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High-Fidelity Small-Body Lander Simulations

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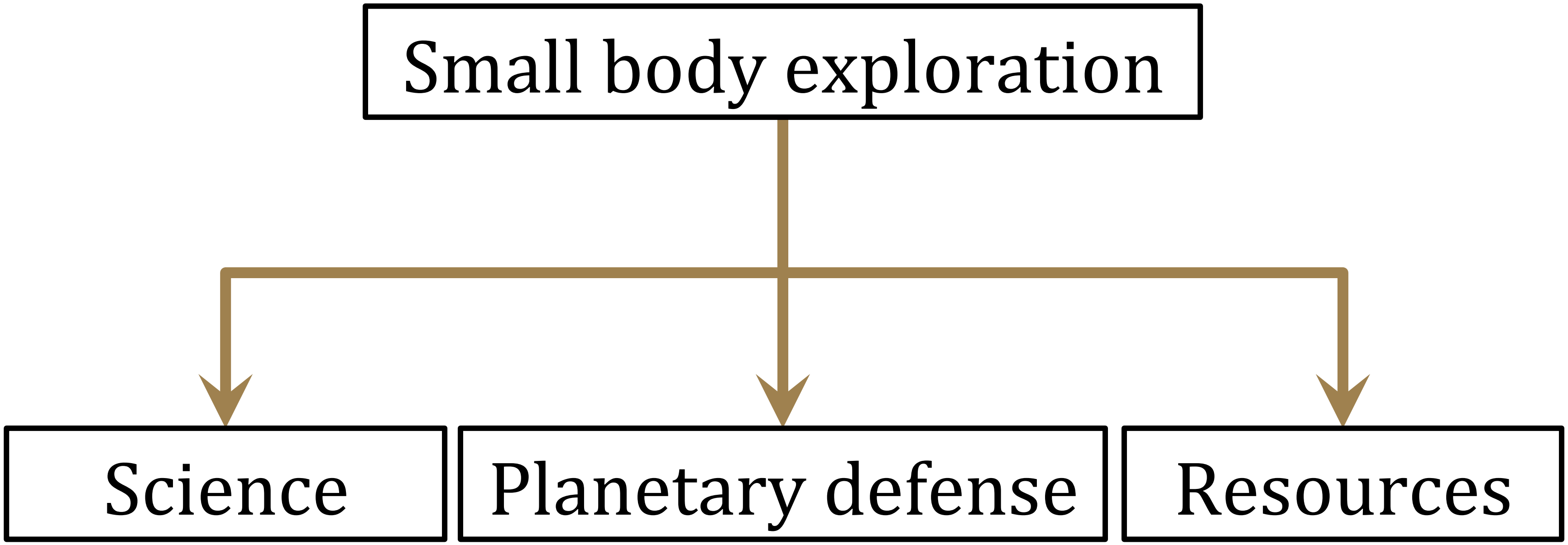
Introduction



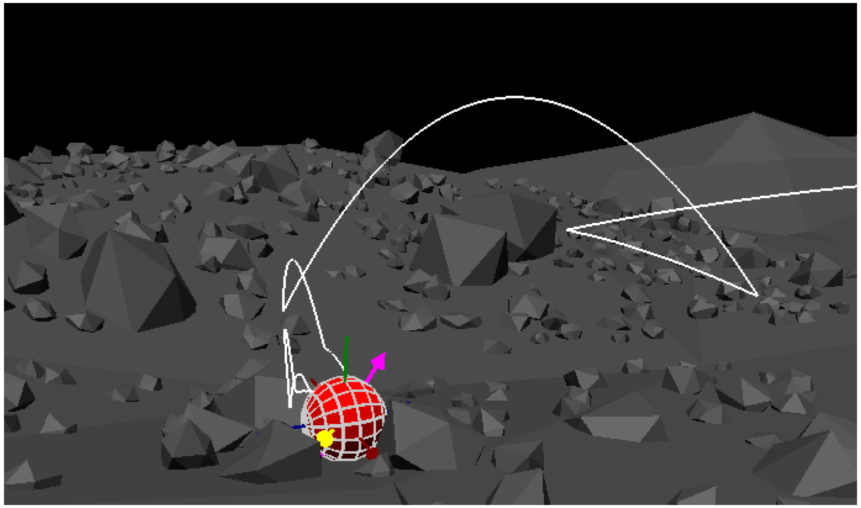
→ Increase mission return with **lander** and **surface mobility** operations

→ Design requires **high-fidelity modeling**

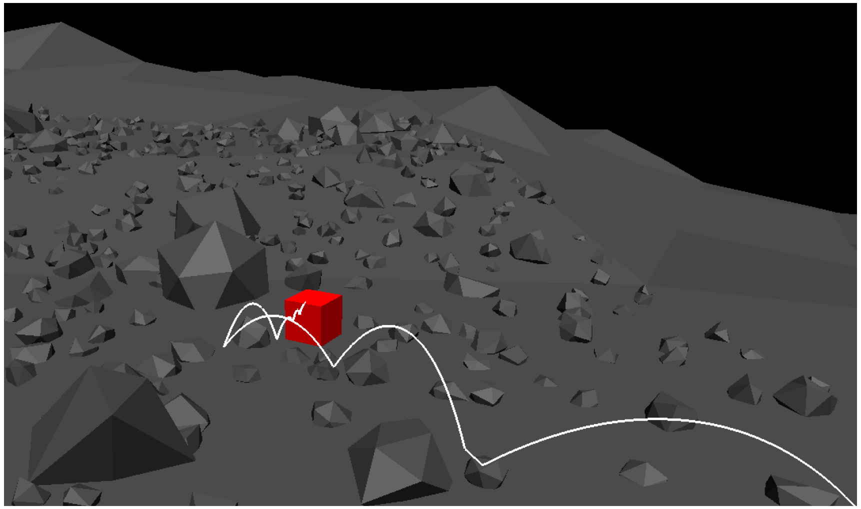
Contents

Framework

- *SAL* software package
- Previously: spherical landers
- Currently: extension to **arbitrary shapes**



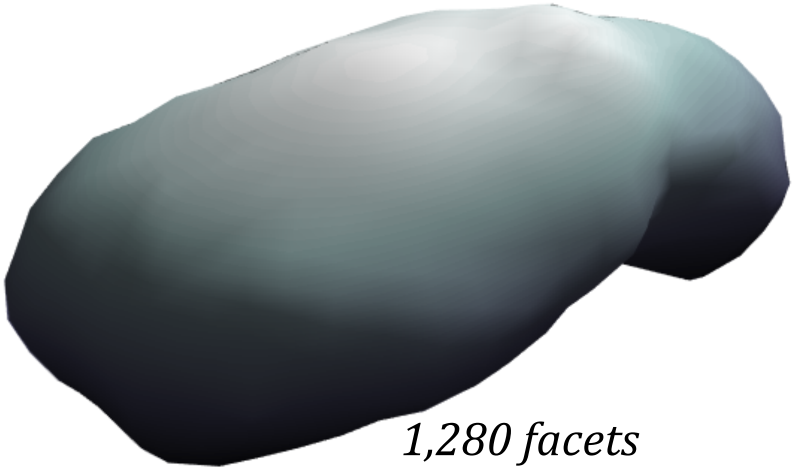
- Integration with RK5(4) in C++, event capability
- Propagation relative to rotating target frame



Gravity

- Constant-density **polyhedron** model, expensive
- Method 1: Linearization
  - Acceleration: $\mathbf{g}(\mathbf{r}) \simeq \mathbf{g}(\mathbf{r}_0) + (\mathbf{r} - \mathbf{r}_0) \cdot \mathbf{\Gamma}(\mathbf{r}_0)$
  - Error control with Δr_{max}
- Method 2: Reduced-resolution gravity model
  - Error control with resolution

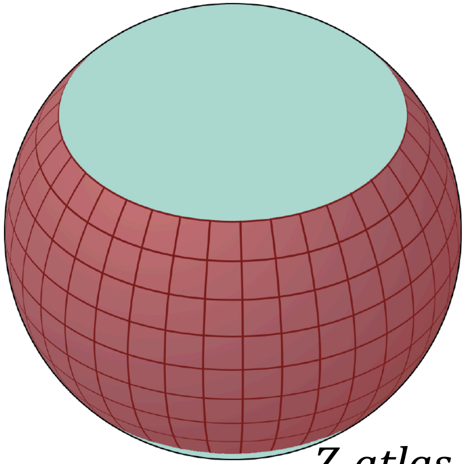
200,000 facets



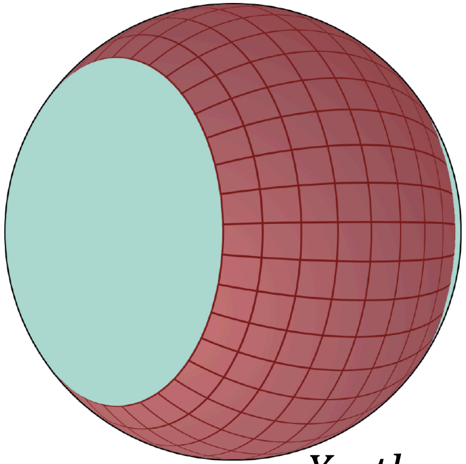
1,280 facets

Surface

- Surface interactions govern dissipation, high-resolution model necessary
- Challenge: collision detection with *global* surface and rocks
- Method 1: Atlas
  - Latitude/longitude grid of small *local* worlds
  - **Fast** collision detection with single **active local world**



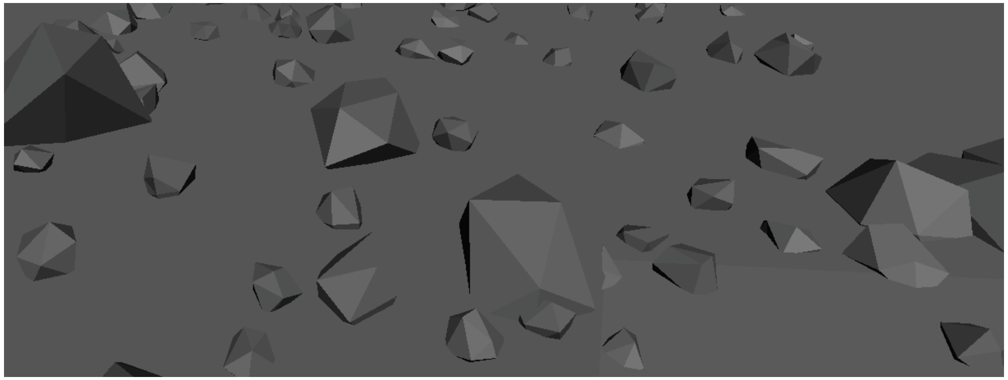
Z-atlas

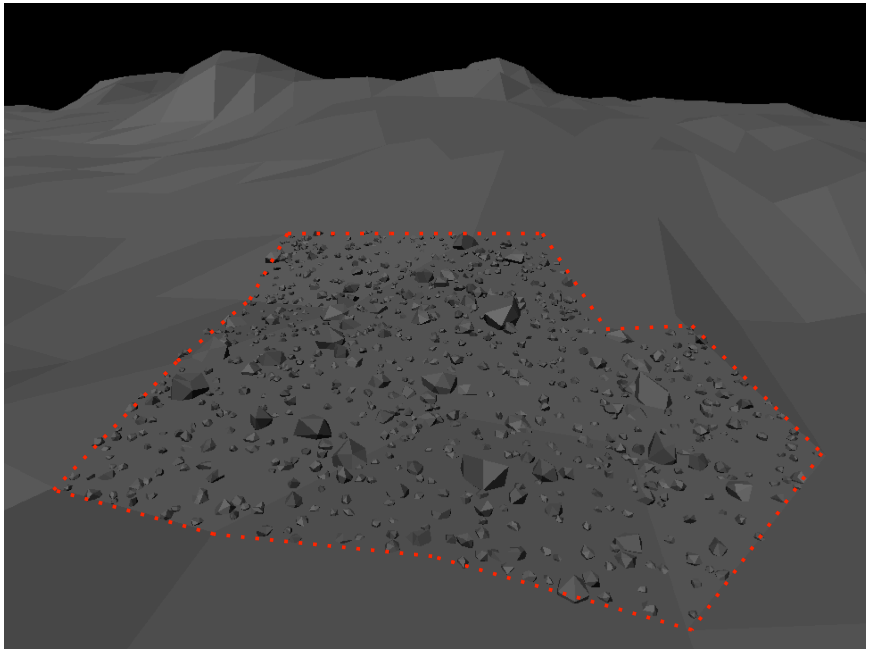


X-atlas

Surface

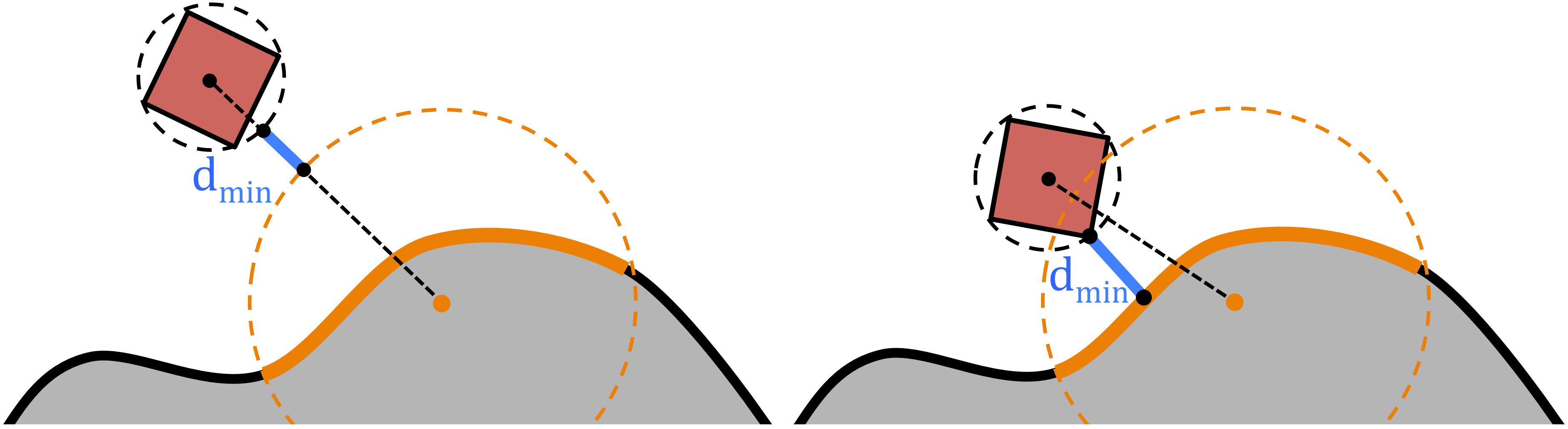
- Method 2: Surface rock distribution
  - Affects energy and topographic dissipation
  - Previously: stochastic model, limitations
  - Full model is necessary, large # of rocks
  - **Procedural generation** on *active* local world
  - Modified icosahedron





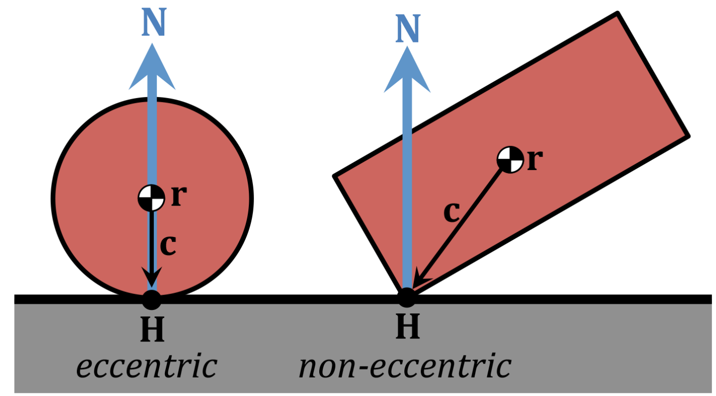
Surface

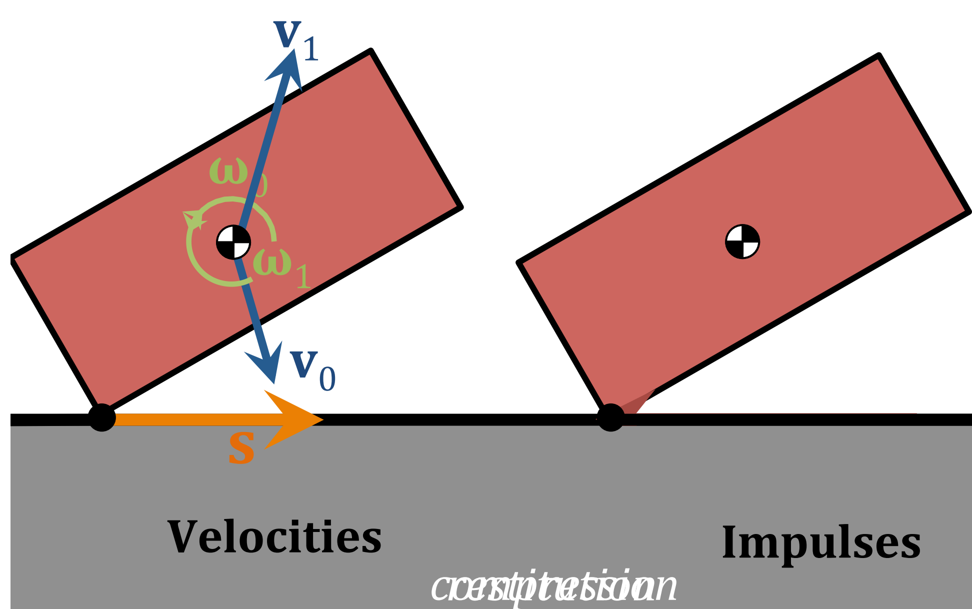
- Method 3: Bounding spheres
  - Defined for local worlds, rocks, and lander
  - Fully encompass target
  - **Trigger** finer collision detection
  - Fast detection for large # of features



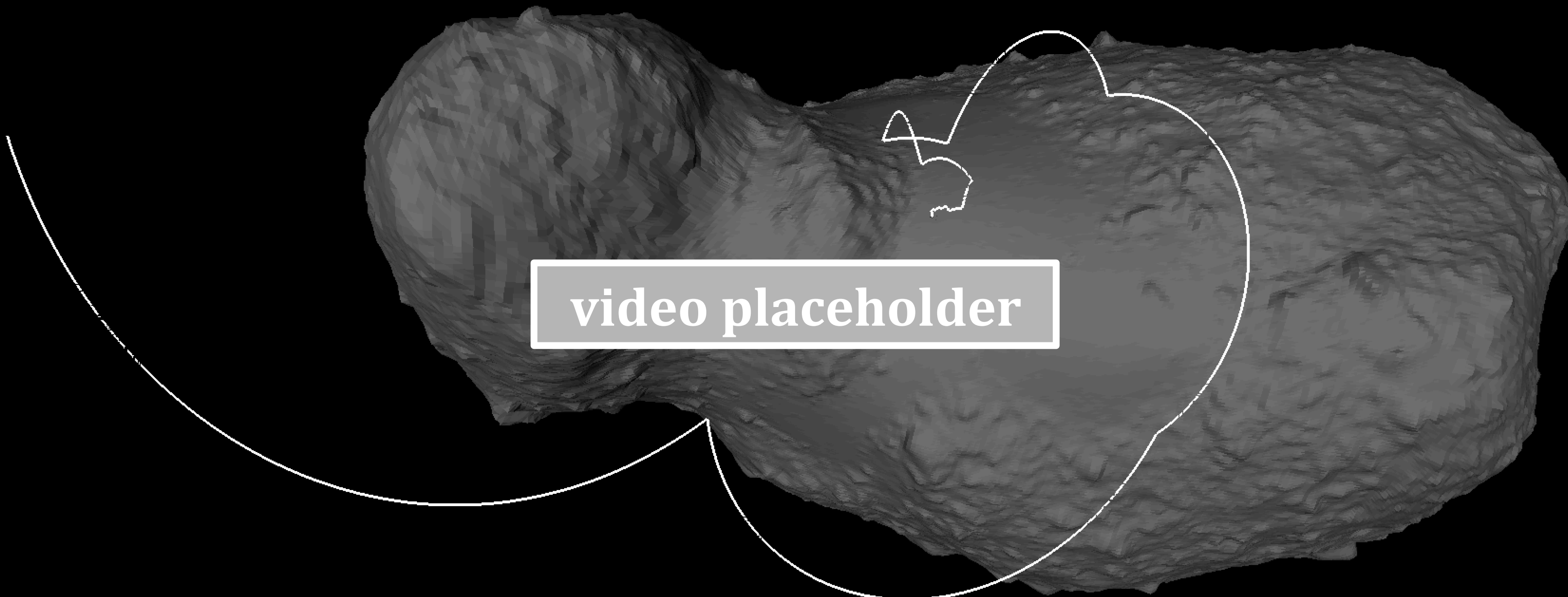
Collisions

- Impact of arbitrary shapes:
  - *Non-eccentric*, coupling of normal force and friction
  - Integrated using **time-like** normal impulse ***p***
  - Governed by *e* and μ
  - Sliding velocity *s*, slip vs. stick
  - Contact when $v_N \sim 0$





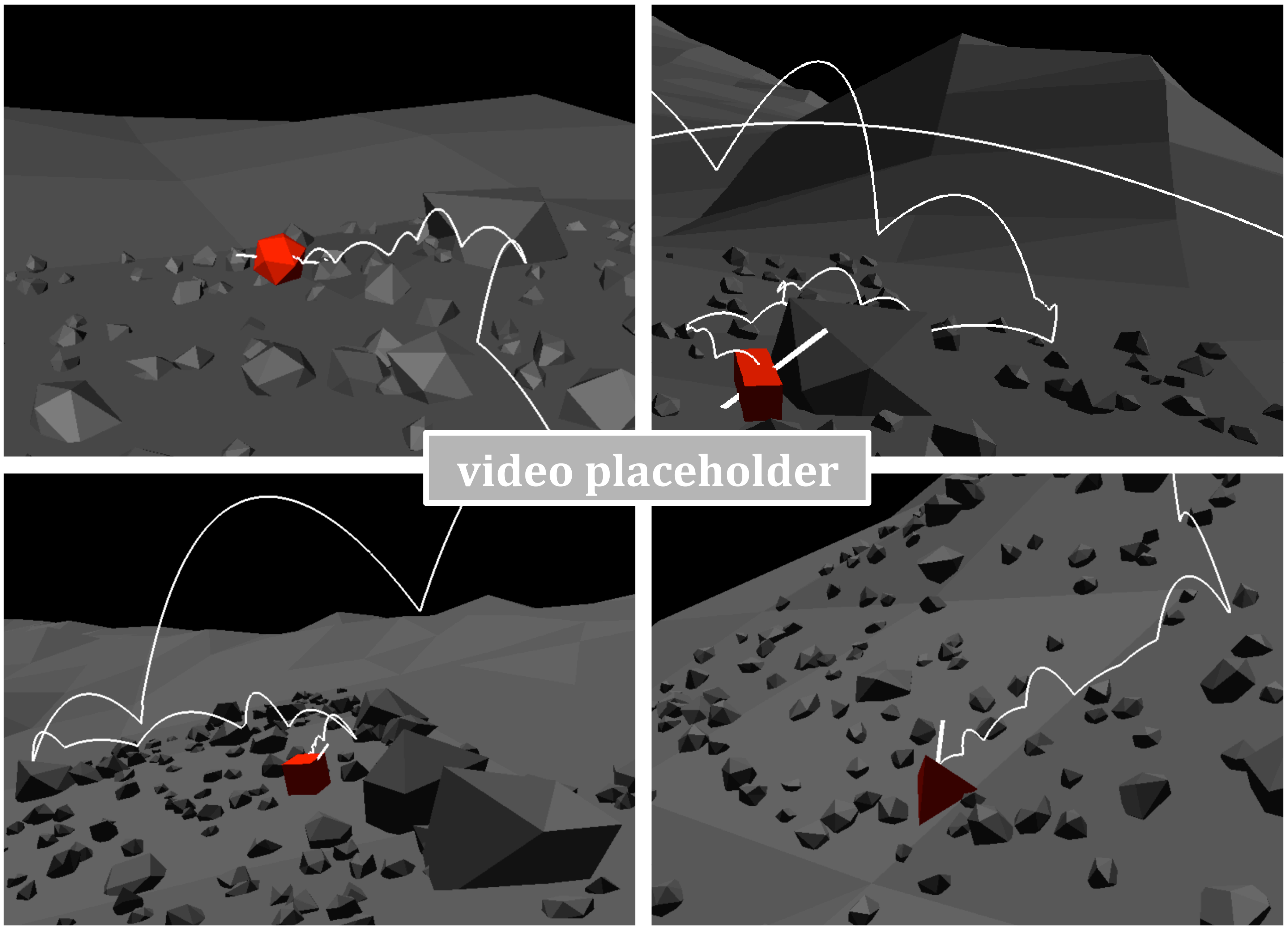
Sample deployment to Itokawa



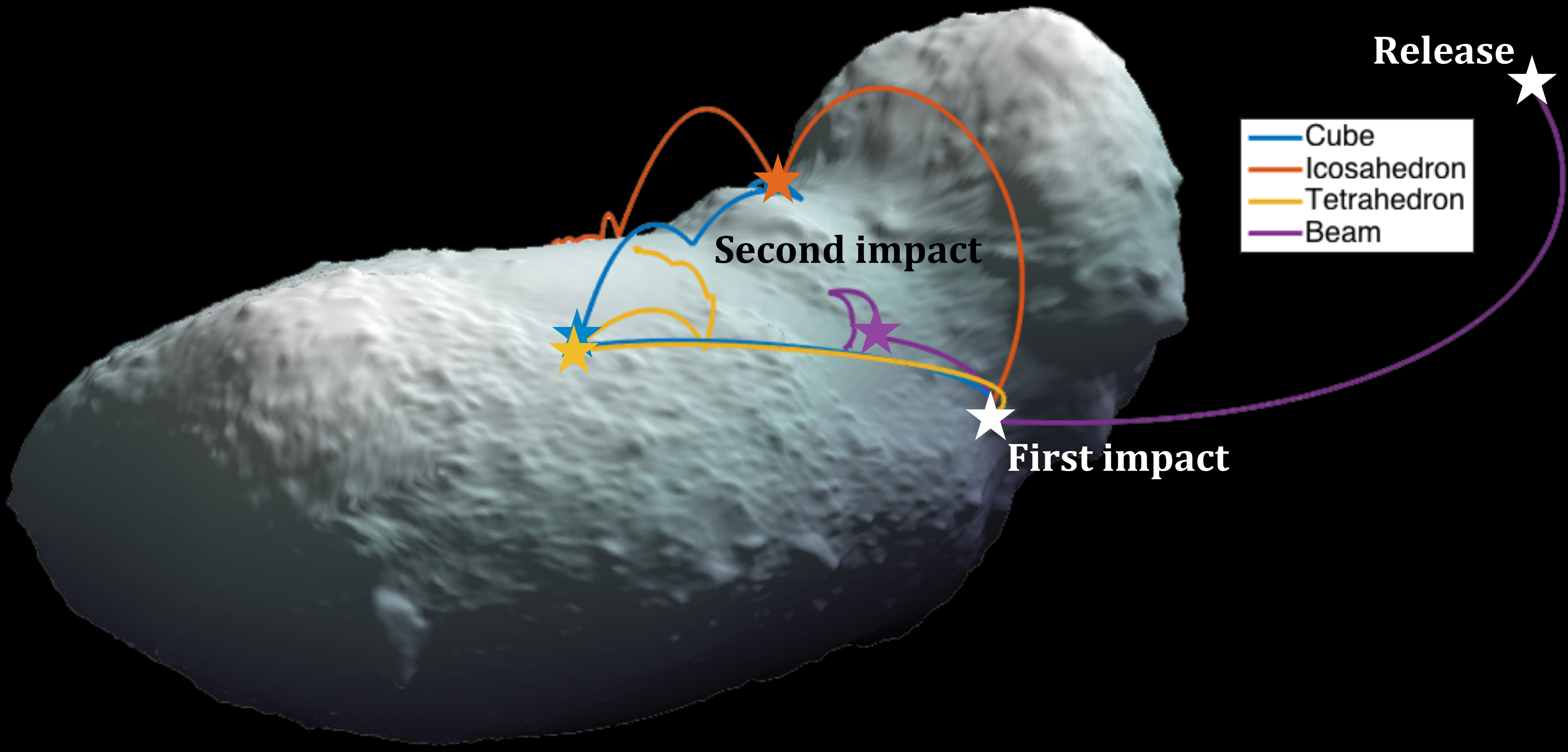
Results

- Verification of deployment strategy
- Effect of uncertainty in:
  - Release conditions, *e.g.* altitude
  - Surface interaction properties, *e.g.* e and μ
  - Rock distribution
- Surface mobility operations
  - Control strategy
- Lander/rover shape optimization
- Visualization in OpenGL

Lander shape comparison



Impact locations

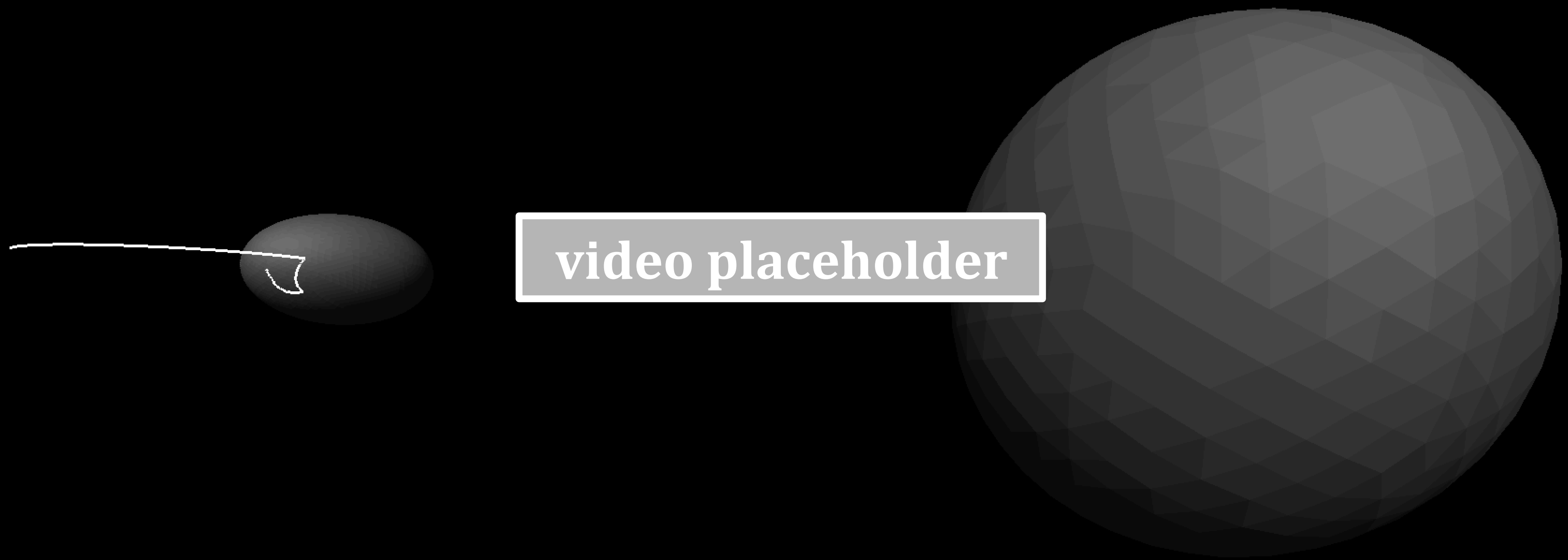


Conclusions

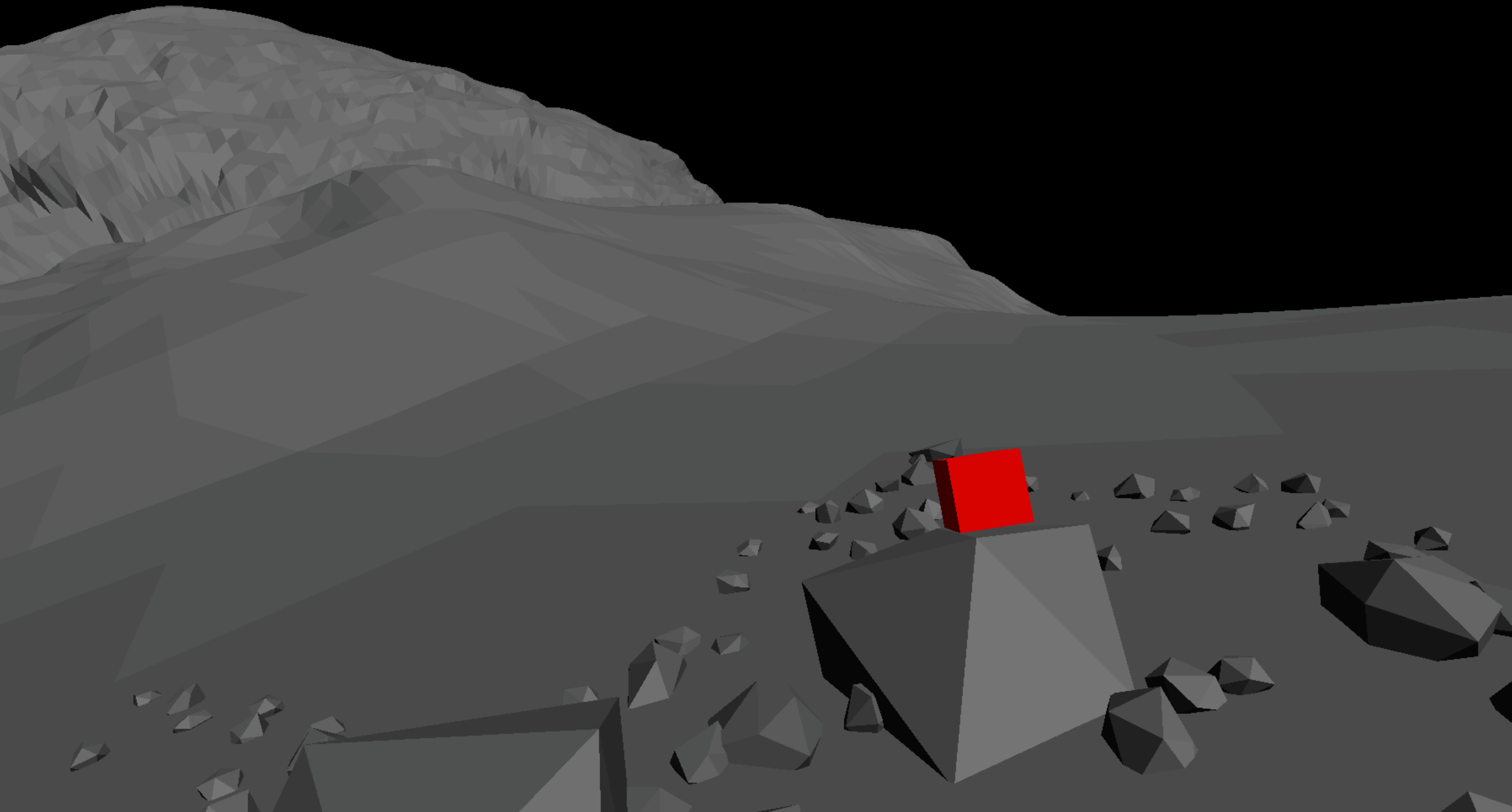
- Elements required for high-fidelity simulations
- Methods to reduce numerical burden:
  - Gravity (linearization/resolution)
  - Surface (atlas/rocks/spheres)
- Collision handling of arbitrary shapes
- Enables design and verification of lander/rover

- Future work:
  - Shape optimization
  - Contact motion
  - Mission scenarios

Sample Mascot-2 deployment to Didymoon



Questions?



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