ASHRAE TC 9.9 Technical Bulletin

Edge Computing Highlights

1. IT Equipment Warranty Risks
   a. Temperature Excursions
   b. Humidity Excursions
   c. Air Quality Excursions
2. Practical Solutions to Avoid Warranty Risks

Edge Computing: Considerations for Reliable Operation

Introduction

According to Gartner, by the year 2025 more than 75% of enterprise-generated data will be created and processed outside the traditional data center or cloud **[1]**.

- **Data Handling.** Instead, some of this data will be handled by so-called "edge" computing solutions or "edge" data centers.
- **Edge** (not new). Although the concept of edge computing is not new and has been around for many years, "edge" is a somewhat subjective term.

There are a number of resources in the public domain that provide a good definition of what comprises edge computing **[2-6]**.

- **Edge Definition.** For the purposes of this paper, "edge" refers to computing that is carried out at or near the source of the data.
- **Edge Difference.** Edge data centers can deliver cloud-like capabilities similar to those found in centralized data centers, but with much lower latency and lower data transport costs due to their proximity to the end user.

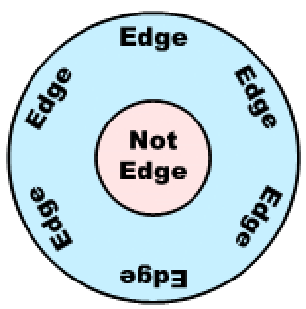

Figure 1 – Enterprise-Generated Data
(Greater than 75% at the Edge)

Rapid growth of edge computing is being driven by new classes of digital growth that require local processing, i.e., where the data set is too large and/or the application is too latency sensitive to be transmitted back to a centralized cloud server.

- **Digital Growth Areas.** Growth in edge computing can be attributed to expanding and emerging applications, including:
  - Online shopping
  - Internet of things (IoT)
  - Artificial intelligence (AI)
  - Streaming (i.e., videos, video conferencing)
  - 5G
  - Blockchain
  - Remote learning
  - Telemedicine
- **Data Volume Growth.** One way to think about the growth of edge computing is: as the volume of data grows, that data is becoming heavier and denser and more difficult to move **[7]**.
- **Local.** Data sets are now so large it makes more sense to process and store them locally rather than transport them to a regional cloud data center.
- **More Edge Data Centers.** The net result is there will be many more edge data centers to complement the large cloud data centers that are the foundation for IT processing and storage.

This technical bulletin explores the challenges of designing and maintaining small data centers that are surrounded by

- Semi-controlled or even uncontrolled external environments.

Scope and Problem Statement

Figure 2a – Example of One Small Rack Enclosure

Figure 2b – Example of One Large Multi-Rack Enclosure

This technical bulletin has been written to highlight the environmental and reliability challenges of small edge data centers. Examples of small data centers include:

- Modular data centers fabricated from steel shipping containers
- Prefabricated edge pods
- Small stand-alone brick-and-mortar data centers
- Phone-booth-sized enclosures that hold a single rack
- Very small enclosures that hold only one or two servers

These small data centers generally include a preassembled and pretested enclosure all of the compute, storage, networking, power, cooling, security, and management.

What these examples all share is a close proximity to an outdoor or semi-controlled environment such that opening the outer door of the data center could DRAMATICALLY impact the temperature, humidity, or inlet airstream reaching the IT equipment inside.

The hazards encountered by edge data centers are the same as those for conventional data centers, but the risk levels differ because edge data centers generally have a smaller count of IT equipment, a smaller physical enclosure size, and connectivity challenges associated with being remote.

Consider a phone-booth-sized environmentally controlled enclosure with a single rack of IT equipment in an outdoor location or a semi-controlled location such as a warehouse.

Scope and Problem Statement (continued)

Will any of the following occurrences impact the IT equipment performance, reliability, or manufacturer's warranty?

- **Cold Day** (Figure 3a) **-**What would happen to the inlet airstream to the IT equipment if the door was opened on a very cold day (i.e., –5°C, 23°F) that was below the specified limit of the IT equipment?
- **Air Pollution** (Figure 3b) **-** What if opening a door let in high levels of air pollution that could cause corrosion?
- **Dust** (Figure 3c) **-**What if the data center was located in a dusty climate where air coming in through the door bypassed the filtration system?
- **High Humidity** (Figure 3d) **-** What if service needed to be done on a rainy day when the relative humidity was close to 95% rh, i.e., above the IT equipment's specified limit?

Figure 3a – Servicing Equipment on a Cold Day

(Can cause air temperature to dip below the IT equipment specification limits.)

Figure 3b – Opening Enclosure Door

(Can allow air pollution into the enclosure.)

Figure 3c – Opening Enclosure Door

(Can allow dust into the enclosure.)

Figure 3d – Opening Enclosure Door

(Humidity can bypass enclosure environmental controls, possibly causing condensation,)

This Technical Bulletin addresses:

Environmental and reliability risks of designing and maintaining small edge data centers provisioned with off-the-shelf commercial IT equipment.

IT Equipment Warranties

Before deploying a small edge data center, it is especially important to understand the IT equipment supplier's warranty and over what range of conditions their warranty applies.

For each piece of IT equipment you plan to deploy, carefully check **[8]**:

- Allowable temperature
- Rate of change of temperature
- Humidity range
- Dew-point limits
- Dust filtration
- Air quality requirements

Environmental specification conditions, on which warranties are based, can be exceeded by opening the data center door to the outside conditions.

- **Most equipment suppliers** specify a temperature range, relative humidity range, and dew-point limits.
- **Some equipment suppliers** even have specifications for temperature rate of change as well as air quality specifications for dust and pollution.
- **Violations** violating an IT equipment manufacturer's specification conditions should be avoided, as they could potentially nullify the warranty and compromise the equipment performance and reliability.

Do NOT violate
IT Equipment Warranty

Environmental - Control

Check the specifications for each piece of IT equipment you plan to deploy and then design and maintain the enclosure to support the narrowest of those specification ranges.

- **Performance Impact.** Temperature excursions above specification limits can cause processor throttling and a reduction of system performance.
- **End-of-Life Impact.** Prolonged high-temperature excursions can also reduce the life of certain types of components, such as
  - Electrolytic capacitors
  - Integrated circuits
  - Batteries
  - Hard disk drives
  - Fans
- **Hard Drive Impact.** Excursions above and below environmental limits can compromise hard drive functionality **[9]**.
- **ESD Impact.** Electrostatic discharge (ESD) can damage critical components. Conditions that increase the probability of ESD include **[10]**:
  - **Humidity Excursion.** Humidty below specified limits..
  - **Wrist Strap.** Not using properly functioning and grounded wrist strap.
  - **Non-ESD Floors.** Standing on non-ESD floor surfaces.
- **Corrosion.** Prolonged exposure to high humidity can lead to corrosion of the chassis and corrosion of exposed copper traces, especially if pollutants are present **[11]**.

Environmental - Control during Servicing

Mitigate Risk of Exceeding Warranty Limits during Servicing

If temperature and humidity warranty limits could be exceeded by exposure to outdoor conditions, consider the following:

a. **Scheduling Solution.** Service the equipment at a different time of day or delay service until outdoor conditions improve.

b. **Mantrap Solution.** Use a mantrap or air lock as applied in larger data centers, but in this case use it to minimize the environmental shock to IT equipment inside the data center.

c. **Tent.** Use a temporary environmental containment device (tent) with a heater or A/C unit to enclose the door of the enclosure so when the door is opened, the temperature change the IT equipment is exposed to is within specified limits.

Brief Excursions during Servicing

There may be instances where short (i.e., a few minutes long) excursions occur and it is therefore difficult or impractical to maintain strict adherence to temperature and humidity specifications.

- **Excursions within Warranty.** Be sure to check with your IT equipment supplier to make sure the extent and duration of any excursions won't void the warranty.
- **Humidity Inrush.** Avoid conditions where an inrush of high humidity could cause a condensation event.
- **Condensation.** Condensation events are specifically prohibited by most supplier and industry specs **[8]**.

Monitor Temperature and Humidity during Servicing

The technician should have a way to monitor both temperature and humidity of the IT equipment inlet air in real time.

- **Handheld or Firmware.** This could be as simple as a portable handheld unit temporarily attached to the front of the IT equipment, or it could be a readout of the inlet air temperature from the IT equipment firmware.
- **Humidity Measurement.** If the firmware gives only a readout of the inlet air temperature, it will be necessary to have an additional device to monitor humidity.

Rate of Change during Servicing

Temperature rate of change and condensation rate of change specifications for temperature are often overlooked.

- **Rate of Change Requirement.** A rate of temperature change requirement specifies how many degrees the temperature is allowed to change in a given period of time.
- **ASHRAE Rate of Change.** The ASHRAE temperature rate of change guideline for equipment other than tape is 20°C (36°F) in an hour and no more than 5°C (9°F) in any 15 minute period **[8]**.
  - It is important to note this is not an instantaneous rate of change.
- **Open Door Impact.** Opening the door of a small edge data center or enclosure can create a situation of rapid temperature and/or humidity change (violate rate of change specifications).
  - This is more apt to be a problem with very small enclosures (i.e., 1 rack or less).
  - If there is not room for a service person to work standing inside, the enclosure door could remain open for extended periods of time.

Condensation Due to Temperature Change During Servicing

Another possible consequence of temperature change is condensation.

- **Temperature Drop.** If the air temperature drops below the dew point, condensation could occur inside the enclosure and on the IT equipment, especially if the space inside the enclosure is air conditioned.
- **Dew Point.** Depending on the dew point of the air, it is possible for a condensation event to occur even within some temperature rate of change specifications.
- **Morning Extremes.** It is common to have very high outdoor humidity and dew-point readings in the morning.

This is why the use of a temporary environmental containment unit (tent) is so important.

Know your temperature rate of change specifications, check dew-point values, and use a temporary containment structure, when appropriate, to avoid condensation and stay within temperature rate of change limits.

As discussed in the previous section, have a means of monitoring the IT equipment inlet air temperature and humidity in real time.

Air Quality and Corrosion

Air quality, which includes both gaseous pollutants and dust, is an important consideration for small edge data centers.

- **Gaseous Pollution.** Gaseous pollution can lead to IT equipment failures from corrosion of exposed copper and silver on components and printed circuit boards (PCBs).
- **Dust and Lint.** Dust and lint can clog inlet air filters and can foul heat sinks.
  - The net result is diminished airflow, increased fan power draw, reduced cooling efficiency, and possible throttling of the processor and performance degradation.

Evaluation of local outdoor air quality for small edge data centers should be carried out with the same rigor as for large brick-and-mortar data centers. The amount of dust and gaseous pollutants can vary widely by location and can even be seasonal or short term.

- **Coal-Fired Plants.** Centralized coal-fired steam plants are used in parts of Asia to provide heat for buildings in winter. These plants often burn high-sulfur coal, polluting the airstream with corrosive sulfur—but only seasonally.
- **Seasonal and Short - Term Events**
  - **Agriculture.** Spraying of agricultural crops with insecticide can put unexpected pollutants in the airstream.
  - **Seasonal Winds.** Seasonal and prevailing winds can stir up large amounts of dust, especially if there is construction nearby.
  - **Short-Term Winds.** Short-term changes in wind direction can intermittently blow industrial pollutant streams (e.g., sulfur from a tire factory or paper mill) over the data center.
  - **Ocean Spray.** Some types of dust (e.g., fine salt particles from the ocean) can even be corrosive.
  - **Other Short-Term Events.** Other event examples include nearby grass mowing, street cleaners, and heavy vehicle exhaust during rush hour.

For more information on dust and gaseous pollution, consult ASHRAE Datacom Series Book 8, *Particulate and Gaseous Contamination in Datacom Environments*, Second Edition **[12]**.

Environmental Control - Contamination

Design

Edge computing data centers and enclosures for edge computing should be designed to meet the following requirements:

- **Incoming Air.** ASHRAE MERV 11 or MERV 13 filtration requirements for incoming air.
- **Recirculating Air.** ASHRAE MERV 8 requirement for recirculating air streams **[12]**.
- **Filtration Requirements.** The ASHRAE filtration requirements are designed to capture most of the particle load from both man-made and naturally occurring sources.

Gaseous Pollutants

The ASHRAE recommendations for gaseous pollutants are defined in terms of a net copper and silver corrosion rate. Small edge computing data centers and enclosures should be designed and maintained to meet the ASHRAE **[12]** and ISA **[13]**corrosion limits.

- **Corrosion Rate.** The recommended corrosion limits are:
  - **For Silver.** <200 angstroms/month
  - **For Copper.** <300 angstroms/month (an angstrom is 10^{-10} m).

Corrosion Measurement

Corrosion measurement can be through metal coupons or monitoring systems.

- **Metal Coupons.** Corrosion rates are commonly measured using polished metal coupons of copper and silver and exposing these coupons for a time period of one month and then measuring the thickness, in angstroms, of corrosion product formed.
- **Monitoring Systems.** Alternatively, there are also corrosion rate monitoring systems that can be networked to provide real-time corrosion rate data **[14]**. These systems can detect seasonal and short-term changes in air quality.

Gaseous Pollutants

In locations where there is a large amount of automobile exhaust or gaseous pollutants from a manufacturing process (e.g., paper mill, tire and rubber factory, petroleum refinery), it may be necessary to install chemical filtration to meet the corrosion requirement and avoid corrosion-induced IT equipment failures.

Remote Monitoring

Small edge data centers and edge computing enclosures should have remote monitoring of filter performance by means of both

- **Filter Differential Pressure.** Differential pressure across the air filters and
- **Corrosion.** Monitoring of the potential for corrosion-related IT equipment failures by way of corrosion-monitoring sensors.

Electric Power Equipment Enclosures

The National Electrical Manufacturers Association (NEMA) is a North American standards body that publishes standards for enclosures for electric power equipment **[15]**.

- **Enclosure Classes.** NEMA standards define different classes of enclosures that have resistance to temperature, humidity, and pollution.
- **Edge Computing.** NEMA standard enclosures may be applicable for some types of edge computing.

Other Considerations

Site Selection

Site selection for edge data centers is important because the data centers need to be close to the data they are processing for low latency.

- **Edge Versus Cloud Data Centers.** Edge data centers may have less site selection latitude than traditional brick-and-mortar cloud data centers.
- **Seasonal Pollutant.** Seasonal pollutants that may not show up from a single site measurement.
- **Self-Driving Cars.** Edge data centers to support traffic management and self-driving cars may include non-ideal locations such as polluted urban areas and dusty rural areas.

Filtration can address the pollutants but has its own issues:

- **Periodic Service.** Most types of filtration require periodic cleaning and replacement.
- **Frequent Service.** If the air quality at a site is less than ideal, the filters will require service more often.
- **Remote Monitoring.** Filters should be equipped with remote monitoring of differential pressure across the filter to alert maintenance staff of the need for filter cleaning or replacement.
    - Remote monitoring is especially important in locales that may have sporadic naturally occurring events such as dust storms and ash falls from volcanic activity.

A hazard analysis on natural disasters (floods, tornadoes, wildfires, hurricanes, lightning, and earthquakes) should also be considered (same as with brick-and-mortar data centers) **[16]**.

Energy Efficiency Impact

Data centers are shifting from a centralized model of large data centers to a more decentralized mix of both large and small data centers.

The decentralization trend has implications for:

- Energy Efficiency
- Sustainability
- Energy Conservation

Some examples of the energy impact of edge computing include:

- **Data Center Fleet.** Less efficient, small/edge data centers can dilute the data center fleet energy efficiency and increase operating expense.
- **Cooling.** Cooling system selection for a small edge data center should balance up-front cost and the long-term operational cost of power.
    - A small direct expansion (DX) cooled edge data center enclosure may be less energy efficient than a large data center with built-in economization and a more sophisticated environmental control system.
- **Modular Edge Data Centers** present several thermal challenges that separate them from conventional brick-and-mortar facilities.
    - **Weather Impact.** The small footprint and reduced insulation of small edge data centers disproportionately increases the thermal impact of outdoor conditions (e.g., heat load from the sun).
    - **Airflow Management.** Modular data centers and small enclosures may be challenged in employing good airflow management techniques.

Other Considerations (continued)

Reliability

Reliability is impacted by:

- Location
- Containment Structure
- Redundancy

Edge data center reliability can be particularly challenging.

- **Location Impact on Reliability**
  - **Workload Proximity.** Edge data center site selection is driven by proximity to workload and low latency vs. risk avoidance.
  - **Environmental.** Edge data centers can have a higher reliability risk from factors such as dust, pollution, and extreme temperature and humidity.
  - **Power.** Power at some locations may be less reliable.
  - **Remote Location.** Remote locations without on-site service will have longer mean repair times because of long drive times for service personnel.

- **Containment Structure Impact on Reliability**
  - **Smaller Containment Structure.** Smaller structures (e.g., sheet metal vs. brick and mortar) can make IT equipment in an edge data center more closely coupled to the outdoor environment.
  - **Opened Door.** Open doors can violate temperature, humidity, and other specification limits.
  - **Power and Cooling Equipment.** Power and cooling equipment are often in the same structure as the IT equipment which can impact conditions and therefore reliability.

- **Redundancy / Alternative Sources Impact on Reliability**
  - **Quantity Impact.** A smaller number of IT equipment pieces can have a larger reliability impact if one piece fails.
  - **Longer Service Times.** More redundancy may be needed to compensate for longer service times if the location is remote and on-site service is not available.
  - **Physical Separation.** With a small data center, it is more difficult to physically separate redundant equipment.
  - **Power and Cooling Redundancy.** Smaller data centers may require redundancy for power and cooling.
  - **UPS.** An uninterruptable power supply (UPS) may be needed, especially for unstaffed and remote facilities.
  - **Battery Storage.** Battery storage, if needed, should have the correct ventilation, thermal, and fire suppression equipment for batteries.

A backup cooling system may be required to guard against rapid temperature rise (minutes) and IT equipment shutdown from a cooling system failure.

Without good design for reliability practices, an edge data center can become a weak link in a data center fleet.

Weak Link
(in edge DC or fleet)

With well thought out design, an edge data center can have reliability comparable to a large brick-and-mortar data center.

Other Considerations (continued)

Data Center Infrastructure Management (DCIM)

The disparate nature of edge data centers makes the role of remote management and monitoring not only central, but ever more critical, to their operational performance.

Tools such as Data Center Infrastructure Management **[17]** play a key role in ensuring that all the relevant parameters can be remotely monitored.

Parameters such as the following need to have remote monitoring capability:

- Temperature
- Humidity
- Corrosion Rate
- IT Equipment Health
- Physical Intrusion
- Water Intrusion
- Fire

The number and physical placement of sensors is very important. Sensors should be located to measure the environment of the IT equipment.

DCIM should be tied directly to the equipment firmware.

- **Proactive Damage Prevention.** DCIM can act to proactively prevent IT equipment damage by taking actions such as powering down the equipment.
- **Human Intervention Dependence.** Many issues will become catastrophic if they rely on human intervention alone.

Summary

The IT center of gravity is shifting from large cloud data centers to end users and places where the data is being generated, i.e. the edge. This is taking place to:

- Reduce latency
- Reduce data transfer amount over a network

Small edge computing data centers can come with their own set of challenges.

Outdoor or semi-controlled environments mean that opening the data center's outer door can dramatically impact temperature, humidity, or air quality. Key points are the following:

1. Check IT equipment specifications (each piece).
   - Design enclosure to support the narrowest of those specification ranges.
   - Design means to maintain specifications when opening enclosure door (i.e., tent).
2. Select cooling system to meet capex, opex, and sustainability targets for site and data center fleet (where applicable).
   - Consider uninterruptable cooling for remote/unstaffed sites.
3. Design-in enough redundancy and remote servicing capability to support your service staffing strategy whether that is on-site or remote.
4. Maintain ASHRAE monthly angstrom corrosion limits
   - Silver = 200
   - Copper = 300 (may require chemical filtration)
5. Integrate DCIM-based remote monitoring of
   - Environmental parameters (i.e., temperature, humidity, corrosion) and
   - Alerts and service alarms (i.e., for air filter performance).
6. During service, monitor IT equipment inlet air (both temperature and humidity).
   - Stay within the rate of change limits and above the dew point.

References

[1] "What Edge Computing Means for Infrastructure and Operations Leaders," Rob van der Meulen, October 3, 2018, accessed on 5/7/2020.
https://www.gartner.com/smarterwithgartner/what-edge-computing-means-for-infrastructure-and-operations-leaders/

[2] "What is edge computing and why it matters," Keith Shaw, *NetworkWorld*, November 13, 2019, accessed on 3/2/2020.
https://www.networkworld.com/article/3224893/what-is-edge-computing-and-how-it-s-changing-the-network.html

[3] "What is edge computing? Here's why the edge matters and where it's headed," Scott Fulton III, *ZDNet*, August 9, 2019, accessed on 3/2/2020.
https://www.zdnet.com/article/where-the-edge-is-in-edge-computing-why-it-matters-and-how-we-use-it/

[4] "What is edge computing?" Paul Miller, *The Verge*, May 7, 2018, accessed on 3/2/2020.
https://www.theverge.com/circuitbreaker/2018/5/7/17327584/edge-computing-cloud-google-microsoft-apple-amazon

[5] "Edge Data Centers," Telecommunications Industry Association (TIA) White Paper, October 18, 2018, accessed on 3/2/2020.
https://www.tiaonline.org/wp-content/uploads/2018/10/TIA_Position_Paper_Edge_Data_Centers-18Oct18.pdf

[6] "Types and Locations of Edge Data Centers: Scoping Locations That Work for Your Needs," Telecommunications Industry Association (TIA) White Paper, October 2019, accessed on 3/2/2020.
https://tiaonline.org/what-we-do/technology/edge-data-centers/

[7] "Data Gravity is Shifting the Data Center Network. But in Which Direction?" Rich Miller, *Data Center Frontier*, November 12, 2019, accessed on 4/16/2020.
https://datacenterfrontier.com/data-gravity-is-shifting-the-data-center-network-but-in-which-direction/

[8] *Thermal Guidelines for Data Processing Environments*, 4th ed, ASHRAE Datacom Series Book 1, Atlanta: ASHRAE, 2015.

[9] "Environmental Conditions and Disk Reliability in Free-cooled Datacenters," Ioannis Manousakis, Sriram Sankar, Gregg McKnight, Thu D. Nguyen, and Ricardo Bianchini, 14th USENIX Conference on File and Storage Technologies (FAST '16), February 22–25, 2016, Santa Clara, CA, USA.

[10] "The Effect of Humidity on Static Electricity Induced Reliability Issues of ICT Equipment in Data Center," David Pommerenke, Atieh Talezadeh, Xu Gao, Fayu Wan, Abhishek Patnaik, Mahdi Moradianpouchehrazi, and Yunan Han, ASHRAE Research Project RP-1499 Final Report, October 2014, Atlanta: ASHRAE.

[11] "Impact of Gaseous Contamination and High Humidity on the Reliable Operation of Information Technology Equipment in Data Centers," Jensen Zhang, Rui Zhang, Roger Schmidt, Jeremy Gilbert, and Beverly Guo, ASHRAE Research Project RP-1755 Final Report, October 2019, Atlanta: ASHRAE.

[12] *Particulate and Gaseous Contamination in Datacom Environments*, 2nd ed, ASHRAE Datacom Series Book 8, Atlanta: ASHRAE, 2013.

[13] ANSI/ISA 71.04-2013, *Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants*, Research Triangle Park, NC: International Society of Automation.

[14] Purafil OnGuard Smart, accessed on 6/9/2020.
https://www.purafil.com/products/monitoring/active-monitoring/onguard-smart/

[15] NEMA Standards Publication 250-2003, *Enclosures for Electrical Equipment (1000 Volts Maximum)*, Arlington, VA: National Electrical Manufacturers Assoc.

[16] "Mapping America's Wicked Weather and Deadly Disasters," Tim Meko, April 25, 2019, accessed on 5/10/2020.
https://www.washingtonpost.com/graphics/2019/national/mapping-disasters/

[17] *Advancing DCIM with IT Equipment Integration*, ASHRAE Datacom Series Book 14, Atlanta: ASHRAE, 2019.

This technical bulletin was developed by

ASHRAE Technical Committee (TC) 9.9
Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment

TC9.9 Technical Bulletin Contributors

Jon Fitch - Dell EMC (lead author)

Ben Coe
Dave Quirk - DLB Associates
Don Beaty - DLB Associates
Dustin Demetriou - IBM
Jason Matteson - Iceotope
Mark Bailey - Dell EMC
Matthew Archibald - nVent
Micah Sweeney - EPRI
Paul Artman - Lenovo
Rajendera Kapoor - Star Consultants
Roger Schmidt - IBM
Sama Aghniaey - Harris Design Studio
Shlomo Novotny - Consultant
Tozer Bandorawalla - Intel
Trey Wiederhold - Dell EMC
Ty Schmitt - Dell EMC
Tyler Duncan - Dell EMC

Joe Lombardo - DLB Associates (cover and page design)