VERTIV™

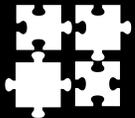**since 1965**
Long history of <mark>pioneering</mark> data center infrastructure technologies for mission critical applications.

Today a <mark>global organization</mark> listed on the NY Stock Exchange with a team of 27,000+ people and revenues of $6.9bn (2023) from projects in 130+ countries.

Specialist in critical digital infrastructure with the most complete <mark>portfolio in power and cooling solutions</mark> wrapped in <mark>software</mark> platform and unmatched <mark>services</mark> offering.
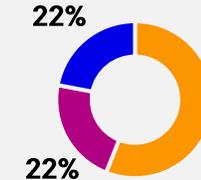
Strong position in HPC/AI with <mark>technology partnerships</mark> and <mark>collaboration</mark> with industry leaders.
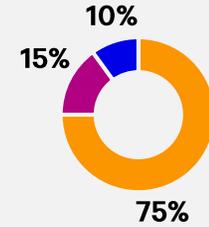
nVIDIA.

Sales ~$6.9B
Employees ~27,000

22% 56% 10% 15%
22% 75%

- AMER
- EMEA
- APAC

- Data centers
- Comm networks
- Comm'l & Ind'l

Customers include:
Alibaba, Alstom, America Movil, AT&T, China Mobile, Equinix, Ericsson, Reliance, Siemens, Telefonica, Tencent, Verizon, Vodafone

Manufacturing sites: 22

Service centers: 240+

Reach: 130+ countries

Note: All figures 2023FY.

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Vertiv is a leading innovator with the most complete **critical digital infrastructure** portfolio in the industry.

Power
Power Train
We have all the "cars" from grid-to-chip, alternative energy interaction, controls and management.

Medium- and Low-Voltage Switchgear/ Switchboard

3-Phase UPS Systems

DC Power

Power Distribution, Transfer Switches

Busbar

Cooling
Thermal Chain
We have all the "links" from chip, server, row heat collection, through data hall and facility heat rejection, controls and management.

Air Handlers

Chillers

Rear-Door Heat Exchangers

Immersion Cooling

Direct Expansion

In-Room Cooling

Direct-to-Chip Coolant Distribution

IT Systems
IT Systems Set
We have the components from distributed IT to gigawatt data center sites.

1-Phase UPS

Rack PDU

Racks and Enclosures

Rack Cooling

IT Mgmt Devices, Software, High-Performance KVM

Integrated solutions
Integrated solutions
for outdoor and indoor IT data rooms.

Smart Modules

Integrated Aisles and Rows

Power Modules

Mega Mods

Services
Project and Lifecycle Services
extend value of install base and maximizes market expertise.

Lifecycle Services

Digital Services

Project Services

AI is here, and it is here to stay.

It will **transform** our IT, it will **transform** our businesses, it will **transform** our lives.

> " *AI is one of the most important things humanity is working on. It is more profound than electricity or fire.*
> — Sundar Pichai, CEO
> **Google**

> " *This is the **first time that a technology** developed in Silicon Valley benefits the lives of everyday people so quickly and so tangibly.*
> — Satya Nadella, CEO
> **Microsoft**

> " *We are fundamentally changing how computing works and what computers can do. The next industrial revolution has begun.*
> — Jensen Huang, CEO & Founder
> **NVIDIA.**

> " *AI is on the fast track to becoming ubiquitous — at home, at work, and everywhere in between.*
> — Predictions 2024: AI
> **FORRESTER®**

> " *Gen AI could potentially raise annual labor productivity growth by around 1.5pp over a 10-year period, and eventually raise global GDP by 7%.*
> — Joseph Briggs, Sr. Global Economist
> **Goldman Sachs**

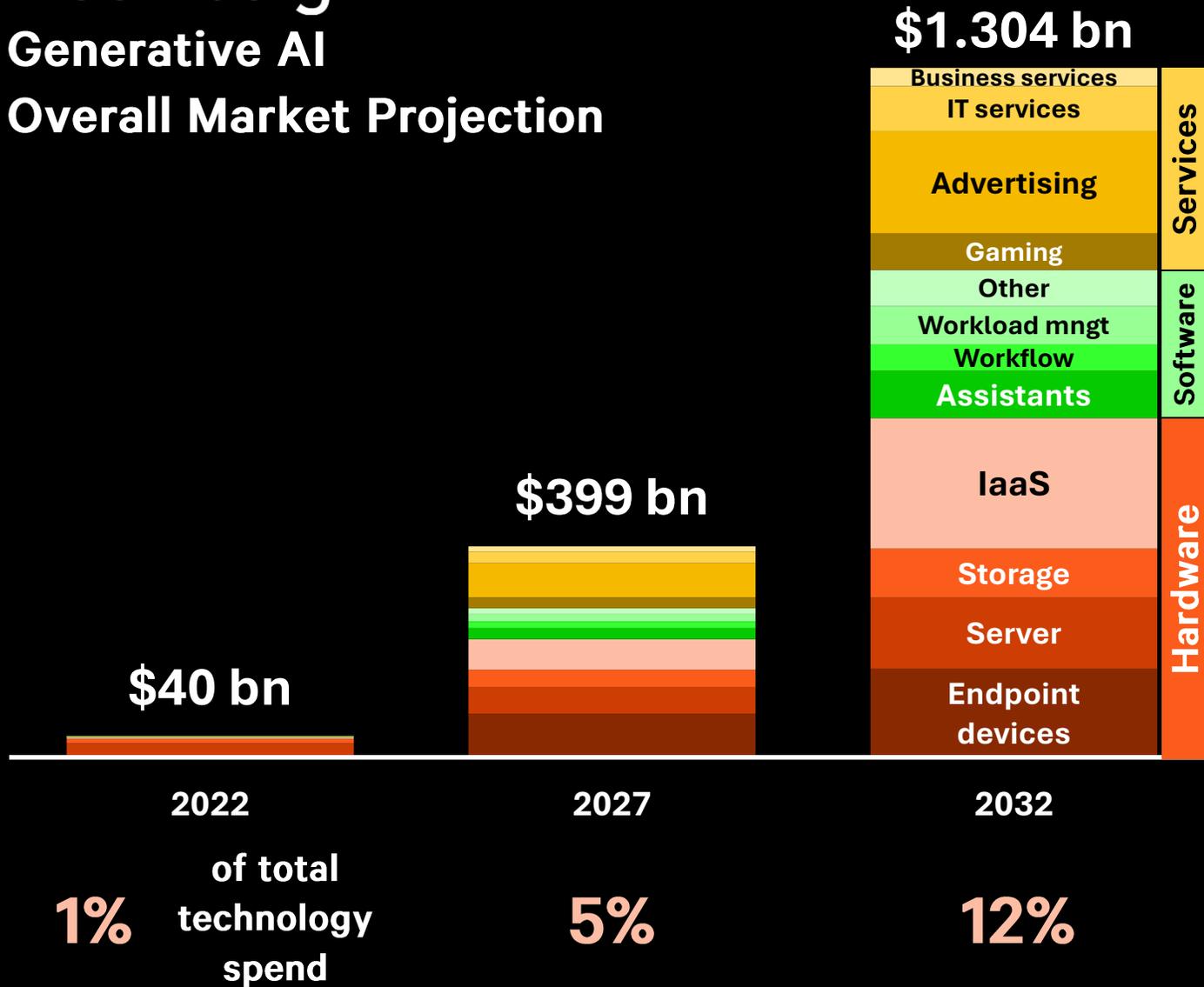> " *AI workloads (are) leading to a broad proliferation of accelerated computing infra-structure. This will require investments in next-generation data center physical infrastructure to support new architectures with higher power and thermal management requirements.*
> — Lucas Beran, Research Director
> **DG**

Bloomberg
Generative AI
Overall Market Projection

$1.304 bn

2032
Business services
IT services
Services
Advertising
Gaming
Other
Workload mngt
Workflow
Software
Assistants
IaaS
Hardware
Storage
Server
Endpoint devices

$399 bn

$40 bn

2022

of total technology spend

1%

2027

5%

2032

12%

AI represents an extraordinary opportunity.

Bloomberg projects generative AI to be a **$1.3-trillion business** by 2032.

Source: Bloomberg Intelligence

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As AI expands, **rack density is on the rise** with low density racks becoming the exception rather than the rule.

Number of racks installed by rack density.

From 2021, more than a thousand racks over 100kW/rack expected to be installed yearly.

Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	Density
>100 kW									2%	
70-100 kW	3%	4%	1%	1%	1%	2%	3%	5%	7%	
40-60 kW	19%	21%	9%	12%	20%	24%	28%	29%	31%	
20-30 kW			20%	24%	25%	27%	30%	30%	30%	
10-20 kW	78%	74%	70%	63%	53%	47%	38%	34%	29%	
<10 kW										
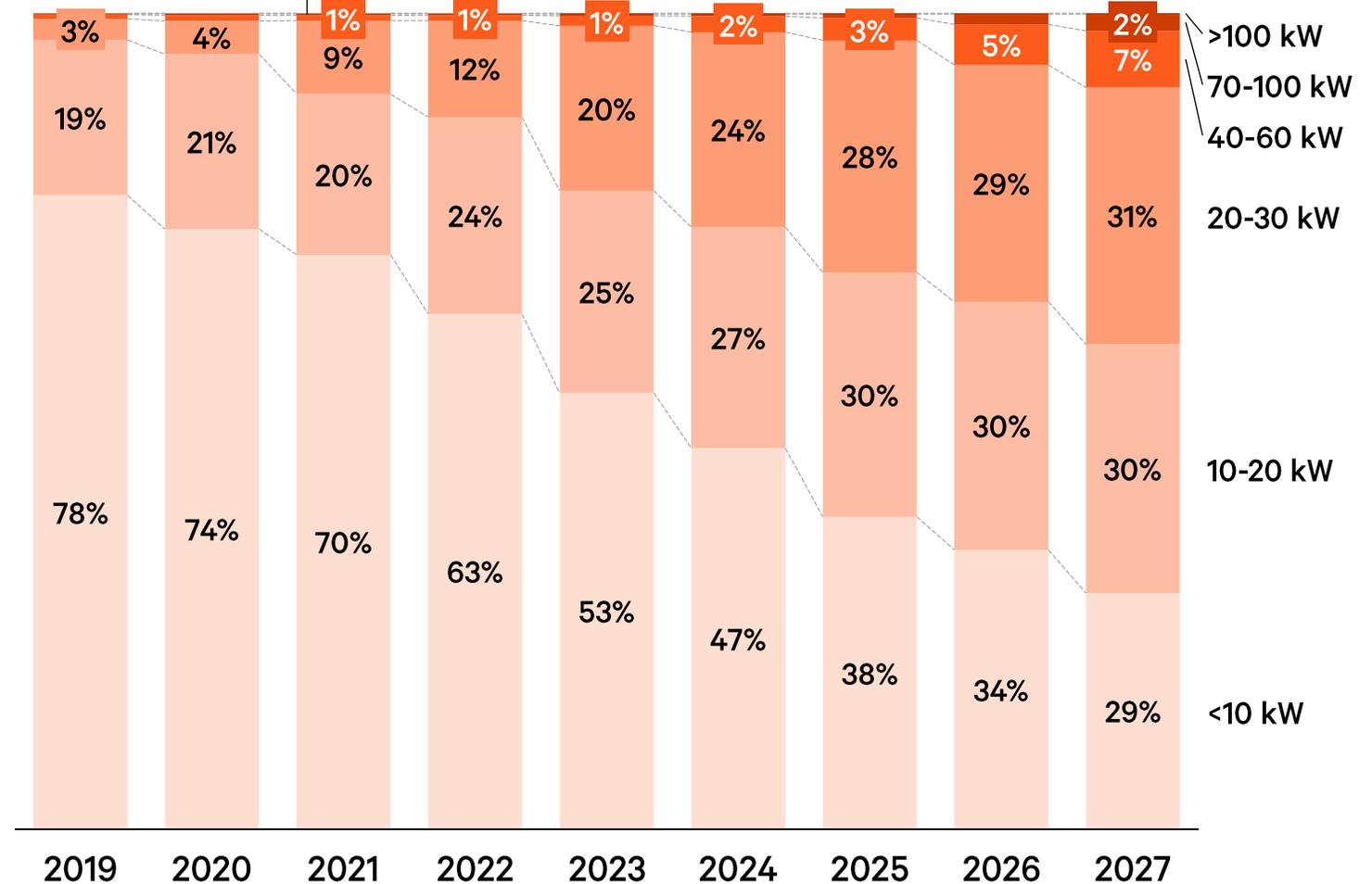
✓ Close **partnership and collaboration with companies leading** the AI revolution.

NVIDIA
intel.

✓ Leader with **most complete portfolio** in power from grid to chip and cooling from chip to reuse, wrapped In **monitoring and control software** and **AI-ready services capabilities** covering product lifecycle.

✓ **Trailblazer innovator** from the days of Ralph Liebert to a NYSE-listed global organization.

✓ Unique capabilities to meet **deployment needs from single rack to entire data center**.

✓ **Global scale** with **resilient operational footprint**, in-market expertise and **field service coverage**.

Your AI critical infrastructure needs are in safe hands with Vertiv. Our offering is unparalleled in the industry.

NVIDIA introduced its flagship launch at GTC2024 side-by-side with Vertiv infrastructure solutions.

NVIDIA DGX SuperPOD™ with GB200 systems
Rendering as presented by Jensen Huang at GTC2024 on 18-Mar-2024. Highlights and captions added.

Vertiv™ Liebert® XDU 1350 coolant distribution units.

Networking racks.

Computing racks GB200 NVL72.

Liquid cooling secondary fluid network feeding computing racks.

NVIDIA | Partner

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Source: NVIDIA GTC2024 Keynote Speech

How to prepare critical infrastructures to AI workloads?

1 Get ready to deploy liquid cooling in your data halls.

2 Don't be afraid to ditch existing paradigms.

3 Tailor power to the reality of AI workloads.

4 Update rack architecture to ensure good rack hygiene.

5 Explore power alternatives and efficiencies.

6 Plan to scale up for future next-generation architectures.

7 Rethink services needed to keep sites running.

8 Adapt your business approach.

1 Get ready to deploy liquid cooling in your data halls.

Prepare for liquid cooling. If not now, soon.

Don't turn off the AC just yet. Air cooling is not going anywhere.

Double check data sheets. IT vendors can have very different specs.

5F

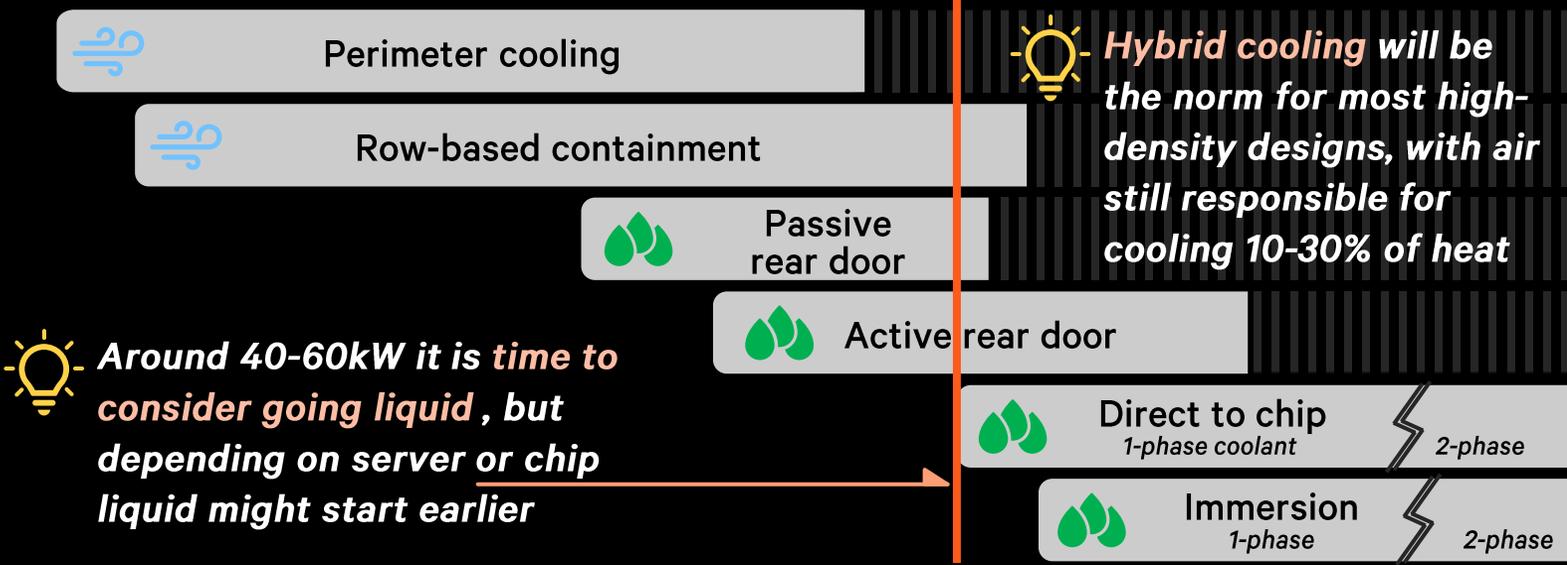Keep in mind the 5Fs when bringing in fluids into the data hall.

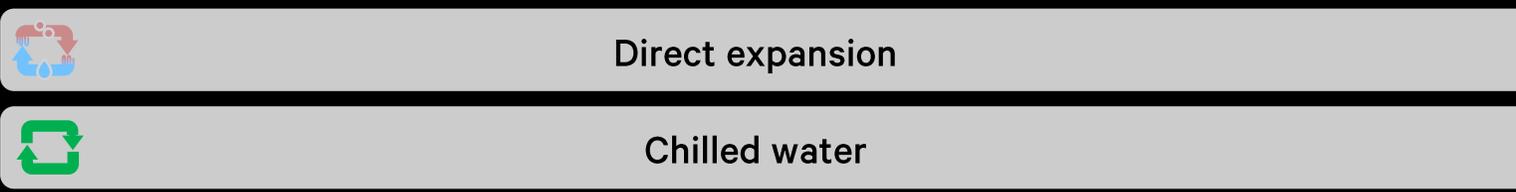Dig deeper into the many liquid options. Applications and sites needs are unique.

More compute packed in the rack is driving rack densities up, making the shift from air cooling to hybrid air-assisted liquid cooling a necessity.

Low density *Up to 10kW*	Medium density *10 to 25kW*	High density *25 to 80kW*	Extreme density *> 80kW*

Technology to extract heat from IT

Perimeter cooling

Row-based containment

Passive rear door

Active rear door

Direct to chip
1-phase coolant — 2-phase

Immersion
1-phase — 2-phase

Hybrid cooling will be the norm for most high-density designs, with air still responsible for cooling 10-30% of heat

Around 40-60kW it is time to consider going liquid, but depending on server or chip liquid might start earlier

**Technology to extract heat from data room**

Direct expansion

Chilled water

Cold plate

- ✓ Highly conductive metal in contact with IT equipment pierced by micro-channels for fluid to go through and collect heat
- ✓ Considerable variety in designs
- ✓ Critical with little room for redundancy
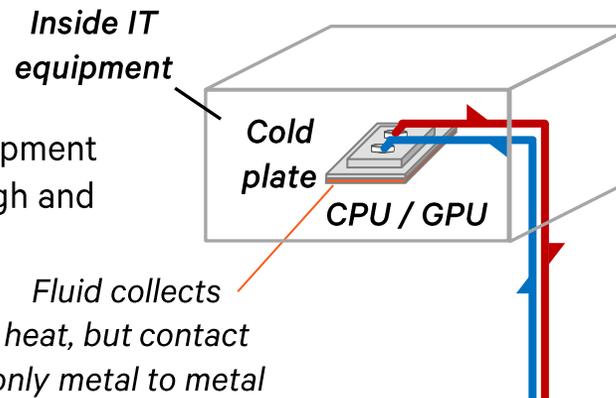
Secondary fluid network

- ✓ Piping, hoses and manifolds carrying the secondary fluid from CDU to cold plate
- ✓ Closed loop with minimal fluid load
- ✓ Equipped with quick disconnects for easier service
- ✓ Requirement to be able to handle system pressure and crucial to avoid leaks and contamination
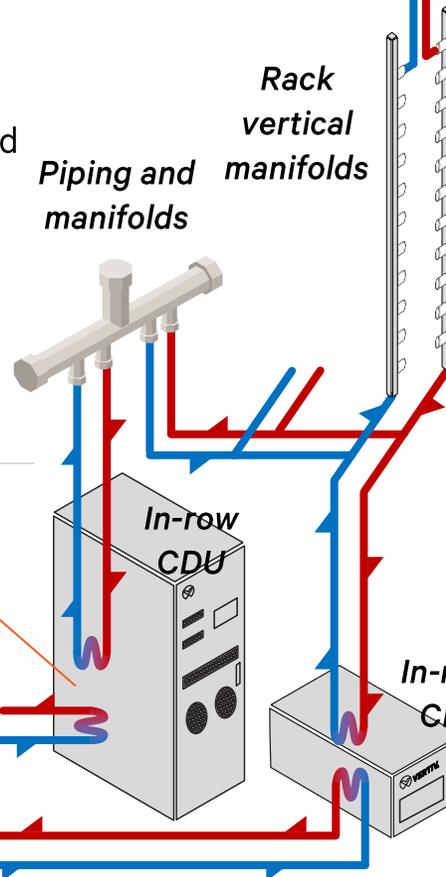
Coolant distribution unit

- ✓ Heat coming from cold plates transferred to primary fluid loop
- ✓ Crucial role in controlling flow rate, system pressure and filtration
- ✓ Redundancy ensured with multiple pumps and connection to UPS

Inside IT equipment

Cold plate

CPU / GPU

Fluid collects heat, but contact only metal to metal

Rack vertical manifolds

Piping and manifolds

Fluids exchange heat, but no contact

In-row CDU

In-rack CDU

Primary fluid *(to / from facility/ chiller)*

Direct-to-chip liquid cooling introduces three new critical pieces of equipment to the server room.

Manifolds and piping in secondary fluid networks are mission critical components part of liquid cooling solutions.

✓ Constructed with non-reactive materials to prevent corrosion and fluid degradation (often food or medical grade).

✓ Designed for low-pressure drop, even flow distribution.

✓ Leak detection, expandability, and ease of installation/ serviceability critical.

In-rack manifolds

✓ In-rack fluid distribution connected to servers via flexible hoses or direct connection.

✓ Connection types and sizes determined by both cold plates and row manifolds.

✓ Space in the back of the rack at a premium with manifolds and connectors.
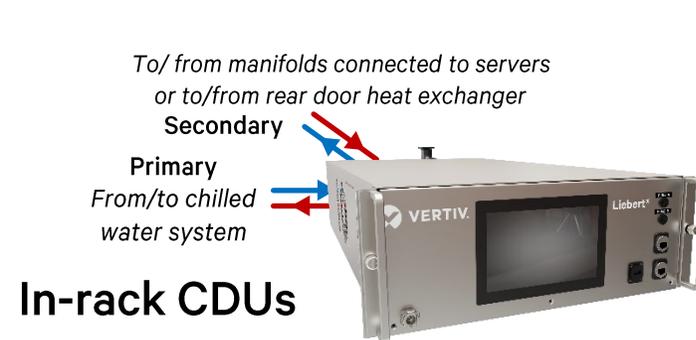

In-row manifolds

✓ Fluid distribution connecting multiple racks to CDUs.
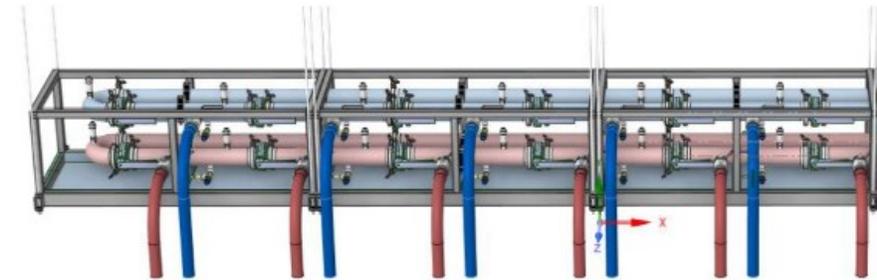
"Simple" pipes and manifolds, but criticality of SFNs demand high engineering, skill to install and operate.

VERTIV   13

CDUs are the ==beating heart of liquid cooling== systems, collecting heat from SFNs and transferring it to primary fluid loops.

✓ Critical component **distributing coolant** to entire system via SFN to cold plates.

✓ Intelligence of cooling solution **controlling flow rates**, ensuring **steady flow rates and inlet temperatures** to IT with embedded monitoring and controls.

✓ **Filtration** to extracting impurities out of SFN.

✓ Pump and power are key points of **redundancy** in the secondary fluid network (cold plate and manifolds are often single points of failure).

To/ from manifolds connected to servers or to/from rear door heat exchanger
Secondary
Primary
From/to chilled water system

In-rack CDUs

✓ Designed for smaller loads or for modular scale-up.

✓ Able to contain blast rates in case of faults.

To/ from floor or overhead coolant distributor connected to manifolds
Secondary
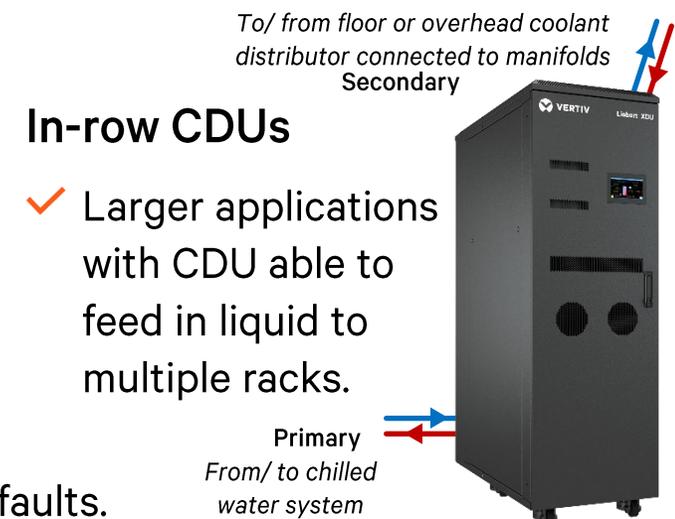
In-row CDUs

✓ Larger applications with CDU able to feed in liquid to multiple racks.

Primary
From/ to chilled water system

2 **Don't be afraid to ditch existing paradigms.**

Mechanical loads cannot be on the "mechanical" bus when coolant distribution is critical.

Integrate power and cooling into optimized holistic infrastructure.

Embrace new levels of temperature and ΔT defaults.

Liquid cooling designs must take into account very short ride-through times in case cooling equipment fails.

**❓ What is thermal inertia / thermal ride-through?**

Thermal inertia: degree of **slowness which temperature changes in system**. A high thermal inertia system can cope for longer time until reaching maximum temperature.
Ride-through time: time between a **loss of cooling systems** and the resulting **interruption of IT systems** in a data center.

Air cooling

Heat is distributed through **large surface** of heat sink.

Volume of air around heat sink **acts as buffer** continuously collecting heat from heat sink and slowly moving with natural convection in case cooling system fails.

Heat sink

Chip
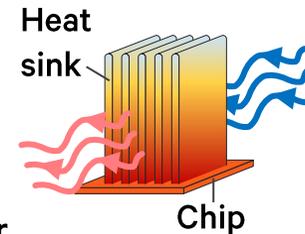
Liquid cooling

Higher heat flux with much **smaller heat exchange surface**.

In case CDU fails, volume stuck within cold plate channels and pipes overheats very quickly and **cannot act as buffer** to the system.

Cold plate

Chip
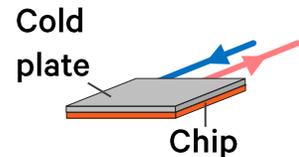
- ✓ IT equipment can **wait a few minutes until generator and cooling fully restarts** without triggering IT shutdown.
- ✓ Cooling plugged on the **mechanical bus**, not the critical power bus.c

- ✓ IT equipment is **forced to shut down in a matter of seconds** if cooling equipment is down.
- ✓ Coolant distribution unit feeding SFN is plugged into a **critical power bus**.

3

Tailor power to the reality of AI workloads.

Size every car of power train for high-density all the way to the grid.

Reassess power design to cope with pulse loads of GPU clusters.

Rethink redundancies and criticality of different AI workloads.

4 **Update rack architecture to ensure good rack hygiene.**

Pack more compute into higher, wider, deeper and heavier IT racks.

Reduce back of rack clutter with high-density rack PDUs

Bring medium voltage as close to the IT as possible.

Anticipate OCP designs and the switch to DC power architectures.

# Higher networking racks are being **redesigned** to handle heavier IT gear.

- ✓ **Stronger racks** to handle additional weight of IT gear and liquid volume and torque.

- ✓ Larger racks to allow for **HD rPDUs, manifolds, larger cables**, inlet/outlet **hoses**.

- ✓ **Retrofitting existing datacenters may become challenging** due to change in rack footprint.

- ✓ Racks must have d**rip pans with sensors** that communicate to a central management controller.

- ✓ **Smart shutoff valves** to rack and row must be used to automatically shut off liquid flow in severe leak situations.

130kg 8U

75kg 8U

53kg 4U

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Higher voltages need to be introduced to server rooms.

Doubling rack power requires **+16% amperage** if voltage moves from 240V to WYE 415V, but **2x amperage** if voltage stays at 240V.

Ampacity (A) vs Voltage (V) chart showing 30kW and 15kW curves.
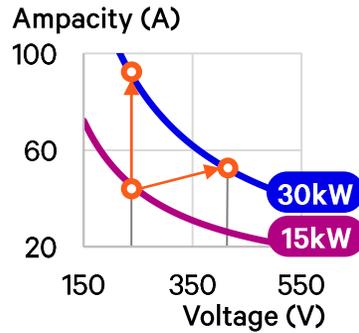
Benefits of lower ampacity systems:

- ✓ **Lower energy losses** in the power distribution.
- ✓ **Lower wiring cost** with smaller diameter wires.
- ✓ **Lower weight and size** of wiring and other power components.


- ✓ **Multiple PDUs per rack to split load often not an option** due to limitation of space in the back of the rack.

- ✓ Higher capacities bringing in both **higher voltages and higher amperages**. New designs coming with WYE 277/480V forcing change in IT as standard server PSUs operate under 250V max. 60-80A PDUs are becoming part of the standard PDU offer, with recent custom units getting ≥100A.

- ✓ **Breaker space becomes a bottleneck**, with novel designs moving breakers from the strip to above the rack by busbar tap-off box.

- ✓ **Input plugs and cable are challenging**, hardwiring becomes needed or higher spec plug designs (e.g. Anderson plugs).

Rack PDUs are undergoing transformative design changes to meet the needs of high-density AI workloads.

6 **Plan to scale up for future next-generation architectures.**

Accelerate and simplify projects with modularity and repeatability.
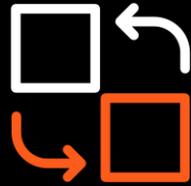
Embed flexibility in designs to scale up with AI use-cases.

Understand how to leverage existing infra retrofitting and have AI in mind in new build.

Plan for the future. Even if its harder than ever to predict it.

Vertiv™ 360AI

Rack solutions

Inferencing & Edge AI

- ✓ AI testing and pilots
- ✓ Edge inferencing

Row and room Solutions

Enterprise & Data Center AI

- ✓ AI lab
- ✓ Model training and inferencing
- ✓ AI row within existing data hall

Facility & data center solutions

Prefab Modular AI Data Centers

- ✓ AI model training at scale
- ✓ AI factory

Modularity and repeatability are key elements to improve ROIs of AI deployments, no matter their size.

Deployment speeds can be reduced significantly with <mark>pre-engineered solutions.</mark>

Vertiv™ 360AI

Reduce Deployment Time up to 50%
Pre-engineered solutions eliminate design cycles and reduce deployment time up to 50%.[1]

Complete Range for the Entire Journey
Solutions available for the entire journey from testing to pilot, with wide range of size and scope from Edge inferencing, to large AI data centers.

Flexibility & Customization
Many heat rejection and form factor options allow for retrofit and reuse of existing cooling systems, minimizing deployment cost and scope.

Interoperability & Seamless Implementation
Only Vertiv can meet both the power and cooling demand of AI, each solution is built from the most advanced portfolio of power and cooling in the industry.
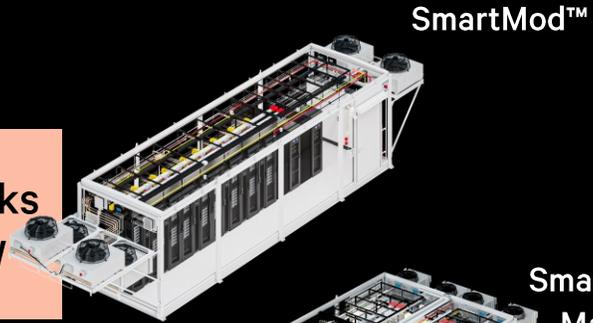
Unmatched Expertise & Support
Support throughout the process from assessment and design, to deployment and lifecycle management.

[1] Vertiv management estimate based on direct market research on pre-engineered solutions, actual results will vary.

Prefabricated data centers are all-in-one modular solutions suitable for **applications small to large**, being used by enterprise and hyperscalers alike.
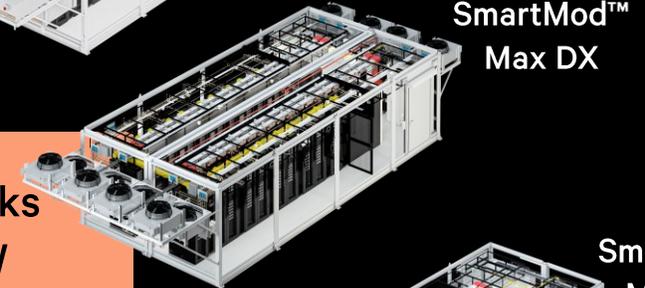
Single module
≤14 IT racks
≤100 kW
SmartMod™

Two modules, DX
≤26 IT racks
≤200 kW
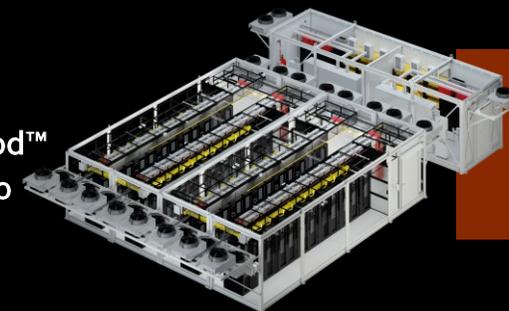SmartMod™ Max DX

Two modules, CW
≤24 IT racks
100-200 kW
SmartMod™ Max CW

Four modules
≤104 IT racks
220-600 kW
SmartMod™ Combo

Power and cooling modules, and data room structure are the **building blocks** of prefabricated data center modular solutions.

⚡ Power modules/ skids

- ✓ Up to 5000A main distribution board with integrated ATS, UPS and batteries (Li-Ion or VRLA).
- ✓ Thermal management systems for electrical infrastructure.
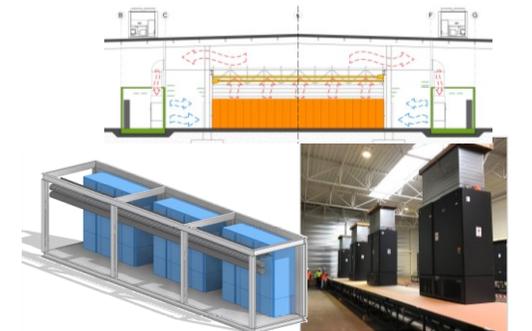- ✓ Access control, CCTV, fire detection and suppression.

▦ Data room super-structure

- ✓ Prefab overhead super-structure for IT data rooms.
- ✓ Busbars and tap-off boxes, cable trays, fiber runners, aisle containment, lights.
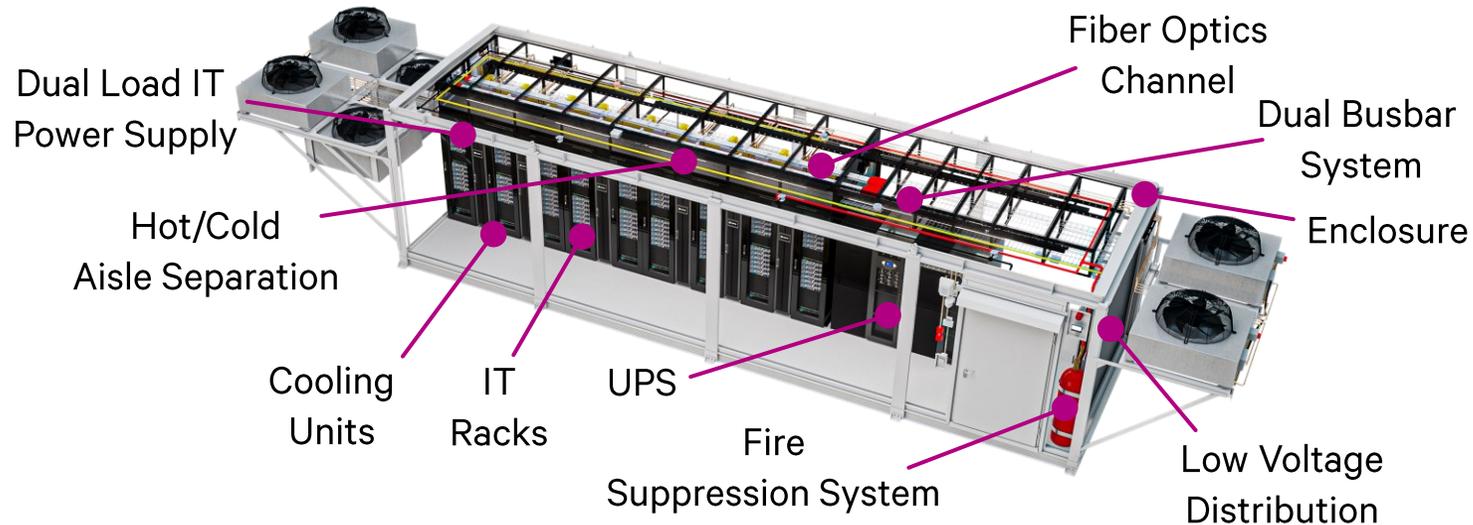- ✓ Fire detection and suppression elements (sensors, pipes and nozzles).
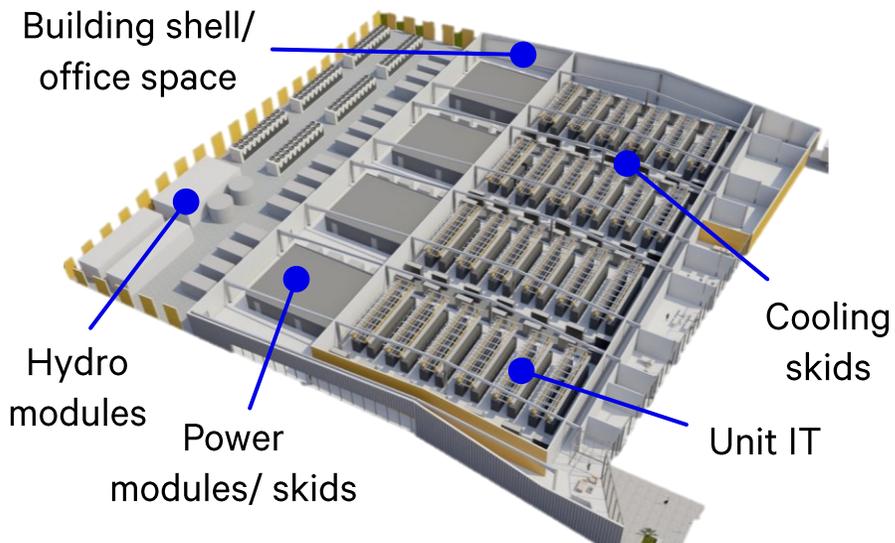
❄ Cooling modules/ skids

- ✓ Placed around perimeter of the data room.
- ✓ Prefabricated piping and valves inside the skid.
- ✓ Variety of cooling options (CW CRAH, Fan wall, DX, IDEC, DEC).

All-in-one standalone prefabricated modular data center

- Dual Load IT Power Supply
- Hot/Cold Aisle Separation
- Cooling Units
- IT Racks
- UPS
- Fire Suppression System
- Fiber Optics Channel
- Dual Busbar System
- Enclosure
- Low Voltage Distribution

Hybrid prefabricated data center with building shell

- Building shell/ office space
- Hydro modules
- Power modules/ skids
- Cooling skids
- Unit IT

On-site traditional construction:
- ✓ Building shell
- ✓ Office space

Off-site prefabricated building blocks:
- ✓ Power modules/ skids
- ✓ Cooling skids
- ✓ Hydro modules
- ✓ Unit IT superstructure

Prefabricated modular data centers can be self-sufficient solutions or hybrid designs integrated into brick-and-mortar building shell.

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7

Rethink services needed to keep sites running.

Ensure service is considered end-to-end from concept to ongoing operational support.

Start training and upskilling teams to meet new infrastructure requirements.

Implement additional monitoring to enhance preventive maintenance.

Successful high-density deployments require expert end-to-end services from site assessment to lifecycle management.

Designing, deploying, and maintaining infrastructure for AI-enabled data centers is challenging.

Vertiv's Global Services for liquid-cooled solutions deliver expertise in site assessment, design, installation, commissioning, and lifecycle management through Vertiv Certified teams

Working in collaboration with industry leaders, Vertiv provides optimal conditions for a long-lasting solution to ensure peace-of-mind throughout the life of your equipment.

Consultation & Assessment

✓ Perform design consultation and assessment customized to specific site requirements:
  — Site visit
  — Product selection
  — System planning/design
  — System layout
  — Integration drawings
  — Computational fluid dynamic (CFD) Digital Twin modeling

Installation & Integration

✓ Manage project and perform assembly services:
  — Rack assembly
  — Busway installation
  — Rack PDU installation
  — Aisle containment
  — Integration from CDU to chip via overhead and rack manifolds
  — Removal of old equipment
  — New Vertiv unit installation

Commissioning

✓ Commission OEM and startup service:
  — Site Acceptance Inspection
  — Startup
  — Site Acceptance Testing
  — Integration System Testing
  — Training

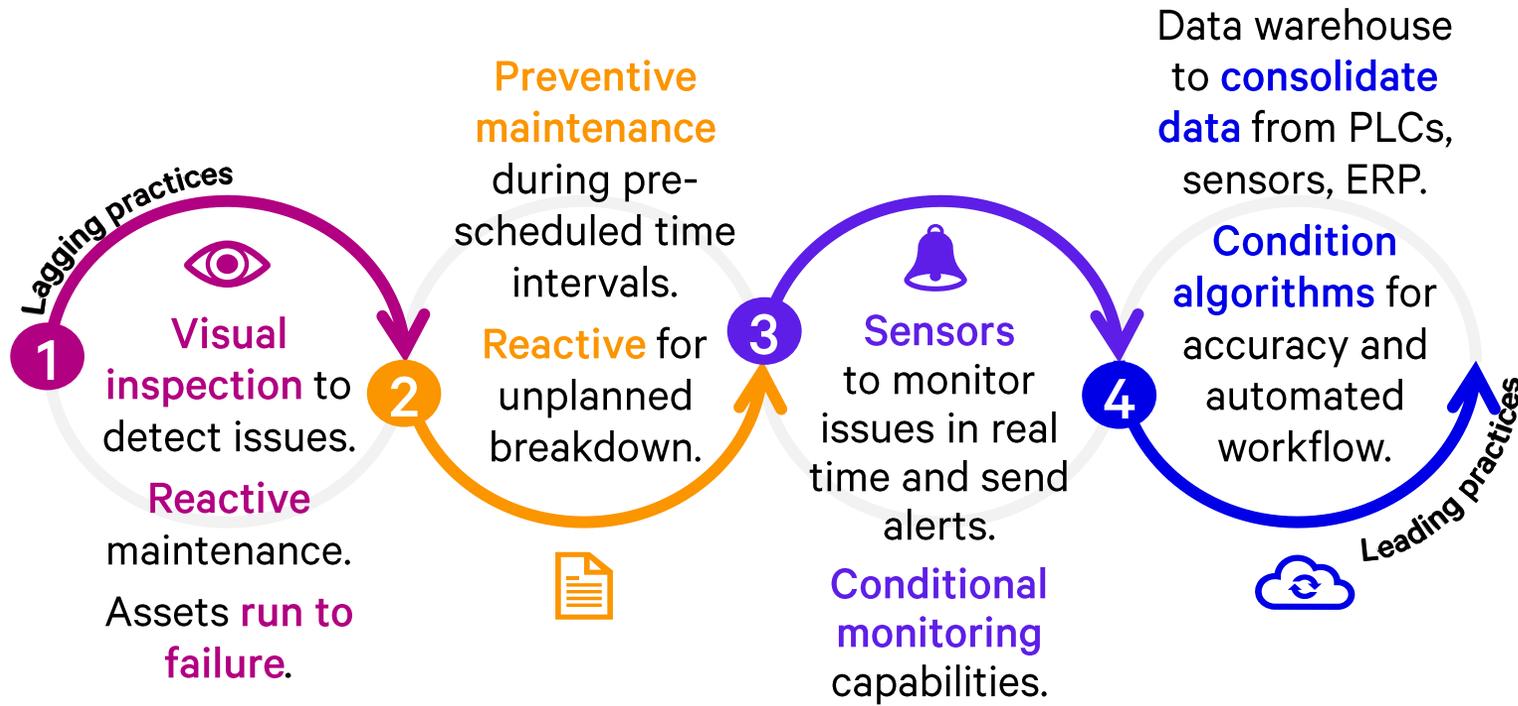## Operational Services

✓ Preventive Maintenance Visits
✓ Parts/Labor Coverage
✓ Emergency Response
✓ Technical Support
✓ Fluid management:
  — Fluid sampling and testing
  — System discharge and recharge
  — Fluid quality remediation

Hassle-free design, deployment, and management for future-proofed data centers in every location.

Evolution of maintenance technologies

Lagging practices

1 Visual **inspection** to detect issues.
Reactive maintenance. Assets **run to failure**.

Preventive maintenance during pre-scheduled time intervals.
Reactive for unplanned breakdown.

2

3 **Sensors** to monitor issues in real time and send alerts.
Conditional monitoring capabilities.

Data warehouse to **consolidate data** from PLCs, sensors, ERP.
Condition algorithms for accuracy and automated workflow.

4

Leading practices

✓ Real time data is analyzed with AI/ML to **detect component anomalies**, performance deviation to a normal and to calculate useful life remaining.

✓ Algorithm output determines when action needs to be taken, **next maintenance** or **planned interim intervention**.

✓ Upkeeping is done within algorithm-driven **proactive maintenance** and **component replacement** program v pure time-based activity.

✓ **Health score** is defined at component, equipment, site and enterprise levels.

Connectivity solutions enhance system reliability and operational condition.

8 **Adapt your business approach.**

Expand partnerships in sales cycle as projects increase complexity.

Collaborate closer between IT and facilities to ensure project success.