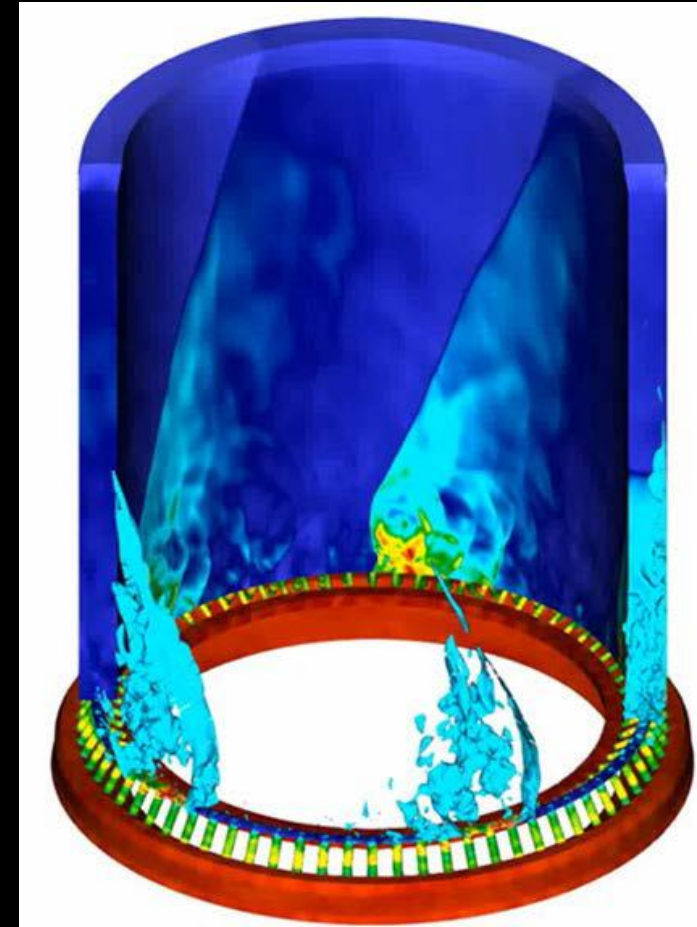


Monthly Space News

Greg Stanley
Feb. 11, 2023

This month's news highlights

- NASA testing Rotating Detonation Rocket Engine
- Other news items
- Main focus: new interest and investment in asteroid mining



NASA tests Rotating Detonation Rocket Engine (RDRE)

- What is it
 - Supersonic combustion as continuous detonations rotating around a ring (1 mile/sec.)
 - Uses methane/liquid O₂ (Other research has used other fuels)
- Why
 - More power, less fuel, perhaps 25% more efficient
- The test at Marshall Space Flight Center
 - Fired 12 times, total of 10 minutes
 - Record 4,000 lbs. thrust for 1 minute, chamber pressure 622 psi
 - Comparisons to some current engines
 - Rocket Lab: Electron Rutherford engine: 5,600 lbs thrust @ sea level,
 - SpaceX: Falcon 9 Merlin 1D engine: 192,000 lbs @ sea level, 1,410 psi
- Next: Develop fully reusable 10,000 pound thrust engine
- Who else? U.S. military, Russia, Japan, China, Poland, ...



Image credit: Air Force Research Lab

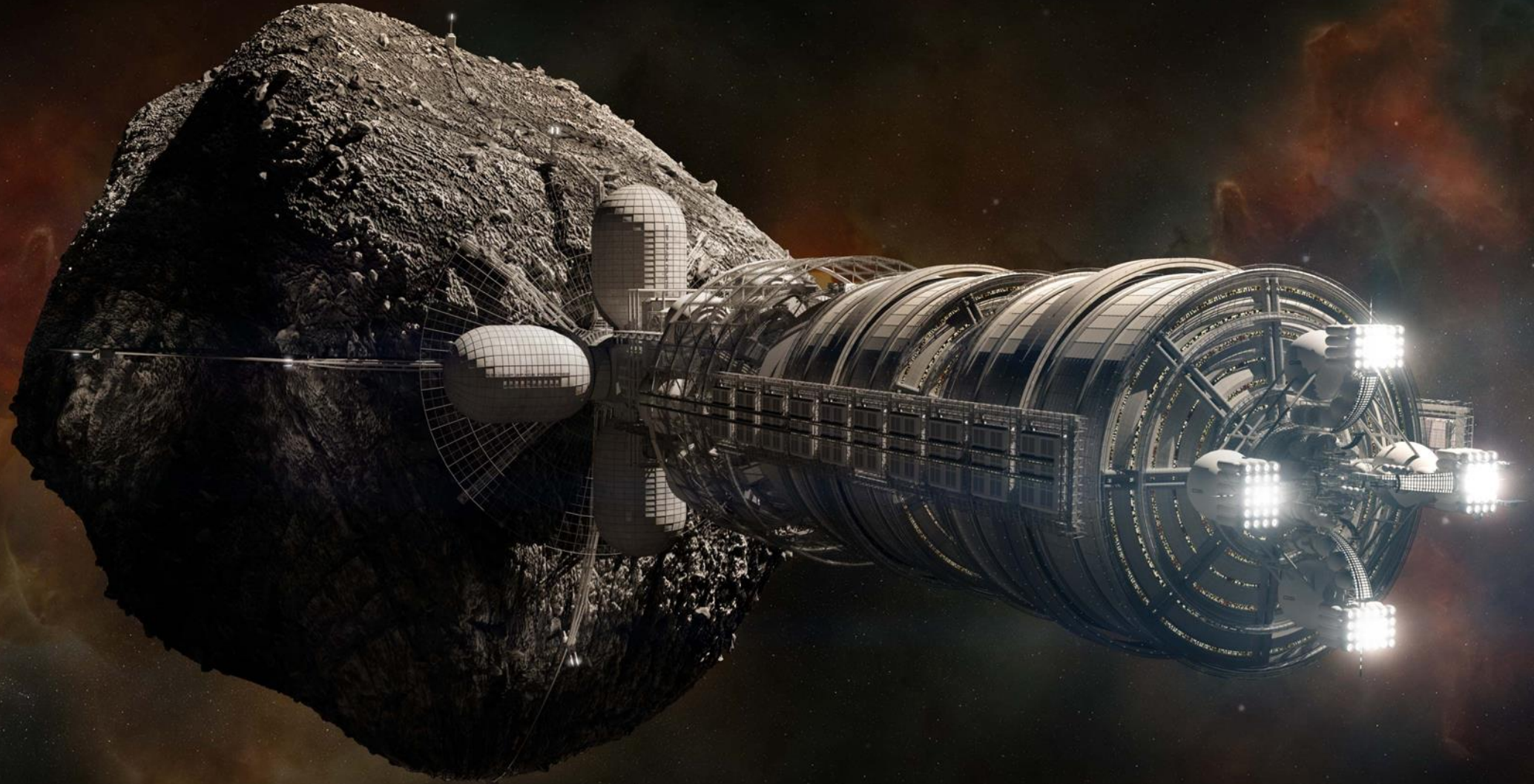
Other news

- Starship “wet-dress rehearsal” for combined Starship upper stage + Super Heavy booster
 - Loaded full 10 million pounds of propellant
- Super Heavy booster static fire test (without Starship upper stage)
 - 31 of 33 Raptor engines fired 15 seconds without damage to launch pad or spacecraft
 - Getting close to launch readiness
 - Potentially launch in a month, if FAA grants launch license
 - Goal: get 100 launches in before carrying people
- Problem with “Lunar flashlight” (cubesat to survey water ice in Moon south pole craters)
 - Thrusters underperforming (the ones with the new replacement for hydrazine)
 - Probably won’t be able to enter planned lunar orbit
 - Will probably switch to a high Earth orbit
 - Would achieve monthly flybys of the lunar south pole



Credit: SpaceX

Interest and investment in asteroid mining is reviving



BRIAN VETSTEEN SPACEAOS.COM

Credit: NSS – Space Settlement Summit 2020

Two major categories of mining in space

- Return to Earth for use on Earth
 - Competing against terrestrial mining
- Use in space
 - Avoids high costs of getting Earth resources like water or propellant up to space
 - Avoids costs of getting back to Earth
 - Might catalyze more rapid expansion into space by reducing dependence on Earth

Asteroid mining venture history

- Burst of enthusiasm in 2010's, with Silicon Valley backing
- Startup companies
 - Planetary Resources (2009 as Arkyd, renamed/reorganized in 2012)
 - Deep Space Industries (DSI) (2013)
- People usually think of metals mining, but ...
- Initial targets were extracting ice from asteroids and selling it in space for propellant manufacturing (or, in DSI case, as propellant)

Previous asteroid mining venture failures

- Planetary Resources and DSI failed, got acquired, disappeared by 2019
 - Business model: high risk, long time to pay back investment
 - Too early for a customer base, and investors won't wait long enough for payout
 - Competition for funding from other new space companies with shorter-term payoff
 - Not enough existing prospecting to identify asteroid resources/high search costs
 - Uncertain costs for transportation
 - Ran out of time to determine if the technology was adequate
 - Need infrastructure in space to process and store the mined materials
 - Didn't succeed in selling other uses of their technology to pay the bills
 - Planetary Resources: hyperspectral sensors, space telescope cubesats
 - DSI: propulsion systems for deep space access starting in LEO (water propellant)

A changing environment for asteroid mining

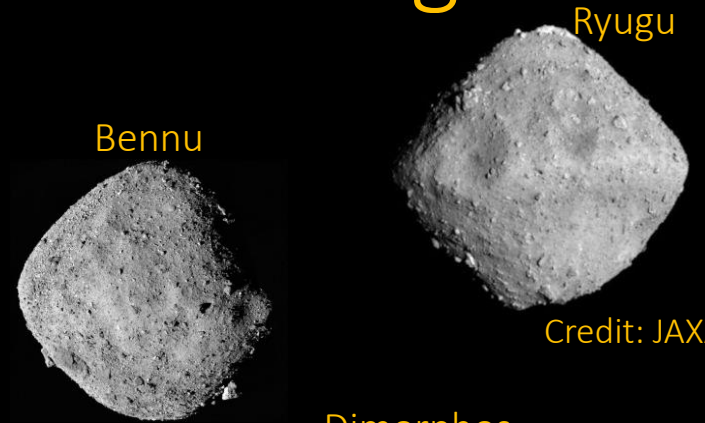
- Space activities are growing, providing more demand for services, propellants in space
- Everyone expects launch costs to continue to drop (e.g., Starship)
 - Lowers cost of launching mining equipment, BUT...
 - Makes terrestrial material launch to space more competitive against space mining
- Space law: less of a risk than in past
 - Outer space treaty had ambiguities
 - No ownership of places, but squatters' rights (non-interference) seem to apply
 - Not clear on who can benefit from extraction. Payments to "all of humanity" unlikely.
 - U.S. SPACE act (2015) gave property rights for extracted materials for U.S. companies
 - Some other countries signed up to this approach with the newer Artemis accords

Asteroid mining challenges

- Economics/business model
 - Funding and long time for payback
 - Market size
 - Bringing in too much would depress prices below profitability
 - Cited \$10 quintillion value for metals in Psyche asteroid can't actually happen
- Finding the asteroids with the desired resources
- Extracting, refining, transporting, storing the desired materials
- Still some risk in space law

Recent missions increase our asteroid knowledge

- Japanese Hayabusa missions 1 and 2 returned samples
 - Hayabusa-2 returned sample of Ryugu in Dec, 2020
- NASA's OSIRIS-REx mission
 - Dust samples from Bennu in October, 2020
 - Returning sample to Earth Sept. 24, 2023
- NASA's DART – crashed into Dimorphos Sept. 26, 2022
- NASA's Lucy probe to examine Jupiter's Trojan asteroids
 - Launched Oct. 16, 2021 on 12 year mission
- NASA's Psyche mission launching Oct. 10, 2023
 - Finally visiting a metallic asteroid



Credit: JAXA

Dimorphos

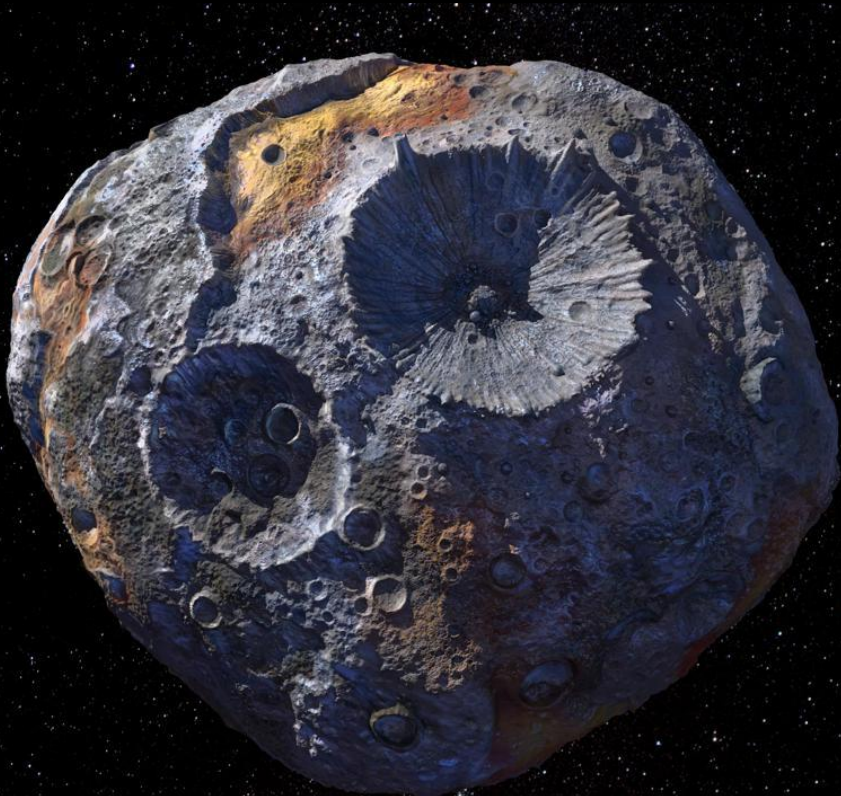


Image credits: NASA, except where noted



Growing knowledge about asteroids

- Old visions of drilling into hard rock or towing asteroids are less likely
 - We're finding that many asteroids are "rubble piles"
 - Metallic asteroids like Psyche are expected to be solid – but that's unknown
 - Haven't visited a metallic asteroid yet



Credits: NASA

Artist's conception of Psyche



Dimorphos before DART impact



Credit: NSS – Space Settlement Summit 2020

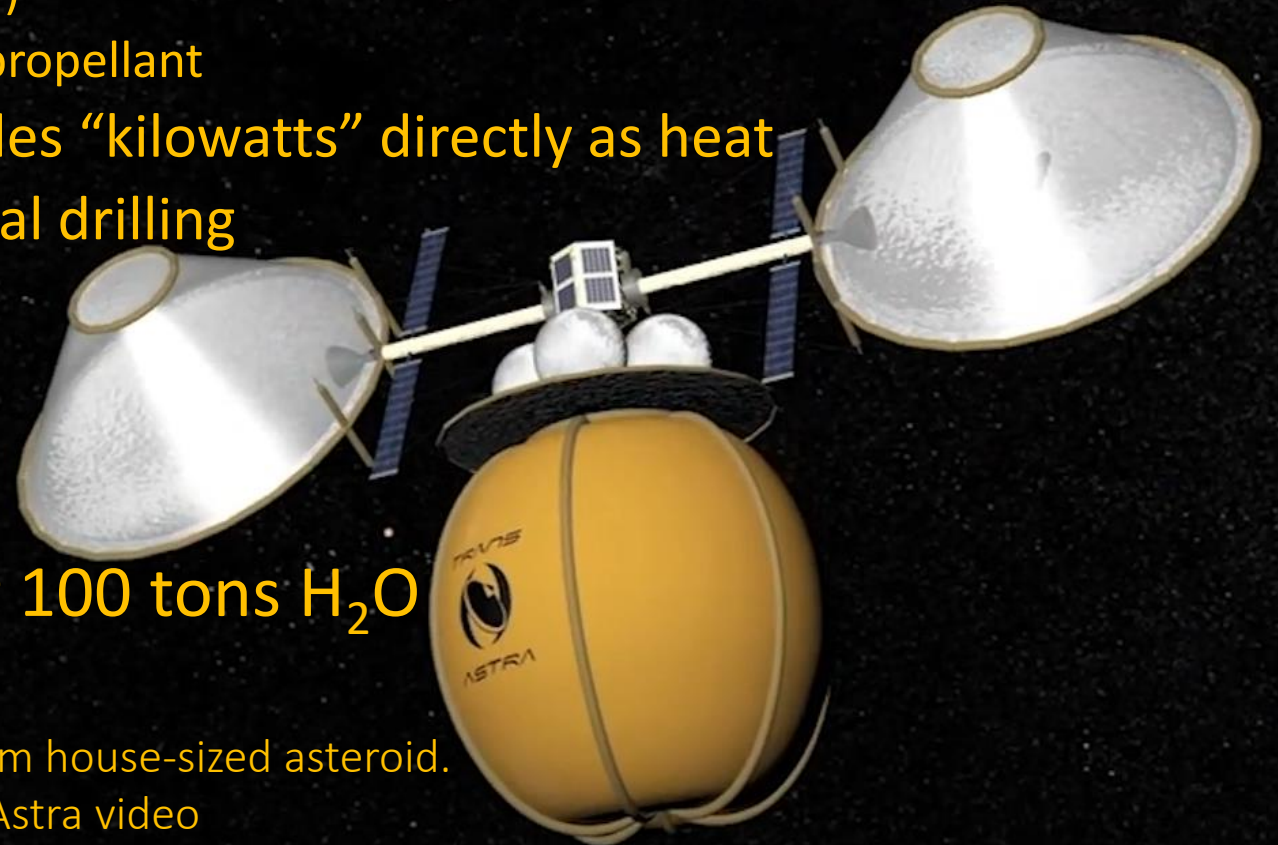
Newer startups for asteroid mining

- TransAstra (2015), focusing on in-space delivery, initially for water
- AstroForge (2022), focusing on bringing platinum-group metals to earth

- Two radically different visions
- Have they solved the problems of the last generation of asteroid mining companies?

TransAstra “optical mining” technology

- “Optical mining”, initially for water
 - Capture the asteroid in a big bag
 - Heat it up with concentrated solar energy from reflectors
 - Fracture asteroid with concentrated light at 4,040 °F
 - Heat drives out volatiles (gases, like water)
 - Capture water in an “ice trap” for rocket propellant
 - No energy cost for mining – Sun provides “kilowatts” directly as heat
 - No mass or maintenance for mechanical drilling
- “Mini Bee” LEO demo 2023 or 2024
 - 250 kg spacecraft
 - NIAC phase 3 project
- After that, 5,000 kg “Honey Bee” for 100 tons H₂O



“Honey Bee” to harvest water from house-sized asteroid.
Image credit: TransAstra video



The Flight of the Mini Bee



Watch later Share

The Flight of the Mini Bee™

Demonstrating Asteroid Mining Technology
in Low Earth Orbit



<https://youtu.be/rmavtBkVjSQ>



MORE VIDEOS

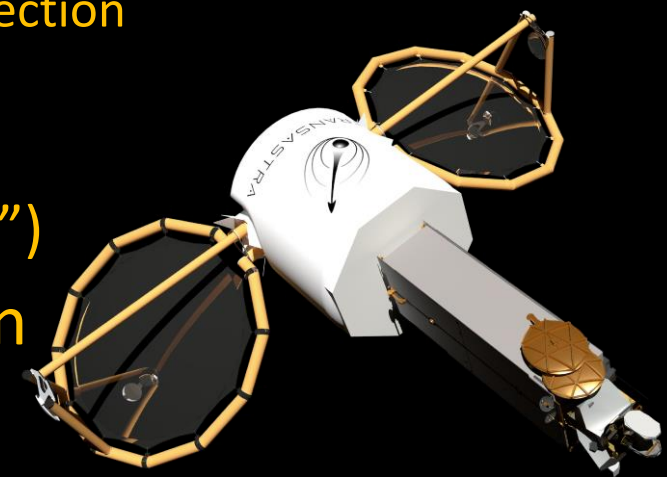
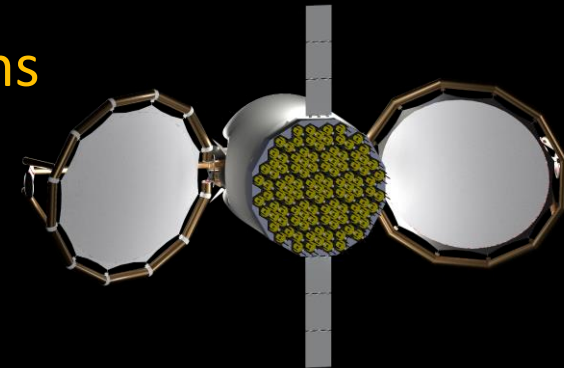
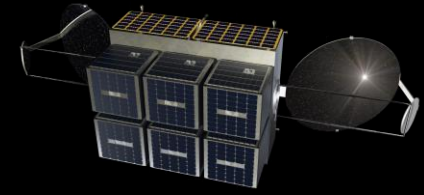
A TransAstra project sponsored by NASA

0:07 / 3:05

YouTube

TransAstra business case

- Fleet of small, inexpensive vehicles to near Earth asteroids will keep early costs low (and avoid saturating markets)
- Value proposition
 - House-sized asteroid could produce 100 tons of H₂O in a few months
 - At \$5,000/lb launch cost, 100 tons from Earth would cost \$1 billion
- Pay the bills in the meantime by getting research grants, licensing intellectual property, services
 - Sutter space telescope for tracking fast moving, faint objects
 - Small near earth asteroids (15-50 ft.), orbital debris, military threat detection
 - Space tugs to distribute rideshare satellites
 - Bag & remove defunct satellites, debris in LEO
 - Solar thermal rocket engine using water propellant (“Omnivore”)
- Near Earth asteroids are cheaper to access than the Moon
 - There may be millions of them (30,000 known)



AstroForge: asteroid metal mining on a small scale

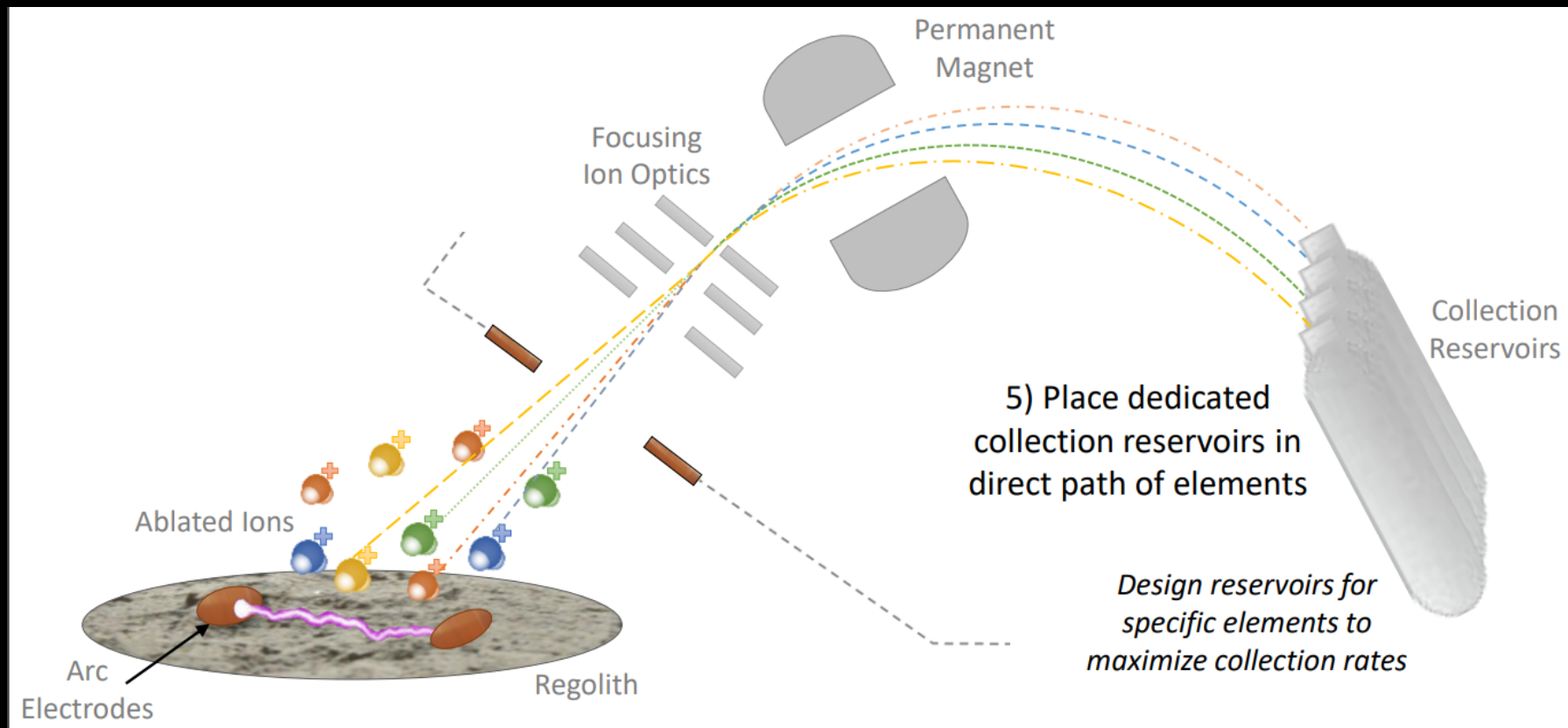
- 2022 startup planning to mine asteroids for metal
- Focusing on platinum group metals
 - In limited supply on Earth, but widely used
 - Platinum, palladium, iridium, osmium, rhodium, ruthenium, ...
- Bring back separated materials to Earth in small quantities (e.g., 100 kg of platinum) with parachute landings.
- Pure play – they consider selling technology along the way a distraction

AstroForge technology

- Excavation moves ore into the spacecraft
- 3 stage extraction process
 - Vaporize parts of the asteroid into a cloud of atoms (using a laser?)
 - Ionize the atoms in the cloud with a positive charge
 - Then sort and collect the atoms somehow (unspecified, probably electromagnetic)

Unspecified AstroForge sorting technology might be...

- ...something like accelerating ions towards a negative grid and using magnets to sort atoms by mass, as in ablative arc mining (Dr. Amelia Greig, UTEP, speaker at the NSS North Houston Space Society, Sept. 4, 2021)



AstroForge: upcoming missions

- Announced 2 Missions this year
 - Brokkr-1 in April, 2023: 6U cubesat to LEO testing refinery tech
 - Vaporize asteroid-like materials and sort out the metals
 - Brokkr-2 in October 2023: bigger, prospecting a near earth asteroid particularly for platinum group metals (PGMs), a flyby
 - (Going as rideshares, so schedules are always at risk)
- Third mission will land on an asteroid, return the sample to earth for analysis and extraction
- Fourth mission do extraction & refining at the asteroid (if suitable)



How many launches since the last meeting (Jan. 7)?














*Includes failed launches if they lift off the launch pad
Only includes launches attempting Earth orbit or beyond*

Falcon Heavy launch of two U.S. Space Force
classified satellites
Jan 15, 2023



Image credit: SpaceX

Launches since last meeting (Jan. 7), page 1

-  Jan 08 – Long March 7A – Shijian-23 (test mission to GEO orbit, unspecified)
-  Jan 08 – Ceres-1 – Galactic Energy (China) – 5 rideshares to Sun-synchronous orbit (SSO)
-  Jan 09 – LauncherOne (Virgin Orbit) – 9 small satellites, 1st UK launch (FAIL)
-  Jan 09 – Falcon 9 – 40 OneWeb internet satellites to polar LEO orbits
-  Jan 10 – RS1 (ABL Space Systems) – 2 small satellites (1st launch, FAIL)
-  Jan 12 – Long March 2C – APStar-6E communications satellite for SE Asia, GEO orbit
-  Jan 13 – Long March 2D – Yaogan-37, Shiyang-22A/B classified satellites to LEO
-  Jan 14 – Long March 2D – 14 satellites to sun-synchronous orbit (SSO)
-  Jan 15 – Falcon Heavy – USSF-67, 2 payloads to GEO orbit (classified)
-  Jan 18 – Falcon 9 – GPS III navigation satellite to Medium Earth Orbit (MEO)
-  Jan 19 – Falcon 9 – 51 Starlink (internet) satellites to LEO
-  Jan 24 – Electron – 3 HawkEye 360 RF monitoring satellites, 1st launch from US (VA)
-  Jan 25 – H-2A (JAXA) – IGS Radar-7 classified reconnaissance satellite to SSO

Launches since last meeting (Jan. 7), page 2

 Jan 26 – Falcon 9 – 56 Starlink internet satellites

 Jan 31 – Falcon 9 – 49 Starlink internet satellites + ION cubesat carrier rideshare

 Feb 02 – Falcon 9 – 53 Starlink internet satellites

 Feb 05 – Proton-M – Elektro-L no. 4 weather satellite to geosynchronous orbit (GEO)

 Feb 06 – Falcon 9 – Hispasat communications satellite for the Americas (GEO)

 Feb 09 – Soyuz-2 – Progress cargo ship to the International Space Station (ISS)

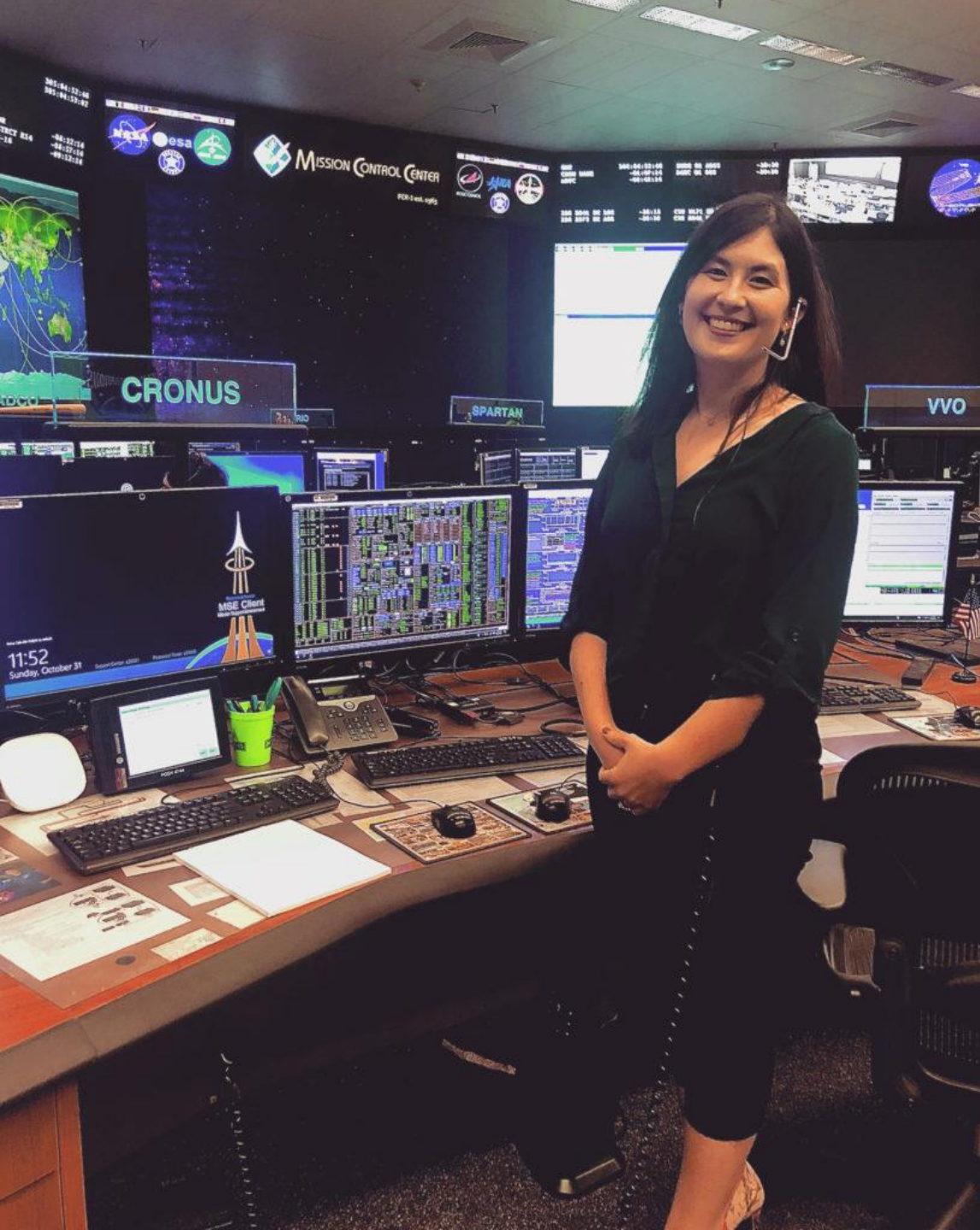
 Feb 09 – SSLV (Small Satellite Launch Vehicle) – 3 satellites to LEO. 2nd flight, 1st success

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Discussion & questions?



Image: NASA



Featured speaker: Jennifer L. Turner

- NASA Johnson Space Center
 - Human Research Program Communications Lead, Technical Integrator
 - ISS Mission Control
- Bachelor's in Computer Science & Engineering, Ohio State

TOPIC: From Mission Control to Mars