Guidance and Control Law for D-SEND#2

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Japan Aerospace Exploration Agency (JAXA) is conducting D-SEND which stands for 'Drop test for Simplified Evaluation of Non-symmetrically Distributed sonic-boom'. The program consists of two phases. The objective of phase I (D-SEND#1) is to establish measurement systems and to obtain base data for sonic-boom. Two flight tests were conducted in May 2010 at the Esrange test site in Sweden, and their missions were completed successfully. The flight tests of phase II (D-SEND#2) will be also performed at the Esrange in July 2013. The objective of D-SEND#2 is to acquire sonic-boom data using a flight experiment vehicle whose configuration is optimized to reduce sonic-boom as shown in Fig. 1 and Table 1. The experiment vehicle is to be lifted to high altitude by a stratospheric balloon, from which it is released at the altitude of 30km and accelerates in free fall. The vehicle will generate sonic-boom at the target Mach number, and sonic-boom will be measured by microphones on the ground and in the air. Therefore, the vehicle has to accomplish various mission requirements such as range control to the measurement system, Mach number and attitude at the start of measurement, and so on.

This paper describes guidance and control law for the D-SEND#2 vehicle. A flight trajectory is designed to achieve those mission requirements. Therefore, this paper summarizes the mission requirements of the D-SEND#2 program. Then the most appropriate flight condition for the sonic-boom measurement will be defined as the target flight condition. A flight trajectory from separation to the target flight condition is optimized for the minimum and maximum flight range respectively by using the simplex method. The guidance and control law comprises of the reference trajectory generation function and the attitude control function. The reference trajectory generation function defines a reference trajectory based on the flight trajectories which are a priori obtained to realize the minimum and maximum flight range. The attitude control function is designed to track the reference trajectory with sufficient accuracy and is designed using the hierarchy-structured dynamic inversion (HSDI) technique.

Fig. 2 and Fig. 3 illustrate the typical result of 6 degree-of-freedom numerical simulation with no error. Table 2 shows the result of Monte Carlo simulations (MCS).

Table 1: Vehicle specifications

Item	Value [Unit]
Length	7.68 [m]
Reference Area	4.891 [m^2]
Mean Aerodynamic Chord	1.912 [m]
Mass	1000 [kg]

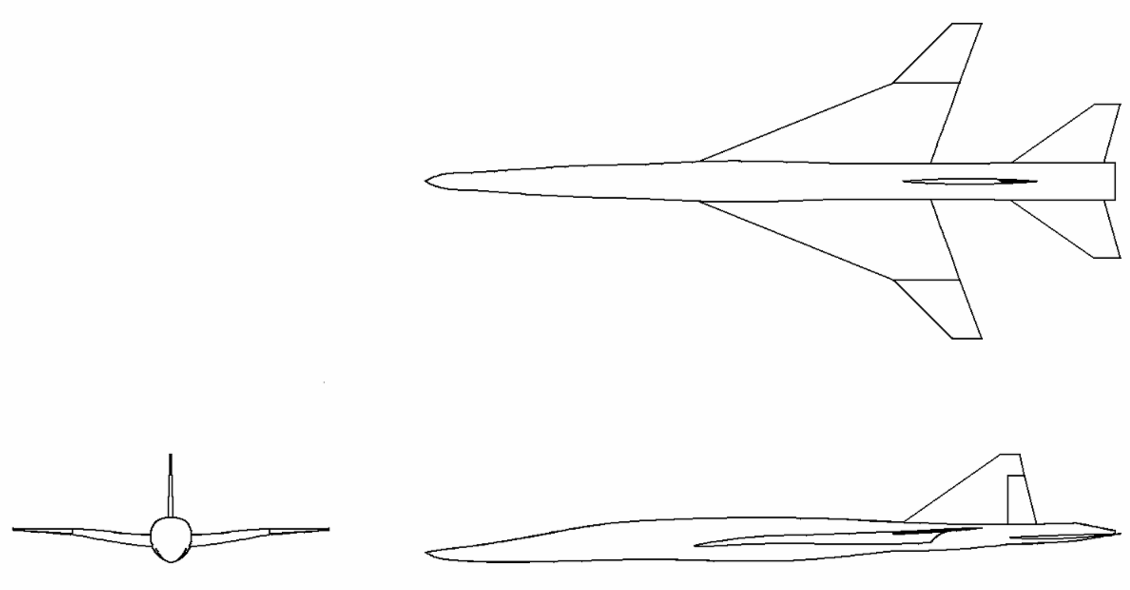

Fig. 1: Vehicle configuration

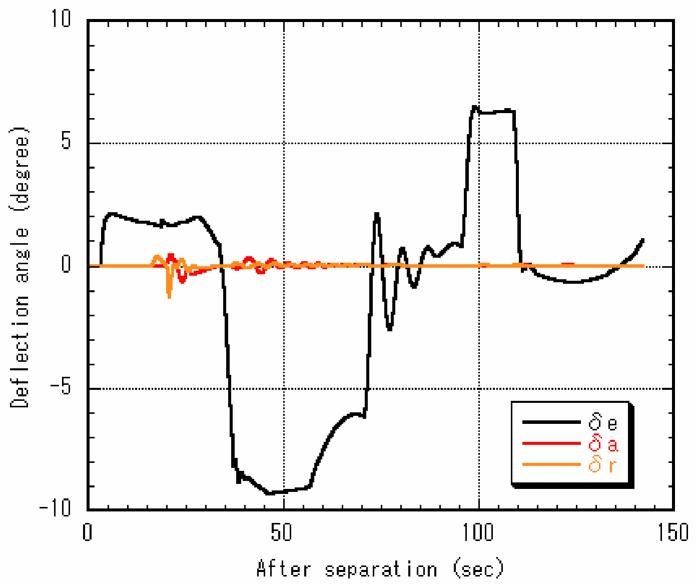

Fig. 2: Time histories of control devises

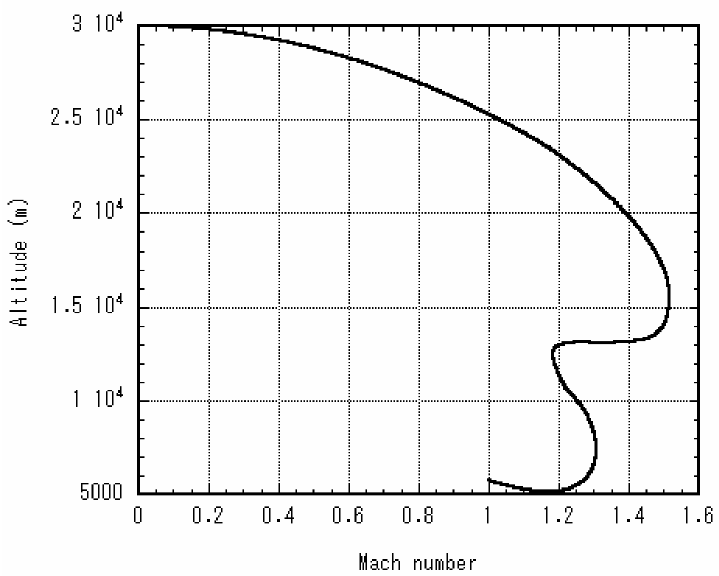

Fig. 3: Altitude-Mach number diagram

Table 2: Result of MCS

Category	Probability [%]
Success	90.4
Mission failure	4.5
Constraint violation	3.4
Flight failure	1.7