ThermoAnalytics Europe LLC

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Thermal & ECLS Software

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Thermal and infrared signature analysis in aerospace and aeronautics

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Abstracts

It is more and more common to use numerical analysis software tools for aerospace and aeronautical applications. Human lives depend on these systems. Based on the wide range of activities, it is more necessary than ever before to predict the thermal behavior and protect equipment and systems from thermal damage. In many cases such systems are not fully protected against extreme thermal loads, such as intense solar impingement.

This presentation shows you the current state of software development at ThermoAnalytics, Inc. TAI's thermal and IR signature analysis software (RadTherm / MuSES) is designed to provide answers to thermal design questions and to cover these deficiencies.

A simple case study presented in this paper will demonstrate how efficiently the application RadTherm / MuSES can predict thermal and infrared behavior of any kind of system.

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Overview

- **Introduction**
- **Procedure**
- **Examples**
- **Conclusion**

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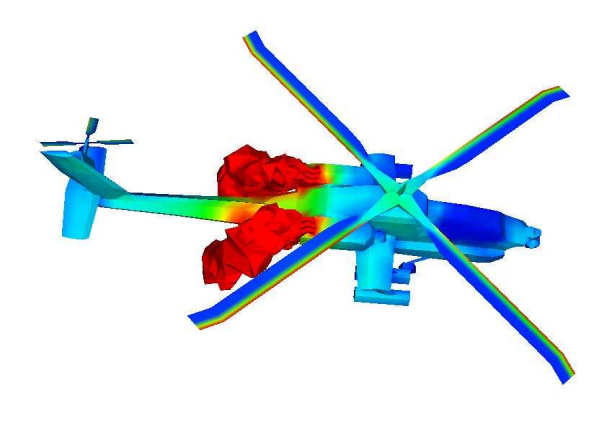
Introduction

Providing State-of-the-Art Software Products for



Commercial Thermal Analysis

Military Signature Analysis

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Thermal and infrared signature prediction is more and more common and useful for

- **discover heat sources**
- **enhanced cover of targets**
- **predict complexe scenarios**
- **find best possibilities**

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History

- 1996 ThermoAnalytics Incorporates
- 1998 RadTherm 4.1 commercial release
- 1999 RadTherm 5.0 released
- 2000 TAI receives Tibbits and Army SBIR Quality Award
- 2001 TAI awarded Army Prime Contractor of the year
  RadTherm interface with CFD & Post-Processors
- 2002 TAI awarded II. Army Prime Contractor of the year

• Introduction
• Procedure
• Results
• Conclusion

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Core Competencies

- Radiation Physics
- Computational Fluid Dynamics
- Thermal System Modeling
- Cross-Platform Software Development
- Code Optimization
- Graphical User Interface Design

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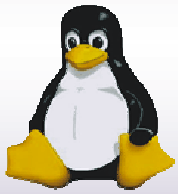
Hardware Partners

Microsoft®



hp invent

Sun microsystems

SiliconGraphics Computer Systems

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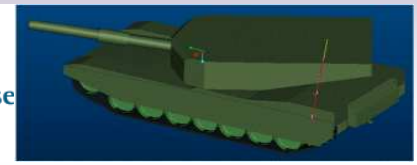
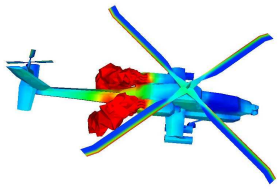
Software Partners

PTC® Enterprise Software Partner

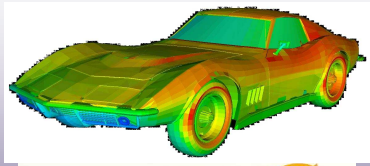


CEI Creator of EnSight

FLUENT INCORPORATED



ICEM CFD Engineering



STAR-CD

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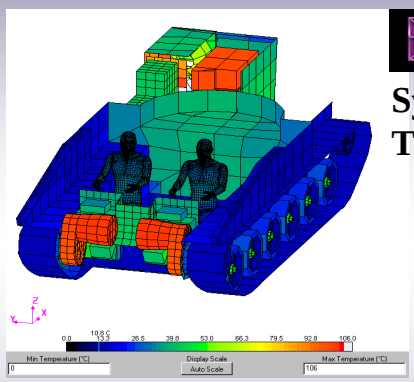
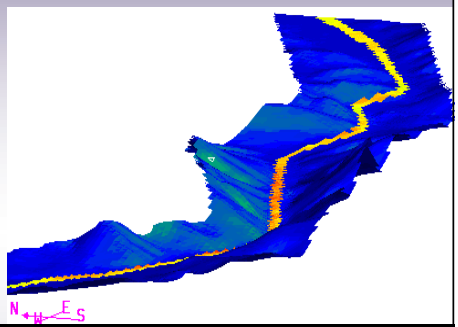
Software Products



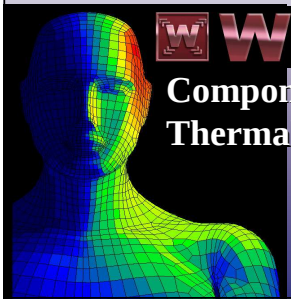
RadTherm

Systems Level
Thermal Modeling



RadThermRT

Road Surface/Terrain Modeling



WinTherm

Component Level
Thermal Modeling

InfraRed
Signature Modeling

MuSES

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Complete Thermal Analysis

- **Radiation**
  - Single and multibounce radiation
  - Automatic calculation of view factors and solar projected (apparent) areas, using a voxel-based ray tracer
- **Conduction**
  - Automatic Conduction Linkages
- **Convection**
  - Specify H and T_{film}
  - Automatic Convection Library
  - Calculated Wind Convection (nat. environ's)
  - 1D Fluid Flow (advection)
  - Import CFD Results

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Advances

- Advanced Thermal Simulation
- Extremely Fast Thermal Solver
- Large-scale system-level Thermal Analysis
- Flexibility to manipulate your system with easy
- Rapid Prototyping
- Integration with CAD/CFD/CAE

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Aerospace Applications

Aircraft in standby or hovering incl. solar loading

Aircraft on mission incl. terrain on lower or upper atmosphere incl. solar loading

Infrared signature in standby, idel, hovering or on mission

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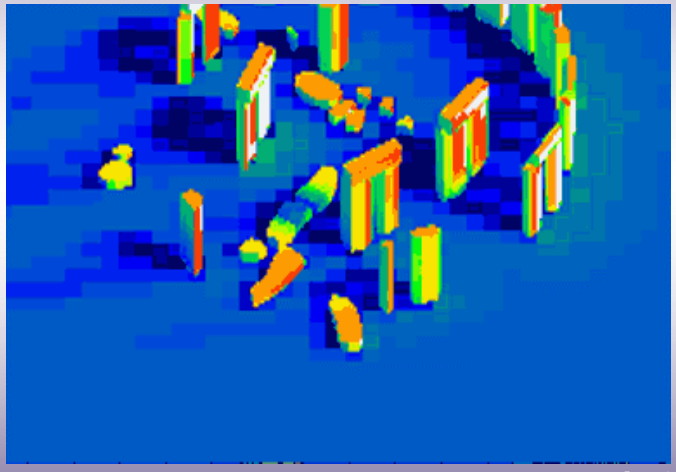
Other Applications

Automotive

Underbody, Exhaust & Underhood, Climat Control & HVAC, Vehicle Interior & Thermal Comfort, Electronics & Lighting

Electronics

Architecture



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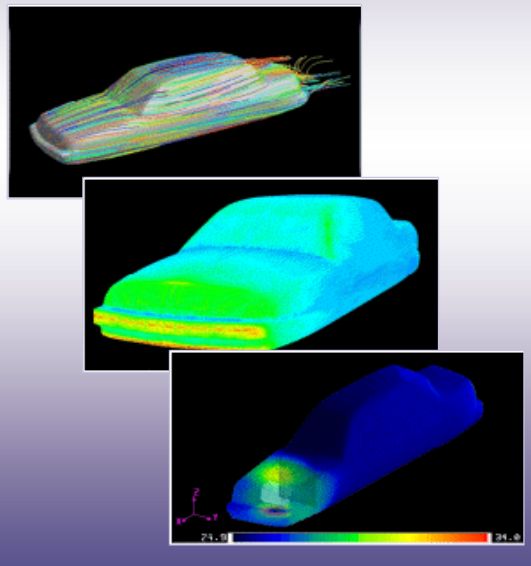
Integration with CFD

Only Surface Geometry

Convection Coefficient & Fluid Temperature

Mix with RadTherm's Other Convection Tools



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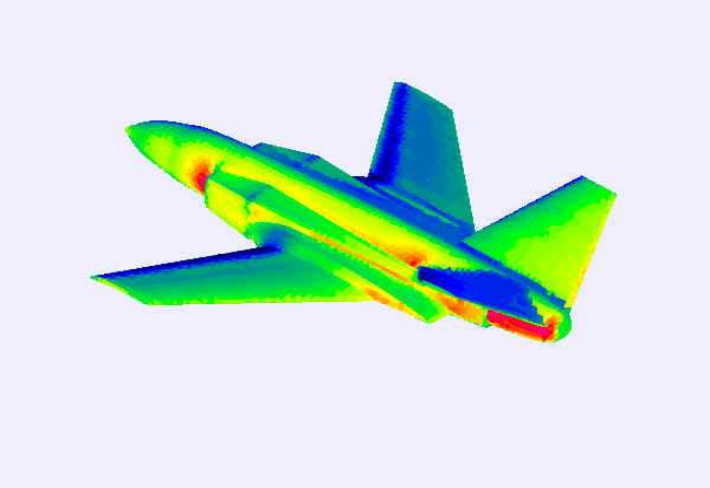
Example

The following example will discrib a project for an UAV system development on an attitute of 30000 ft



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Boundaries

MODTRAN Weather File

to predict
- diurnal direct solar radiance
- diffuse solar radiance
- thermal sky radiance
- apparent ground radiance

Direct solar radiance

to predict the solar radiance, we ran MODTRAN in “transmitted solar irradiance” mode (IEMSCT = 3) using the solar waveband (4,000 to 50,000 cm-1, 0.2 to 2.5 microns)

Diffuse solar radiance

To predict the diffuse solar radiance, we ran MODTRAN in “radiance with solar scattering” mode (IEMSCT = 2) using the solar waveband (4,000 to 50,000 cm-1, 0.2 to 2.5 microns).

Boundaries

Thermal sky radiance

To run the thermal sky radiance simulation we used the same input deck that we used for the diffuse solar radiance except we used a thermal waveband (200 to 5,000 cm-1, 2 to 50 microns). This waveband corresponds to the spectrum typically measured in the field for thermal sky radiance.

Apparent ground radiance

To run the apparent ground radiance simulation we used the same input deck that we used for the thermal sky radiance except:

- Set the zenith to 145 degrees (ANGLE on CARD 3)
- Set the boundary temperature (TBOUND on CARD 1) to diurnal ground temperature
- Set the boundary albedo to the ground reflectivity (SALB on CARD 1)
- Set H2 to 0.0 km (CARD 3)

For the solar and sky simulations, we set TBOUND = 0.0 and SALB = 0.0 to simulate outer space.

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Boundaries

MODTRAN INPUTS

- US STANDARD DAY 1976 Spring/Summer
- Without multiple scattering
- Rural extinction haze 23 km visibility
- Zenith for sky = 55 deg
- Zenith for ground = 145 deg
- Day of year = 188
- UTC = Hancock Time + 4
- Ground albedo = 0.2 (emissivity = 0.8)
- Solar band = 4000 to 50000 cm-1 (0.2 to 2.5 microns)
- Thermal band = 200 to 5000 cm-1 (2 to 50 microns)

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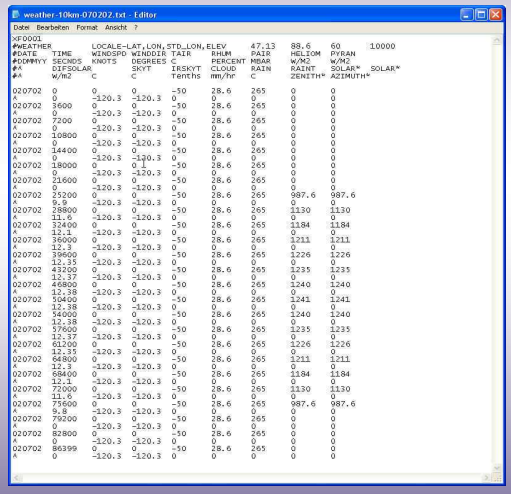
Boundaries

Weather file example



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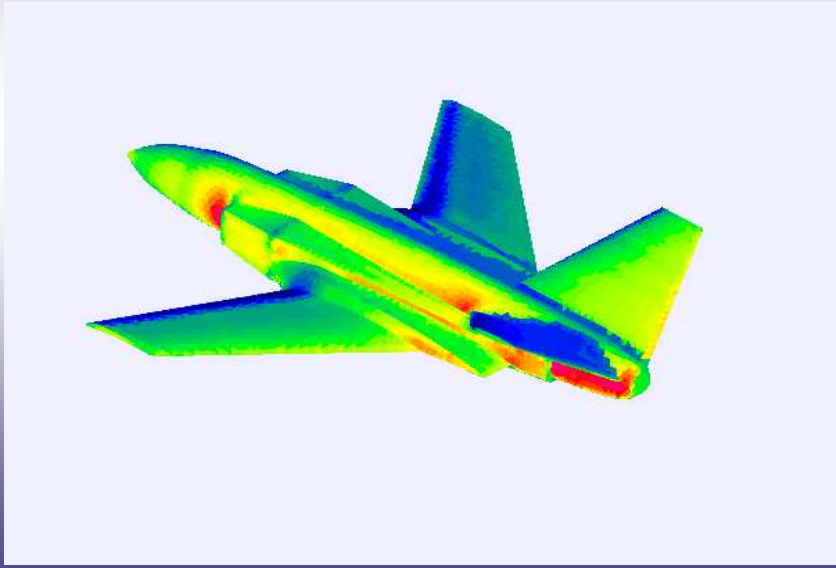
Results

Physical temperature results [time 0900-1400]



Results

IR radiance results [time: 0900 – 1400 / 8 – 12 micron]

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Future Development

Modeling Features Scheduled After RadTherm 7

- User Routines / Hook Functions
- Complex BRDF
- Parallel Solvers
- Scene Model Interface
- Exhaust Flow Interface
- Plume Radiance Interface
- Temperature Dependent Properties
- Directional Water Model
- Ship Wake Model
- Spatial Sky using MODTRAN
- 1D Automated FF Network
- 3D Fluid Flow Modules
- Appendable Parts Library
- Mobility Module
- Solid Elements

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Customers

- US Army, Navy, Air Force, Marines, Coast Guard, NGIC, NAIC
- Flight Safety International
- Los Alamos National Lab
- Booz Allen Hamilton
- Northrop Grumman
- General Dynamics
- Lockheed Martin
- Amherst Systems
- Teledyne Brown
- United Defense
- Sikorsky
- Textron
- Boeing
- S.A.I.C.

- DGA/ETAS - France
- FGAN / FOM – Germany
- DLR - Germany
- TNO - Netherlands
- F.O.A. - Sweden
- Bofors Missiles AB - Sweden
- NDRE - Norway

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Summary

This simple case study should show you how easy it can be to predict potentional heat sources on existing systems, manned or unmanned, in atmosphere or orbital.

Also this case study shows that using **RadTherm / MuSES** makes it easy to find and discover successfully every kind of heat sources, internal and extreme thermal loads, such as intense solar impingement.

It can be used for exsiting systems as well as for new systems in development status.

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Concluction

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And special thanks are due to both co-authors

- **Matthew Monte – ThermoAnalytics, Inc., Michigan, USA**
- **Craig Makens - ThermoAnalytics, Inc., Michigan, USA**

Appendix

There is a seperate paper for more details about MODTRAN data files available. If you wish to receive this please contact us under service@thermoanalytics.de

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Many thanks for you attention !

Your partner for successful thermal and infrared signature prediction in simulation & analysis

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