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ASOCIACIÓN DE INGENIEROS NAVALES Y OCEÁNICOS DE ESPAÑA

TRANSFORMANDO LOS OCÉANOS: INNOVACIÓN e ingeniería naval para un mundo CONECTADO y SOSTENIBLE

WIND-TUNNEL INVESTIGATION OF FRIGATE-HELICOPTER AERODYNAMIC INTERFERENCE AND MITIGATION OF ADVERSE EFFECTS BY FLOW CONTROL

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Experimental Aerodynamics

National Institute for Aerospace Technology (INTA)

Instituto Nacional de Técnica Aeroespacial

CONTENT

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1. INTRODUCTION

Helicopters perform **hovering flight** close to objects and structures.

Military frigates are composed of non-aerodynamic bodies and generate **complex flow patterns** for helicopter operations.

Flow shedding, high-velocity gradients and turbulence intensities

Effect in	→	**aircraft stability**
Increase	→	**Pilot workload**

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1. INTRODUCTION

The **aerodynamic interference** helicopter – frigates can be analyzed…

Numerical studies

- ➢ Modeling pilot responses in flight simulators
- ➢ Pilot's workload estimation

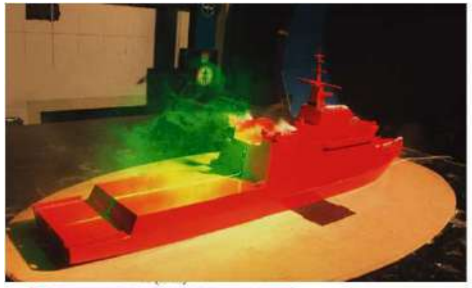
Experimental wind tunnel tests

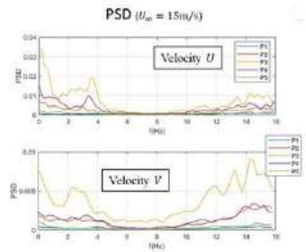
- ➢ Pressure and/or velocity determination
- ➢ Flow visualization (smoke or PIV).
- ➢ Force measurements.

Flow measurements on real frigates.

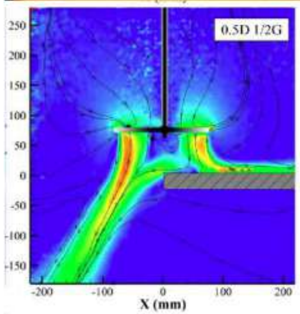
Research in flow control devices to improve the aerodynamic flow around them

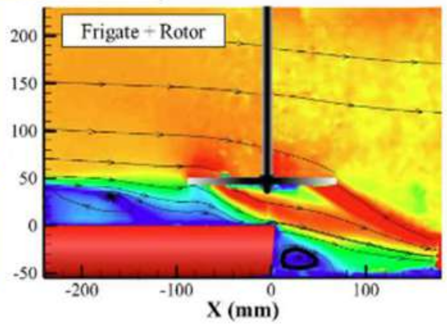
1. INTRODUCTION





Frigate – helicopter interference previous work at INTA





Measurements at **wakes** of commercial and research frigates.

Flow frequency **spectra.**

Studies of helicopter rotors in **ground effect** on the flight deck.

PIV analysis: flow of a helicopter rotor, full helicopter and in combination with frigates.

Force and torque measurements on scaled helicopters during recovery maneuvers.

Flow Control: with passive and active proposals.

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1. INTRODUCTION

The aim of this study is to **present an example of experimental results obtained in the wind tunnel of the National Institute for Aerospace Technology (INTA)** to…

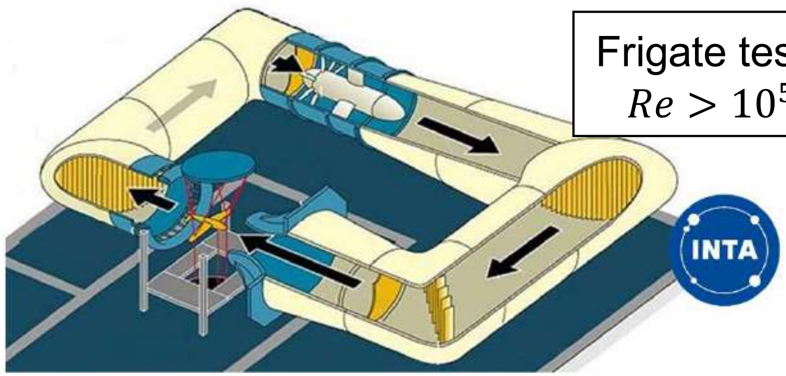
1. Characterize the **aerodynamics on the flight deck** of a frigate
2. Evaluate its possible **interaction with the helicopter maneuvers**
3. Present proposals to reduce the adverse effects found by means of **flow control**.

CONTENT

2. EXPERIMENTAL SET-UP

2.1. INTA T1 Wind Tunnel

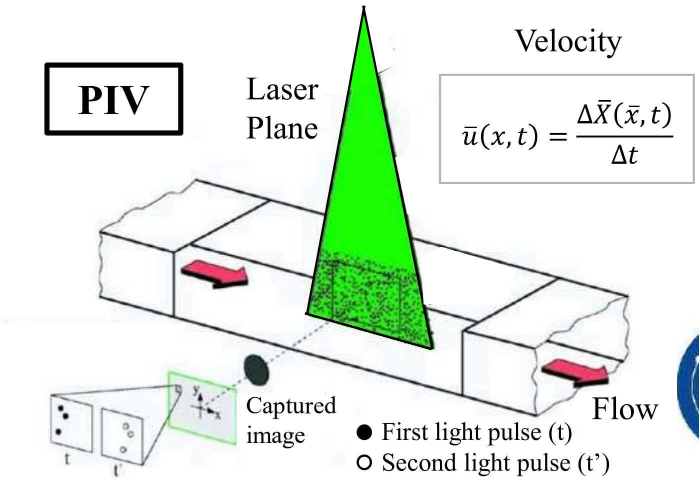
- Closed-circuit
- Elliptical open test section 2 m × 3 m
- Engine power 420 kW
- Max. flow velocity 60 m/s
- Turbulence levels < 0.5 %.

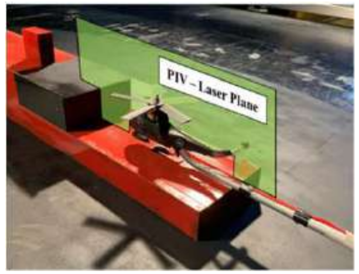


Frigate tests
$Re > 10^5$

2.2. Particle Image Velocimetry (PIV)

- Tracer particles seeded in the flow and are illuminated by a pulsed laser plane (Nd:YAG)
- Photographs capture the particles positions at two times synchronized with the laser pulses, separated (Δt).





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2. EXPERIMENTAL SET-UP

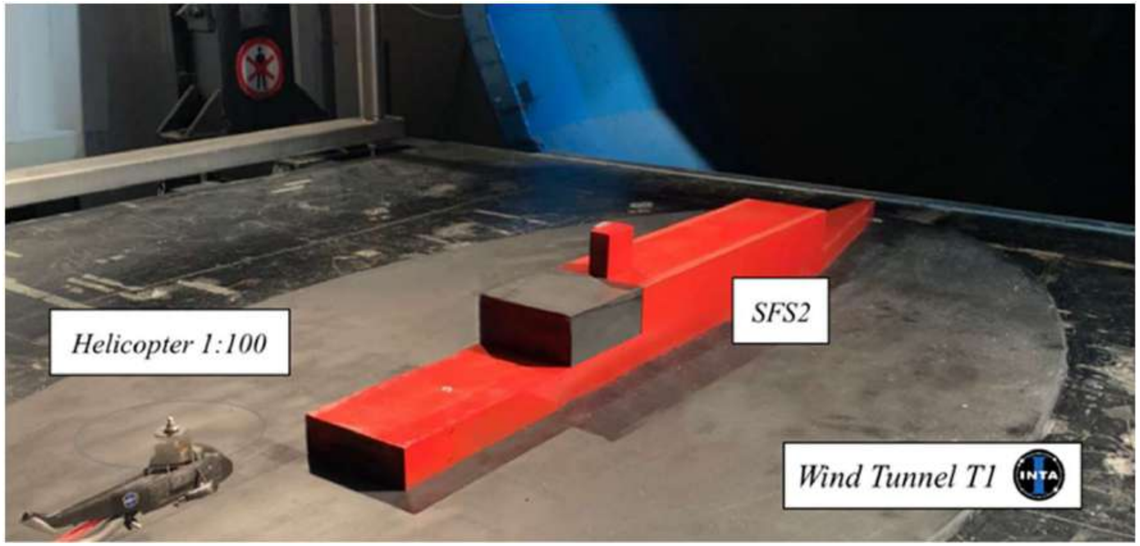
2.3. Frigate model

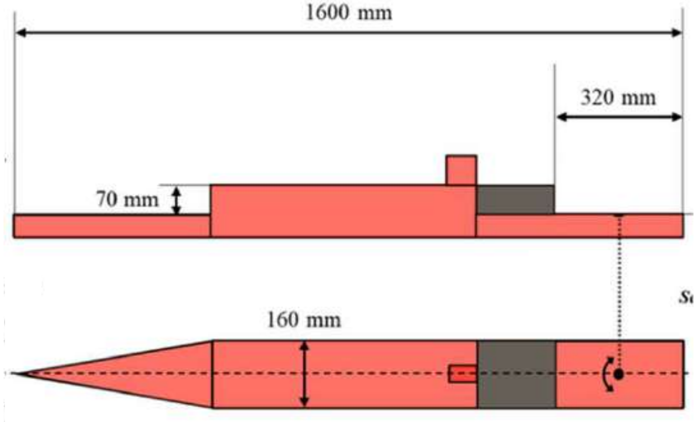
SFS2 - Simple Frigate Shape 2

Proposed by a research group oriented to the analysis of aerodynamic ship wakes, within a Technical Cooperation Program (TTCP).

Basic geometries above the waterline of a generic frigate (bow, superstructure, flight-deck)

Scale	1:100
Wind Velocity	8.5 m/s → $Re > 10^5$





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2. EXPERIMENTAL SET-UP

2.4. Helicopter model

HELIBAL (HELIcopter BALance)

Internal balance with strain gauges

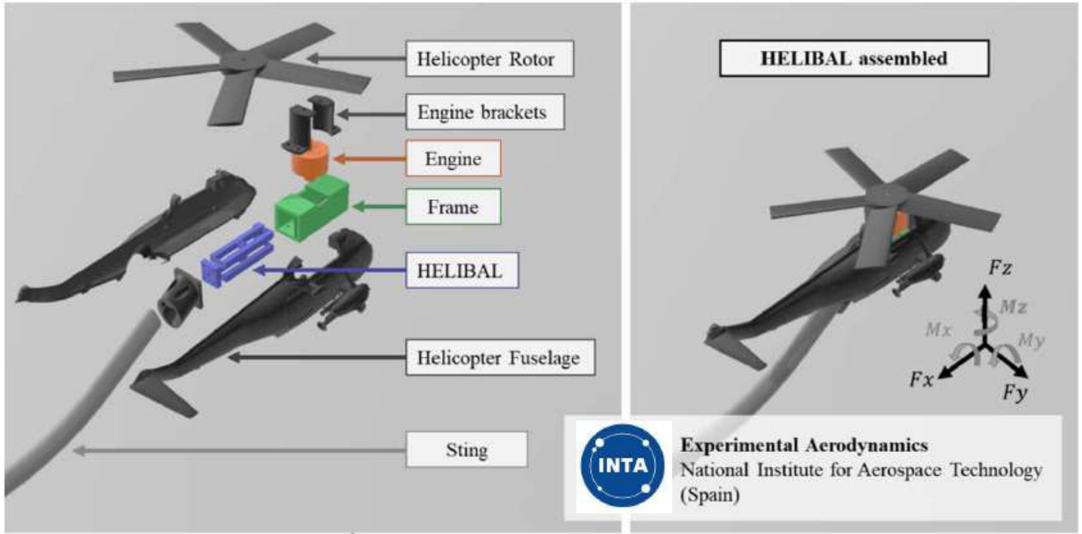
Designed, manufactured, and calibrated in INTA

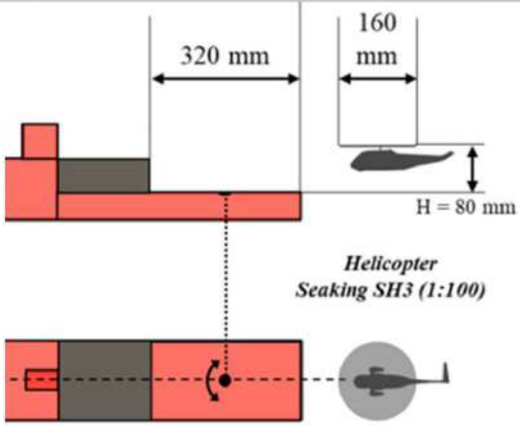
Six-component balance for a scaled helicopter model of a Sea King SH-3.

Forces	Thrust F_z, Drag F_x and Lateral F_y
Torque	Roll M_x, pitch M_y and yaw M_z

Flow similarity
thrust coefficient (C_T) and advance ratio (J) equal for the scaled and real helicopter.

Rotor revolutions	8,500 rpm
Wind tunnel velocity	8.5 m/s





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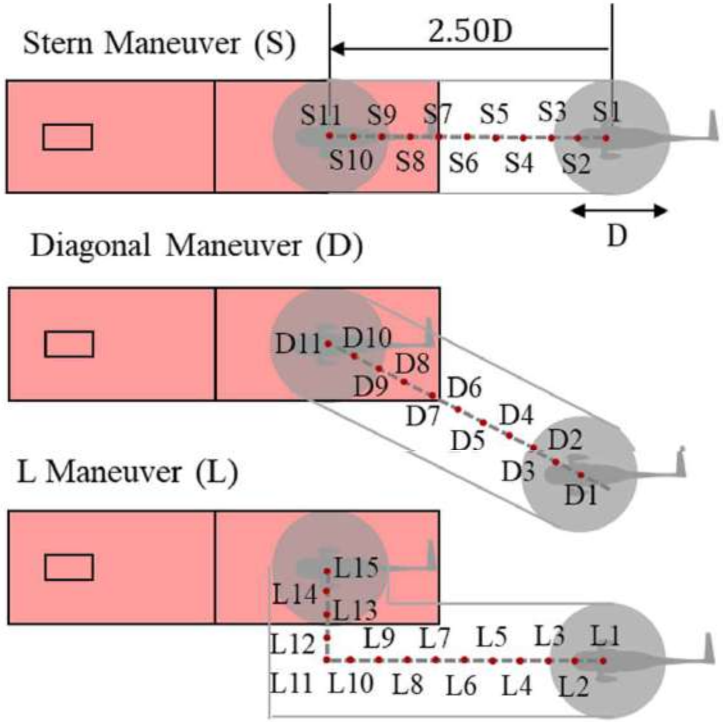
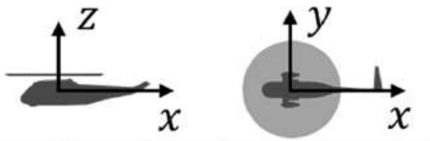
CONTENT

3. RESULTS

Three different recovery maneuvers:

- **Stern (S)**
- **Diagonal (D)**
- **L-Shaped (L)**

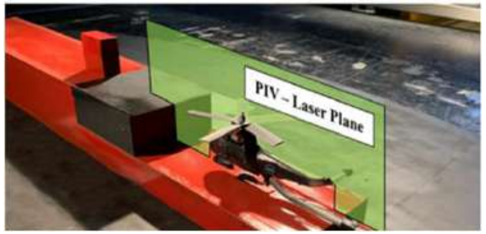


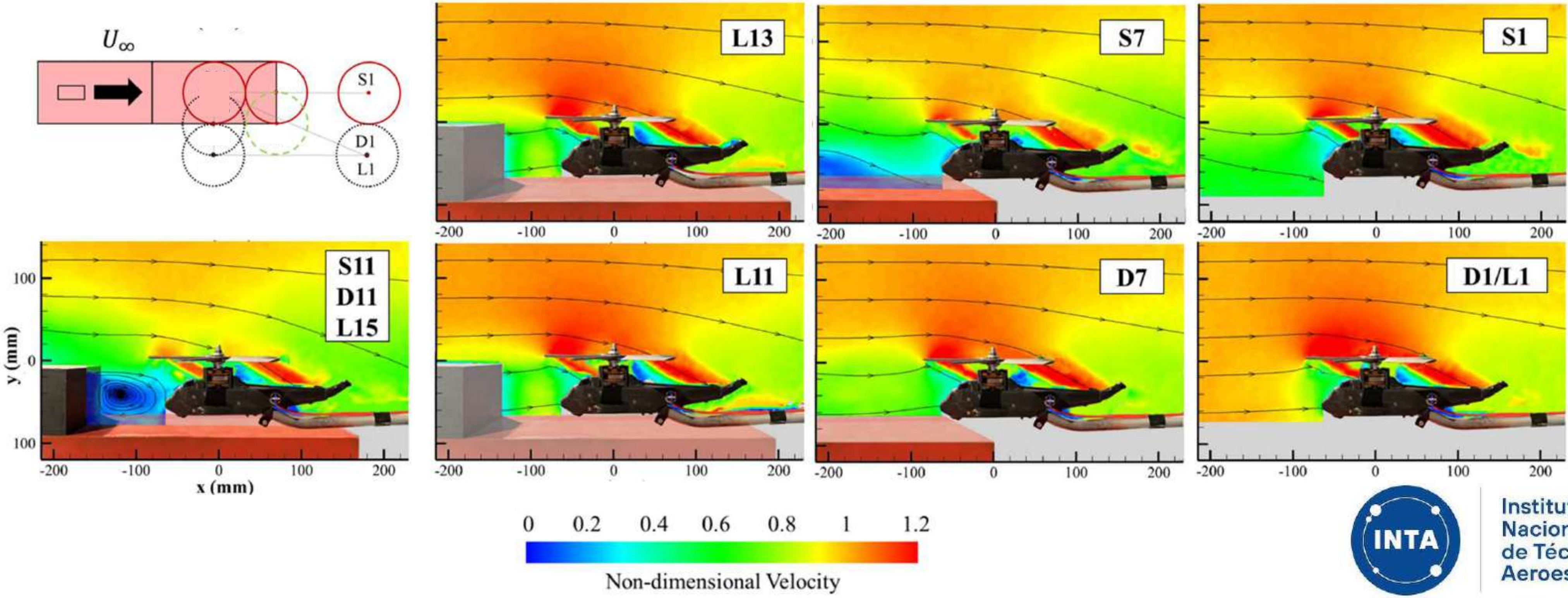


S	D	L	Distance to final
-	-	L1	3.50 D
-	-	L2	3.25 D
-	-	L3	3.00 D
-	-	L4	2.75 D
S1	D1	L5	2.50 D
S2	D2	L6	2.25 D
S3	D3	L7	2.00 D
S4	D4	L8	1.75 D
S5	D5	L9	1.50 D
S6	D6	L10	1.25 D
S7	D7	L11	1.00 D
S8	D8	L12	0.75 D
S9	D9	L13	0.50 D
S10	D10	L14	0.25 D
S11	D11	L15	0.00 D

3. RESULTS

3.1. PIV helicopter and frigate





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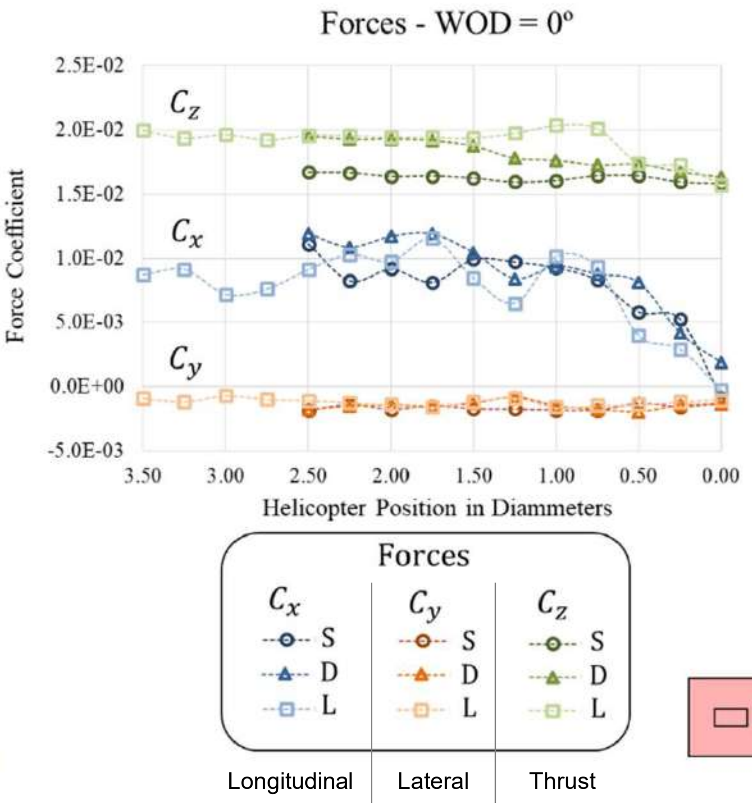
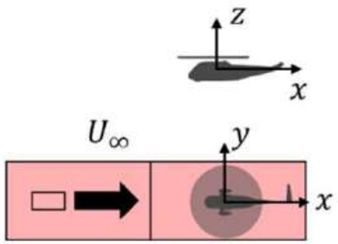
3. RESULTS

3.2. Helicopter aerodynamic forces





Force Coefficient

$$C_i = \frac{F_i}{\frac{1}{2}\rho(\Omega R)^2\, S}$$

Torque Coefficient

$$C_{mi} = \frac{M_x}{\frac{1}{2}\rho\Omega^2\, R^3\, S}$$

where i=(x,y,z), and

ρ	air density
Ω	rotor revolutions 8,500 rpm
R	rotor radius 0.08 m
S	rotor surface 0.0201 m^2

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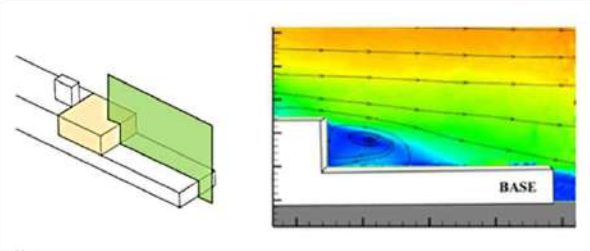
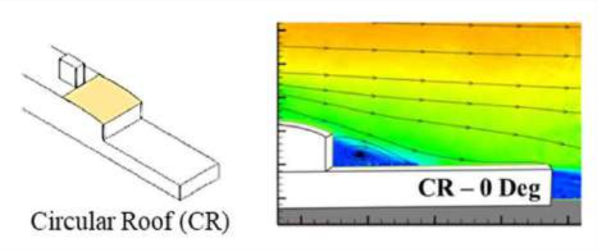
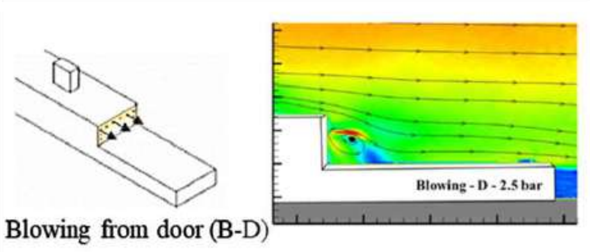
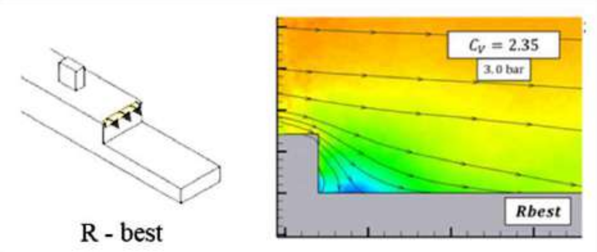
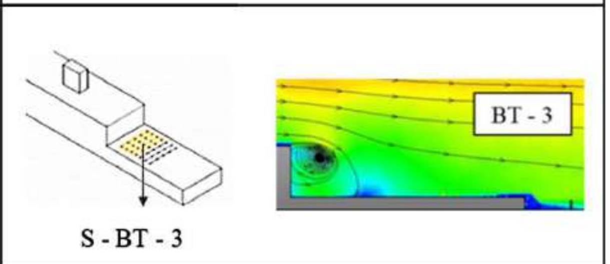
3. RESULTS

3.3. Flow Control

Base	
Passive Flow Control Hangar geometry change	
Active Flow Control Blowing from hangar	
Active Flow Control Coanda Effect	
Active Flow Control Suction from flight-deck	

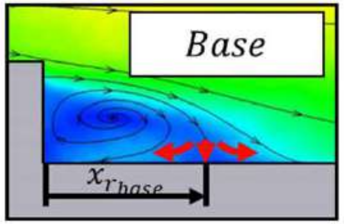
3. RESULTS

3.3. Flow Control

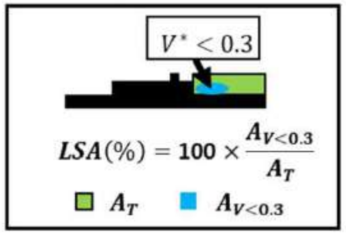
Comparative Analysis

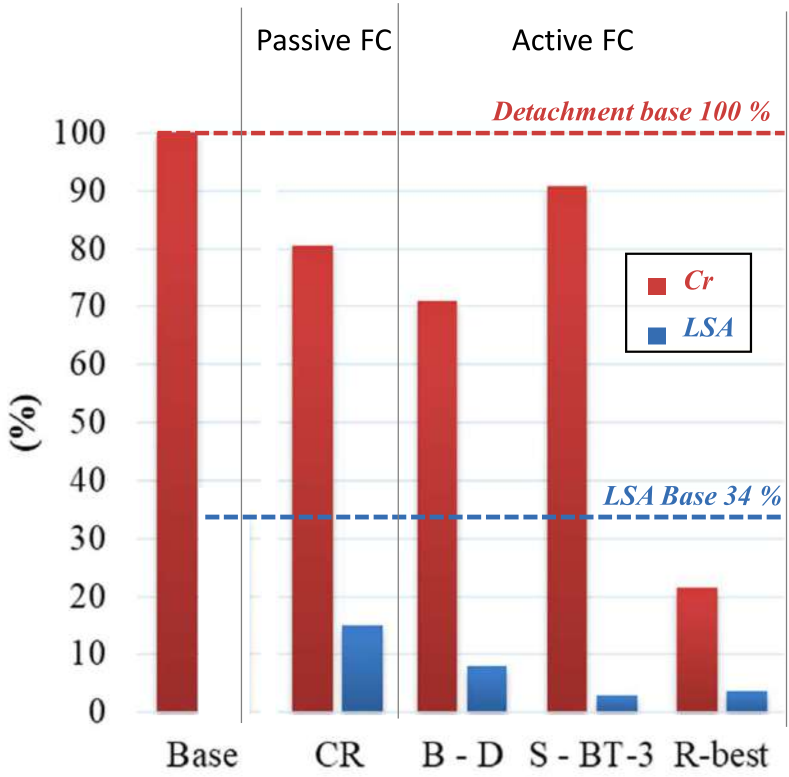
$C_r\ (\%) = 100 \times x_r / x_{rbase}$

Detachment Length



Low-Speed Area (LSA)





Configurations

FC	Flow Control
Base	Base Hangar
CR	Circular Roof Hangar
B – D	Blowing from hangar Door
S – BT – 3	Suction from flight-deck
R-best	Coanda Effect (roof)

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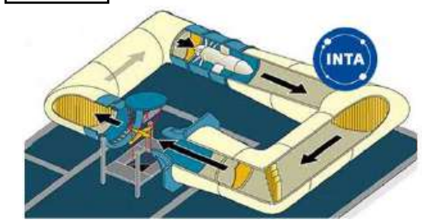
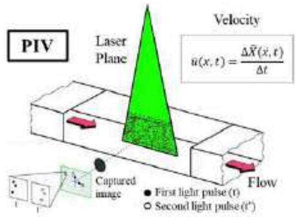
CONTENT

4. CONCLUSIONS

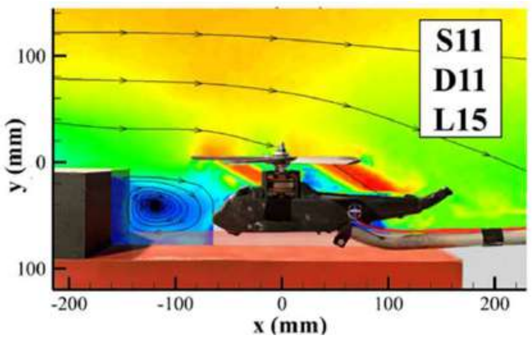
INTA wind tunnel experiments to determine aerodynamic interaction between frigate and helicopter operations

PIV Particle Image Velocimetry





Non-dimensional Velocity Contours

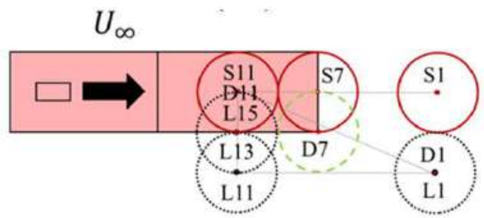


Stern approach (**S**):

Incident velocities 70 – 30 % of the free-stream velocity.

Diagonal (**D**) and L-shape (**L**) approaches:

Initial phases non affected.
Last phases immersed on recirculation region.



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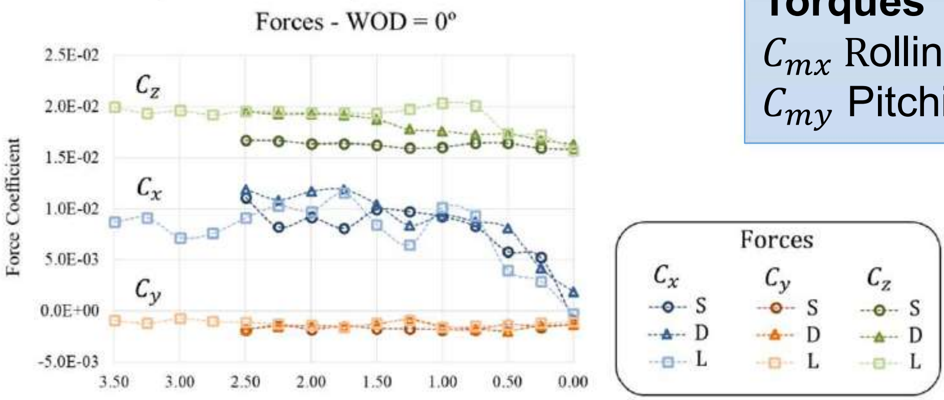
4. CONCLUSIONS

INTA wind tunnel experiments to determine aerodynamic interaction between frigate and helicopter operations

HELIBAL Balance force measurements

Helicopter Aerodynamic Forces



Forces

C_y Lateral force - is practically zero in the three maneuvers.

C_x Longitudinal
C_z Thrust force
- Important reductions at positions < 1.00 D

Torques

C_{mx} Rolling moment - does not change during the maneuvers.

C_{my} Pitching moment - is higher for L maneuver, followed by D and S.

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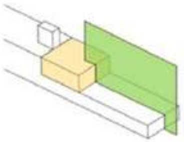
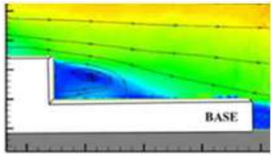
4. CONCLUSIONS

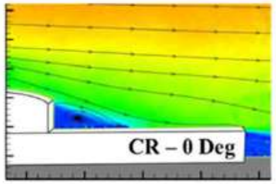
INTA wind tunnel experiments to determine aerodynamic interaction between frigate and helicopter operations

Flow Control

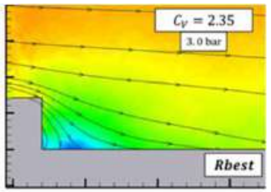




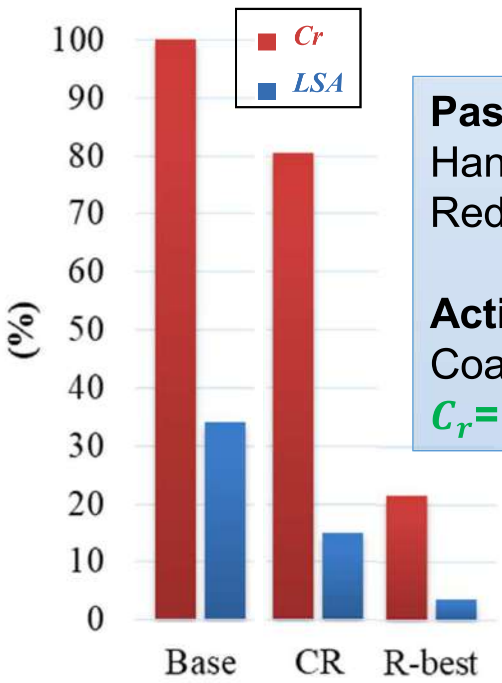
Pasive Flow Control



Active Flow Control



Base	Base Hangar
CR	Circular Roof Hangar
B – D	Blowing from hangar Door
S – BT – 3	Suction from flight-deck
R-best	Coanda Effect (roof)



Cr	Detachment length
LSA	Low Speed Area

Passive Flow Control
Hangar geometry modification
Reductions of C_r 20% and LSA 58%.

Active Flow Control
Coanda Effect
C_r= 22 % and LSA = 4 %

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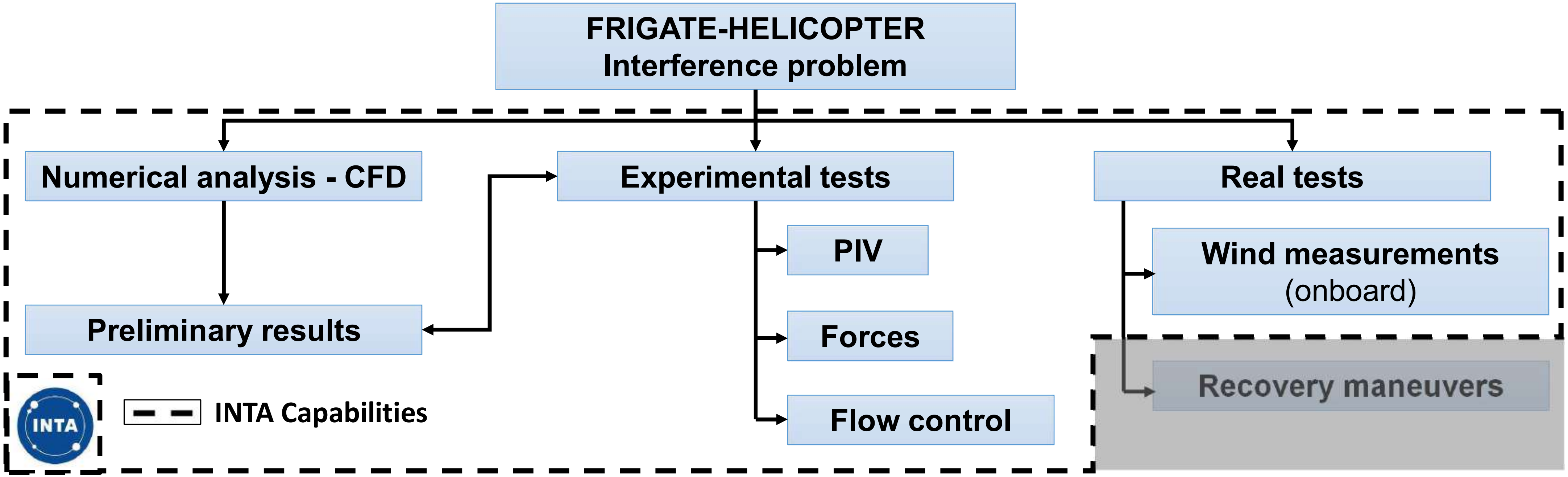
4. CONCLUSIONS



GOAL:
maximum **safety** during **helicopter recovery maneuvers on frigates**.

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THANKS FOR THE ATTENTION

¿Questions?