Senior Design / BS Project
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LLUMA-T Cold Plate Weight Optimization

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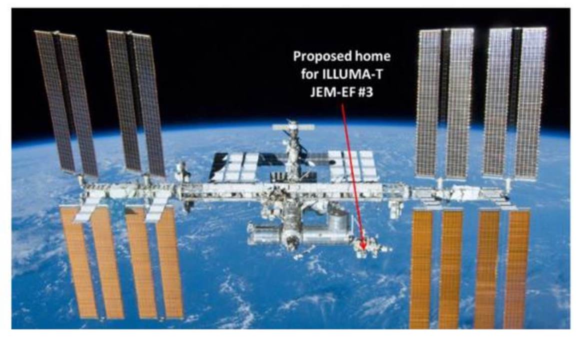
SENIOR DESIGN EXPO

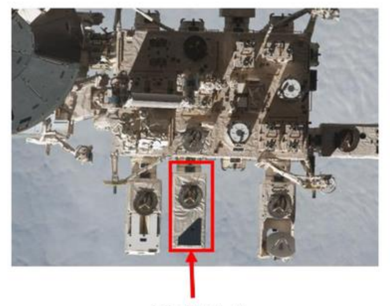
Abstract

The purpose of this project is to redesign the liquid cold plate, an active cooling method of thermal management, for NASA's ILLUMA-T, the terminal component of the first fully operational space-to-ground laser communications. It is imperative that power dense electronics have robust electronics heat reduction; therefore, the cold plate is required. The focus of the redesign is to minimize the weight of the cold plate while maintaining its thermal performance, size, and cost. Minimizing weight is critical in space applications, since every kilogram launched into space has a significant fuel cost; in this case, the cold plate will be flown aboard the International Space Station (ISS) in low earth orbit (LEO). Even launches to LEO can carry a fuel cost of $9000 ~ $20,000. The existing cold plate is unnecessarily heavy, weighing 40.2 kg. redesign methodology produced a 40% lighter plate with a minimized pressure drop. .

Introduction

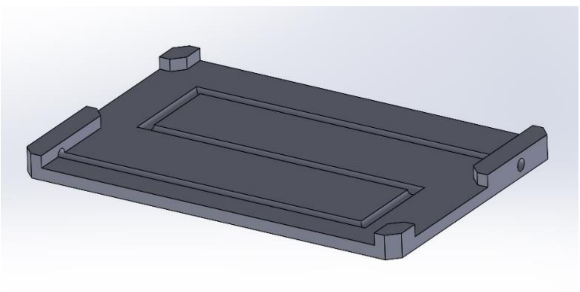
The purpose of this project is to redesign the liquid cold plate, an active cooling method of thermal management, for NASA's ILLUMA-T. The focus of the redesign is to minimize the weight of the cold plate, its pressure drop, and manufacturing cost while maintaining its thermal performance and dimensions. Space electronics need to be maintained within a certain usage temperature range - sometimes they must be heated, and sometimes they must be cooled. Cold plates provide a heat sink for high power electronics, so that necessary heat transfer can occur.[1] This project develops an optical communications user terminal to demonstrate high bandwidth data transfer between LEO and the ground through the geosynchronous Laser Communications Relay Demonstration (LCRD) relay. ILLUMA-T will be the first demonstration of a LEO user of the LCRD system, pointing and tracking from a moving spacecraft at LEO to GEO (geosynchronous orbit) satellite and vice versa, end-to-end operational utility of optical communications, and 51 Mbps forward link to ISS from ground. The speed of optical communications systems is their great advantage.



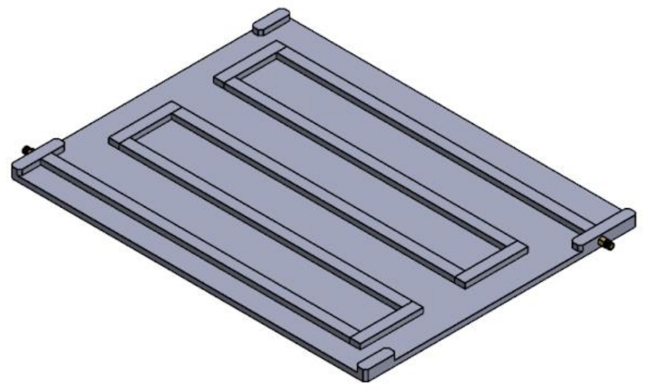


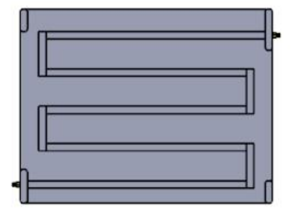
Methods | Design | Analysis

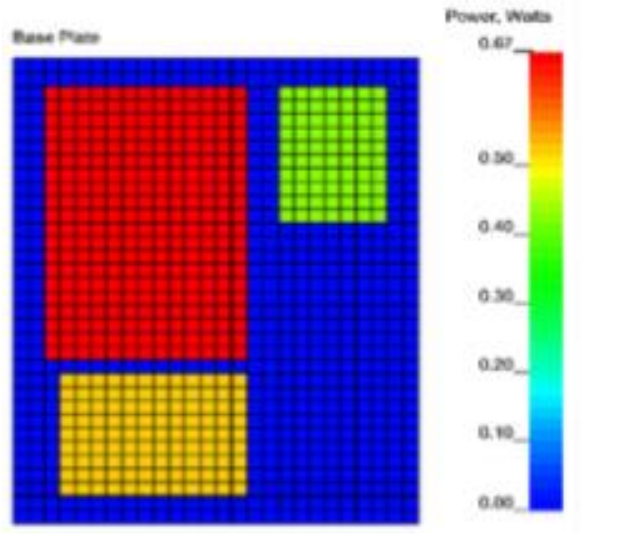
We manufactured a prototype plate half the size of full-size plate due to cost and manufacturing constraints designed to meet all objectives. The 90 degree turns maximize heat transfer and more evenly distribute the heat throughout the plate. The plate is finished by semi-circularly milling and welding on top of the fluid path.an aluminum bar of 1.00 x 0.50-inch cross section. Plate seen below.



Solidworks drawing and fully realized manufactured prototype cold plate. The plate was tested in the lab to ensure proper temperature and pressure drop. The prototype was also modeled in EPAC to determine the temperature gradient of the heat across the plate. This technology was also used to determine the performance of a full-size plate seen below







Results

Prototype Results

	EPAC	Laminar Convection	Turbulent Convection	Experiment
Total Pressure Drop	0.0740 psi	0.0484 psi	0.0624 psi	0.1083 psi

			EPAC	
	Theoretical	Experimental	Free Convection	No Convection
Power Output	300.17 W	300.17 W	300.17 W	300.17 W
Heat Absorbed	300.17 W	180.15 W	227.12 W	300.17 W
Temp. Rise	1.69 C	1.02 C	1.25 C	1.70 C

Full Scale Results

Power Input	Power absorbed by NASA (FC-72)	Full scale model simulated temperature rise (water)	Adjusted full scale model temperature rise for same efficiency as NASA (water)	Temperature rise after conversion of water to FC-72	Temperature rise of NASA simulated model
260 W	250 W	1.43 C	1.37 C	5.38 C	5.55 C

Average temperature of cold plate underneath electrical components		
Modom	Control Electronics	Power Controller
20.20 C	19.16 C	19.40 C

	Pressure Drop (psi)
Frictional	.112
Tube-turn loss	.074
Total	.186

Conclusion

In summation, the objectives of weight and cost minimization set forth for the project were achieved.

Final Results Full Scale Model	
Pressure Drop (Water)	0.186 ± 0.0178 psi
Temperature Rise (Water)	1.37 ± 0.212 C
Temperature Rise (FC-72)	5.38 ± 0.212 C

95.5lbs Original NASA Plate

54.1 lbs Redesigned Plate

43.4% Weight Reduction

$414k Cost Savings

Redesign Results

Hot allowable limits:
Modem: 45C
Control Electronics: 40C
Power Controller: 50 C
Maximum cold plate temperature of 21.11 C and averages under each component 20.2 C, 19.16 C, 19.40 C, respectively

Takeaways

Thermal performance is slightly less than original plate but difference is allowable. Electrical components are well within the allowable temperature limit.

Achievements

Objectives of cost and weight minimization were achieved through the redesign of the full scale cold plate. We also were able to maintain thermal performance

Acknowledgments

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UM COE
$250 Contribution

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