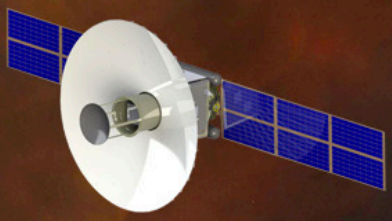
ASTROCHPS

Astro2020 APC Whitepaper

Ultra-Low-Cost Science Missions Enabled by Commercial Hosted Payload Services (CHPS)



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Abstract

In this paper we discuss CHPS (Commercial Hosted Payload Services) a novel, capacity-building mission class capable of achieving more science, more often, and with smaller budget allocations. As with all of the space sciences, the astrophysics community's ongoing struggle to provide sufficient science opportunities for its investigators limits scientific progress and impedes efforts to be more inclusive of early career researchers. With the ever-present potential for massive flagship programs to exceed their budgets, it is critical to support a robust, ultra-low-cost mission class option that ensures scientific progress in any budget environment. We propose that in addition to the traditional paths for flying instruments, the astrophysics community utilize CHPS. AstroCHPS provide a reliable, frequent, and ultra-low-cost option for flying scientific instruments.

Introduction

Few domains of science are as capital-intensive as the space sciences, and there is a monumental challenge to securing adequate funding for larger missions. Fortunately, miniaturization of electronics and launch cost reduction are enabling novel commercial capability that will increase the cadence of space science missions while driving down their cost. This paper discusses a new class of missions enabled by the commercial spaceflight revolution and associated technologies: Commercial Hosted Payload Services (CHPS). Ultra-low-cost AstroCHPS missions give the Astrophysics community SmallSat capabilities at a cost below CubeSats. In this discussion it will be shown how some of the most intractable challenges faced by the Astrophysics community can be eased by leveraging commercial spacecraft as hosting platforms for instruments in orbits from LEO to anywhere in the inner solar system.

Challenges Faced by the Astrophysics Community

As with all of the space sciences, Astrophysics faces two domains of significant challenges: insufficient science opportunities to meet the needs of the community, and budgets dominated by very large projects (i.e. JWST) that result in cost-constraints on the rest of the community's activities. These challenges have second order effects such as limiting career development opportunities and limiting innovation as mission budgets often fail to accommodate higher risk engineering. The long-term health of the astrophysics community requires that a path be found to alleviate these challenges.

Unique Strengths of Commercial Entities

The emergence of new commercial entities - SpaceX, Blue Origin, NanoRacks, Planet, Spire, Rocket Lab - in the Space sector has been well-documented in the media. Commercial entities overwhelmingly produce the vast majority of small spacecraft: only 3% of spacecraft under 200kg were flying NASA missions, 97% were commercial [Bryce Space and Technology]. It is worthwhile to restate the unique strengths of commercial entities versus more traditional space agencies:

- **Profit-motivated efficiency**
  A properly functioning commercial entity is in a constant state of profit optimization. This equates to a relentless pursuit of efficiency and adaptability to match the product offering to market need.

- **Rapid and agile innovation**
  A strength that flows from the profit motive is an incentive for rapid innovation. A robust marketplace forces commercial entities to reinvent themselves and their methods to remain competitive. This feedback loop is of great benefit to a customer who struggles to maximize the value purchased by their limited budget.

- **Dynamic tolerance of risk based on reward**
  The strong motive to achieve profitability requires clear and persistent risk vs. reward calculation. While this is what relegates the funding of pure research to governments, it is also what drives companies to take risks when the potential for profit exists. This dynamic risk tolerance assessment makes commercial entities less likely to become rigid in their risk posture.

AstroCHPS: An Ultra-Low-Cost Mission Class

The miniaturization revolution has been a boon to space scientists looking to do science with smaller pieces of the budget, but it falls short of freeing the scientist to focus on the science. CubeSats are certainly a lower cost platform than larger missions for small instruments, but they still require a PI be responsible for building or procuring an entire spacecraft bus. In fact, the spacecraft development challenge can be exacerbated by the need for extreme miniaturization.

If the revolution in space science thinking that drove the CubeSat as a science platform is combined with the evolving commercial capability in-space, then a new ultra-low-cost mission class emerges: Commercial Hosted Payload Services (CHPS).

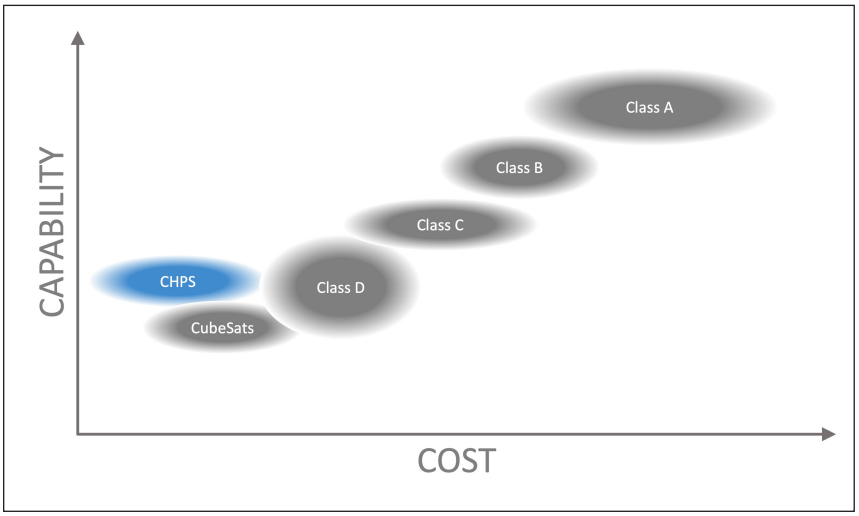

Figure 1: Qualitative illustration of how the CHPS mission class complements other science mission classes with respect to capability versus cost. With CHPS missions, a funding entity can get Class-D science for less than CubeSat cost.

CHPS takes CubeSat-class science instruments and hosts them on larger spacecraft that are developed, built, and owned by a commercial partner. While commercial payload hosting is not novel, the industry is reaching an inflection point where this model will break out of Earth orbit and rapidly extend to the entire inner solar system. Three commercial Lunar landers have been awarded contracts by NASA, more will follow. The CHPS model provides a number of benefits to the small scientific instrument PI:

- **Ultra-Low-Cost**
  A PI can eliminate all spacecraft-related schedule and budget risks by replacing them with a hosting fee. A single flight will contain multiple fee-paying payloads which spreads the flight cost across customers in a similar fashion to the launch rideshare market. **CHPS allows for Class-D mission science at a cost below CubeSat missions**.

- **High Cadence**
  CHPS providers will use a flight proven bus that is produced in volume and flown at a high cadence. By being cognizant of rideshare requirements during bus design, a CHPS provider can have greater flexibility in sourcing flight opportunities.

- **Higher Risk Tolerance**
  Individual CHPS flights are modest in size and cost which makes them more willing to engage in riskier mission profiles, mission assurance margins, and payload types.

CHPS Providers by Location

Earth Orbit	Lunar Surface (CLPS)	Lunar Orbit
• General Atomics Electromagnetic Systems • Nanoracks (ISS hosting) • SEOPS • SES • Loft Orbital • Bartolomeo Platform	• Astrobotic Technology • Draper • Deep Space Systems • Firefly Aerospace • Intuitive Machines • Lockheed Martin • Masten Space Systems • Moon Express • Orbit Beyond	• Surry Satellite Technology Ltd. • Xplore **Interplanetary Space** • Xplore

Table 1: Listing of CHPS providers by hosting location.

Benefits to Astrophysics Community

The CHPS class missions are particularly compelling in the context of the Astrophysics community's needs. By giving the community an ultra-low-cost mission class that does not require spacecraft development, PIs of all stages of their career can fly instruments quicker, more often, and at lower cost. **New CHPS providers entering the market are opening up destinations throughout the inner solar system to this new ultra-low-cost mission class.**

Early Career Development

CHPS are particularly attractive as a mechanism for developing early career scientists into PIs. A CHPS mission puts little agency capital at risk and does not displace other larger missions from launch opportunities. A successful CHPS mission is a natural stepping stone toward being the PI for a CubeSat mission which then opens doors to Class D missions. A typical CHPS mission is a fraction of the SMEX cost cap and programmatically resembles a traditional Partner Mission of Opportunity (PMO).

"For a PI, demonstrated leadership is a must."
– Dr. Thomas Zurbuchen

Technology Maturation

In addition to giving PIs "flight heritage," CHPS missions are also an opportunity to give flight heritage to innovative technologies that are too uncertain to fly on stand-alone missions. A CHPS provider's tolerance for risk scales with profit potential, so a high-risk technology simply means that the hosting fee scales proportionally. Traditional PMO entities are disinclined to allow a high-risk technology on their large missions.

CHPS vs. CubeSats

Taking a CubeSat-class instrument off of the CubeSat and hosting it on a larger spacecraft opens up a number of capability enhancements and at a lower cost than flying a stand-alone CubeSat mission:

• Power
The power available on SmallSats (and larger) is a significant capability improvement over even the largest CubeSat bus. Having more power available frees up additional scarce resources on the spacecraft such as pointing and communication time.

• Communications
CHPS hosting spacecraft provide larger communication apertures. This not only means more returned data, but also less time needed for communications pointing and more time available for instrument pointing.

• Mission complexity and duration
CHPS spacecraft can have robust propulsion and attitude control, enabling more complex mission design, better pointing stability, and longer mission duration.

• High-Performance Computing
An emerging trend in science mission design is the incorporation of high-performance computers onboard the spacecraft to develop higher order data products in an effort to reduce the quantity of downlinked data. Although this is a promising technological innovation, it is seen by many in the community as too "risky" to incorporate in their proposals. CHPS class missions are an excellent opportunity to mature onboard data reduction practices at ultra-low-cost.

Ultra-Low-Cost

CHPS class missions enable science missions throughout the inner solar system to be flown at a fraction of the price of SmallSats or CubeSats. Often a SmallSat mission's budget is no more than 20% science, which means that the funding entity pays 5x the real cost for science. By hosting instruments on CHPS missions, a funding entity can see the non-science overhead drop to being on par with the cost of the science itself.

Commercial hosting services from Surrey Satellite Technology Limited and Astrobotic range from $1.2M - $1.25M per kilogram to the Moon. These examples indicate that small, powerful instruments can be flown very economically beyond Earth orbit.

A CHPS hosted mission potentially allows for a Small Space Mission (defined by the Astro2020 Committee as <$500M) to be done for the cost of a Small Ground Mission (defined by the Astro2020 Committee as <$20M).

Rapid Mission Development and Integration

When hosting a payload with a CHPS provider, the PI is able to focus exclusively on developing their instrument's mission and how the instrument integrates into the partner spacecraft. With a prefabricated spacecraft and flight plan, the total timeline from concept to flight is compressed compared to a stand-alone mission. Ideally, with a robust number of providers, flying an instrument will feel more like buying a plane ticket than building an airplane.

PIs can think science, not spacecraft.

Serious Science in Small Packages

There may be skepticism that much science of value can be done in a CHPS class mission, but the CubeSat revolution has shown surprising potential for small instruments. CHPS allows instruments to grow beyond CubeSat constraints and reach masses from 1kg - 50kg kilograms, or more with some of the commercial Lunar landers. With the expansion of CHPS providers to the inner solar system, PIs now have ultra-low-cost options for putting payloads at novel vantage points. The potential missions are too numerous to fully list in this document, but here are a few exemplary concepts for astrophysics:

- 21cm radio astronomy from far side passes of a lunar orbiter
- Earth/Sun L1 and L2 based observations
- Augmentation of the Event Horizon Telescope from hosted instrumentation in orbit between Earth and Moon
- Occultation observations using the lunar limb
- Particle and fields measurements from well outside of the Earth's magnetosphere

CHPS vs Traditional PMO

The traditional Partner Mission of Opportunity (PMO) has long been a useful mission type for flying payloads without having to develop a stand-alone spacecraft. While these are useful options, they do come with many of the entanglements inherent to government space programs. A PI's space agency may not have had to develop the host spacecraft, but the PI must still fly with a large space agency spacecraft. Table 2 is a succinct comparison of CHPS (a commercial PMO) to traditional PMOs.

CHPS	Traditional PMO
• US entity • Profit motive for maintaining schedule • Tolerant of higher risk based on reward • Complete freedom in launch provider • High mission cadence • Low cost	• Foreign agency • Schedule encumbered by complex motivations and obligations • Typically a large, low-risk tolerance mission • Typically restricted to indigenous launch provider • Infrequent opportunities • Paid by complex trades

Table 2: A comparison of attributes between CHPS and Traditional PMOs.

Recommendation

We respectfully request the Committee endorse AstroCHPS as an ultra-low-cost flight opportunity for astrophysics. The CHPS mission class is an ideal way to develop early career PIs, mature high risk technologies, and maintain a science program that is robust against budget perturbations. Robust funding of CHPS today incentivizes commercial innovation and capacity expansion. Utilizing commercial capabilites will enable the largest number of small flight opportunities for scientists in the astrophysics community.