IN-ORBIT ASSEMBLY OF CUBE SATELLITES WITH NOVEL DOCKING TECHNIQUES

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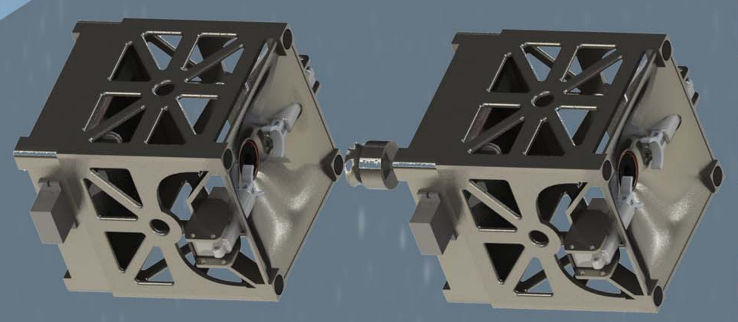
1. INTRODUCTION

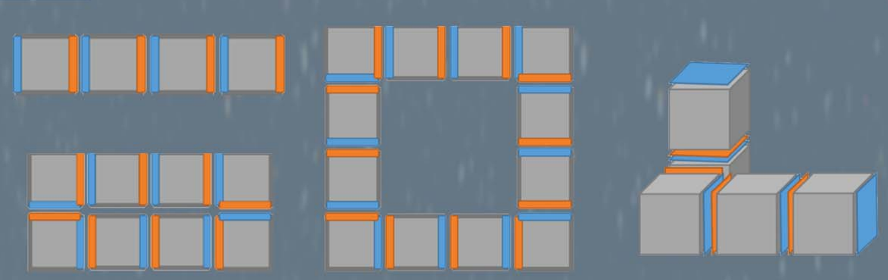
The UN Sustainable Development Goals includes promoting industry, innovation, infrastructure, and future partnerships for furthering goals. To align ourselves with them, we invent a novel technique for docking 1U cube satellites. The ultimate goals are:



1. **Lower the cost** of space craft development through modular deployment and in-orbit assembly.
2. **Encourage partnerships** between organisations for modular-based missions.
3. **Enable new applications** such as in-orbit construction, debris removal, and data transfer during constellation flight.

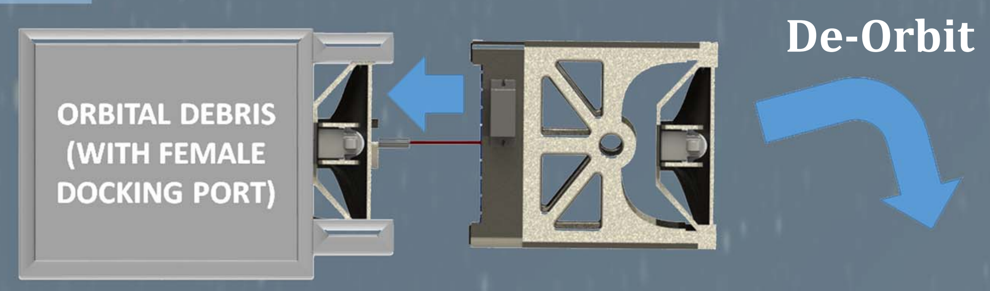
APPLICATION 1

2A. ORBIT ASSEMBLY



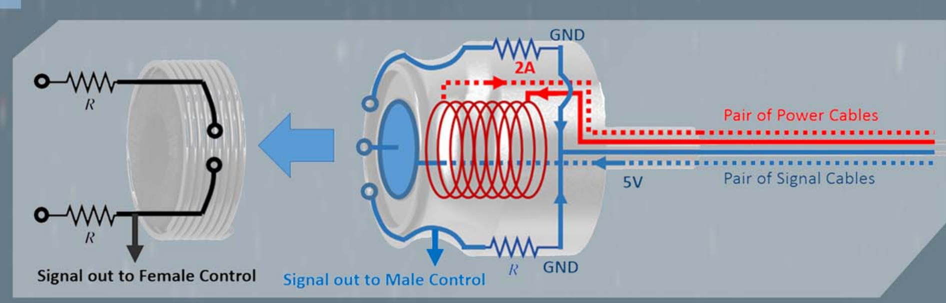
APPLICATION 2

2B. DEBRIS REMOVAL



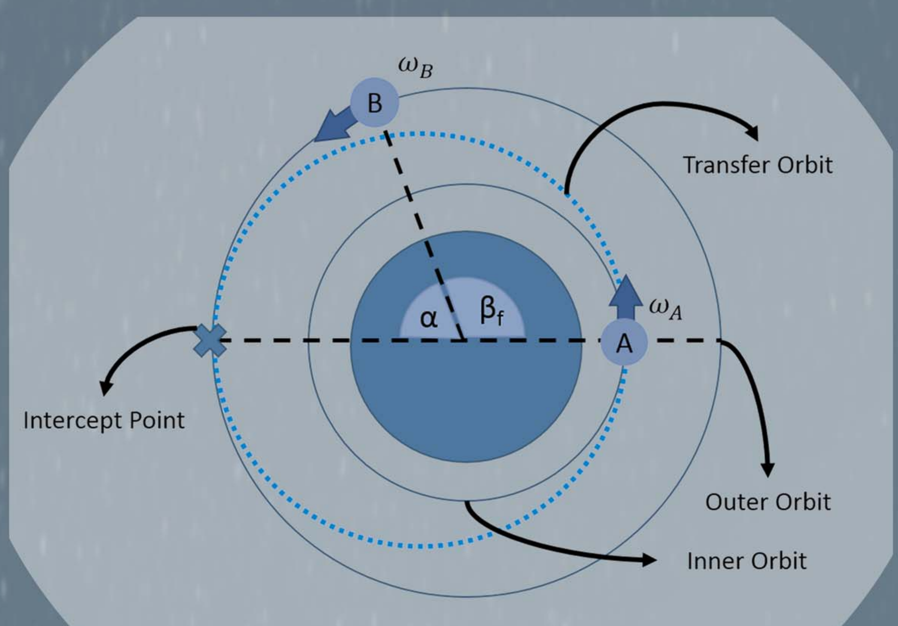
APPLICATION 3

2C. DATA TRANSFER



3. PHASE I - ORBIT RENDEZVOUS

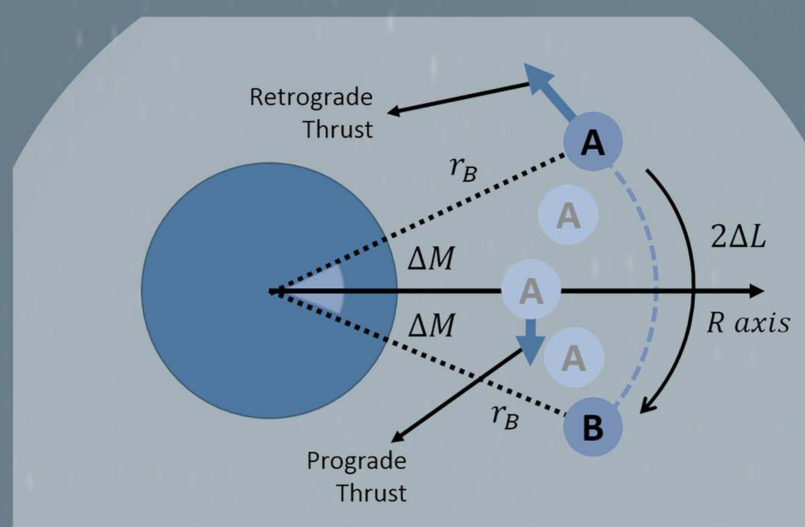
Using a well-timed Hohmann transfer, the target will cover both the altitude difference and catch-up to the true anomaly of the target in a single thruster burn. Requires very precise timing, possibly a long waiting time to get both satellites in the "right position" before thrusts, and accurate determination of anomaly-difference (α, β) between both satellites. The full paper covers all details of the manoeuvre.



PHASE 1: WELL-TIMED HOHMANN TRANSFER

4. PHASE II - IN-ORBIT APPROACH

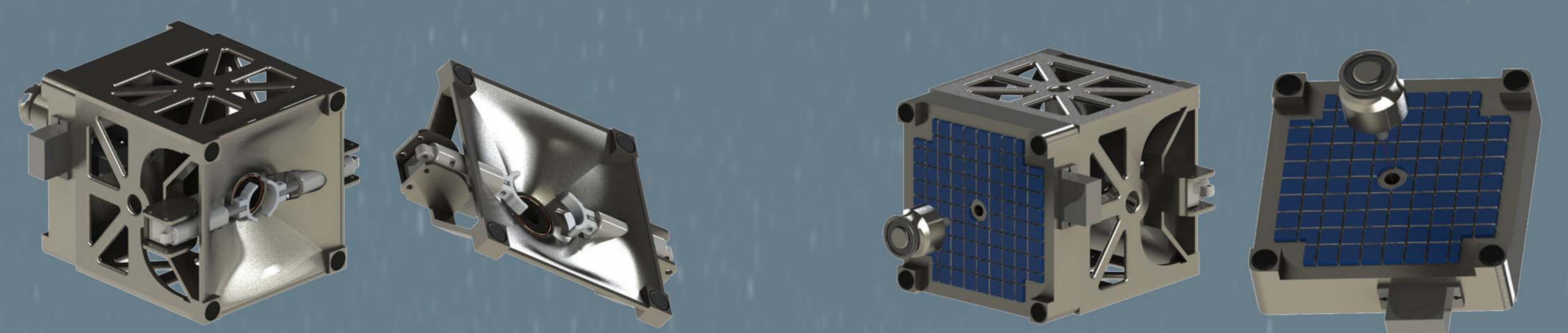
For remainder of distance, first, provide a continuous retrograde thrust to chaser A, so that it descends and speeds up along the in-track to target B. At the midpoint of the trajectory, chaser A fires a prograde thrust instead, causing chaser A to ascend with linear velocity still higher than B but decreasing. Dependent on 3 sensors to read relative distance between satellites. The algorithm can also be repeated again for re-alignment. Details in full paper.



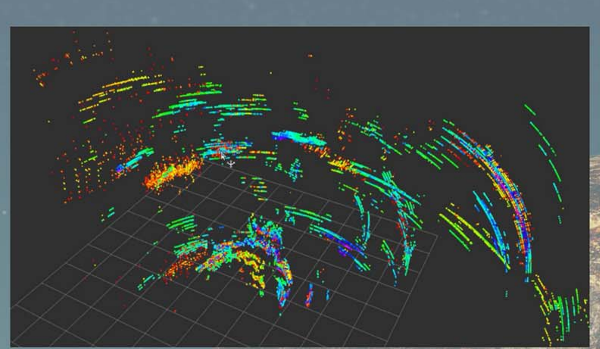
PHASE 2: SLOWLY CORRECT THE ERROR USING AN ITERATIVE IN-ORBIT APPROACH ALGORITHM

5. PHASE III - IN-ORBIT DOCKING

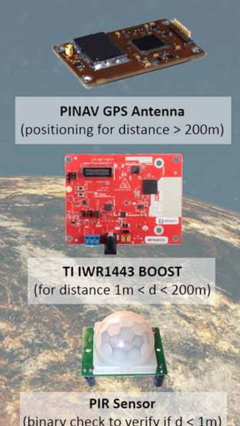
MICRO-DOCK: Modular Installation for CubeSat Rendezvous and Orbital Docking – Simple, modular, and non-androgynous, takes up ~17.6% of a 1U cube volume. Energy efficient, using ~1,644J for the entire docking process. Male & female modules are slim and can fit on any generic 1U cube satellite frame. Using an electromagnet-on-tether-head (EMTH), it can repeatedly (and reversibly) dock and undock. It works by firing the EMTH from male end of CubeSat A to female end of CubeSat B.

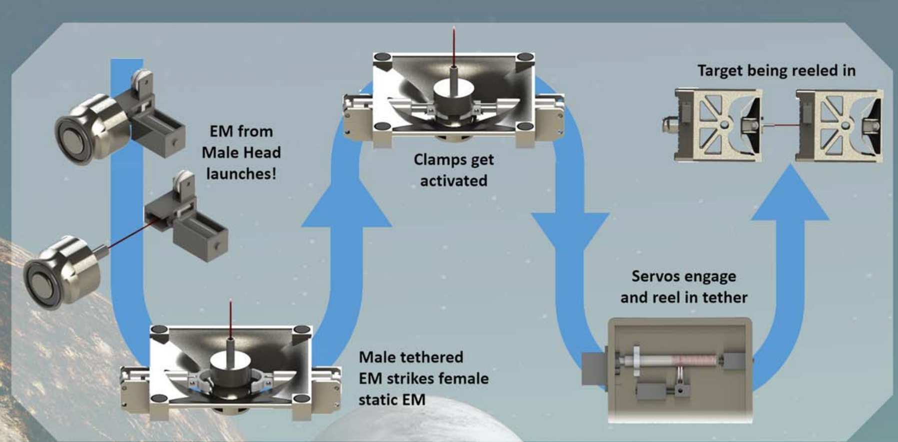


Sensors help align A & B using robotic algorithms on ROS. Ferromagnets guide the entry. Upon contact EMs, a circuit is triggered, and clamps are engaged for hard docking. Then, a servo motor reels in B, until ferromagnets hold them firmly in place.



RADAR image from IWR1443 tested on ROS Kinetic





6. GANTT CHART & BUDGET

	COSTS (USD)	2018				2019				2020			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Preliminary Design Study:	**60000**												
Problem Framing, Mission Scoping	15000												
Needs / Constraints Analysis													
Literature Review													
Initial Spacecraft & Mission Design													
COTS Feasibility Study	30000												
Structure Feasibility Study													
Detailed Spacecraft & Mission Design	15000												
Systems Design Review:	**65000**												
Procurement of COTS Components	20000												
Fabrication of custom docking components	30000												
Preliminary Constructions of Docking Modules													
Mock-Up Tests for Male / Female Docking	15000												
Systems Integration Review:	**90000**												
Full satellite systems integration	75000												
Controlled tests on docking system reliability	15000												
Testing Phase:	**100000**												
Thermal Testing	50000												
Mechanical and Vibration Tests													
Electronics Components Tests													
Full Systems Test	50000												
Launch:	**230000**												
Establish launch command	45000												
Establish ground command	45000												
Establish space command	45000												
Launch!	95000												
	545000												

7. REFERENCES

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LINK TO PAPER

LINK TO VIDEO

UNISEC 2018, 5th MISSION IDEA CONTEST