Test Fixture for Flight Components (Willy)

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NORTHERN ARIZONA UNIVERSITY®

Capstone – Fall 2018

Project Description

- The goal of this project is to design a test fixture that simulates flight conditions experienced by supersonic missiles.

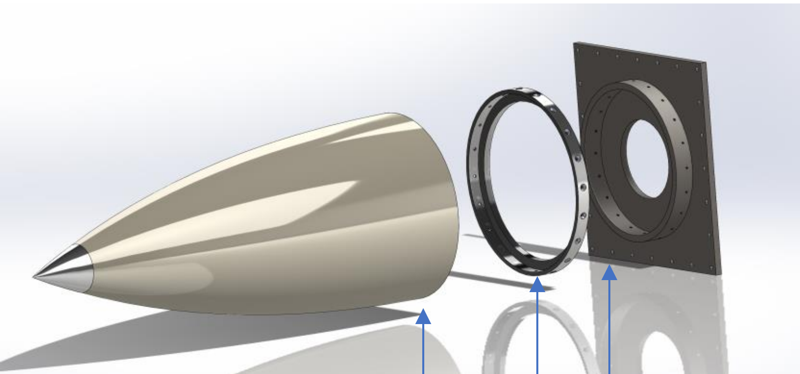
- Our intention is to design a universal test fixture that has quicker assembly.

- Our Client is Chuck Vallance formerly of Raytheon.

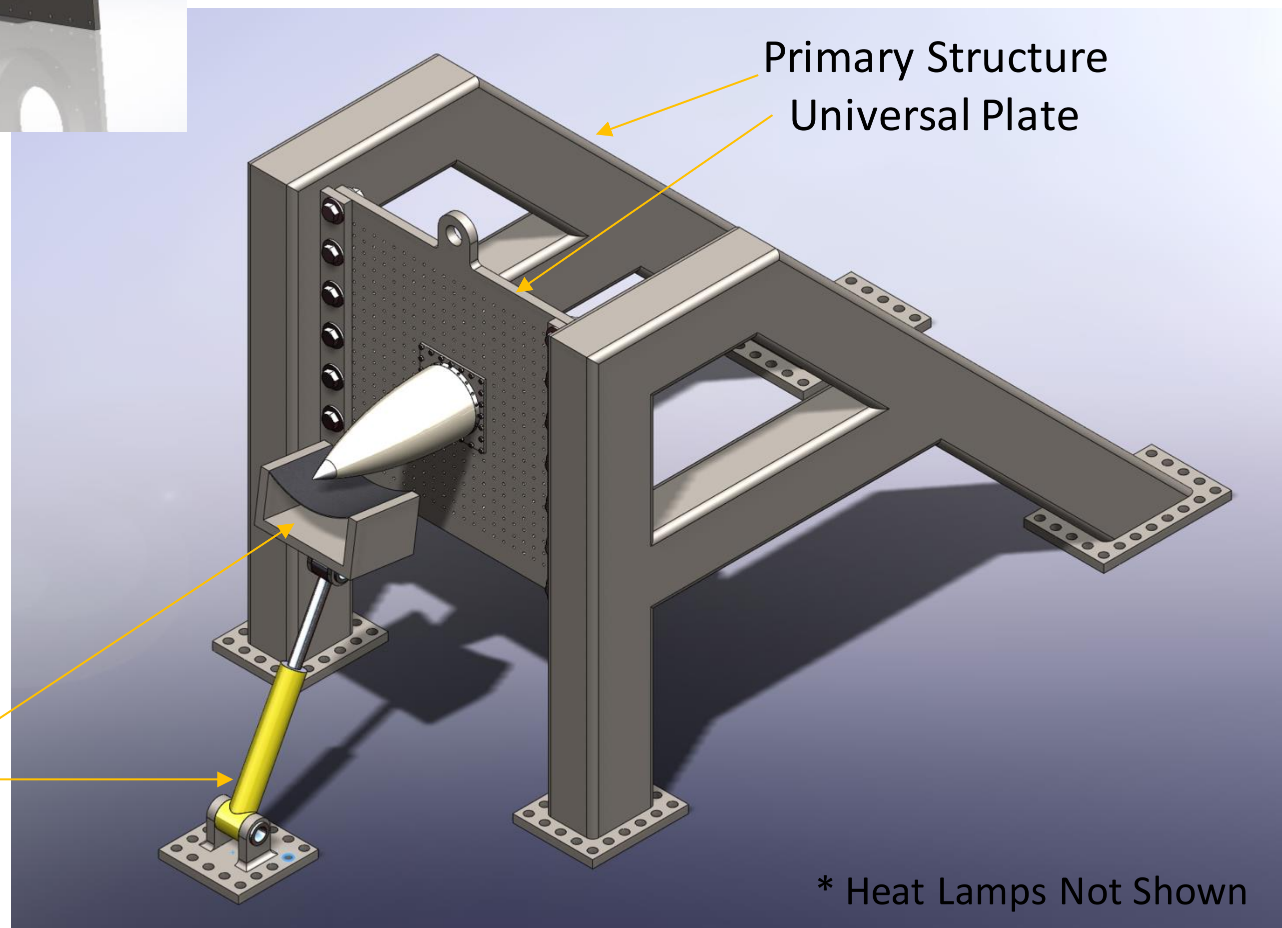
- Client Deliverables
  1)Parameters of Missile Parts
  2)Test/Flight Conditions
  3)CAD Model & Simulation
  4)Scale Model

[1] Raytheon

Project Description



AMRAAM Radome
Mounting Ring
Mounting Plate



Loading Strap
Hydraulic Ram

Design Updates

Hi-TempIR®

Model 5209 High Temperature Infrared Heater

Product Data Sheet

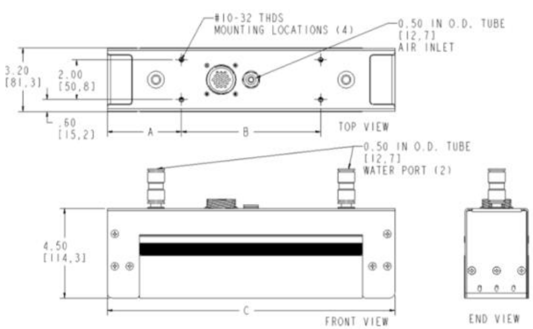
High Temperature Infrared Heater

The Model 5209 Hi-TempIR® heater is designed to provide high-intensity infrared heat onto localized areas.

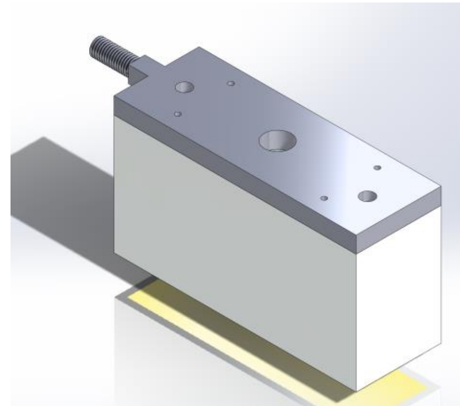
Typical applications for this heater include:

- Stress relieving
- Metal brazing processes
- Aerodynamic heating simulation
- Thermal stress testing

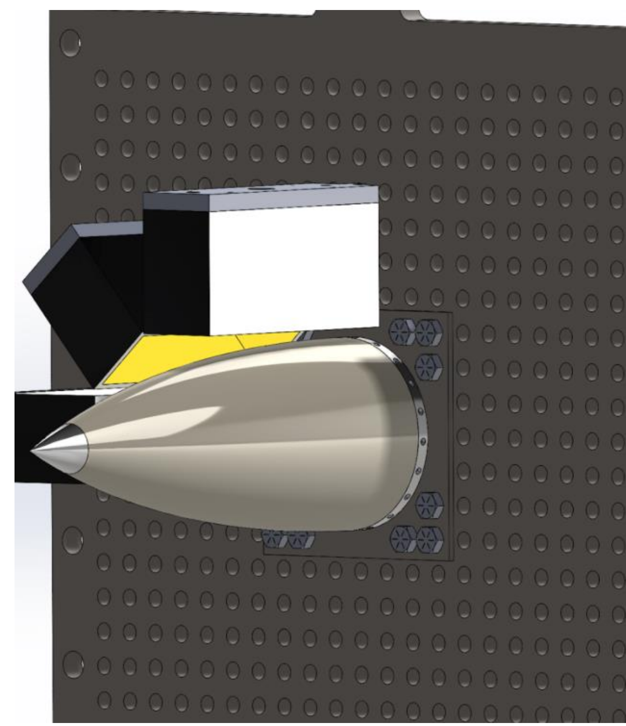
Dimensions – Model 5209



Model Number	Dimension, Inches (mm) A	B	C
5209-05	1.8 (45.7)	5.5 (139.7)	9.10 (231.1)
5209-10	3.73 (94.7)	7.00 (177.8)	14.45 (367.0)
5209-16	3.73 (94.7)	12.63 (320.8)	20.08 (510.0)

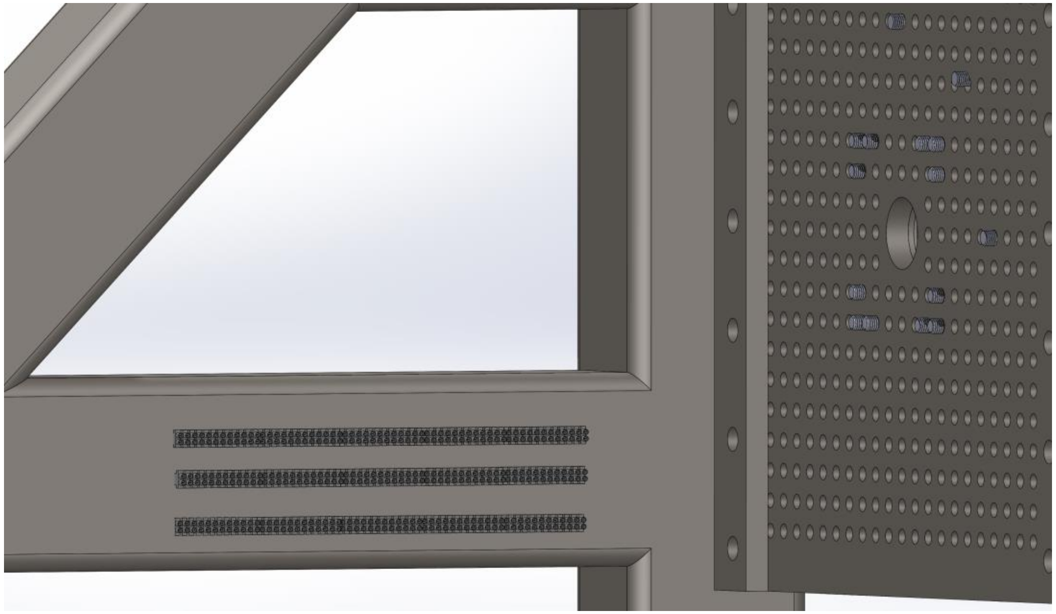


5/8" Bolt Pattern



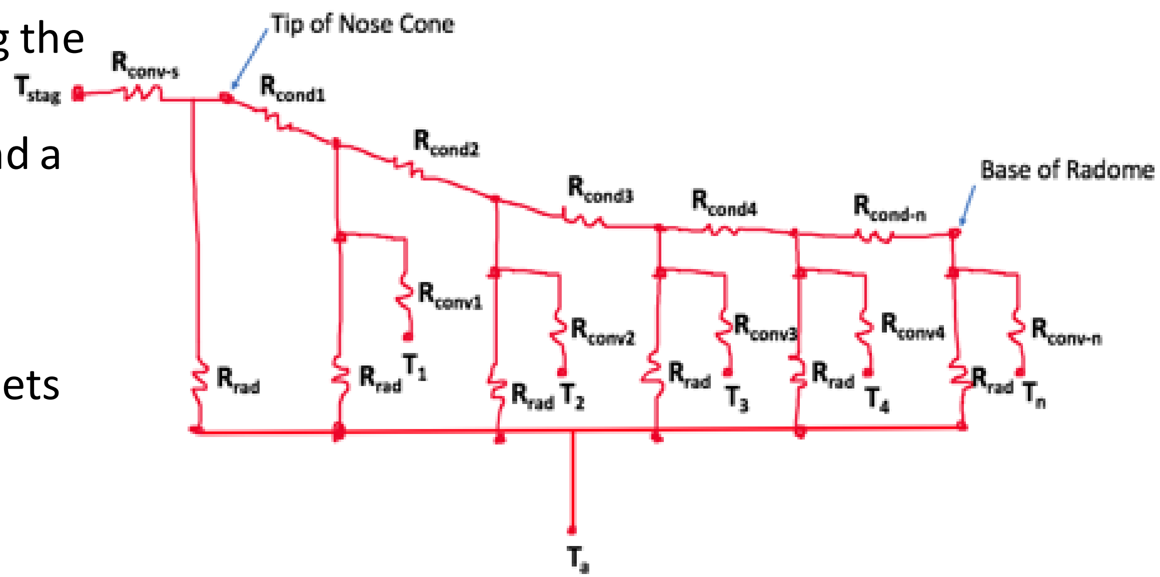
Design Updates

Circular Connectors and Terminal Blocks



Analytical Reports – Temperature and Heat Flux Distribution

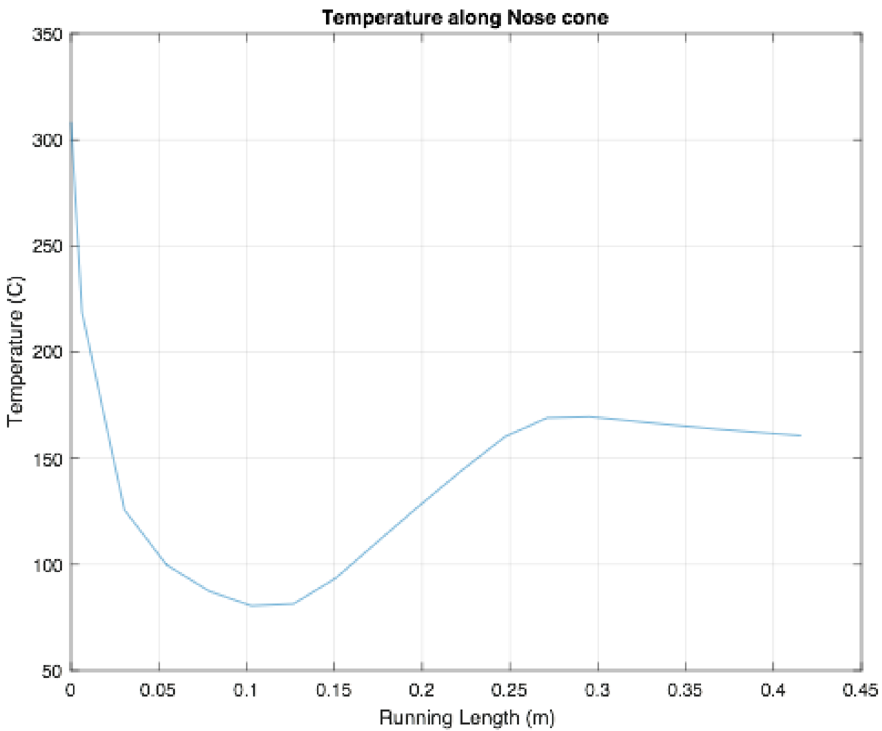
- Temperatures were found using the aeroheating values from last semester's heat flux analysis and a finite-differencing method
- Temperature distribution is important to ensure the heat flux applied from the lamps meets or exceeds the temperatures in flight
- It will also be used to determine thermal expansion in the bolts



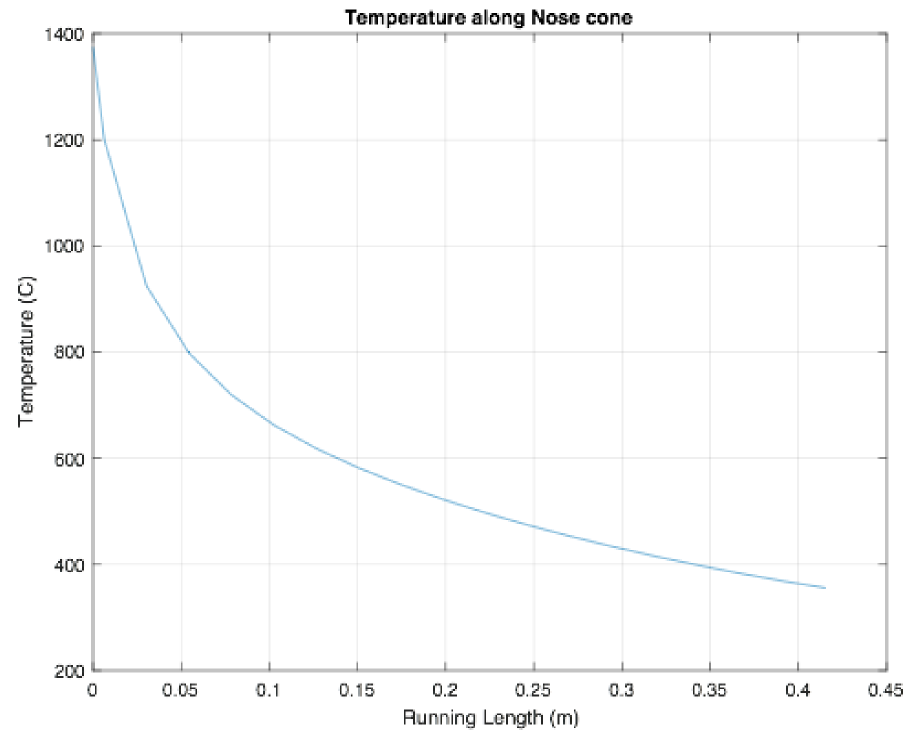
Resistive Network

Flow Chart of Code

Analytical Reports – Temperature and Heat Flux Distribution (cont.)



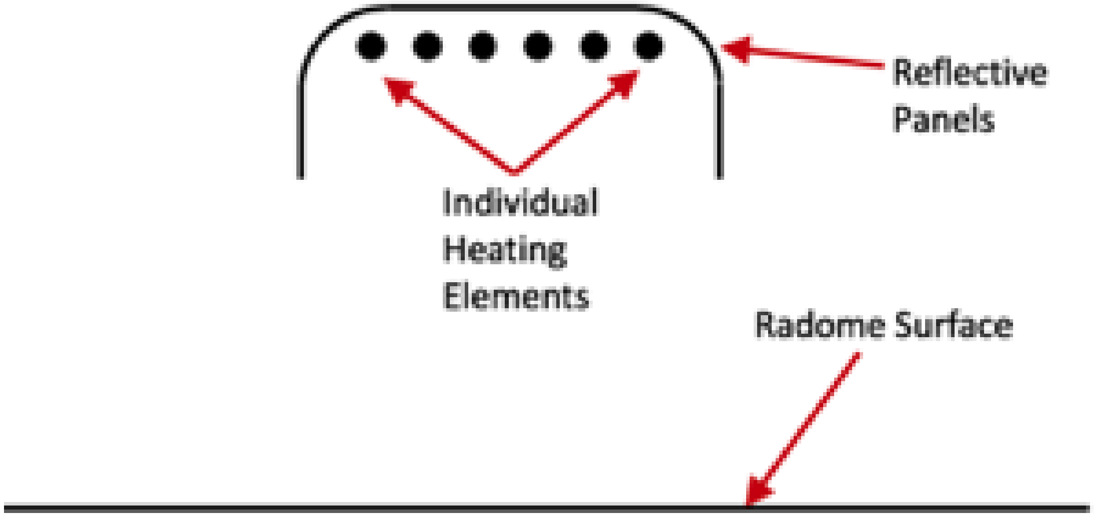
Flight Conditions

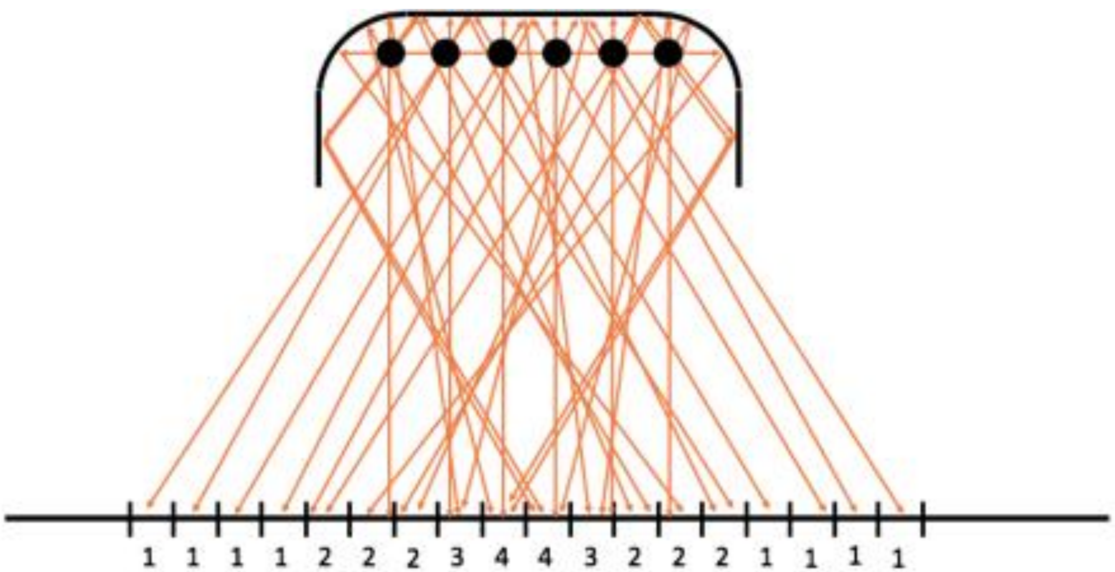


Test Conditions

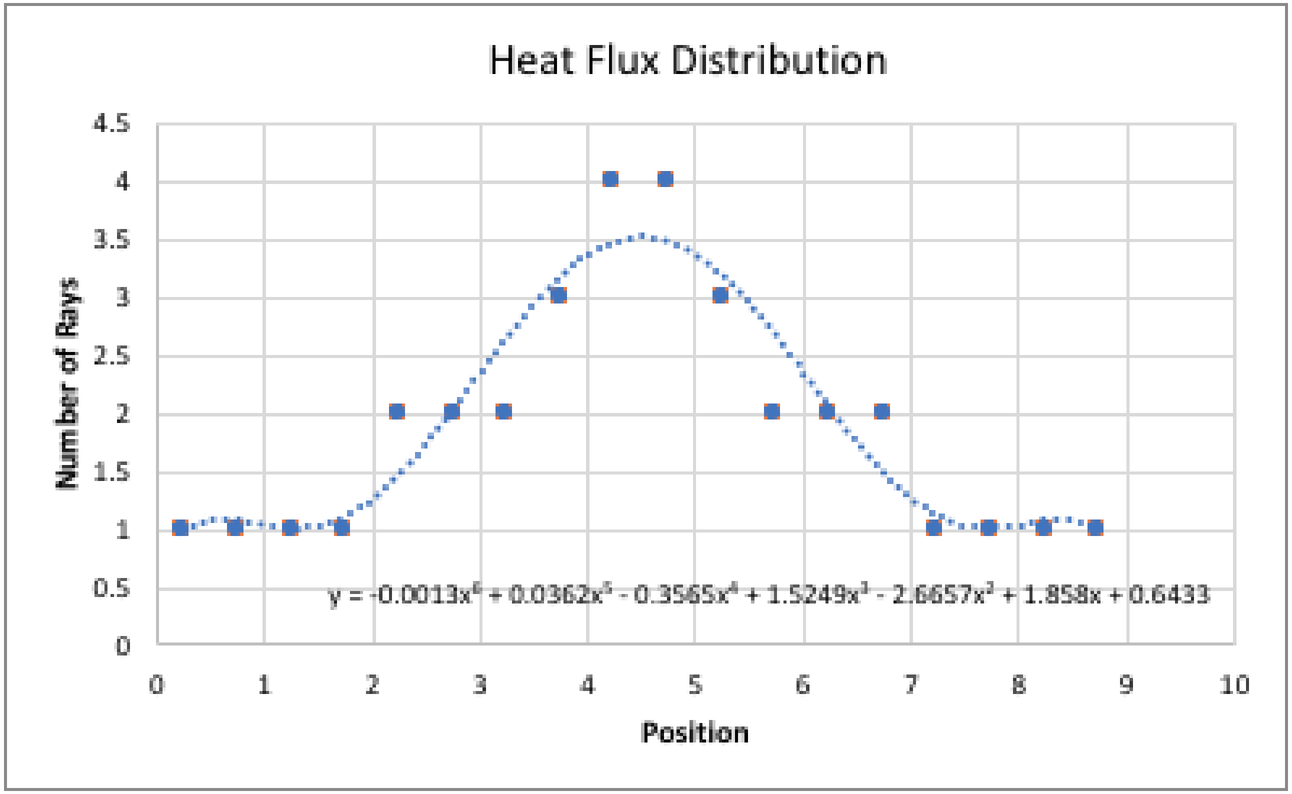
Analytical Reports – Temperature and Heat Flux Distribution (cont.)

- A method called ray-tracing was used to look at the heat flux distribution on the surface of the radome
- This analysis helps determine the spacing of the quartz lamps and ensures every part of the radome receives 50 W/cm2 ± 10%



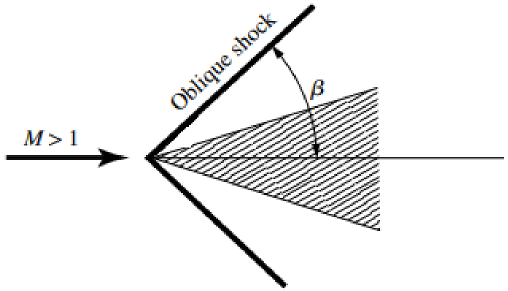


Analytical Reports – Temperature and Heat Flux Distribution (cont.)



- The quartz lamps span from position 2 to 7
- This analysis tells us that the heat flux peaks in the center of the lamps
- Lamps will be positioned right next to each other for now
- Further analysis will need to be done to get the exact spacing of the lamps

Analytical Reports - Compressible Flow



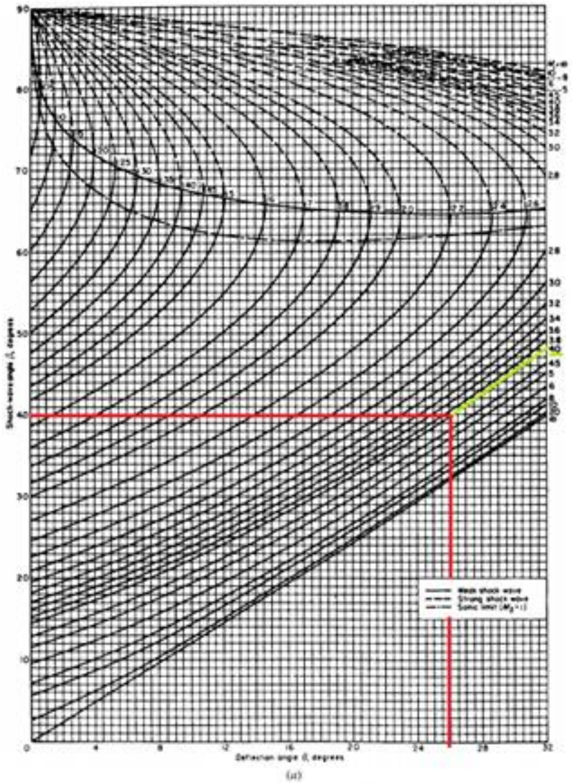


Figure 9.9 Oblique shock properties: $\gamma = 1.4$. The θ-β-M diagram. (Source: NACA Report 1135, Ames Research Staff, "Equations, Tables and Charts for Compressible Flow," 1953.)

Inputs

Angle of Radome – 26°

Speed – 4,051 ft/s (Mach 4)

Altitude – 20,000 feet

Angle of Attack – 10°

Air Density at Altitude – .0317 lbf/ft^3

Outputs

Shock Wave Angle (β) – 40°

Air Speed Post Shock wave– Mach 2.57

Stagnation Pressure Post Shock Wave – 7.72 X Freestream Pressure

Coefficient of Drag – 0.585

Force of Drag – 40,627 lbf

Moment from A.O.A. – 45,503 in-lb

Analytical Reports – Plate and Floor Bolt

- Foor Bolts
  - SAE Grade 5
  - 5/8"-18 steel bolts
  - Fastener length of 1.96" or greater
- Design Changes
  - Front leg from 18 to 6 bolts
  - Back leg from 22 to 8 bolts
- For AMRAAM Plate Bolts
  - Redone calculations to match floor bolts
  - Bolts can be reduced from 24 to 8 bolts
- All bolts now match and meet required factor of safely

Analytical Reports - Beams

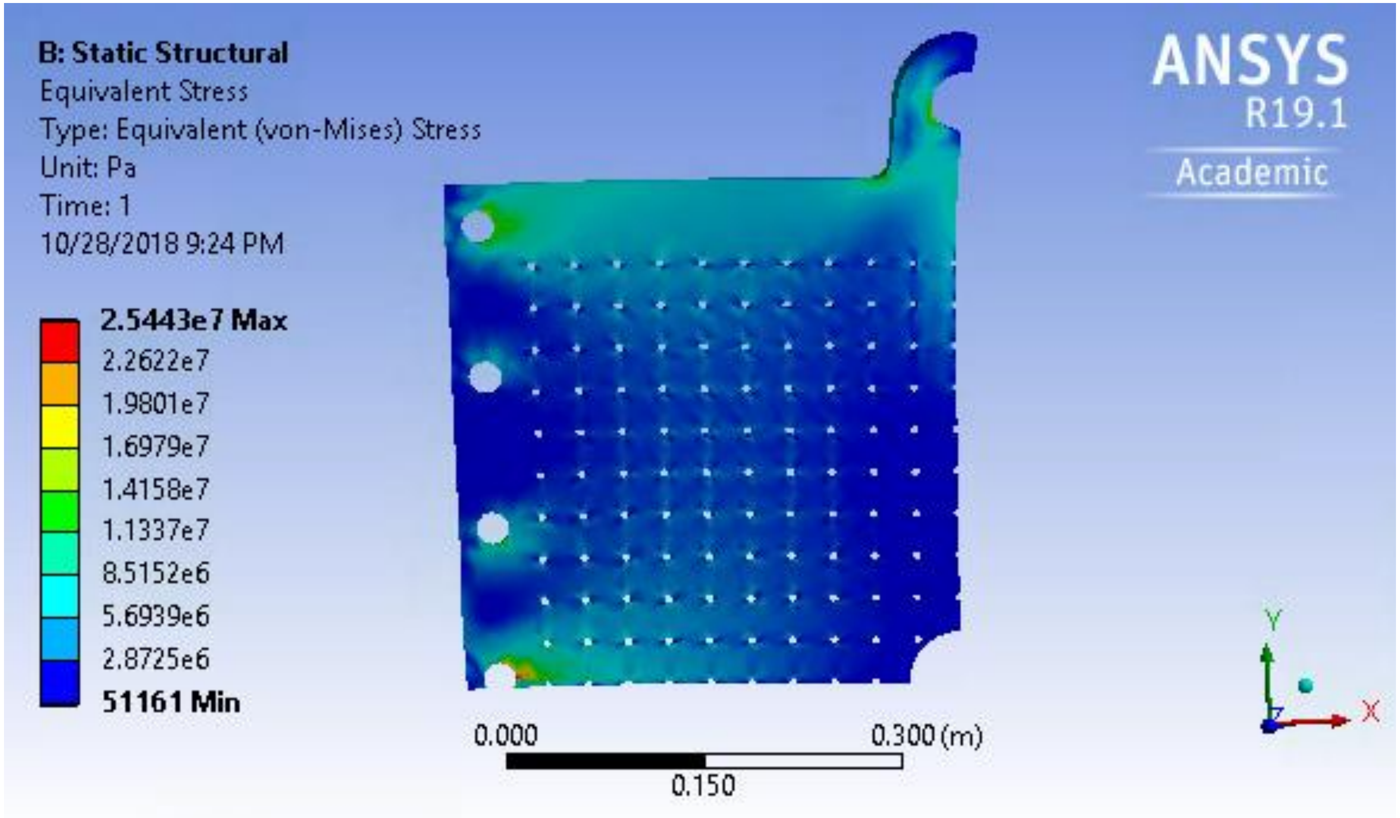
- With input force on the radome of 2014 lbf
- The maximum moment on the upright is 163,308 in.lb
- Calculating the stress

$$\sigma_{max} = \frac{Mc}{I}$$

M = Moment
C = distance from neutral axis to max stress
I = Moment of inertia

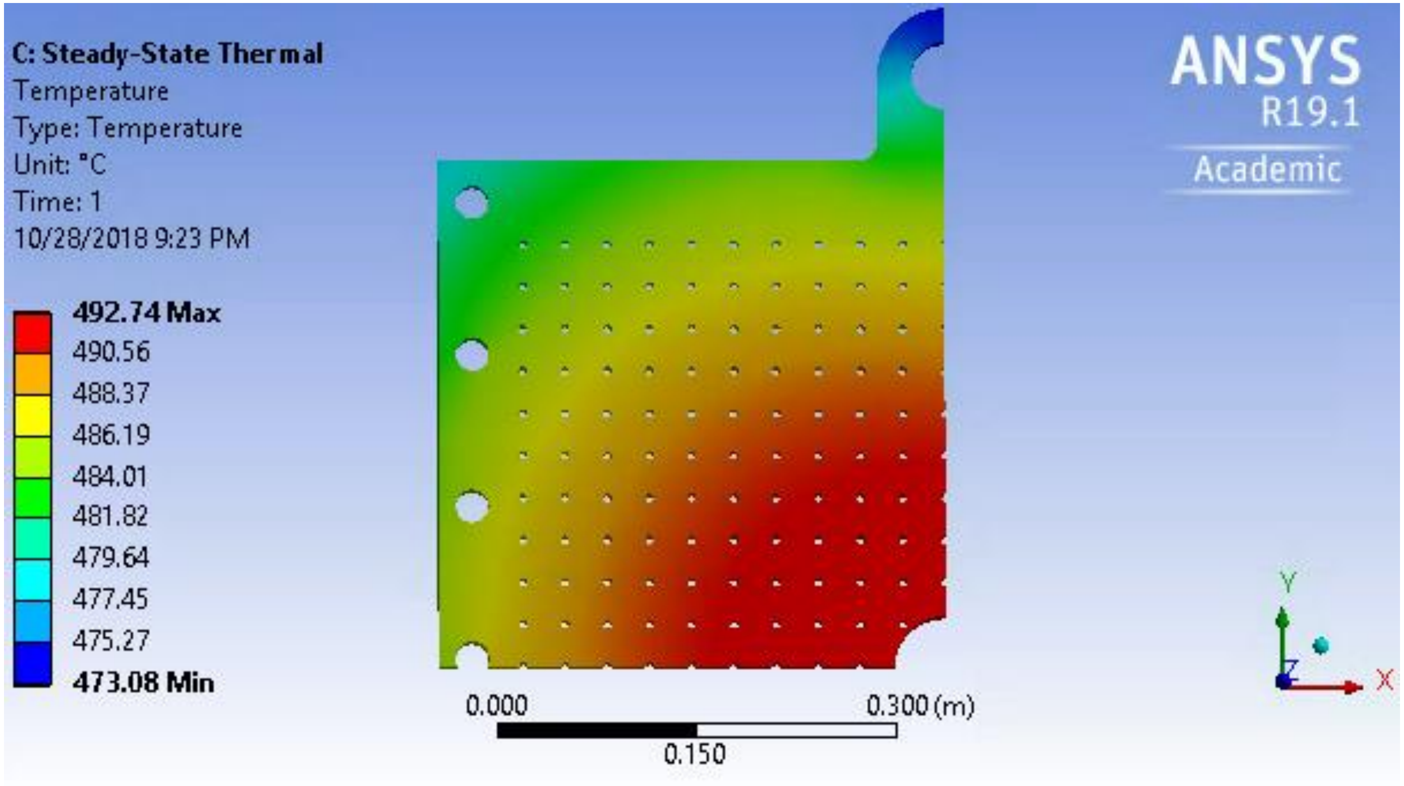
- 180 mm x 180 mm square beam, t = 6 mm
- Moment of inertia is 2036.52 cm^4
- The maximum stress is 8156 N/cm^2
- Yield strengh of 430 steel is 34500 N/cm^2
- Factor of safety is 4.23

Additional Analysis – Plate Stress



- A structural analysis was performed to identify high stress concentrations and potential points of failure.
- Quarter symmetry was used to reduce the number of nodes and elements needed
- Max stress was 25.4 MPa, Steel fails at 250 MPa
- However, this analysis does not take thermal expansion into account

Additional Analysis – Plate Stress



- Structural analysis depends of the results of the thermal analysis
- Entire plate has roughly the same temperatures

Additional Analysis – Power and Water Requirements

The Model 5209 Hi- TempIR

- The heater uses 6 KW of power
- The junction box id designed to accept 240 volt
- Flexible tubing and plumbing fittings are supplied with each heater
- Cooling water flow rate is 1 GPM
- Twenty feet of cooling water tubing are supplied each heater
- Cooling air flow is 4 SCFM at 3 PSI with a regenerative blower of 20 CFM at 6.2 PSI
- 10 feet length of flexible tubing for the air flow
- It takes 3 minutes to be safe to touch the heater

Additional Analysis – Time Study

Item	Description	Quantity	Time (min)	Total (min)
1	Forklift A-Frame	2	7	14
2	Forklift Universal Plate	1	7	7
3	Torque Bolts w/ Nuts	12	1.5	18
4	Torque Bolts w/o Nuts	32	1	32
5	Assemble Radome	1	30	30
6	Connect Thermocouples	150	2	300
7	Connect Strain Gauges	25	2	50
8	Forklift Hydraulic Ram	1	7	7
9	Connect Heat Lamps	8	5	45
10	Connect Air/Water Lines	24	1.5	36

*not all inclusive

Moving Forward - Gantt Chart

Task	Person Assigned	Start Date	Completion Date	27-Aug	3-Sep	10-Sep	17-Sep	24-Sep	1-Oct	8-Oct	15-Oct	22-Oct	29-Oct	5-Nov	12-Nov	19-Nov	26-Nov	3-Dec	10-Dec
Final Proposal Report Rewrite	All	27-Aug	29-Aug																
Individual Post Mortem	All	27-Aug	31-Aug																
Website Check 1	Aziz	10-Sep	14-Sep																
Progress Presentation	All	7-Sep	17-Sep																
Hardware Review 1	All	20-Sep	3-Oct																
Individual Analysis II																			
-Bolt Calculations	Shanna	20-Sep	12-Oct																
-Box Beam Calculations	Aziz	20-Sep	12-Oct																
-Compressible Flow Calculations	Israel	20-Sep	12-Oct																
-Quartz Lamp Calculations	Lexie	20-Sep	12-Oct																
Hardware Review 1 Summary	All	3-Oct	5-Oct																
Peer Evaluation 1	All	5-Oct	7-Oct																
Midpoint Report	All	8-Oct	19-Oct																
Midpoint Presentation/HR2	All	13-Oct	29-Oct																
Power and Water Requirements	Aziz	13-Oct	29-Oct																
Plate Stress Analysis	Lexie	13-Oct	29-Oct																
Bolt Thermal Expansion	Shanna	13-Oct	29-Oct																
Assembly Time Study	Israel	13-Oct	29-Oct																
Hardware Review 2 Summary	All	24-Oct	2-Nov																
Peer Evaluation 2	All	26-Oct	4-Nov																
Website Check 2	Aziz	28-Oct	9-Nov																
Draft of Poster	All	26-Oct	9-Nov																
Draft of Operation Manual	All	26-Oct	9-Nov																
Final Product Testing Proof	All	26-Oct	12-Nov																
Final Presentation	All	12-Nov	26-Nov																
Final Poster	All	12-Nov	26-Nov																
Final Operation Manual	All	12-Nov	30-Nov																
Final Report	All	20-Nov	7-Dec																
Final CAD and BOM	Israel	26-Nov	5-Dec																
Website Check 3	Aziz	7-Dec	10-Dec																
Peer Evaluation 3	All	10-Dec	12-Dec																

Schedule

2nd Semester Tasks	Estimated Completion Date
Progress Presentation	September 17th, 2018
Hardware Review 1	October 1st, 2018
Calculations / Design – 2nd Iteration	October 5th, 2018
Individual Analysis II	October 8th, 2018
Midpoint Report & Presentation, Hardware Review 2	October 22nd, 2018
Final Product Testing Proof	November 12th, 2018
Final Presentation and Poster	November 26th, 2018
Final Report and CAD Package	December 3rd, 2018

Budget

- Available Capstone funds: **$800**
- Actual Expenses to Date: **$25**
- Remaining Funds: **$775**

#	Item	Unit Cost	Units	Total	Supplier
1	5/8-11 X1½" HH	$1.16	45	$52.20	https://www.mcmaster.com/standard-hex-head-screws
2	5/58" Washer	$0.73	45	$32.90	https://www.mcmaster.com/90107a035
3	5/8" Nut	$0.30	24	$7.29	https://www.mcmaster.com/95462a533
4	Signal/Power Connector, 37 Poles	$53.93	4	$215.72	https://www.mcmaster.com/8903t74
5	Signal/Power Connector, 7 Poles	$15.95	4	$63.80	https://www.mcmaster.com/8903t36
6	12 Circuit Terminal Block	$26.40	15	$396.00	https://www.mcmaster.com/terminals
7	8x6x3/16" A550 Box Tube	$42.30	25	$1057.50	https://www.metalsdepot.com/steel-products/steel-rectangle-tube
8	Quartz Heat Lamps	$679.00	10	$6790.00	http://www.infratechheatersusa.com/lighting/
9	Hydraulic Ram	$655.12	1	$655.12	http://www.tooldiscounter.com/
	Total			**$9270.41**	

- Anticipated Full-Scale Expenses: **$9270.41 + Labor**
- Anticipated Model Expenses: **$40** - 3D printed

Hardware Review 2

Our project is analytical, so we are using analyses to validate that the system works.

The following analyses have been completed thus far:

1. Compressible Flow/Mechanical Loading Calculations
2. Quartz Lamp Spacing Calculations
3. Box Beam Dimension Calculations
4. Threaded Fastener and Bolt Dimension Calculations
5. Plate Stress Analysis
6. Power and Water Requirements
7. Time Study

Almost every major subsystem has been validated with calculations. A few analyses still need some adjustments.

Conclusion

In the final month, the team will finalize the validation calculations and additional analyses. The reduction of material and threaded fasteners is still our primary objective.

References

[1] Raytheon.com, 'Mission, Global Defense', 2017. [Online]. Available: https://www.raytheon.com/capabilities/missiledefense. [Accessed 2/7/2018]

[2] J.D. Anderson, Jr., Fundamentals of Aerodynamics. New York, NY: Mc Graw Hill, 2011
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