TPS Sizing for Access-to-Space Vehicles

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Abstract

A study was carried out to identify, develop, and benchmark simulation techniques needed for optimum TPS material selection and sizing for reusable launch vehicles. Fully viscous, chemically reacting, Navier-Stokes flow solutions over the Langley wing-body single stage to orbit (SSTO) configuration were generated and coupled with an in-depth conduction code. Results from the study provide detailed thermal protection system (TPS) heat shield materials selection and thickness sizing for the wing-body SSTO. These results are the first ever achieved through the use of a complete, trajectory based hypersonic, Navier-Stokes solution database. TPS designs were obtained for both laminar and turbulent entry trajectories using the Access-to-Space baseline materials such as tailorable advanced blanket insulation (TABI). The TPS design effects (material selection and thicknesses) of coupling material characteristics to the aerothermal enviroment are illustrated. Finally, a sample validation case using the shuttle flight data base is included.

For the laminar trajectory, the TPS areal mass density is 1.2 lbm/ft^2, while the turbulent trajectory yields slightly less than 1.3 lbm/ft^2. An additional conclusion from this study is that the TABI blankets will have to be manufactured in thicknesses greater than 1.5-2.0 inches. Further, if typical turbulent flow conditions are found on these SSTO vehicles during re-entry, some of the baseline materials may experience significant over-temperatures.

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Relationship Between Ames Complementary Analysis Tasks For All Candidate TPS

TPS System Integration Task → Engineering analysis of life-cycle performance (vehicle+operational) performance

↓ Required Vehicle System Data

↑ Benchmarks Along Trajectory

TPS Point Design Task → High-fidelity aerothermal environments and TPS sizing

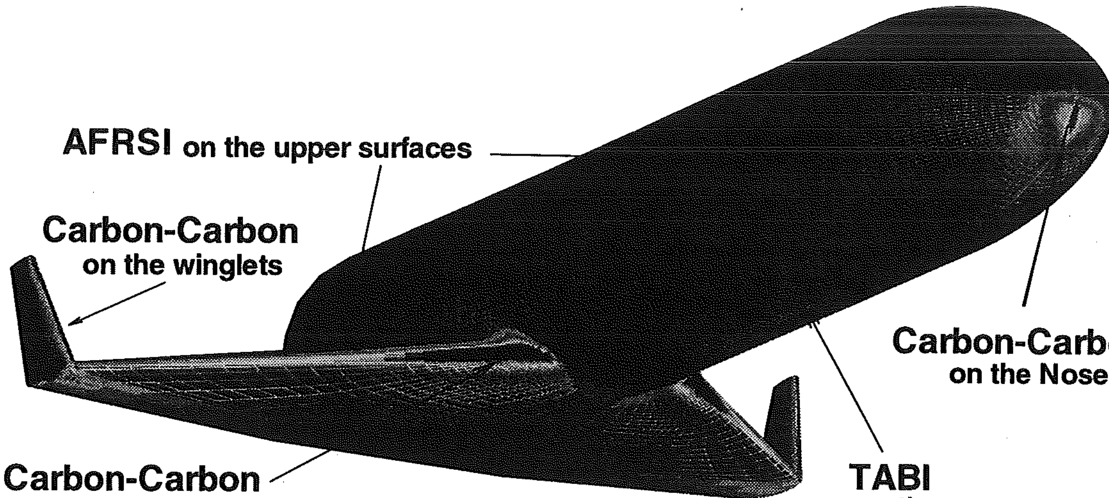
↓ Environments & TPS Selection

↑ Accurate Surface B.C.

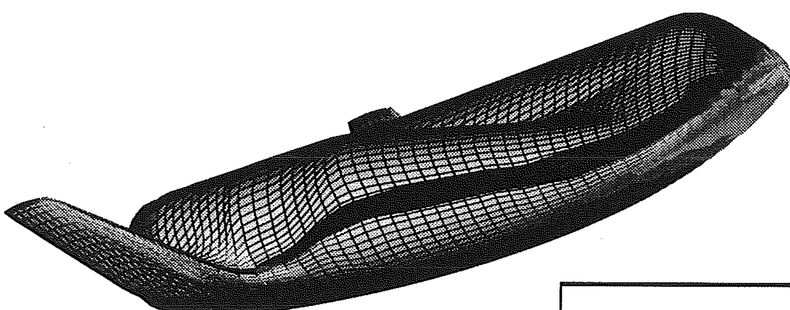
Surface Catalysis Task → Accurate TPS surface propertycharacterization

Tasks provide quantative methodology for assessing life-cycle performance (including operations) of all candidate TPS and thus OMB TPS criteria

TPS Sizing for Access to Space Vehicles

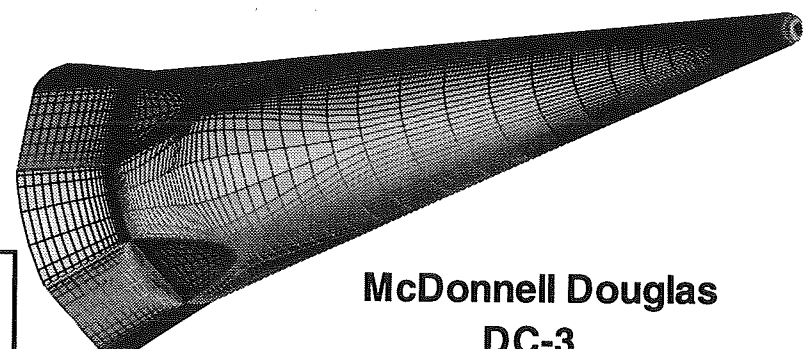


Winged Body Configuration



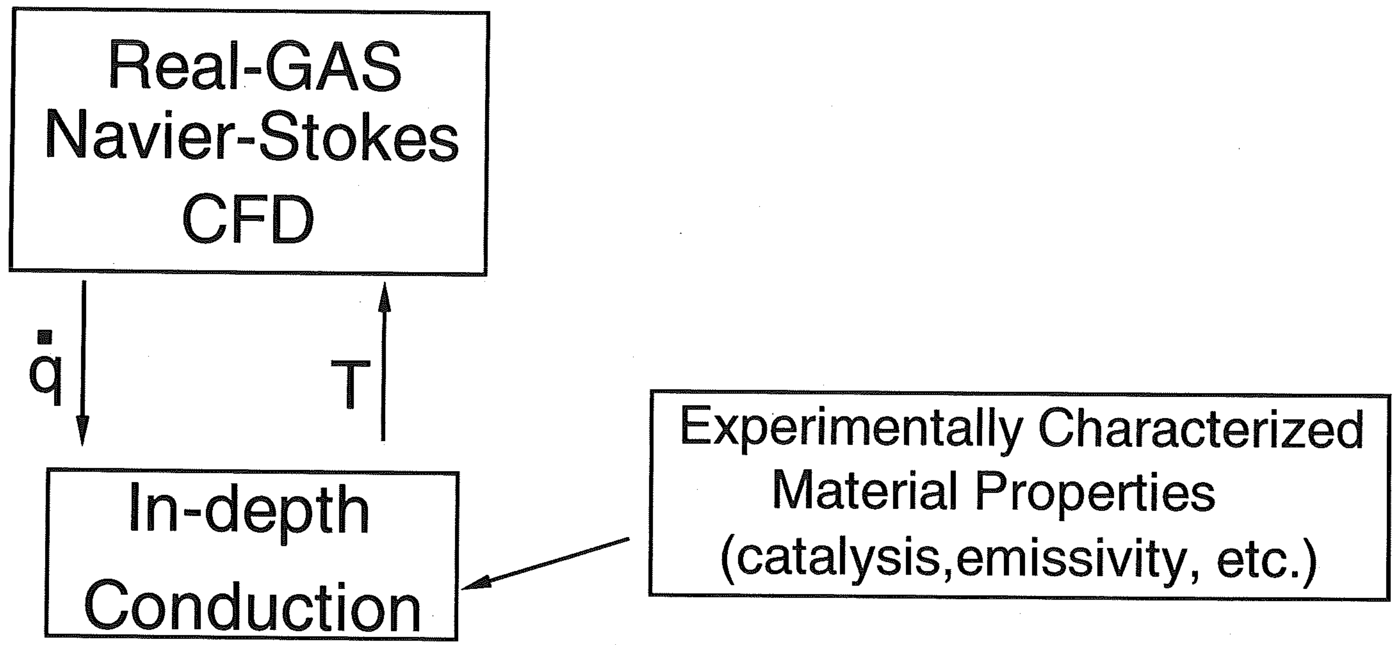
Lockheed Lifting Body

Use of New TPS Technology Reduces Life Cycle Cost by 20%

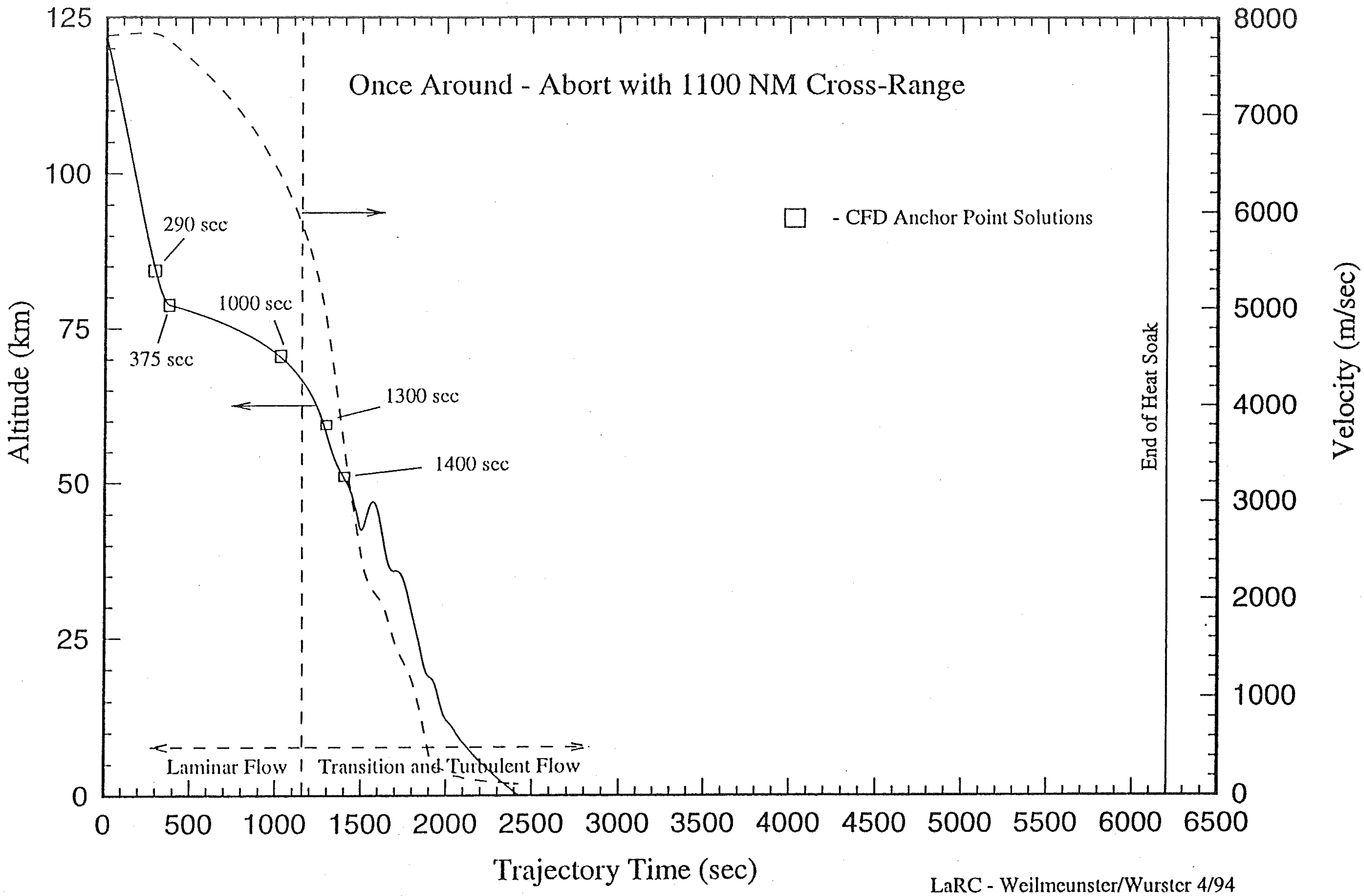


McDonnell Douglas DC-3

Fully Coupled Thermal Analysis for TPS Sizing

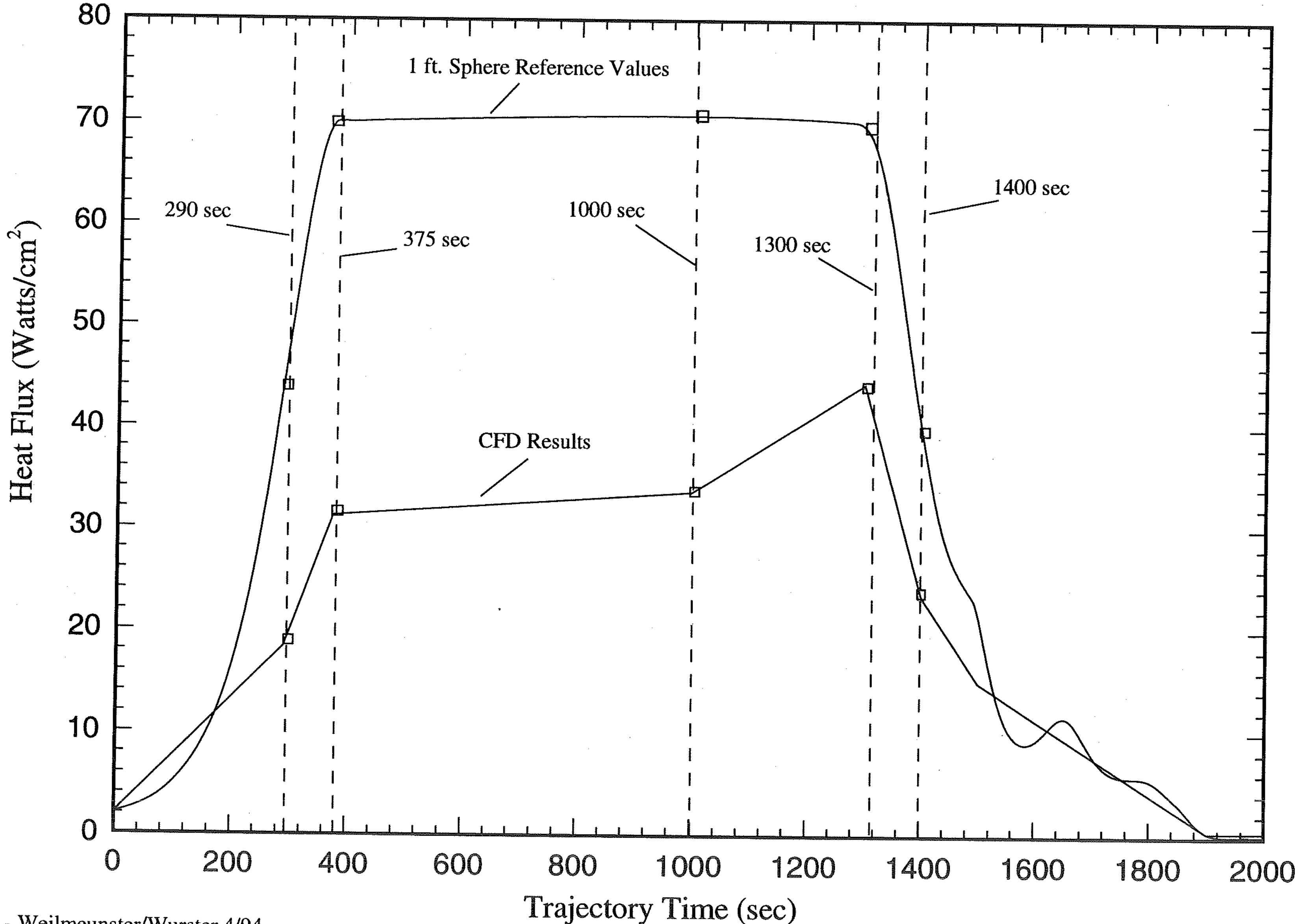


Trajectory (Altitude - Velocity) Plot for the LaRC SSTO Vehicle



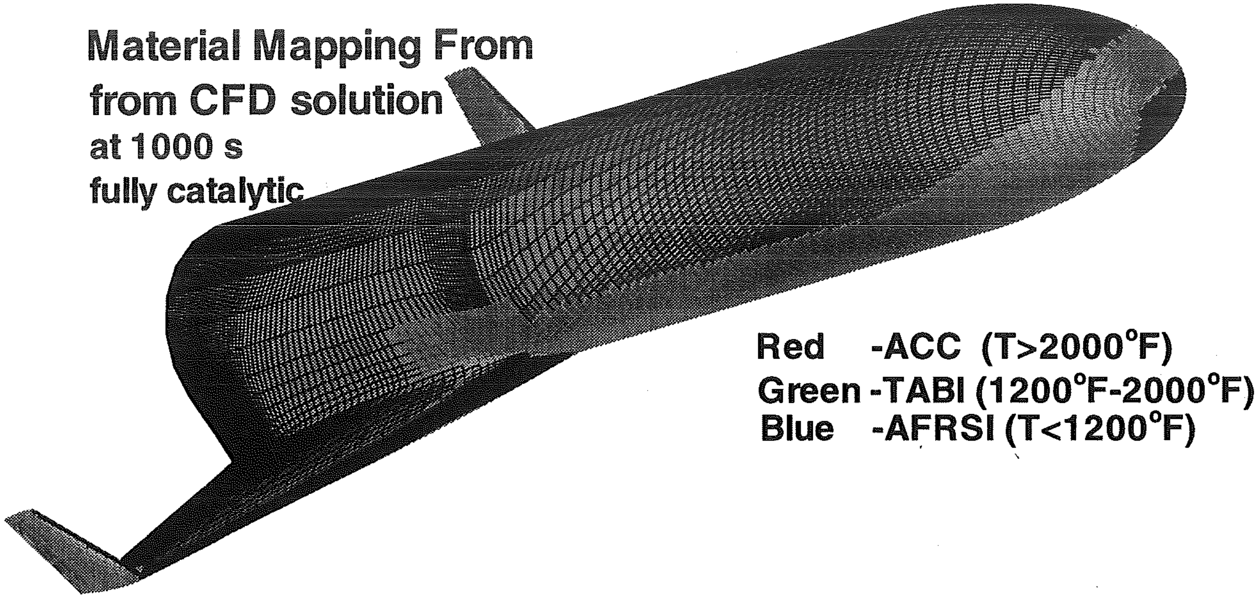
LaRC - Weilmeunster/Wurster 4/94

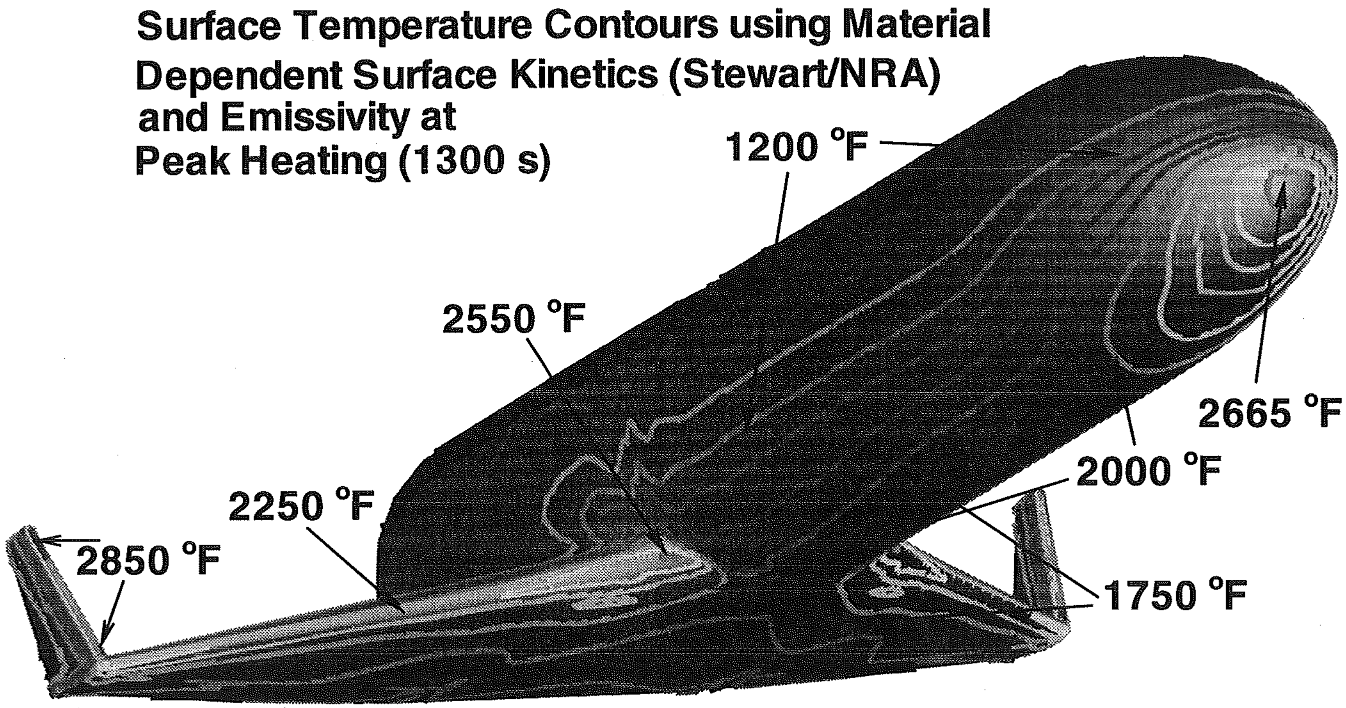
Stagnation Point Heating Plot for LaRC SSTO Trajectory



LaRC - Weilmeunster/Wurster 4/94

ARC/ST - W.D.Henline/G.E.Palmer/Y.-K.Chen/D.R.Olynick 4/4/95



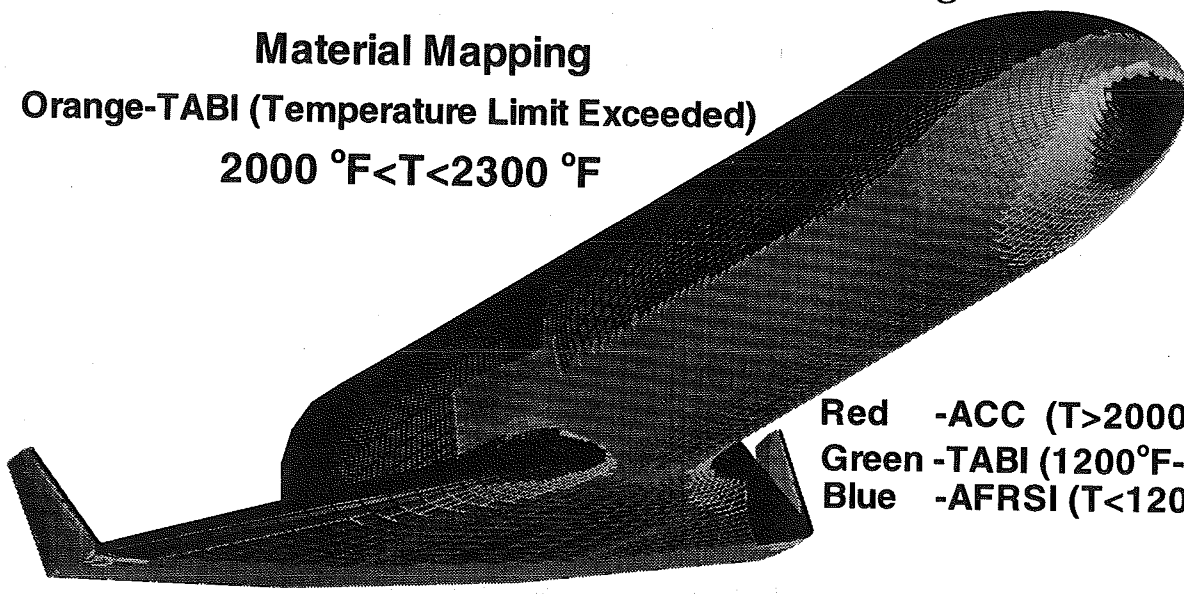


Winged Body Configuration 1300 s

Material Mapping

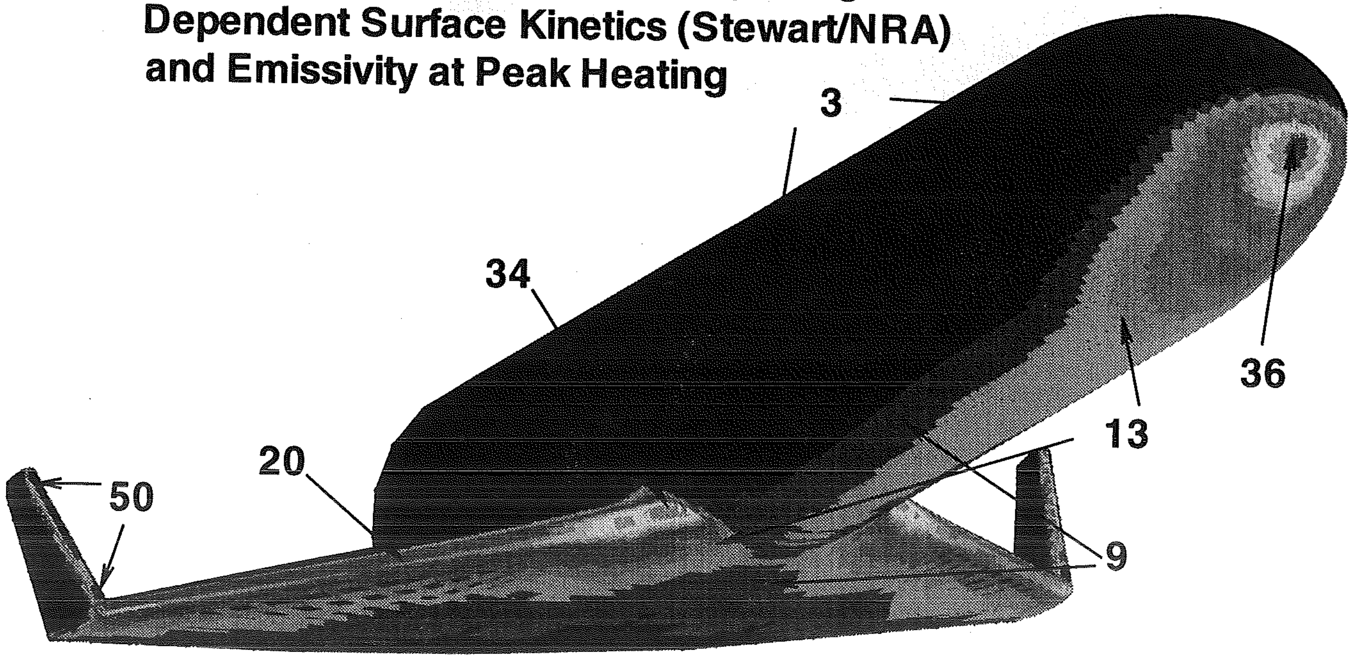
Orange-TABI (Temperature Limit Exceeded)

2000 °F<T<2300 °F

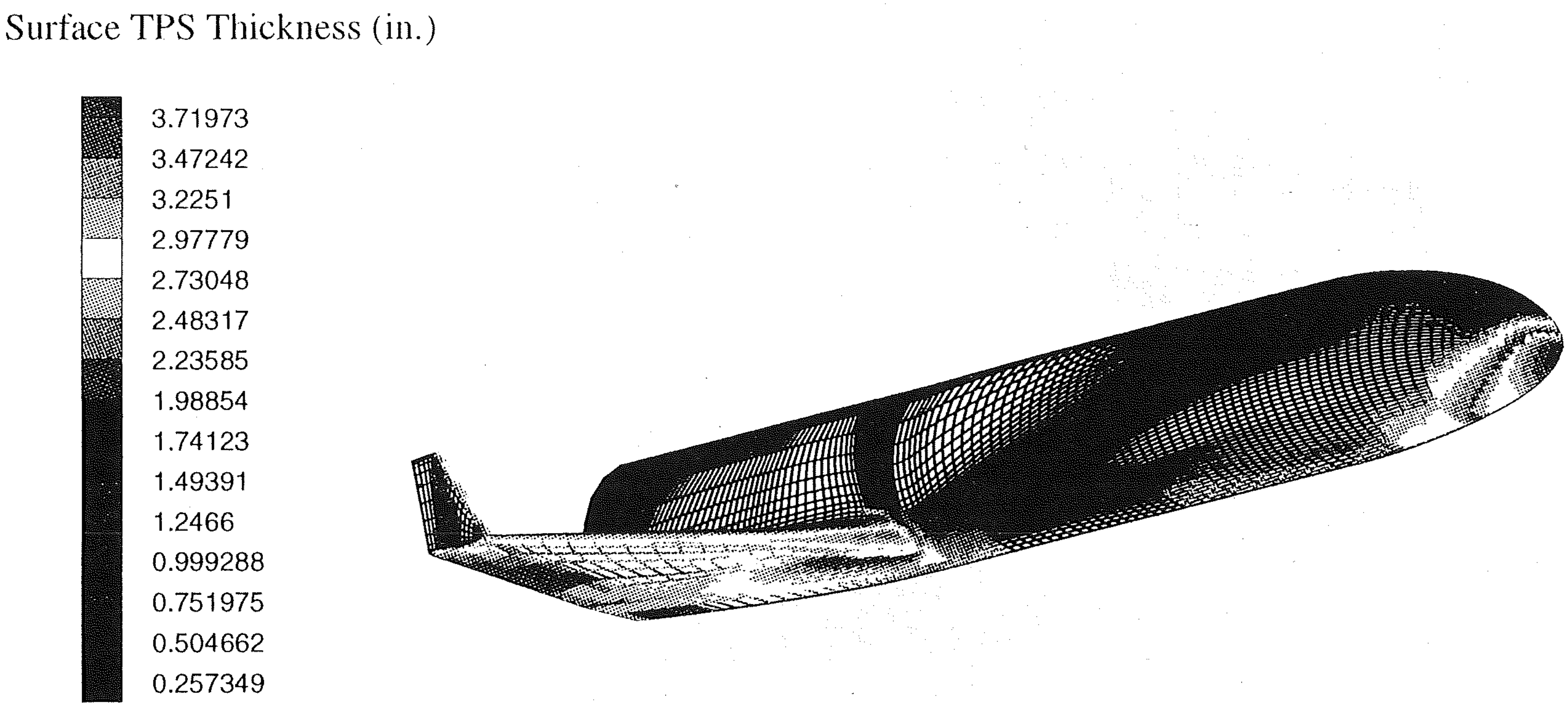


Red -ACC (T>2000°F)
Green -TABI (1200°F-2000°F)
Blue -AFRSI (T<1200°F)

Heat Transfer Contours (W/cm²) using Material Dependent Surface Kinetics (Stewart/NRA) and Emissivity at Peak Heating

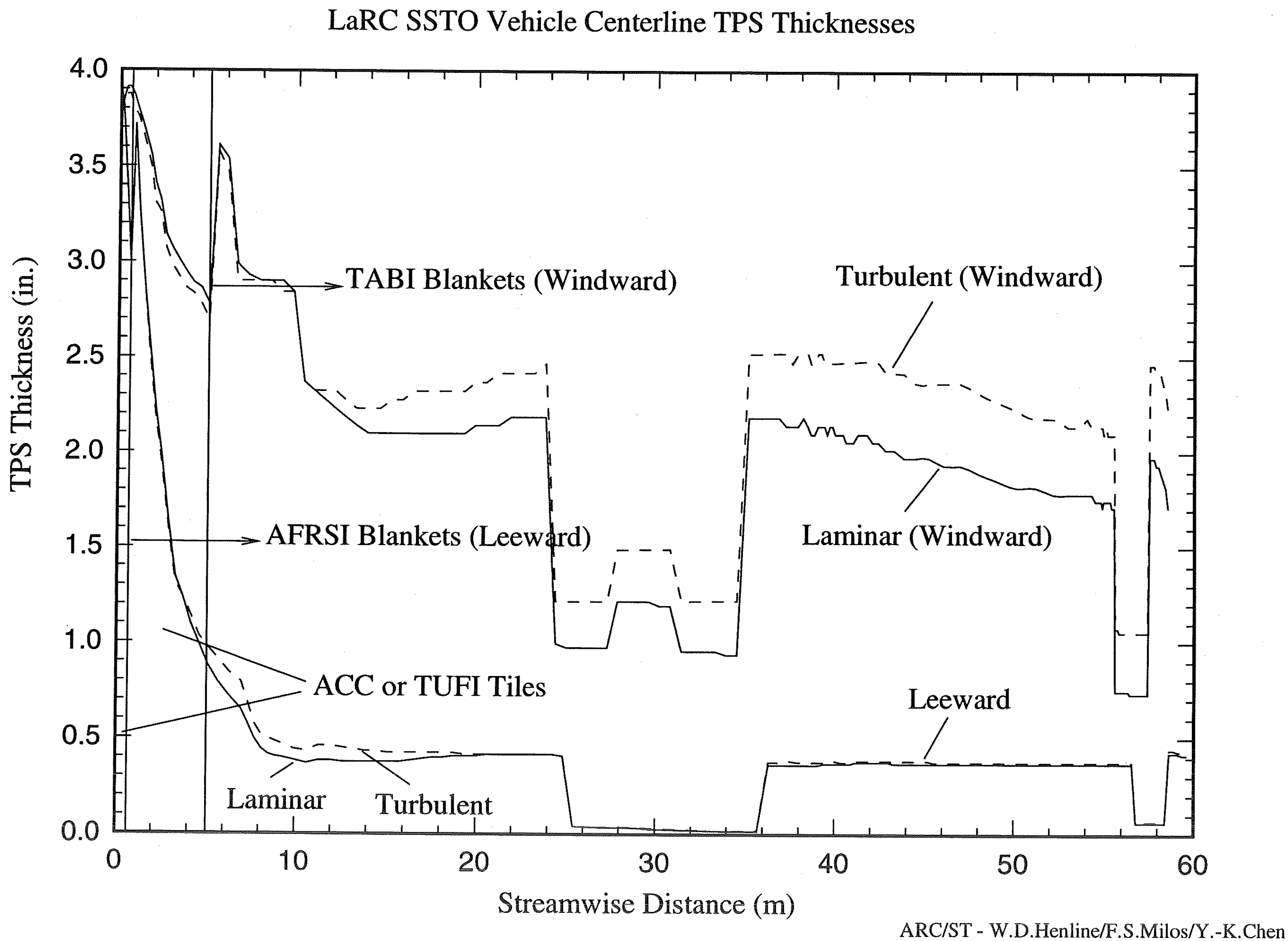


Winged Body Configuration 1300 S

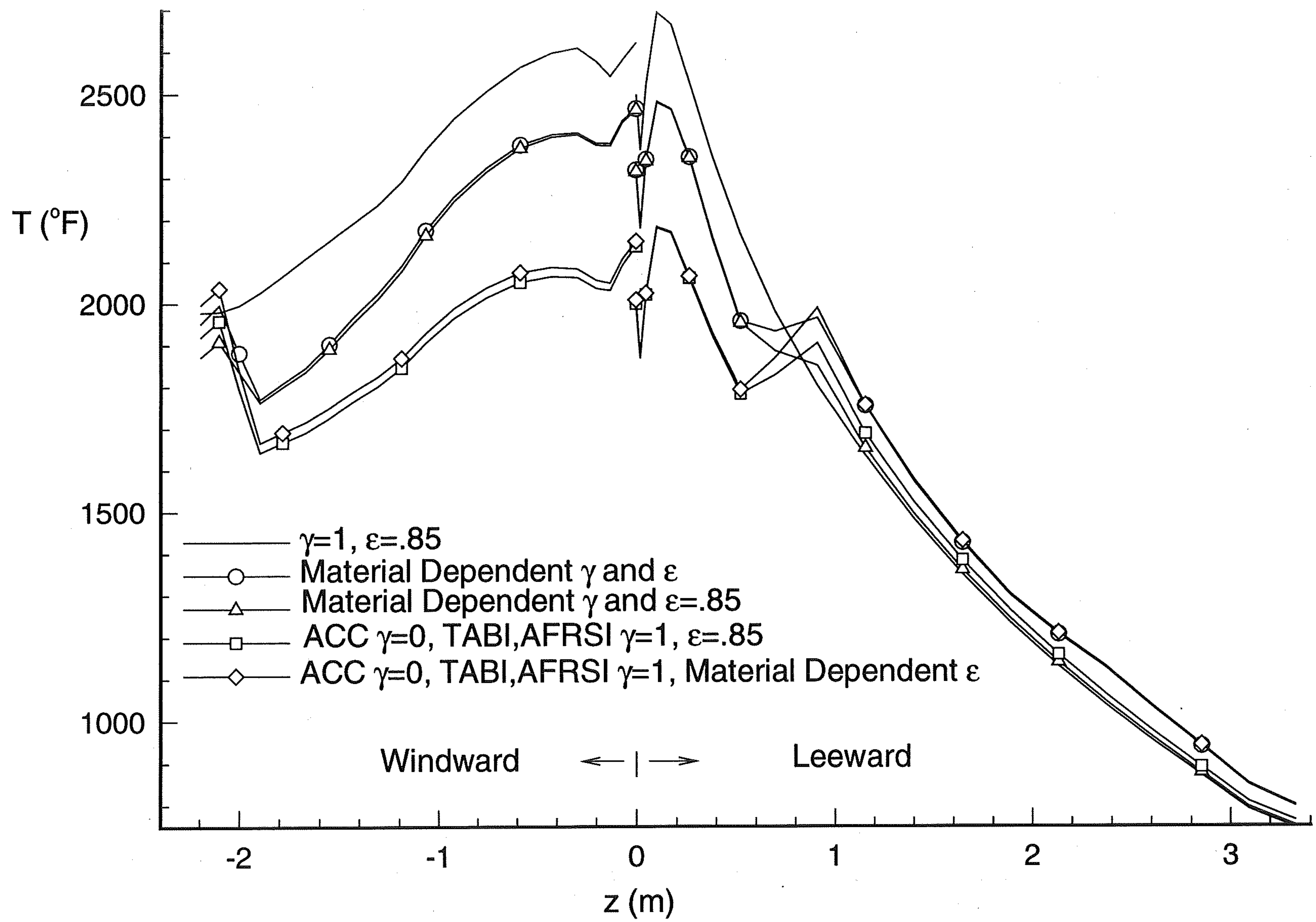


Top Layer TPS Thickness (in.) for the LaRC Winged Body SSTO Vehicle (Total Heating Time, 6200 sec)

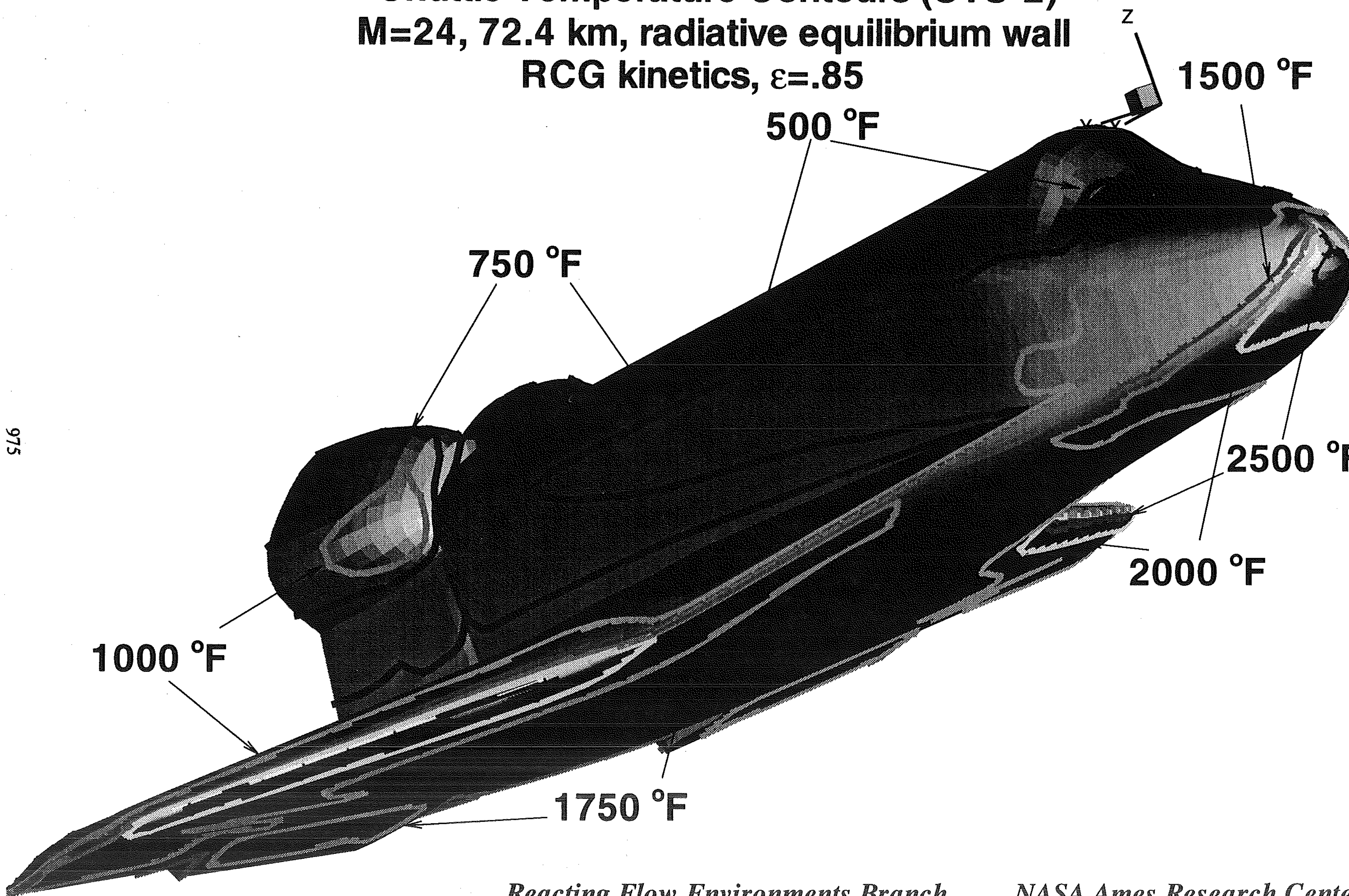
(TURBULENT FLOW SOLUTION)


LaRC SSTO Vehicle Centerline TPS Thicknesses
TPS Thickness (in.)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
Streamwise Distance (m)
TABI Blankets (Windward)
Turbulent (Windward)
Laminar (Windward)
AFRSI Blankets (Leeward)
ACC or TUFI Tiles
Leeward
Laminar
Turbulent
ARC/ST - W.D.Henline/F.S.Milos/Y.-K.Chen

Effect of TPS Material Properties on Surface Temperatures



Shuttle Temperature Contours (STS-2)
M=24, 72.4 km, radiative equilibrium wall
RCG kinetics, ε=.85



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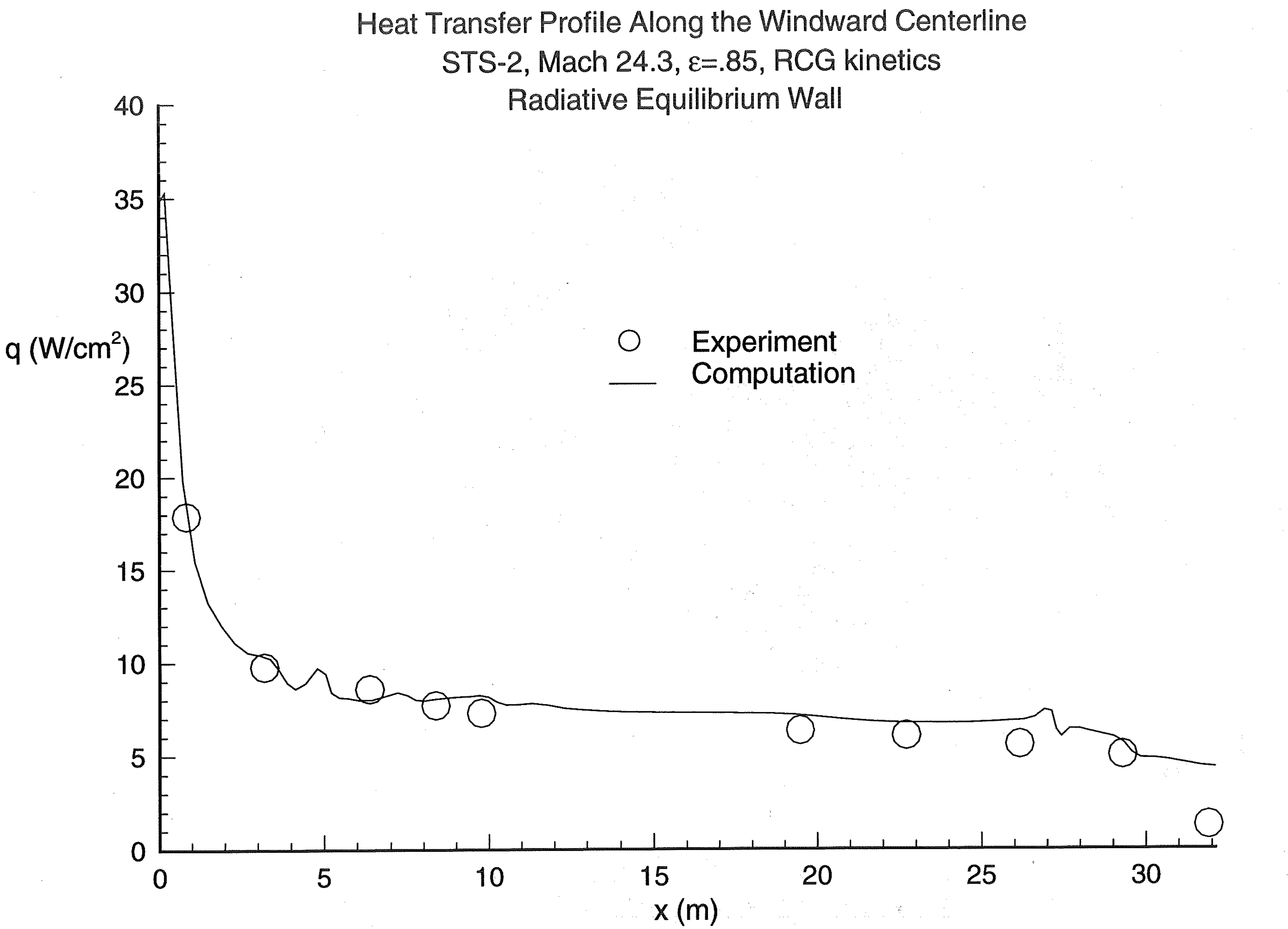

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