



Deep Space Mission Opportunities for Small Satellite Designs

Small Satellite Design Course
National Institute of Aerospace (Member Universities)

Robert Moses
12 February 2019



- **Moon Case**
 - SIRONA
- **Mars Case**
 - MAC
 - MarCO
- **Going Deeper Into Space?**
 - Mission Opportunities
 - Mission Barriers
 - Mission Enablers
- **Summary**



SIRONA

- a low-cost platform for lunar exploration –

G. Bailet¹

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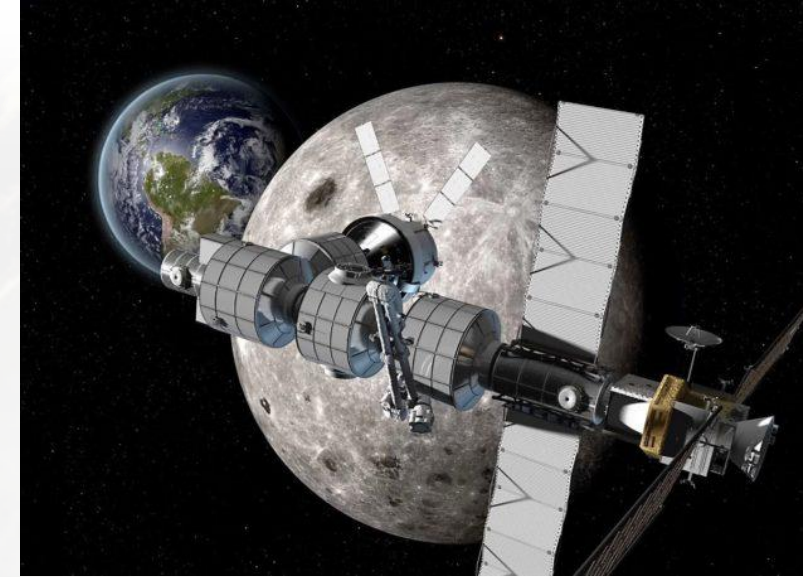
²CentraleSupélec, Université Paris-Saclay, France

Mission Objectives



Scientific Objective (ASTERICS)

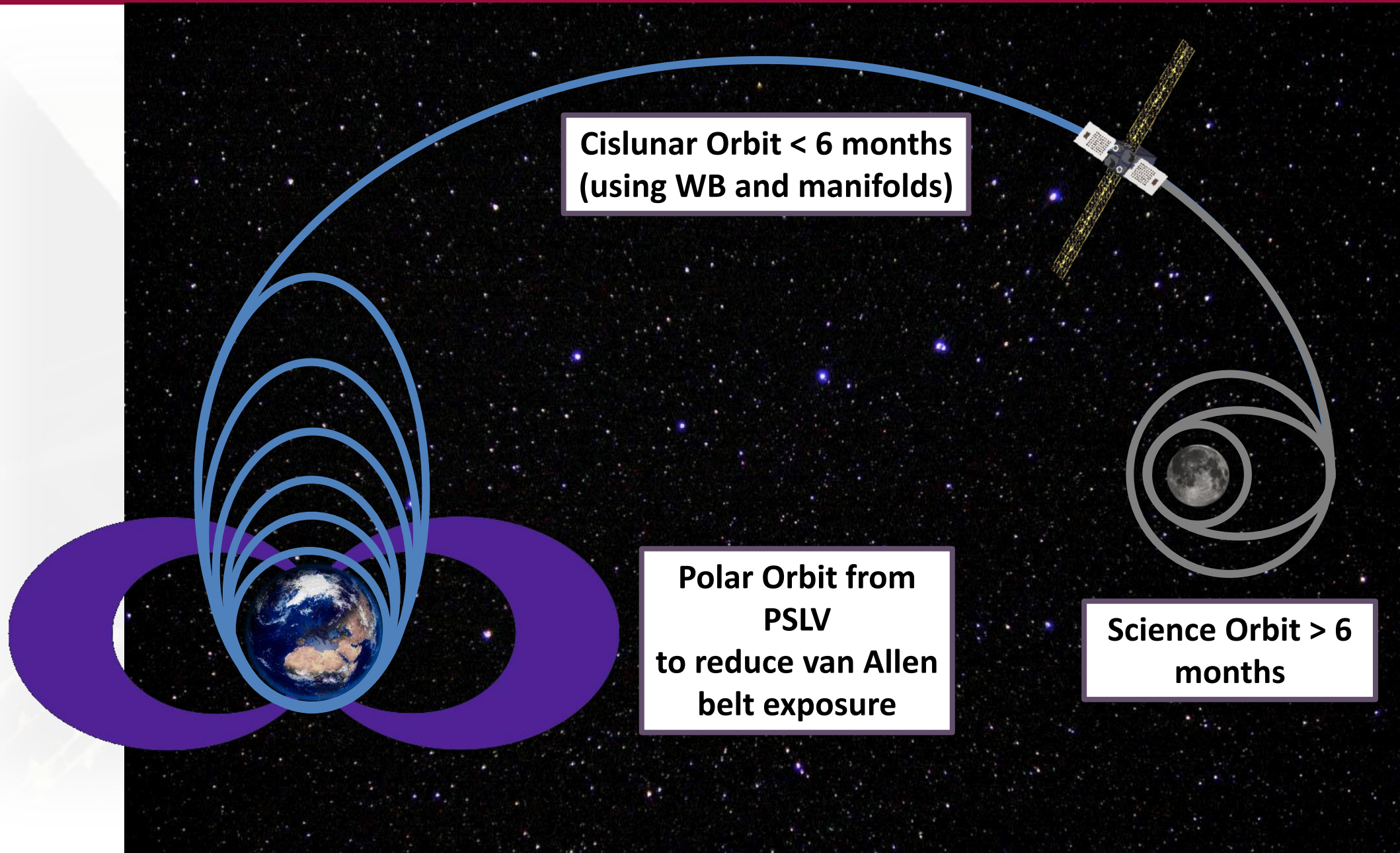
- **Test the hypothesis** of the Lunar Cataclysm
- Demonstrate the capabilities of a deployable telescope for Cube/SmallSats
- **Improve database** of LRO with additional data and different lightning conditions



Industrial Objective (OBELICS)

- **Optimize Radiation Shielding** for future human mission farther than LEO (Cislunar Station, Lunar/Martian colonies...)
- Study the **effect of Radiations** on biological samples
- Gather **long term data** surpassing Apollo program that lasted a maximum of 7 days at a time

Mission Profile



Platform design



SIRONA
Undeployed configuration



SIRONA
Deployed configuration

(Saint-Emilion Wine Bottles are for scale purposes and are not intended to promote the amazing french products)

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Magnetoshell Aerocapture Concept (MAC)



<https://www.geekwire.com/2017/uw-team-wins-nasas-nod-small-satellites-magnetic-braking-systems/>

Mars Cube One (MarCO)



<https://spacenews.com/marco-success-vindicates-use-of-cubesats-on-deep-space-missions/>

<https://www.jpl.nasa.gov/cubesat/missions/marco.php>

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Our Capabilities Today...will they create New Missions Tomorrow?



Capabilities Include:

- Lunar CubeSat Missions
- Mars CubeSat Missions
- Cheap(er) LEO Access via Reusable Rockets

Do these capabilities allow new missions deeper into Space?

<https://www.nasa.gov/smallsat-institute/recent-smallsat-news>

List of CubeSats on Wikipedia



CC-BY-SA, Wikimedia Foundation, Inc.,

https://en.wikipedia.org/wiki/List_of_CubeSats

Google: “small satellite missions deep space”



Planetary Science Deep Space SmallSat Studies

<https://www.hou.usra.edu/meetings/smallsat2018/> ▼

The Planetary Science **Deep Space SmallSat Mission** Concepts meeting will be held Sunday, March 18, 2018, at The Woodlands Waterway Marriott Hotel and ...

The Small Satellites Paving The Way For Low-Cost Exploration Of ...

<https://www.fastcompany.com/.../the-small-satellites-paving-the-way-for-low-cost-exp...> ▼

May 4, 2018 - When **NASA's** next Mars **mission** takes off this Saturday, it will be accompanied by two **small** escorts that could transform the future of space exploration. ... that **NASA** hopes will one day allow us to explore **deep space** on the ...

^[PDF] Lean Small Satellite Missions Require Lean Access to Space - unoosa

www.unoosa.org/.../S21_03_J_Casas_Panelist_Natal_Brazil_Sept_2018_Lean_Small_... ▼

by J Casas

United Nations/Brazil Symposium on Basic Space Technology. "Creating Novel Opportunities with **Small Satellite Space Missions**". Natal, Brazil, 11 - 14 September 2018. Joseph Casas ... **Deep Space**. SLS Block 1B Crew. As Early As 2023.

Deep Space 1 - eoPortal Directory - Satellite Missions

<https://earth.esa.int/web/eoportal/satellite-missions/d/deep-space-1> ▼

DS1 (**Deep Space 1**). DS1 is the first **satellite mission** in **NASA's** New Millennium Program (NMP). A major ... **Small deep-space** transponder. In addition, the ...

^[PDF] Small Satellites: A Revolution in Space Science - Keck Institute for ...

kiss.caltech.edu/final_reports/SmallSat_final_report.pdf ▼

3.1 **Small Satellites** for Revolutionary Space Science: Why Now? space science at all levels from observational techniques through **mission** concept **deep space** power and propulsion systems, communication for Direct to Earth (DTE).

MarCO success vindicates use of cubesats on deep space missions ...

<https://spacenews.com/marco-success-vindicates-use-of-cubesats-on-deep-space-missio...> ▼

Nov 26, 2018 - MarCO success vindicates use of cubesats on **deep space missions** ... The success of MarCO demonstrates that such **small satellites** — each ...

How Small Satellites Are Providing Low-Cost Access to Space

theinstitute.ieee.org › Tech Topics › Communications

Nov 12, 2018 - The global **small satellite** market is expected to grow to more than US ... The pair, the first microsatellites to support a **deep space mission**, are ...



<https://www.hou.usra.edu/meetings/smallsat2018/>

...Require Lean Access to Space”



United Nations/Brazil Symposium on Basic Space Technology
"Creating Novel Opportunities with Small Satellite Space Missions"

Natal, Brazil, 11 - 14 September 2018

"Lean Small Satellite Missions Require Lean Access to
Space"

Joseph Casas
NASA Marshall Space Flight Center
Joseph.casas@nasa.gov

http://www.unoosa.org/documents/pdf/psa/activities/2018/Symposium_Brazil_BSTI/presentations/oral/S21_03_J_Casas_Panelist_Natal_Brazil_Sept_2018_Lean_Small_Satellite_Missions_Require_Lean_Access_003.pdf

New Headlines and Concepts in the news often...

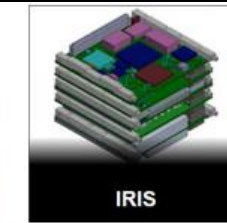
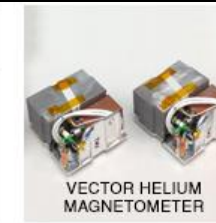


<http://theinstitute.ieee.org/technology-topics/communications/how-small-satellites-are-providing-lowcost-access-to-space>

JPL is leading the way in exploring the scientific potential of Small Sats



<https://www.jpl.nasa.gov/cubesat/technology.php>



So far, the scientific possibilities of CubeSats haven't been well explored. JPL is working to change that by harnessing its more than 50 years of experience with spacecraft to develop groundbreaking scientific instruments and technology.

CubeSat Instrumentation: Powerful Payloads and High Scientific Return

JPL has long been a world leader in developing instrumentation for collecting data on everything from Titan's rivers to distant exoplanets. A major emphasis of JPL's CubeSat efforts has been to adapt these technologies to work with the CubeSat form factor and CubeSat-level budgets.

Already, JPL has made important breakthroughs in miniaturizing instruments. Powerful technologies used for major space missions -- magnetometers, spectrometers, cameras, and radiometers -- have been reduced to CubeSat-compatible sizes while maintaining comparable (and sometimes more) power than the previous generation of instruments.

In one notable example, JPL engineers managed to reduce the size of a magnetometer used on the Cassini mission to the size of a fist. Innovations like these will have a game-changing impact on the scientific possibilities for small, low-cost spacecraft.

Small Satellite Technology: Giving Small Spacecraft Big Capabilities

Most previous CubeSat missions have been confined to low-Earth orbit. JPL is pioneering the technology that will allow them to go farther and do more than ever before.

The Lab's deep technical expertise and mature infrastructure are ideal for developing and supporting small satellites with interplanetary and deep space capabilities. JPL has developed CubeSat-sized radios capable of using the Deep Space Network, which is being utilized by a wide range of mission, from Mars rovers to the Voyager spacecraft. And JPL has made unparalleled progress in developing extremely small, radiation-hardened computers that can survive these distant journeys.

A major draw of the CubeSat platform for science is its low cost, and JPL is working to adapt these new technologies to a variety of budgets. JPL's deep space telemetry data and trajectory design technologies are scalable based on budget and scientific requirements, and new technology designs have a strong emphasis on cost-effectiveness.

An Augmented Cassini Mission...



NANOSATELLITE PROBES IN INTERPLANETARY SPACE:

AN AUGMENTED CASSINI MISSION

A Thesis

presented to

the Faculty of California Polytechnic State University,

San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

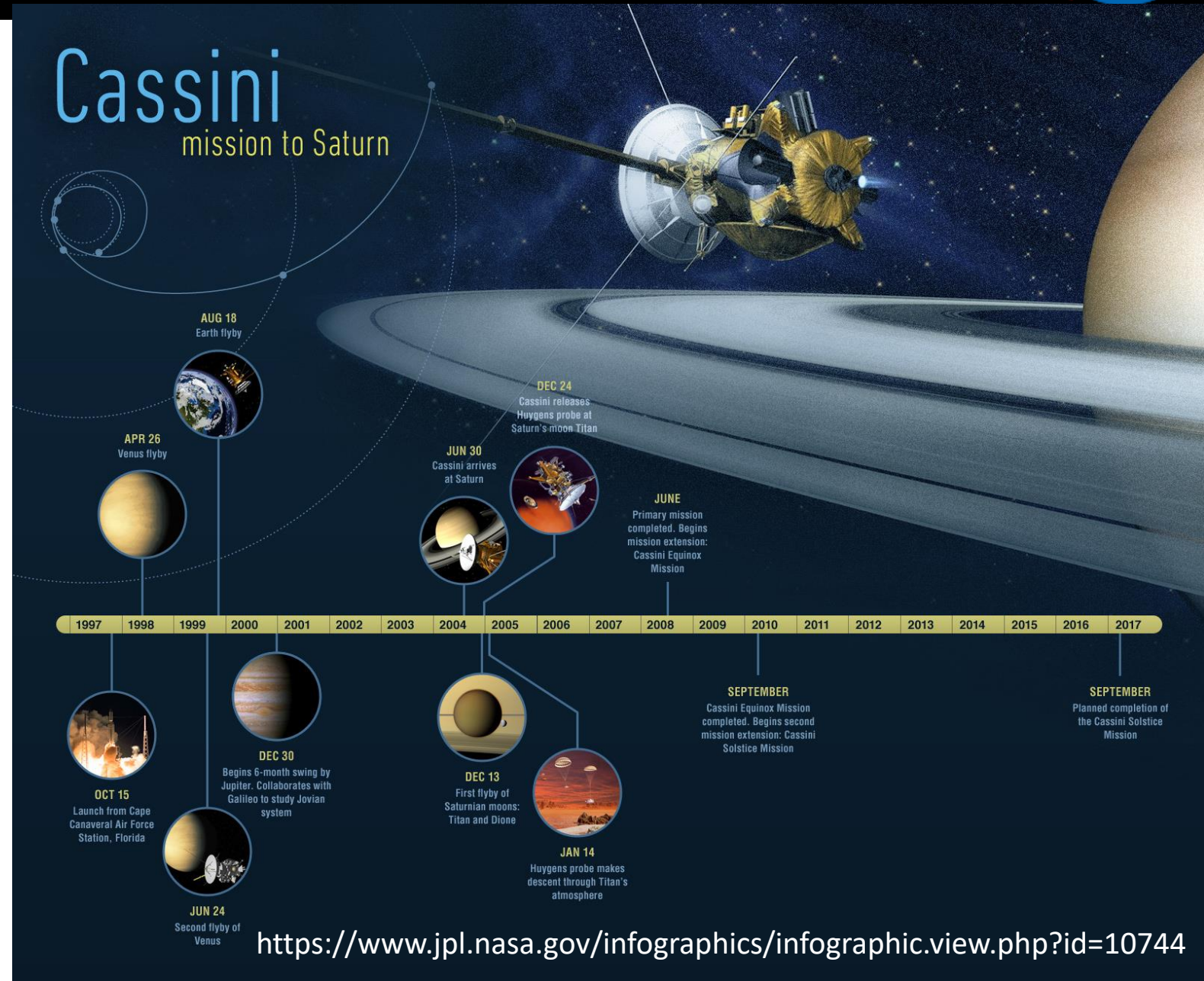
Master of Science in Aerospace Engineering

by

Trent T Voris

July 2017

<https://pdfs.semanticscholar.org/b367/aa986dbc4e8cc7f103cd590d6ad432ed5161.pdf>



<https://www.jpl.nasa.gov/infographics/infographic.view.php?id=10744>

https://www.researchgate.net/publication/261146608_CubeSat_Technology_on_Titan_Exploration

MarCO: Taking CubeSat Technologies Interplanetary...to Alpha Centauri



<https://www.centauri-dreams.org/2018/09/21/marco-taking-cubesat-technologies-interplanetary/>

- **Propellant constitutes most of the mass** of what goes in the launch vehicle
- Is propellant only needed to get there or is it also needed to achieve orbit?
- Can I **use a decelerator cost-effectively instead of propellant to slow down** when I get there?
- How **can I reduce inert mass** without giving up engineering characteristics, especially margins?
- Is getting there slower a possibility? Is time on my side?
- Other factors?

The Enabling Characteristics of Propellant-less Orbit Capture...



[https://digital.lib.washington.edu/researchworks/
bitstream/handle/1773/42172/Kelly_washington_
02500_18961.pdf?sequence=1&isAllowed=y](https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/42172/Kelly_washington_02500_18961.pdf?sequence=1&isAllowed=y)

Advanced Aerocapture System for Enabling Faster-Larger Planetary Science & Human Exploration Missions

Robert W. Moses, NASA Langley Research Center

Innovation

- Blunt body aeroshells are used at destinations with atmospheres primarily for deceleration. But some lift is desired for steering
- Traditional approaches (Center of Gravity shift & trim tabs) provide lift via Angle-of-Attack (AoA) changes, but this also degrades drag
- During the hypersonic ionization phase of the atmospheric entry, asymmetric Lorentz forces produce lift while the aeroshell remains at 0 deg AoA to maximize aero drag

Potential & Benefits

- Enables 800% increase in payload mass delivered at Neptune via aerocapture if the aeroshell can fly a specific entry corridor
- Preliminary ionization calculations suggest great opportunity for Neptune and other destinations
- Extensible to other Ice and Gas Giant missions
- Enables human-scale payloads into Mars orbit or landed precisely on Mars surface
- NASA-ULA LOFTID HIAD Earth test opportunities
- Enable new orbiter or sub-Flagship Class Mission

Technical Approach

- Build on ongoing NASA research in Regenerative Aerobraking and recent NASA Space Technology Research Fellowship work at GA Tech in Magnetohydrodynamics (MHD) for whole-body drag modulation, energy harvesting, and reduced heat loads
- Demonstrate asymmetric Lorentz Forces, both theoretically and experimentally, to generate lift
- Size system components and design a vehicle concept that would illustrate feasibility
- Identify requirements for more comprehensive ground testing and system flight demo



Evaluation Notes

Reducing Spacecraft Mass without Compromising...



<https://www.veloxint.com/>

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- **Many Deep Space Mission Concepts for Small Satellites are on the drawing board**
- **Several organizations seem to be leading the way**
- **Technical challenges are becoming easier due to advancements in technologies**
 - Reusable Rockets
 - Advanced Manufacturing
 - More about this by Dennis Bushnell...
- **Be mindful of the rocket equation for getting there and staying there**
- **Propellant-less Orbit Capture offers some benefits**

Some Takeaways to Consider...



- **Determine the Value per pound of this approach for going smaller**
- **New Capabilities versus Limitations**
- **What new technology is required to overcome any Limitations?**
 - Inert Mass and non-propellant orbit capture (mentioned above)
 - Quantum Electronics?
 - Multiple satellites or swarms acting in concert?
- **Can miniaturize only so far?**
 - “Smart Dust” is the smallest?
 - What is it?
 - What can it be used for?
 - Other?
- **NASA does R&D on payload systems that could be miniaturized to fly on a commercial Small Sat**
- **They are many developers and competition in the world wide Small Satellites market**
 - CubeSat is just one?