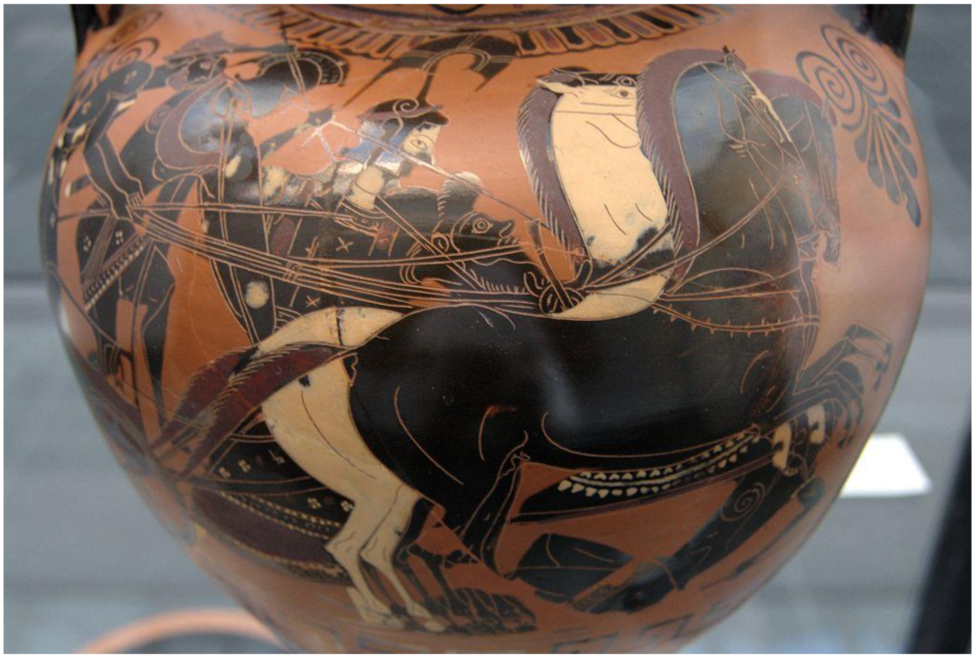

Fear and Panic on Mars: Surface bombardment as a method of excavation, mining and terraforming

09.04.2021

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Description of problem and its importance.

Prospecting, mining, excavation, and long-term terraforming are all promising areas of activity on planned Martian settlements [1]. Terrestrial techniques such as the use of earth movers, drills, explosives and manual labour are unsuitable or impractical for use on Mars until very large-scale industrial bases are constructed. Even if these machines were created, moving them across the Martian surface requires large expenditure of fuel, energy and human involvement, even if automated robots are widely deployed. If mining and prospecting can be made more efficient and able to be carried out over a larger area, any existing Martian settlements will be able to grow significantly faster, improving the chances of establishing permanent and sustainable habitation of Mars.

Description of the initial solution.

Mars has two main satellites, Phobos and Deimos which orbit 9,400km and 23,000km, respectively, above the Martian surface. With a mass of the order 10^{15} to 10^{16}kg [2], they represent a ready supply of gravitational potential energy which can be harnessed by deorbiting material from these satellites and guiding it to a predetermined point on the surface of Mars. The amount of energy released on impact could be used in several ways: systems of artificial crater can be created for use as locations for bases, larger craters can expose deeper layer of Martian rock for investigation by prospectors, controlled impacts combined with seismographic readings can be used to map the internal structure of mars, and in the case of large-scale mining operations, bombardment may be an effective method of preparing mineral-rich rocks for transport and processing.

Evaluation and comparison of the solution.

The following calculations were made to generate an order-of-magnitude estimation of the gravitational potential energy potential released by deorbiting 1kg from a Phobic or Deimotic orbit to Mars' surface.

Key information:

Mass of mars: $6.39 \times 10^{23}\, kg$
Radius of Mars: 3400km
Phobos orbit: 9400km
Deimos orbit: 23000km

Phobos calculation:

$$\Delta GPE = \frac{GMm}{r_{Moon\ orbit}} - \frac{GMm}{r_{Surface}} = GM(\frac{1}{r_{Moon\ orbit}} - \frac{1}{r_{Surface}})$$

$$GM(\frac{1}{9.4\times10^{6}} - \frac{1}{3.4\times10^{6}}) = 6.67 \times 10^{-11} \times 6.39 \times 10^{23} \times (\frac{1}{9.4\times10^{6}} - \frac{1}{3.4\times10^{6}}) = 4.26213 \times 10^{13} \times - 1.9 \times$$

$$= - 8.5 \times 10^{6} J/kg$$

This is approximately double the $4.6 \times 10^{6} J/kg$ that is generated by TNT.

Deimos calculation:

$$GM(\frac{1}{2.3\times10^{7}} - \frac{1}{3.4\times10^{6}}) = 6.67 \times 10^{-11} \times 6.39 \times 10^{23} \times (\frac{1}{2.3\times10^{7}} - \frac{1}{3.4\times10^{6}}) = 4.26213 \times 10^{13} \times 2.5 \times 1$$

$$= - 10.3 \times 10^{6} J/kg$$

This is over double the $4.6 \times 10^{6} J/kg$ that is generated by TNT [3].

This basic physics shows that the amount of energy released from a collision (ignoring heating effects in the atmosphere) is superior to that of common explosives suchs as TNT and nitrogylcerine, which are currently used in mining operations. Not only can this method release more energy, it offers significant advantages over using traditional explosives.

The transportation of high-explosives to Mars, or their manufacturing on the Martian surface requires considerable resources to do at all, let alone safely and the ability to move them across the surface of the planet poses similar problems. The small, reusable spacecraft which could remove material from the surface of the moons and de-orbit them would have access to 10^{16}kg of matter. 6×10^{9} kg of explosives are used for mining on earth annually [4]. This shows that even if satellite material was used as a replacement for blasting explosives on Mars, it would take millions of years to use up all the material present in the moons.

Modifications and improvements proposed to the initial solution.

After further investigation, we believe that the controlled de-orbit of Martian satellite material as a source of instant energy poses enormous benefits both directly and indirectly, but the fact that the J/kg are not orders of magnitude above conventional explosives poses problems. Due to atmospheric drag, the conversion from GPE to kinetic energy at the impact site will not be the maximum calculated above. Explosives can also be placed inside geological structures and below the surface, whereas this technique is reserved for the superficial activity alone.

However, the lowered yield of Joules per kg can be compensated for by sending down more mass in each bombardment. For large-scale surface blasting, this would be a highly economical method. We also propose that the bombardment technique be combined with the use of artificial hydrological cracking. Liquid water can be used to infiltrate new cracks formed by the shocks of bombardement and consequently freeze and then crack rocks into smaller, more easily transportable pieces.

With the asteroid belt significantly closer to Mars than earth, techniques and technology first developed on Phobos and Deimos could be applied to asteroid mining in the future. De-orbiting material that in itself could be mined is highly desirable. Mar's lower delta V makes it an excellent site for manufacturing material for the rest of the solar system, and it will require heavy metals found in asteroids to do so.

Ideas for further development.

If we had more resources, we would like to carry out a far more extensive calculation on the energy released and required in de-orbiting Martian lunar material. We would like to answer the following questions:

-How much energy is lost to atmospheric drag and can this be reduced significantly?

-Does giving the falling objects a rocket boost towards the planet make sense economically, providing we can manufacture rocket fuel on Mars?

We would also like to study existing craters and rock samples from Mars to understand how existing mining techniques would work on Martian rock.

We would like to investigate the numerous techniques already in development to de-oribt space junk, and see if any of them hold promise as a scalable solution to the in-orbit mining of Phobos or Deimos.

There is a huge potential for malevolent use of this technology and any such use would be very hard to stop once in process. We advise that we look at other times where dangerous technologies have been successfully limited and regulated across international and economic systems such as nuclear non-proliferation, the use of chemical weapons or the mass banning of toxic or environmentally harmful industrial compounds.

Team bio.

Alex and Ye are a great team who believe in making the world a better place. Ye is an environmental engineer from Hangzhou, China, and Alex is an astrophysicist from the New Forest, United Kingdom. When they grow up, they dream of being prospectors on Mars where they brave the wild and harsh conditions of the Martian surface to risk death in return for the chance of finding rare metals to sell for Martian dollars.

References.

[1] How to live on Mars by Robert Zubrin, page 112, Three Rivers Publishing, 2008

[2] https://mars.nasa.gov/all-about-mars/moons/summary/ - Information on moon orbital radii and masses

[3] http://physics.nist.gov/Pubs/SP811/appenB8.html - TNT joules, third table.

[4] https://www.grandviewresearch.com/industry-analysis/explosives-pyrotechnics-market - used in estimating the current global explosive consumption in mining