Experimental Flight of KIT Student's Rocket in France

Koji Okuda*, Yuji Ujimoto*, Yuta Otsuka*, Takaya Sato*, Takuya Shidooka*, Daijiro Semba*, Kenichi Tominaga*, Junichi Fukuda*, Yuta Yamamoto*, Kazuki Wada*, Shinichi Sagara*, and Koichi Yonemoto*

*Kyushu Institute of Technology, 1-1 Sensui, Tobata, Kitakyushu, Fukuoka, 804-8550, Japan
(Tel/Fax : +81-93-884-3179; E-mail: yonemoto@mech.kyutech.ac.jp)

Abstract: KIT Student's Rocket has been developed by a student group of Kyushu Institute of Technology for rocket launch campaign held at La Courtine in France since 2006. This paper introduces the newest design of rocket. The rocket has the body length of 2120mm, and weighs 14.6kg and can reach to an altitude of about 700m by a solid rocket motor provided by CNES (the French Centre National D'Etudes Spatiales). The rocket is controlling rolling attitude during ascent phase and then deploying a parafoil at the apogee of the trajectory for recovery guidance to an aiming point.

Keywords: Rocket, Parafoil recovery system, Guidance and control, Roll control by aileron

1. INTRODUCTION

Under the control of CNES (Centre National D'Etudes Spatiales), the French non-profit organization Planète Sciences has been conducting for amateur clubs, such as university students and young engineers, an experimental rocket launch campaign called "La Campagne Nationale de Lancement" .[1]

The purpose of the rocket launch campaign is not only to make their dream come true but also to teach them how the actual development is processed.

In addition to the technical process toward rocket launch, the amateur clubs learn a lot of team work and project management concerning schedule and budged. These kinds of practical activity are important and necessary aspects for actual development [2].

A student group of Kyushu Institute of Technology has been participated in the French experimental rocket launch campaign since 2006 [3-5]. This paper focuses on the technical aspect to introduce the newest design and development of the rocket launched in 2008.

After the ignition, the rocket reaches to an altitude of 500m in 11 seconds. During the coasting flight, the roll is controlled by ailerons to maintain the doors of ejection system bay upward. At the apogee, the door of ejection system bay is opened, and a drogue chute is ejected to deploy parafoil. When the rocket begins to perform steady gliding flight and the onboard microcomputer establishes signal processing from GPS (Global Positioning System) satellites, the navigation calculation starts to guide the rocket to an aiming point. Fig.1 shows the mission sequence.

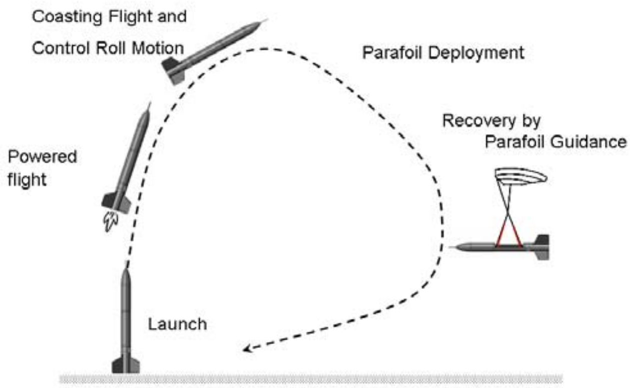

Fig. 1 Mission sequence

2. ROCKET PROFILE

2.1 Outline of rocket

The KIT student's experimental rocket for the rocket launch campaign in 2008 consists of four major structural components called nose cone, avionics bay, ejection system bay and engine bay as shown in Fig. 2. The rocket has the total length of about 2.3m including the pitot tube, and weighs about 15kg. The major dimensions of rocket and aerodynamic parameters are summarized in Table 1.

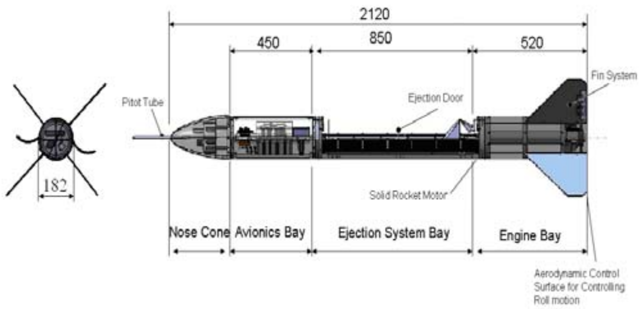

Fig. 2 KIT student's experimental rocket

Table 1 Major dimensions and aerodynamic parameters

Specifications			Requirement [6]
Total length L	[mm]	2,314	≤ 4000
Body diameter ϕ	[mm]	182	$40 \leq \phi \leq 200$
Mass M	[kg]	14.8	≤ 15
Lift derivative C_n	[-]	19.2	$15 \leq C_n \leq 40$
Moment derivative $C_m = M_S \times C_n$	[-]	54.5	$40 \leq C_m \leq 100$
Drug coefficient C_D	[-]	0.34	NA
Static margin M_S : in terms of body diameter (before combustion)	[-]	2.8	$2 \leq M_S \leq 6$
Launcher exit speed	[m/s]	21	≤ 20

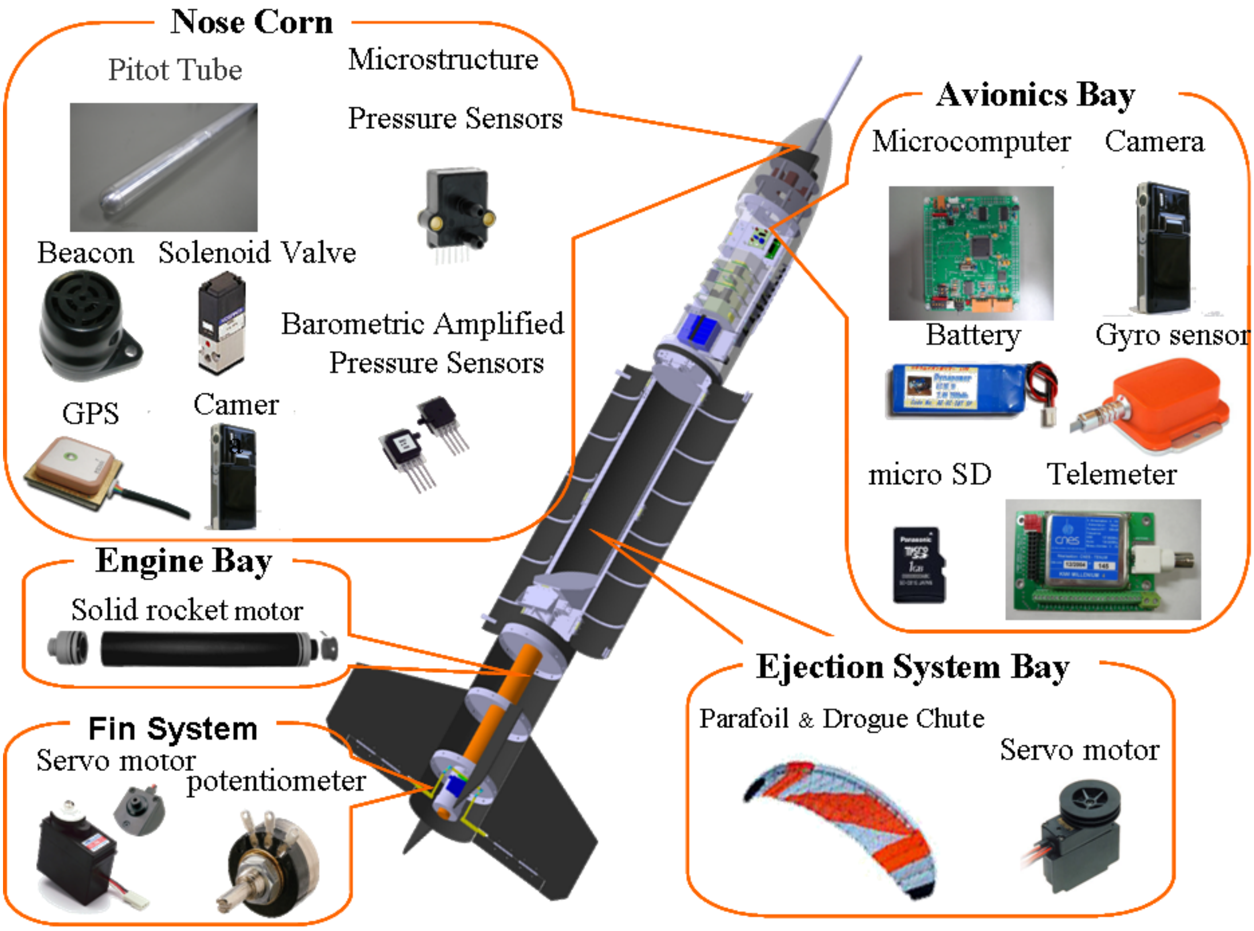

Fig. 3 Onboard equipments

2.2 Structure

The nose cone is made of GFRP (Glass Fiber Reinforced Plastic). The rocket body is a monocoque structure made of four CFRP (Carbon Fiber Reinforced Plastic) tubes that are reinforced by aluminum alloy flanges and stringers. These body tubes are fastened at each flange by bolts. The four fins are made of CFRP plate to realize static stability. The two fins in the opposite side have ailerons, respectively.

Onboard equipments in the rocket are shown in Fig. 3. A pitot tube, a GPS antenna and a video camera for forward view are installed in the nose cone.

Three microcomputers, a GPS processor, a gyro sensor, a video camera for backward view, batteries, a telemeter, and a search beacon are equipped in the avionics bay.

There are a drogue chute, a parafoil, two servo motors that pull up risers to parafoil, and two servo motors that open the door in the ejection system bay.

Two servo motors that actuate ailerons of fin system and a solid rocket motor are equipped in the engine bay.

3. AVIONICS

The experimental rocket has an avionics system that consists of four electronic subsystems, such as NGC (Navigation, Guidance and Control) system, actuator system, telemetry system, and search system as shown in Fig. 4.

3.1 Navigation, Guidance and Control System

The NGC system has three microcomputers. The first microcomputer processes GPS data for navigation.

The Second microcomputer calculates control commands of aileron (aerodynamic control surface) based on the gyro data, and actuates servo motors by PWM signal.

The Third microcomputer sends flight data to telemeter system and writes the data in the SD card. The specifications of the microcomputer, GPS and gyro sensor are shown in Table 2, Table 3, and Table 4, respectively.

Table 2 Microcomputer (SH7047)

CPU	Sixteen 32bit general registers Maximum clock rate: 49.152 MHz
Memory	ROM:256Kbytes, RAM:12Kbytes
Timer	Five 16bit timer channels
Serial communication interfaces (SCI)	3 channels
I/O ports	73 input/output pins,16 input pins

Table 3 GPS (Superstar Ⅱ)

Dimension	46 x 71 x 13 [mm]
Mass	22 [g]
Serial communication	2 x TTL level asynchronous data ports from 300 up to 19200 bps
Output message	NMEA or proprietary binary (NMEA types GGA, GSA, GSV, RMC, ZDA, GLL plus proprietary messages)
Sampling frequency	5 [Hz]

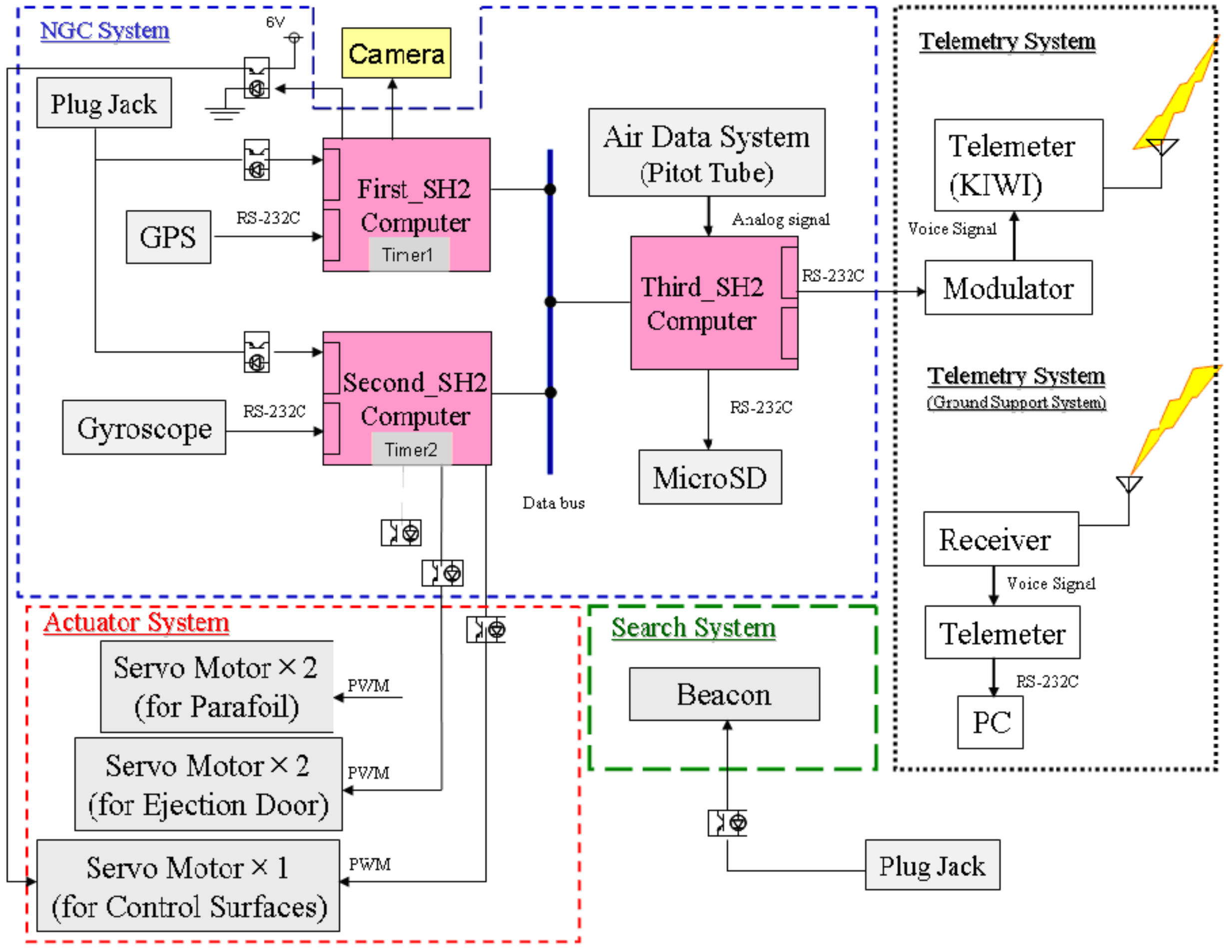

Fig. 4 Onboard avionics

Table 4 Gyro sensor (MTi)

Dynamic range	all angles in 3D
Angular resolution	0.05° RMS
Static Accuracy (roll/pitch)	<0.5°
Static Accuracy (heading)	<1.0°
Dynamic Accuracy	2° RMS
Update Rate	Max 100 Hz

3.2 Telemetry System

The block diagram telemetry system is shown in Fig. 5. The flight information is converted to voice signal and transmitted by the telemetry system called KIWI [7] to the ground support equipment of CNES. The specification of the telemetry system is shown in Table 5.

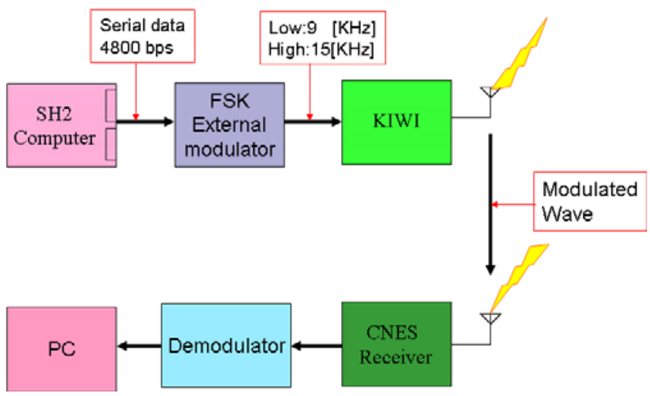

Fig. 5 Onboard and ground telemetry system

Table 5 Telemetry system

Transmission frequency 1, 2	137.95, 138.5 [MHz]
Serial communication	4800 [bps]
FSK modulator chip	XR2206
FSK demodulators chip	XR2211
Low state, high state	9 [KHz], 15 [KHz]

3.3 Power supply system

The power supply system has four batteries of 7.2 Volts DC as shown in Fig. 6.

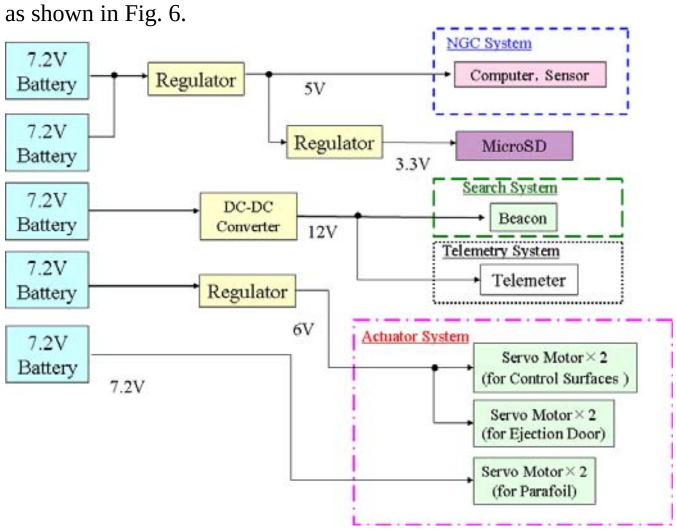

Fig. 6 Power supply system

The first and the second batteries supply 5V DC through the regulator to the NGS system. The third battery supplies 12V DC through the DC-DC converter to the telemetry system and the search system respectively. The fourth and the fifth batteries supply 7.4V DC to the servo motor used for controlling parafoil risers and regulated 6V DC to the servo motors to open the ejection doors and to control ailerons of fin system.

4. Ejection system bay

4.1 Parafoil recovery system

The parafoil recovery system is shown in Fig. 7. The servo motors draw the right and left control lines of the parafoil to deflect the right and left trailing edges respectively. The deflection of trailing edge causes drag increase to yield yawing moment for turn maneuver.

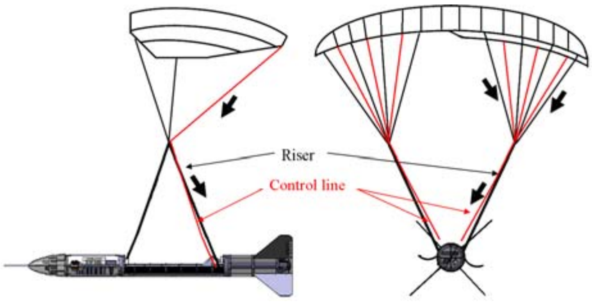

Fig. 7 Parafoil risers and control lines

4.2 Ejection system

The parafoil ejection sequence is shown in Fig. 8. A drogue chute is ejected immediately after the ejection door is opened. The drogue chute pulls out the parafoil to deploy.

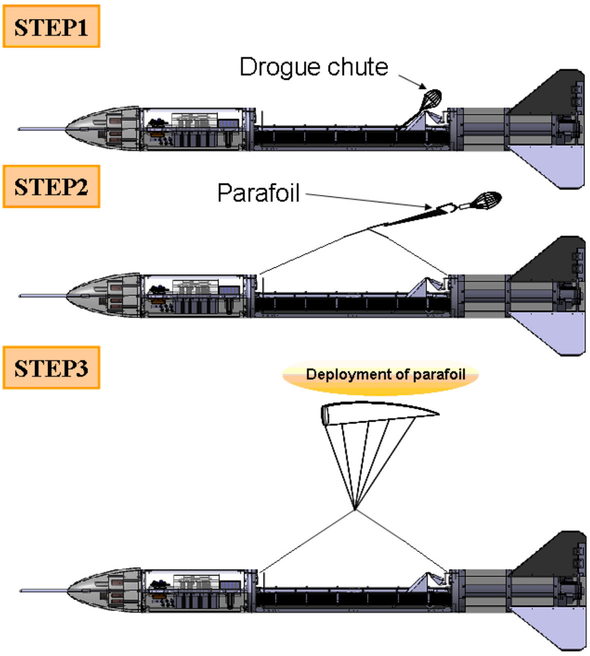

Fig. 8 Ejection sequence

The ejection system bay is shown in Fig. 9 and Fig. 10. Two ejection doors are attached by spring hinges on each side of body. The parafoil is folded up and stored in the container made of cloth. Since the container cloth is stuck to inside of the bay by Velcro, it can be removed and attached easily.

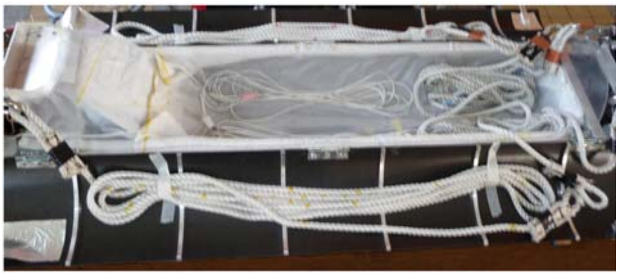

Fig. 9 Parafoil container

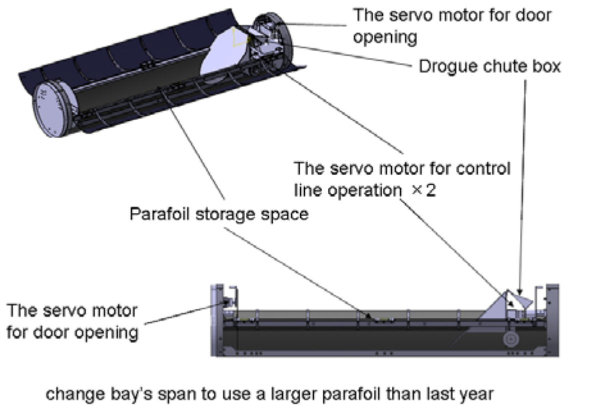

Fig. 10 Ejection system

The drogue chute ejection system is shown in Fig. 11. There is a sector board to lock the drogue chute ejection box. The servo motor rotates the sector board to release the drogue chute ejection box immediately after the ejection doors open.

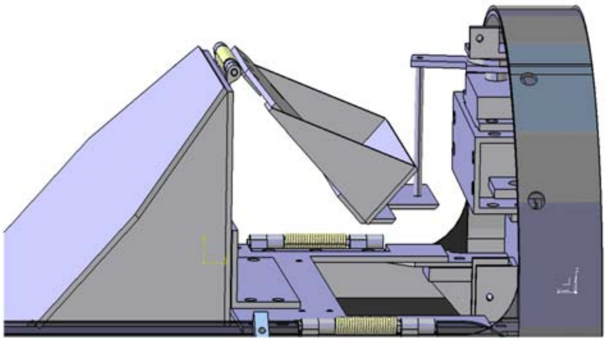

Fig. 11 Drogue chute ejection system

5. Fin system

The fin system is illustrated in Fig.12 and Fig. 13.

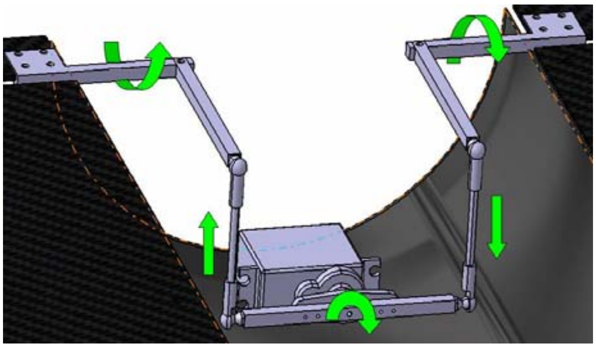

Fig. 12 Servo motor linkage of aileron

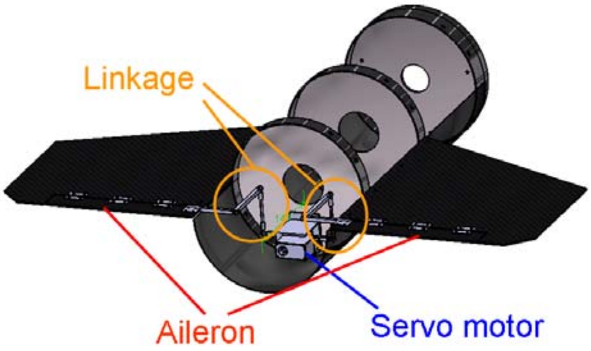

Fig. 13 Fin system

The two ailerons are integrated to the two fins in the opposite side respectively. The each aileron is connected to the servo motor by a mechanical link shaft.

The purpose of the fin system with aileron is to control rolling motion of rocket so as to eject the drogue chute upward. If the drogue chute is ejected downward, there is a risk that the parafoil drawn by the drogue chute collides with the body of rocket to result in deployment failure. Therefore the rolling attitude at the instance of drogue chute ejection is considered one of the important events to achieve successful parafoil gliding.

6. GROUND TESTS

The basic ground tests conducted prior to the final review tests are introduced.

5.1 Gliding test

Fig. 14 shows the gliding test using a full-scale dummy rocket and the actual parafoil. The dummy rocket was released from the emergency stair of the eighth floor of a tall building in the university campus. The glide ratio and the turning radius were measured by the gliding tests.


Fig. 14 Parafoil gliding test

5.2 Wind tunnel test

The wind tunnel test was conducted to demonstrate the control law of fin system using a test setup as shown in Fig. 15. It took about 2 seconds for the rocket to achieve the target angle from a large disturbed roll angle for the free stream velocity of 20m/s.

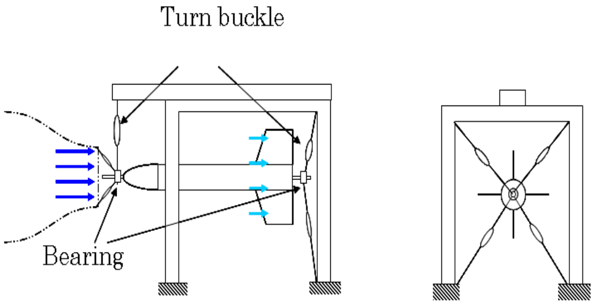

Fig. 15 Wind tunnel test of fin system

7. ROCKET LAUNCH CAMPAIGN

Fig. 16, 17, and 18 show the pictures of actual rocket launch.

The KIT student's experimental rocket was launched in July 31th, 2008 in the La Courtine military camp. After the apogee, the rocket has succeeded to eject the parafoil. But it couldn't control the parafoil completely. Finally the rocket was lost in the forest of La Courtine.

However, acquired data is only the photographs and video movies because the telemeter was cut off immediately before the launch, and it was not able to collect the main body of the rocket taken a picture of from the distance.


Fig. 16 Ignition of rocket

Fig. 17 Powered flight of rocket

Fig. 18 Gliding using parafoil

ACKNOWLEDGMENTS

The authors would like to thank all the volunteers of the Planete Sciences and the specialists of CNES for their kind supports and hospitalities when we faced critical problems in La Courtine. In addition to aforementioned personnel, the authors wish to extend the acknowledgment especially to Mr. Christophe Scicluna for his vital encouragement of our participation in this rocket launch campaign in France.

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