Homework 5
N-body Simulation (CUDA)

Introduction to Parallel Computing - 2022 Spring

Illustration Credits: https://www.irasutoya.com/

Spec

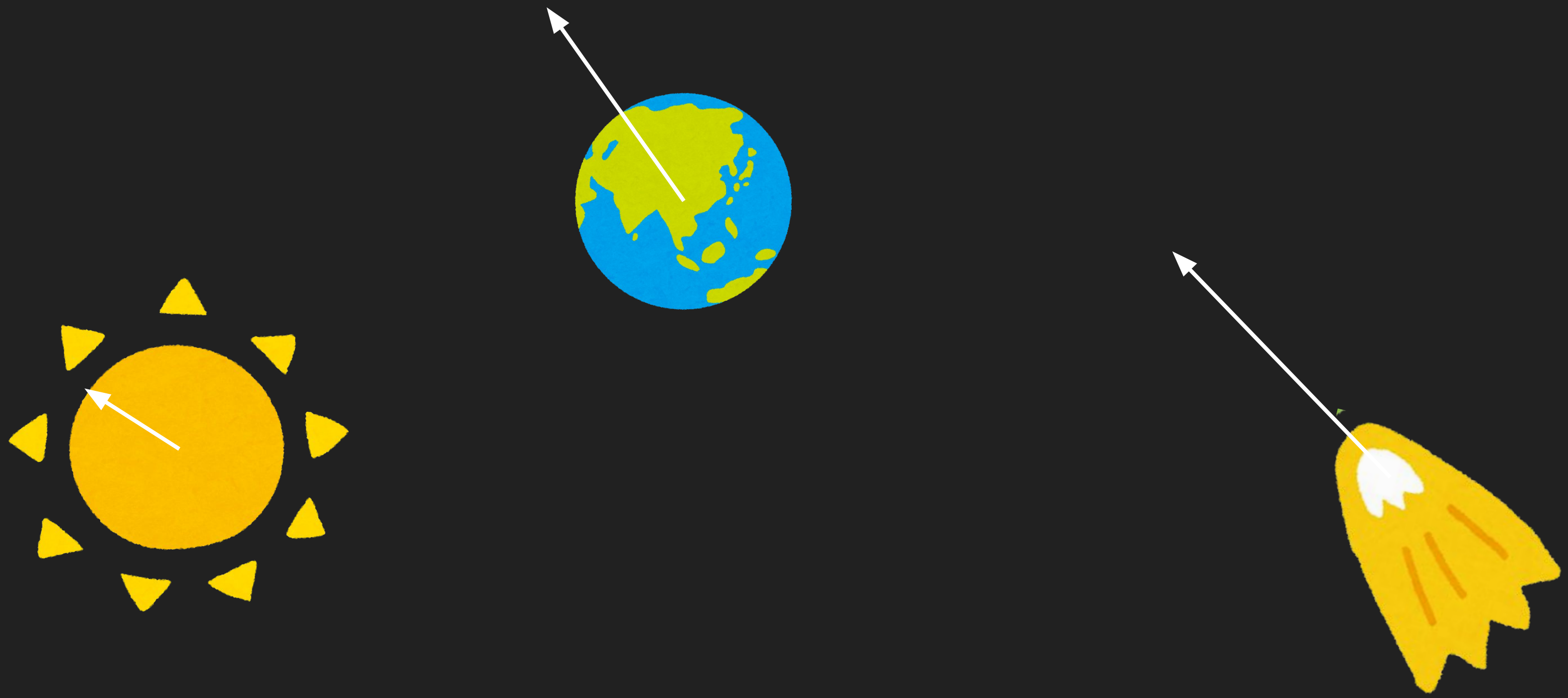
https://hackmd.io/@ipc22/hw5

N-body Simulation

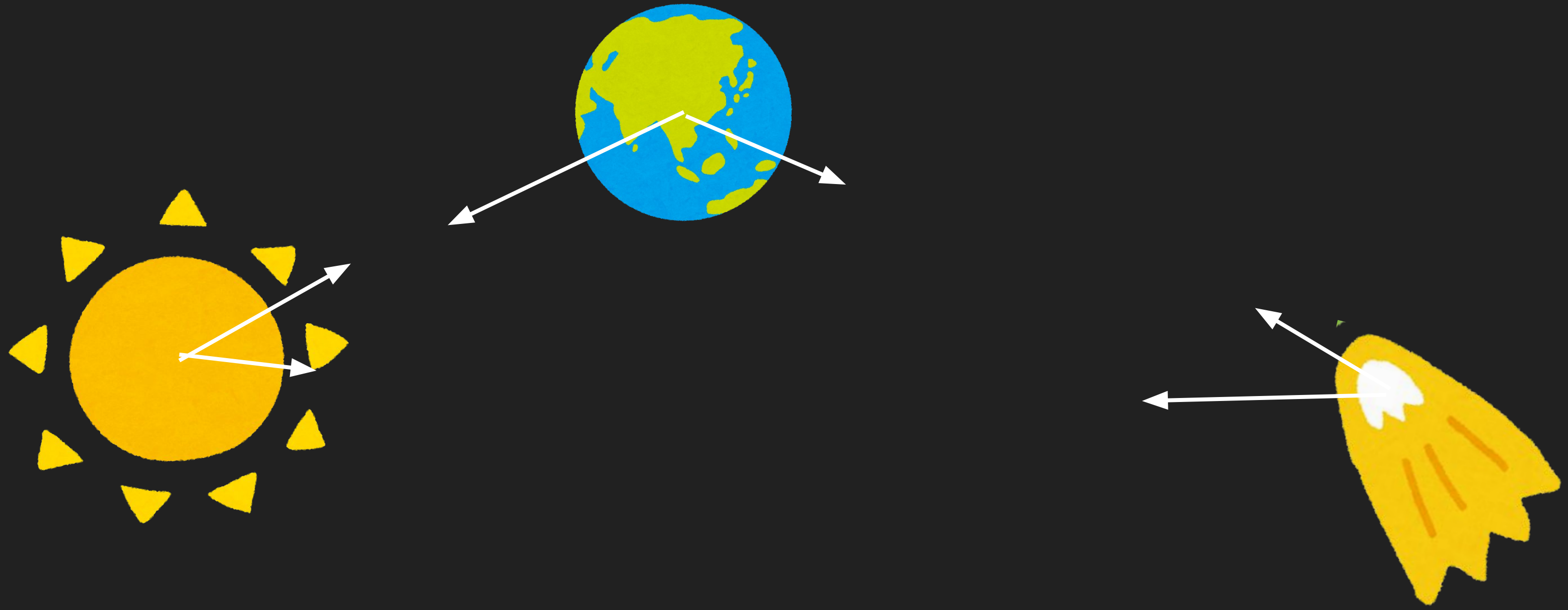
N-body Simulation: Idea

1. N-body is used to predict the motion of celestial bodies. We break continuous time into discrete **time steps**. The time difference of each time step is given by $\boldsymbol{\Delta t}$.
2. At each time step:
   a. Calculate the accelerations applied to each body.
   b. Update the velocities using the accelerations of each body.
   c. Update the positions using the velocities of each body.

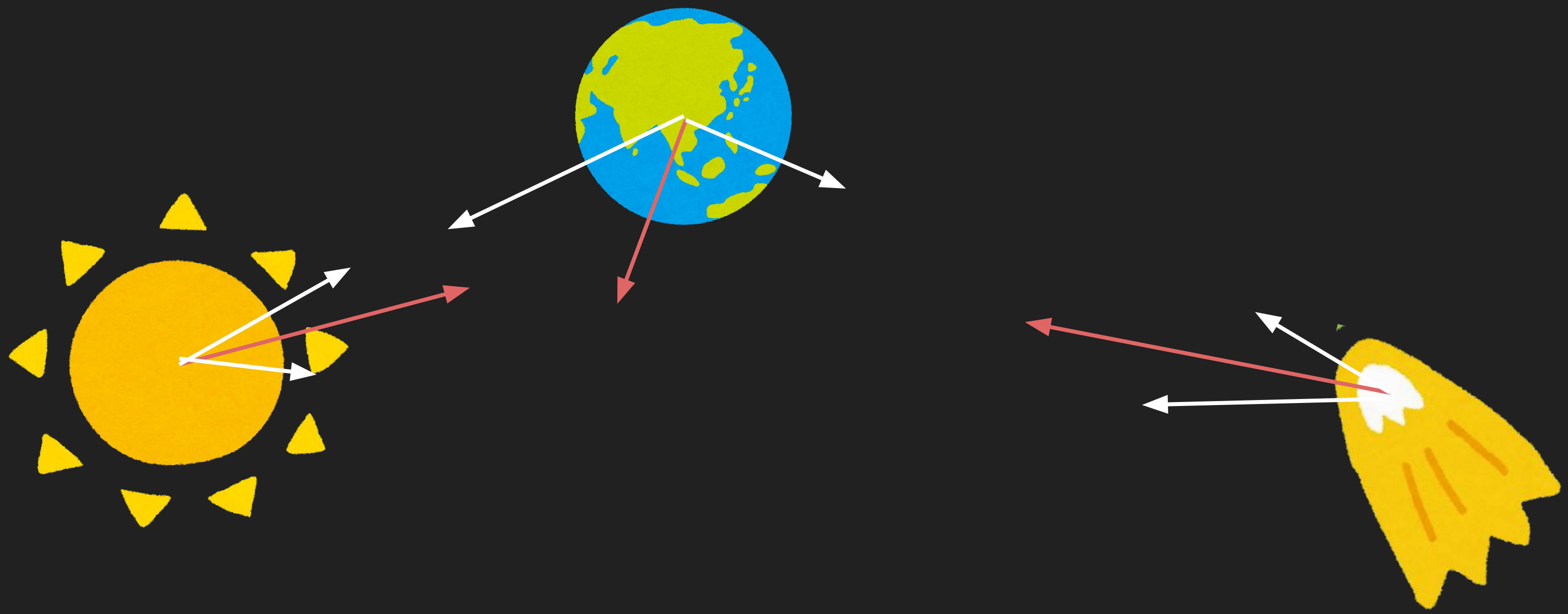
Initial State: Positions & Velocities



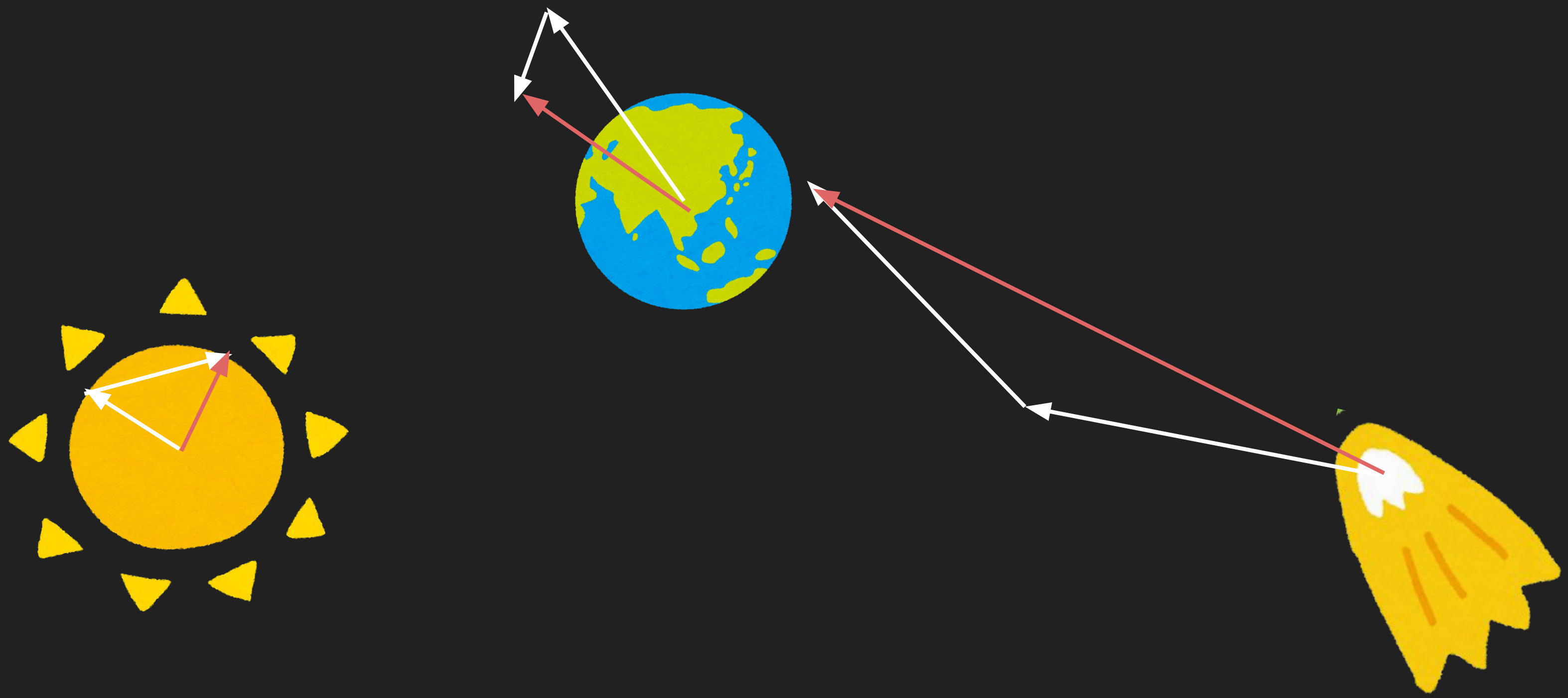
Compute Forces



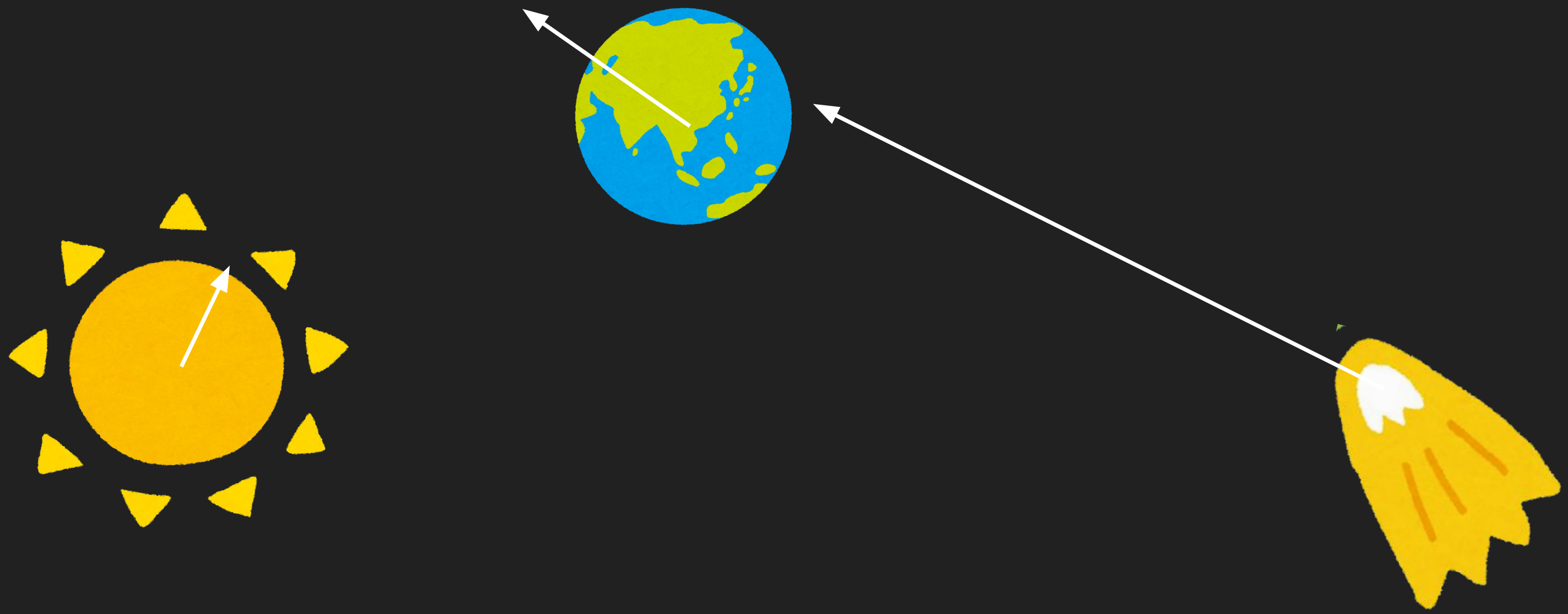
Compute Forces



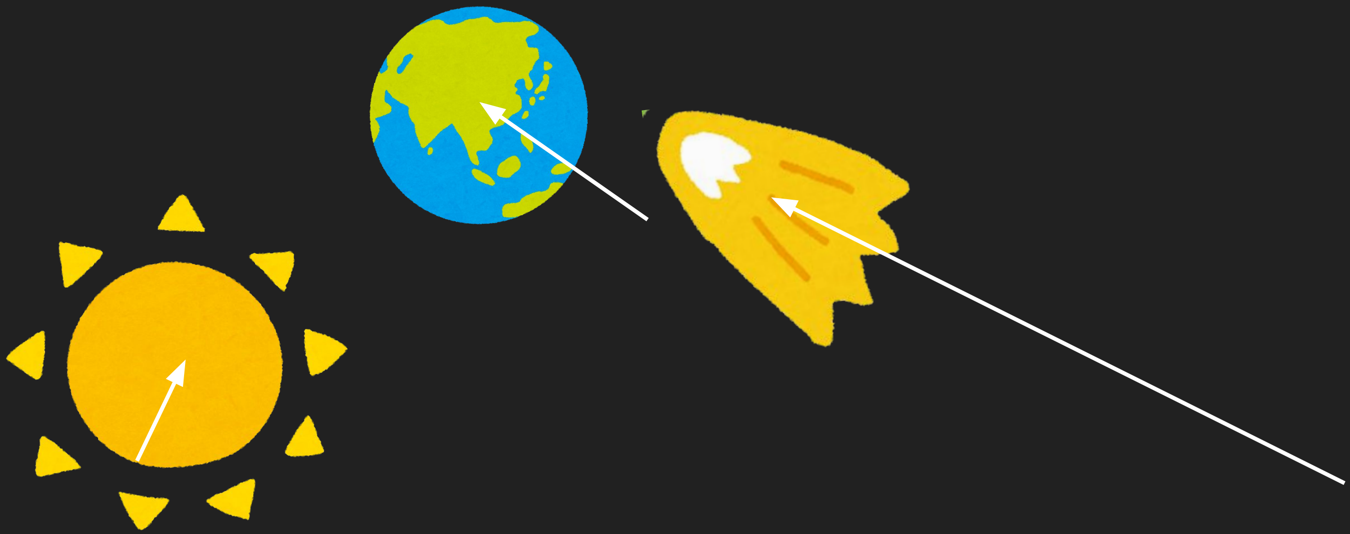
Update Velocities



Update Positions



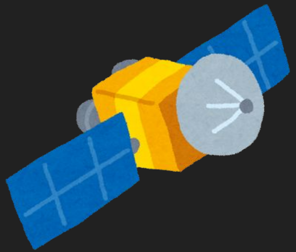
Update Positions



Crisis

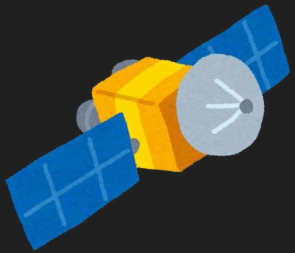
In the future, human beings have developed a technology to create artificial gravity. Space travel is as normal as driving a car. One day, Planetary Defense Agency discovered that terrorists intend to use this technology and disguise **gravity-generation devices** into seemly harmless civilian spacecrafts. They want to use these gravity devices to induce multiple asteroids to hit the colonized planet with high population. If their plan works out, the planet will face massive destruction.

Your mission is to determine whether the terrorist's plan will work and how to prevent it from attack.



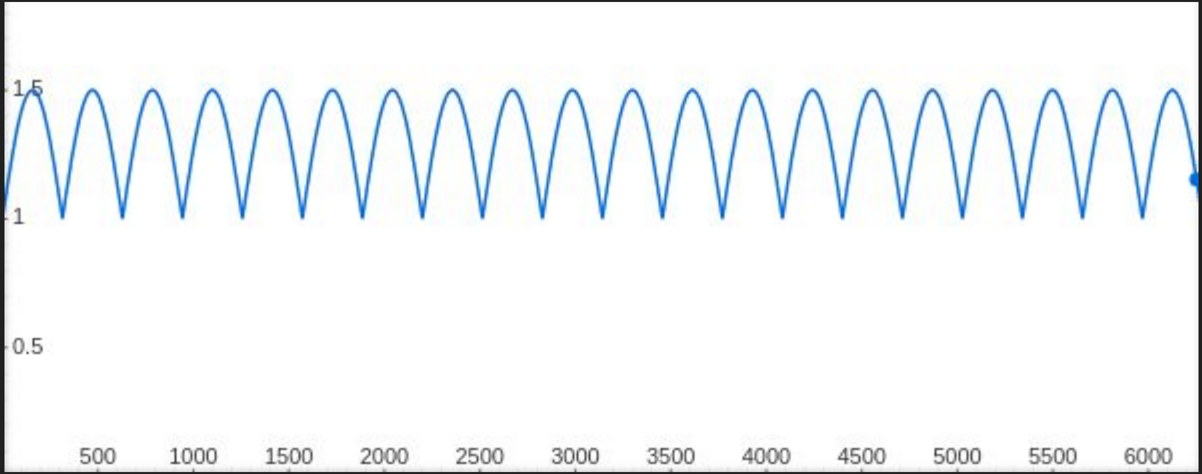
Crisis

We will assume that the collision happens if the distance between the asteroid and the planet is less than 10^7 m.



Gravity Devices

Gravity devices (type=device) have a special property: their masses will fluctuate. Refer to the spec for the detailed formula.



Counter-Attack

Planetary Defense Agency has to act quickly because the asteroids are so fast that it's infeasible to deflect their direction once the asteroids get near to the planet. The best solution they can do is to destroy such gravity devices with space missiles in order to eliminate the gravitational pull.

The missile carries some explosives and fuels just enough to reach the targeted gravity device. Launching the missile has a cost positively correlated to the time that the missile will travel.

Counter-Attack

For the ease of simulation, we will assume:

- The missile is sent from the planet
- The missile can guide itself to hit the gravity device with minimal distance, i.e., it travels in a constant velocity relative to the planet.
- The missile has zero mass and is unaffected by gravity
- A gravity device's mass becomes zero after it is destroyed
- The missile reaches the device when the travel distance is greater than the distance between the planet and the targeted device

The Problem

Run the simulation for a given amount of time steps (defined by the spec) and output the answers to the following questions:

1. If there were no gravity devices, what is the minimal distance between the planet and the asteroid?
2. At what time step will the asteroid hit the planet?
3. Can the collision be prevented if a missile is launched to destroy one of the gravity devices? If so, determine the gravity device to destroy which saves the planet and with the lowest cost.

Input

N planet-id asteroid-id
qx0 qy0 qz0 vx0 vy0 vz0 m0 type0
qx1 qy1 qz1 vx1 vy1 vz1 m1 type1
qx2 qy2 qz2 vx2 vy2 vz2 m2 type2
...

Input: Number of Celestial Bodies

N planet-id asteroid-id
qx0 qy0 qz0 vx0 vy0 vz0 m0 type0
qx1 qy1 qz1 vx1 vy1 vz1 m1 type1
qx2 qy2 qz2 vx2 vy2 vz2 m2 type2
...

Input: The ID of the Planet Under Consern

N planet-id asteroid-id
qx0 qy0 qz0 vx0 vy0 vz0 m0 type0
qx1 qy1 qz1 vx1 vy1 vz1 m1 type1
qx2 qy2 qz2 vx2 vy2 vz2 m2 type2
...

Input: The ID of the Asteroid Under Consern

N planet-id <u>asteroid-id</u>
qx0 qy0 qz0 vx0 vy0 vz0 m0 type0
qx1 qy1 qz1 vx1 vy1 vz1 m1 type1
qx2 qy2 qz2 vx2 vy2 vz2 m2 type2
...

Input: Positions of Bodies at step=0

N planet-id asteroid-id

<u>qx0 qy0 qz0</u> vx0 vy0 vz0 m0 type0

<u>qx1 qy1 qz1</u> vx1 vy1 vz1 m1 type1

<u>qx2 qy2 qz2</u> vx2 vy2 vz2 m2 type2

...

Input: Velocities of Bodies at step=0

N planet-id asteroid-id

qx0 qy0 qz0 <u>vx0 vy0 vz0</u> m0 type0

qx1 qy1 qz1 <u>vx1 vy1 vz1</u> m1 type1

qx2 qy2 qz2 <u>vx2 vy2 vz2</u> m2 type2

...

Input: Mass of Bodies at step=0 (fluctuates if type=device)

N planet-id asteroid-id

qx0 qy0 qz0 vx0 vy0 vz0 <u>m0</u> type0

qx1 qy1 qz1 vx1 vy1 vz1 <u>m1</u> type1

qx2 qy2 qz2 vx2 vy2 vz2 <u>m2</u> type2

...

Input: Type of Body

N planet-id asteroid-id

qx0 qy0 qz0 vx0 vy0 vz0 m0 <u>type0</u>

qx1 qy1 qz1 vx1 vy1 vz1 m1 <u>type1</u>

qx2 qy2 qz2 vx2 vy2 vz2 m2 <u>type2</u>

...