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Infrared Sensing Aeroheating Flight Experiment

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ISAFE

ISTEF

SPAWAR Systems Center San Diego

Infrared Sensing Aeroheating Flight Experiment

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CHART 1

Instruments of the Ballistic Missile Defense Organization/Innovative Sciences and Technology Experimentation Facility (BMDO/ISTEF) collected imagery from the STS-96 and STS-103 landings at Kennedy Space Center, Florida on 6 June and 27 December 1999. Midwave infrared data provided vehicle body surface thermal measurements in support for NASA X vehicle development. Ground-based observations were proposed as an adjunct measurement of boundary layer transition from laminar to turbulent flow, possibly reducing the number of on-board thermal sensors required. Initial comparisons with shuttle thermocouple data indicate temperature measurement agreement on the order of five percent. The video rate, high-resolution thermal maps are also suitable for producing movie sequences for comparison to CFD predictions and wind tunnel results. The shuttle served as a surrogate target to provide data for development of processing techniques. These capabilities are additionally applicable to support ongoing programs, such as ABL for scoring and kill assessment An additional collection is planned to assess performance at higher target altitudes.

This work was performed under BMDO contract N66001-95-D-0088.

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ISAFE Objectives

ISTEF

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- For NASA LaRC
  - Measure surface temperature of experimental vehicles in high resolution during supersonic/hypersonic reentry, specifically transition from laminar to turbulent flow
    - Observe experimental vehicle tests: X33, X34, X37, Hyper-X
    - Deliver to NASA high resolution thermal map movie
    - Compare to CFD model & wind tunnel predictions
    - Compare to sparse vehicle surface thermocouple data
    - Demonstrate/validate low cost ground based capability and techniques using Shuttle
- For BMDO
  - Demonstrate capability with possible application for low cost target scoring for ABL & SBL, as well as AIT testing

Unclassified CHART 2

The work described here was performed under an Interagency Agreement between the National Aeronautics and Space Administration, Langley Research Center, and the Ballistic Missile Defense Organization, which states in part:

"BACKGROUND AND PURPOSE

The validation of experimental and computational predictive techniques is essential for the success of future space transportation technology development. Conservatism in design must be eliminated or minimized to enable low cost space transportation. The aerodynamic and aeroheating disciplines are the drivers for vehicle design and provide critical inputs to other disciplines such as control system design, materials, and structures. Aerodynamic and aeroheating data provide the input for thermal protection system (TPS) material selection and sizing, which must represent the minimum weight to ensure survivability and reusability. For autonomous landing vehicles, the aerodynamic performance and margins must be known precisely throughout the entire flight trajectory. To achieve these goals of optimum design of future RLV's, reduced vehicle design cycle time, and to enhance U.S. space launch competitiveness, designers must have highly accurate, calibrated and validated tools for prediction of aerodynamic performance and aeroheating characteristics. Aerothermodynamic flight data provides the ultimate means for tool validation. Once validated, these tools may be used with confidence for the next generation of RLV's and vehicles such as military spaceplanes, and Shuttle Orbiters.

The objective is to extract highly accurate aerodynamic performance and aeroheating characteristics from flight measurements taken during Shuttle and X-33 hypersonic flights for the purpose of providing 1) benchmark data for validation of ground experimental and computational prediction techniques essential for the optimum design and flight of future RLV's, and 2) information required to determine flight margins, address anomalies, and mitigate long-term risk for the next-generation reusable launch system."

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STS-96

ISTEF

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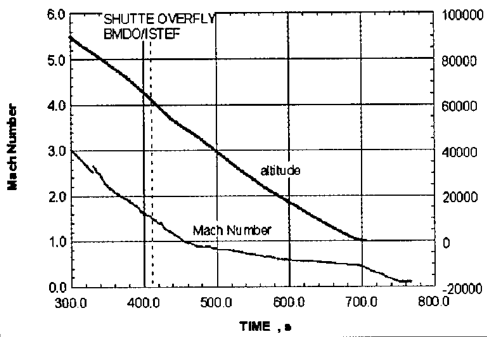
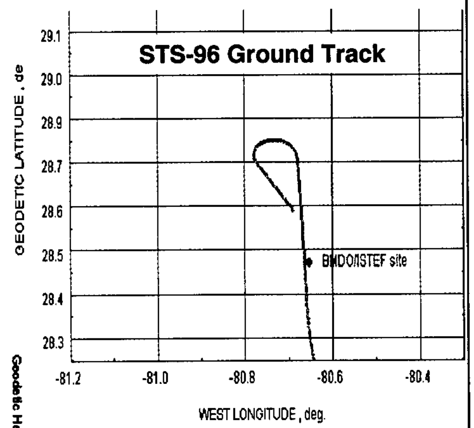
- **Provide initial data set**
  - Quick response (3 weeks) for local demonstration
  - establish interagency working relationship
  - convert series of MWIR intensity images to thermal map movie
  - include ceramic tile emissivity as a function of temperature
  - compare results to thermocouple data





- **Observed portion of trajectory**
  - Observation of transition not expected
  - Manual acquisition and tracking
  - Altitude range observed: 80 - 60 kft
  - Mach range observed: 3.0 - 1.5

CHART 3

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STS-96 Results
Thermal Movie and TC Data

ISTEF

SPAWAR Systems Center San Diego

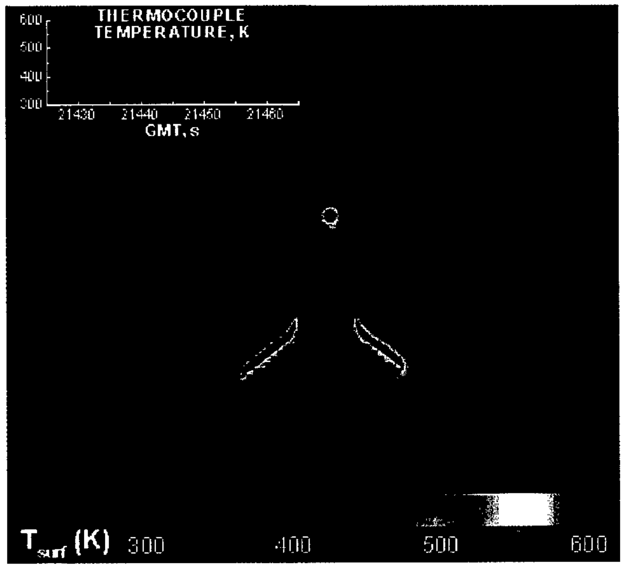

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CHART 4

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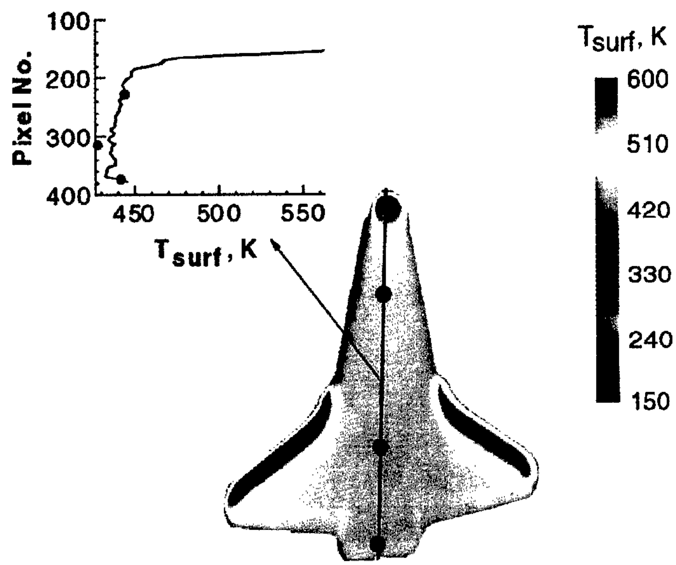

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CHART 5

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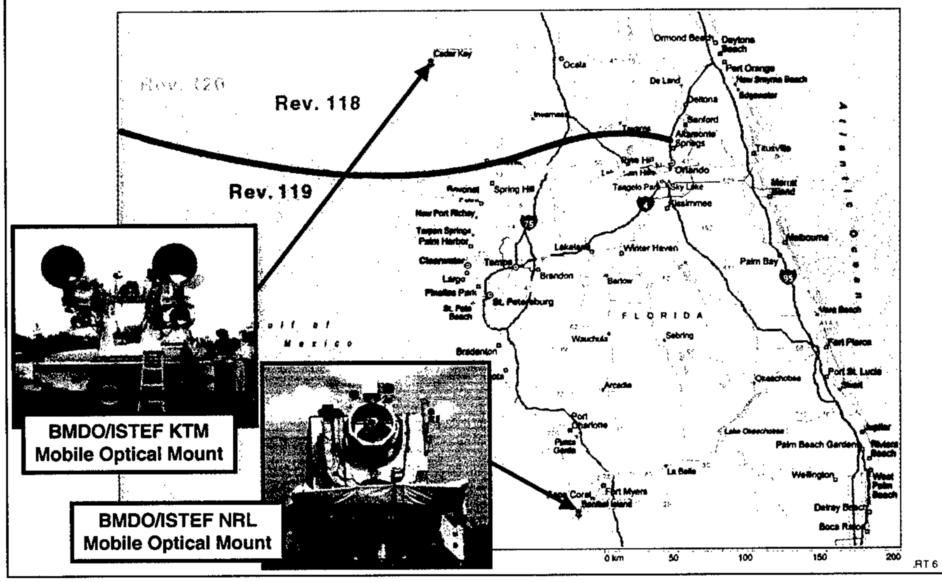
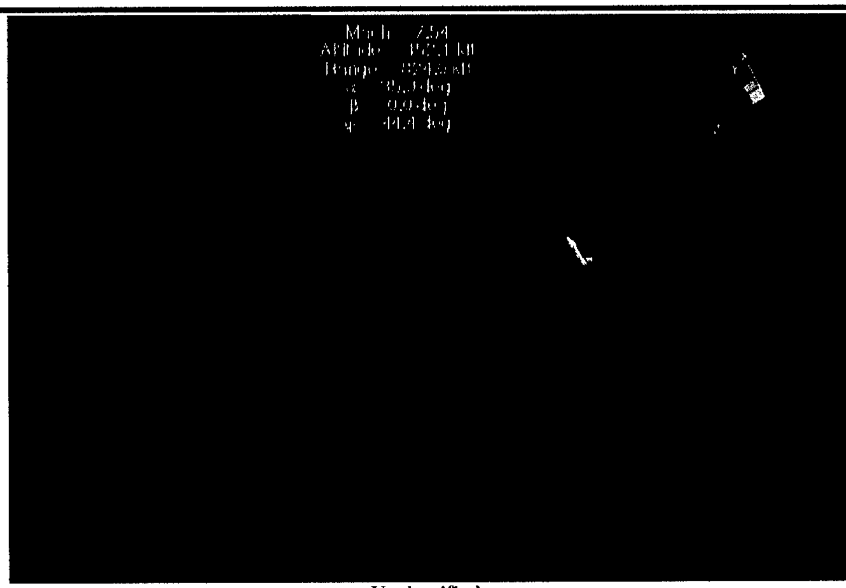
STS-103 Reentry Ground Tracks and Observation Locations

ISTEF

SPAWAR Systems Center San Diego



STS-103 Results
Thermal Movie with TC data



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STS-103 Results

ISTEF

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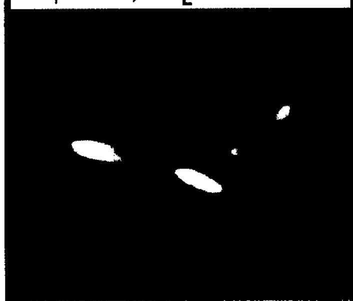
STS-103 Reentry (1999:361:23:51:59.16)

$M_\infty = 4.9$, $h = 118600$ ft $\alpha = 25.0°$, $\phi = -43.1°$, $Re_L = 23.0 \times 10^6$



Experimental Orbiter Heat Transfer Wind Tunnel

$M_\infty = 6.0$, $\alpha = 25.0°$, $Re_L = 6.2 \times 10^6$

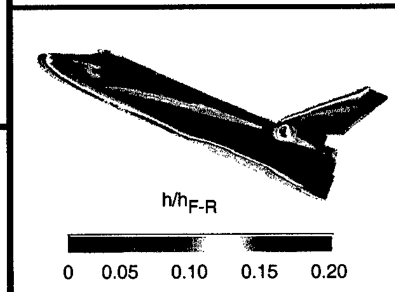


CHART 8

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ORBITER SURFACE MATERIALS

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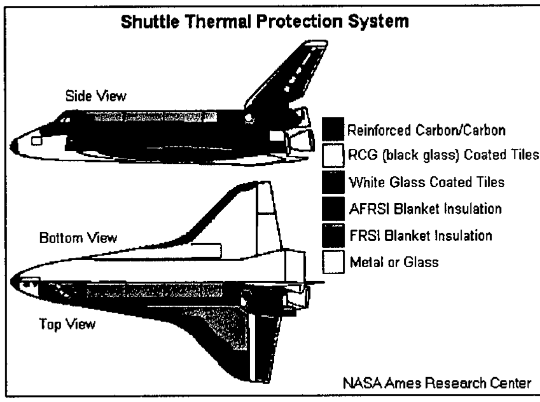
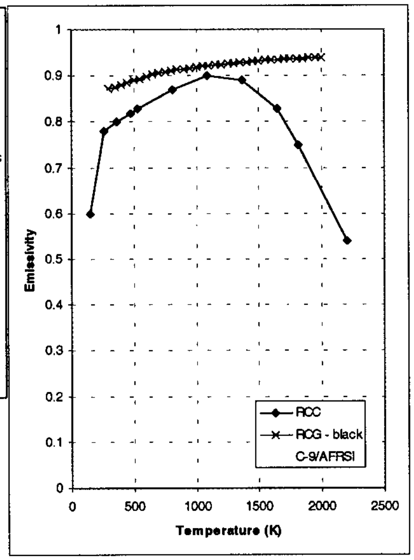


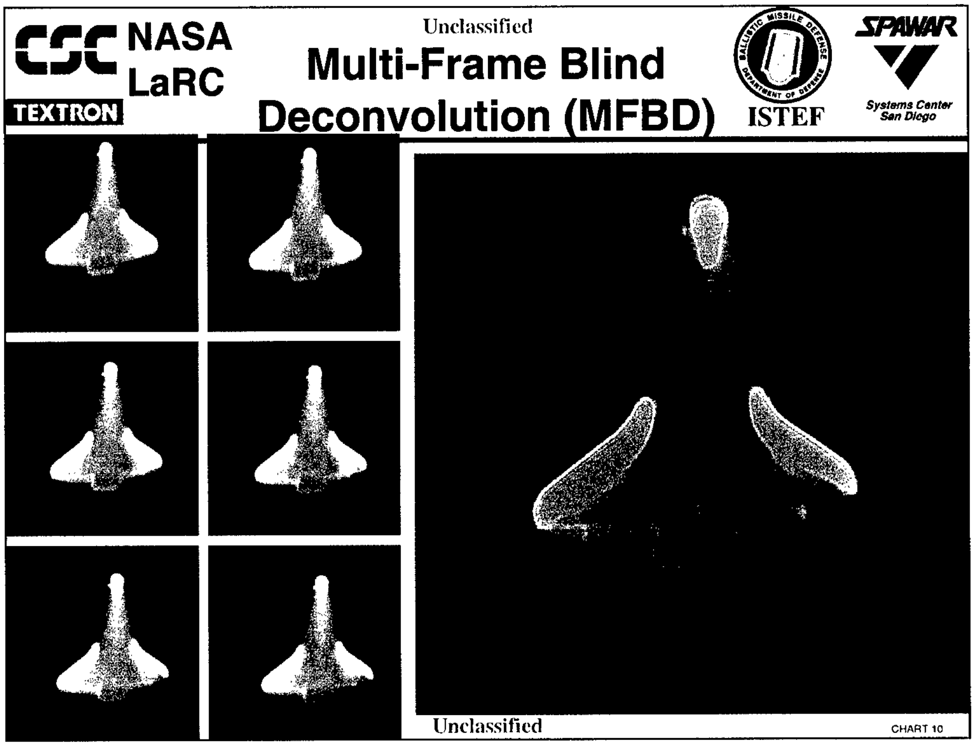


Preliminary temperature reduction for tracking sequence performed for candidate atmosphere using two different emissivity profiles

- RCG
- C9 coated AFRSI

Unclassified

CHART 9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Multi-Frame Blind Deconvolution (MFBD)
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CHART 10

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Summary and Future Efforts

ISTEF

SPAWAR Systems Center San Diego

- Summary
  - Demonstrated low cost ground base high resolution thermal imaging sufficient to observe transition given correct ground site relative to trajectory and vehicle attitude
- Future
  - Further observations of Shuttle reentry for capture of laminar to turbulent transition
  - Detail planning for X34, X33, X37 observations
  - Further discussions with ABL