# Passive Deployment Demonstration of Shape Memory Alloy Type Aeroshell Using Hyper Sonic Wind Tunnel

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## 1. Background & Objective

Recently, a low ballistic coefficient flight vehicle using a deployable membrane aeroshell has been proposed as a new atmospheric entry system. The application of the deployable aeroshell technology may open a new world of planetary exploration by small probes in the future, that is, 3D network exploration by a flock of scattered probes as shown in Figure.1. In order to realize Nano-class-lander (~1kg) for the new planetary exploration, an innovative low-mass and simple deployable aeroshell is necessary. Then, **we proposed the SMA(Shape Memory Alloy)-type aeroshell**, which is a deployable aeroshell concept utilizing membrane that are fitted between SMA ribs. The most important feature of the SMA-type aeroshell is that it can deploy by heating, so it might be able to deploy automatically by the aerodynamic heating without any sensors and actuators during atmospheric entry.

In this study, we demonstrate the passive deployment of SMA-type aeroshell due to aerodynamic heating by using a hypersonic wind tunnel. And we observed the passive deployment behavior of the SMA-type aeroshell and its aerodynamic characteristics are evaluated.

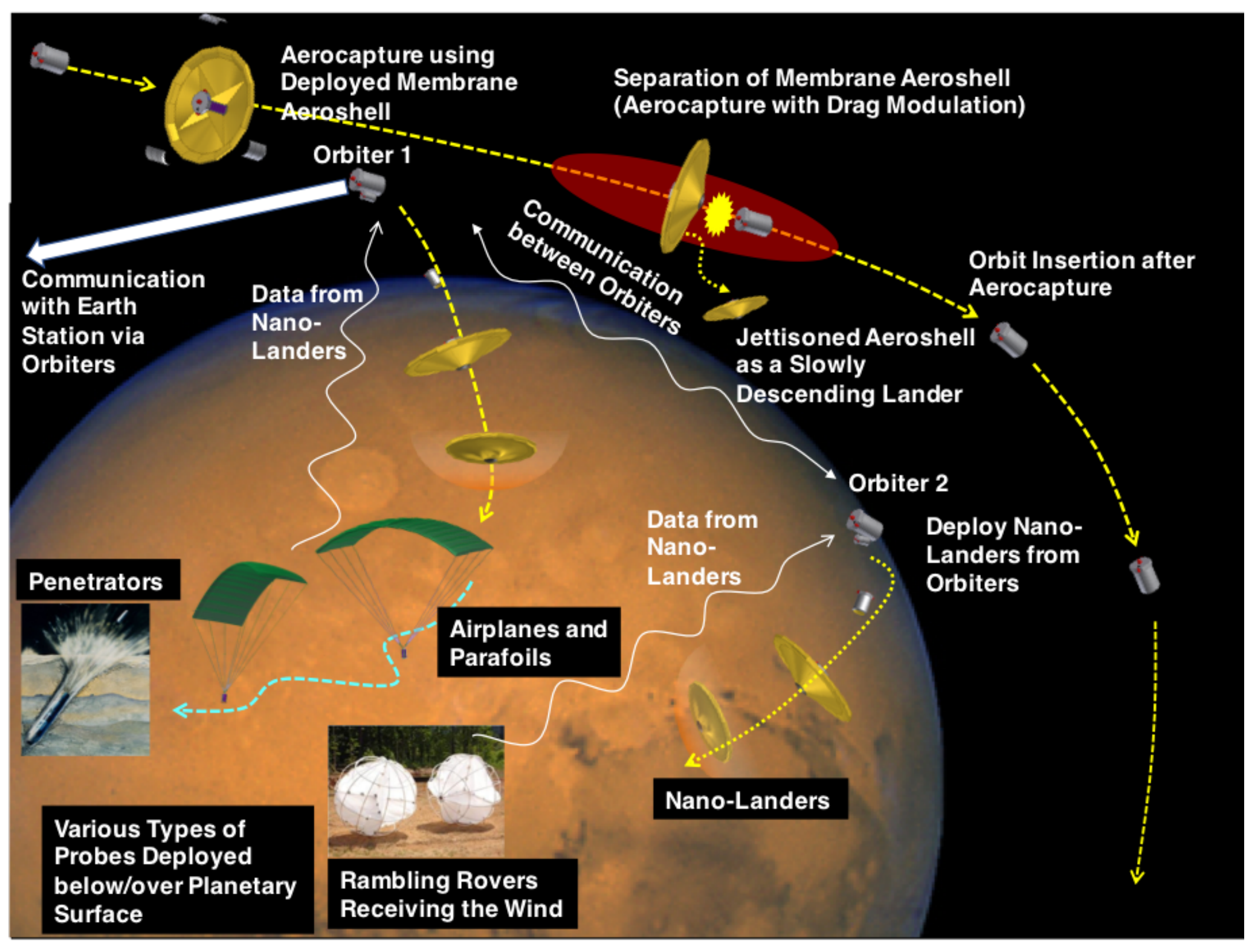

Fig.1: The conceptual image of 3D network-type planetary exploration by the flock of scattered probes using the deployable aeroshell technology

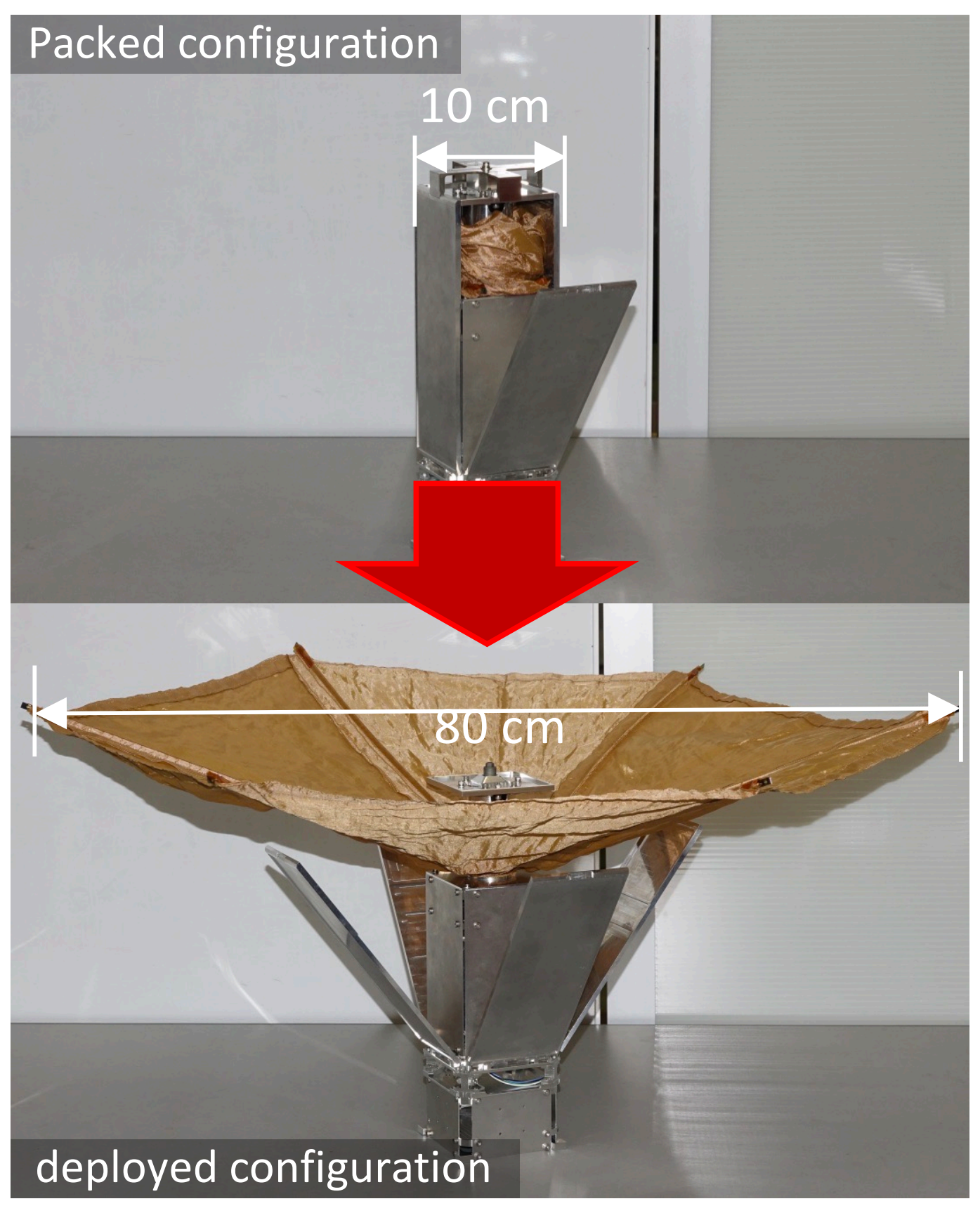

Fig.2: Packed and deployed configuration of the SMA-type deployable aeroshell

## 2. Hypersonic wind tunnel test

We used a 1.27 m hypersonic wind tunnel at JAXA Chofu Aerospace Center. This wind tunnel is a high-pressure blowout/vacuum suction type intermittent hypersonic wind tunnel with a measurement chamber of 1.27 m nozzle diameter, which can generate airflow of Mach 9.45.

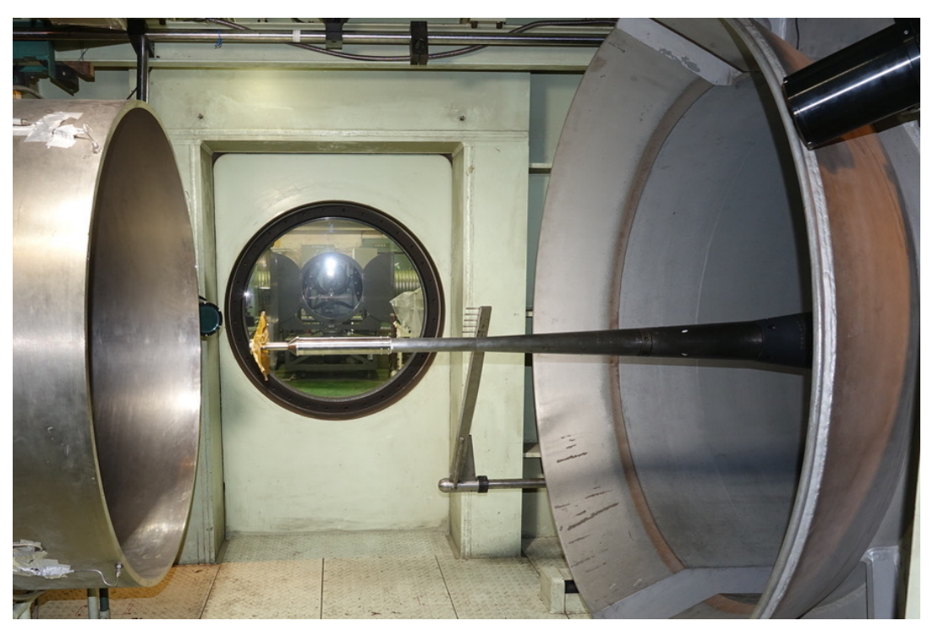

Fig.3: 1.27 m hyper sonic wind tunnel at JAXA Chofu Aerospace Center

### Testing models

In this test, six SMA (Ti-Ni, linear memory) plates of 5 mm wide and 0.75 mm thick with a phase transformation temperature of 70°C were used as the framework of the aeroshell.

ZYLON filament fabric (material: poly(para-phenylene benzobisoxazole) fiber, which has high strength and heat resistance, was used for the membrane.

The wind tunnel models were regular hexagonal pyramidal aeroshells with a diameter of 200 mm, one with a 70° flare angle and the other with a 45° flare angle.

The head of the model is a blunt part (material: SUS) with a diameter of 42 mm and a radius of curvature of 42 mm, which resembles atmospheric entry capsule.

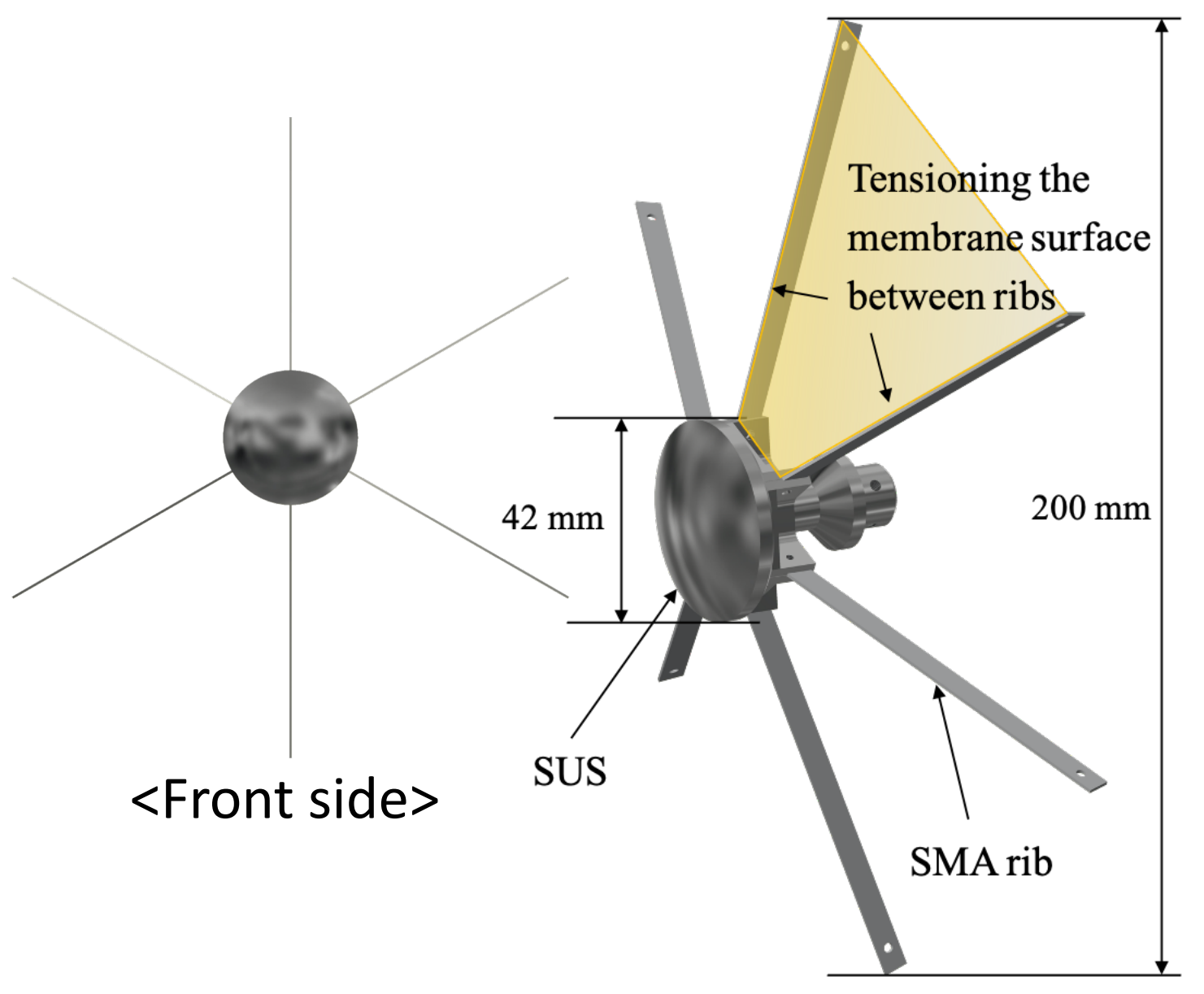

Fig.4: Conceptual diagram of the test model

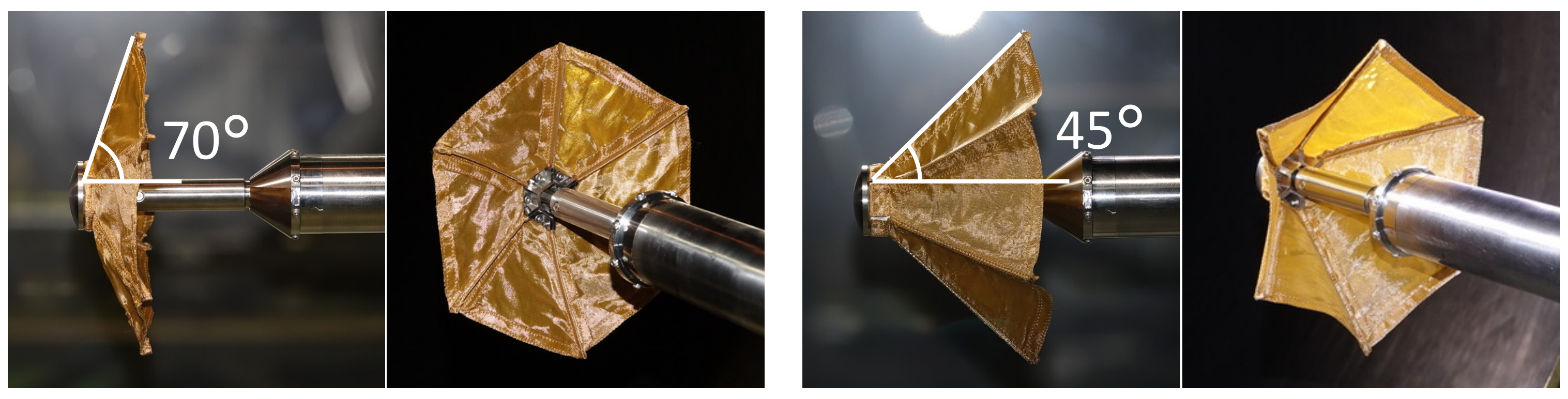

Fig.5: The wind tunnel model with SMA-type deployable aeroshell
(Left: Flare angle 70°, Right: Flare angle 45°)

### Testing conditions

Before blowing, test model with SMA aeroshell was compactly packed. All the SMA frames were distorted in the same direction, and the aeroshell was folded compactly by wrapping it around the cylinder at the center of the model.

The airflow conditions for this test are shown in Table.1.For the test on the model with a flare angle of 70°, the blowing duration was 20 seconds, and for the test on the model with a flare angle of 45°, it was 30 seconds.

Table.1. Airflow conditions for the test

| | |
|---|---|
| Air tank pressure | 1.0 MPa |
| Dynamic pressure | 2142.1 Pa |
| Stagnation point temperature | 650 ℃ |
| Mach number | 9.45 |

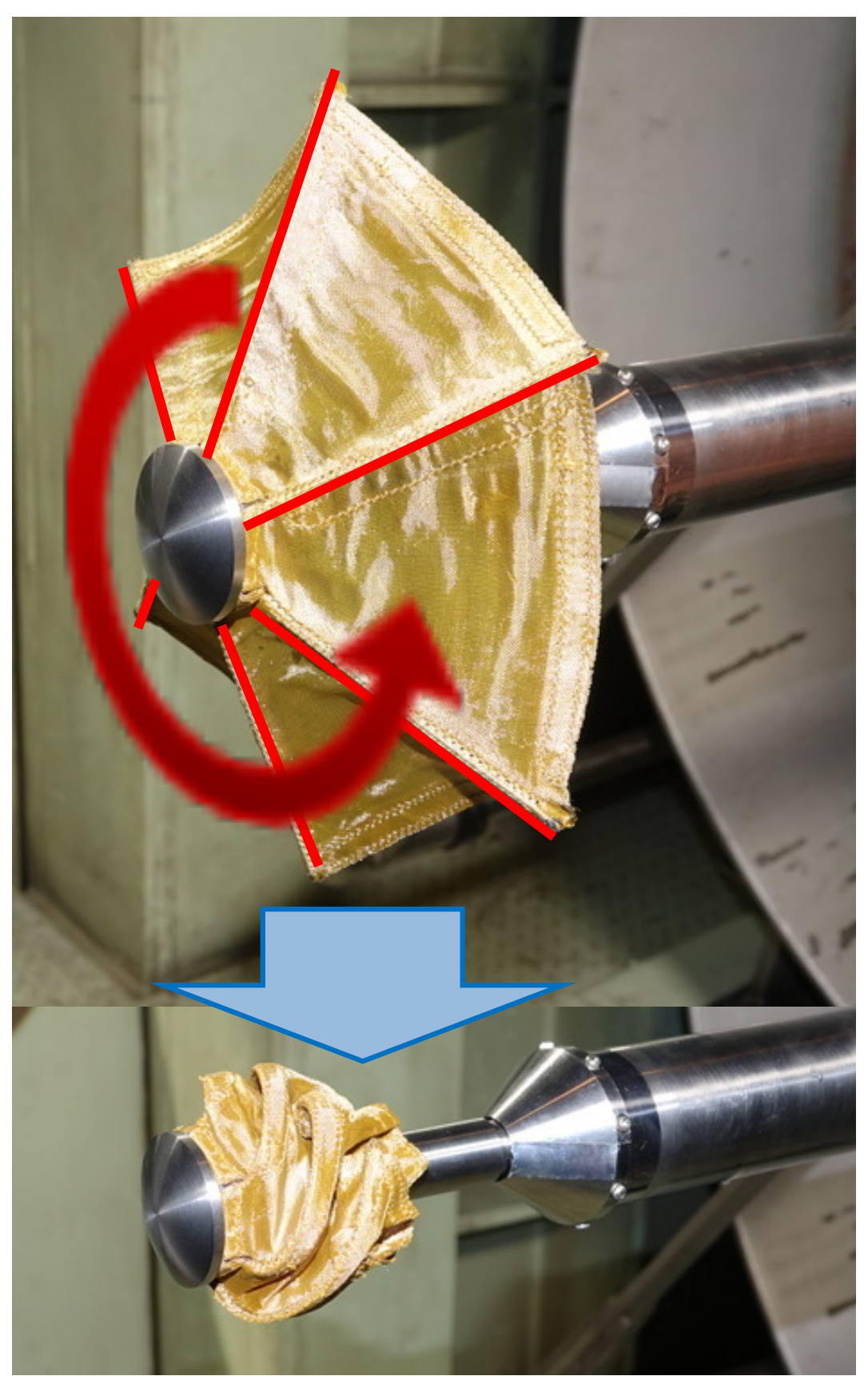

Fig.6: Packed configuration of the SMA-type aeroshell before blowing

## 3. Results

In this test, the SMA-type aeroshell deployed completely passively as the SMA ribs returned to a straight shape under aerodynamic heating in the hypersonic airflow.

Especially, the membrane surface is heated most strongly at the location where the shock waves generated by the capsule at the front and the aeroshell interfere with each other. The model with a flare angle of 45° was heated up to about 350°C on average. On the other hand, the model with a flare angle of 70°, which the shock-shock interaction was more severe, was heated more intensely, up to 450°C on average, resulting in faster aeroshell deployment.

With the deployment of the aeroshell, the drag coefficient of the model with a flare angle of 45° increased to 0.4, and that of the model with a flare angle of 70° increased to 0.92 (about 7 times larger than that before deployment). Side and lift coefficients were stable at very small values.

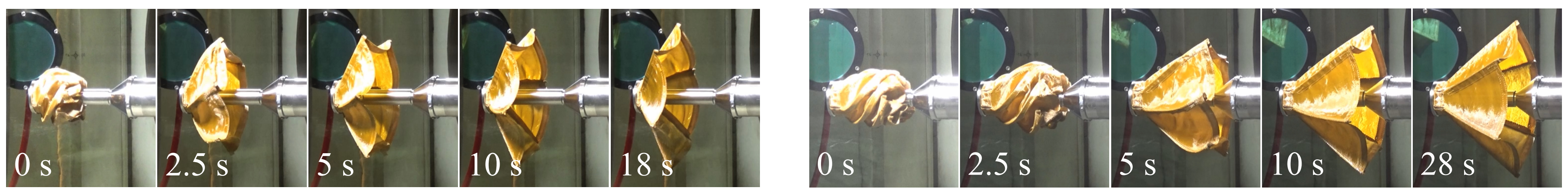

Fig.7: Passive deployment of SMA-type aeroshell in the hyper sonic airflow
(Left: Flare angle 70°, Right: Flare angle 45°)

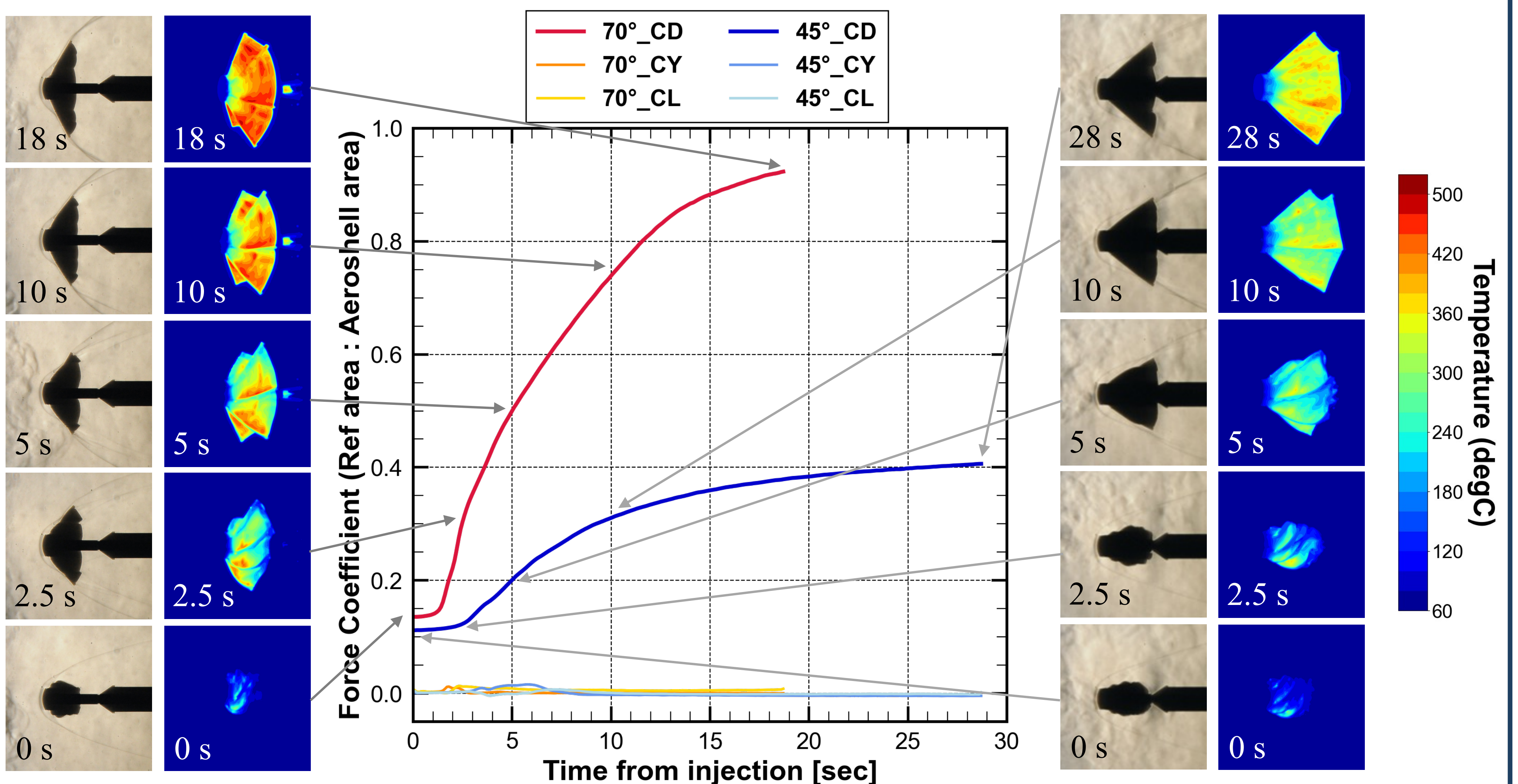

Fig.8: Time histories of force coefficients and surface temperature distributions of aeroshells and visualized images of the flow field using the Schlieren method

In both models, the rolling moment peaked during the deployment of the aeroshell, but its value became smaller as the deployment progressed due to the high symmetry of the models. Pitching moment and yawing moment were stable at very small values.

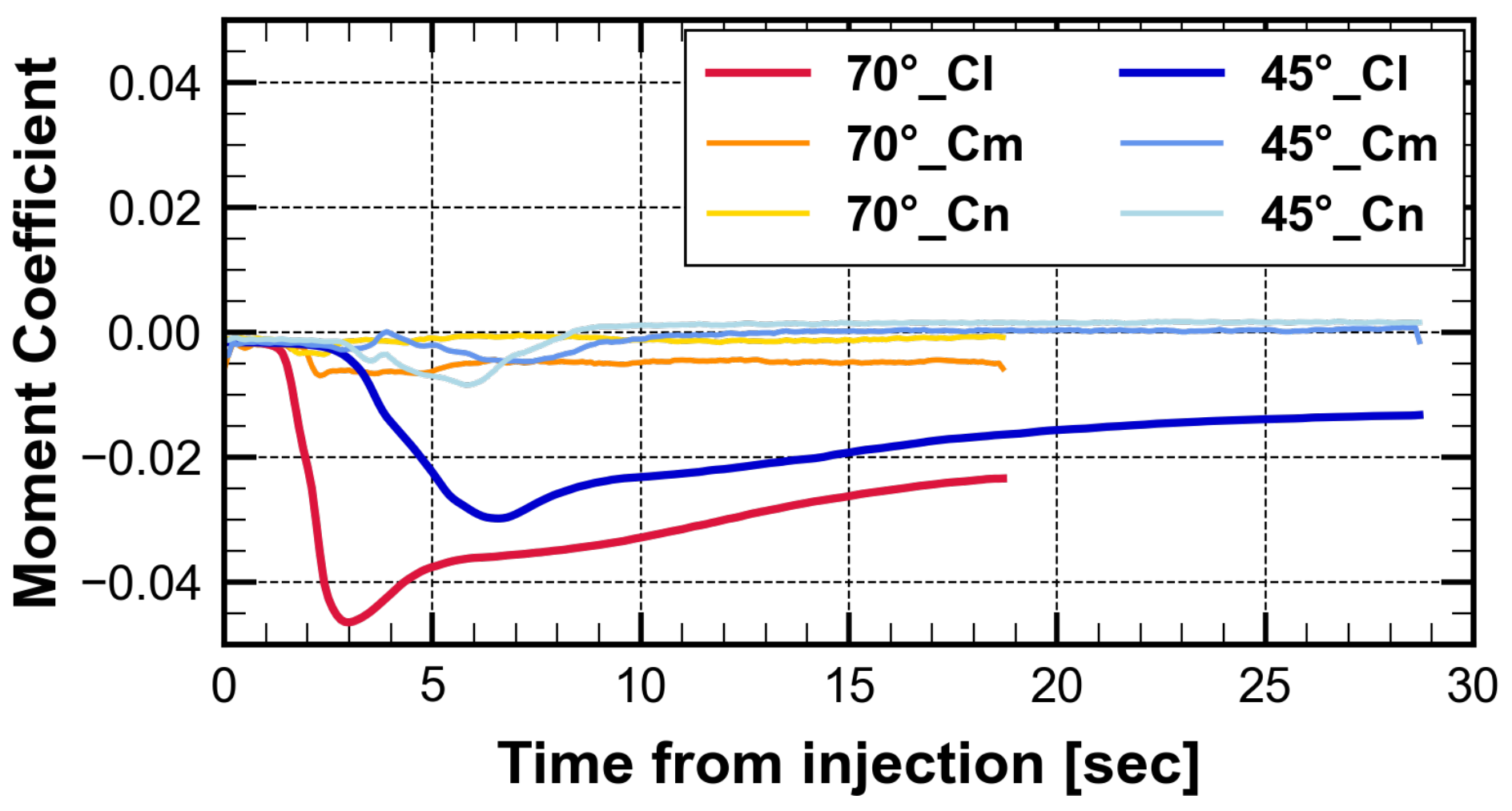

Fig.9: Time history of the moment coefficient

## 4. Conclusions & Future Work

The results of this test suggested that the SMA-type aeroshell can be an innovative simple atmospheric entry system that enables passive deployment during atmospheric entry.

As for the flare angle, we will continue to search for the best angle around 70°, because 70° is more efficient in increasing drag with less mass and volume resources.

In 2022, we plan to demonstrate the deployment technology of the SMA type aeroshell in low Earth orbit in the technical demonstration mission "BEAK", that is 3U-nano-satellite deployed from ISS.

18th International Planetary Probe Workshop