



COLLEGE OF ENGINEERING  
**HONORS PROGRAM**  
UNIVERSITY OF MICHIGAN

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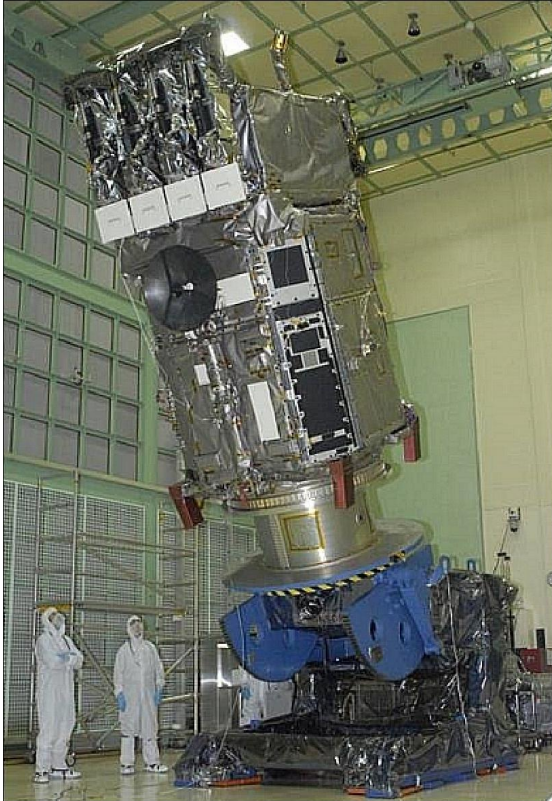
# **MiTEE CubeSat Program:** Integration of Geophysical Models for EDT Propulsion Modeling Environment



**Presented By:**  
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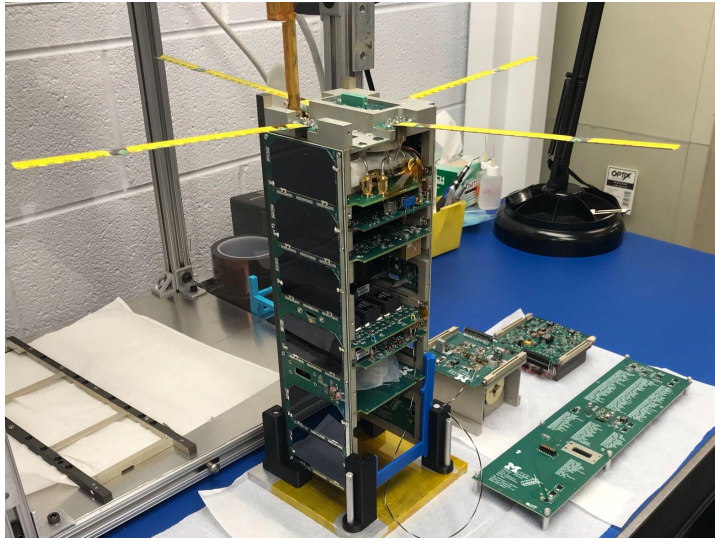
**Capstone Advisor:**  
Prof. Brian Gilchrist

# Spacecraft Economics is Complicated!



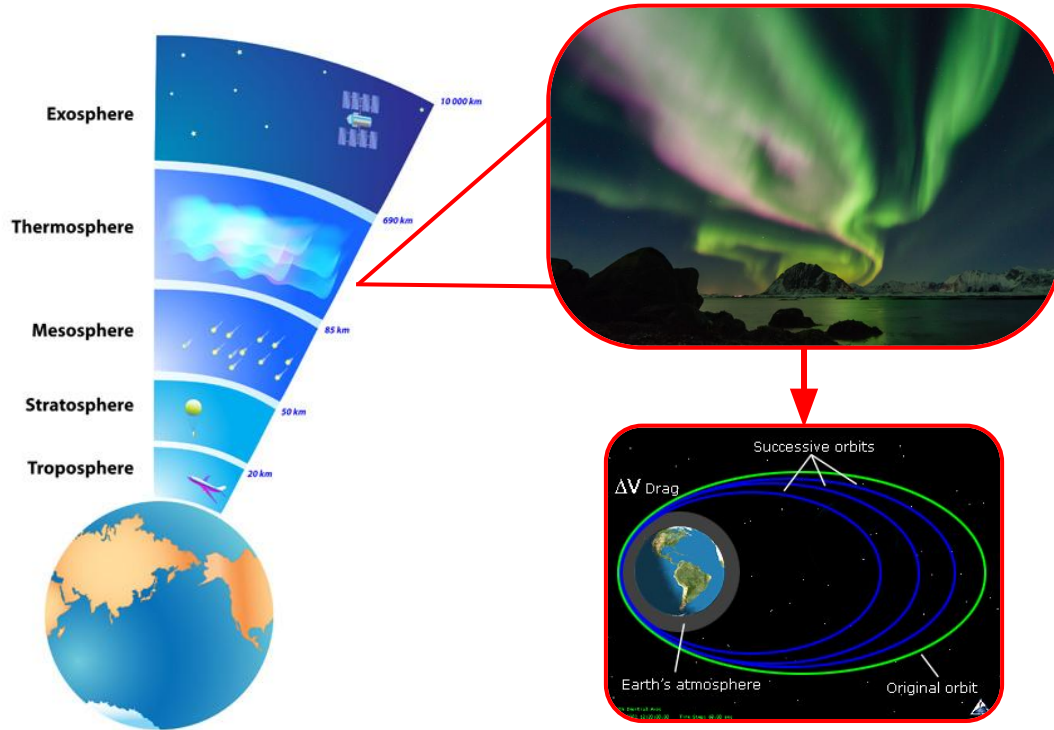
- Cost on the order of thousands of \$/kg to put a satellite in LEO
- Traditional satellites can cost several million dollars just to design and manufacture, then also weigh several thousand kilograms... \$\$\$\$
- “Mo’ money, mo’ problems”... forced to pack as much instrumentation as possible into one satellite

# So let's make things small... a SmallSat!



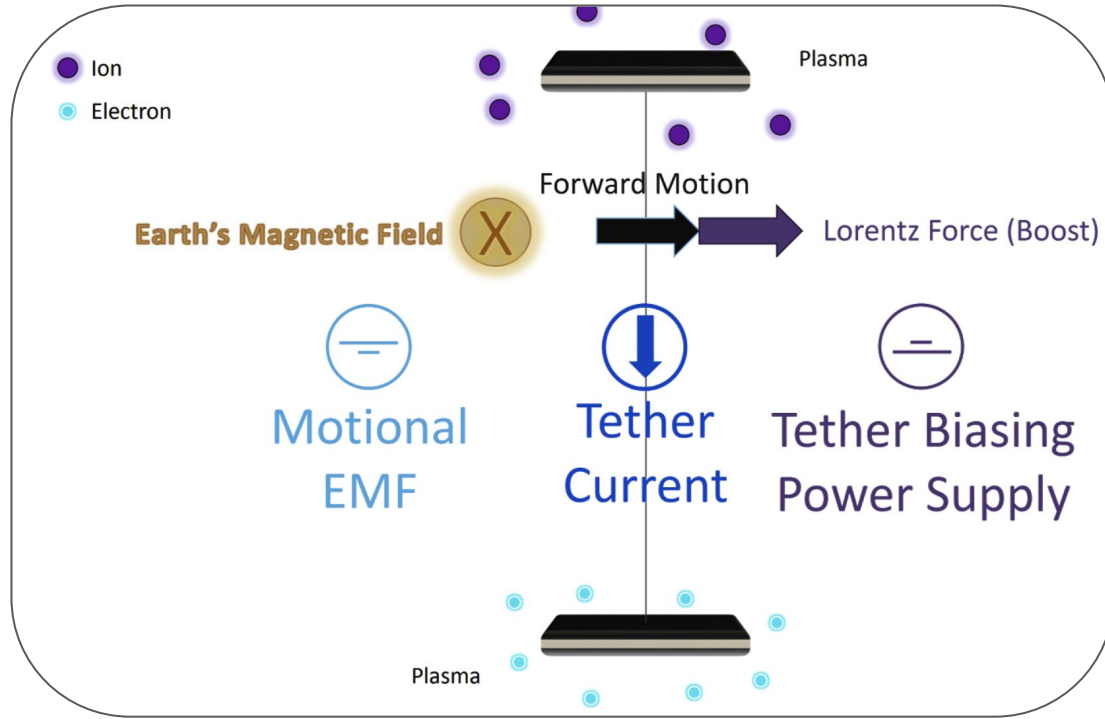
- Compress a satellite down to the size of a loaf of bread
- Think of how the first computers required an entire room. Now look at your smartphone!
- Substantially cheaper and enables a measurement distinction over temporal and spatial space

# Space is Complicated...



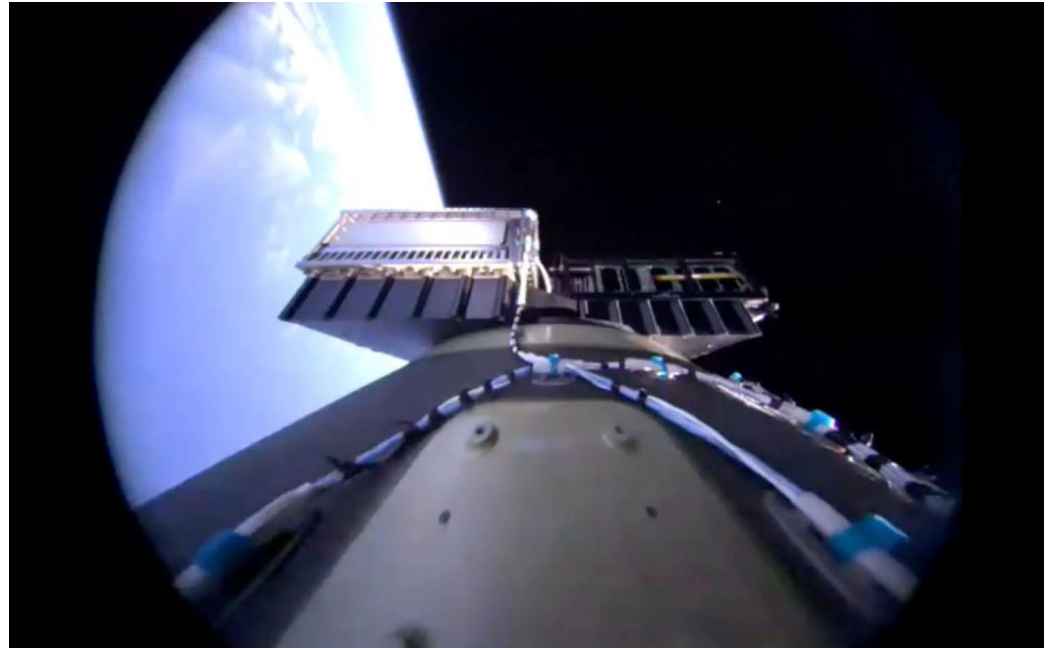
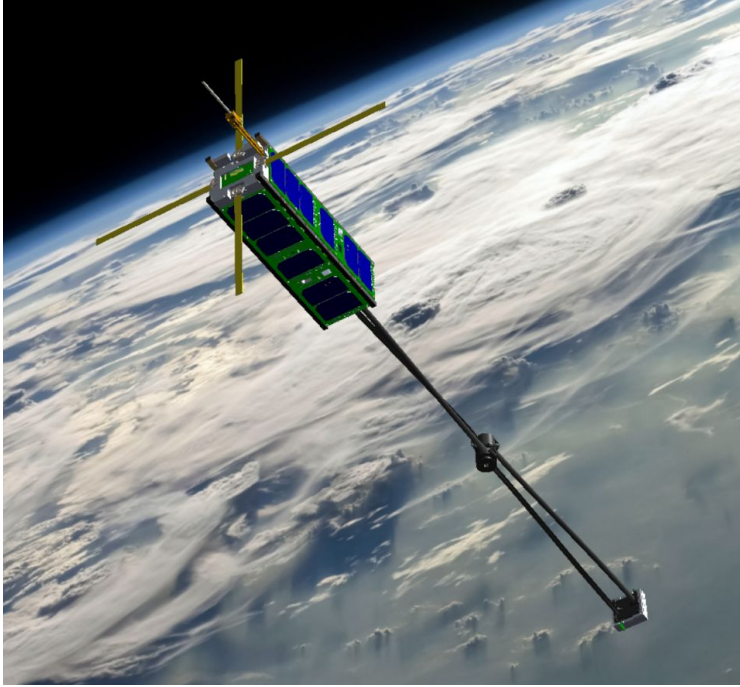
- We typically think of space as a pure vacuum...
- But there's actually a lot of "stuff", just spread out really far
- Orbital drag becomes a BIG issue

# What if we Turned the Problem into an Asset?

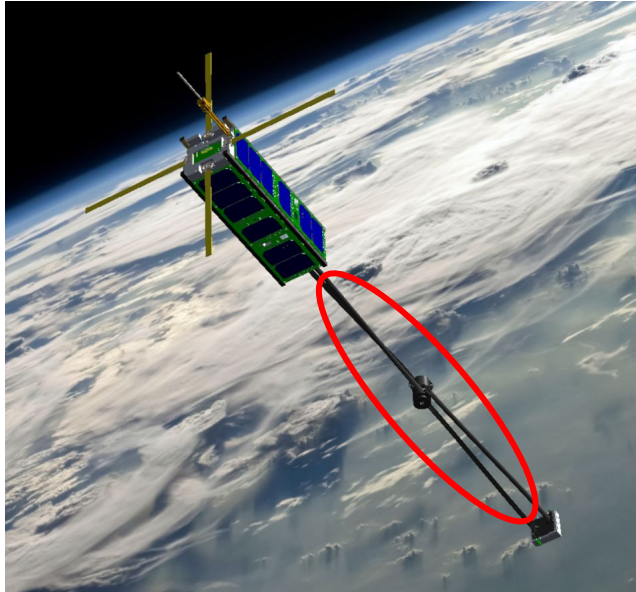


- Use Electrodynamic Tether (EDT) propulsion!
- Operates on the principle of collecting electrons from the ionosphere to generate a Lorentz boosting force

# Introducing the MiTEE Program



# EDT Propulsion Still Needs to be Proven



- MiTEE-1 is the path finder program and MiTEE-2 will build upon its success and data
- **Problem:** Space is still complicated! We need a robust and capable modeling environment to design the spacecraft
- Both electrodynamics and non-rigid body mechanical motion need to be considered



# Intro to TeMPEST

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WARNING: Setting bare tether absorptivity to 0.2 (Al 0061-T6)!
WARNING: Insulated tether emissivity <= 0.01
WARNING: Setting insulated tether emissivity to 0.66 (Silv Teflon)!
WARNING: Insulated tether absorptivity <= 0.01
WARNING: Setting insulated tether absorptivity to 0.00 (Silv Teflon)!
Reading in solar activity predictions from "/Users/mitchemiller/tempest/data/solarmag_schatten.dat"
Reading in solar activity historical data from "/Users/mitchemiller/tempest/data/F10.7_monthly.abs"
Reading in historical geomagnetic indices from "/Users/mitchemiller/tempest/data/Kp_Ap_monthly.dat"

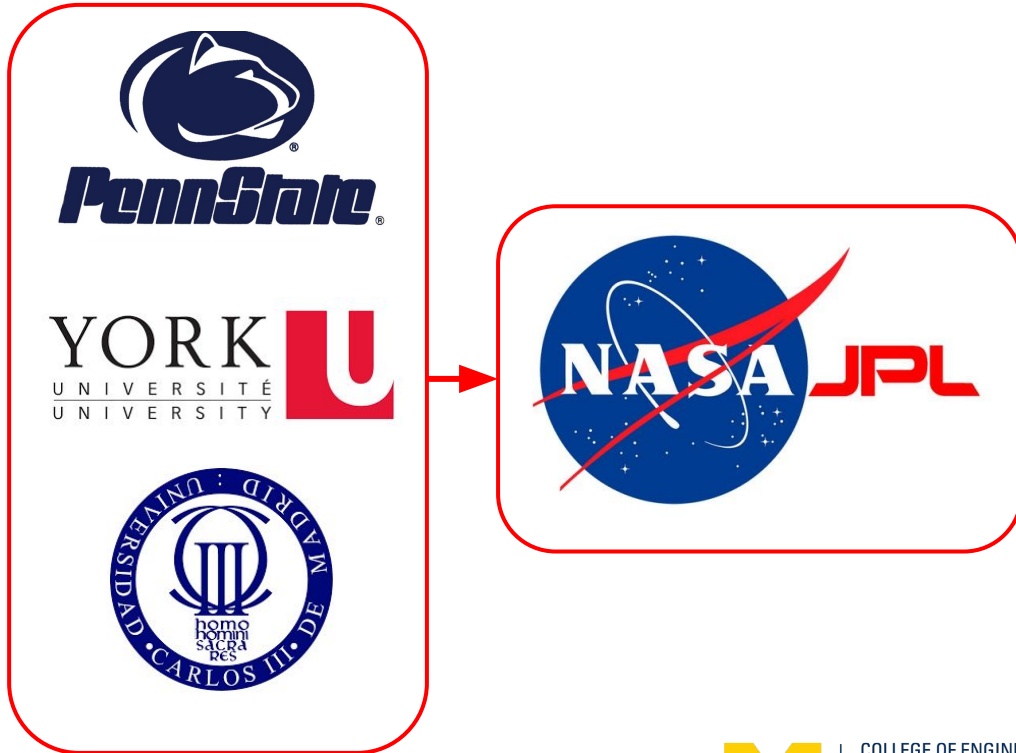
-----
Ephemeris Time = 001/00:00:00.000 2010
-----
Apogee Altitude = 500.000 (km)
Perigee Altitude = 500.000 (km)
-----
Inclination = 20.5000 (deg)
RAAN = 0.0000 (deg)
Argument of Perigee = 0.0000 (deg)
True Anomaly = 0.0000 (deg)
-----
Simulation Start = 001/00:00:00.000 2010
Simulation Stop = 001/00:00:00.000 2010
Time Increment = 000/00:00:10.000
-----
Tether Start Pos = 0.000 (km)
Tether End Pos = 1.300 (km)
Ex Boom Length = 50.000 (m)
Ey Boom Length = 50.000 (m)
-----
Perturb Orbit = YES
Decay Orbit = YES
Ballistic Coeff. = 100.000
-----
Radius of Apogee = 6871.200 (km)
Radius of Perigee = 6871.200 (km)
Semi-major Axis = 6871.200 (km)
Eccentricity = 0.00000000
-----
Mean Motion = 0.0011085 (rad/s)
= 0.06351 (deg/s)
Orbital Period = 94.4732 (min)
-----
Libration Time 0 = 001/00:00:00.000 2010
-----
IP Lib Magnitude = 0.0000 (meters)
OP Lib Magnitude = 0.0000 (meters)
Radial Lib Magnitude = 0.0000 (% elongation)
-----
IP Initial Phase = 0.000 (deg)
OP Initial Phase = 0.000 (deg)
RA Initial Phase = 0.000 (deg)
-----
IP Libration Period = 54.5441 (min)
OP Libration Period = 47.2366 (min)
EL Libration Period = 54.5441 (min)
-----
Due to the effects of the Sun, Moon and Earth's oblateness:
Precession of RAAN = -6.747891 (deg/day)
Precession of Arg Perigee = 10.986216 (deg/day)
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- TeMPEST was an early EDT propulsion/energy harvesting tool first developed in the 90s
- The EDT community is small, but dedicated and needed TeMPEST updated to 2020s standard
- My goal was to update and reevaluate geophysical and solar models for an accurate environment



# Next Steps and Future Work



- This project is designed to continue throughout the development of MiTEE-2
- Collaboration and model validation activities with university partners
- Integrate with NASA JPL's DARTS software for mechanical system model



- **Both economical and the physical limitations and are major drivers for the space industry**
- **As SmallSat become more and more widely used, there is a technological need for more advanced propulsion systems**
- **To help demonstrate EDTs as a viable on-orbit technology, advanced modeling software is necessary to prove systems virtually before sending them to space**

**Thank you!**  
Questions?