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ICAO Workshop, October 18th 2011

AlfaBird: Alternative Fuels And Biofuels for Aircraft Development

prepared by Dr Laurie Starck, Dr Ludivine Pidol, Nicolas Jeuland (IFP Energies nouvelles) and the Steering Committee
based on a collective work in the Alfa-Bird project

Outline

- **Overview of the project**
  - Context
  - Objectives and main figures
  - Workplan
- **Some main results**
- **Key points and R&D need**

Overview of the project

OBJECTIVES and MAIN FIGURES

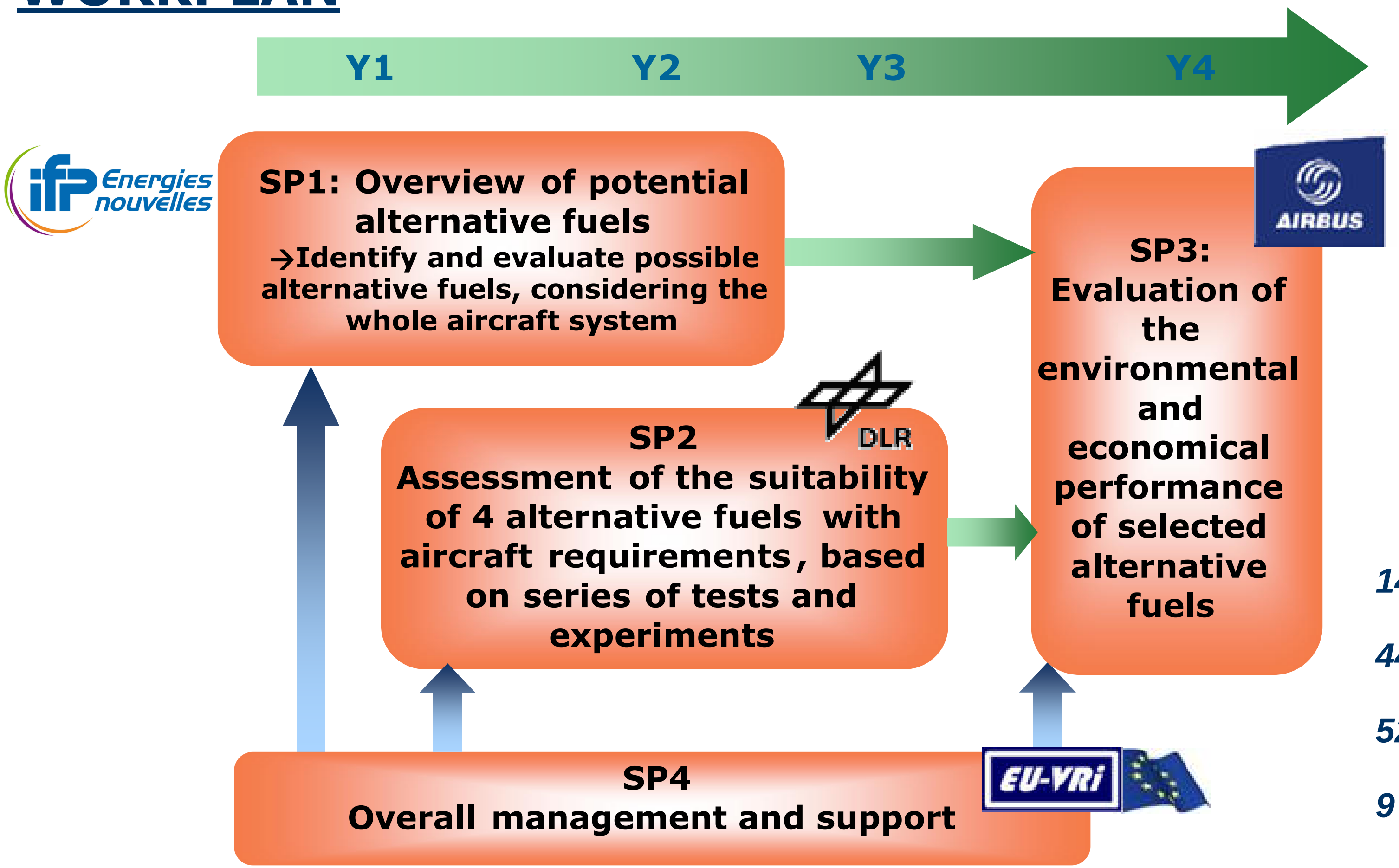
- **AlfaBird:** Alternative Fuels And Biofuels for Aircraft Development

- **Main objective:** to develop the use of alternative fuels in aeronautics with a long-term perspective:
  - Considering the possibility of revisiting fuel specifications
  - Reconsidering the whole aircraft system (fuel, engine and ambience)

- European Community's Seventh Framework Programme (FP7/2007-2013)
- 23 main beneficiaries from 8 countries
- Total Budget: 9 750 000 €; EC Grant: 6 820 000 €
- Start: July 2008; End: June 2012
- Website: http://www.alfa-bird.eu-vri.eu

Overview of the project

WORKPLAN



14 Work Packages

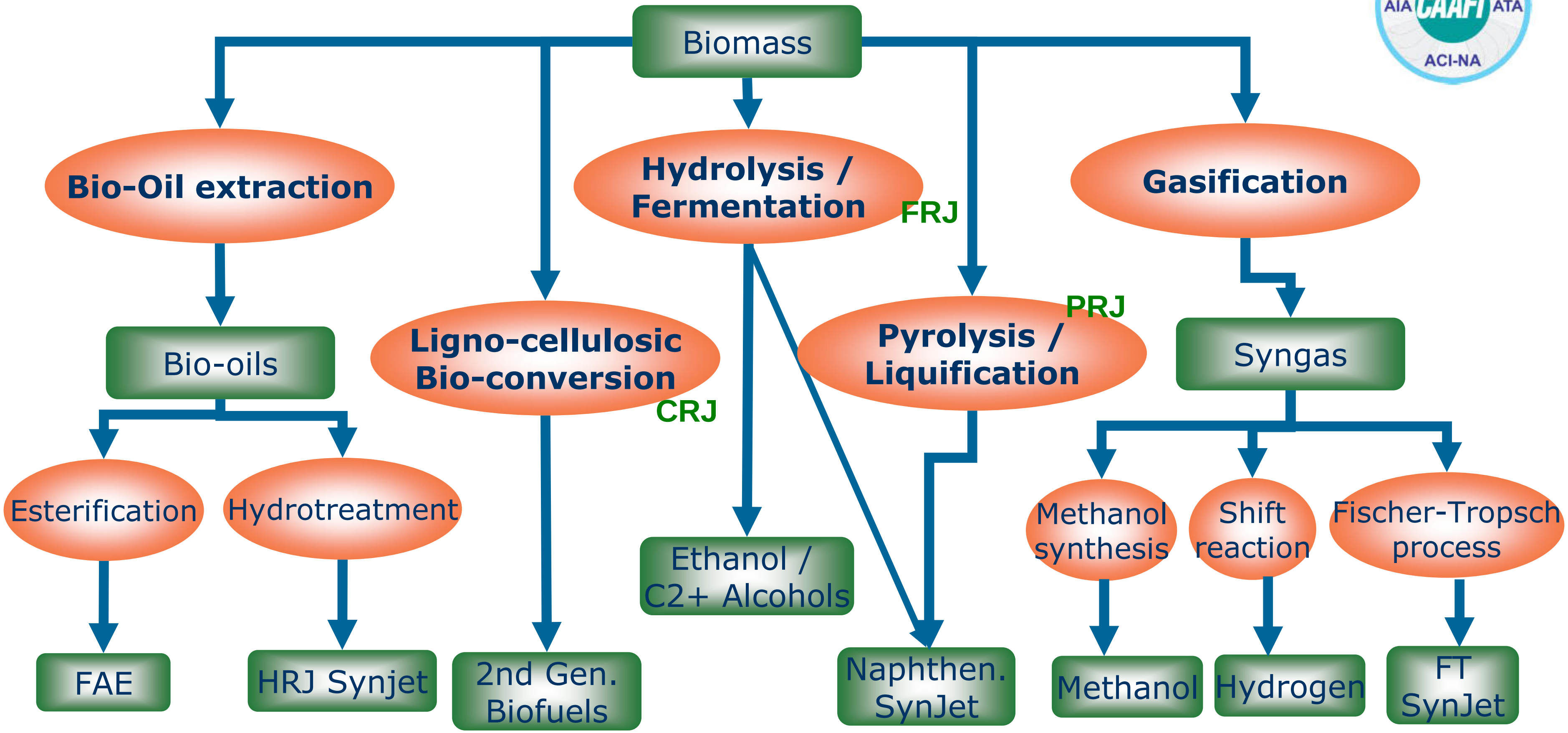
44 tasks

52 deliverables

9 Milestones

SP1 - Selection of the 4 main promising pathways

Fuel survey and economy: selection of 12 blends



Certified by end 2011:
HRJ Hydrotreated Renewable Jet
FT Fischer Tropsch Process

Targets for 2013, 2014:
FRJ Fermentation Renewable Jet
PRJ Pyrolysis Renewable Jet
CRJ Catalytic Renewable Jet

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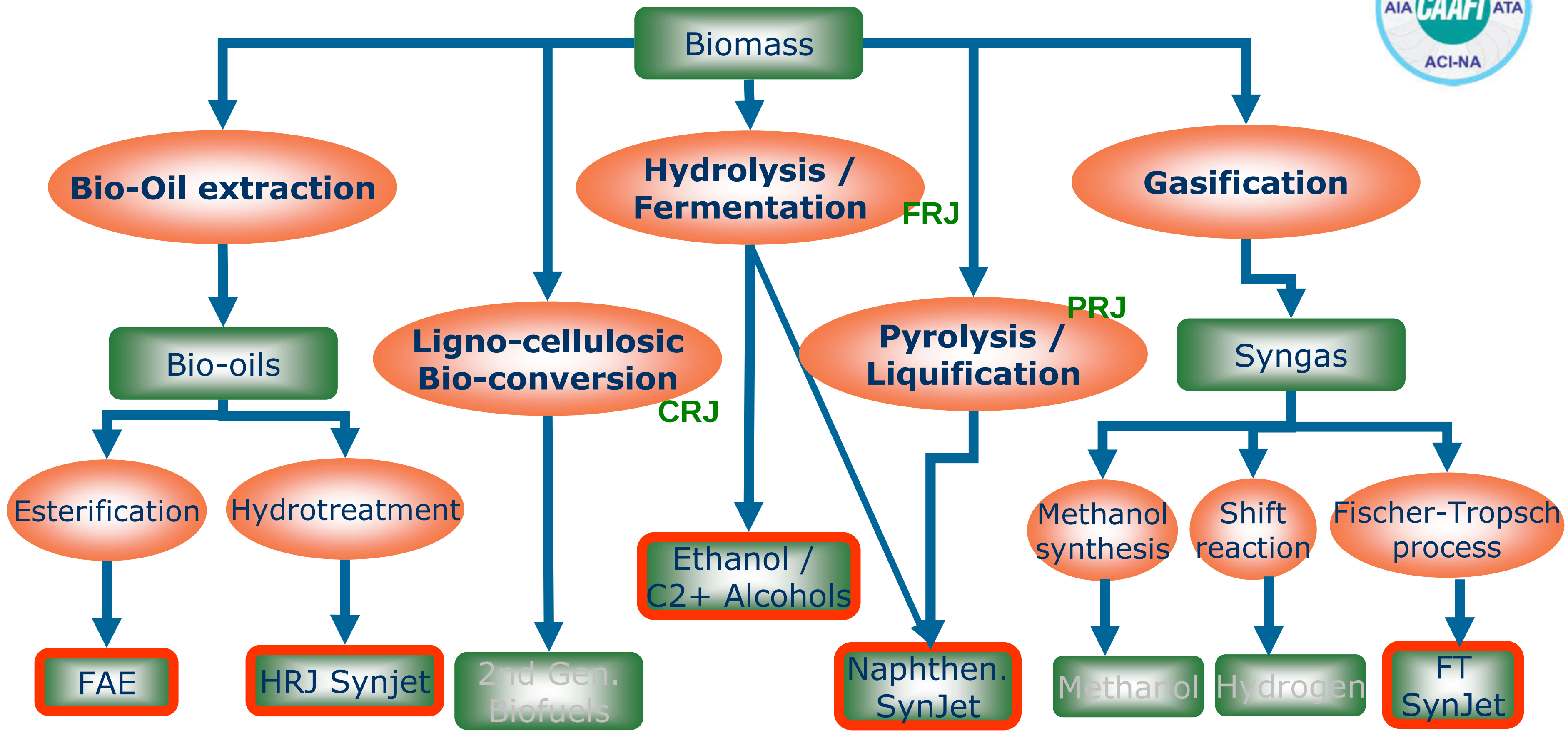
SP1 - Selection of the 4 main promising pathways

Fuel survey and economy: selection of 12 blends



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SP1 - Selection of the 4 main promising pathways

Fuel survey and economy: selection of 12 blends

- **Blends could be outside Jet fuel specification compositional boundaries**

- **FRL: Fuel readiness level defined by CAAFI**
  a measure of the fuel's progress towards full commercialisation

- **Fuel matrix built around three axes:**
  - Paraffinic compounds ➔FRL 7-9 *Short term view*
  - Naphthenic compounds ➔FRL3 *Middle term view*
  - Oxygenated compounds ➔FRL1 *Long term view*

- **Based on standard characterization**
  ASTM D7566: allowing up to 50% Fischer-Tropsch fuels "synthetic paraffinic kerosene" SPK in jet fuel blends

FSJF
FT-SPK
FT-SPK+50% Naphthenic cut
FT-SPK + 20% Hexanol
FT-SPK + 10% Furane
FT-SPK + 20% Furane
FT-SPK + 30% Furane
FT-SPK + 10% FAE
FT-SPK + 20% FAE
FT-SPK + 30% FAE
FT-SPK + 50% HRJ
FT-SPK + 75% HRJ

FSJF: Fully Synthetic Jet Fuel
FT–SPK: Fischer-Tropsch Synthetic Paraffinic Kerosene
HRJ: Hydrotreated Renewable Jet fuel
FAE: Fatty Acid Esters

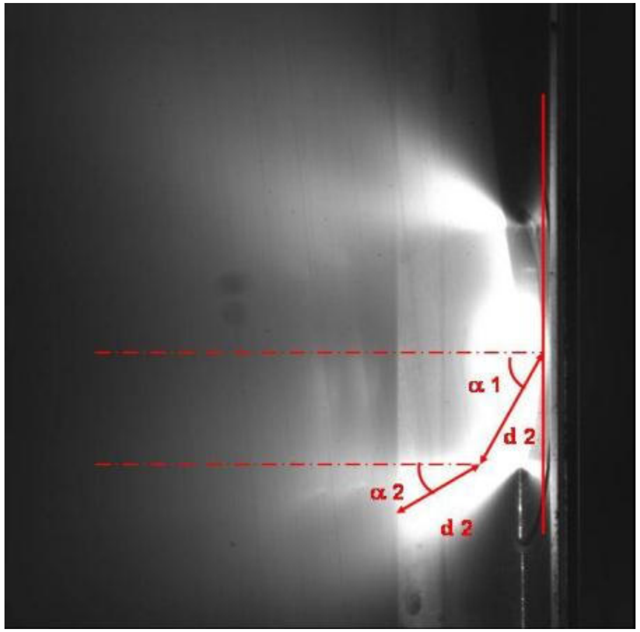
SP2 – Assesment of the suitability

- **Four SP2 fuels retained**
  - FSJF, FT-SPK, FT-SPK + 50% naphthenic cut, FT-SPK + 20% hexanol
- **Tests from aircraft tank-to-engine exhaust under progress**
  - From fundamental experiments to realistic conditions
  - Characterization of injection and combustion behaviors of the AF
    - *Laminar flame speed, droplet stream, auto-ignition delay times, …*
    - *Spray injection in a chamber (non-reactive, reactive)*
    - *Pollutant emission (soot formation, Emission Index, …)*
  - Characterization of compatibility of the AF with engine and aircraft systems
    - *Ageing and permeability tests*
    - *Fuel thermal stability*
    - *Gauging issues*
  - Safety, standards and regulations issue
    - *Explosion tests, post-crash fire test*
    - *Impact on the standards*
- **Comparisons between the four SP2 fuels**
  - Relative comparison: reference fuel FSJF
  - Absolute comparison when possible: Jet-A1

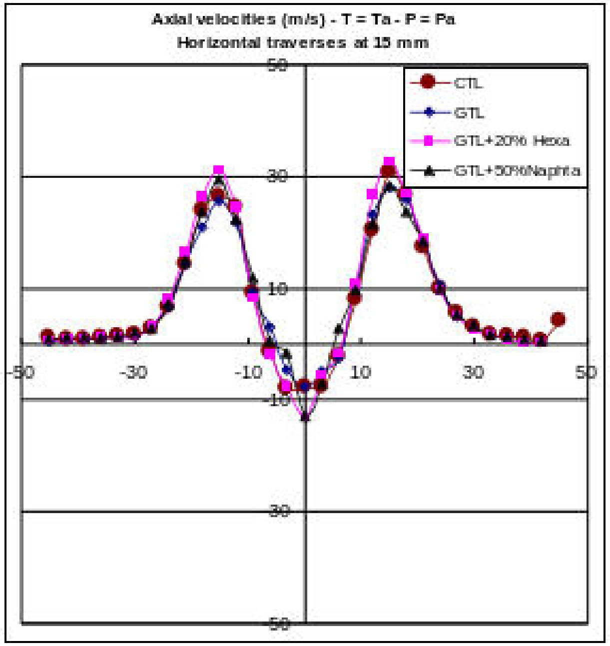
SP2 – Assesment of the suitability

➢ Injection & combustion tests (combustion chamber)

– Atomization-Evaporation under non-reactive conditions



Spray geometry



Droplet velocity

Spray configuration

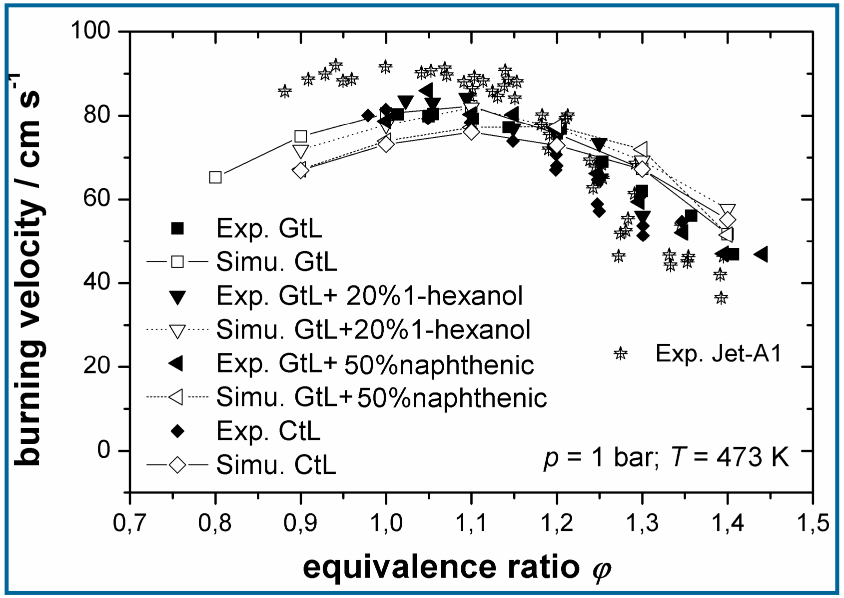
Droplet velocity

– 1 < P < 10 bar ; 293 < T < 553 K ; industrial injection system

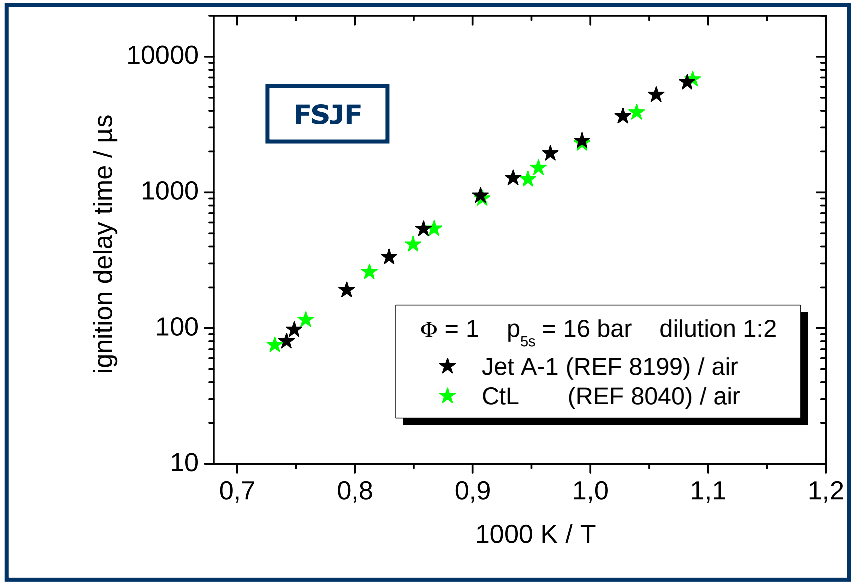
– Similar behaviors of the AF with respect to the geometry, the granulometry and the velocity distributions

SP2 – Assesment of the suitability

- **Injection & combustion tests (combustion chamber)**
  - High pressure burner and shock tube test rigs



Laminar flame speed

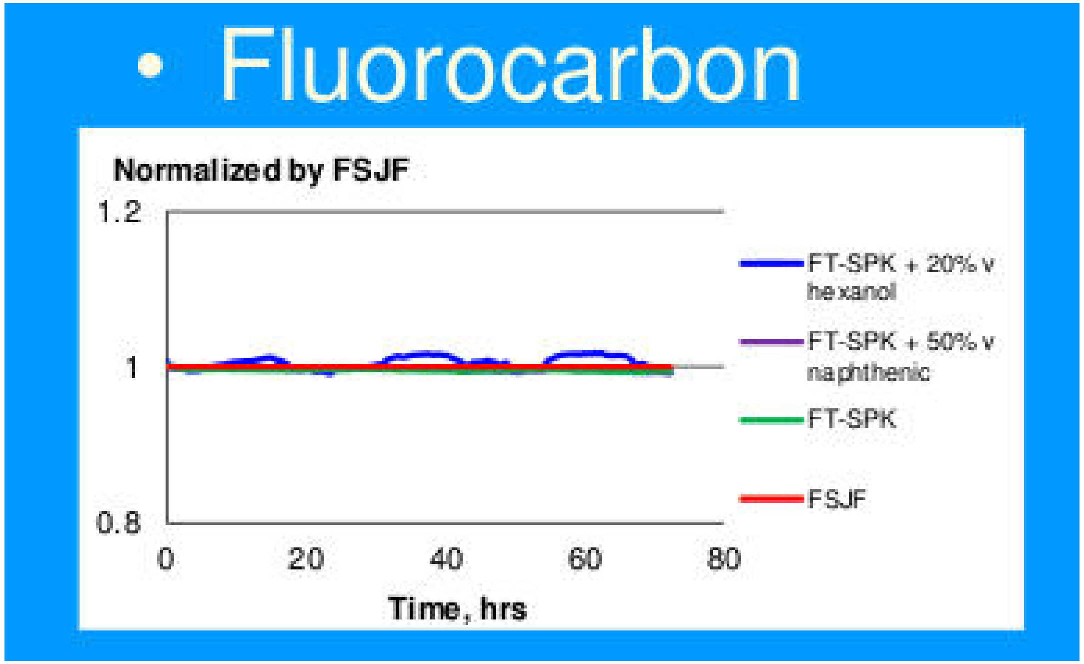


Ignition delay times

- Laminar flame speed: comparison with Jet-A1 depends on φ
- Ignition delay time: very similar

SP2 – Assesment of the suitability

➢ Material compatibility (engine system)



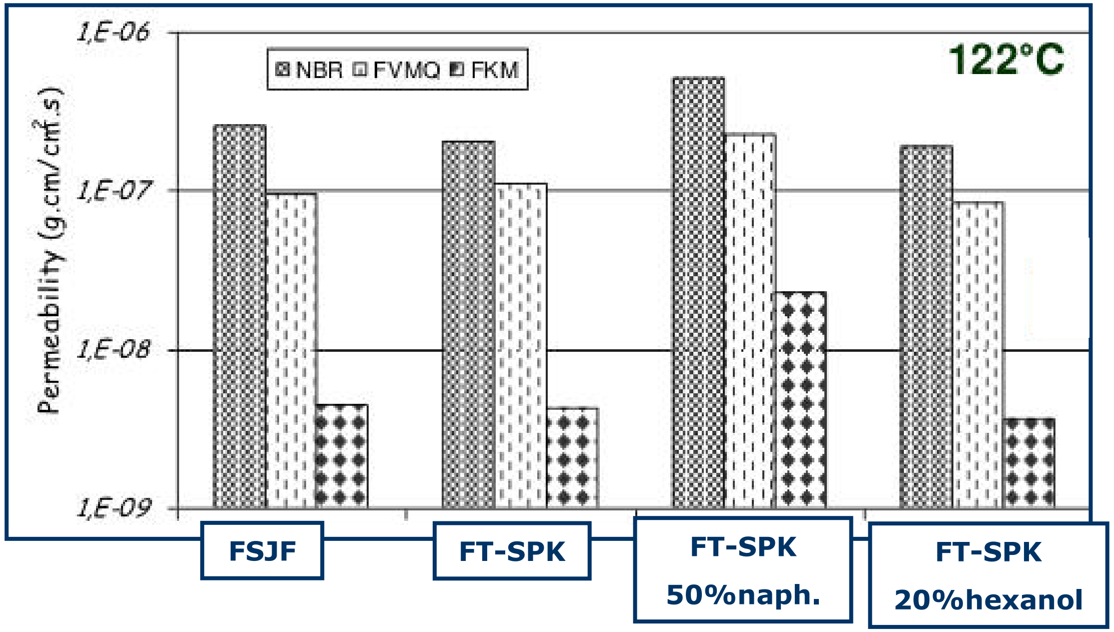
Stress relaxation tests

O-rings

- 3 materials: nitrile, fluorosilicon, fluorocarbon
- Best compatibility for the fluorocarbon
- Nitrile O-ring affected by the fuel's composition

SP2 – Assesment of the suitability

➢ Operational compatibility (aircraft system)



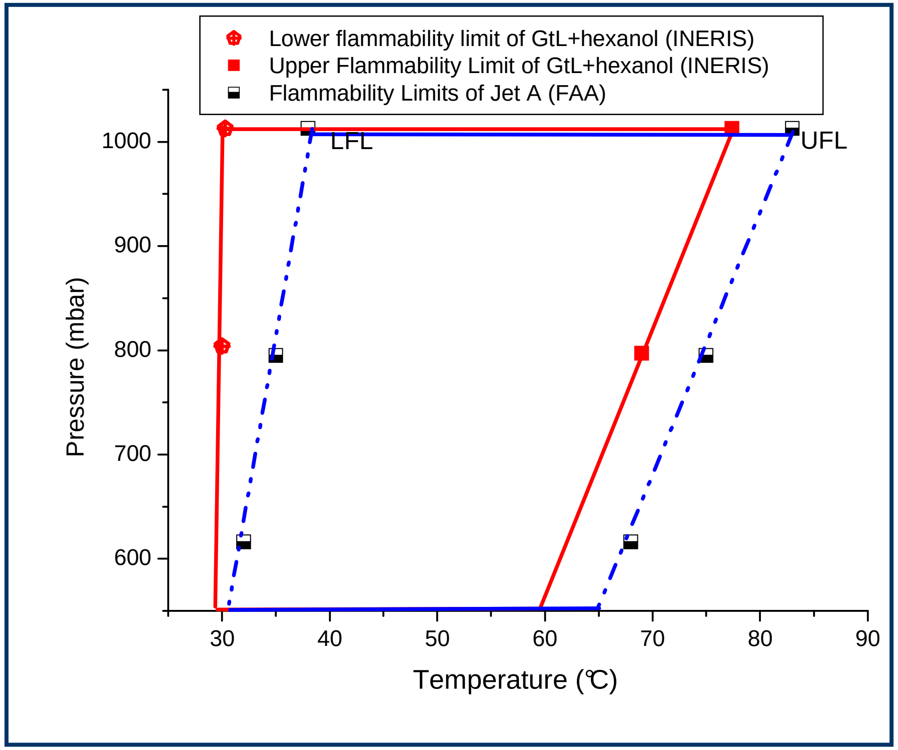
Permeability tests

Elastomer compatibility

- No large differences for FSJF, FT-SPK, FT-SPK + 50% naphthenic cut
- Increase of permeability for the blend Gtl + hexanol (diffusion)

SP2 – Assesment of the suitability

➢ Safety, standards and regulations

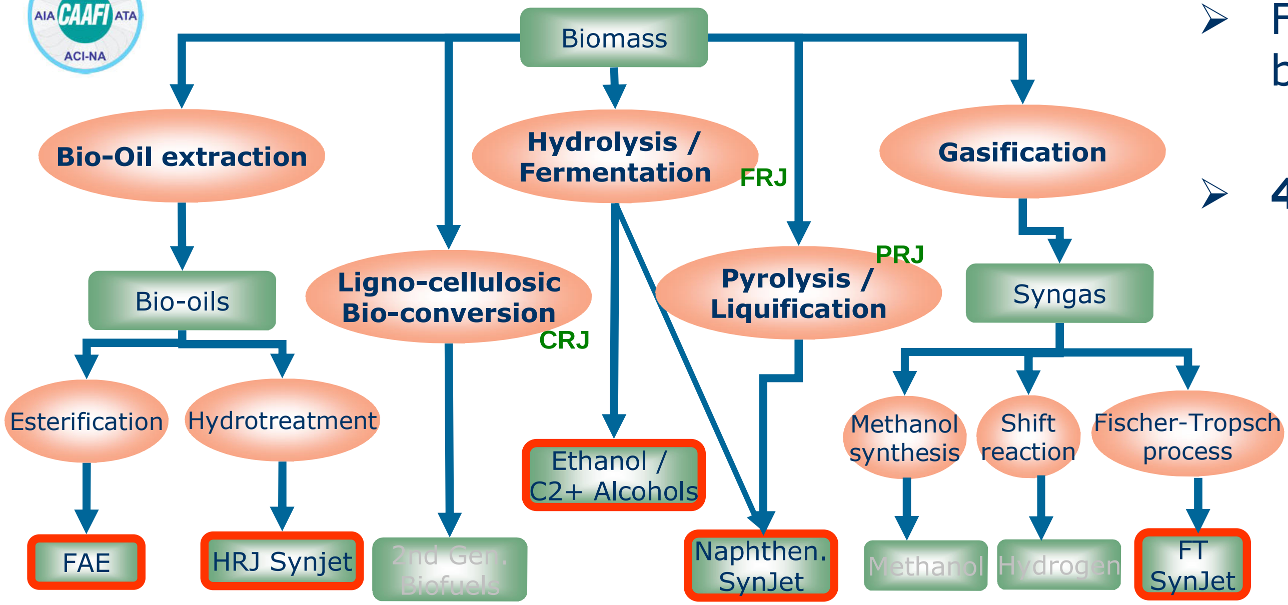


Flammability limits

FT-SPK + 20% hexanol

– Shifts of the flammability domain wrt to the altitude

Conclusions and prospects



- From characterization of 12 blends
- **4 selected fuels:**
  - FSJF ➔ FRL 7-9
  - FT-SPK ➔ FRL 7-9
  - FT-SPK + naphthenic cut (50%) ➔ FRL 3
  - FT-SPK + hexanol (20%) ➔ FRL 1

- **ALFA-BIRD considers alternative fuels for aeronautics with short, middle and long term views**
  - → Outside today's Jet fuel specification (ASTM D7566 – 50% SPK): pure paraffinic, very few aromatics....
- **Complementary with other initiatives and demonstration, with a constant search of exchanges and cooperation**

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Conclusions and prospects

Next steps of ALFA-BIRD:

➢ **Experimental tests for injection and combustion**

ONERA/SNECMA – [4-20] bar

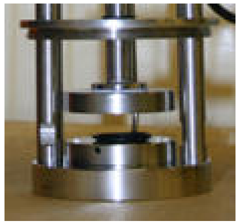
Low NOx lean-burn combustion systems

APU USFD – 4 bar

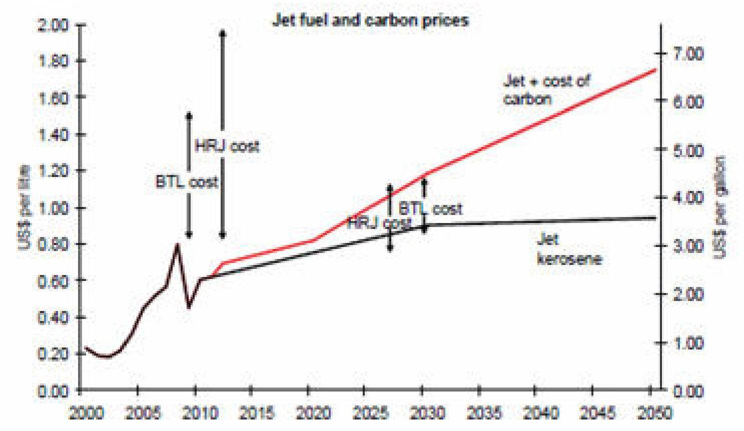
rich-burn system

➢ **Material compatibility**

Dynamic elastomer testing (USFD)

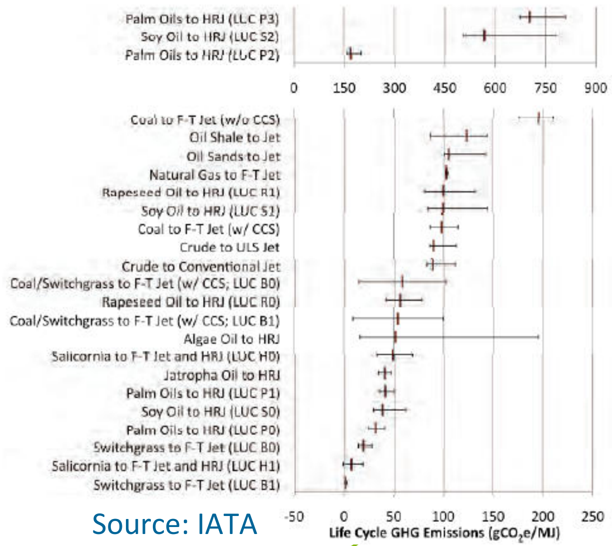


➢ **Economical evaluation**



Source: IATA

➢ **Environmental balance**



Source: IATA

IFP Energies nouvelles

Acknowledgments

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