CubeSat Robotic Manipulator

Preliminary Design Proposal

Cole Sterba

William Albertini

Alice Sukhostavskiy

Caleb Arbreton

A.J. Presto

Shealyn Miller

Table of Contents

Mission Overview/Scope

Preliminary Design

Estimated Cost

Leads/Primary Responsibilities

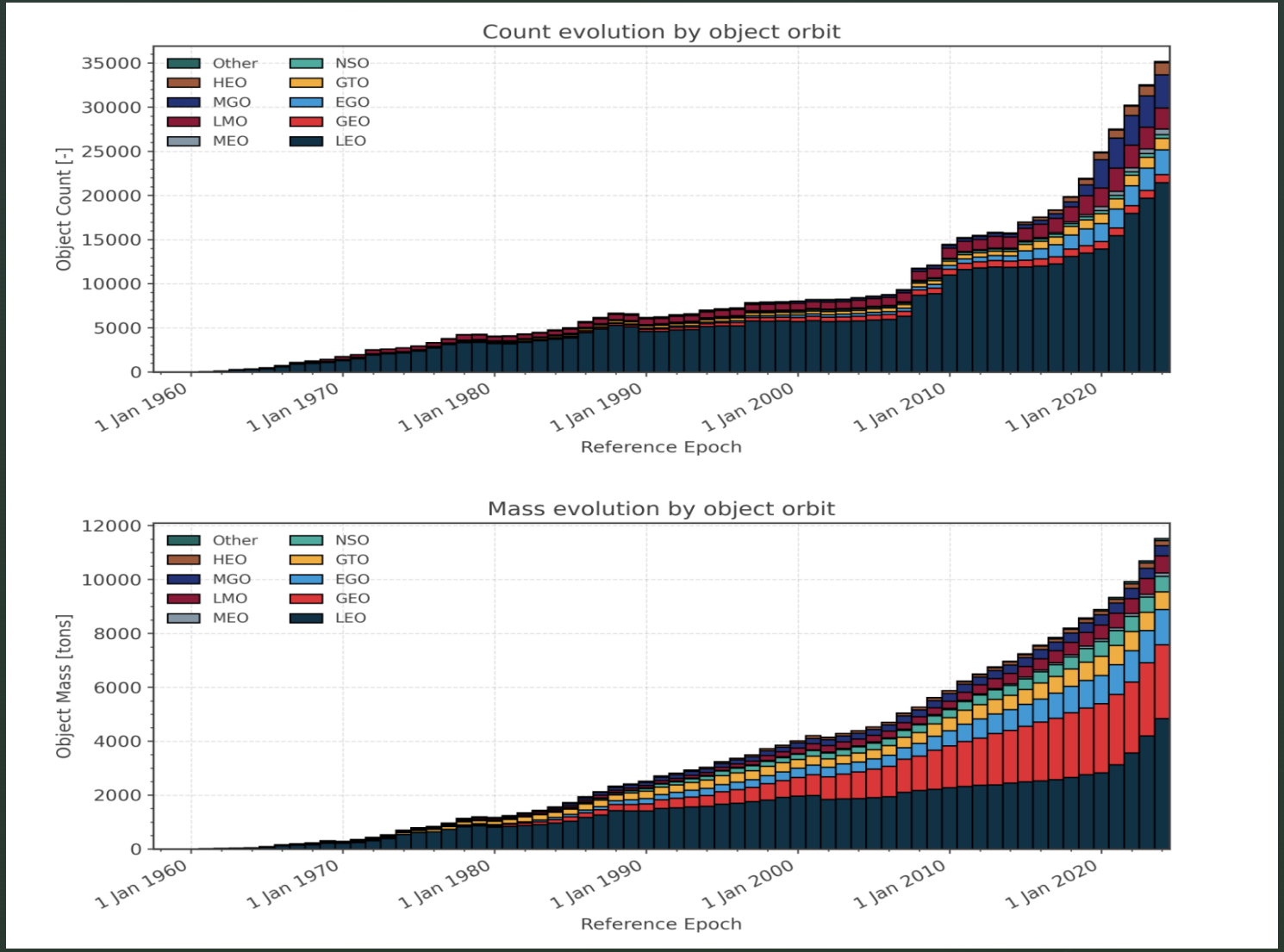
Mission Overview/Scope

Mission Background

- LEO is the most actively used orbit (around 84% of satellites reside in LEO[1])
- Large amounts of debris left in LEO (intentional and unintentional)
- Debris ranges in size from fragments to entire structures (rocket bodies or dead spacecraft)
- Space debris are projectiles moving at large velocities, making space less accessible
- Ever increasing

Popular orbit regimes[3]

Mission Background Cont...



Orbital objects by regime[2]

Mission Background Cont...

Orbital Regime	PL	PF	PD	PM	RB	RF	RD	RM	UI	Total
LEO	9564	5801	102	228	957	3062	40	575	1128	21457
GEO	792	3	3	9	65	0	0	0	42	914
EGO	521	1	1	48	199	87	3	2	1930	2792
GTO	53	28	1	10	233	201	12	52	727	1317
NSO	280	0	0	1	95	0	0	2	35	413
MEO	75	0	4	49	24	54	1	4	426	637
LMO	82	137	5	46	246	587	23	214	1043	2383
MGO	66	65	1	2	176	2152	4	0	1294	3760
HEO	30	13	0	1	55	113	0	0	1139	1351
Other	44	0	0	5	5	0	0	0	90	144
Total	11507	6048	117	399	2055	6256	83	849	7854	35168

Orbital objects by type by regime[2]

Mission Outline

Vision:

To contribute to the sustainability and shared use of space

Mission:

Creating a cost-effective solution to the ongoing orbital debris issue

Values for the mission:

Cost, usability, low Complexity, ease of deployment and operation

Mission/Project Scope

- Design and manufacture of a self-contained robotic manipulator for debris retrieval
- Remote operation
- Modular system (simple interfaces so it can be deployed on multiple platforms)
- Designing initially for a 3U Cubesat
- Primary considering of LEO operation (accessibility, large amount of debirs, communication access)
- CubeSat will de-orbit after collecting orbital debris

Preliminary Design

Initial Design

(subject to future changes)

- 4-5 degrees of freedom
  - Revolute shoulder and elbow joint for in plane translational motion (with possibility of third joint for out of plane motion)
  - Two revolute wrist joints for roll and yaw motion of end effector
- 2-4 prong clamp end effector
  - Each prong features a conformable surface for increased traction
- Lidar and camera aided remote operation
  - Lidar to help with coordinate position of object in workspace
  - Camera to help locate and grab object once close enough

Similar Designs

Orbital maintenance concept[5]

Aquatic robotic manipulator with 2-prong clamp[4]

Additional Considerations

- Utilizing an onboard ADCS (ie reaction wheels) for additional positional degrees of freedom

- Latching onto larger debris and using onboard thrusters to accelerate orbital decay

Estimated Cost (Cost Breakdown)

Item Name	Cost (dollars)	Amount
Servos + Angular Encoders	50	6
Material	300	N/A
Lidar Sensor	200	1
Camera	100	2
Power Supply	70	1
Computer and/or shield (ie raspberry pi 5)	200	1
Total	1270	

Leads/Primary Responsibilities

Subsystem Leads

- Coding/controls: Will
- Electrical: Cole
- Manufacturing: Caleb
- Mechanisms/Actuation: AJ
- Structures/CAD: Alice
- Systems: Shealyn

Proposed Platform Name:

B.O.W.S.E.R.

Bad Orbital Waste in Space Elimination Robot

Appendix: Work Cited

[1] Ieva. (2024a, January 3). *How many satellites are in space?*. NanoAvionics. https://nanoavionics.com/blog/how-many-satellites-are-in-space/

[2] ESA. (2023, December 6). *Space environment statistics*. Space Environment Statistics · Space Debris User Portal. https://sdup.esoc.esa.int/discosweb/statistics/

[3] Roberts is an adjunct fellow with the CSIS Aerospace Security Project and a graduate research fellow at the Massachusetts Institute of Technology's (MIT) Astrodynamics, T. G. (2022, June 14). *Popular orbits 101*. Popular Orbits 101. https://aerospace.csis.org/aerospace101/earth-orbit-101/#:~:text=Although%20over%2090%20percent%20of,smaller%20subset%20of%20satellite%20systems.

[4] "Underwater Manipulator Arm." *HDT Global*, 1 Sept. 2020, www.hdtglobal.com/product/adroit-m-undersea-manipulator/.

[5] Nance, Abigail, and Max Thibault. *CubeSat-Scale Robotic Arms in Space*, Naval Academy, mstl.atl.calpoly.edu/~workshop/archive/2023/presentations/2023_Day2_Session6_ThibaultNance.pdf. Accessed 20 Jan. 2024.