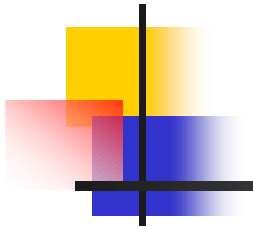


Overview of Research Experience and Capabilities

J. R. Culham, M.M. Yovanovich and P. Teertstra

Microelectronics Heat Transfer Laboratory
Department of Mechanical Engineering
University of Waterloo
Waterloo, Ontario N2L 3G1

MHTL Reseach Capabilities

- Experimentation
- Modelling
- Numerical CFD analysis

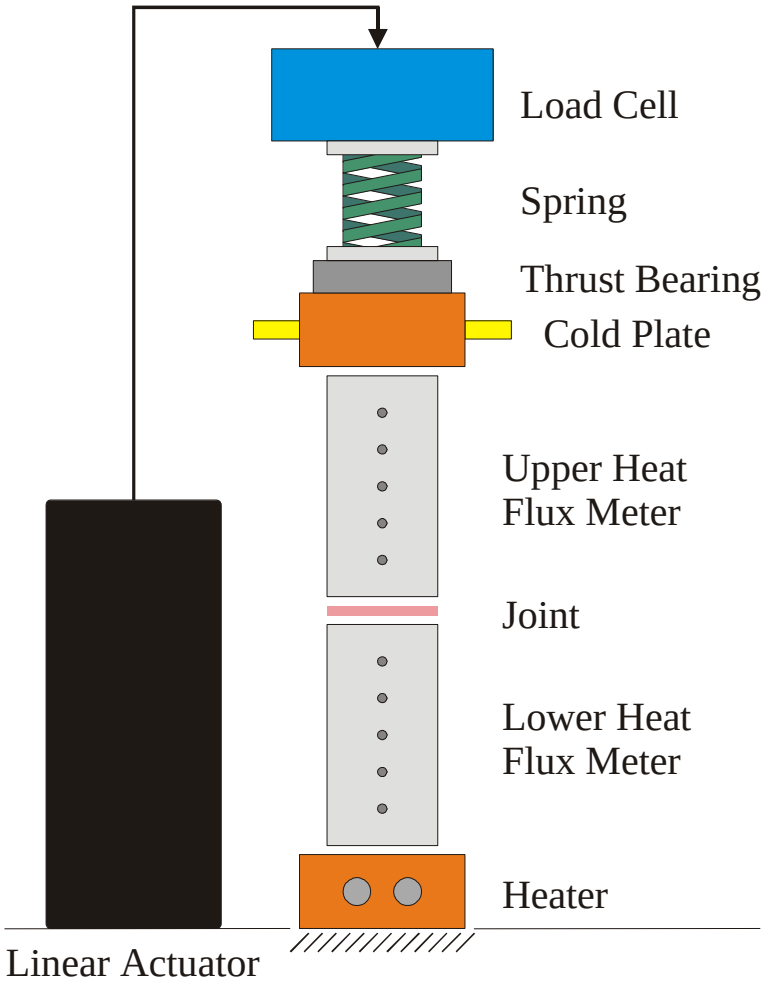
Experimental Facilities

- Thermal interface material testing
- Air cooled heat sinks
  - ✓ thermal resistance and pressure drop
  - ✓ bypass
- Liquid cooled heat sink testing
- Thermal contact resistance for low contact pressures

Thermal Interface Material Test

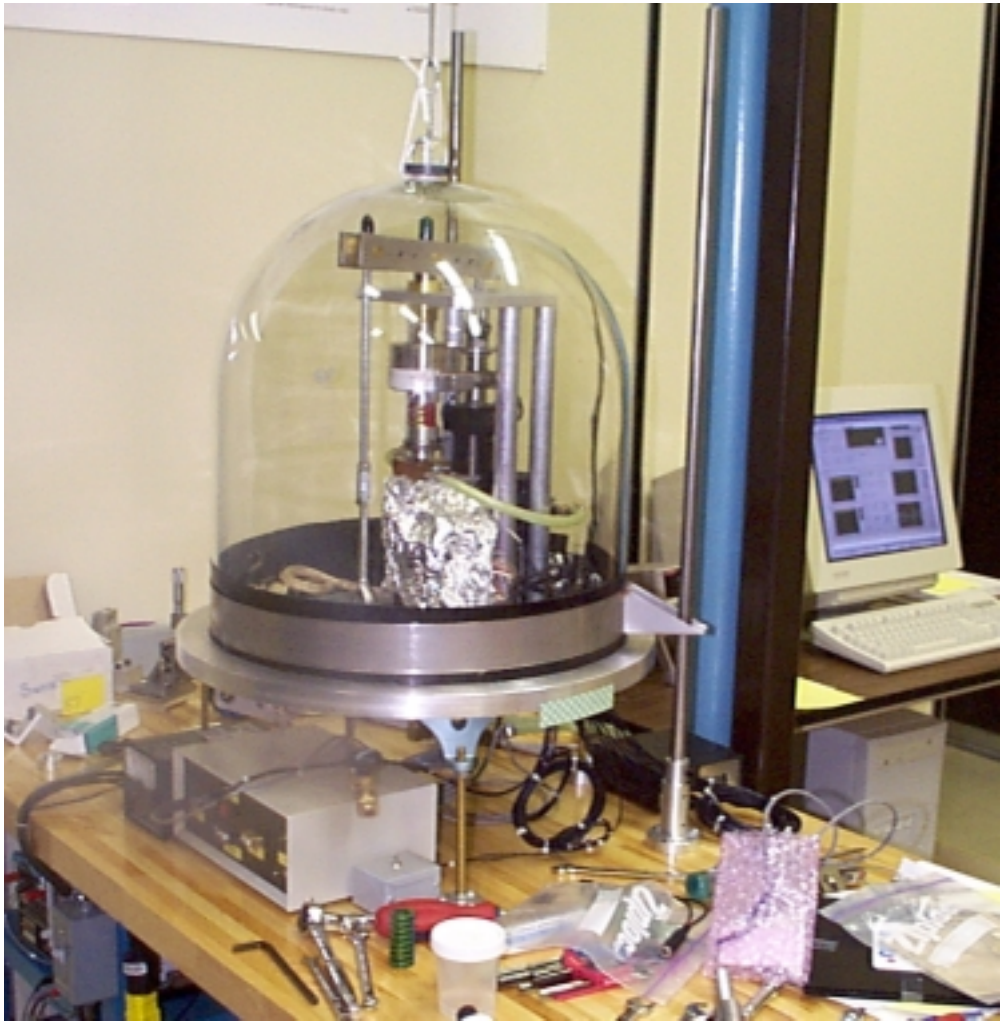
- Design, build & commission test apparatus & data acquisition interface for testing interface materials:
  - ✓ Measure joint resistance and thermal conductivity as function of:
    - interface temperature
    - contact pressure
    - material properties
    - surface characteristics
  - ✓ in-situ thickness measurement: sub micron precision

Apparatus

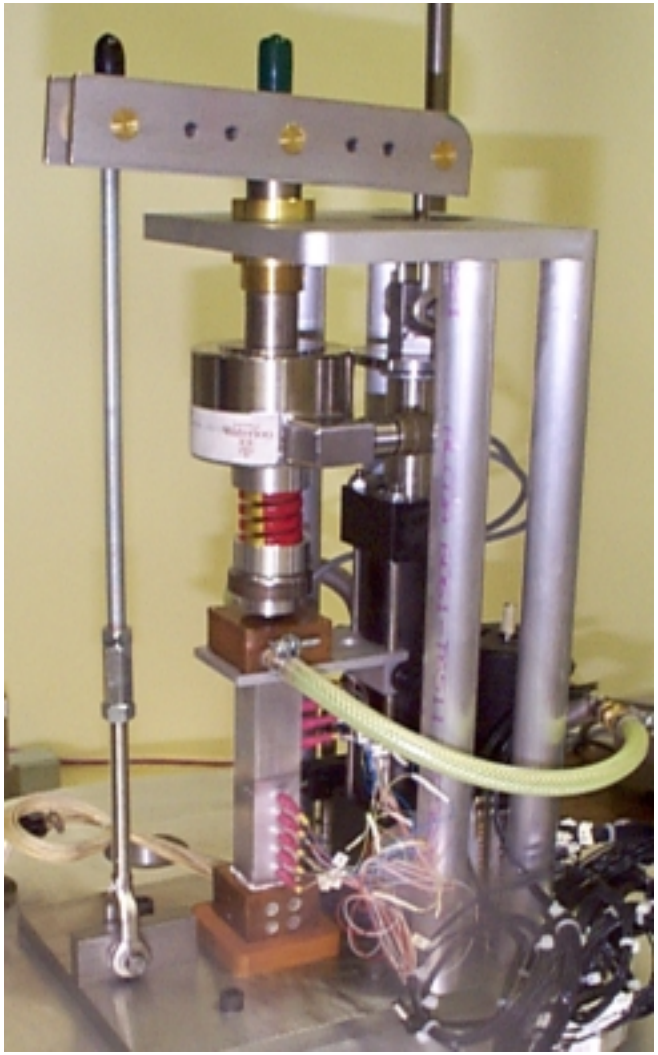


- Load cell
  - ✓ 100 or 1000 lbs
- Spring to compensate for thermal expansion
- Thrust bearing to remove torque loads
- Linear actuator
  - ✓ digitally controlled stepper motor
  - ✓ 400 steps / rev
    0.1 inch per revolution

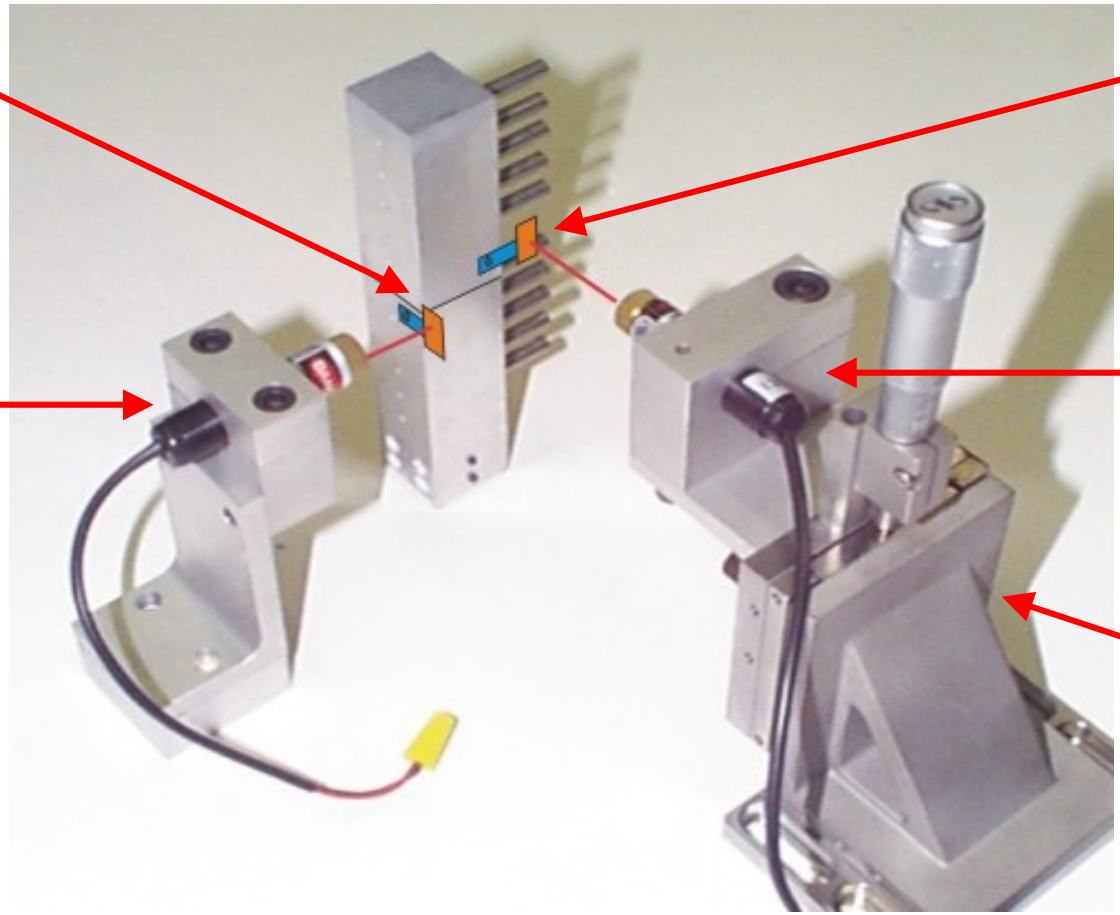
Thermal Interface Material Test



Thermal Interface Material Test



Thickness and Deflection



Air Cooled Heat Sink Tests

- Single-sided and back-to-back testing
- Wind tunnel
  - ✓ 18 inch x 18 inch x 24 inch tall section
  - ✓ 0 – 10 m/s
- Instrumentation
  - ✓ Keithley 2700 data acquisition system
  - ✓ 150 V, 7 A programmable DC power supply
  - ✓ Differential pressure transducers
  - ✓ Dantec hot wire anemometer
  - ✓ Pitot probe

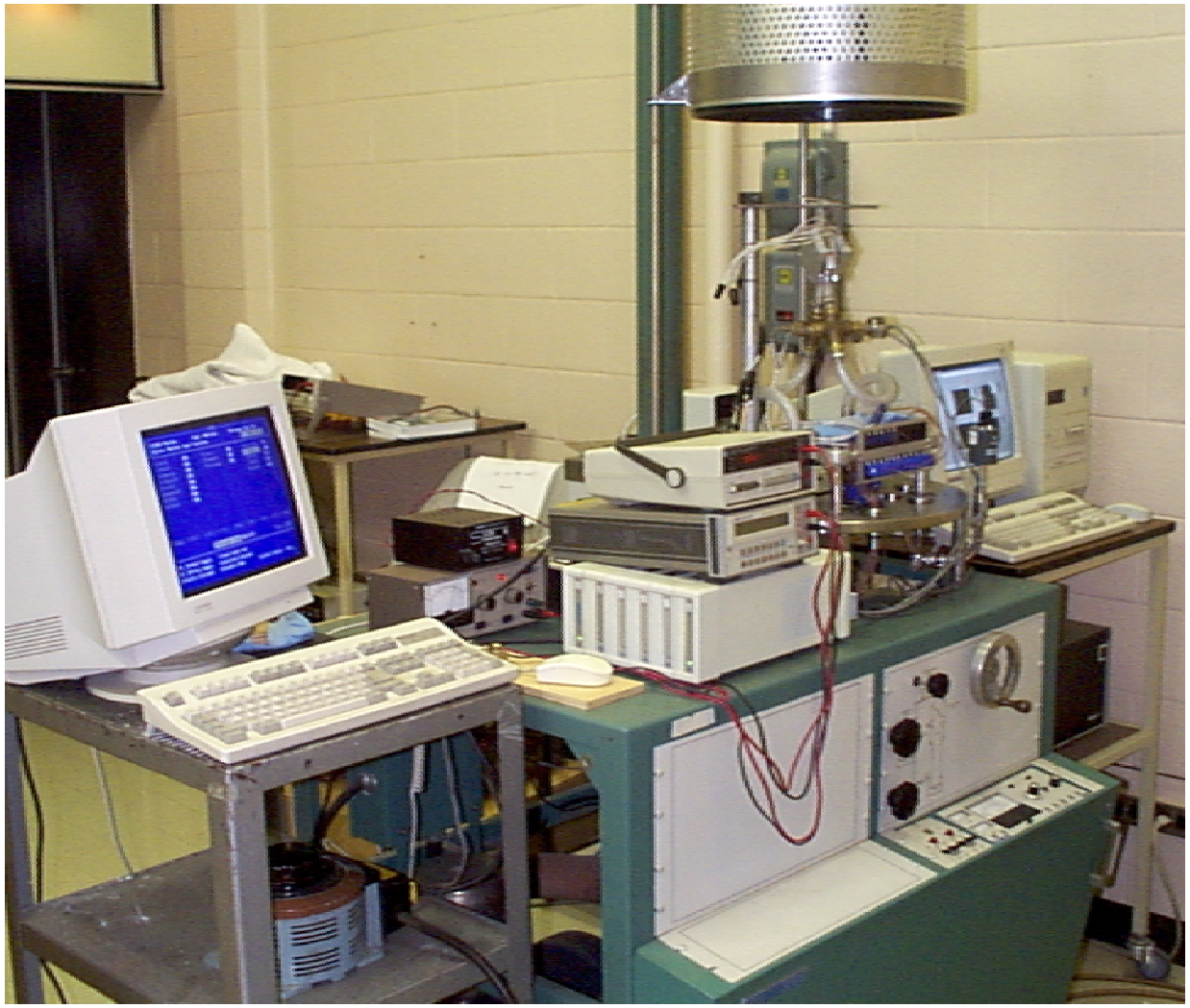
18” x 18” Open Circuit Wind Tunnel

Heat Sink Bypass Measurement

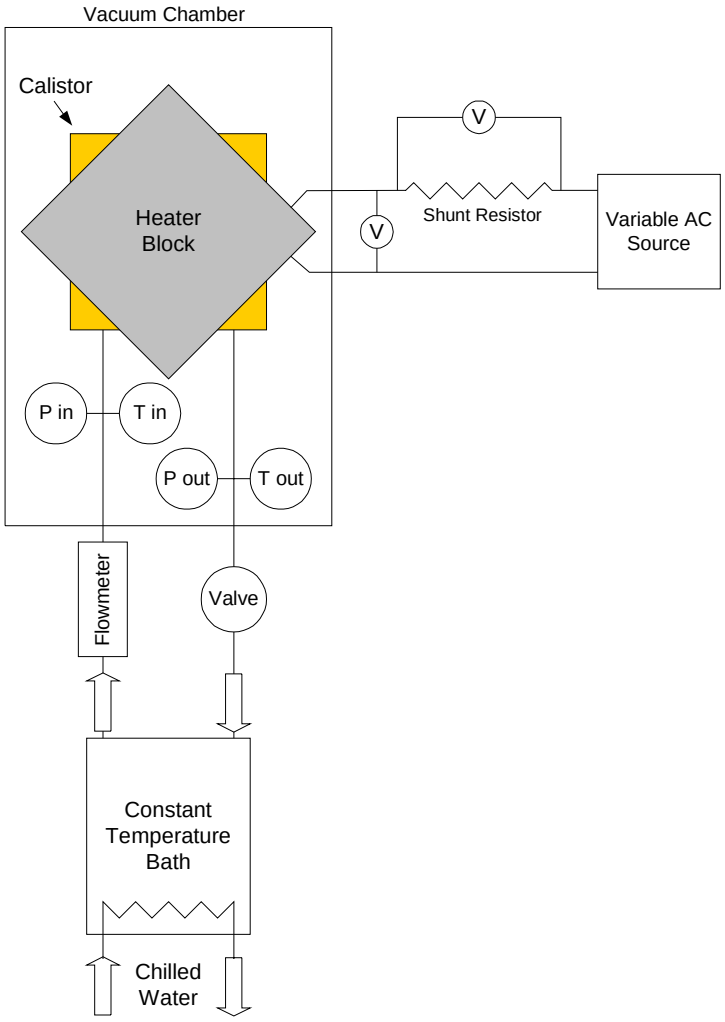
Liquid Cooled Heat Sinks

- High heat flux applications
- Vacuum environment to reduce losses
- Measurements:
  - ✓ power
  - ✓ temperature
  - ✓ flowrate
  - ✓ pressure drop
  - ✓ fluid temperature rise

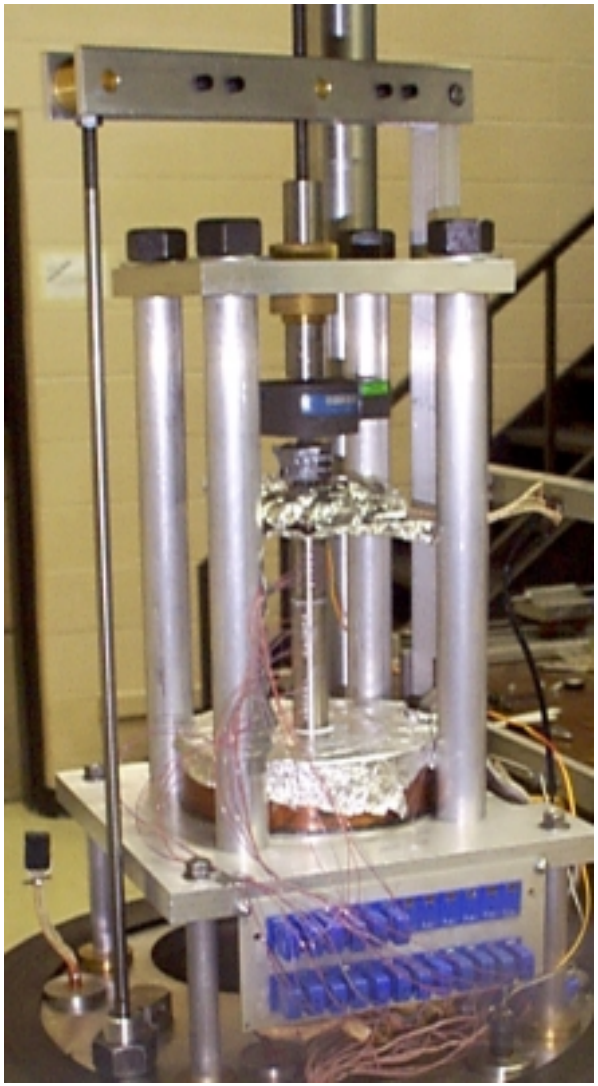
Liquid Cooled Heat Sinks



Liquid Cooled Heat Sinks



Thermal Contact Resistance at Low Contact Pressure

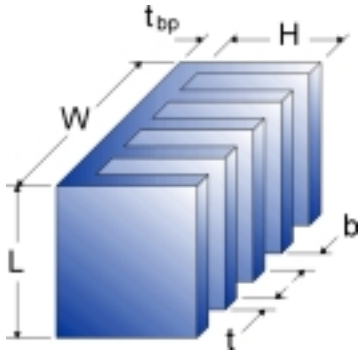


Model Development

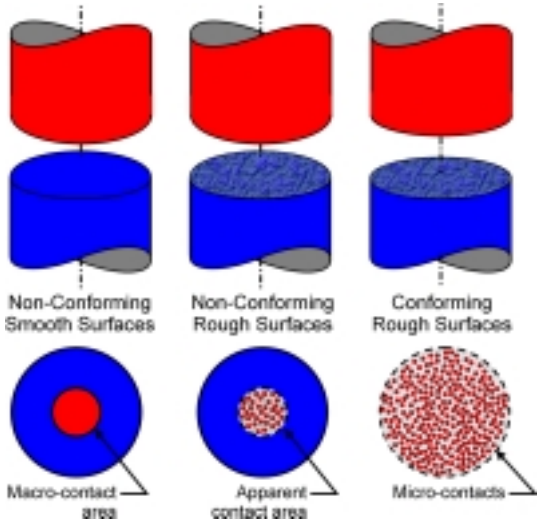
- Thermal model development:
  chip level → cooling medium
  - ✓ heat sink optimization
  - ✓ modeling & characterization of thermal interfaces
  - ✓ modeling of spreading & constriction resistance
  - ✓ modeling of conduction & convection in PWBs
- Technology transfer:
  - ✓ Excel spreadsheets
  - ✓ Web-based analysis tools

Model Development

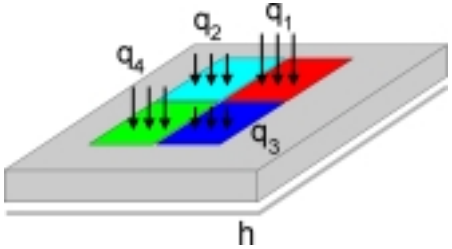
- Heat sink optimization model
  - ✓ shrouded, air-cooled, plate fin heat sink
  - ✓ interactive web-based modeling tool



- Thermal resistance models
  - ✓ non-conforming, smooth surfaces
  - ✓ conforming rough surfaces
  - ✓ Excel spreadsheet models



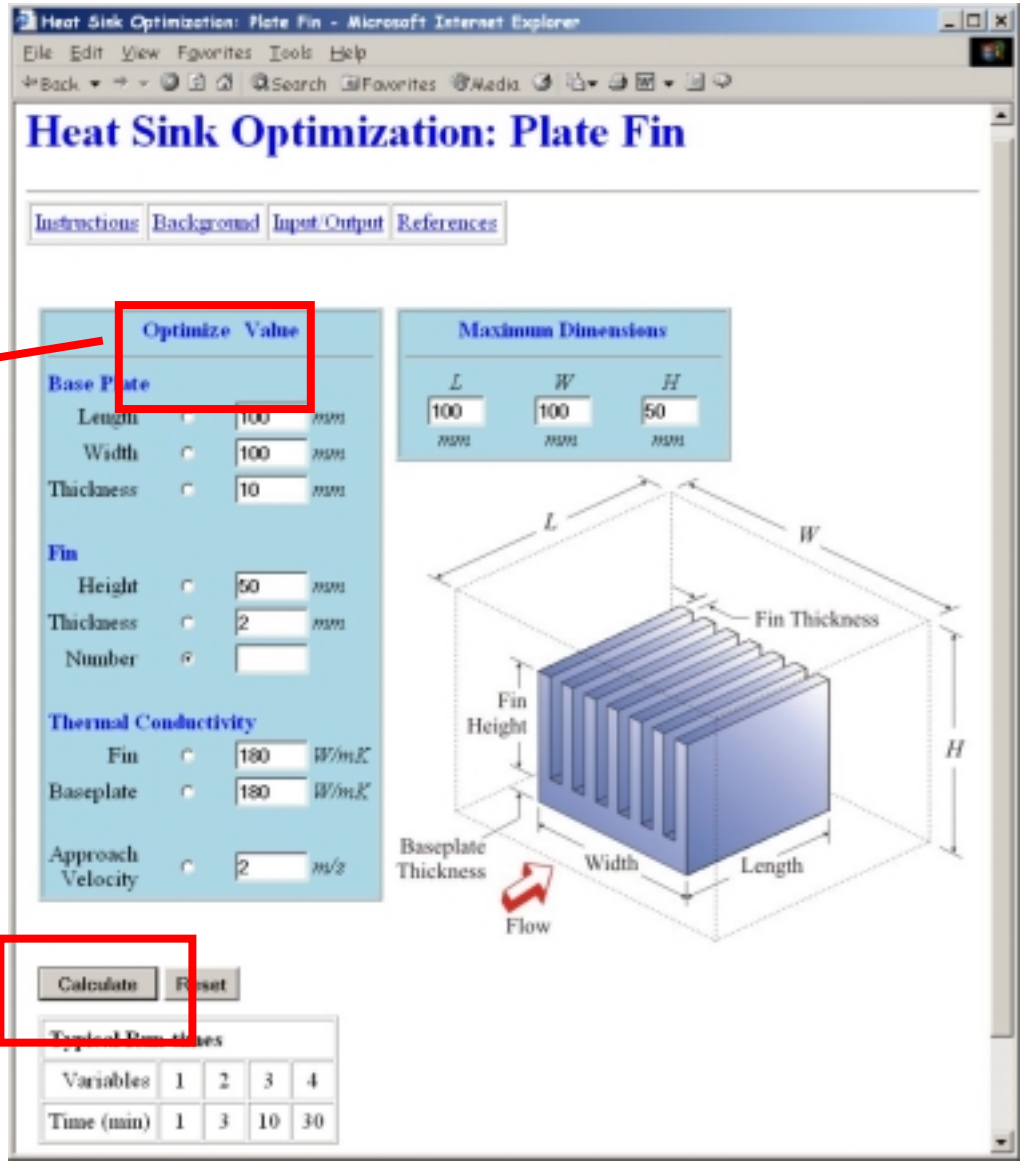
- Spreading resistance model for
  - ✓ multiple discrete sources
  - ✓ interactive web-based modeling tool



Value: provide specific values for constrained parameters

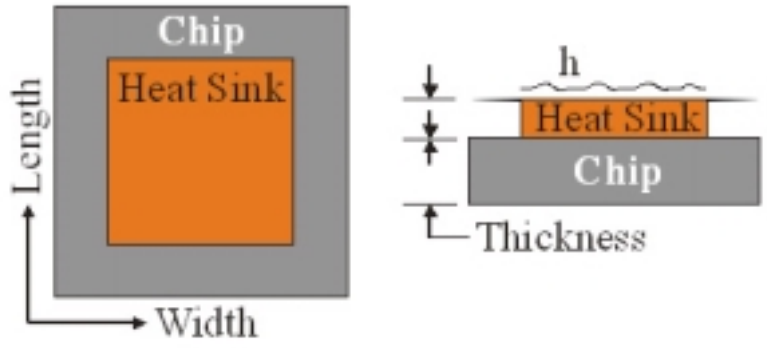
Optimize: indicate parameters to be optimized

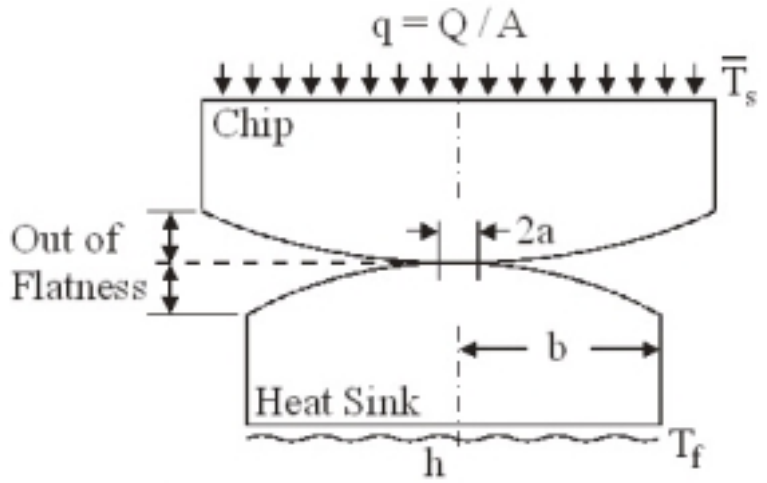
Calculate: run optimization code to calculate design parameters for maximum thermal-fluid performance



Web URL: http://mhtlab.uwaterloo.ca/onlinetools/optimize/index.html

Contact Resistance for Non-Conforming Smooth Surfaces





$$R = \frac{\overline{T}_s - T_f}{Q} \qquad h = \frac{Q_{\text{heat sink}}}{A_{\text{interface}} \Delta T_{\text{heat sink}}}$$

Chip and Heat Sink Geometry

	Chip	Heat Sink
Width (mm)	15	6
Length (mm)	15	6
Out of flatness (mm)	0.00762	0.00762
Thickness (mm)	0.75	0.5

Gap

Material	Air
P(atm)	1
T (°C)	50
k(W/m.K)	0.028
Beta [-]	1.643
Alpha [-]	2.44
Lambda (Micro m)	0.064

Chip and Heat Sink Material

	Chip	Heat Sink
	Silicon	Al 6063T5
k (W/m.K)	125	209
E (GPa)	163	70
Poisson ratio	0.30	0.30

Results

	Resistance (K/W)
Chip	
Heat Sink	
Gap	
Total	
Decimals	3

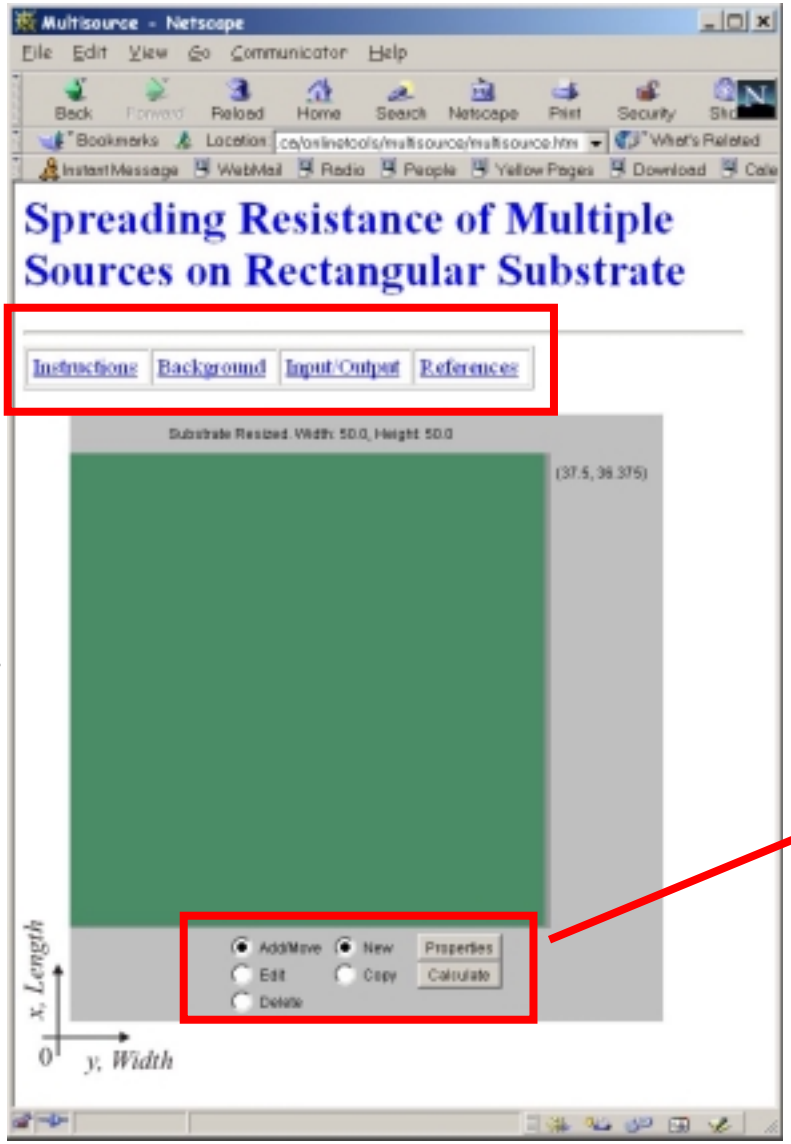
Condition

h (W/ (m^2.K))	500
Contact Load (N)	7.41

Calculate

Exit

Help

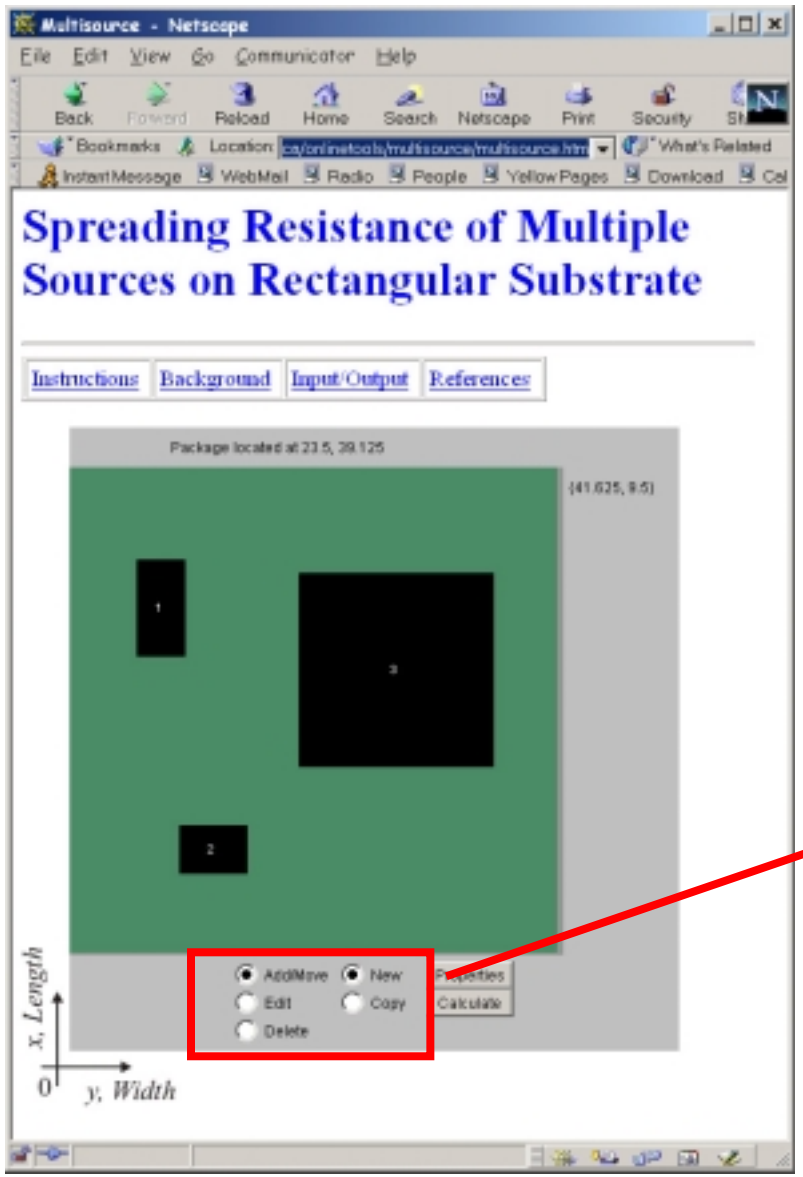


Instructions: user's guide & sample problem
Background: governing eqns. & model development
Input/Output: data entry & units
References: publications & sample pdf files

Properties: set substrate & source properties
Add/move, Edit, Delete, New, Copy: on screen package placement

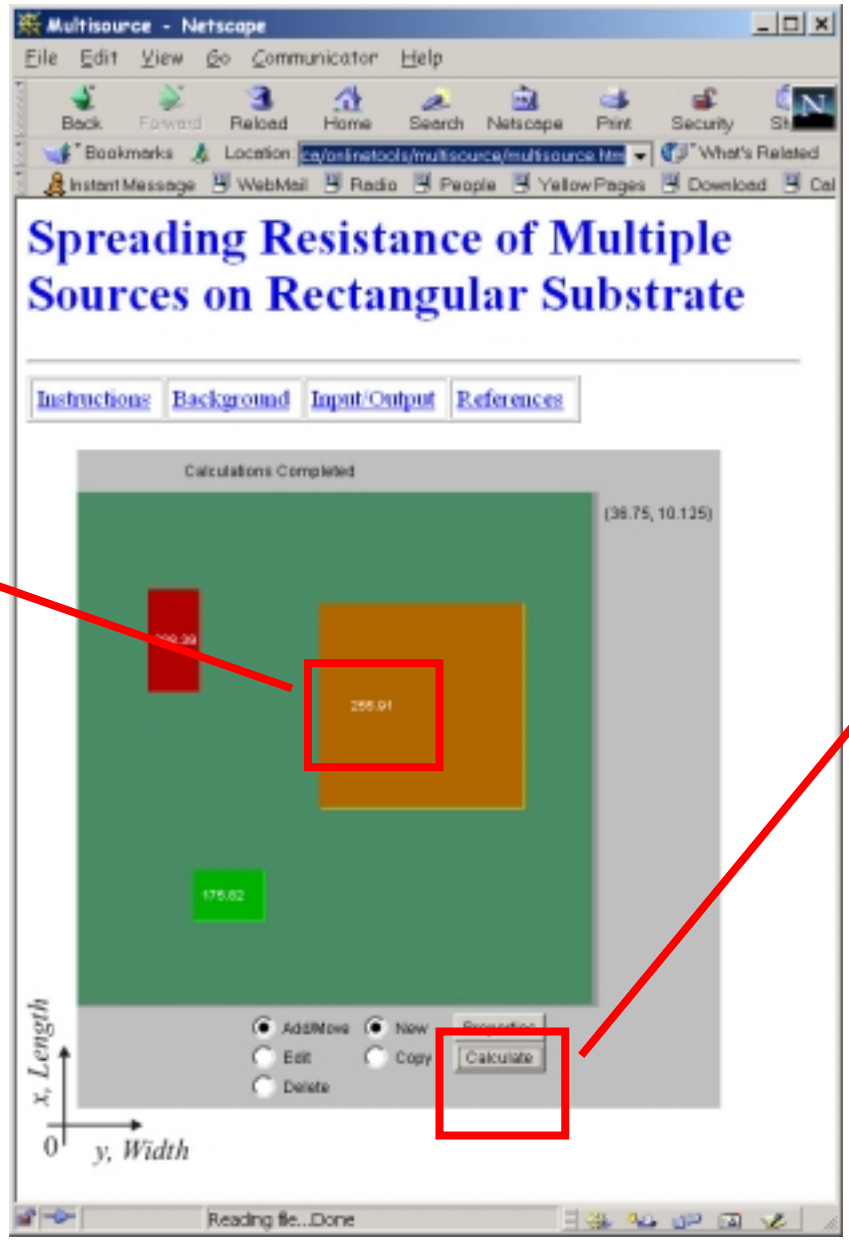
Note: Java source requires Netscape (IE will not work)

Web URL: http://mhtlab.uwaterloo.ca/onlinetools/multisource/index.html



Add a new source: a pop-up window will appear for entering heat source inputs
- click on substrate to place current heat source

Mean source temperature rise - ^{o}C



Calculate: click calculate to obtain mean heat source temperature rise for each source

- Java-based code will be executed on local CPU
- typical run times are approximately 10 seconds per source

Numerical CFD Analysis

- CFD modelling to support analysis:
  - ✓ parametric studies
  - ✓ validation
- Computing facilities
  - ✓ Sun Blade 1000 server
- Software
  - ✓ IcePak
  - ✓ Flotherm
  - ✓ I-DEAS