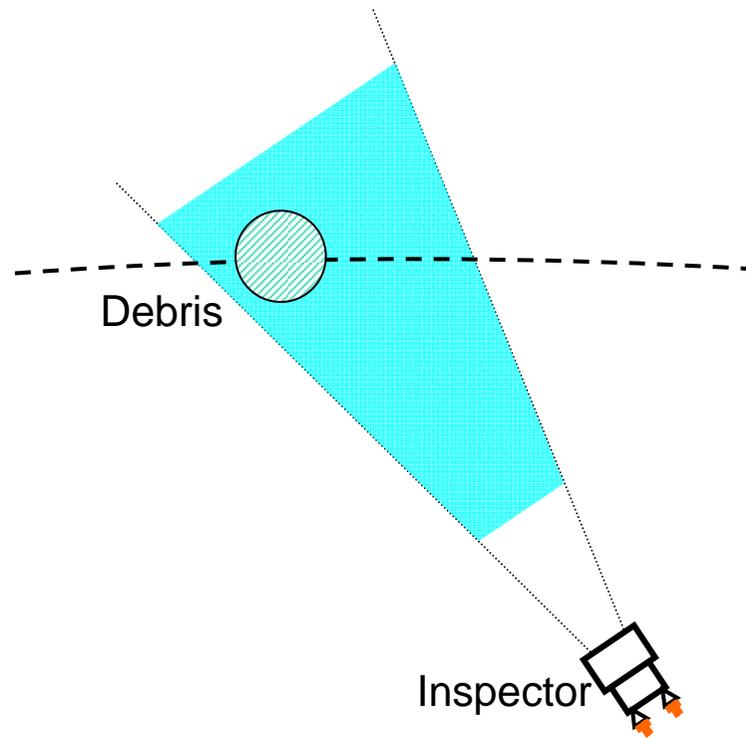


Welcome to 6th Spacecraft Control System Design Contest

June 10, Friday
14:40 – 16:40
at Room A1



The Theme of the 6th Spacecraft Control System Design Contest is
“Debris Inspector”

Outline of the problem

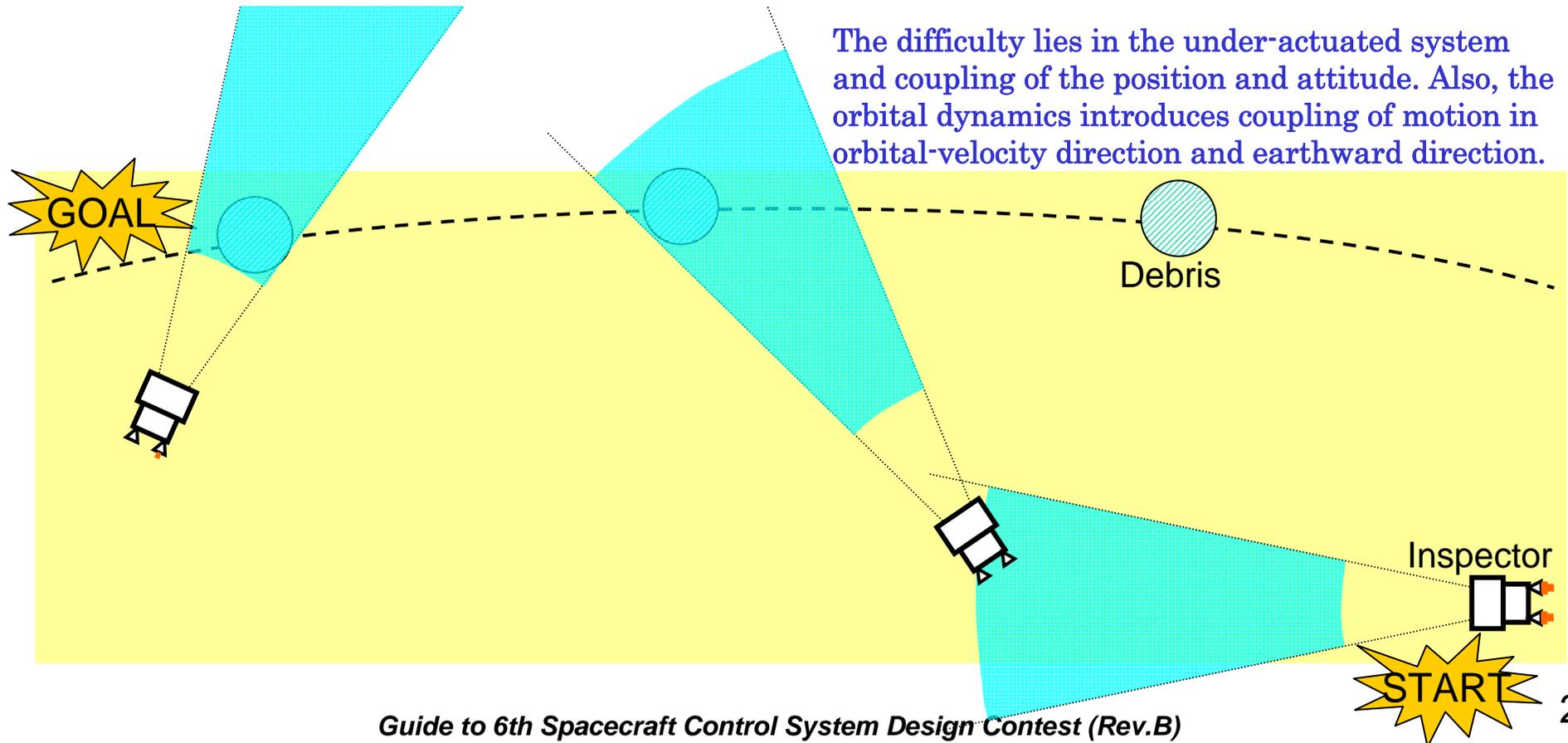
An inspector spacecraft is orbiting the earth. It tracks a debris flying nearby and orients its telescope to monitor the debris for the specified period of time.

Evaluation is made how efficiently the inspector monitors the debris (ratio of the total monitor time to total delta V shall be maximized.)

In the beginning, both the debris and the inspector spacecraft are in a near-circular orbit. The initial relative position and velocity of the debris is unknown beforehand.

The inspector has only a pair of thrusters. Each thruster can output a continuous thrust from zero to the upper limit. The telescope can monitor the debris when the debris distance is within the specified range and the debris direction is within the specified field of view.

The difficulty lies in the under-actuated system and coupling of the position and attitude. Also, the orbital dynamics introduces coupling of motion in orbital-velocity direction and earthward direction.



- Model of the debris

The debris flies in a circular orbit with the orbital rate of 1.0×10^{-3} rad/s.

- Coordinates

The Hill coordinates is defined as follows (Fig. 1):

- Origin O_D : the c.m. of the debris
- x-axis x_D : along the zenith of the debris
- y-axis y_D : along the orbital velocity of the debris
- z-axis z_D : along the angular momentum vector of the debris's orbital motion

The reference frame ($O_R-x_Ry_R$) is defined such that it is inertially fixed and coincides with the Hill coordinates at $t=0$.

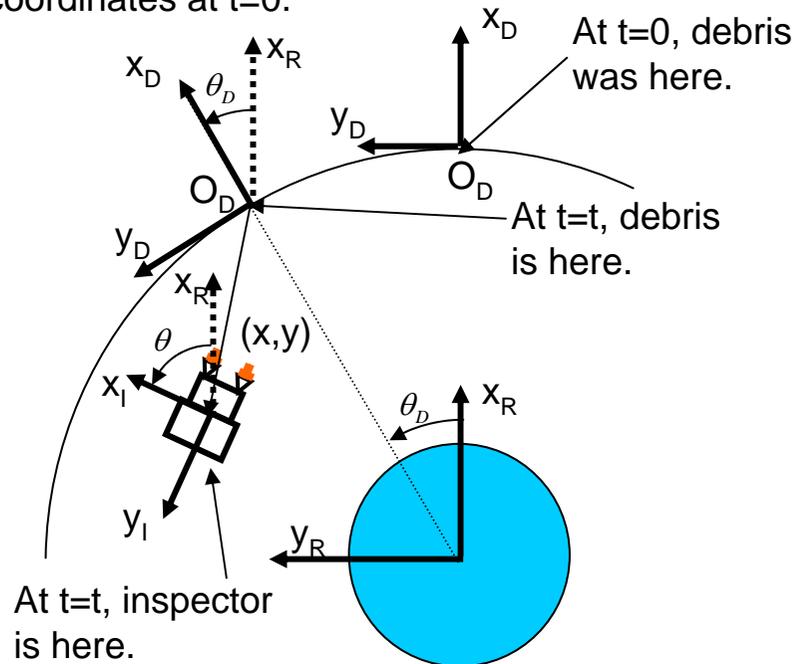


Fig 1. Definition of the Hill coordinates

- Model of the inspector

The debris inspector flies in the same plane as the debris.

Thruster nozzle position and direction: see Fig. 2.

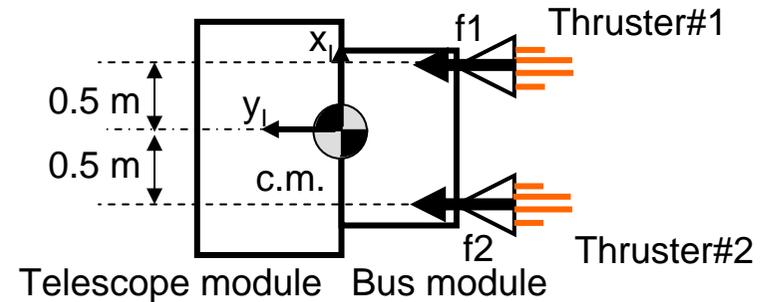


Fig 2. Thruster configuration

Thruster output: Thrusters #1 and #2 generate forces f_1 and f_2 , respectively. The generated forces are continuous between 0.0 to 5.0 N.

Mass: 100 (dry mass) + m_f (fuel mass) [kg]
 m_f begins with 4 kg and decreases as

$$\frac{dm_f}{dt} = -\frac{f_1 + f_2}{gI_{sp}}$$

where g is gravitational acceleration (9.80 m/s^2) and I_{sp} is specific impulse (100 s).

Moment of inertia around its c.m. (center of mass): I_I . I_I begins with 52 kgm^2 and decreases as

$$\frac{dI_I}{dt} = \frac{R^2}{2} \frac{dm_f}{dt}$$

where R is representative radius (1 m).

- Monitoring the debris

The telescope can monitor the debris when the debris distance is within the specified range and the debris direction is within the specified field of view (Fig. 3).

- Initial conditions

The position and velocity of the inspector are given in the Hill coordinates. The position, velocity, attitude and body rate of the inspector are detectable but unknown beforehand.

- Equations of motion

a) Translational motion

$$\ddot{x} = 2\omega\dot{y} + 3\omega^2x + a_x$$

$$\ddot{y} = -2\omega\dot{x} + a_y$$

$$\begin{pmatrix} a_x \\ a_y \end{pmatrix} = \frac{1}{m_I} \begin{pmatrix} \cos(\theta - \theta_D) & -\sin(\theta - \theta_D) \\ \sin(\theta - \theta_D) & \cos(\theta - \theta_D) \end{pmatrix} \begin{pmatrix} 0 \\ f_1 + f_2 \end{pmatrix}$$

(x, y) : position of the inspector in the Hill coordinates

(\dot{x}, \dot{y}) : velocity of the inspector in the Hill coordinates

(a_x, a_y) control acceleration by thrusters in the Hill coordinates

ω : orbital rate of the debris (1.0e-3 rad/s)

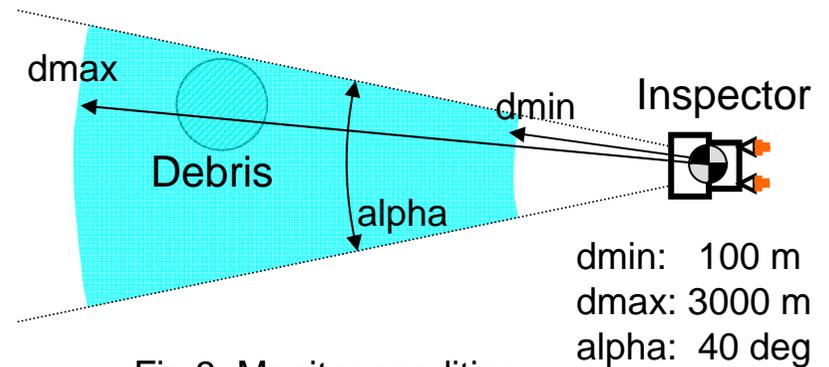


Fig 3. Monitor condition

b) Rotational motion

$$\ddot{\theta} = \frac{f_1 r - f_2 r}{I_I}$$

r: moment arm of the thruster (0.5 m)

- Detailed specifications of software to be prepared by participants

Matlab[®] program (“m file”) should be prepared in the form of the following function. Please refer to the sample program to be distributed for the detailed information such as the size of the vectors.

```
function [f1, f2] =Control(pos,vel,the,dthe,ml,ll,mF,theD,Tmon,t,smt)
```

INPUTS

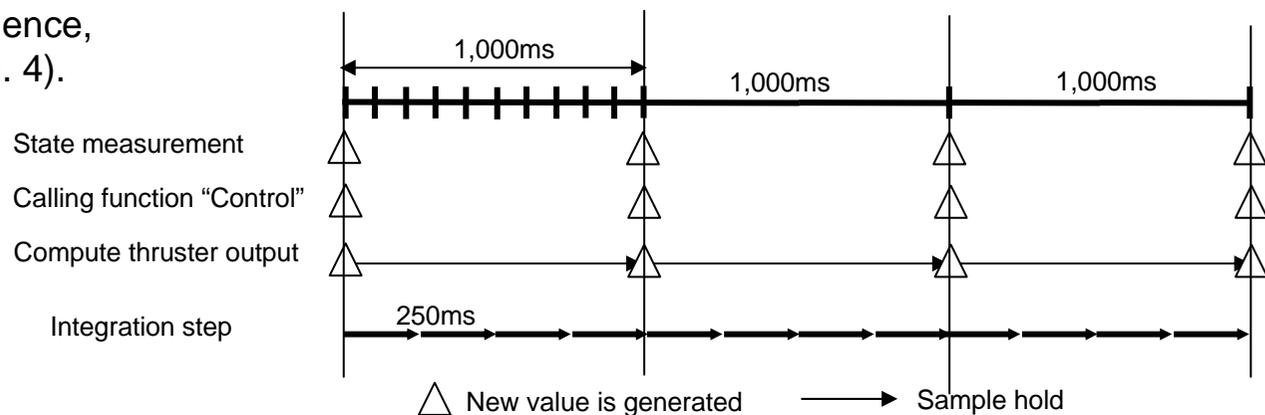
- “pos”: the position of the c.m. of the inspector expressed in the Hill coordinates [m]
- “vel”: the velocity of the c.m. of the inspector expressed in the Hill coordinates [m/s]
- “the”: the attitude of the inspector [rad]
- “dthe”: the body rate of the inspector [rad/s]
- “ml”: the mass of the inspector [kg]
- “ll”: the moment of inertia of the inspector around its c.m. [kgm²]
- “mF”: the mass of remaining fuel [kg]
- “theD”: the travel angle of the debris [rad]
- “Tmon”: total monitor time [s]
- “t”: simulation time [s]
- “smt”: total simulation time [s]

OUTPUTS

- “f1, f2”: the thruster command [N]

Regarding calling/calculation sequence, please see timing chart below (Fig. 4).

There is no time delay in measurement or actuation.



Matlab is a trademark of MathWorks Inc. (<http://www.mathworks.com/index.shtml>)

Fig. 4 Calling/calculation sequence

- Contest procedure

Participants (an individual or a team) should prepare Matlab[®] program to realize their original control algorithms. These programs will be installed into PC* at the contest site and their performance will be displayed on screen using computer graphics (these simulators and graphics will be prepared by the contest organizer). Short (approximately 5 min) presentation should also be given by the participants to describe their controller designs.

The controller design which receives the best evaluation will be awarded.

*The PC at the contest site uses Matlab version 7.7.0 (R2008b) installed on Windows-XP. Participants have chances to install their programs and check interfaces before the contest.

- Evaluation

Evaluation is made from two points of view.

- 1) Maximize the total monitor time
- 2) Minimize the fuel consumption

The **monitoring efficiency** is defined as the ratio of total monitor time to the total simulation time multiplied by the ratio of the remaining fuel to the initial fuel. The monitoring efficiency is expressed in the percentage and is rounded off to the integer value (i.e. the LSB of the monitoring efficiency is 1%).

Each participant is given two simulation cases which are the same among the participants.

The controller design that **maximizes the average value of the monitoring efficiency** will be awarded.

If two or more controller designs achieve the same maximum monitoring efficiency, they are given another simulation case. If their results are the same again, the prize will be shared.

Student Category 1st Prize: (with ¥50,000 extra prize*)
General Category 1st Prize: (with ¥30,000 extra prize*)

*The amount of extra prize may be changed.

- Contest venue and schedule

The contest will be held at Room A1. The preparation room (Room C2) is provided for the participants to install their programs and check interfaces. The tentative schedule is as follows;

May 27 (Fri) Deadline for contest application
May 30 (Mon) E-mail sent to the representative applicants for confirmation of the e-mail address
June 9 (Thu) 16:30-18:30 Preparation at Room C2 (installation, interface check, etc.)
June 10 (Fri) 10:30-12:00 Preparation at Room C2 (installation, interface check, etc.)
June 10 (Fri) 14:40-16:40 Contest at Room A1
June 10 (Fri) 19:00-21:00 Commendation & Closing Ceremony on the Tropical Beach
(Award ceremony)

- How to apply

Please fill in the following application form and send it to the contest organizer by May 27 (Fri). If you make entry as a group, please write the group name and the representative person.

Yoshikawa.Shoji@ap.MitsubishiElectric.co.jp

----- Application Form to ISTS 6th Spacecraft Control System Design Contest -----

Category: Student or General

Name:

Affiliation:

Address:

TEL:

E-mail:

- Revision history

11.04.28 Contest guide and sample program A was created (Rev. A).

11.05.24 Rev. B was created. There are 3 updates.

1) In page 4, the equation for control acceleration is corrected.

2) Revision history is added in page 8.

3) The M-files "Dlmain.m" and "Dlanim" are corrected in the sample program B.

(Please refer to "readme.txt".)