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Fraternité*

Cross-disciplinary research for preparing the future

Riad Haidar

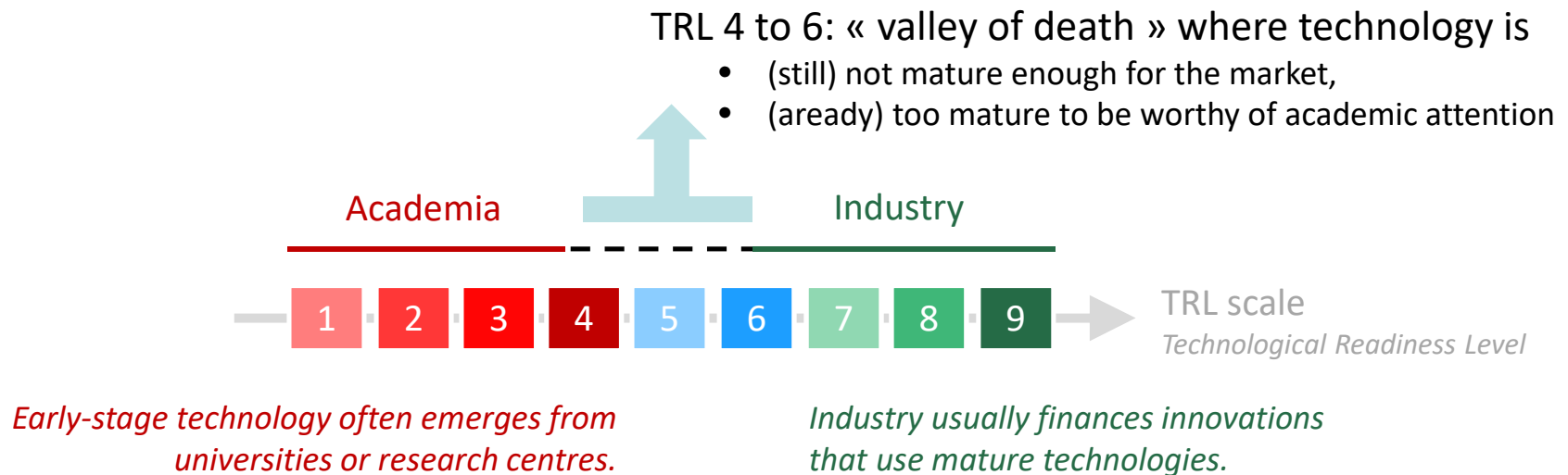
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ONERA

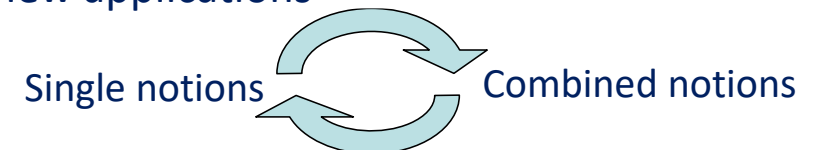
THE FRENCH AEROSPACE LAB

What are we talking about?



That is room for cross-disciplinary research:

- ⇒ i.e. combine/align basic single notions (sometimes outside their standard field of application) in order to stimulate new notions or reach new applications
- ... and even return to basic notions to progress.



Cross-disciplinary research

At "medium" TRL, the combination of single disciplines can be an **efficient driver** for research and innovation...

- ... with an ability to generate IP and single-disciplinary results (or even breakthroughs)
- ... with an ability to inspire educational initiatives at graduate degree (eg, Paris-Saclay Institutes)
- ... with an ability to catch investments (eg, european EIC Transition, french ANR PRCI)



the apparent « applications top »

the un-apparent (often un-expected) amount of cross-disciplinary efforts and results.

This often needs heavy investments (skills, manpower and technical means)

... but good news: timescales are in the range of 2 to 4 PhD projects

Cross-disciplinary research: a few inspiring examples

Fourier-Transform spectro-imager

Quantum Gravimeter with cold atoms

Passive night vision (all year, 5 night-levels)

ONERA, the french Aerospace Research Lab.



Main facts & figures

- Public sector body established in 1946
- 2120 people on 8 geographical locations
- 350 (16%) PhD students, 30 Post-docs
- Budget: roughly 236 €million (55% of contract work)
- Largest fleet of Wind Tunnels in Europe
- High-level research for the benefit of Civil Aerospace industry and Defence industry



Cross-disciplinary research: a few inspiring examples

from basic science to applied technology

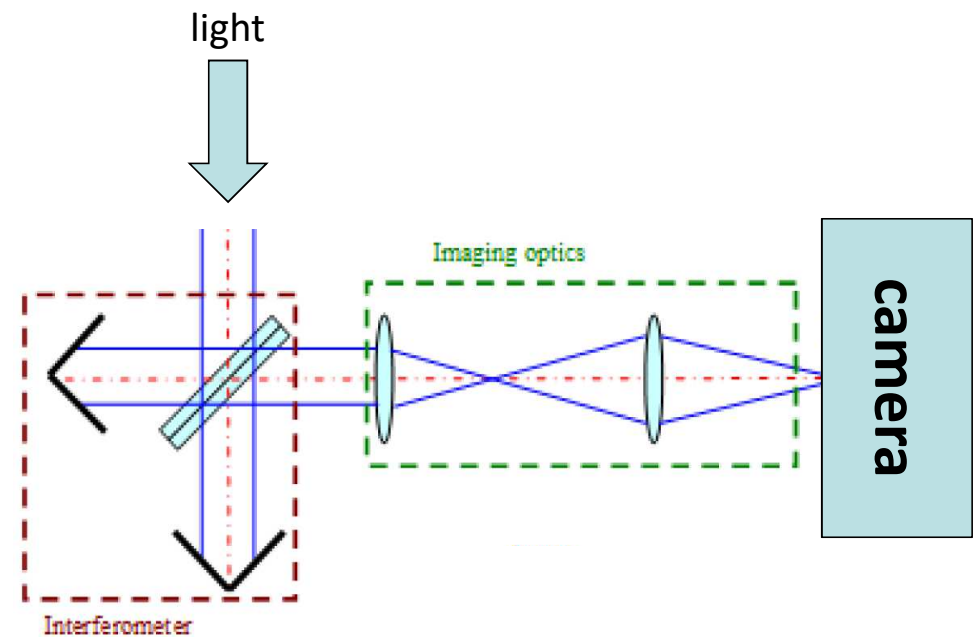
Fourier-Transform spectro-imager

Basic science:

- FT spectrometry

Application driver:

- Airborne hyperspectral (thermal) imaging



Cross-disciplinary research: a few inspiring examples

from basic science to applied technology

Fourier-Transform spectro-imager

2 to 3 PhD-duration

3 patents, about 15 « core » journal articles



SC physics: IR focal planes



FT spectrometry



Cryogeny and vacuum science



FT-imaging signal treatment



Material sciences for thermal IR



2008

2015

2019

Cross-disciplinary research: a few inspiring examples

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Fourier-Transform spectro-imager

2 to 3 PhD-duration

3 patents, about 15 « core » journal articles



+ Airborne

Cross-disciplinary research: a few inspiring examples

Fourier-Transform spectro-imager

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Cross-disciplinary research: a few inspiring examples

from basic science to applied technology

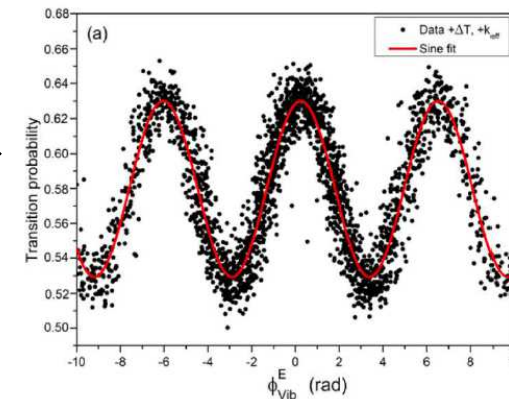
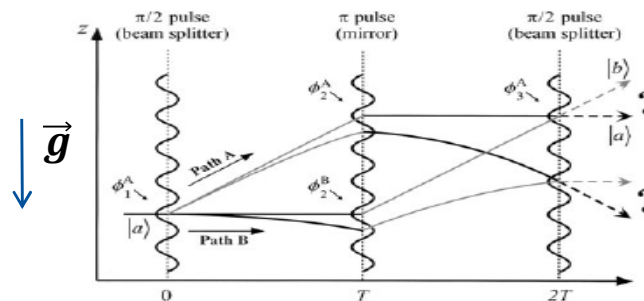
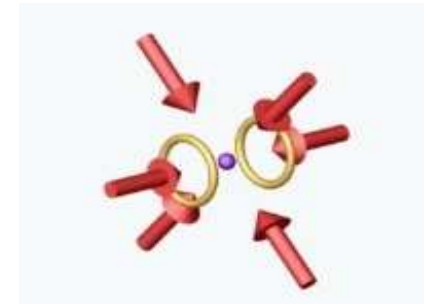
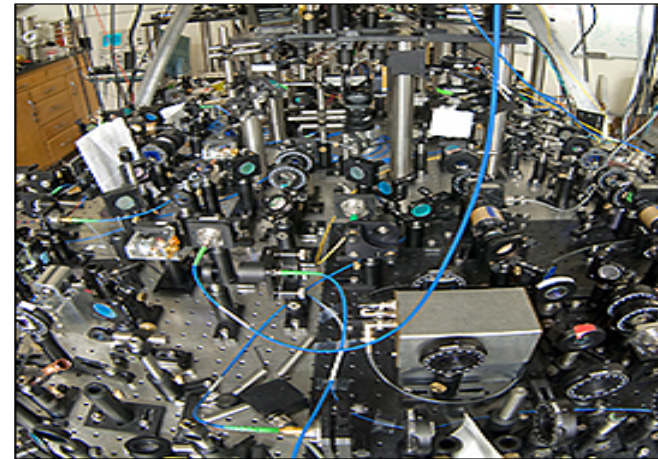
Quantum Gravimeter with cold atoms

Basic science:

- Cold atoms interferometry

Application driver:

- Calibration-free, high-precision gravimetry



$$\propto \frac{1 + \sin(k \cdot g \cdot T^2)}{2}$$

Cross-disciplinary research: a few inspiring examples

from basic science to applied technology

Quantum Gravimeter with cold atoms for onboard applications

3 to 4 PhD-duration

6 patents, about 25 « core » journal articles



Laser conversion, telecom optics



Cold atom interferometry



Cryogeny and vacuum science and technology



Signal treatment



2003

2014

2022

Cross-disciplinary research: a few inspiring examples

from basic science to applied technology

Quantum Gravimeter with cold atoms for onboard applications

3 to 4 PhD-duration

6 patents, about 25 « core » journal articles

1m



+ Sea/Air-borne/Space-borne

Cross-disciplinary research: a few inspiring examples

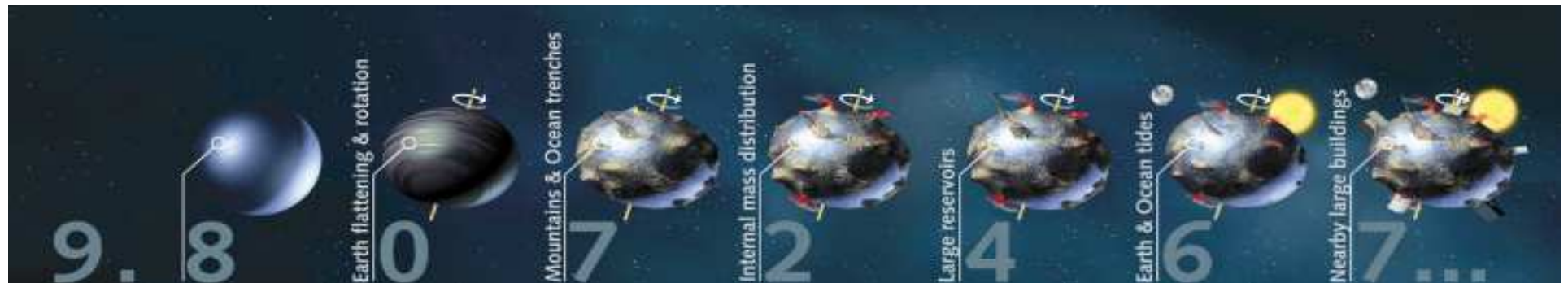
from basic science to applied technology

Quantum Gravimeter with cold atoms for onboard applications

Back to basic science: measuring gravity for geophysics/geodesy, sub-surface detection...

The constituents of "g"

$g =$



Earth flattening
and rotation

Internal mass
distribution

Nearby large
buildings

Cross-disciplinary research: a few inspiring examples

Fourier-Transform spectro-imager

Quantum Gravimeter with cold atoms

Passive night vision (all year, 5 night-levels)

Cross-disciplinary research: a few inspiring examples

from basic science to applied technology

Passive night vision (all year, 5 night-levels)

Basic science:

- Night-glow in the NIR

Application driver:

- All/Any night vision



Nightglow phenomenon (moonless night): here 2 clouds in contrast against a background sky, illuminated by the NG emission.

Cross-disciplinary research: a few inspiring examples

from basic science to applied technology

Passive night vision (all year, 5 night-levels)

2 to 3 PhD-duration

7 patents, about 12 « core » journal articles



Nightglow OH phenomenon (84 km)

Stray-light for astronomers...

... but light source for night-imaging



NIR imaging protocols

SC physics, material physics (cut-off wavelength)



Nanophotonics technology (spectral/angular filters)



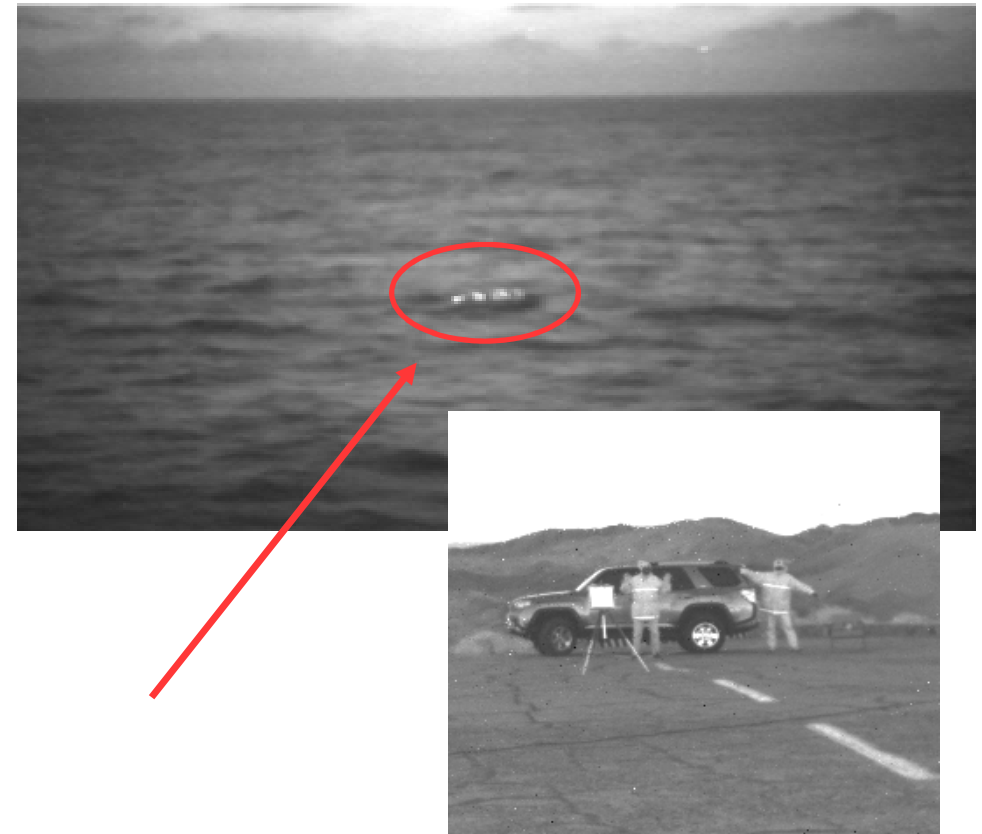
Cross-disciplinary research: a few inspiring examples

from basic science to applied technology

Passive night vision (all year, 5 night-levels)

2 to 3 PhD-duration

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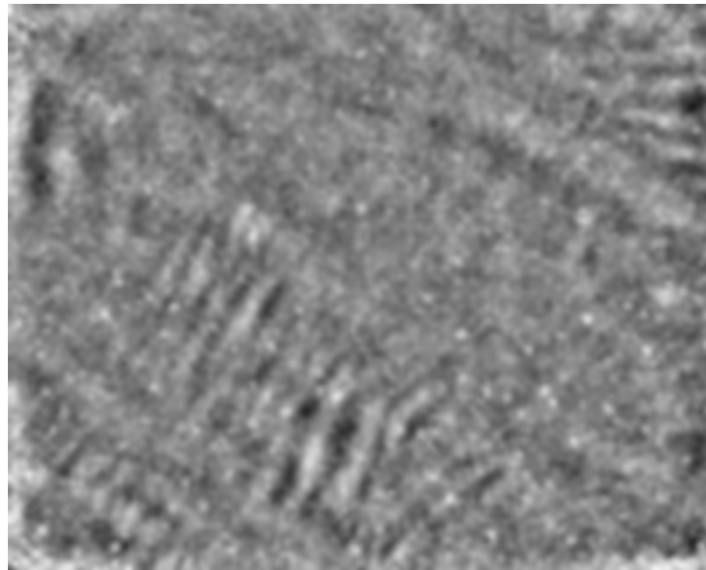


Cross-disciplinary research: a few inspiring examples

from basic science to applied technology

Passive night vision (all year, 5 night-levels)

Back to basic science: observation and study of gravity waves



© ARISE consortium

*SWIR image showing gravity waves propagating in the OH layer.
Moon-less night, and cloud-less sky.
(area 120km x 160km)*

Cross-disciplinary research: a few inspiring examples

Fourier-Transform spectro-imager

Quantum Gravimeter with cold atoms

Passive night vision (all year, 5 night-levels)

Reduction of aerodynamic drag by riblets

Cross-disciplinary research: a few inspiring examples

Reduction of aerodynamic drag by riblets

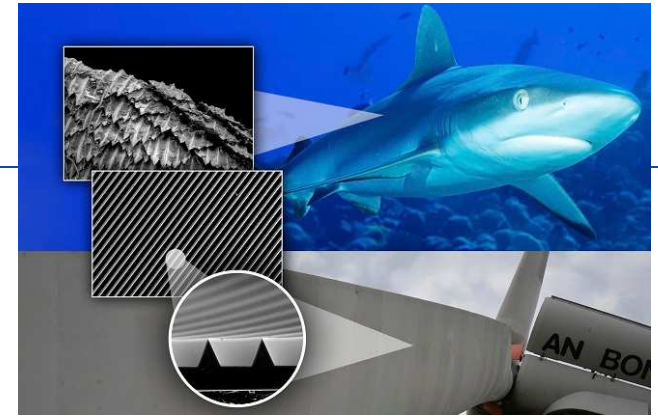
Basic science:

Using the shark skin principle

- ⇒ reduction of near-wall turbulence
- ⇒ reduction of friction (through turbulence simulations)

Application driver:

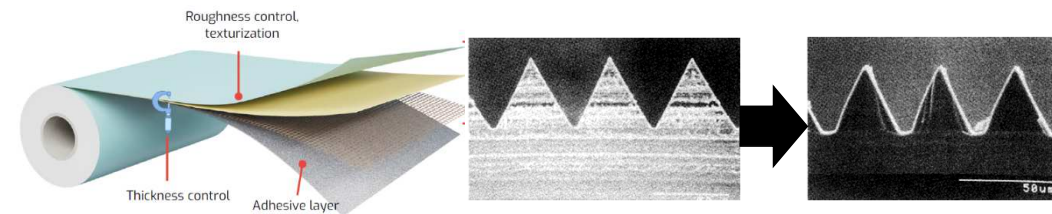
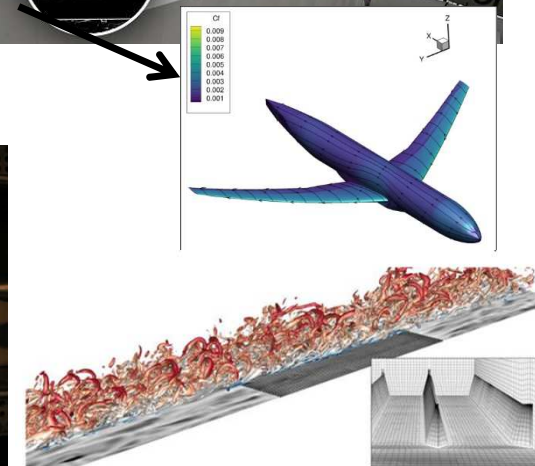
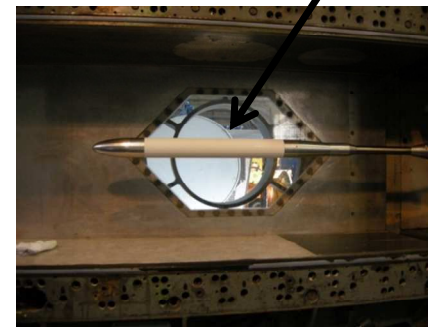
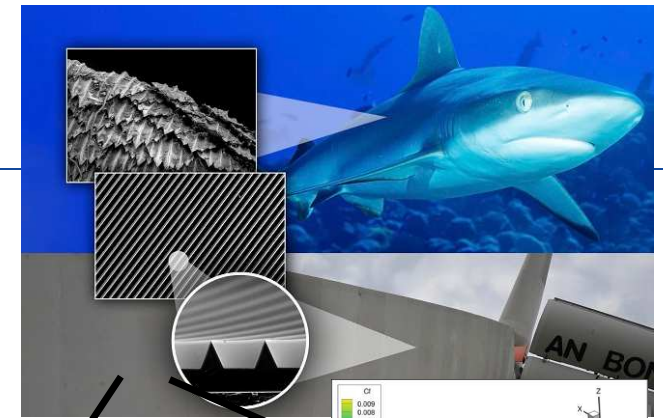
Reduce aircraft fuel consumption (lower drag)



Cross-disciplinary research: a few inspiring examples

Reduction of aerodynamic drag by riblets

- Airbus A320 - 1989 flight tests: 1.5% fuel savings
- Wind tunnel tests 2000-2010 demonstration of up to 10% potential reduction in frictional drag
- Shape and size optimization, and high-fidelity simulations (LES-DNS)
- Ongoing works: controlling erosion / fouling effects industrialisation of the texturing process / large surfaces (textured paint films)

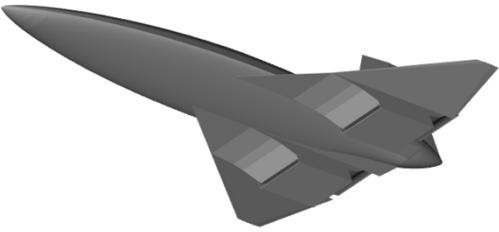


A selection of challenges for cross-disciplinary research

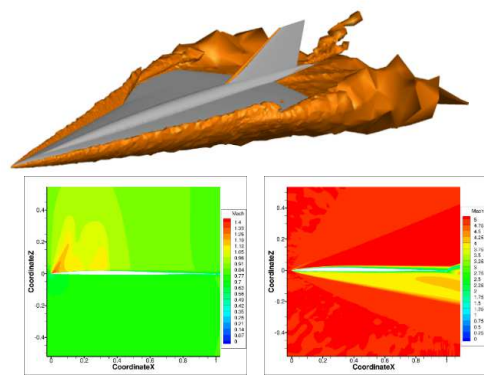
H2-propulsion aviation (aircraft, H2-production and tanking, airport infrastructures, impacts)

Hypersonic airplanes

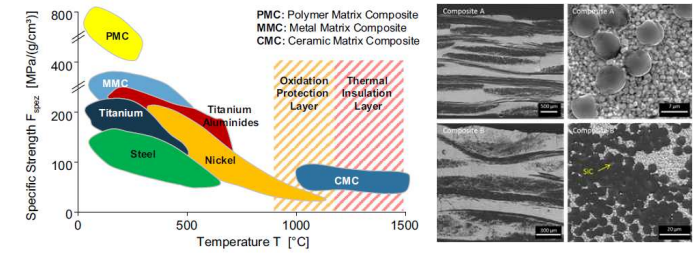
Re-usable launchers



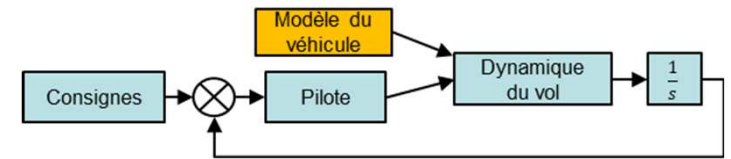
aerodynamics



materials



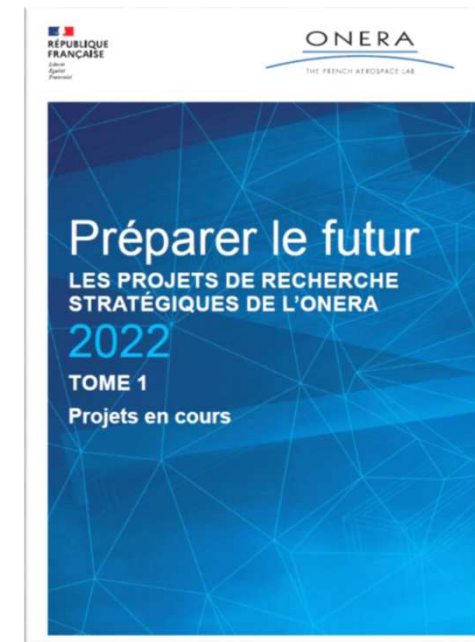
piloting



Thank you for attention

The ONERA initiative (... and also that of similar research establishments)

	<i>now running</i>
Federative research project (4 FTE x 4 years) <ul style="list-style-type: none"> <i>Cross-disciplinary, TRL 2/3 to TRL 5/6.</i> 	28
Federative research actions or networks (1 FTE x 2 to 3 years) <ul style="list-style-type: none"> <i>Cross-disciplinary actions or networking.</i> 	14
Exploratory research actions (0.5 FTE x 1 year) <ul style="list-style-type: none"> <i>High-risk, high-gain, fast-track process</i> 	20
... and also mono-disciplinary research project (2 FTE x 3 years)	55
Collaborative / Co-funded PhD	175
Fully hired post-docs	11
In-kind contribution to collaborative research programs with industry (incl. for PhD and post-docts projects)	63



Cross-disciplinary research: a few inspiring examples

from basic science to applied technology

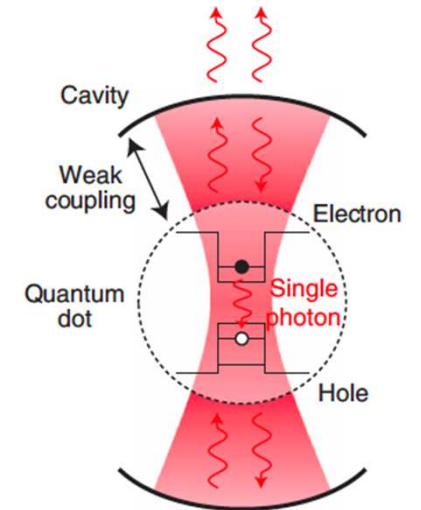
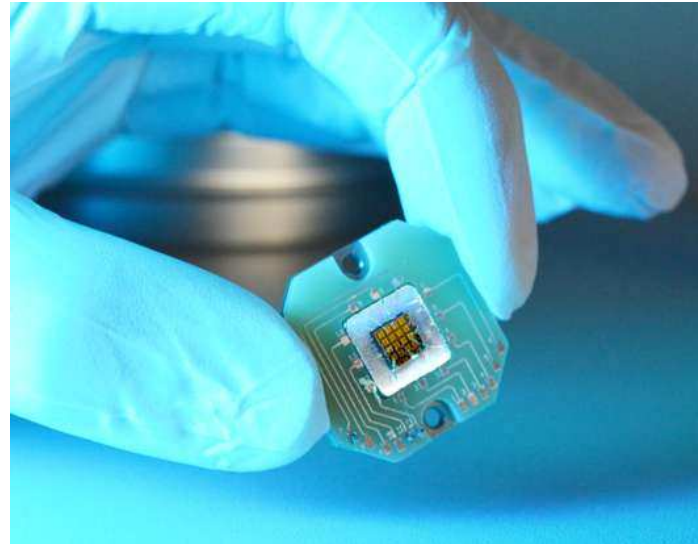
Single photons sources

Basic science:

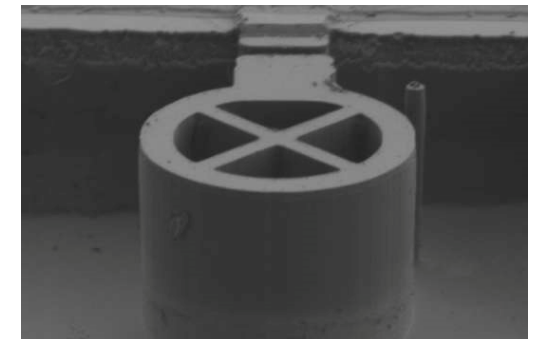
- Artificial atoms

Application driver:

- Quantum computing and telecoms



Senellart's group
CNRS/C2N



Cross-disciplinary research: a few inspiring examples

from basic science to applied technology

Single photons sources

5+ PhD-duration
about 50 « core » journal articles

Quantum mechanics (Single photons)
Semiconductor physics

Electromagnetism at the nanoscale

Electrically controlled light sources

Cryogenic lithography

Clean-room science and technology

