Compact Component Modelling

- Introduction
- Compact Model Topologies
- Deriving Compact Models
  - The Computational Cold Plate Test
  - The DELPHI Approach
- Compact Models in FLOPACK

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The Traditional Approach θ_{ja} and θ_{jc}

- The θ_{ja} and θ_{jc} approaches lump all heat paths together as one - use with caution.
- θ_{ja} and θ_{jc} are environmentally dependent.
- Inaccuracies in predicting junction temperatures can be as high as 100%!

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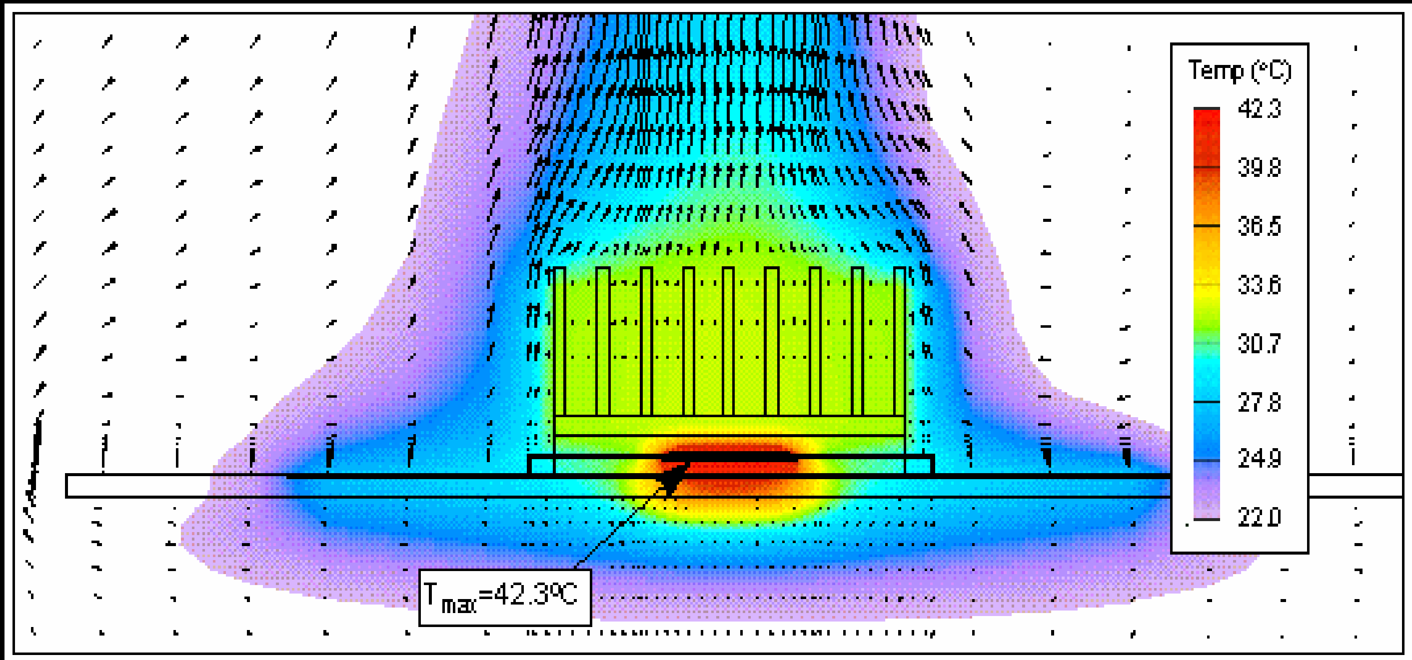
Detailed Models



- A Detailed Model attempts to capture thermal behavior of a package by reproducing the physical structure of the package as completely as possible

Compact Models

- A Compact Model seeks to capture the thermal behavior of the package accurately at pre-determined (critical) points
  - junction
  - case
  - etc.

- .... by using a reduced set of parameters to represent the package
  - These parameters need not be geometric

- The most popular approaches use some sort of thermal resistance network representation

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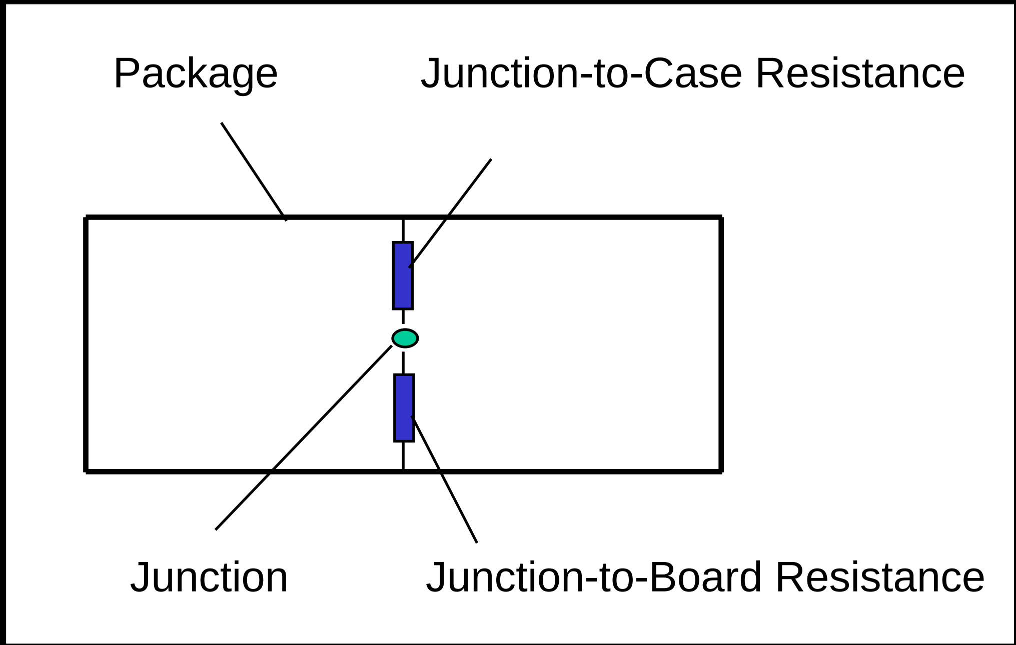
Topologies

- Two-resistance network



Topologies

- Two-resistance network
  - Simplest topology
  - Easy to extract
  - Easy to implement in most tools
  - Relatively inaccurate (~ 30%) for absolute results
  - Often sufficiently accurate for trends/parametric studies

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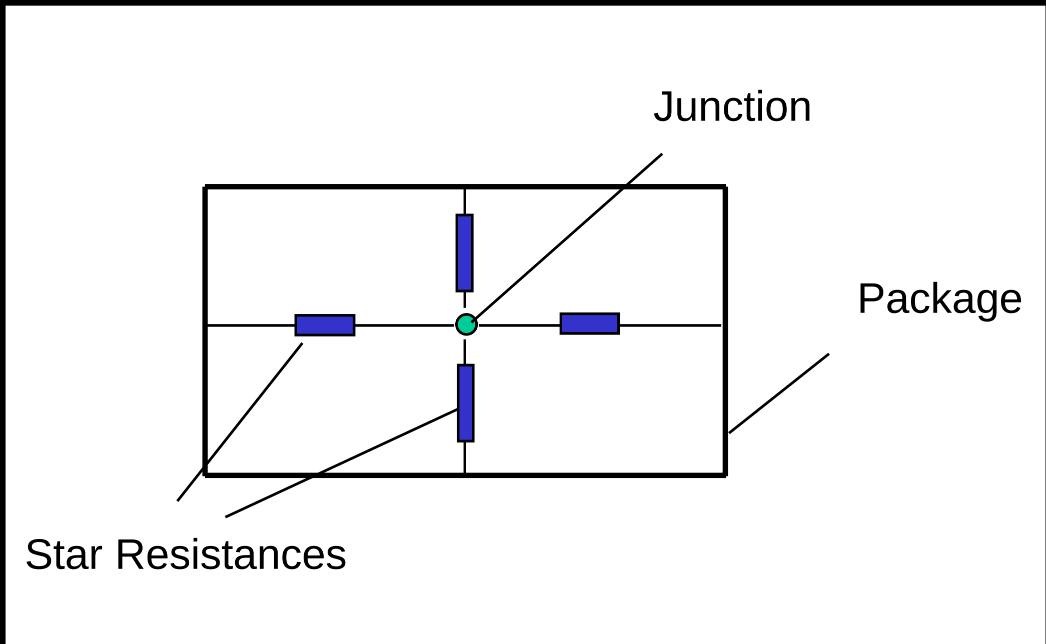
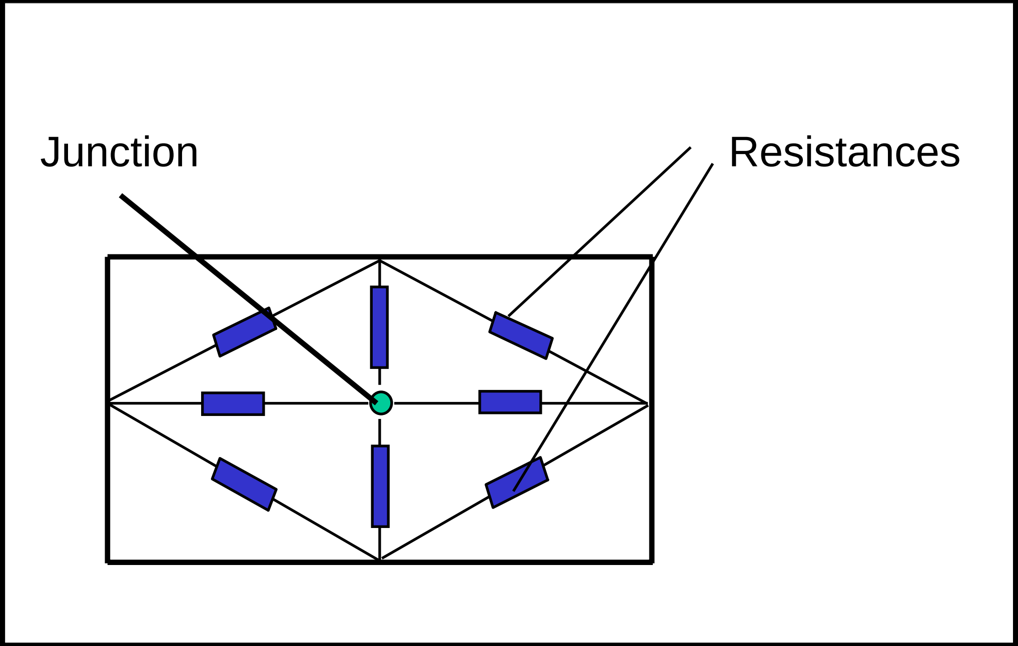
Topologies

- Star Network
  - Allows for mutiple resistances
  - All resistances must be connected to junction node



Topologies

- Shunt Network
  - More “complete” than a Star network
  - Allows for resistances connecting surface nodes



Deriving Compact Models

- Several methods proposed
- We shall consider two
  - The "Computational Cold Plate Test"
  - The DELPHI Approach

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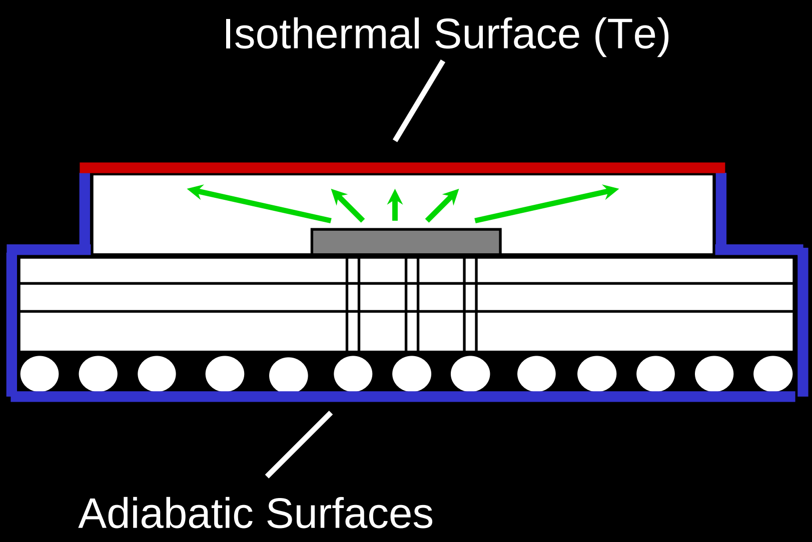
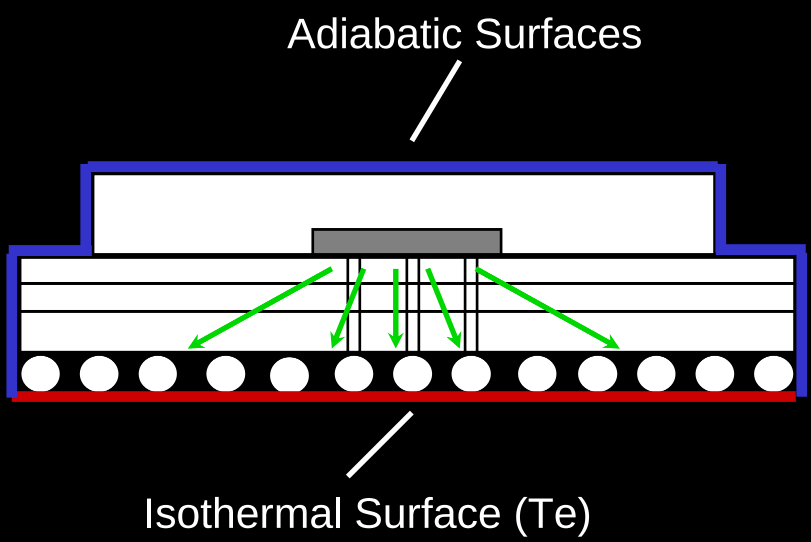
Deriving Compact Models

- "Computational Cold Plate" Test
  - Can be used to extract a 2-resistor model from a detailed model
  - Consists of two simulations



Junction-to-Case Simulation



Junction-to-Board Simulation

Deriving Compact Models

- Computational Cold Plate Test
  - $R_{jc} = (T_j - T_e)/P$
  - $R_{jb} = (T_j - T_e)/P$

  T_j = Junction Temperature
  T_e = Temperature of Isothermal Surface
  P = Package Power

- How accurate is this method?
  - Because of the “unrealistic” nature of the heat flux path lines in the two simulations, the resistances derived will tend to **under predict** the junction temperature
  - This could be as much as 50%!

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Deriving Compact Models

- Recommendation
  - Use Computational Cold Plate Test only to get ball park estimates of junction temperature
  - Useful for predicting trends (parametrics)
  - For greater accuracy, use detailed models or more complex compact models (where available)

The DELPHI Approach

- What was DELPHI?
- Project that proposed new methodologies for creating and validating component computational models
- Ultimate Goal
  - To enable component manufacturers to supply validated compact thermal models of their parts to end-users

- Results were
  - Detailed model understanding of some package types
  - 2 experimental systems
    - Double Cold Plate and
    - Submerged Double Jet Impingement
  - Complex compact model networks for some package types
  - **A methodology to tie these together**

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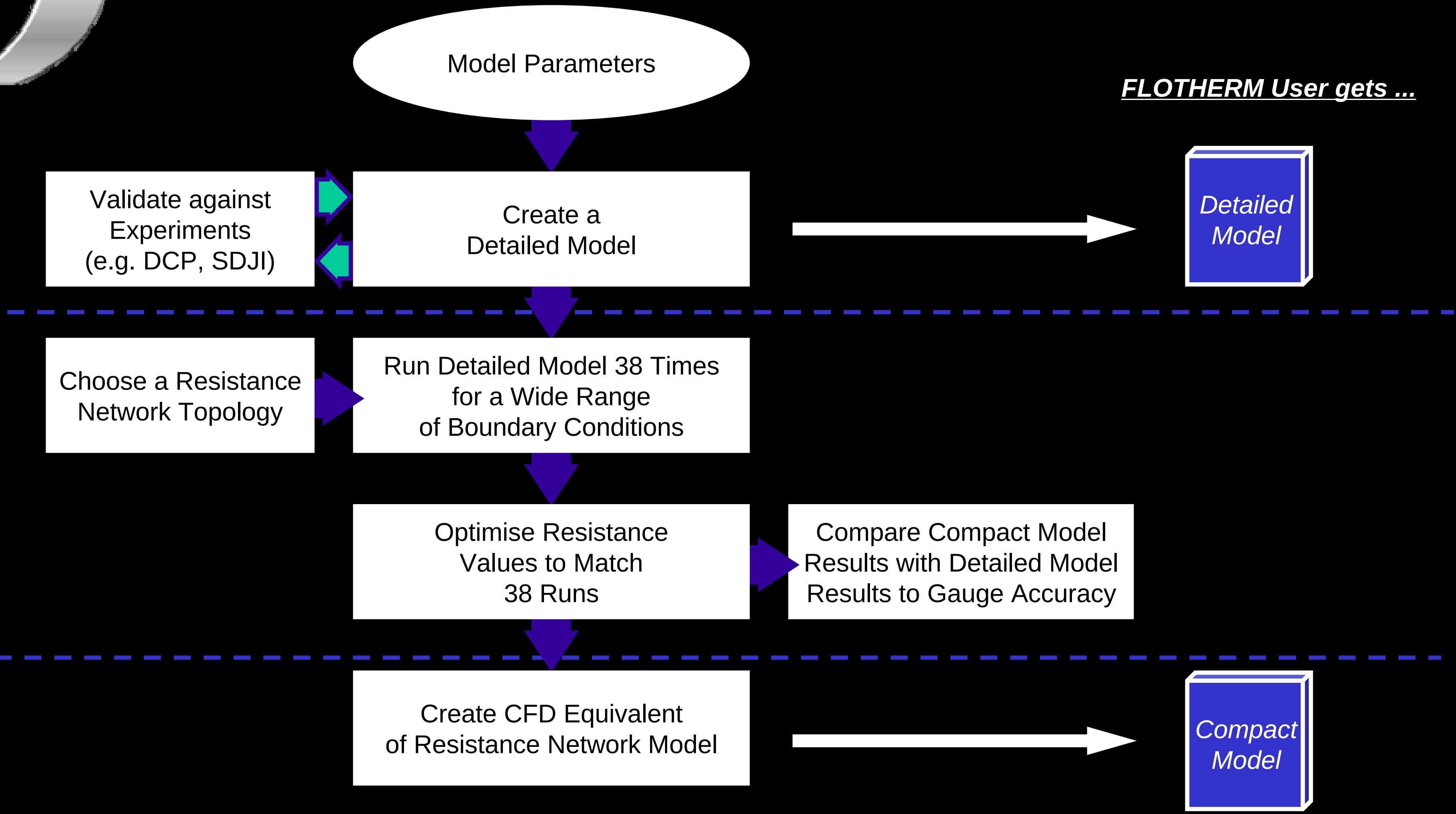
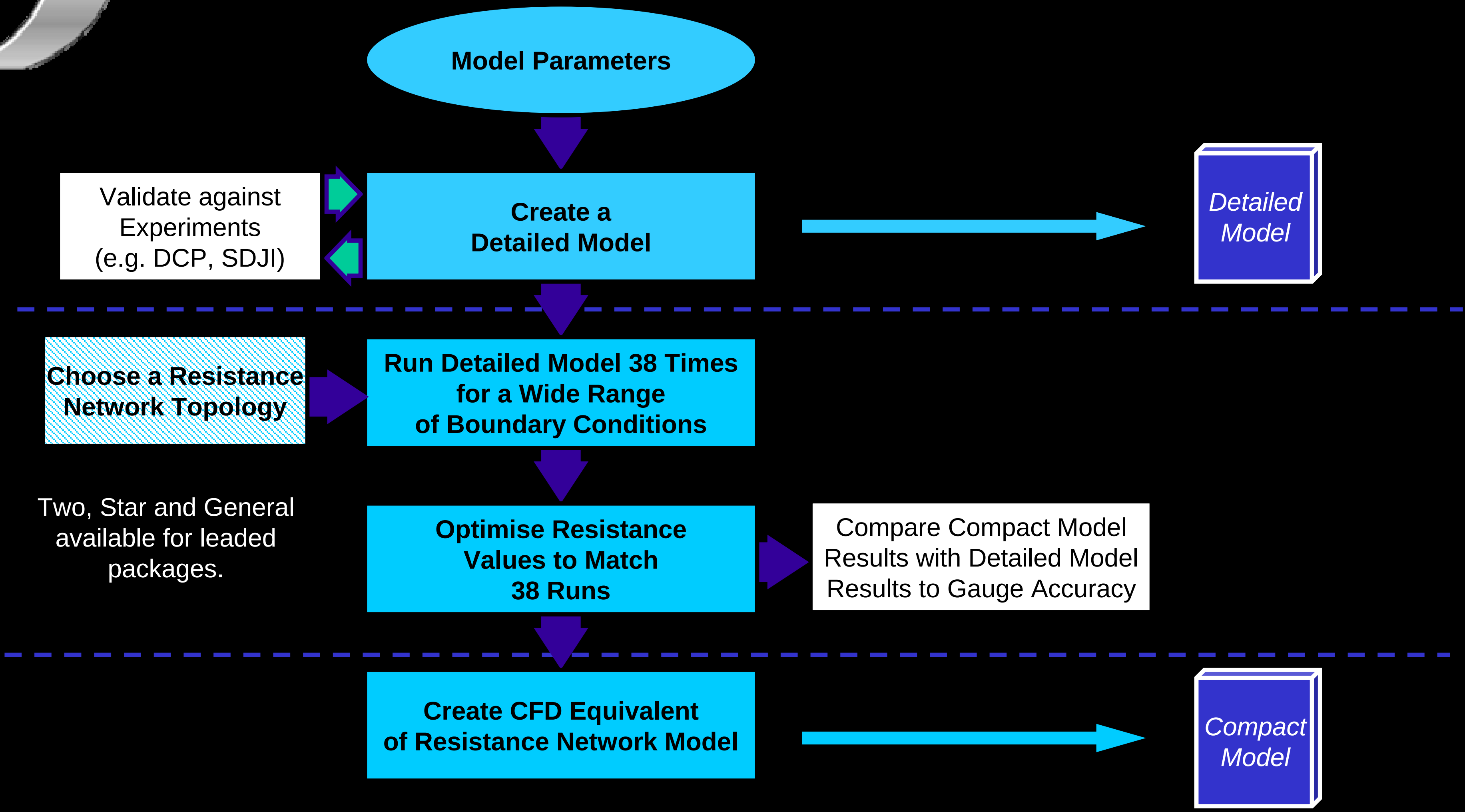
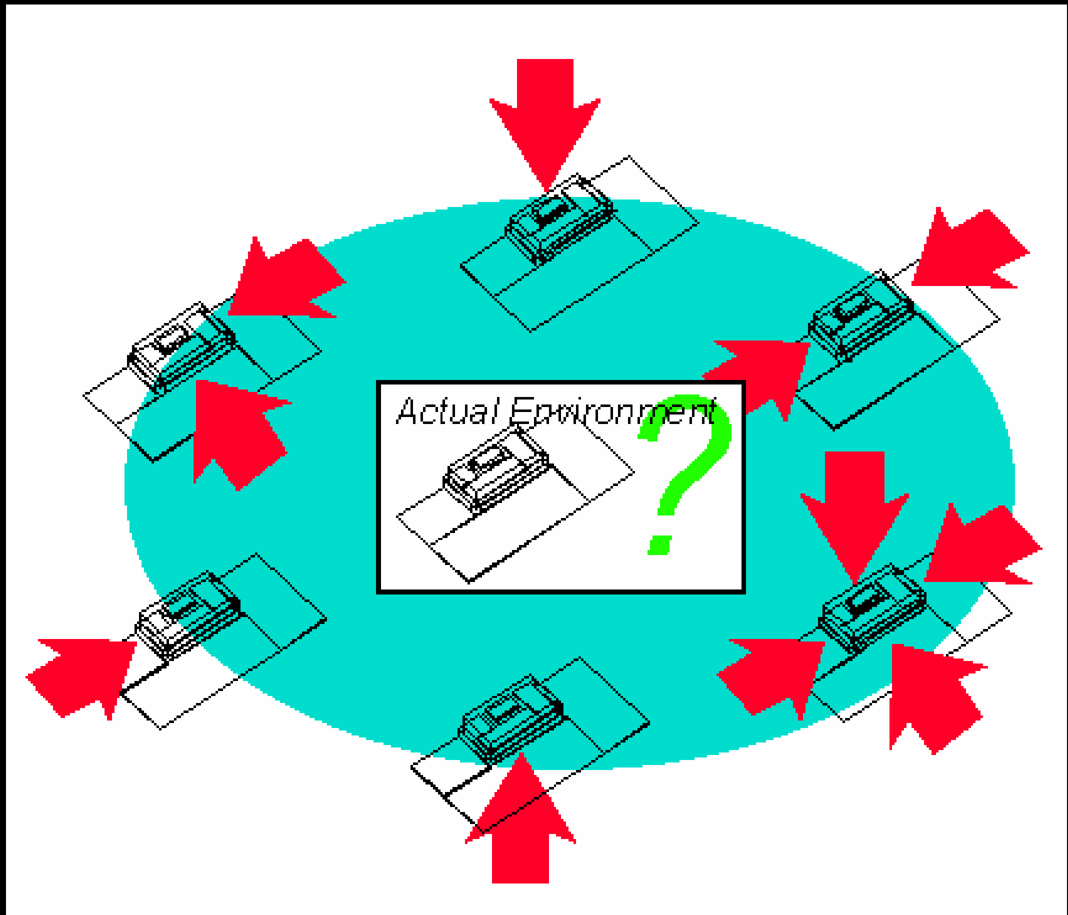
The DELPHI Methodology



FLOPACK Today



38 Boundary Conditions?

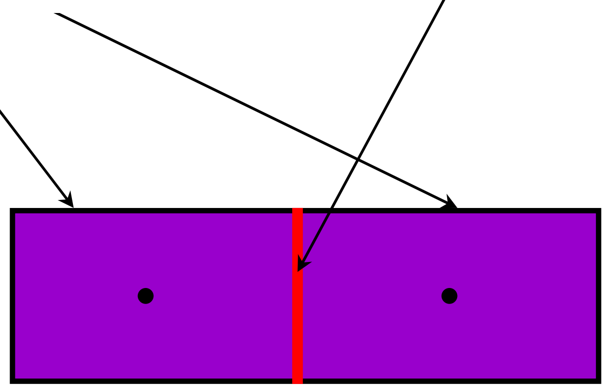


- By applying a wide variety of extreme conditions, we are fairly sure that the real conditions are within these bounds

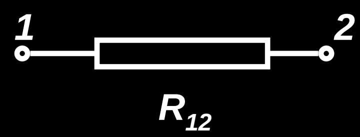
Implementing Nodes & Resistances in FLOTHERM

High conductivity Cuboid Blocks (say k = 1000 W/mK) act as isothermal Nodes

Collapsed Cuboid set node-to-node Resistances

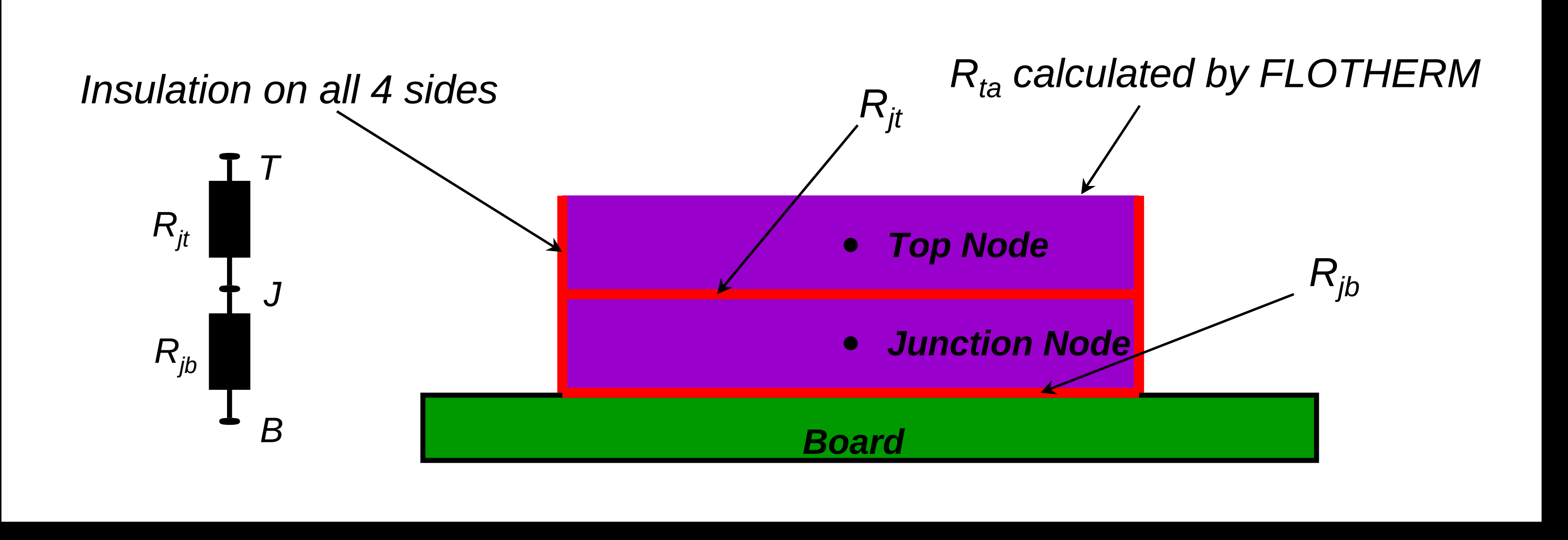


Which is mathematically equivalent to:



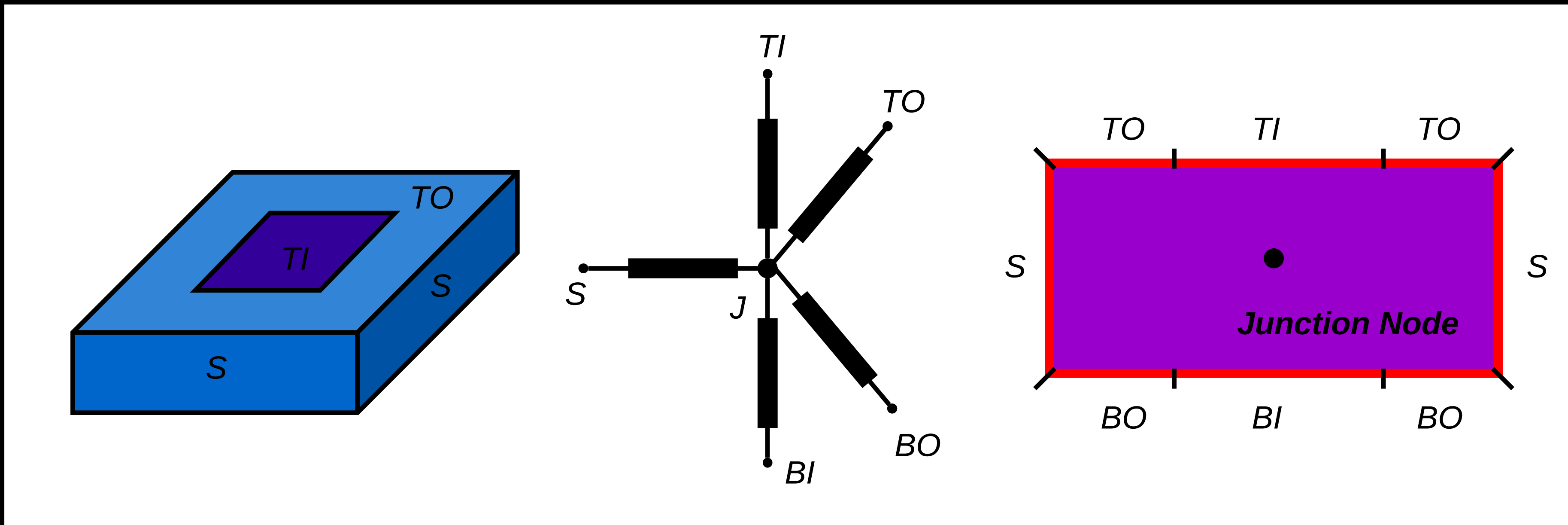
Implementing the 2 Resistor Model

- All power is dissipated in Junction block
- Moderate accuracy (20 - 30%) for most components but will predict trends correctly; easy to tweak.....



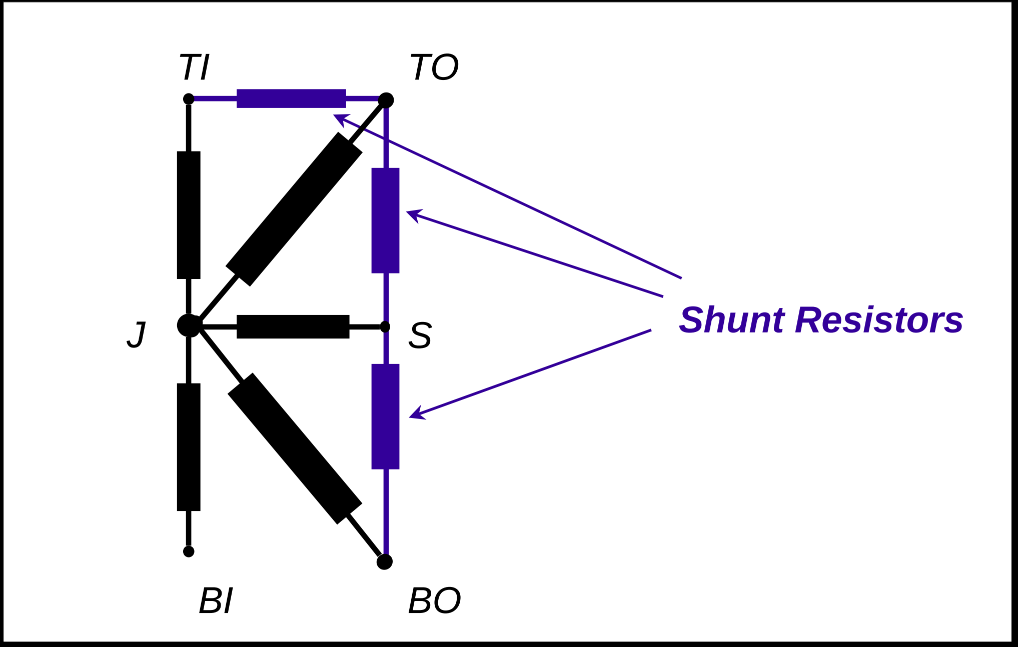
Implementing the Star Model

- The surface of the Junction node is covered with plates to set individual resistances

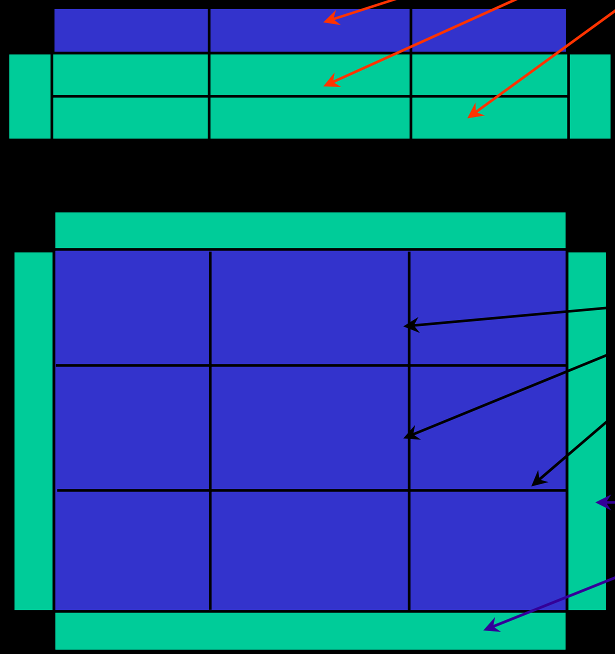


Arbitrary Resistance Networks

- Most components need more complex networks, especially when heat spreading within the component is significant (PBGA, PQFP …)
- Often involve "Shunt" resistors



The 27 Node Model



*27 high conductivity **Cuboid Blocks** in 3 layers of 9 create isothermal "nodes"*

*Resistive **Plates** set node-to-node resistances.*

If needed, peripheral leads can be modeled using additional high conductivity blocks.

27 Internal Nodes Max. plus Leads
Shunt Resistances allowed

Compact Models in FLOPACK

- 2-Resistor Compact Models
  - Available through the FLOPACK web site for all package types
  - R_{jt} and R_{jb} data can be measured by manufacturers
- Star Compact Models
  - Available through the FLOPACK web site for leaded packages
  - Easy to set up
  - Accuracy often same as 2-resistor models
- Complex Compact Models
  - Maximum accuracy; some in use
  - Available through the FLOPACK web site for leaded packages
- Compact Model SmartPart in Version 3.1 of FLOTHERM
  - Embedded resistor network solver

International Standards

Experience with compact models embedded within CFD

- Comparison of T_J for Detailed and Compact Models

		Fine grid	Coarse grid
Total cells in model (x,y,z)		89x39x70	43x17x32
Package #	Power (W)	Detailed Model $T_J - T_\infty$ (°C)	Compact Model $T_J - T_\infty$ (°C)
1	3	77.1	77.2
2	0.5	57.6	57.9
3	0.5	45.1	45.3
4	0.5	34.6	35.2
5	0.5	34.5	35.3
6	0.5	45.2	45.5

- Compact model results change little as grid is coarsened