Executive Summary Team 2

Problem Chosen: B
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Problem Statement: Find the smallest asteroid that will have a strong enough gravitational pull to keep probes on its surface. Develop a method to land a small probe on the asteroid with a minimal amount of bouncing. Develop a spring that will allow the device to hop without generating thrust.

Given the reference website[1], multiple variables were predetermined about the probe and its launch. Each probe was disk-shaped, measuring 7 inches wide by 2.8 inches tall, with a mass of roughly 2.4 lb. The probe is also expected to remain in the air for up to 15 minutes after a single hop before landing, and to move up to 50 ft horizontally.

The main-lander, the device carrying the probe, has been previously navigated into an orbit of the asteroid. Using onboard thrusters, the main-lander is propelled towards the surface. When the main-lander hits and momentarily stops on the surface, it ejects the two cylindrical probes (only one considered here). The acceptable radius the probes can travel from the original landing point is 25 meters.

From Newton's universal law of gravitation, a differential equation can be modeled to determine the smallest asteroid the probe can land on.

$$F = \frac{Gm_1 m_2}{r^2} \rightarrow \frac{d^2x}{dt^2} = \frac{Gm_2}{x^2}$$

G is the gravitational constant, x is the distance of the probe to the center of the asteroid, and m_2 is the mass of the asteroid. Apart from a few asteroids whose densities have been empirically found, many asteroids are assumed to have a density of 2g/cm^3. However, for asteroids like Ryugu, of spectral class C, their densities are generally assumed to be 1.38g/cm^3. Therefore, the density that is proposed in this summary is 1.38g/cm^3.

The initial velocity of the probe when it is released is calculated using a selected maximum distance from the predetermined landing position. It is assumed that the probe is released parallel to the surface of the asteroid. The equation below in the x-component is used:

$$V_{(x,initial)} = \frac{x}{t}$$

Where V is the initial velocity of the probe when released, x is the distance in the x direction from the predetermined landing point, and t is time.

In order to prevent bouncing, the final velocity of the probe in the y-component must be minimal. This velocity can be calculated using the formula below:

$$V_{(y,final)} = \sqrt{2gy}$$

Where V is the final velocity of the probe in the y direction, g is the acceleration due to gravity on the surface of the asteroid, and y is the height at which the probe is released.

The force exerted by the spring cannot exceed a force that would allow the probe to reach the escape velocity. Using the equation below, an acceptable spring force can be solved through interpolation. A spring can then be found with a similar constant. Assuming the acceleration due to gravity is known on the asteroid, Hooke's Law can be used.

$$F_{spring} = -kx$$

K is the spring constant, and x is the distance that the spring is compressed. Using this equation, and having picked out spring with a known constant, the x can be determined to obtain the travel distance of 50 ft in the time span of 15 minutes.

References:

1. Wall, Mike. "Japanese Spacecraft Successfully Snags Sample of Asteroid Ryugu." *Space.com*, Space, 22 Feb. 2019, www.space.com/japanese-asteroid-probe-lands-ryugu.html.