The Problem of the 12th Global Trajectory Optimisation Competition

— *Sustainable Asteroid Mining* —

Submission Format for Solution Files

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The solution file contains all trajectories of Mining Ships. Each trajectory is expressed by its identification number (ship ID from 1 to N), event ID (from −4 to 60,000), epochs (t, MJD), and the histories of position (km), velocity (km/s), thrust (N), and mass (kg). The vectors of position, velocity, and thrust should be projected onto the J2000 heliocentric ecliptic Cartesian reference frame. The file format is summarized in Table 1 and described below.

Table 1 Solution File format

Line num in file	*Data*
Line 1	1 0 t r_x r_y r_z v_x v_y v_z m
Line 2	1 0 t r_x r_y r_z v_x v_y v_z m
⋮	⋮
Line i	1 −1 t_i 0.0 0.0 0.0
Line $i+1$	1 −1 t_i T_x T_y T_z
⋮	⋮
Line $i+j+1$	1 −1 t_{i+j} T_x T_y T_z
Line $i+j+2$	1 −1 t_{i+j} 0.0 0.0 0.0
⋮	⋮
Line k	1 −2* t_k r_x r_y r_z v_x v_y v_z m
Line $k+1$	1 −2 t_k r_x r_y r_z v_x v_y v_z m
⋮	⋮
Line p	1 60000† t_p r_x r_y r_z v_x v_y v_z m
Line $p+1$	1 60000 t_p r_x r_y r_z v_x v_y v_z m
⋮	⋮
Line q	2 0 t r_x r_y r_z v_x v_y v_z m
Line $q+1$	2 0 t r_x r_y r_z v_x v_y v_z m
⋮	⋮

The solution file must be an ASCII text file, and the format is defined in *Data* section of Table 1. Each line of the file has the following format: two integers followed by several floating point numbers.

* event ID −2, −3, or −4 for planetary flybys

† event ID from 1 to 60,000 for asteroid rendezvous

The numbers must be separated by spaces.

The file can be divided into N sections according to the ship ID (the first integer of each line increased from 1 to N). The first section and the beginning of the second section are shown in Table 1 as an example. Each section lists the events of launch from the Earth, burning arcs, rendezvous, and flybys, which are indicated by the event ID (the second integer of each line) in order of epochs (the first floating point number of each line). The second integer at the first line of each section is 0, indicating that this ship is leaving the Earth at its initial time. The second integer −1 represents burning arcs, −2 Venus flyby, −3 Earth flyby, −4 Mars flyby, and an asteroid ID represents rendezvous with this asteroid. Multiple lines with the same epochs are used to represents the events that occur at the same time. There are two types of formats for floating point numbers, depending on the events:

a. Event ID = −1

At the moment the thruster is switched either from shutdown to burning or vice versa, two lines must be listed with the same epochs but different thrusts. A burning arc is presented by starting with a line and ending with a line both with a zero thrust vector, and by evenly distributing lines with thrust components between the boundary lines. So, the second and penultimate lines have the same epochs with the first and last lines, respectively, but the thrust vectors are both nonzero. There is no need to provide data for coast arcs. The time interval between two successive lines in the burning arc has to be one day, and a partial-day increment from the antepenultimate line to the last two lines is permitted. Note that, when the solution is verified, the state and mass of each Mining Ship will be propagated by numerically integrating the differential equations of the state and the mass, of which the thrust will be approximated by a third Lagrange interpolating polynomial.

b. Event ID = 0, −2, −3, −4 or asteroid ID

The events of launches, rendezvous, and flybys are all represented by two lines consisting of the values of epochs, positions, velocities, and masses immediately before and after the events. The two lines corresponding to launch should be listed with the same epochs, positions, and masses, but with different velocities, of which the first one is the heliocentric velocity of the Earth, and the second one is the heliocentric velocity of the Mining Ship. The two lines corresponding to rendezvous should be listed with the same epochs, positions, and velocities, but with different masses as the ship unloads a miner or retrieves resources. The two lines corresponding to planetary flyby should be listed with the same epochs and positions, with the two heliocentric velocities of the Mining Ship satisfying the GA constraints, and with the mass difference for Earth flyby being equal to the mass of resources unloaded on the Earth. The errors in position, velocity, and mass will be evaluated by propagating the state and mass of the Mining Ship between two successive events (event IDs 0, −2, −3, −4 or asteroid ID).