University of Florida

Department of Mechanical and Aerospace Engineering

Fall 2016

Aerospace Design 1 (EAS4700)

Instructor: Dr. Riccardo Bevilacqua

www.riccardobevilacqua.com

https://www.facebook.com/ADvancedAutonomousMUltipleSpacecraftLaboratory

Outline

- Introductions
- Research at UF
- Syllabus
- The design challenge

My story at a glance

M. Sc. In Aerospace Engineering from *Sapienza* University, Rome, Italy, 2002.

Project Engineer in Mission Analysis at *Grupo Mecanica del Vuelo*, Madrid, Spain, 2003.

Ph. D. in Applied Mathematics, Aerospace Engineering focus, from *Sapienza* University, Rome, Italy, 2007.

Post-Doctoral appointment at *NPS* , Monterey, CA (National Research Council), 2007-2010

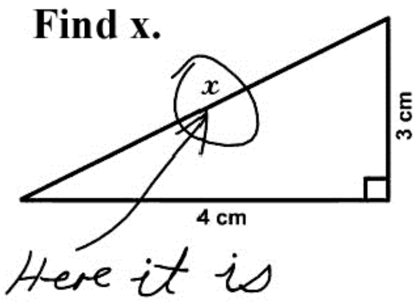
RPI, Faculty, 2010-2014

UF (yes!), Faculty, 2014-2016

What we do in a nutshell (ADAMUS lab)

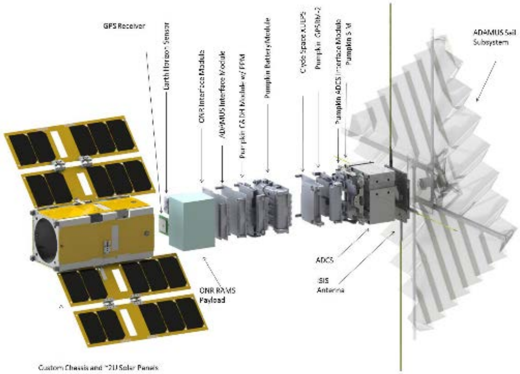
Guidance, Navigation, and Control (GNC) for multi-spacecraft (S/C) systems:

1. **Theory**



2. **Laboratory testing w/ spacecraft simulators**

3. **Mission & S/C design**



Multiple S/C systems allow for low-cost orbit insertion, reconfiguration-ability, upgrade-ability…

<u>NASA’S MISSIONS TO MOON AND MARS WILL BE BASED ON TWO ON-ORBIT DOCKING CAPSULES</u>

Credit: Defense Advanced Research Projects Agency

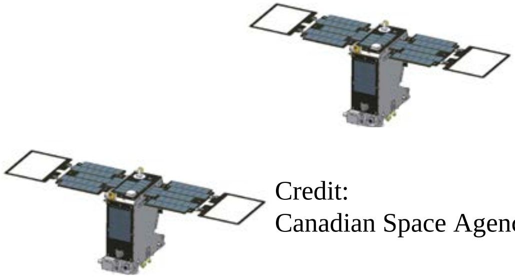
CURRENT AND PAST

- Differential drag missions:
  - **JC2Sat**: joint Canadian-Japanese
  - **InKlajn-1**: Israeli Nano-Satellite Association
- **ESA Automated Transfer Vehicle (ATV, ISS re-supply vehicle)**
- **DARPA Orbital Express**, 2007
- **NASA DART**, 2005
- National Space Development Agency of Japan’s **ETS-VII** in 1998

Credit: European space Agency

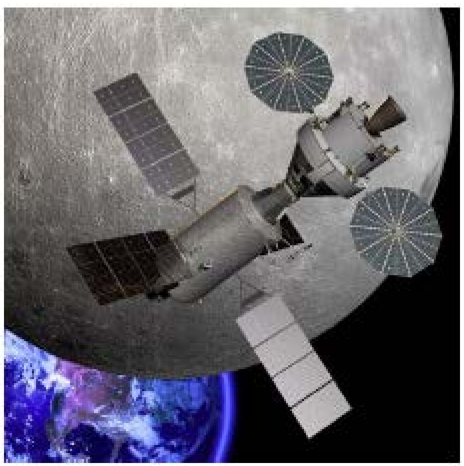
FUTURE

- **AFRL’s Autonomous Nano-satellite Guardian Evaluating Local Space (ANGELS)**
- **DARPA F6 System**
- **<u>UF’s PADDLES</u>**



Credit:
Canadian Space Agency

Near Earth Asteroids exploration!!!



JSC/ES4/Dr. Steve Koontz

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- Spacecraft in the past:

  - independent from each other

  - interacting operations controlled manually by operators (for example docking and rendezvous operations).

  - Autonomous Operations reduced to very simple tasks

- Spacecraft today and in the future:

  - Spacecraft modularity (cost and failure tolerance)

  - Automatic assembling operations in space are becoming a problem of major importance

  - GNC for automatic docking and rendezvous operations increasingly studied/applied

The limiting factors for in-space GNC algorithm testing are:

- The launching cost per pound:

  •The average Cost-per-lb to Low Earth Orbit (LEO) ranges between 3,632 $ and 4,587 $ *

  •The average Cost-per-lb to GEO Tranfer Orbit (GTO) ranges between 9,243 $ and 11,243 $ *

- The high risk factor in case of failure

•As published by the Center for Strategic and Budgetary Assessments
http://www.csbaonline.org/wp-content/uploads/2011/02/2001.02.01-Military-Use-of-Space.pdf

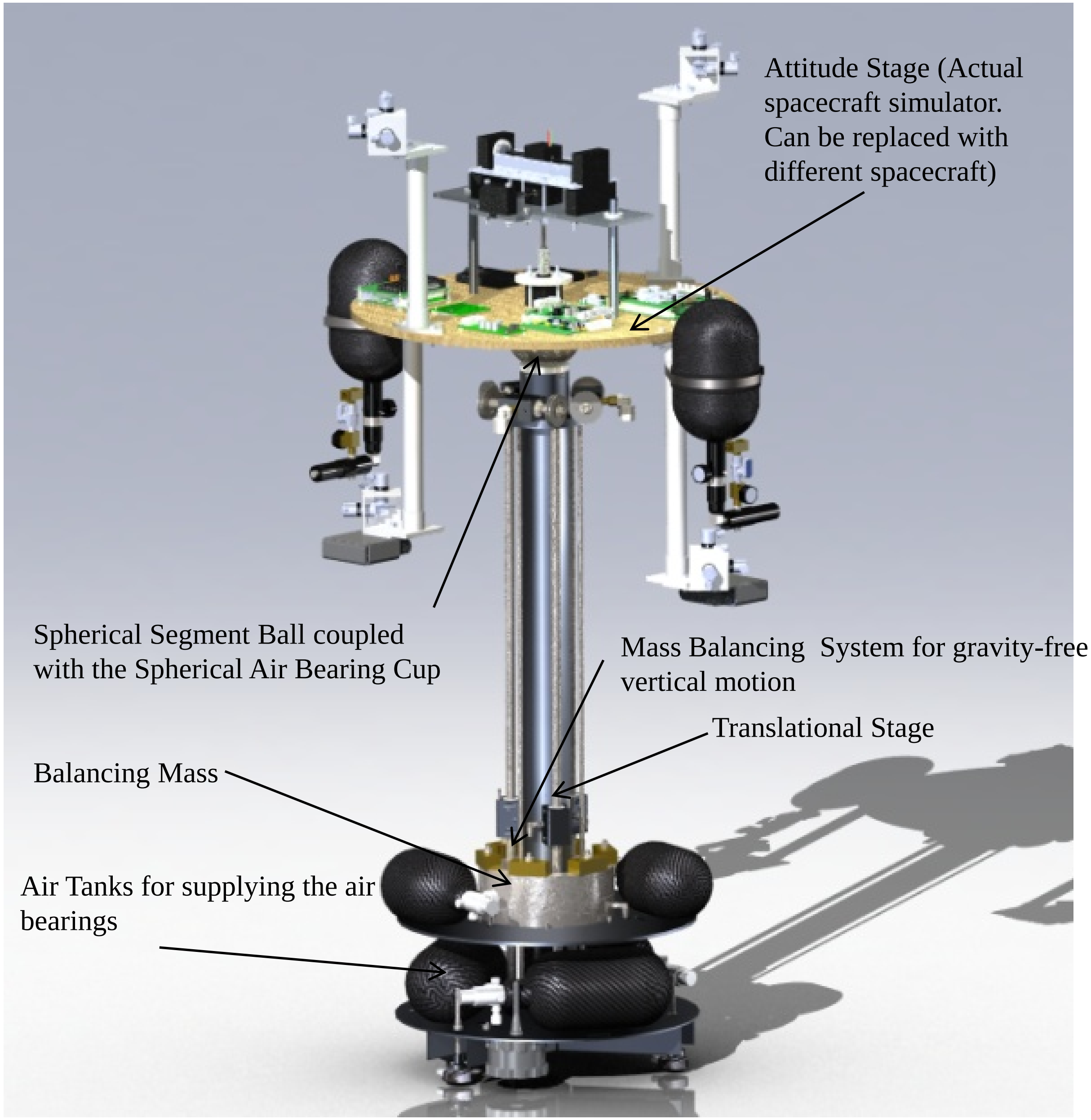
- Software Simulations:

  - cost <<in-space testing

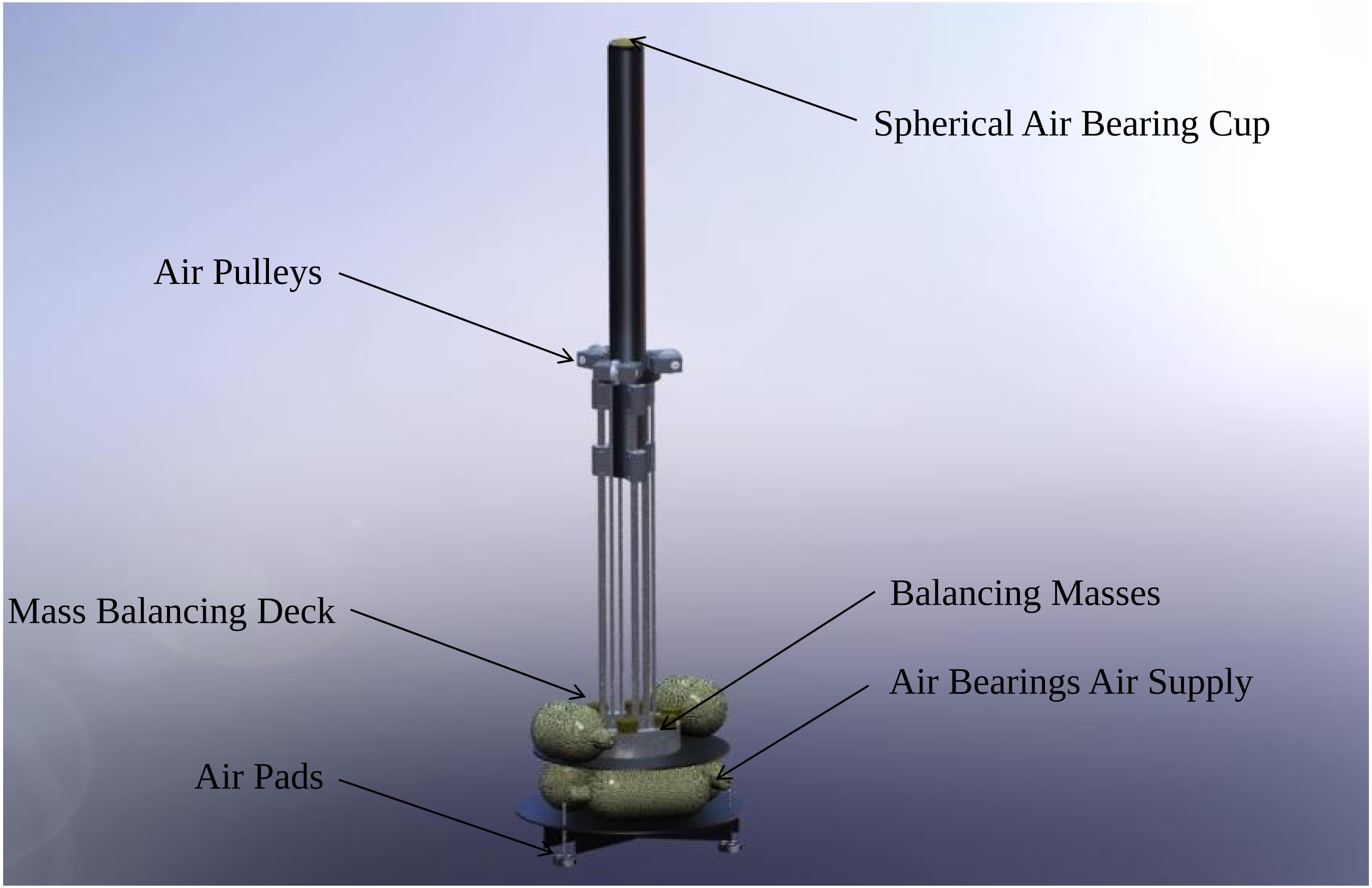
  - Tuning easily performed without any failure risk or cost

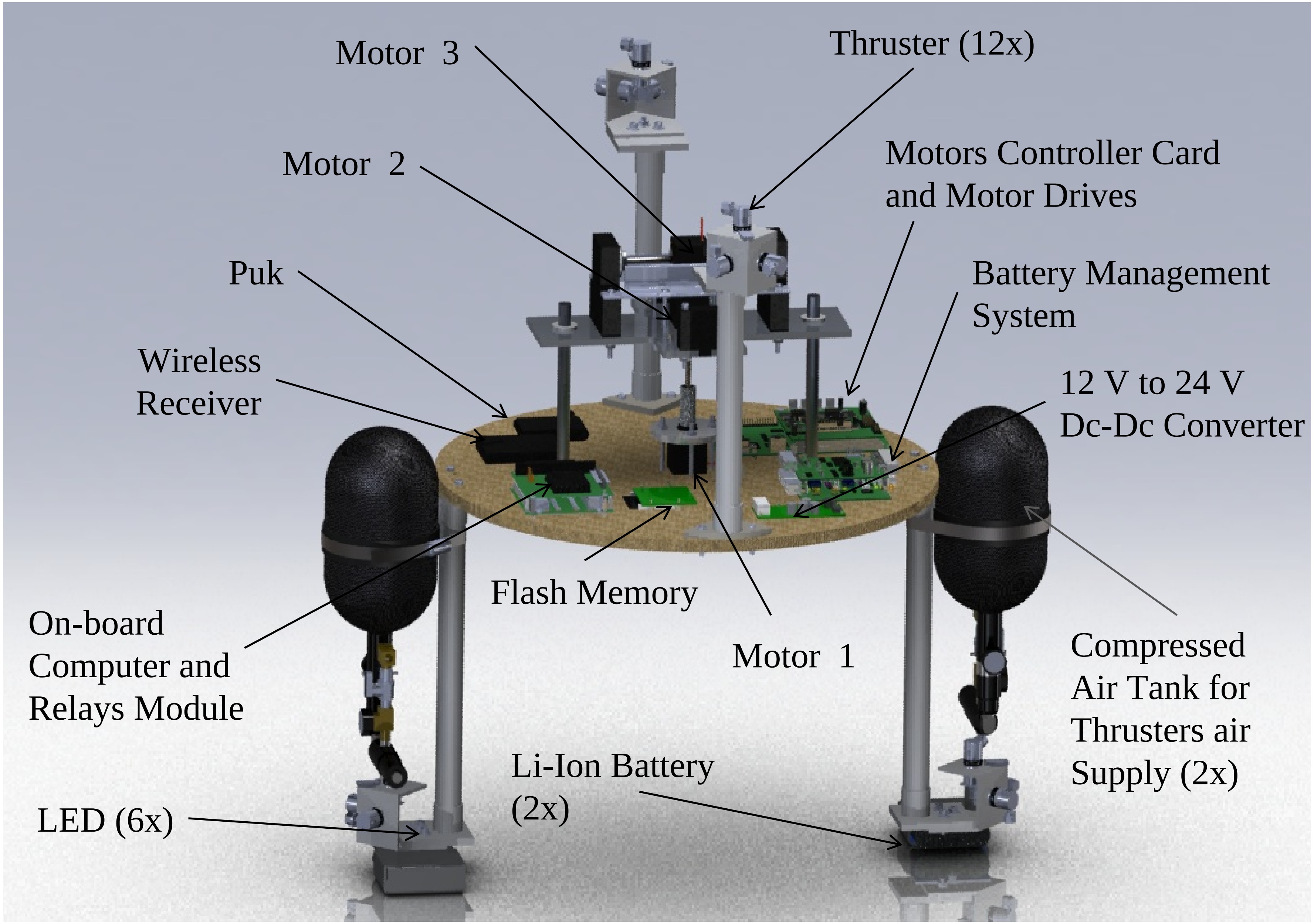
  - Very often the simulations are not able to reproduce exactly the spacecraft hardware, producing **results that may be drastically different on the field**

The 6 DOF ADAMUS Lab. Experimental Platform

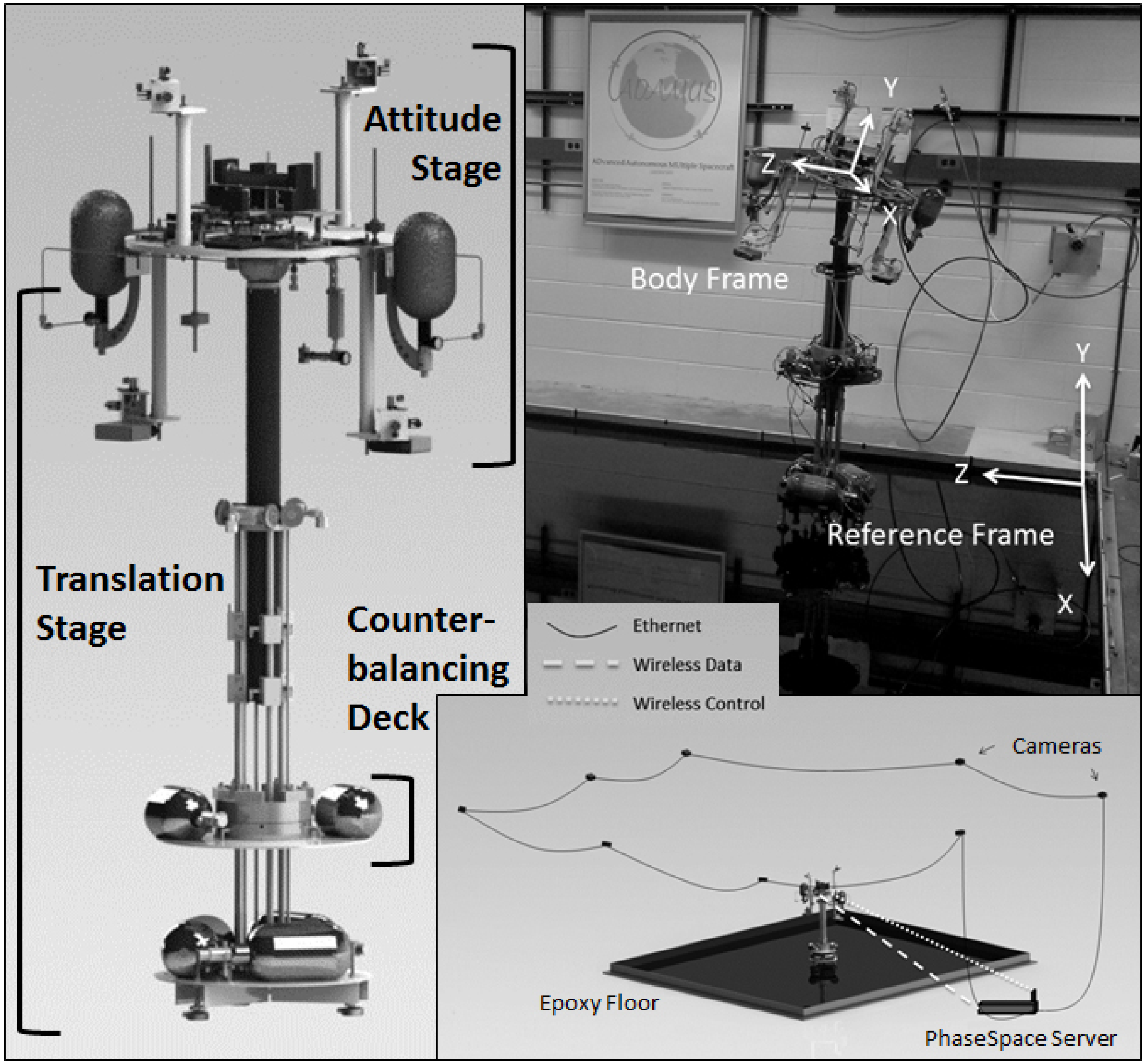


The Translational Stage

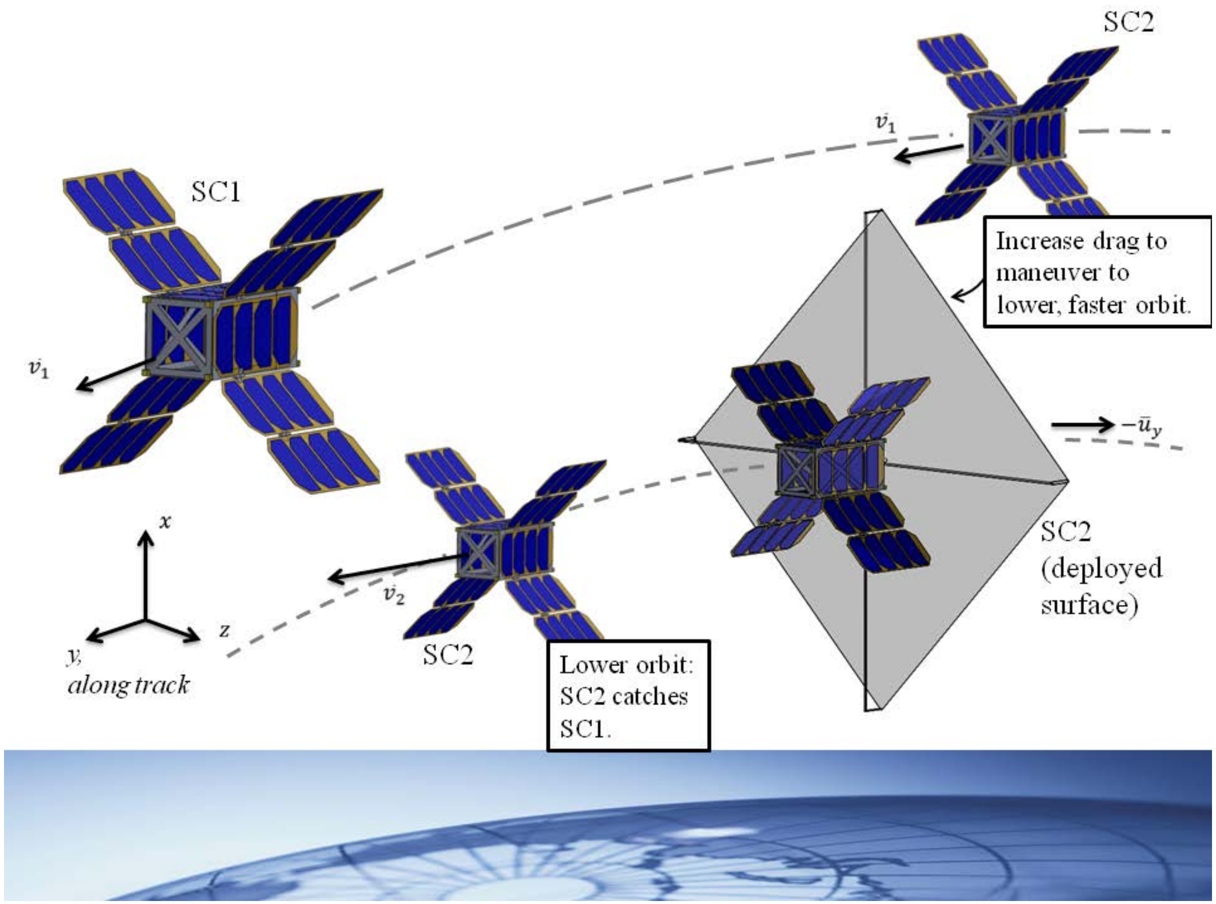



Motor 3
Thruster (12x)
Motor 2
Motors Controller Card and Motor Drives
Puk
Battery Management System
Wireless Receiver
12 V to 24 V Dc-Dc Converter
Flash Memory
On-board Computer and Relays Module
Motor 1
Compressed Air Tank for Thrusters air Supply (2x)
Li-Ion Battery (2x)
LED (6x)

Laboratory testing of GNC with HITL



Propellant-less control of LEO S/C based on Differential Drag



3U Cubesat, hosting a deployable sail in 0.5U

Clear mylar used for the sail (space qualified, and letting sun get through)

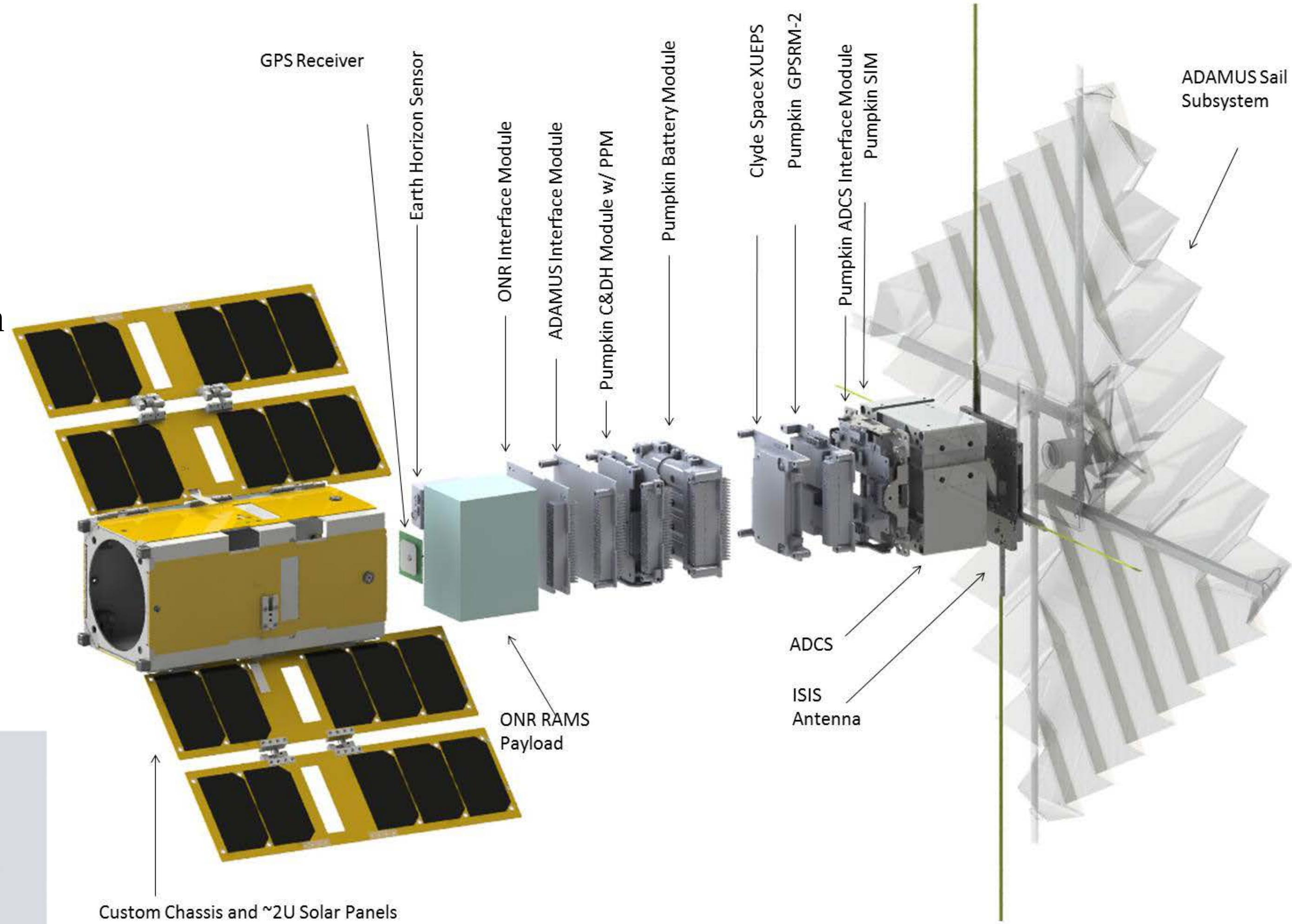
Sail design based on an origami folding pattern, to maximize surface, and minimize volume when contracted

AFOSR
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

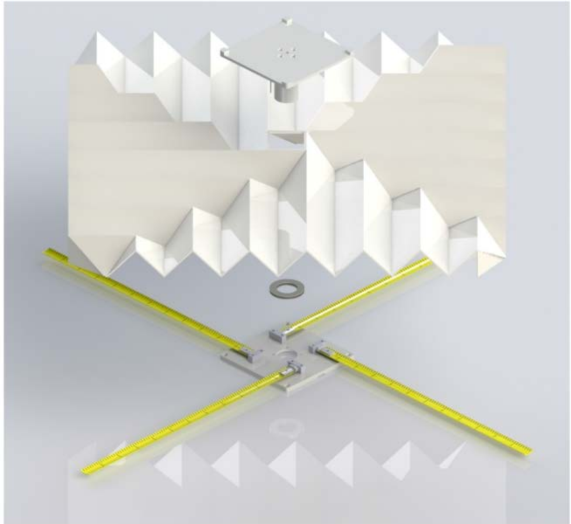
PADDLES Propellant-less Atmospheric Differential Drag LEo Spacecraft

Orbit requirements:

1. From ISS (<450km)
2. Circular
3. Any inclination
4. RAMS pointing within 3 deg.



$0.01m^2$ to $0.15m^2$



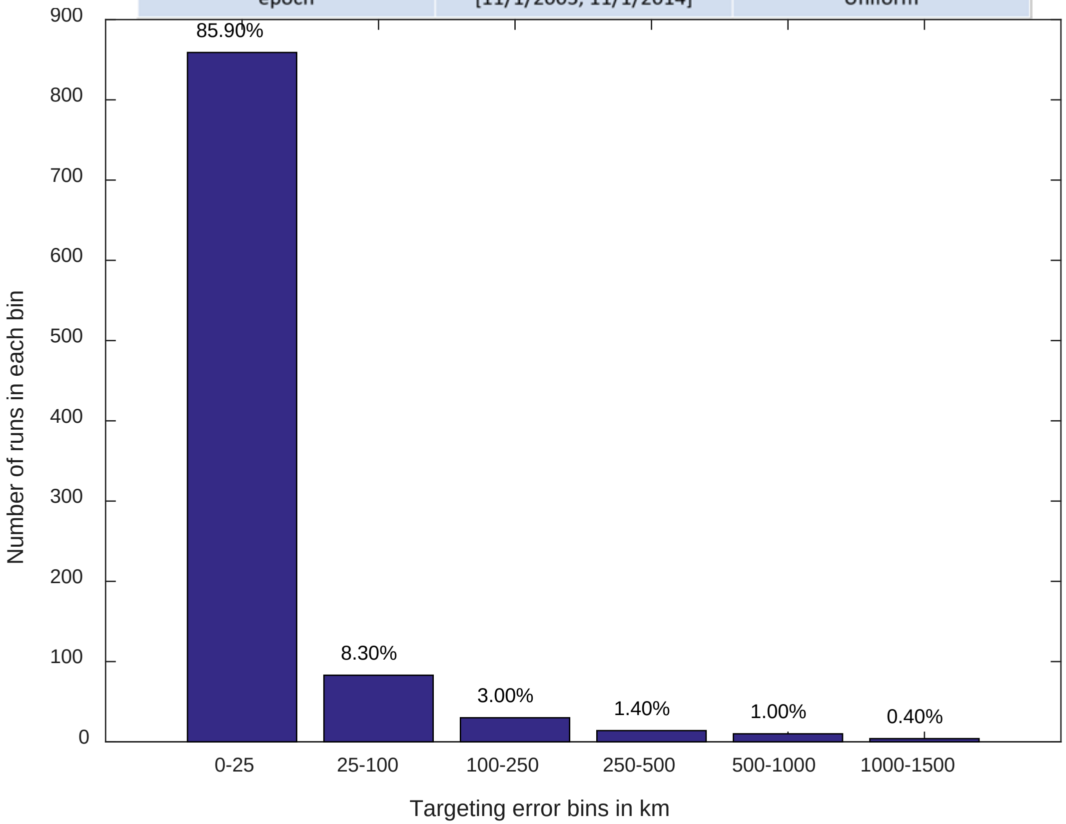
Dave Guglielmo and Riccardo Bevilacqua, "Propellant-less Atmospheric Differential Drag LEo Spacecraft (PADDLES) Mission", SmallSat Conference 2014, Utah.

Colin Mason, Grace Tilton, Nomita Vazirani, Joseph Spinazola, David Guglielmo,Riccardo Bevilacqua, Johnson Samuel, "Origami-based Drag Sail for CubeSat Propellant-freeManeuvering", 5th Nano-Satellite Symposium, November 2013, Tokyo, Japan.

Prof. Riccardo Bevilacqua

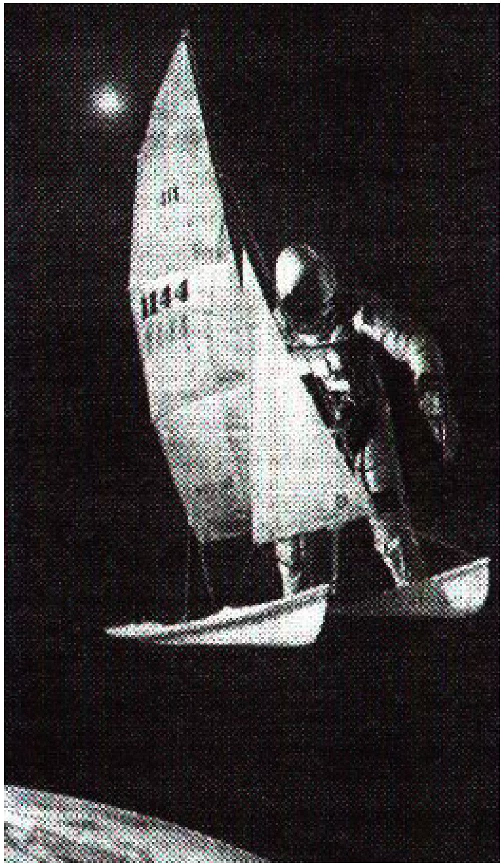
Drag controlled re-entry

Variable	Range	Probability Distribution
Semi Major Axis	[6668, 6778] km	Uniform
True Anomaly	[0, 360] degrees	Uniform
Eccentricity	[0, .004]	Uniform
Right Ascension	[0, 360] degrees	Uniform
Argument of the Periapsis	[0, 360] degrees	Uniform
Inclination	[1, 97] degrees	Uniform
Impact Latitude	[0, inclination-.001] degrees	Uniform
Impact Longitude	[-180, 180] degrees	Uniform
Cb_{max}	[.033, .067]	Uniform
Cb_{min}	[.0053, .027]	Uniform
epoch	[11/1/2003, 11/1/2014]	Uniform

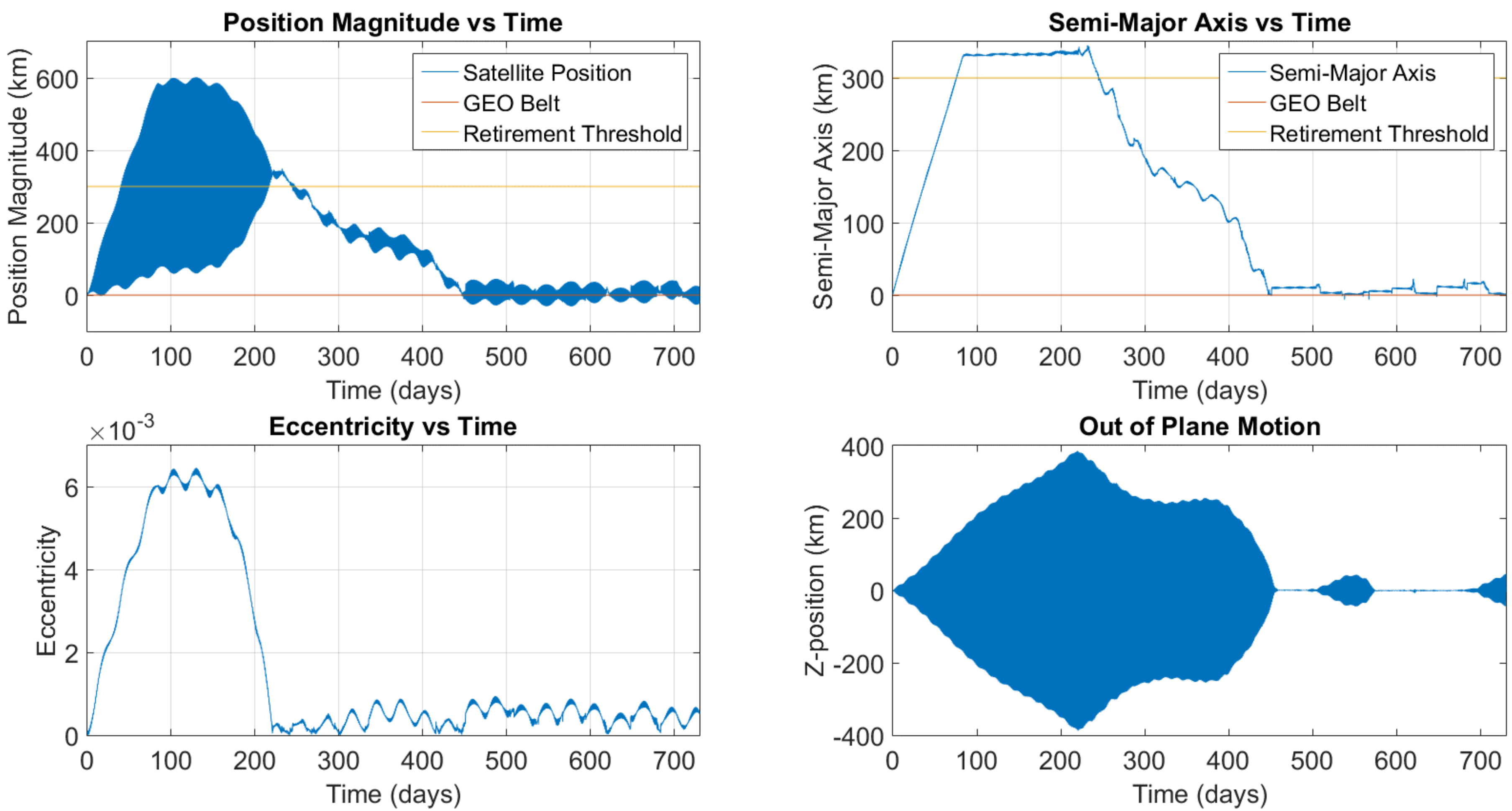


Above LEO: Solar Sailing

- Utilize SRP force to propel a spacecraft
- Virtually infinite delta V
- Non-Keplerian Orbits
- Reduce propellant dependency
  - Reduce fuel cost
  - Reduce propellant mass
  - More resources for sensors or payloads
  - Extend lifetime of satellite



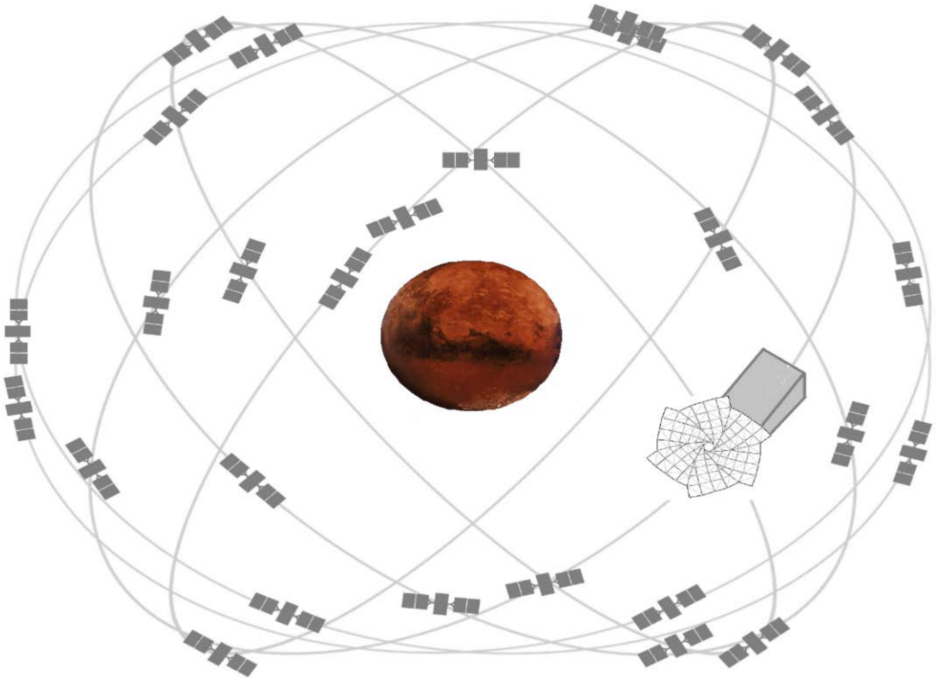
Representative results



SRP Future Work

Applications for Martian orbit

- Solar Sailing GPS & Telecom



Conference in FL next year

http://www.cubesat.org/
http://www.vs.afrl.af.mil/UNP/
check on facebook too:
http://www.facebook.com/pages/University-Nanosat-Program/103367739717198

ADAMUS researchers

Yes, 5 years old but absolutely current:
http://www.nasa.gov/offices/oct/college_letter_detail.html

My own take:
http://www.orlandosentinel.com/opinion/os-ed-mars-front-burner-070516-20160701-story.html

…facts about me…

1. Married with one daughter and one son (observable, not controllable).

2. I can grow some serious hair (anticipating those who will google my name under images…).

3. I can (could…) finish a marathon.

4. I am STK certified, so you will be too. AGI's visit

5. I am co-chairing MAE's GRAC.

Your turn

Name
Where you come from
Where you may want to go
Interesting facts about you

Syllabus link

BEFORE GOING TO SLEEP
Space Tourism Adventures in Earth Orbit and Beyond
Michael Van Pelt
Copernicus Books

SOME MORE...
Space Vehicle Design, Second Edition
Griffin, French
AIAA Education Series
Spacecraft Mission Design, Second Edition
Brown
AIAA Education Series

Syllabus (continued)

...AND MORE!!!

- Tactical Missile Design, Second Edition
- Current State of the Art on Multidisciplinary Design Optimization
- Space Vehicle Design Criteria, Archive
- AIAA Aerospace Design Engineers Guide, 5th Edition
- Getting things done (I strongly recommend!)

More texts, articles, and other materials will be also chosen based on the selected projects of the groups.

FOR RESEARCH:

- AIAA Journal of Guidance, Control and Dynamics (see www.aiaa.org)
- AIAA Journal of Spacecraft and Rockets
- AAS Journal of Astronautical Sciences
- Proceedings of AIAA Guidance, Navigation and Control Conference
- IEEE Publications

Syllabus (continued)

- Each member of a team is expected to present a part of the technical presentations and answer questions on his/her own.

- All Students should be present for all presentations.

- Presentation time slot: do not even think about making other plans for those days!

LONG TERM BENEFITS

1. You will learn STK, that should be obvious…

2. You should become familiar with Matlab & Simulink (see this)

3. You are here starting to deal with real work…and people!

1st homeworks

- Install STK and request EDU license (instructions on my site)
- Read the project description to discuss next time
- We will use this template for tracking tasks – update me every week

Roster

My idea is:

- Orbital mechanics and maneuvers (STK)
- Attitude mechanics and maneuvers (Simulink)
- Power (needs input from orbit and attitude)
- Structure (CAD: mass, moments of inertia, etc.)
- Communications (link budget)
- Costs, thermal, radiation and systems engineering

Final Remarks

IN CLASS:

No cell phones, no texting, unless you have emergency situations.
No laptops open while I talk.
No leaving while class is ongoing.

DO NOT DISTRACT YOUR COLLEAGUES!

I AM NEVER LATE IF NOT FOR A VALID REASON→ DO NOT COME LATE TO MEETINGS

Your feedback is fundamental for the instructor.

-Speak out (without overdoing it).
-Help developing/maintaining an enjoyable atmosphere in the class.
-Get to know your colleagues, they will likely be your co-workers!

STRONGLY RECOMMENDED
Rehearsals of your presentations

UNDERSTAND THAT WHATEVER PROBLEM WE WORK ON,
IT IS NEW FOR ALL OF US

Final Remarks (continued)

1) "*Ancora Imparo*" -- Michelangelo

2) You should enjoy all courses…but this one in particular!
Take advantage of it to work together and learn what that means!

3) I will make my experience available for those who really want to pursue careers in space

4) DO NOT GET RUSHED TO BUILD SOMETHING. THIS IS ONLY ONE SEMESTER, AND YOU SHOULD TAKE IT AS A LEARNING EXPERIENCE, AND PREPARATION FOR WORK.

5) http://www.youtube.com/watch?v=e7DEw70LVWs

6) http://www.u2.com/news/title/u2-and-nasa-create-video-to-celebrate-collaboration

7) My little ones can watch this for hours:
http://www.youtube.com/watch?v=II7QBLt36xo

Final Remarks (continued)

1) Being an aerospace engineering is the coolest job

2) It takes patience

3) It takes perseverance

4) It takes one million failures and one success

5) It takes love and passion

6) It takes men and women

7) It takes flawed human beings to create flawless flying machines

8) …and we could be in one of those videos. And above all we could have the honor and bare the responsibility of being the leaders in science and technology.

'The future doesn't belong to the fainthearted; it belongs to the brave.'
-- Ronald Reagan on January 28 of 1986 after the disaster with space shuttle Challenger.