Experimental project for the aerodynamic characteristics of ALFLEX using MSBS

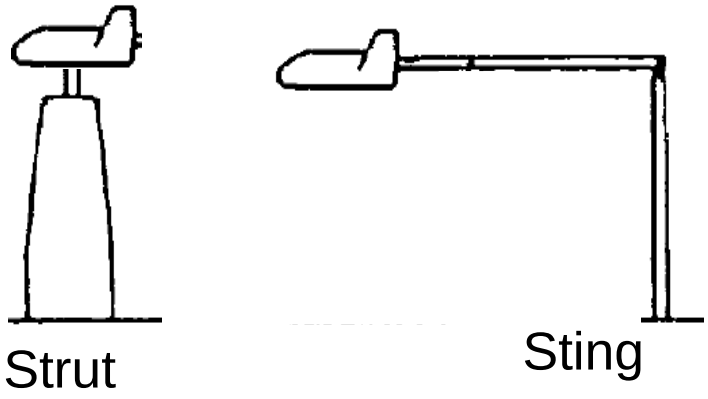
Position measurement summary report

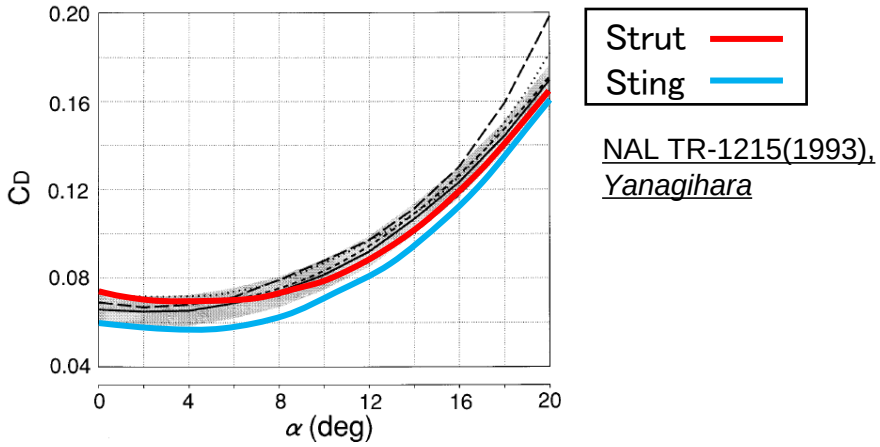
M2 Masatoshi Horiguchi

Backgrounds

- What's ALFLEX?
  - Technology demonstrator for future space plane
  - Development of automatic landing technology

- Previous research
  - Low-speed wind tunnel tests (drag measurement)





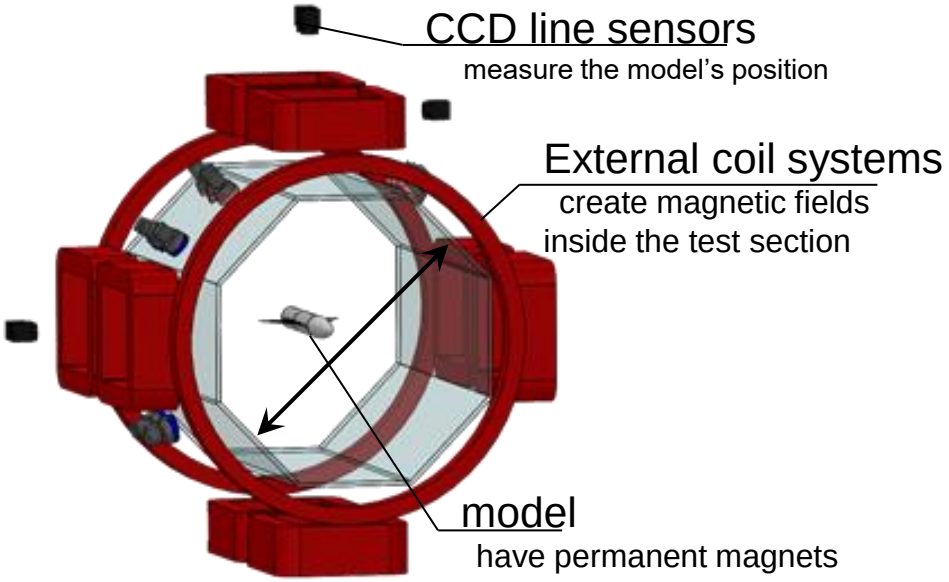
NAL TR-1215(1993), *Yanagihara*

We need to conduct wind-tunnel tests without support

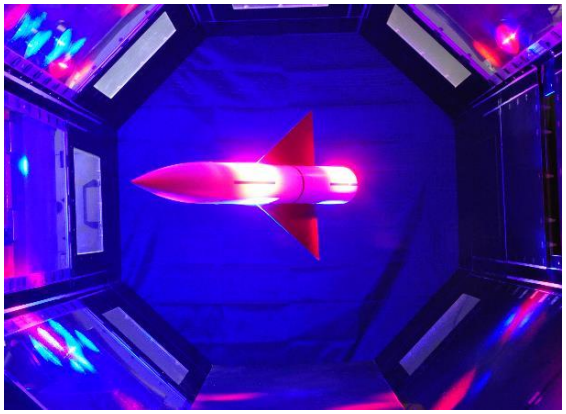
Magnetic Suspension and Balance System

MSBS

- Models supported using magnetic forces
- Aerodynamic forces measured by coil current

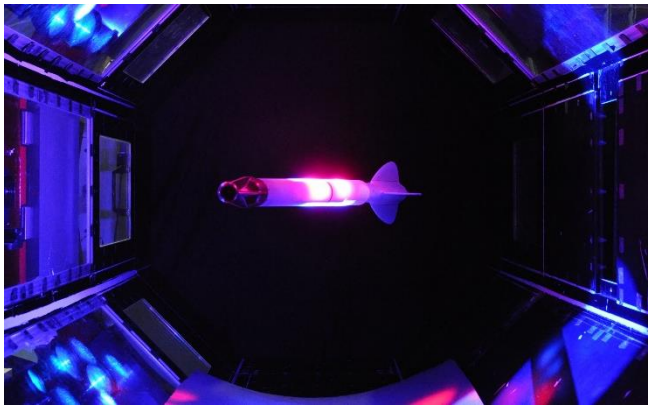


Levitation model



AGAED-B Senda (2017)

Cylinder Nagike (2017)



Turbo jab Sasaki(2019)

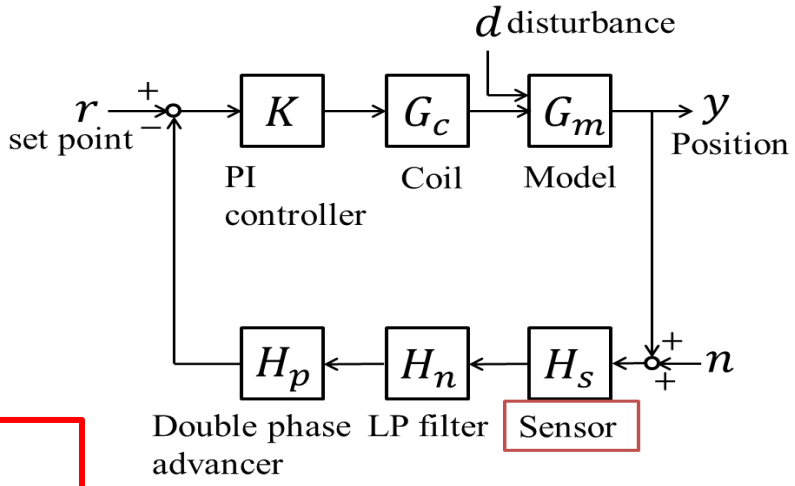
Current MSBS can levitate an axisymmetric model

MSBS & Position Measurement

MSBS

- Coil subsystem
- Position measurement subsystem
- Control subsystem

Position measurement is important

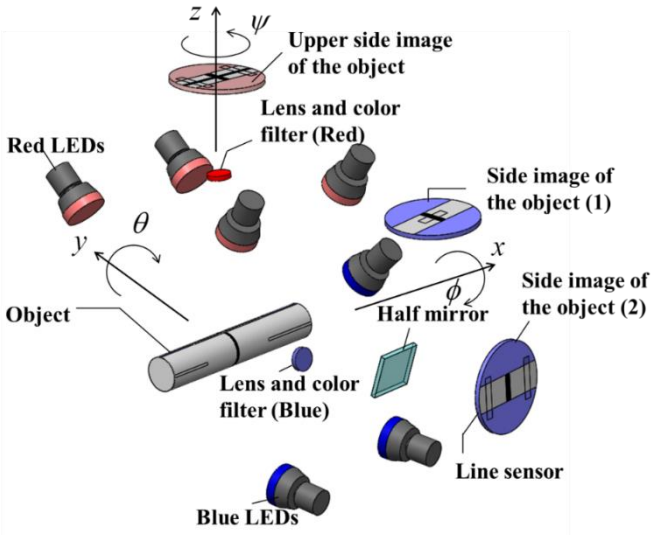


Block diagram of 1-m MSBS

Position measurement subsystem

- Blue and red LEDs
- CCD line sensors
- Lenses and color filters
- Half mirrors

We need to detect the edges of a model and makers



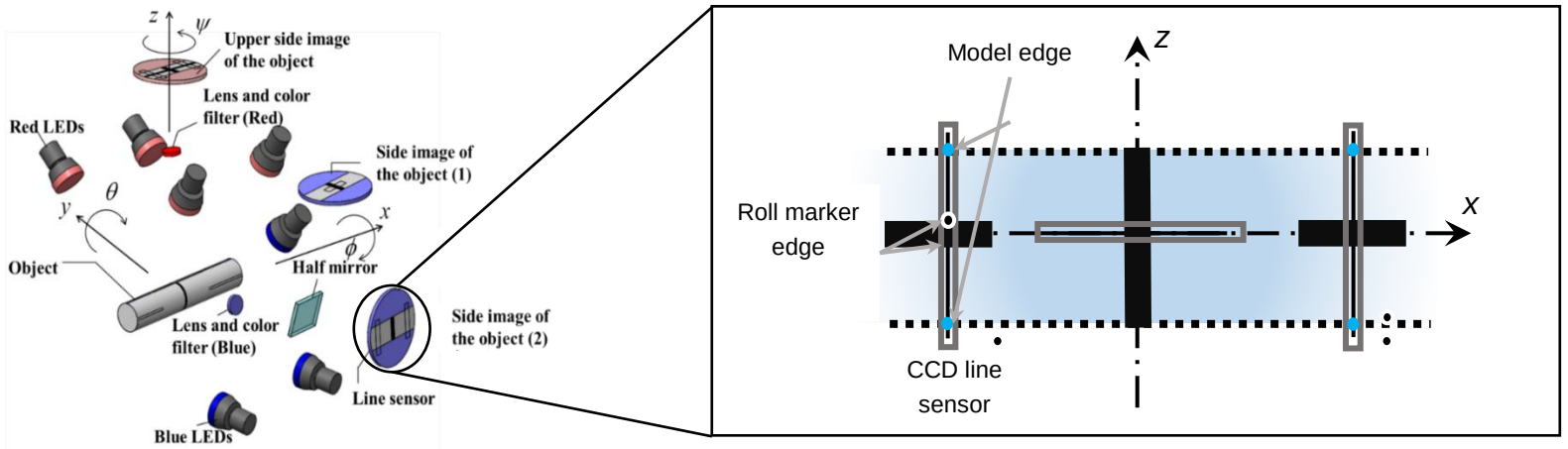
Position sensing subsystem at 1-m MSBS

Objectives

Propose a new method for measuring the position of a non-axisymmetric model such space plane model

- Problems due to model non-asymmetry
  - ✓ Changing-edge situation
  - ✓ Obstacle parts
- Levitation test

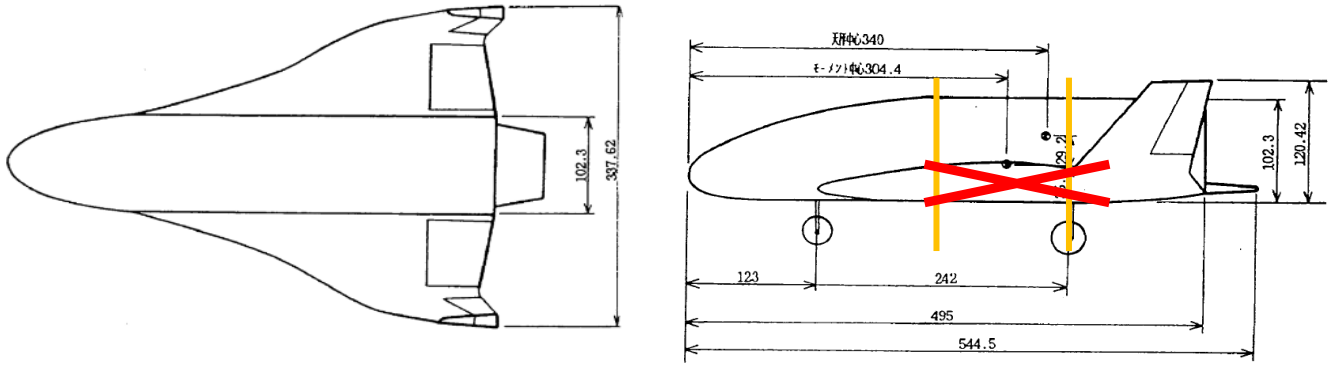
Obstacle parts problem



Position sensing subsystem at 1-m MSBS

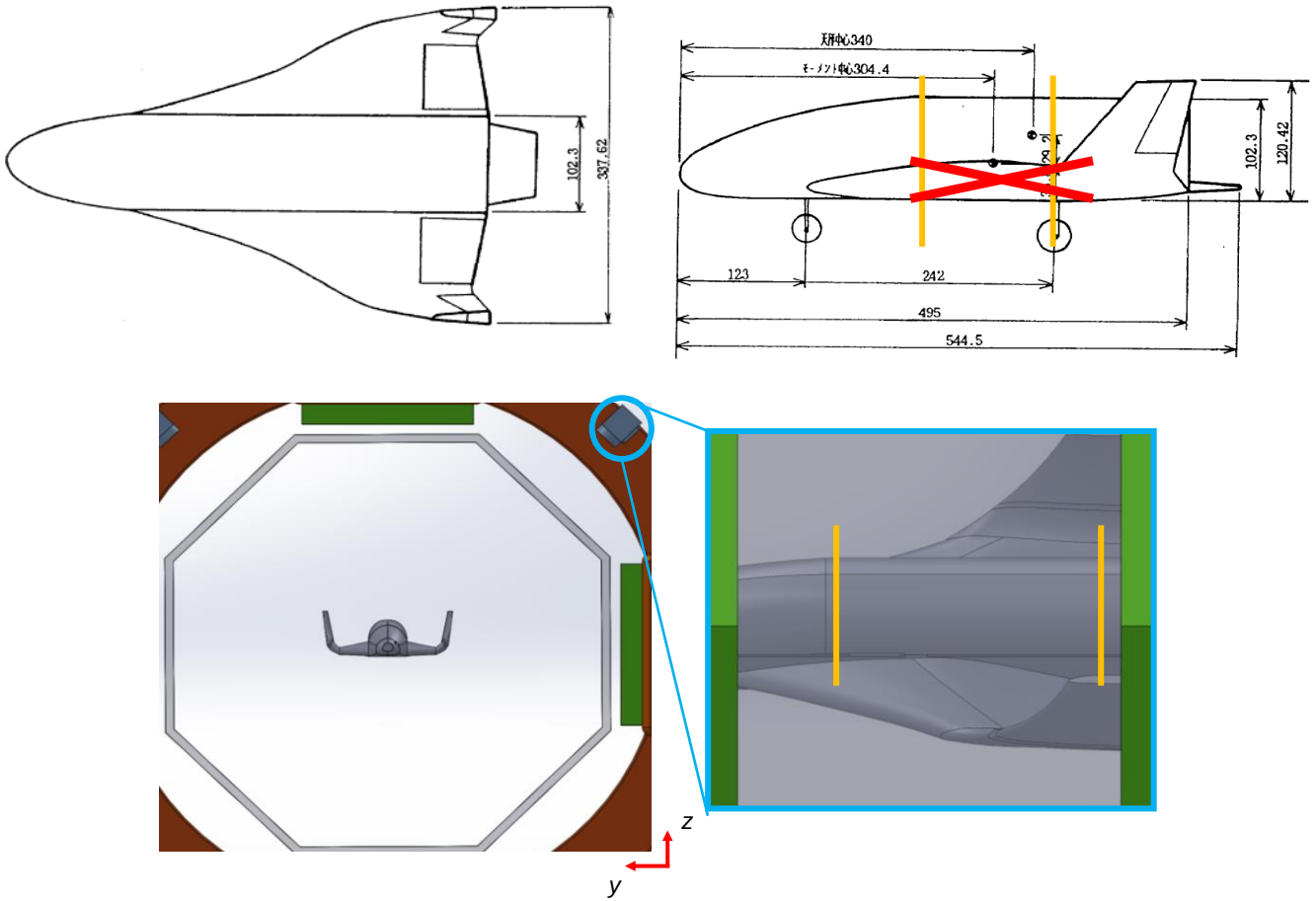
Image on sensor screen

Conventional sensors placed at 90 and 180 deg around the *x*-axis.



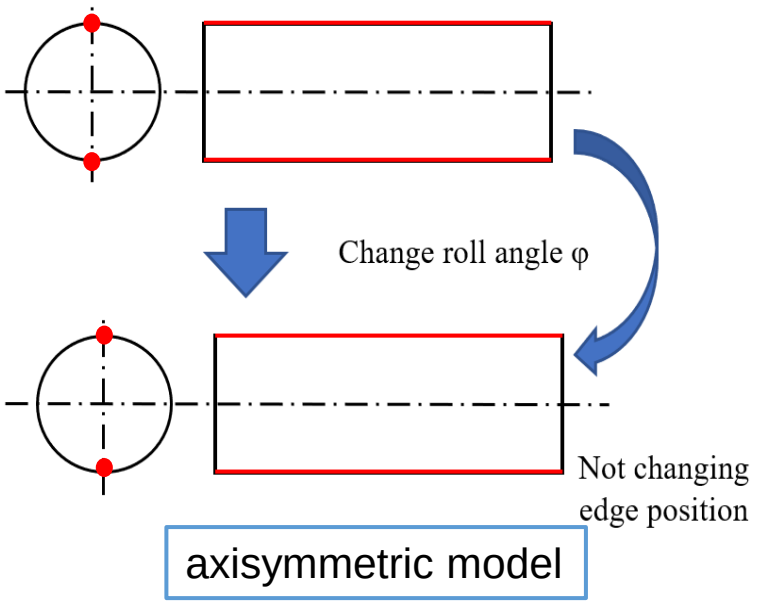
Wings are obstacles to position measurement

Obstacle parts solution

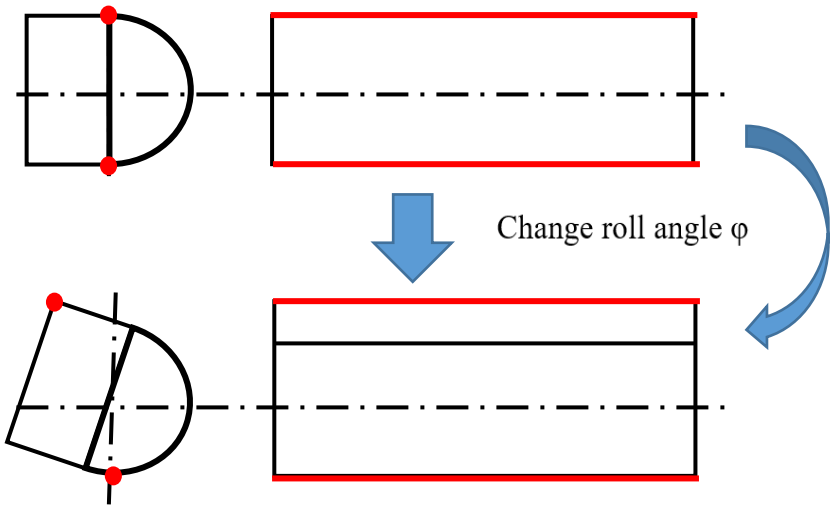


Change camera angle to avoid obstacles

Changing edge problem



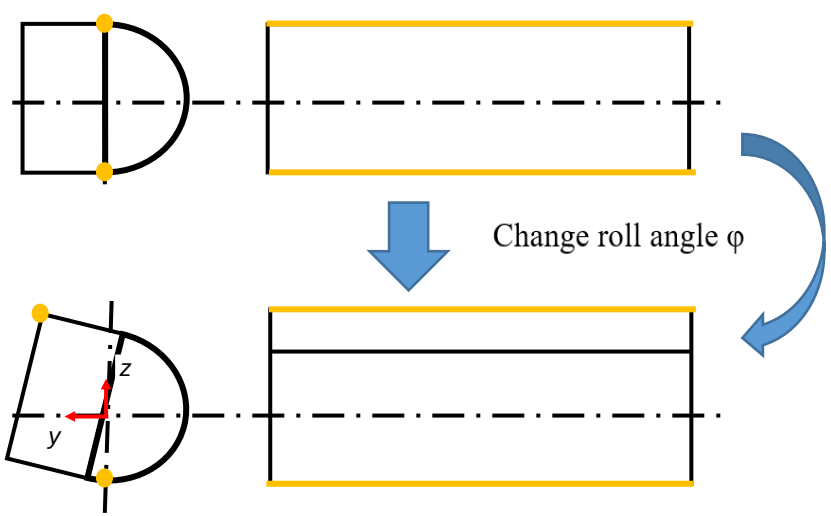
axisymmetric model

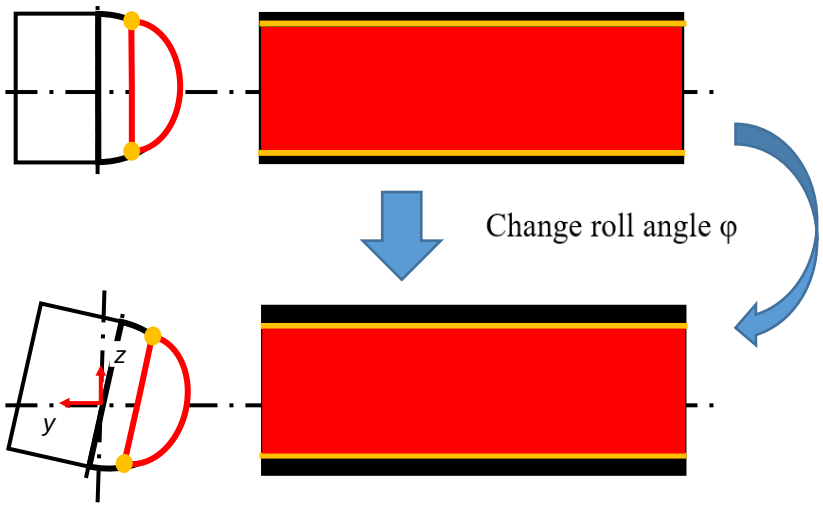


non-axisymmetric model

Non-axisymmetric model,
the edge position changes when a roll angle occurs

Changing Edge solution

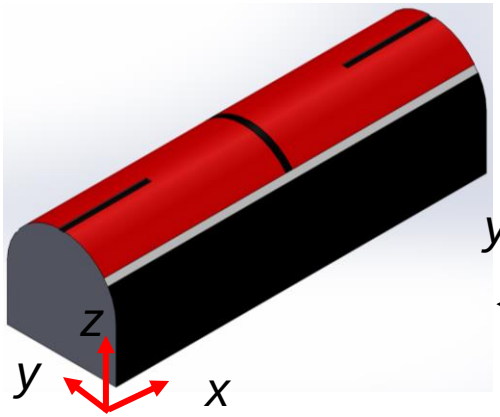


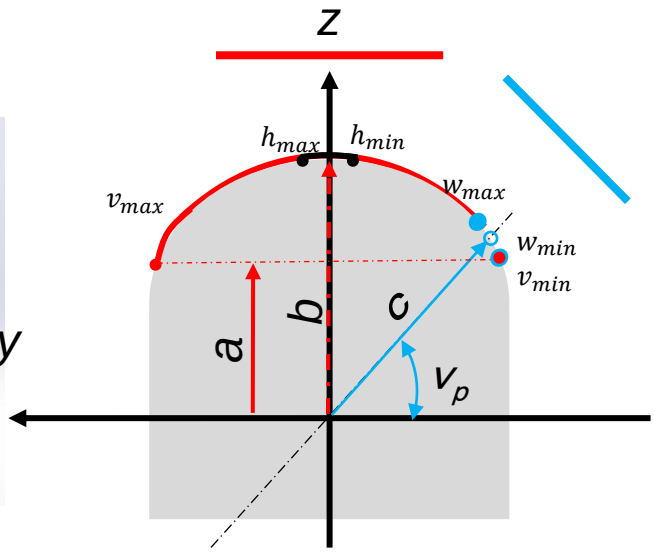


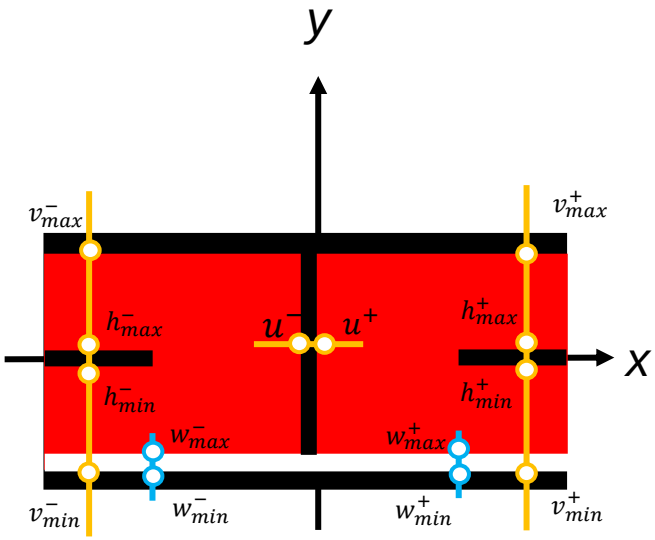
Color coding to two colors prevents interference of reflected light

Edge detection is possible without changing the edge position of the model

New Position Measurement Method







$$\left|\frac{x_0}{l}\right|, \left|\frac{y_0}{l}\right|, \left|\frac{z_0}{l}\right|, |\theta|, |\psi|, |\phi| \ll 1$$

$$P = \frac{v^+_{max} + v^+_{min} - v^-_{man} - v^-_{min}}{4} \sim -u_0\psi \qquad H = \frac{h^+_{max} + h^+_{min} + h^-_{man} + h^-_{min}}{4} - \frac{v^+_{max} + v^+_{min} + v^-_{man} + v^-_{min}}{4} \sim -n(b-a)\phi$$

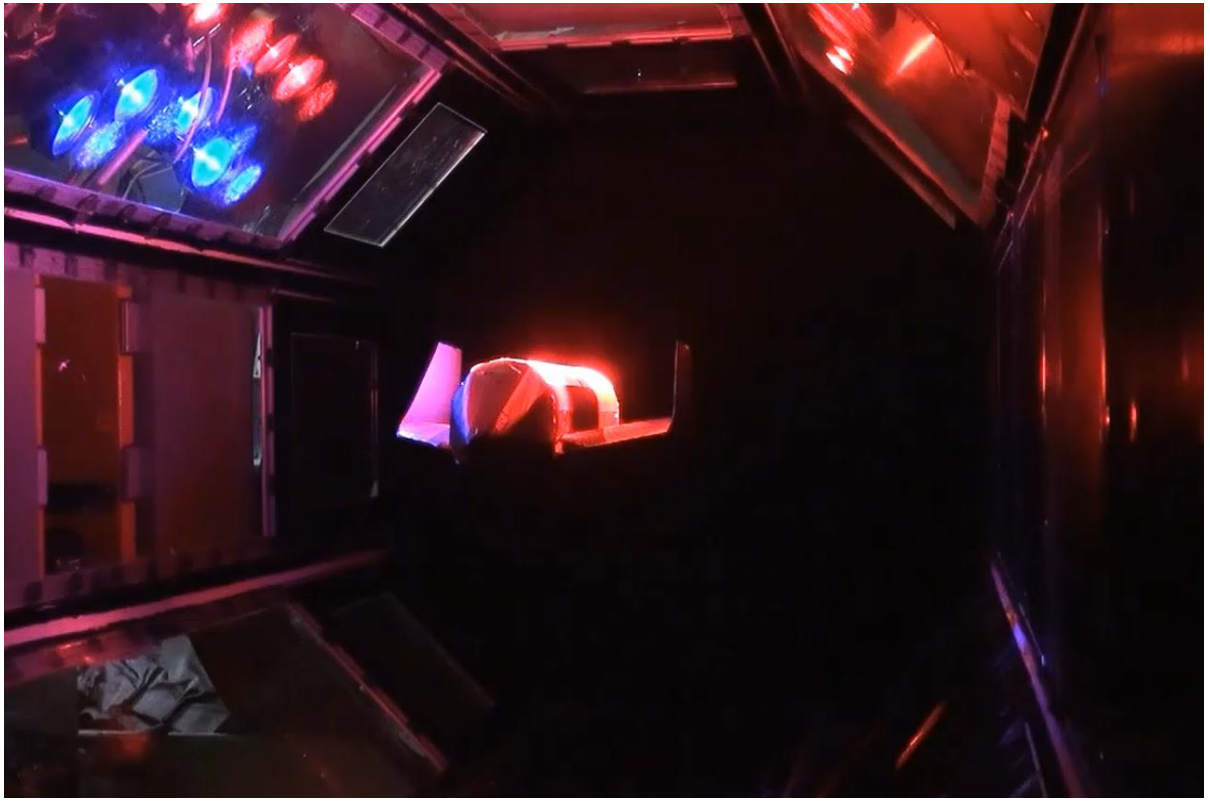
$$T = \frac{w^+_{max} + w^+_{min} - w^-_{man} - w^-_{min}}{4} \sim -u_0(\psi sin\alpha + \theta cos\alpha) \qquad V = \frac{v^+_{max} + v^+_{min} + v^-_{man} + v^-_{min}}{4} \sim -na\phi - ny_0$$

$$U = \frac{u^+ + u^-}{2} \sim -n(x_0 - a\theta) \qquad W = \frac{w^+_{max} + w^+_{min} + w^-_{man} + w^-_{min}}{4} \sim -n(y_0 sin\alpha + z_0 cos\alpha + c\phi)$$

Measurement of 6 axes is possible

Levitation test

Levitation model



Levitation movie (pitch θ = +3 deg)

Levitation to θ and ψ = ±3 deg achieved by this positional measurement

Conclusions and Future plan

Conclusions

Propose a new method for measuring the position of a non-axisymmetric model such space plane model

- Edge-switching can be prevented by color coding
- Levitation up to 3 deg of yaw and pitch angle were achieved using the proposed method

Future plan

- Development of a high angle of attack position measurement method
- Acquisition of aerodynamics