Thermal Model Development for Ares I-X

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Outline

- Background
- Modeling Process
- Lessons Learned
- Aeroheating Application
- Conclusions
Ares I-X: Background

♦ Flight test vehicle for CLV
♦ Operational first stage (SRB)
♦ Active Roll Control System (RoCS) on Upper Stage
♦ Upper Stage, Crew Exploration Vehicle, and Launch Abort System portions
  • Inactive with representative mass and OML
♦ Scheduled launch from KSC April 15, 2009
♦ Developed and built by multiple organizations
  • JSC, MSFC, LaRC, GRC, KSC, ATK, LMA/ULA, TBE
♦ Purpose is to test and measure launch and separation of CLV-style vehicle
Thermal Model Development

♦ Full vehicle model
  • Model in Thermal Desktop 5.1, Mechanical Desktop 2008
  • Model template and code for applying aeroheating from MSFC
  • CM/LAS and FS models developed at LaRC
  • USS model from GRC
  • FSAM model from LMA
  • RoCS model from TBE
  • Model integration and runs at LaRC

♦ Temperatures mapped to NASTRAN for thermal stress analysis
Thermal Model Details

♦ Full vehicle model includes:
  • Full 3D exterior vehicle geometry and mass
  • Temperature dependent material properties
  • Solar and earth flux, ambient air and winds
    (planet modeling method in TFAWS-08-1017)
  • Interior air conduction, convection
  • Internal and external radiation
  • Contact and air exchange between segments
  • Through-thickness gradients
  • Ground structures
  • Ascent aeroheating
  • Avionics size, mass, power
  • ECS, fan, avionics timelines
  • Personnel and lighting powers
  • Aft skirt purge, igniter heater, propellant temp
  • Hot/cold cases

♦ 7000 nodes

♦ 1,781 klb (2% low)
Thermal Cases

♦ Vehicle Assembly Building (VAB)
  • Ambient from measured thermal data
  • Can run with ECS and avionics on or off
  • Sets start temperature for rollout

♦ Rollout
  • Run for 24 hr following 24 hr in VAB with ECS off
  • Solar and earth radiation load

♦ On-pad
  • ECS/fan functionality, aft skirt purge
  • Solar and earth radiation, avionics power timeline

♦ Ascent
  • Ascent aeroheating, avionics heating
  • Runs 125 seconds

♦ Descent
  • FS only; aeroheating, avionics heating
Modeling Lessons Learned

♦ Import of multiple submodels led to greater understanding of how pre-work and model standardization save integration time

♦ Naming
  • Standardized (e.g., 1\textsuperscript{st} 3 characters of submodel name define segment)
  • Simple
  • Applies to submodels, layers, radiation groups, case sets

♦ Limit number of submodels, layers

♦ Comments

♦ Utilities>>Notes to comment model

♦ Calculated expressions

♦ Standard coordinate system

♦ Boxes instead of separate surfaces
Pre-modeling Coordination

♦ Pre-define
  • Software and version
  • Units
  • Symbols
  • Symbol Groups
  • Coordinate system
  • Planet modeling method
  • Deliverables

♦ Use template model file if possible, with
  • Units
  • Symbols
  • Symbol Groups
  • Coordinate system(s)
  • Material and optical properties
  • Common logic blocks
Model Checking

♦ Verify submitted model before importing into integrated model
  • View by thermal & optical props, radiation groups, etc.
  • Run a mass check and make sure the model mass is correct
  • Output SINDA data to check
  • Look for duplicate nodes
  • View active sides
  • Check units (both thermal and fluid submodels)
  • Run submitted model and check results against those submitted
Model Import Process

♦ Run check cases of both integrated and submitted models beforehand; compare to post-integration results
  • SUBMAP or similar useful to check heat flow between submodels

♦ Multiple steps necessary to ensure correct transfer

♦ Detailed export/import process steps given in manuscript
  • Tip: to bring over a contactor or conductor and re-attach it, temporarily attach it to something exported

♦ Consider:
  • Symbols
  • Units and coordinate system
  • Properties and aliases
  • Radiation groups
  • Contactors
  • Correspondence data
  • Logic Manager objects
  • Orbits and case sets
  • Layers

Fold contactor back to imported part to bring over
Model Logic

♦ Logic blocks used for all scenarios across multiple cases

♦ Logic actions based on symbols
  • Hot/cold case, location, hold, abort
  • Sequencing times, power levels
  • ECS flow and temperature
  • Number of personnel

♦ Simplifies
  • Switch between hot/cold case
  • Launch time change
  • Timeline changes
  • Power level changes
  • Sequencing updates

♦ Ares I-X examples
  • STRTIME, RUNTIME, OFFSETL (launch time of day), TIME2L (time remaining until launch), sw_ & pw_ for avionics switching and power, casedef, loc_def, casehold, caseabt, SKY_TMP, AIR_TMP, GND_TMP
  • Symbol naming guidelines (th_, cc_, etc)
Restarts with Fluid Lumps

- Standard restarts use only thermal node temperatures in restart
- Ares I-X incorporates huge air volumes - 100’s of lbs of air
  - Important to capture air state between cases
- Ares I-X method modified to include fluid temps in restart
- TD 5.2 will include this option

![Graphs showing temperature changes over time](image)

0 1 0 2 0 3 0 4 0 5 0 6 0
Time [sec]

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Software Standardization

♦ Version of software standardized between model developers
  • Thermal Desktop
  • AutoDesk

♦ Compiler version also critical
  • E.g., built-in (Lahey) versus Intel compilers
  • Compiler settings and defaults
  • Differing compilers between organizations led to different model behavior
Aeroheating Application

♦ Aeroheating applied to Ares I-X during ascent and descent

♦ Aeroheating loads supplied in MINIVER text files
  • Enthalpy and convective coefficient at three wall temps at each time
  • Times in 0.5 to 5 sec increments
  • 2000 body points over vehicle

♦ User logic applied heating during Sinda/Fluint run
  • Interpolation for time, wall temperature

♦ Manual mapping of body points to TD model time-consuming

♦ BPMapper code developed for automated mapping
BPMapper

- Maps each TD node to closest body point (BP)
- Divides nodes into clean skin and protuberance for mapping
- Select coordinate transformation
- Define custom mappings
- Lists:
  - Distance and BP for each node
  - All nodes exceeding pre-set error distance
- Rapid remapping for new mesh or model import
- Graphical verification critical
  - BPMapper writes file for graphical verification of BP mapping
  - Sinda/Fluint run writes file for graphical verification of aeroheating map
  - Crucial to verify mapping and aeroheating assumptions
Boundary Condition Mapper for CFD

♦ New feature in TD 5.2 for interpolated heating from CFD file
  • Boundary Condition Mapper (BCM)

♦ Map2CFD code developed at LaRC
  • Imports Tecplot file format
  • Scale, invert, combine multiple geometries
  • Outputs file for TD BCM use

♦ Aeroheating loads
  • Used for thermal run
  • Automatic interpolation for location, time, wall temperature

♦ Benefits
  • Use CFD results directly
  • Avoid mapping single BP to location
Conclusions

♦ Pre-model development coordination crucial
  • Use template file

♦ Model standardization saves time and headaches

♦ Consistent model import process developed

♦ Powerful model logic facilitates analysis

♦ Improved aeroheating options developed
  • BPMapper
  • Map2CFD

♦ Graphical aeroheating verification reduces errors

♦ Lessons learned on Ares I-X can be applied to other missions involving import of multiple models
  • Critical for future Constellation work
  • Useful for others performing large-scale analysis
Acknowledgments

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♦ Avionics submodels supplied by Gary Holmstead (LMA)
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