【Grant-in-Aid for Scientific Research (S)】

Dynamic and Liquid Propellant Rotating Detonation Engine Physics Elucidation: Ballistic and Orbital Flight Demonstration

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Purpose and Background of the Research

●Outline of the Research

The rotating detonation engine is becoming capable of generating detonation waves at extremely high frequencies (1-100 kHz or higher), and there is active research in Japan, Europe, the U.S., and Asia with a view to practical application as a high-performance engine for space use. Since 2015, this research group and a number of research institutes have been actively conducting research. On July 27, 2021, using the S-520-31 sounding rocket of JAXA's Institute of Space and Astronautical Science (ISAS), the researchers performed the world's first demonstration of a detonation engine system. successfully completed the world's first space flight demonstration test of the detonation engine system.

As shown in the roadmap in Fig. 1, this research aims to [1] elucidate the physical mechanism regarding the Pressure Gain Combustion (PGC) performance of a "dynamic" rotating detonation engine with extremely high performance, [2] clarify the physics of a "liquid propellant" detonation engine, [3] confirm the feasibility of the "liquid propellant" detonation engine as a detonation rocket engine by installing it on the second stage of the sounding rocket S-520-34 and confirming its feasibility in space ballistic flight, and [4] verify it by flight of the rotating detonation engine system with a kick motor, reaction control system, and retention thruster in Earth orbit.

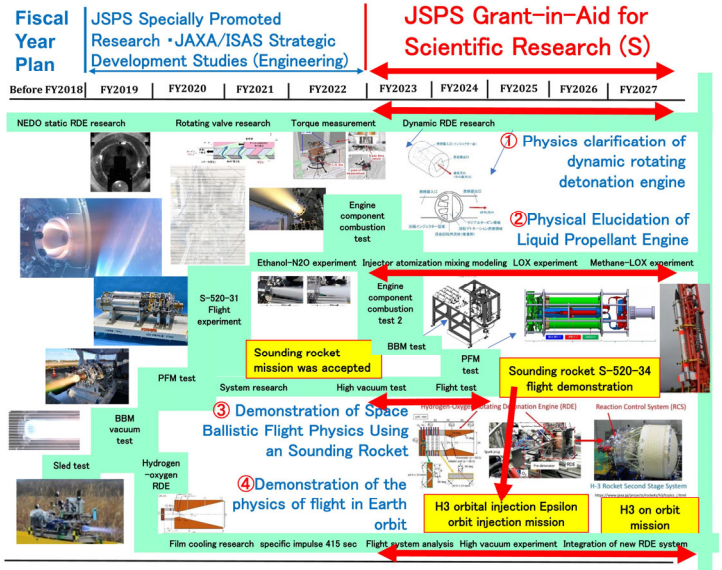

Figure 1. Roadmap of this research

●Research objective

The research group will utilize the results of the Grant-in-Aid for Specially Promoted Research for 2019-2022 to [1] elucidate the physical mechanism of Pressure Gain Combustion (PGC) performance in "dynamic" rotating detonation engines, which are 10-100 times more powerful than conventional engines. In addition, we will elucidate the physics (fluid, atomization, vaporization, and chemical reactions including shock waves) of detonation engines using [2] "liquid propellant," which is absolutely indispensable for the establishment of rocket systems. Demonstration experiments at the space ballistic flight level, which this research group is leading worldwide, will be conducted for the [3] "liquid propellant" detonation engine system. [4] Flight demonstrations in Earth orbit will be conducted with H-3, Epsilon, etc. in the final year of the project.

Expected Research Achievements

●Elucidation of the physics of the detonation engine and creation of a new aerospace propulsion system)

This research will (1) elucidate the physics of the limits of pressure gain in "dynamic" detonation engines. Internal pressure and temperature distribution of the engine, force and torque measurements by 6-axis force sensors, internal visualization of the flow using a high-speed camera, numerical analysis and construction of a theoretical analytical model will be conducted, and (2) elucidate the physics of the "liquid propellant" engine shown in Figure 2. The interaction of injector, atomization, vaporization, and mixing characteristics with detonation waves (shock waves) is extremely complex. Focusing on the relationships among pressure, temperature, subcooling, distance from critical state, latent heat of evaporation, injector diameter, collision angle, configuration, Lupe number, heat exchange with combustor wall, and atomization/vaporization characteristics of pressurized liquid, we will elucidate them experimentally and numerically. The aims are (3) to elucidate the physics of sounding rocket flight systems, and to clarify the physics of engine operation under high vacuum and microgravity, and the physics of the supply system during flight, and (4) to elucidate the physics of the Earth's orbital flight system. The four basic physics will be elucidated and demonstrated in space to realize a high-performance, innovative detonation engine system as shown in Figure 3.

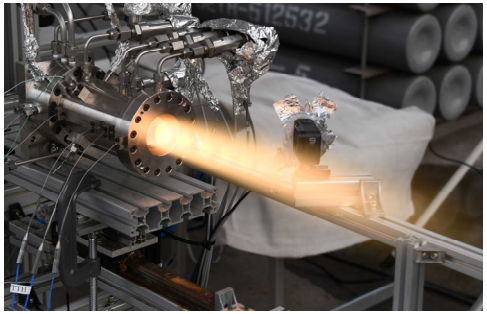

Figure 2. Liquid propellant detonation engine

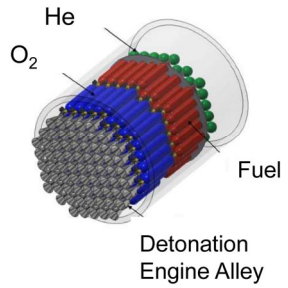

Figure 3. Revolutionary detonation engine system

Homepage Address, etc.	http://www.prop.nuae.nagoya-u.ac.jp/index.html