Statement of Work

- Parabolic Flight Service for Droplet Combustion Experiment in Microgravity -

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Korea Aerospace Research Institute

Contents

1. Introduction

1.1 Introduction of SOW (Statement of Work)

- ❍ This Statement of Work describes the requirements for "Parabolic Flight Service for Droplet Combustion Experiment in Microgravity".
- ❍ The experiments will be conducted using the droplet combustion apparatus developed by KARI (Korea Aerospace Research Institute) in microgravity condition provided through the parabolic flight.
- ❍ This service is not only a parabolic flight campaign but also a technical support for performing the experiment such as installing the apparatus in the airplane, testing the apparatus, and supporting the testers to operate the apparatus on a flight.

1.2 Introduction of function & purpose of the system

- ❍ The purpose of the system is to assist to investigate the droplet combustion characteristics in microgravity at reduced atmospheric pressures.
- ❍ To perform the experiments, a specially designed combustion chamber which provide a secured test bed during the flight will be used.

2. Droplet Combustion Apparatus & Experiment Procedure

2.1 Droplet combustion apparatus

- ❍ Droplet combustion chamber
  - Figure 1 displays a schematic diagram of the droplet combustion apparatus which contains a combustion chamber with optical access windows and electrical access ports.
  - The experimental apparatus was designed to be capable of measuring the soot volume fraction, flame temperature, flame radiative emission, and droplet burning rate of the isolated droplet flame in microgravity condition.
  - To this end, the combustion chamber designed to operate at the

atmospheric pressures ranging from 0 to 5 atm. (abs.) includes the laser-backlit diagnostic apparatus, high resolution CCD cameras and electro-mechanical components.

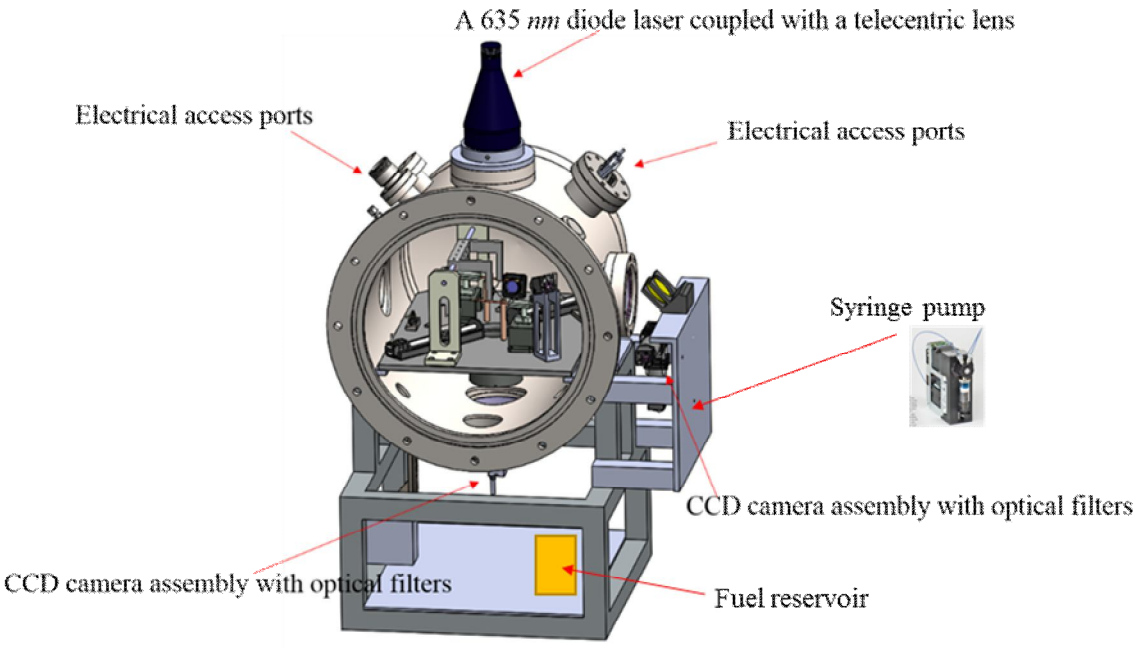

Figure 1. A schematic diagram of the droplet combustion apparatus

❍ Laser-backlit diagnostic apparatus

- The laser-backlit diagnostic apparatus for measurements of the droplet burning rate and soot volume fraction is the most critical component of the microgravity experiment.
- For the laser-backlit diagnostic apparatus, a 635 nm diode laser coupled with a telecentric lens assembly was attached to a top optical access window.
- The laser beam is expanded to 70 mm in diameter and is then collimated through the telecentric lens assembly. The expanded and collimated laser beam was redirected through the bottom optical port.
- Note that each of the optical access port was sealed with a 120 mm diameter BK7 window (with the thickness of 25 mm).
- The laser beam passing through the combustion chamber was focused using a plano-convex lens fitted to the bottom optical port. The

focused laser beam was then reflected toward a CCD camera. In front of the CCD camera, optical filters were applied to improve the quality of images captured by the CCD camera.

- Two additional CCD cameras (outside the chamber, see Figure 1) are used to image the flame through the eastern optical port of the combustion chamber. In front of cameras, optical filters were used to obtain unsaturated flame images for the various experimental conditions (e.g. different oxygen concentrations, inert substitutions).
- The luminous droplet flame images were reflected toward a high-resolution CCD camera using a second 75 mm diameter mirror positioned at 45 degree.

❍ Combustion experiment platform

- Figure 2 displays the schematic of the combustion platform inside the combustion chamber on which single droplet is generated and deployed on a 15 μm SiC fiber or free floating in microgravity using two opposed hypodermic needles.
- Fuel was pumped by a solenoid-activated micro syringe and was delivered through each hypodermic needle attached to a separate rotating motor.
- The dispensed fuel forms a liquid bridge and the rapid motion of needles in opposite direction deposits the droplet onto a 15 μm SiC fiber or makes the droplet float in microgravity. The 15 μm SiC fiber was used to tether the formed droplet and to prevent it from moving out of the field of view.
- The droplet deployed or suspended is ignited using two horizontally opposed Kanthal hot wire igniters. Igniters were heated for approximately 5 seconds and were retracted after ignition to minimize the thermal effects of the glowing igniters on the droplet heating.
- The ignition process is monitored using a CCD camera installed on the combustion platform inside the combustion chamber. The flame radiative emission was measured using a radiometer. The radiometer was placed about 10 cm from the droplet center and was coupled to

an amplifier which allowed the voltage signal.

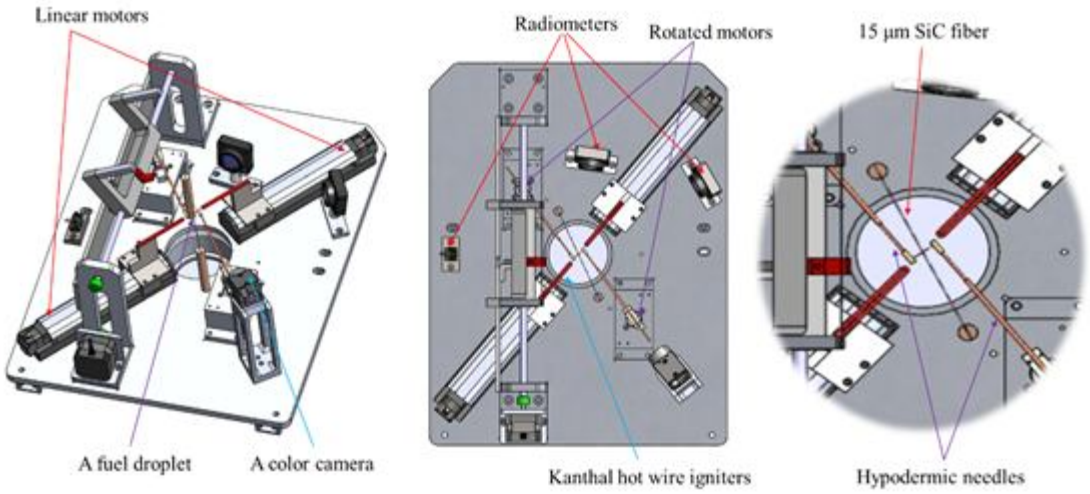

Figure 2. A schematic of the combustion platform inside the combustion chamber

❍ The system's operating environment

- Droplet combustion Experiments will be performed at reduced pressure conditions (the atmospheric pressure inside chamber will be maintained below 1 atm. (abs.)).
- The atmospheric environments inside the chamber will be regulated with the different concentration of oxygen (less than 30% in volume) blended with N2, He, or CO2.

※ Please note that our experimental device configuration may change to optimize its performance.

2.2 Experimental procedures (System Operating Procedures)

Basically, the operation of the apparatus are conducted by KARI passengers during the parabolic flight, however, most experimental procedures are automated and pre-programed to work functionally during the parabolic flight, following the sequence listed below;

① Turn on a diode laser

② Turn on all CCD cameras installed on the system

③ Turn on the radiometer
④ Bring hypodermic needles together to make a liquid bridge
⑤ Dispense the fuel thorough two hypodermic needles simultaneously
⑥ Ignitors are placed close to needles
⑦ Retract hypodermic needles to produce floated single droplet in microgravity
⑧ Energize the ignitors and move them back to reduce thermal effects to droplet formed in microgravity
⑨ Stop the operation of experiment when a droplet flame is extinguished

3. Parabolic Flight Service Requirements

This parabolic flight service includes not only two parabolic flight campaigns but also technical supports for performing the experiment such as installing the apparatus in the airplane, testing the apparatus, and supporting the passengers to operate the apparatus on a flight.

The provider of the parabolic flight service shall meet the requirement of section 3.1 and 3.2

3.1 Activities for parabolic flight campaign

3.1.1 The parabolic flight

1) Two flight campaigns shall be provided.
   - The minimum 20 parabolas per flight shall be provided.
   - The microgravity time during one parabola shall be provided for at least 12 seconds unless a critical safety issue during the flight occurs.
2) The microgravity degree
   - The level of microgravity should be about 0.001G or less for 12 seconds.

3.1.2 Flight schedule

1) The two flights shall be provided between the end of Oct. and the end of Nov. 2018.
2) Each of flights shall be offered once a day.

3.1.3 Passengers

1) Each flight shall have at least three passengers on board to operate the apparatus and to test the instrument.
2) Personal flight suit and bag for passengers shall be provided.

3.1.4 Research rack (section) supply

1) Research rack (section) in the flight shall be provided for mounting the apparatus of the following size and mass.
   - 150cm (L) x 70cm (W) x 150cm (H)
   - approximately 250kg (including support equipment of the apparatus)
2) Electrical power
   - The plane shall provide electrical power of 20A in DC 26V ~ 28V.
   - The plane shall provide electrical power of maximum 20A in AC 220~230V, 60 Hz or equivalent.
3) The vacuum port on board shall be provided.

3.1.5 Technical support on flight

1) In flight coach assistance shall be provided.
2) On board experiment assistance in case of emergency and unexpected (accidental) events shall be provided.

3.2 Technical support of research flight

3.2.1 Technical support on ground

1) Technical support related to prepare engineering documentation for the preparation of parabolic flight shall be provided.
2) Technical support for planning the parabolic flight experiment for the safety, interface with the aircraft, and its support system hardware shall be provided.
3) Technical support for the integration of the apparatus in the research section of the aircraft shall be provided.
4) Technical support for the arrangement and testing of the support system in the aircraft for parabolic flight experiment shall be provided.
5) Technical support for the pre-test inside the aircraft shall be provided

before flight.

6) Compressed gas handing support (including compressed gas ordering on site) shall be provided.

3.2.2 Other support

1) Arrangement for the parabolic flight experiment implementation shall be provided.
   - schedule
   - workplace for the integration and testing on ground
   - flight permission and its related documentation
   - coordination for the parabolic flight
2) Orientation/Training for passengers
   - Before the flight, the flight training related the parabolic flight shall be provided to passengers.
3) Experimental apparatus handling support
   - Experimental apparatus handling support (including shipping back to KARI upon completion of flight) shall be provided.
4) Insurance
   - Insurance shall be provided to the passengers liability and third party liability insurance.

3.3 Compliance Check Table for the parabolic flight service

The companies(service supplier) participating in bidding for this parabolic flight service are required to submit a brief plan including a check table for meeting the requirements in section 3.1 and 3.2 by referring to the following example table.

Example)

#	List	C	NC	PC	Note
3.1.1	1) Two flight campaigns	v			
	2) The microgravity degree	v			
3.1.2	Flight schedule	v			
3.1.3	Passengers	v			
3.1.4	1) Mechanical Interface	v			
	2) Electrical Interface	v			
	3) Vacuum port	v			
3.1.5	Technical support on flight	v			
3.2.1	1) Technical support on ground			v	
	2) Technical support on ground			v	
	3) Technical support on ground	v			
	4) Technical support on ground	v			
	5) Technical support on ground	v			
	6) Technical support on ground	v			
3.2.2	1) Other support	v			
	2) Other support	v			
	3) Other support			v	
	4) Other support		v		

[C: Compliance, NC: Non-Compliance, PC: Partial Compliance]