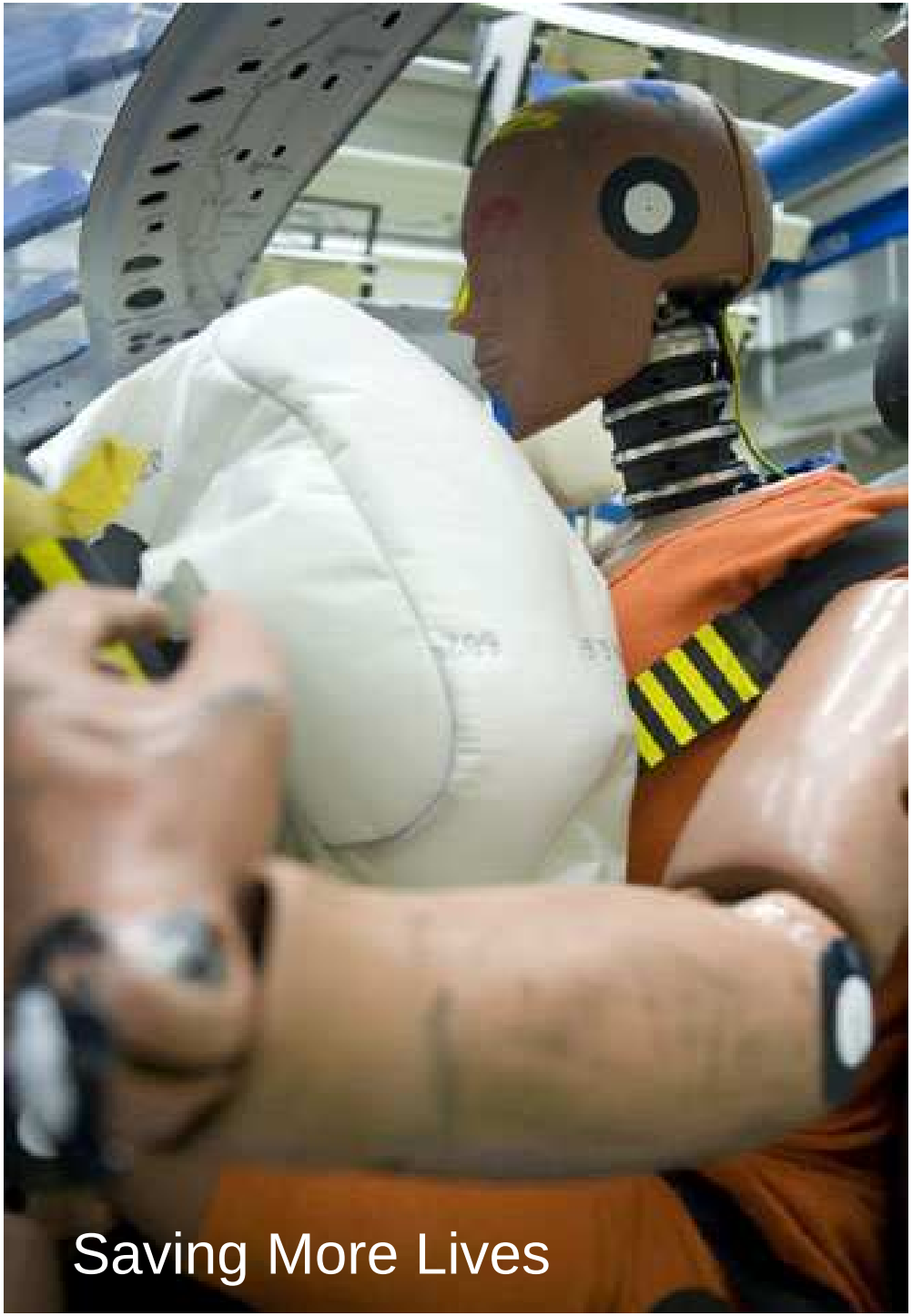

L’apport de la pyrotechnie à la sécurité automobile

Hôtel des Ingénieurs Arts & Métiers
Iéna, 5 décembre 2016

Franck LEBAUDY
Autoliv
Directeur R,D&E Inflator Europe

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L’apport de la pyrotechnie à la sécurité automobile

- Quels besoins en sécurité automobile ?
- Sécurité passive
- Quels résultats obtenus en sécurité automobile ?
- Pyrotechnie : spécificités, solutions et avantages
- Marché sécurité automobile
- Besoins futurs

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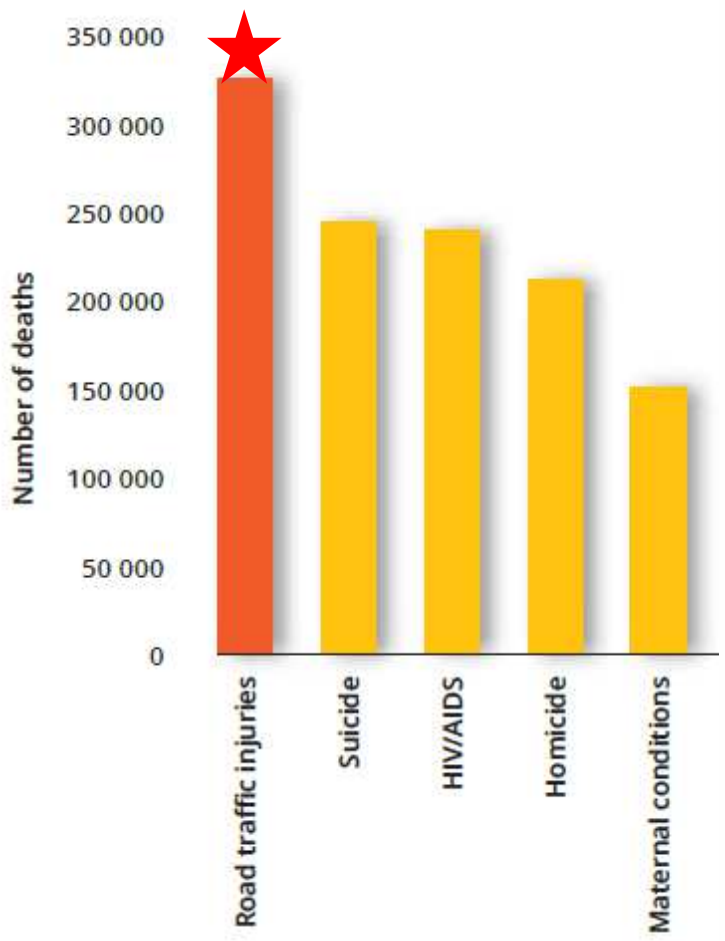
Quels besoins en sécurité automobile ?

= 30 x 

= 30 x 

en $\frac{\textit{nombre de tués}}{\textit{(milliard de passagers x km)}}$

Top 5 causes of death, people aged 15-29 years, 2012



Source : Global status report on road safety 2015, WHO

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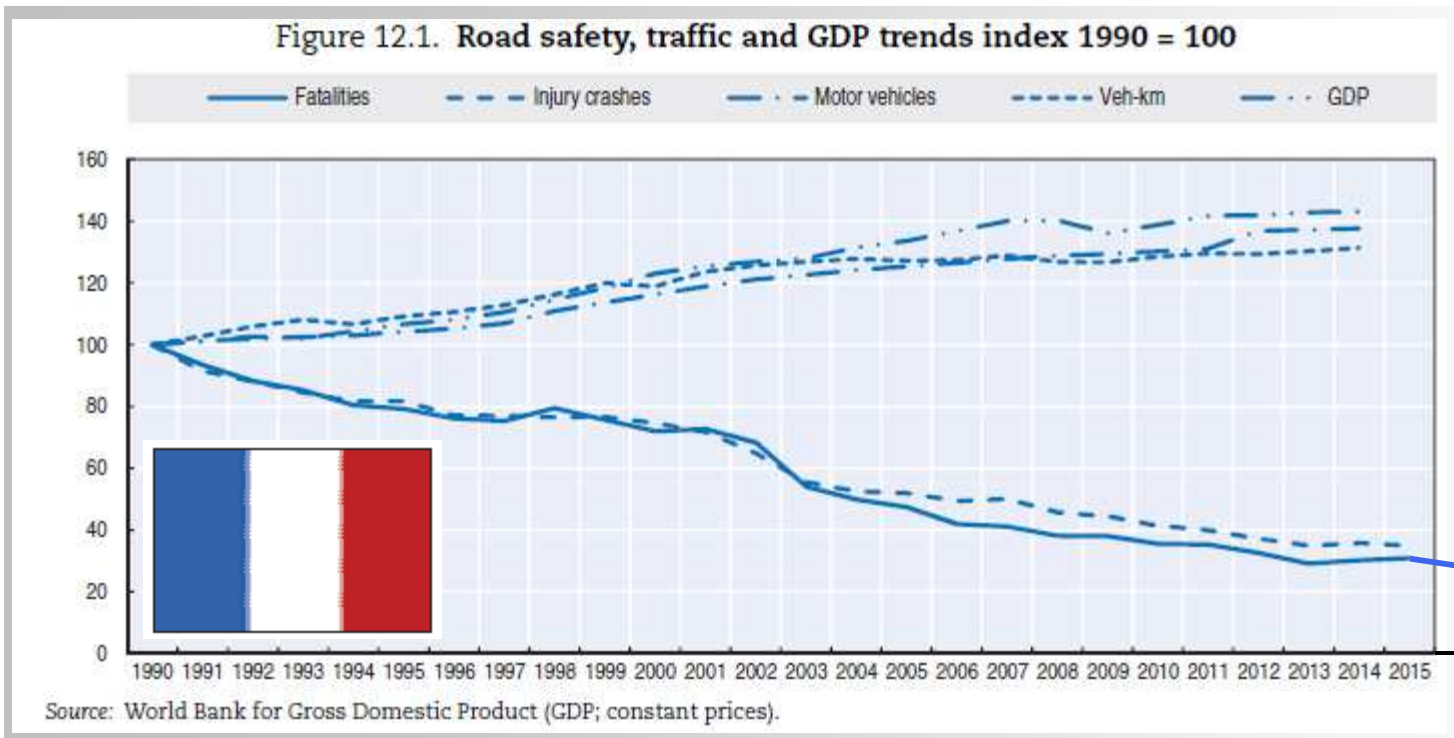
Quels besoins en sécurité automobile ?



Action ONU
Global road safety
2011-2020
-50% morts

<2000 morts

2020

France, 2015

- ~56 600 accidents 3 461 morts ~71 000 blessés
- Perte de PIB/GDP -1,5%

Source : ONISR-Observatoire national interministériel de la sécurité routière

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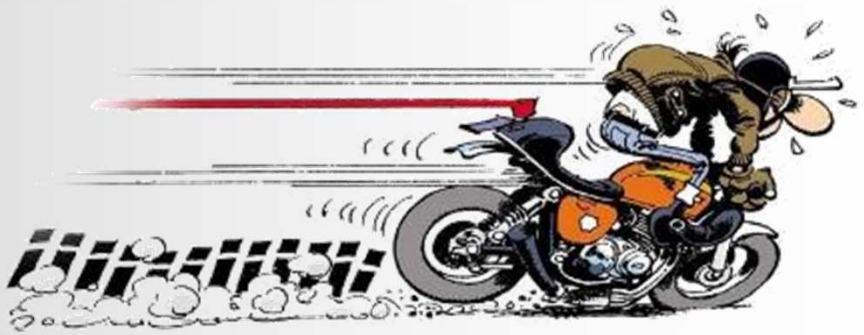
Sécurité passive

- Par opposition à la **sécurité active** dont le but est **d'éviter l'accident**

  exemple: les **freins**



- La **sécurité passive** permet de **réduire les conséquences** d'un accident

  exemple: le **casque**

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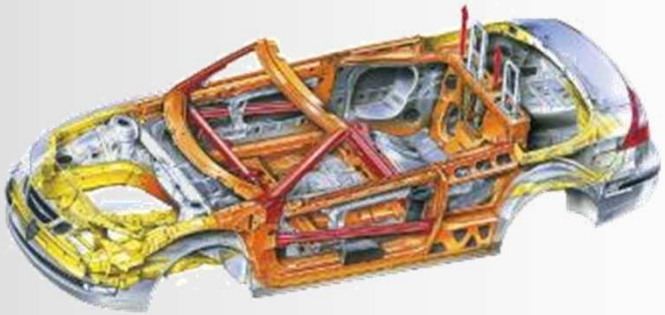
Sécurité passive

Dans une voiture, les éléments clés de la sécurité passive sont:



- Structure du véhicule

- Ceintures et prétensionneurs

- Airbags

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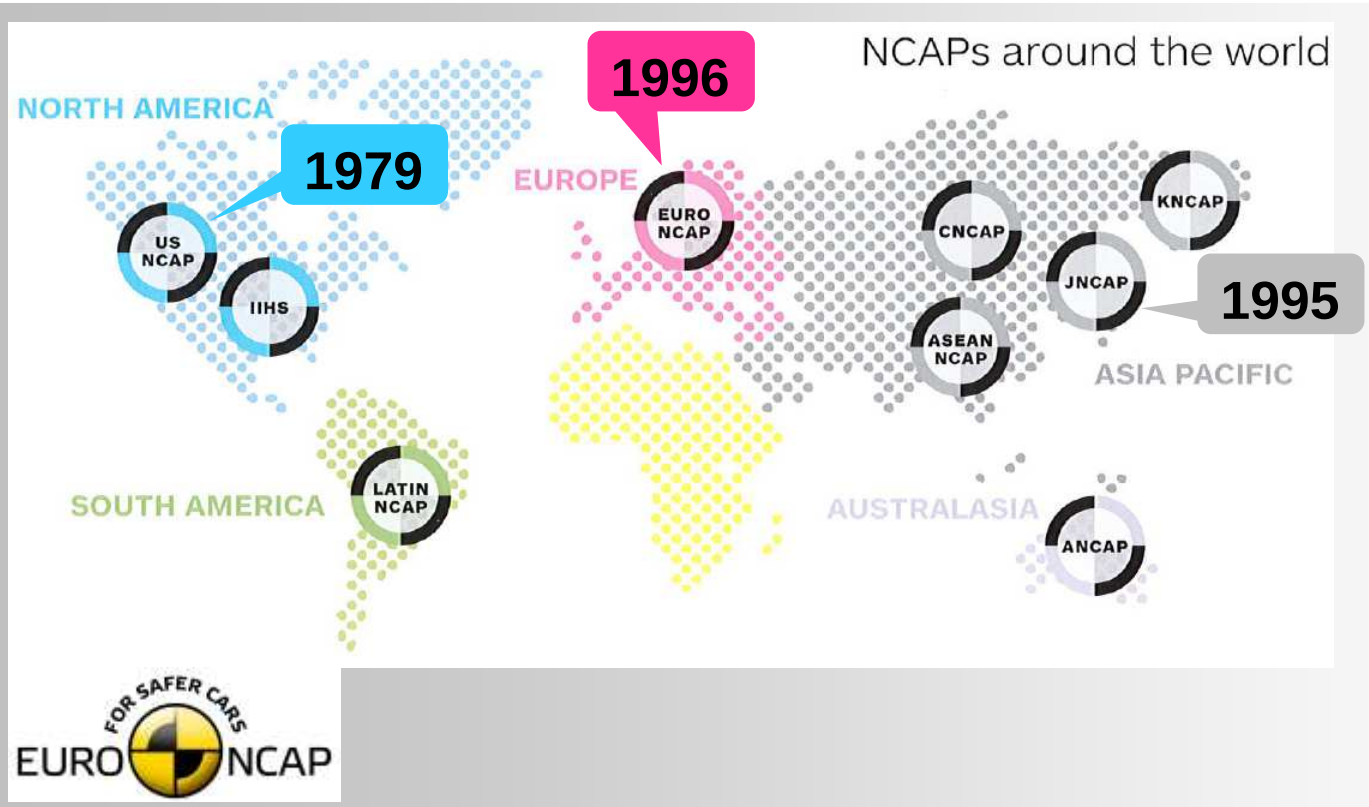
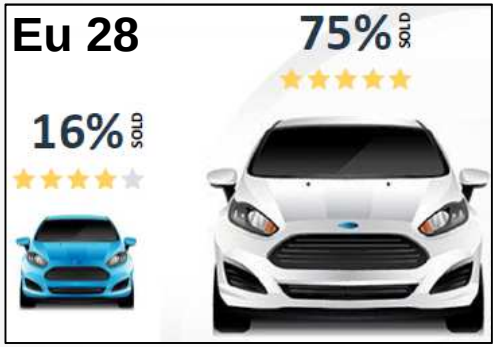
Quels résultats obtenus en sécurité automobile ?



N ew
C ar
A ssessment
P rogram

Copyright © 2016 Euro NCAP. All rights reserved.



- soutenue par des gouvernements européens, clubs automobiles, associations de consommateurs, compagnies d'assurance.
- évaluation indépendante des performances de sécurité des véhicules
- évaluation de la sécurité passive mais aussi active (SBR, AEB, SAS, LDW LKA)

http://www.euroncap.com/fr/

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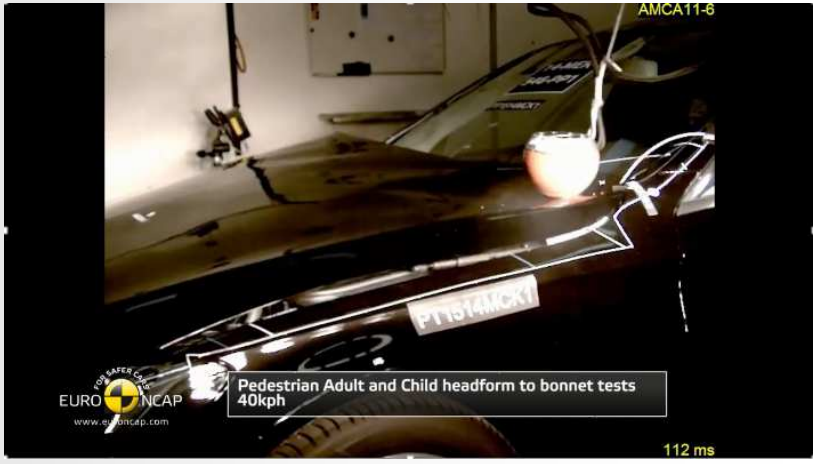
Quels résultats obtenus en sécurité automobile ?
Crash Tests 2014 – Mercedes Class C



http://www.euroncap.com/fr/

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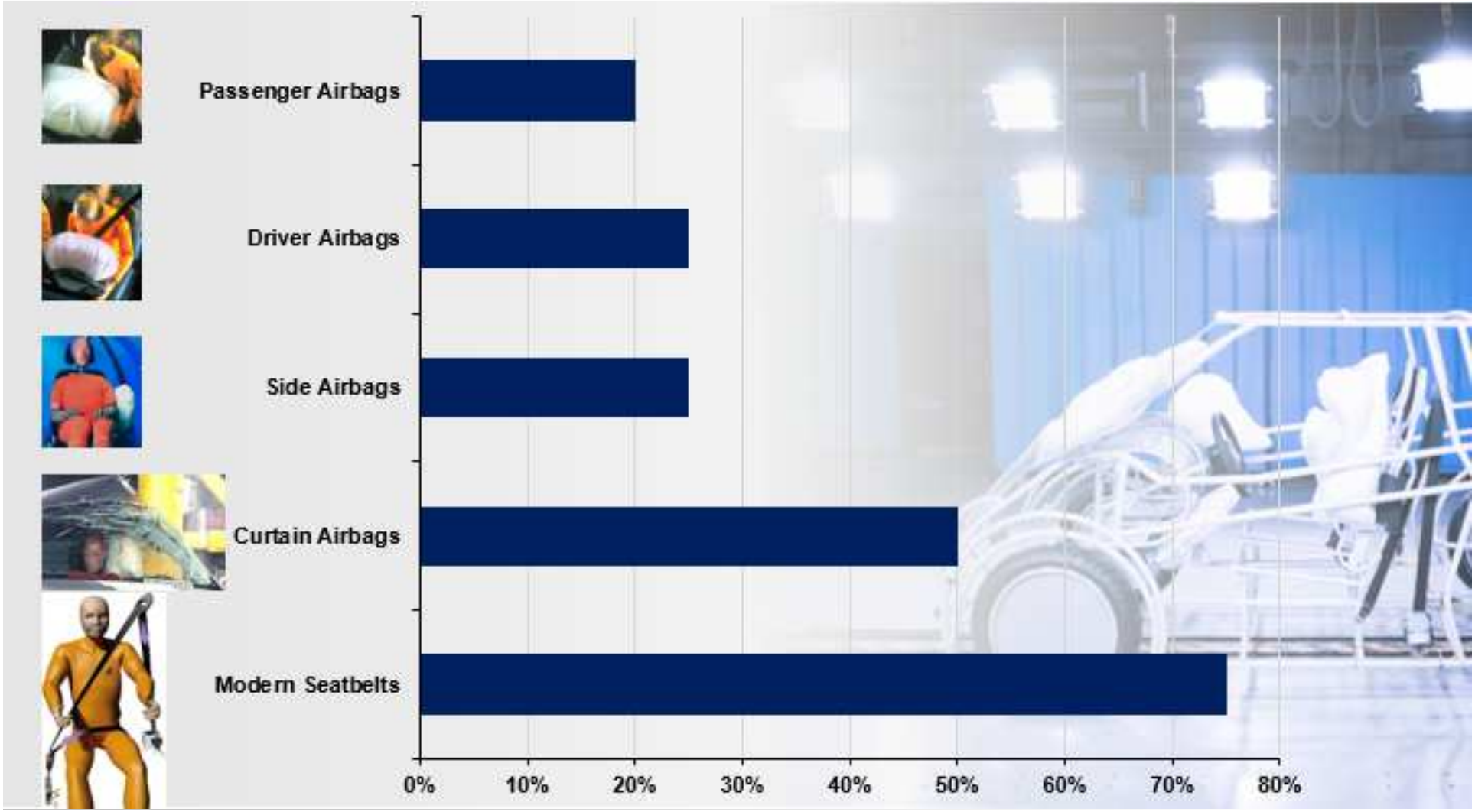
Quels résultats obtenus en sécurité automobile ?
Réduction des risques de blessures



Source: Glassbrenner 2009, McCartt & Kyryshenko 2007, samt Crandall 2000

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Solutions pyrotechniques
Spécificités

- Fonctionnement mono-coups et auto-destructif
- Disponibilité /Pas de maintenance produit
- Phénomènes très dynamiques *(P, T, vitesses,…)*
- Expertise en R&D : chimie, thermo, dynamique des fluides, mécanique, moyens d'investigation spécifiques, robustesse prédictive et expérimentale *(analyse fonctionnelle, physique, AMDEC, Pdiagram, 6sigma,…)*
- Sensibilité produits et process *(fabrication, manipulation, transport, destruction…)*
- Règlementation complexe et multiple
  - Matières premières et produits de combustion
  - Autorisations de mise sur le marché
  - Classement au transport

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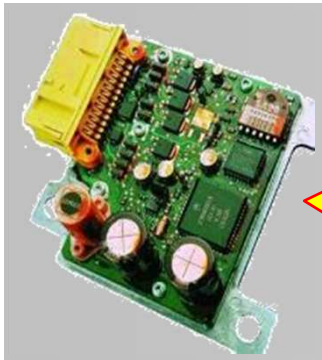
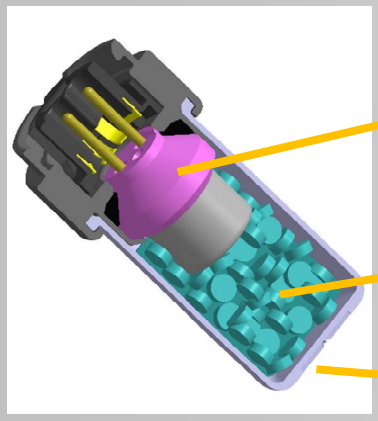
Solutions pyrotechniques
Prétensionneurs de boucle de ceinture



unité de contrôle électronique (ECU/ACU)

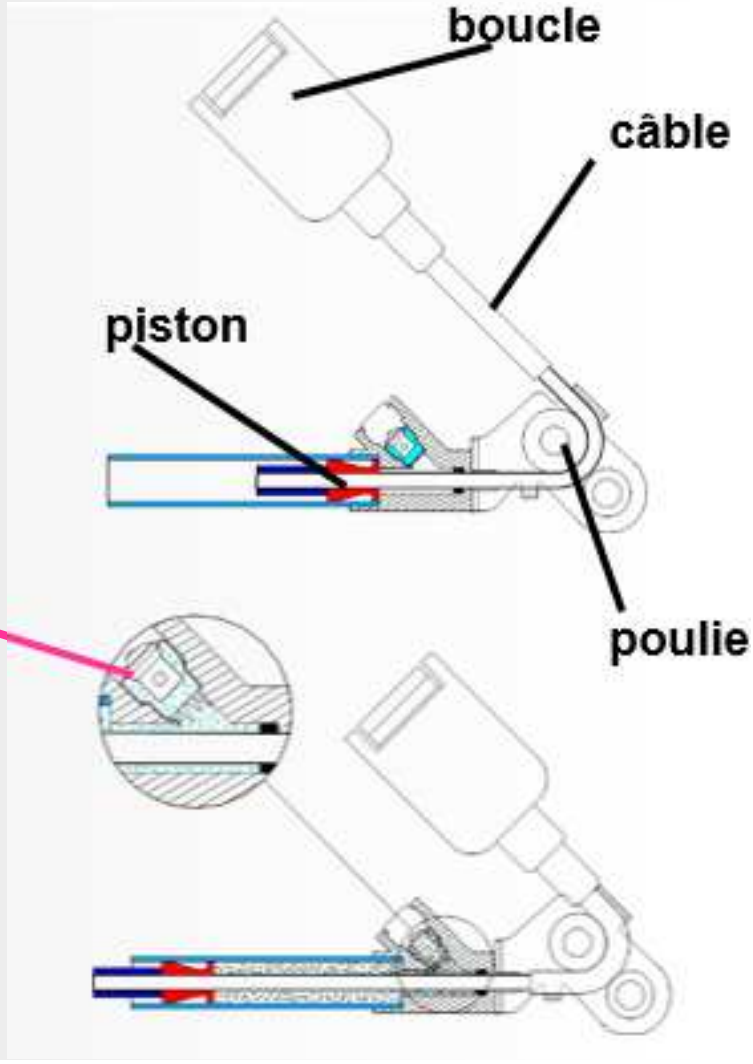
MGC
micro générateur de gaz



allumeur pyrotechnique

propergol

enveloppe métallique



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Solutions pyrotechniques
Prétensionneurs de boucle de ceinture

temps de fonctionnement du MGC
5 millisecondes (ms)

Un clin d'oeil ~

100ms = 0.1s

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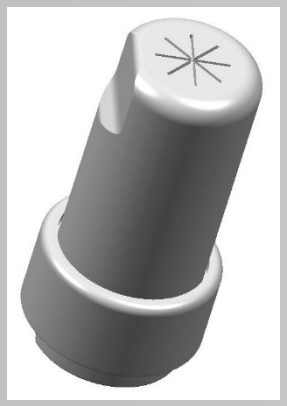
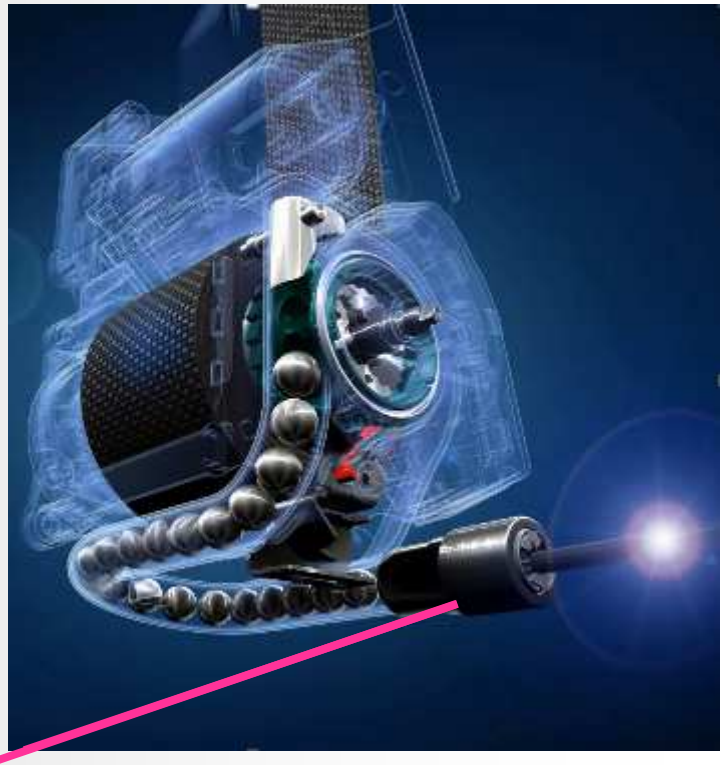
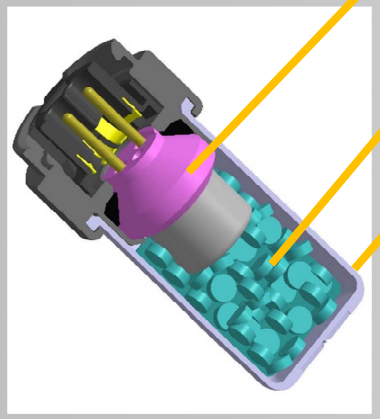
Solutions pyrotechniques
Prétensionneurs de rétracteur de ceinture







allumeur pyrotechnique

propergol

enveloppe métallique

MGC
micro générateur de gaz

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Solutions pyrotechniques
Prétensionneurs de rétracteur de ceinture

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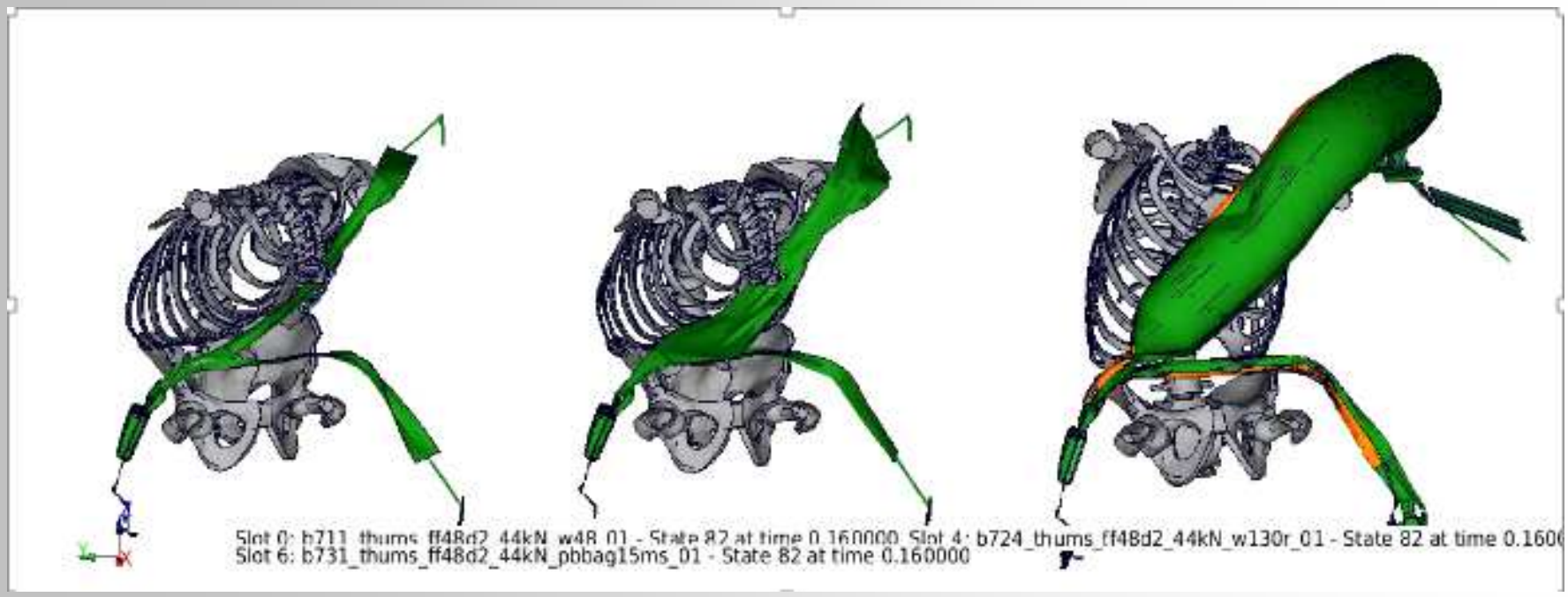
Solutions pyrotechniques
Ceinture gonflable Bag-in-belt

ceinture classique	ceinture élargie	ceinture gonflable Bag-in-belt



- Augmentation de la surface d’appui
- Limitation des efforts et risques de blessure
- Meilleur retenue

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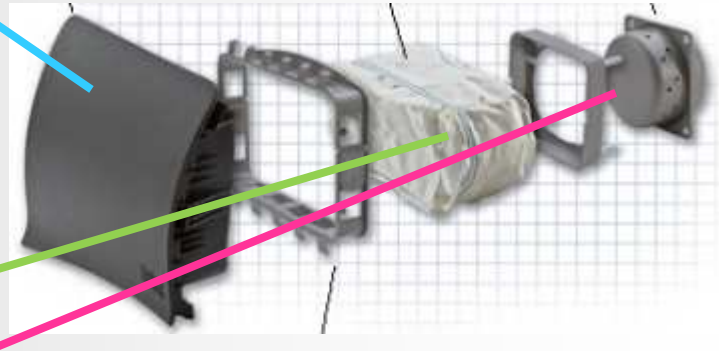
Solutions pyrotechniques
Générateur de gaz pour airbag

conducteur

couvercle plastique

sac tissu PA ou PET

passager avant



rideau gonflable

générateurs de gaz

- **100% pyrotechnique (propergol solide)**
- **hybride (propergol et gaz comprimés)**
- **hybride (gaz comprimés réactifs)**
- **gaz comprimés inertes**

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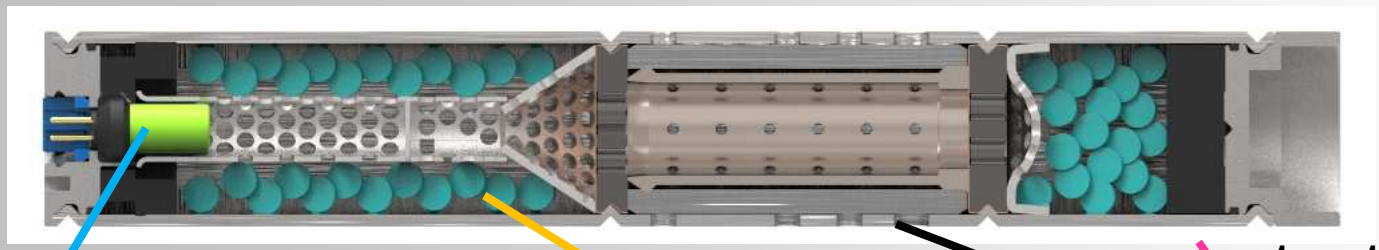
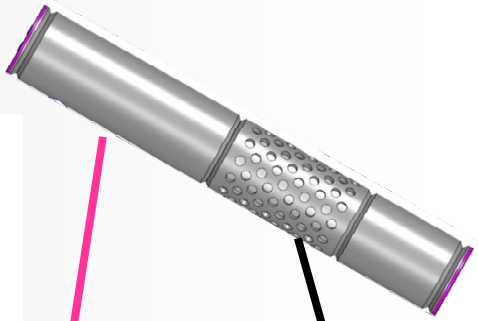
Solutions pyrotechniques
Générateur de gaz pour airbag

ex. : APP-2T
pour airbag passager

- 100% pyrotechnique (propergol solide)





structure métal sertie ou soudée

propergol solide (pastilles)

diffusion des gaz

allumeur

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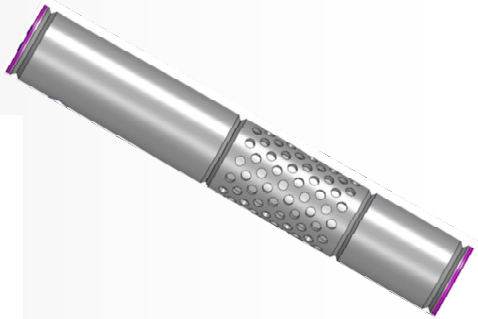
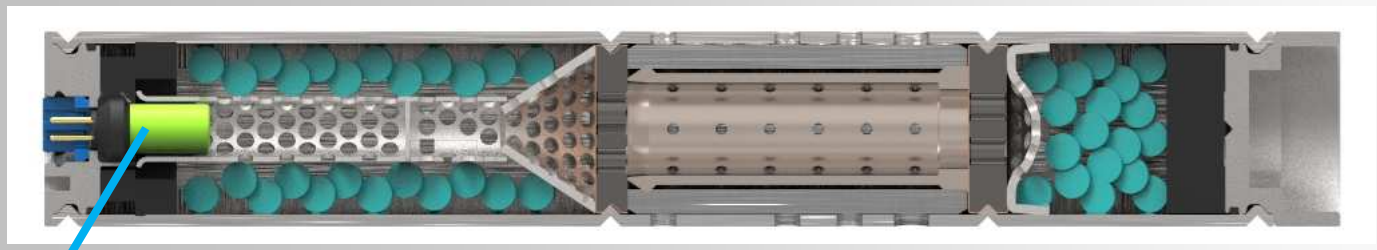
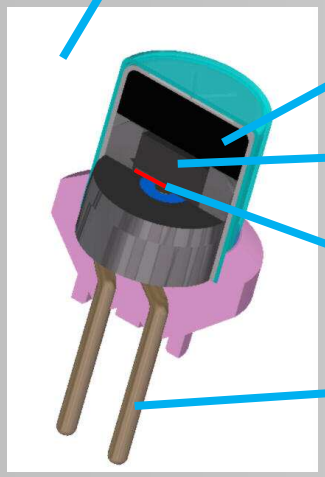
Solutions pyrotechniques
Générateur de gaz pour airbag

ex. : APP-2T
pour airbag passager



- 100% pyrotechnique (propergol solide)





poudre pyro secondaire

poudre pyro primaire

filament

broches de connection

allumeur

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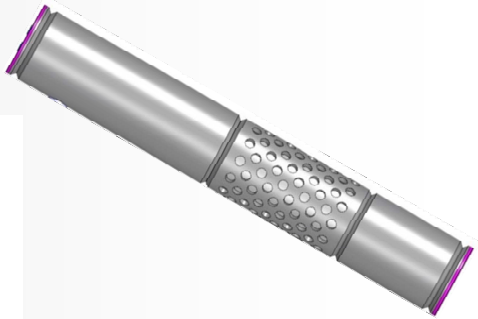
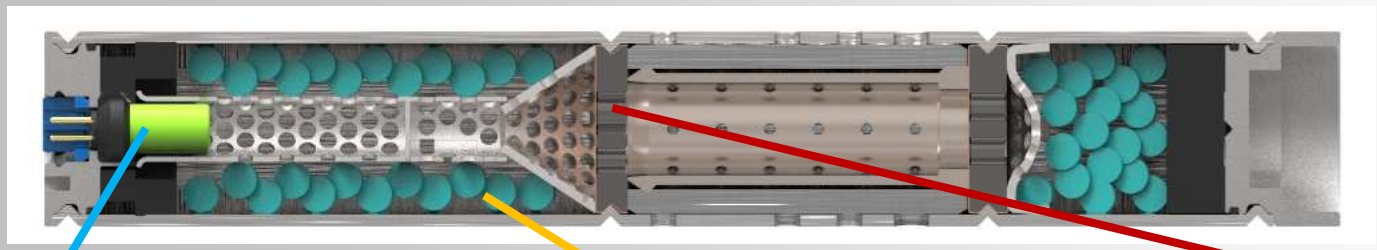
Solutions pyrotechniques
Générateur de gaz pour airbag

tps de fonctionnement : 40 à 50 ms
pression de fct : 20 à 35 MPa

ex. : APP-2T
pour airbag passager

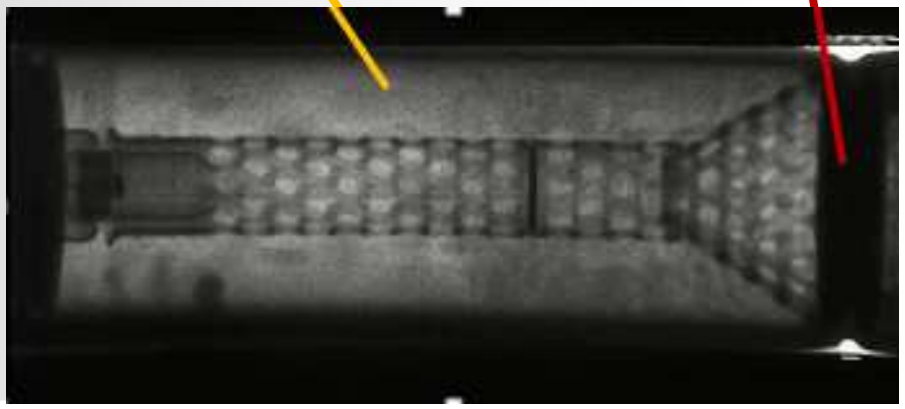


- 100% pyrotechnique (propergol solide)



tuyères
(contrôle débit)

propergol solide
(pastilles)



allumeur

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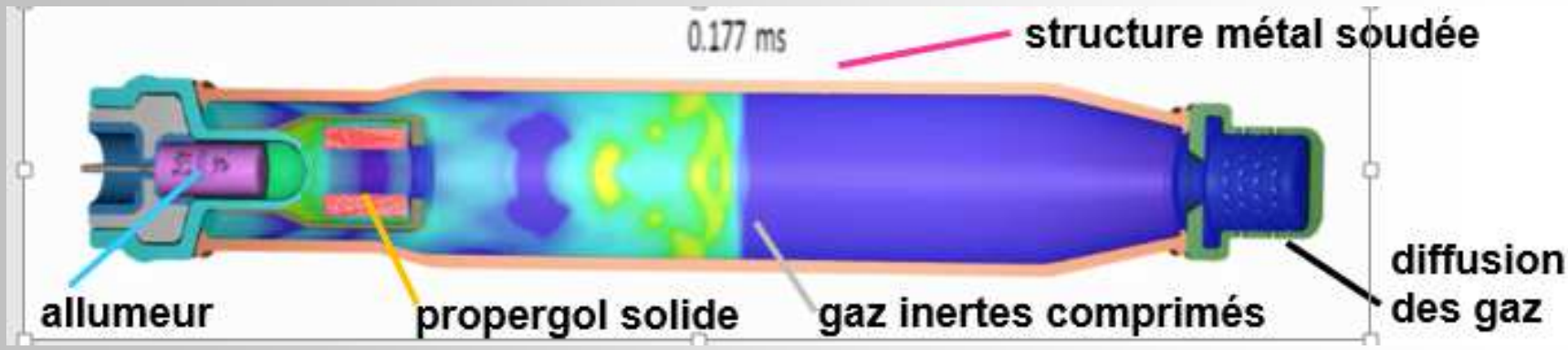
Solutions pyrotechniques
Générateur de gaz pour airbag

tps de fonctionnement : 25 ms
pression de stockage : 50 MPa
pression de fct : 90 MPa

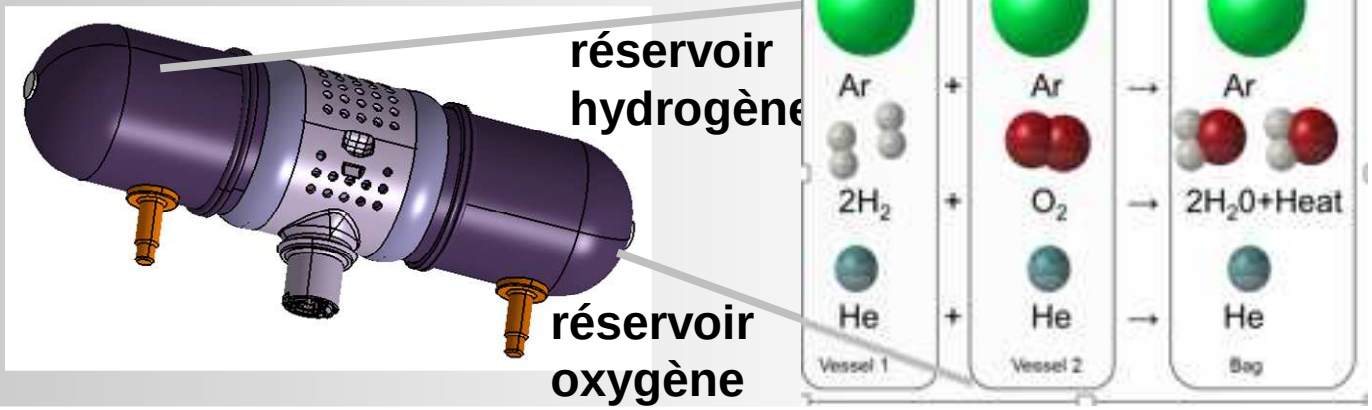
ex. : ACH-2.4
pour rideau gonflable

- hybride (propergol et gaz comprimés)



- hybride (gaz comprimés réactifs)

APG-1
pour airbag passager



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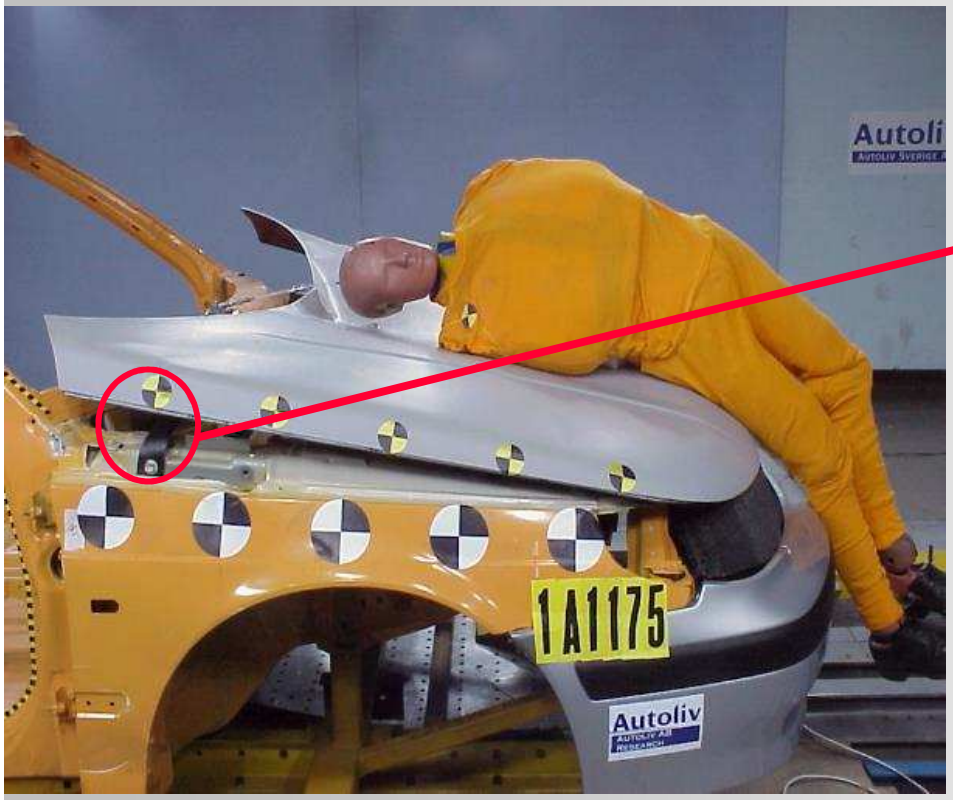
Solutions pyrotechniques
Protections piéton

- Levage de capot :
  pistons, bielles, charnières



piston tissu

- Airbag tête piéton

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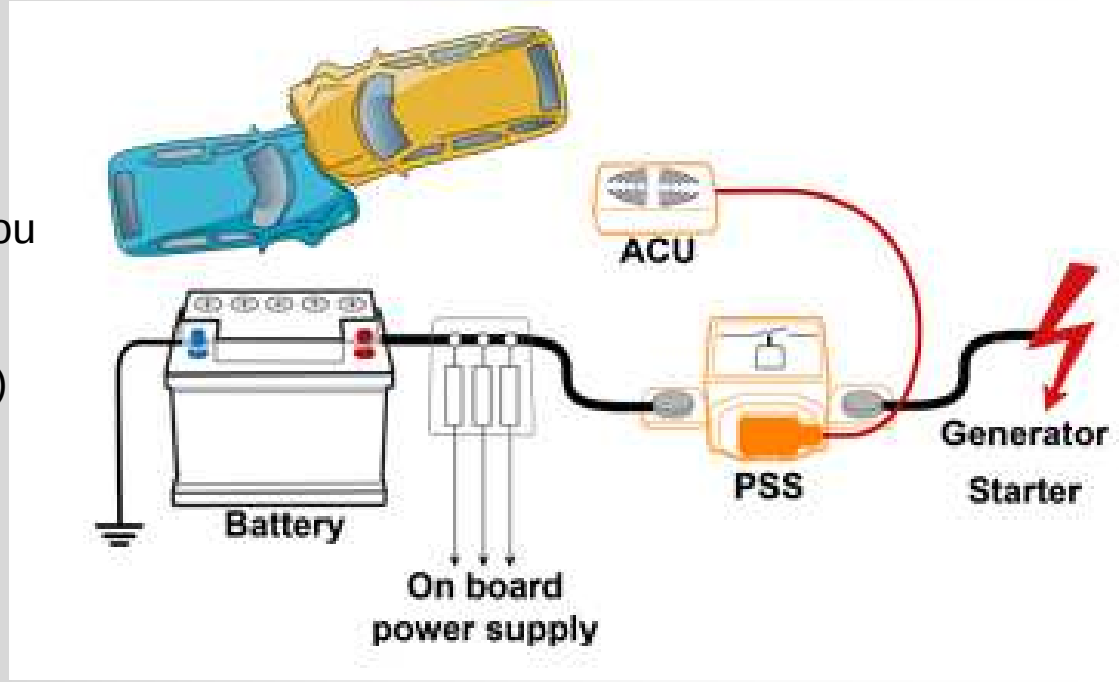
Solutions pyrotechniques
PSS-Pyro Safety Switch

- Sécurité « tertiaire » = après l'accident
- Isoler la batterie pour protéger les occupants et intervenants des risques d'électrocution ou de prise en feu par court-circuit
- Moteurs à explosion, électriques, hybrides, piles à combustible

PSS-1 et PSS-2 en production
PSS-3 en 2017

- Courant nominal à travers PSS :
  - 200 A à 125 °C (longue durée) ou
  - 300 A à 85 °C (longue durée)
- Courant maximal (à 20°C) :
  - 2000 A sur 10s (PSS-1 / PSS-3)
  - 2000 A sur 5s (PSS-2)
- Temps d'ouverture : < 3 ms

PSS-4 : plus fortes énergies
PSS-6 : piles à combustible



http://pyroswitch.com/

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Solutions pyrotechniques
PSS-Pyro Safety Switch PSS-1

http://pyroswitch.com/

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La pyrotechnie : élément incontournable en sécurité automobile

Comme pour la propulsion spatiale, la défense, la sécurité civile,…

les avantages de la pyrotechnie font son succès :

- Forte énergie concentrée en un faible volume et faible masse
- Déclenchement immédiat
- Temps de fonctionnement très court
- Fiabilité (reproductibilité, résistance, durée de vie)
- Compatible grande série

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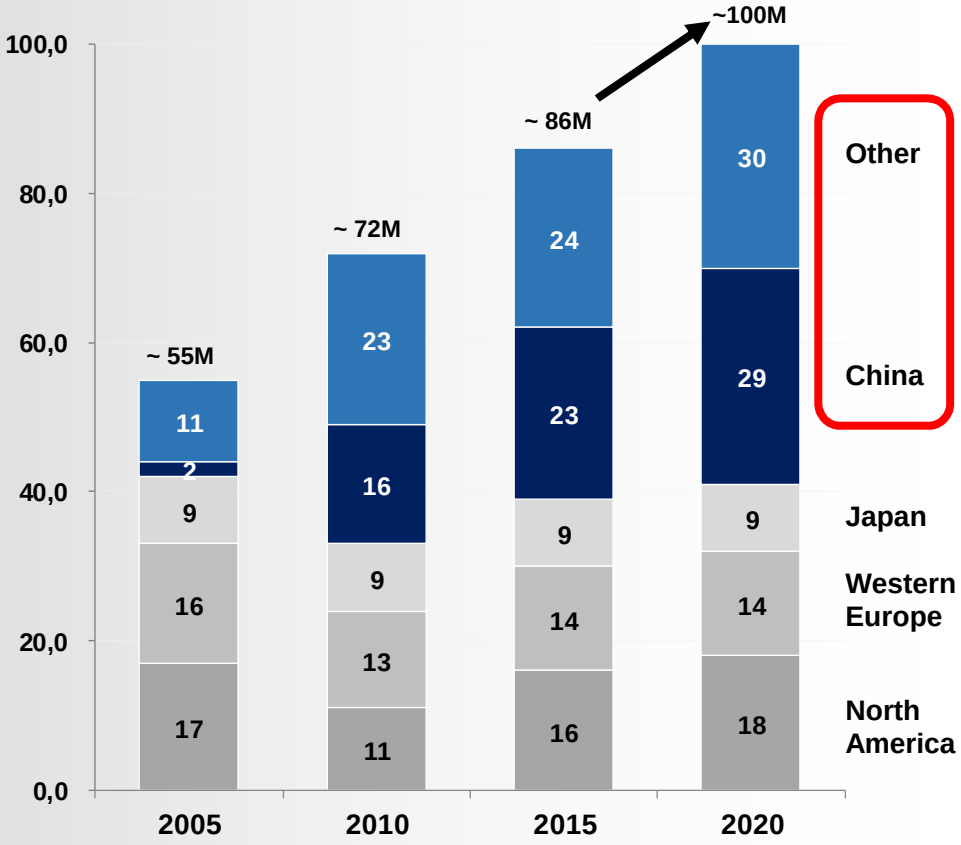
Marché sécurité automobile
Volumes

Source : Global status report on road safety 2015, WHO

Light vehicle production



Source: IHS @ January 16, 2015

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Marché sécurité automobile
Top 3 équipementiers « retenue »

39% OF GLOBAL PASSIVE SAFETY* MARKET SHARE

145 MILLION SEATBELTS

140 MILLION AIRBAGS

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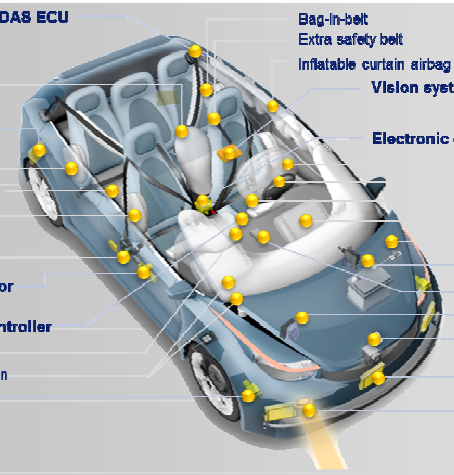

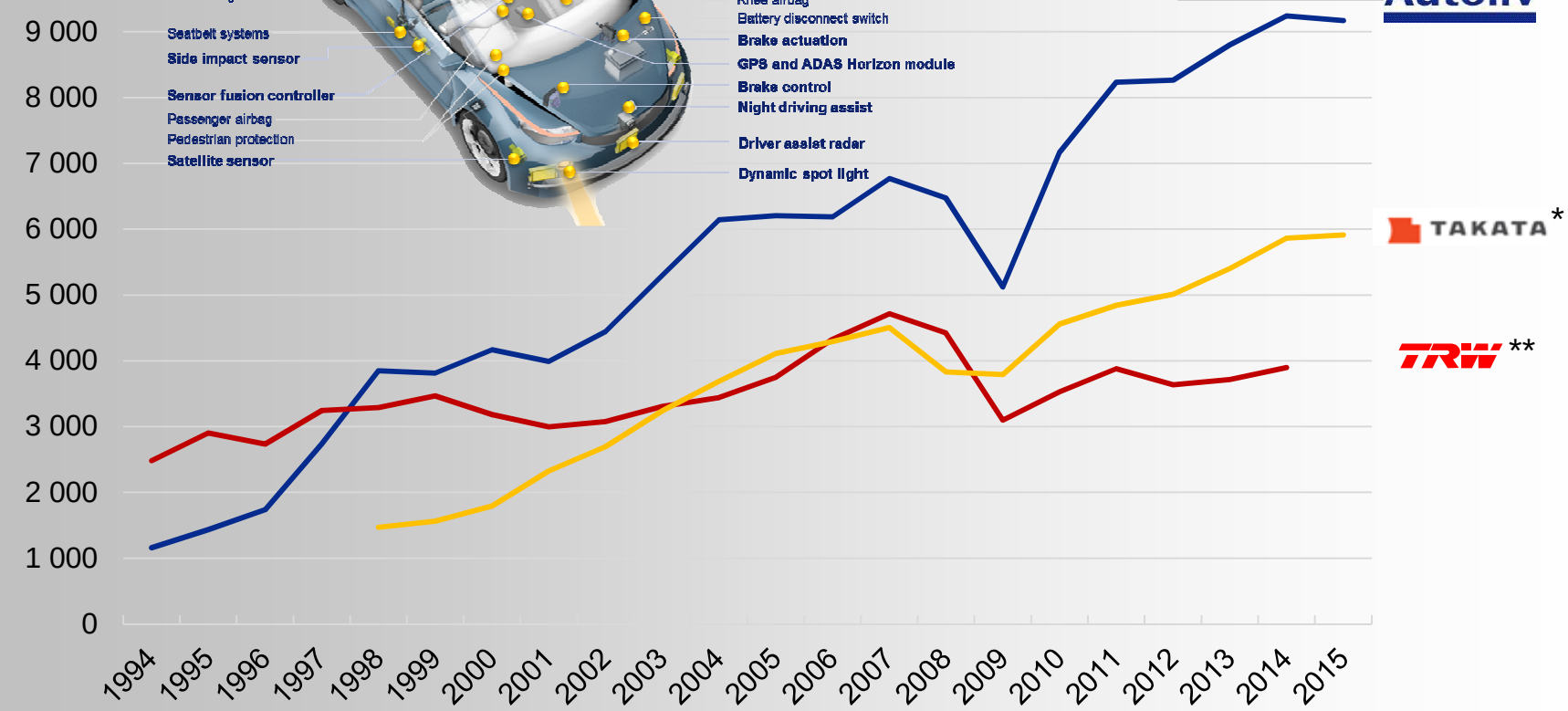

(*) Based on DIR estimate for 1998-2005.
(**) No data for 2015 available as TRW was acquired by ZF in May 2015.

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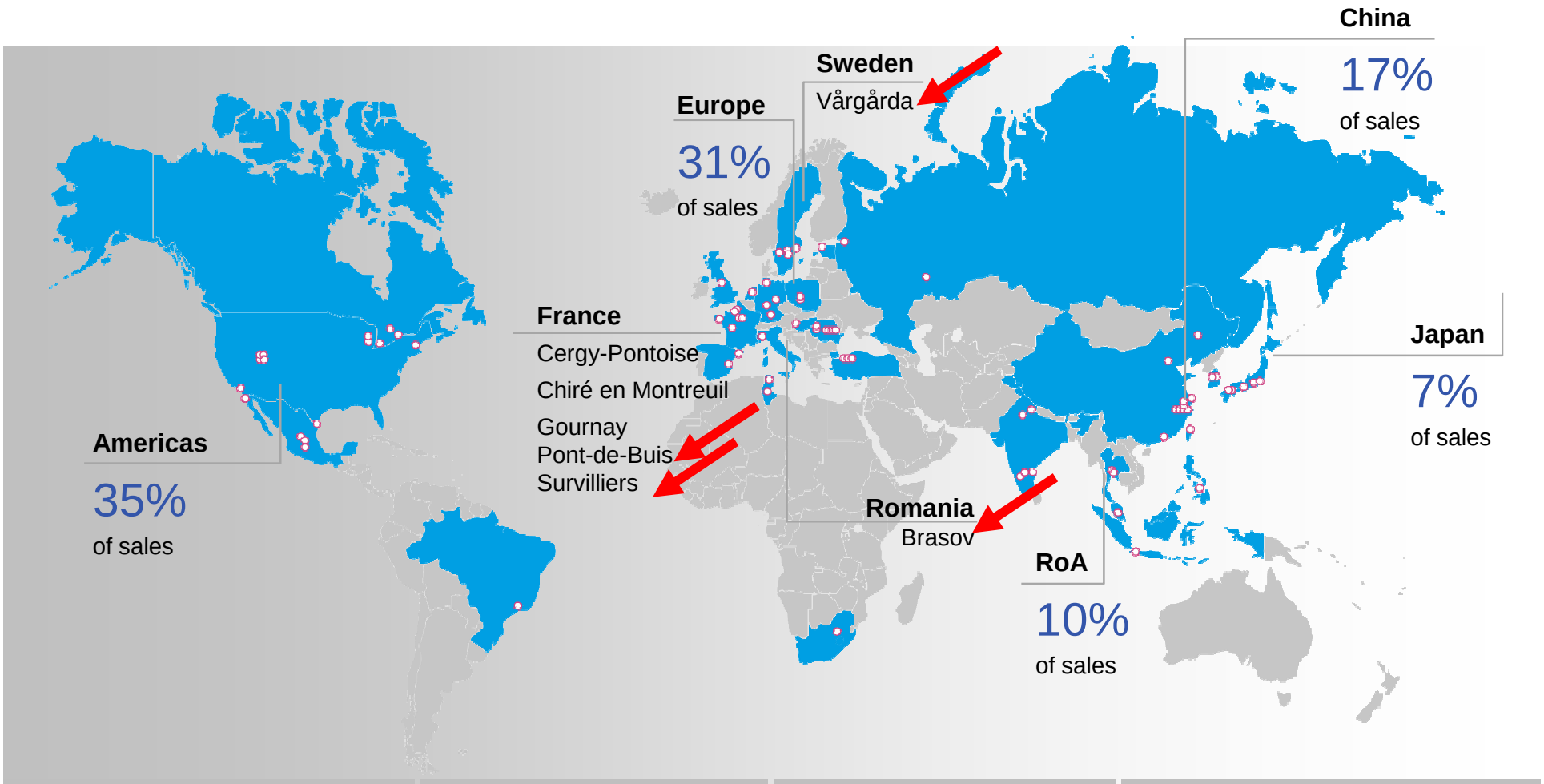
Autoliv's Superior Global Presence

pyro R,D&E Europe



~67,000 ASSOCIATES | **>83** FACILITIES | **27** COUNTRIES | **WORLDS LARGEST** AUTOMOTIVE SAFETY SUPPLIER

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et demain ?

- Contraintes masse, prix augmentent
- Besoins géographiques augmentent
- Accidentologie :
  - essai « oblique » (future USNCAP)
  - essai « far side » (EURO NCAP 2018)
- Airbag en sécurité active (precrash) :
  - airbag latéral PRE-SAFE® Mercedes-Benz
- PHEV-Plug-in-Hybrids & Electrical Vehicles :
  - China-NCAP 2018 : critères spécifiques
- Diversification : protection individuelle
  - sports à risques,
  - personnes âgées

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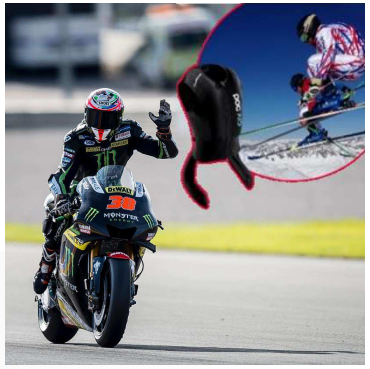
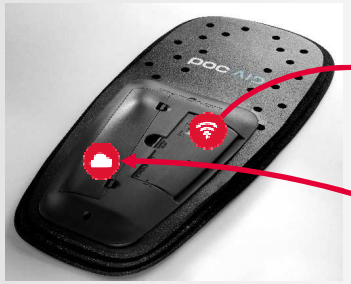
THE POTENTIAL OF WEARABLE AIRBAG SYSTEMS: EXAMPLE FOR THE PROTECTION OF MOTORCYCLISTS



In&box



Back protector

Smartphone App

Inflator

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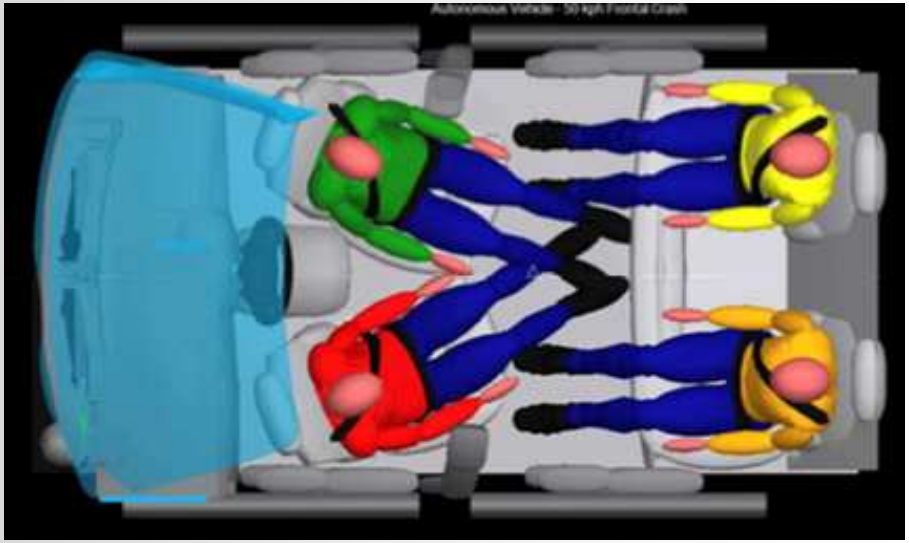
et après demain ?

- EURO NCAP roadmap 2020/2025 :
  - quadricycles,
  - 2 roues motorisés,
  - camions
  - post-crash = sécurité « tertiaire » des occupants et intervenants
  - véhicules autonomes : « automated is not accident-free »



Source: KSS Key Safety Systems @ airbag2016, 30 novembre 2016

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Real Life Safety
The Road to Saving More Lives

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Merci !

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AIRBUS SAFRAN LAUNCHERS

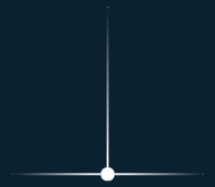
Eric Giraud
Directeur Produits Equipements & Services

Arts & Métiers ALUMNI

Af3P

AIRBUS SAFRAN LAUNCHERS

1 Introduction



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Why so much success ?

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Continuous gas generant innovation the reason for airbag technology success

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2 How does an airbag work ?

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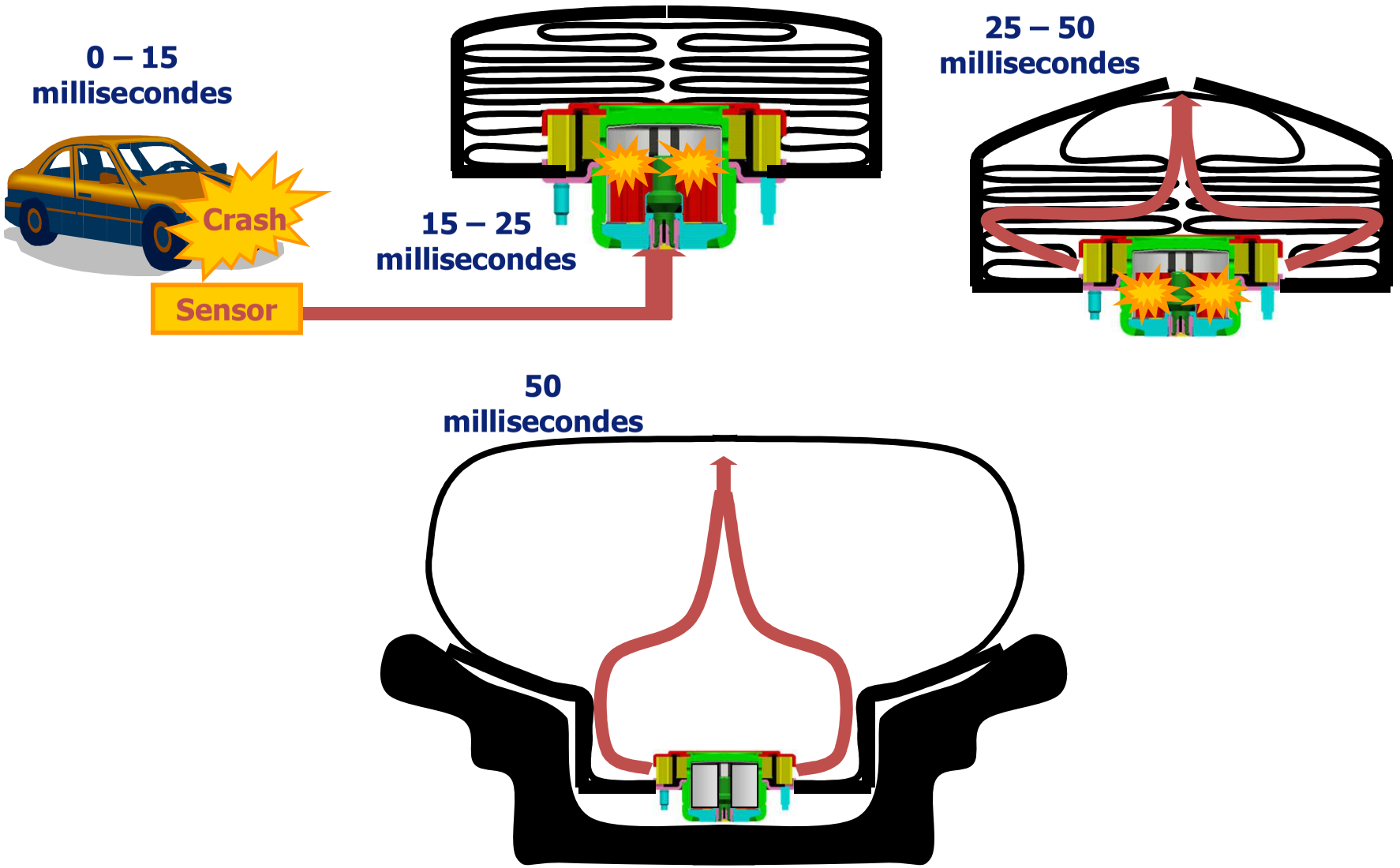
How does it work (1/2)



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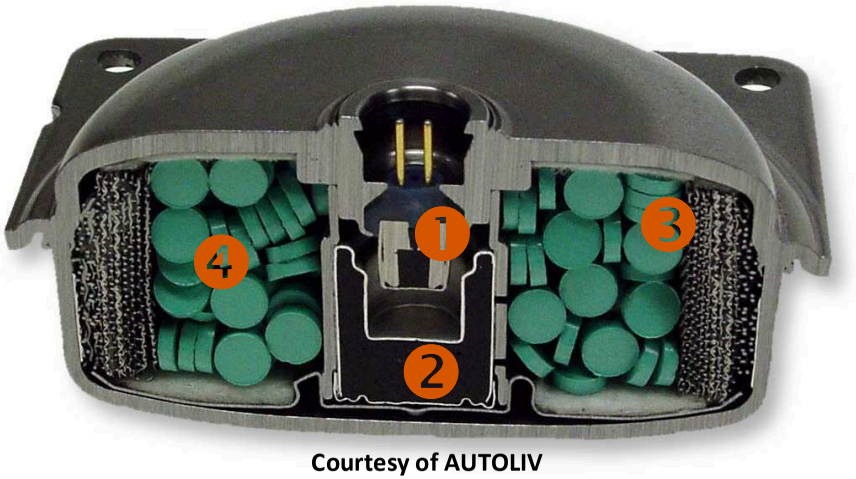
How does it work (2/2)

Overview of energetics and gas generant in an inflator :

IGNITER :	~200 mg/inflt ❶
IGNITION BOOSTER :	~500mg à 1g/inflt ❷
AUTO IGNITION MATERIAL :	~100 à 200 mg/inflt ❸
GAS GENERANT :	~3 à 20g/inflt (side), 15 à 100g/inflt (frontal) ❹

Courtesy of AUTOLIV



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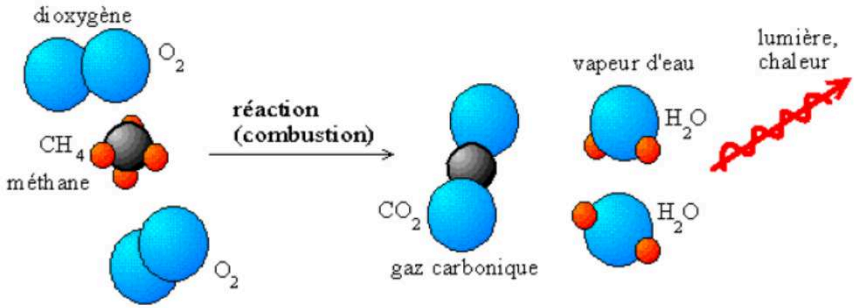
What is a Gas generant ?



Oxydo-reduction reaction

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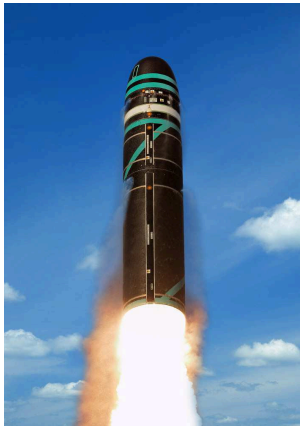
What is a Gas generant ?



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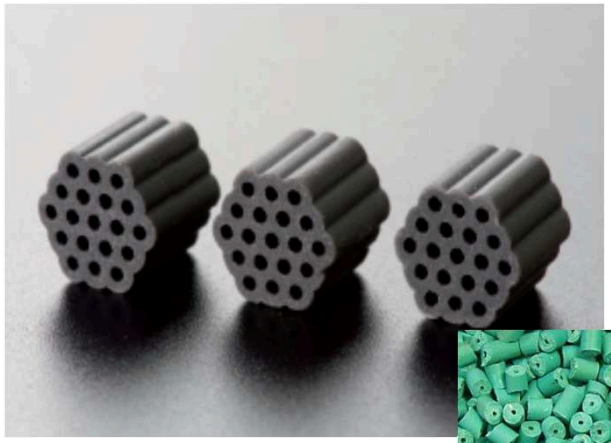
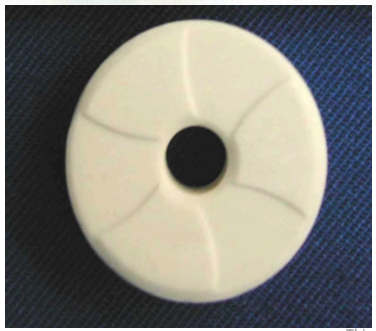
What is a Gas generant ?





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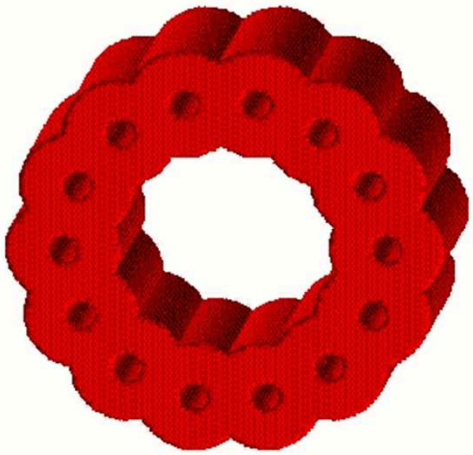
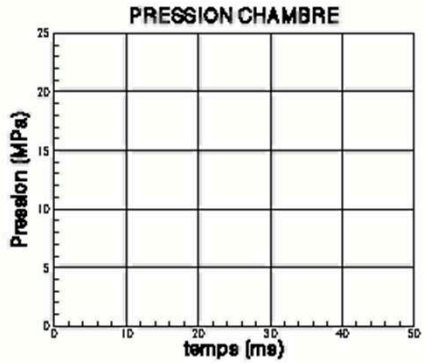
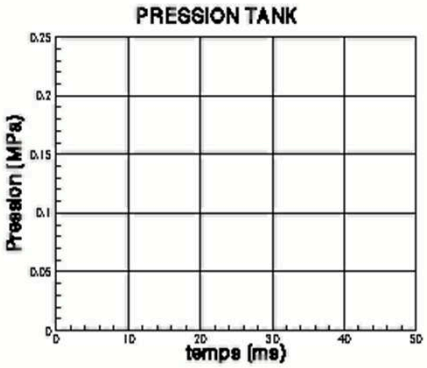
How does it burn ?







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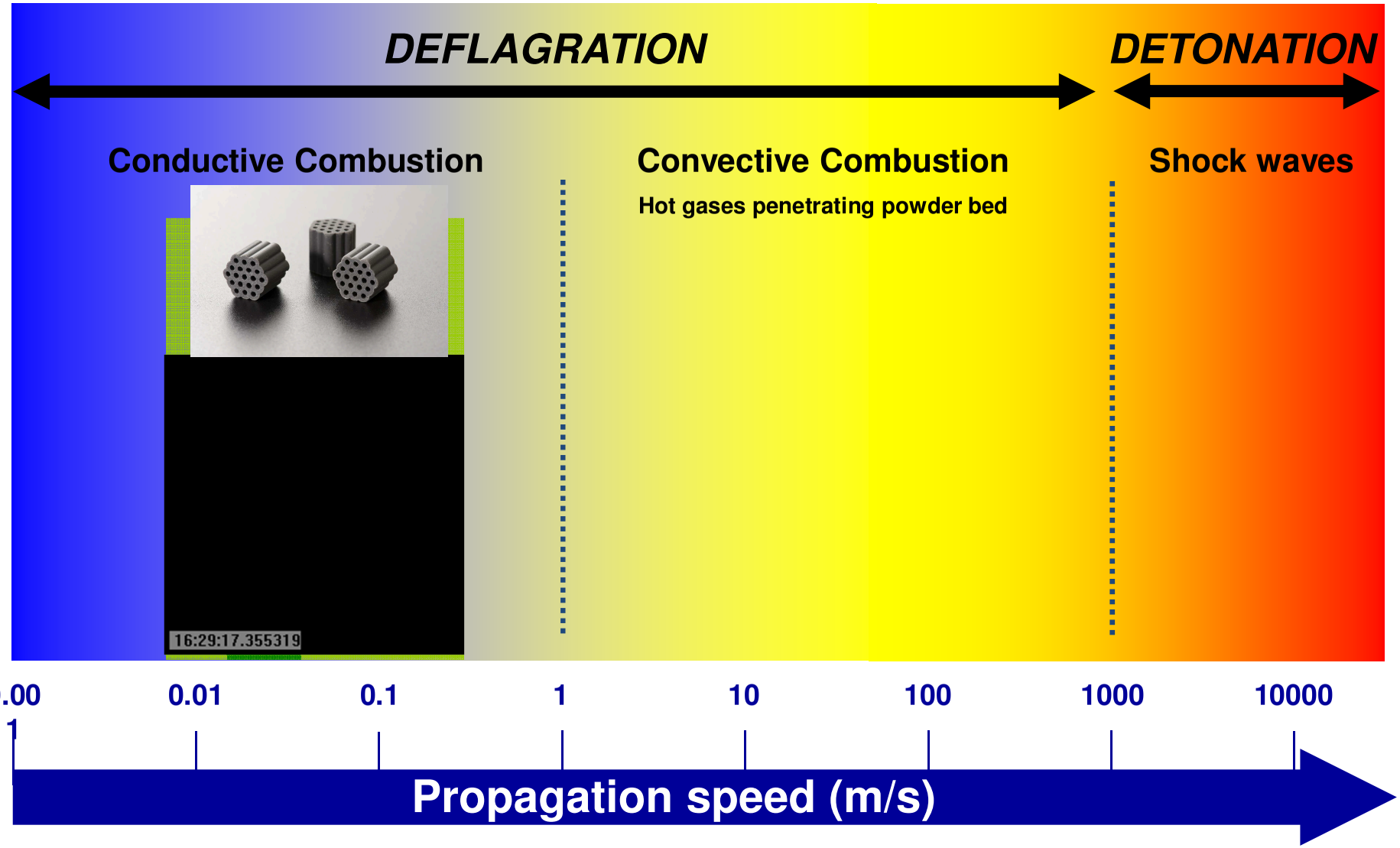
Airbags don’t explode !



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3 Technical requirements

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Technical requirements

Functionnal requirements

+

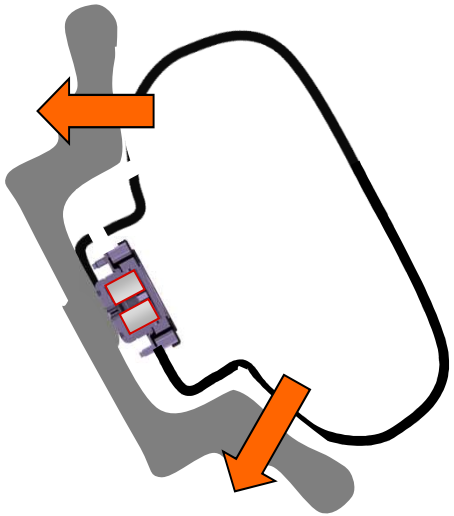
Automotive standards requirements

Bag volume (10 to 120 L)

→ *High gas yield composition*

Time for bag inflation (10 - 50 ms)

→ *High burning rate composition*



Passenger safety

→ User friendly effluents (no CO, NOx, HCl, SO2, …)

→ Smokeless

Functionning range :

-35° C / + 85° C

Bag integrity

→ *Low combustion temperature*

→ *Low particles content*

Workers Safety

→ *No toxic raw materials*

→ *No shock, ESD, friction sensitivity*

Withstand car environments :

✓ Ageing 3000h @ 110° C (Honda test)

✓ Ageing 504h@ 80° C+ moisture

✓ Thermal cycle (-40 / +90° C)

✓ vibration

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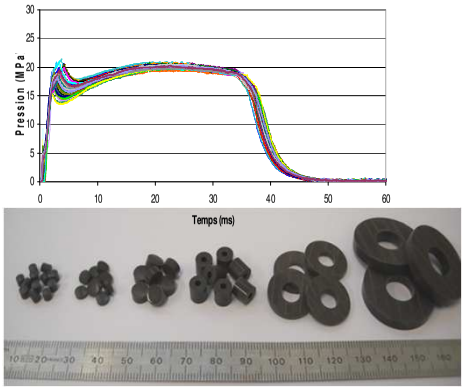
Typical Gas generant design loop

Composition

OXYDIZER + FUEL
+ Additives

Best Compromise



COMBUSTION T°

GAS YIELD
PARTICULATE CONTENT
EFFLUENT TOXICITY

AGEING in T°

PROCESSABILITY

SAFETY

BURN RATE
+ T° SLOPE

COST

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Where does it leads ?

Are so much constraints leading to a one and only solution on the market ?

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4 Competing solutions

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Who are the competitors ?

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Competing technologies

- Solutions proposed to the market are influenced by :
  - Market trends
  - Available molecules on the market
  - Companies history
  - Existing industrial means

- Three industrial examples :
  - Composite extrudlets solution from DAICEL
  - Composite extruded solutions from HERAKLES
  - Metallic complex based solutions from AUTOLIV

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Market trends illustration through steering wheel evolution

Before

After

SIZE ↓ WEIGHT ↓ PRICE ↓ EFFICIENCY ↑

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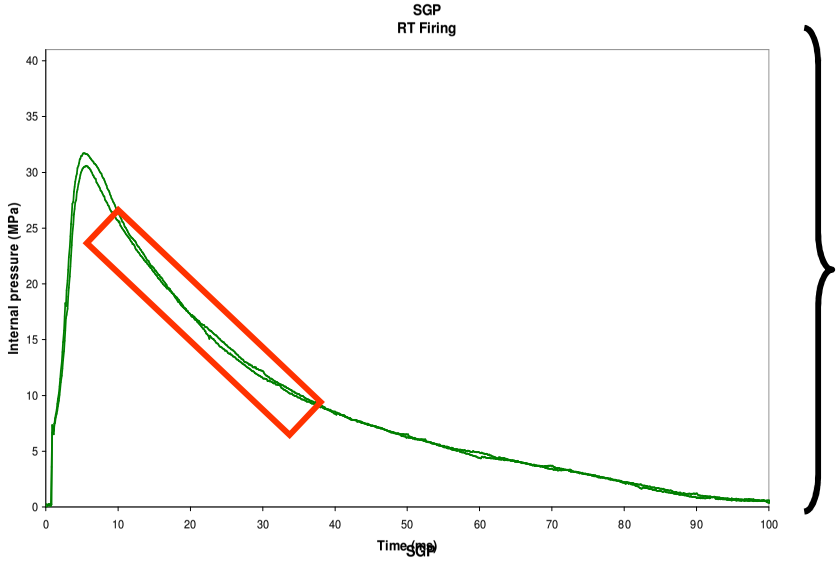
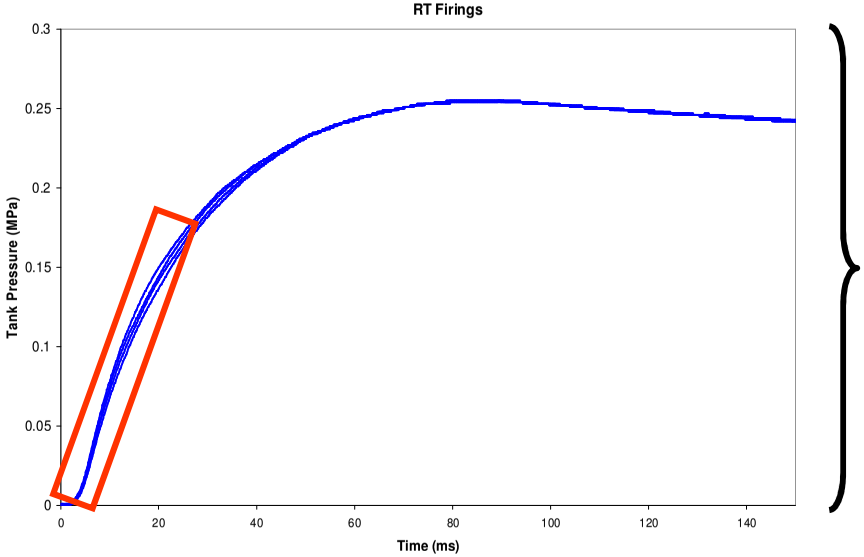
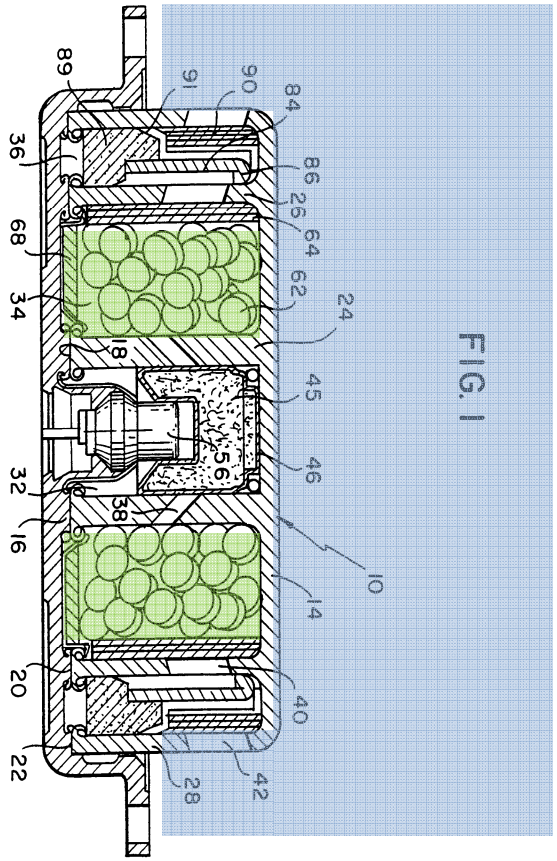
Where efficiency comes from ?





Internal pressure

Tank (bag) pressure



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Where do DAICEL come from ?

1950-1959

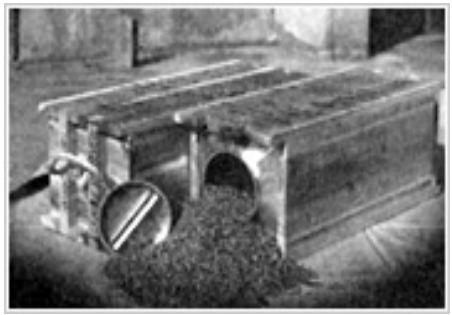
DAICEL Group

Jul. 1953

The Aboshi Plant begins to manufacture tri-acetyl cellulose (TAC) for photographic film and begins supplying Fuji Photo Film Co., Ltd.
The Aboshi Plant begins production of gunpowder.

Jun. 1954

The Kawachi Plant (presently the Harima Plant) established and begins the manufacture of smokeless gunpowder.



From Daicel website

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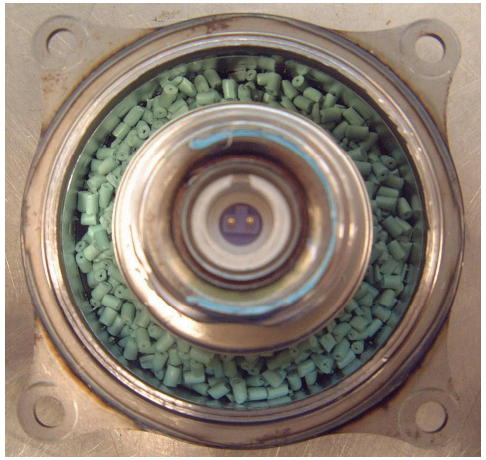
What kind of Solution is Daicel providing to the market ?

Extruded composite propellant

- Smokeless gunpowder like
- Use of water as a solvant

Daicel used to master :

- Extrudlets production and particularly drying
- Extrudlets functionning



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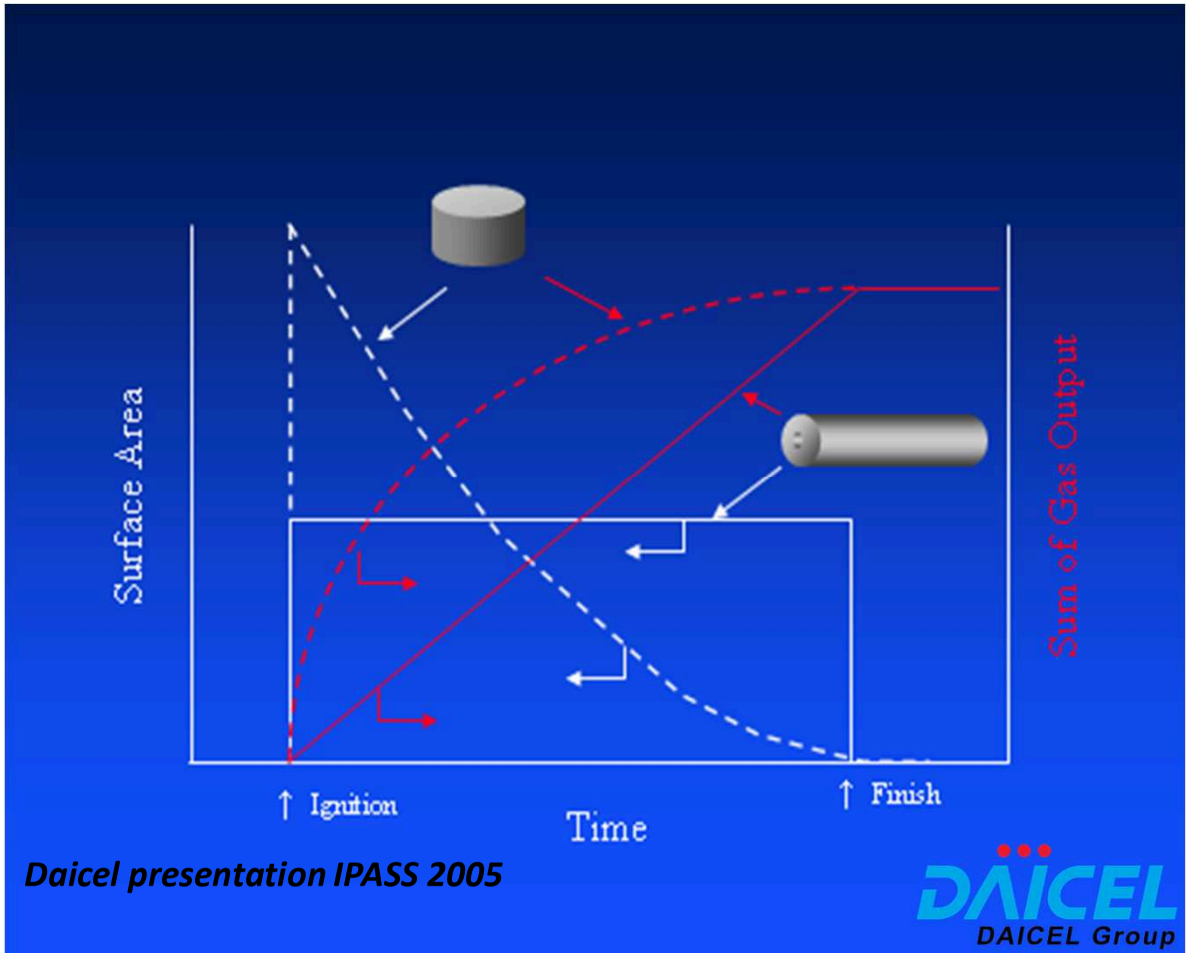
Is there a competitive advantage for the market ?

Extruded composite propellant

Smokeless gunpowder like



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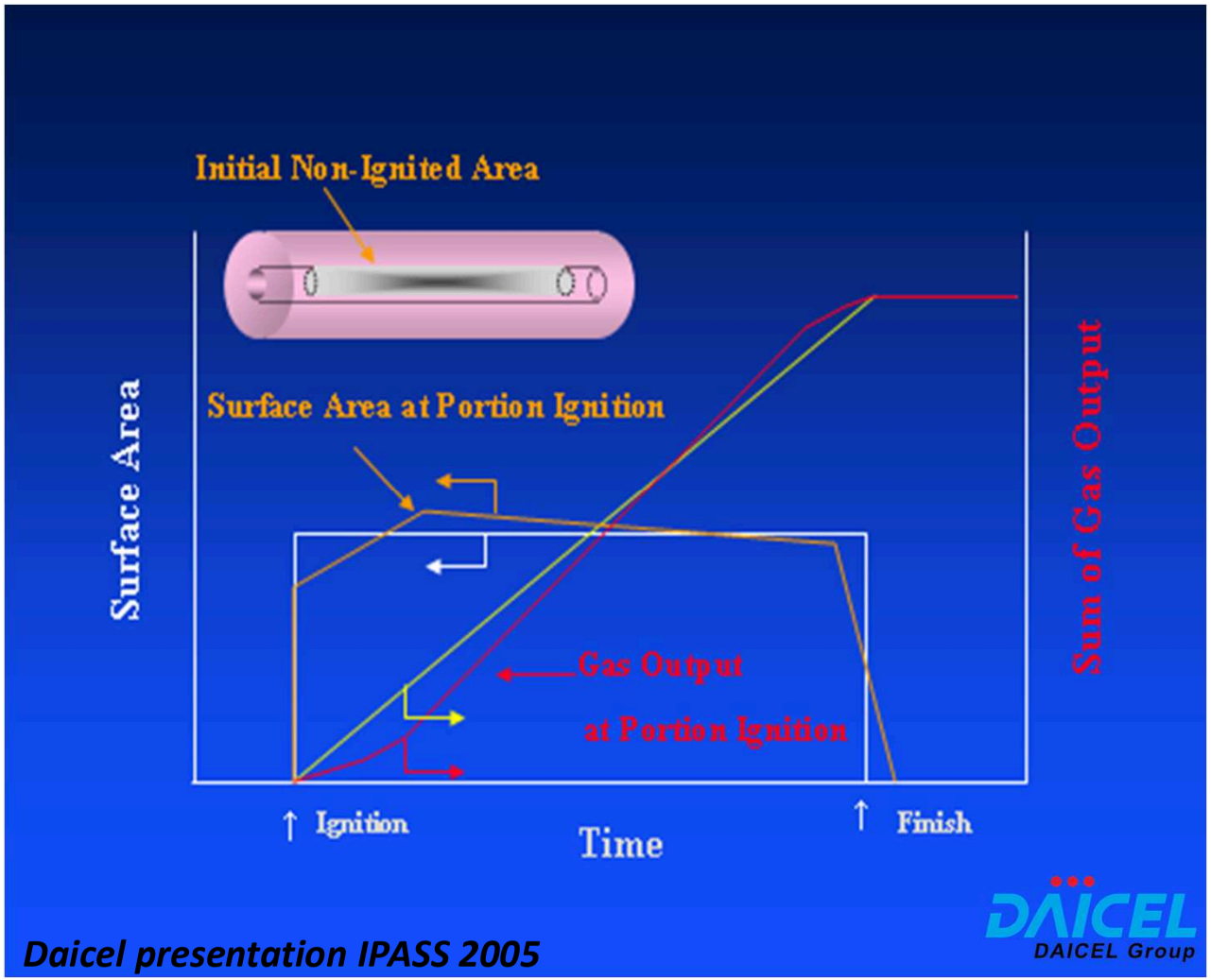
Is there a competitive advantage for the market ?



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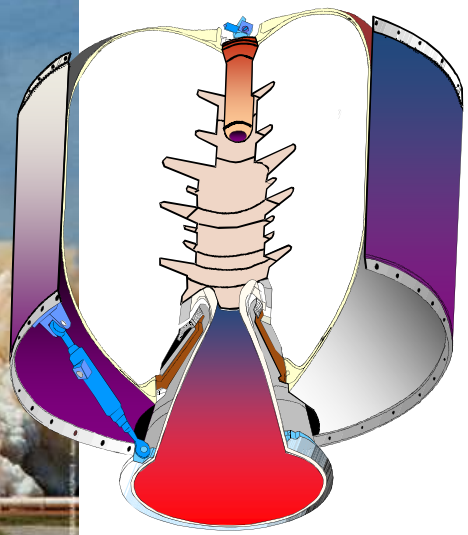
Where do Airbus Safran Launchers solutions come from ?

Core business : space launchers and missiles motors design and production

SNPE MATÉRIAUX ÉNERGÉTIQUES GROUPE SNPE → SAFRAN SME → SAFRAN Herakles → AIRBUS SAFRAN LAUNCHERS



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Airbus Safran Launchers grains solutions for airbags

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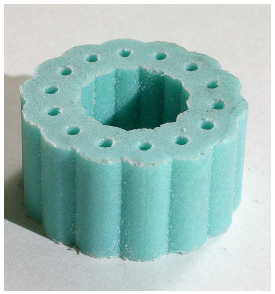
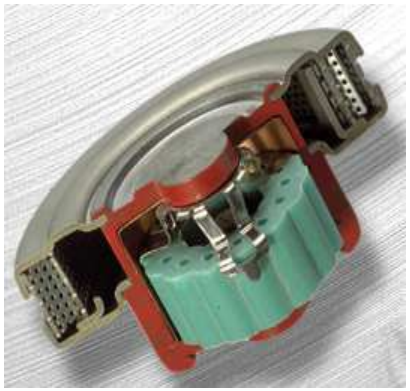
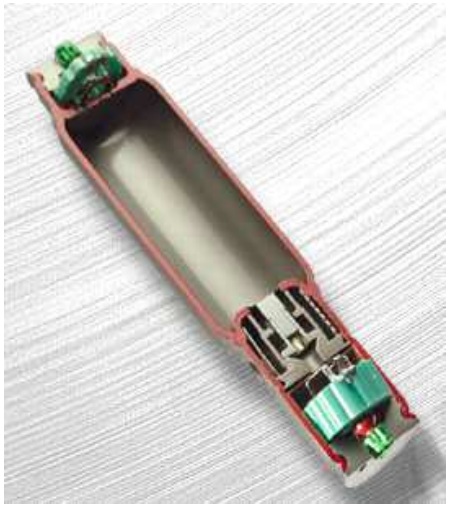
Main interest of grain shape design

Easy and quick assembly







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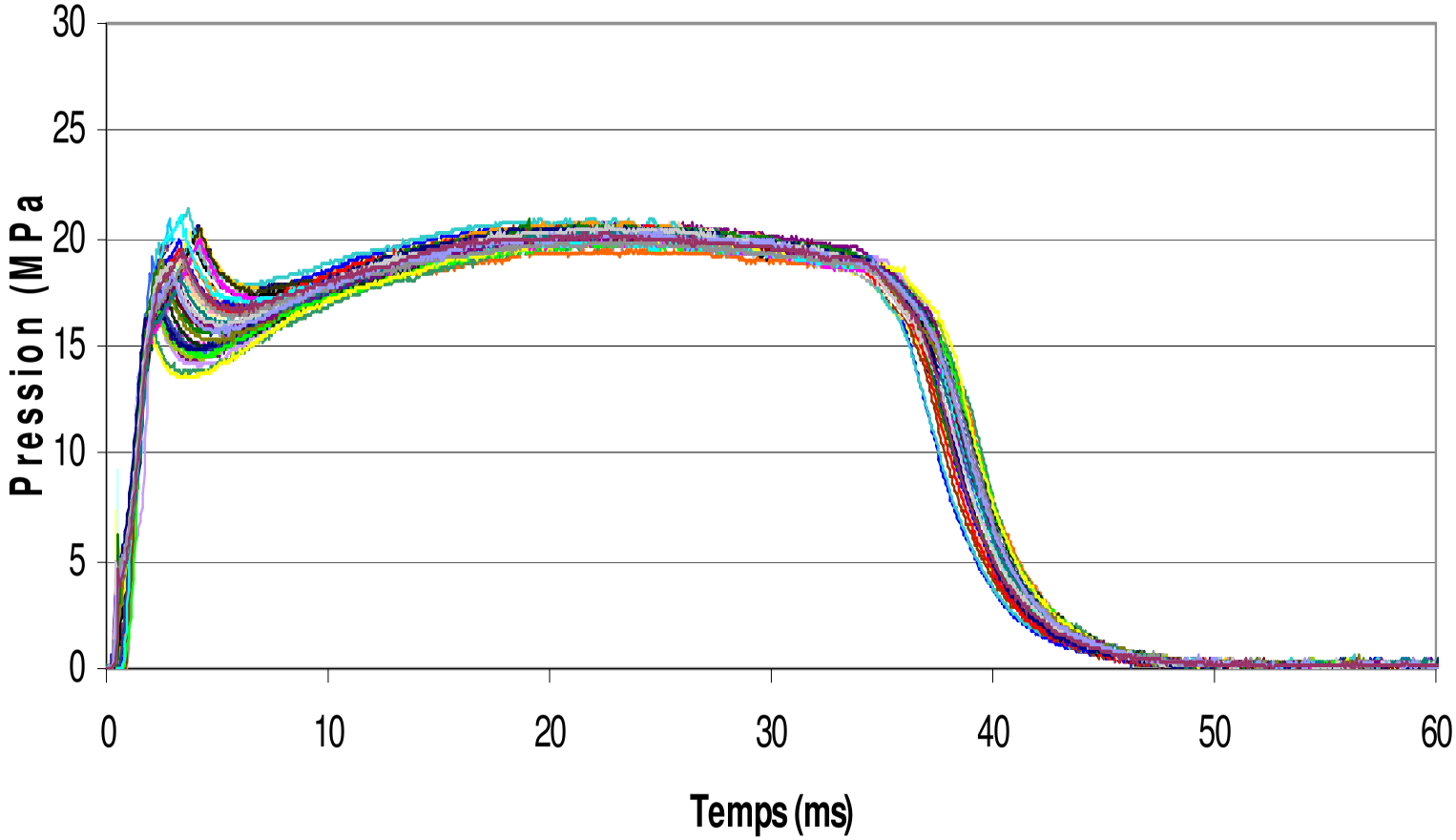
Main interest of grain shape design

➔ Inflator reproducibility – Pressure vs time in combustion chamber



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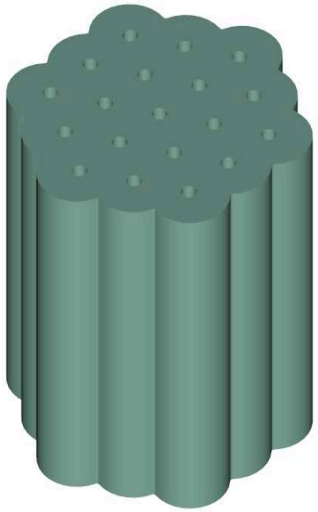
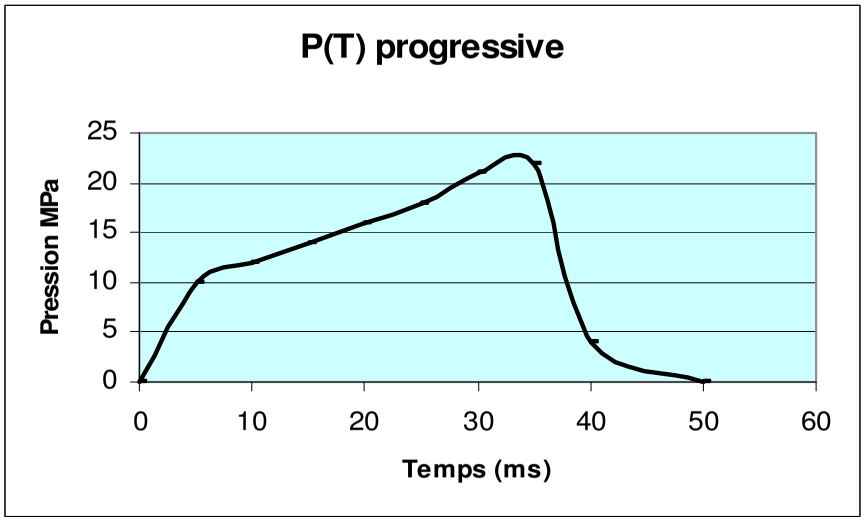
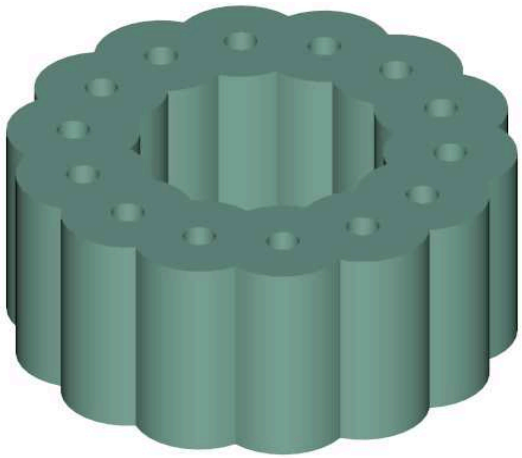
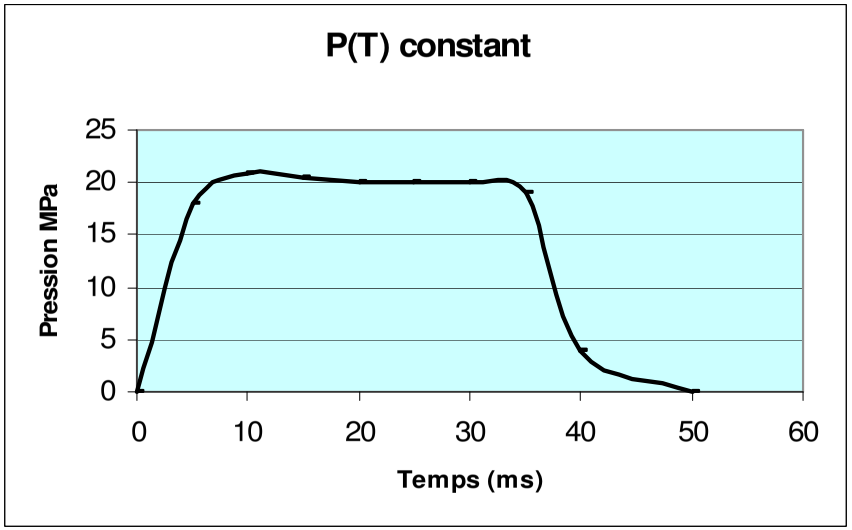
Main interest of grain shape design









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Where do AUTOLIV ASP come from ?

The merger of two chemistry companies

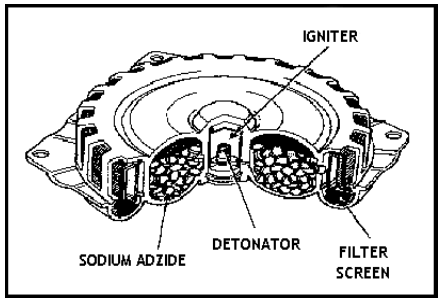
1982

Thiokol

Morton salts

Morton Thiokol Inc.

$$2NaN_{3(s)} \dashrightarrow 2Na(s)+3N_{2(g)}$$



1997

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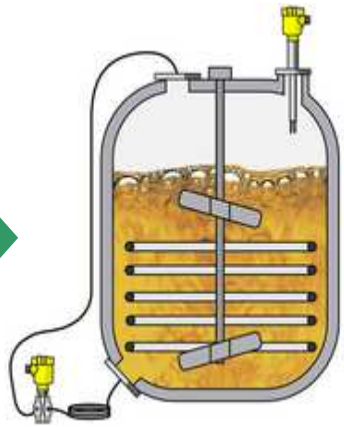
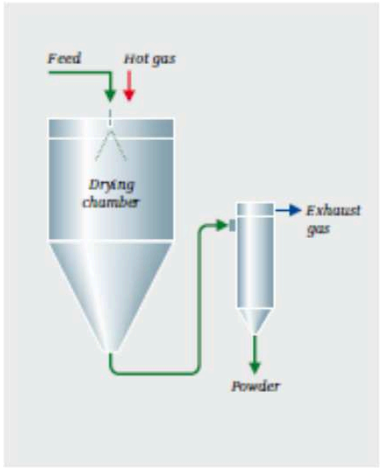
AUTOLIV Spray drying Process

Raw material wet mix



Chemical reaction



Spray drying

Tabletting

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Gas Generant innovation allowed by AUTOLIV process

IPASS communication
2013 by Ivan Mendenhall

Discovery of CuGUN

- Addition of guanylurea nitrate to basic copper nitrate containing gas generants, caused a color change in the slurry, and an increase in burning rate.
- Further work showed that CuGUN could be prepared by reaction of cupric hydroxide or basic copper carbonate with guanylurea nitrate.

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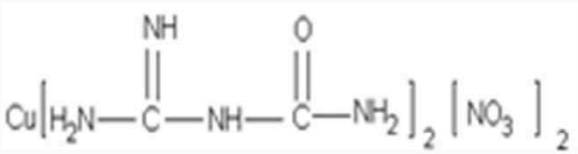
What is CuGun ?

Thermochemical Properties of CuGUN

- **Structure**



Mol. Wt. - 391.546 g/mole

Δ_f Form. – (-1238.5 KJ/mole)

Density - 1.94 g/cc

MP - Decomposes exothermically at 250 °C

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Is there a competitive advantage for the market ?

Cool Burning Gas Generant Properties

Characteristic	Current Tech.	Cool Burning Tech.	
Density g/cc	1.94	2.21	↑
Combust. Temp K	1845	1622	↓
Mol gas/100g	2.86	2.54	↓
Mol gas/100cc	5.55	5.61	↑
Rb @ 21MPa (mm/sec)	20.76	20.68	↔
Slope	0.38	0.361	
Constant	6.566	6.586	

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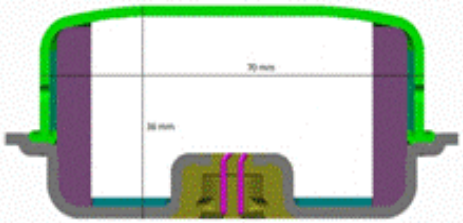
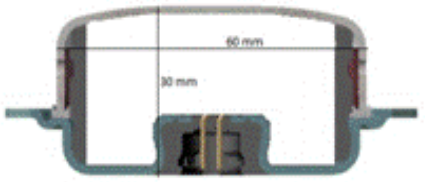
Inflator Comparison

Current Technology



•195 KPa Performance
•434 grams total weight

Cool Burning Technology



•195 KPa Performance
•280 grams total weight

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COMPETITION IS GOOD FOR THE MARKET !!!!

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5 What's NEXT ?

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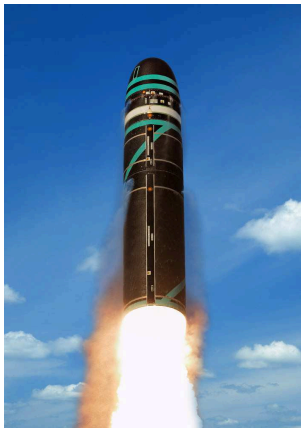
AIRBUS SAFRAN LAUNCHERS, LEADER EUROPÉEN DE L'ACCÈS À L'ESPACE

MARCHÉ CIVIL

- Maître d'œuvre du développement et de la production des lanceurs Ariane 5 et Ariane 6
- Motorisation du lanceur Vega
- Etudes et R&T des futurs systèmes de lancement



DÉFENSE

- Responsable du système de missiles balistiques de la force de dissuasion océanique française

PRODUITS, ÉQUIPEMENTS, SERVICES

À partir de ses activités d'origine, Airbus Safran Launchers propose un ensemble de produits dérivés et services associés dans les domaines civils et militaires.

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With whom do we want to compete ?

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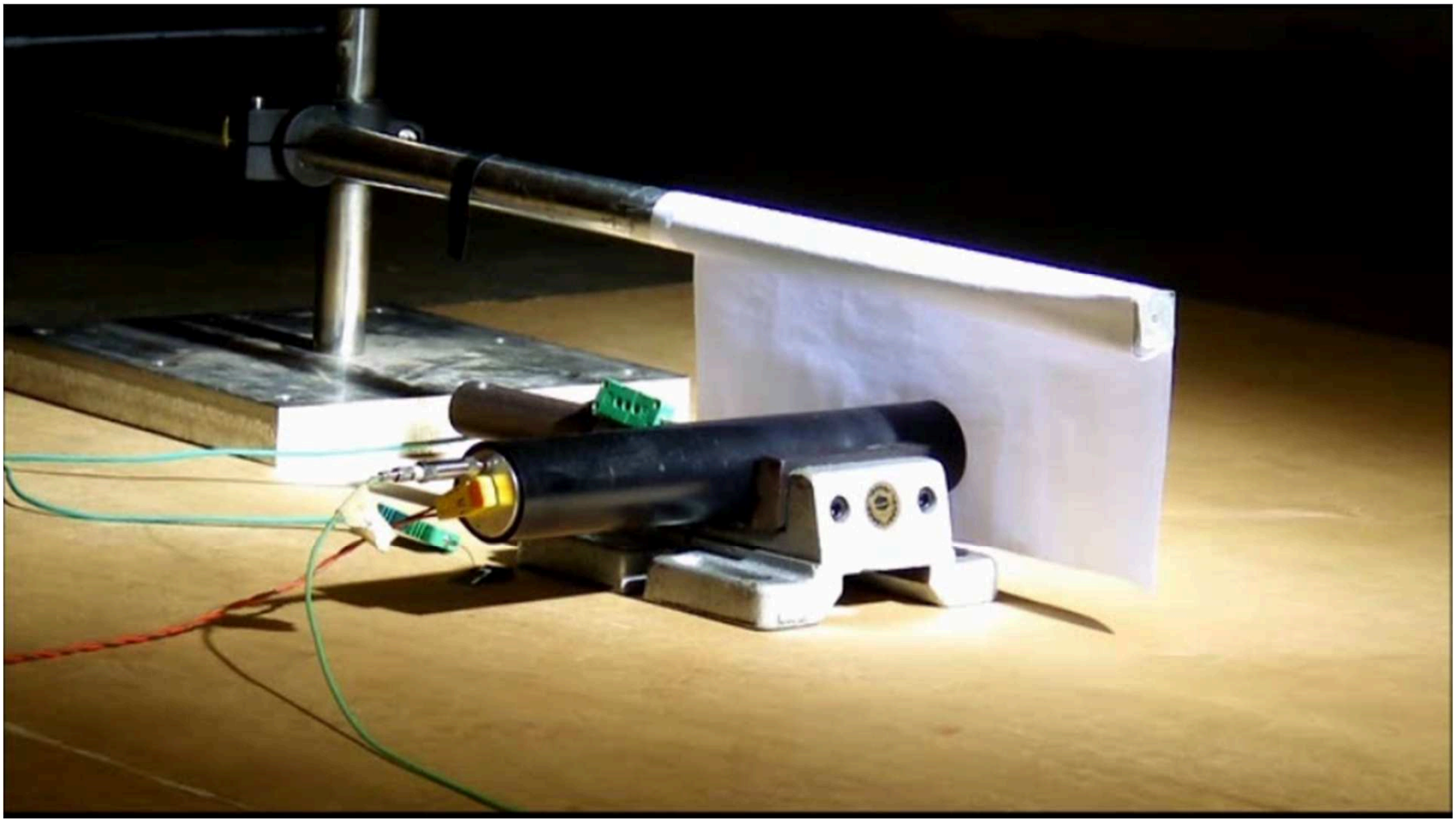
How do we want to compete ?



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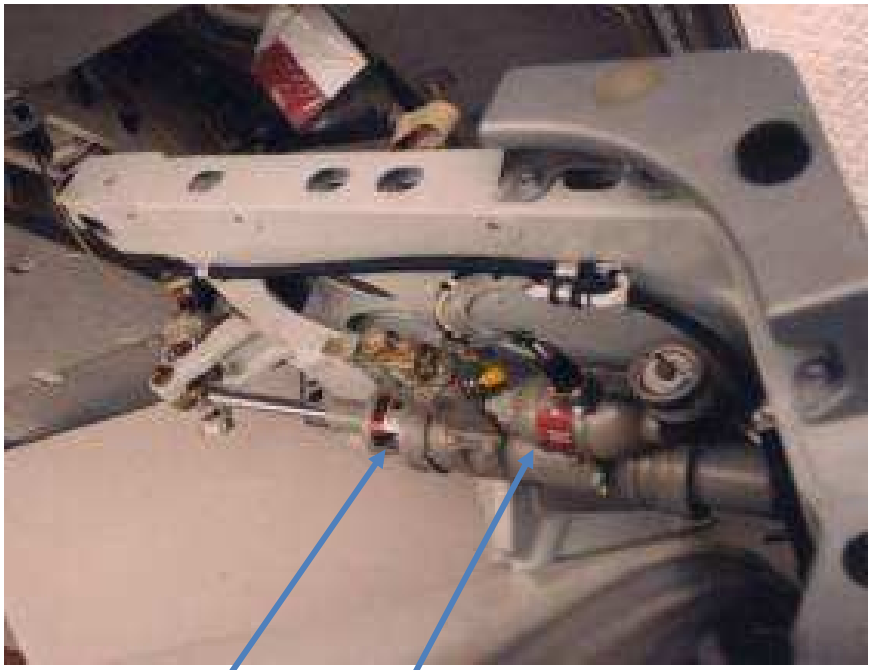
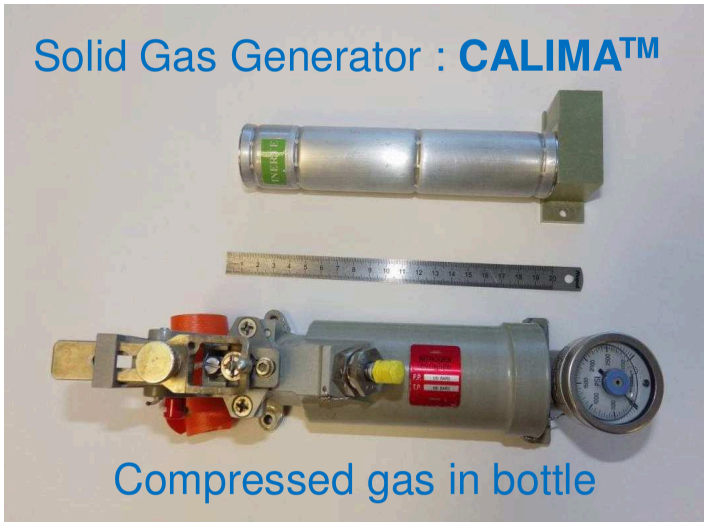
Solid Gas generator for safety door opening



Actuator

Bottle of
Compressed air



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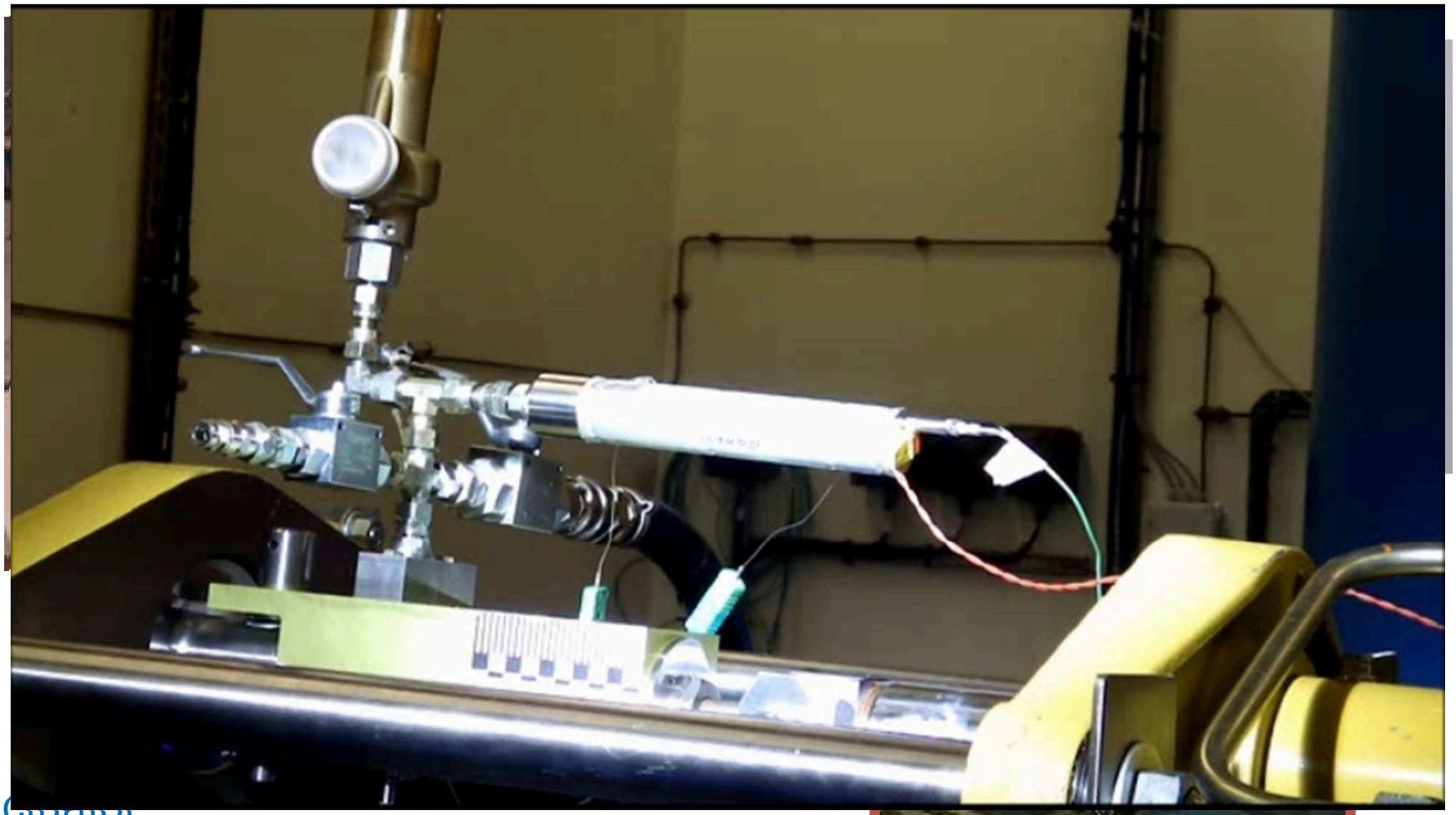

Actuator

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Thyphoon™ embbedded solutions

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Conclusions

Pyrotechnic gas generant are exhibiting :

- reliability
- disponibility
- performances

The drop of combustion temperature, allowed by new chemistry has made the challenge of competing against compressed air solutions a dream come true.

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Other examples

High gas yield composition based on PSAN from TAKATA

WO 99/46222 PCT/US99/04514

Table 3 - Comparative Gas Production

U.S. Patent No.	mol gas/ 100 g prop.	mol gas/ 100 cm^3 gas generant	cm^3 gas generant/ mol gas	Comparative Propellant Volume For Equal Amount of Gas Output
4,931,111 Azide	1.46	3.43	29.17	193%
5,139,588 Nonazide	2.18	4.96	20.16	133%
5,431,103 Nonazide	1.58	5.26	19.03	126%
Present Invention	4.00	6.60	15.15	100%

ASL patent, 1999

Cool Burning Gas Generant Properties

Characteristic	Current Tech.	Cool Burning Tech.	
Density g/cc	1.94	2.21	↑
Combust. Temp K	1845	1622	↓
Mol gas/100g	2.86	2.54	↓
Mol gas/100cc	5.55	5.61	↑
Rb @ 21MPa (mm/sec)	20.76	20.68	↔
Slope	0.38	0.361	
Constant	6.566	6.586	

IPASS International Pyrotechnic Automotive Safety Symposium AWARD 2013

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Autoliv

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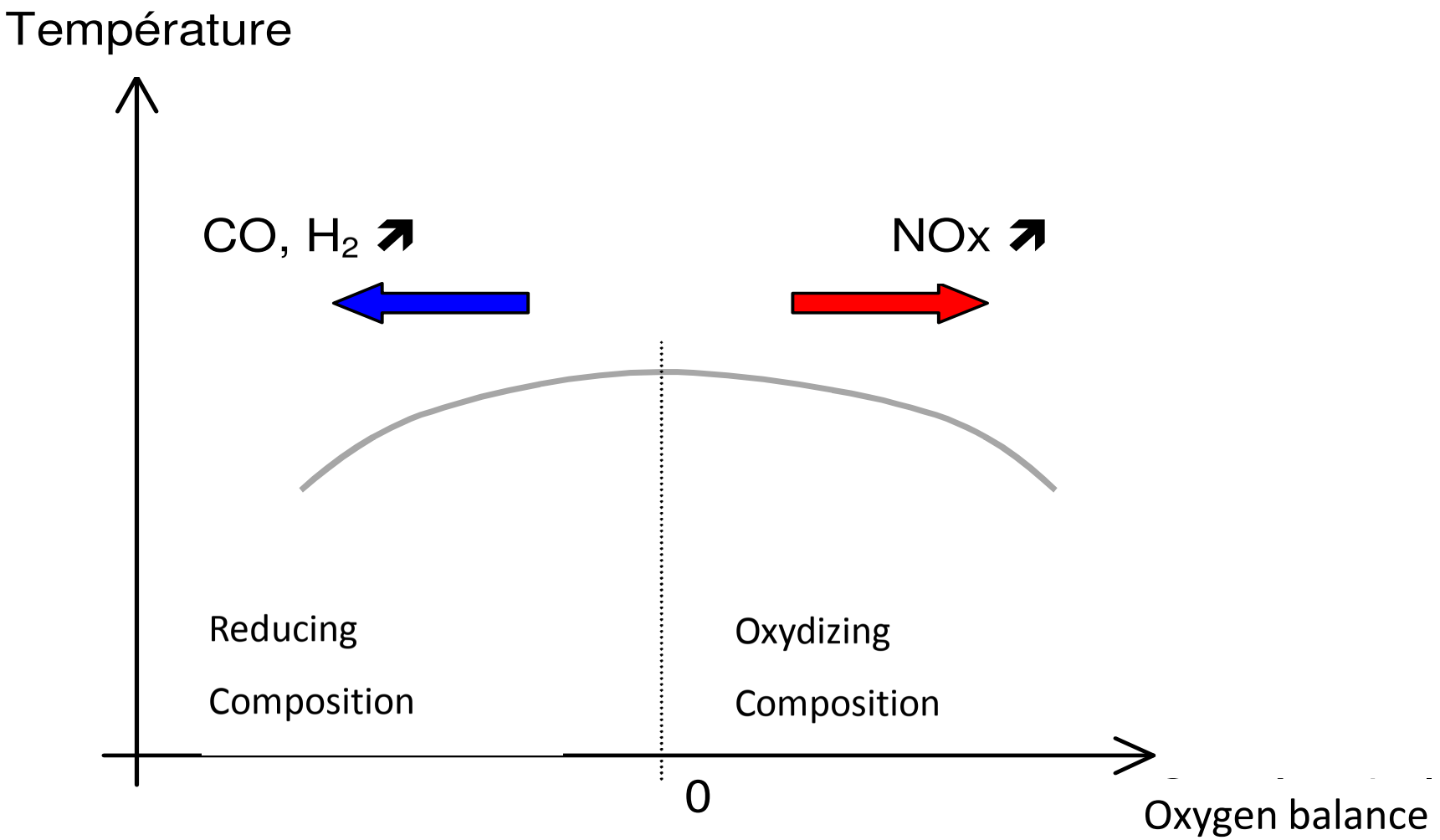
Example : Effluent toxicity management (1/3)



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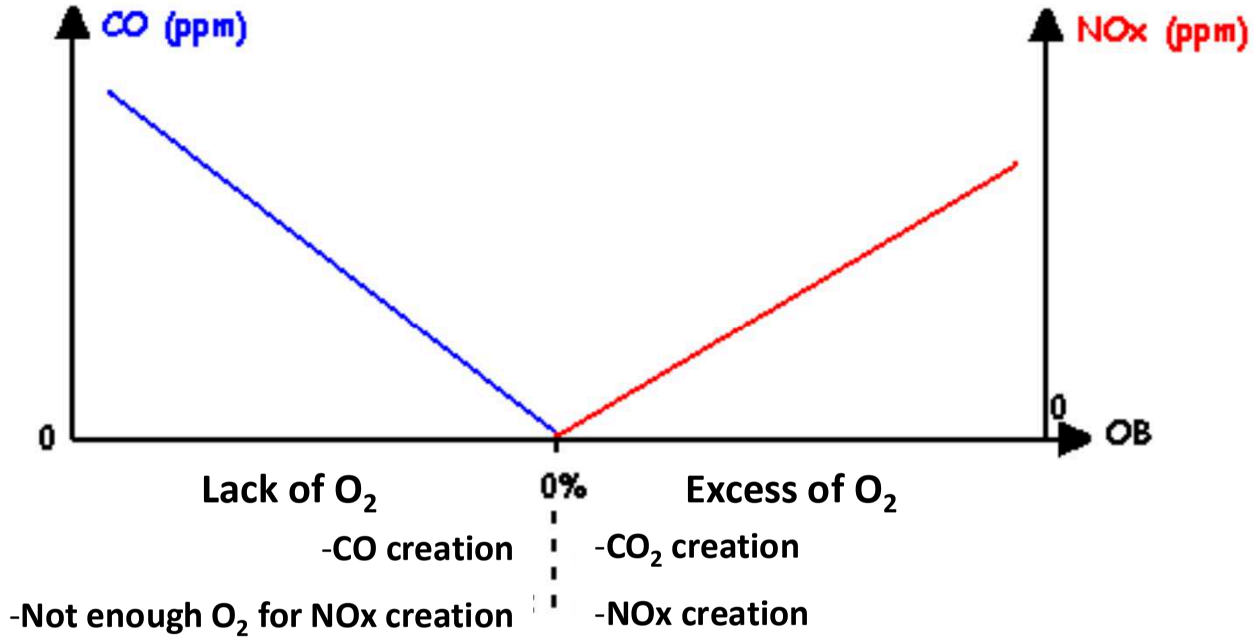
Effluents Toxicity : theoretical aspects (2/3)

➔ How to manage it ?

1- Mainly depending on combustion efficiency (inflator conditions)

2- CO and NOx rate are related to the oxygen balance of the composition

Ideal case:



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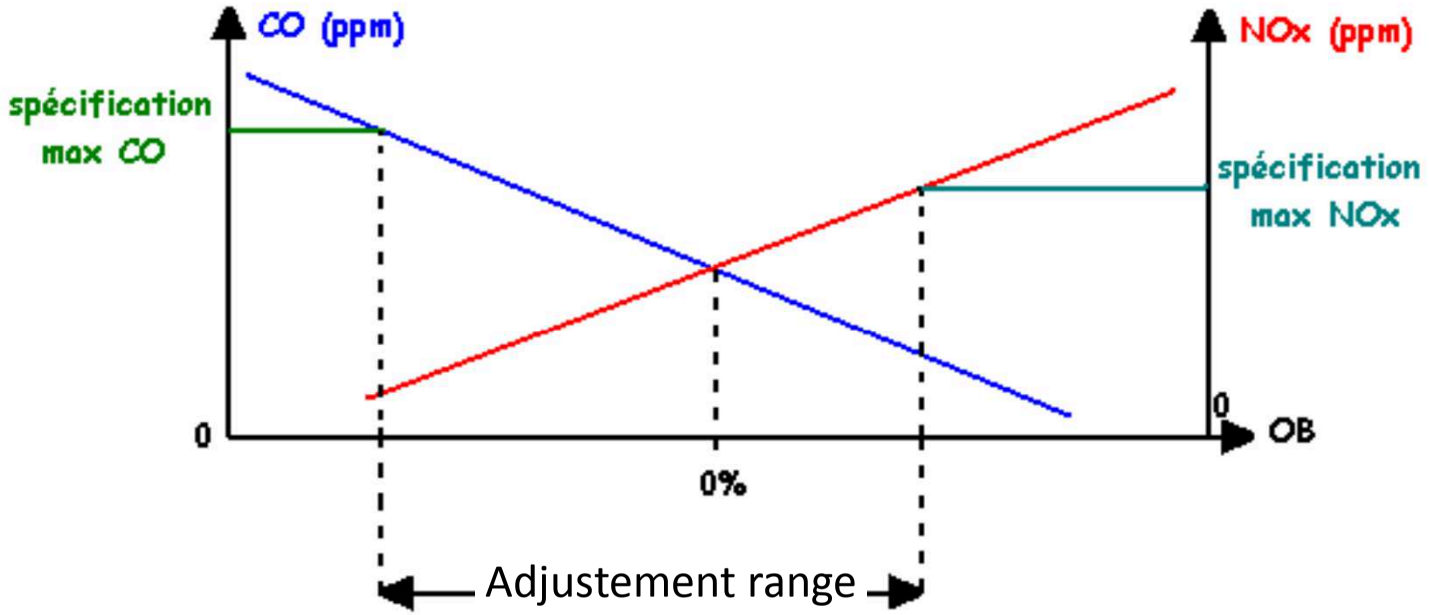
Effluents Toxicity : real life (3/3)

➔In real life reaction kinetics are changing the game



➔Loops with inflators development team are required

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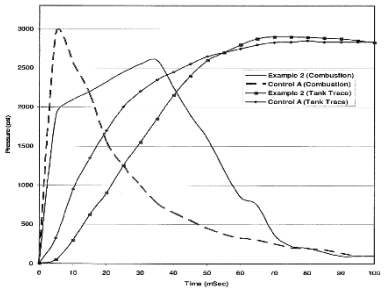
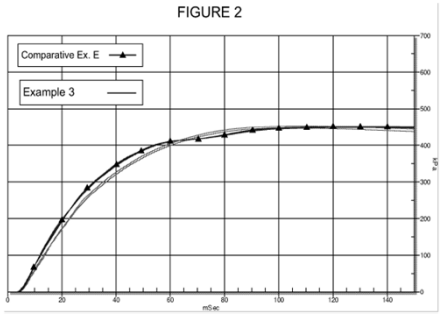
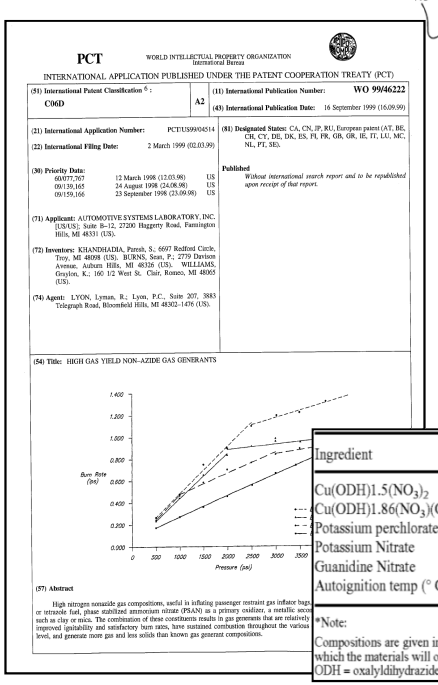
Market requirements are pushing hard on technology improvement

“Continuous gas generant innovation the reason for airbag technology success”







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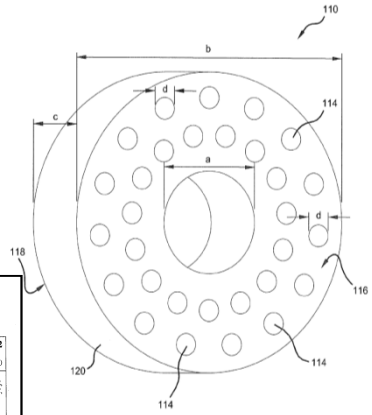
(54) Title: HIGH GAS YIELD NON-AZIDE GAS GENERANTS

(57) Abstract

High nitrogen nonazide gas compositions, useful in inflating passenger restraint gas inflator bags, or tetrazole fuel, phase stabilized ammonium nitrate (PSAN) as a primary oxidizer, a metallic secondary such as clay or mica. The combination of these constituents results in gas generants that are relatively improved ignitability and satisfactory burn rates, have sustained combustion throughout the various level, and generate more gas and less solids than known gas generant compositions.

Ingredient	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5
$Cu(ODH)1.5(NO_3)_2$	75.36	—	72.38	—	20
$Cu(ODH)1.86(NO_3)(OH)$	—	61.56	—	57.86	—
Potassium perchlorate	24.64	38.44	—	—	32.60
Potassium Nitrate	—	—	27.62	42.14	—
Guanidine Nitrate	—	—	—	—	47.40
Autoignition temp (° C.)	163	168	163	168	163

*Note:
Compositions are given in weight percent; auto-ignition temperature is the temperature at which the materials will openly burn at a temperature ramp rate of 10° C./minute;
ODH = oxalyldihydrazide ($C_2H_6N_4O_2$).



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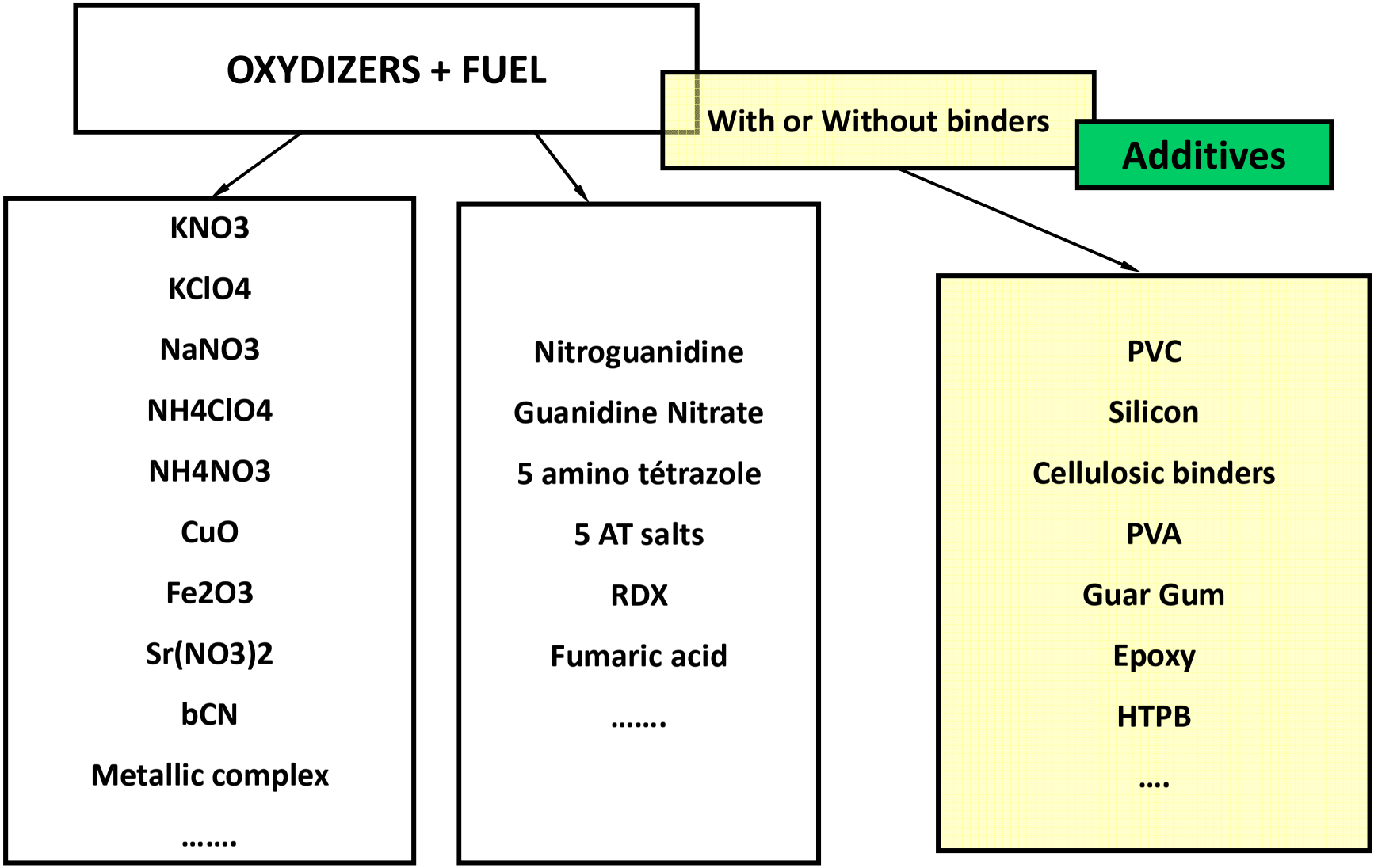
A wide field of candidate molecules



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