An Experimental and Numerical Study to Analyse Mixed Convection Regime in a Fuselage Crown Compartment

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Presented by M. Geron

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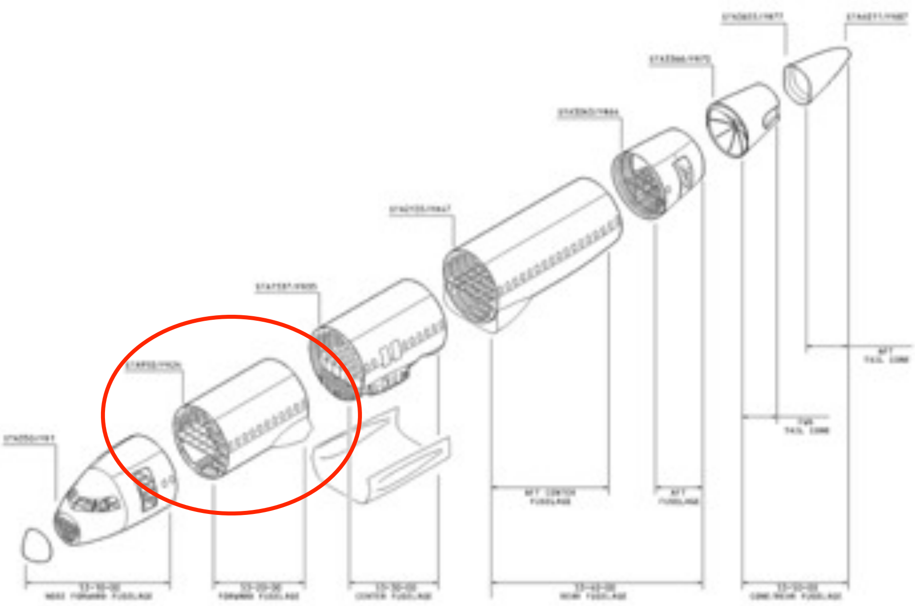
Overview

- MAAXIMUS project
- Test Case Description
- Model description
  - Numerical
  - Experimental
- Numerical Results
- Numerical and experimental comparison
- Way forward



Overall Project Objectives:

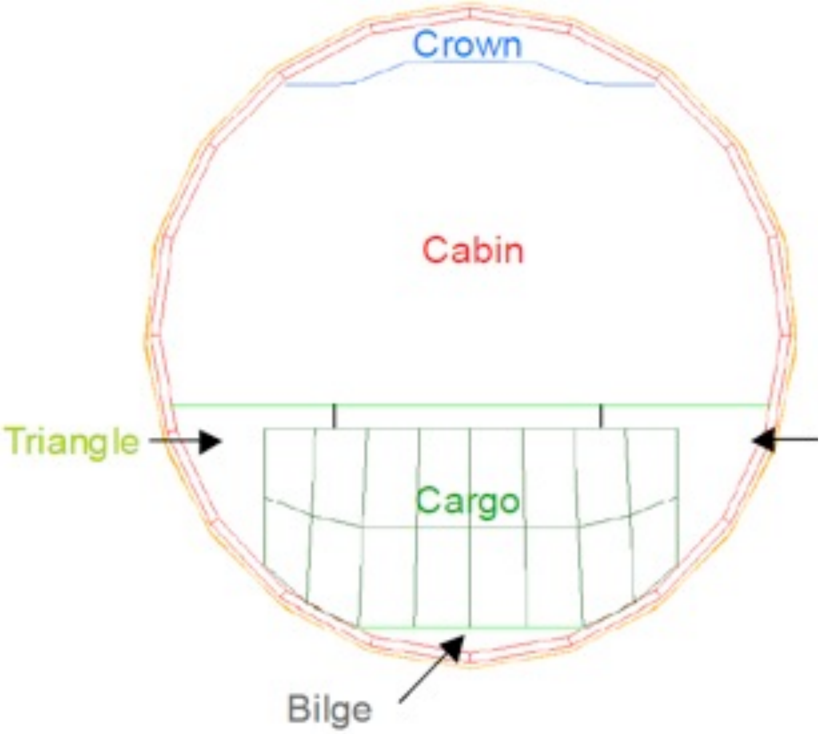
Weight Reduction – replacing the number of parts with *'one-shot'* technology

Final Assembly Reduction – adapt production lines for composites

Simulation-based Design – reduce dependence on physical testing

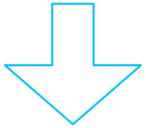
Understanding Composite behaviour – reliability and safety

MAAXIMUS-Thermal Activity

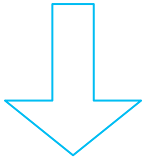


Improve thermo analysis

- Global Thermo Analysis at barrel scale

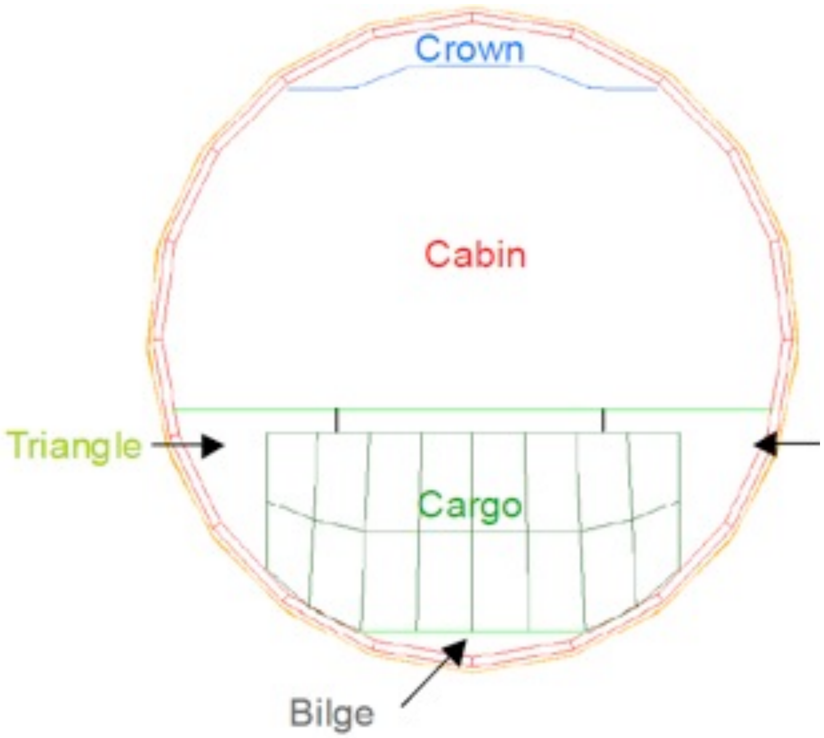


- Different Thermal behaviour of Composite Material
- Predict tools improvement



- More detailed thermal analysis

MAAXIMUS-Thermal Activity



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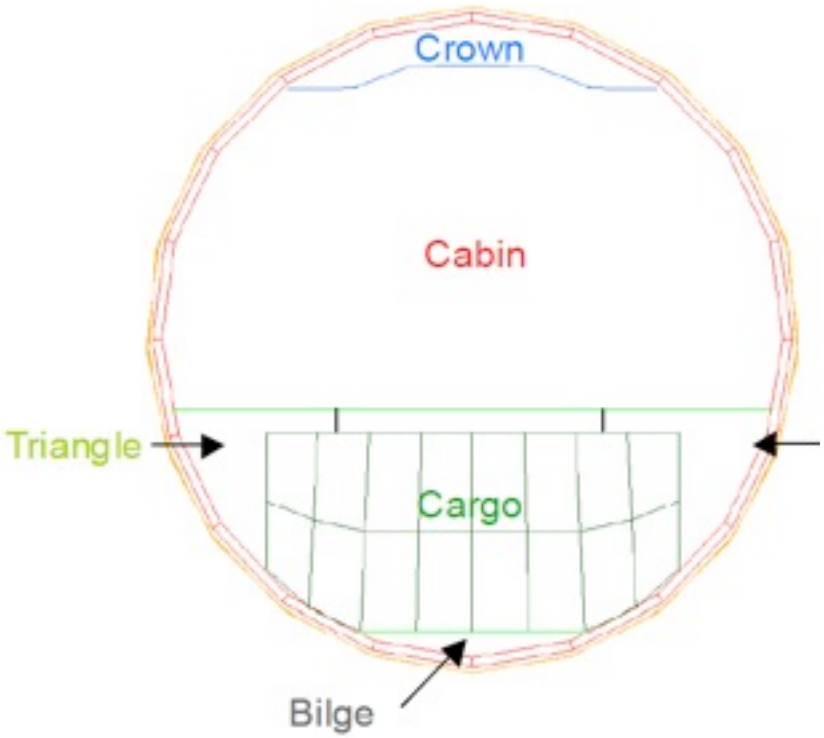

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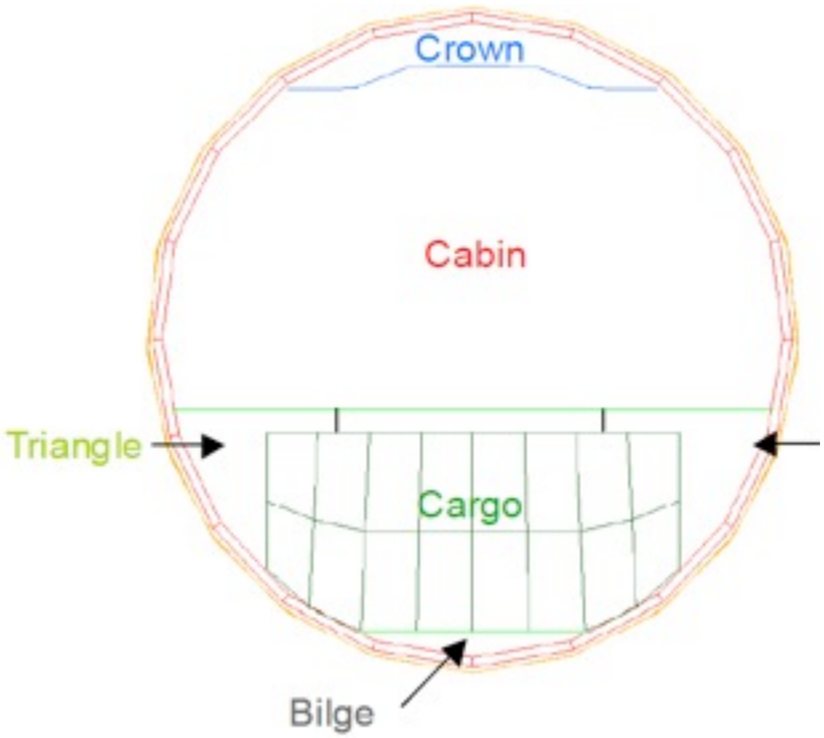

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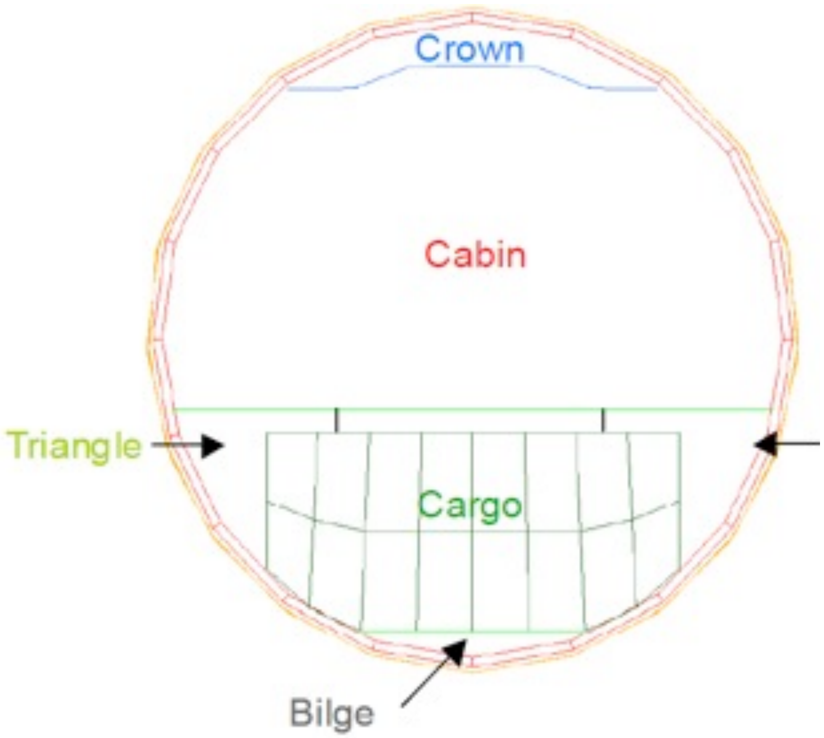

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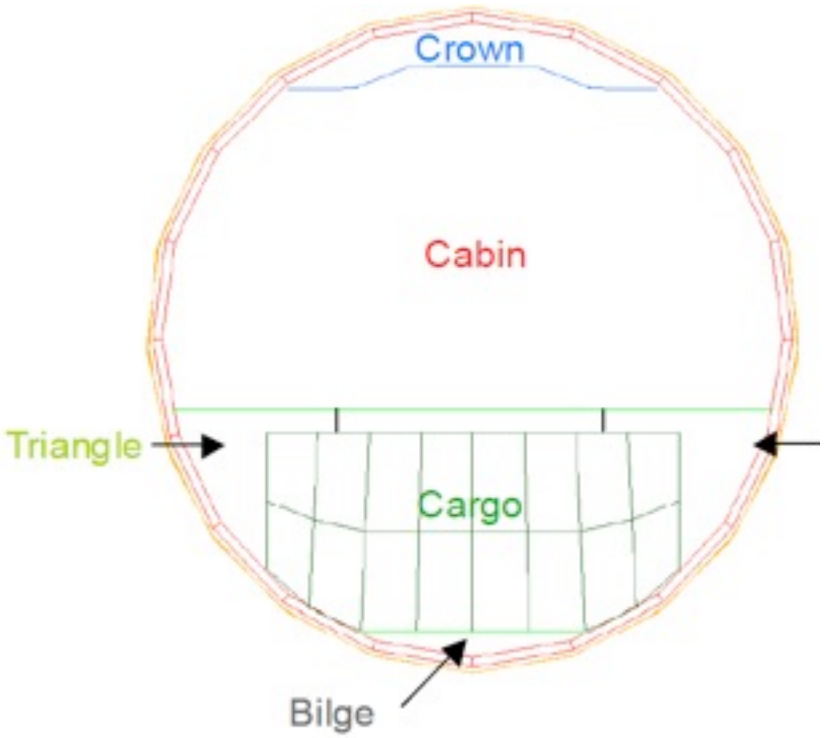

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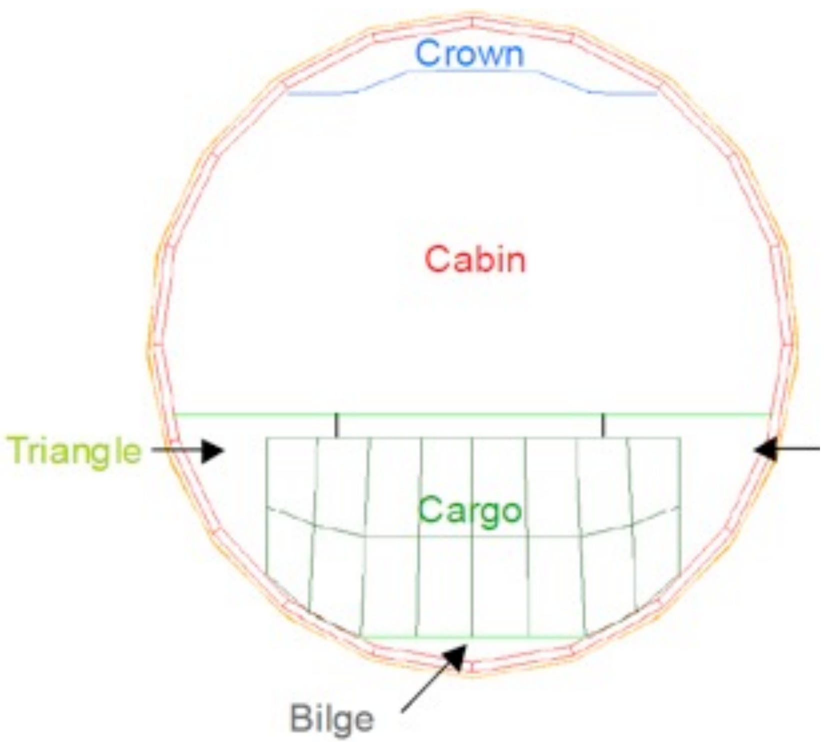

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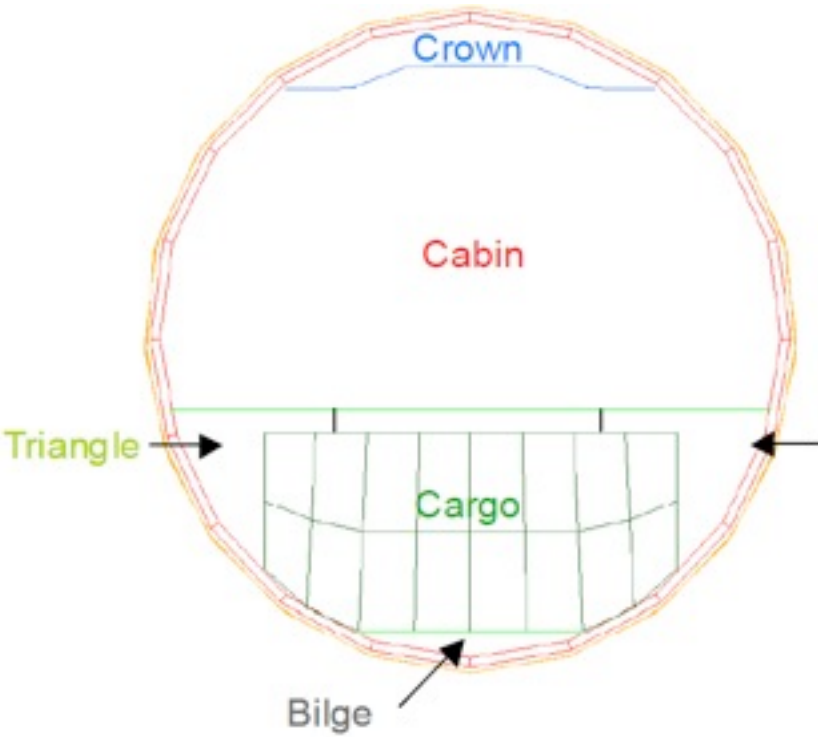

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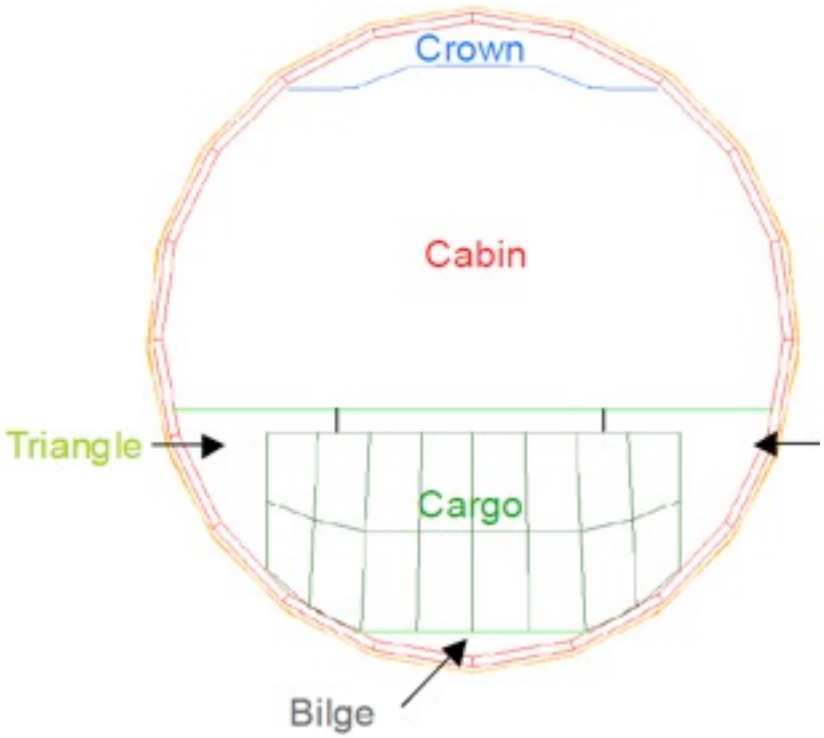
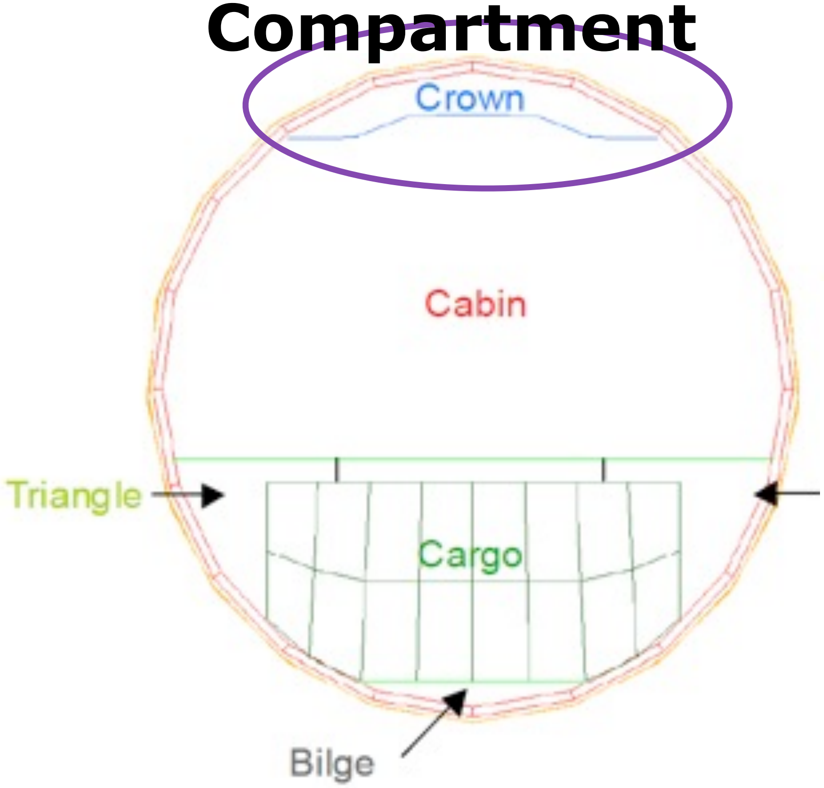


- Analysis and modelling
- of the thermal behaviour
- of fuselage
- confined compartments

- Crown Compartment



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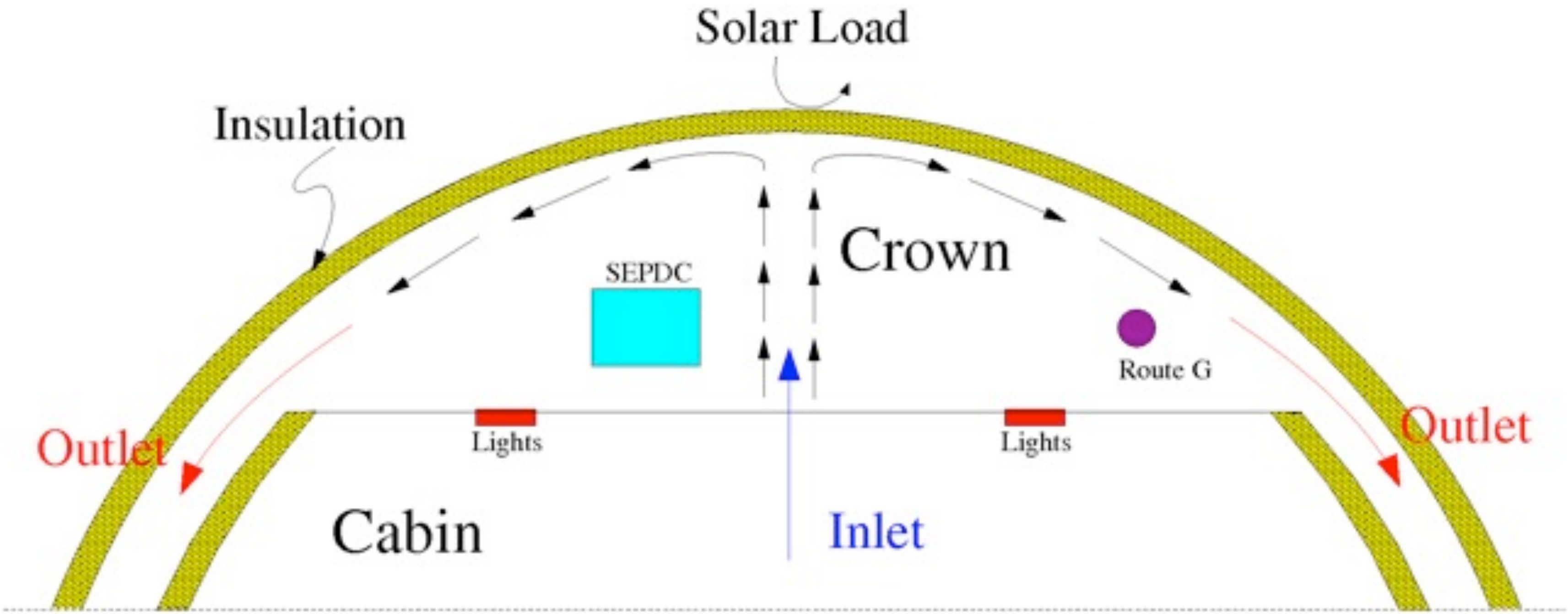
Crown Compartment



- Complex compartment to model
- Solar Load
- Air Flow
  - Air condition
- Obstruction elements
  - Pipes
- Dissipating Elements
  - Lights
  - Electrical wires
  - Power supply

Crown Compartment Physical Model

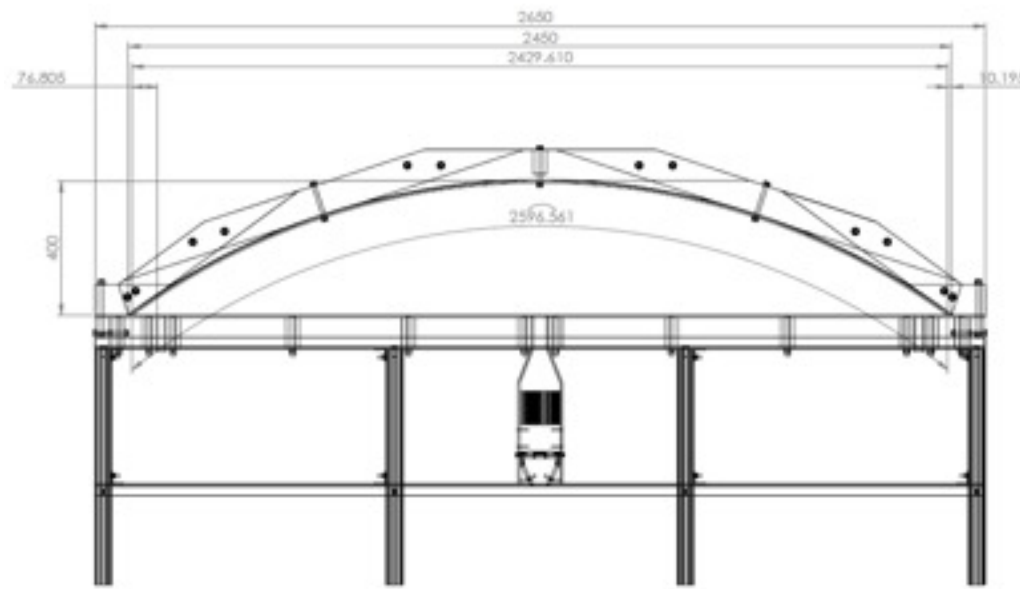
Drafting of 3D models and 2D working drawings:

- Width and height are kept same as an actual crown

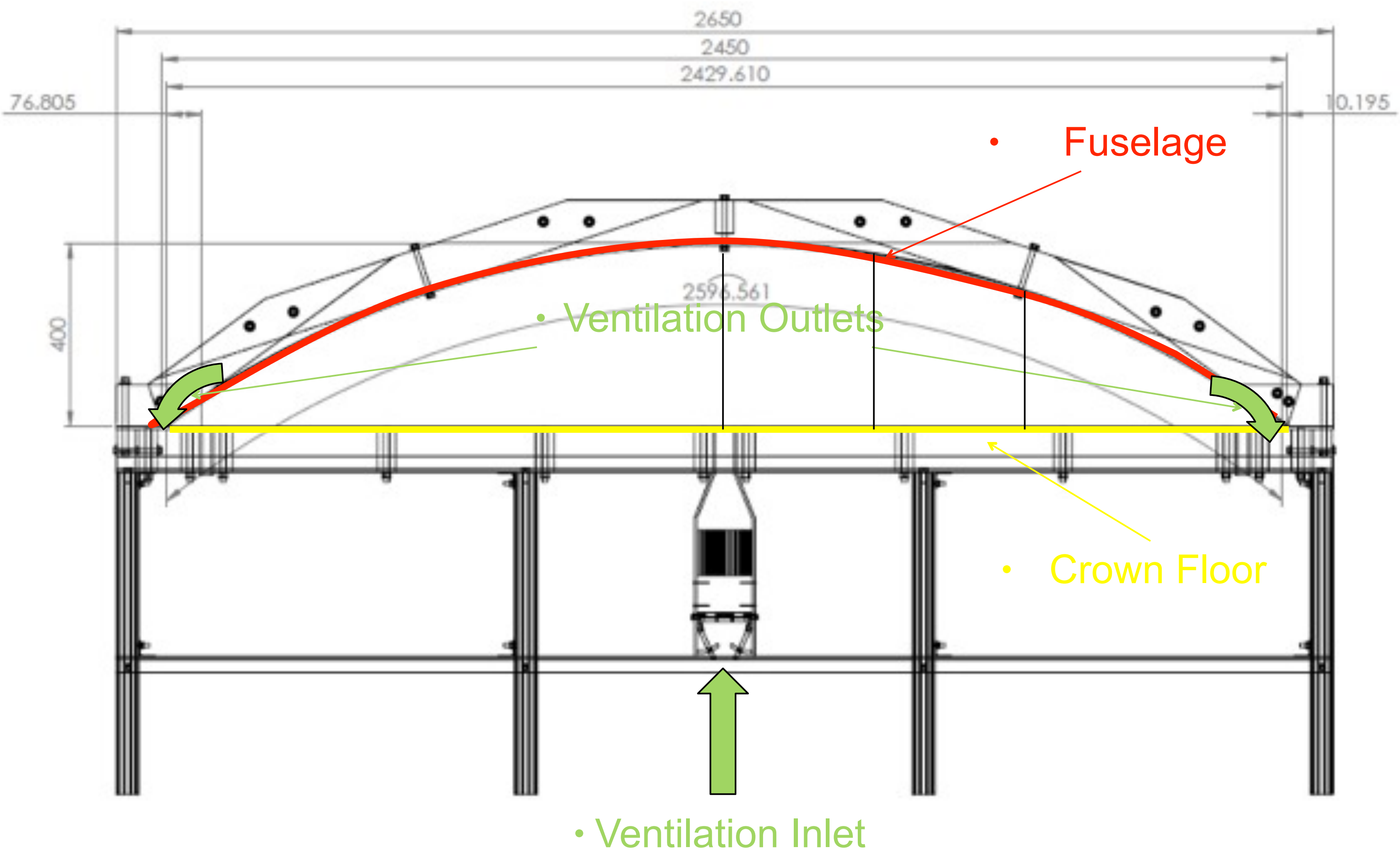
  (2.45m x .4m)
- Depth reduced to 2 frames

  (1.17m)
- Air inlet = 40mm
- 2 x Air outlets = 20mm
- Material Used
  - Polycarbonate
  - Rockwool
  - Glass
- 1 layer insulation

  (50 mm)



Crown Compartment Rig Design



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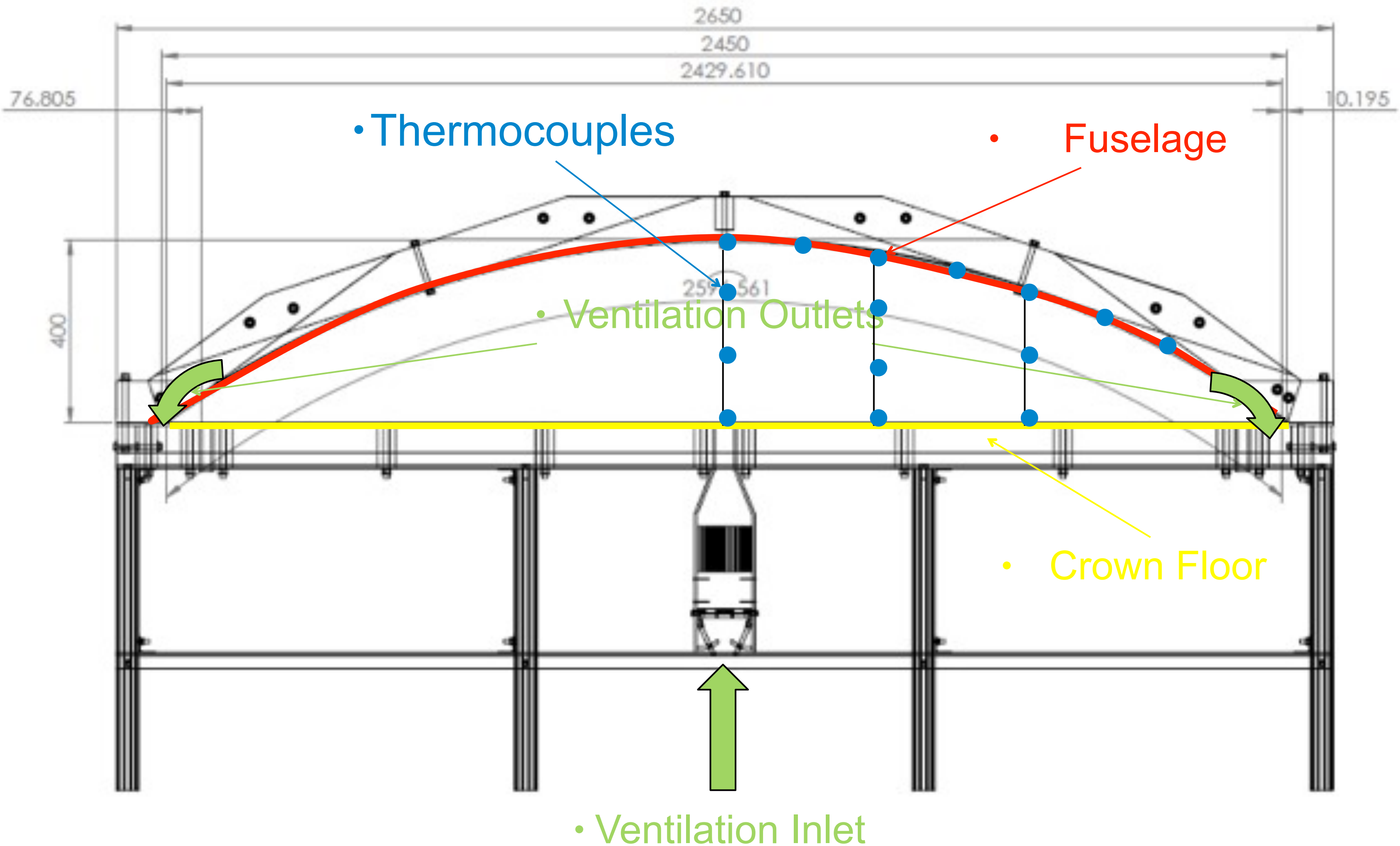


Physical Model

Physical Model Detail

Boundary Conditions

- Experimental Rig
  - Fuselage Temperature
    - Temperature maintained constant by PID controller and 12 heater mats
  - Air flow
    - Mass flow supplied by 10 fans series 400F
- Numerical Set-up
  - Fuselage Temperature
  - Velocity inlet
  - Crown floor Temperature

Flow Characteristics

- Convection Regime
  - Grashof Number Gr=6.5E+8
    - Transition Flow
  - Reynolds Number Re=359.4
    - *Laminar Flow*
  - Richardson Number
    - Forced convection negligible

$$Ri = \frac{Gr}{\mathrm{Re}^2} \approx 4680$$

- Modelling
  - Laminar Navier-Stokes equations
  - Boussinesq Approx. $g' = g \frac{\rho_2 - \rho_1}{\rho}$

Numerical Method and Solution Strategy

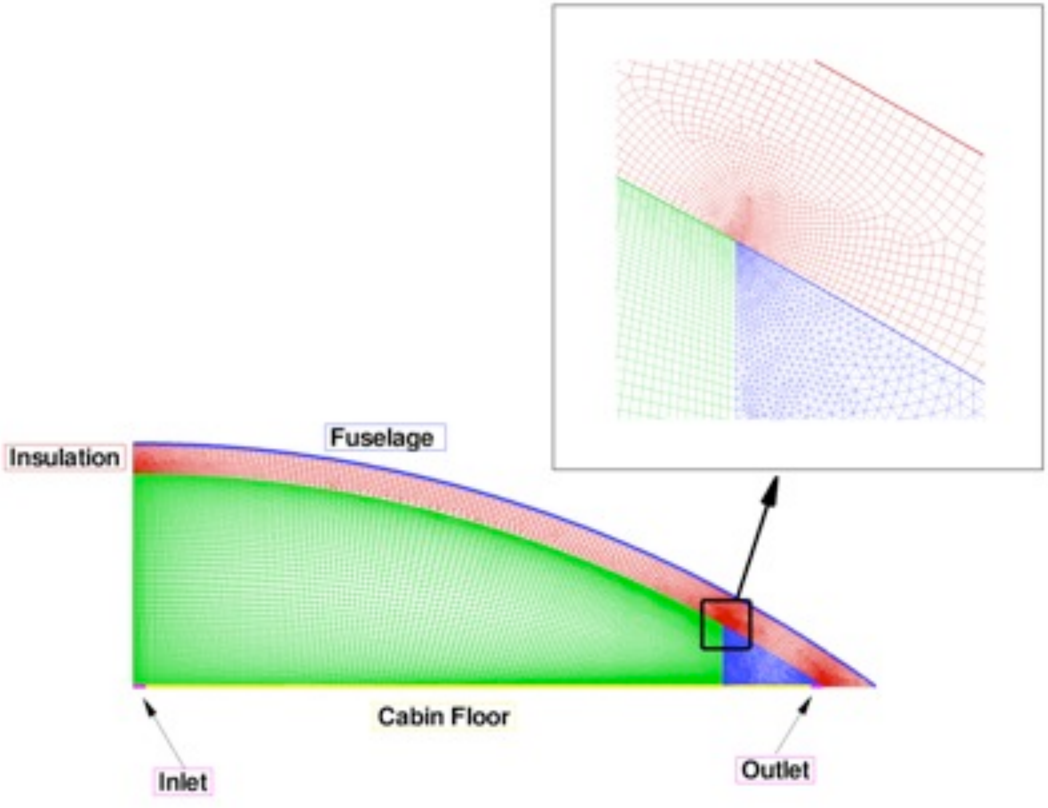
- Spatial Discretization
  - Pressure based coupled algorithm
  - Second order upwind scheme
- Time Discretization
  - First Order Scheme
- Green Gauss cell based scheme

$$\Delta t \approx \frac{\tau}{4} \approx \frac{L}{\sqrt{g\beta \Delta T L}} = 0.01s$$

- 5000
- time steps

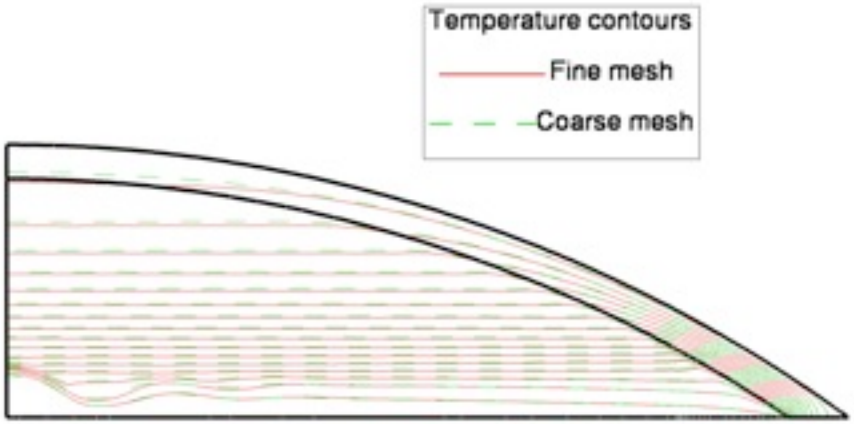
Steady → **Unsteady** → **Steady State**

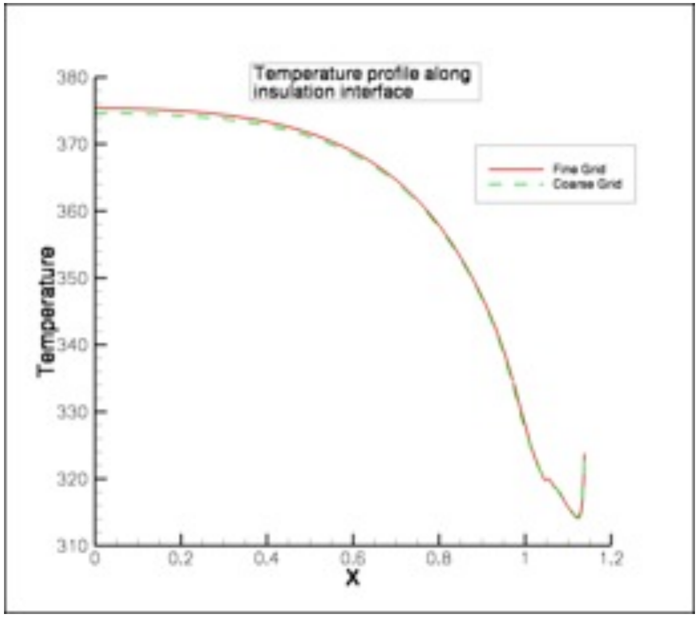
Domain and Mesh



- Domain
  - 2D
  - Symmetrical
  - Solid Zone
    - Insulation
  - Fluid Zone
    - Air
- Mesh
  - Multi-block
    - Structured
    - Unstructured
  - Wall mesh refinement

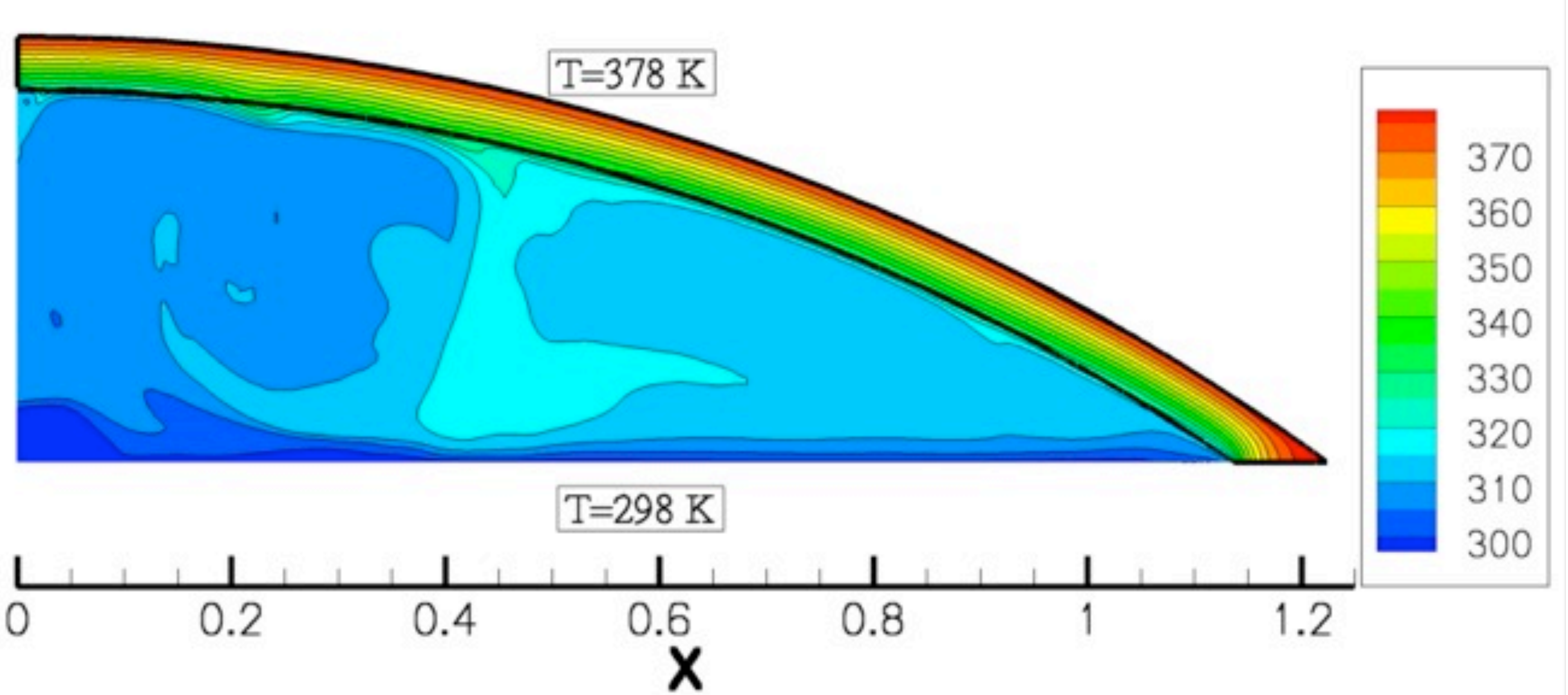
Grid Independence Analysis





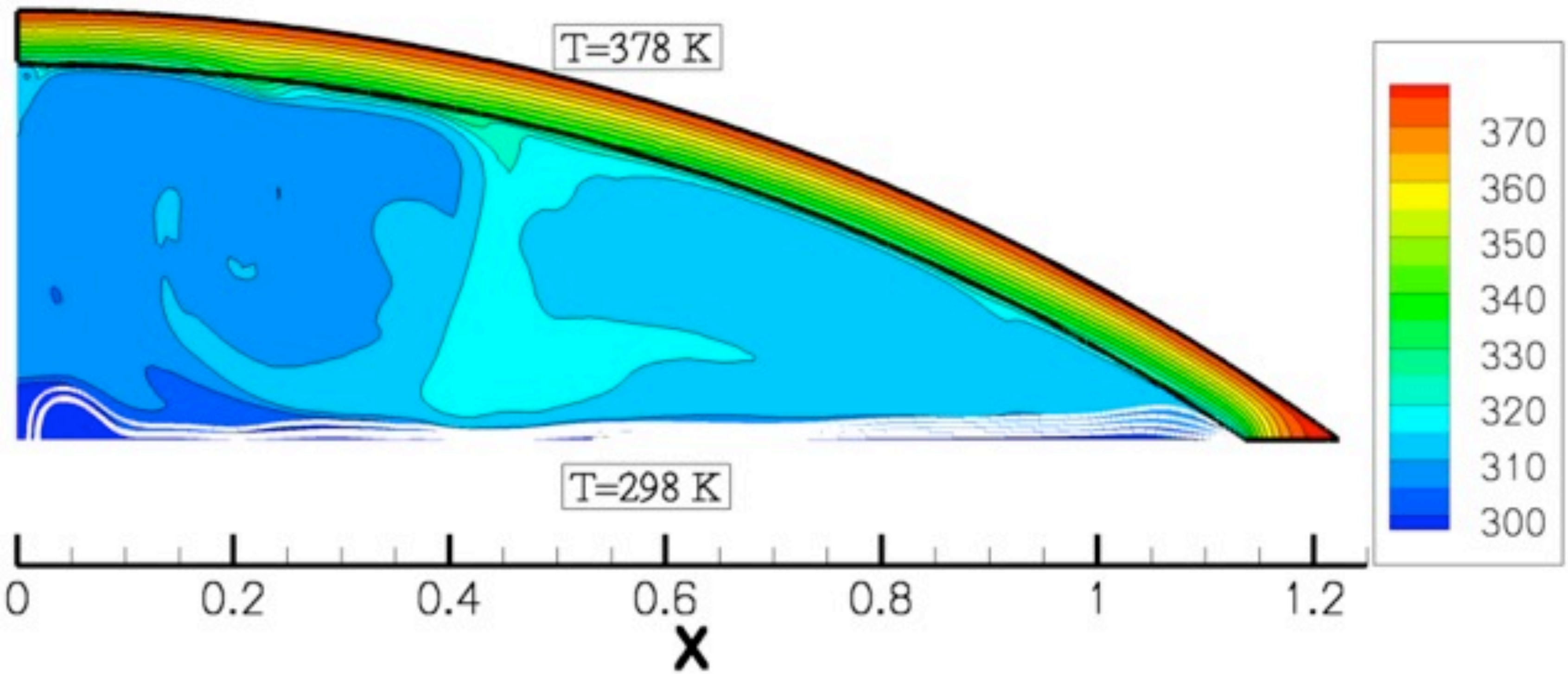
	AVG Temp	Plume height
Fine Grid	368.8340 338.1415 306.2025	1.74858
Coarse grid	368.5463 337.6625 306.0645	1.76623
GCI%	0.266858 0.484628 0.154185	3.4532

Results: Temperature Iso-Lines



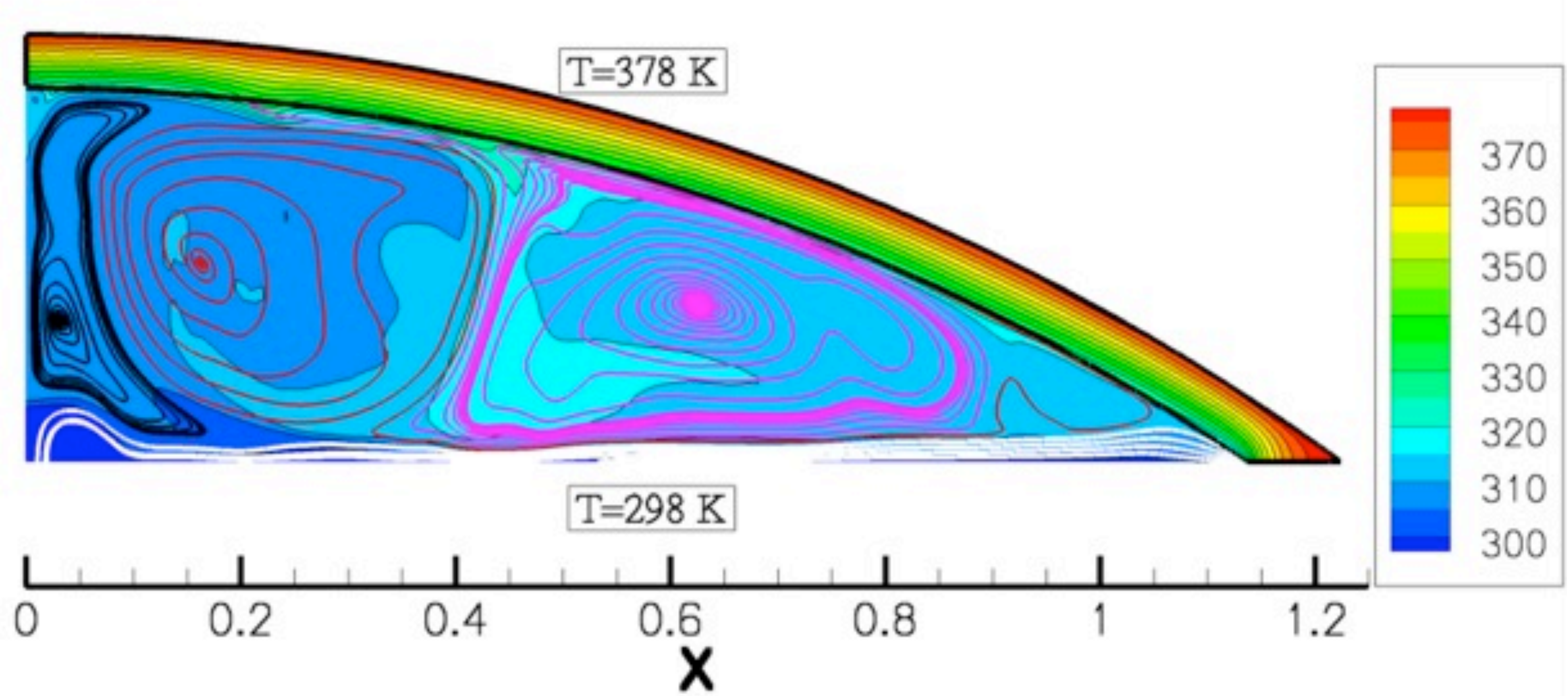
- ΔT (Ins.) = 50 K
- ΔT (Crown) = 30 K
- Temperature contours connected to flow features.

Results: Core Flow



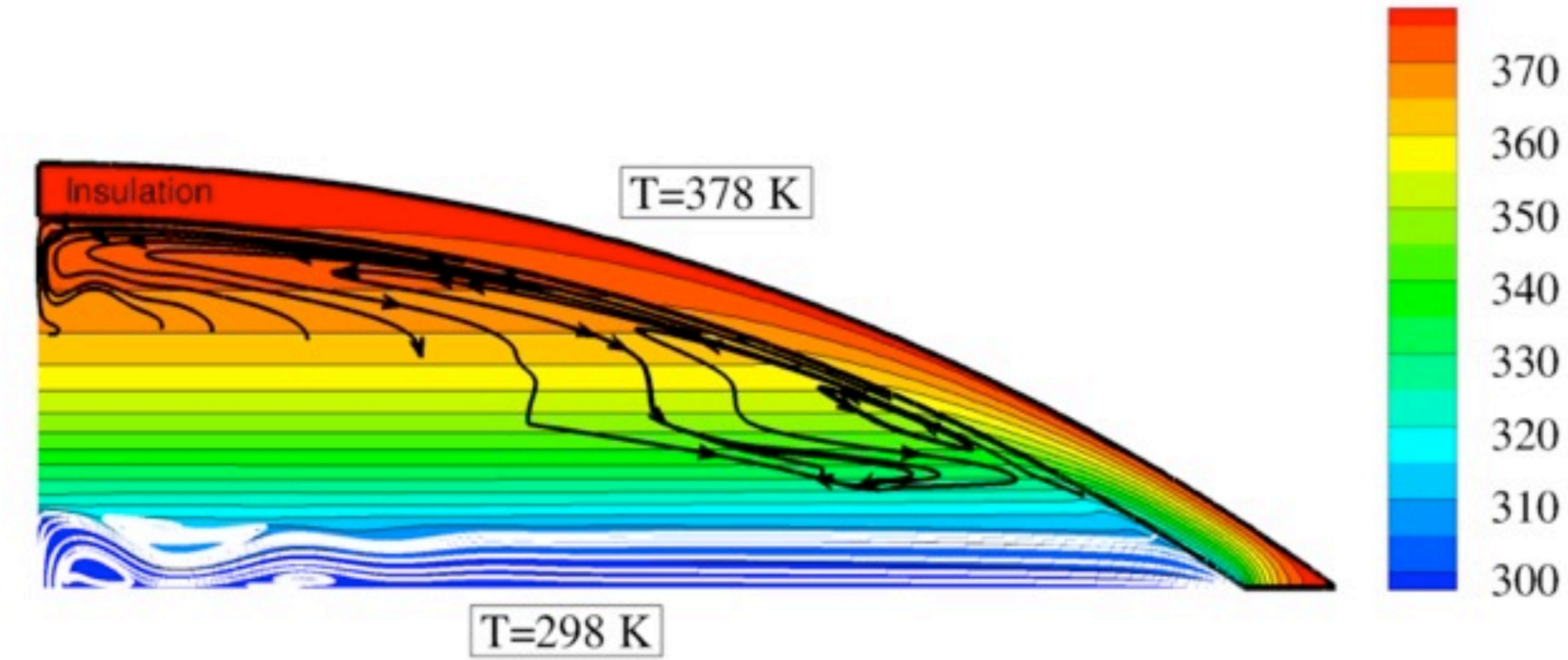
•Flow entering from inlet remains confined at the bottom of the compartment

Results: Buoyancy Driven Flow



- Three major recirculating zones are present due to buoyancy effects
- Unsteady behaviour of eddies
- Convergence problem

Unsteady Laminar Simulation



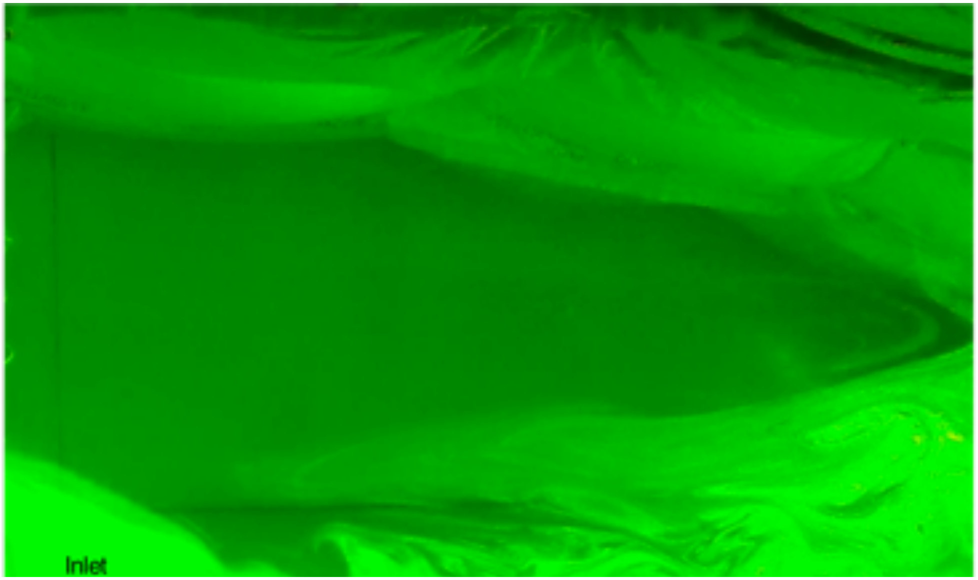
- Steady Solution utilised as initial solution
- Unsteady solution run

→

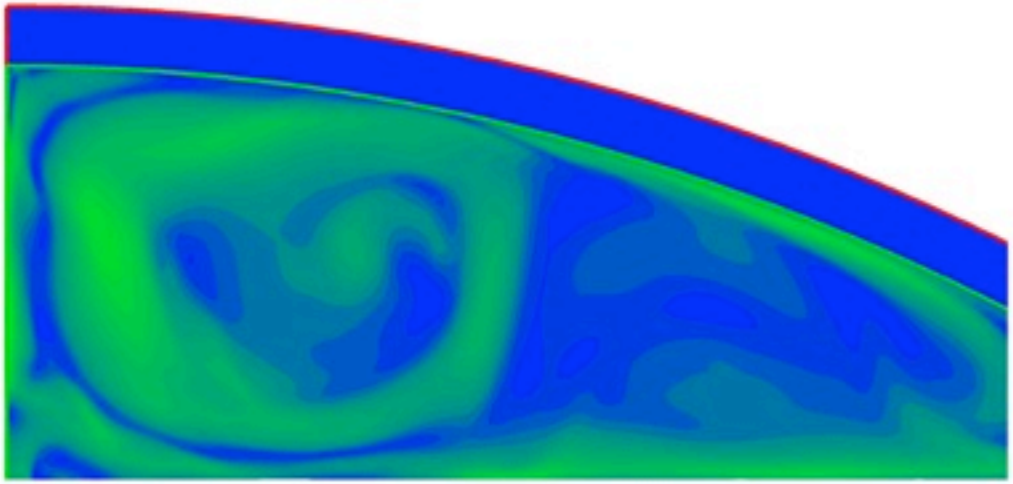
- Convergence reached
- but
- wrong solution

Flow Features Comparison

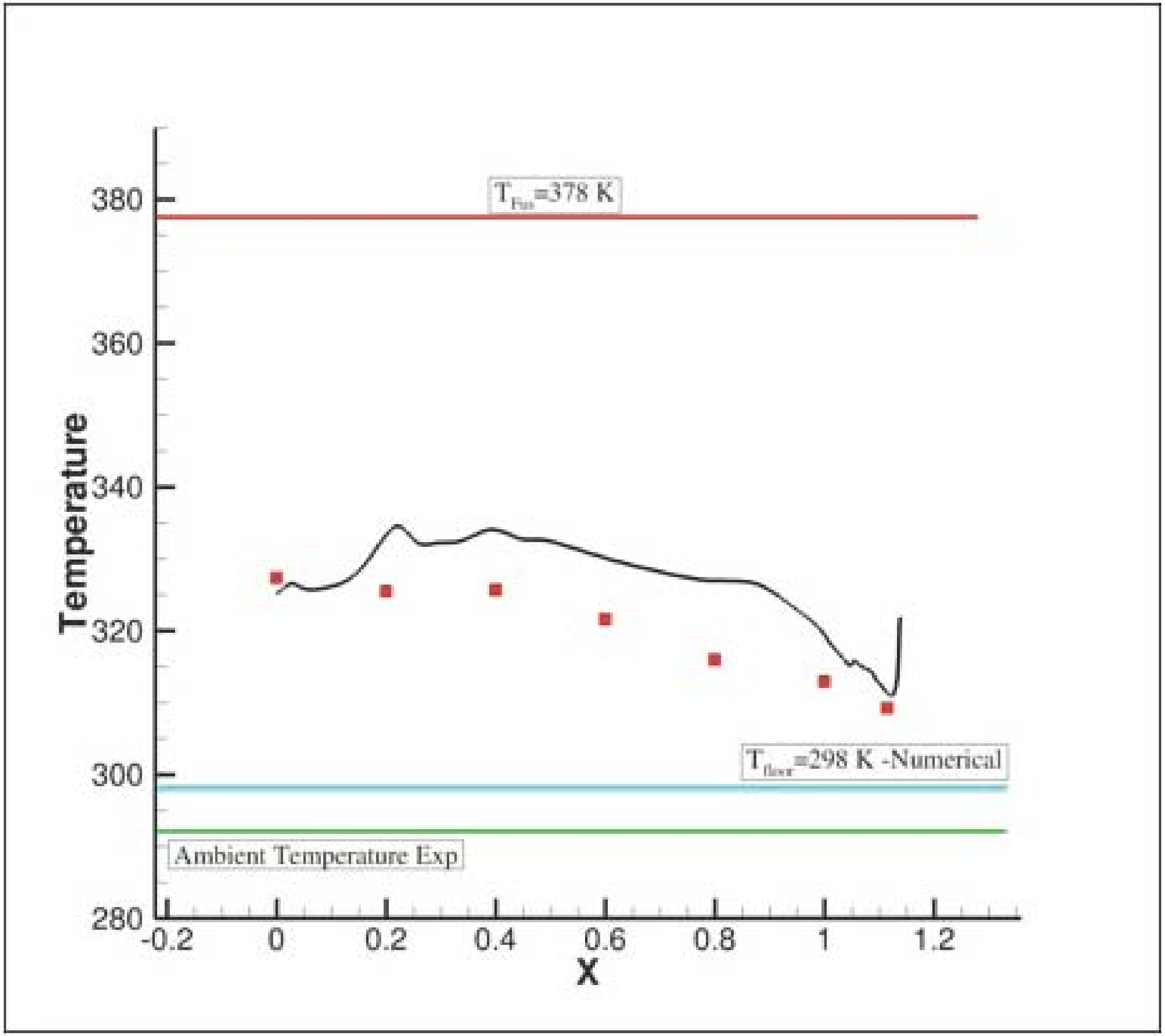
- Flow Visualization of inlet region and crown floor



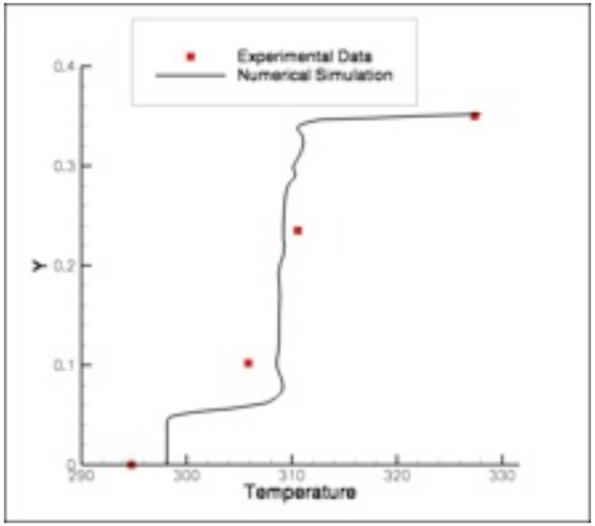
- Numerical simulation
- (steady flow)

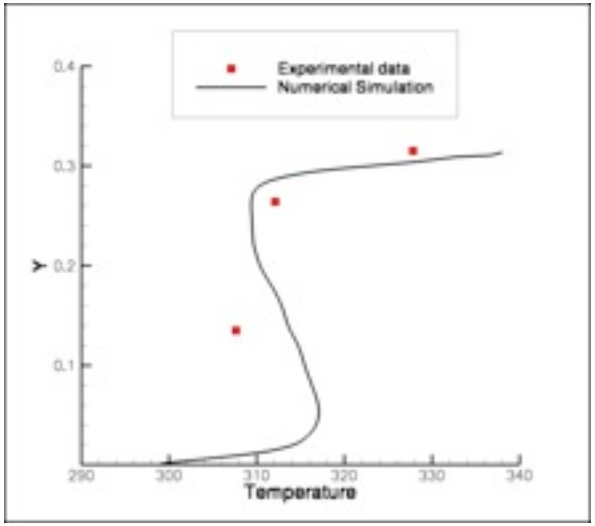


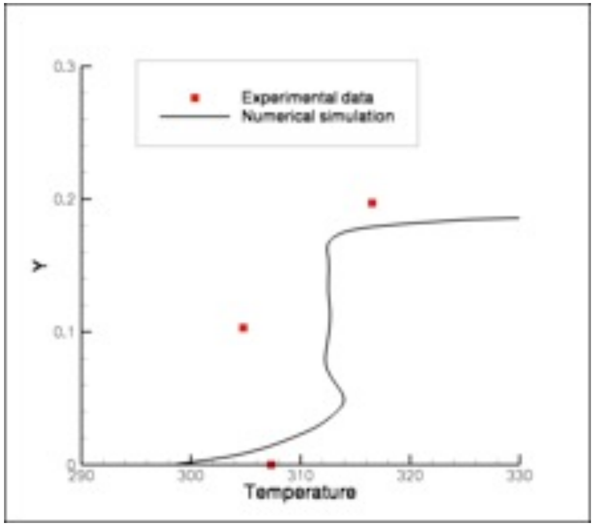
Insulation Temperature



Vertical Temperature Profiles







- a) Mid-section (x=0)
- b) Section 2 (x=0.4)
- c) Section 3 (x=0.8)

Conclusion

- Crown Compartment has been studied both numerically and experimentally
- Only one configuration analysed
  - Necessity to expand the comparison
- Numerical results
  - Steady results needs to be achieved
  - Solution strategy seems to fail for this configuration
  - Turbulent flow should be investigated
- Experiments
  - Necessity to acknowledge flow structures
    - PIV measurements are necessary

.....THE END

THANK YOU FOR YOUR ATTENTION

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