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# High temperature composite overview in France

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Eric Bouillon
*Eric Bouillon, Safran Ceramics*

CERAMICS

# Ceramic Matrix Composites In France: 40 Years Of Innovations

Santa Fe, November 5th, 2017

Marc MONTAUDON, COO, Safran Ceramics

SAFRAN




sep les nouveaux espaces

Snecma Moteurs groupe snecma

Messier-Bugatti Groupe SAFRAN

SAFRAN Herakles

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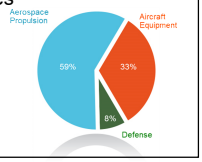
**€15.8 BILLION**
in sales #




**€2.4 BILLION**
in adjusted recurring operating income #

**€1.7 BILLION**
in R&D expenditures #

Over **850 INITIAL PATENTS** #

# 2016

**1 SINGLE-AISLE COMMERCIAL JET TAKES OFF** every **2 SECONDS,** powered by our engines*

**MORE THAN 54,000 LANDINGS** a day using our equipment

**80 SUCCESSFUL ARIANE 5 LAUNCHES** in a row**

**3,000 MILITARY AIRCRAFT** fitted with our inertial navigation systems

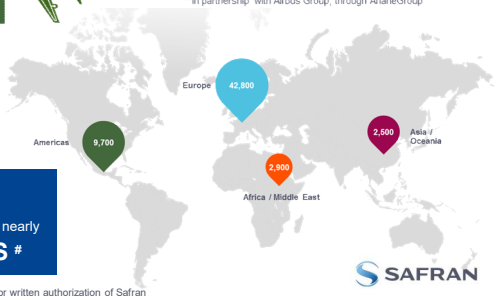
**1 OUT OF EVERY 3 HELICOPTER TURBINE ENGINES** sold worldwide

**OVER 35,000 POWER TRANSMISSIONS** totaling over 850 million flight-hours

**18,400 NACELLE COMPONENTS** in service

**500 KM OF ELECTRICAL WIRING** on an Airbus A380

*in partnership with GE, through CFM International
**in partnership with Airbus Group, through ArianeGroup




Nearly **58,000 EMPLOYEES** in nearly **30 COUNTRIES** #

3



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# Chapter 1

# The Tale of Carbon-Carbon

4 Safran Ceramics – November 2017



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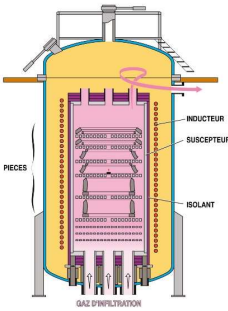
## 1) 1969-1979: acquire, taste and improve a processes toolbox

**Preform**
- Fabric lay-up
- Felts
- « 4D »…

**Vapor Route**

Preform → CVI → Machining → CVI → Final Part




**Liquid Route**

Preform → Impregnation → Carbonization → Machining → Final Part

nx

Resin

Pitch



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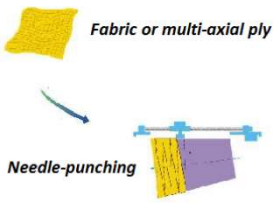
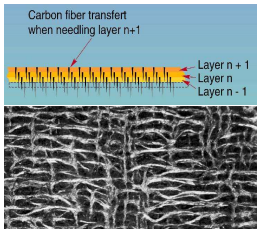
## 2) 1982: invent a technological/economical rupture, Novoltex® texture




- **Automative process**
- **Various shapes (thin plates, parallelepipedic blocks, cylinders, cones, etc.)**
- **Homogeneous pores network w/o bottlenecks**
- **Handlable & self-supporting w/o toolings**

} ***perfectly adapted to any densification route, particularly CVI!***



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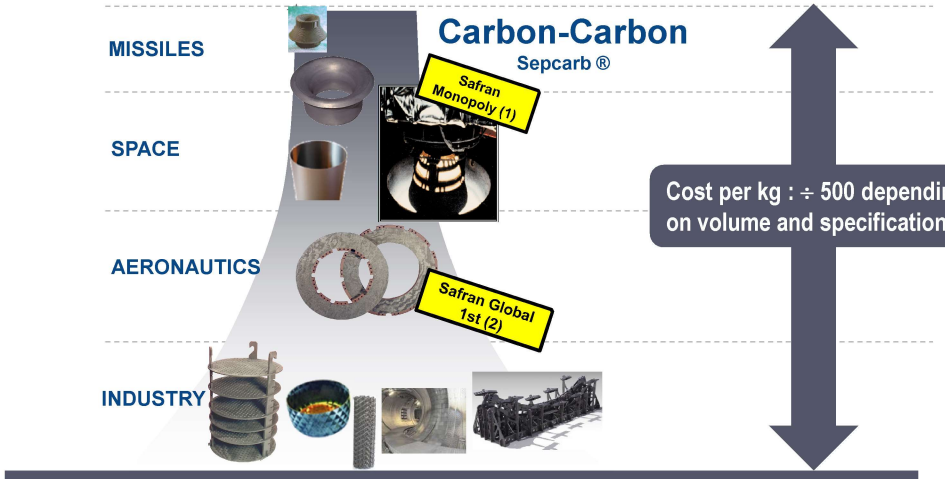
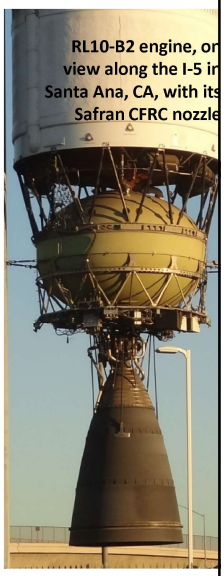
## 3) >1985: Develop a material range and extend the scope



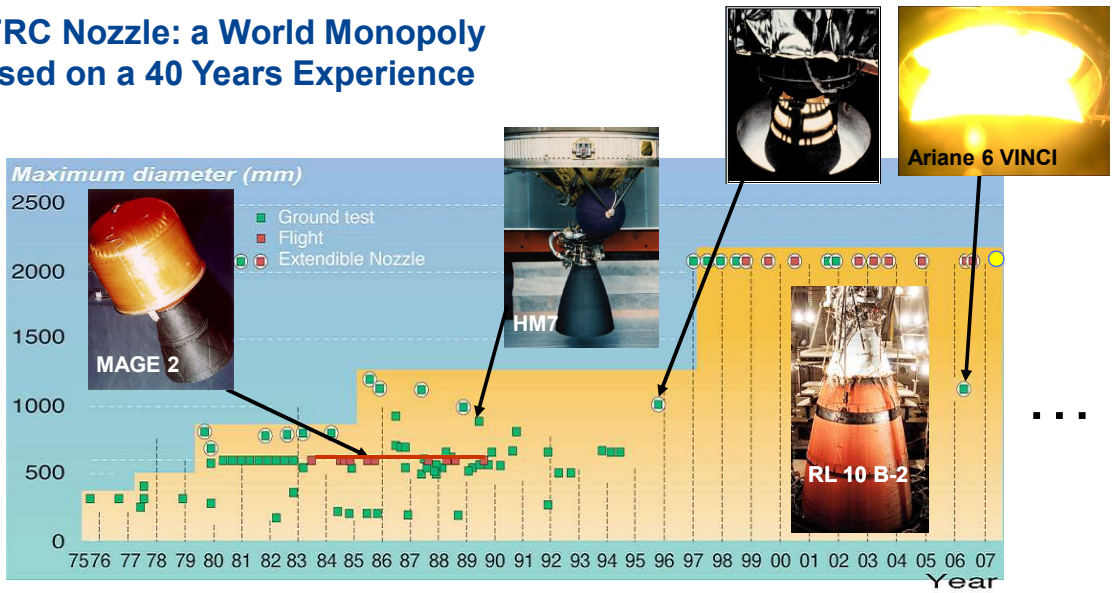

2016 Deliveries **~7500 parts + 1,100 tons of brakes**

(1) Through our ArianeGroup subsidiary
(2) Through our Safran Landing Systems subsidiary

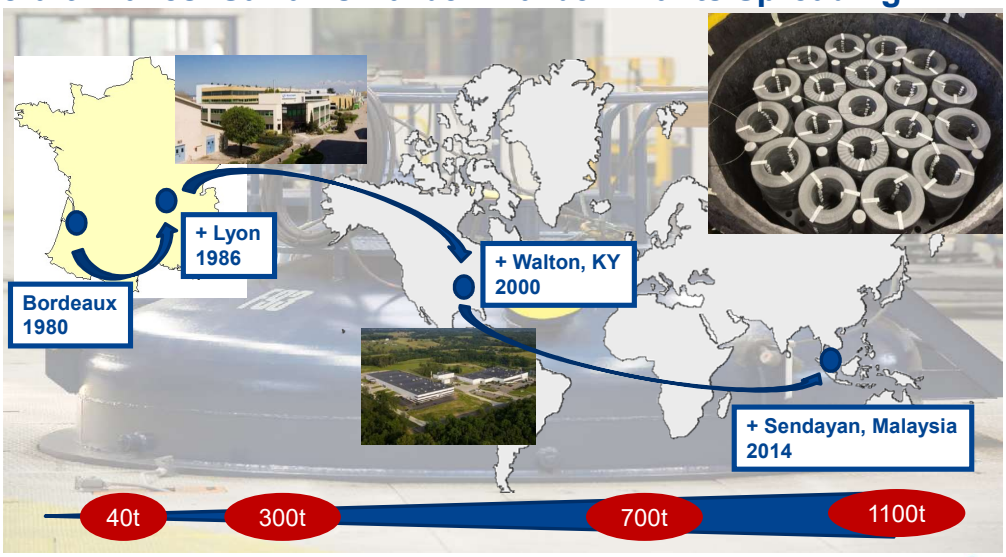





## CFRC Nozzle: a World Monopoly based on a 40 Years Experience



## Aircraft Brakes: Safran's Carbon-Carbon Plants Spreading

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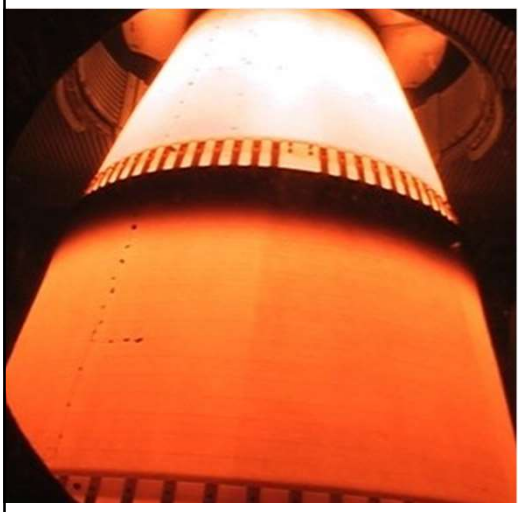

# Chapter 2

# The Tale of Ceramic Matrix Composites



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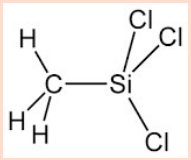
## 1977: First Ceramic Matrix Composite

- Densification of a carbon preform
- Chemical Vapor Infiltration from methyltrichlorosilane




Laboratoire de Chimie du Solide (now LCTS)
University of Bordeaux

Pr. Roger NASLAIN

## 1979: First Industrial Furnace

SEP (now Safran), Bordeaux

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## The Process Toolbox

SiC Chemical Vapor Infiltration

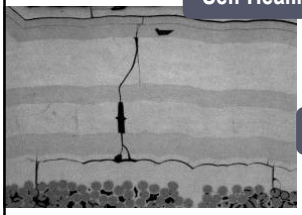
Preform
- Novoltex ®
- 2D tows or fabrics
- 3D Weaving

Slurry Incorporation

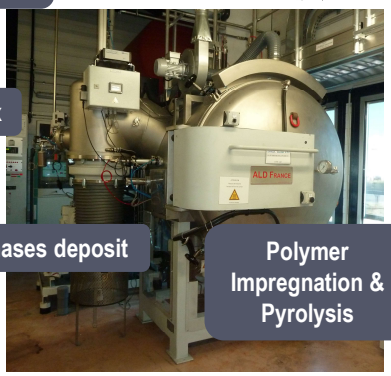
Melt Infiltration of Silicon

Oxide sintering

Self Healing Matrix



Interphases deposit



Polymer Impregnation & Pyrolysis

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## Carbon-Carbon / Carbon-Ceramic

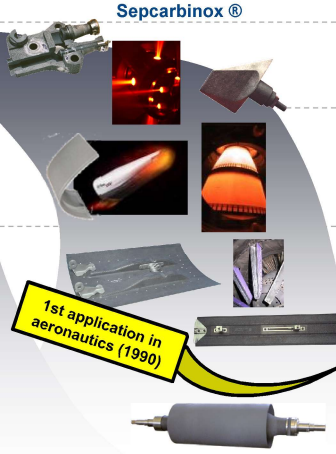
Sepcarb ® — Sepcarbinox ®

MISSILES

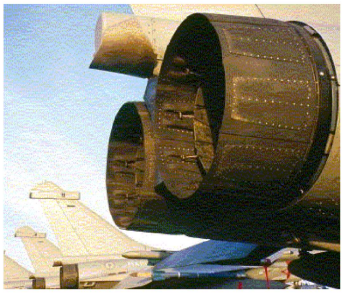
SPACE

AERONAUTICS

INDUSTRY



1st application in aeronautics (1990)



French Fighter Rafale's nozzles since 1990

also successfully ground (>11,000 TACs) and flight tested (>1,000h) on F-15, F-16

2016 Deliveries ~5000 parts

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## Hot Gas Valves Experience

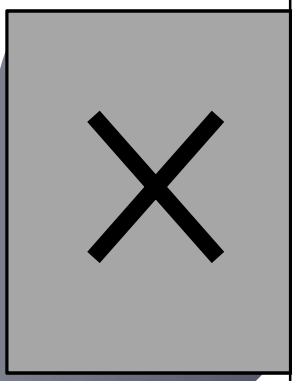
Military serial application

80s

90s

00s

10s



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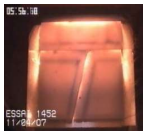
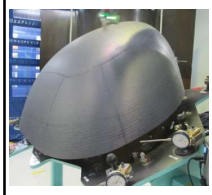
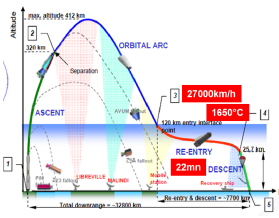
## ESA's IXV Atmospheric Re-Entry Demo: TRL6 for a re-usable CMC Nose and Thermal Protection System (Feb 2015)







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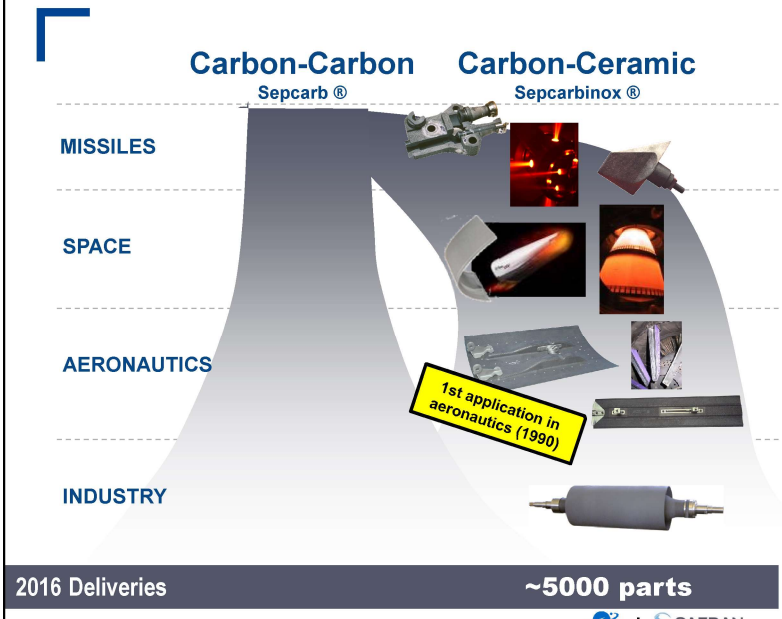


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## Then came the Silicon Carbide Fibers…

Courtesy of Nippon Carbon K.K. (now NGS Advanced Fibers, K.K.)





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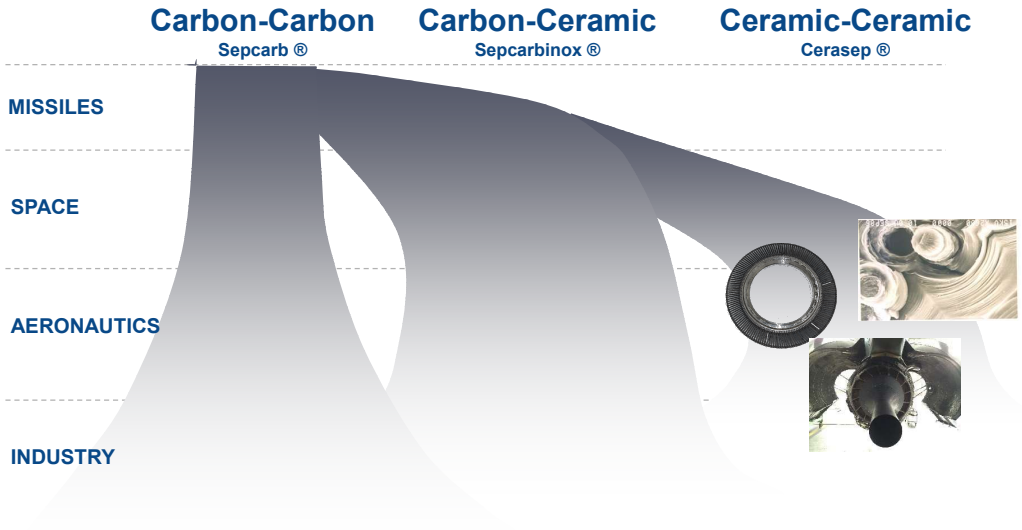




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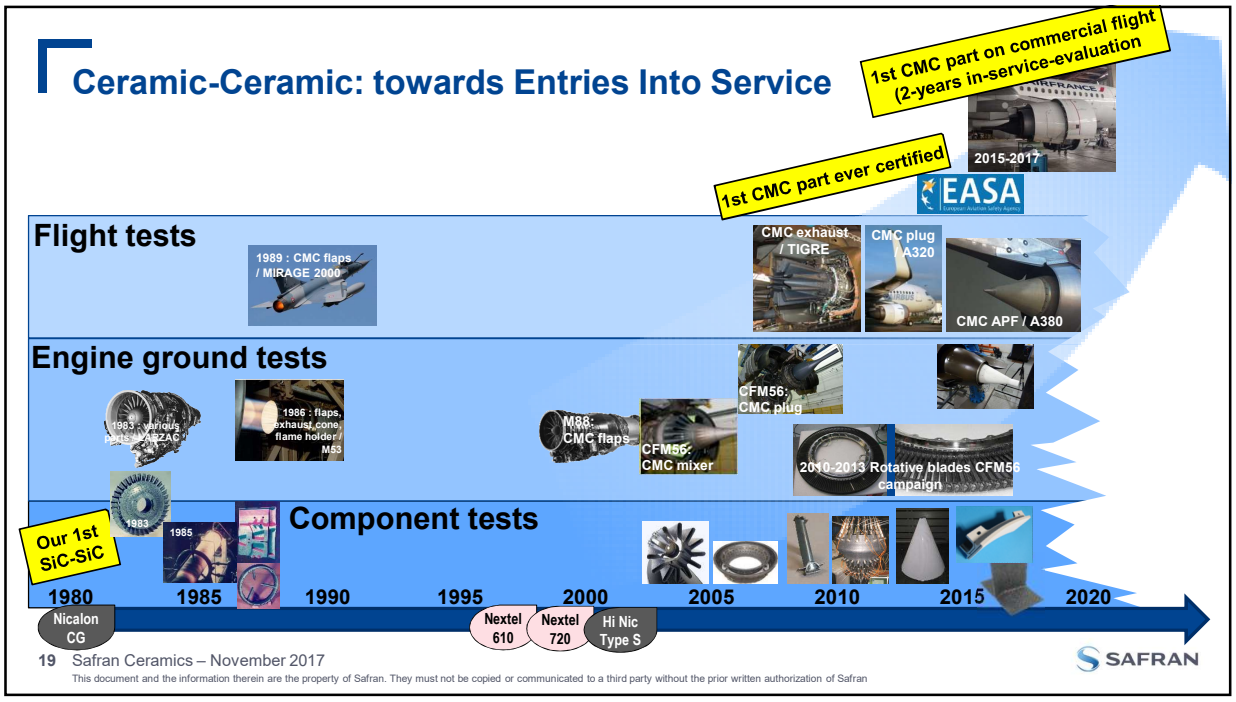
## Ceramic-Ceramic: towards Entries Into Service







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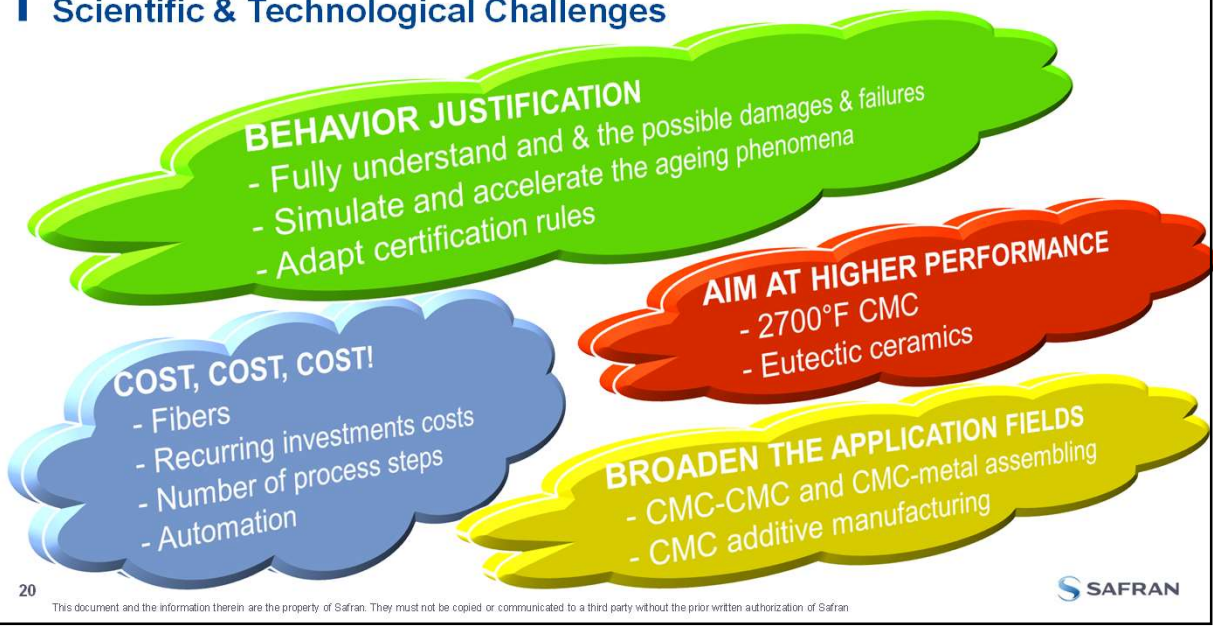
## Scientific & Technological Challenges







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