Development of SmarT Eco-friendly anticontamination technologies for LAminaR wings

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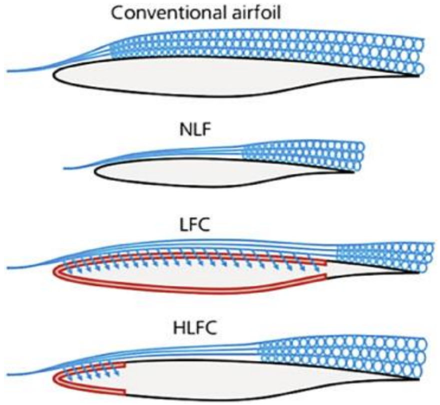
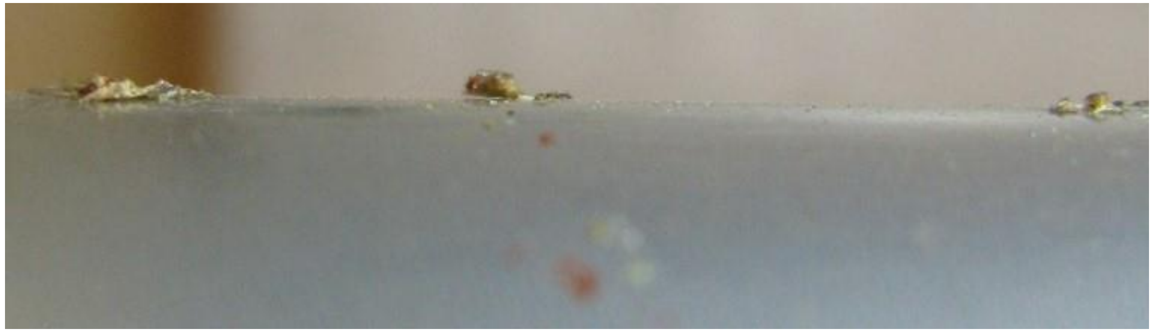
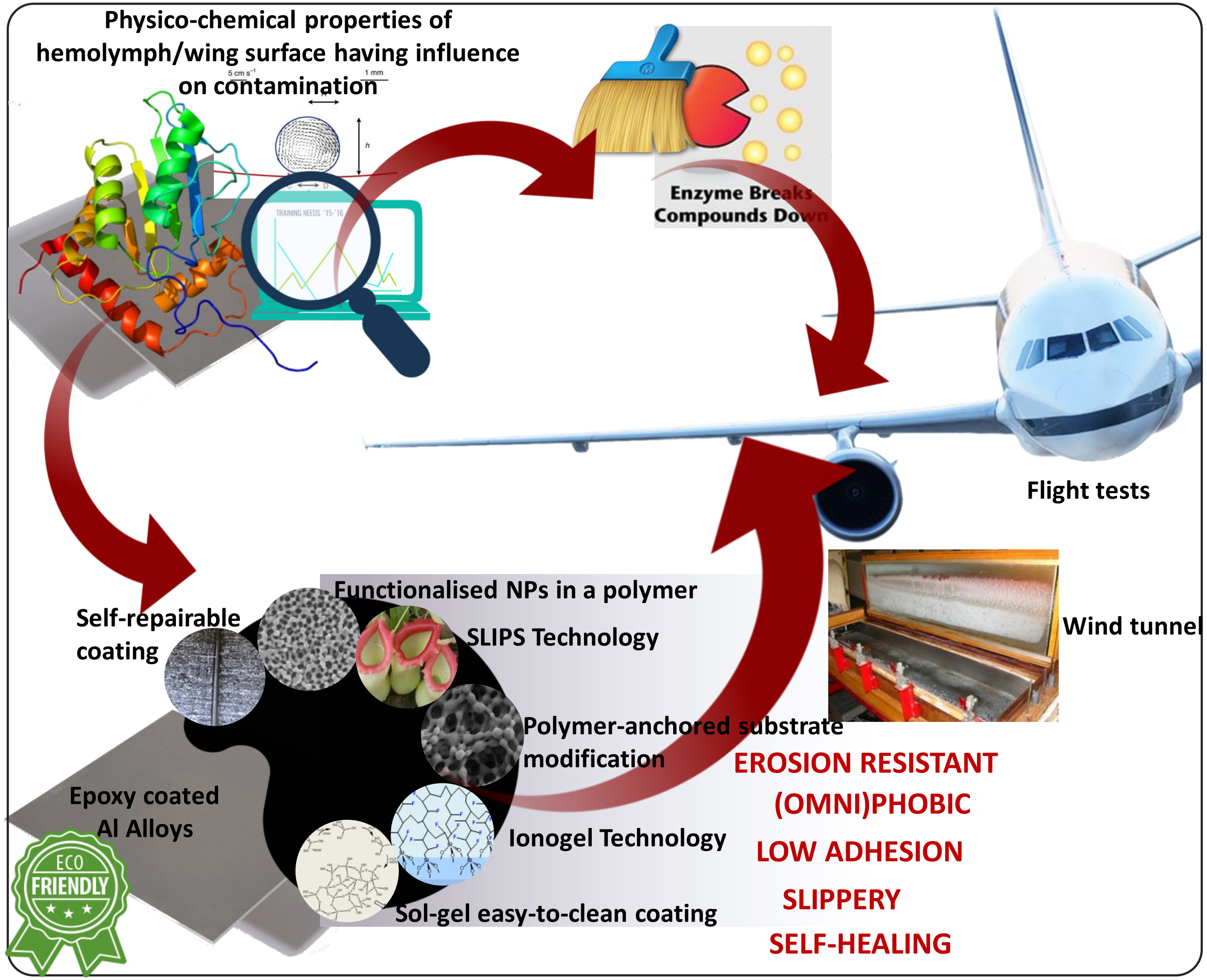
The project STELLAR aims at producing sustainable solutions to reduce drag on aircrafts and enable laminar flow over time with direct impact on fuel consumption

The project aims at contributing to aviation's ecological footprint reduction, targeting a 50% reduction of wing friction and up to 5% reduction of fuel consumption and subsequent lower CO_2 emission.

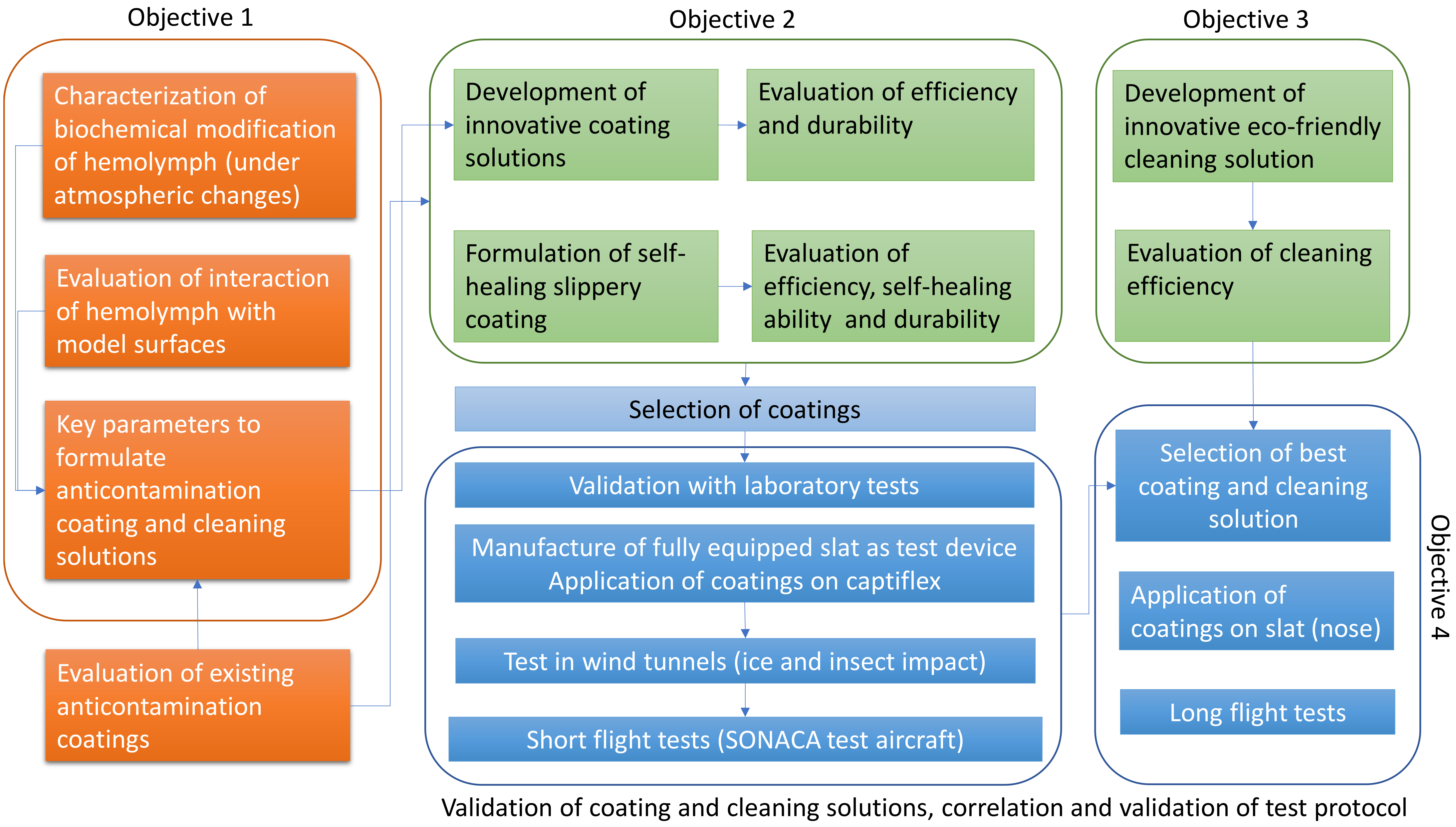
<u>Deposition of insects is the main cause of pollution on the leading edge surface</u>; it modifies substantially how the air flow is distributed on the nose and continues all along the wing surface.
https://www.aerospace-technology.com/projects/airbus-breakthrough-laminar-aircraft-demonstrator-europe-blade/



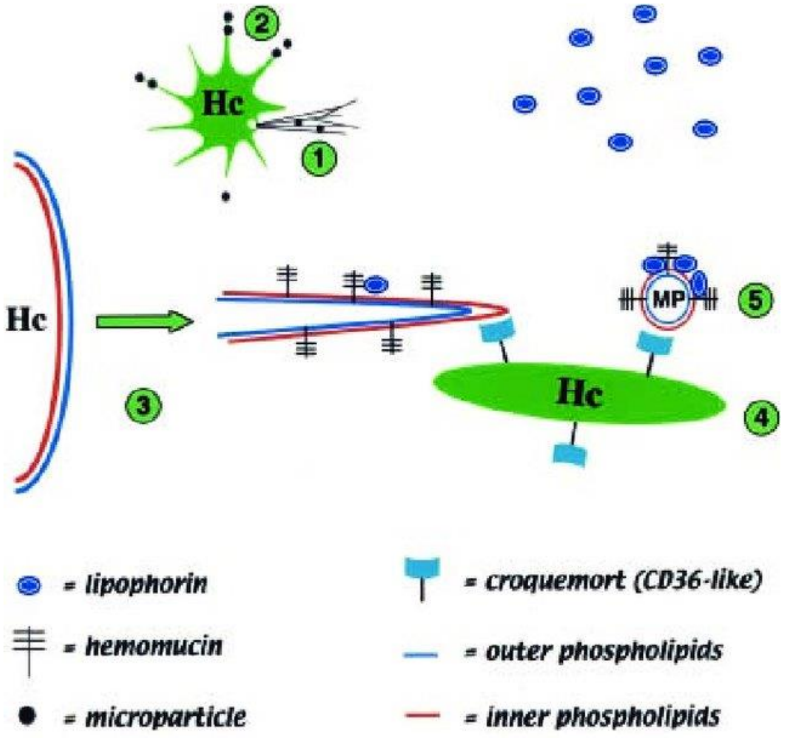



Physico-chemical properties of hemolymph/wing surface having influence on contamination
Enzyme Breaks Compounds Down
Flight tests
Wind tunnel
Functionalised NPs in a polymer
Self-repairable coating
SLIPS Technology
Polymer-anchored substrate modification
Epoxy coated Al Alloys
Ionogel Technology
Sol-gel easy-to-clean coating
ECO FRIENDLY
EROSION RESISTANT
(OMNI)PHOBIC
LOW ADHESION
SLIPPERY
SELF-HEALING

Overall approach and methodology



Impact on modification of atmospheric conditions (RH, T°, etc) on biochemical modification of hemolymph and physico-chemical properties

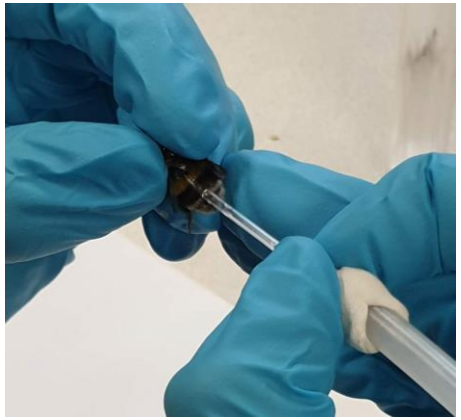


Hemolymph = fluid present in the circulatory system of insects
After an insect has been wounded -> cascade of chemical reactions known as **coagulation**

Coagulated hemolymph is very sticky, viscous and shows very strong adhesion to glass, plastics and other materials.

-> compare behaviour variations of hemolymph in its natural state and once it is deposited on aircraft surface, under real working operating conditions (pressure, T°C, RH, UV)

Impact on modification of atmospheric conditions (RH, T°, etc) on biochemical modification of hemolymph and physico-chemical properties

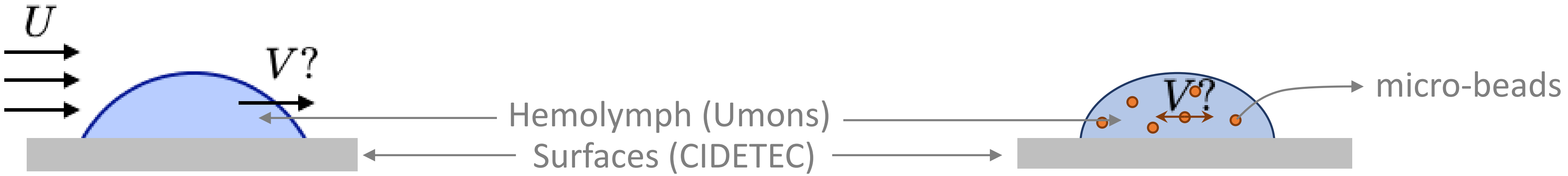


- Direct suction of the haemolymph thanks to a pulled glass capillaries
- Suction of hemolymph under the tergite 2 (dorsally)
- Quick and easy method for sampling hemolymph only minimizing contamination with cuticle debris or molecules from the digestive tract
- Stabilization : coating applied on storage tubes

Physico-chemical behavior of hemolymph (analogues) on different model surfaces

1. Wind-tunnel

2. Micro-rheology



Adhesion on surfaces under controlled wind

Viscosity near surfaces (Brownian motion of micro-beads)

- Correlation between biochemical modification and physico-chemical behavior (rheology and adhesion)
- Understanding the type of interaction with the different model surfaces

-> Design of the ideal surface

Development of coating solutions

Knowledge on interaction between hemolymph and surfaces

Knowledge from previous projects on same topic

HOPIN

Development of coatings providing efficient and durable anticontamination (target : 80-100% of residues removal)

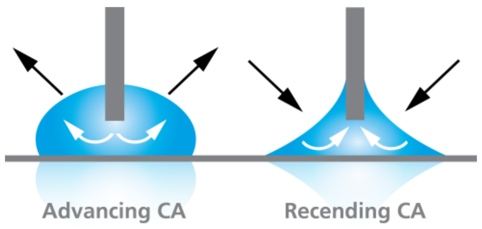
Durability in flight conditions : impact resistance,water and sand erosion, UV, thermal cycling

Substrate : anodized aluminium mainly

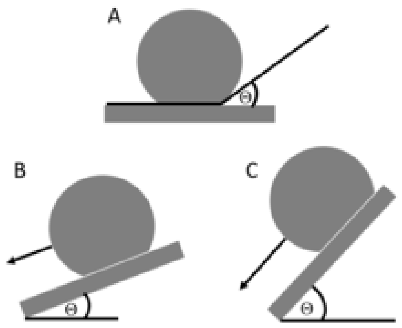
Strategies :

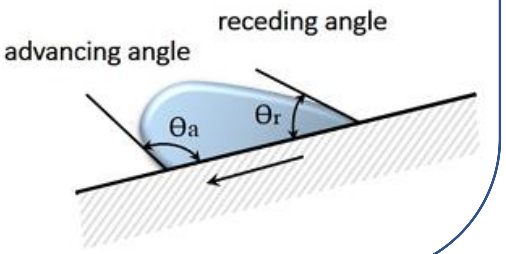
- Hydrophobic/ominiphobic coatings (with low sliding angle with water and hexadecane)
    - Parameters : surface tension, roughness, hardness
- Self-healing slippery coatings:
    - Self-repairable polymeric chains
    - Slippery effect

Contact angle



Sliding angle



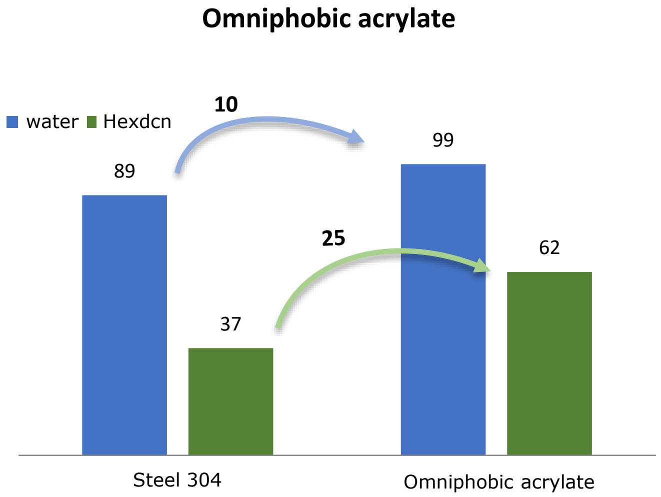


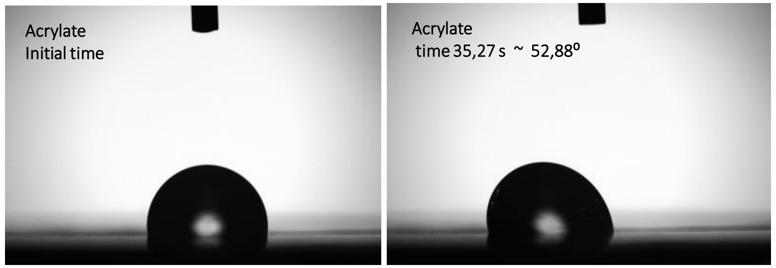
Water -> Hydrophobicity

Hexadecane -> Oleophobicity

→ Correlation with anti-adhesion and/or cleanability

Example of an omniphobic coating with little or no sliding:





WCA: 100°
HxCA: 62°

No sliding
53°

Coating (on SS3O4)	Type of Coating	WCA (°)	WSA (°)	HexdCA (°)	HexdSA (°)	Cleanability (Schneider's solution)
CID.ST1	Cross-linked perfluorinated polymer	108°	55°	64°	15°	OK
CID.ST2	Acrylic polymer	100°	No sliding	62°	14°	OK
CID.ST3	Soft sol-gel coating	98°	53°	38°	12°	OK
CID.ST4	**Sol gel + perfluorinated polymer**	**109°**	**29°**	**68°**	**4°**	**OK**
CID.ST5	**Sol gel + perfluorinated polymer**	**120°**	**17°**	**65°**	**3°**	**OK**
CID.ST6	IONOGEL-based	80°	8°	65°	3°	NOK
MANO.ST1	Sol gel (FSIL)	109°	18°	61°	14°	OK
MANO.ST3	Sol gel (FSIL)	109°	28°	54°	43°	OK
MANO.ST4	**Sol gel (FSIL)**	**117°**	**13°**	**55°**	**27°**	**OK**
Commercial	Silicone	113	> 90	50°	54°	OK

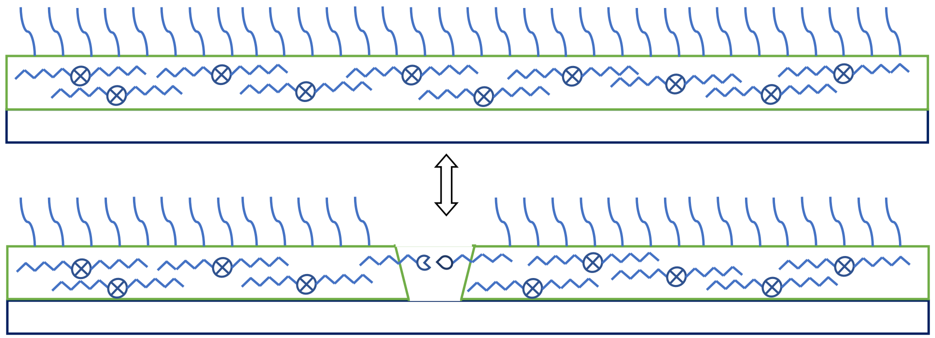
WCA : Water Contact Angle
WSA : Water sliding Angle (10µl)
HexdCA : Hexadecane Contact Angle
HexdSA : Hexadecane Sliding Angle (10 µl)

Self-healing slippery coating

Commercial 2K PU

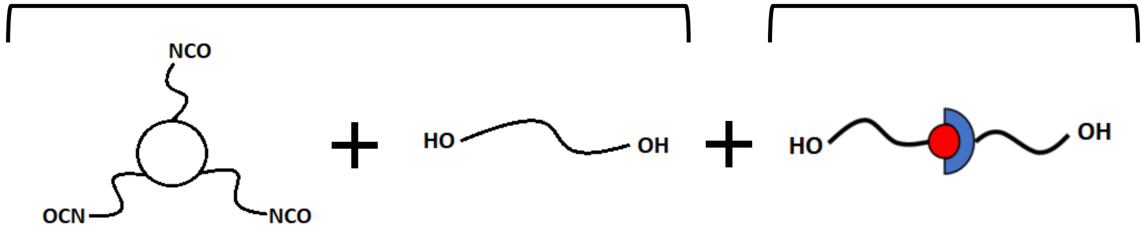
Self healing 2K PU

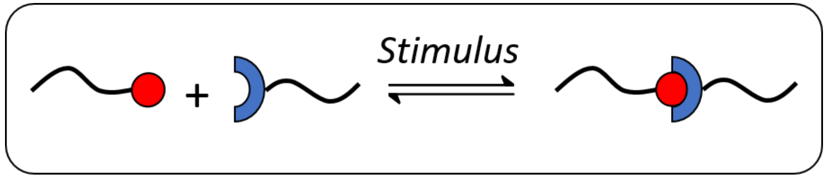
Hydrophobic/slippery 2K PU



Self-healing slippery coating

Commercial classic 2K PU resin | Self-healing Agent (SHA)





Compromise between mechanical properties and self-healing ability

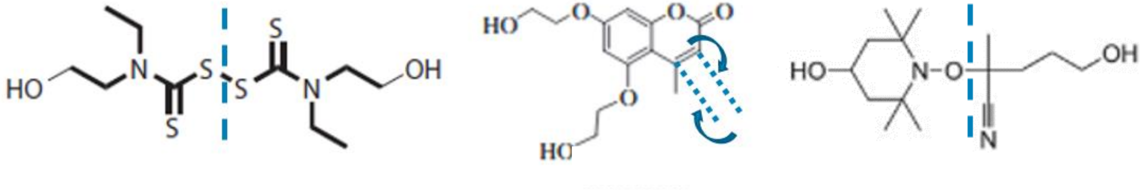
Required investigations:

- SHA amount and incorporation ratio
- Chains lengths
- Reticulation points density
- Co-solvent amount and share with water

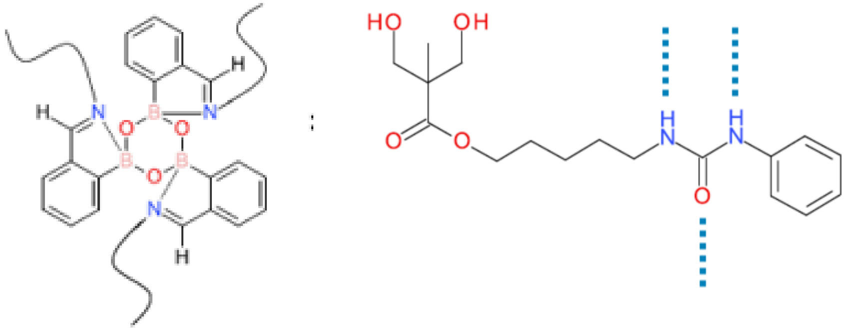
Thermal and mechanical tests to assess:

- Self-healing properties and abilities
- Influence of SHA on properties of film
- Influence of SH cycles on properties

Light responsive SHAs



Humidity responsive SHAs



MATERIA NOVA

Development of coating solutions

<u>Substrates</u>

- Stainless steel 304
- Titanium
- Epoxy composite samples
- **Clad Aluminium**

<u>Laboratory qualifying tests</u>

- FLEXIBILITY (Mandrel bending) (steel 304)
- SCRATCH RESISTANCE (clad alu/composite)
- ADHESION (clad alu/composite)
- IMPACT RESISTANCE (clad alu/composite)
- CONTACT ANGLE MEASUREMENTS (304/clad alu/Composite)
- SLIDING ANGLE MEASUREMENTS (clad alu/composite)
- CLEANABILITY TEST (clad alu/composite)
- STONE CHIPPING (clad alu)

Selection of coatings (3-4) that will be applied on final substrate (anodized aluminium)

<u>Durability tests</u>

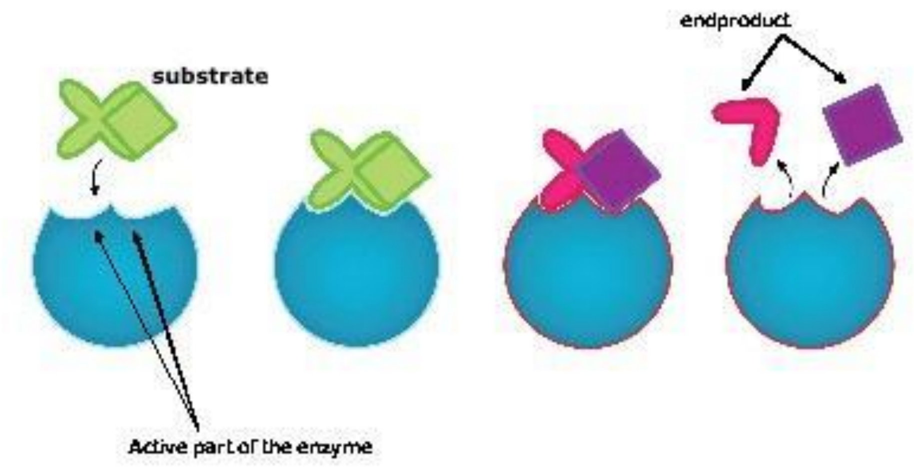
- ADHESION - (clad alu)
- ACCELERATED WEATHERING (clad alu)
- RESISTANCE TO SOLVENTS (clad alu)
- THERMAL CYCLING (clad alu)
- HUMIDITY (clad alu)
- WATER EROSION RESISTANCE (clad alu)
- SAND EROSION RESISTANCE (clad alu)

Selection of coatings for testing under simulated (wind tunnel) and real environmental conditions (short and long flight tests)

Development of eco-friendly cleaning solution

Removal of 100% of insect debris, hemolymph and degradation residues
Environmentally friendly by:

- Limiting VOC emission (reduction of solvent : max 10%)
- Improving environmental impact (measured through LCA)
- Limiting impact on waste water treatment



Enzyme

Enzyme blend active on hemolymph and other relevant components

Surfactants

SOPURA surfactant blend enzyme compatible

Functionality : Foaming, desorption and emulsification

Validation of the products

- Laboratory scale : specific requirements (including durability)
- Tests under simulated environment : wind tunnel
- Performance tests on real parts and exposure to ambient conditions in real flight operations

Fuel tank of SONACA Aircraft fully equipped with sensors with Captiflex^{TM} : one test device for wind tunnel and short flight tests to allow correlation between tests

Biochemical modification of hemolymph (WP3)

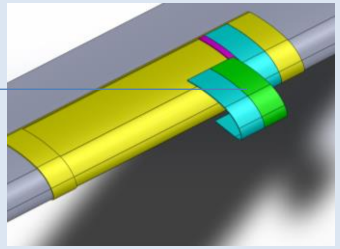
Atmospheric conditions data

Coupons for laboratory testings

CaptiFlex ™

Icing wind tunnel testing (CWT-1) (erosion tests)

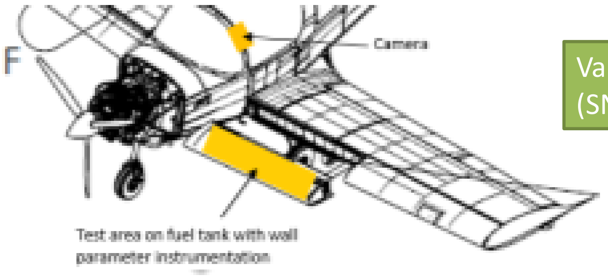
Sensors (pressure, temperature, RH)



VKI L1 Wind tunnel test : impact on insect on leading edge

Short flight tests on Sonaca Aircraft 200 with monitoring of atmospheric conditions

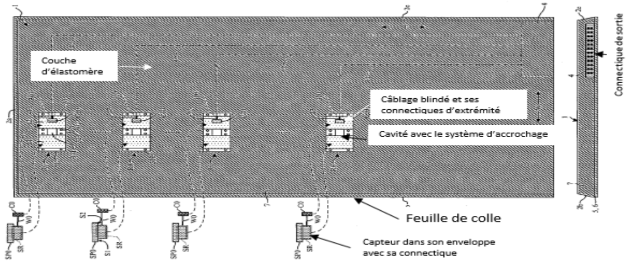
Validation of coating performances on commercial aircraft (SN Brussels Airlines) – correlation between tests



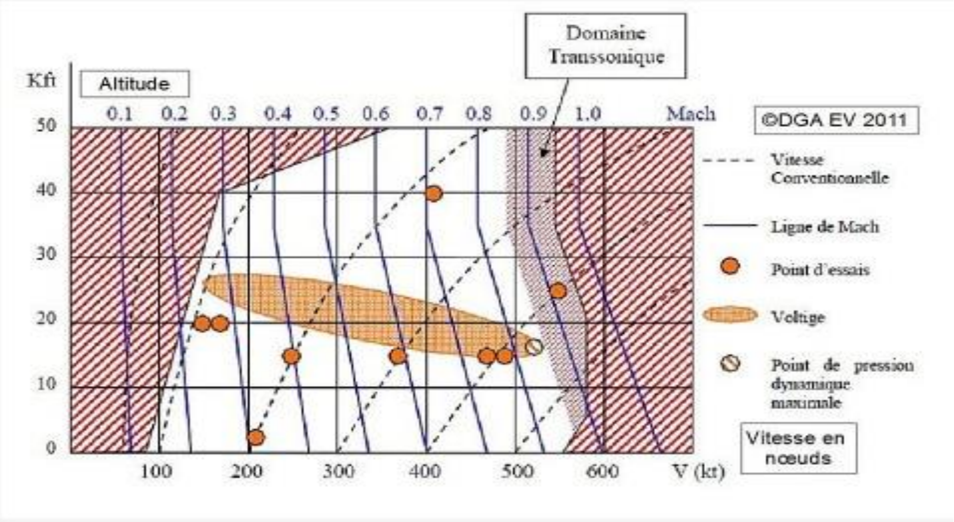
CaptiFlex™ : technology for sensors installation

- Patented
- Vibration lab test : no impact for H(jω)
- Flight test with DGA EV

V = 216 m/s; Q = 320 hPa; load factor -1 à +5



Each cavity receives a cover. CaptiFlex ™ sticks to the wall and can integrate different types of sensors (pressure, temperature, accelerometer…) simultaneously



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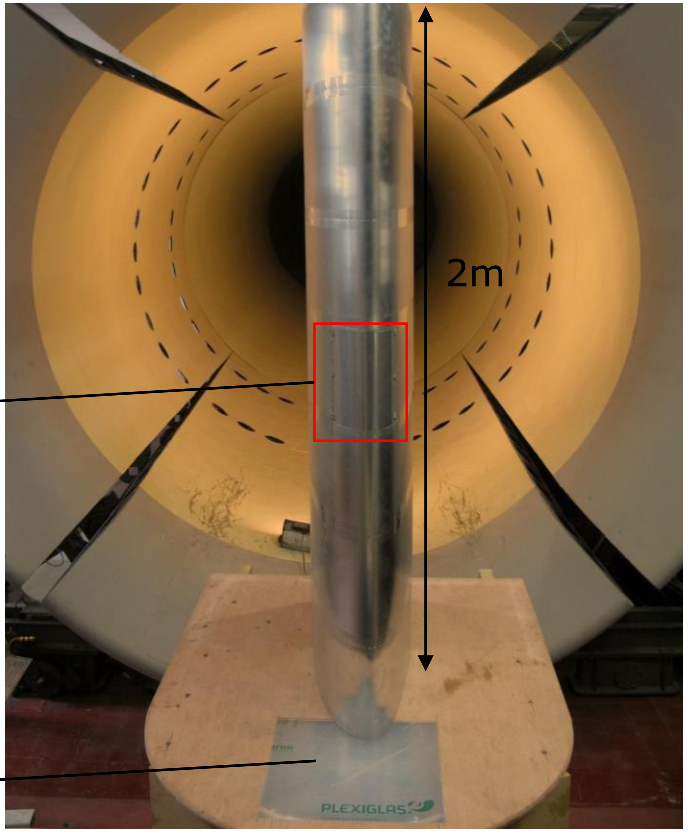
Wind tunnel tests

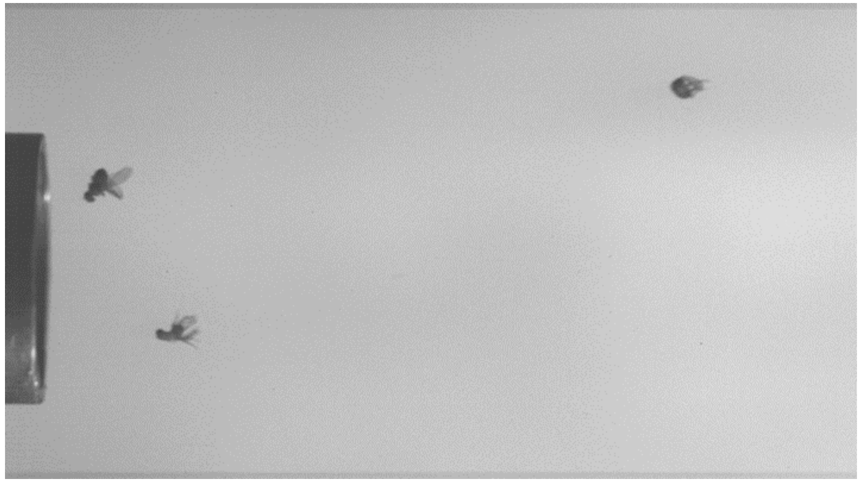
Simulation of dynamic pressure corresponding to take-off and climb and land phases (max 50 m/s)



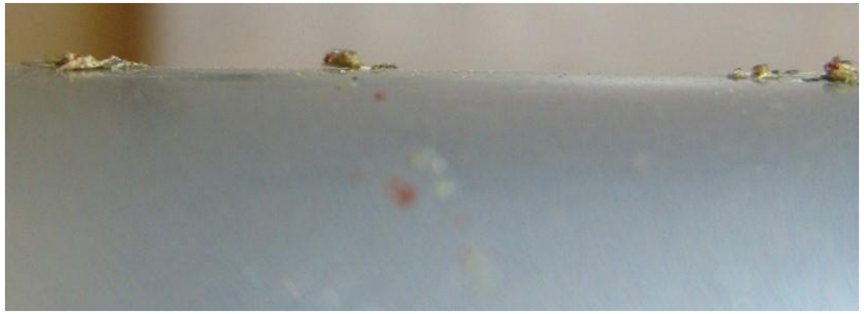
sample

Camera location

Specific setup for insect injection



Impact analysis (residue number and size)



Short flights with test Aircraft from Sonaca Aircraft : Sensors/coatings on fuel tank
Correlation with tests in wind tunnel

- Design of all parts is based on easy repairability and replacement of components.
- The leading edge is fixed to the wing and the fuel tank
- The service ceiling for this aircraft is 13.000ft
- Cruising speed 115 kts
- Positive load factor 4.4g

Long flight tests with commercial Aircraft

Manufacture of a complete slat with anticontamination coating on the leading edge by SONACA (min 6 months flight tests)

STELLAR PROJECT

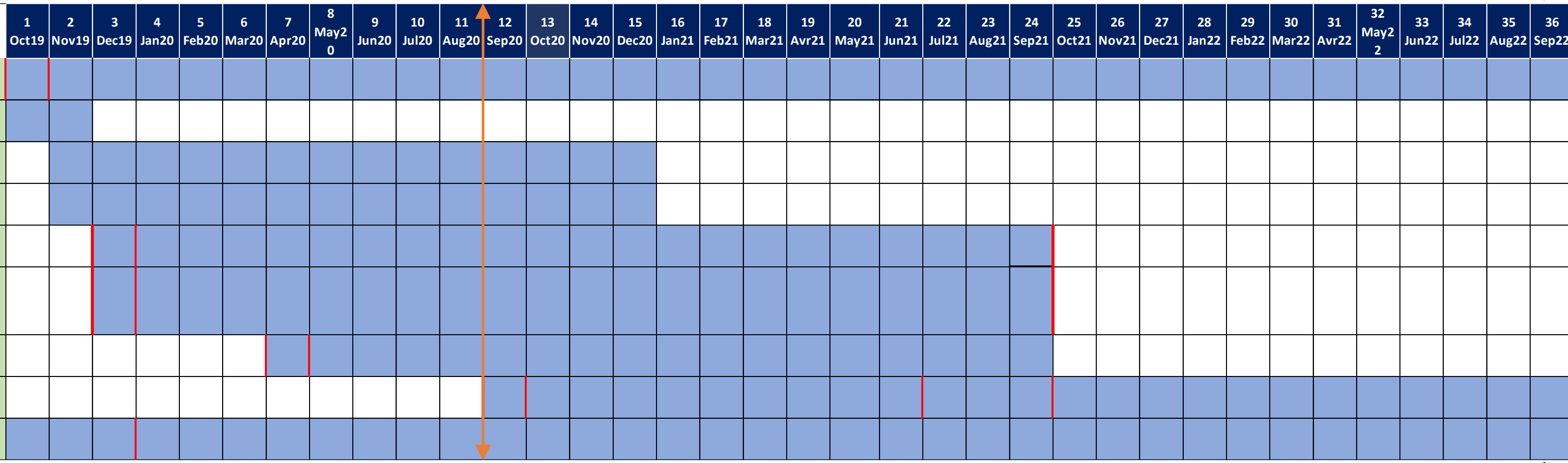
Starting Date : October 1st 2019

Duration : 36 months (could be extended due to COVID 19)

Coordination : Materia Nova

Topic Manager : AIRBUS (Th. Fol)

STELLAR	Leader(s)	Months
WP1 : Project Management	MaNo	1-36
WP2 : Survey and report of previous work and publications	CID	1-2
WP3 : Biochemical modification of hemolymph	IBS	2-15
WP4 : Identification of physico-chemical key factors of surface contamination	ESPCI	2-15
WP5 : Development of Surface coating solutions	CID	3-24
WP6 : Development of self-repairing slippery surface	MANO	3-24
WP7 : Development of pre or post contamination cleaning solution	SOP	7-24
WP8 : Validation	SON	12-36
WP9 : Dissemination and exploitation	MANO	1-36



This project has received funding from the European Union's **Horizon 2020** research and innovation programme under Grant Agreement n° 864769

THANK YOU FOR YOUR ATTENTION !

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