SCI-328 Symposium
Flight Testing of Unmanned Aerial Systems (UAS)
Segovia, Spain, 12-13 May 2022

Experimental Analysis of UAVs Operations on Military Frigates

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1.0 INTRODUCTION

National Institute for Aerospace Technology (INTA):

Public Research Organization that depends on the Spanish Ministry of Defence.

It is responsible for performing **scientific research activities and prototypes** in its field of knowledge, as well as for providing technological services to companies in the industry, universities and other institutions.

INTA specializes in **technological research and development** in

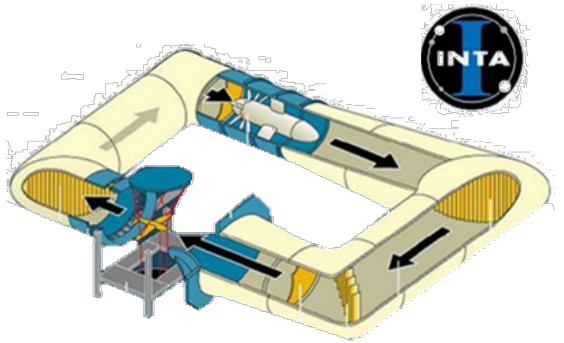
- **Aerospace**
- **Aeronautics**
- **Hydrodynamics**
- **Security and defense technologies.**

1.0 INTRODUCTION

National Institute for Aerospace Technology (INTA):

Experimental Aerodynamics

- Aerospace
- **Aeronautics** → *Sub-Directorae Generale* **Aviation Systems** → *Department* **Flight Physics** → *Area* **Aerodynamic Testing**
- Hydrodynamics
- Security and defense technologies.



Low-Speed Wind Tunnel

1.0 INTRODUCTION

National Institute for Aerospace Technology (INTA):

Experimental Aerodynamics

Wind-Tunnel testing of:

- **Frigate Aerodynamics**
- **Helicopter Aerodynamics**
- **Unmanned Aerial Vehicles (UAVs)**
- Civil Engineering (Buildings, Airport terminals…)
- Others: MARS2020, filters…

Aerodynamic Interference

Aircraft - Frigates

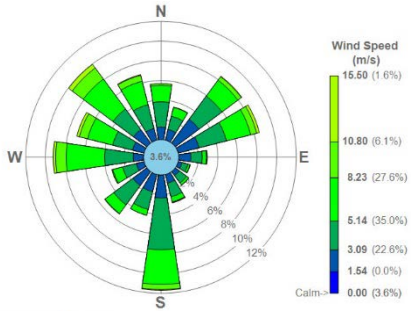
1.0 INTRODUCTION

National Institute for Aerospace Technology (INTA):

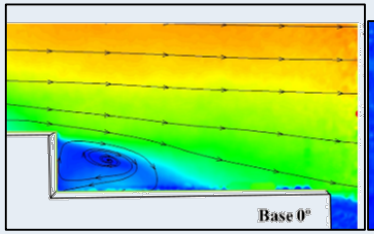
Experimental Aerodynamics

Aerodynamic Interference (Frigate – Aircraft)

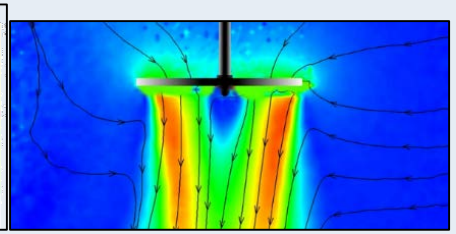
- ❑ Commercial Testing ⟶ **Flight Envelopes**
- ❑ **Research & Development**



Aerodynamic Characterization

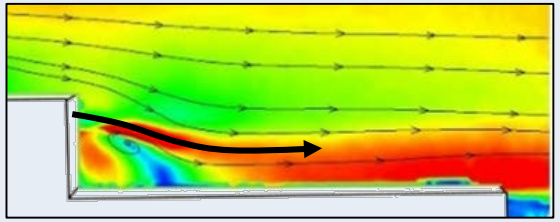


Frigate Aft-Deck



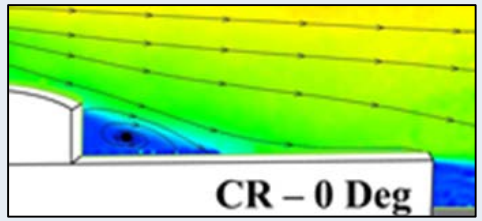
Rotor Aerodynamics

Active Flow Control



Blowing

Passive Flow Control



Hangar Geometry Changes

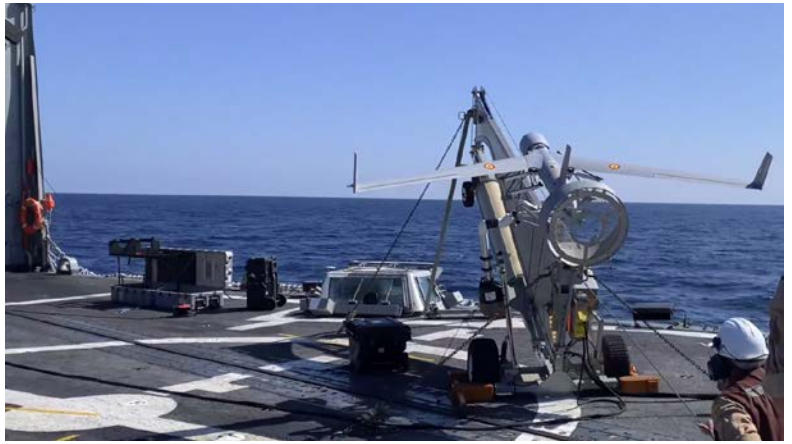
1.0 INTRODUCTION

THE PROBLEM:

UAV flights around frigates can be complex and high-risk operations.

- ❑ Ship movement
- ❑ Turbulent flow generated by the non-aerodynamic shapes of the frigate

Numerical, wind-tunnel and full-scale flight tests are essential to know possible interferences with UAVs operations.

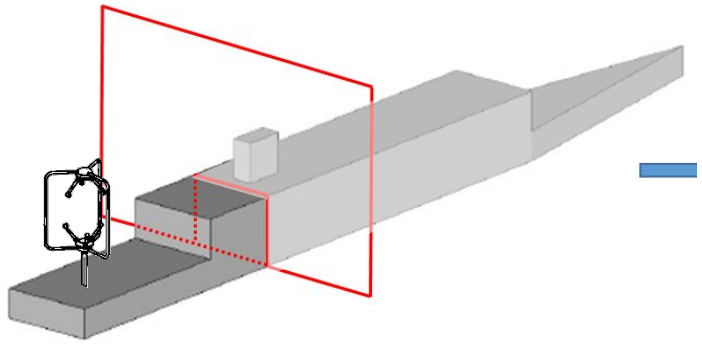


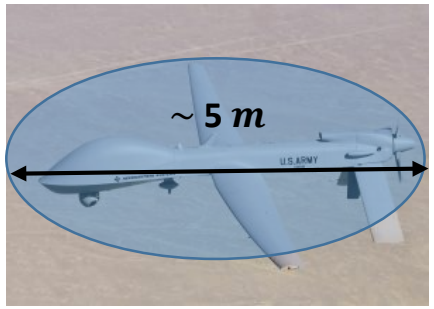
Flight tests of Scan Eagle above "*Reina Sofía*" spanish Frigate.

1.0 INTRODUCTION

GOALS OF THE STUDY:

- Create a three-dimensional model of a descending step which represents a scaled aft-deck of a frigate.
- Select the proper scale of the model (1:20) for wind tunnel testing
- Take velocity measurements by means of PIV and ultrasonic anemometry in wind-tunnel for **amplitude and frequency analysis.**





Unmmaned Aircraft Vehicle (UAV)

1:20 scale

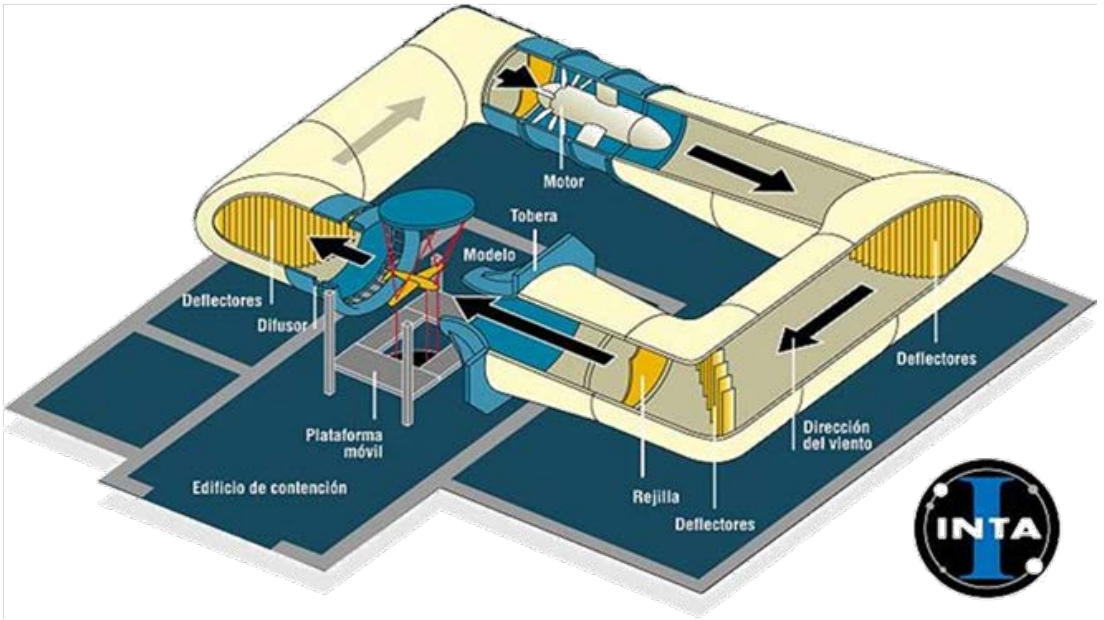
Ultrasonic Annemometer (measurement volume)

2.0 EXPERIMENTAL SET-UP

2.1 Low-speed wind tunnel

Low-speed wind tunnel T1 - National Institute for Aerospace Technology (INTA)

- Torrejón de Ardoz (Spain)
- Closed-circuit
- Open and elliptical test section of 2 m × 3 m
- Moving platform that represents the sea surface
- Maximum velocity of 60 m/s
- Engine power of 450 kW at 420 V.
- Low turbulence intensity (≤ 0.5 %)
- Reynolds number up to 4 million/m.

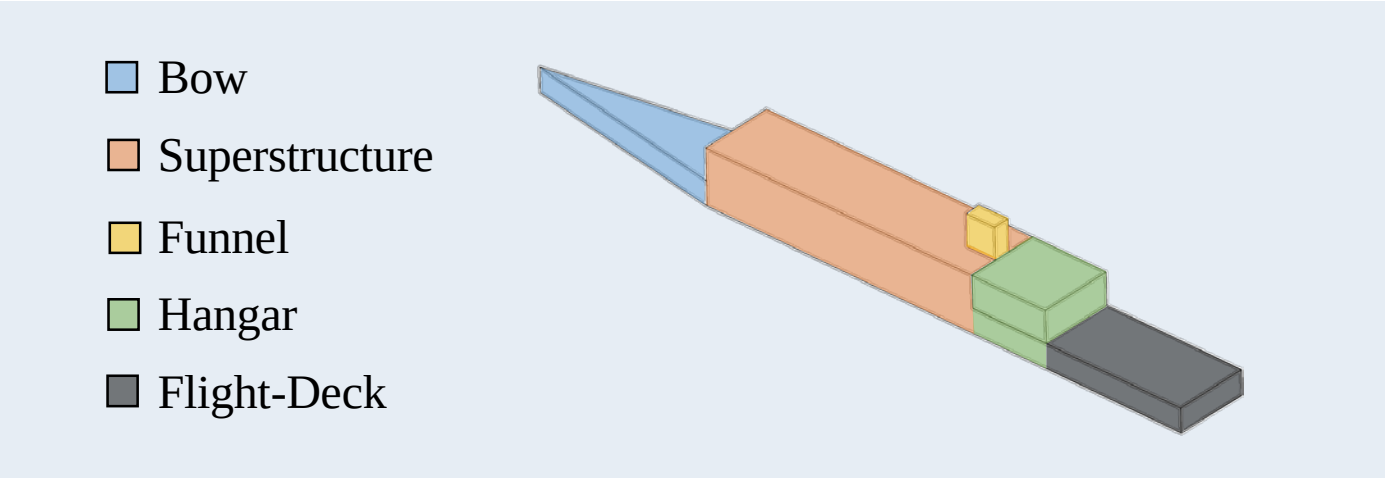


2.0 EXPERIMENTAL SET-UP

2.2 Frigate aft-deck scaled model

SIMPLE FRIGATE SHAPE

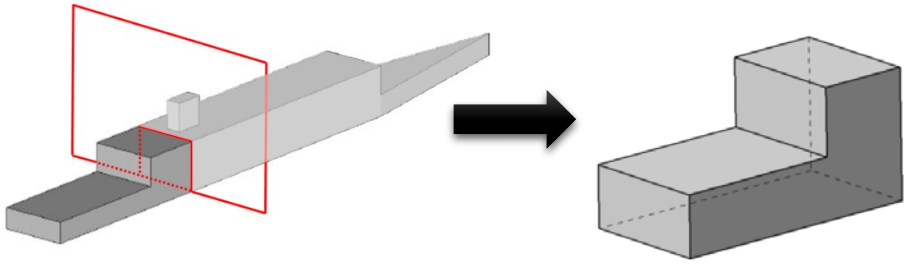
- Simplified model to investigate the basic flow fields of a frigate
- Defined by The Technical Co-operative Program (TTCP)



2.0 EXPERIMENTAL SET-UP

2.2 Frigate aft-deck scaled model

The geometry of the rear part of a frigate forms a descending step geometry.



Simple Frigate Shape

1:22 frigate aft-deck

Its maximum size is limited by the non-blockage condition.

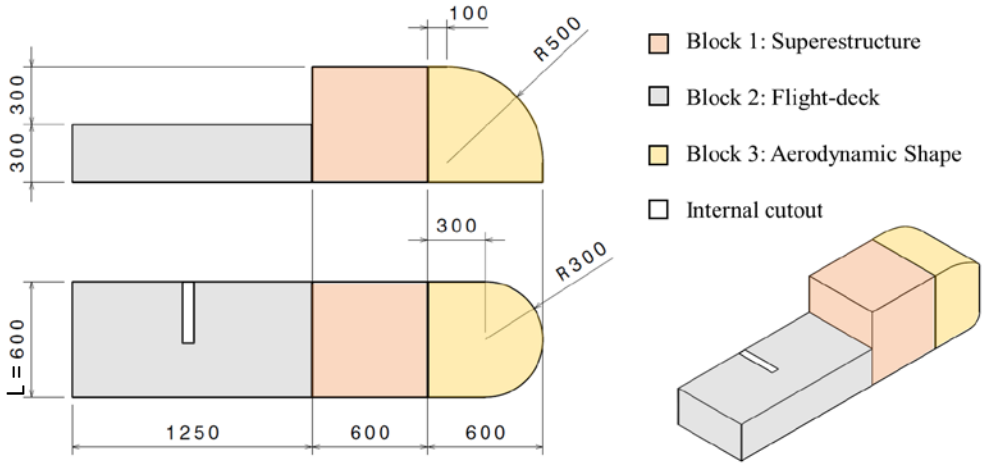
(< 10 % WT test section)

The model tested is composed of **three blocks**:

1) Rear part of the frigate superstructure 60 × 60 × 60 cm^3

2) Frigate aft-deck and its dimensions are 1250 x 60 x 30 cm^3

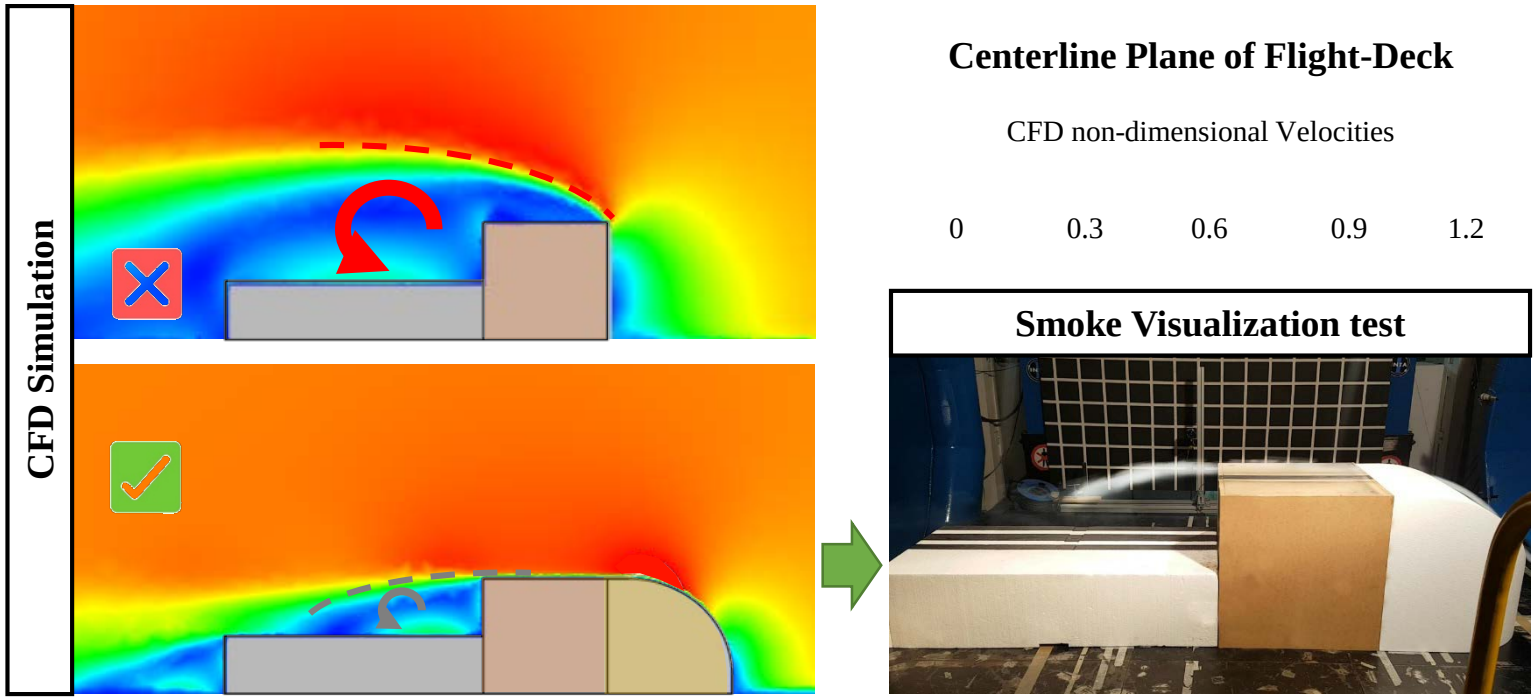
3) Aerodynamic block to avoid an abrupt detachment of the flow



2.0 EXPERIMENTAL SET-UP

2.2 Frigate aft-deck scaled model

To check the proper working of the **third block**, CFD simulation and a smoke visualization test were performed:



2.0 EXPERIMENTAL SET-UP

2.3 Particle Image Velocimetry (PIV)

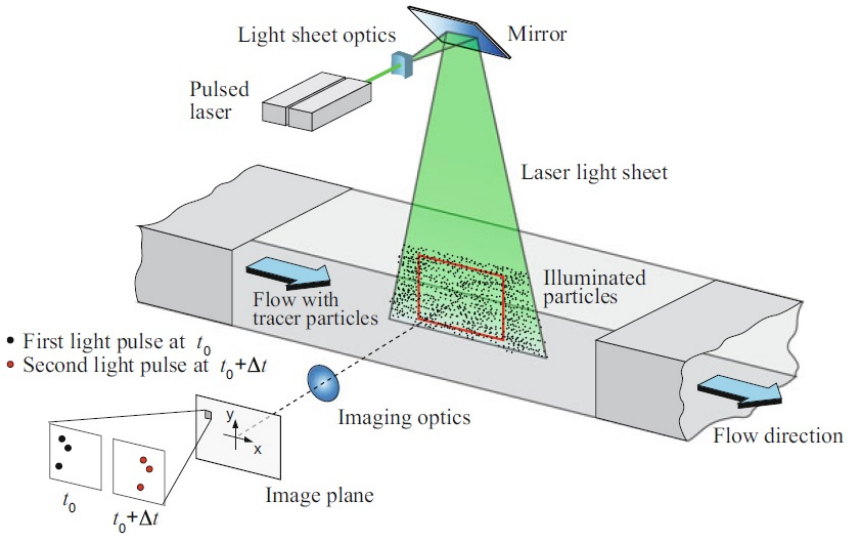
Advanced velocity measurement technique. Captures the position of small particles seeded in the flow in order to measure their displacement and velocity, which corresponds to the velocity of the flow.

Components:

- ❑ Particles seeding system.
- ❑ Two pulsed neodymium lasers
- ❑ Camera.
- ❑ Synchronizer (Laser – Camera)
- ❑ Computer.

Set-Up for experiments:

- ❑ Field of View (FOV) of 50 cm
- ❑ Fast Fourier Transform (FFT) for the correlation process
- ❑ Analysis window of 32 × 32 pixels
- ❑ Delay time between laser pulses of 25 μs.



2.0 EXPERIMENTAL SET-UP

2.4 Ultrasonic anemometry

WindMaster
1590-PK-020/W

Ultrasonic anemometry is a three components velocity measurement technique based on the use of ultrasonic waves.

An ultrasonic pulse is emitted from the upper transducer to the opposite transducer. Another pulse is emitted in the opposite direction. The times that the pulses last to travel the distance between the transducers is measured.

$$t_1 = \frac{L}{c+V} \qquad t_2 = \frac{L}{c+V}$$

As the velocity of sound (c), distance (L), and times are known, the velocity of the flow is,

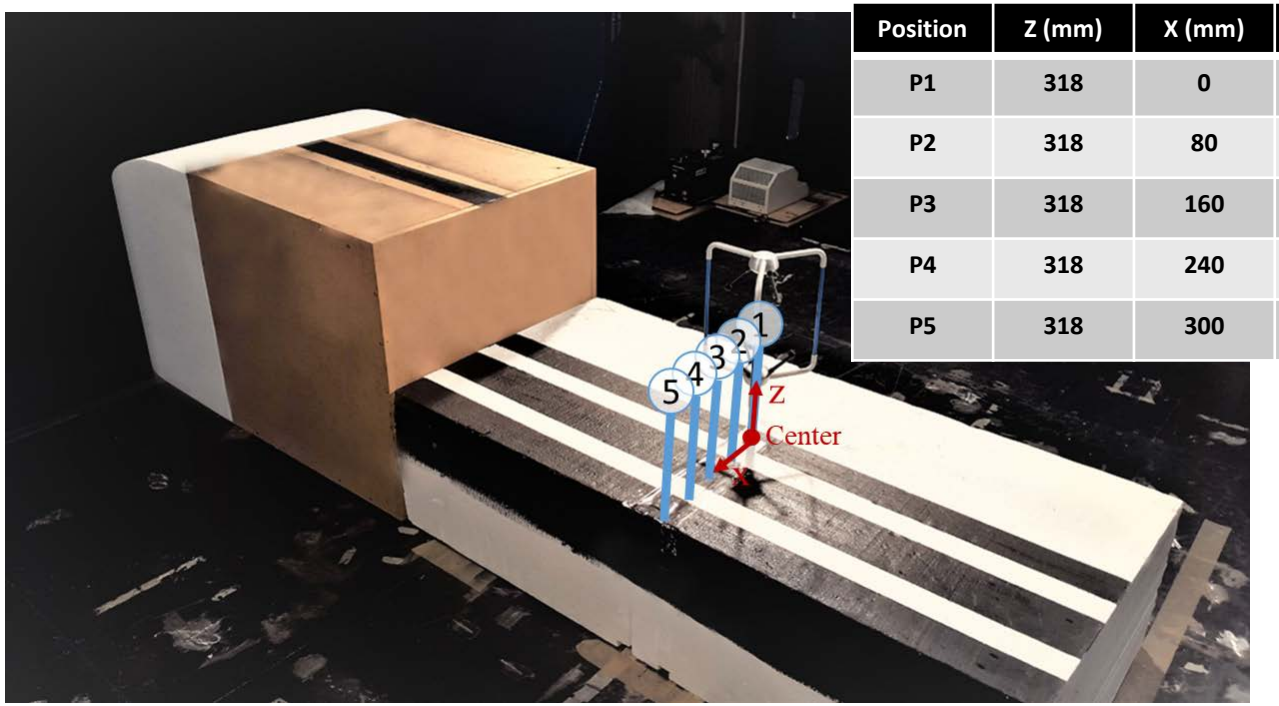
$$V = \frac{L}{2}\left(\frac{1}{t_1} - \frac{1}{t_2}\right)$$

Data sampling:
8 Hz, 20 Hz, or 32 Hz

2.0 EXPERIMENTAL SET-UP

2.4 Ultrasonic anemometry

The anemometer is placed in **five positions** where the UAV can be during maneuvers above the flight deck:

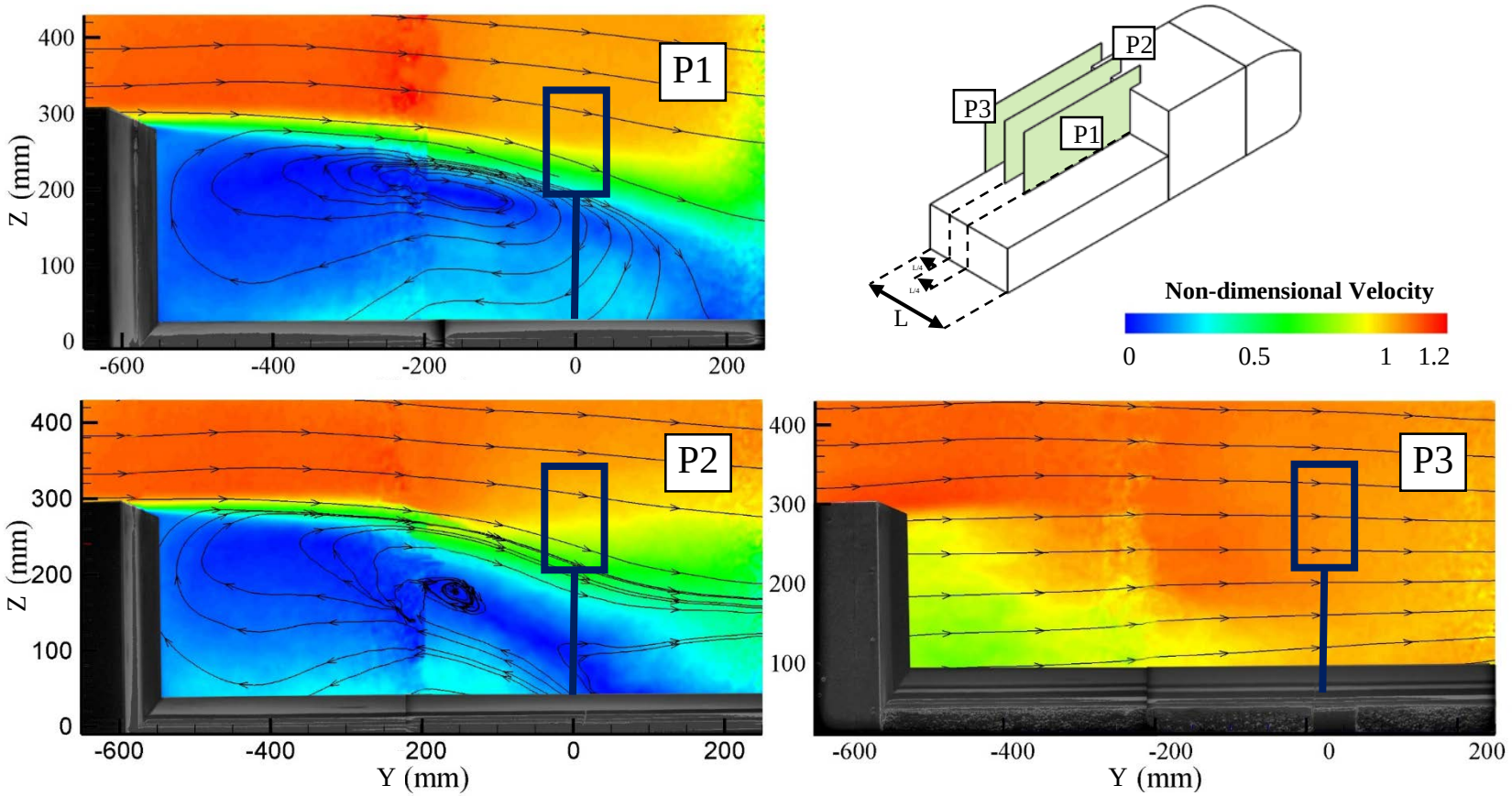


Position	Z (mm)	X (mm)	X/L
P1	318	0	0
P2	318	80	0.13
P3	318	160	0.27
P4	318	240	0.4
P5	318	300	0.5

- **Z = 318 mm** is inside the shear layer produced by the flow detachment on the superstructure.
- Complex zone for the operation of UAVs, with high **velocity gradients** and **turbulence** intensity.
- Data is taken for 1 minute at wind speeds of U_∞ **=10 and 15 m/s.**

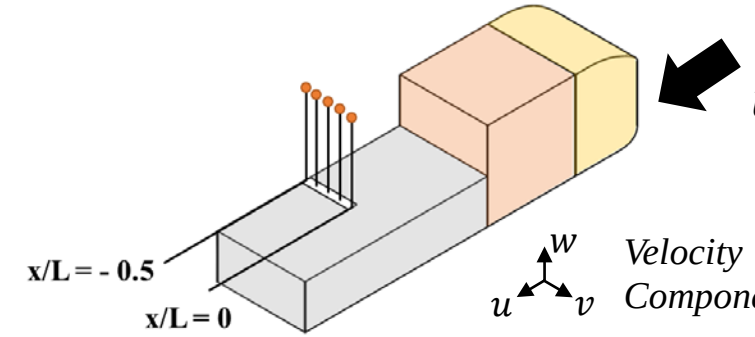
3.0 RESULTS

3.1 PIV Non-dimensional velocity maps

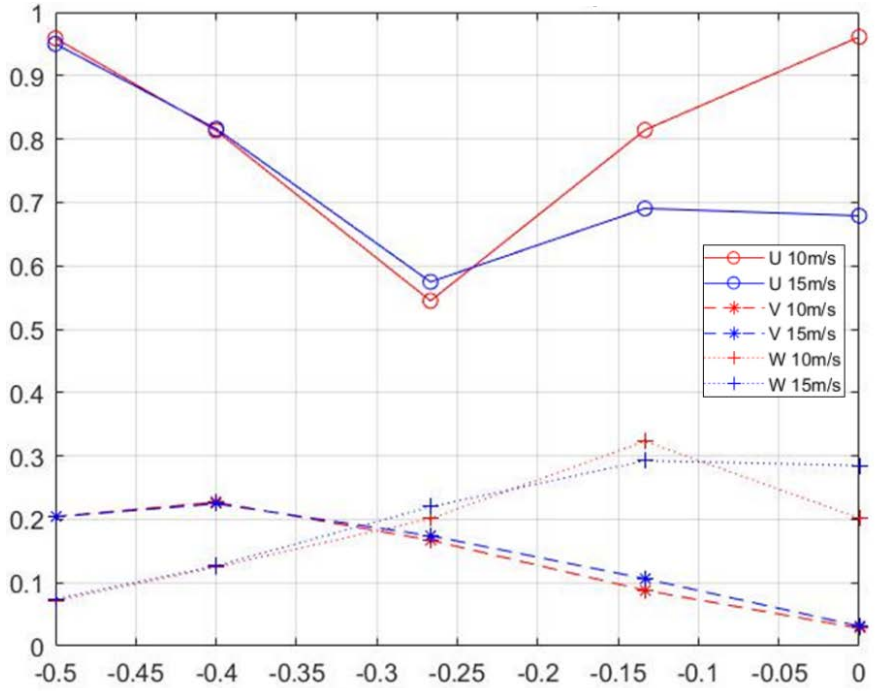


3.0 RESULTS

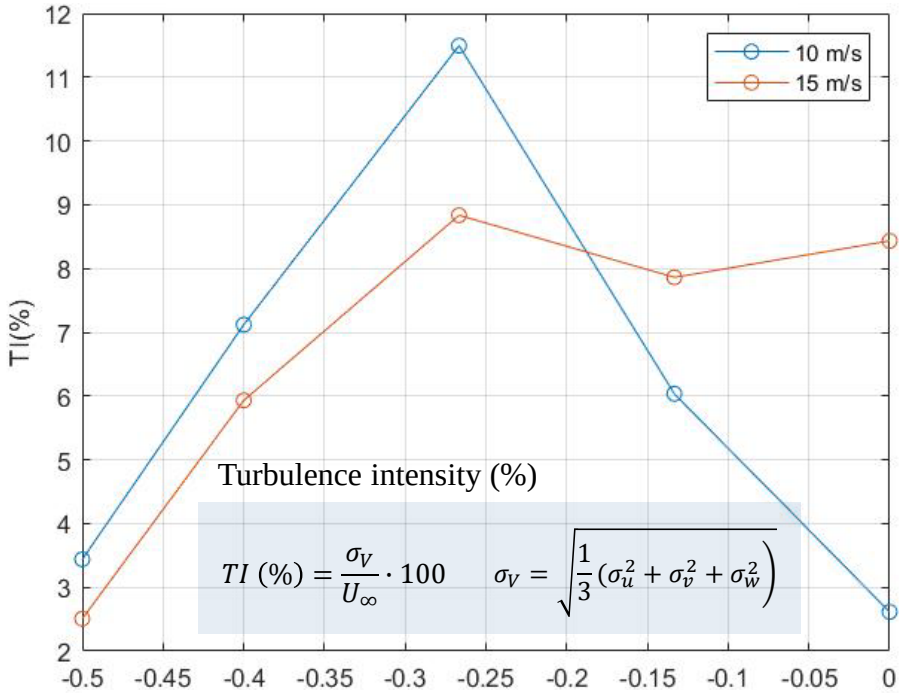
3.2 Ultrasonic anemometer: velocity measurements



Non-dimensional velocity

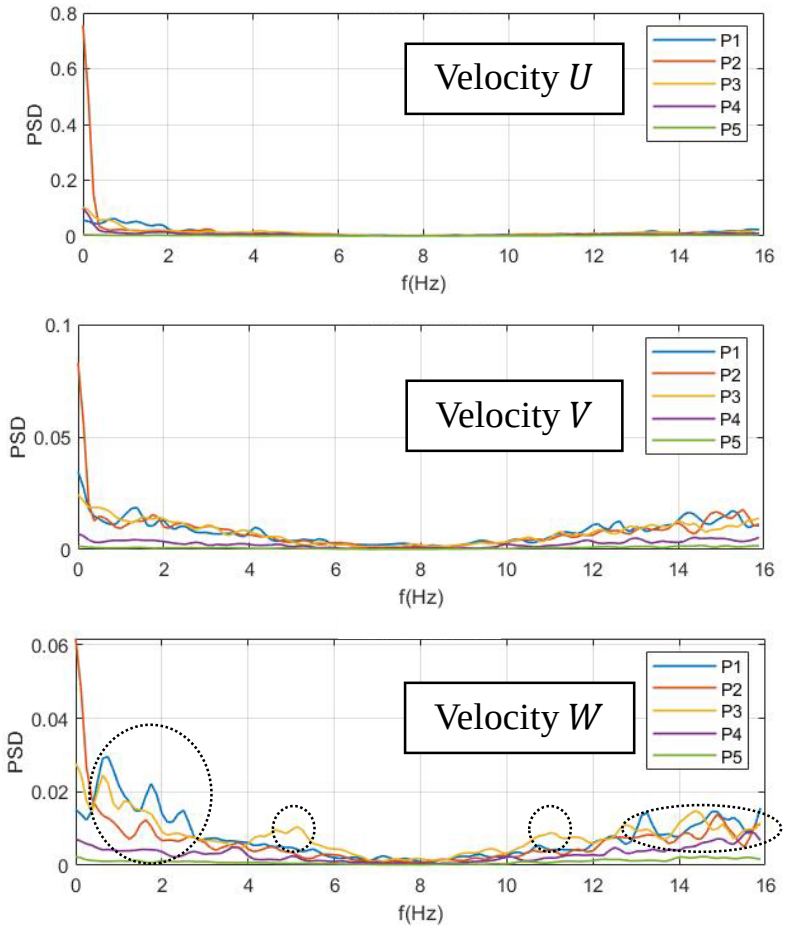


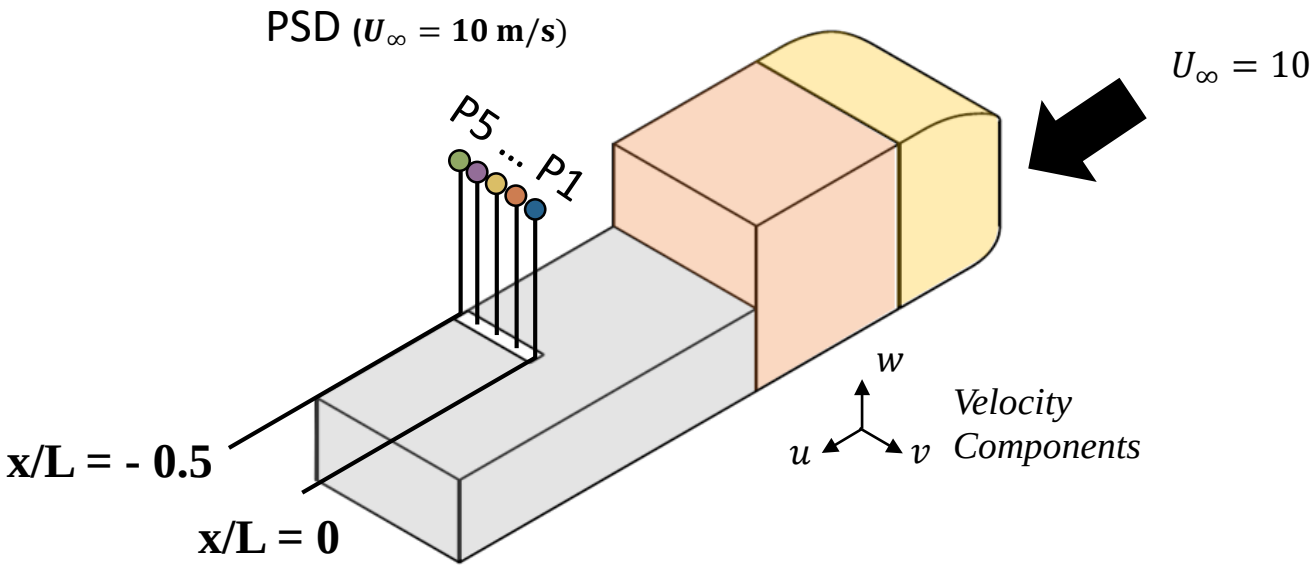
Turbulence Intensity (%)



3.0 RESULTS

3.3 Ultrasonic anemometer: spectral analysis

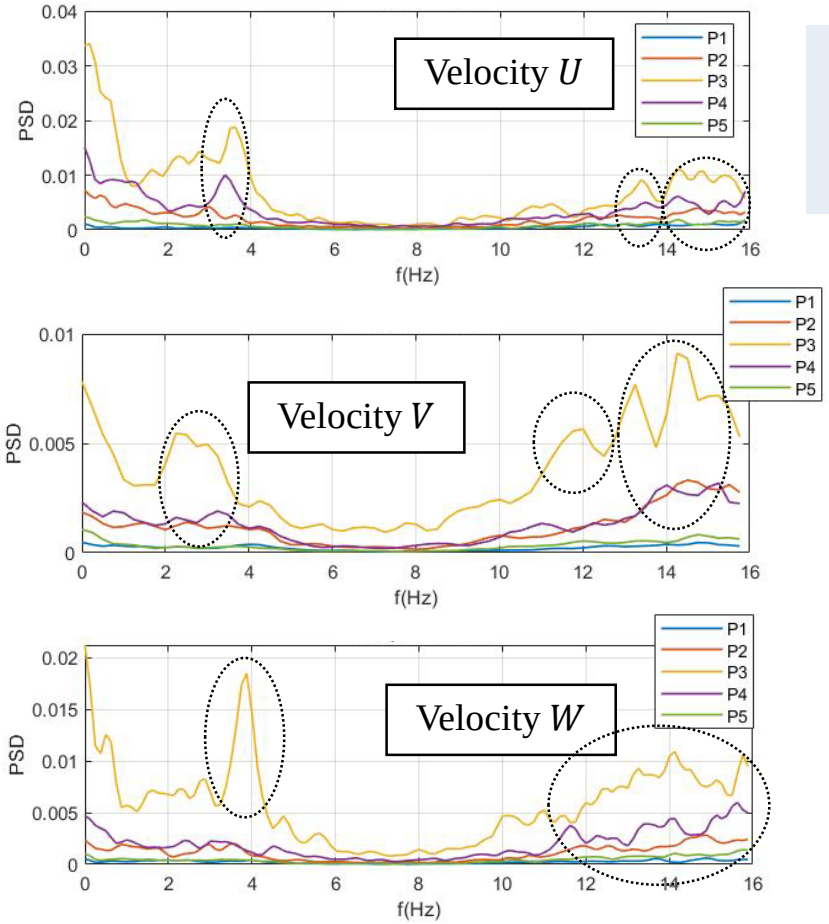




P1	P2	P3
1-2.5 Hz	1 Hz	5 Hz
13 Hz	1.8 Hz	11 Hz
15 Hz	15 Hz	13; 14.5 Hz

3.0 RESULTS

3.3 Ultrasonic anemometer: spectral analysis



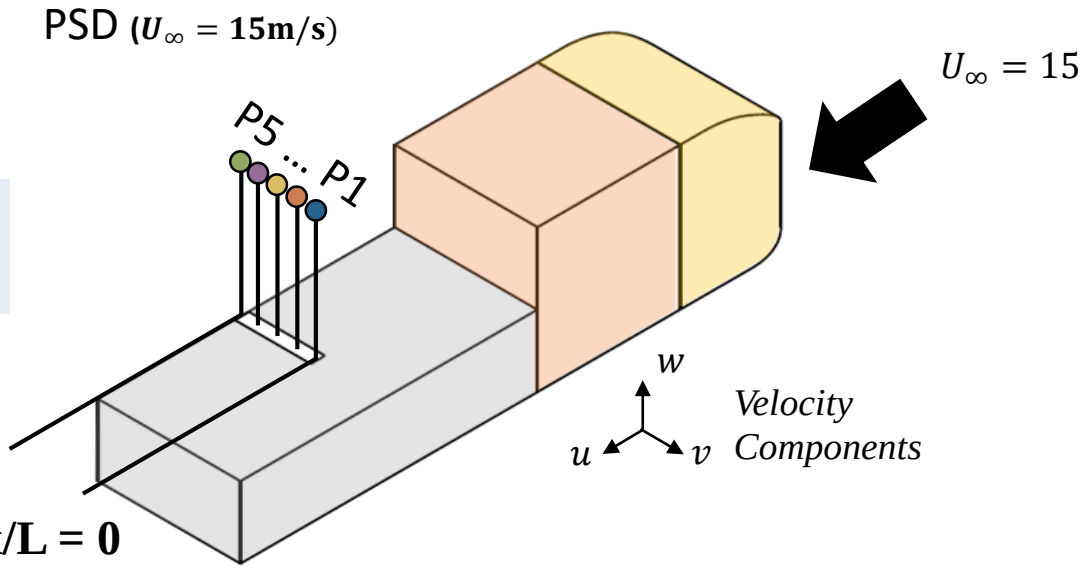
P3; P4
2-4 Hz
13-16 Hz

P3
3 Hz
12 Hz
13 Hz

P1; P2; P3
14-16 Hz

P3
4 Hz

P2; P3; P4
12-16 Hz

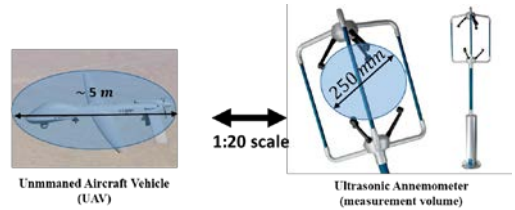


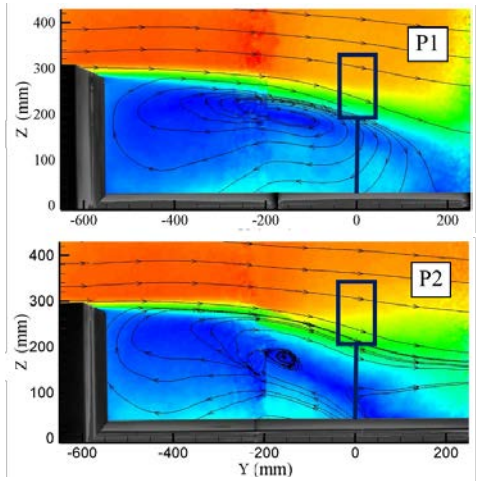
4.0 CONCLUSIONS

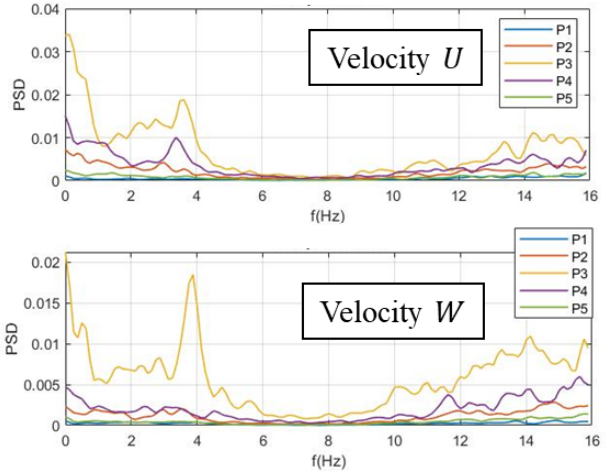
Flow inside the turbulent wake of the rear part of a frigate has been experimentally analyzed.

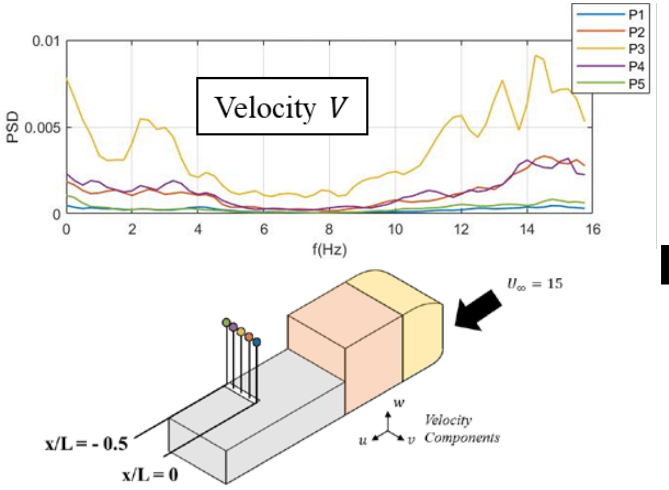
Velocity and turbulence intensity at different points where a UAV can operate around a frigate has been studied.

- ❑ PIV for obtaining non-dimensional velocity maps above the flight deck.
- ❑ Ultrasonic anemometer to measure the three components of velocity, turbulence intensity and **spectral analysis**.









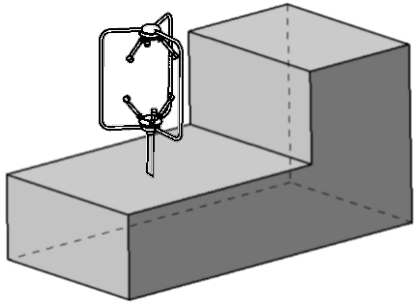
High frequency Peaks
1-4 Hz
11-16 Hz

UAV's Operations

4.0 CONCLUSIONS

4.1 Next-steps

1^{st} Step
Wind Tunnel Measurements



1:22 frigate aft-deck

2^{nd} Step
Full-Scale Measurements

Full-Scale Frigate

3^{rd} Step
UAV Flight-Tests on Frigate

MQ-8B Fire Scout above a frigate flight-deck

THANKS FOR THE ATTENTION

QUESTIONS