Embedded Data Centers

2016 Better Buildings Summit

Tuesday, May 10, 3:45-5:00PM

Speakers

- Moderator
  - Dale Sartor – Lawrence Berkeley National Laboratory
- Presenter/Panelists
  - John Musilli – Intel Corporation
  - Brandon Hong – Lawrence Livermore National Laboratory

IMBEDDED DATA CENTERS OPPORTUNELY OR NEMESIS

John Musilli

Data Center Architect

Intel Corporation

5/2016

U.S. Department of Energy
Better Building Summit
Washington DC.
May 10,2016

“Imbedded data centers are not a problem, but just an opportunity to re-use an existing infrastructure at an efficiency level equal to new construction or standalone data center designs.”

Embedded Data Center Advantages

Existing Building Envelope Provides

- Building- shell
- Power- building electrical sub-station distribution installed
- Outside plant-water, cooling and power infrastructure connectivi
- Ventilation-make-up air
- Security- walls fence
- Parking
- Logistics- loading docks

Room Level Changes

Air Movement

- Air Segregation
- Flooded Supply Air Design

Space Management

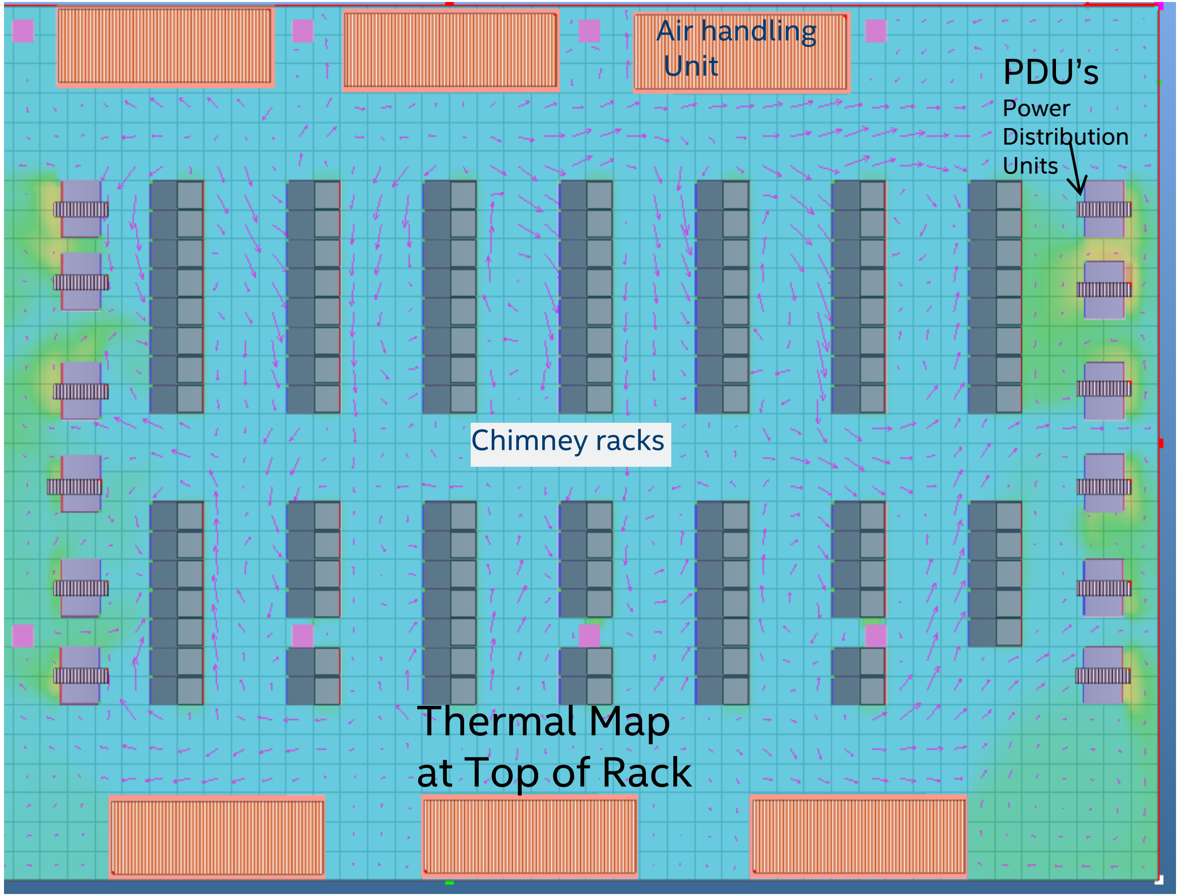
- Densification- “Getting More With Less”

Facility Level Changes

Economizer Opportunely

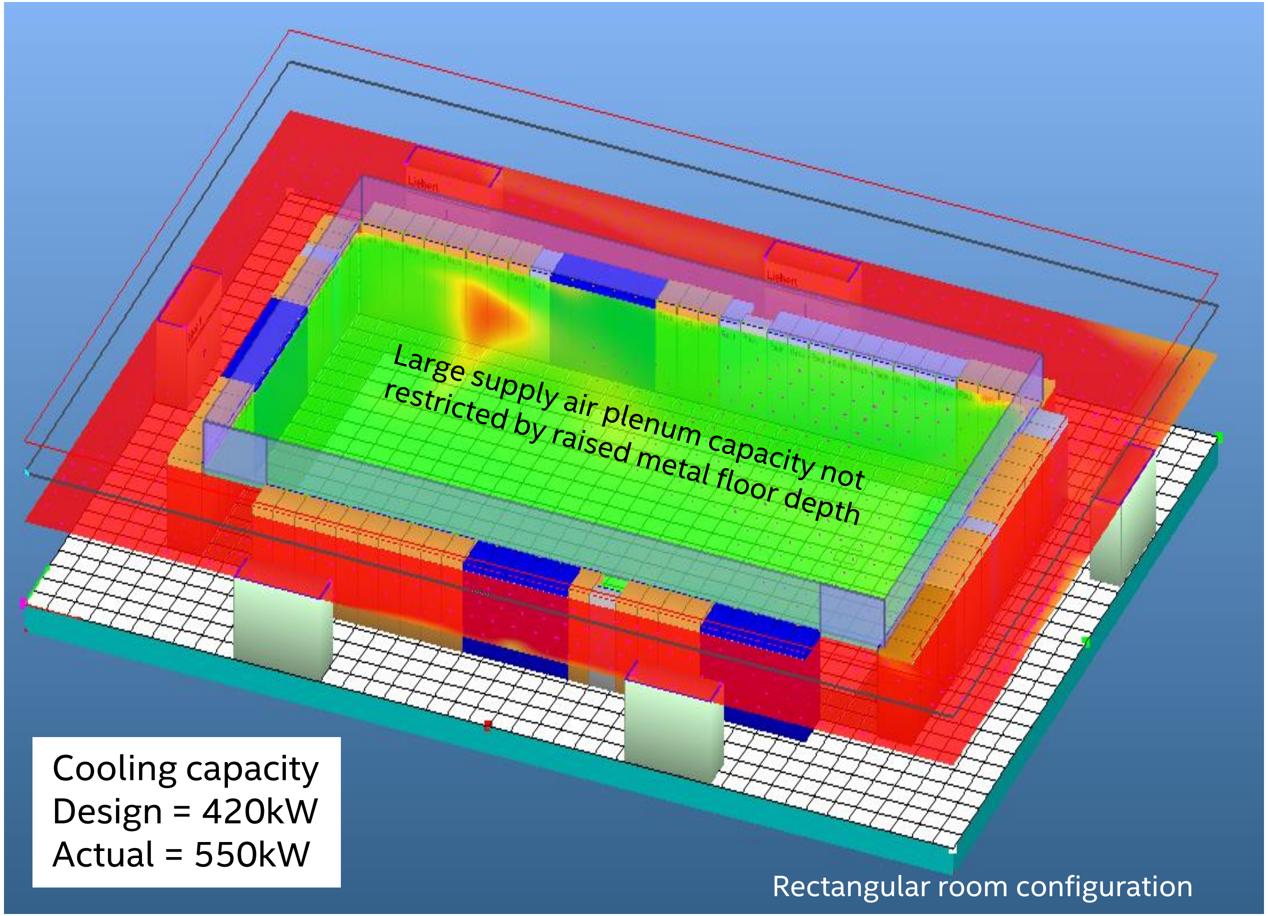
- Evaporative cooling-Use existing cooling towers posable use of return water loop
- Air Side economizer- Take advantage of climate zone, exterior walls, and roof exhaust

Chimney Cabinet- Flooded Air Design



- 30 kW per Rack
- No Raised Metal Floor
- Flooded Supply Air Design
- Segregated Air
- Chimney cabinets
- Above Ceiling Return Air Plenum

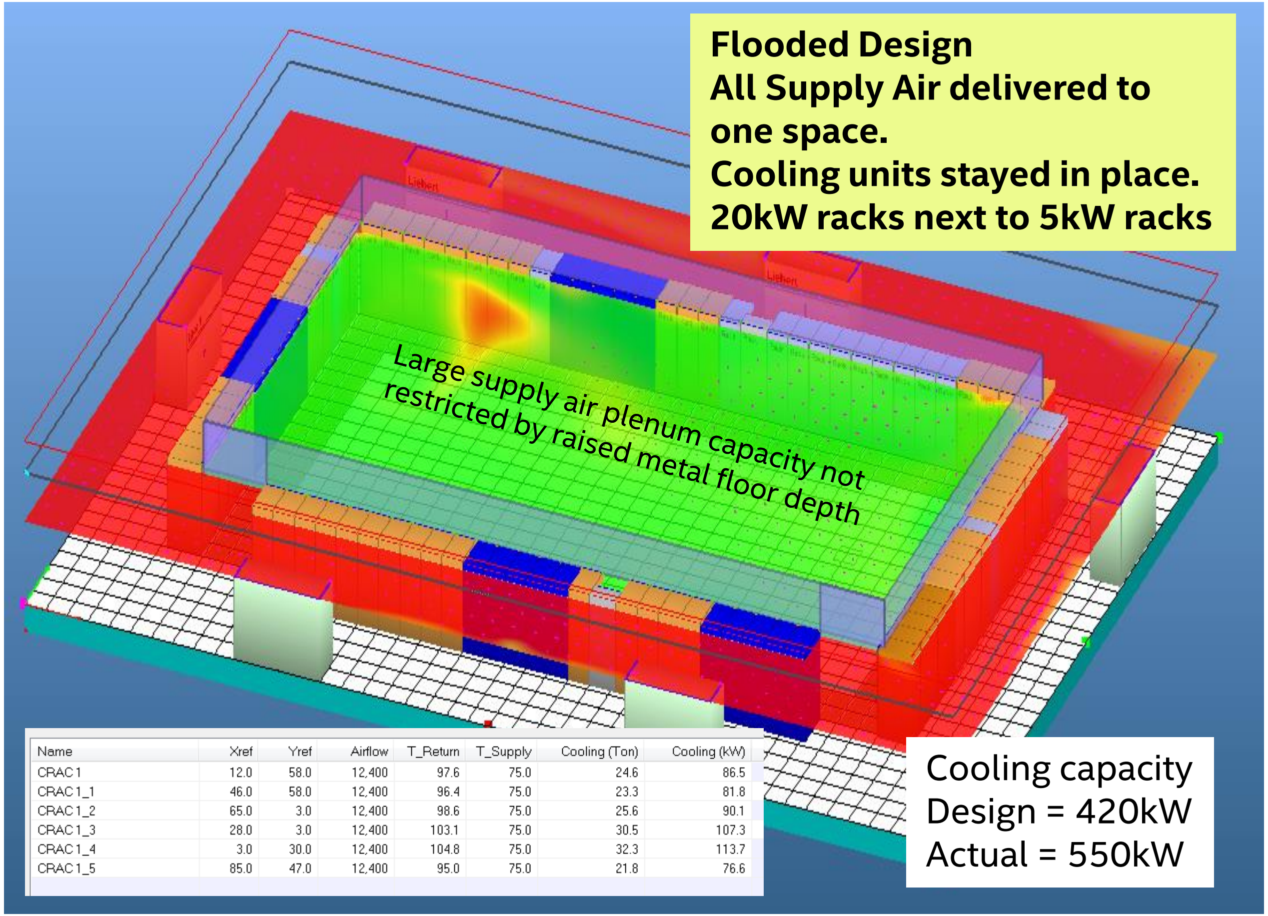
Rack cooling layout to improve capacity without CRAC unit addition or moves



Flooded Design
All Supply Air delivered to one space.
Cooling units stayed in place.
20kW racks next to 5kW racks

Improved layout
Airflow room level is "N + 1"without any airflow distributions issues

Cooling layout to improve capacity without CRAC unit addition or moves



Flooded Design
All Supply Air delivered to one space.
Cooling units stayed in place.
20kW racks next to 5kW racks

Large supply air plenum capacity not restricted by raised metal floor depth

Name	Xref	Yref	Airflow	T_Return	T_Supply	Cooling (Ton)	Cooling (kW)
CRAC 1	12.0	58.0	12,400	97.6	75.0	24.6	86.5
CRAC 1_1	46.0	58.0	12,400	96.4	75.0	23.3	81.8
CRAC 1_2	65.0	3.0	12,400	98.6	75.0	25.6	90.1
CRAC 1_3	28.0	3.0	12,400	103.1	75.0	30.5	107.3
CRAC 1_4	3.0	30.0	12,400	104.8	75.0	32.3	113.7
CRAC 1_5	85.0	47.0	12,400	95.0	75.0	21.8	76.6

Cooling capacity
Design = 420kW
Actual = 550kW

Object Count

Summary Counts

Object	Count
Downflow CRACs	6
Perforated Tiles	184
Server Racks	94
Vertical Partitions	6

Counts by Style

Downflow CRACs
Upflow CRACs
Perforated Tiles
Server Racks

Heat Load Density

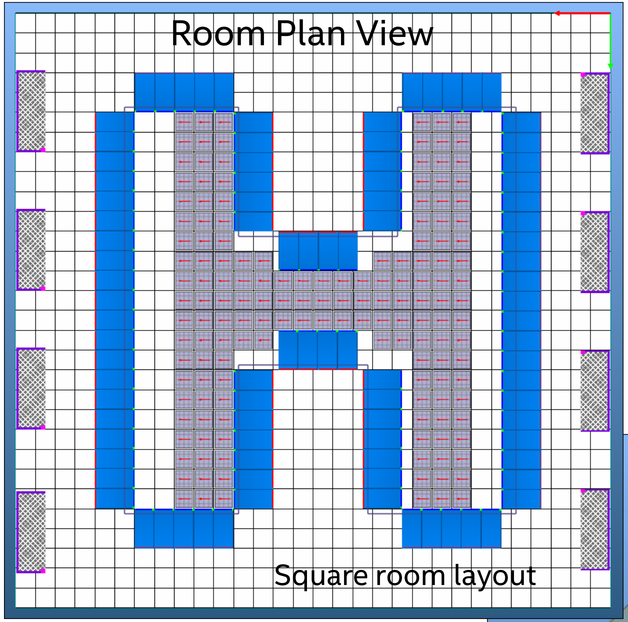
Net Floor Area: 5,224 sq ft
Heat Load Density: 106 W/sq ft
Explain...

Total Heat Load and Airflow Rates

Total Heat Load: 556 kW
Total Airflow Demand: 55,629 CFM
Total Airflow Supplied: 74,400 CFM

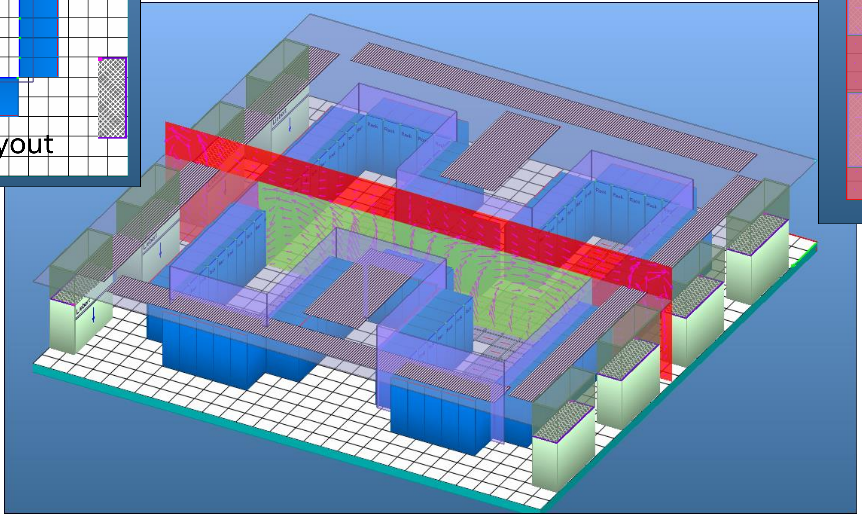
Improved layout
Airflow room level is "N + 1"without any airflow distributions issues

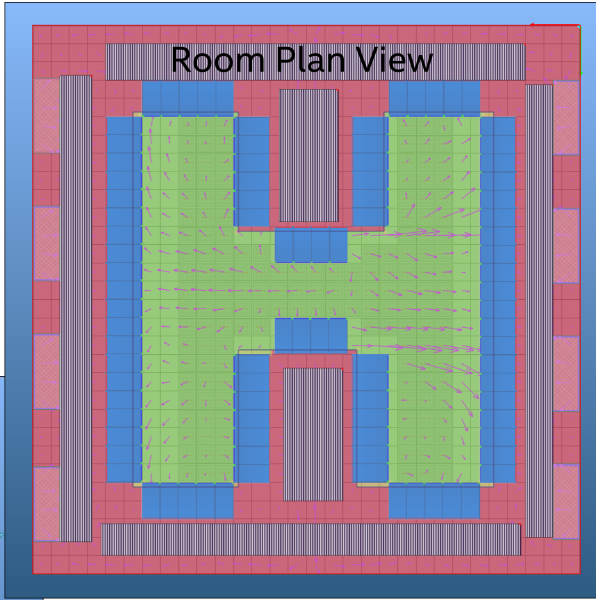
Flooded Room Design with "H" Layout



High density and low density rack power mix

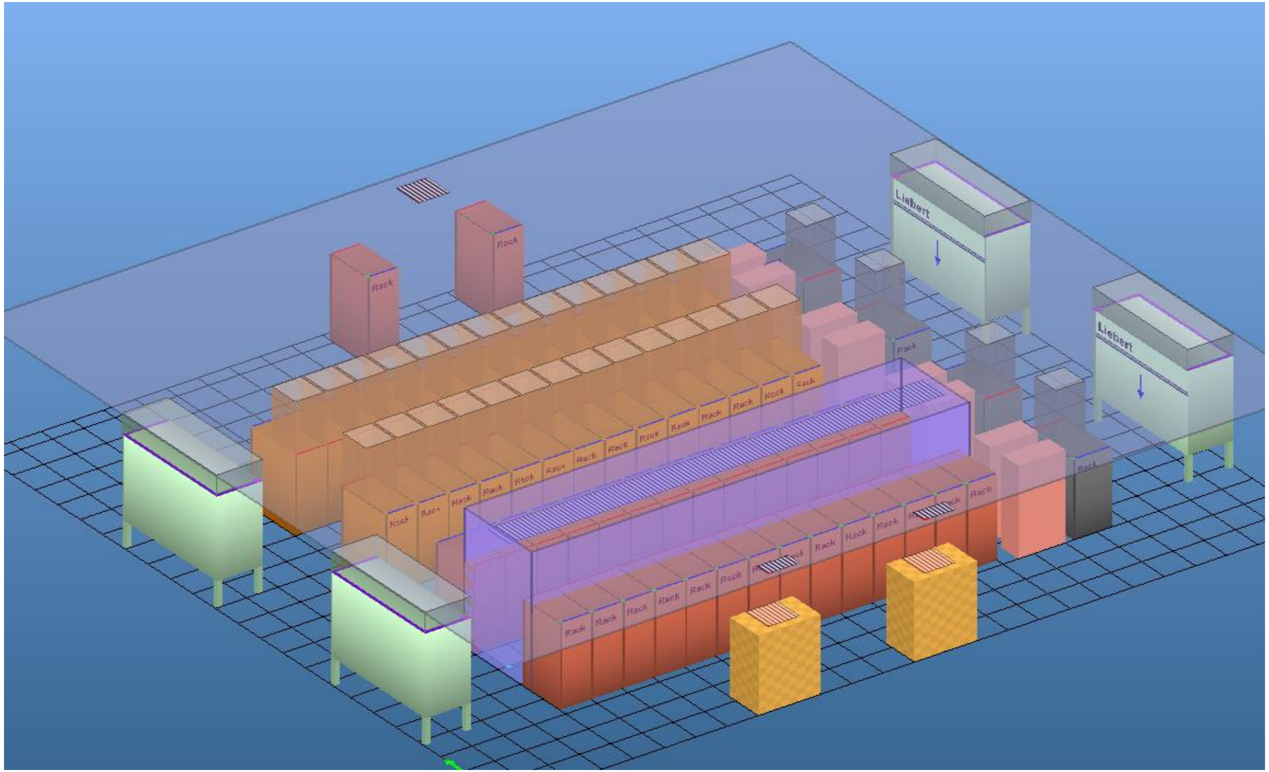
This layout provides 40% more rack bays then racks placed as a square perimeter





Thermal images of room

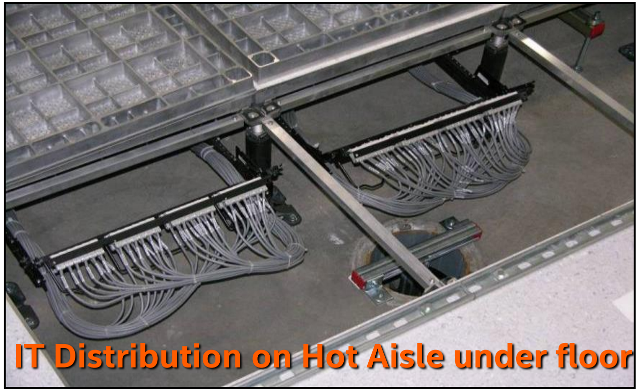
Segregated Air -No Raised Metal Floor Supply with Above Ceiling Return Air Plenum



Raising the air handlers above the raised metal floor allows a room with poor underfloor distribution or capacity to increase the effective cooling density.

Some facilities use an RMF ,raised metal floor, as an access floor for power, cooling and network infrastructure. This does not prohibit a flooded air design—we simply consider the RMF elevation as the slab height, and raise the room air handlers' supply path above the RMF.

Hot Aisle Isolation



Hard Panel Hot Aisle Enclosure

Sliding panels above cabinets to close air gap to create hot aisle enclosure.

End of rows closed off to create hot aisle enclosure.

Rear of cabinets.

Vented ceiling tiles. Return air to ceiling plenum.

Full height panels for missing cabinets.

Slab floor

Air Segregation Various Methods

Solid Panel HAE End Caps with Soft Wall over Server Racks

Hard wall and soft wall installation in same room

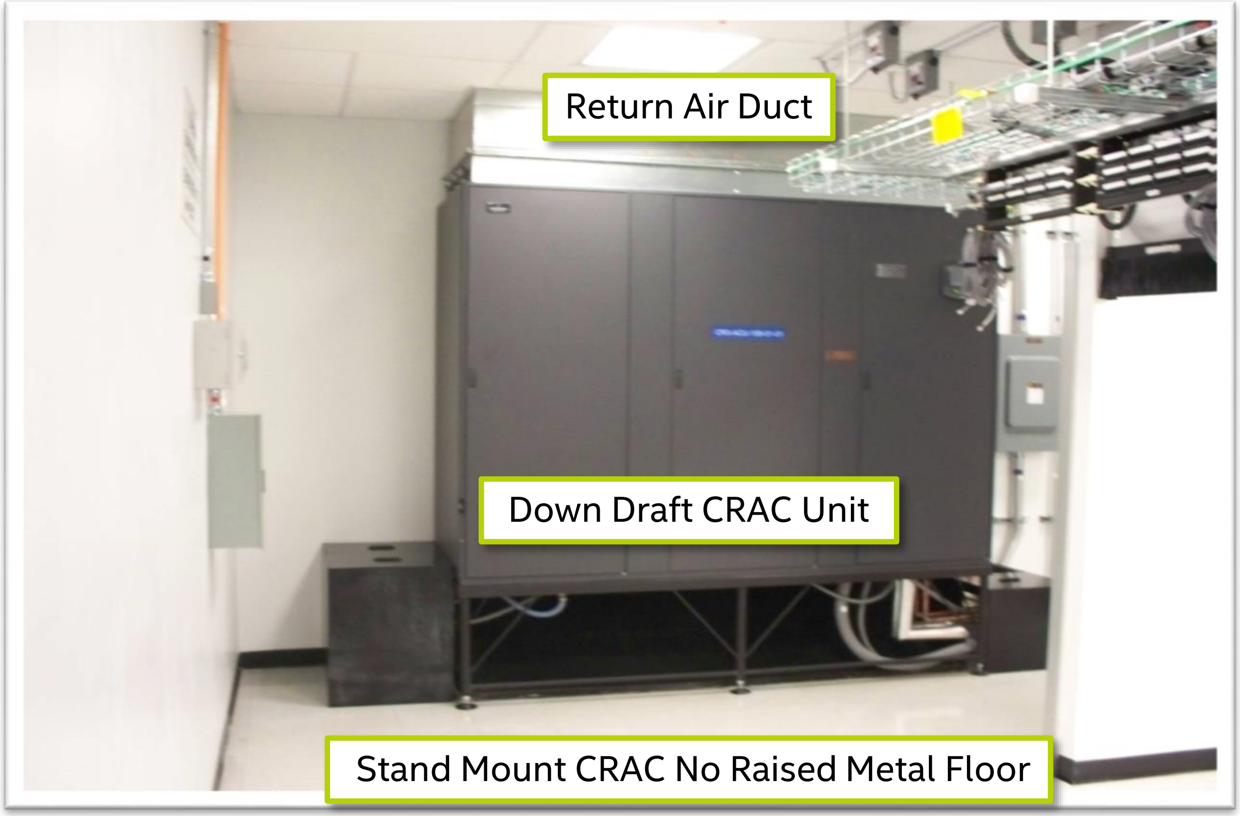
Flexible Curtain Hot Aisle Enclosure

Example of a Floor to Ceiling Filler Panel

Moveable Wall Room Dividers

Chimney cabinets

Air Segregation – No Raised Metal Floor



Space Management

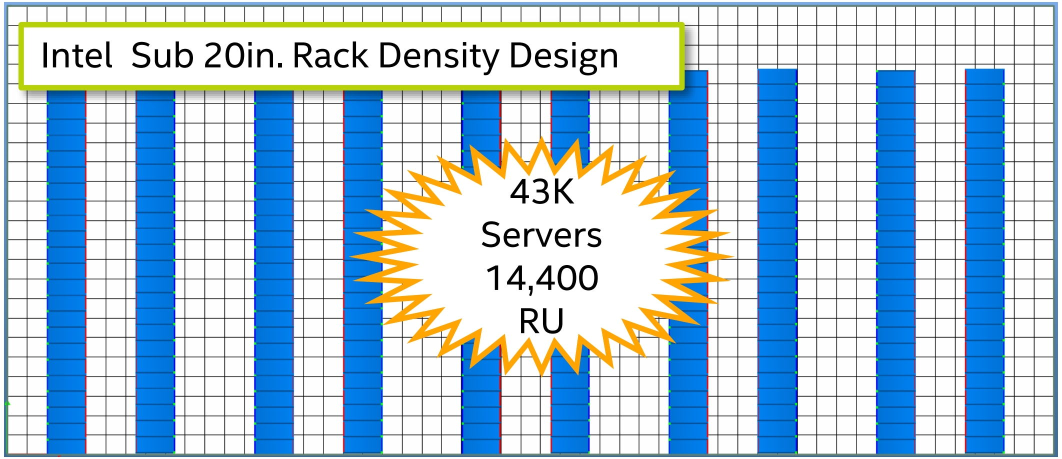
Server Rack Density

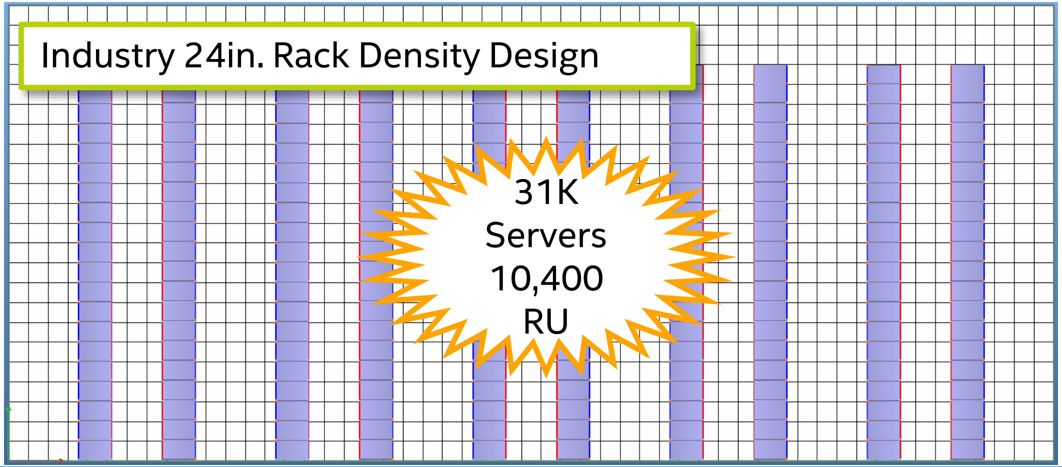
Rack Physical Density Intel Vs Industry Today

38% server rack capacity increase in same floor space.

COMPARE: Both footprints are 5,000 sq.ft.

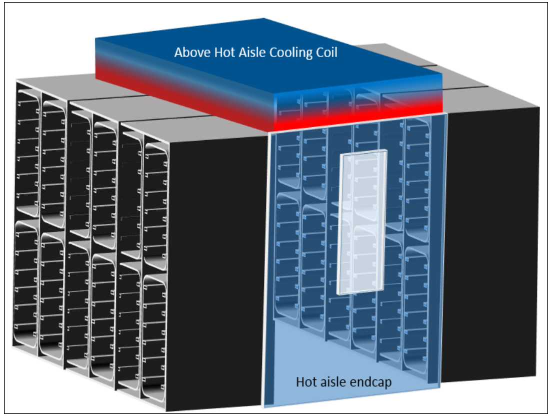
- Intel **Sub 20 inch Rack** Density
  - **240**
  - **60U Racks**
  - 14,400U Total
  - 43k Servers
  - 1,100 watts/ sq.ft.
- Standard **24 inch Rack** Density
  - **200**
  - **52U Racks**
  - 10,400U Total
  - 31k Servers
  - 864 watts/ sq.ft.





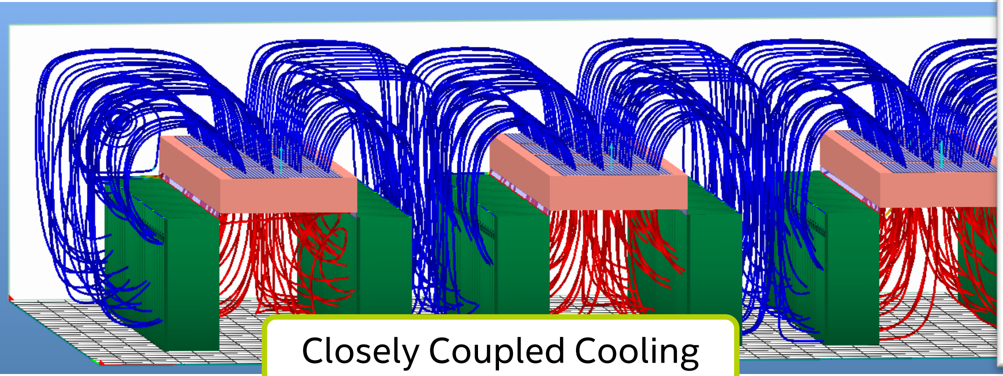
Compute Modules - 300kW-400kW - 720 RU capacity

- 2 rows of 6 racks = 12 racks total 10' long x 24' wide module footprint including supply air aisle
- 10' wide hot aisle
- 4' deep racks- 720 RU capacity
- 3' cold aisle (split 6' aisle)
- Approximately 1,100 watts/ sq.ft. room density 1300w/sf. module density

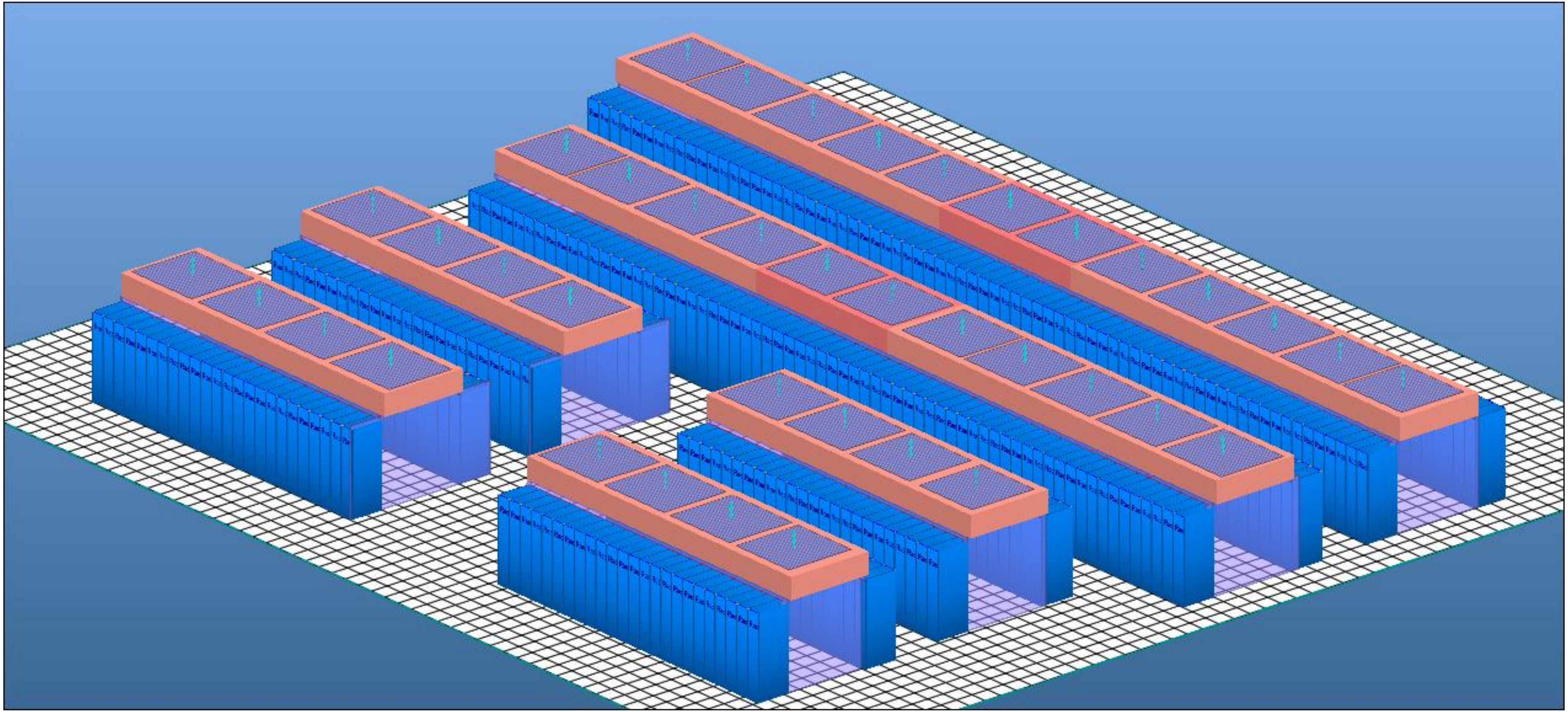


Close Coupled Cooling Compute Modules 1.1MW

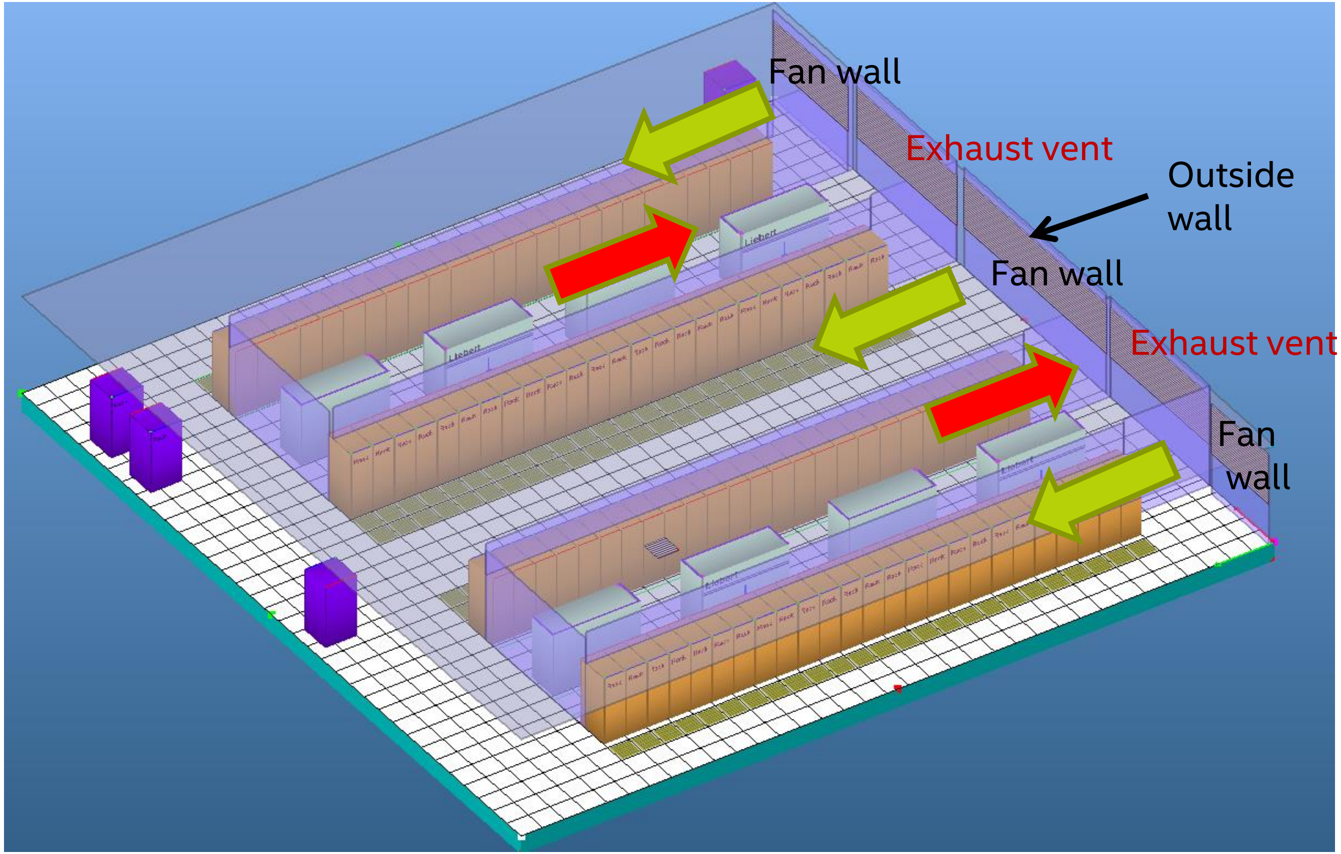
- 2 rows of 24 racks = 48 racks total
- 40’ x 24’ module footprint
- 10’ wide hot aisle
- 4’ deep racks
- 3’ cold aisle (split 6’ aisle)
- Approximately 1,100 watts/ sq.ft.



Larger data center layout 10MW capacity



Outside Air for “N Plus One" Cooling Capacity



Electrical Loss Management

Power Loss and Electrical Efficiency

- 415/240vac rack power distribution for reduced cost per kW and lower transformer and power distribution losses.
- 12kV to 415/240 Substation reduces actual total transformer losses to sub 2%.
- High efficiency transformers reduce electrical losses.
- Utility as second source reduces electrical losses from UPS conversion and max UPS utilization with STS.

Typical Performance Data: High Voltage—15 kV Class; Low Voltage—600 V Class

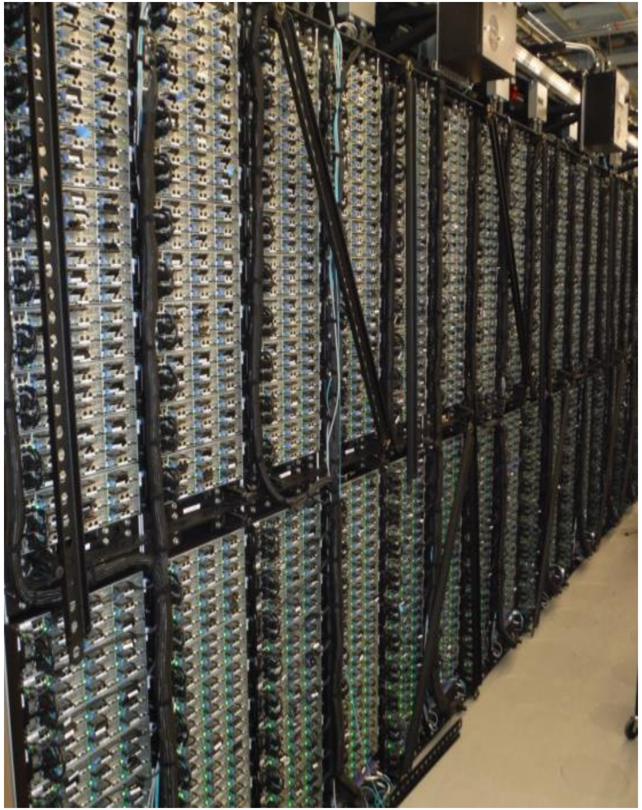
kVA	No Load Losses (Watts)	Full Load Losses (Watts)	Total Losses (Watts)	Efficiency						
				133%	125%	100%	75%	50%	25%	Maximum
225	800	3300	4100	97.83	97.93	98.21	98.45	98.58	98.24	98.58 @ 50% load
300	1000	4000	5000	98.02	98.10	98.36	98.58	98.68	98.36	98.68 @ 50% load
500	1300	6000	7300	98.24	98.32	98.56	98.77	98.89	98.68	98.90 @ 45% load
750	2000	7900	9900	98.42	98.49	98.70	98.87	98.95	98.69	98.95 @ 50% load
1000	2400	10000	12400	98.51	98.58	98.78	98.94	99.03	98.80	99.03 @ 50% load
1500	3300	13200	16500	98.68	98.74	98.90	99.06	99.13	98.91	99.13 @ 50% load
2000	4100	16000	20100	98.80	98.85	99.08	99.13	99.20	98.99	99.20 @ 50% load
2500	4800	19300	24100	98.84	98.89	99.05	99.17	99.24	99.05	99.24 @ 50% load
3000	7500	34000	41500	98.33	98.41	98.64	98.83	98.94	98.73	99.94 @ 50% load
3750	9500	37000	46500	98.52	98.58	98.78	98.93	99.01	98.76	99.01 @ 50% load
5000	11500	40000	51500	98.78	98.83	98.98	99.10	99.15	98.89	99.15 @ 50% load

Summary of Efficiency Measures

- Air Segregation
  - No Raised Metal Floor reduce construction cost mitigate room hotspots caused by the floor plenum limitations.
  - Air segregation preferred hot aisle solution with ceiling return air plenum or air handling unit in hot aisle.
  - Chimney cabinets raise supply air temperature, raise return air temperature and reduce bypass air.
- Air Management
  - Flooded supply air design provides supply air to all racks high density and low density regardless of demand.
  - Variable Frequency Drives energy savings on pump and fan motors.
  - Old airflow volume 160 CFM -200/kW .
  - Current airflow volume 80 CFM -108/kW.
- Cooling management
  - Evaporative cooling Wet side economization
  - Free cooling Outside air Dry side economization.
  - Raise Return Air Temperature provides higher efficiency and capacity for heat rejection through cooling coils.
  - Raise Supply Air Temperature to 80F with conditioned power environments and 80°F to 95°F in utility power environments.
  - Raise Return Chilled Water Temperature increase the efficiency of the chillers.
- Room Design Efficiency
  - 1,100 watts/ sq.ft. Power and cooling density.
  - Multi Tier room design takes advantage of N+1infrastructure stranded capacity through lower tier load sheading.
  - Densification maximizes power, space and cooling distribution reducing construction cost and improving efficiency.

Wet Side and Dry Side Economization

Evaporative Cooling Wet Side Economizer 1100 watts/sf.



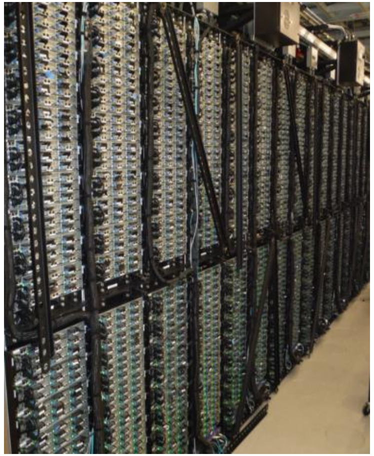
Evaporation type
Cooling towers option for
Gray Water supply

Plate heat exchangers
Used to segregate
cooling tower water from
data center cooling coils

Data center cooling water
main line distribution
3600GPM, 25MW capacity

Data center Hot Aisle flex
cooling lines to overhead
cooling coils

Close Coupled Cooling
overhead cooling coils 330kW
cooling capacity per coil system

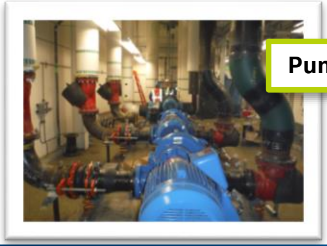


60U Server racks

Close-Coupled Cooling Solution Components

Cooling Coils in Top of Hot Aisle

22" Water Lines

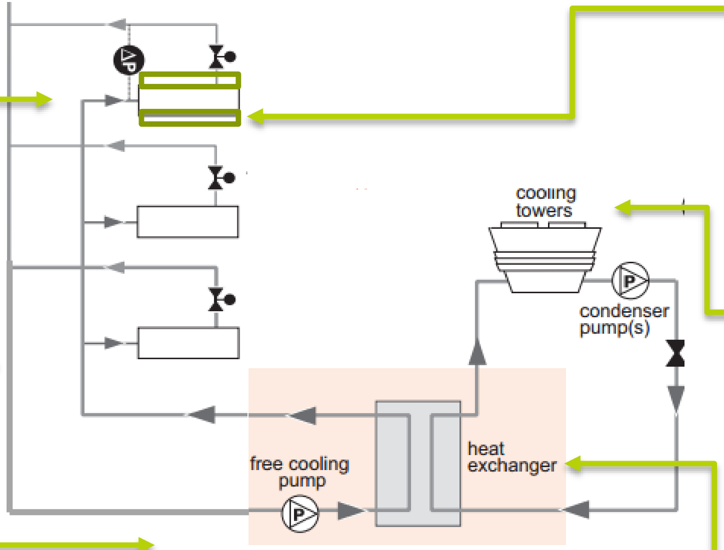


Pumps

Servers

Cooling Towers

Plate Heat Exchanger



Close Coupled Cooling Design Layout

- Evaporative cooling tower water only solution
- Primary and secondary loop, plate heat exchanger separates the water
- DC air is recirculated, heat rejected through cooling towers only

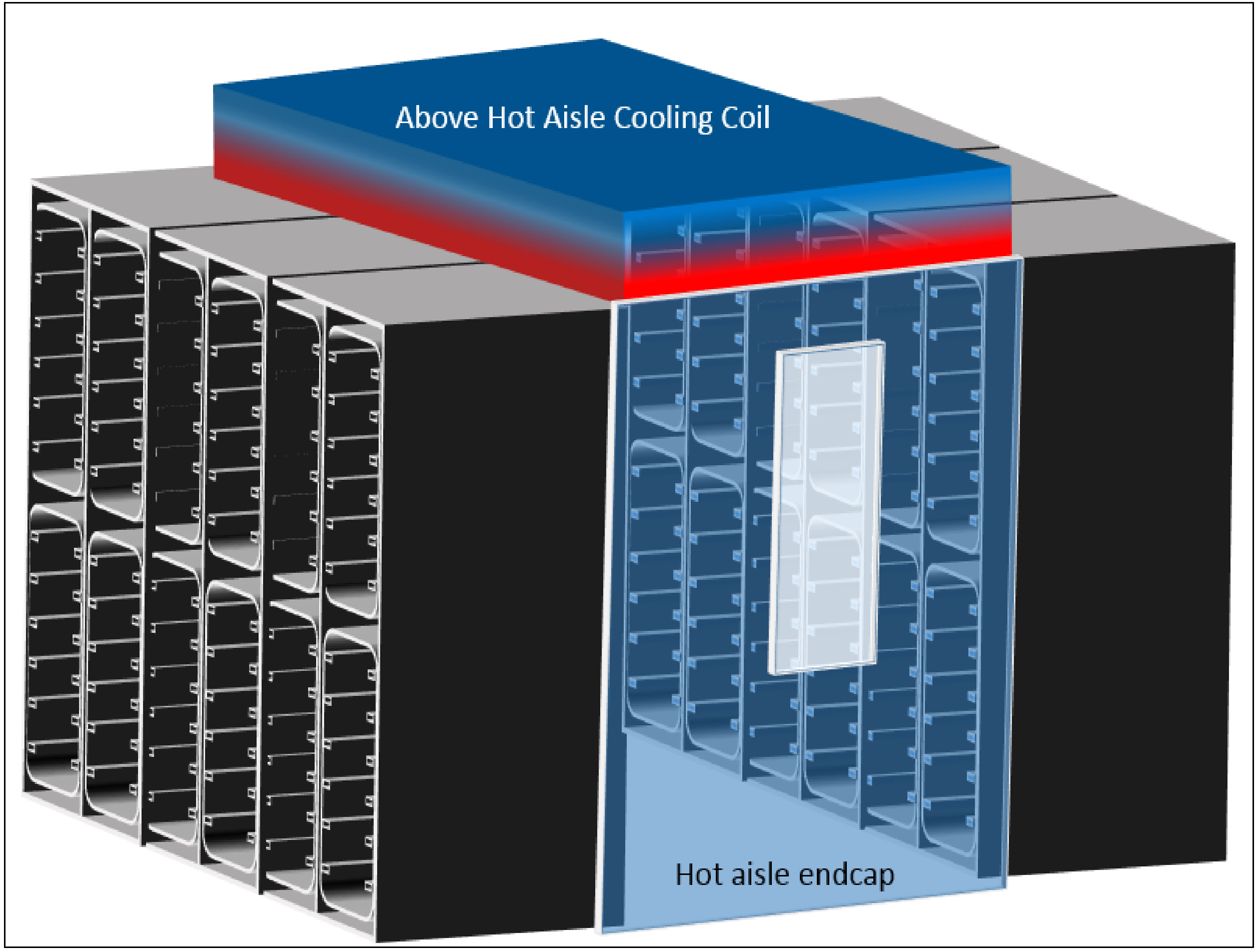
Close Coupled Cooling Room level

Modular Build
10ft X 24ft Increments
from center cold aisle
to center of cold aisle

Server Racking
Sub 20in wide in 30u increment
30u, 60u and 90u elevation

Fit-Up Module
Insert provides on site
and offsite compute device fit-up

Close Coupled Cooling
Coil provides 330kW cooling
per twelve 60u racks



High Density Compute Modules

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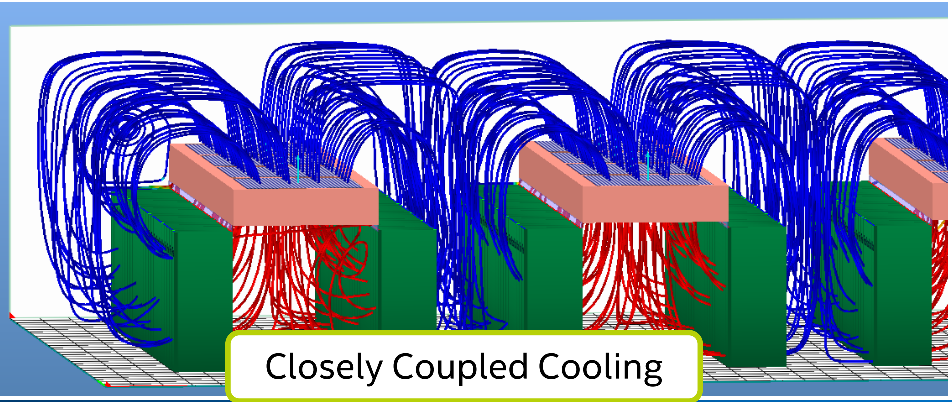
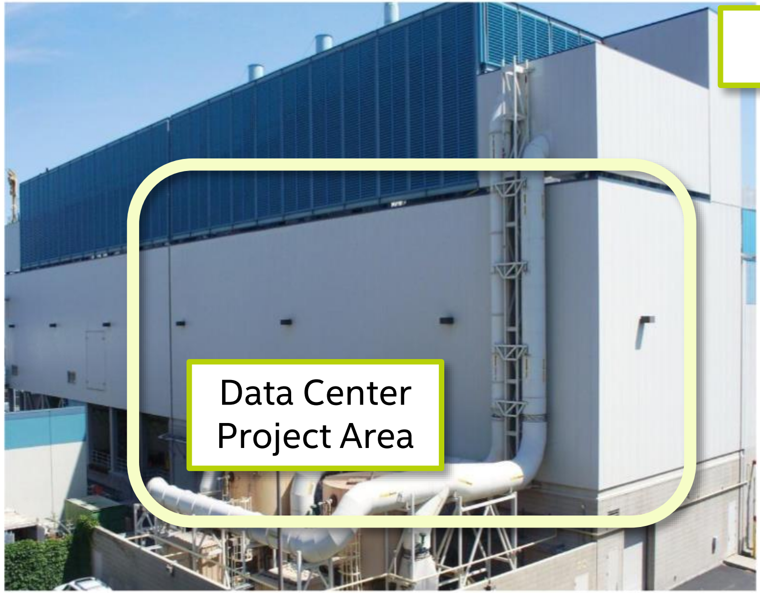
- Approximately 1,100 watts/ sq.ft.



Free Cooling Dry Side Economization

Second Story Space With Outside Walls - Retrofit



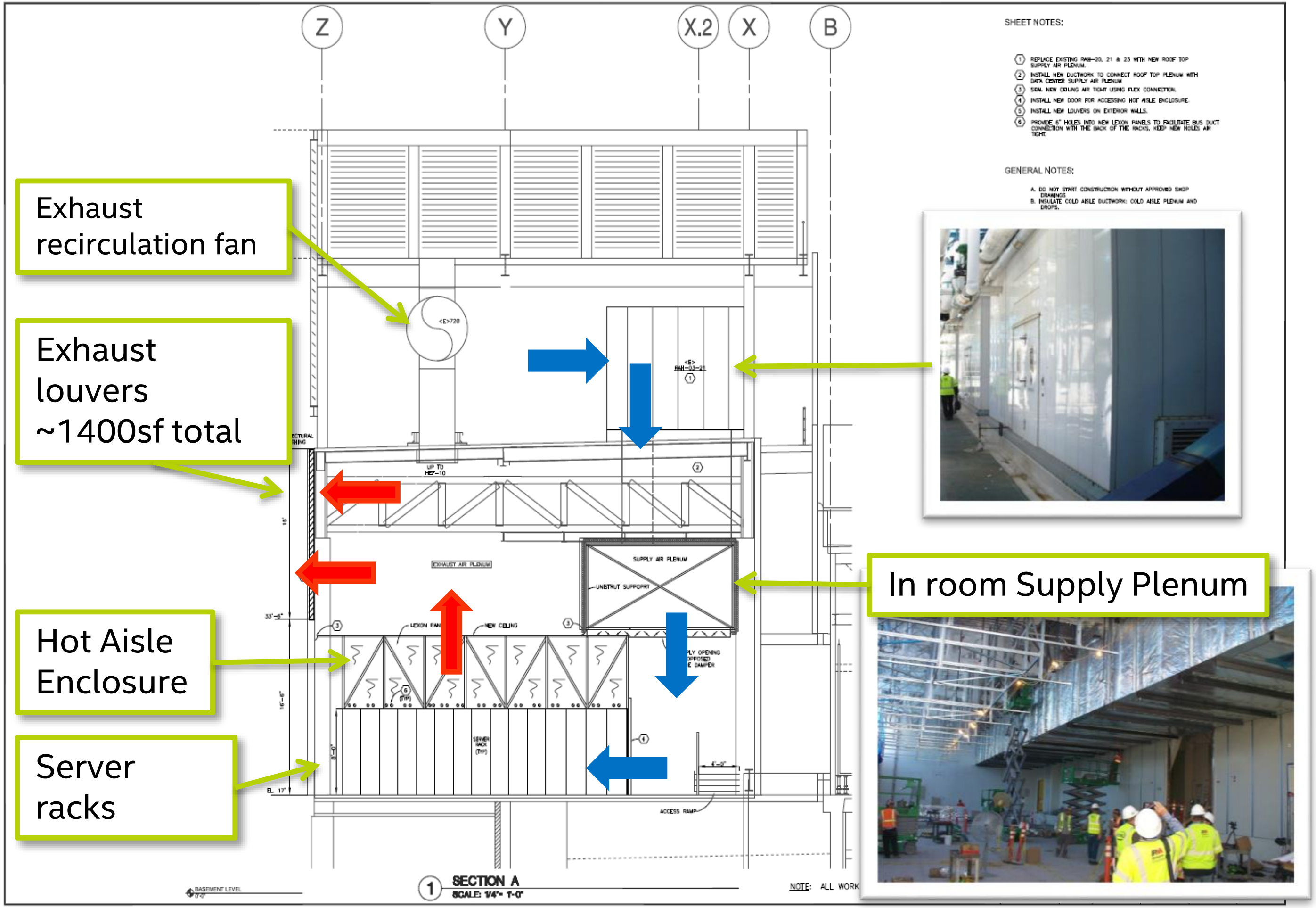
Before and after Photos

- 1,200 sq.ft. vents in wall, exhaust louvers.
- Smaller pressure relief vent in end wall, in case the wind is blowing against the exhaust.

Cooling Management

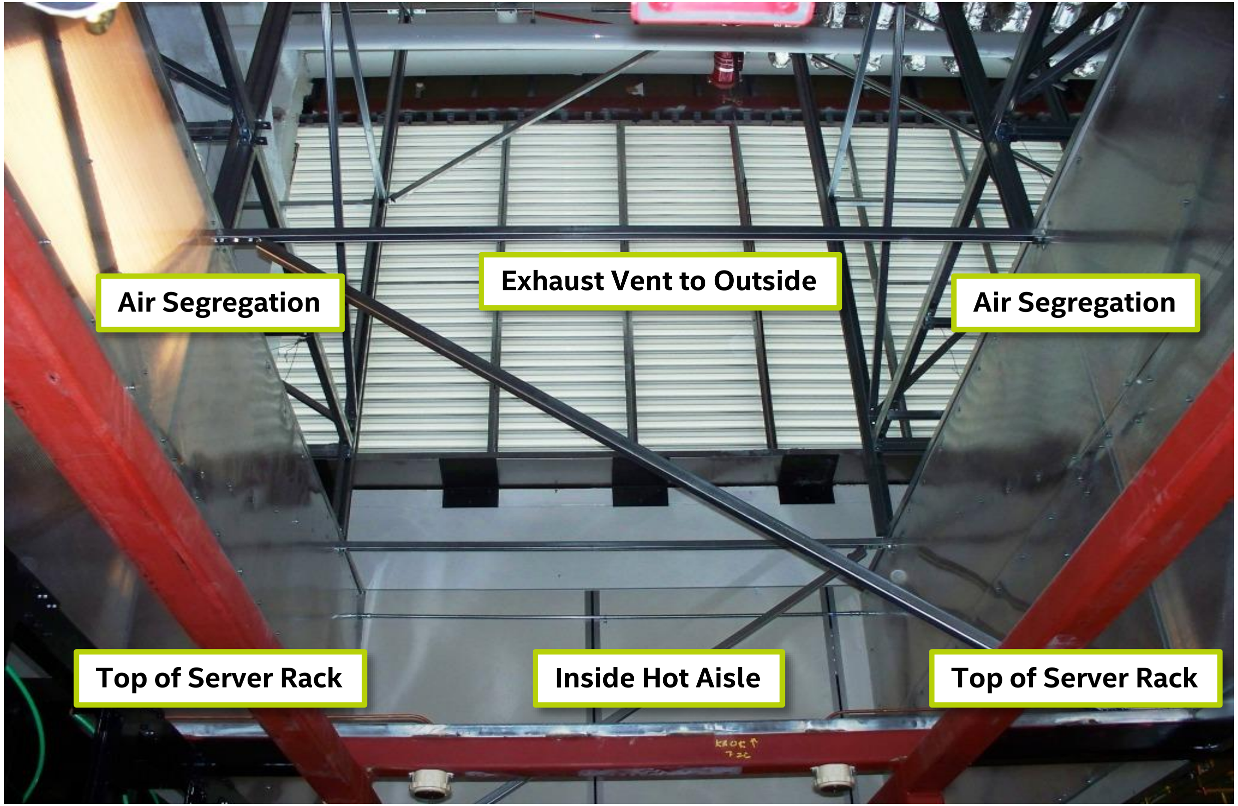
Outside Air Flow Design

- View of building end.
- Photo shows supply plenum.
- Big recirculating fan to prevent condensation during excessive cold weather 6ºF.
- 540,000 cfm at 95ºF.
- 400,000 cfm at 80ºF.
- PUE Annualized 1.06 at night as low as 1.03

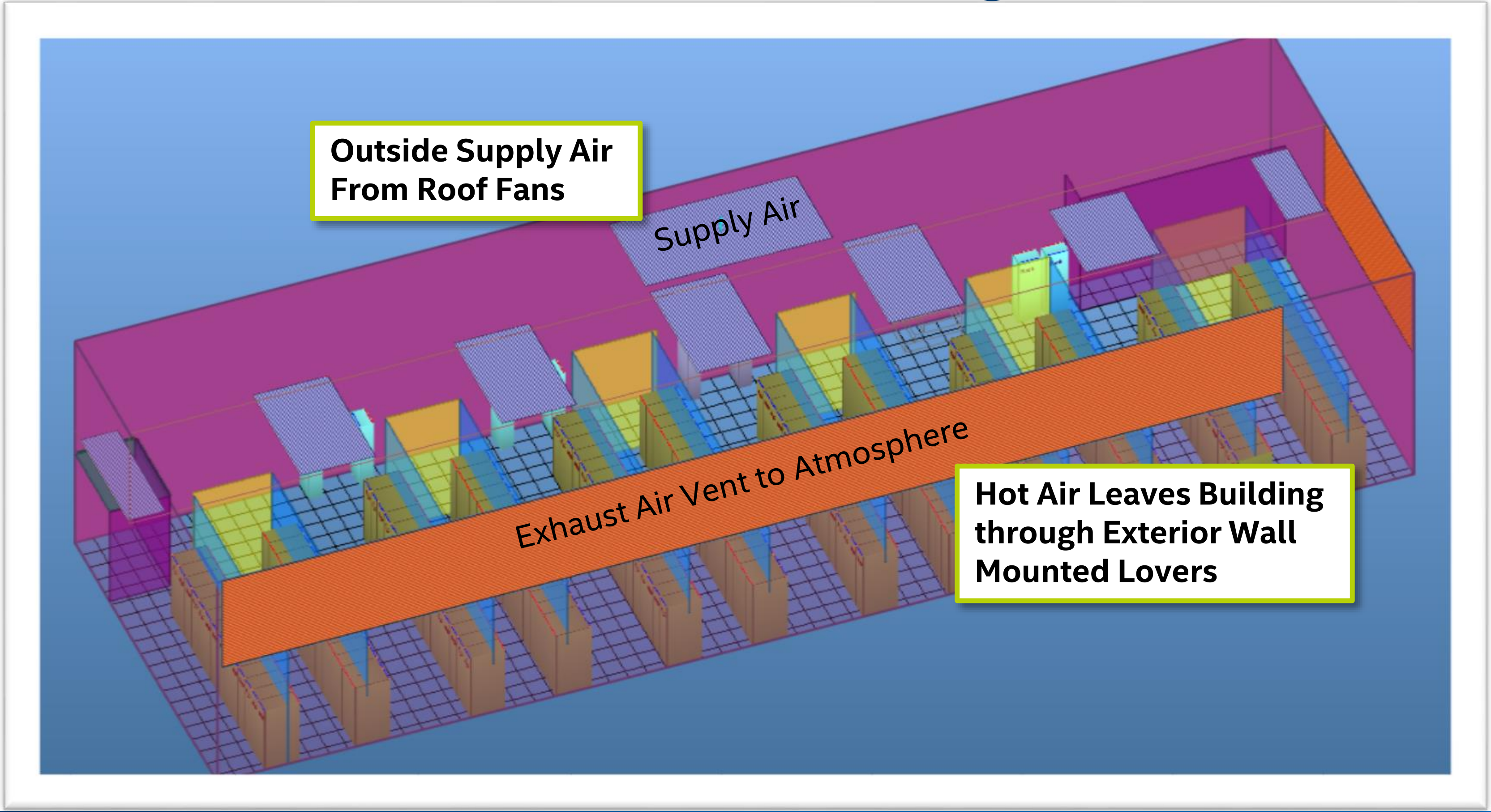


Hot Aisle Exhaust Vents to Outside

- View standing in hot aisle looking up.
- Exhaust vent is just covered by a louver.
- Plastic panel at top of rack, segregates hot from cold aisle.



Outside Air Room Model – Free Cooling Air Side Economizer

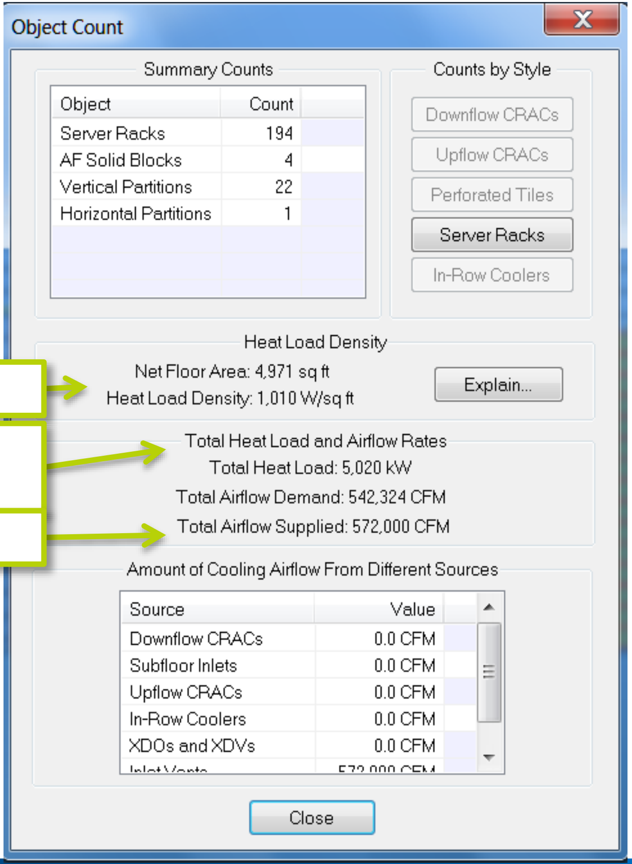


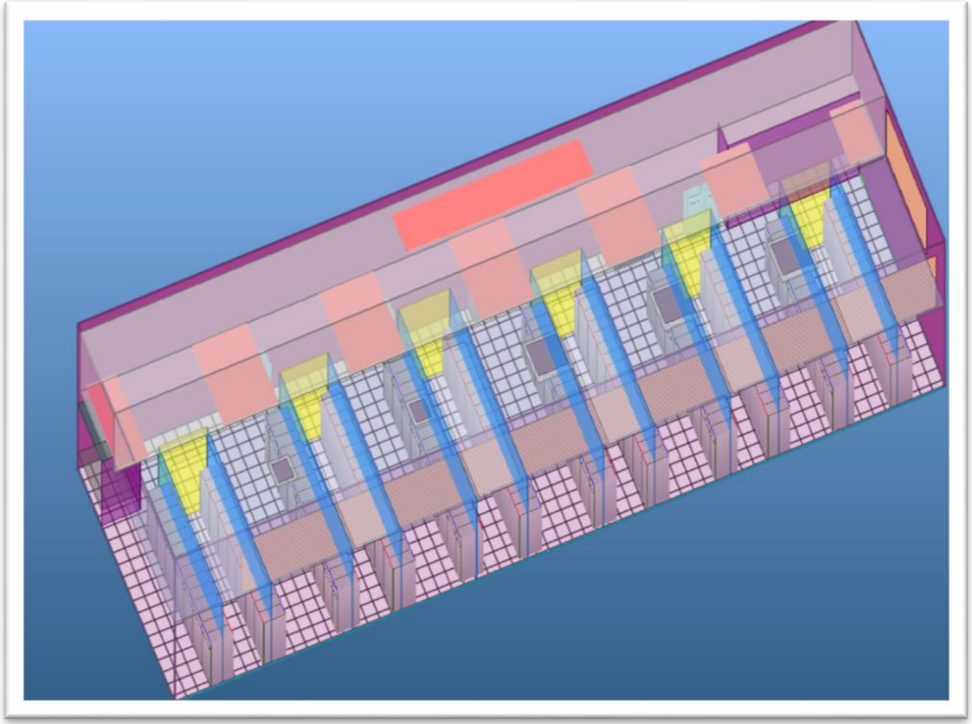
Power Density –1,100 watts per net sq.ft.)

Power Density

Total Room Design

Airflow





Questions

Next Generation Facilities for High Performance Computing (HPC) Embedded Data Center Design Approach

Better Building Summit
May 10, 2016

Brandon Hong, PE
HPC Systems Engineer

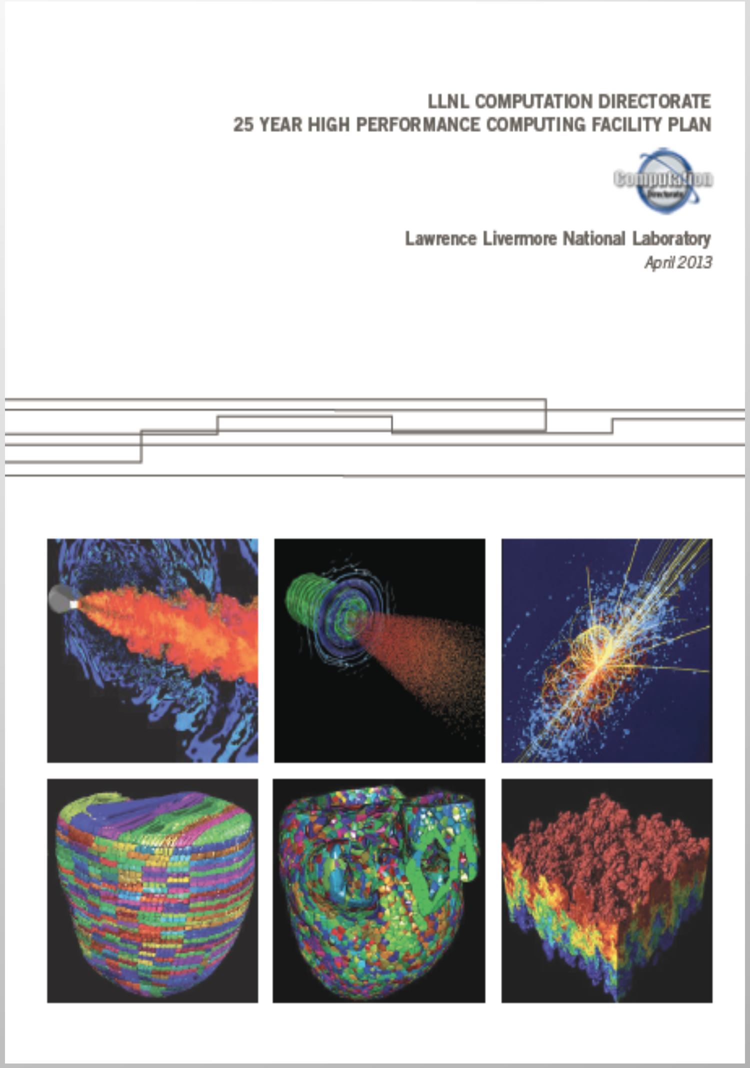
LLNL-PRES-457823

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

25 Year Facility Master Plan Developed to Meet Next Gen HPC

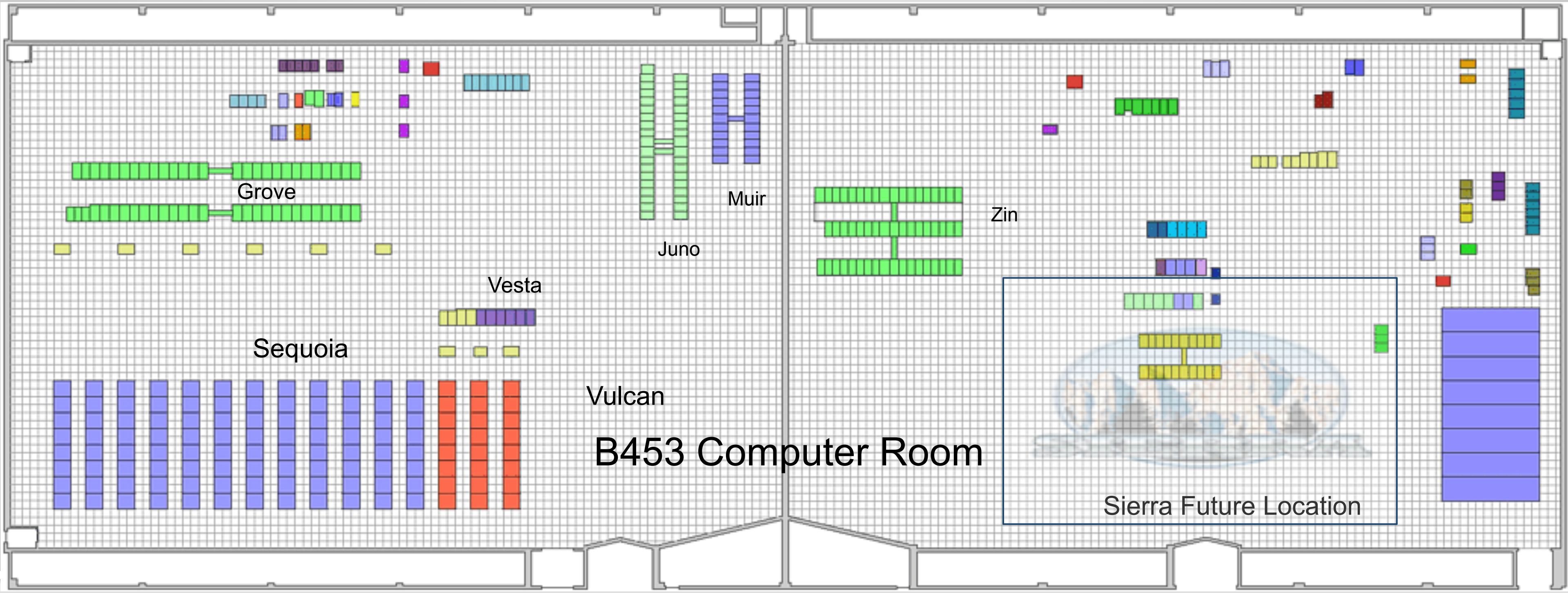
- HPC Facility Road Map
  - Facilities are 10 to 60 years old
  - Limitations with existing Livermore Computing (LC) facilities
  - Site-wide HPC consolidations
  - Technical Alternatives Analysis
    - — "Remodel vs. Build New"
    - — Detailed Cost Modeling

- Next Gen HPC = Unique Facility Innovation
  - Liquid Cooling Advances
  - Efficient Electrical Distribution
  - Robust Structural Solutions
  - Sustainable HPC Modular Embedded Solutions



Livermore Computing (LC) Complex Highlights

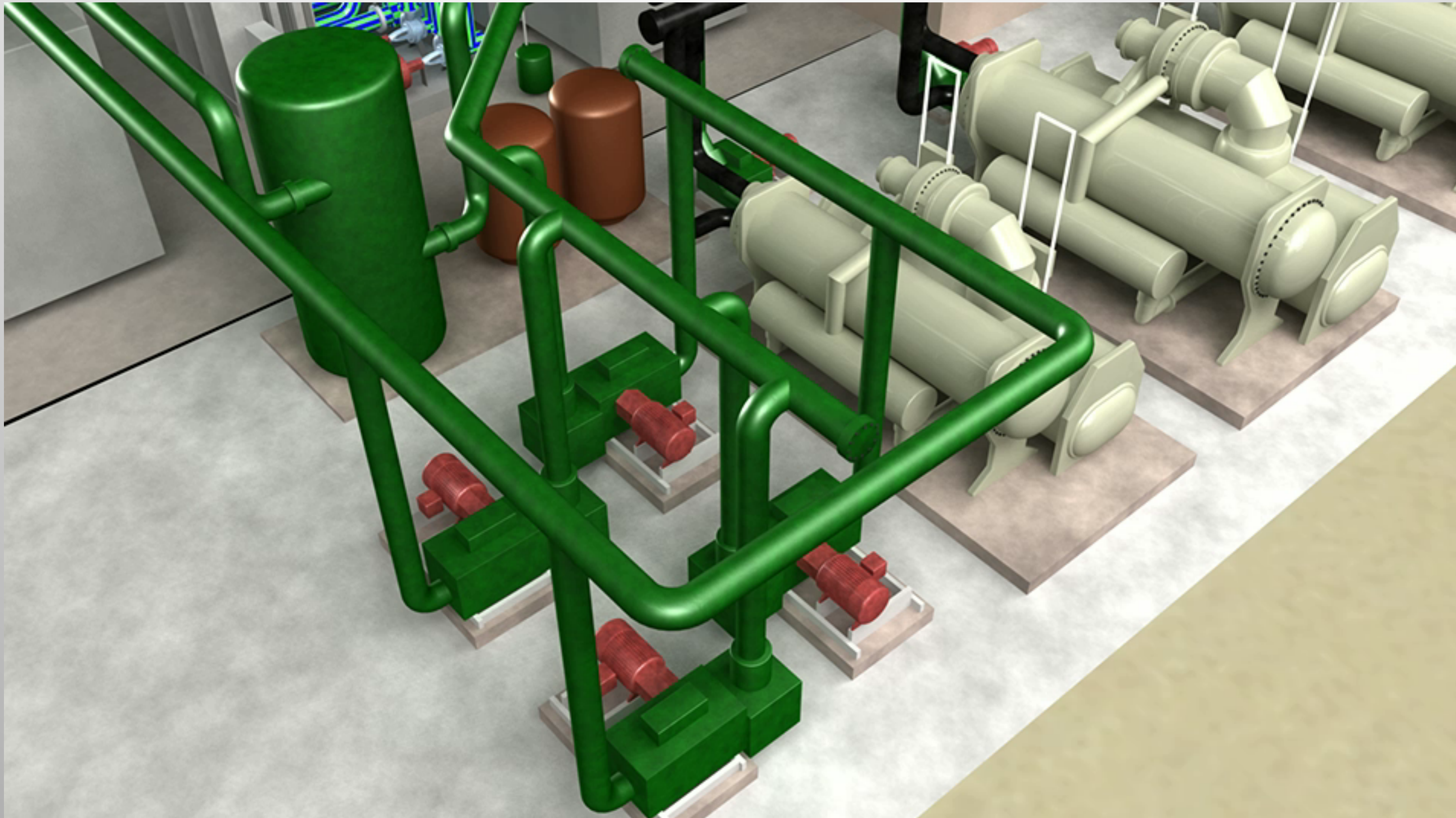
- 100K SF and 50 MW across the complex in facilities ranging from 10 – 60 years old
- B-453 houses key Top 500 computers
  - Sequoia (20 PF – 9.6MW – 4000SF) and Vulcan (5 PF – 2.4MW – 1000SF)
- Other facilities house smaller less dense systems
- B-453 construction completed in 2004 – Perpetual modifications to scale with technological advances.



B-453 Facility Distribution Challenges - Facility Design Concepts Date to 1998

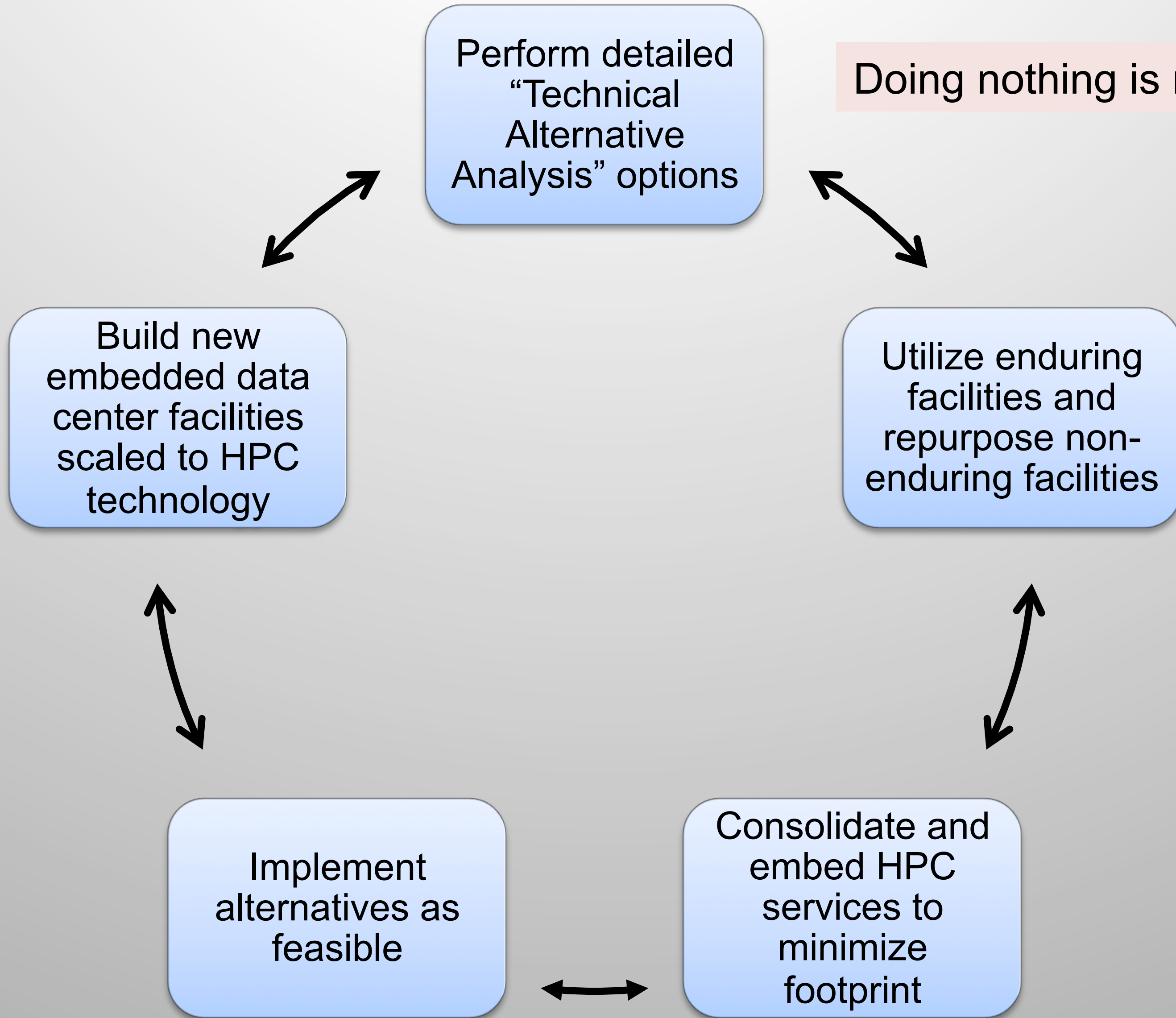
Next Gen HPC Push Facility Electrical, Mechanical and Structural Infrastructure

Next Gen HPC Pushes Facility Boundaries
B-453 Sequoia Installation Challenges



Future Facility Strategy Plan for Next Gen HPC

Doing nothing is not an option

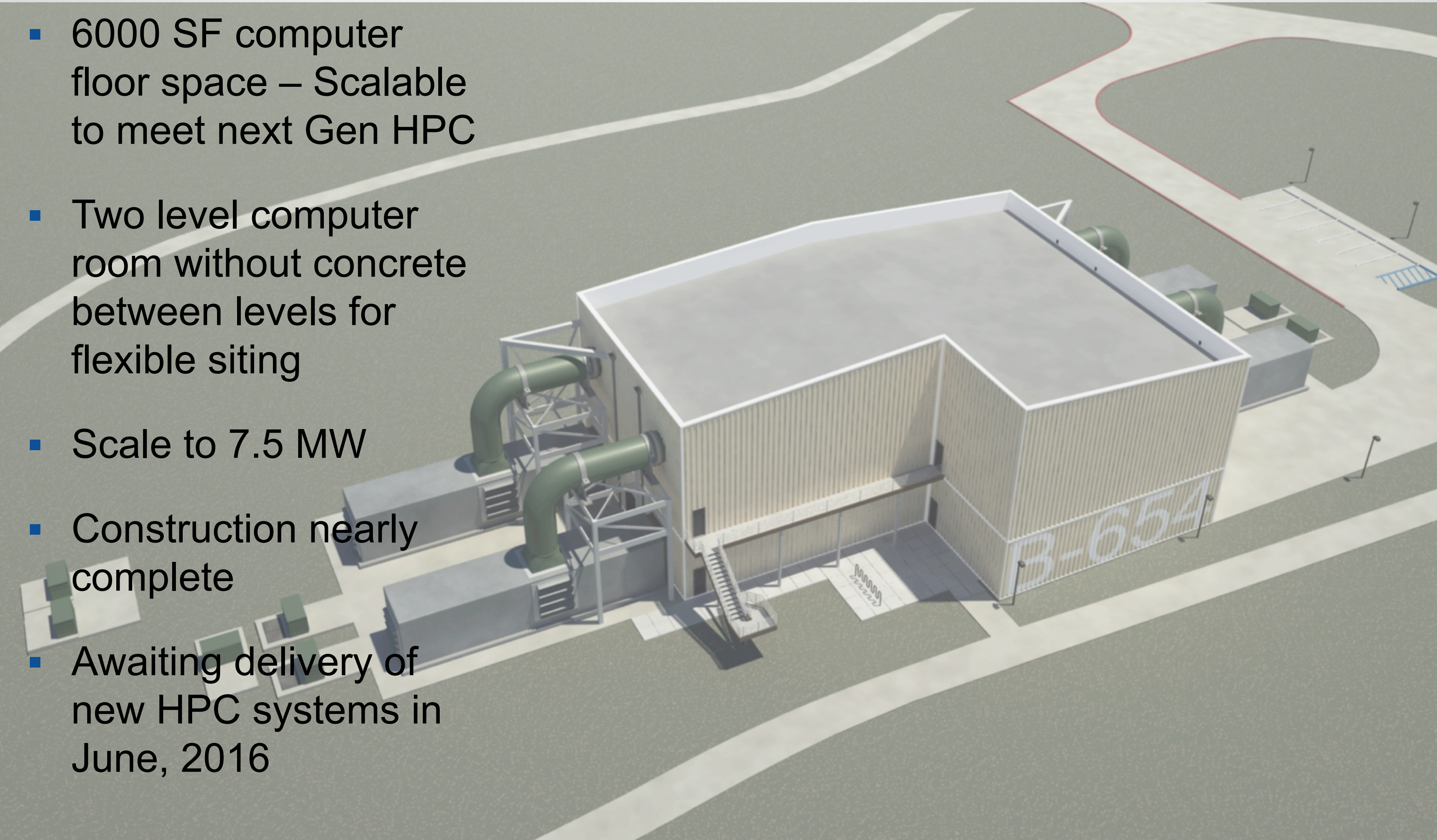


Next Gen HPC Sustainable Modular Embedded Design Approach

- Clear, unencumbered space and accommodate increased weights
- Scalable mechanical and electrical infrastructure
- Advanced liquid cooling options with free evaporative cooling
- Build what is needed to scale with current HPC technology
- Repurpose equipment from other LC facilities

First Embedded HPC Modular Approach Nearing Completion

- 6000 SF computer floor space – Scalable to meet next Gen HPC
- Two level computer room without concrete between levels for flexible siting
- Scale to 7.5 MW
- Construction nearly complete
- Awaiting delivery of new HPC systems in June, 2016



Successful Next Gen HPC Requires Embedded Planning and Execution

Develop a Master Plan, Road Map or Strategic Plan

- Identify embedded capabilities
- Identify gaps
- Retire non enduring solutions
- Promote enduring embedded solutions
- Execute consolidations
- Identify embedded innovative solutions
- Perform alternative analysis and develop cost models
- Leverage embedded solutions based on future technologies

Lawrence Livermore National Laboratory