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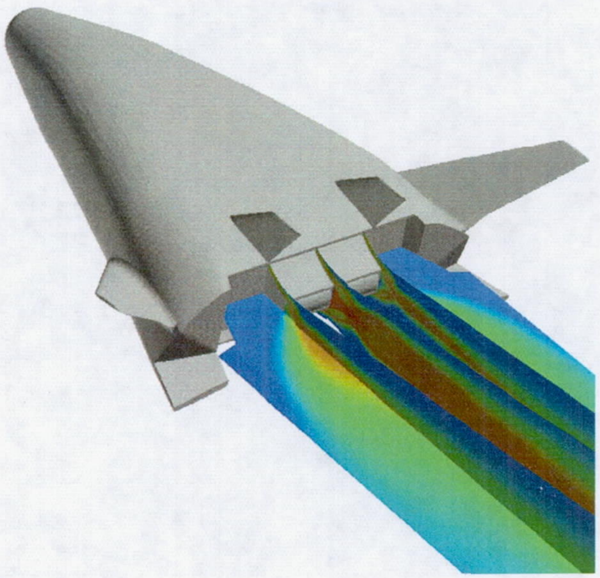
p20

Analysis of X-33 Linear Aerospike Plume Induced Base-Heating Environment During Power-Pack Out



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NASA – Marshall Space Flight Center

April 4-5, 2001

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Acknowledgment

- John Suter of X-33 Program Office

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CFD Analysis of X33 Flex Seal Environments During PPO

- Objective
  - Predict dual-engine base-heating at 57% PL at sea level
  - Predict dual-engine base-heating during PPO at 3 ascent abort trajectories
- Approach
  - 3D turbulent chemically reacting computational fluid dynamic and heat transfer analysis (FDNS, GASRAD and GRASP)
  - Full-vehicle and slip stream effects with dual-engine, 40-thruster, and base-pillow bleeds
  - Benchmarks
    - 7.75% scaled model cold flow test
    - 2.25% scaled model hot flow test
    - Installed full-scale engine hot-fire test

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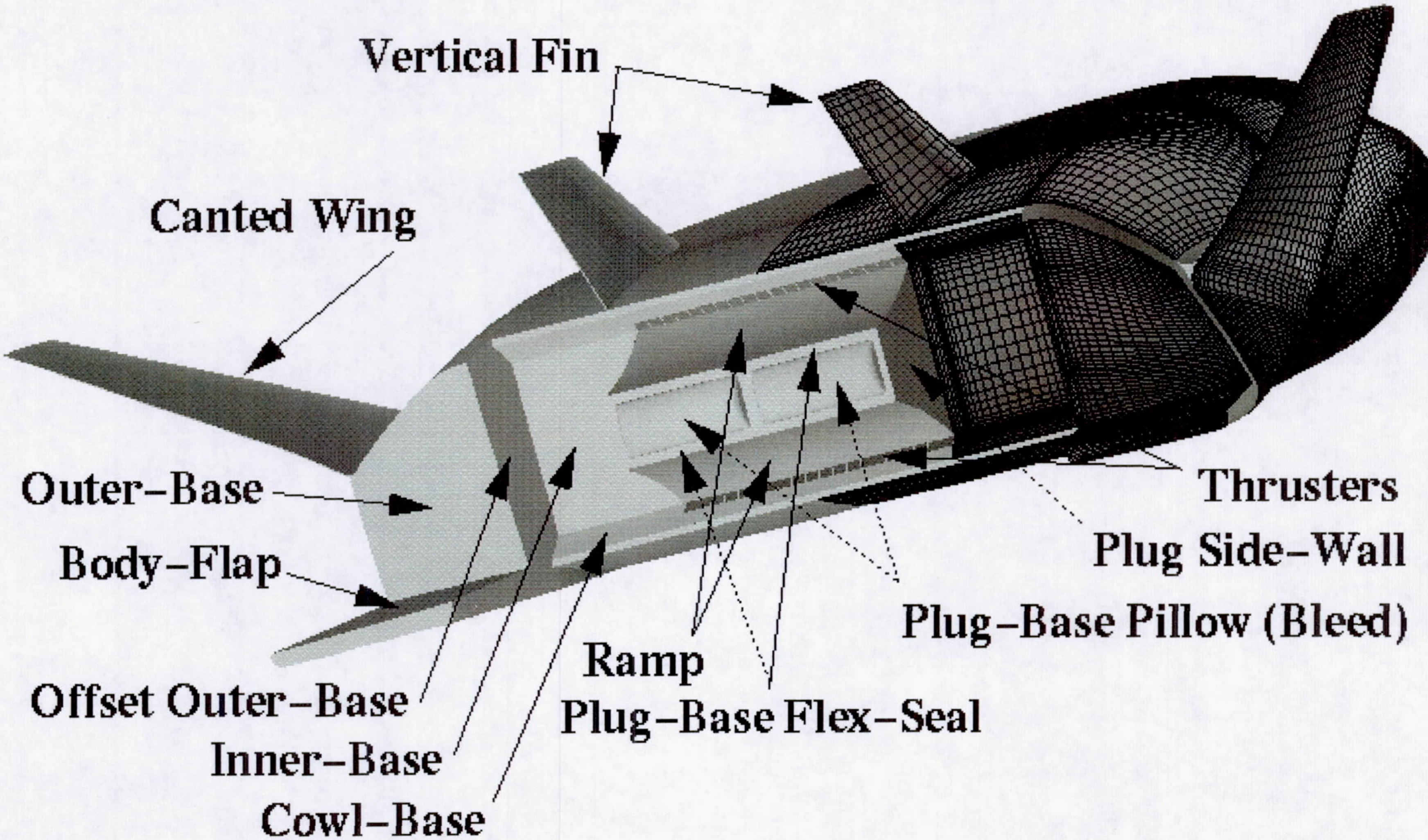
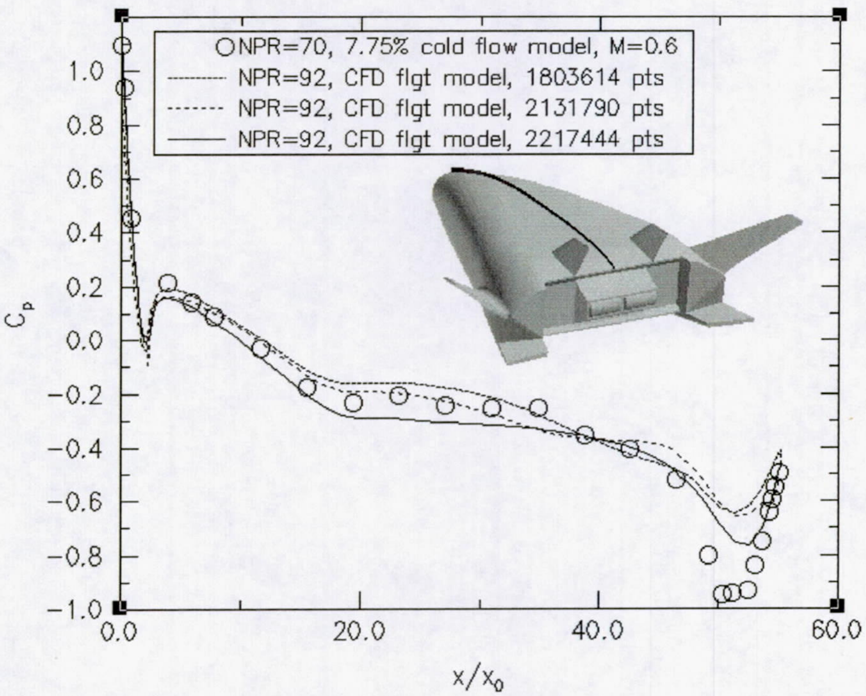
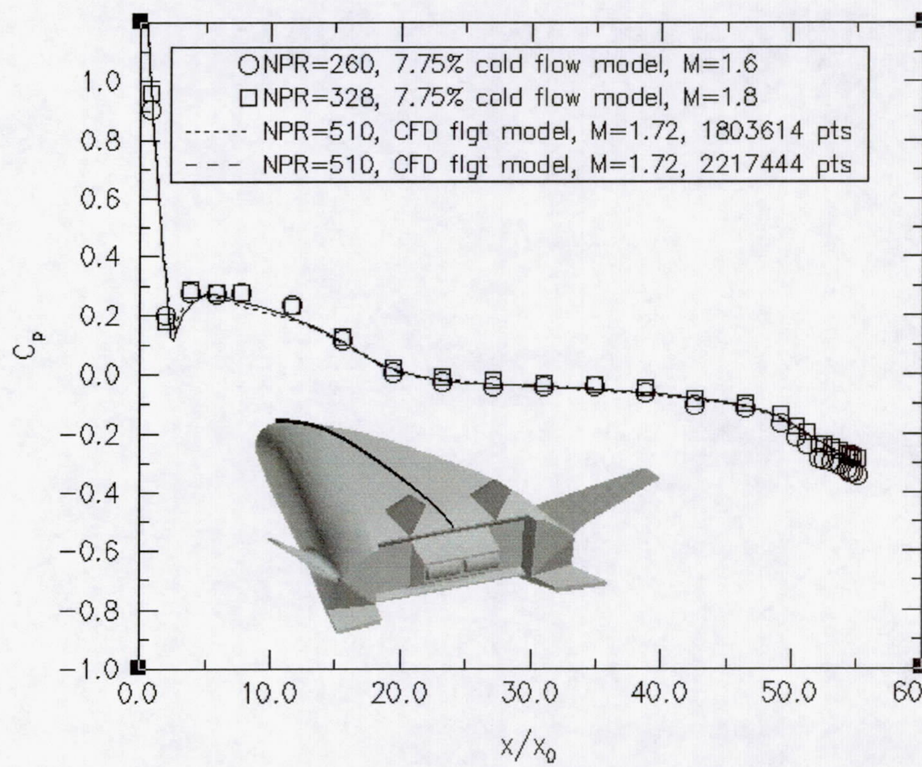
Layout of an X-33 Full-vehicle Surface Computational Grid with Surface Definitions



Comparison of Forebody and Aftbody Pressure Coefficients with a 7.75% Scaled Model Cold Flow Test





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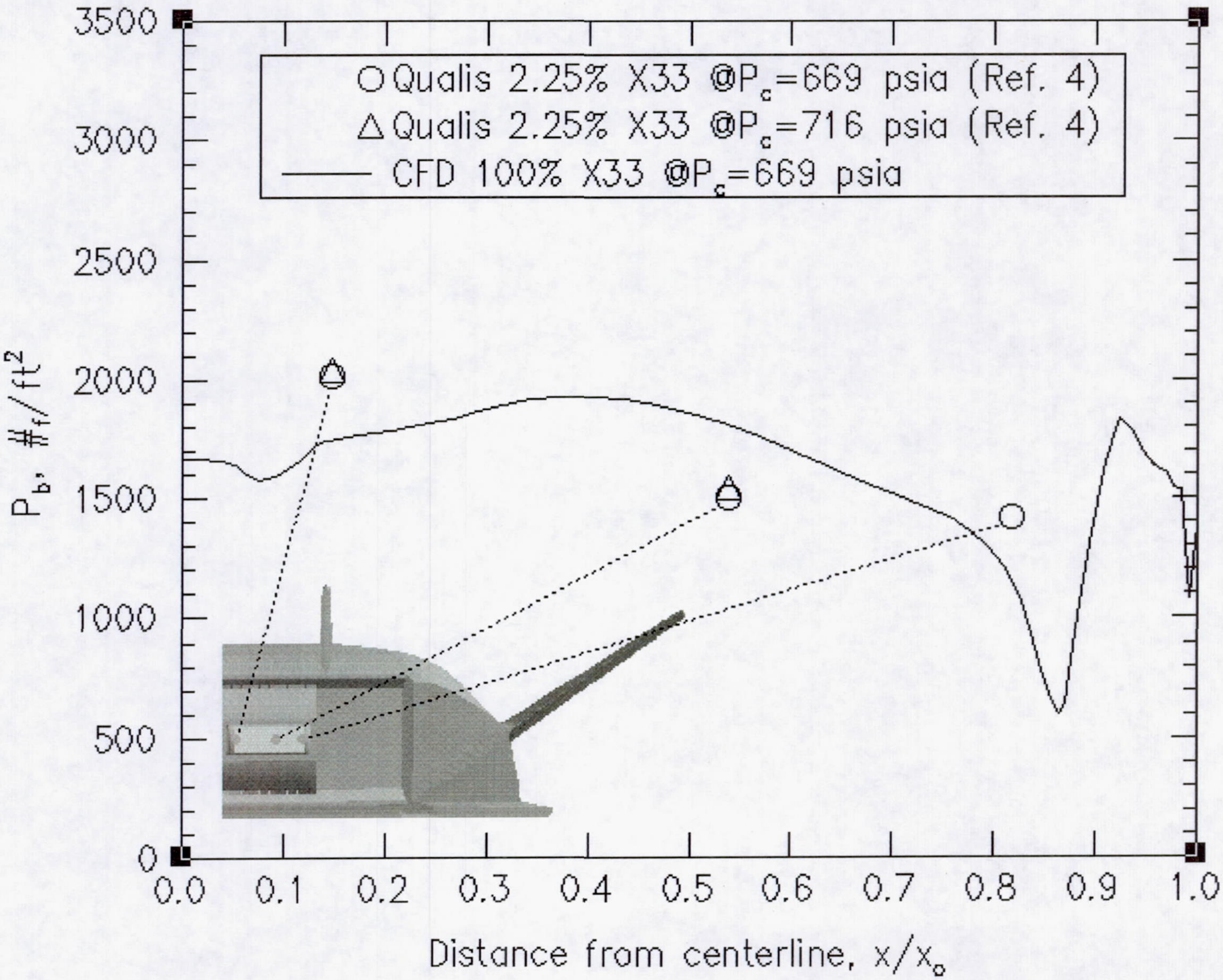
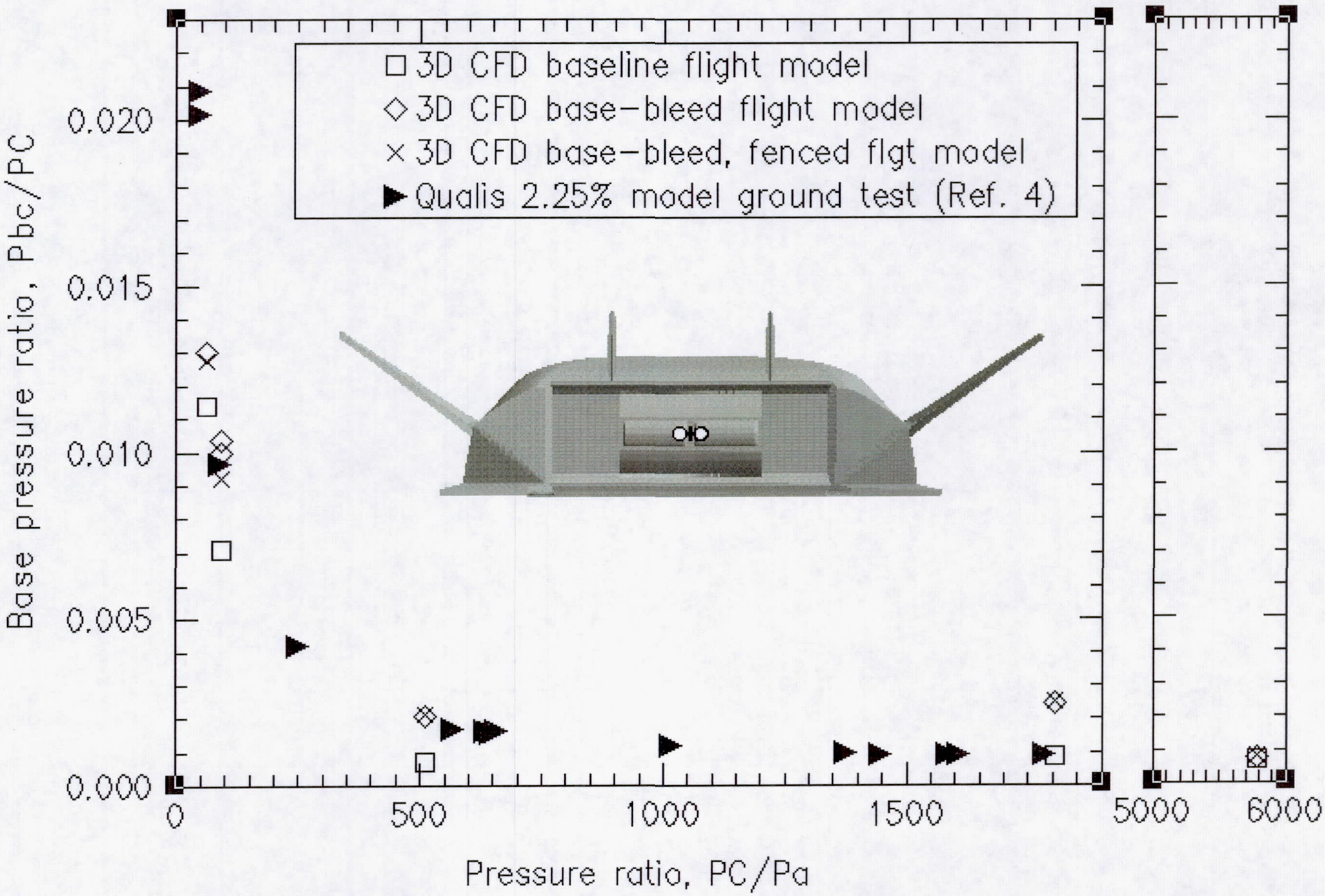
Comparison of Sea-Level Pillow Pressures with a 2.25% Scaled Model Hot-Fire Test



Comparison of Base Characteristic Pressures with a 2.25% Scaled Model Hot-Fire Test



Comparison of Base Horizontal Centerline Convective Heat Fluxes with a 2.25% Scaled Model Hot-Fire Test

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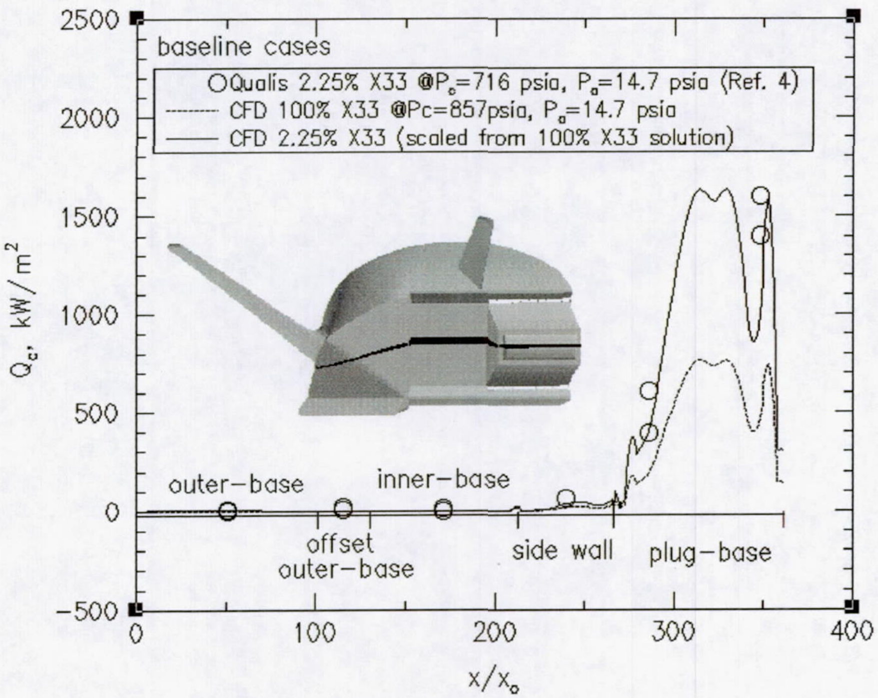
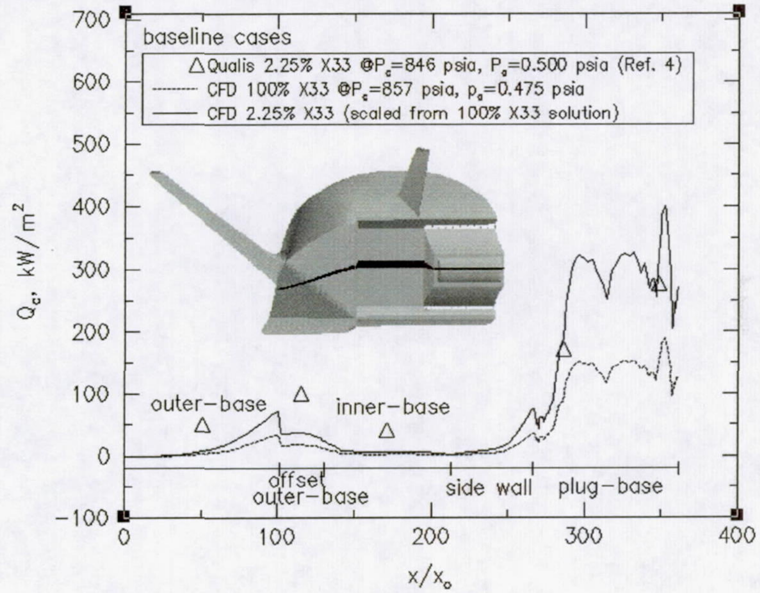
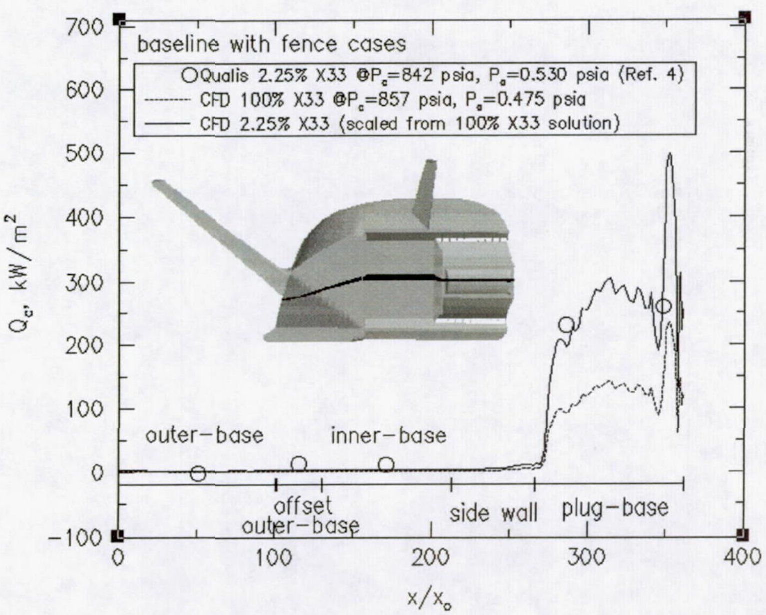
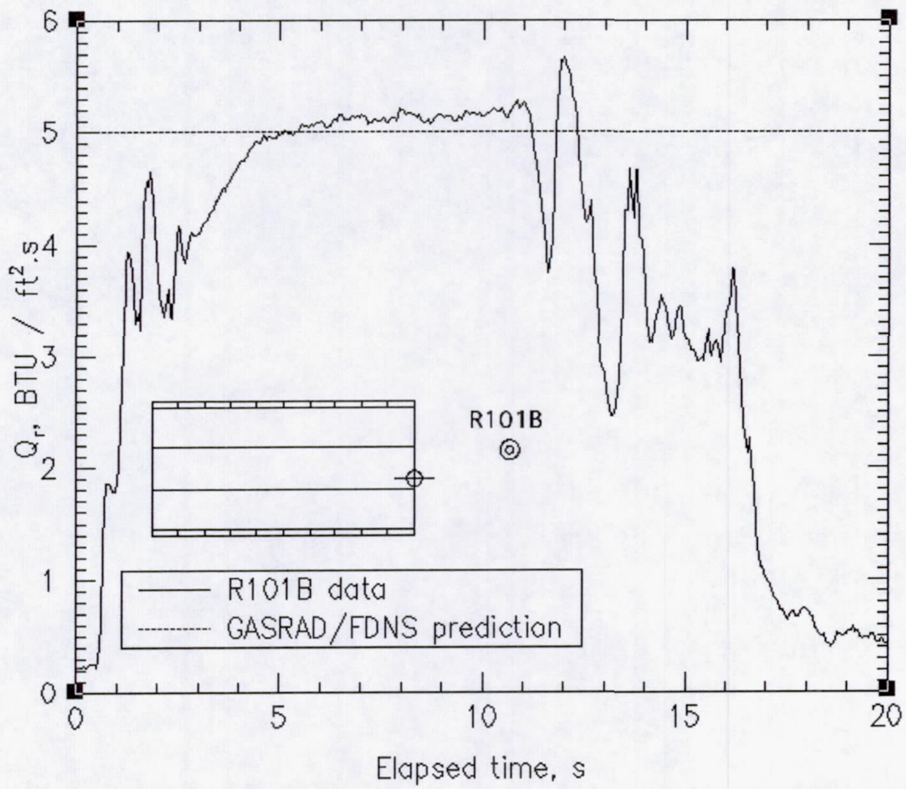
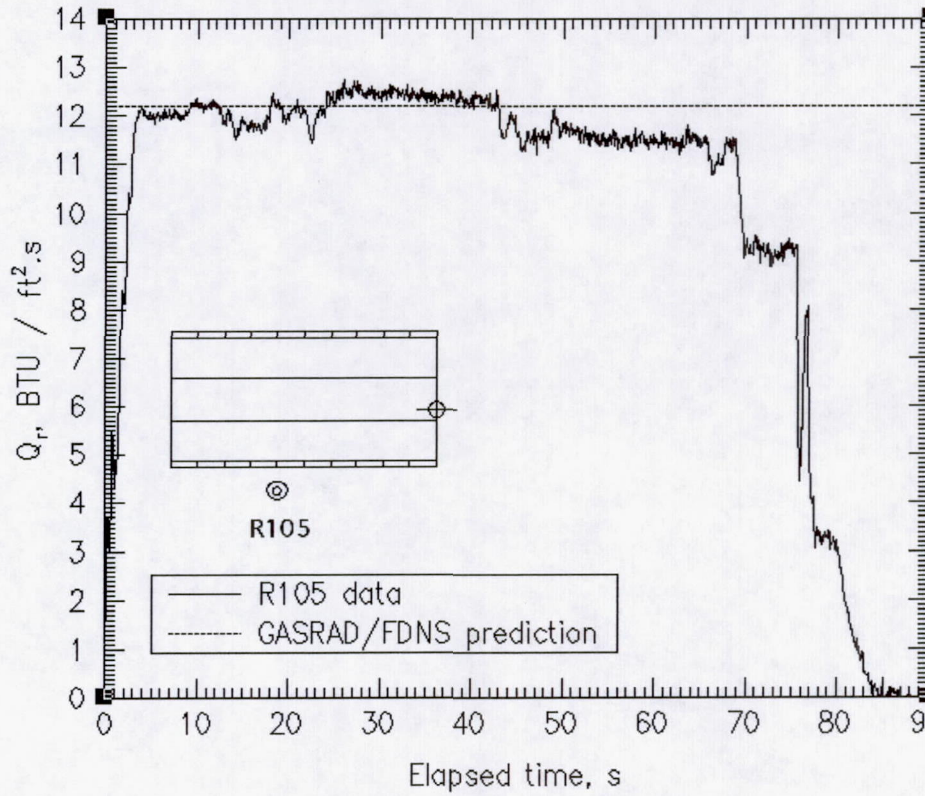




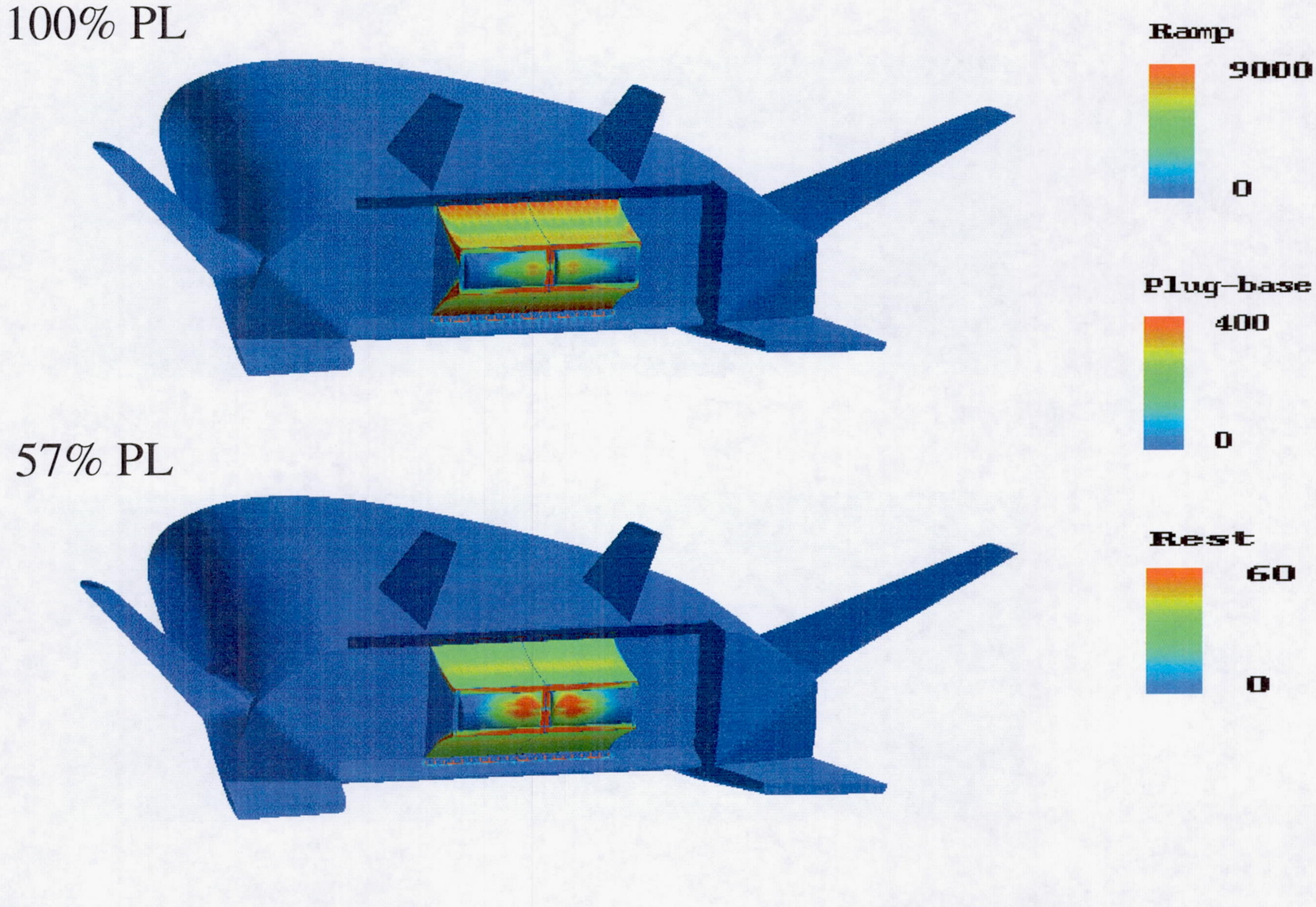


Comparison of Cowl and Inner-Base Radiative Heat Fluxes with an Installed Engine Test

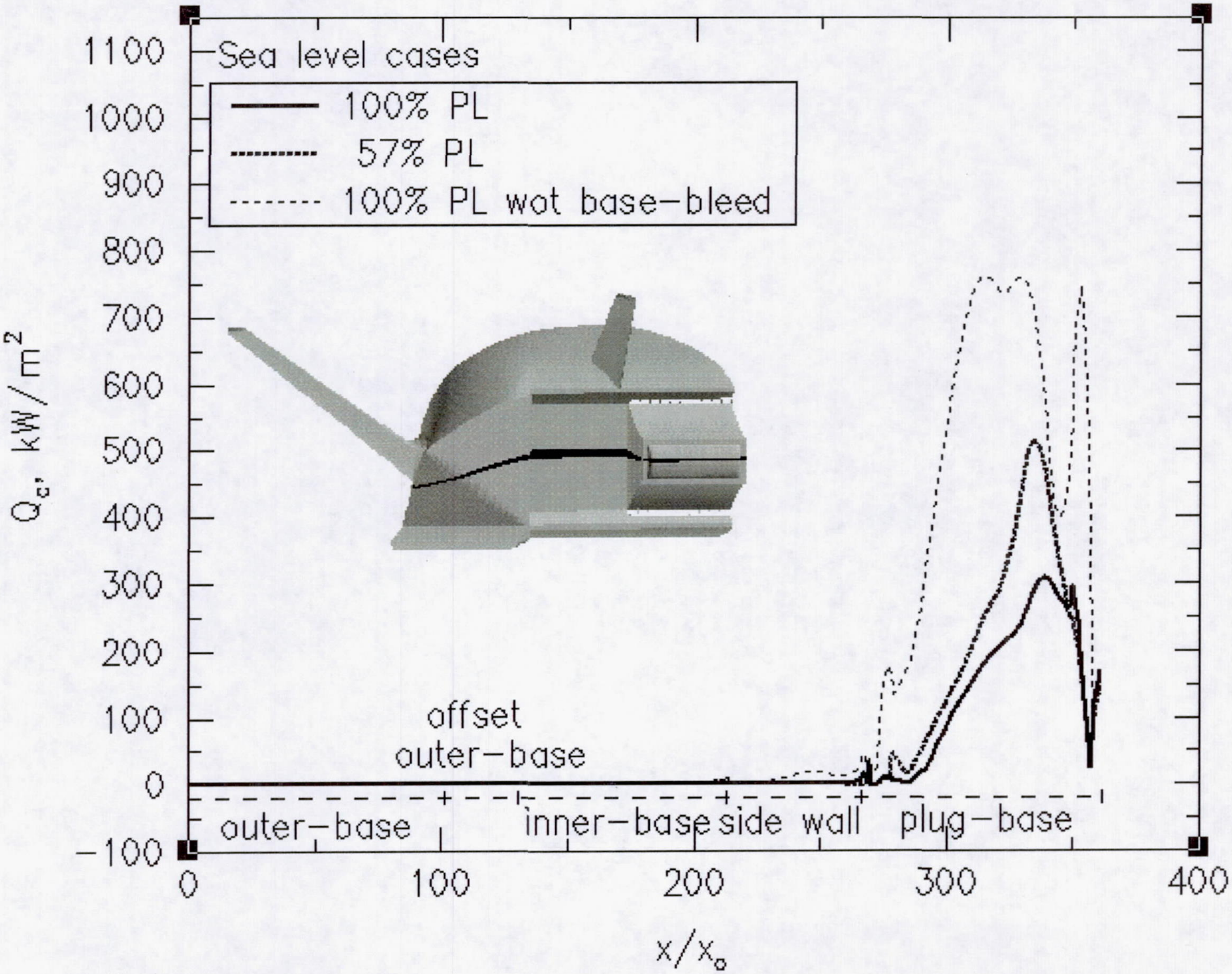




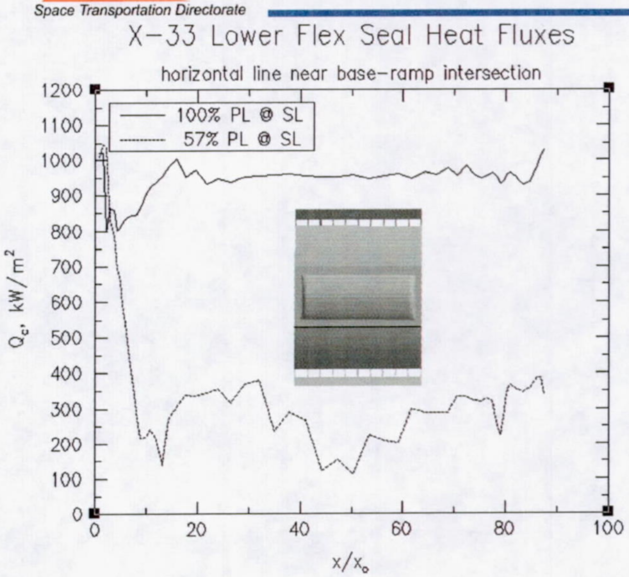
Preliminary Sea Level Qc (KW/m^2) Contours

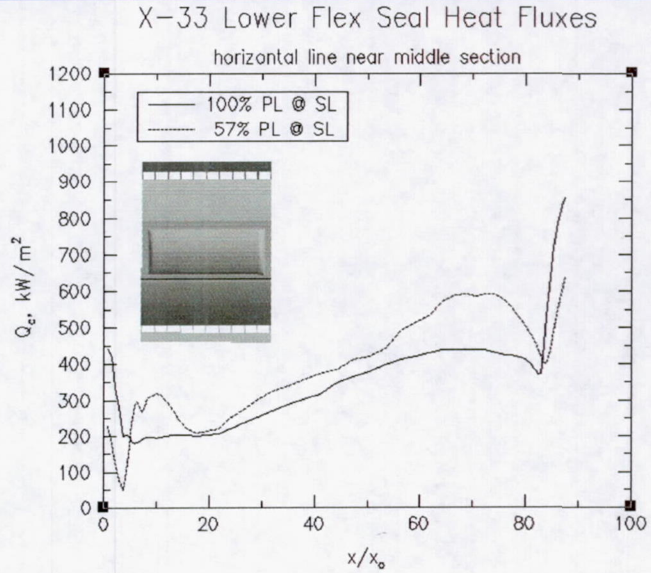


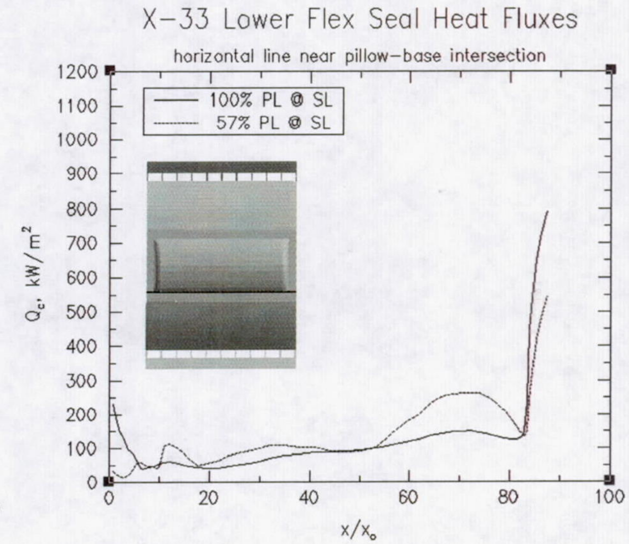
Preliminary Sea Level Qc (KW/m²) Results

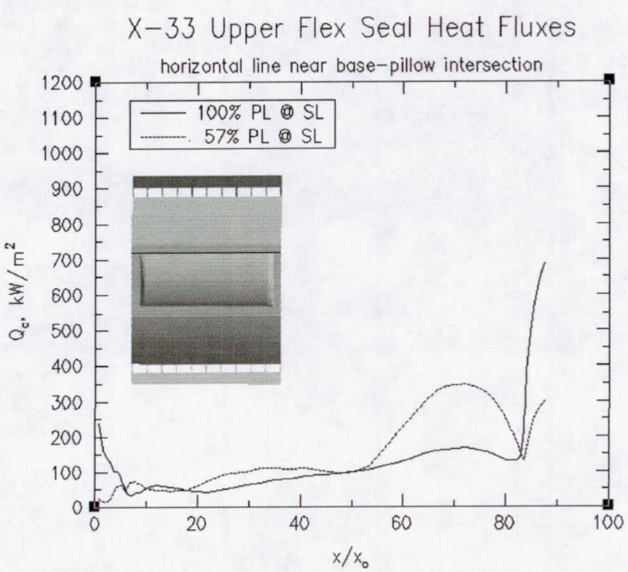


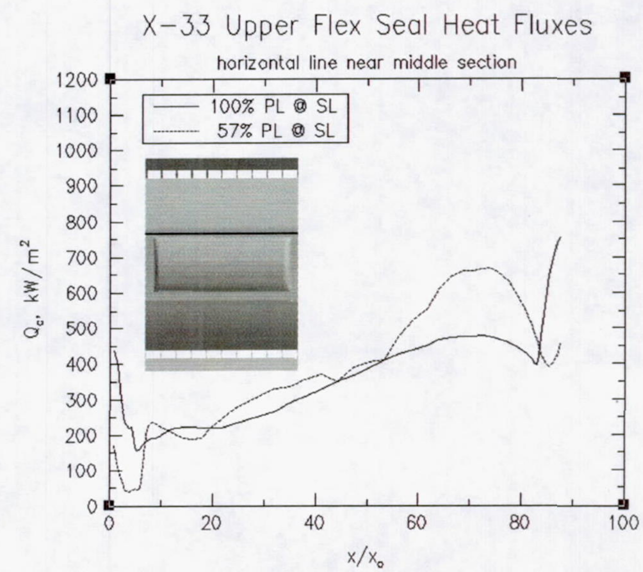
Preliminary Sea Level Qc (KW/m²) Results

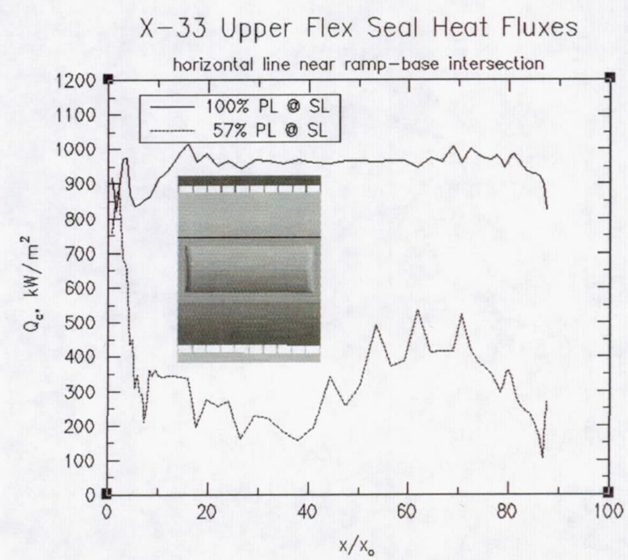




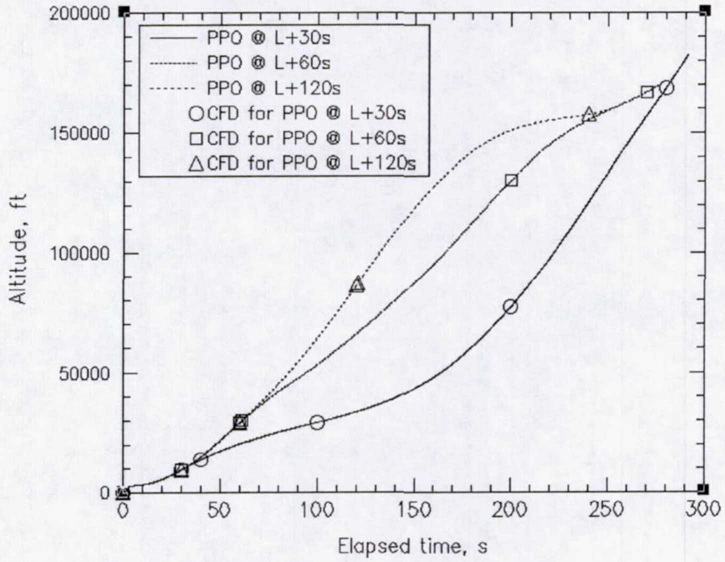


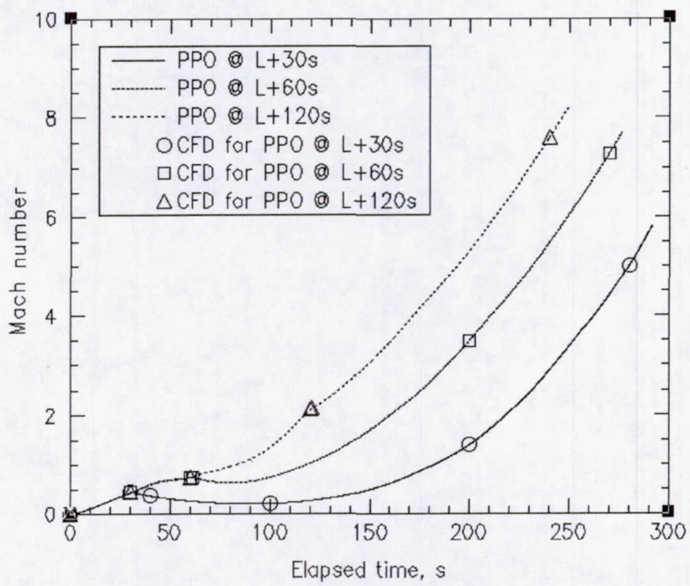


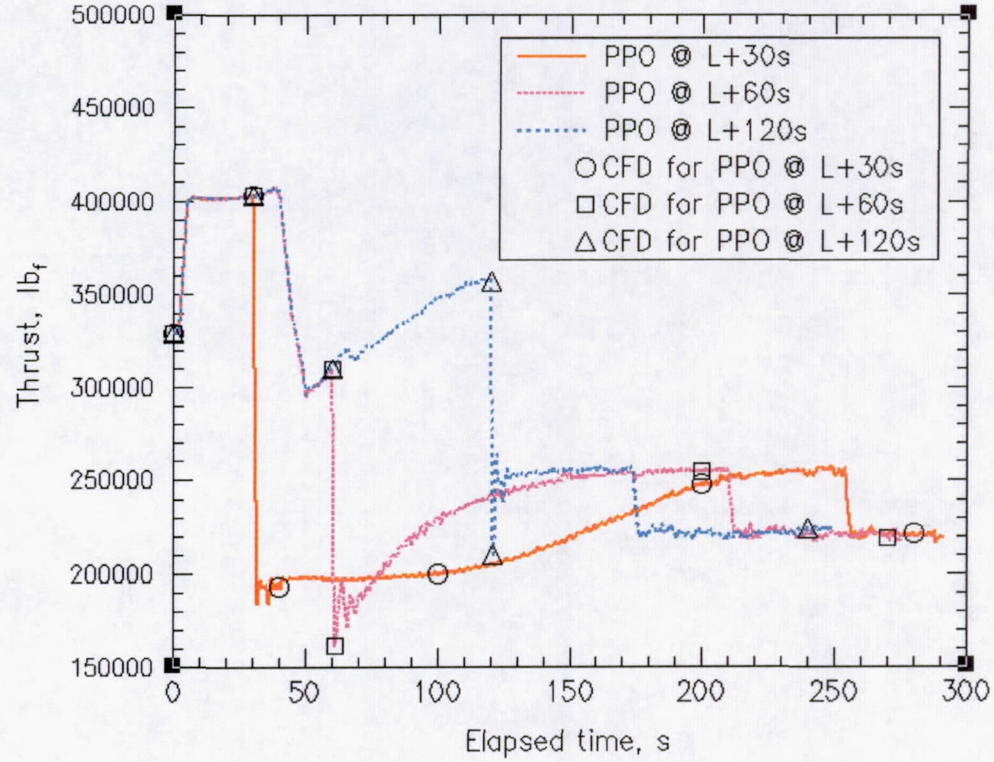




PPO Trajectory







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Run Matrix for PPO @ Launch + 30 s

Case	t, s	M_∞	h, ft	$\%PL_{LE}$	$\%PL_{RE}$	$\dot{m}_{LE,bb}$	$\dot{m}_{RE,bb}$
1	0	0.00	0	82	80	9.9	9.7
2	30	0.44	9495	100	100	12.1	12.2
3	40	0.37	13821	49	48	9.0	2.9
4	100	0.21	28954	50	49	9.1	3.0
5	200	1.39	77217	51	48	9.1	3.0
6	280	5.00	168498	46	40	7.9	2.6

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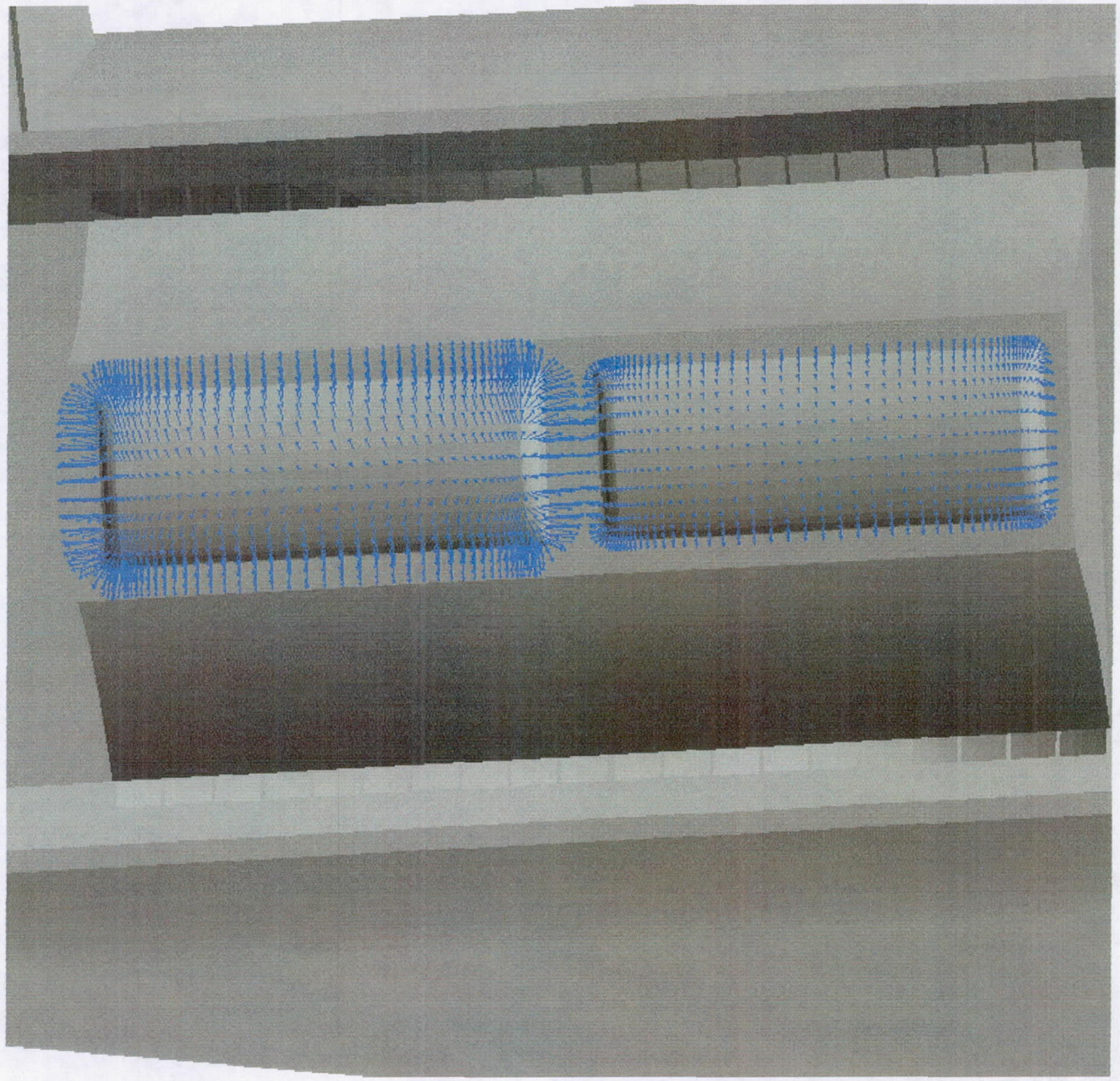
Base-bleed Vectors after a PPO



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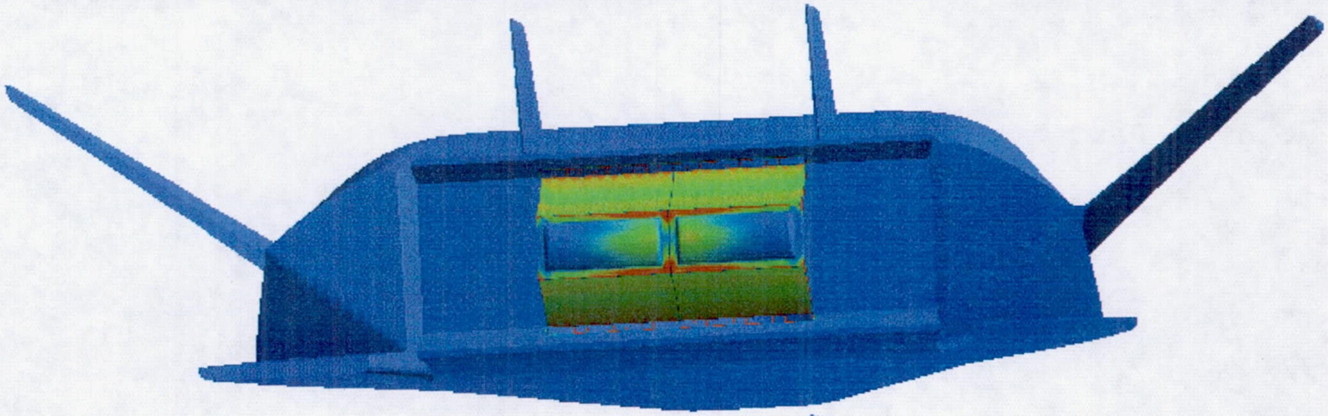
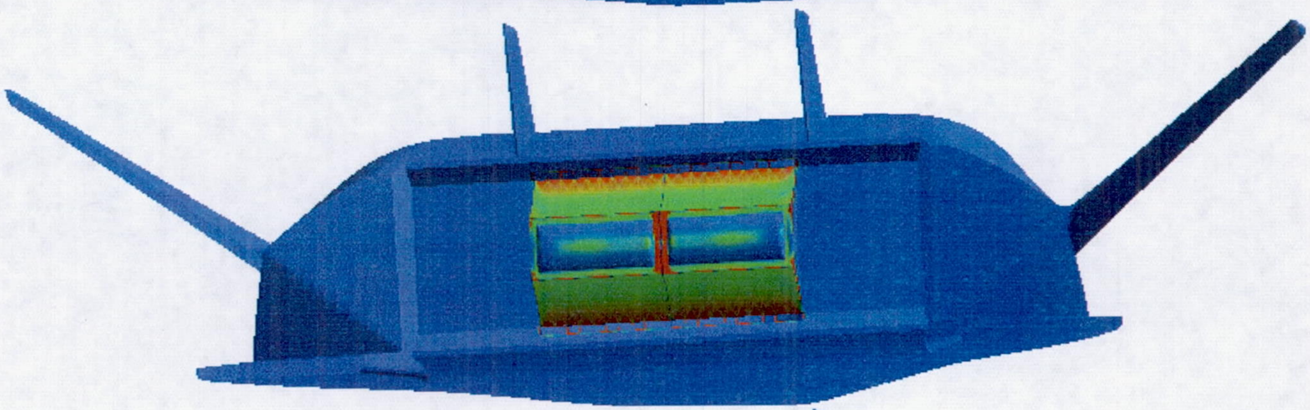
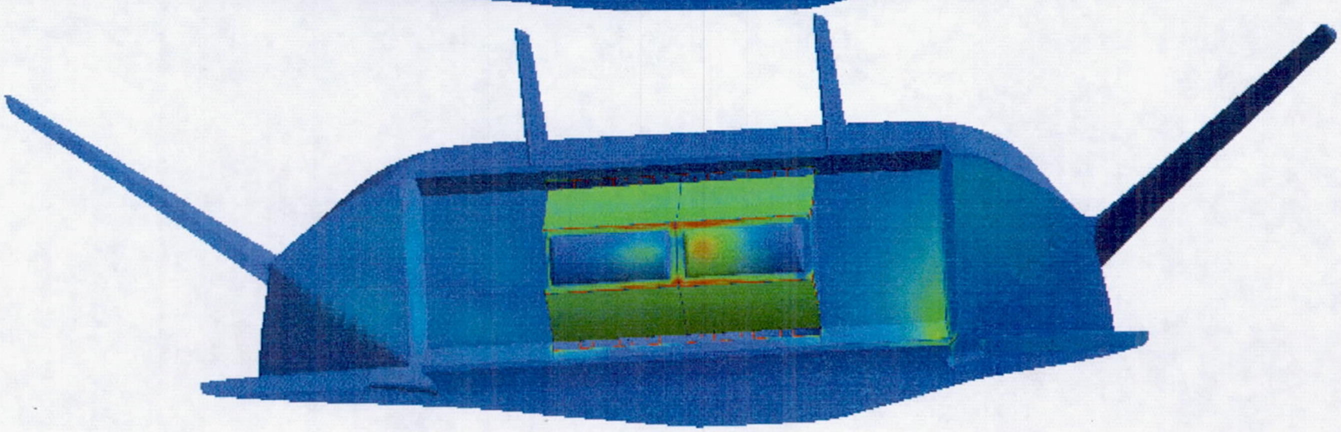
Preliminary Qc Contours for PPO @ Launch + 30 s



0 s



30 s



40 s

Preliminary Qc Contours for PPO @ Launch + 30 s

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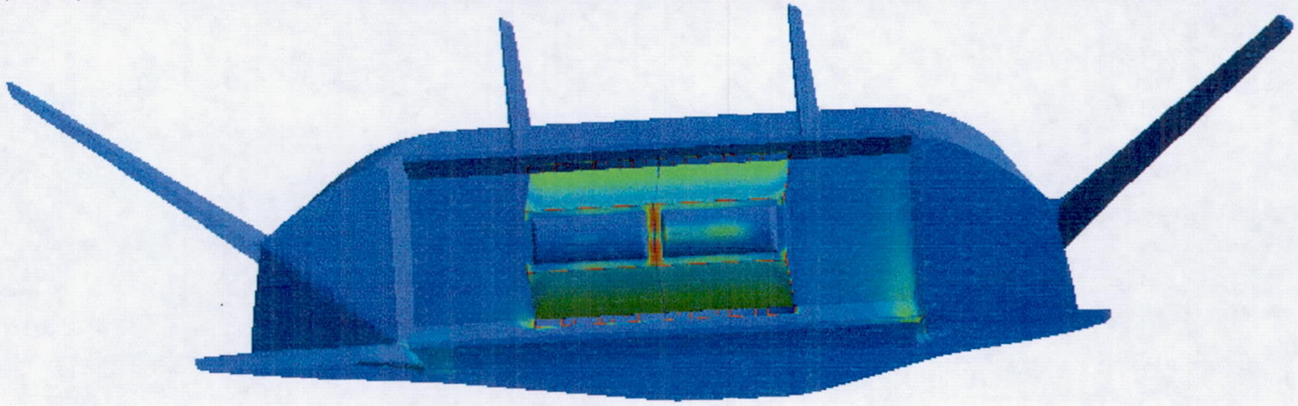
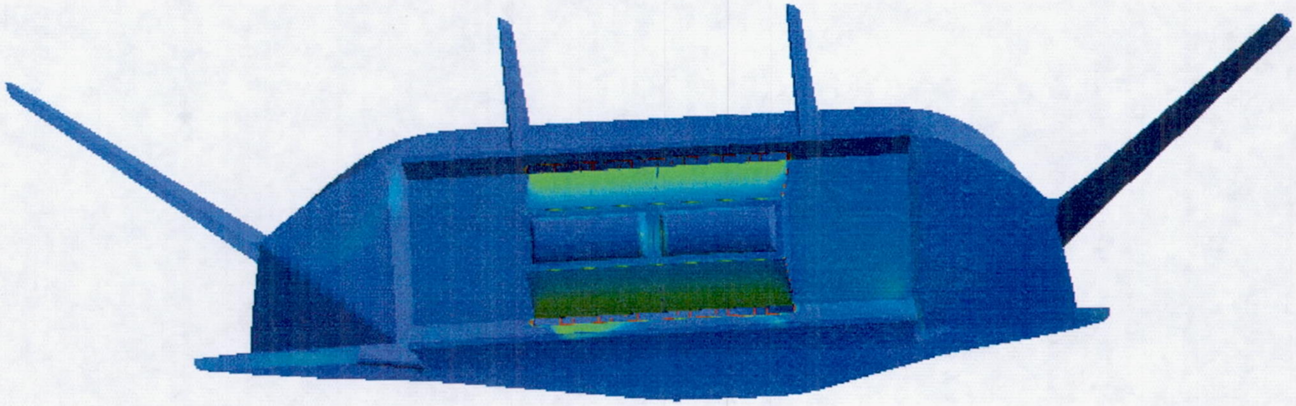
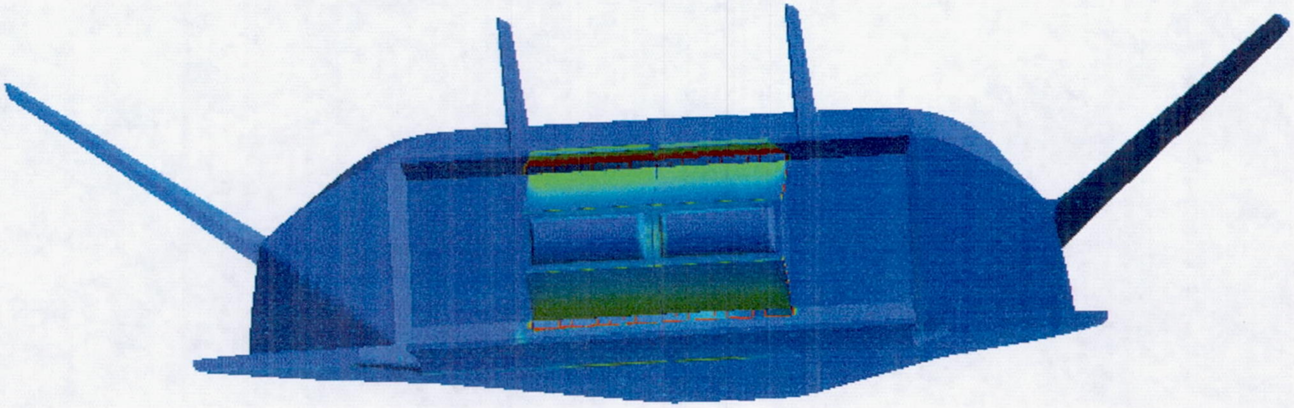


100 s

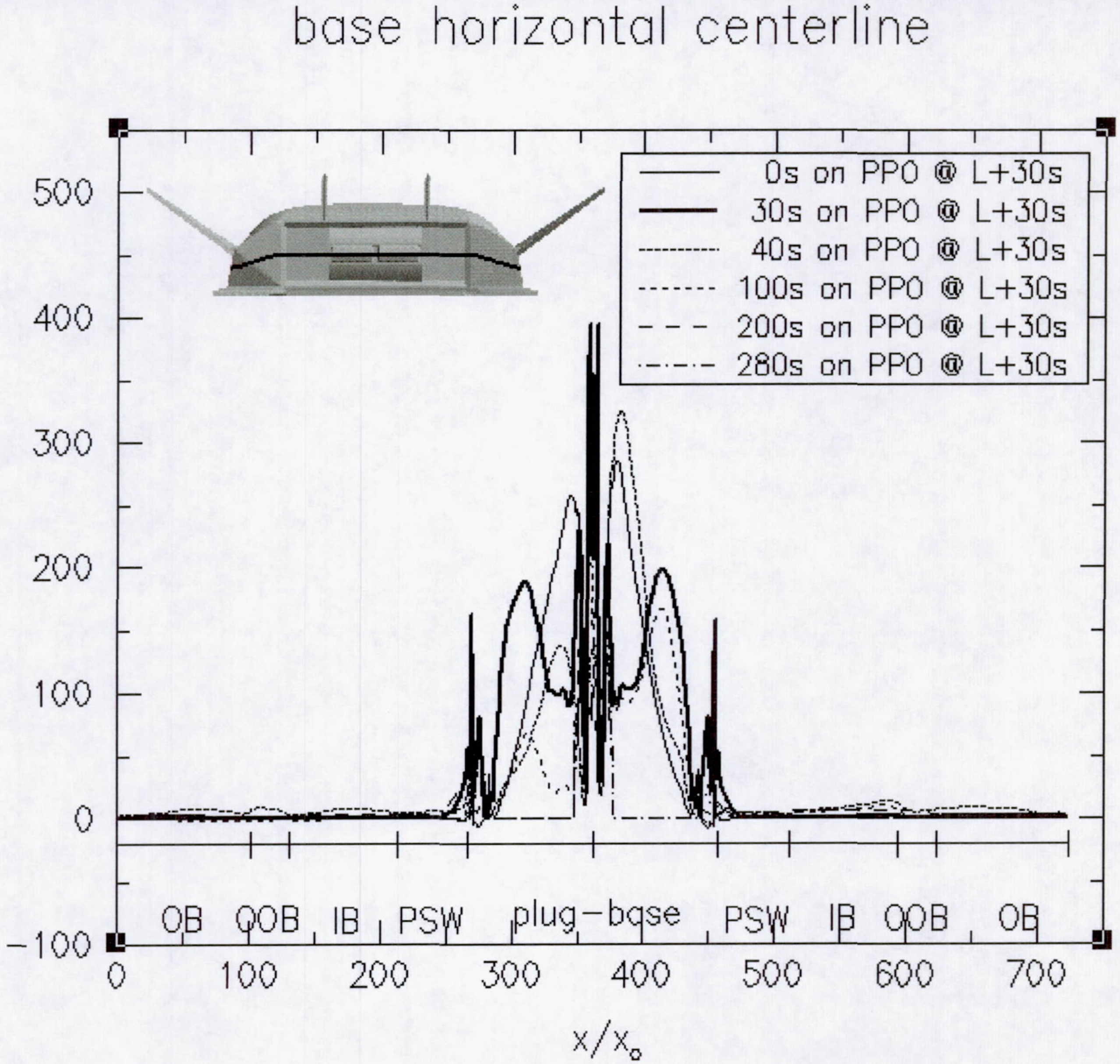


200 s

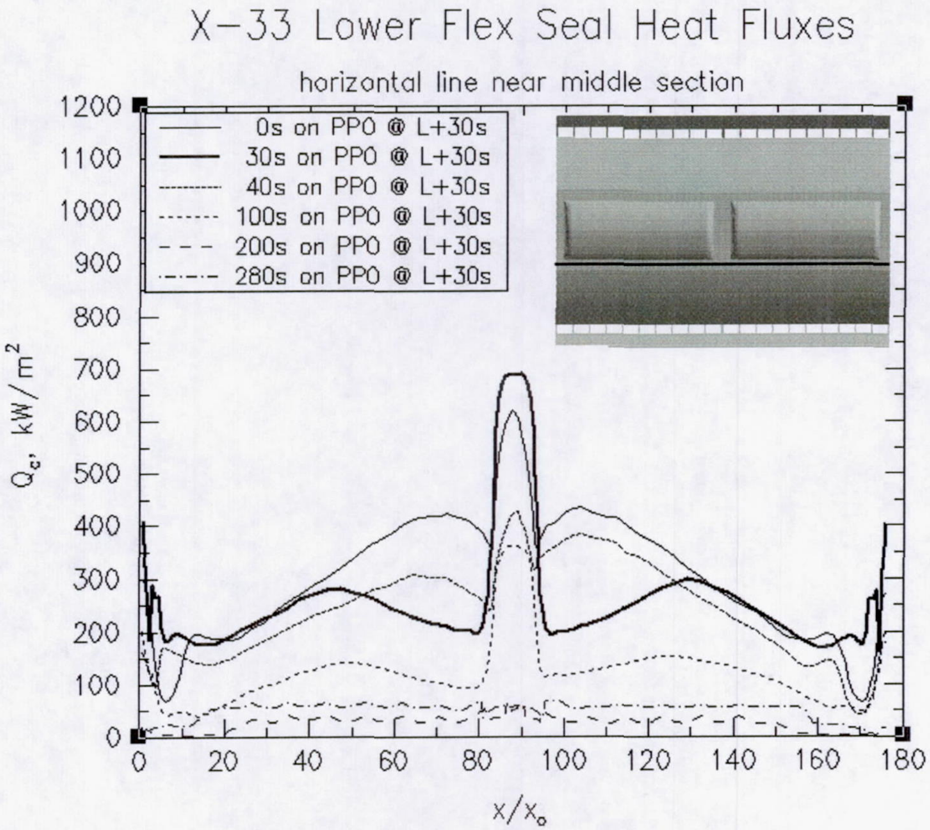


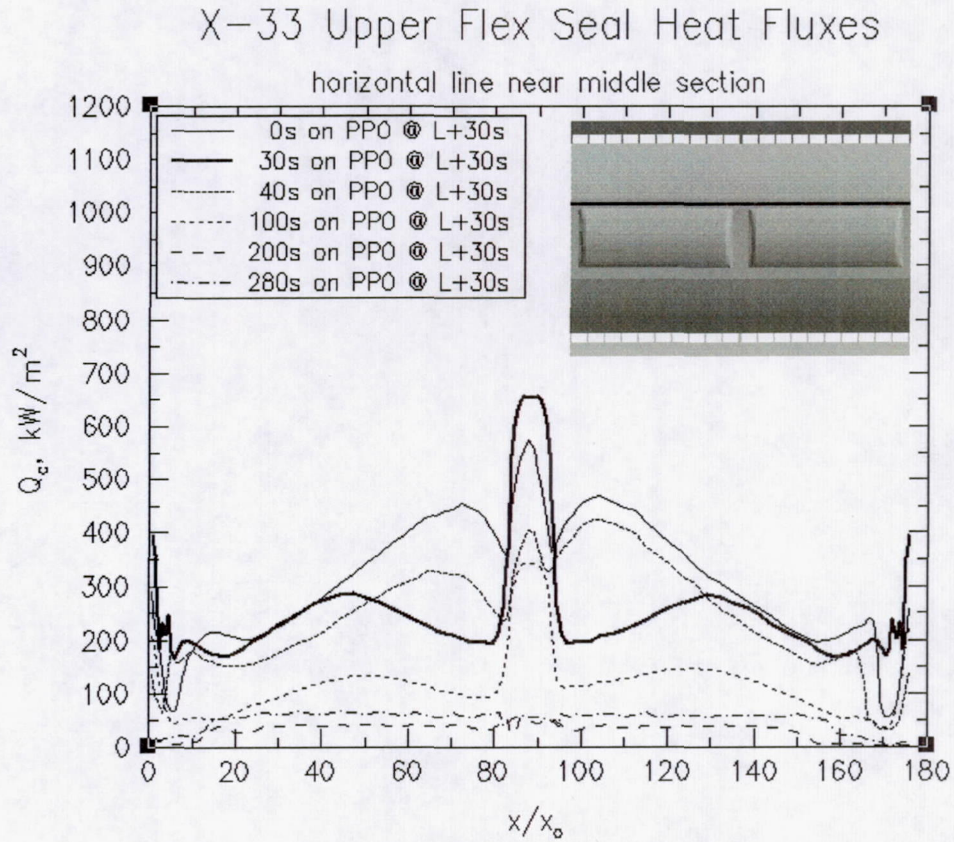
280 s

Preliminary Qc Results for PPO @ Launch + 30 s



Preliminary Qc Results for PPO @ Launch + 30 s





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Summary

- A systematically anchored computational fluid dynamics and heat transfer model is being used to study the effect of reduced power level on base-heating environment during sea level testing and during PPO.
- Preliminary results show that convective heating is higher for 57% PL than that for 100% PL on most of the pillows and flex seals during sea level testing. This agrees with test observations.
- Preliminary results of PPO @ L +30 s show that convective heating on pillows and flex seals on the "off" engine side is higher than that on the "on" engine side.
- Future work includes study of PPO @ L + 60 s and PPO @ L + 120 s trajectories to bracket the heating envelope and radiative heating calculations.