Asteroid Mining

Review of Methods

Syahrim Azhan Ibrahim

Image: theweek.com

OSIRIS-REx will travel to a near-Earth asteroid called Bennu and bring a small sample back to Earth for study. The spacecraft was launched in Sept. 8, 2016 [1].

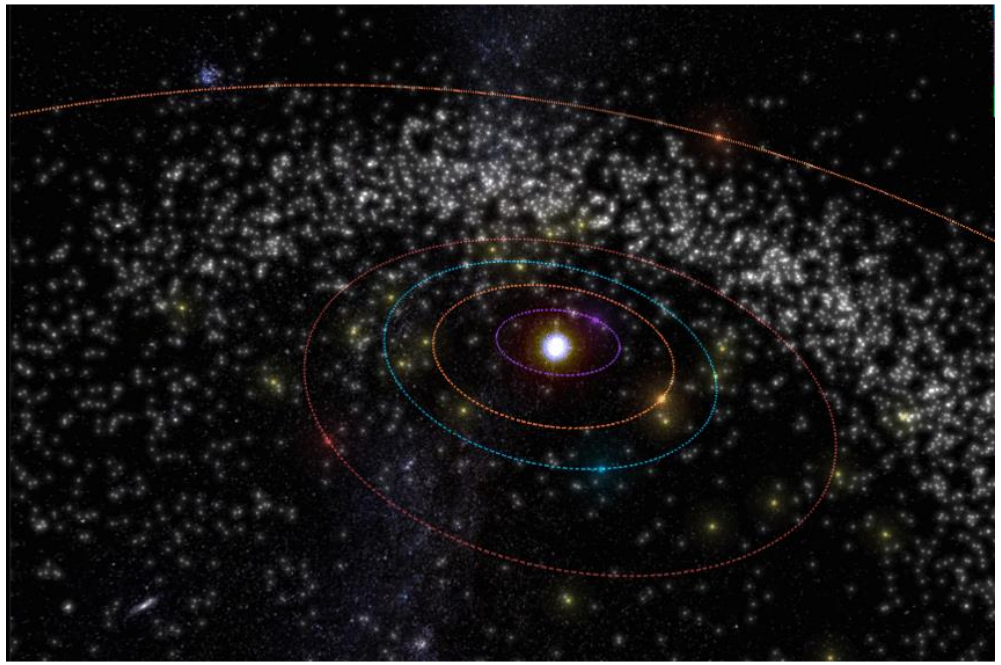
[1] http://www.asteroidmission.org/

Content

- How valuable is asteroid mining?
- How to target the right asteroid?
- Space Mining Companies

How valuable is asteroid mining?

- NASA estimates the asteroid belt hold $700 quintillion of bounty. Near Earth Asteroids (NEA) are likely target for mining.



-

Asteroid types	Resources
C-type	Water, other volatiles and carbonaceous compounds.
S-type	Rocks, Nickel and Iron.
M-type	Nickel, Iron, PGMs, Cobalt, Gold

- Most cost effective asteroid target (NEA) as listed by www.asterank.com

Name	Type	a (AU)	e	Value ($)	Est. Profit ($)	Δv (km/s)	Group
Ryugu	Cg	1.189	0.190	95.02 billion	34.53 billion	4.663	APO (PHA)
1989 ML	X	1.272	0.137	13.94 billion	4.38 billion	4.889	AMO
Nereus	Xe	1.489	0.360	4.71 billion	1.39 billion	4.985	APO (PHA)
Bennu	B	1.126	0.204	9.05 billion	2.50 billion	5.096	APO (PHA)
Didymos	Xk	1.644	0.384	62.25 billion	16.40 billion	5.163	APO (PHA)

How to target the right asteroid?

1. Remote Sensing Methods[2]:

- The optical telescopes decide spin rate and size.
- The radar determines the 3-D shape.
- The IR telescopes determine albedo and refine the type of asteroid.

2. Variables to determine[2]:

Delta V	A lower Delta-V - preferably below 5 km/s - allows less energy loss during transportation, thus allowing for more tools instead of fuel onboard.
Spin rate	A high spin rate complicates any interaction with the asteroid, and it is hence not recommended to prospect it.
Size	Must be big enough to ensure that the missions produce enough ore or H_2O to be worth the cost and effort.
Orbit	A good asteroid target will have an orbit that revisits Earth often, and is typically not inclined.
Type	DSi and PR target C-type in their prospecting mission. Future missions will be M-type.

[2] http://www.planetaryresources.com/

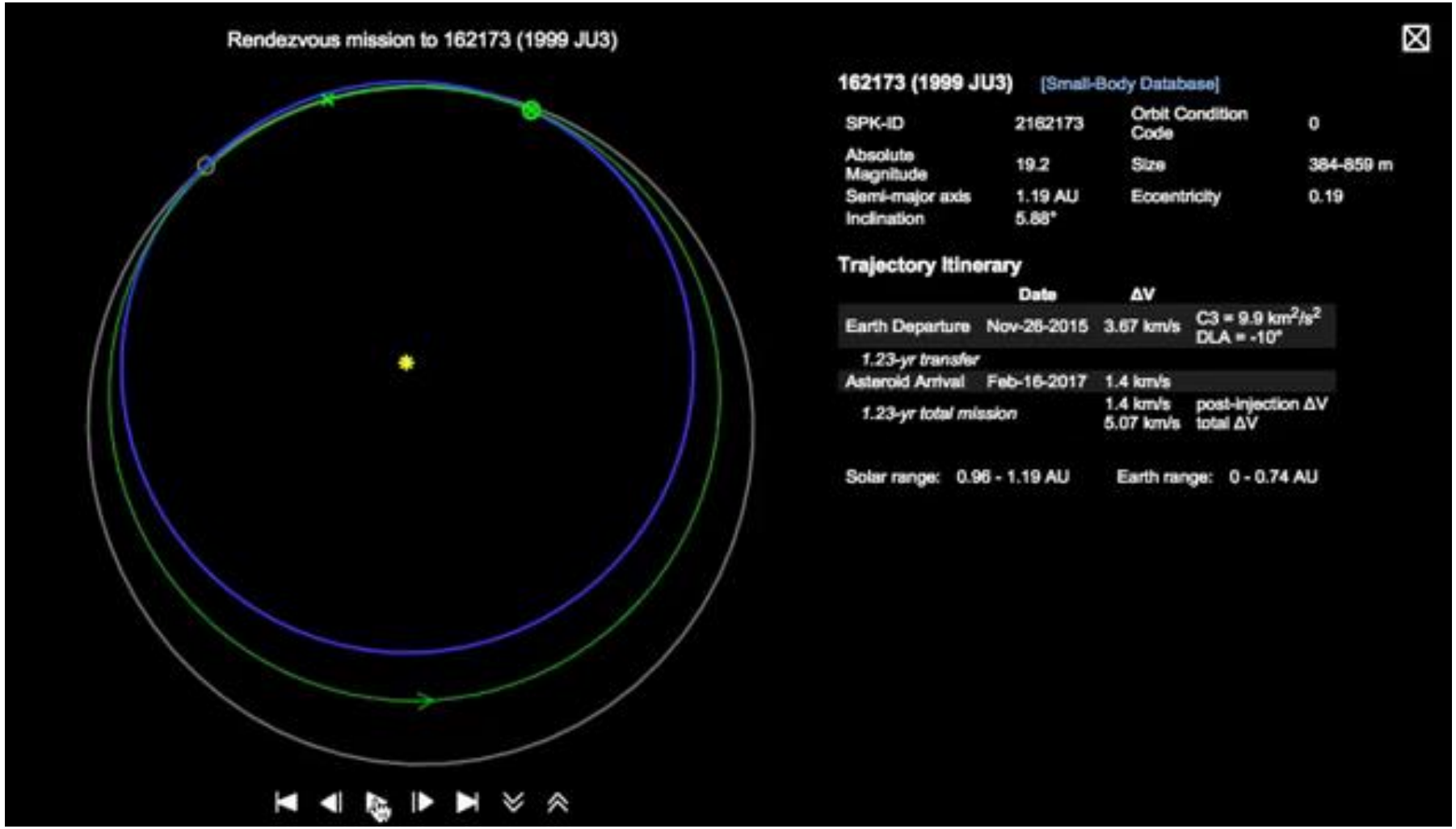
How to target the right asteroid?

Ryugu asteroid: low Delta-V, large size, modest rotation rate, and C-type.

- Earth
- Asteroid
- Spacecraft

Hayabusa 2 [3]:

- Launched December 2014.
- ETA to Ryugu: July 2018.
- Survey the asteroid for a 1 ½ year.
- Depart in December 2019.
- Return to Earth in December 2020.



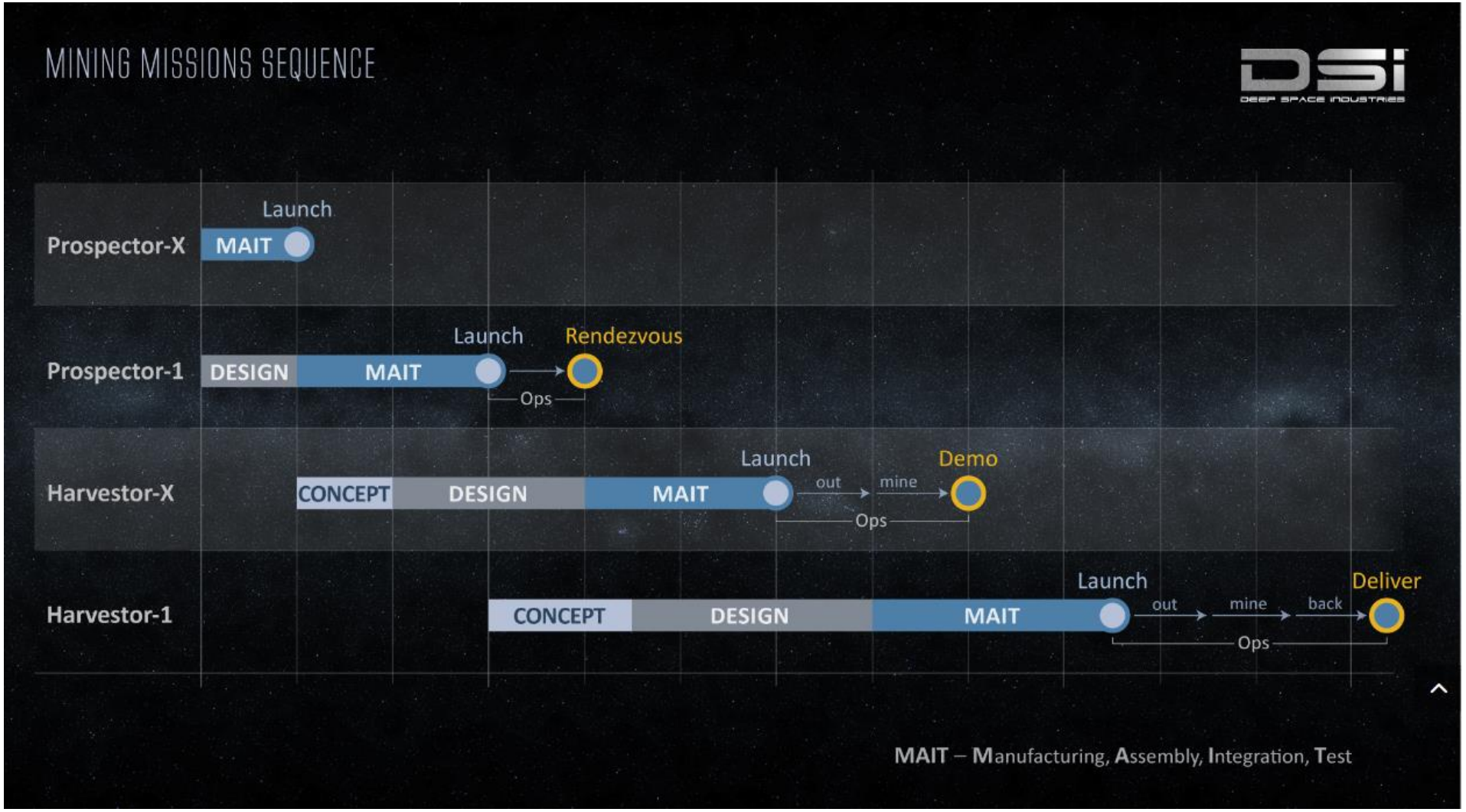
Video: http://www.planetaryresources.com/

[3] http://global.jaxa.jp/projects/sat/hayabusa2/

Space Mining Companies

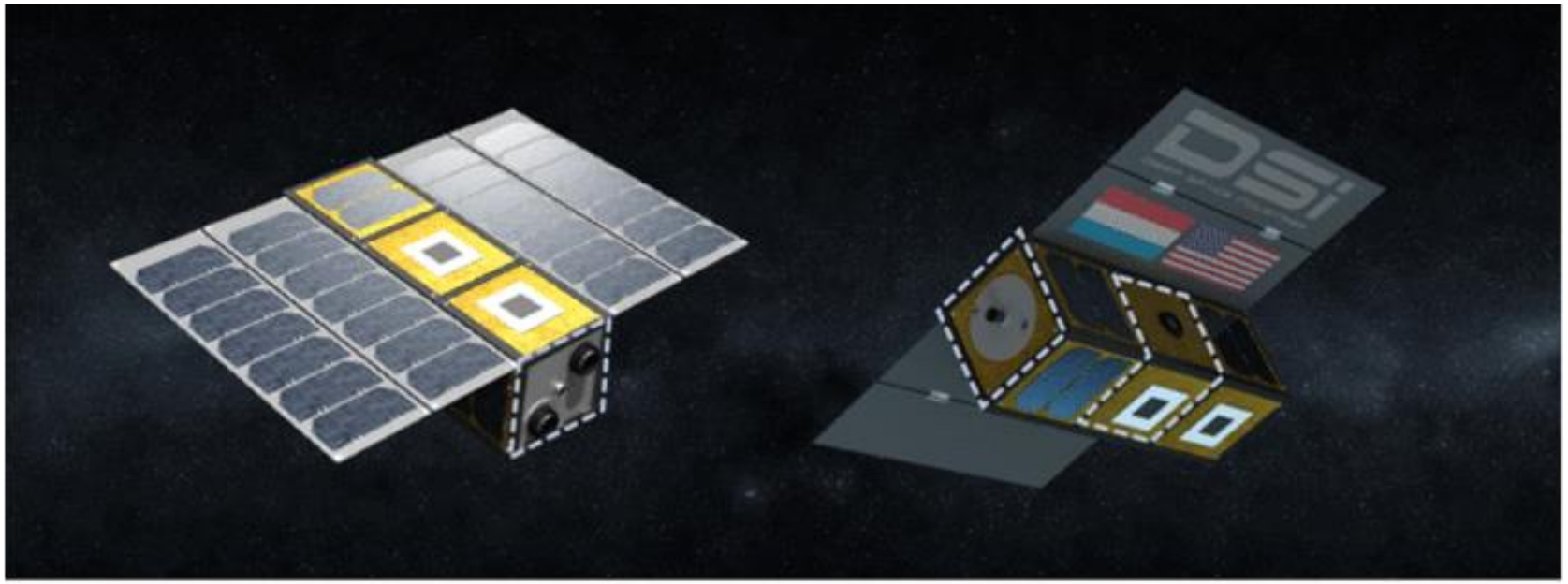
- OSIRIS-Rex costs about $1 billion [4].
- Hayabusa-2 costs about $275 million [5].
- Private companies like DSi and PR plan to use cost effective mission architecture.
- Steps in asteroid mining technology development [2,6]:
  1. Exploring and prospecting for asteroids.
  2. Harvesting and returning asteroids material.
  3. Processing those materials in space and on earth.

[4] http://www.businessinsider.com/the-value-of-asteroid-mining-2016-11
[5] http://spaceflightnow.com/news/n1409/01hayabusa2/#.WCHHIS197cs
[6] http://deepspaceindustries.com/


MINING MISSIONS SEQUENCE
DSI
DEEP SPACE INDUSTRIES
Prospector-X
Launch
MAIT
Prospector-1
DESIGN
MAIT
Launch
Rendezvous
Ops
Harvestor-X
CONCEPT
DESIGN
MAIT
Launch
out
mine
Demo
Ops
Harvestor-1
CONCEPT
DESIGN
MAIT
Launch
out
mine
back
Deliver
Ops
MAIT – Manufacturing, Assembly, Integration, Test

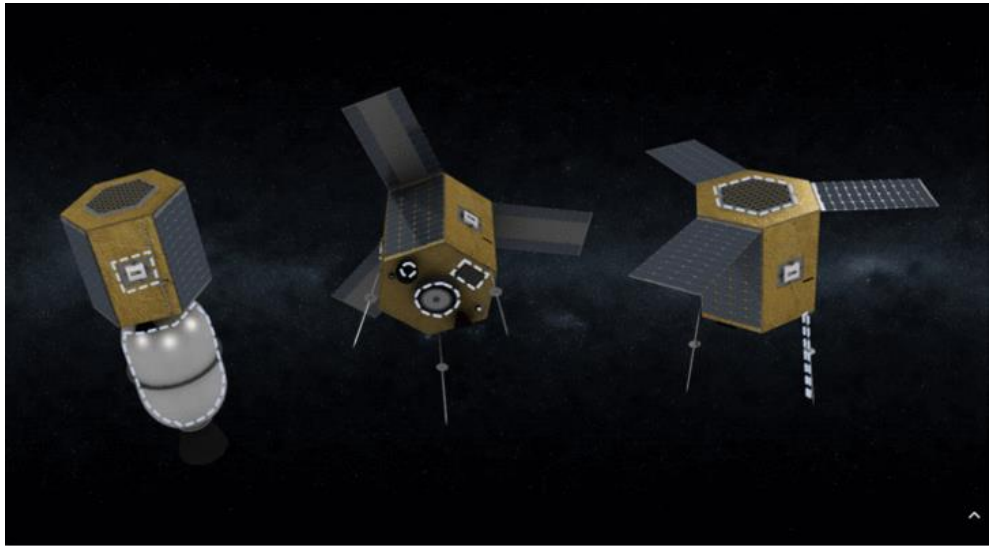
[6]

Prospector-X [6]



- An experimental, low Earth orbit CubeSat to demonstrate several key Prospector-1 technologies notably its power system, optical navigation, water-based propulsion system, and deep space avionics.
- Scheduled for launch in Q3 2017.

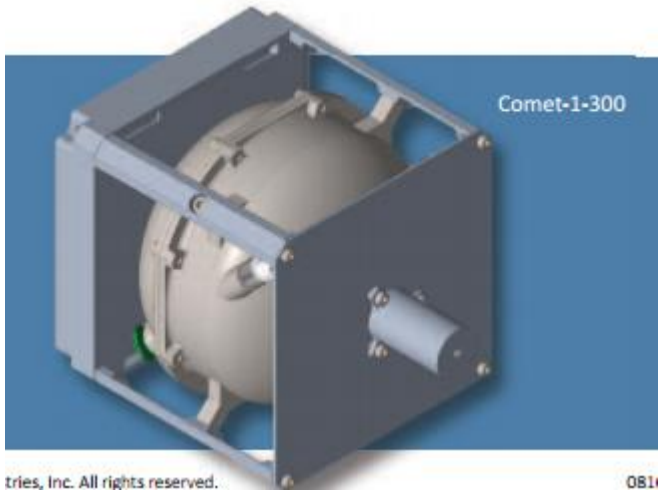
Prospector -1 [6]

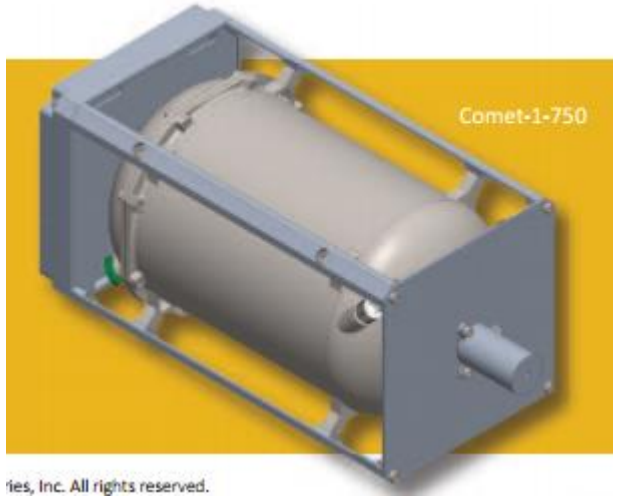


- Mission – Prospecting for resources, particularly water, extractable from the surface of a volatiles-rich target asteroid.
- The mission involves dispatching the satellite using all-chemical propulsion to an asteroid, followed by the use of water electrothermal propulsion for cruise, rendezvous, and proximity operations.
- After that a much larger Harvestor spacecraft would be dispatched to extract and process its resources.
- Target cost is tens of millions.

- Cornerstone technology [6]:

DSI Comet-1 CubeSat and Microsatellite Water Thrusters

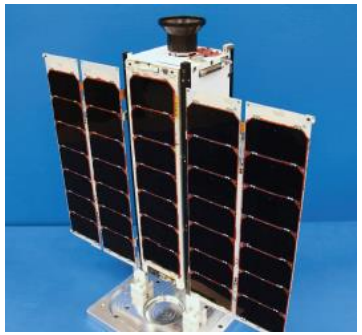




PLANETARY RESOURCES®

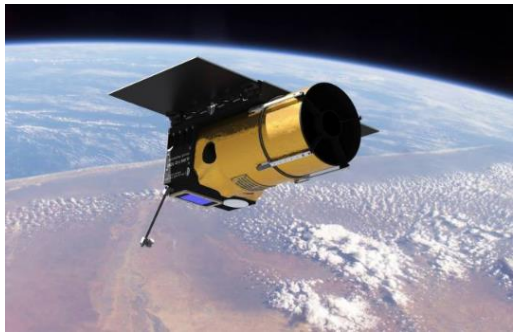
Arkyd series spacecraft for prospecting NEA [2]

Arkyd-3R

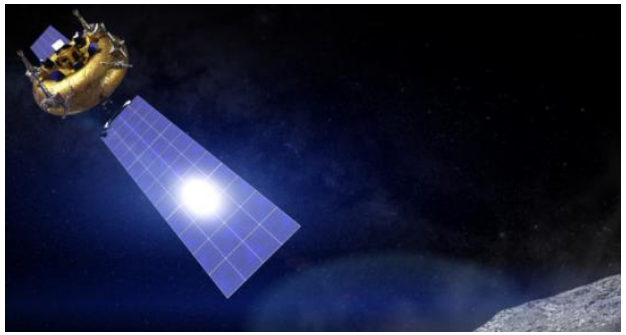


Arkyd-6

Arkyd-100



Arkyd-200

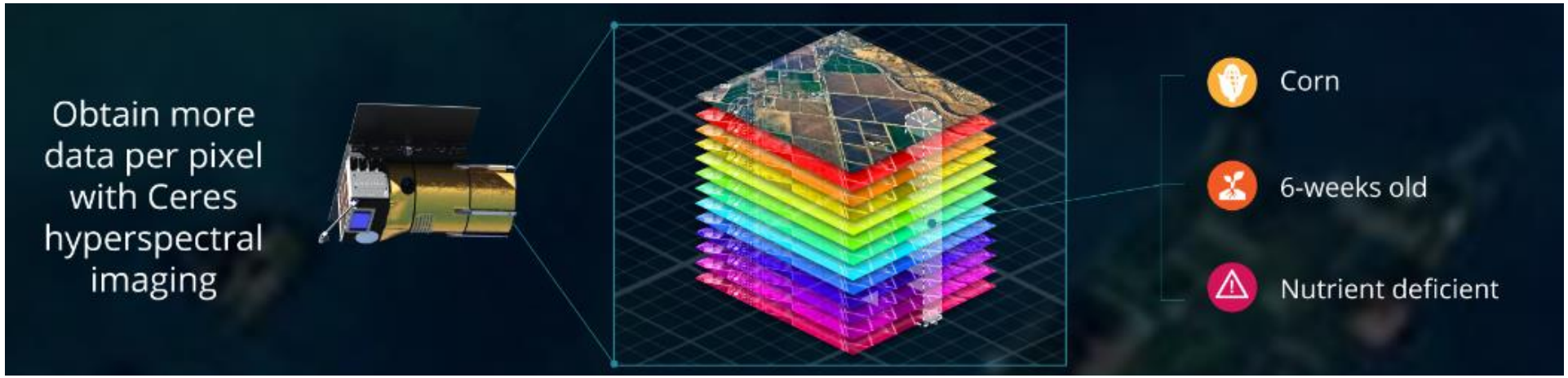


Spacecraft	Purpose
Arkyd-3R	Demonstration on core spacecraft functions. Deployed from ISS in 2015
Arkyd-6	Demonstration of PR's Mid Wave IR (MWIR) imaging instrument.
Arkyd-100	• Utilizes a larger optical aperture consists two different sensor elements on its shared aperture: MWIR imager & Visible-NIR Hyperspectral imager • Demonstration of small propulsion technology but will remain in Earth orbit for operations.
Arkyd-200	• Designed to escape the confines of Earth-orbit. • To utilize optical communications to an Earth station

PLANETARY RESOURCES®

- Cornerstone technology [2]:

  MWIR imaging instrument; Ceres



Conclusion

- The technology related to prospecting and space mining are still being developed and require much testing.
- The DSi and PR approach to the technology are similar. They leverage the increasing capabilities of nano and micro satellites to run cost effective asteroid exploration mission.
- Another example of CubeSat's potential. Arkyd-3R was delivered to ISS, 6 months after launch failure of Arkyd-3 [2].