ENTRY FLIGHT REGIMES: APOLLO AND ORBITER

ALTIMETER, FT

0 5000 10 000 15 000 20 000 25 000 30 000 35 000 40 000
VELOCITY, FT/SEC

ORBITER

OFT DESIGN

HEATING BOUNDARY

0.1 ATM

1 ATM PRESSURE

APOLLO LUNAR RETURN

APOLLO ORBITAL RETURN

FIGURE 1
DESIGN AND FLIGHT TEST ENVIRONMENTS

- △ APOLLO LUNAR RETURN
- ▽ APOLLO ORBITAL RETURN
- ○ SHUTTLE ORBITER
- ▲ FLIGHT
- ▼ DESIGN

MAXIMUM HEATING RATE, BTU/FT²-SEC

INTEGRATED HEAT LOAD, BTU/FT²

RADIATION EQUILIBRIUM TEMPERATURE, °F (ε = 0.9)
DESIGN HEATING METHODOLOGY

WIND TUNNEL CALIBRATION OF HEATING MODELS

REPRESENTATIVE FLOW MODELS

FUSELAGE LOWER CENTERLINE

HEATING RATE

CALIBRATION FACTOR

DATA FAIRING

ECKERT FLAT PLATE

FIGURE 3
LOGIC FOR PREDICTING BOUNDARY LAYER TRANSITION ON THE ORBITER

WIND TUNNEL DATA

SMOOTH BODY

ANALYSES

DATA CORRELATION

--- EXTRAPOLATION \( \alpha = 30, 40 \)

\( \bullet \) FAIRING OF W.T. DATA

\( \bullet \) CALCULATION

EXTRAPOLATION TO FLIGHT

SMOOTH BODY PREDICTIONS

\( (Re/Y/M) = 0 \) f(X/L)

W.T. DATA

TIME, SECONDS (14414.1)

FLOW FIELD SIMULATIONS

\( \bullet \) RE, MI \( \theta \)

\( \bullet \) REk

K = 0.3''

\( (Re/Y/M) = 0 \) f(X/L)

W.T. DATA

TIME, SECONDS (14414.1)

ROUGH BODY PREDICTIONS

\( K = 0.3'' \)

\( (Re/Y/M) = 0 \) f(X/L)

W.T. DATA

ROUGH BODY CONDITIONS

DATA CORRELATION

\( Re/Y k = 0.1L \)

X/L

FIGURE 6

X/L

X/L

X/L

X/L

(Re/Y) x = 0.1L
SURFACE CATALYSIS FLIGHT PREDICTION PROCESS

\[ \frac{\partial V}{\partial X} = \frac{V_{i+1} - V_{i-1}}{2\Delta X} \]

Finite Rate Inviscid Flow Field Code

\( \gamma(T_w) \)
Energy Transfer Catalytic Recombination Coefficients

\[ \dot{q}/q_{FC} = f(a, T, X) \]
Stagnation Point Theory

Boundary Layer Code

Orbiter Heat Flux Predictions

Figure 5
ORBITER FLOW FIELD RESULTS

CROSS FLOW SPEED CONTOURS

\[ \alpha = 30^\circ \]

\[ M_\infty = 8 \]

\[ Re_L = 2 \times 10^6 \]

\[ X/L = 0.5 \quad 0.4 \quad 0.2 \]

FIGURE 4
COMPARISON OF STS-3 FLIGHT DATA WITH PREFLIGHT TEST PREDICTIONS: FORWARD WINDWARD CENTERLINE

SURFACE TEMPERATURE, °F

ENTRY TIME, SEC

FIGURE 7A
COMPARISON OF STS-3 FLIGHT DATA WITH PREFLIGHT TEST PREDICTIONS: MIDBODY WINDWARD CENTERLINE

**Figure 7B**
COMPARISON OF STS-3 FLIGHT DATA WITH PREFLIGHT TEST PREDICTIONS: AFT WINDWARD CENTERLINE

FIGURE 7C
STS-3, ORBITER INFERRED AND PREDICTED HEAT FLUX

400 SEC INTO ENTRY
23 900 FT/SEC, VELOCITY
246 000 FT ALTITUDE
40° ANGLE OF ATTACK

FLIGHT DATA
CATALYSIS EXPERIMENT
NONCATALYTIC
FULLY CATALYTIC
PREFLIGHT TEST PREDICTION

SURFACE HEAT FLUX, BTU/FT²-SEC

NORMALIZED DISTANCE DOWN WINDWARD CENTERLINE, X/L

FIGURE 8
WINDWARD

-2,270° LEEWARD

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ENTRY BONDLINE THERMAL RESPONSE,
MIDBODY WINDWARD

FIGURE 15

TEMPERATURE, °F

DESIGN PREDICTION
DESIGN TRAJECTORY
JSC PREDICTION
STS-1 DATA
STS-1 TOUCHDOWN
TAEM

TIME, SEC

TEMPERATURE, °K

0 500 1000 1500 2000 2500 3000 3500

100 150 200 250 300 350 400 450
MATRIX OF UNDERSTANDING

TESTING
- RESEARCH
- TECHNOLOGY
- COMPONENT
- SUBSYSTEM
- MODEL
- SYSTEM

ANALYSIS
- EQUATIONS, CONSTITUATIVE RELATIONS
- PERSPECTIVE
- MODELING
- CORRELATION
- NUMERICAL COMPUTATION
- NUMERICAL SIMULATION

● UNDERSTANDING
● CONFIDENCE
● CAPABILITY