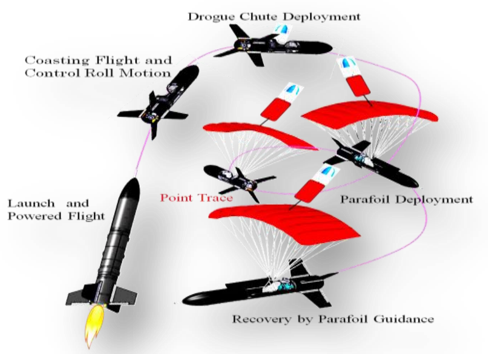
Report on the current state of “Japanese University Rocket Projects”

Version 1.0



October 2011

UNISEC
University Space Engineering Consortium

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INTRODUCTION

University Space Engineering Consortium (UNISEC) has compiled a report on the current state of " Report on Japanese University Rocket Projects" in October 2011. The latest version of report has also been made available on the Internet at the UNISEC web site.
http://www.unisec.jp/member/jurocket-e.html

In response to requests, the UNISEC continues this activity and will publish a revised and updated edition of the above report in the future.

We hope this report can support professionals and students who are interested in Space Engineering Education in Japanese Universities.

Comments, queries and information with respect to this report are most welcome.

UNISEC
University Space Engineering Consortium

University Space Engineering Consortium
Central Yayoi 2F, 2-3-2 Yayoi, Bunkyo-ku
Tokyo 113-0032, Japan
Tel/Fax:+81-3-5800-6645
E-mail:einfo@unisec.jp

www.unisec.jp

Report on
Japanese University Rocket Projects

University/ Organizer	**Akita University**	
Supervisor	Yutaka WADA Ph.D. Assistant Professor	
Contact	+81-18-889-2806	Email:wada@mono.akita-u.ac.jp
URL	http://www.mono.akita-u.ac.jp/ http://www.noshiro-space-event.org/en/index.html	

Keywords

Hybrid Rocket, Launch, Combustion, Space Education

【1】Overview and Science Highlights of the project

1. Application of low melting point thermoplastics to hybrid rocket fuel
2. Development of a small sounding hybrid rocket
3. Application of small hybrid rocket to science and engineering education with experience of project execution for university student

Launch site information

1. Noshiro space park (Asanai 3rd Kousai Taiseki-jyo in Akita prefecture)
   Rockets launch and recover from ground and maximum altitude is 500m.

2. Used place of swimming area in Ochiai, Noshiro city, Akita prefecture
   Rockets launch from the beach and recover from sea and maximum altitude is a several ten km high.

Fig.1 Noshiro space park

Fig.2 Sea launch place

Launch history

Date	Name	Altitude	Note
22, Mar. 2010	ASSP09-HTJ-12	150m	Failure to parachute recovery
22, Aug. 2010	ASSP10-HTJ-13	176m	Success to recovery
24, Aug. 2011	ASSP11-HTJ-14	288m	Success to CANSAT carrying

Fig.3 HTJ-12

Fig.4 HTJ-13

Fig.5 HTJ-14

Launch plane

Date	Name	Altitude	Note
xx, Sep. 2011	ASSP11-HTJ-15	500m	Confirmation of float structure
xx, Oct. 2011	ASSP11-HTJ-16	1.2km	Challenge to Sea launch

【2】Achievements in Space Engineering Education through Rocket Activities (or Plan)

Past Rocket Activities

Data	Name	Target
Aug. 2009	5th Noshiro Space Event	Univ. student in Japan
Aug. 2010	6th Noshiro Space Event	Univ. student in Japan
Aug. 2011	7th Noshiro Space Event	Univ. student in Japan
Mar. 2010	Rocket Girl Training Course	High school student in Akita

Akita university curriculum

Name: Project Seminar in department of mechanical engineering

Target: 2nd Akita univ. student (1 year)

Content: Development of small hybrid rocket and launch in Noshiro Space Event

Plan Rocket Activities

Data	Name	Target
Aug. 2012	7th Noshiro Space Event	Univ. student in Japan

【3】Papers

"Combustion model of tetra-ol glycidyl azide polymer", Yutaka Wada, Yoshio Seike, Nobuyuki Tsuboi, Katsuya Hasegawa, Kiyokazu Kobayashi, Makihito Nishioka, Keiichi Hori, Proceedings of the Combustion Institute, Vol.32, pp.2005-2012 (2009)

"COMBUSTION MECHANISM OF TETRA-OL GLYCIDYL AZIDE POLYMER AND ITS APPLICATION TO HYBRID ROCKET", Yutaka Wada, Yoshio Seike, Makihito Nishioka, Nobuyuki Tsuboi, Toru Shimada, Katsuya Hasegawa, Kiyokazu Kobayashi, Keiichi Hori, Advancements in Energetic Materials and Chemical Propulsion by Begell House, Inc. pp.1099-1114, (2009)

【4】Recent overseas researchers who collaborated with us (for a short period)

n/a

【5】Important mention, if any

n/a

University/ Organizer	**Hokkaido University / Laboratory of Space Systems**	
Supervisor	Harunori NAGATA, Professor	
Contact	+81-11-706-7193	Email: nagata@eng.hokudai.ac.jp
URL	http://mech-me.eng.hokudai.ac.jp/~spacesystem/index_e.html	

Keywords

CAMUI-type Hybrid rocket, Solar orbit transfer vehicle, Liquid droplet radiator, Pulse detonation engine

【1】Overview and Science Highlights of the project

A mission of a rocket is to accelerate payloads such as satellites. Recently, a demand of the launch of micro satellite is drastically increasing. However, there is no small launcher provided for the launch of micro satellites because miniaturizing liquid rocket is difficult and solid rockets using explosives result in high launch cost.

Using CAMUI type hybrid rocket, we develop a small launch system of safe and low cost for micro satellites, and develop a new market of small-scale space utilization.

Milestones to the space;

Launch into 60 km altitude to sample the stratospheric air.

Launch into 100 km altitude to provide micro gravity environments.

【2】Achievements in Space Engineering Education through Rocket Activities (or Plan)

We have been getting to original rocket project since 2008. The members of this project are first year master's degree student in our laboratory. The purpose of this project is to develop an automatic return rocket system with the CAMUI hybrid rocket motor. This system will enable students who develop the CanSat to provide a tool of convenient launch experiment. As the second year of this project, we developed the 1.3-m-long CAMUI hybrid rocket. The rocket have an avionics system which can do wireless communications with ground-based station using the bluetooth technology. And we launched the rocket twice. For a propulsion system, we designed and produced the CAMUI hybrid rocket motor whose thrust level is 310 N. The avionics system is composed of a microcomputer, angular velocity sensors. The data of the sensors are transmitted to a personal computer on the ground by the bluetooth.

【3】Papers

✧ Journal Publications

- Harunori Nagata, Shunsuke Hagiwara, Masahiro Nohara, Masashi Wakita, Tsuyoshi Totani, "Optimal Fuel Grain Design Method for CAMUI Type Hybrid Rocket," 47th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, San Diego, CL, AIAA-2011-6105, July 31-Aug. 3, 2011.
- 野原 正寛, 金子 雄大, 萩原 俊輔, 永田 晴紀, 「遺伝的アルゴリズムを用いた CAMUI 型燃料グレインの最適設計」, 日本機械学会論文集Ｂ編, Vol. 77, No. 777, pp.1249-1258, 2011.
- Yudai Kaneko, Kouichi Kishida, Nobuyuki Oshima, Takuji Nakashima, Masashi Wakita, Tsuyoshi Totani, Harunori Nagata, "Effect of Temporal Variations of Internal Ballistics on Fuel Regression Rate in the CAMUI Hybrid Rocket," Journal of Space Engineering, Vol.3, No.1, pp.52-65, 2010.
- Harunori Nagata, Shunsuke Hagiwara, Yudai Kaneko, Masashi Wakita, Tsuyoshi Totani, Tsutomu Uematsu, "Development of Regression Formulas for CAMUI Type Hybrid Rockets as Functions of Local O/F," 46th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, Nashville, TN, AIAA 2010-7117, 25-28 July 2010.

✧ Dissertations

- 岩城裕樹、水を推進剤とした太陽熱スラスタの熱設計手法の確立およびラバールノズル内超音速流れに伴う伝熱が推力および比推力に与える影響、2010.
- 金子雄大、CAMUI 型ハイブリッドロケットの燃料後退特性におよぼす流れ場の影響、2010
- 松岡常吉、対向流中における固体燃料管内燃え広がりの火炎特性、2010.

✧ Master's thesis

- 亜酸化窒素の触媒分解反応を用いたハイブリッドロケット用点火器の開発
- 液滴ラジエータにおける作動流体の自動循環制御手法
- 拡大する環状流路でのデトネーション波の挙動
- CAMUI 型固体燃料後退速度式の導出方法に関する検討

【4】Recent overseas researchers who collaborated with us (for a short period)

1. Name and Affiliation of Co-researcher
   Research Theme
2. Name and Affiliation of Co-researcher
   Research Theme

【5】Important mention, if any

n/a

University/ Organizer	**Kyushu Institute of Technology** **Space Systems Laboratory**	
Supervisor	Koichi Yonemoto, Prof. Dr. Eng.	
Contact	+81-93-884-3179	Email: yonemoto@mech.kyutech.ac.jp
URL	http://www.mech.kyutech.ac.jp/yonemoto/index.html http://www.mech.kyutech.ac.jp/yonemoto-lab/	

Keywords

Winged Rocket, Hybrid Rocket, Hybrid Navigation, Real-time Guidance, Genetic Algorithm, Robust Control, Dynamic Inversion, CFRP Tank, LOx, LH2

【1】Overview of the Project

The Space Systems Laboratory at the Kyushu Institute of Technology ("Kyutech" hereafter) has been studying unmanned suborbital winged rockets toward the development of eventual fully reusable space transportation systems, since 2005. These are expected to be able to provide reconnaissance for scientific or disaster-preventing purposes. The winged rocket has a novel challenging system as follows:

1) INS-GPS-ADS Hybrid Navigation
   In order to identify flight state precisely, a hybrid navigation that integrates INS-GPS-ADS (Inertial Navigation System - Global Positioning System - Air Data System) is developed.
2) Real-time Guidance
   To ensure flight safety during malfunction, real-time optimal trajectory calculation is essential. A real-time guidance methodology that utilizes Genetic Algorithm (GA) and its implementation on the Field Programmable Gate Array (FPGA) make it possible.
3) Robust Control
   Because the flight speed of reusable spacecraft covers wide range, robust and easily configurable control is necessary. We have developed robust controls based on H_∞ theory, dynamic inversion theory, and adaptive control theory.
4) Carbon Fiber Reinforced Plastics (CFRP) Liquid Oxygen and Hydrogen Tanks
   One of the critical problems of propellant tanks for future reusable space transportation systems is weight reduction by replacing metal components such as aluminum with composite materials. We have investigated liquid hydrogen tank using a clay that can barriers hydrogen gas and liquid oxygen tank using a super engineering plastic which is compatible with oxygen.

In order to evaluate these research themes, we have launched winged rockets that has CFRP structure and the Hybrid Rocket propulsion system time and time again (Fig. 1).

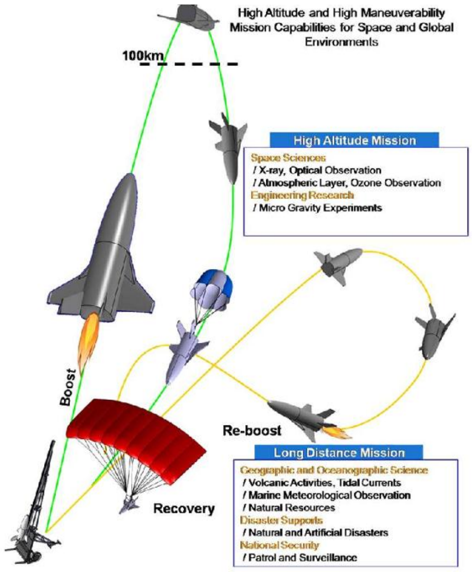


Fig. 1 Unmanned suborbital winged rocket.

【2】Research and Educational Achievements

The development schedule of experimental winged rockets until 2012 is shown in Fig. 2.

The flight experiments of a small-scale experimental winged rocket called WIRES (WInged REusable Sounding rocket) #11, was completed with success in fall 2009.

Kyutech started to design and manufacture two kinds of larger experimental rocket designated WIRES #12 and WIRES #14 in 2009. The former is a conventional rocket without a main wing, and the latter is a winged rocket. WIRES #12 is a pre-experimental rocket aiming to establish the efficacy of the design of the CFRP body structure and new recovery system. WIRES #14 is a winged rocket propelled by a novel hybrid rocket called CAMUI (CAscaded MUltistage Impinging-jet) being developed by Hokkaido University, that will conduct fully autonomous flight using hybrid navigation and real time onboard guidance associated with an advanced control system.

In 2011, Kyutech is going to start developing a larger winged rocket, WIRES #15, to reach an altitude of more than 5 km. This rocket will be able to conduct full real-time onboard guidance taking flight area restrictions into account, and will also be able to demonstrate all the necessary technologies for avionics, structure, subsystems, and propulsion to reach an altitude of 100 km, the entrance of space.

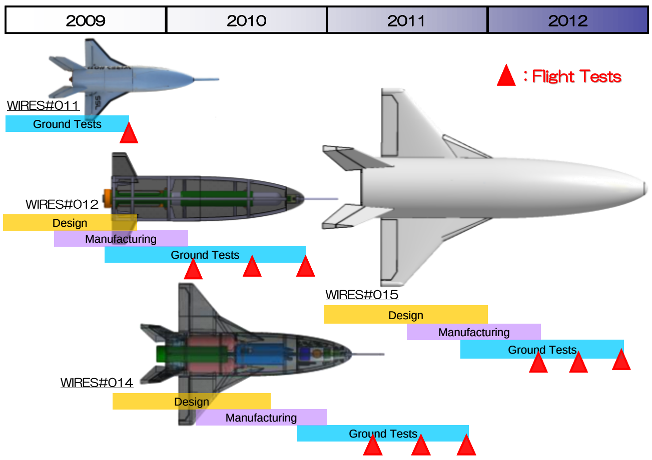


Fig. 2 Development schedule of winged rocket.

(1) Winged Rocket Launch

<u>WIRES #11</u>

The small-scaled experimental winged rocket WIRES #11 (Fig. 3) employs a semi-monocoque structure using GFRP (Glass Fiber Reinforced Plastic) skins and frames/stringers made of wood, has two elevons and two rudders as aerodynamic control surfaces, and is launched by solid rocket motors up to an altitude of about 500 m. The dimensions are shown in Table 1 below. The aerodynamic design employs a body of the HIMES (HIghly Maneuverable Experimental Space vehicle) type, as was defined by JAXA/ISAS (Japan Aerospace Exploration Agency / the Institute of Space and Astronautical Science) in the 1980s.

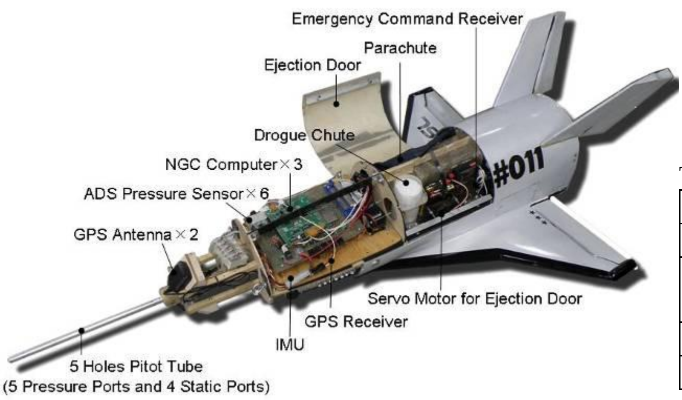
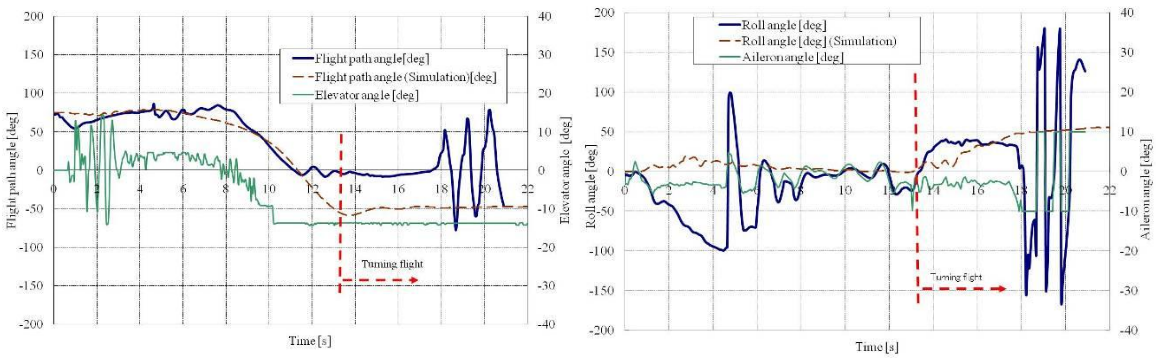


Fig. 3 WIRES #11.

Table 1 Major dimension of WIRES #11.

Total Mass	[kg]	7.6
Body Length	[m]	0.90
Body Diameter	[m]	0.21
Wing Area	[m^2]	0.14
Wing Span	[m]	0.65

WIRES #11 has been launched five times in total. The last flight was conducted in October 2009. The purpose of the flight was to evaluate the attitude control performance designed by H∞ theory, the flight path angle guidance at the ascent phase, and turn maneuverability after the apogee. All the flight data acquisition (GPS, Air Data System and IMU) was successful (Fig. 4).



(a) Flight path angle

(b) Roll angle

Fig. 4 Flight profile of WIRES#11.

WIRES #12

WIRES #12 (Fig. 5) is a pre-experimental rocket to establish the efficacy of the CFRP body structure design and new recovery system. It is capable of reaching an altitude of 1.1 km using a commercial hybrid rocket (HyperTEK M1000). The main dimensions are shown in Table 2.

The recovery system consists of a main parachute, drogue parachute, and airbags, as shown in Fig. 6. The drogue parachute will be deployed to reduce the flight velocity down to 50 m/s, which is below the permissible velocity for the deployment of the main parachute. The airbags are deployed for the winged rocket to relief shock in landing. The drogue parachute also may be used in case of emergency, if a malfunction of the navigation or guidance and control system occurs.

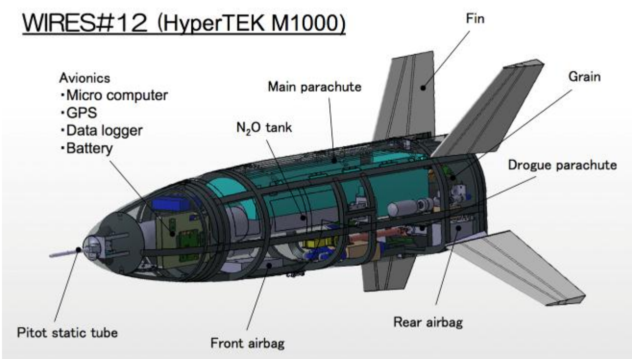


Fig.5 WIRES #12.

Table 2 Main Dimensions of WIRES #12.

Total Mass	[kg]	34.5
Body Length	[m]	1.50
Body Diameter	[m]	0.21

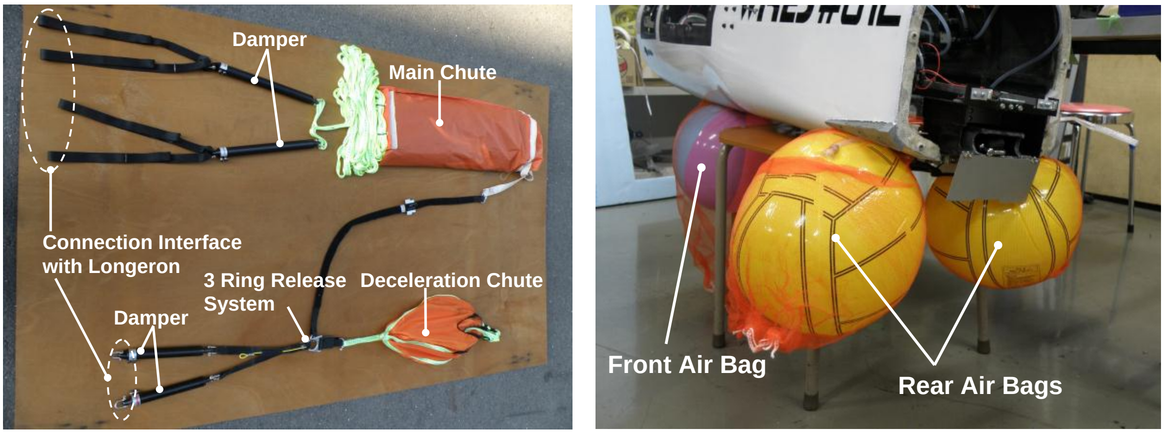


Fig. 6 Main parachute, drogue parachute, and airbags.

WIRES#12 was launched for the first time on July 27, 2010. Due to a problem (it filled with oxidizer), the hybrid rocket did not demonstrate full performance, but did reach an altitude of about 300 m (Fig. 7). Since the maximum altitude was far lower than anticipated, it did not have enough time for the emergency system to completely deploy the main parachute after the ejection of the drogue parachute. Therefore, WIRES #12 crashed into the ground on its nose. The next flight experiment will be done in summer 2011.

Fig. 7 First flight test of WIRES #12.

WIRES #14

WIRES #14 (Fig. 8) is the winged rocket that conducts fully autonomous flight using hybrid navigation and real time onboard guidance associated with an advanced control system in succession to CFRP structure (Fig. 9) and the avionics of WIRES #12. The main dimensions are shown in Table 3. It will be propelled by a hybrid rocket, CAMUI, developed by Hokkaido University, and is expected to reach an altitude of about 1.7 km. The flight profile is shown in Fig. 10. The vehicle will be able to perform gliding experiments during free flight before the ejection of the drogue parachute.

WIRES #14 has the most advanced navigation, guidance, and control system, employing four high-performance micro-computers and an FPGA (Field Programmable Gate Array), which communicates with each other and measurement sensors by CAN (Controller Area Network). It has a telemetry system and an independent emergency system to deploy the drogue parachute, main parachute, and air bags by a command transmitted from the GSE (Ground Support Equipment) manually. The first launch of WIRES #14 is planned in winter 2011.

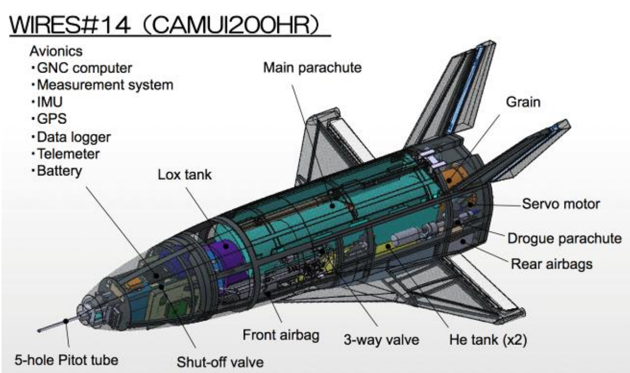


Fig. 8 WIRES#14.

Table 3 Main Dimensions of WIRES #14.

Total Mass	[kg]	50
Body Length	[m]	1.5
Body Diameter	[m]	0.33
Wing Area	[m2]	0.47
Wing Span	[m]	1.1

Fig. 9 Winged rocket structure made of CFRP.

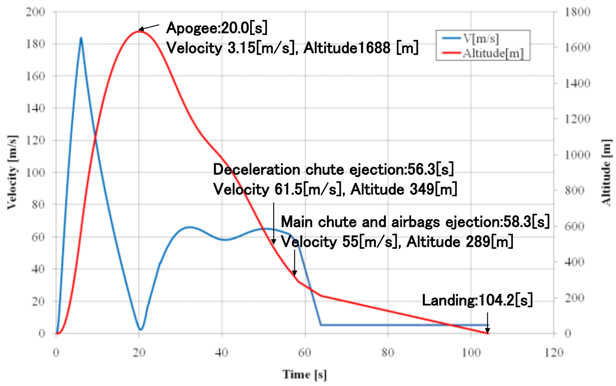


Fig. 10 Flight profile of WIRES #14.

(2) Research Issues

<u>INS/GPS/ADS Hybrid Navigation</u>

A hybrid navigation methodology using unscented Kalman filter was developed and implemented on an on-board electronics system of winged rocket (Fig. 11).

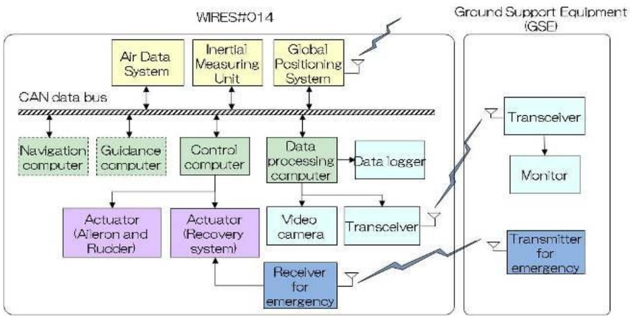
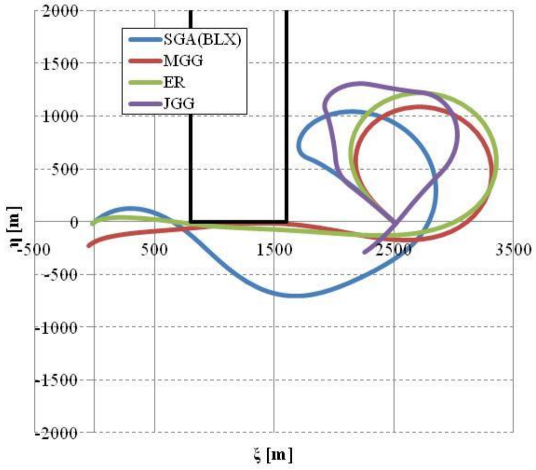


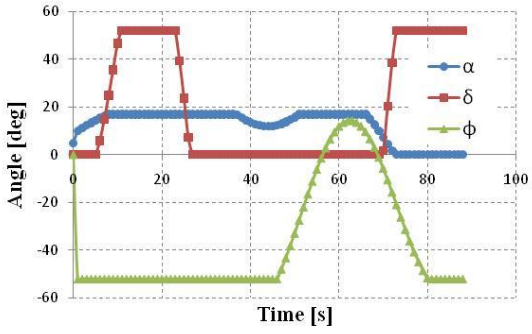
Fig. 11 Avionics of WIRES #14.

<u>Real-time Guidance using Genetic Algorithm</u>

A real-time guidance methodology that utilizes genetic algorithm was developed. It succeeded in real-time quasi-optimal trajectory generation under the constraint of flight restricted area existence (Fig. 12). The design of the implementation on the field programmable gate array is almost finished and flight experiment will be carried out by using winged rocket.



(a) Trajectory



(b) Control inputs

Fig. 12 Optimization of trajectory.

<u>Robust Control</u>

A H-infinity controller and a PID controller that utilizes dynamic inversion technique were developed. Their performances were verified using software simulator and hardware-in-the-loop simulator based on comparisons with a conventional PID controller.

<u>Carbon Fiber Reinforced Plastics (CFRP) Liquid Oxygen and Hydrogen Tanks</u>

Prototype composite tanks were produced. A prototype 4.3 litter liquid hydrogen tank using gas barrier clay was designed and manufactured (Fig. 13), and water and liquid hydrogen filling tests were conducted (Fig. 14). In addition, A preliminary liquid oxygen composite tank for an experimental winged rocket was designed and manufactured using the compatible plastics (Fig. 16). The impact ignition characteristics of various plastics in the liquid oxygen environments were studied to investigate their compatibility using ABMA (Army Ballistic Missile Agency) -type impact tester specified by ASTM (American Society for Testing and Material) (Fig. 16).

Fig. 13 Prototype liquid hydrogen tank.

Fig. 14 Liquid hydrogen filling test.

Fig. 15 Prototype liquid oxygen tank.

(a) Ignition reaction

(b) Specimens after impact test

Fig. 16 Ignition test of CFRP.

【3】Papers

✧ Journal Publications (since 2008)

・Wakita, M., Yonemoto, K., Akiyama, T., Aso, S., Kohsetsu, Y., and Nagata, H., "Development Project of Winged Experimental Rocket Led by University Consortium," Transactions of the Japan Society for Aeronautical and Space Sciences, Space Technology Japan, Vol. 7, 2009, No. ists26, pp.13-18.

・Yonemoto, K., Yamamoto, Y., Ebina, T., and Okuyama, K., "Application of CFRP with High Hydrogen Gas Barrier Characteristics to Fuel Tanks of Space Transportation System," Transactions of the Japan Society for Aeronautical and Space Sciences, Space Technology Japan, Vol. 7, 2009, No. ists26, pp.21-26.

・Yonemoto, K., Yamamoto, Y., Ebina, T., and Okuyama, K., "High Hydrogen Gas Barrier Performance of Carbon Fiber Reinforced Plastic with Non-metallic Crystal Layer," SAMPE'08, CD-ROM, Long Beech Convention Center, Long Beach, CA, USA, May 18-22, 2008.

✧ Contributions (since 2008)

・Yonemoto, K., Goto, H. and Murakami, K., Narumi, T., and Matsumoto, T.,"Liquid Oxygen Compatibility Plastics and Its Application to Composite Tank," 28th International Symposium on Space Technology and Science, 2011-c-08,Okinawa Convention Center, Gonowan, Japan, June 5-12, 2011.

・Miyamoto, S., and Yonemoto, K., Narumi, T., and Matsumoto, T.,"Real-Time Guidance System by Implementing Genetic Algorithm on Field Programmable Gate Array," 28th International Symposium on Space Technology and Science, 2011-d-42, Okinawa Convention Center, Gonowan, Japan, June 5-12, 2011.

・Narumi, T., Yonemoto, K., Matsumoto, T.,Sagara, S., Nagata, H., Yoshimasa Ochi, Y., Ishimoto, S., and Mugitani, T. , "Flight Tests of Environmentally Optimal Guidance and Control System Using Small-scaled Winged Rocket," 28th International Symposium on Space Technology and Science, 2011-g-26, Okinawa Convention Center, Gonowan, Japan, June 5-12, 2011.

・Fukuda, K., Abe, K., Kamoda, H., Goto, H., Nishihara, K., Miyamoto, S., Shigetomi, A., Fujii, S., Sagara, S., Akahoshi, Y., and Yonemoto, K., Narumi, T., and Matsumoto, T., "Flight Test Result of Kyutech Student's Experimental Rockets "Ninja-10" and "Sakura" in France," 28th International Symposium on Space Technology and Science, 2011-g-33, Okinawa Convention Center, Gonowan, Japan, June 5-12, 2011.

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・Tsuji, N., Inoue, Y., Miyata, S., Muranaka, Y., Zimba, Y., Watanabe, D., Ishitsu, K., Suenobu, T., Kawasaki, T., Hirano, K., Yano, T., Fukuda, K., Sagara, S., and Yonemoto, K., "Launch Campaign of KIT Student's Experimental Rocket "Ninja-09"in France," JSASS-209-5560, the Proceedings of 2009 Asia-Pacific International Symposium on Aerospace Technology, pp.331-336, Gifu, Japan, November 4-6, 2009.

・Okuda,K., Yonemoto,K., and Akiyama, T., "Hybrid Optimal Trajectory Generation Using Genetic Algorithm and Sequential Quadratic Programming," ICCAS-SICE 2009 and ICROS-SICE International Joint Conference, Fukuoka, Japan, August 18-21, 2009.

・Yonemoto, K., and Kaji, S., "H∞ Control of Winged Rocket and Its Flight Test," ICCAS-SICE 2009 and ICROS-SICE International Joint Conference, Fukuoka, Japan, August 18-21, 2009.

・Yonemoto, K., Shidooka, T., and Okuda, K., "Development and Flight Test of Winged Rocket," the 27th International Symposium on Space Technology and Science, ISTS 2009-g-16, Tsukuba, Japan, July 5-12, 2009.

・Shimozawa, T., Sagara, S., and Yonemoto, K., "Digital Adaptive Control of a Winged Experimental Rocket," the Proceedings of the 19th Workshop on JAXA Astrodynamics and Flight Mechanics, pp.179-184 (Total 410 pages), Institute of Space and Astronautical Science/Japan Aerospace Exploration Agency, Kanagawa/Sagamihara, Japan, July 30-31, 2009.

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・Okuda, K., Ujimoto, Y., Otsuka, Y., Sato, T., Shidooka, T., Semba, D., Tominaga, K., Fukuda, J., Yamamoto, Y., Wada, K., Sagara, S., and Yonemoto, K., "Experimental Flight of KIT Student's Rocket in France," the Proceedings of the 2008 KSAS-JSASS Joint International Symposium on Aerospace Engineering, Jeju Island, Korea, November 20-21, 2008, pp. 364-369.

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✧ Books

・Koichi Yonemoto, "Flight Dynamics and Controllability of Winged Reentry Vehicle: Lessons Learned," the 21st Century COE Program, International COE of Flow Dynamics Lecture Series, Volume 4, Tohoku University Press, March 2006.

✧ Dissertations (2011)

・Test Production and Evaluation of Liquid Hydrogen Pipe and Tank Made of Clay Film Compound CFRP

・Decomposition and Distribution of Profile and Induced Drag around Three-dimensional Wing by Wake Measurement

・Application of Dynamic Inversion Theory to Flight Control Law

・Impact Ignition Phenomenon and Mechanism of Resins LOX(Liquid Oxygen) Environment

・Variable-pressure Wind Tunnel of Aspect Ratio Effects on Three-Dimensional Wing at Low Reynolds Number Flow

・Mach Number Effect at Low Reynolds Number Flow around Two-dimensional Airfoil

✧ Master's thesis (2011)

・$H\infty$ theory Robust Control Performance for the Lateral/directional Motions of Winged Rocket

・Filter Effect of INS/GPS/ADS Hybrid Navigation and It's Experimental Consideration

・Aerodynamic Characteristics of Three-dimensional Wings and Flow Visualization by Hydrogen Bubble Method in Towing Fluid Tank

・PIV Visualization of Vortex Structure around Three-Dimensional Wing and Relation to Aerodynamic Characteristics

・Analysis of Airfoil Effects on Flow around Main Wing of Mars Airplane by Numerical Simulation

【4】Recent overseas researchers who collaborated with us (for a short period)

1. Mr. Jérôme Hamm, Representative Technical Reviewer of Rocket of Planete Sciences (France)
   Development of Student Experimental Rocket and Its Flight Experiment.
2. Mr. Christophe Scicluna, Representative Technical Reviewer of Rocket of Planete Sciences (France)
   Development of Student Experimental Rocket and Its Flight Experiment.
3. Dr. Ahsan Choudhuri, Professor and Chair, Department of Mechanical Engineering Director, NASA Center for Space Exploration Technology Research, University of Texas at El Paso
   Winged Rocket Development Project.

【5】Important mention, if any

Since 2006, small experimental rockets have been developed by students of the Kyushu Institute of Technology, most of them belong to our laboratory, for an annual rocket launch campaign held in France. The CNES (Centre National D'Etudes Spatiales) and the French non-profit organization Planète Sciences have been conducting an annual experimental rocket launch campaign called "La Campagne Nationale de Lancement," since the 1960s, for amateur clubs comprising university students and young engineers. Last year, we developed two rockets (Fig. 17 and Table 4).

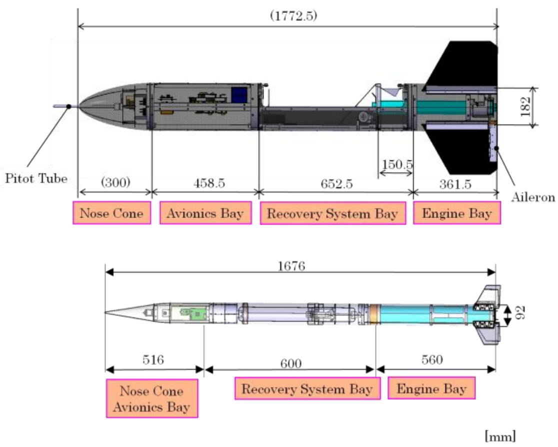

Fig. 17 KIT student's experimental rockets.

Table 4 Major dimensions and aerodynamic parameters.

Specification Issues				Requirement
		Ninja	Sakura	
Total length L	[mm]	1772.5	1676	$\leq$ 4000
Body diameter ϕ	[mm]	182	92	$40 \leq \phi \leq 200$
Mass M	[kg]	13.1	6.77	$\leq$ 15
Lift derivative C_n	[-]	17.4	15.4	$15 \leq C_n \leq 40$
Moment derivative $C_m = M_S \times C_n$	[-]	40.5 44.3	48.3 66.5	$40 \leq C_m \leq 100$
Drag coefficient C_d	[-]	0.32	1.05 ~0.34	NA
Static margin M_S : in terms of body diameter	[-]	2.3 2.6	3.14 4.33	$2 \leq M_S \leq 6$
Launcher exit speed	[m/s]	21.7	35.5	$\geq$ 20
Maximum altitude	[m]	635	3211	NA

One of the rockets named Ninja-10 was developed in order to research and test point tracing while gliding using a parafoil (Fig. 18). It reaches a height of approximately 635 m, 12 s after ignition. In order to maintain the doors of the ejection system bay facing upward, the roll angle of the rocket is controlled by using ailerons. At the apogee, the door of the ejection system bay opens, and a drogue chute is ejected to deploy the parafoil. Unfortunately, although Ninja-10 had passed various qualification ground tests, it was not allowed to be launched because of strong wind conditions.

The other rocket named Sakura was developed to achieve supersonic flight (Fig. 19). Sakura's mission was accomplished successfully; the maximum Mach number the rocket achieved was 1.07 (Figs. 20 and 21). Further, Sakura was recovered safely by using a two-stage parachute system that was deployed after the rocket reached an apogee of approximately 3300 m.

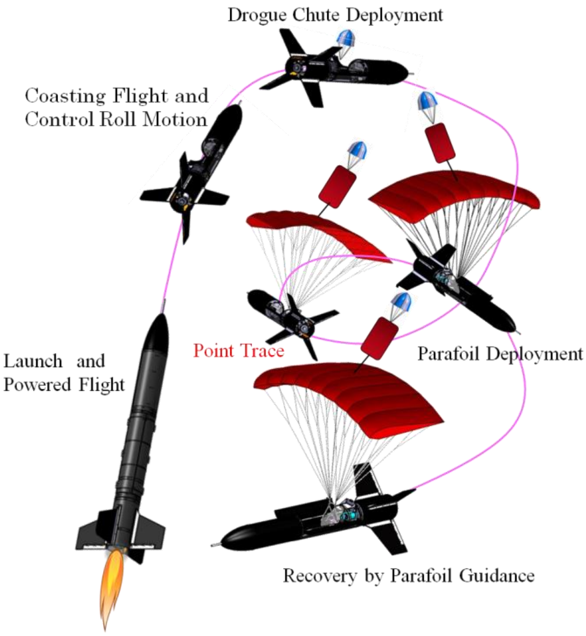

Fig. 18 Mission sequence of Ninja-10

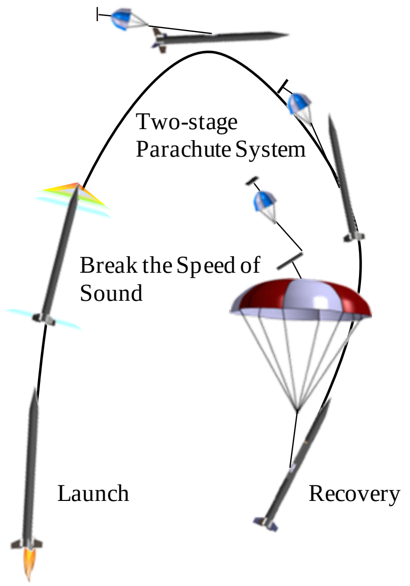

Fig.19 Mission sequence of Sakura.

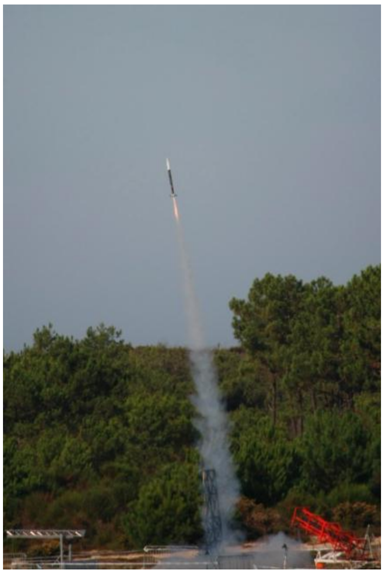

Fig. 20 Flight test of Sakura.

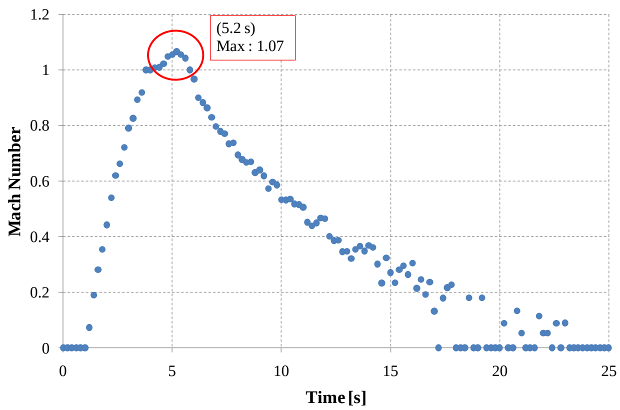

Fig. 21 Mach number change.

University/ Organizer	**Tokai University**	
Supervisor	Ichiro Nakagawa, Professor	
Contact	+81-463-58-1211	Email:nakagwa1@keyaki.cc.u-tokai.ac.jp
URL	Email:nakagwa1@keyaki.cc.u-tokai.ac.jp	

Keywords

Hybrid Rocket, Ramjet

【1】Overview and Science Highlights of the project

The number of hybrid rocket launches is 25.
The hybrid rockets uses WAX fuel.
The parachute separation devise is developed originally.
The maximum altitude is approximately 1km.
We launch hybrid rockets during spring and summer holidays.
Our launch sites are Noshiro in Akita or Taikicho in Hokkaido.

This rocket was launched successfully in 24/8/2011.

【2】Achievements in Space Engineering Education through Rocket Activities (or Plan)

- We have student rocket project as an extracurricular class
- They conduct design, manufacture experiments and launch of original hybrid rockets for themselves.
- Target is to learn expert knowledge, technical skill and teamwork.
- Members are about 50 students, from freshman to master's degree course students.

【3】Papers

✧ Journal Publications

・Hikone, S. and Nakagawa, I. "Regression rate characteristics and burning mechanisms of paraffin-based fuels for hybrid rockets", Proceedings of the school of engineering of Tokai university, vol. 50, No.1, 2010.

✧ Master's thesis

・Hikone, S., "A study on regression rate and burning mechanisms of WAX fuels for hybrid rockets", 2010.

【4】Recent overseas researchers who collaborated with us (for a short period)

1. Name and Affiliation of Co-researcher
   Research Theme
2. Name and Affiliation of Co-researcher
   Research Theme

【5】Important mention, if any

n/a

University/ Organizer	**Wakayama University** **Institute for Education on Space**	
Supervisor	Hiroaki Akiyama, Director / Prof.	
Contact	+81-73-457-8505	Email: Email:akiyama@center.wakayama-u.ac.jp
URL	http://www.wakayama-u.ac.jp/ifes/	

Keywords

Launch Site, BalloonSat, Rocket Girls and Boys, CanSat

【1】Overview and Science Highlights of the project

Wakayama University has been working mainly on setting up launch site for student rocket project in Japan. Also, student space activity in Wakayama University itself, such as not only rocket project but also BalloonSat project has been held. It is very important for them to have their "playground" to experience such project; Therefore Wakayama University focuses on preparing those ground such as launch site, experiment or launch environment for BalloonSat and miscellaneous event for many project activity.

Student project in Japan, for instance, they have launched about 10 rockets as of now, and they are planning to keep the activity. The launchers they have been using are the ones Wakayama University owns; one is used in Kada, Wakayama, and the other is used in Izu-Oshima Island. Launch opportunity is open almost any time for any group of student project.

Other than university student's activity, Wakayama University also hold annual project for High school students called "Rocket Girls and Boys", which they can experience project management through developing hybrid rocket. CanSat competition for high school students have been also held annually throughout Japan and Wakayama University is organizing those events.

【2】Achievements in Space Engineering Education through Rocket Activities (or Plan)

As official educational program in Wakayama University, there has been student rocket project for any grade of students for half a year. Also, in the second half term of this year, project management course by utilizing hybrid rocket will start, and this is also for any grade/department of students.

As unofficial one, a program called rocket girls and boys for high school students, as mentioned above has been organized by Wakayama University too.

【3】Papers

n/a

【4】Recent overseas researchers who collaborated with us (for a short period)

3. Name and Affiliation of Co-researcher
   Research Theme
4. Name and Affiliation of Co-researcher
   Research Theme

【5】Important mention, if any

Wakayama University has prepared/is preparing model rocket (solid engine rocket) for program called CanSat Leader Training Program (CLTP). There will be the second CLTP this fall.

Other Important Universities

This is a list of Japanese universities that you may want to check their activities.
The information will be added into this report in the near future.

1. Tokyo Metropolitan University – Aerospace Engineering, Graduate School of System Design, http://www.sd.tmu.ac.jp/en/graduate/aerospace.html

University Space Engineering Consortium
Central Yayoi 2F, 2-3-2 Yayoi, Bunkyo-ku
Tokyo 113-0032, Japan
Tel/Fax:+81-3-5800-6645
E-mail:einfo@unisec.jp

www.unisec.jp