

Automatic creation of reduced-order models using Thermal Desktop

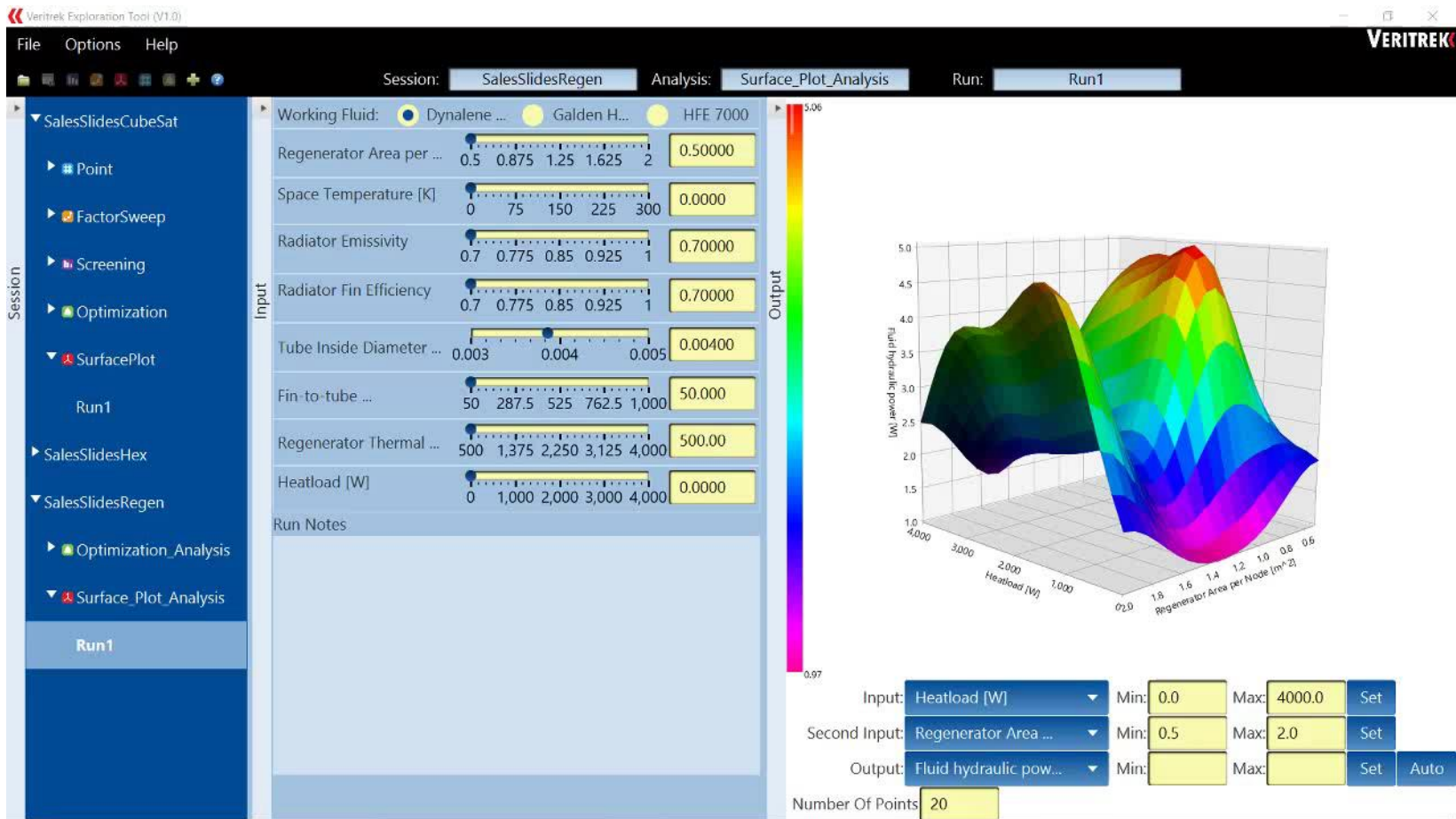


TFAWS
JSC • 2018

Derek W. Hengeveld, LoadPath
Jacob A. Moulton, LoadPath

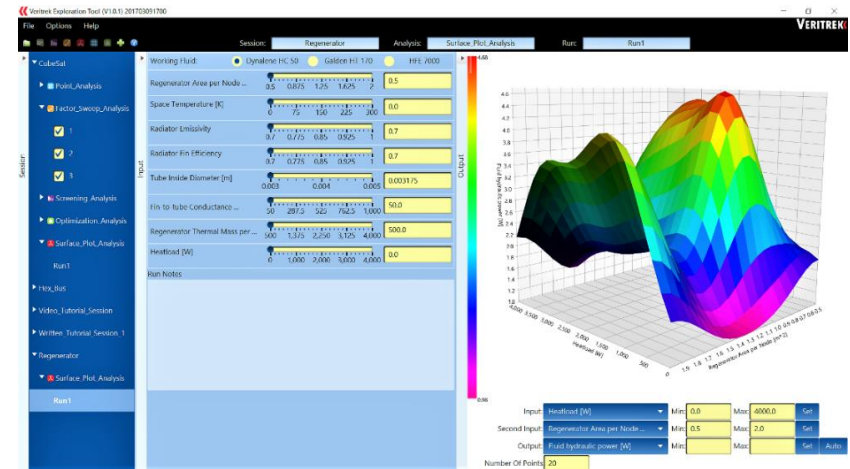
Thermal & Fluids Analysis Workshop
TFAWS 2018
August 20-24, 2018
NASA Johnson Space Center
Houston, TX

- Why Reduced-Order Models (ROMs)



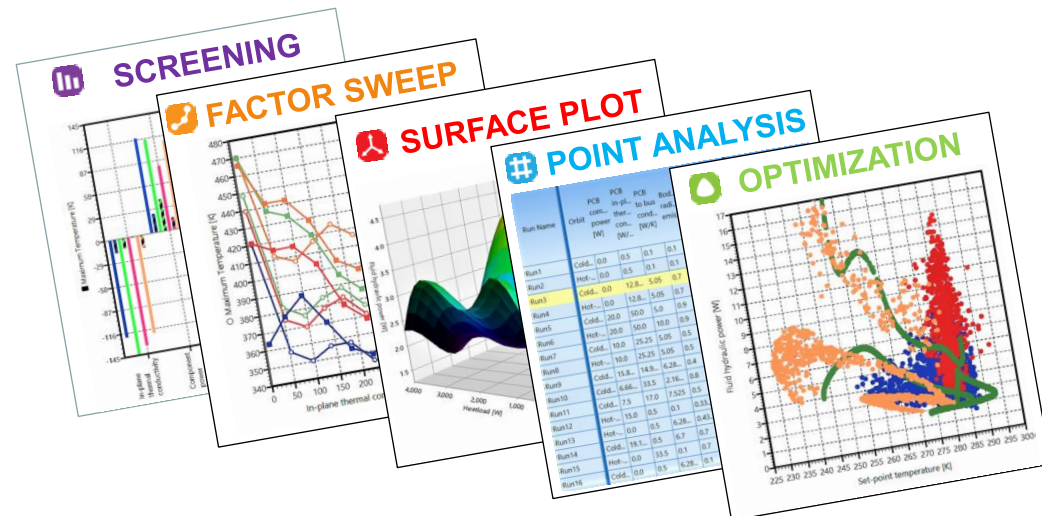
- Advantages

- Rapid analysis: 1000s of simulations in seconds
- Intuitive user interface encourages collaboration
- More effective data exploration through advanced analysis capabilities

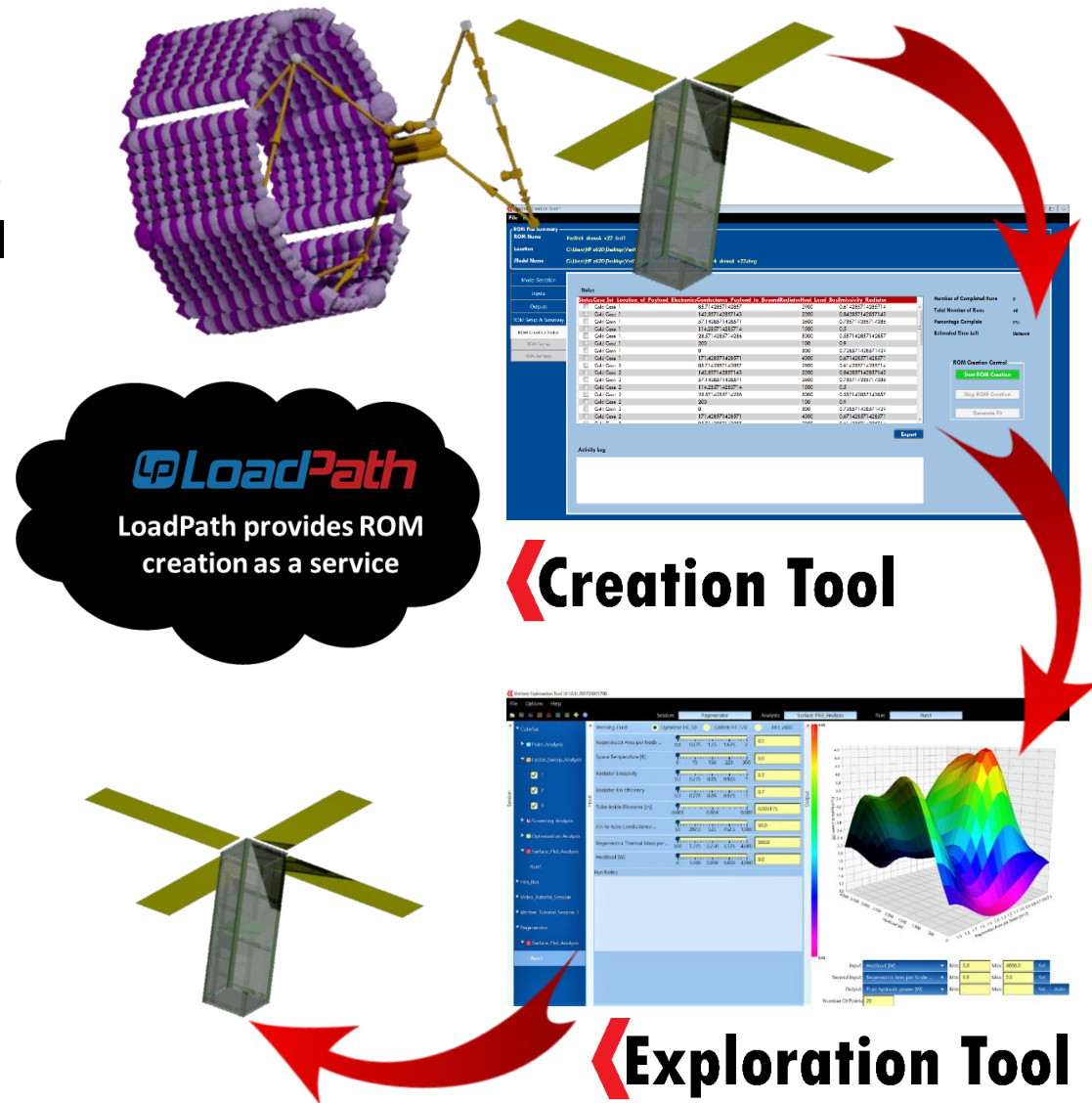


- Built for Thermal Desktop®

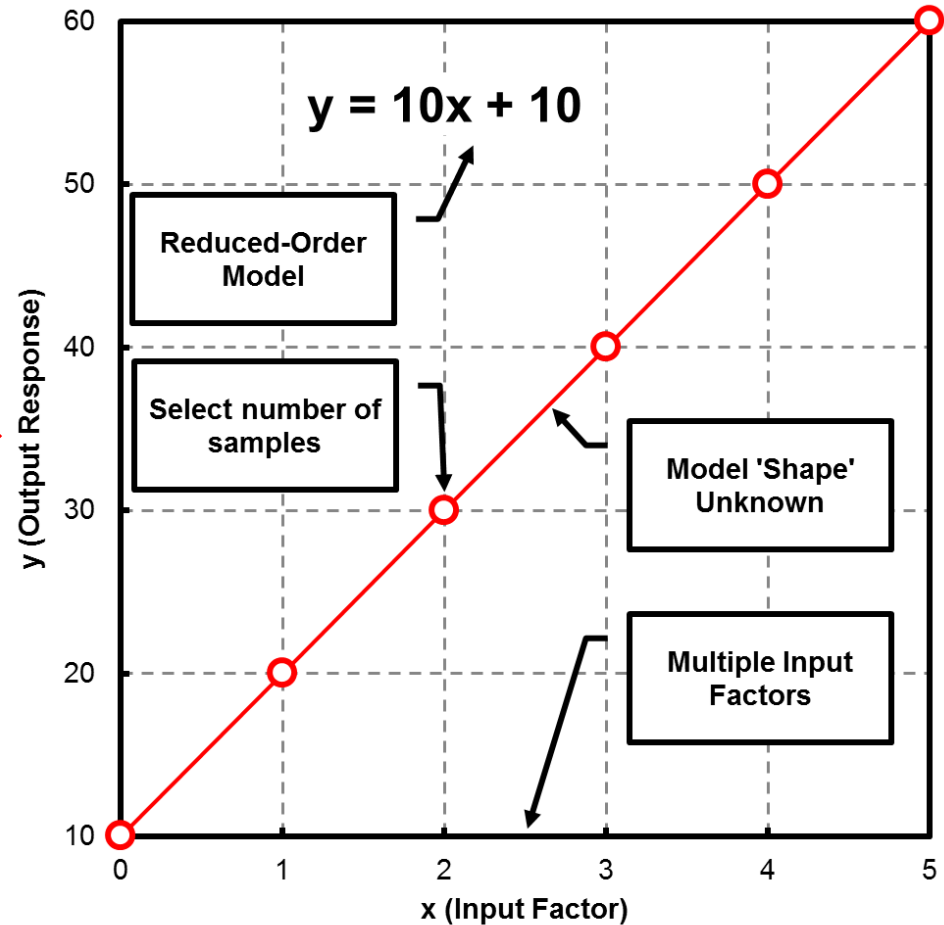
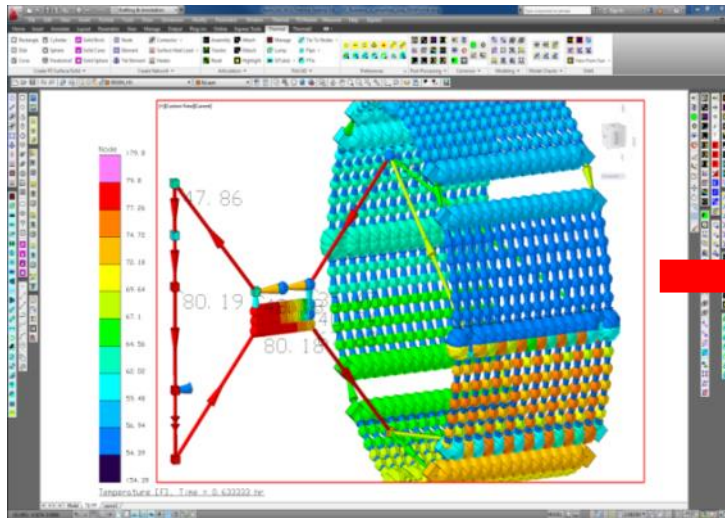
- Relates input factors (e.g. power) to output responses (e.g. temperature)
- Leverages TD 6.0 API



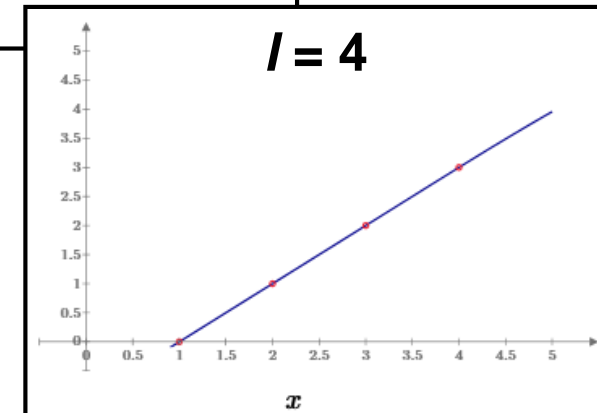
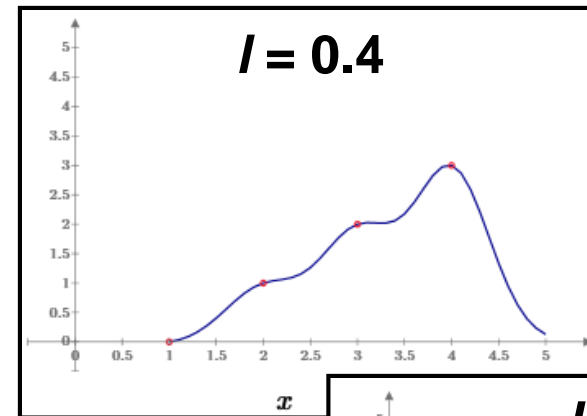
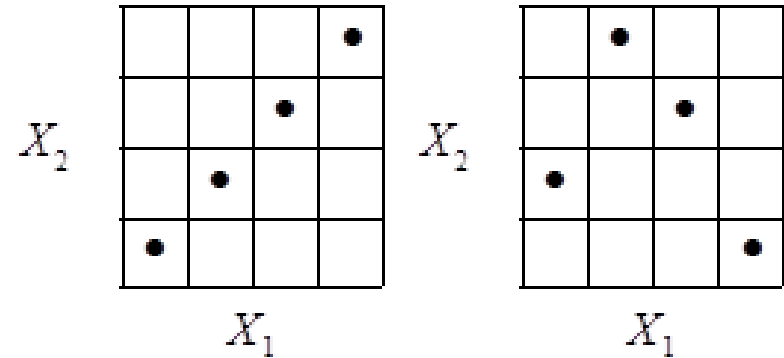
- What is a reduced order model?
 - An accurate surrogate of a high fidelity model
 - Based on intelligent sampling then data fitting
 - Acts as a statistical emulator
 - Sampling based on Latin Hypercube methods
 - Data fitting based on Gaussian-Process methods



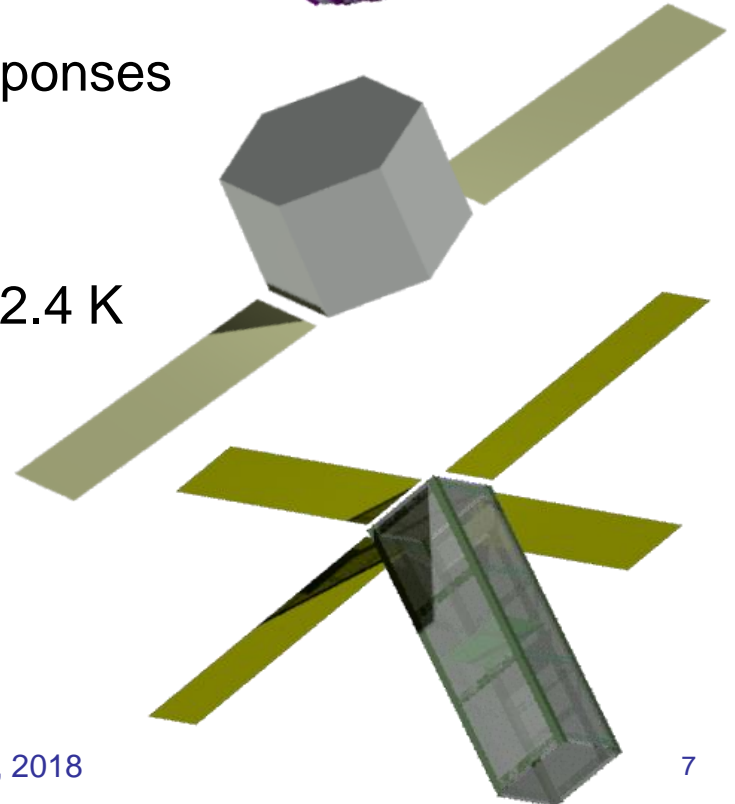
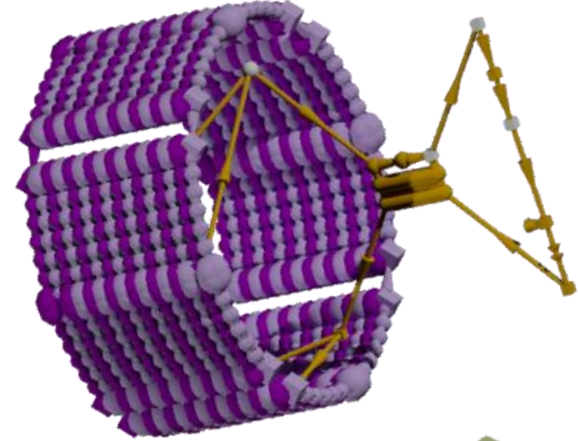
- Sampling then data fitting



- **Latin Hypercube Sampling**
 - A method for efficiently filling a design space
 - The range of each Input Factor (e.g. X) is divided into N intervals
 - N = number of samples
 - Each interval is used only once
 - Maximize the minimum distance between points
- **Gaussian Process model**
 - Does not impose specific model structure
 - E.g. ' $f(x) = mx + c$ ' not needed
 - Can fit a wide-range of data without prior knowledge of 'shape'
 - Based on training data
 - Covariance matrix populated using squared exponential function
 - Optimized hyperparameters needed
 - Can fit data exactly
 - Useful for computer simulations
 - Provide confidence intervals



- Orion Crew Exploration Vehicle (CEV)
 - External fluid loop
 - Temperature: 1.6 K max residual mean and 5.0 K standard deviation
 - Power: 0.2 W max residual mean and 1.93 W standard deviation
 - Did poor job of replicating output responses with discontinuities
- Air Force Hex Bus
 - Standard deviation of 5.1 K (T_{\max}), 2.4 K (T_{\min}), and 2.5 K ($T_{\max d}$)
- 3U CubeSat
 - Evaluated heat pipe performance
- JPL Mars Helicopter
 - Tomorrow 2:45 pm in Spinnaker



Process Flowchart

Thermal Desktop® Model

Creation Tool

Select and Set-up Input Factors and Output Responses

Set-up and Generate Sampling Points

Run using
Thermal
Desktop®

Run Sampling Points to generate Training Data

Run Training Data through a Data-fitting Algorithm

Run using
Thermal
Desktop®

ROM Testing

ROM Creation is complete

Accuracy of ROM is verified

Exploration Tool

Use any of the five analysis features to perform rapid thermal analysis



TD API Capabilities



- Thermal Desktop® 6.X API
 - Provides improved capabilities
 - Supports creating and modifying the following entities
 - Case Sets
 - Conductors
 - Fluid Submodels
 - Heater/Heatloads
 - User Arrays/Code
 - Nodes
 - Optical Properties
 - Symbols
 - Thermophysical Properties
- TD features
- Expressions
 - Network Logic
 - Registers
 - Units
 - Others
- Miscellaneous functionality
 - Capture Graphics area
 - Run Case Set
 - SaveAs
 - Others
 - Contact CR Tech for a demo



Creation Tool



Veritrek Creation Tool

File Help

ROM File Summary

ROM Name *Live Demo Completed*

Location *C:\Users\JacobMoulton\Desktop\Veritrek\aved demo sessions*

Model Name *C:\Users\HP z620\Desktop\Veritrek CT\VeritrekCT_demoA_v22\VeritrekCT_demoA_v22.dwg*

Model Selection

- Inputs
- Outputs
- ROM Setup & Summary
- ROM Creation Status
- ROM Testing
- ROM Summary

ROM Name

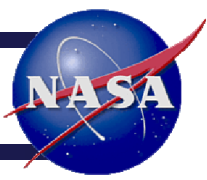
Live Demo Completed

Thermal Desktop Model

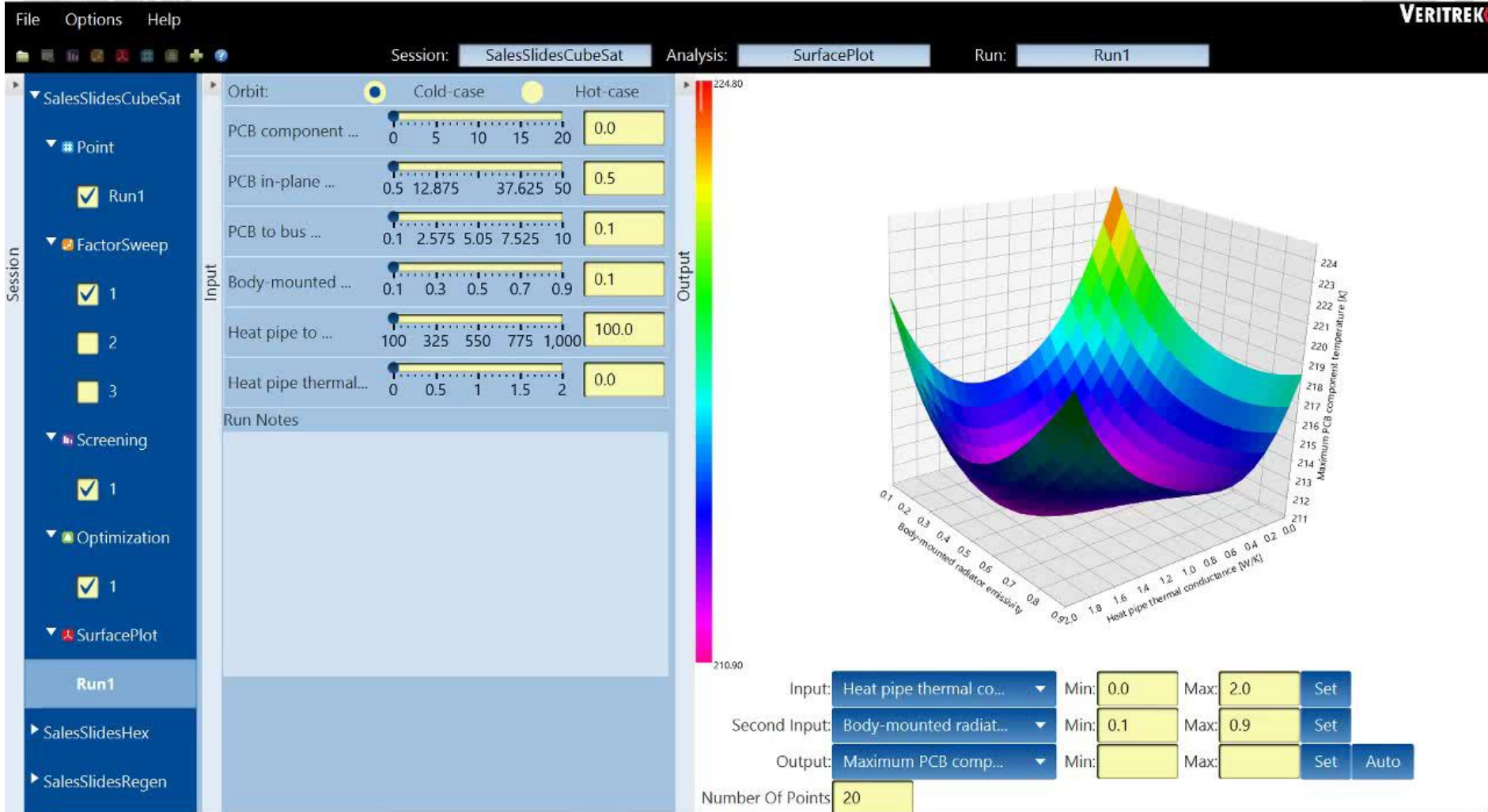
C:\Users\HP z620\Desktop\Veritrek CT\VeritrekCT_demoA_v22\VeritrekCT_demoA_v22.dwg



Exploration Tool

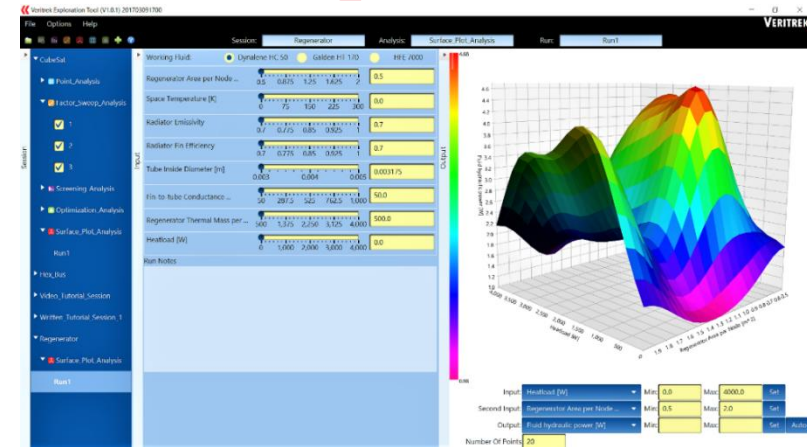


Veritrek Exploration Tool (V1.0)

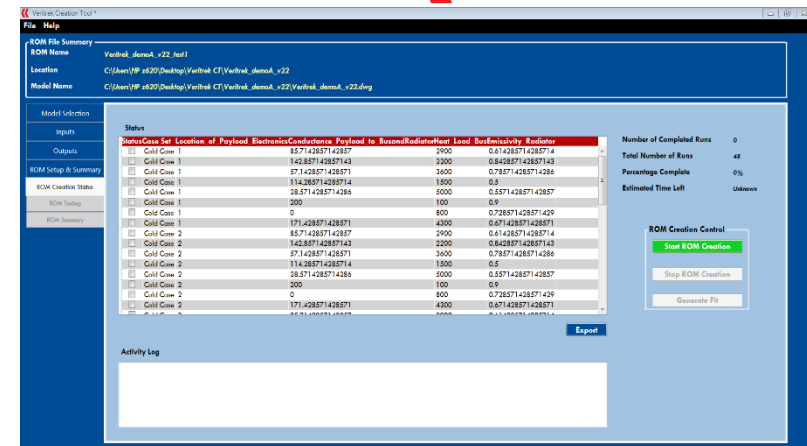


- **Exploration Tool**
 - Product release (August 2017)
 - Product update v2.0 (November 2017)
 - Working with customers to integrate new features
- **Creation Tool**
 - Beta version available
 - Currently having users testing and using – interested?
 - Commercial release (August 2018)
 - LoadPath ROM creation

◀ Exploration Tool



◀ Creation Tool



Acknowledgements

- This material is based upon work supported by Small Business Innovative Research projects with the Air Force Research Laboratory and NASA

