox Communications, **Derek DiGiacomo**, SCTE/ISBE, and **Dave Higgins**, Comcast (Retired).

2. What Questions can CFD Answer?

Air flow modeling is an engineering tool that enables visualization of air flow patterns and is an effective tool to show existing air flow conditions as well as highlight areas of over-cooling or heat congestion. One can modify and visualize the model on a computer screen to determine the impact of proposed changes. Quite often the ‘logical’ approach is not the best approach to improving air flow. Air flow patterns are impacted by many factors and to rely just on matching cooling capacity to IT load can result in excess or insufficient cooling.

CFD provides a visible representation of the air flow that will reveal hot spots, movements of heat under various scenarios allowing ‘what if’ analysis to optimize solutions. This will enable air flow to be optimized improving cooling performance resulting in increased energy efficiency. The solutions are presented graphically showing problem and complaint areas which therefore can then be better understood and evaluated by senior management. This is all done without disruption to the existing facility.

Right sizing the cooling to the IT load is key to improving energy efficiency. Equipment layout that causes obstructions to air flow can result in excess cooling volume. The perception of hot spots generally drives the conclusion that more cooling capacity is required; when in fact changes to air flow patterns by using blanking panels or reconfiguration of rack equipment may solve the problem.

CFD can provide insight into the following questions:

a) Is cooling effectiveness being impacted by equipment obstructions or placement of cooling systems?
b) Is there sufficient cooling capacity to handle forecasted increase in IT load?
c) At what heat load level will additional cooling be needed for the site? And what is the best placement for the cooling?
d) Does N+1 cooling capacity exist?
e) How would failure of a cooling system impact air flow dynamics and therefore heat levels?
f) What is the cause of hot spots and how can they be resolved?
g) Where is the best placement for higher density equipment?
h) Is air containment required to solve cooling issues?

A key benefit of CFD is that different solutions or design alternatives can be tested to a good level of confidence without incurring significant cost and time for deployment of each proposed solution works.

3. When to use CFD

CFD can provide details on air flow for management to clearly see issues and related solution(s) and can help justify funding of the solution(s).

CFD can be used in either raised floor or slab situations.

Other factors to consider are:

- Size of facility- smaller facilities tend to have more turbulent air flow patterns making the interpretation of CFD results more difficult.
- With a completely random air flow, (e.g. no hot aisle/cold aisle discipline, and no AFO), using CFD becomes very complex although not out of the question.
- No rack row placement discipline also makes CFD complex to implement.
- CFD is a representation of air flow. Technology changes (e.g. refrigerant upgrade, floating head) do not need CFD as those technologies don’t involve air flow.

3.1. Payback Perspective:

a) Most needed- in large facilities, such as a large facilities Class D or A - C with significant hot/cold air mixing issues and high utility rates
b) May be needed- medium or small facilities in high cost areas, medium facilities with cooling performance issues, or any site that will undergo significant changes in IT heat load
c) Least needed- in newer facilities designed from the start with proper airflow management/aisle configurations or smallest facilities, such as a Class D, with low utility rates
   - Exception: if many smaller facilities with similar issues and layouts, MSOs can amortize the cost of CFD for one site across many sites and payback in a reasonable timeframe

3.2. Performance Perspective:

a) Critical facility – To predict or visualize how an action or modification impacts the critical environment, without putting assets at risk.
b) Size and complexity – Redistribute Rack Rows…mixed aisles.
c) Large cooling units – reduce opex and complexity by replacing a large number of small units with fewer larger cooling units.

3.3. To help answer the question, “What actions do I want to take and what do I want to accomplish?”

CFD is a computational tool and like all computer tools the output is dependent on the input. Here are a few key problems and questions to pose for CFD to assist in solving.

a) How can better and more stable cooling be provided for the equipment?
b) What can be done to generate energy savings, capital avoidance or regain lost capacity?
c) Determine the next steps for air flow optimization.
d) Is containment a viable option, how can this be implemented to reduce capital and operating costs?
e) Get corporate buy-in, use CFD to visualize air flow improvement from various scenarios, costs, and ROI to enable better understanding by management.
f) Facilities (operations team) buy-in can be enhanced by visualizing impacts of solutions and operational practices so that the impact on facilities can be better understood by those who are directly involved in their maintenance.

4. In House or Outsource CFD Modelling

4.1. When should I do this myself?

The following are points to consider.

a) More than 10 projects to use CFD modeling on.
b) Engineers on staff who understand air flow management.
c) Engineering staff has the time to learn and use the software, develop and validate the baseline model, identify appropriate iterations to be evaluated and to be trained on the interpretation of the results.
d) Engineering staff has knowledge and time to do detailed audits of the facilities

e) Engineering staff has time to update floor maps of the facility, update or draw out the mechanical drawings showing the cooling units, ducting, cabling and document the data needed for the CFD model.
f) Engineering staff who can provide a clear business case with payback, ROI (return on investment) for management to evaluate.

4.2. When would I hire a contractor to do the CFD modeling?

Some points to consider are as follows.

a) Fewer than 10 projects to use CFD modeling on.
   i. Too few sites to bring in house economically
b) No expertise in air flow management
c) Engineering staff is already overcommitted and does not have the time to:
   i. Learn the software
   ii. Conduct the audits and gather the needed documentation
   iii. Update the floor plans, and mechanical drawings, cabling, ducting etc. for the CFD model
   iv. Develop the knowledge and experience to interpret results and provide conclusions or to decide the next step(s) or solution(s)
   v. No staff to take the CFD results and provide a clear business case with payback, ROI for management to evaluate.

5. Client Options for Computational Fluid Dynamic Software

5.1. Primarily subscription-based offerings

- Licensed and installed for local processing
- Licensed and online
- Online only (cloud-based)

5.2. Pricing structures

- Pricing can be fixed, time-based, or facility size-based (e.g. lower cost for facilities less than 10,000 sq. ft., full price for larger/any sized facility)

5.3. Capabilities to consider in acquiring CFD software

- Modeling method (discrete type such as finite element method, finite volume method, etc.)
- Drag and drop of common equipment types [servers, CRAC (computer room air conditioning) units, etc.]
- Note that telecom edge facilities have specialized equipment that must typically be added to/customized for any library of equipment types
- Ability to include common airflow solutions (blanking panels, aisle containment, directional diffusers, etc.)
- Ability to model common obstructions in cable edge facilities

- Level of detail outputs on cooling units, rack temperatures, ducting airflow volumes, supply plenum static pressure
- Visualization of supply and return air flow patterns

5.4. Typical products in the market

- **6Sigma** from Future Facilities, a UK-based consultancy that specializes in CFD tools for industry
- **Flovent** from Flomerics Group (FLO), also based in UK.
- **TileFlow** from Innovative Research Inc. of Minnesota, USA.
- **CoolSim** software from ANSYS, a Pennsylvania, USA maker of engineering simulation products.

6. Benefits of Modelling

There are a number of benefits in using a CFD software modeling tool for air flow analysis. As in any modeling solution the baseline model must be rigorously validated to ensure it is a good representation of the facility's current air flow patterns. Without this step the results derived from the modeling will be of little value.

Some specific key benefits and reasons for using a CFD modeling tool are:

1. Identify and "see" air flow patterns that cause cooling issues. Issues such as hot spots may be caused by lack of air flow to a particular area in a room and in other cases caused by lack of heat removal. Site modeling can highlight other factors such as excess air flow and static pressure thus enabling the right remedial action to be taken.
2. CFD can be used to analyze the impact of projected increases in IT heat load. Using a 'What if additional load is added?", CFD can model the result of adding load on the cooling system to determine if it is adequate or if additional capacity is required. In addition, it can provide the preferred location of additional cooling equipment or determine where higher density IT racks should be implemented.
3. Allow the "testing" of alternative solutions to air containment without incurring the cost of trial and error implementation. CFD modeling can test alternatives such as full aisle containment, end of row or rack chimneys, and provide performance data on each.
4. CFD modeling can be used in cases to replace end of life cooling units and reposition cooling systems to improve air flow. A baseline model can be easily adjusted to reflect new location or capacity and determine how that affects the cooling in the site.
5. Cooling unit failure scenarios can be run to determine if N+1 capacity exists. Modeling can offer insight into the impact of failure of a particular unit compared to others.

CFD as a tool can be applied to help find effective solutions to AFO. As such it does not have any financial aspect. The tool can provide information that can be used financially:

- Create business cases demonstrating clear payback and ROI.
- Operational Savings
- Capital Cost Avoidance.

The term ‘capital avoidance’ can also be referred to as ‘production margin’ or ‘regaining lost capacity’. As mentioned in the key benefits, using CFD to find solutions that reduce inefficiencies while cooling a facility and allow additional equipment to be added thereby avoiding building a new facility.

7. Building and Validating a CFD Model

A CFD technician’s skill level and degree of understanding of the specific critical infrastructure facilities will greatly affect the accuracy of the outcome. It can be compared to an automobile mechanic; the more experience and higher skill level will result in a better, more reliable outcome. Like any software product CFD models require the input of many variables. Detailed mapping of the room architecture, obstacles, penetrations, building envelope and infrastructure components is required. Gaps in racks, equipment orientation, missing rack doors or sides will greatly affect the models. This data input can be quite extensive.

It can be difficult to accurately define the actual heat profile at any given time from servers, routers, storage arrays and in-rack devices. This includes device information affecting the IT load, heat generation (watts) and cooling capabilities. Most locations will not have accurate electrical consumption loads on rack devices and “nameplate data” de-rated to 60% of full load is typically used. This guesstimate is a variable that can lead to errors and usually results in skewed data but is generally accepted as “close enough.”

Validating the baseline model is key to having a good representative model to build on. The validation process can be the most intensive and is largely dependent on the data collected during the audit process.

- Comparing the model rack inlet temperatures and exhaust to the audit data is one method.
- Comparing measured cooling unit return air temperature to the model output is also useful.
- Measured static pressure comparisons to the model can be used.

During the validation process the model will require fine tuning to better match the facilities true conditions. The more comparisons that can be used, the more accurate the baseline model will be thereby building a solid base for changes. In environments with ongoing changes the baseline model should be kept up to date otherwise it will no longer be representative.

Once the baseline model is validated, new iterations can be run testing alternative measures that could be deployed in the site. These could range from simply adding more perforated tiles to full containment or addition of more cooling capacity. CFD modeling outputs provide both graphical and statistical data. Once the baseline conditions are noted, any iterations with changes will reflect a new set of data that can be compared to the baseline to determine if the change has had a positive or negative impact.

7.1. Data Inputs: Room

A basic set of data required for a CFD model must include the following items.

1. Dimensions and type of room – raised floor, solid
2. Placement of rack rows
3. Placement of HVAC

7.2. Data Input: Racks

1. Rack equipment by rack and RU (Rack Unit, 1.75”)

2. Rack dimensions with RU width
3. Open RUs and blanked RUs, by rack and RU locations
4. Rack physical location
5. Inlet and exhaust temperatures by rack and row

7.3. Data Input: HVAC

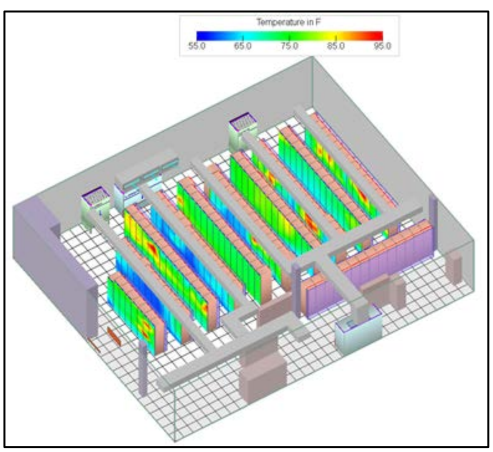
1. CRAC, RTU, Wall Pack, or In-Row Cooling
    - Nameplate data for each unit
    - Air flow volumes, cooling capacity, turning vanes, air supply/return form, extensions,
    - Current controls, thermostat or BAS (building automation system)
    - Supply and return set points
    - Measured supply and return temperature
    - Location of thermostat control
2. Ducts locations
    - Location of supply diffusers and return ducts
    - CFM (cubic feet per minute) and temp at each of the above
    - Type of ducting – hard, flex
3. Non-Ducted
    - Location of unit
    - Directional flow of air from Supply

Issues being investigated may require much more data such as when multiple cooling units are being analyzed with different operational parameters or failure scenarios.

8. Examples of CFD Model Solutions

The following is an example of using a CFD tool to show the impact of an AFO program. This could simply be installing blanking panels following the CFD from the baseline through the prediction of the results of the AFO to a possible 'what if' involving increasing the CRAC set point. These results can then be used to drive a financial model and generate associated costs and ROI for air flow improvements.

First the existing site CFD Model – Baseline show in Figure 3.



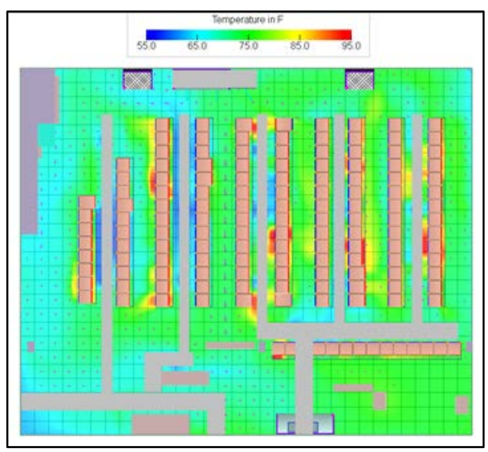


Figure 3 - CFD Baseline Example

After air flow optimization the CRAC units are at the same set point temperature and show improved air flow with no hot spots. Cold aisles have cooler areas showing potential to increase set points. This is shown in Figure 4.

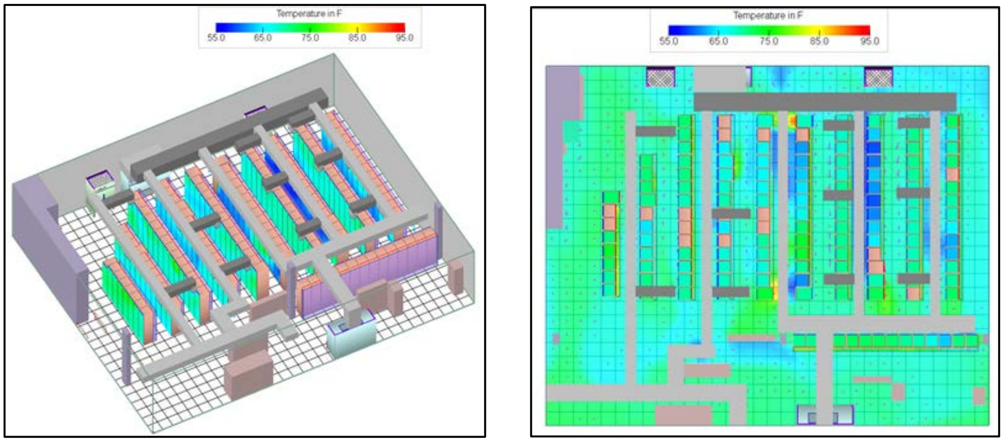


Figure 4 - CFD after AFO

Finally, what if after AFO the set point is increased? All rack inlet temps below 75^0 F – CRAC Set Point temperatures increased by 2^0 F, shown in Figure 5.

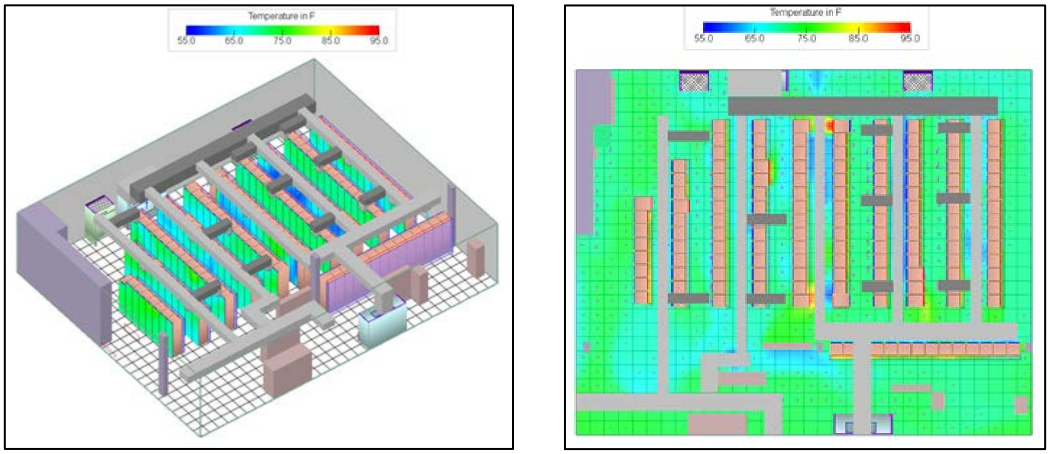


Figure 5 - CFD Model of Increased Set point

9. Summary

This article posed the question: “Computational Fluid Dynamics (CFD) – Is It The Right Tool To Improve Cooling In Your Facilities?” To answer this question the following must be taken into consideration: “What actions do I want to take?” and “What do I want to accomplish?” The answers to those questions combined with the facility baseline and a clear understanding of the facility details, the room size, existing air flow and rack layout and complexity will help in deciding whether or not CFD is the right tool to use.

10. Abbreviations

AFO	air flow optimization
BAS	building automation system
CFD	computational fluid dynamics
CFM	cubic feet per minute
CRAC	computer room air conditioning
HVAC	heating, ventilation and air conditioning
IT	information technology equipment
MSO	multiple system operator
opex	operational expenditures
ROI	return on investment
RU	rack unit (1.75”)
RTU	remote terminal unit?
SCTE•ISBE	Society of Cable Telecommunications Engineers International Society of Broadband Experts

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