



**Innovative Research, Inc.**

*A Computational Fluid Dynamics Company*

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**A Flow Network Modeling (FNM) Tool**  
**MacroFlow™**  
**for Improving Productivity of**  
**Thermal Design of Electronic Systems**

**Presentation at CoolCON 2004**

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# What Innovative Research Offers

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## ◆ General-Purpose Software Products

- COMPACT<sup>TM</sup> - a general-purpose CFD package
- MacroFlow<sup>TM</sup> - a system-level tool for the analysis of flow networks
- TileFlow<sup>TM</sup> - a simulation tool for airflow distribution in raised-floor data centers

## ◆ Consulting and Construction of Customized Codes

- Greater geometrical flexibility
- Appropriate numerical algorithms
- Advanced mathematical models for complex physical phenomena

# Typical Thermal Challenges in the Design of Electronic Systems

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## Air-Cooled Systems

- ◆ Layout Options
- ◆ Flow Balancing
- ◆ Venting Options
- ◆ Filter Degradation
- ◆ Bypass Effect
- ◆ Fan Failure
- ◆ Sizing of
  - Fans
  - Screen
  - Heat Sinks
  - Heat Exchangers

## Liquid-Cooled Systems

- ◆ Flow Distribution and Balancing
- ◆ Manifold Maldistribution
- ◆ Provide Scalability
- ◆ Prevent Cavitation
- ◆ Sizing of
  - Cold Plates
  - Pumps
  - Heat Exchangers
  - Tubes and Hoses
  - Orifices

# Objective of the Presentation

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The technique of  
**Flow Network Modeling (FNM)**  
as incorporated in MacroFlow enables you  
to analyze **many design options accurately**  
in a **very short time.**

**MacroFlow is a productivity tool.**

# Modeling Options for Thermal Design

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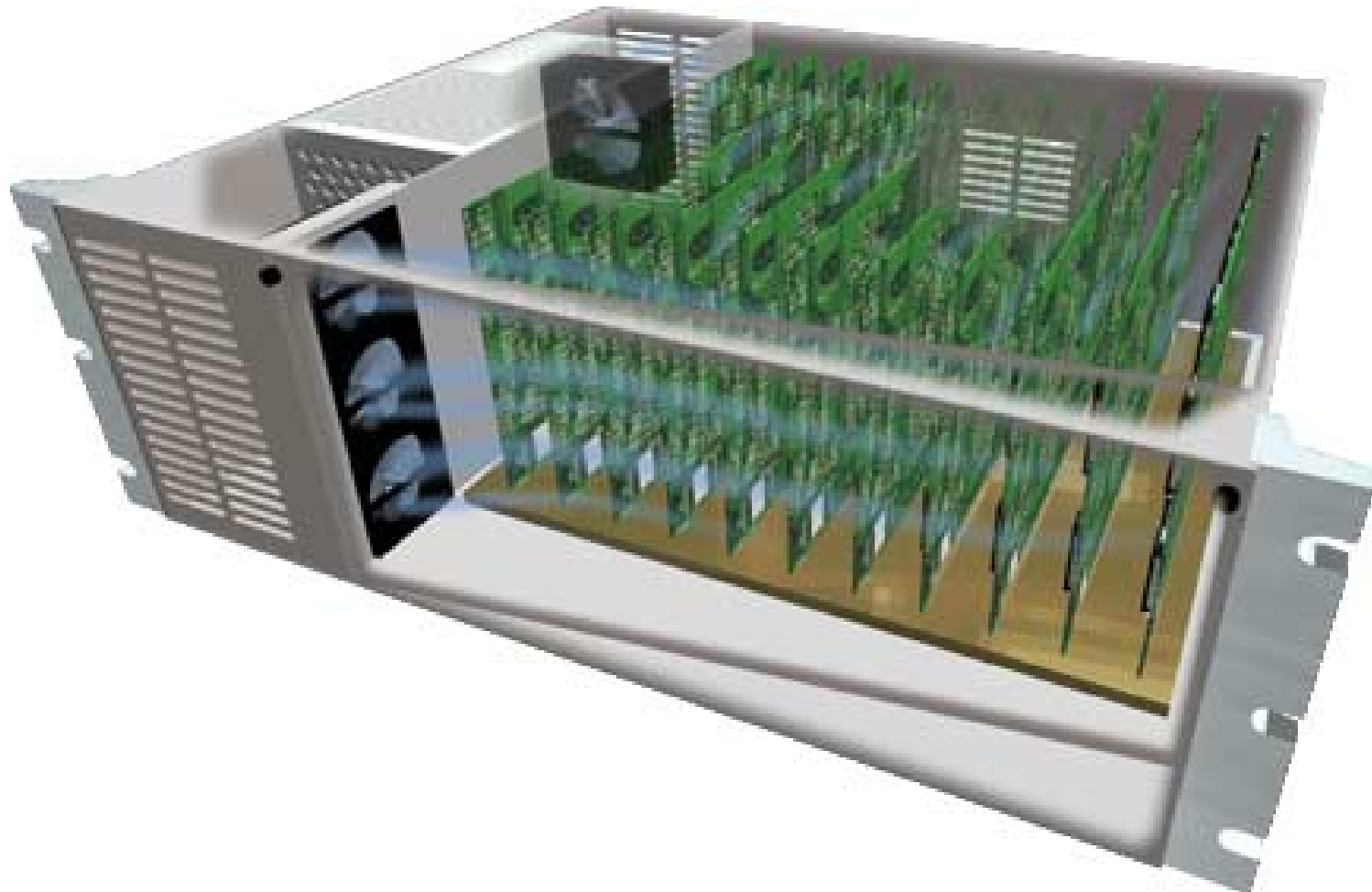
- ◆ Hand Calculations (HC)
  - Tedious and very limited
- ◆ Spreadsheets (SS)
  - System-specific, inflexible, and time intensive
- ◆ Flow Network Modeling (FNM)
  - Simple, fast, and accurate
- ◆ Computational Fluid Dynamics (CFD)
  - Time intensive for model definition, solution, and postprocessing
  - Largely inapplicable for the analysis of liquid-cooling systems

# What is Flow Network Modeling?

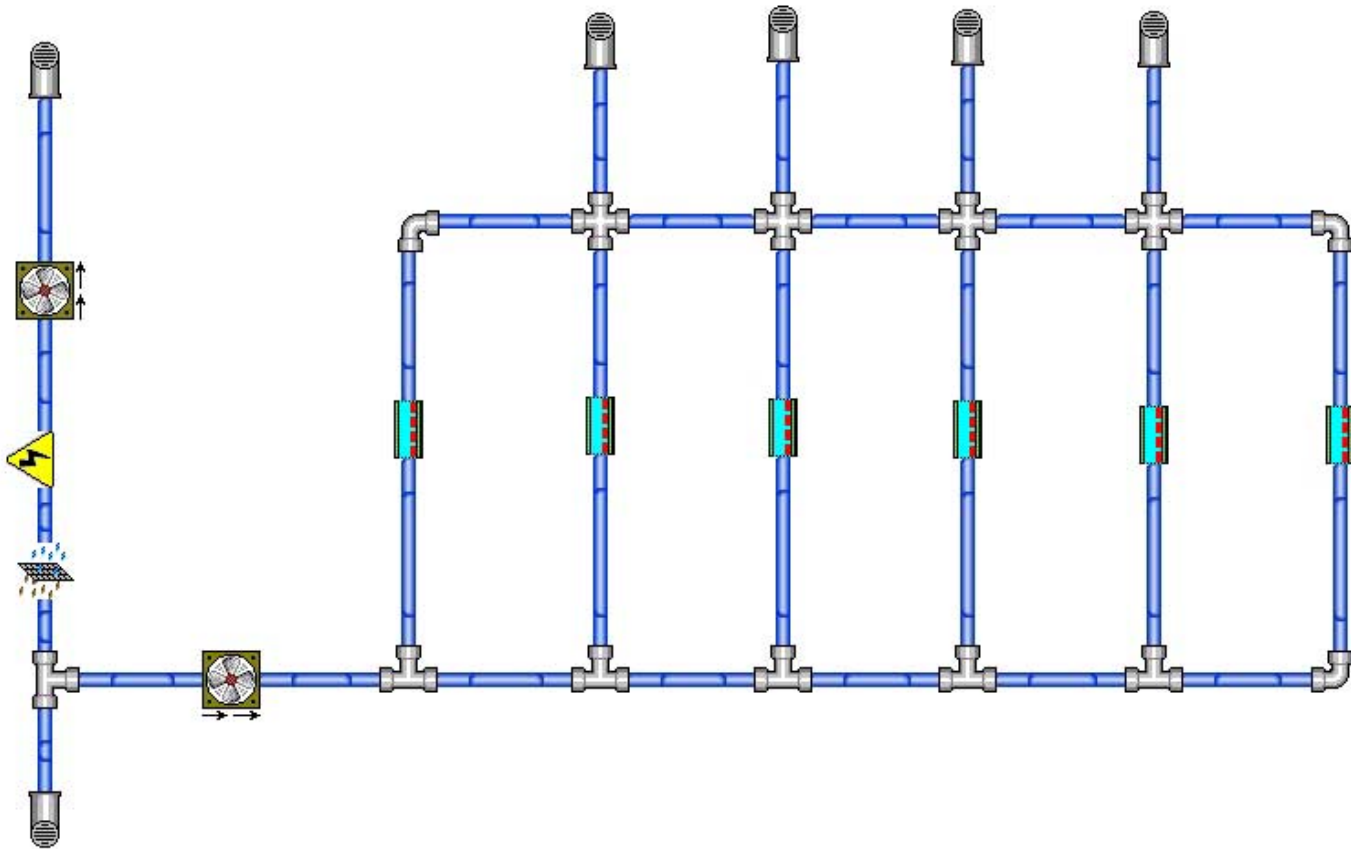
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- ◆ A flow network model of a cooling system is constructed by describing the flow paths through tubes/ducts, orifices/screens, cold plates/heat sinks, pumps/fans, junctions etc.
- ◆ The flow and thermal resistance relationships for each flow path or component need to be specified. They can be obtained from handbooks, vendor specs, in-house testing, or CFD analysis.
- ◆ The flow rates, pressures, and temperatures throughout the system are calculated by solving mass, momentum, and energy conservation equations.

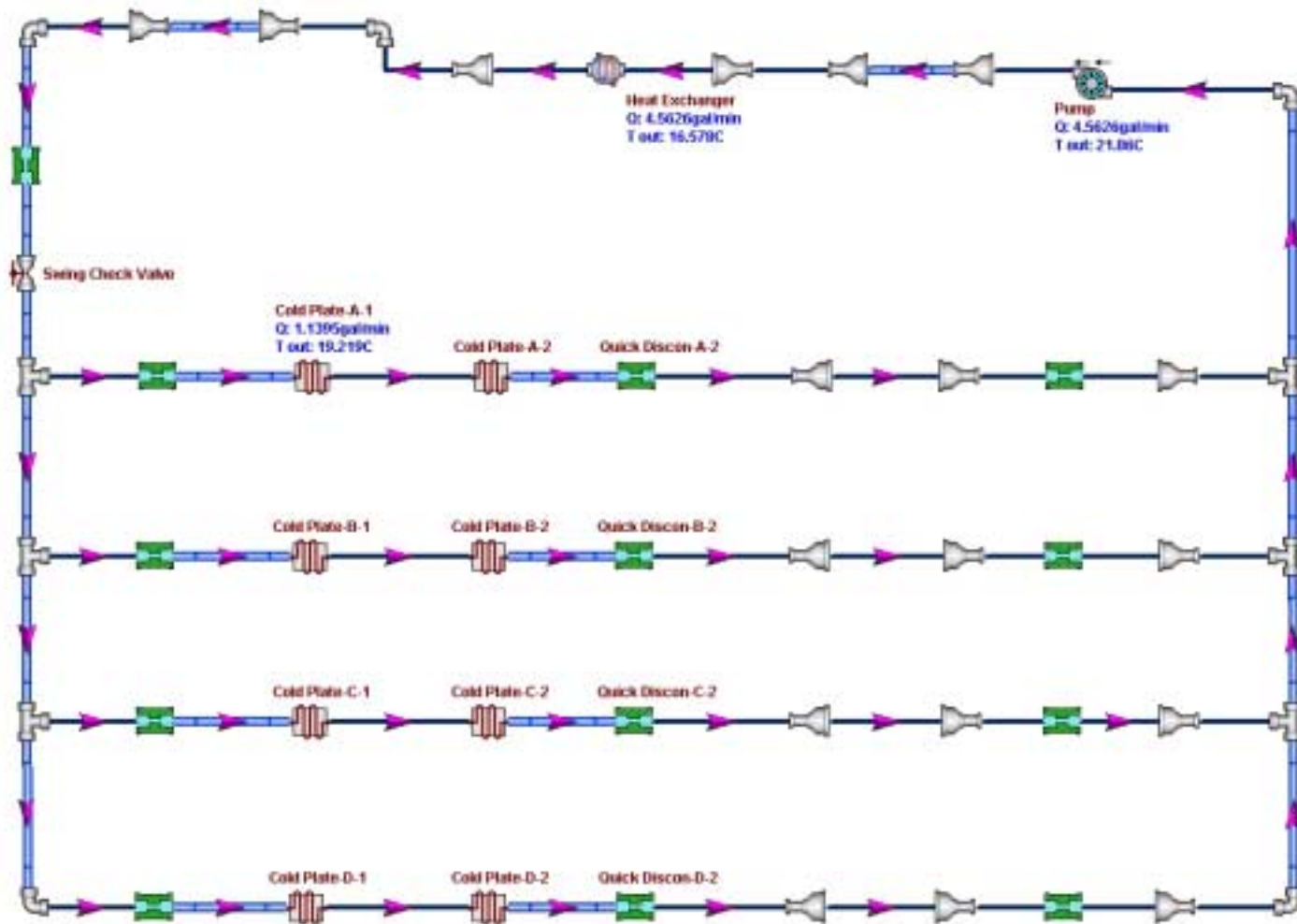
# Complex Real Systems: Air-Cooled Rack Mounted System



# Network of the Model Rack-Mounted Cabinet



# Network Model of a Liquid-Cooling System



# Complementary Nature of FNM and CFD

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- ◆ Examine hundreds of design alternatives by FNM (Conceptual Design) and select a few promising designs for CFD analysis (Detailed Design).
- ◆ Use FNM for an entire system and provide boundary conditions for the CFD analysis of a subsystem.
- ◆ Use CFD at the component level and provide the resulting flow resistances to the network model.

# Thermal Design Process

## Conventional and Enhanced

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### Conventional

Test-Based

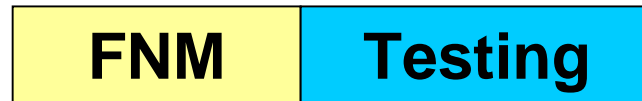


CFD-Based



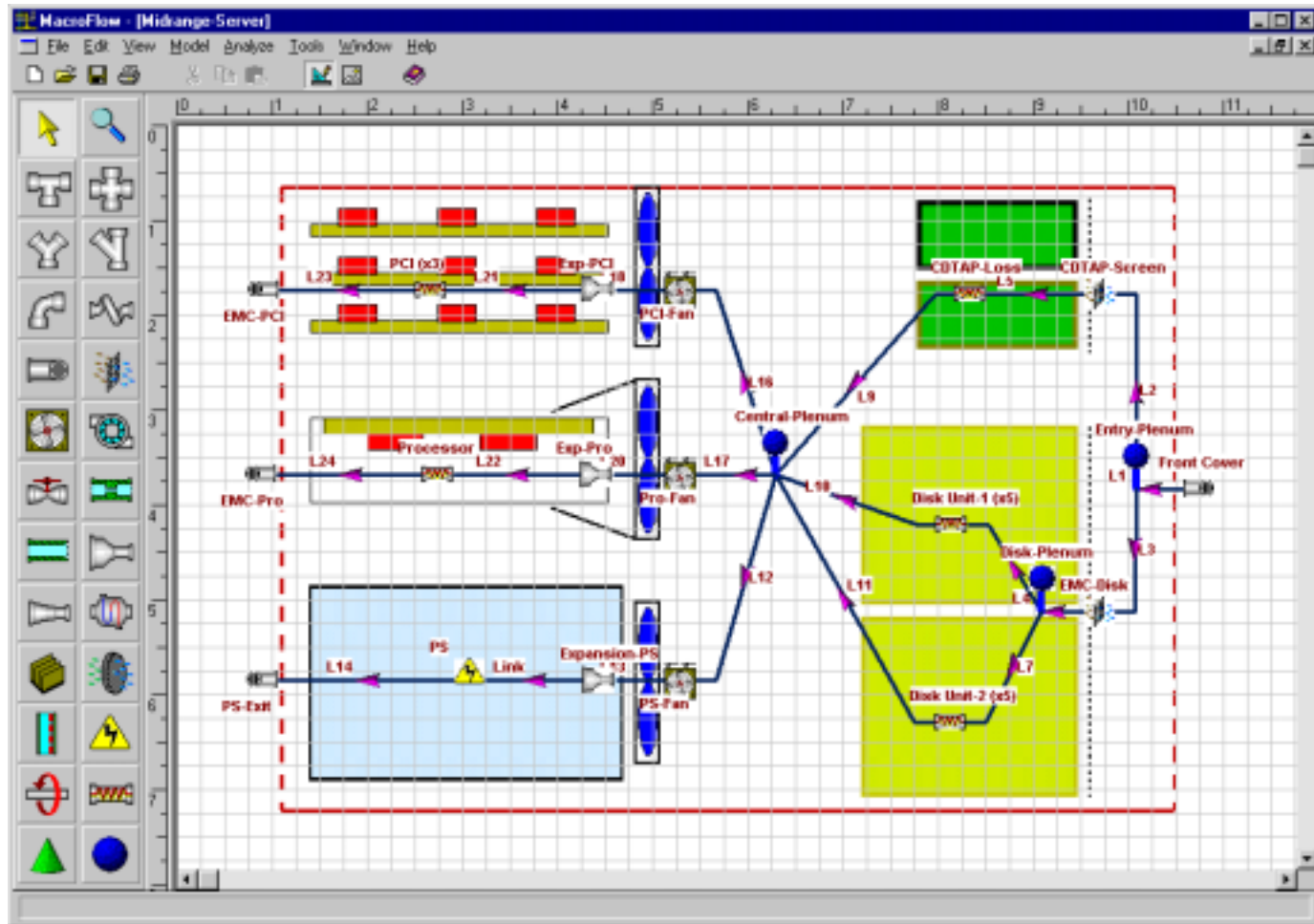
### Enhanced

FNM-Based



# MacroFlow™

## A Flow Network Modeling Tool for Thermal Design



# Capabilities of MacroFlow

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- ◆ An integrated and easy-to-use GUI for network construction, solution control, and display of results
- ◆ A comprehensive component library for modeling electronic cooling systems
- ◆ An extensive database of vendor-supplied off-the-shelf components
  - Cold Plates (Lytron)
  - Heat Exchangers (Lytron)
  - Quick Disconnects (Aeroquip)
  - Filters (Universal Air Filter)
  - Fans (Comair-Rotron, Dynamic Air)
- ◆ Customizable and expandable structure
- ◆ Robust and efficient direct solution technique
- ◆ Comprehensive post-processing in terms of plots, tables, animation, and more

# Applications of MacroFlow

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- ◆ MacroFlow has been extensively validated using experimental measurements and CFD analysis.
- ◆ It is applicable for the analysis of closed and open air- and liquid-cooled systems in the following applications:
  - Computer servers and mainframes
  - Defense electronics
  - Automatic test equipment
  - Telecom cabinets
  - Semiconductor processing

Demonstration of  
MacroFlow

# Closing Remarks

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- ◆ **Flow Network Modeling** is a simple, fast, and accurate methodology for the design of electronic cooling systems.
- ◆ The promise of FNM is delivered by **MacroFlow** through its ease of use, flexible and customizable structure, speed of execution, and comprehensive post-processing.
- ◆ Use of MacroFlow substantially **shortens the design cycle** and significantly improves the productivity of the thermal design engineer.