Presented at the 2011 COMSOL Conference

Conjugate Heat Transfer for Wireless Power Amplifier

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Outline

- Introduction
- Problem Statement
- COMSOL
  - Physics
  - Modeling
- Conclusions
  - Present Solution
  - Future Considerations

Introduction

- Matthew J. Williamson, P.E.
- Kansas State University Salina
- Engineering Technology

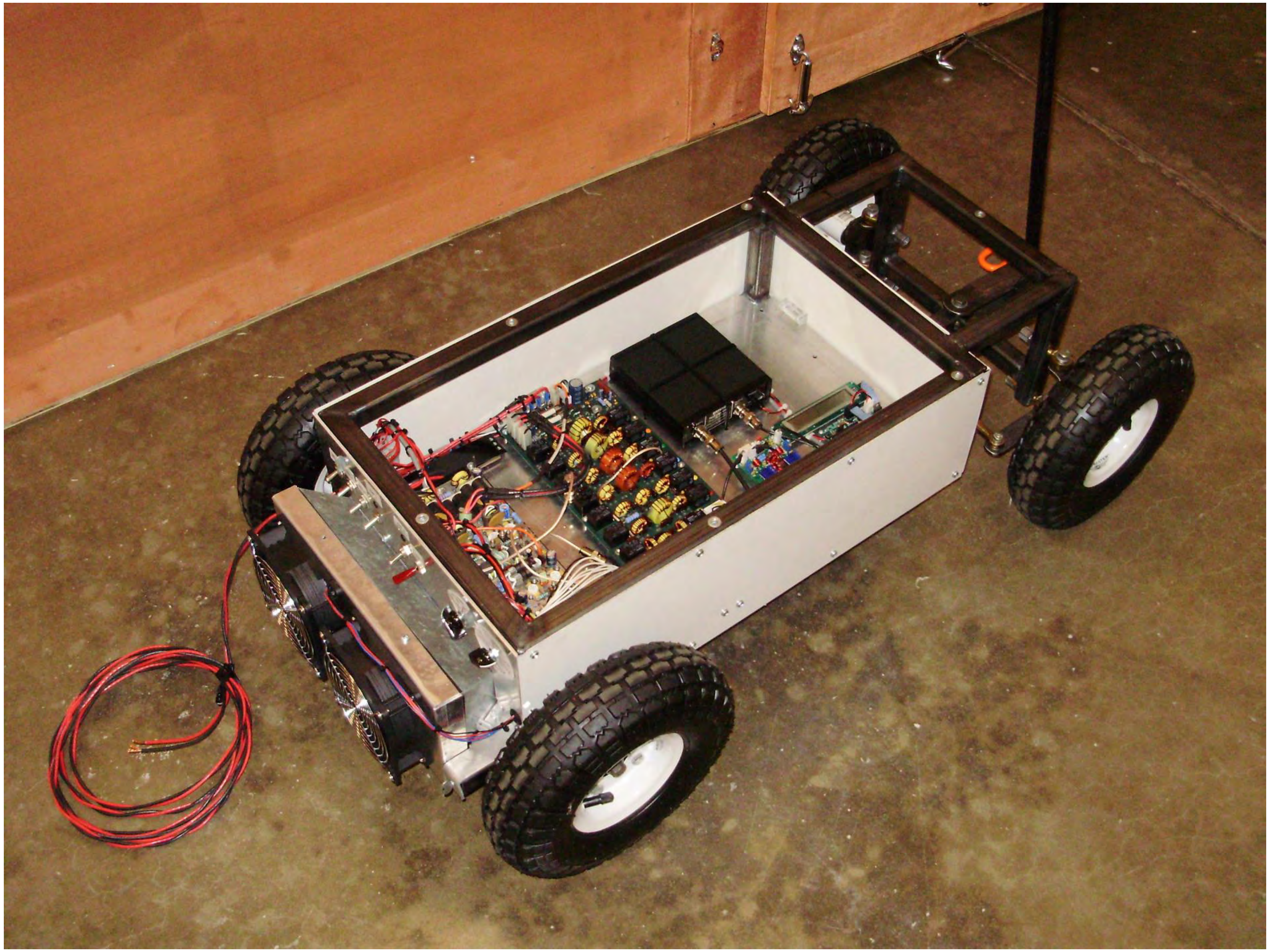
Problem Statement

- Wireless Power Transfer for Remote Aerial Systems
  - Maintain operation of remote systems
- Thermal management
  - Use existing wireless power amplifier
  - Use existing heat sink
  - Maintain temperatures below 150^{o}F

Problem Statement

- Interested in a practical and achievable solution
- Cart built to simulate ground vehicle and act as a proof-of-concept

Problem Statement



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COMSOL - Physics

- Utilized Conjugate Heat Transfer Module
  - Heat Transfer in Solids
    - Aluminum Heat sink
    - Galvanized Steel ducts
  - Heat Transfer in Fluids
    - Air
- Stationary Solution

COMSOL - Physics

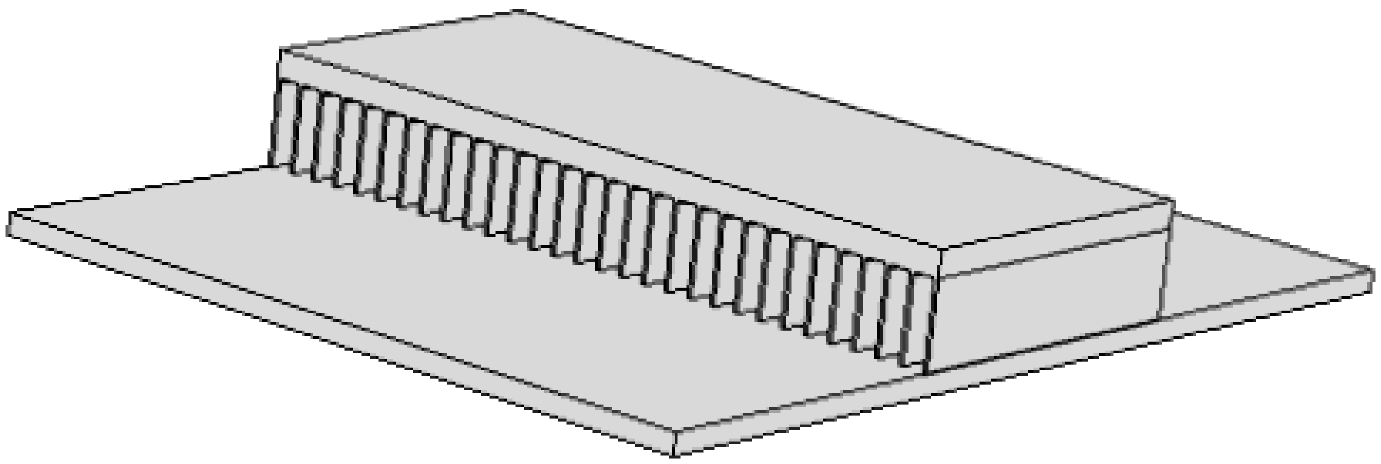
- Boundary Conditions
  - Fluid Inlet
    - Atmospheric Pressure
  - Fluid Outlet
    - Variable velocity over outlet area
  - Ambient temperature
    - Variable throughout the study
    - Fixed at air inlet
    - Exposed solid surfaces bound to “radiate-to-ambient”

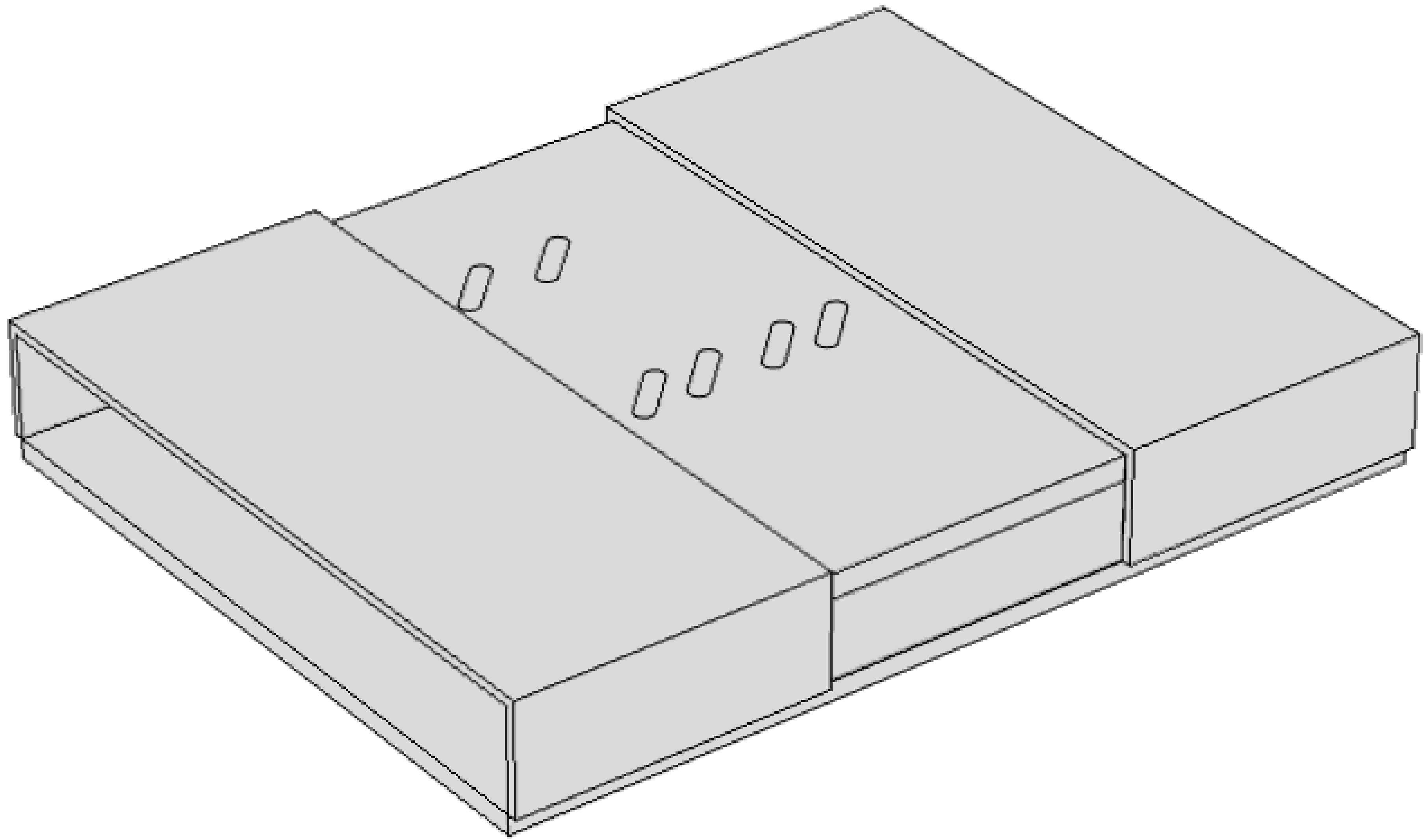
COMSOL - Physics

- Boundary Conditions
  - Boundary Heat Source
    - Assumes all 200 W from Amplifier is applied to heat sink
    - Uniformly Distributed over the top surface of the -OR-
    - Concentrated over six contacts between amplifier and heat sink
- Mesh
  - Free Tetrahedral, Coarser
  - More fine solutions tested, but with diminishing returns

COMSOL – Modeling

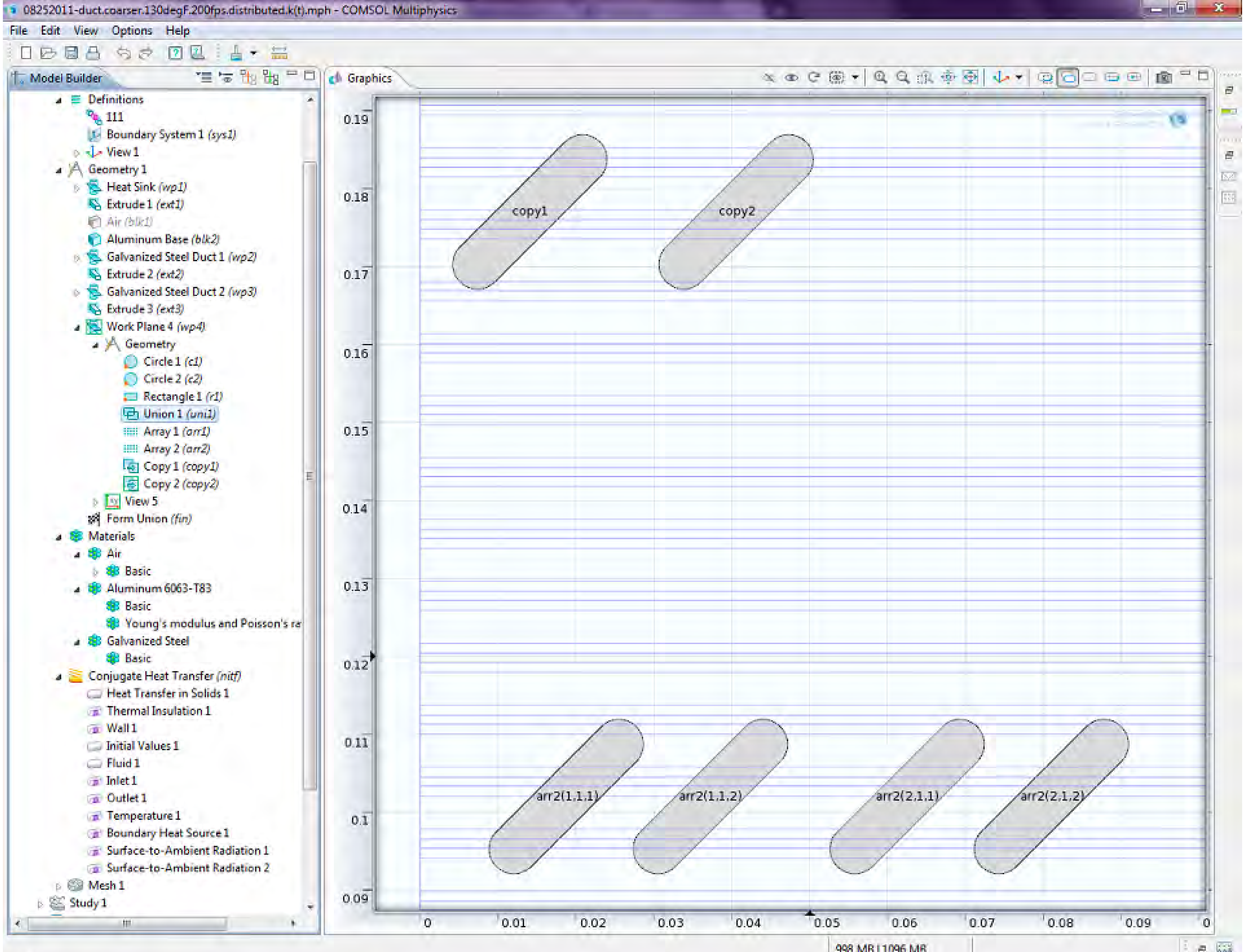
- Heat Sink
  - Measured
  - Modeled parametrically
    - Including fin thickness, number, fillet, etc.
  - Material properties from library
    - 6000-series aluminum,
    - Added surface emissivity = 0.77
- Base plate
  - Material properties from library
    - 6000-series aluminum
    - Added surface emissivity = 0.77





COMSOL - Modeling

- Ducts
  - Built in-house from 1/8" thick galvanized steel
    - Material properties collected from available references
    - Conductivity = 89 W/m*K and surface emissivity = 0.28
  - Inlet and outlet match finned faces of heat sink
- Variability of models
  - Models were tested that utilized constant and temperature-dependant thermal conductivity
  - Uniformly distributed and concentrated boundary heat sources were used


08252011-duct.coarser.130degF.200fps.distributed.k(t).mph - COMSOL Multiphysics
File Edit View Options Help
Model Builder
Definitions
111
Boundary System 1 (sys1)
View 1
Geometry 1
Heat Sink (wp1)
Extrude 1 (ext1)
Air (blk1)
Aluminum Base (blk2)
Galvanized Steel Duct 1 (wp2)
Extrude 2 (ext2)
Galvanized Steel Duct 2 (wp3)
Extrude 3 (ext3)
Work Plane 4 (wp4)
Geometry
Circle 1 (c1)
Circle 2 (c2)
Rectangle 1 (r1)
Union 1 (uni1)
Array 1 (arr1)
Array 2 (arr2)
Copy 1 (copy1)
Copy 2 (copy2)
View 5
Form Union (fin)
Materials
Air
Basic
Aluminum 6063-T83
Basic
Young's modulus and Poisson's ra
Galvanized Steel
Basic
Conjugate Heat Transfer (nitf)
Heat Transfer in Solids 1
Thermal Insulation 1
Wall 1
Initial Values 1
Fluid 1
Inlet 1
Outlet 1
Temperature 1
Boundary Heat Source 1
Surface-to-Ambient Radiation 1
Surface-to-Ambient Radiation 2
Mesh 1
Study 1
Graphics
copy1
copy2
arr2(1,1,1)
arr2(1,1,2)
arr2(2,1,1)
arr2(2,1,2)
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0
0.01
0.02
0.03
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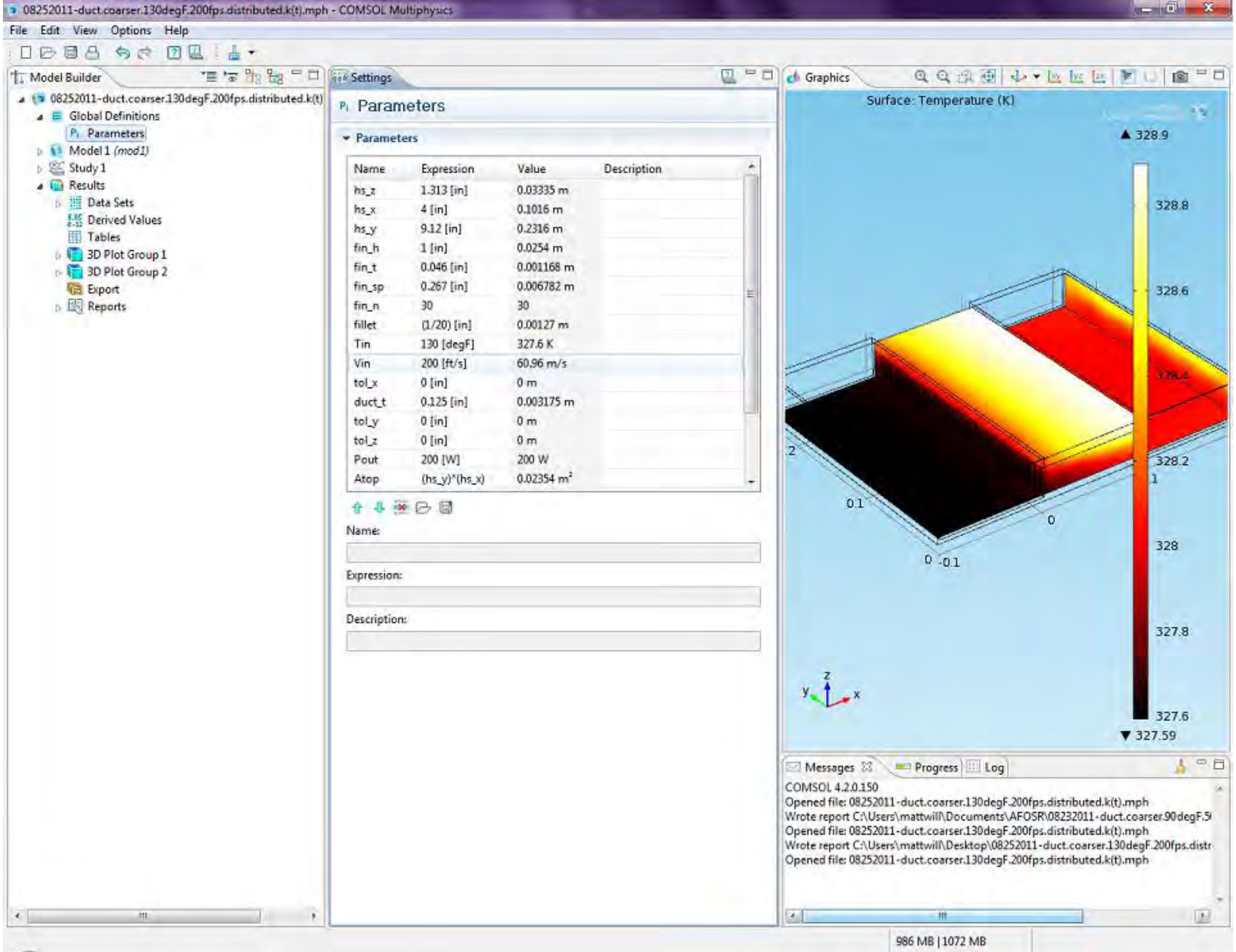
0.09
998 MB | 1096 MB



Parametric Modeling

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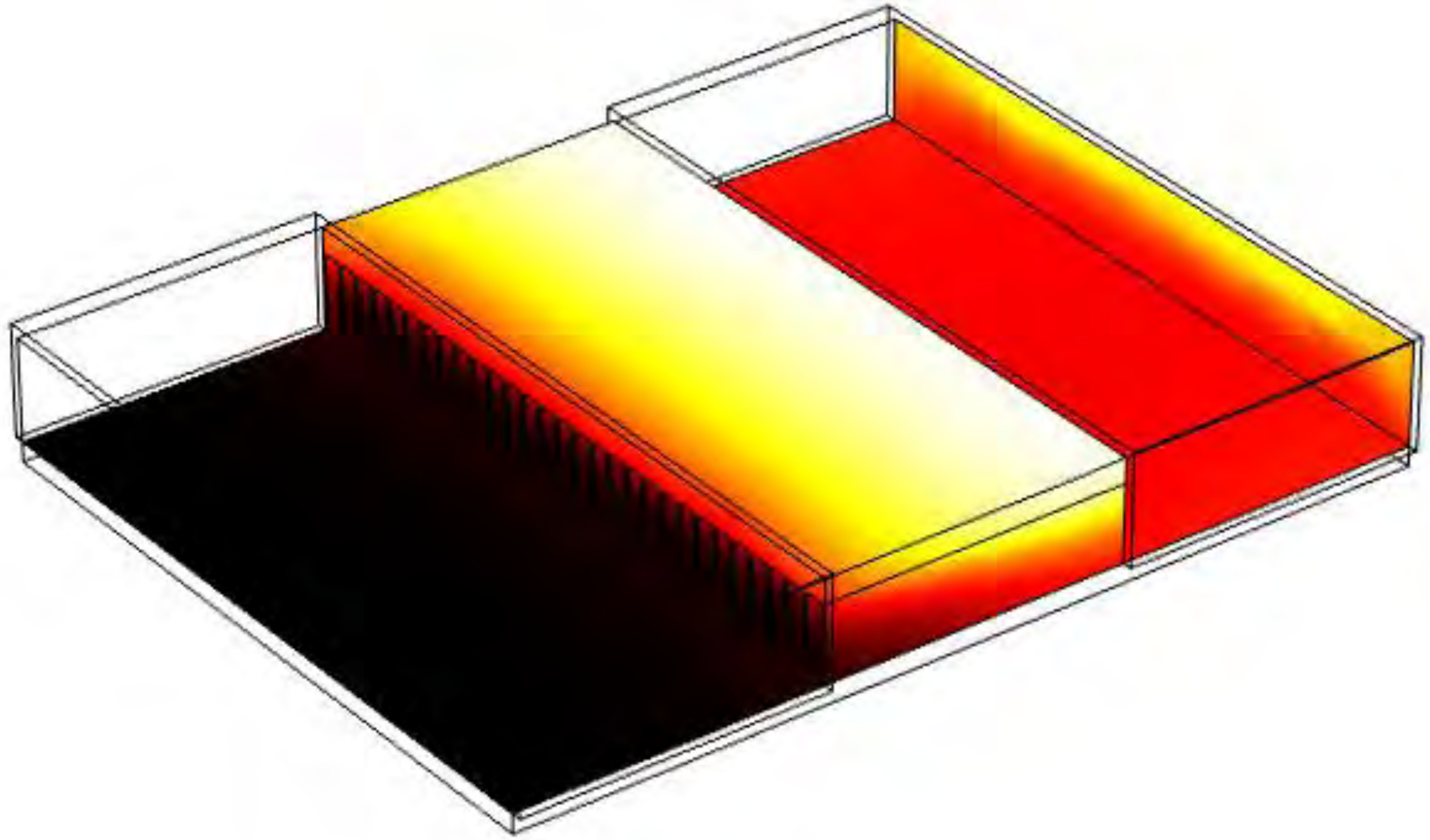

Max. Temp. Results

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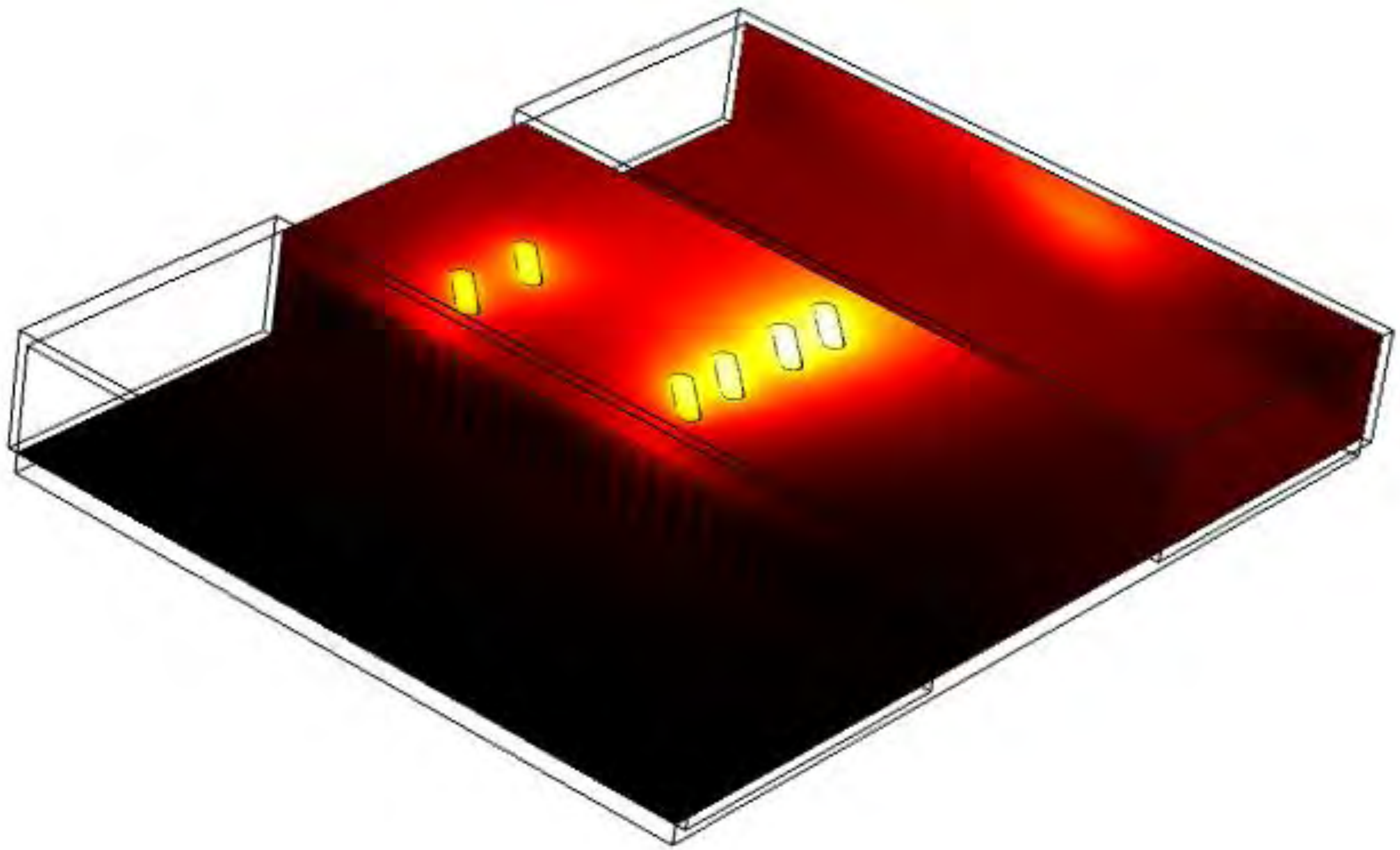

Max. Temp. Results

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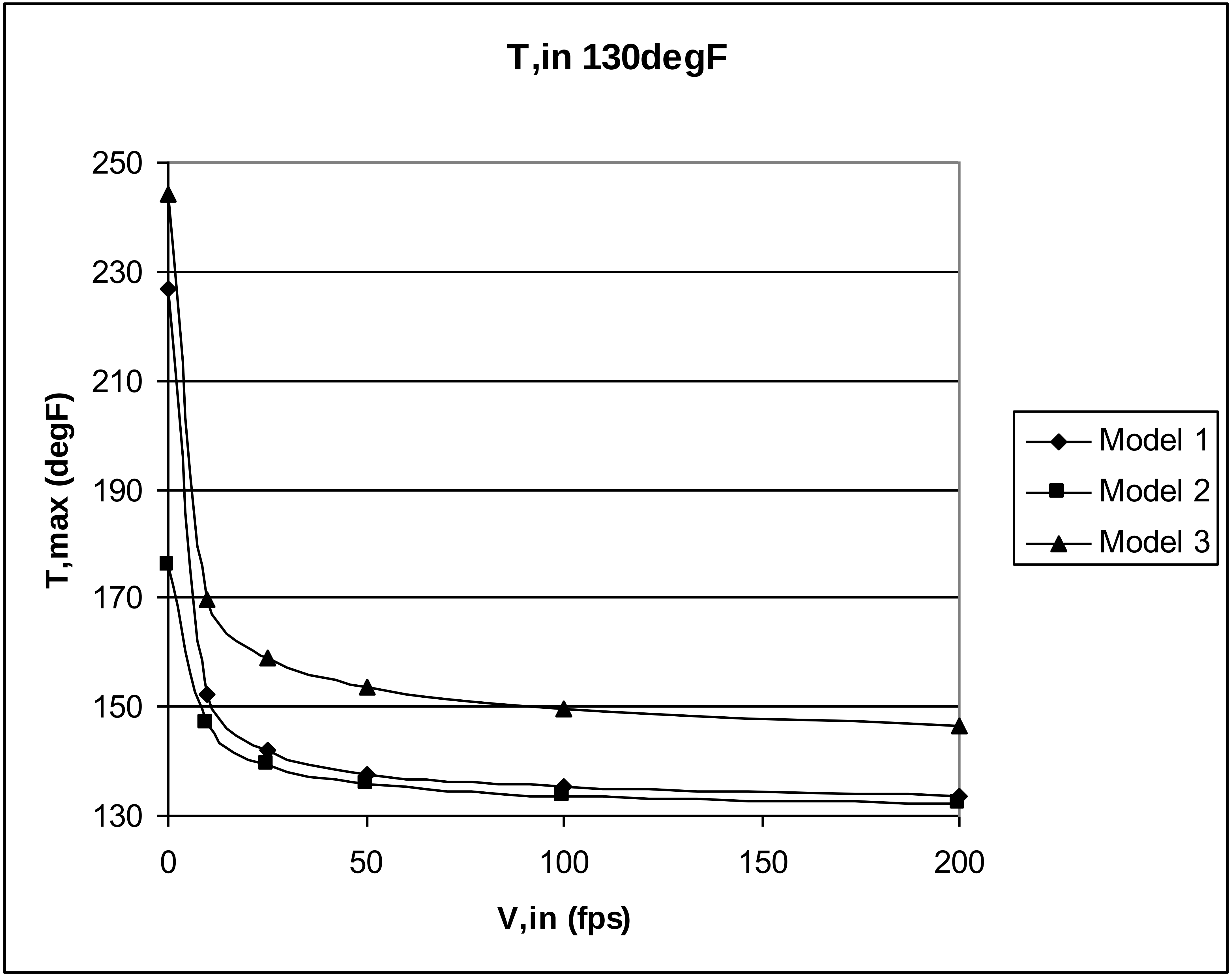
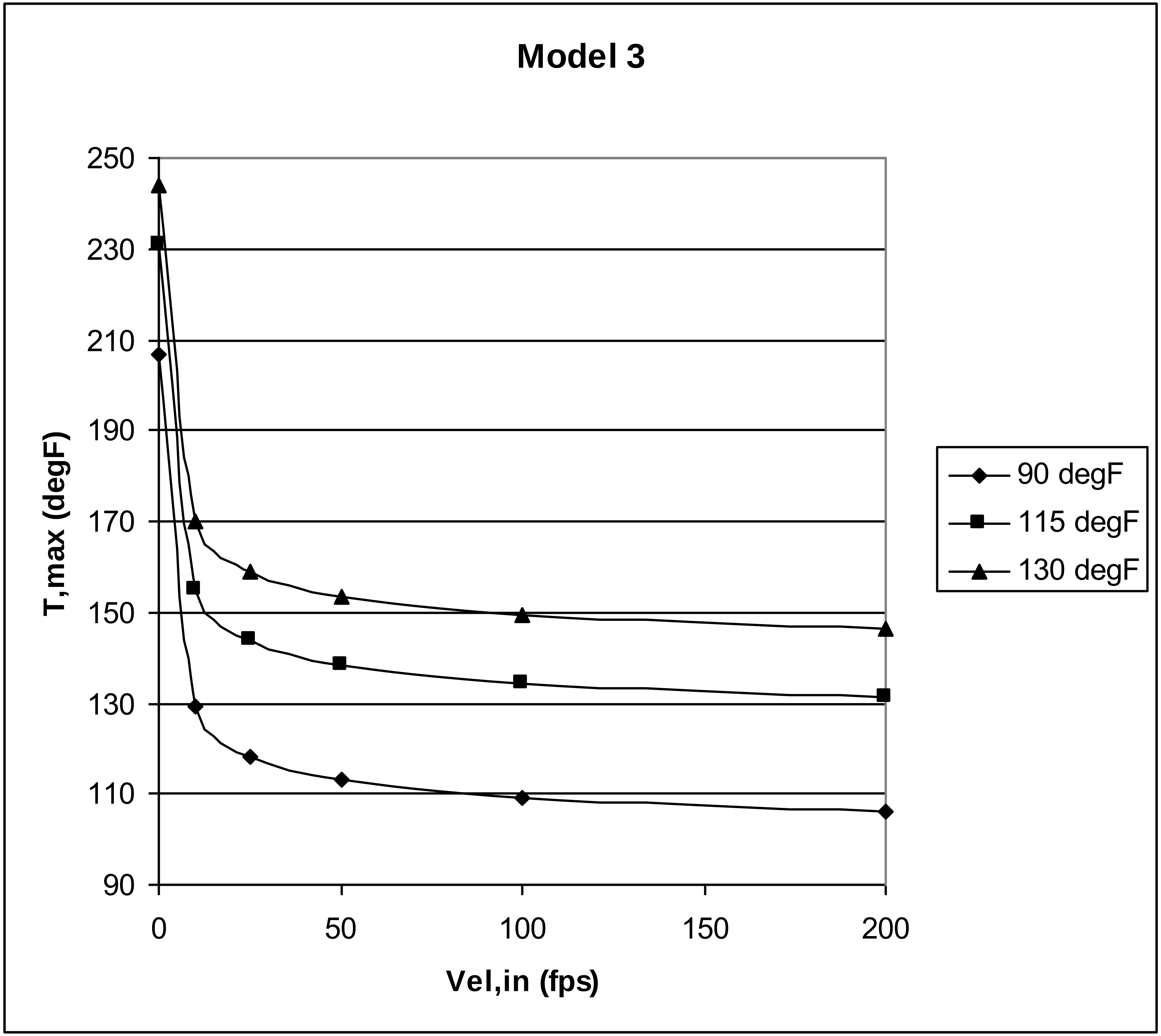
Conclusions

- Maximum temperatures on the heat sink show the need for some air flow in order to maintain stable working conditions for the wireless amplifier
- Velocity needs vary with ambient temperature and model assumptions


T,in 130degF
T,max (degF)
250
230
210
190
170
150
130
0
50
100
150
200
V,in (fps)
Model 1
Model 2
Model 3



Model 3
250
230
210
190
170
150
130
110
90
T,max (degF)
0
50
100
150
200
Vel,in (fps)
90 degF
115 degF
130 degF

Conclusions

- Experimental data to validate model predictions
- Other Solutions, reduced weight and power needs
  - Changes in heat sink geometry
  - Dielectric fluids
  - Micro-fans