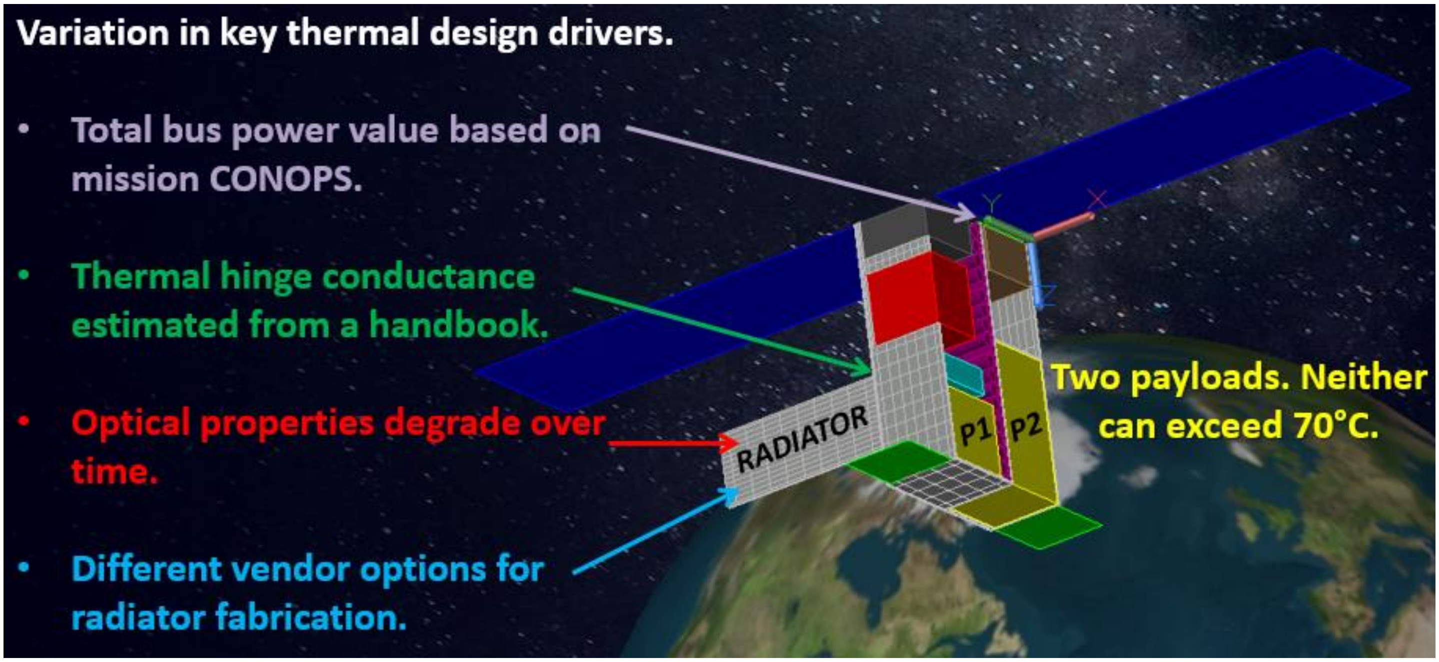
How to Perform a Sensitivity Study using Veritrek and Thermal Desktop®

Performing a sensitivity study allows you to determine how potential variation in design parameters impacts system behavior. In this example, you will see how to use Veritrek and Thermal Desktop® to quickly evaluate thermal design sensitivites for a 6U CubeSat that includes two payload components, each limited to 70°C. To meet this requirement, a deployable radiator was necessary to increase heat dissipation. However, variability in design parameters made it difficult to predict system on-orbit thermal behavior. To overcome this challenge, Veritrek is used to create a reduced-order form of a Thermal Desktop® model, to assess thermal design sensitivities and quickly determine how to mitigate mission risk.

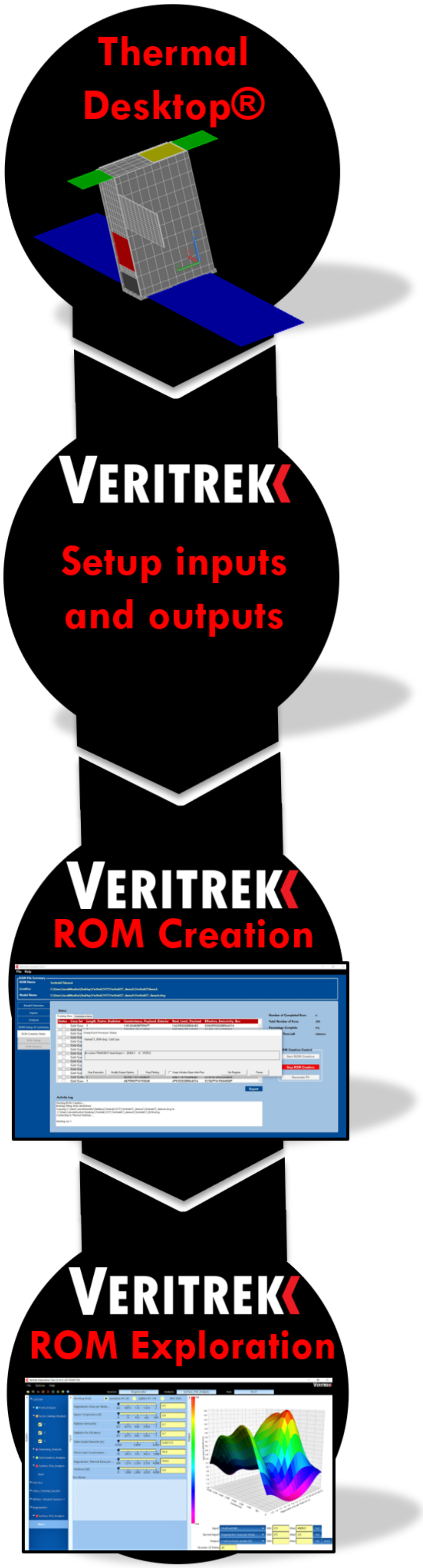
The goal of this sensitivity study is to ensure the deployable radiator design allows mission success, even with variability in the radiator's key thermal design drivers.



Key thermal design drivers for the deployable radiator design include:

- **Radiator surface absorptivity and emissivity**. Optical properties will degrade over time, such that beginning of life (BOL) values differ from the end of life (EOL) values.
- **Radiator xy thermal conductivity**. The radiator can be purchased from a broad range of vendors each with unique thermal performance (eg. standard aluminum (Al), honeycomb, embedded heat pipes, high-k materials, etc.), cost, and lead times.
- **Thermal hinge total conductance**. The conductance value for the hinge connecting the radiator to the bus was estimated using generic handbook values.
- **Total bus power value**. Total bus power becomes a trade with mission CONOPS (concept of operations). It can be adjusted in the system at the expense of payload operation frequency and duration.

E-mail: veritrek@loadpath.com
www.veritrek.com



Using Veritrek's unique capabilities, you will be able to determine whether the deployable radiator design is successful in keeping the payloads below 70°C, quantify how much the payloads' temperature will change due to variation in optical property or conductance values, and provide convincing evidence that all possible design risks and options have been explored. The following steps show you how to perform this sensitivity study.

Step 1: Create a Thermal Desktop® model of the 6U CubeSat with your deployable radiator thermal design. Use symbols to control your thermal design drivers, and include at least one Case Set to simulate the CubeSat's environment.

Step 2: Use your Thermal Desktop® model's symbols to setup input factors for your reduced-order model (ROM). Include the thermal design driver symbols mentioned earlier, as input factors.

Name	Nominal	Min	Max
Radiator_abs	0.20	0.15	0.35
Radiator_emi	0.85	0.70	0.90
Radiator_xy_conductivity (W/m-C)	400	100	450
Thermal_hinge_conductance (W/C)	2.5	0.5	5
Total_bus_power (W)	100	10	200

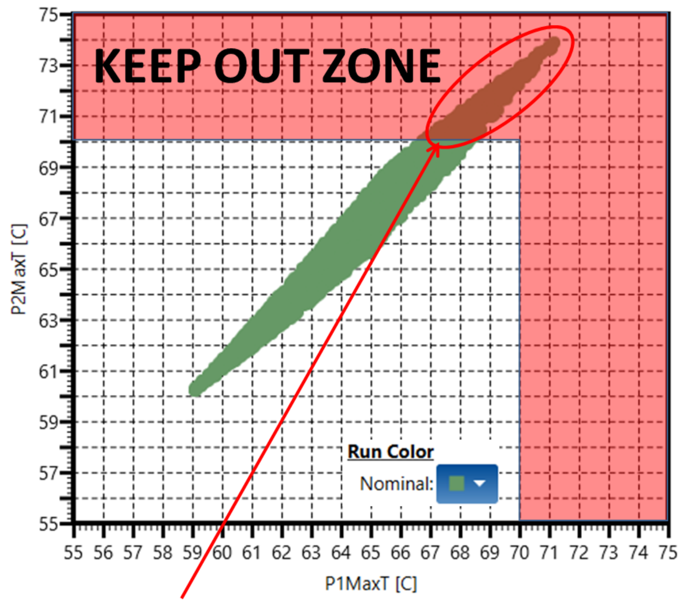
Step 3: Define the output responses that you want to track. Here you want to track the maximum value of both payload node groups, P1MaxT and P2MaxT.

		Temperature		
Name	Type	Min	Mean	Max
P1MaxT	Node Group			✓
P2MaxT	Node Group			✓

Step 4: Create and test your reduced-order model in the Veritrek Creation Tool. This is performed automatically by Veritrek.

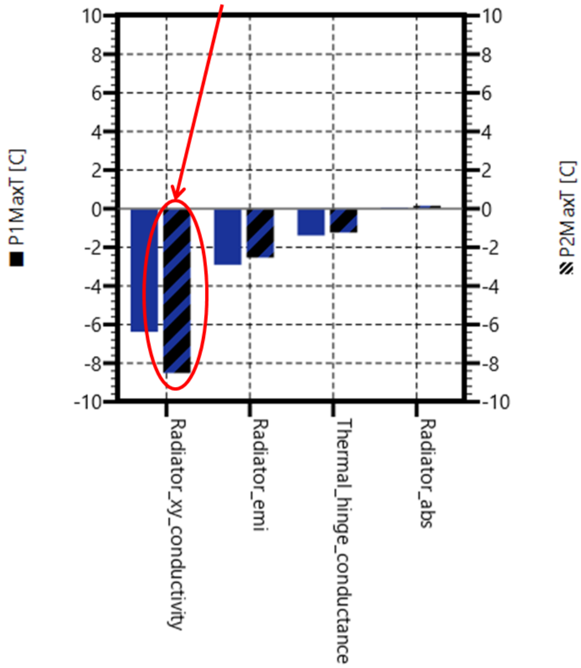
Step 5: Use the Veritrek Exploration Tool to learn about the sensitivity of your radiator's thermal design.

E-mail: veritrek@loadpath.com
www.veritrek.com



These points in the design space are in the keep out zone, and show there is risk in the nominal design.

The variation in the radiator's xy conductivity can cause P2MaxT to change by 8°C.



Step 5a: Use Veritrek's Optimization Analysis feature to examine maximum payload temperatures resulting from your design variabilities and options.

The nominal total bus power is 100 W, based on estimations of the system's power requirements. All other input factors have variability as discussed before. Set up your Optimization Analysis run as shown below.

Include	Factor Name	Low Value	High Value	Nominal Value
☐	Case Sets	LEO Orbit	LEO Orbit	LEO Orbit
☑	Radiator abs	0.15	0.35	0.15
☑	Radiator emi	0.70	0.90	0.70
☑	Radiator xy conductivity [W/m-C]	100.0	450.0	100.0
☑	Thermal hinge conductance [W/C]	0.50	5.00	0.50
☐	Total bus power [W]	10.0	200.0	100

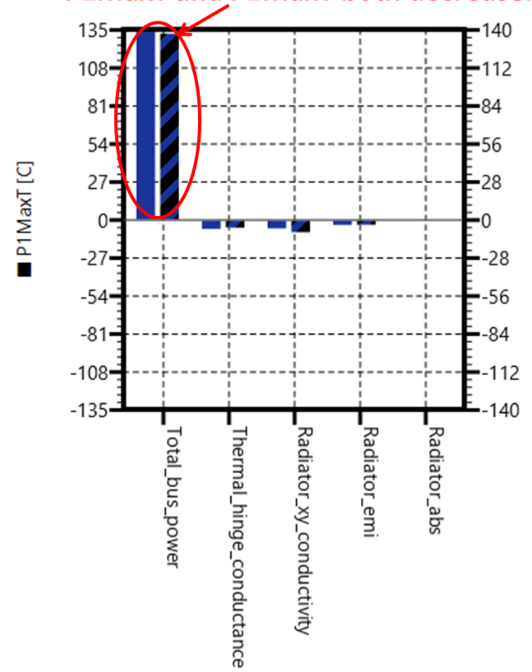
The result is a plot with thousands of points. Each point represents a P1MaxT and P2MaxT result from a unique combination of input variables. The results show that there are multiple scenarios in your radiator design's variation that produce payload temperatures higher than 70°C.

Step 5b: Use Veritrek's Screening Analysis feature to identify where exactly the design risk is coming from.

Veritrek's Screening Analysis feature allows you to quickly quantify how input factor variability impacts payload temperatures. The x-axis lists each variable input factor, while the y-axis quantifies how P1MaxT (solid bar) and P2MaxT (hatched bar) vary. The bar graph results show that the deployable radiator's xy conductivity causes a non-trivial amount of variation in P1MaxT (~6°C) and P2MaxT (~8°C); but also that as the xy conductivity value increases, P1MaxT and P2MaxT both decrease (as you can observe by the negative value associated with the bar graphs).

With this knowledge, you quickly realize there is design risk in using a radiator with lower xy conductivity (i.e. standard Al). Now, you can use Veritrek to act on this information, and start exploring design adjustments to mitigate the observed risk. Design Option 1 is to optimize the radiator's xy conductivity by using a high-k material. It is certainly possible to optimize this parameter, but there is likely a trade-off with schedule and/or budget.

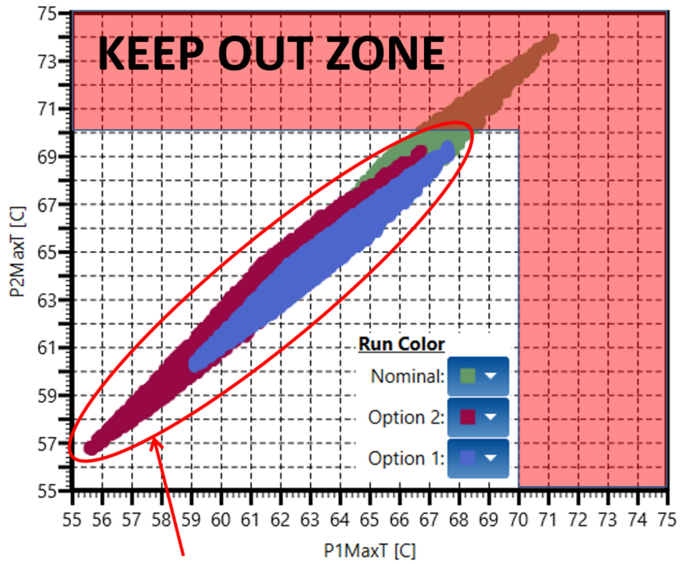
As the total bus power value decreases, P1MaxT and P2MaxT both decrease.



Step 5c: Use Veritrek's Screening Analysis to explore other design adjustments options, and inform an adjustment decision that mitigates the observed risk.

The bar graphs show that as the total bus power level increases, P1MaxT and P2MaxT increase as well; and so consequently, if you were to decrease the total bus power, P1MaxT and P2MaxT will both decrease. This is a second potential design (Design Option 2).

Lowering the total bus power value will have an impact on mission CONOPS, such as reduced payload operation duration and frequency. You can first see how much the total bus power would need to change to mitigate the design risk, before assessing the impact on the mission CONOPS and determining whether Design Option 1 or Design Option 2 should be made.



Two design options to avoid risk:
Option 1: 100 W bus with high-k radiator
Option 2: 95 W bus with standard Al radiator

Step 5d: Use Veritrek's Optimization Analysis to find a design solution that works.

Create two additional runs in your Optimization Analysis plot for your two design options, to observe the adjusted design envelopes: Design Option 1 using a 100 W bus with an optimized high-k radiator, and Design Option 2 with a 95 W bus and standard Al radiator.

Results show that Design Option 1 (blue dot plot) and Design Option 2 (maroon dot plot) both meet mission requirements as the payload temperatures will not exceed 70°C in either adjusted design. You can then take these results and assess which design adjustment option works better for your mission's operation, budget, and schedule.

By performing a sensitivity study with Veritrek, you were able to identify mission risk in your nominal system and radiator design, and you were also able to quickly determine two possible design changes that can be made to mitigate the risk. By providing you with thousands of data points and several easy-to-read plots that communicate all of this information to your team, Veritrek gives you the power to focus on improved and optimized design solutions. Veritrek enables a sensitivity study to be performed quickly and efficiently, giving teams better understanding of their thermal design space and giving you more high-quality thermal design information to make smarter, data-driven decisions.

Click here to start your free trial today!

E-mail: veritrek@loadpath.com
www.veritrek.com