Low Energy Multi-Impact Experiments on (99942) Apophis

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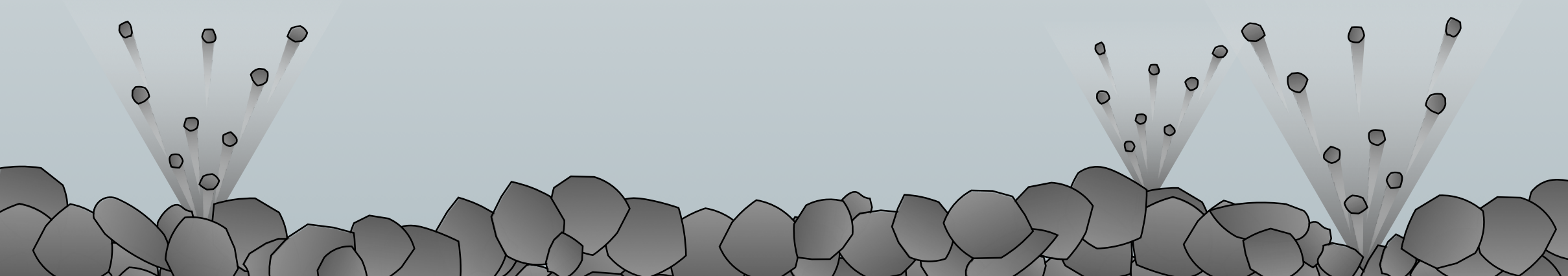


Low Energy Multi-Impact Experiments on Apophis

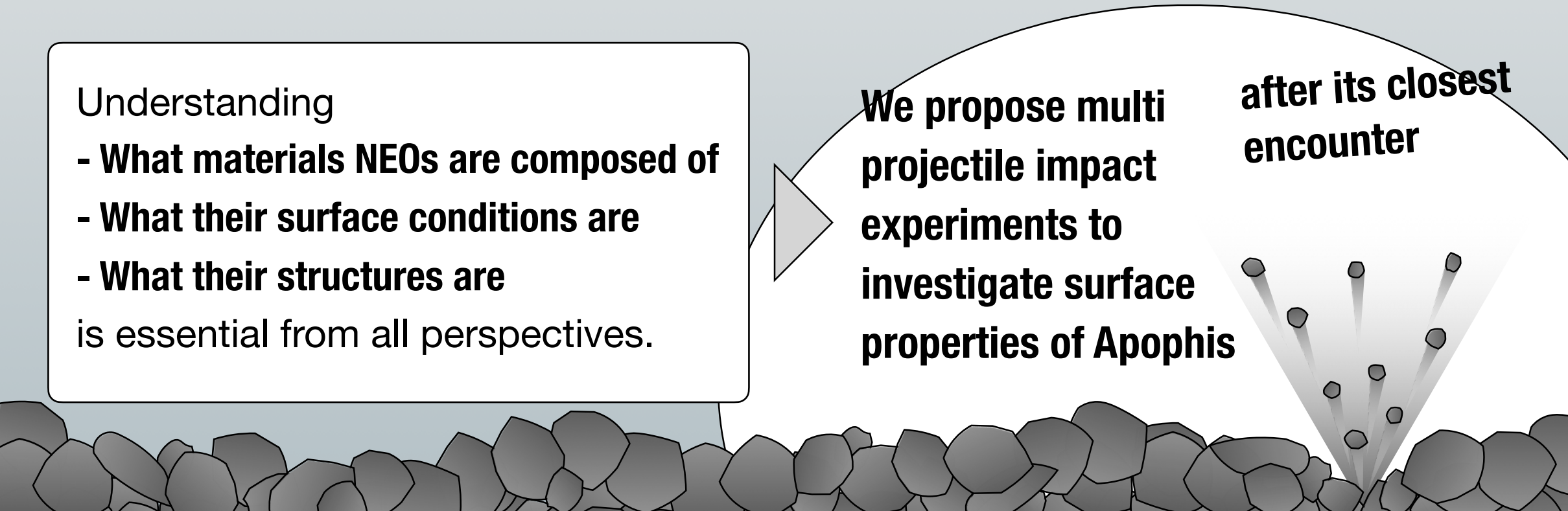
Near Earth Objects

- Target bodies of sample-return missions (e.g., Itokawa, Ryugu, Bennu)
- Potential Earth impact (Planetary Defense)
- Space resource utilization (rare earth elements, precious metals, water, etc.)

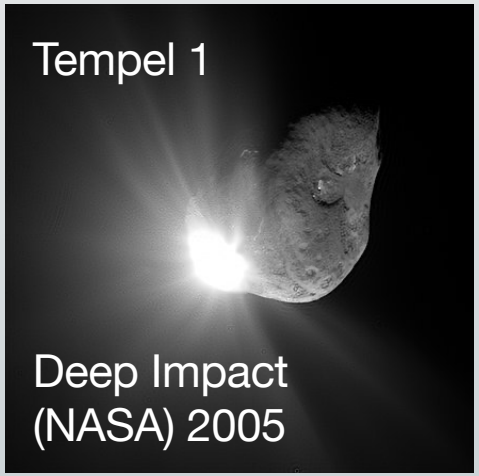
Understanding
- What materials NEOs are composed of
- What their surface conditions are
- What their structures are
is essential from all perspectives.

We propose multi projectile impact experiments to investigate surface properties of Apophis

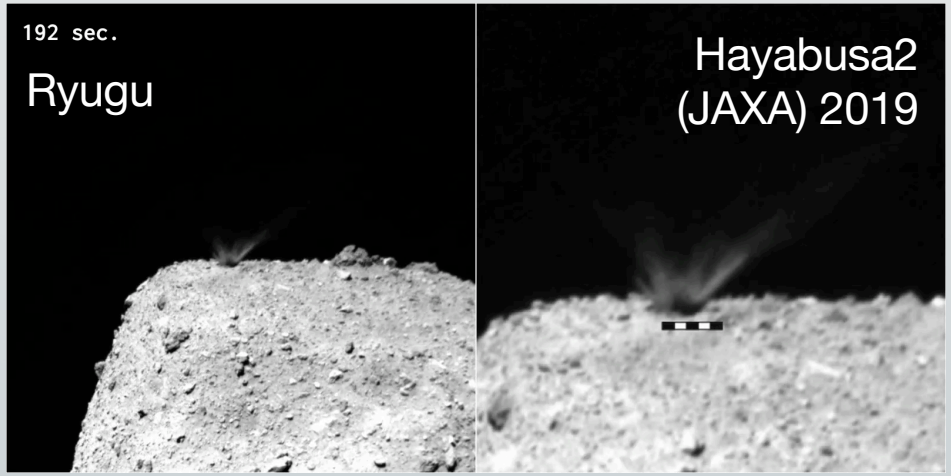
after its closest encounter



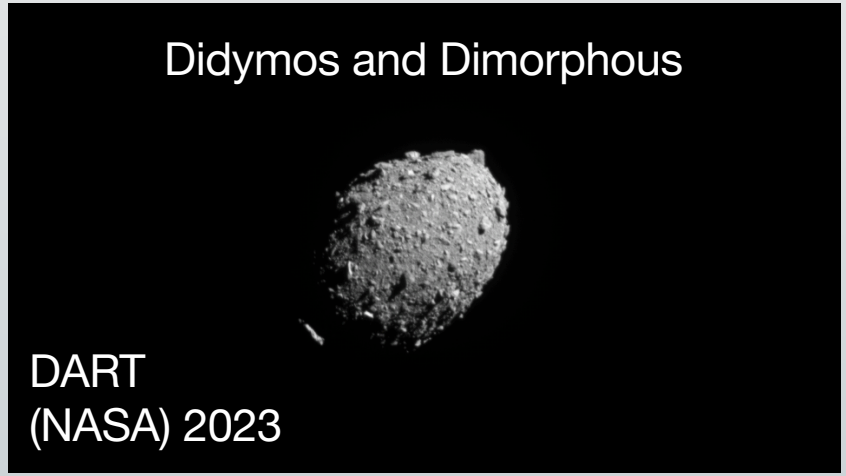
Impact experiments have huge impacts!



Sugita+ (2005)



Arakawa+ (2020)

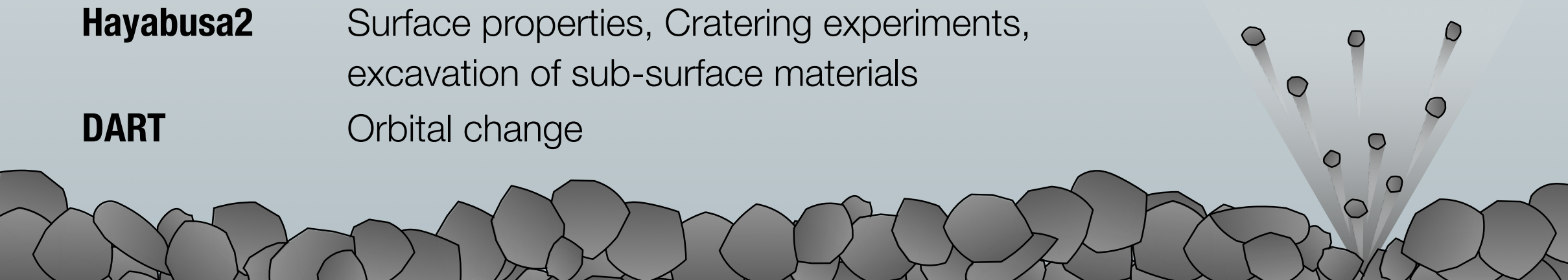


Cheng+ (2023)

Deep Impact Observation of comet interior

Hayabusa2 Surface properties, Cratering experiments, excavation of sub-surface materials

DART Orbital change



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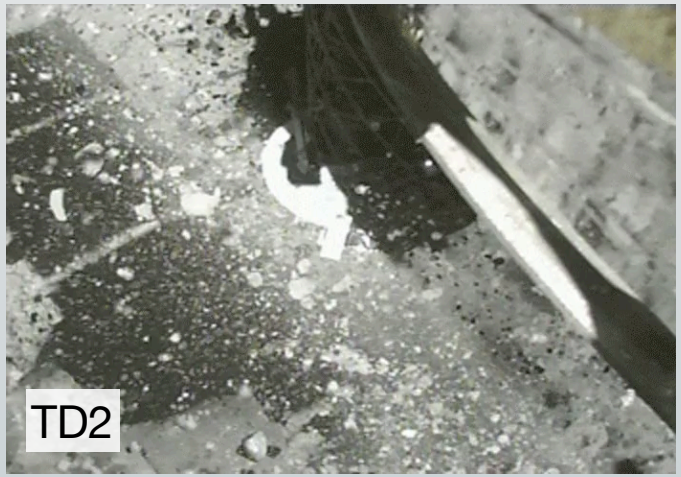
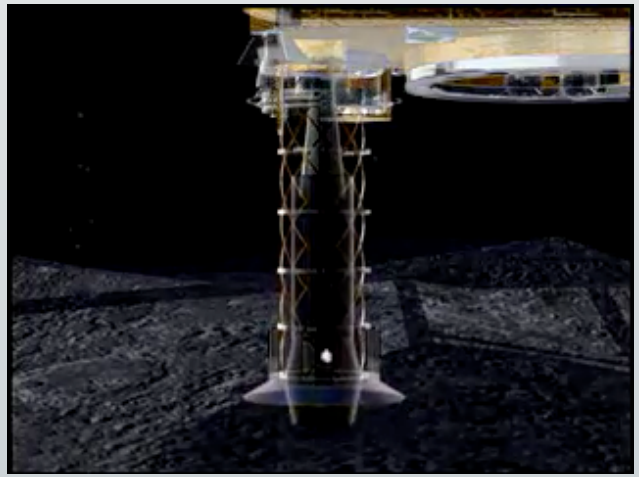


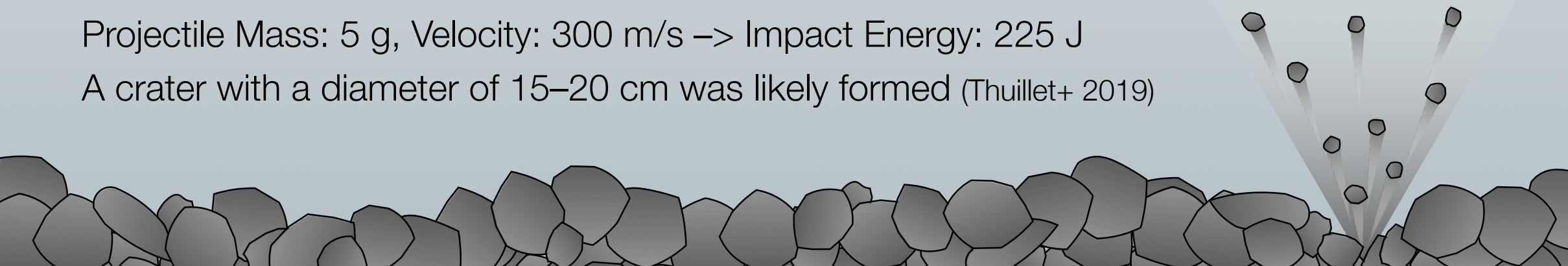


Morota+ (2020); Tachibana+ (2022)

Hayabusa2 Projectile shooting for sampling (Tachibana+ 2014; Sawada+ 2017)

Projectile Mass: 5 g, Velocity: 300 m/s –> Impact Energy: 225 J

A crater with a diameter of 15–20 cm was likely formed (Thuillet+ 2019)



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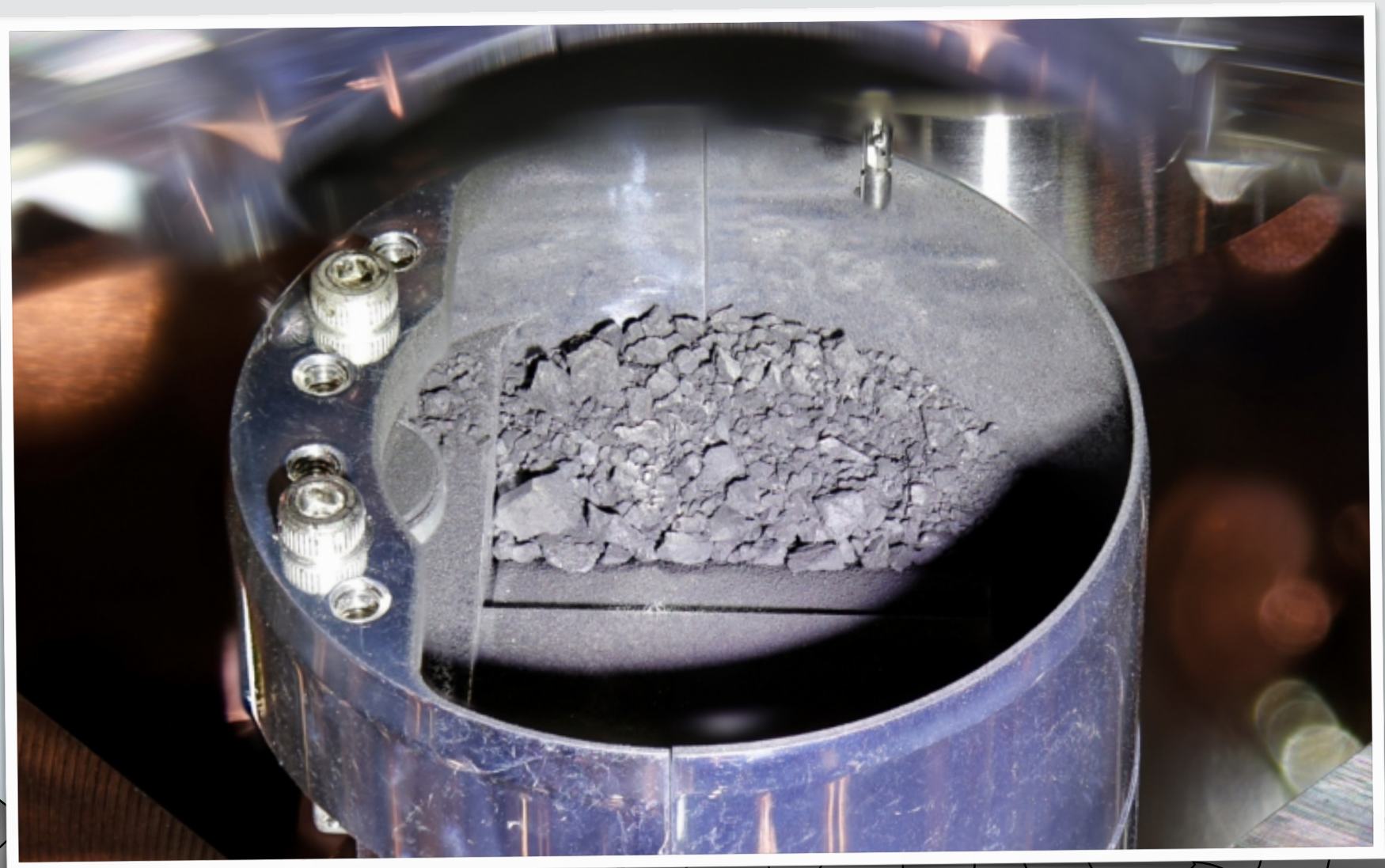

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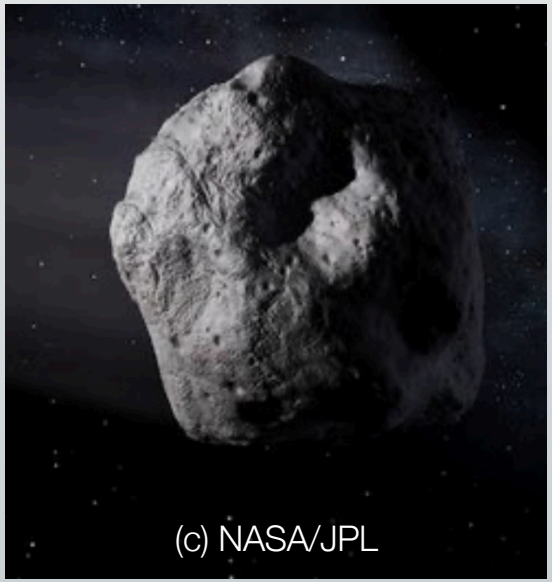
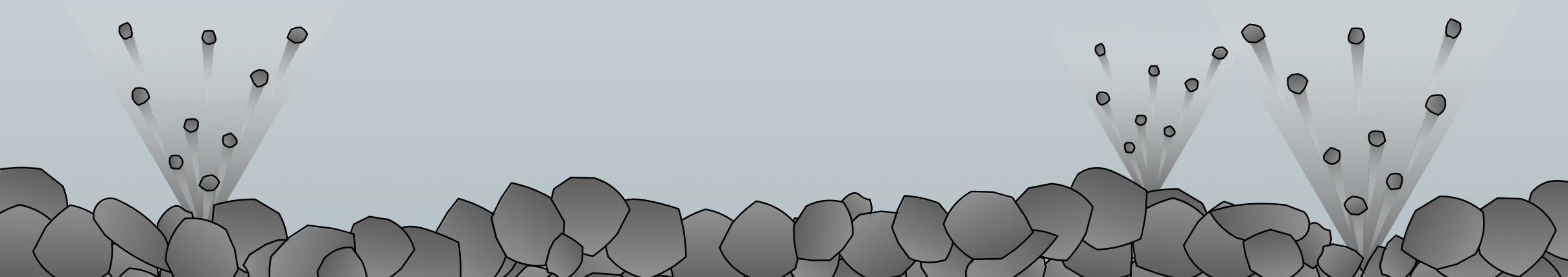


- **10–20 projectiles, 50–100 J/projectile (v < 150 m/s)**
  - – Surface properties (e.g., cohesiveness)
  - – Space weathering & Sub-surface obs.
  - – Variation of surface properties
  - – Simulation of natural impacts
  - – Comparison with Itokawa, Ryugu, Bennu, etc.
  - – Physics of cratering



ALE's Low-Energy Multi-Impact Experiment (ALEMIE)

ALE Co.,Ltd.: *Space startup company to create the world's first human-made shooting star*

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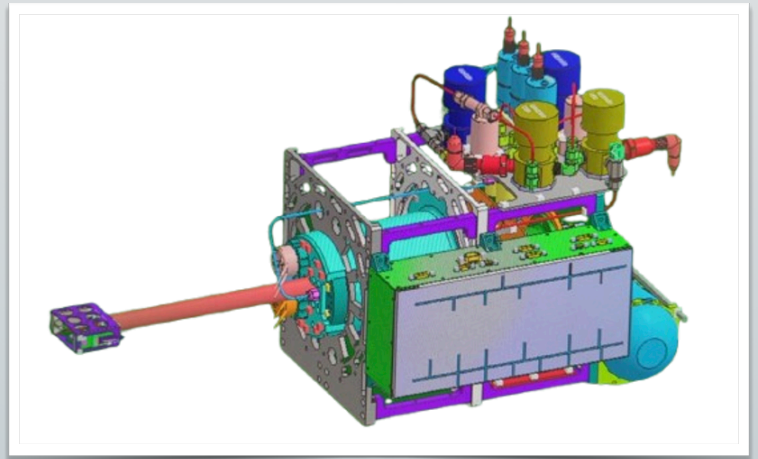

ApophisExL !

(Nakamura-Messenger+ 2025)

– operates using a compressed gas propulsion system, utilizing He or N_2

– capable of launching 1-cm metallic spheres with controlled velocities

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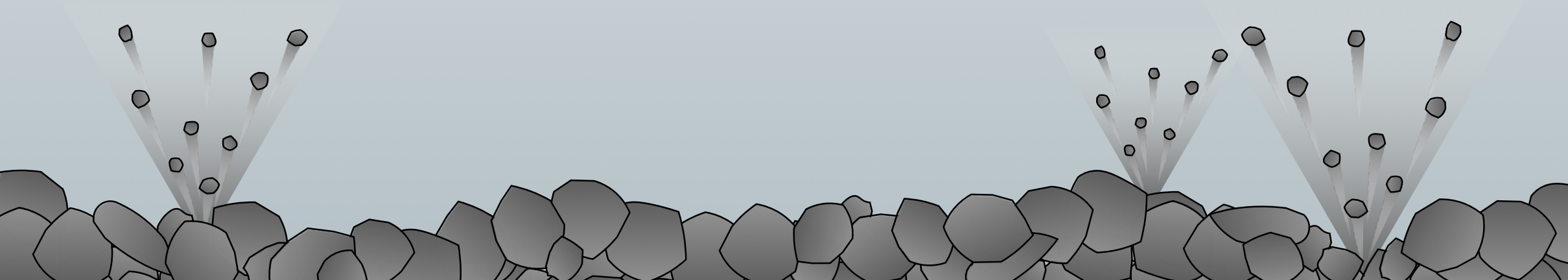
  - *– Energies of these impacts are so low that they will not alter the Apophis's orbit*
  - *– ALEMIE will provide us with additional opportunities for dynamic exploration of Apophis, complementing the effect of Earth's tidal forces and OSIRIS-APEX's STIR and with unique scientific insights and enhance the overall value of all Apophis missions*



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ALEMIE will further deepen the scientific results obtained from other onboard instruments of the spacecraft and and potentially initiate a new era of 'dynamic' exploration of Solar System bodies! e.g., observation of sub-surface, physical properties of surface materials, dust ejection, volatile resources, SR, etc.