TFAWS Passive Thermal Paper Session

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ASSESSMENT OF THE MARS HELICOPTER THERMAL DESIGN SENSITIVITIES USING THE VERITREK SOFTWARE

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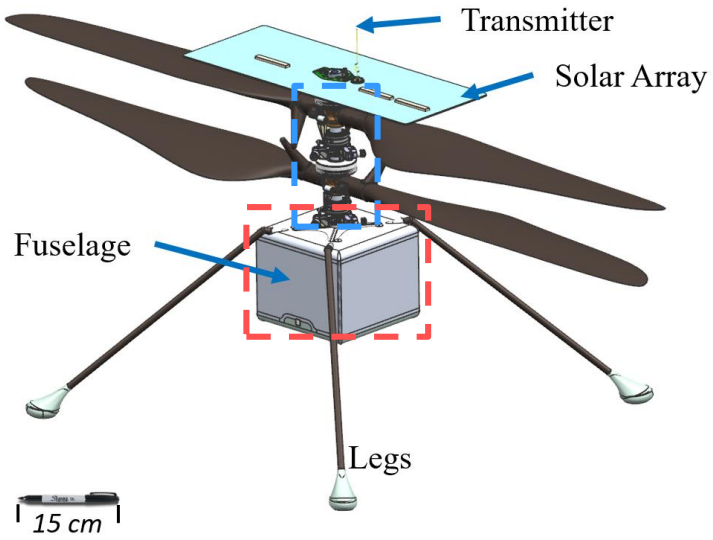
Thermal & Fluids Analysis Workshop
TFAWS 2018
August 20-24, 2018
NASA Johnson Space Center
Houston, TX

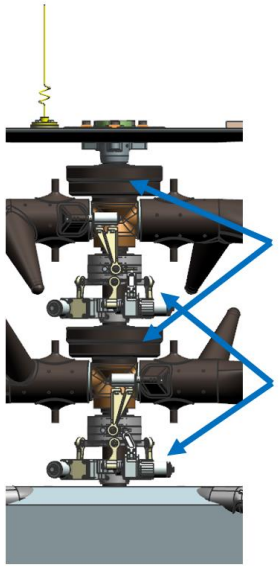
Mars Helicopter Overview

- The Mars Helicopter is a planned technology demonstration with the Mars 2020 (M2020) mission
  - The helicopter will be part of the rover payload
  - Project status was recently updated from a concept to a confirmed payload
- Primary mission objectives
  - Fly up to five times for as long as 90 seconds each
  - Capture aerial images from cameras
- Desire is for helicopter to demonstrate heavier-than-air vehicles on other planetary bodies and evaluate alternative Mars exploration methods

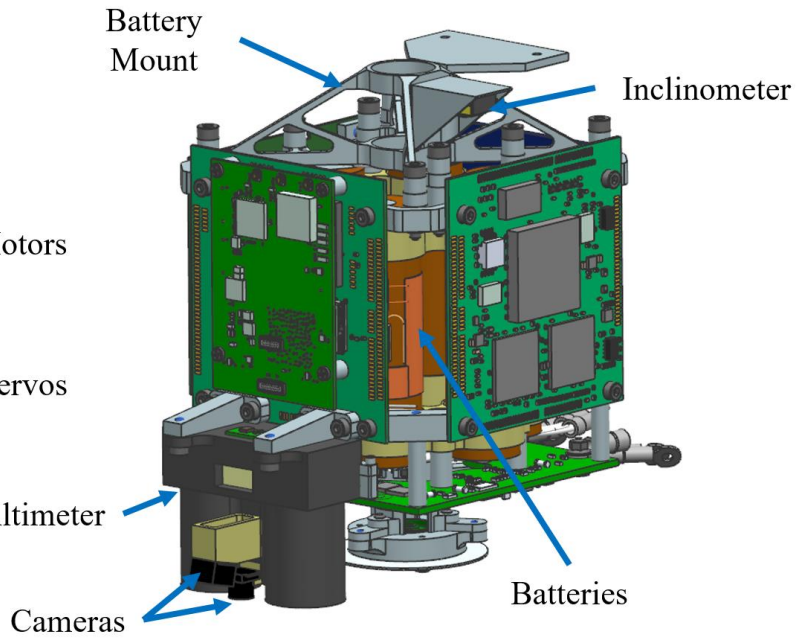
Architecture of a Mars Helicopter



Exterior



Propulsion Components



Internal Electronics

Helicopter Challenges

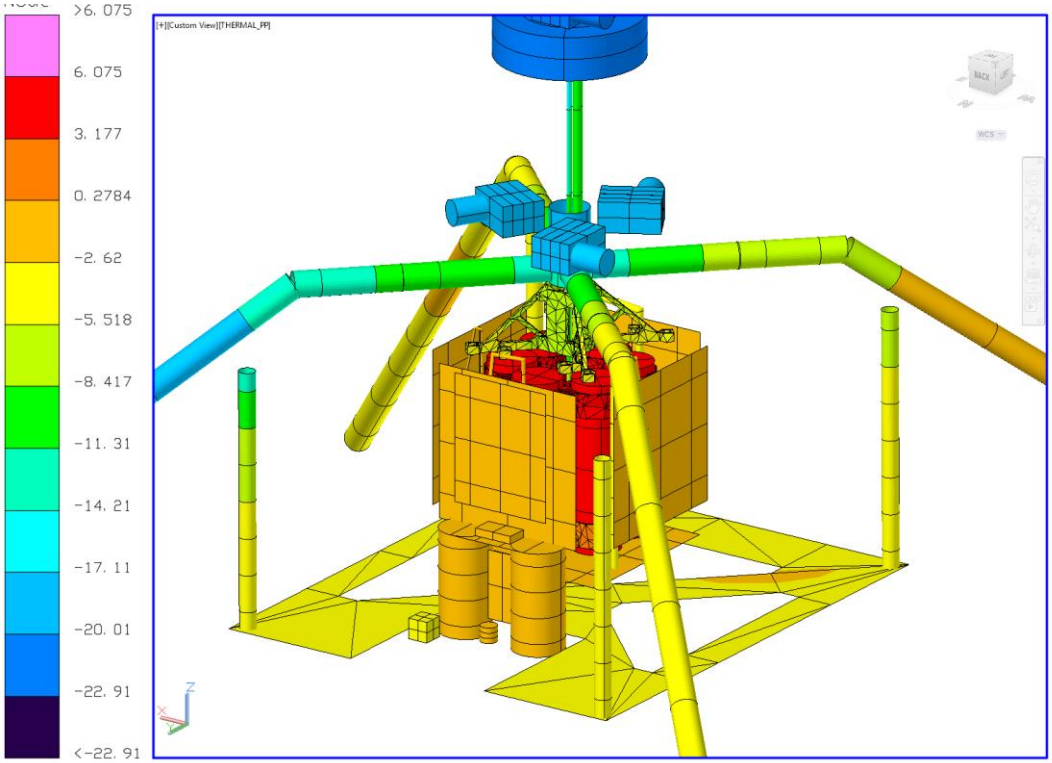
Thermal Design Challenges:

- Mass constrained
- Power constrained
- Volume restricted
- Low power modes
- High power modes
- AUTONOMOUS

- …first timer!

Need a quick and effective way to explore the sensitivities of the thermal system's drivers

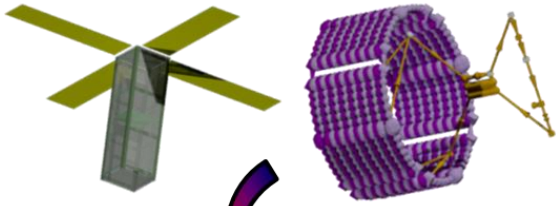
Thermal Desktop® model



What is Veritrek?

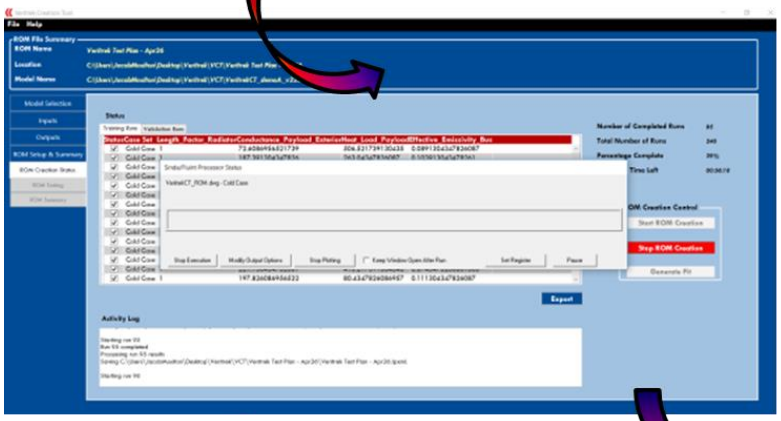
- Veritrek is an engineering analysis suite that enhances the traditional thermal analysis process
- Leverages the power of reduced-order models

Thermal Desktop® Model

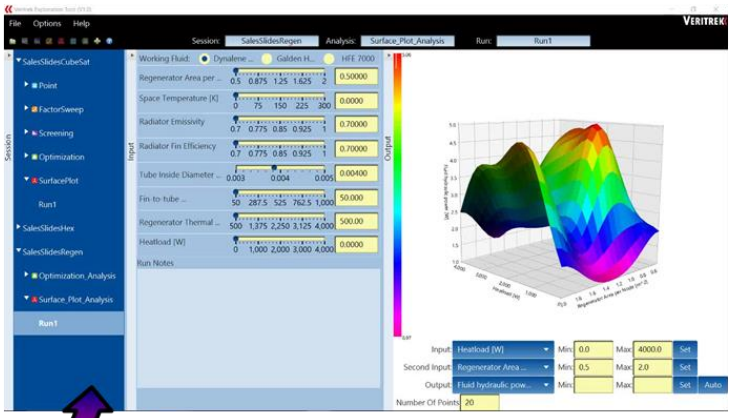


VERITREK benefits include

- Reduced modeling costs
- Enable more optimized designs
- Improves schedule through faster analysis
- Fosters collaboration



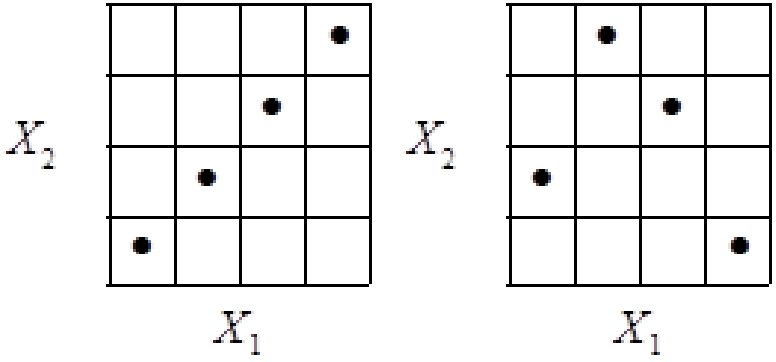
Creation Tool



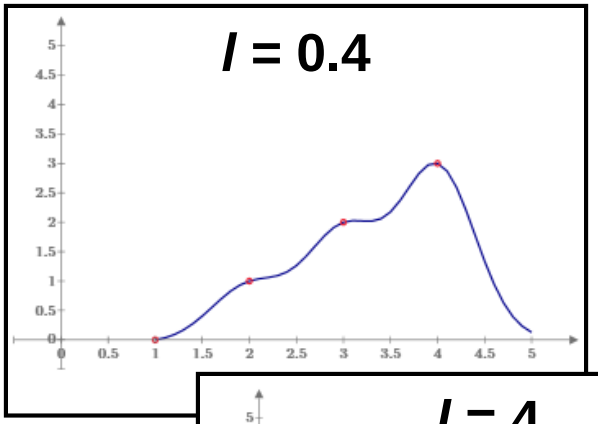
Exploration Tool

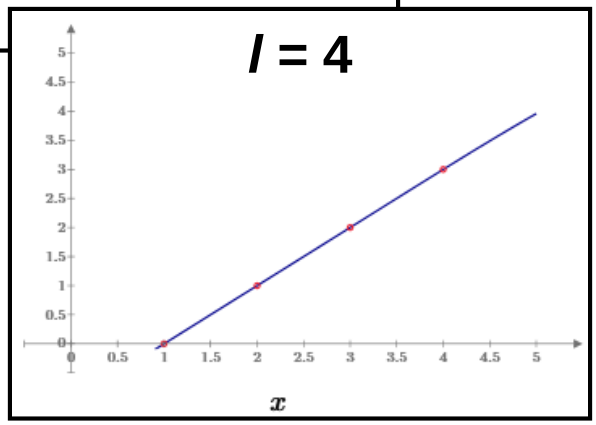
Reduced-order model Development

- Sampling
  - Latin Hypercube Sampling space-filling design
  - Results in a set of sampling points used for generating training data



- Data-fitting
  - Gaussian process regression methods
  - Provides exact fit to the training data





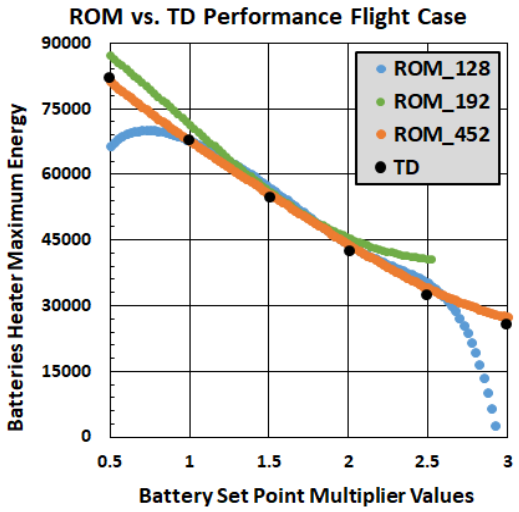
Mars Helicopter ROM

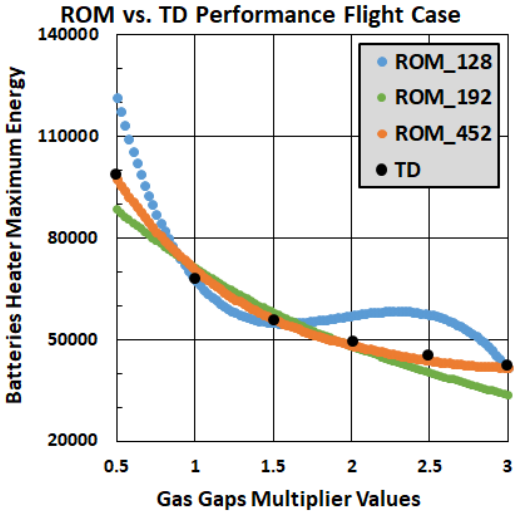
- 6 Input Factors
  - Gas gaps multiplier, Rotor Sensor and Battery Cables Conduction multiplier, Solids Conduction multiplier, Heatloads multiplier, Battery Set Point multiplier, Convection
- 2 Case Sets
  - Non-flight Cold Case, and Flight Hot case
- 36 Output Responses
  - **Energy Tracker** for batteries, upper sensor package, servos, prop, NAV, and lower sensor package
  - **Maximum and Minimum Temperature** for all components

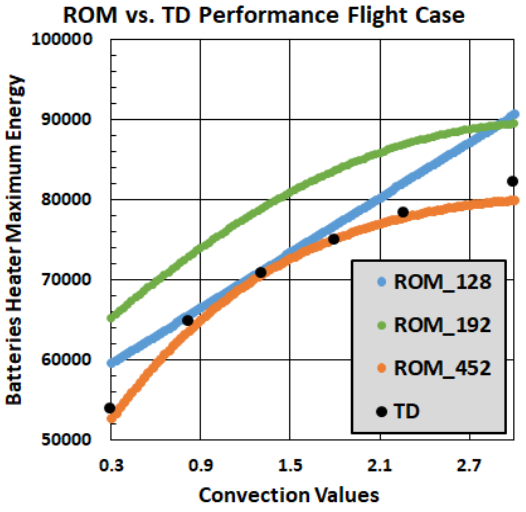
Iteration	# Sampling Points Used	Total Time for ROM Creation
1	128	~ 3 days
2	192	~ 4.5 days
3	452	~10 days

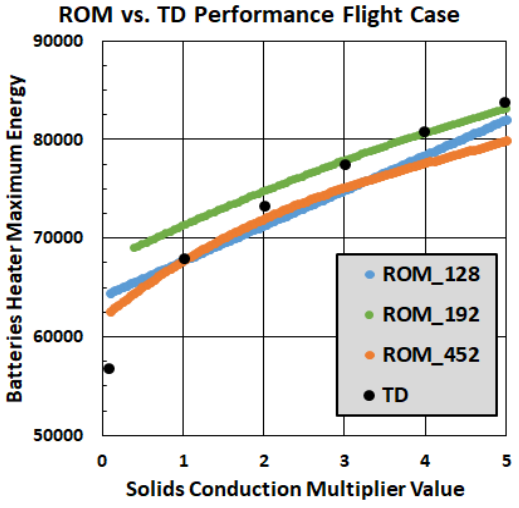
* The system used to generate the ROM was a W10 laptop running ACAD 2017 and TD 6.0 Patch 11, with a 4-core Intel Core i-7 processor at 2.80 GHz.

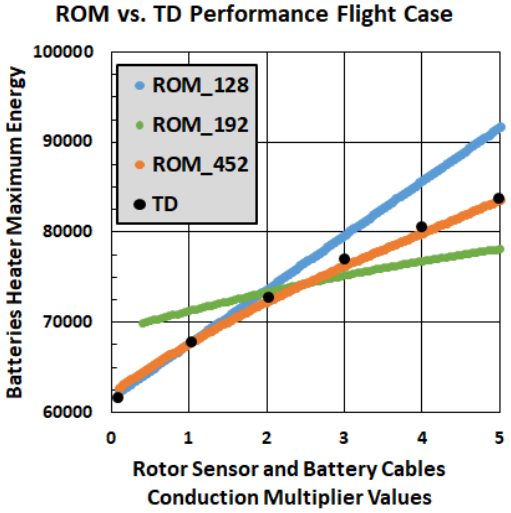
Mars Helicopter ROM Performance

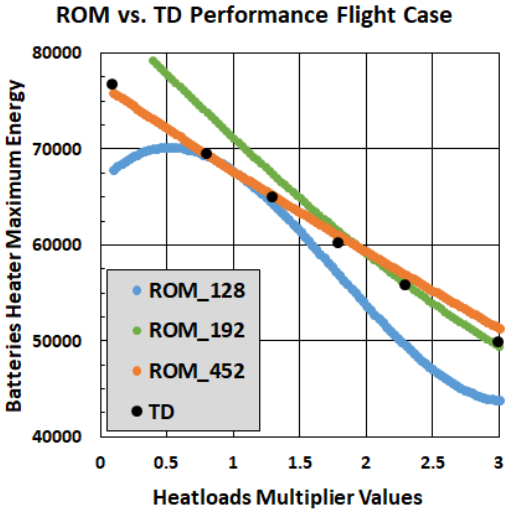








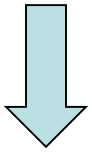




Sensitivity Analysis Cases

Thermal design sensitivities

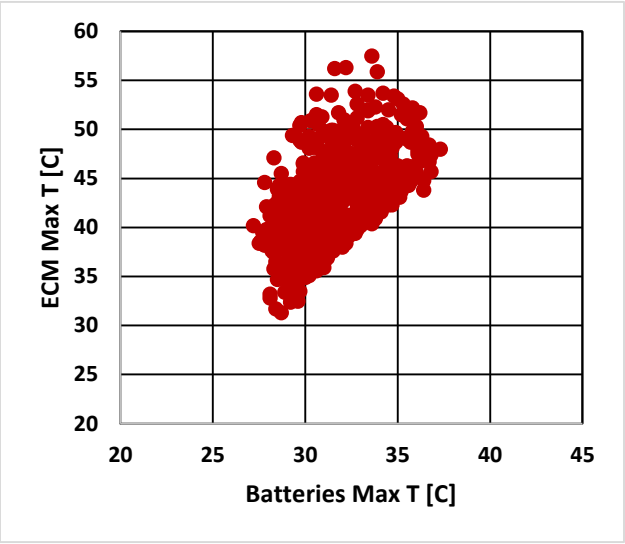
Symbol Name	Description
Wind speed and heat transfer coefficient	Heat transfer coefficient of fuselage and other external components
Heat loads uncertainties	Changes the power dissipated by the electronics during operation
Gas Gaps within fuselage	Changes the insulation gas gaps within the fuselage
Cables and wires conductivity	Wires running from the batteries and the ECM to the sensors and to the rotor assembly components
Fasteners and bonding conductance	Conductance of fasteners and other paths within the fuselage
Battery Heater set point	Changes the batteries' heater set point during night survival

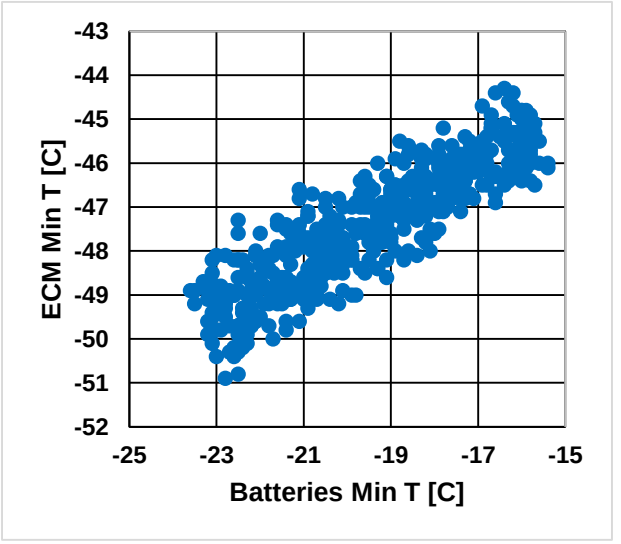


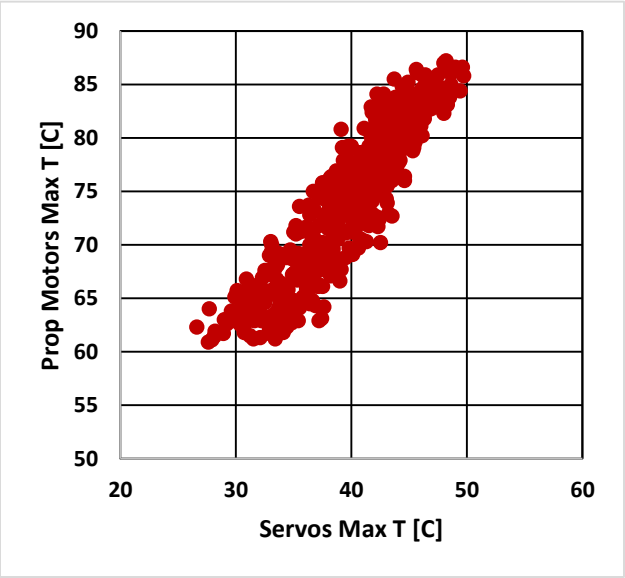
Hot Case - Jezero 30 Flight	Low Value	High Value
Convection - wind speed [m/s]	0	2.5
Heat loads	nominal	50% more (30% for high power modes during flight)
Gas Gaps	50% less	50% more
Cables Conductivity	80% less	100% more
Fasteners/Bonding Conductivity	80% less	100% more
Battery Set Point	-22	-15

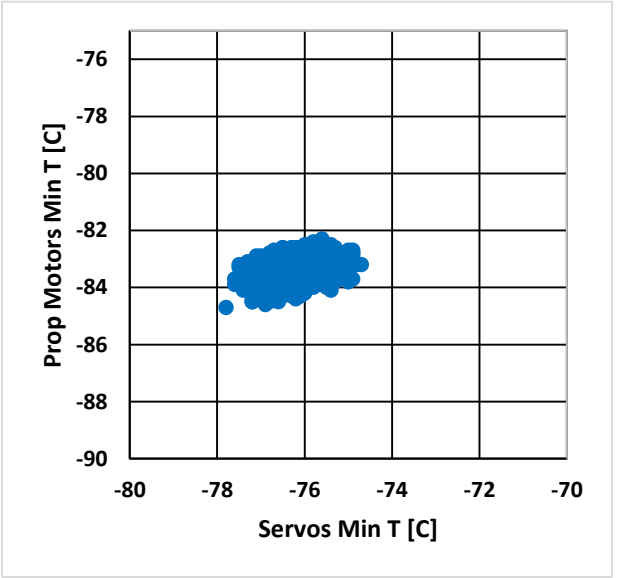
Cold Case - Jezero 60 NON Flight	Low Value	High Value
Convection - wind speed [m/s]	5	7.5
Heat loads	50% less	nominal
Gas Gaps	50% less	50% more
Cables Conductivity	80% less	100% more
Fasteners/Bonding Conductivity	80% less	100% more
Battery Set Point	-22	-15

Results: uncertainties predictions

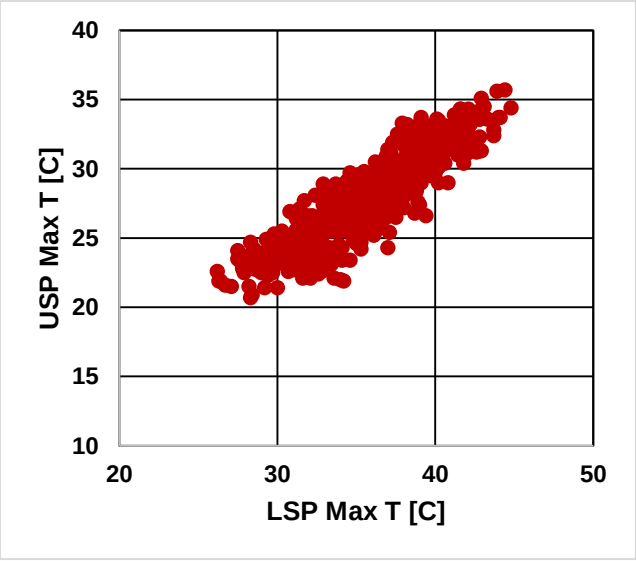


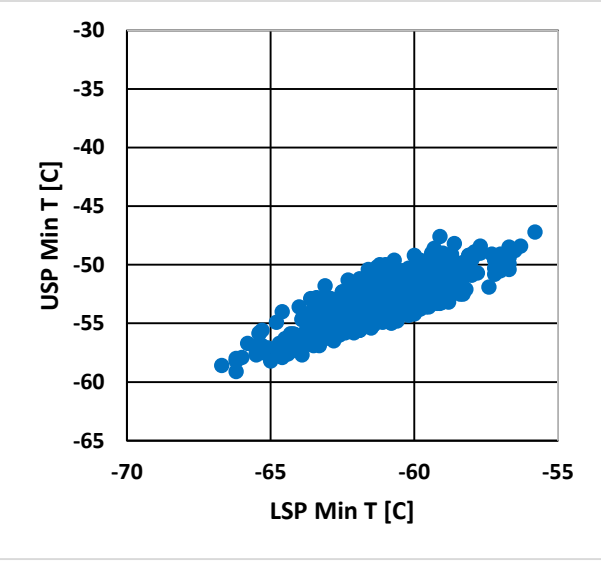




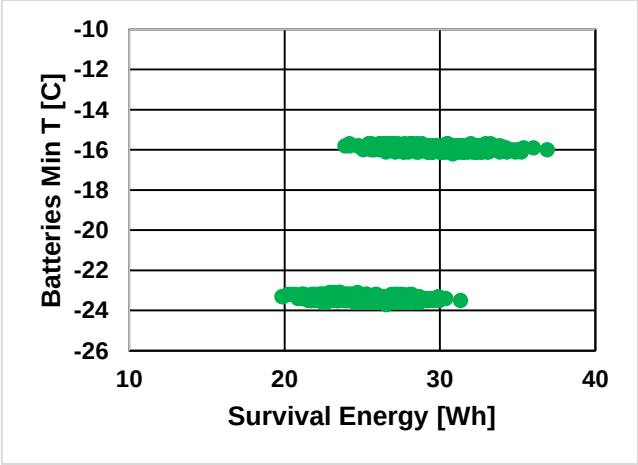


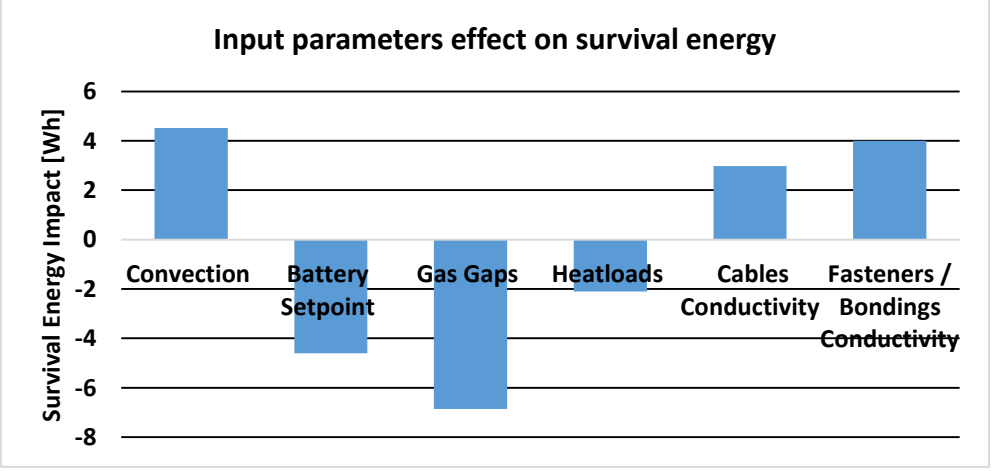
Results: uncertainties preditions





Survival energy





Conclusions

- 1) Thermal design sensitivity studies of the Mars Helicopter and 2) Final assessment and verification of the thermal design, were both made easier and more effective with use of the Veritrek software

- Sensitivity results provided JPL with a better understanding of the critical components of the Mars Helicopter system and potentially allow JPL to utilize these results to optimize mission operation routines.

Future Work

- JPL plans to use the Veritrek software suite for future work that will investigate uncertainties in coatings optical properties, in order to study the thermal design sensitivities even further.
- Additional applications of the software might include thermal model correlation after thermal vacuum test of the Mars Helicopter flight model.

- **ACKNOWLEDGEMENTS**
- This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. The authors would like to thank **Michael Pauken, Tyler Schmidt, Jennifer Miller and Mark Wagner** for the contribution and support to the Mars Helicopter Project.