BRADFORD SPACE LOGISTICS

MISSION SERVICES

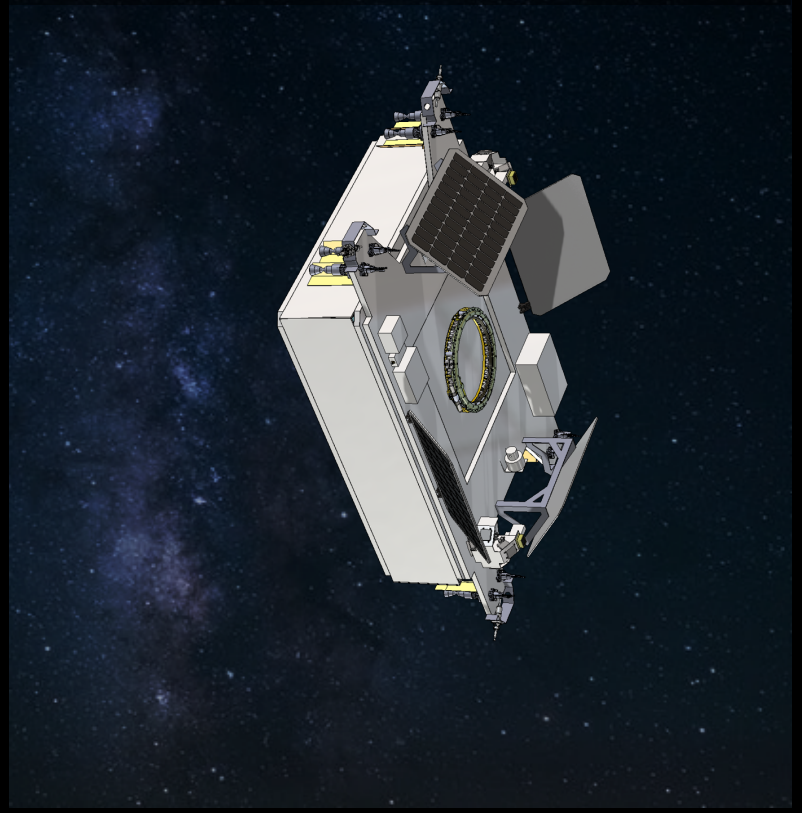
ENABLING A NEW IN-SPACE ECONOMY

Interplanetary Small Sat Conference
3-4 May 2021
Christian Carpenter

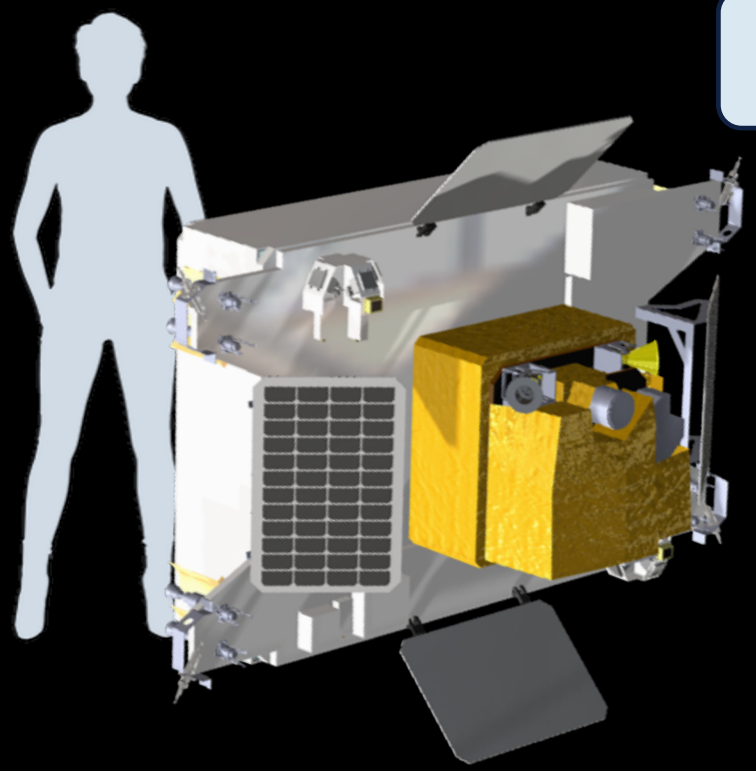
BEYOND LEO
THE NEXT STEP IN SPACE

SpaceX revolutionized transport to space

Now it's time to revolutionize the beyond LEO economy



BRADFORD SOLUTION - SQUARE ROCKET
SPACE LOGISTICS MISSION SERVICES



Access to deep space from Low Earth Orbit

- **Super-fast transport shuttle for space-to-space travel**
- **Interoperable with all major launch vehicles (SpaceX, ULA, NGC, and others)**
- **Powered by high performance propulsion**
  - ECAPS HPGP – the “Gold Standard” in green propulsion technology enables low-cost operations
  - Pump system enables "square tank" high volume utilization.
    This breaks the “mass fraction boundary” in high delta-v smallsat design

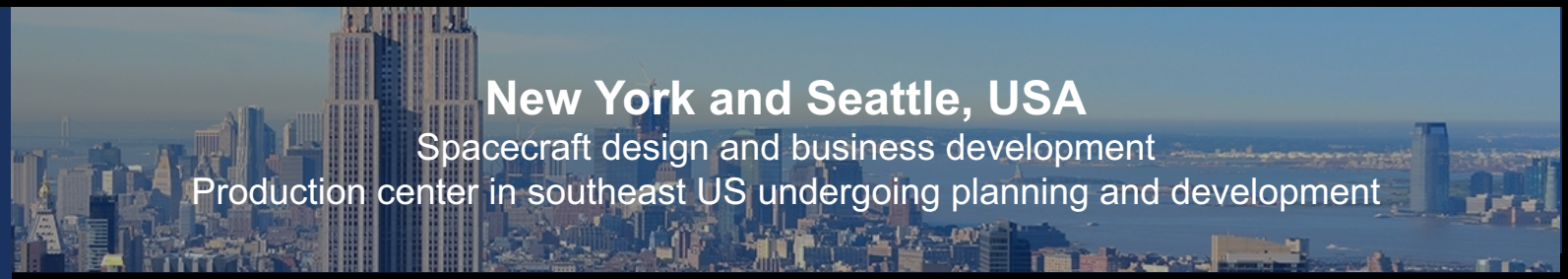
Square Rocket is a game-changer:
a low cost, high-speed space transport

FULL STACK SPACECRAFT DEVELOPMENT

- 44k sq ft of facilities
- Over 70 engineering, R&D, production, and admin staff
- Heritage technology - over 2000 products in space
- Close relationships with customers around the world
- Trusted by commercial and govt agencies for quality space systems

US-owned Company

Core technologies, facilities, and operations in Europe enable agile U.S. spacecraft production



New York and Seattle, USA

Spacecraft design and business development
Production center in southeast US undergoing planning and development

Grinsjon, Sweden

Three fully-equipped propulsion test fire facilities

Belval, Luxembourg

Avionics development center

Heerle, Netherlands

Fully-equipped engineering & production center for attitude control and propulsion systems

Solna, Sweden

High-performance thruster production & development center

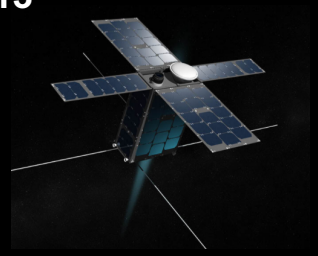
PRODUCT DEVELOPMENT HISTORY

7 YEARS OF HIGH DELTA-V DEEP SPACE SMALLSAT DESIGN

DEEP SPACE INDUSTRIES

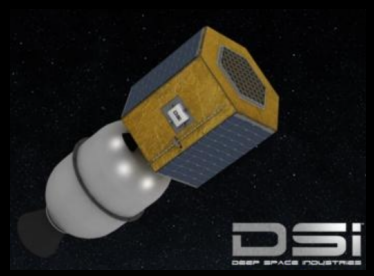
Designed for ~4000 m/s (EP)

~2013



FireFly™

2015



Prospector-1

Star-booster concept, plus H2O Comet propulsion system for cruise, rendezvous, and return

2018

bradford space

Designed for 5000 m/s (CP)

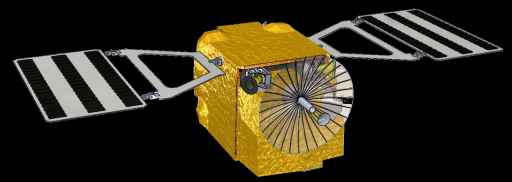
2016-2019

Explorer

Featuring *Meteor* ISRU biprop
Designed for 5000 m/s
Reached TRL 3/4

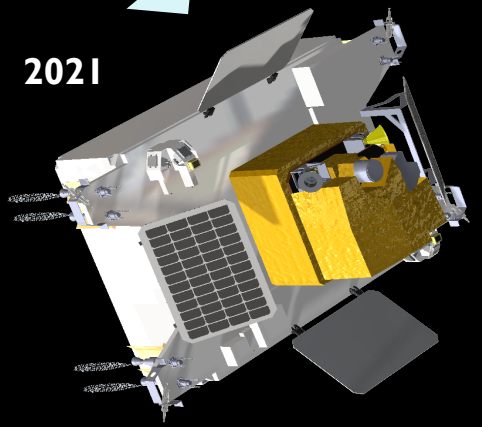
2020

Designed for ~1700 m/s **but using mature ECAPS propulsion**



2021

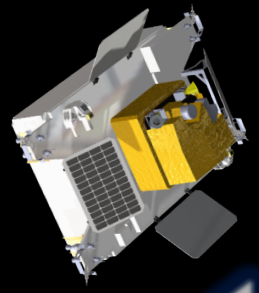
Square Rocket
powered by ECAPS



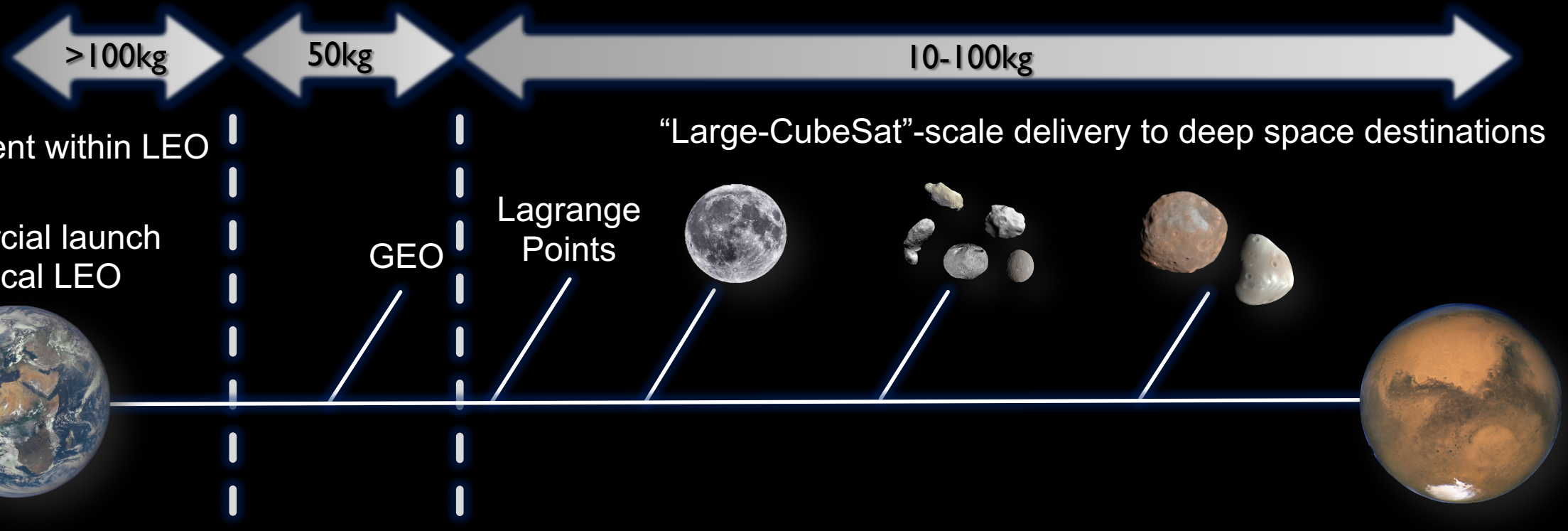
Many years of accumulated deep space mission design knowledge has influenced Square Rocket

Separate the delta-v challenge from the high-performance deep space satellite challenge

ORBITAL TRANSPORT MISSIONS – INITIALLY LAUNCHED TO LEO



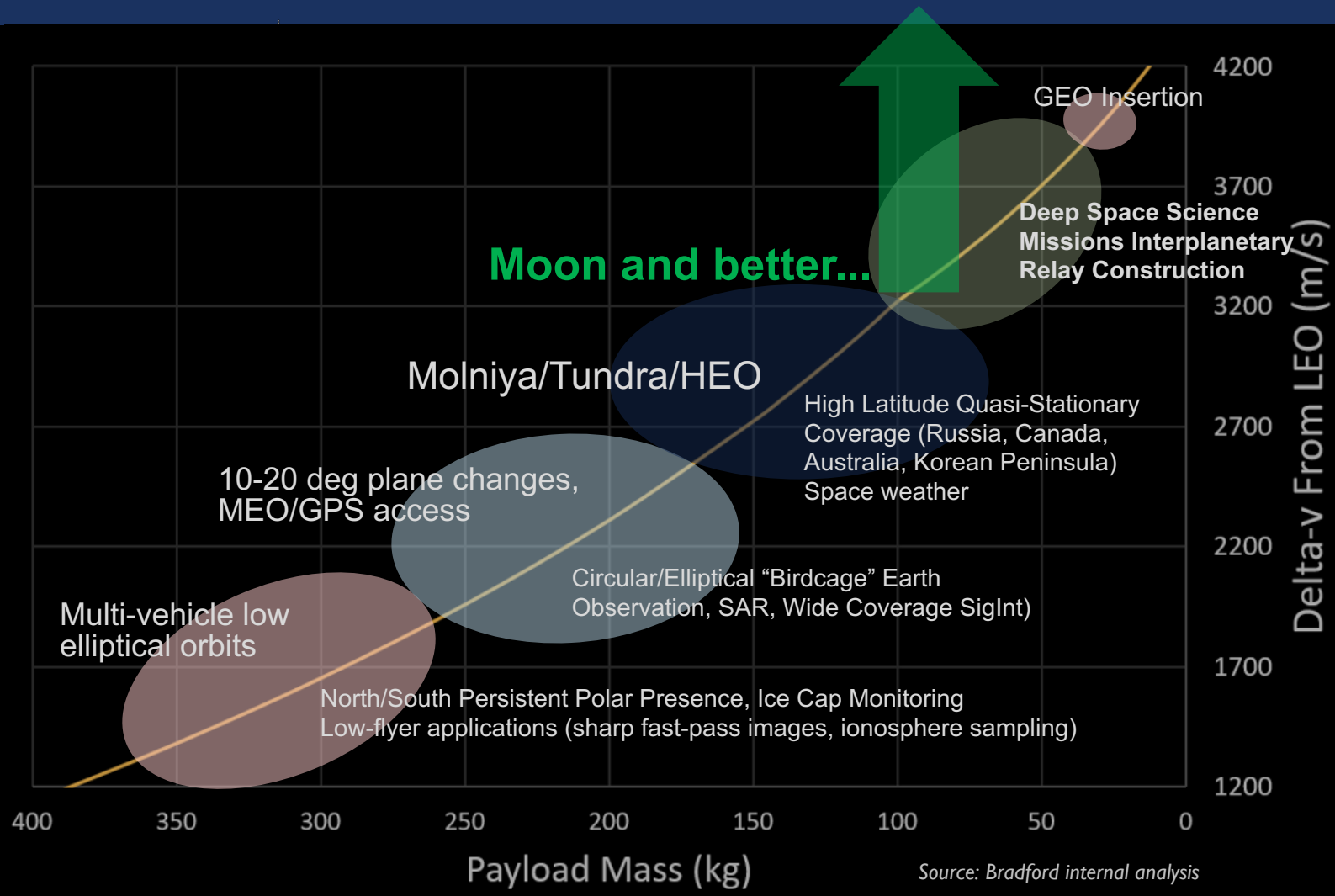
- 10kg to 100kg class payload delivery to LEO, GEO, Moon, Asteroids, and Mars
- Fast transit through the Van Allen Belts
- Low-cost, launch-vehicle-independent deep space missions



TRANSPORT DESTINATIONS AND SERVICES

SIGNIFICANT FLEXIBILITY IN DESTINATIONS AND TRAJECTORIES

- Delivering payloads up to 300 kg (CM-limited) to orbits previously inaccessible without a dedicated launch vehicle.
- High-Earth orbit and deep space destinations become accessible to small sats from LEO or GTO.
- Payload mass can be traded for delta-V (time to destination).

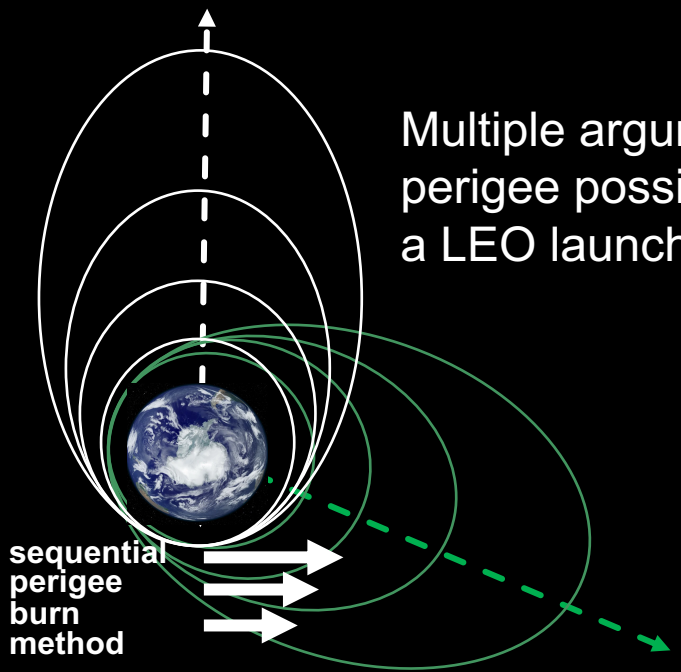


Source: Bradford internal analysis

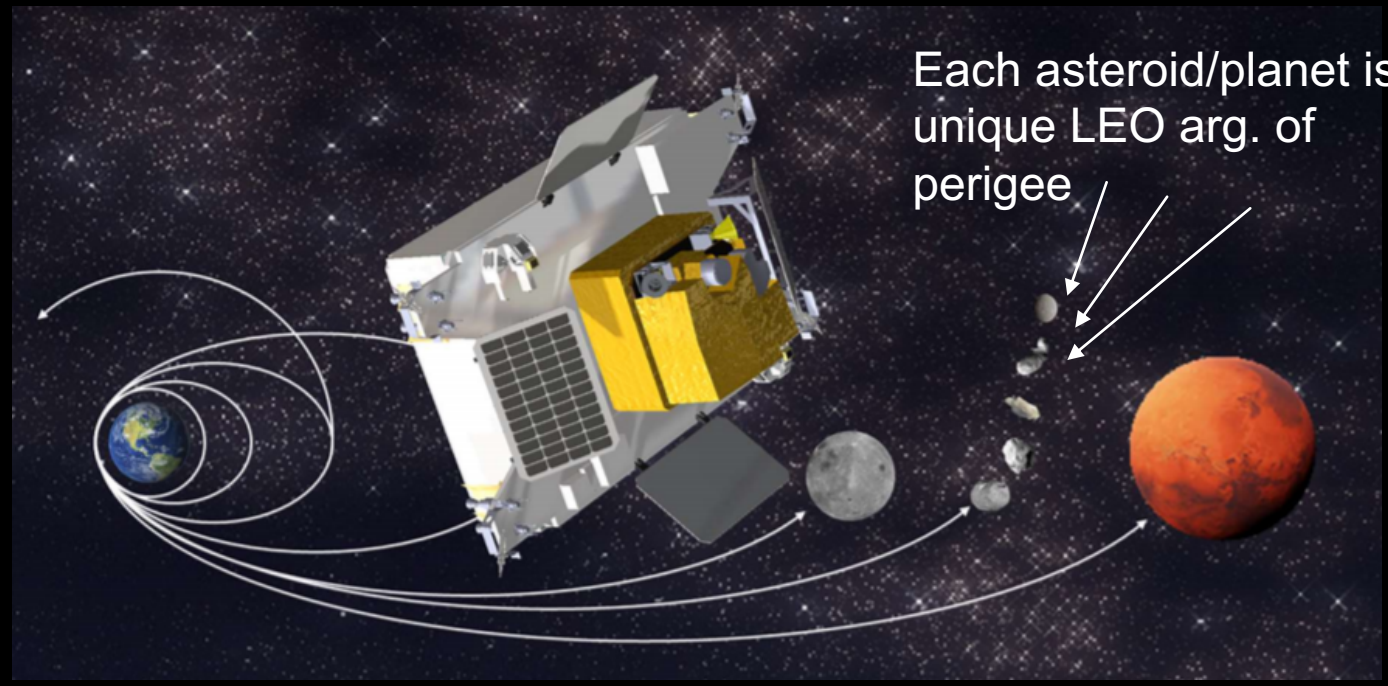
“LEO TO ANYWHERE” VS “GTO TO SOME PLACES”

Starting in LEO opens up your flight opportunities to interplanetary destinations more so than GTO, despite the higher delta-v required

- More frequent LEO launches
- Better control of argument of Pe

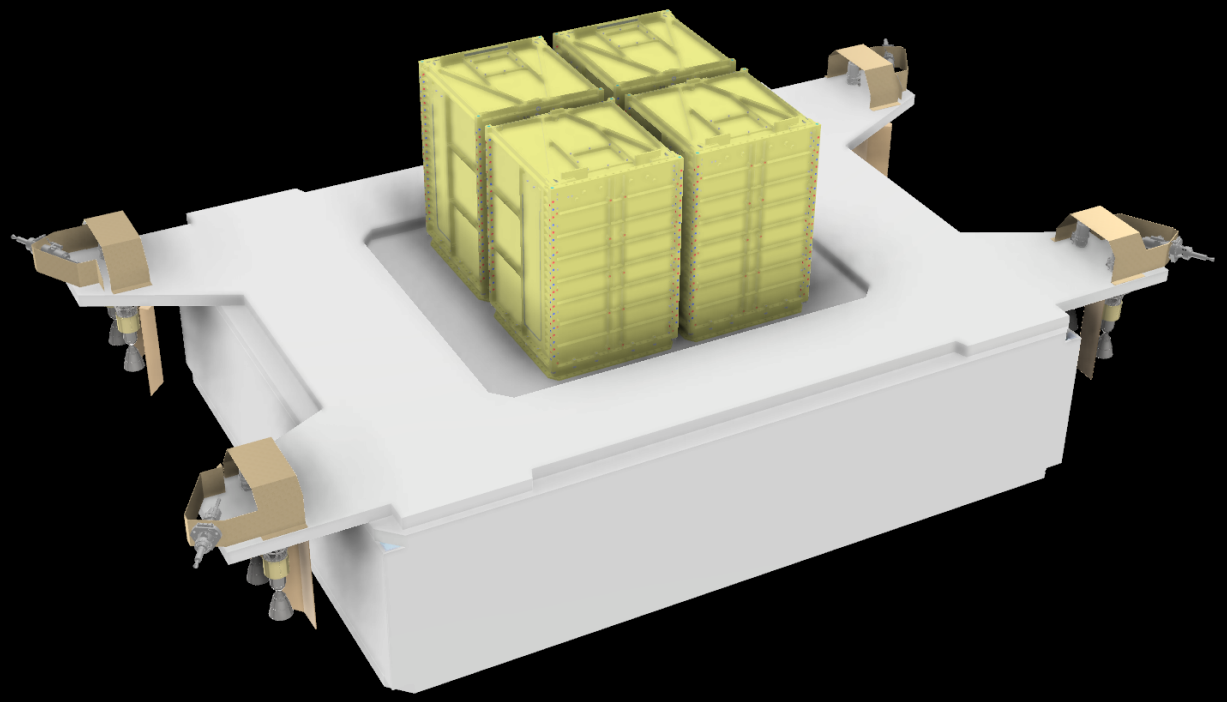


Multiple arguments of perigee possible from a LEO launch



Deep space destinations (especially asteroids) require control of argument of perigee. LEO initial launch is required to make these destinations broadly accessible

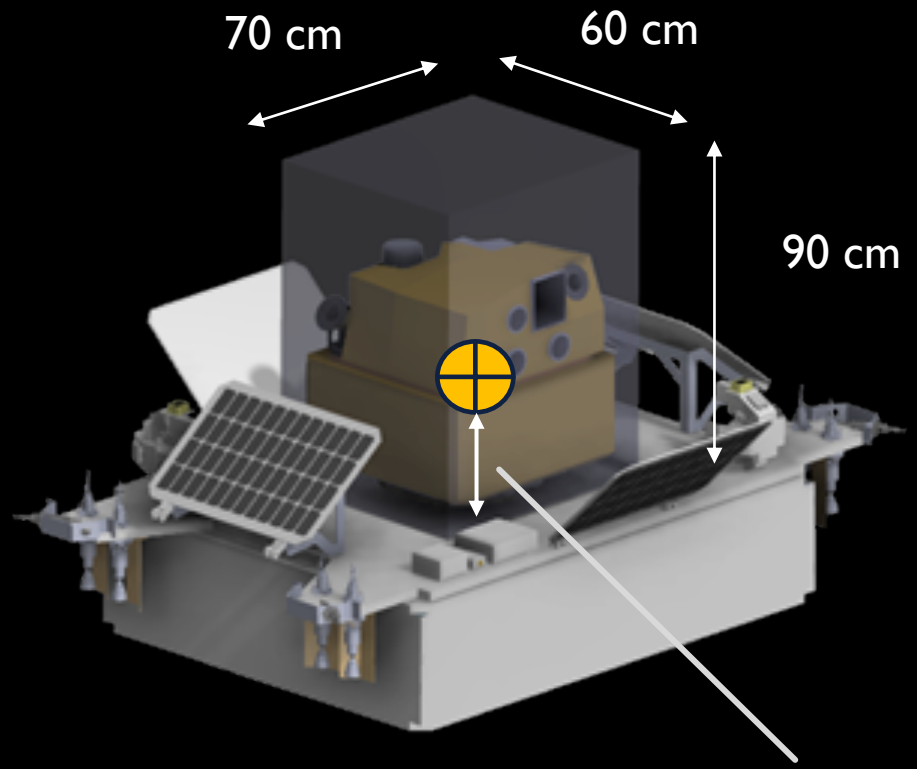
SQUARE ROCKET PERFORMANCE
MULTIPLE INTERPLANETARY PAYLOADS IN ONE LAUNCH



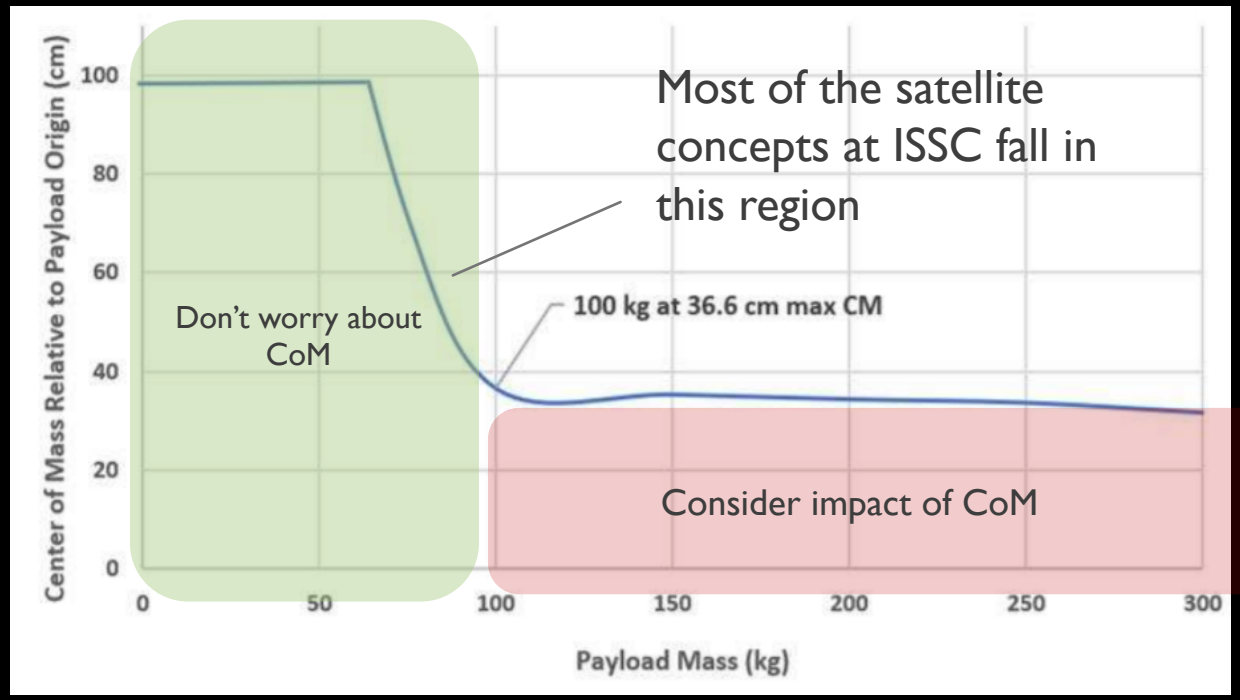
Configuration	Approx Mass	Destinations from LEO
4 x 12U	100 kg	High lunar orbit, Earth-Sun Lagrange Point 1/2
3 x 12U	75 kg	Low lunar orbit, Venus intercept
2 x 12U	50 kg	GEO, Mars intercept
1 x 12U	25 kg	Mars orbit

Multiple destination deployments possible.
Ex: one vehicle to deploy lunar south and north polar high elliptical orbit.

PAYLOAD ACCOMMODATION
PAYLOAD ENVELOPE & CENTER OF MASS



Square Rocket Center of Mass Constraints



No more than 36 cm if total delivered payload is over 100 kg.
Under 100 kg, CoM location is less critical.

BEYOND LEO
RIDESHARE LAUNCH OPPORTUNITIES

- Compatible with most low-cost launch vehicles.
- Provides flexibility in reaching orbits previously inaccessible without a dedicated launch.
- Small Sat operations in the deep space environment are different than in LEO.
- For more information on deep space design guidelines for small spacecraft, see Appendix 1 in the Bradford Space Logistics Square Rocket Spacecraft Payload User's Guide* and contact us for more information.

* https://www.bradford-space.com/logistics-services

QUESTIONS?

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