Reducing Energy Costs in the Data Center by Improving Airflow Management

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President

Applied Math Modeling Inc

Applied Math Modeling Inc

- Founded in 2008 as a spin-out of the ANSYS Corporation.
- Responsible for Development, Sales, & Support for the CoolSim Data Center Modeling application through partnership with ANSYS Inc.
- Focused on delivering cost-effective engineering simulation tools using a SaaS model of delivery & support.
- Staffed by industry experts in the field of CFD sales, development, and support.

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Why is CFD Modeling Necessary?

- It’s very difficult to predict airflow behavior without years of experience
  - And even then you can be surprised
- Modeling allows for the understanding and planning of conditions *before* they occur
  - Failure mode and DR planning
  - Modeling of “proposed” increases in thermal loads
- CFD helps you to make a case for changes you would like to make, but cannot gain agreement
  - It is a decision support tool

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CoolSim

Benefits of Data Center Airflow Modeling

- User can perform "what if" studies of potential changes to the data center
  - Addition of servers or cooling capacity
  - Analysis of failure scenarios
  - Optimization of equipment placement
  - Exact understanding of maximum loading of a given data center.
- Allows users to visualize the airflow and temperature within the data center and make informed decisions on cooling or equipment placement.
- Provides the insight necessary to enable significant cost savings potential in new data center designs or operational costs of existing data centers.

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Isn't CFD Expensive and Hard to Use?

- Yes, historically CFD modeling has been too expensive and too hard to use:
  - But things are GUI's are getting better
  - Tools are becoming more automated
  - And prices are becoming reasonable
- At the right entry price and "ease of use" CFD modeling becomes quite attractive
  - Informed managers make better decisions

How Does CoolSim Work?

- CoolSim incorporates ANSYS Fluent CFD technology
  - Same software used in Aerospace and Automotive
- All meshing, solving, and post processing are performed on a remote HPC cluster.
- CoolSim uses a subscription based SaaS (Software as a Service) model where price is correlated to anticipated annual use.

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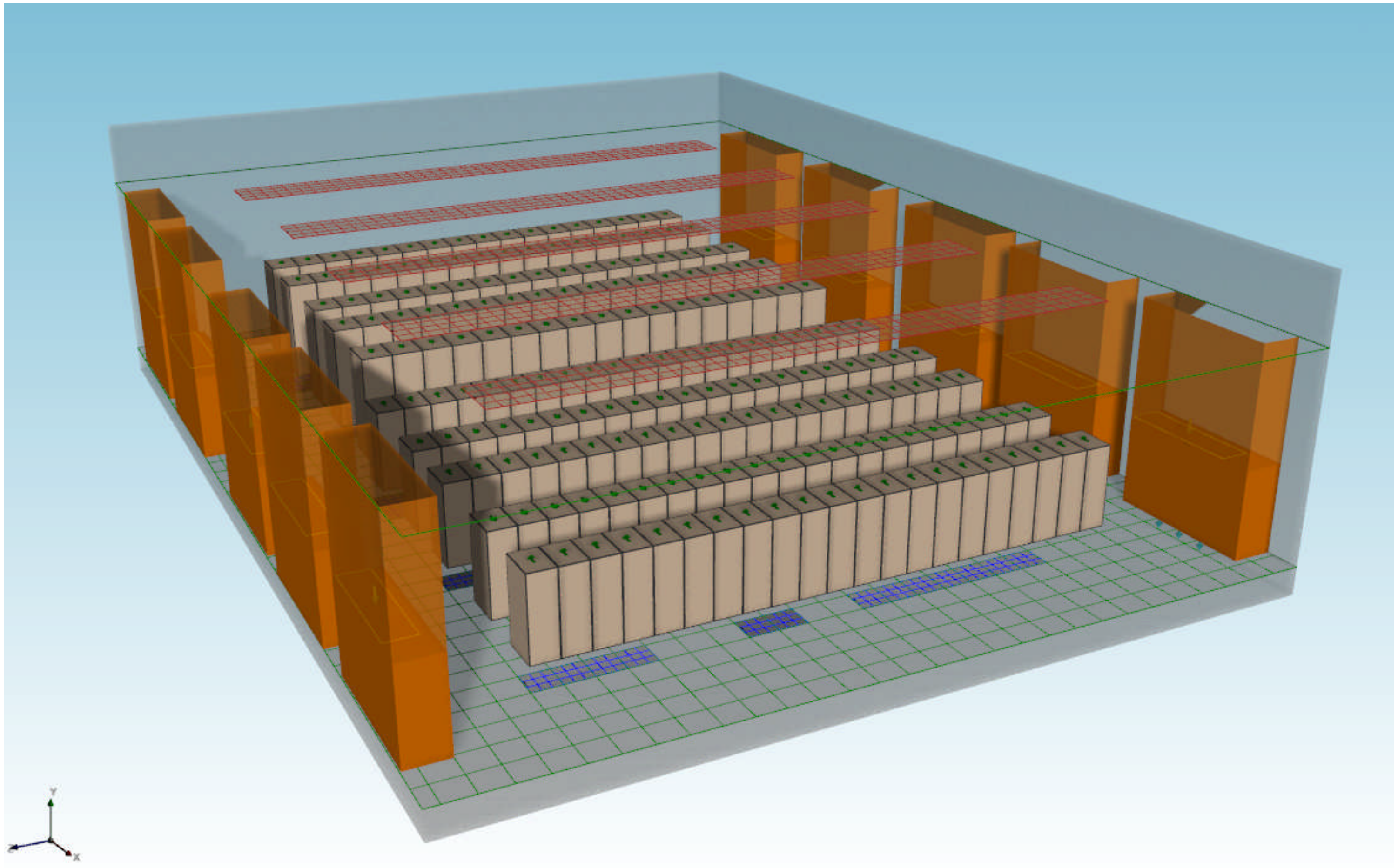
How Does CoolSim Work?

- CoolSim is a highly automated tool
  - User builds a model of a data center using easy to use GUI
    - Includes libraries of common cooling equipment and equipment racks, and IT equipment
  - Model is automatically meshed, solved, and post processed
    - Embedded knowledge drawing upon 20 years of CFD modeling experience from aerospace and automotive markets
  - Results are presented in 3D HTML output reports
    - Eliminates costly “human time” in post processing
    - Eliminates “human error” in post processing output plots
  - User learning curve measured in hours
    - Run times average less than an hour

Case Study

- Data Center is a raised floor design of 5000 sq ft and 362 kW of IT load with ceiling return plenum.
- DX based perimeter downflow cooling capacity is 561 kW.
  - Ratio of 1.55 x required cooling capacity
  - Airflow ratio is currently 1.52x
    - Rack demand is 57,020 CFM
    - Cooling airflow is 87,000 CFM
- Interested in improving the overall efficiency.
  - Potential to raise IT load and/or lower overall PUE and/or operational costs.

Base Model Configuration



Validating Simulation Output

CRAC Performance Report							
CRAC Unit Name	Ave. Return Temperature (^oF)	Measured Return Temp	Measured Return vs Simulated Return Temperature	Ave. Supply Temperature (^oF)	Temperature Drop Across CRAC	Supply Flow Rate (CFM)	Heat Removal (kW)
Downflow Units							
ahu61 (C, 1)	67	67	0%	52	15	14,500	70.56
ahu105 (S, 1)	70	71	1%	54	16	14,500	76.01
ahu149 (AH, 1)	75	73	3%	68	7	14,500	31.66
ahu116 (S, 29)	69	68	1%	54	15	14,500	68.51
ahu1510 (AG, 29)	73	69	6%	63	10	14,500	45.95
ahu72 (B, 29)	66	66	0%	51	15	14,500	72.03
ahu83 (K, 1)	off			off		off	off
ahu127 (Z, 1)	off			off		off	off
ahu94 (I , 29)	off			off		off	off
ahu138 (Z, 29)	off			off		off	off
Total	--			--		87,000	364.82
Average	70	69	2%	57	13	--	60.8

- Measurements agree with simulation output within 2% error
- Temperature drop across cooling units average = 13 F
- Crac 149 is producing only 31.6 kW of cooling due to poor delta T

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Base Model Energy Calculations

Initial Baseline Calculations			
Total Rack Heat Load	364.5	kW	
PDU and UPS Heat Load	36.4	kW	
Cooling Power (measured)	269.1		
Cooling Unit COP	1.5		
Rack Airflow Requirement	57020	CFM	
Number of CRAH's	6		
Supply Airflow Rate from CRACs	87000	CFM	
Fan Power per CRAC	8.0	kW	
Total Fan Power	48	kW	
Total Energy for Cooling Data Center	349.3	kW	
Total Data Center Energy	750.2		
DCIE	48.6%	%	Well below “typical”
RTI (Return Temperature Index)	66%		Net by-pass Airflow
RCI (Rack Cooling Index) Low	-39%		Poor, rack inlets too cold
RCI (Rack Cooling Index) High	100%		Good
Cost of Electricity	0.09	$/KWH	
Estimated Cost to Operate Data Center	$598,041	$/Yr	

Metrics are indicating over cooling and excess air supply

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Base Model Energy Calculations Zone 2 “off” (Trail 2)

Same Design, Cooling Zone 2 Off (Trial 2)			
Total Airflow From Cracs	58000	CFM	
Rack Airflow Requirement	57020		
Number of CRACs	4		
Total Fan Power	32	kW	
Total Energy for Cooling Data Center	322.6	kW	
Total Data Center Energy	723.5	kW	
Revised DCIE	50%		Previously 48.6%
RTI (Return Temperature Index)	98%		Previously 66%
RCI (Rack Cooling Index) Low	26%		Previously -39%
RCI (Rack Cooling Index) High	100%		Same
Cost of Electricity	0.09	$/KWH	
Estimated Cost to Operate Data Center	$576,725	$/Yr	
Cost Savings per year	$21,316.03		

Metrics are improving, still a long way to go….

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Improving Thermal Efficiency

- Separate hot and cold air from mixing
  - Hot Aisle Containment is preferred in this case.
- Increase supply airflow temperature.
  - Improves mechanical efficiency of cooling system
    - 1.8F increase yields 3.5% efficiency improvement.
  - Widens the window of “free-cooling” if economizer is used.

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Next Steps

- Now that containment has unified rack inlet temperatures, two things can be done to improve efficiency, and/or improve the PUE/DCIE:
  – Reduce Fan Speeds or Turn Off Fans
    - DX units have limitations on reducing fan speeds
  – Increase cold air supply temperature
    - Increase cold air supply to 68 F
- These can be modeled using CoolSim

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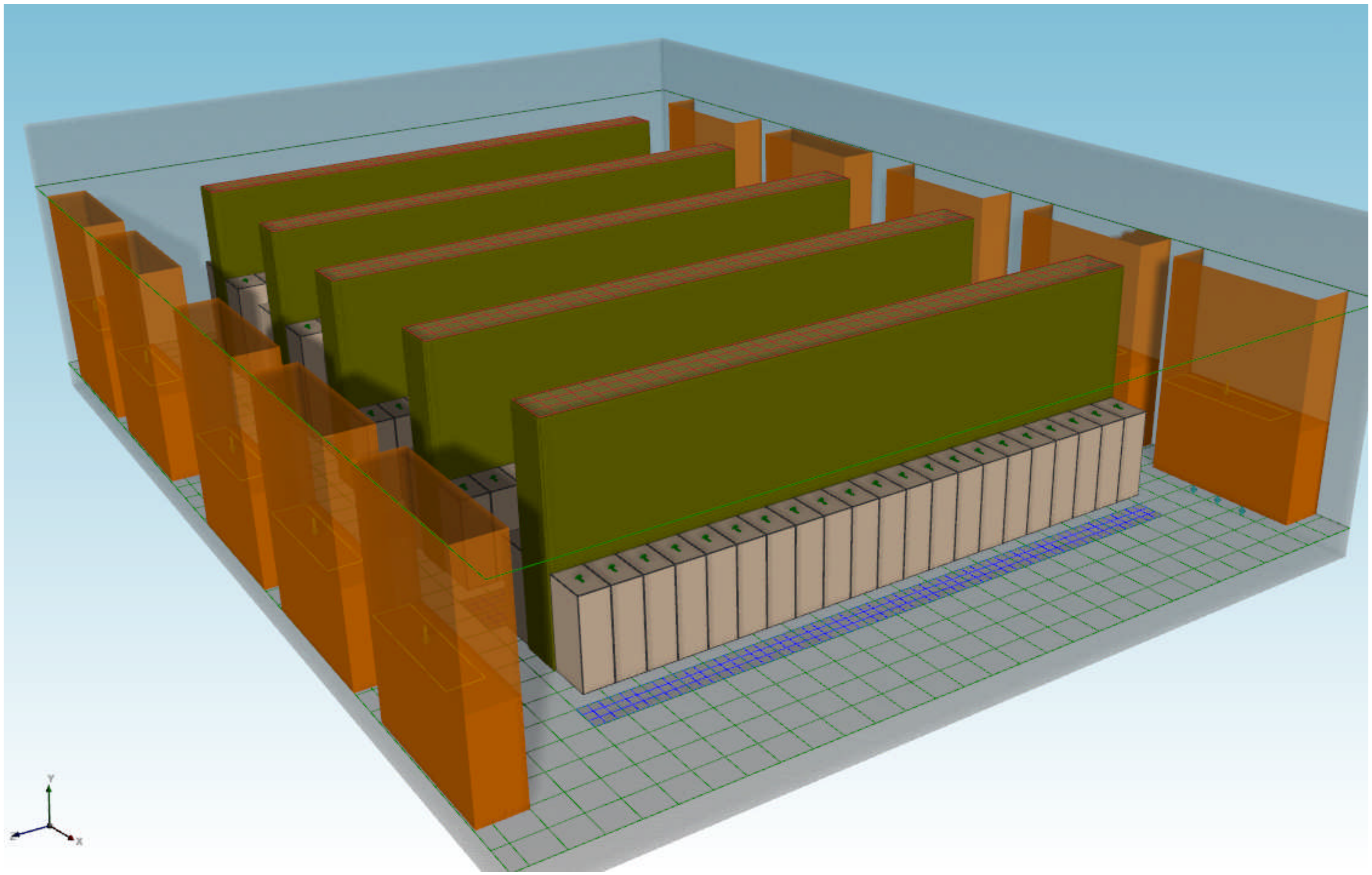
New Model Using Hot Aisle Containment



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Recalculate Data Center Energy

Hot Aisle Contained ST=68F			
Total Airflow From Cracs	87000.0	CFM	
Rack Airflow Requirement	57020.0		
Number of CRAH's	6		
Total Fan Power	48	kW	
Increase in Supply Temperature (Ave)	11.00	F	
Energy Savings from Mechanical System	21.39	%	
New COP	1.81		Increased from 1.5
Total Energy for Cooling Data Center	296.2	kW	
Total Data Center Energy	697.1	kW	
Revised DCIE	52%		Improving to "typical" of 55%
RTI (Return Temperature Index)	66%		Net Bypass Airflow
RCI (Rack Cooling Index) Low	100.0%		Good, up from -39%
RCI (Rack Cooling Index) High	100.0%		Good
Cost of Electricity	0.09	$/KWH	
Estimated Cost to Operate Data Center	$555,718	$/Yr	
Cost Savings per year	$42,323.60		

An estimated $42k per year in energy savings…

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Recalculate Data Center Energy

(Zone 2 Off)

Hot Aisle Contained, Zone 2 off (4 CRACs On) ST = 68F			
Total Airflow From Cracs	58000.0	CFM	
Rack Airflow Requirement	57020.0		
Number of CRAH's	4		
Total Fan Power	32	kW	
Increase in Supply Temperature (Ave)	11.00	F	
Energy Savings from Mechanical System	21.39	%	
New COP	1.81		Increased from 1.5
Total Energy for Cooling Data Center	271.4	kW	
Total Data Center Energy	672.3	kW	
Revised DCIE	54%		"Typical"
RTI (Return Temperature Index)	98%		Good
RCI (Rack Cooling Index) Low	100.0%		Good, up from -39%
RCI (Rack Cooling Index) High	99.6%		Good
Cost of Electricity	0.09	$/KWH	
Estimated Cost to Operate Data Center	$535,910	$/Yr	
Cost Savings per year	$62,131.09		

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An estimated $62k per year in energy savings…

Returns and Risks

- Assuming cost of containment using thermal curtains is ~ $20,000, the ROI is 6 months.
  - Assumed 6 CRACs running
- But what about safety margin and CRAC failure?
  - Modeling CRAC failure provided confidence that a Zone failure is still not a problem.
  - Recommendation is to operate current IT load with 5 CRACS to provide N+1 level of service.

Conclusion

- Separating the Hot and Cold airstream using Hot Aisle Containment yielded a number of benefits:
  - Increased temperature delta across CRACs
    - Improved heat transfer rate
  - Evened the contribution by each CRAC
    - Even load on cooling units improves reliability and lifespan
  - Enabled supply air temperatures to be increased
    - Improving the efficiency of the cooling system
      - Reducing overall cost of operation
- CFD modeling can be used to “test” scenarios prior to implementation and predict outcome

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Summary

- The density of computer equipment will continue to increase compounding cooling problems.
- Typical data centers draw 2X more power than required by the IT equipment alone for cooling the computer equipment.
- Increasing the thermal efficiency of the data center can create savings from 30-70% per year in operational costs.
- Using CoolSim CFD based modeling as a means to predict potential improvements Data Center efficiency is very cost effective and necessary as part of the design or modification process.
- The potential electricity cost savings from a 1MW data center are in the range of $2-4M over a 10 year period.

For More Information

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