FTB (Flying Test Bed) Experiment for Lunar Landing

Shuichi SASA, Space Technology Research Center, E-mail: sasa@nal.go.jp

Keywords: SELENE, Flying Test Bed (FTB), Moon Landing, Stereo Camera, Model Following

1. Introduction
An automatic lunar landing mission (SELENE-B) is now being studied in the Japanese SELenological and ENgineering Explorer project. The objectives of the mission are to develop technologies for future lunar exploration and to acquire scientific data of the moon. In this mission, a lander will make a soft-landing at a predetermined point meaningful for lunar science. Obstacle detection and controls for safe landings are serious technical subjects.

In this paper, the flight test results of a SELENE-B flying test bed (FTB), and the design of a model-following controller are described.

2. Flight experiments of FTB
The FTB is similar to the SELENE-B lander in size, mass, and moments of inertia. A jet engine is used as its main thruster, and it is equipped with a reaction control system (RCS) powered by engine bleed air.

The flight experiments using the FTB were conducted in Hokkaido over the past 3 years with the National Space Development Agency (NASDA) and the Institute of Space and Astronautical Science (ISAS). The FTB’s dynamics, basic performance of the FTB’s Guidance, Navigation & Control System (GNCS) and obstacle avoidance sensor systems were evaluated in the experiments. Figure 1 shows the FTB just before landing.

3. Model validation and GNCS evaluation
Using the flight test data, the mathematical model of the FTB was evaluated.

Figure 2 shows the recorded and simulated time histories of a flight under wind turbulence. Both time histories coincide well and the reliability of the mathematical model used in the simulation was evaluated.

In the experiments, the lander was able to land at a specified target within 50cm distance, and nominal GNCS performance was verified.

4. Stereo Camera Evaluation
Obstacle detection technology using a stereo camera was evaluated in the flight experiments.

The stereo camera system was attached facing downwards on the FTB (Figure 3 up).

Figure 3 (left) shows an image of a model crater placed on the ground and geographical feature detection results by the stereo camera (right). The shape of the crater was detected accurately. These results were obtained after careful calibration of the optical systems. Such calibration in space becomes a serious technology in an actual lunar landing.
5. Model-Following System using FTB

It would be desirable for the FTB to have the same dynamical characteristics as the SELENE-B lander for GNCS development. A model-following system to compensate for the differences between the FTB and SELENE-B was designed.

Figure 4 shows an overview of the Dynamical Closed Loop Test (DCLT) of the lander. The model-following controller comprises a Proportional Integral Derivative (PID) controller and a mathematical model of the lander. A high-order controller is firstly designed by a method such as H-infinity or mu-synthesis, and PID controller parameters are determined by a controller order reduction method in the frequency domain. Figure 5 shows simulation time histories.

The response curves of FTB are almost same as those of SELENE-B simulation.

6. Conclusions

The flight test results of a SELENE-B flying test bed (FTB), and the design of a model-following controller are described.

References