Abstract

Space debris poses an increasingly serious threat to satellites and spacecraft. Our project will aim to mitigate this problem using an array of kilowatt-class lasers, powered by photovoltaics. An experiment was implemented to study this using a directed energy system to completely vaporize or propel space debris out of Earth’s orbit.

The Problem

• Space debris accumulating
• Kessler syndrome: Debris will continuously build up causing collisions
• 2007 - China destroys their spacecraft creating debris
• 2009 - Debris from Russian satellite destroys American satellite
• 2015 - American satellite explodes because of faulty battery

The Solution

DE-STAR
• Array of powerful lasers
• Orbits Earth
• Powered using solar panels
• Use ablation to push debris out of orbit or completely vaporize

Goals

• Use laser ablation to decrease amount of debris
• Observe how the laser reacts with materials of low thermal conductivity
• Determine how powerful the laser will need to be
• Measure the thrust produced

Acknowledgements

Special thanks to NASA for their NASA California Space Grant, my mentor, Travis Brashears, Lina Kim, Ross Melzer, and the Deep Space Laboratory: Philip Lubin, Travis Brashears, Payton Battliner, Jonathon Madajian, Aidan Gilkes, Jana Georgieva, Olivia Sturman, Kenyon Prater

The Setup

Laser
• Frequency: 808nm
• Attached to thermolectric coolers
• Fed through fiber optic cable to lens

Torsion Balance
• Measures thrust produced by sample of space debris
• Sample holder on left
• Counterweights
• Mirror in center
  • Measurement laser - reflects off mirror onto detector which measures movement

Vacuum Chamber
• Simulate space - low pressure
• Roughing pump and turbo molecular pump used
• Two quartz windows
• One for ablation laser
• One for measurement laser

Thrust Produced

• Different materials ablated 5 power levels
• Carbon Fiber - most easily ablated
• Stainless steel and titanium very little thrust

Thrust of Multiple Samples

Discussion and Conclusion

Tests
• Carbon requires 715 kJ/mol to vaporize - unable to be delivered by laser
• Polymethylpentene - holds fibers together - can be ablated
• Ablation not maximized since ablated too easily
• Same amount of thrust at each power level
• All of the polymer is vaporized
• Coupling Coefficient - 19.2 µW

• Aluminum
  • Coupling Coefficient - 10.4 µW
  • High thermal conductivity - 237 W/mK
  • Low heat of vaporization - 293 kJ/mol

• Ceramic Paint - Able to be ablated easily
• Stainless Steel
  • Low thermal conductivity - 15 W/mK

• Titanium
  • Low thermal conductivity - 180 W/mK
  • High heat of vaporization - 425 kJ/mol
  • Both stainless steel and titanium - high luster - reflect laser

Problems and Future Work

• Macor Holder - Gave incorrect results
• Bumped into cable - Use automatic focusing
• Not a complete vacuum - Diffusion pump
• More tests and more materials
• CubeSat - Tests in space

References

[Accessed: July 26, 2015].
[Accessed: July 12, 2015].

http://periodictable.com/Properties/A/VaporizationHeat.an.html
http://www.spacesafetymagazine.com/space-debris/kessler-syndrome/
https://www.engineersedge.com/heat_transfer/thermal-conductivity-metals-alloys.htm