AN OVERVIEW OF SAFRAN CONTRIBUTION TO AVIATION DECARBONATION
SAFRAN AT A GLANCE
AN INTERNATIONAL HIGH-TECHNOLOGY GROUP

**4 CORE BUSINESSES:**
- Aerospace propulsion
- Aircraft equipment
- Aircraft interiors
- Defense

**WORLD’S No.3 AEROSPACE COMPANY**
(excluding aircraft manufacturers)

**Nearly 81,000 EMPLOYEES in 30 COUNTRIES**

**€24.6 BILLION** in revenue*

**€3.8 BILLION** in adjusted recurring operating income*

**€1.7 BILLION** in R&D expenditures*

**More than 1,200 FIRST PATENTS APPLICATIONS filed**

*as of 12/31/2019
**as of 09/30/2020
FINANCIAL AND STOCK MARKET DATA

REVENUE BY BUSINESS SECTOR IN 2019*

- Aerospace Propulsion: 48.9%
- Aircraft Interiors: 13.5%
- Aircraft Equipment, Defense, Aerosystems: 37.6%

CAPITAL SHAREHOLDING STRUCTURE**

- Public: 81.3%
- French State: 11.2%
- Employees: 7.4%
- Treasury shares: 0.1%

*as of December 31, 2019
**as of July 31, 2020
BOOSTING AIR TRANSPORT PERFORMANCE

No. 1 WORLDWIDE
- single-aisle commercial jets engines, in partnership with GE*
- helicopter turbine engines
- landing gear
- wheels and carbon brakes**
- electrical wiring interconnection systems for aircraft
- mechanical power transmissions systems**
- oxygen systems

No. 2 WORLDWIDE
- electrical power generation
- aircraft engine nacelles

A WORLD LEADER
- onboard power electronics
- fuel systems
- APUs for business jets, helicopters and military aircraft
- seats for commercial airplanes

*through CFM International, a 50/50 joint company between Safran Aircraft Engines and GE
**mainline commercial jets with over 100 seats
PROPULSION: THE BROADEST POWER RANGE

(1) Rolls-Royce Turbomeca Ltd, a 50/50 joint company between Safran Helicopter Engines and Rolls Royce

(2) PowerJet is a 50/50 joint company between Safran Aircraft Engines and UEC Saturn (Russia)

(3) CFM International is a 50/50 joint company between Safran Aircraft Engines and GE (USA)

(4) By Europrop International (EPI), a consortium of Safran Aircraft Engines, Rolls-Royce, ITP and MTU Aero Engines

(5) In collaboration with GE (USA)

(6) Through the Engine Alliance (Safran Aircraft Engines 10%, Safran Aero Boosters 7.5%)

(7) In collaboration with GE (Safran Aircraft Engines 23.7%)

(8) Through Europropulsion, a 50/50 joint company between Safran and Avio (Italy)

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A COMPREHENSIVE RANGE OF AIRCRAFT PROPULSION SYSTEMS AND EQUIPMENT

- Cockpit
  - Control systems
  - Panel & displays
  - Seats
- Avionics
  - Inertial navigation systems
  - Flight data acquisition unit
- Electrical flight actuators
- Cabin interiors
  - Seats
  - IFEC – In-flight entertainment & connectivity
  - Cabin lighting
- Oxygen systems
- Auxiliary Power Unit (APU)
- Power & data wiring
- Exterior lighting
- Lavatories, water & waste
- Engines
  - Engine control systems (FADEC)
  - Power transmission systems
  - Power distribution and generation
- Cargo containers and pallets
- Nacelles and components
- Electrical flight actuators
- Galleys & equipment
- Landing gears
  - Braking & landing control systems
  - Wheels and carbon brakes
- Inerting & fuel systems
- Evacuation slides and life rafts
- Anti icing & de-icing
- Inletting
SAFRAN, A KEY PLAYER ONBOARD CIVIL HELICOPTERS

Cockpit
- Pilot seats
- Autopilot
- Cockpit controls
- Cockpit panels
- Flight control computer
- Windshield wiper systems
- Oxygen equipment

Navigation systems
- Inertial navigation systems
- Attitude & heading reference system

Flight data management
- Recording & transmitting units
- Analysis services

Propulsion
- Engines from 500 to 3,000 shp
- Engine control unit
- Power transmission

Auxiliary Power Unit (APU)

Fuel systems
- Flexible tanks
- Gauging systems
- Fuel circulation systems

Cabin
- Passenger seats

Vision
- Electro-optical systems
- External lighting

Electrical systems
- Wiring
- Electrical distribution
- Electrical generation
- Power electronics & conversion

Flight control systems
- Electromechanical actuators

Safety systems
- Floats and rafts
- Life vests
- De-icing
- Pilot and passenger protection
- Cockpit voice & flight data recorder
- Ventilation systems

Landing systems
- Landing gear
- Wheels and brakes
- Electric braking systems
- Braking and landing control units and actuators

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R&T SAFRAN HOT TOPIC:
AVIATION DECARBONATION
WHERE DO WE START FROM?
2018 GREENHOUSE GASES EMISSION: Civil Aviation ~ 900 Millions of Tons of CO₂
FOCUS ON THE 33.1 GT OF CO₂ AND ON THE PART RELATED TO TRANSPORTATION

Total related to the transport: 8 GT of CO₂
AVIATION MAIN DRAWBACKS

Impacts

- Global
  - Greenhouse effect
  - Climate change

- Local
  - Air quality & Noise
  - Effect on human health

Operations close to airports
Overall aircraft mission
NON CO₂ EMISSION AND RELATED PHENOMENA

Climate Forcings from Global Aviation Emissions and Cloudiness

Warming from global accumulation of carbon dioxide and water vapor

Exhaust plume (no contrail formation)

NO₂ emissions lead to warming from increased ozone and reduced methane and water vapor

Possible ice cloud changes from soot

Sulfate and soot direct radiative effects

Stratosphere

Troposphere

Reflective solar radiation

Warming from contrail cirrus

Contrail plume

Sulfate aerosol increases reflectivity of low altitude clouds

Near-ground emissions

Solar radiation terrestrial radiation

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NON CO₂ EMISSION AND RELATED PHENOMENA

Atmospheric effects of emissions from aviation

- Emissions
  - CO₂
  - H₂O
  - NOₓ
  - VOC
  - SO₂
  - Particles

- Changes in atmospheric composition
  - > ΔCO₂
  - > ΔH₂O
  - < ΔCH₄
  - > ΔO₃
  - ΔParticles

- Contrails
- ΔClouds

- Climate forcings
- Direct greenhouse gases
- Indirect greenhouse gases
- Direct aerosol effect
- Clouds
DECARBONISING AVIATION: SAFRAN’S VISION

EIS
100% BioFuel
-30 % new A320

Breakthrough on aircraft fuel consumption
~40-50%

Optimized air traffic
~10%

Low to zero Carbon fuels/energy
~30-40%

Ramp-up of alternative fuel use
### 3 TOP PRIORITIES

<table>
<thead>
<tr>
<th>01</th>
<th>ULTRA-EFFICIENT FUTURE AIRCRAFT</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>30% lower fuel consumption</td>
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</tbody>
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**ULTRA-EFFICIENT ENGINE**
successor to the LEAP (“New Generation Narrow Body”)

**E-TAXI – EMBEDDED TECHNOLOGY**
Electrification

**LIGHTENED EQUIPMENT AND MODIFIED**
aircraft configurations (thin wings, etc.)

<table>
<thead>
<tr>
<th>02</th>
<th>ALTERNATIVE FUELS</th>
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**OVERCOME TECHNICAL BARRIERS**
to the use of 100% alternative fuels

**ADAPT ENGINE/AIRCRAFT TO HYDROGEN FUELS**

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<tr>
<th>03</th>
<th>ALTERNATIVE PROPULSION</th>
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**NEW AIR MOBILITY, COMMUTER & REGIONAL A/C**
used as lab to test (electric/hybrid propulsion systems, fuel cells, etc.)
THE PATH TO SUCCESSFUL DECARBONIZATION

**2020**
- Long-haul: 100% jet fuel
- Regional (Short/medium-haul): 80% improvement in energy efficiency since the start of commercial aviation
- Commuters and helicopters

**2030-35**
- "Skip a generation"
- Disruptive aircraft with thermal propulsion, ultra-efficient and greater use of alternative fuels
- Small electric aircraft
- Hybrid regional aircraft
- New air mobility (Short-range)

**2050**
- Future aircraft with carbon-free energy source
- Green synthetic fuel and/or liquid hydrogen
- Fuel cells
- Ultra-high energy density batteries

Public policy and regulations + Technology

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ULTRA-EFFICIENT FUTURE AIRCRAFT: ULTRA-EFFICIENT ENGINE

Aviation consumption divided by 5 during the last 60 years
Among them, 70% from the motor

<table>
<thead>
<tr>
<th>Motor</th>
<th>Bypass Ratio</th>
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<tbody>
<tr>
<td>JT8D</td>
<td>~0</td>
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<tr>
<td>CFM56-5B</td>
<td>6</td>
</tr>
<tr>
<td>LEAP-1A</td>
<td>11</td>
</tr>
</tbody>
</table>
ULTRA-EFFICIENT FUTURE AIRCRAFT: ULTRA-EFFICIENT ENGINE

Average fuel burn of flights departing from Europe = 3.4 l/100km/pax*

Average CO2 emitted in Europe in 2018 = 3.4*0.8*3.16/100 = 86 g/pax/km**

This average includes the freight which is transported in addition to passengers.

* EASA European aviation environmental report
** Mass of CO2 emitted by 1 Kg kerosene = 3.16 Kg
** Kerosene specific mass = 0.8 Kg/l
MORE ELECTRICAL APPLICATIONS

And

ALTERNATIVE PROPULSION
E-Taxi

Climb-out

Takeoff

3-minute main engine start-up

Final approach

3-minute main engine cool-down

6-minute taxi-in

Gate

14-minute taxi-out

Main engine taxing  Electric Taxiing

https://www.safran-landing-systems.com/systems-equipment/electric-taxiing-0

ENVIROMENTAL BENEFITS
Compared with an aircraft taxiing using its jet engines, Electric Taxiing will reduce emissions by up to:

-51% NOx

-61% CO2

-62% HC

-73% CO
E-Taxi

4% fuel savings offered by electric taxiing

73% potential reduction in carbon emissions during taxiing
E-Taxi
MORE AND MORE ELECTRIC APPLICATIONS

A Step by step approach to hybridization and/or all electric propulsion

- Electric taxiing
- Drone cargo
- Helico Micro hybridization
- VTOL
- 10 Pax aircraft
- Mild hybrid SMR
- 40 Pax regional
- Distributed propulsion

Power

- 100 kW
- 500 kW
- 1 MW
- 10 MW

- 2022
- 2025
- 2025+
- 2030+
- 2040 - 2050
A Step by step approach to hybridization and/or all electric propulsion

AIRCRAFT PROPULSION PROJECTION

- **Optimized Non-Propulsive Energy Generation**
  - < 5 % elec. pwr

- **Electric Assistance to Gas Turbine Engine**
  - < 10 % elec. pwr

- **Parallel/Series Hybrid**
  - 20-50 % elec. pwr

- **Series Hybrid / Turbo-electric**
  - 100 % elec. pwr

- **> 10 MW**
  - SMR
    - 200-300 PAX

- **5-10 MW**
  - Regional
    - 100-150 PAX

- **2-5 MW**
  - Regional
    - 50-100 PAX
    - Business Jets

- **1-2 MW**
  - Commuters
    - Helicopters
    - UAVs

- **x00 kW**
  - General Aviation

**EIS**

- **Today**
- **+ 10 yrs**
- **+ 20 yrs**
- **+ 30 yrs**
- **+ 40 yrs**
NEW ARCHITECTURES, NEW APPLICATIONS

Cargo logistics drone - Electric propulsion

1 - Batteries
2 - Power Management
3 - Electrical motors
4 - E-propellers
NEW ARCHITECTURES, NEW APPLICATIONS

Air taxi - Distributed hybrid propulsion

1 - Turbogenerator
2 - Batteries
3 - Power Management
4 - Electrical motors
5 - E-propellers
NEW ARCHITECTURES, NEW APPLICATIONS

Commuter - Combined series / parallel hybrid propulsion

1 - Turbojet
2 - Generator
3 - Batteries
4 - Power Management
5 - Electrical motors
6 - E-propellers
SUPERCONDUCTIVITY VS HIGH VOLTAGE: TODAY’S CHALLENGE?
APPLICATIONS IN A COMPLEX POWER RANGE

Intensity (I) (Ampère)

Power (W ou k W) ~ U I

Threshold of physical mechanisms leading to insulation degradation

<< High Voltage >> ?

SAFRAN applications

Univ. Illinois

GREEN Univ. Lorraine
APPLICATIONS IN A COMPLEX POWER RANGE

Power (W or kW) ~ U I

Threshold of physical mechanisms leading to insulation degradation

SAFRAN applications

- Superconductivity?
- Materials (LTS, MTS, HTS) and Processes
- Cooling

SAFRAN

- High Voltage?

- Partial Discharges
- Space charge
- Electrical Arc
CONCLUSIONS ?
Climate changes drive the R&T works to reduce CO$_2$ fingerprint.

Electrification of an increased number of functions including the propulsion may appear as an enabler of this reduction.

More Electrical Power being necessary, such a penetration will only be possible if the voltage is increased or if superconducting concept and associated technologies are developed.

Increasing the voltage may lead to consequences to be mitigated.

Specific efforts in the field of materials and processes are necessary for superconductivity to become a tangible technology.

We are living a revolution
Enjoy what you do and have a great conference!