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(Review)

# Reusable Sounding Rocket

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**Abstract**

The Reusable Sounding Rocket is a fully re-usable sub-orbital sounding rocket that takes-off and lands vertically from/on the same launch site. The Reusable Sounding Rocket recovers its payload: one can make repeated use of instruments, recover samples, have a big data storage onboard, and so on. The Reusable Sounding Rocket can be launched daily. The target cost for operation is 1/10 of the existing sounding rocket, S-310. The duration of $\mu$g environment is about 3 minutes. The payload bay is in the nose-cone and its volume is 0.8m in diameter and 1m in height. The maximum mass of the payload is 100kg.

**Keyword(s):** Sounding Rocket, Microgravity experiment
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## 1. Introduction

Institute of Space and Astronautical Science (ISAS) has been operating expendable sounding rockets for scientific researches. Since the sounding rockets launch to the sea, the payload recovery costs too much and is almost impossible. Therefore the sounding rocket experiments have been limited: The user cannot reuse the payload, nor recover the sample. The user can get data via telemetry downlink only. The expendable system leads to high launch cost, long durations for launch preparation and a few launch opportunities in a year. The improvement of the sounding rocket experimental environment is desired.

A future space transportation system requires space transportation cost reduction of 1/100 compared to the present cost. A reusable system is inevitable to realize the cost reduction as well as technology innovation. ISAS has studied a reusable rocket as a future space transportation system. As the first step, the reusable rocket demonstrator 'Reusable Vehicle Testing' (RVT) was developed in 1997. RVT demonstrated (1) vertical take-off and landing, (2) reusability of liquid oxygen (LOX) and liquid hydrogen (LH2) rocket vehicle, (3) composite light weight cryogenic tanks, (4) 24 hour streamlined turn-around operation, and so on, until 2003 with yearly upgrades of vehicle. The maximum altitude of RVT test was 42m. The last flight version of RVT and its streamlined turn-around operation are shown in **Fig. 1**, and **Fig. 2**, respectively.

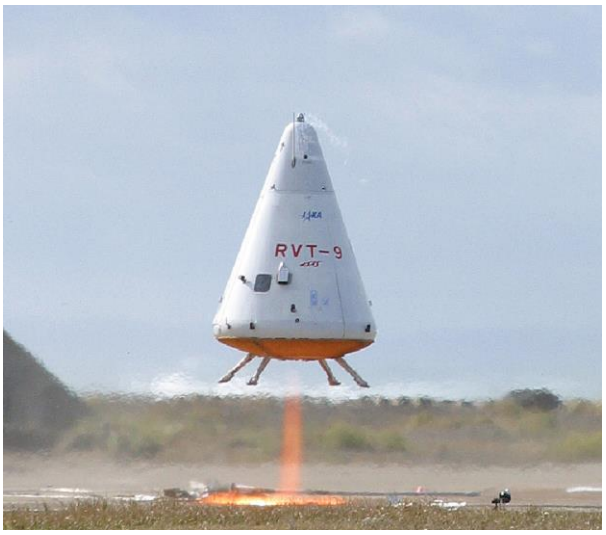


**Fig. 1** Reusable Vehicle Testing (RVT).

As a next step, a ballistic flight vehicle, which is reusable and can be used as a sounding rocket, - 'Reusable Sounding Rocket' - has been proposed to be developed.

## 2. Reusable Sounding Rocket

The mission of Reusable Sounding Rocket is (1) a ballistic flight whose apogee altitude is higher than 100km, carrying more than 100kg of payload, and coming back to the same launch site, (2) that the rocket is reusable more than 100 times, (3) that the turnaround time is less than 24 hours, (4) the operation cost for 1 flight is order of 1/10 of the cost of the present expendable sounding rocket, S-310, and (5) that the Reusable Sound Rocket system is practicable from the technology and financial point of view: The Reusable Sounding Rocket system makes available in 5 years once its development project starts.

The conceptual design was conducted to define the feasible Reusable Sounding Rocket system. Vertical take-off and vertical landing system was adopted to keep the turn-around time less

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**Fig. 2** Streamlined Turnaround Operation.

**Table 1** Reusable Sounding Rocket specification.

| | |
|---|---|
| Fuselage length | 13.5m |
| Fuselage diameter | 2.7m square |
| Payload mass | 100kg |
| Gross mass | 11.6ton |
| Dry mass | 4.4 ton |
| Propellant | LOX/LH2 |
| Thrust (sea level) | 40kN x 4 |
| Isp (sea level) | 320sec |
| Engine cycle | Expander bleed |
| Throttling | 40 – 100% |

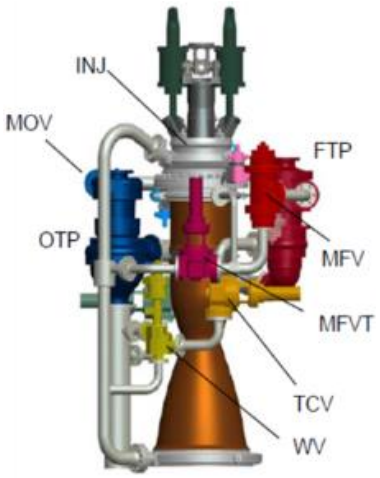


**Fig. 3** Reusable Engine.

than 24 hours. The Uchinoura Space Center (USC) was selected as the launch site to make use of the existing launch supporting facilities and save the total cost to be practicable. The 1 fail operative and 2 fail safe system architecture was incorporated in the system design. The lessons learned that were obtained in the RVT activities were taken into account.

The specification of Reusable Sounding Rocket is shown in **Table 1**. The vehicle comes back to the launch site even if the 1 engine fails. The LOX/LH2 expander bleed cycle engine (**Fig. 3**) was adopted so that the future space transportation system makes use of the operation lessons learned of the Reusable Sounding Rocket. The 40kN class engine is best from the development point of view: The verification of the reusable engine requires many operations and long time.

The flight trajectory launched from USC and the mission profile are shown in **Fig. 4** and **Fig. 5**, respectively. The rocket

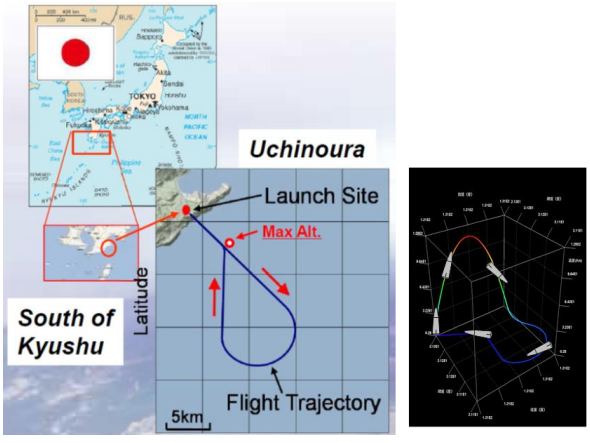


**Fig. 4** Flight Trajectory Launched from Uchinoura Space Center.

flies toward the sea with 100% throttle of the engines initially. Several minutes after (depending on the mission), the engines are cut-off and a ballistic flight starts. The micro-gravity environment of 3 – 5 minutes (depending on the gravity level and the altitude of the apogee) is obtained until the reentry to the atmosphere. The vehicle glides in the atmosphere towards the launch site. Before the landing the turn-over maneuver is conducted and the engines are re-ignited. By controlling the engine throttling level the landing is very soft. The low-gravity environment and aerodynamic load level are shown in **Fig. 6** along with the summit altitude.

The mission operation timeline is shown in **Fig. 7**. The payload setup is finished a day before the launch. The late access to the payload is allowed till 4 hours before the launch. The early access to the recovered payload is 3 hours after the launch. The payload unloading is possible after 6 hours or later from the recovery of the vehicle.

The payload bay is in the nose-cone of the vehicle. The command interface (I/F), the analog/digital telemetry I/F, electric power supply I/F, acceleration and environmental monitoring, and data recorder I/F are prepared as the user I/Fs. The envelope of the payload bay is 0.8m in diameter and 1m in height. The pay load mass is less than 100kg. The airframe of the Reusable Sounding Rocket and the payload bay is shown in **Fig. 8**.

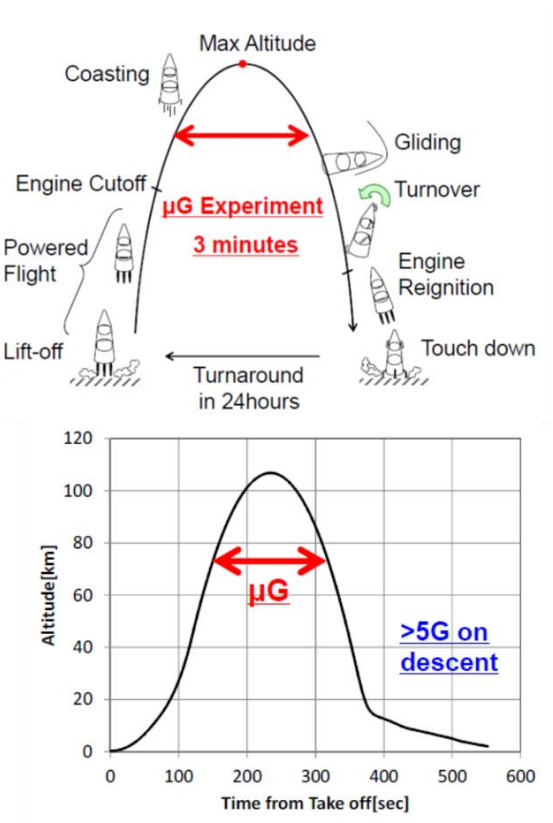


**Fig. 5** Mission Profile.

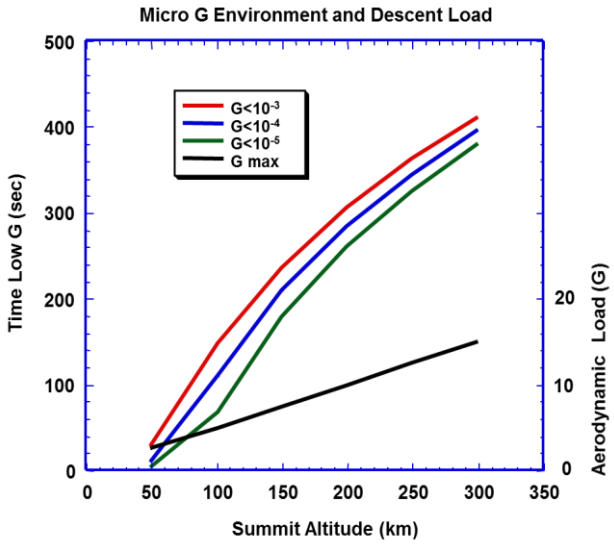


**Fig. 6** Micro-gravity environment duration.

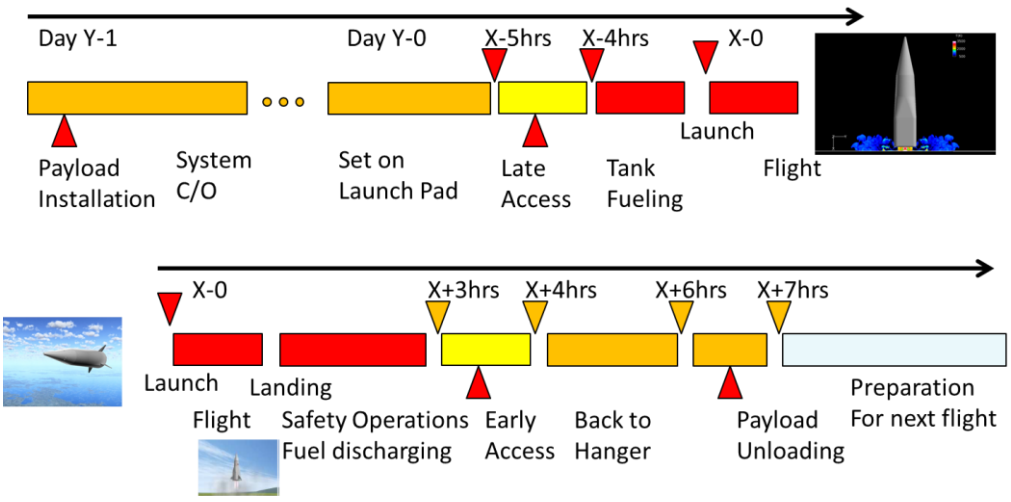


**Fig. 7** Mission operation timeline.

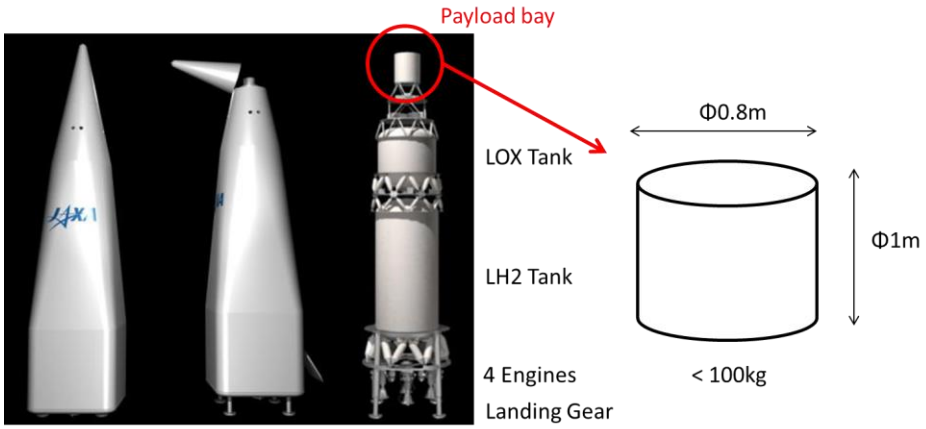


**Fig. 8** Reusable Sounding Rocket airframe and payload bay.

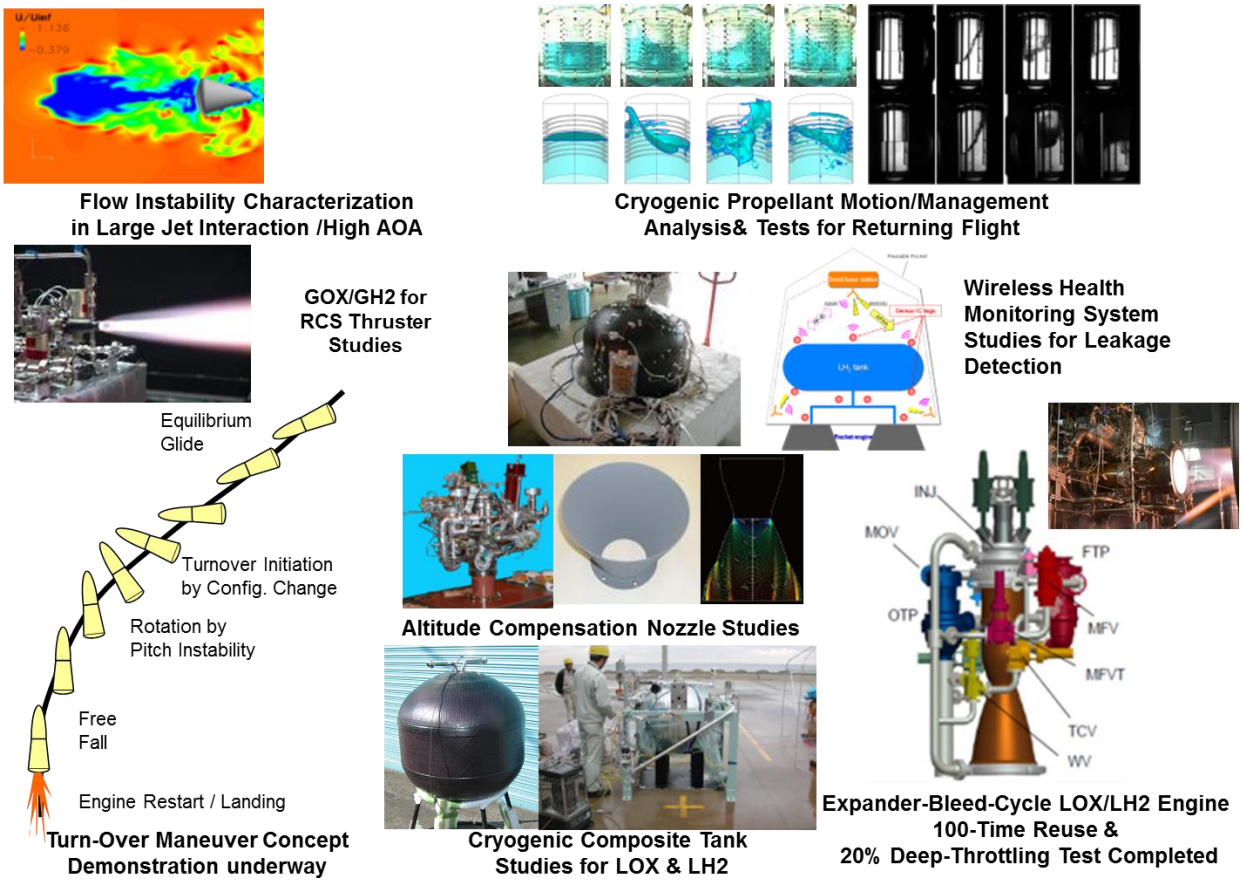


**Fig. 9** Technology maturing studies.

## 3. Various Technical Maturing Studies and the Reusable Sounding Rocket Technology Demonstration

The various technology maturing studies (**Fig. 9**) have been conducted such as (1) the flow instability characterization in large jet interaction under the high angle of attack, (2) the cryogenic propellant motion management, (3) the turn-over maneuver demonstration, (4) cryogenic composite tank, (5) the expander-bleed-cycle LOX/LH2 engine 100 times reuse and 20% deep throttling, and so on. **Figure 10** shows the Reusable Sounding Rocket technology demonstration conducted in 2010-2015. (1) The repeated operation demonstration, (2) the demonstration for

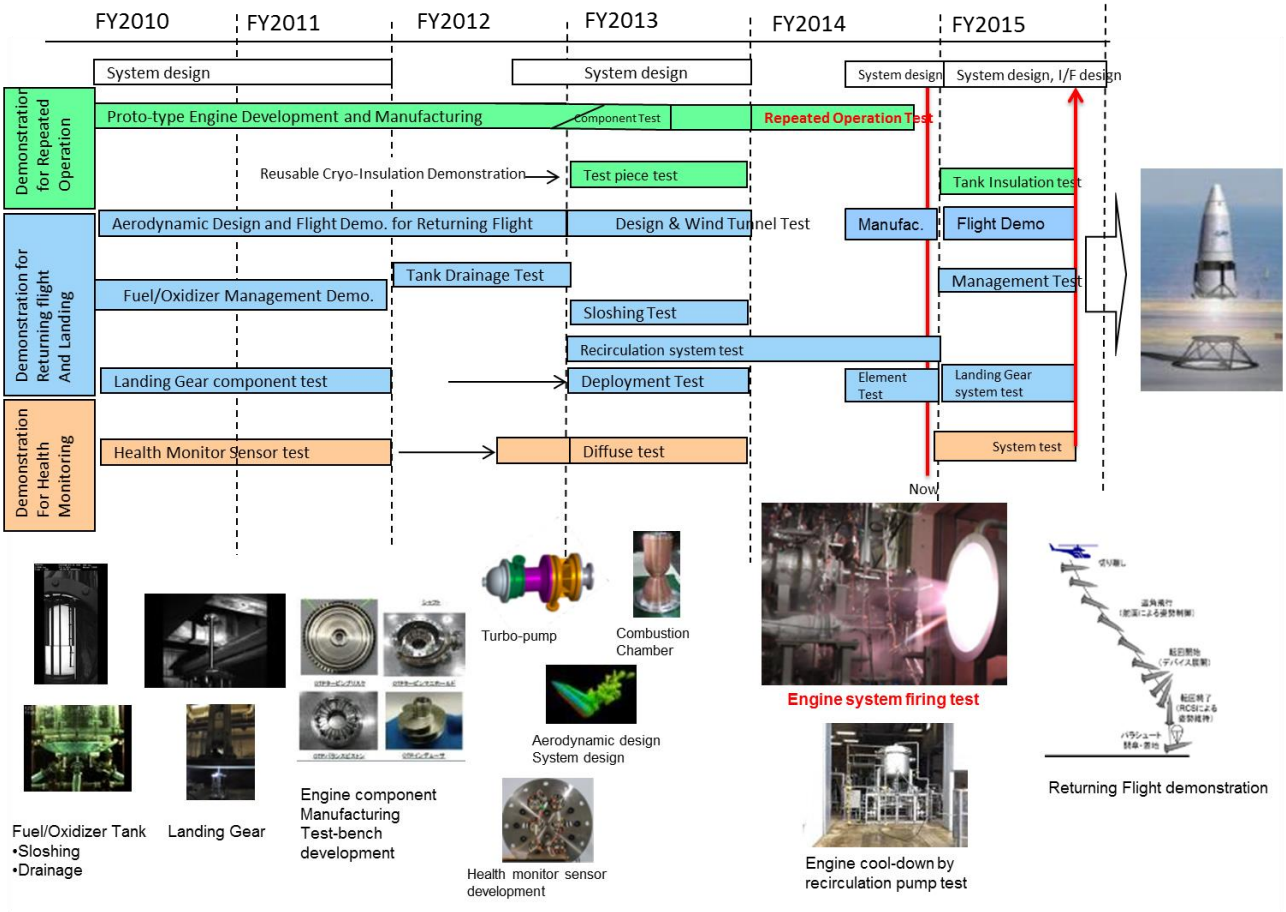


**Fig. 10** Reusable Sounding Rocket technology demonstration.

**Fig. 11** Reusable Sounding Rocket designer's image.

returning flight and landing, and (3) the health monitoring demonstration have been done. Especially, 100 times reusable engine was developed and demonstrated by the ground firing test.

## 4. Concluding Remarks

The Reusable Sounding Rocket concept and design were presented. One-order-of-magnitude cost reduction, daily turn-around, and payload recovery will be realized. The technology demonstration project has been being conducted. The conceptual designer's image is shown in **Fig. 11**.

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