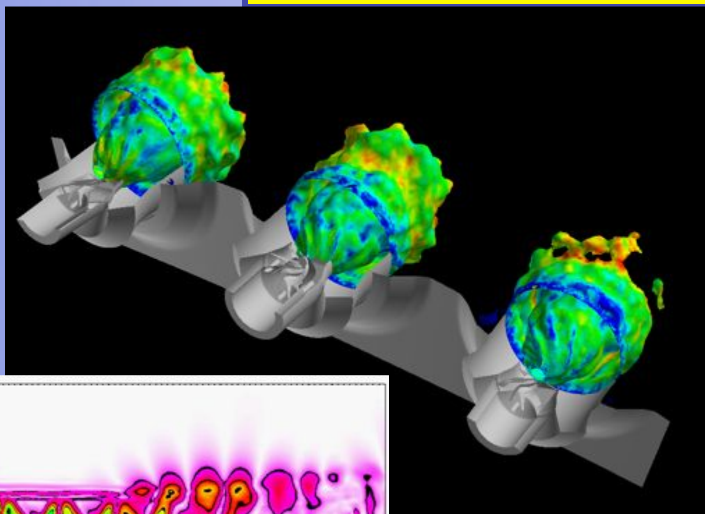
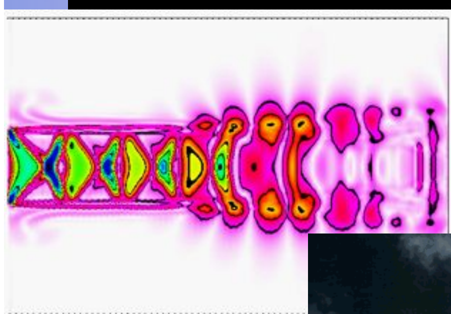
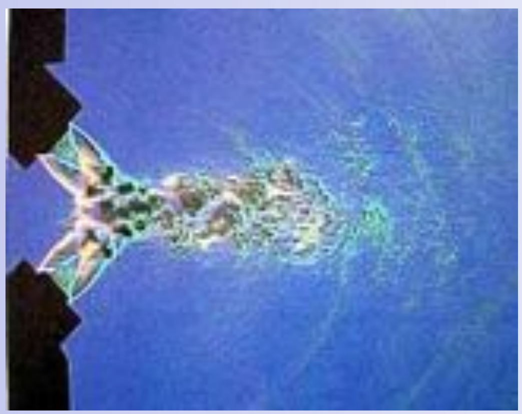
INTRODUCTION TO COMBUSTION







T. Poinsot
poinsot@imft.fr
CNRS

Combustion: > 90 percent of energy on earth





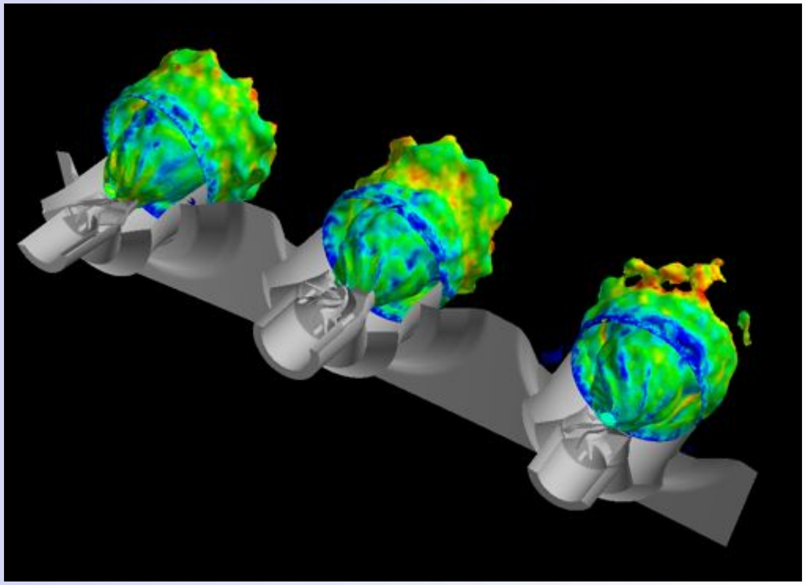





Combustion: the first engine of our society

What would we do without:

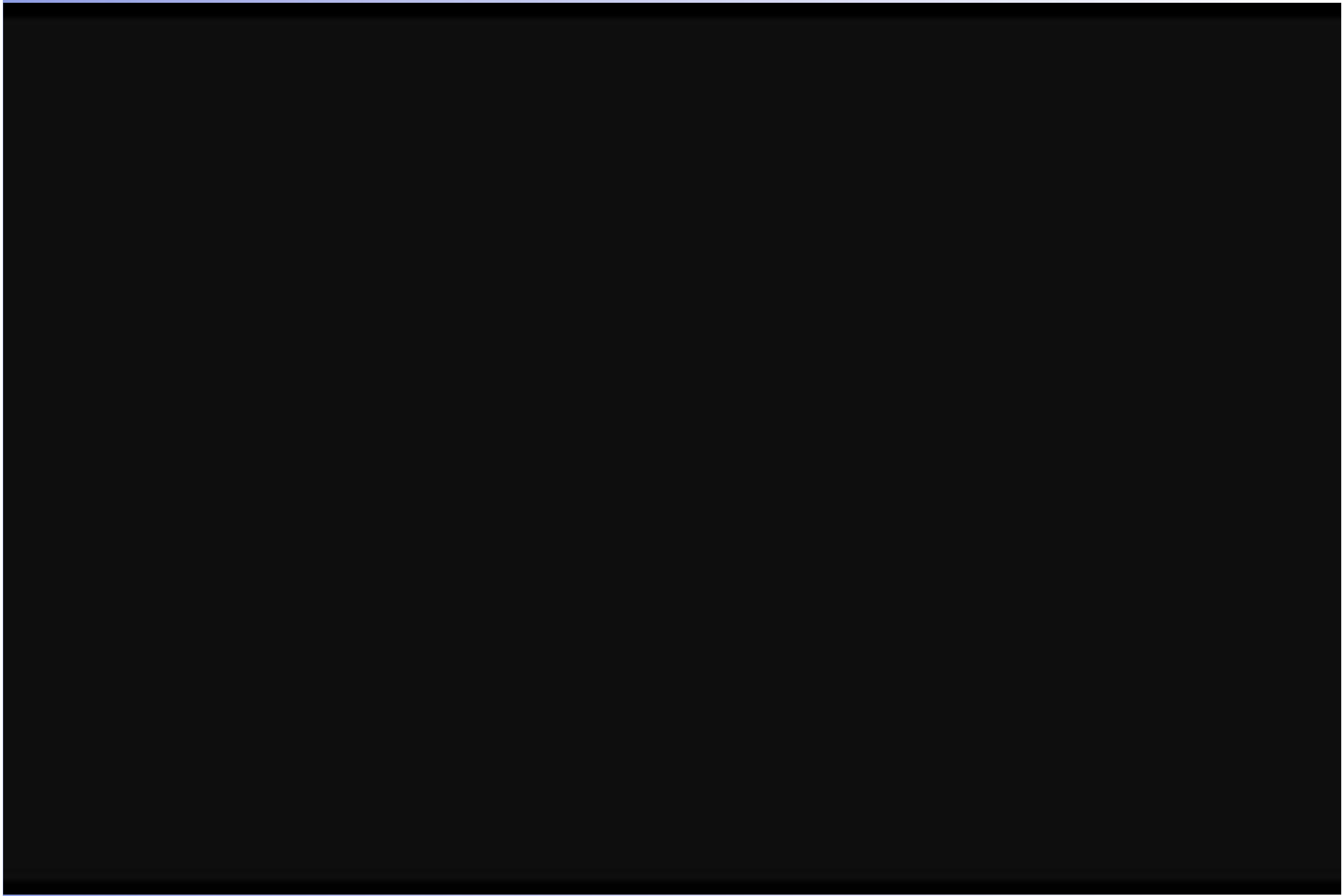
- car
- helicopter, aircraft, boat
- heater
- BBQ
- lighter
- gas in the kitchen
- industrial furnaces
- power plants
- wood fire
- etc…




Satellites…


Ariane V

Delta IV
Thom Baur © The Boeing Company



Military:

Mastering combustion is the key to military independence:
- Rockets, missiles
- Helicopters, fighters
- Bombs… (this is combustion too)

Present aircraft

Future aircraft

Terrorism and combustion

A missile carrying a nuclear bomb is as difficult to build as the bomb itself

Let us forget now army applications.

For all other applications, combustion is often the only solution and will remain so for a long time

TWO BASIC EQUATIONS:
ENERGY ON EARTH TODAY = COMBUSTION

ENERGY ON EARTH TOMORROW = COMBUSTION

RENEWABLE ENERGIES WILL REPLACE COMBUSTION BUT:
- IT WILL TAKE A VERY LONG TIME
- IT WILL BE ONLY FOR A PART OF THE ENERGY PRODUCED BY COMBUSTION

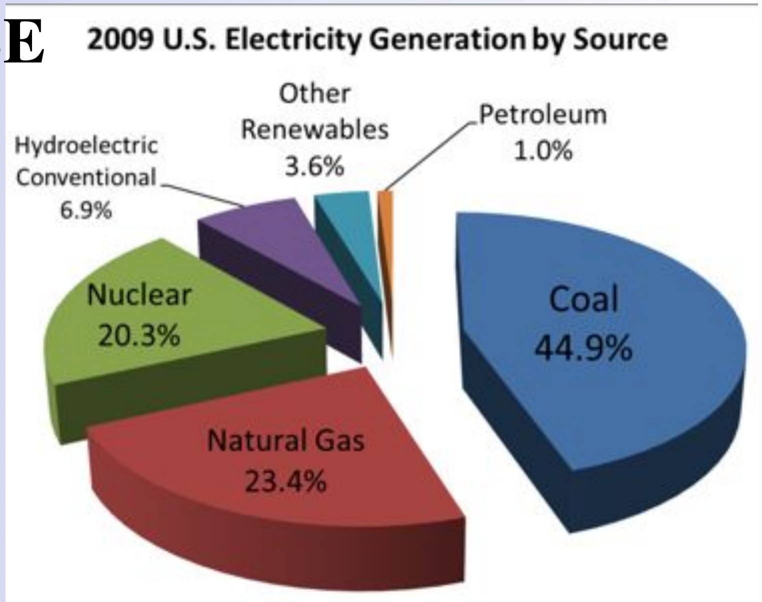
IN THE NEXT 50 YEARS, COMBUSTION WILL REMAIN THE FIRST ENERGY SOURCE

ENERGY MARKET: 2010/2030

- **RENEWABLE ENERGIES INCREASE FASTER THAN COMBUSTION**

- **BUT THE GLOBAL DEMAND FOR ENERGY ALSO GROWS (typically 2.6% PER YEAR)**

- **ENERGY PRODUCTION BY COMBUSTION MUST ALSO INCREASE**

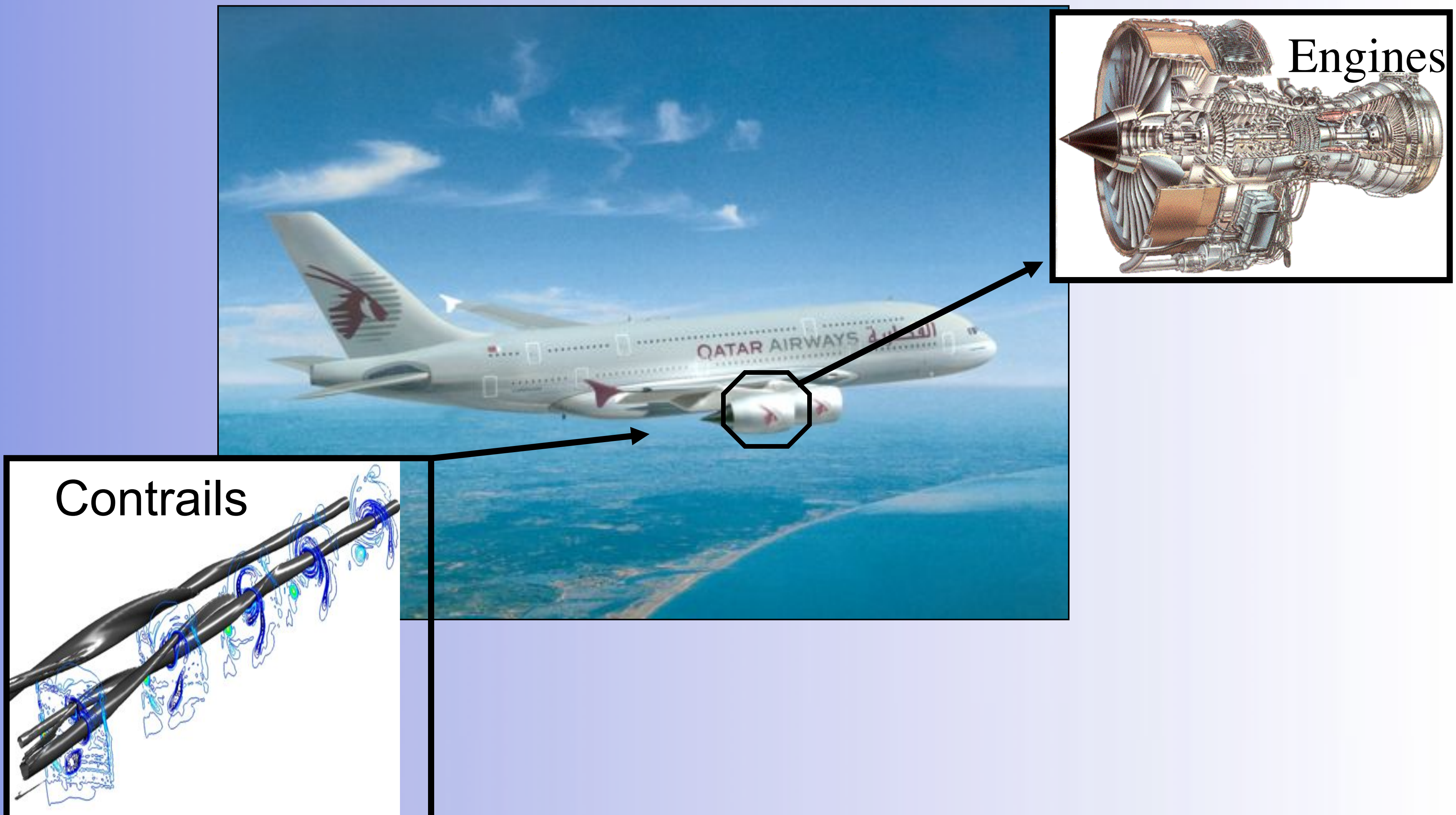


COMBUSTION SCIENCE MUST ALLOW THIS WITHOUT INCREASING EMISSIONS, WASTING FOSSIL FUELS OR MAKING CLIMATE CHANGE WORSE

Combustion is also the first source of pollution


IS THIS TRUE ?
Le 14 Mai 2008 à 20h à l'ENAC
Complexe Scientifique de Rangueil
7 avenue Edouard Belin, 31055 TOULOUSE

Combustion affects climate also through contrails:


Engines
QATAR AIRWAYS
Contrails

Pollutants ?: TWO MAIN TYPES

CnHm + O2 -->
CO2 + H20 + (CxHy+ CO + NO + soot + etc)

- can be avoided: CO, NO, CHx, soots. Impressive progress in the last 30 years

- can not be avoided: CO2, H20 ==> appear necessarily if you burn CnHm. The only solution is to maximize efficiency to obtain 1 W with as little fuel (and CO2 and H20) as possible

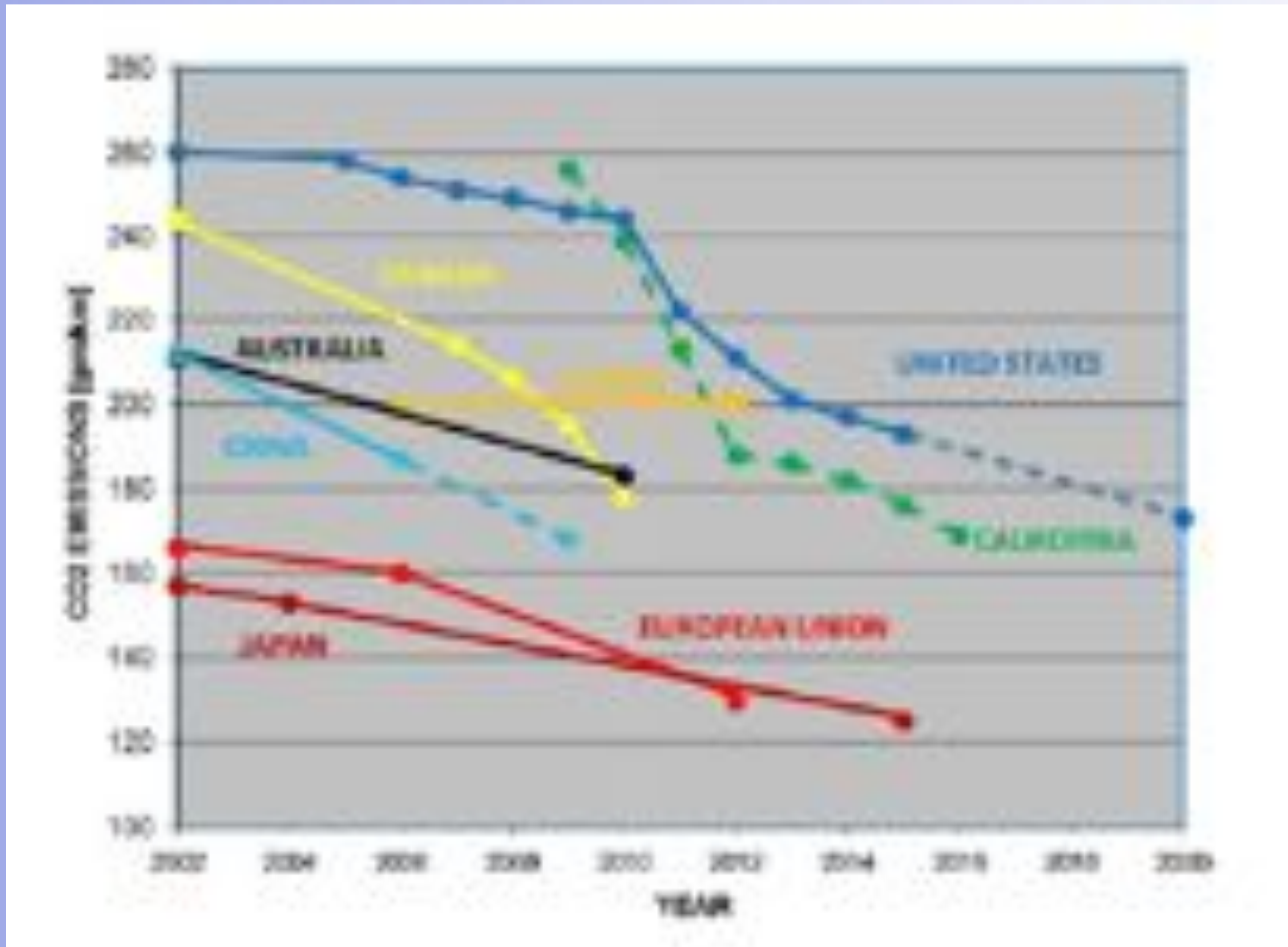
Is combustion work ecological ?

Since combustion is the first energy source in this world and since we wont be able to replace it soon, optimizing it is the first ecological action.

Combustion science today:

- **Very large impact on society**
- **Very sophisticated technology**

COMBUSTION IS ALSO POLITICS:



Source: R. Sawyer

Combustion and Climate:
R. Sawyer, 2008, 32th Symp. (Int.) on Comb.

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Proceedings of the Combustion Institute 32 (2009) 45–56

Proceedings of the Combustion Institute

www.elsevier.com/locate/proci

Science based policy for addressing energy and environmental problems

Robert F. Sawyer

Mechanical Engineering Department, University of California, Berkeley, CA 94720-1740, USA

Global warming and effect of combustion

Guessed by Fourier in 1824

Role of CO2 shown by Arrhenius in 1896: doubling CO2 would raise earth temperature by 5 degrees

If you want to be more precise, talk to GIEC

1-GLOBAL WARMING IS OCCURRING

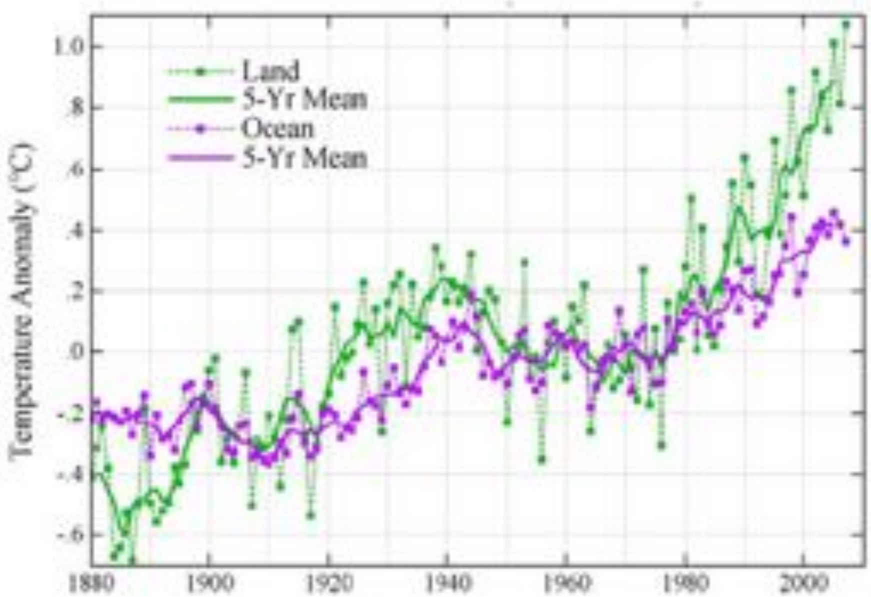


Fig. 4. Global mean land and ocean temperatures since 1880. (Ref.: Goddard Institute for Space Studies, Data and Images, 2008. http://data.giss.nasa.gov/gistemp/graphs/.)

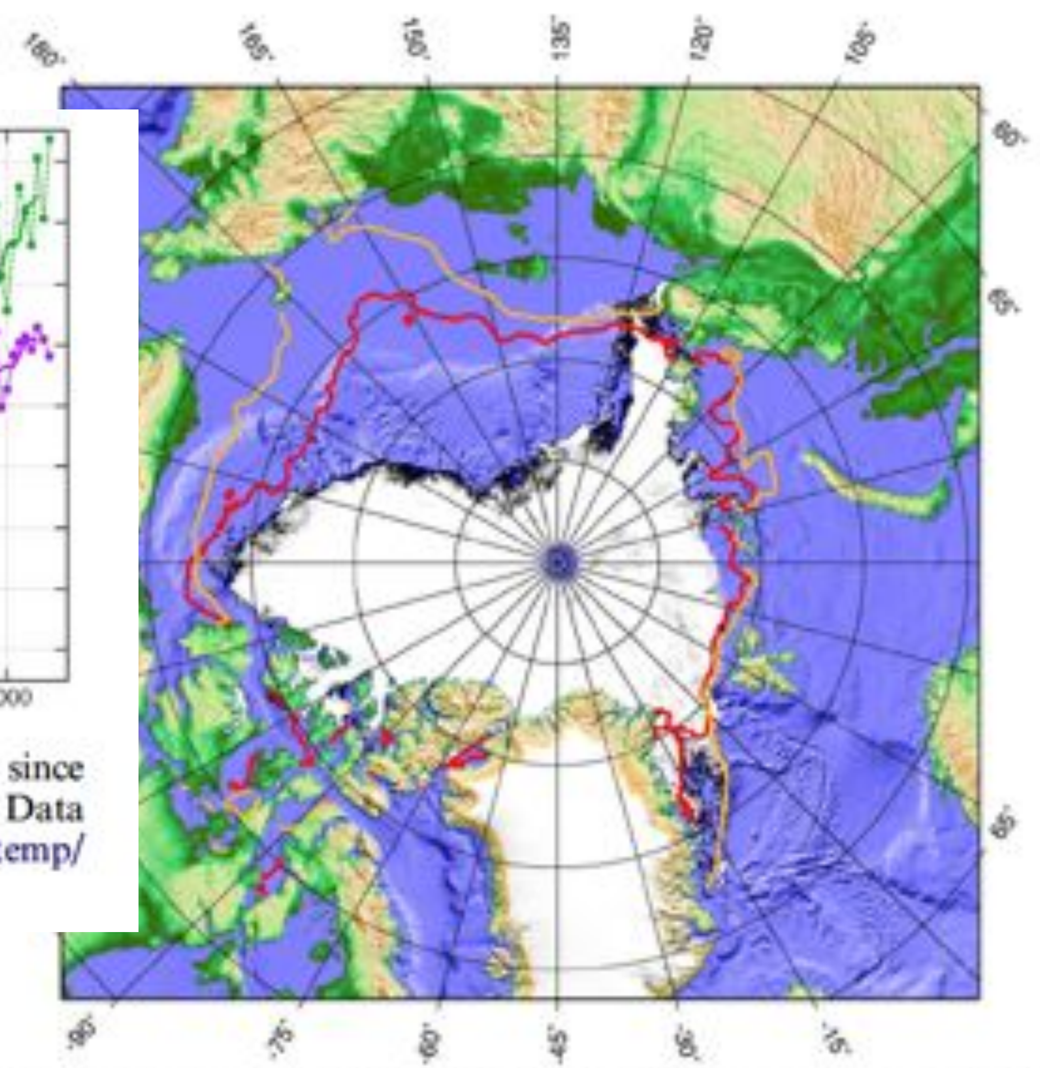


Fig. 6. Universitat Bremen records of September arctic sea ice extent. 50% ice concentrations, orange: 1997-1983, red: 2002–2006. (Ref.: Spreen, G., L. Kaleschke, and G. Heygster (2008), Sea ice remote sensing using AMSR-E 89 GHz channels, J. Geophys. Res., doi:10.1029/2005JC003384. http://www.iup.uni-bremen.de:8084/amsr/SeaIceMinimum2007-contour50.png.)

2 - WE ARE THE CAUSE OF GLOBAL WARMING

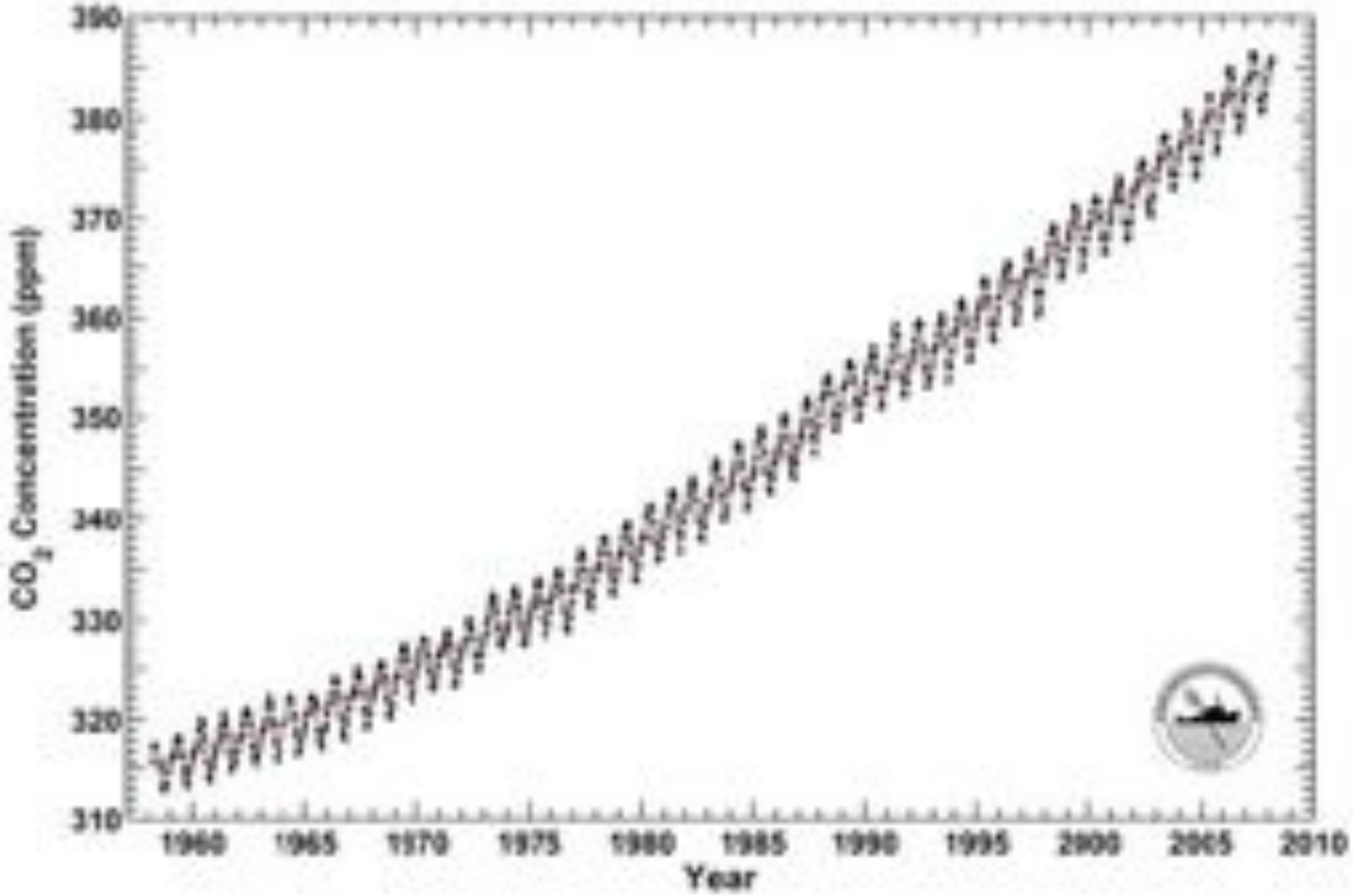
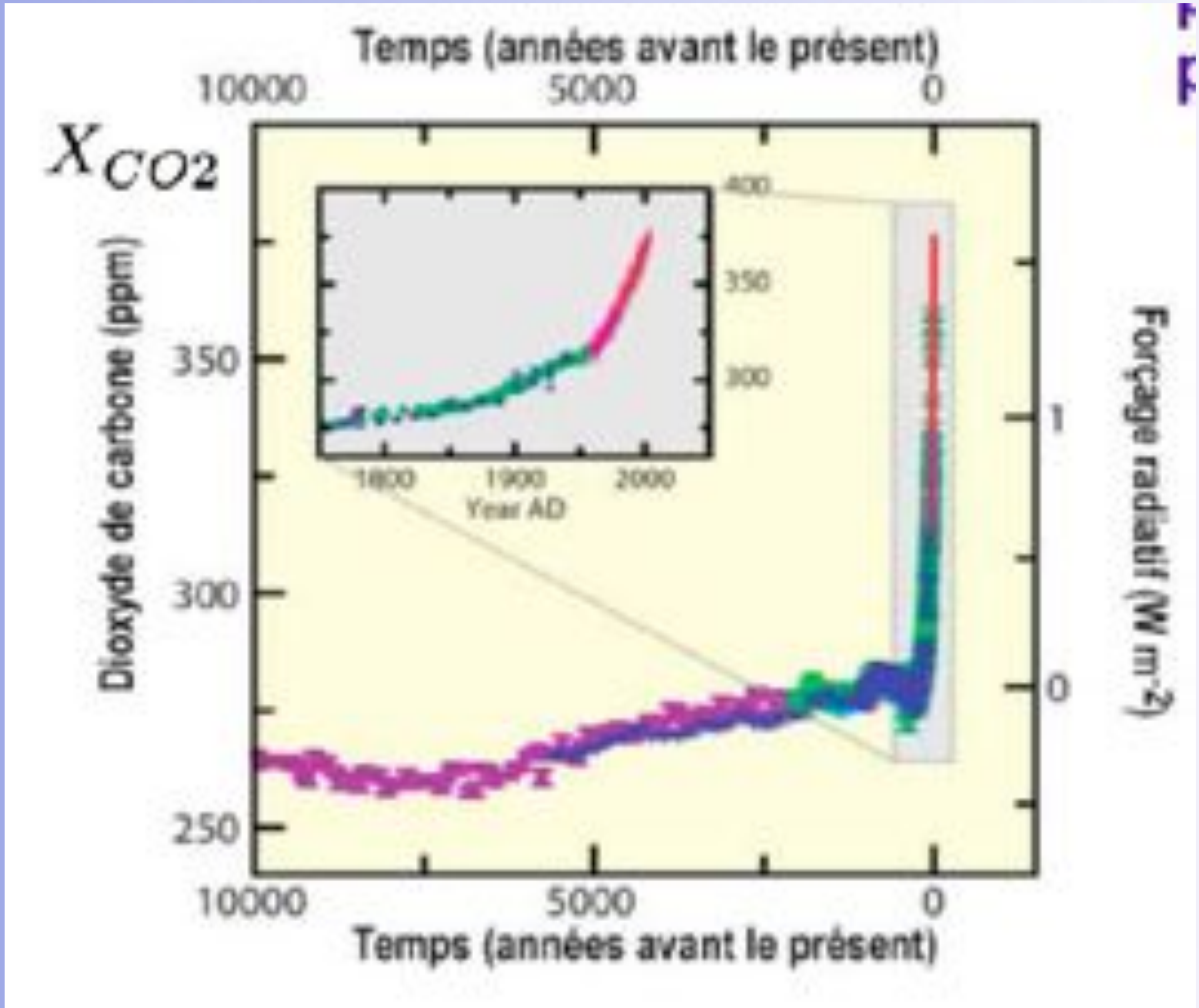


Fig. 2. "Keeling Curve," carbon dioxide concentrations measured at Mauna Loa, Hawaii. Line shows carbon



Temps (années avant le présent)
10000
5000
0
X_{CO2}
400
350
300
1800
1900
2000
Year AD
Dioxyde de carbone (ppm)
350
300
250
Forçage radiatif (W m⁻²)
1
0
10000
5000
0
Temps (années avant le présent)

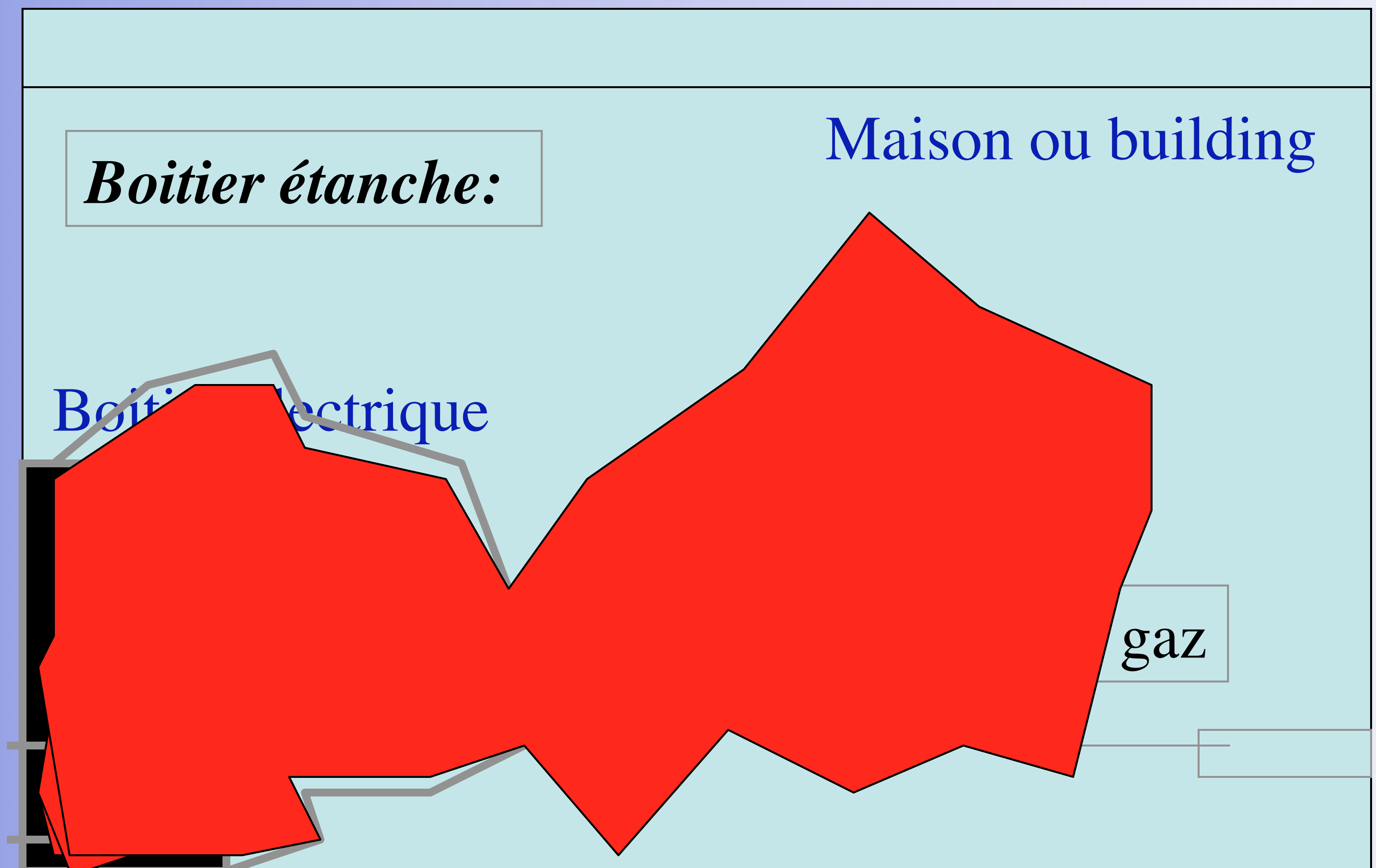
GIEC 2007

Combustion we do not want:

Out of control combustion:

- forest fires
- fires in houses and appartments
- electrical safety
- transportation accidents
- gas explosion in mines
- explosions in buildings

Electrical safety:



Boitier étanche:
Maison ou building
gaz

Deflagration / Detonation

Deflagration: ***pschitt/wrouff*. Pressure is almost constant**

Detonation: ***boom*. This is a flame + a shock**

Deflagrations can become detonations (DDT: Deflagration to Detonation Transition)

Examples: (building safety)

Deflagration:

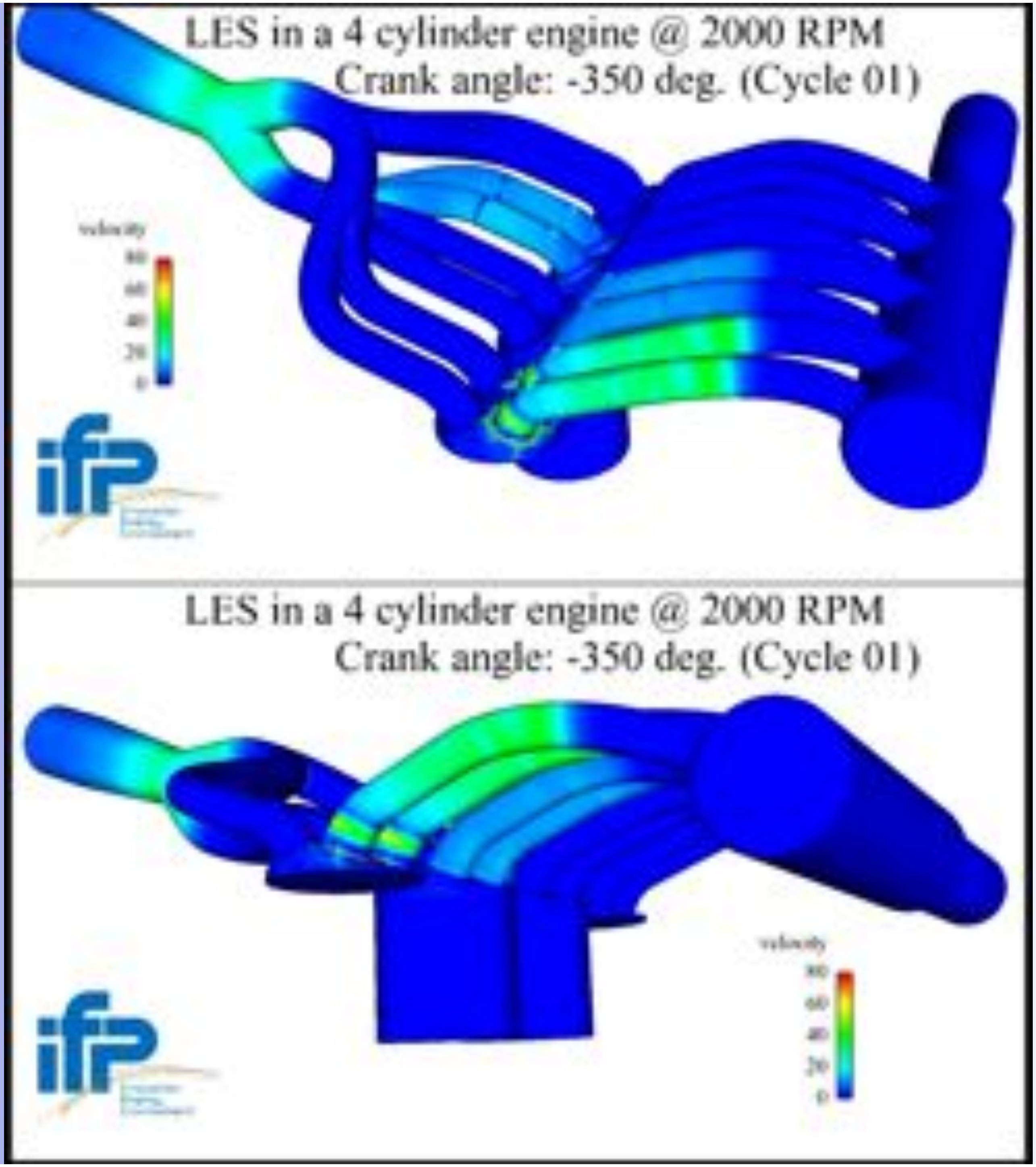

© GIL

Detonation

SO WE NEED BETTER COMBUSTION SYSTEMS !

THE PROBLEM IS THAT IT IS NOT SO EASY !

Combustion technology already is very optimized and complex:



LES in a 4 cylinder engine @ 2000 RPM
Crank angle: -350 deg. (Cycle 01)
velocity
LES in a 4 cylinder engine @ 2000 RPM
Crank angle: -350 deg. (Cycle 01)
velocity

And big !

900 000 horsepower
100 trs/min
6000 liters/hours

Industrial furnaces

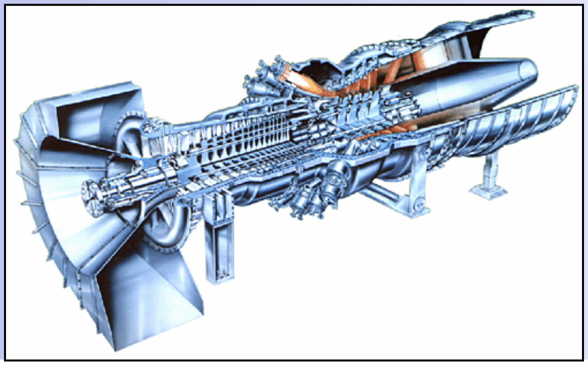
Gas turbines

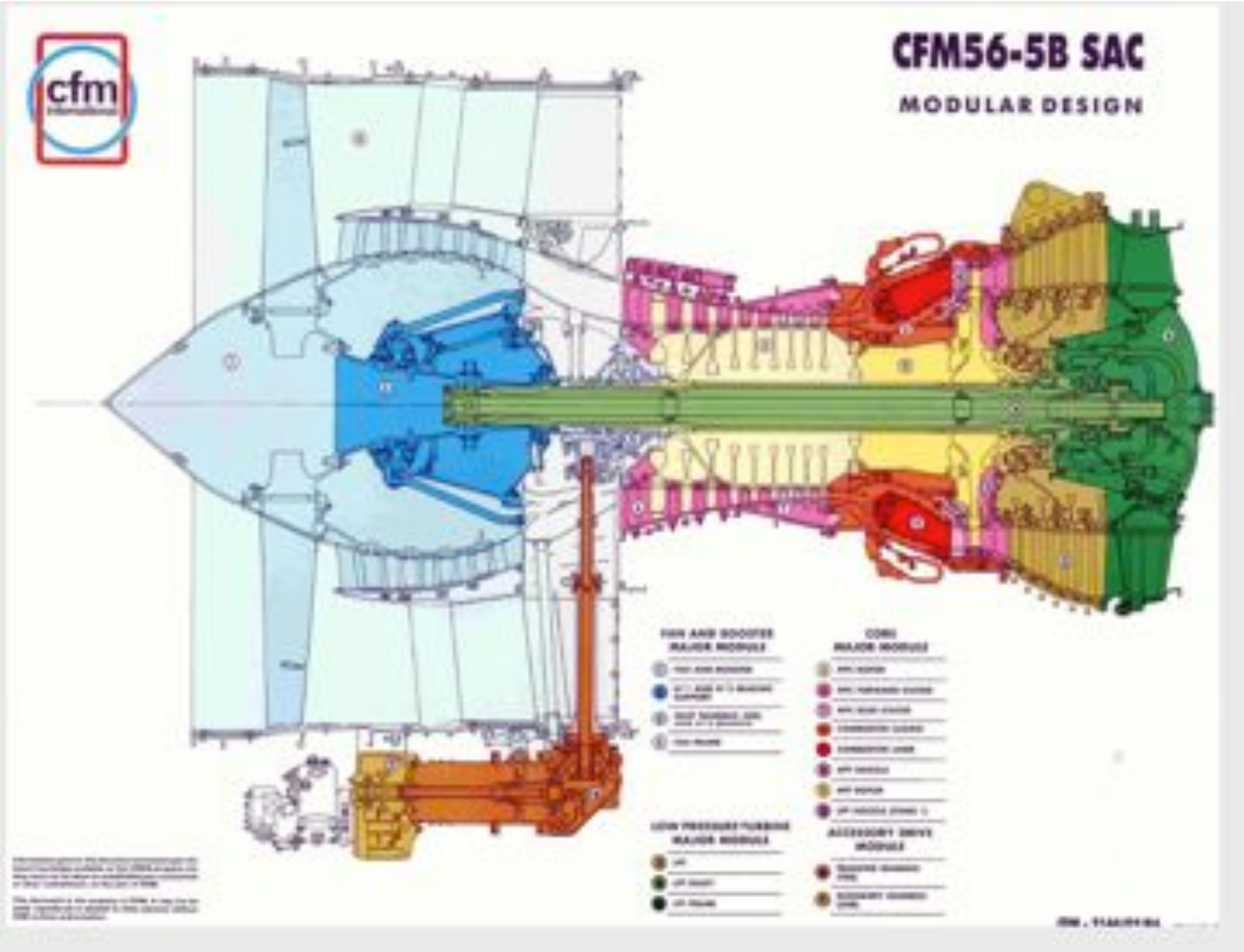
AERONAUTICAL:

- Aircraft (SNECMA, RR, MTU, Fiat Avio, GE)
- Helicopter (Turbomeca)
- Boats

INDUSTRIAL:

- Electricity (Siemens, Alstom, GE, Westinghouse)




CFM56-5B SAC
MODULAR DESIGN
FAN AND BOOSTER MAJOR MODULE
CORE MAJOR MODULE
LOW PRESSURE TURBINE MAJOR MODULE
ACCESSORY DRIVE MODULE

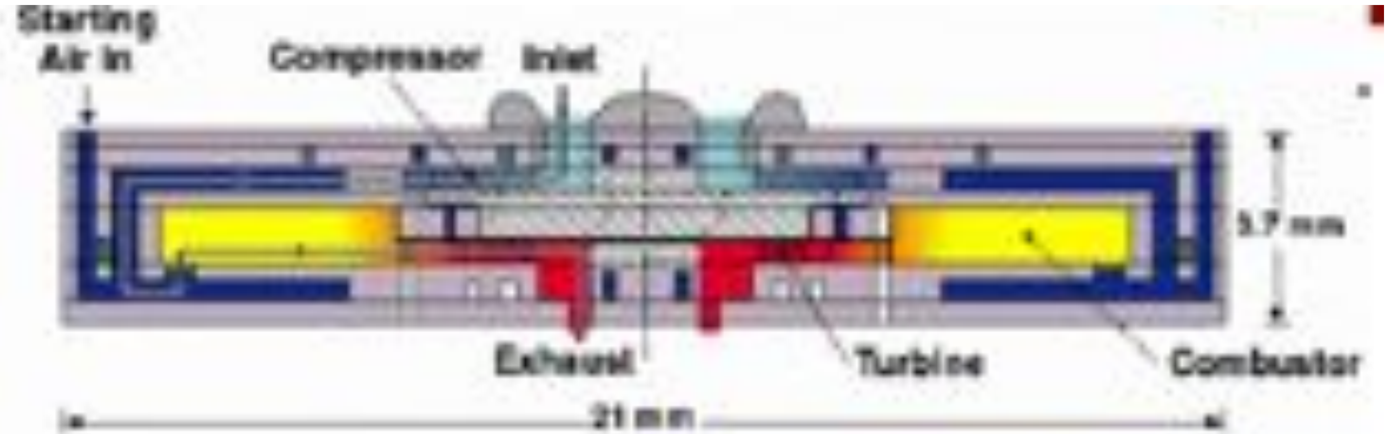
Turbines : small to big

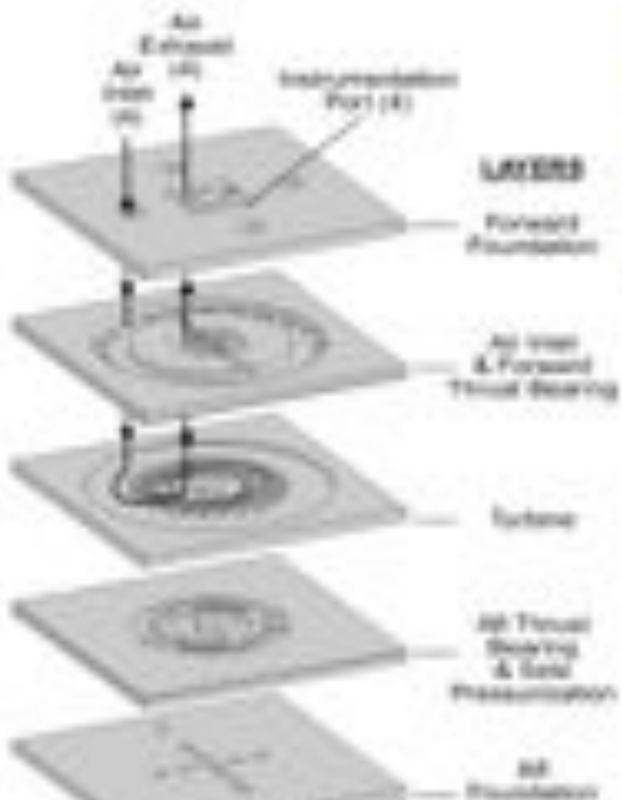
50W

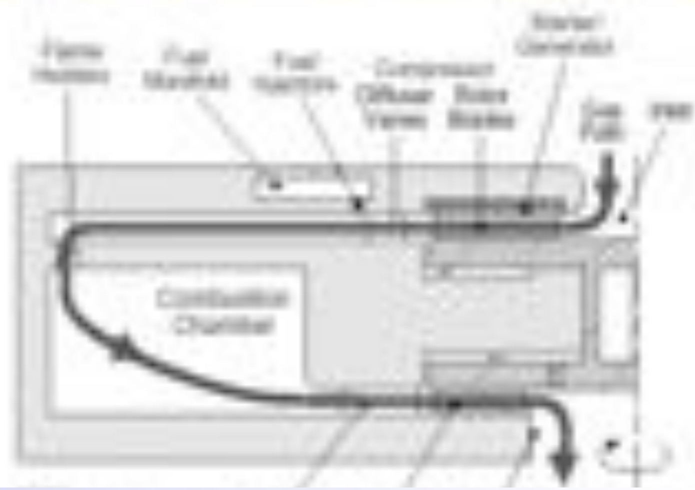
GT-26

275MW

Microturbines:







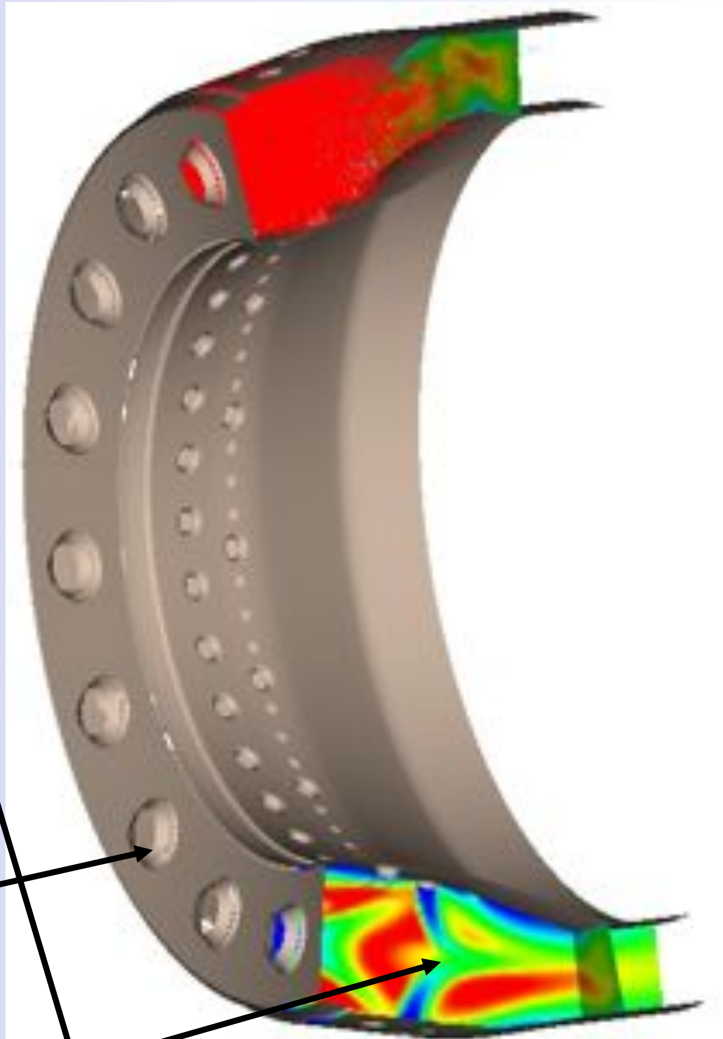
100 g of CH_4 contains 15 times more energy than 100 g of battery

EXOTIC TURBINE

Integrated RANS / LES Computations
of a Jet Engine

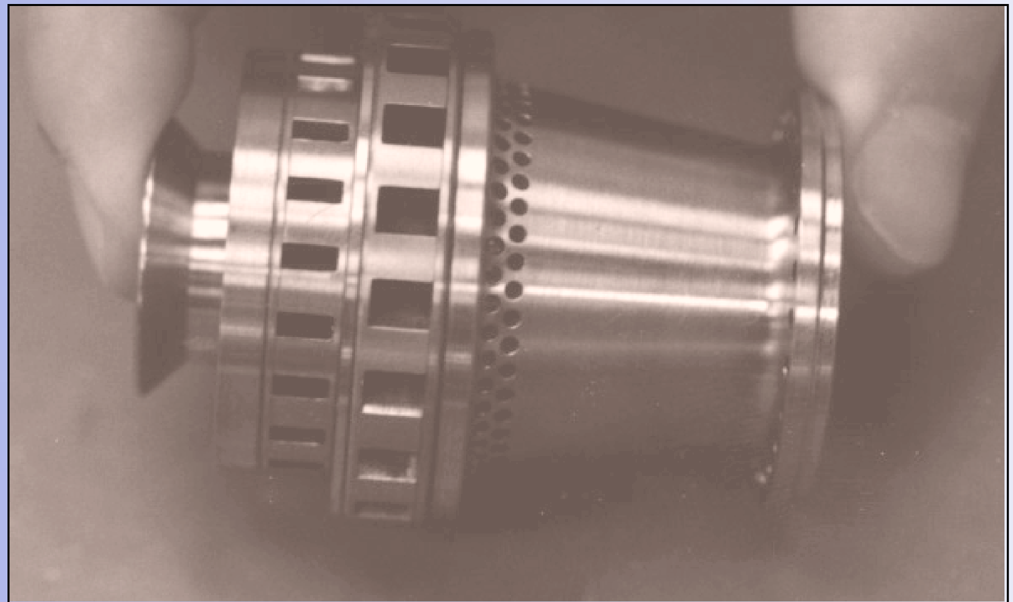
Stanford University ASC Center

Gas turbine combustion chamber:



BRULEUR (BURNER)

CHAMBRE DE COMBUSTION (COMBUSTION CHAMBER)



Combustion: complex mechanisms

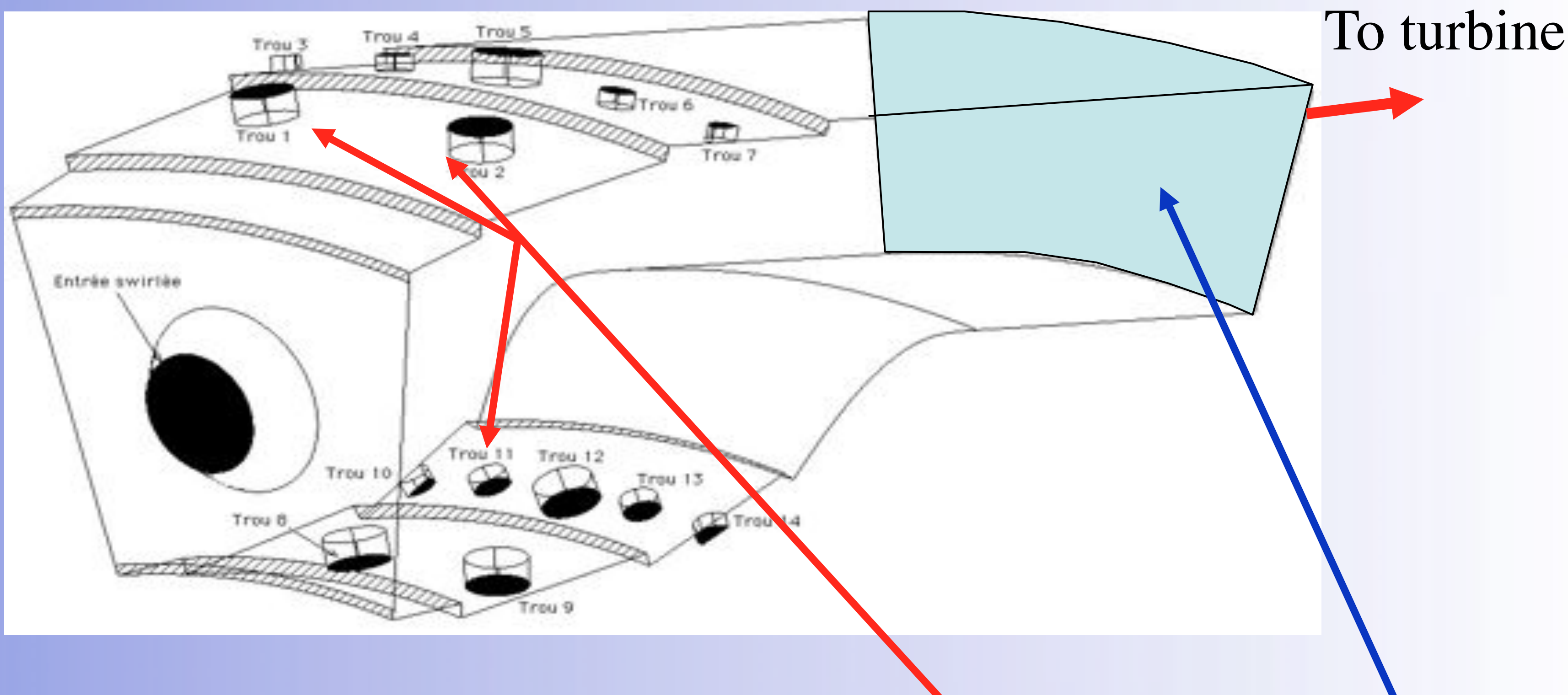
AIRCRAFT GAS TURBINE

LES OF REACTIVE TWO-PHASE FLOW

TEMPERATURE : 525 K
PRESSURE : 1 ATM
FUEL : JP10

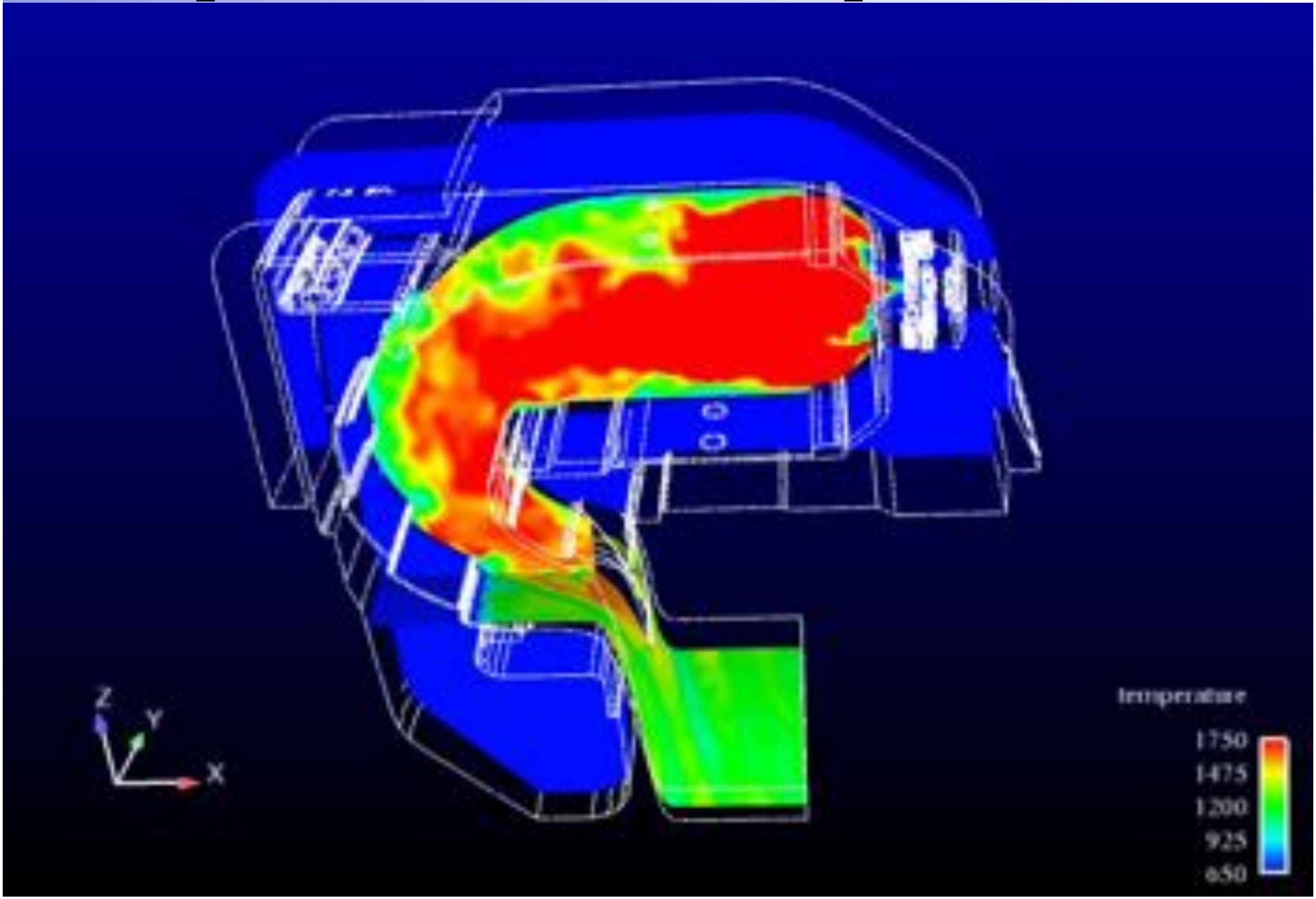
Life of an engineer in gas turbine companies:

- Turbine blade should not burn
- Efficiency should be high
- CO and NO must be low

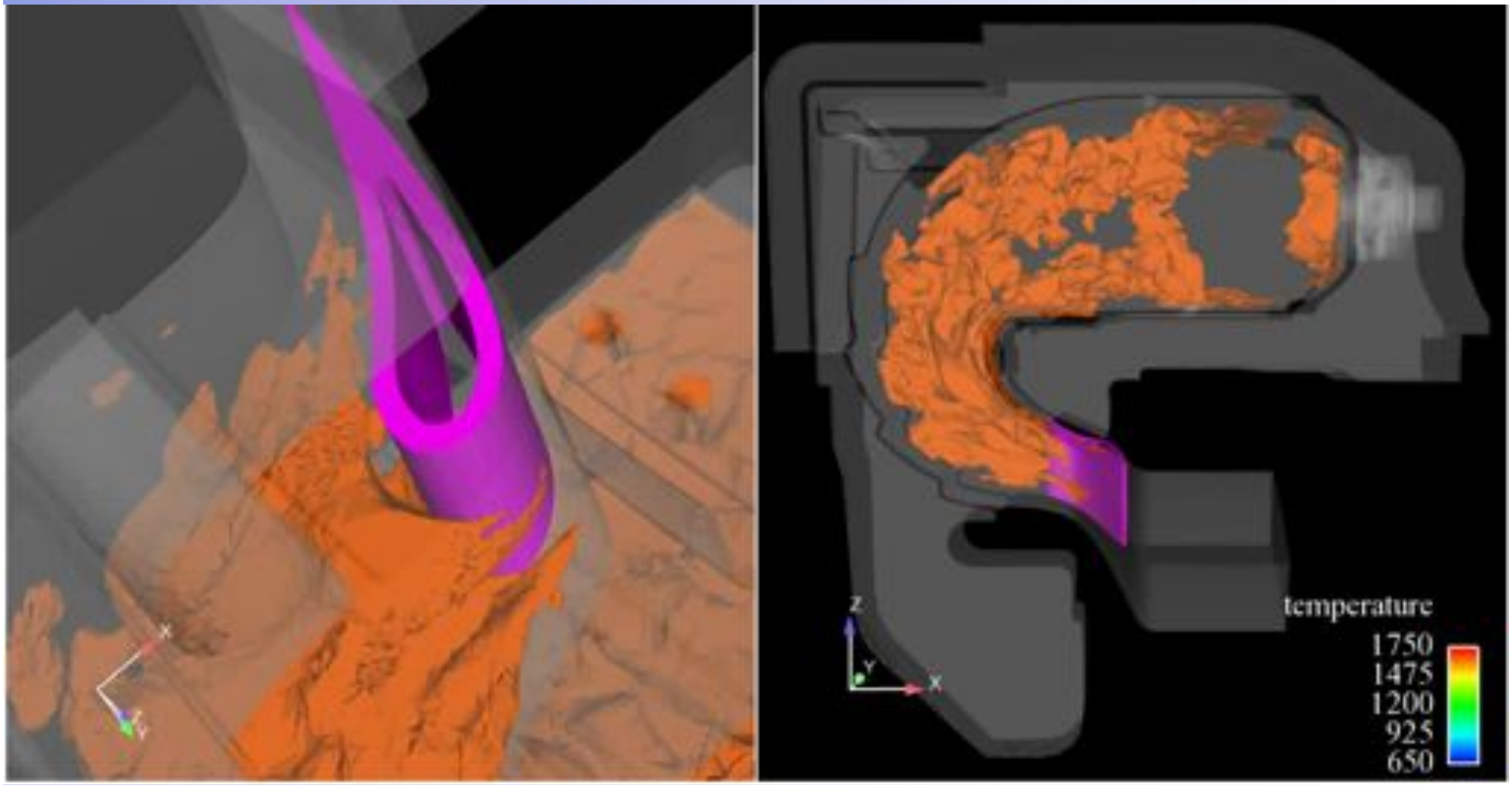


Optimization process: modify dilution jets to homogeneize temperature

Temperature field in helicopter chamber



Hot spots hitting the first stator blade

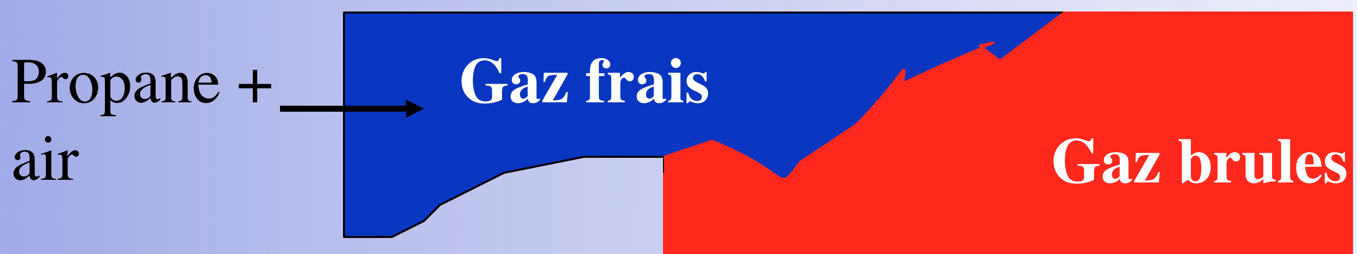


Objectives of combustion science :

- Ensure combustion chambers do not burn
- Minimize pollutant emission
- Maximize efficiency and minimize fuel consumption

This requires serious optimization work and this is what combustion experts have been doing for a long time !

Yes, we can optimize combustors BUT:



Film NASA
1980
2000 im/s

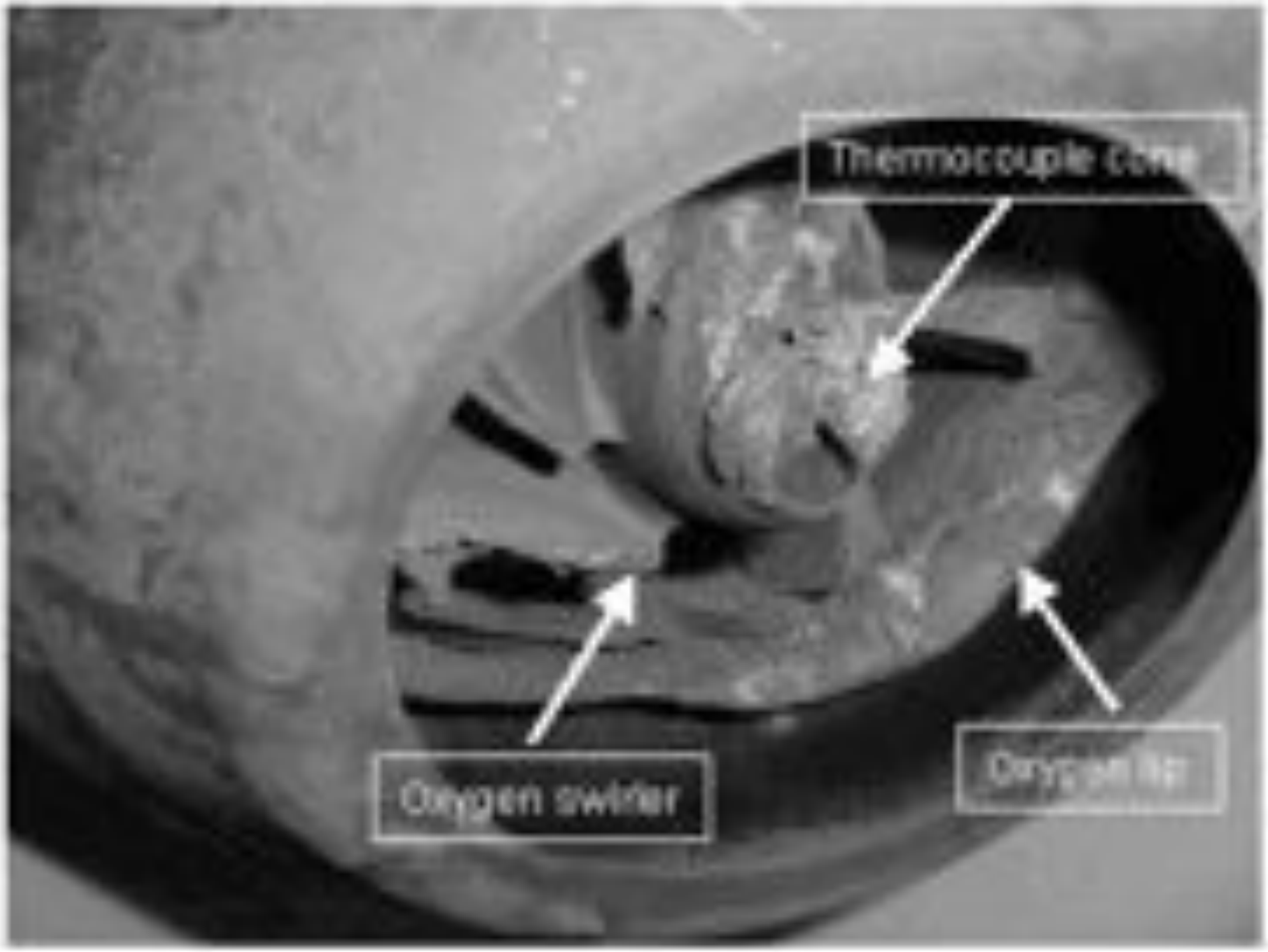
Flames do not always react to optimization as expected:

Combustion instabilities:

- Apollo / Ariane IV
- Post combustion
- Gas turbines
- Furnaces

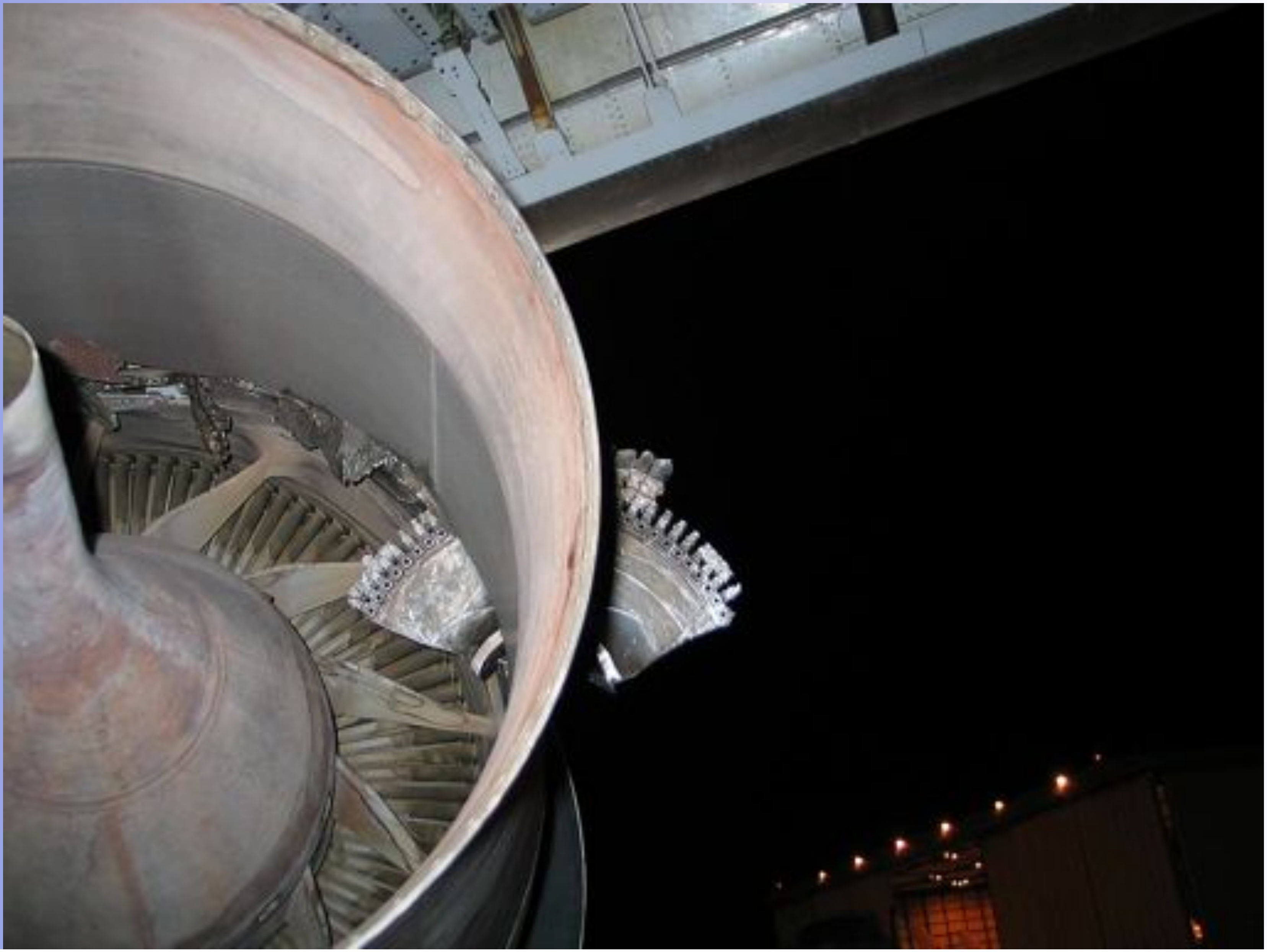
Rocket Engine Test Facility (NASA, 1957)

INDUSTRIAL GAS TURBINES



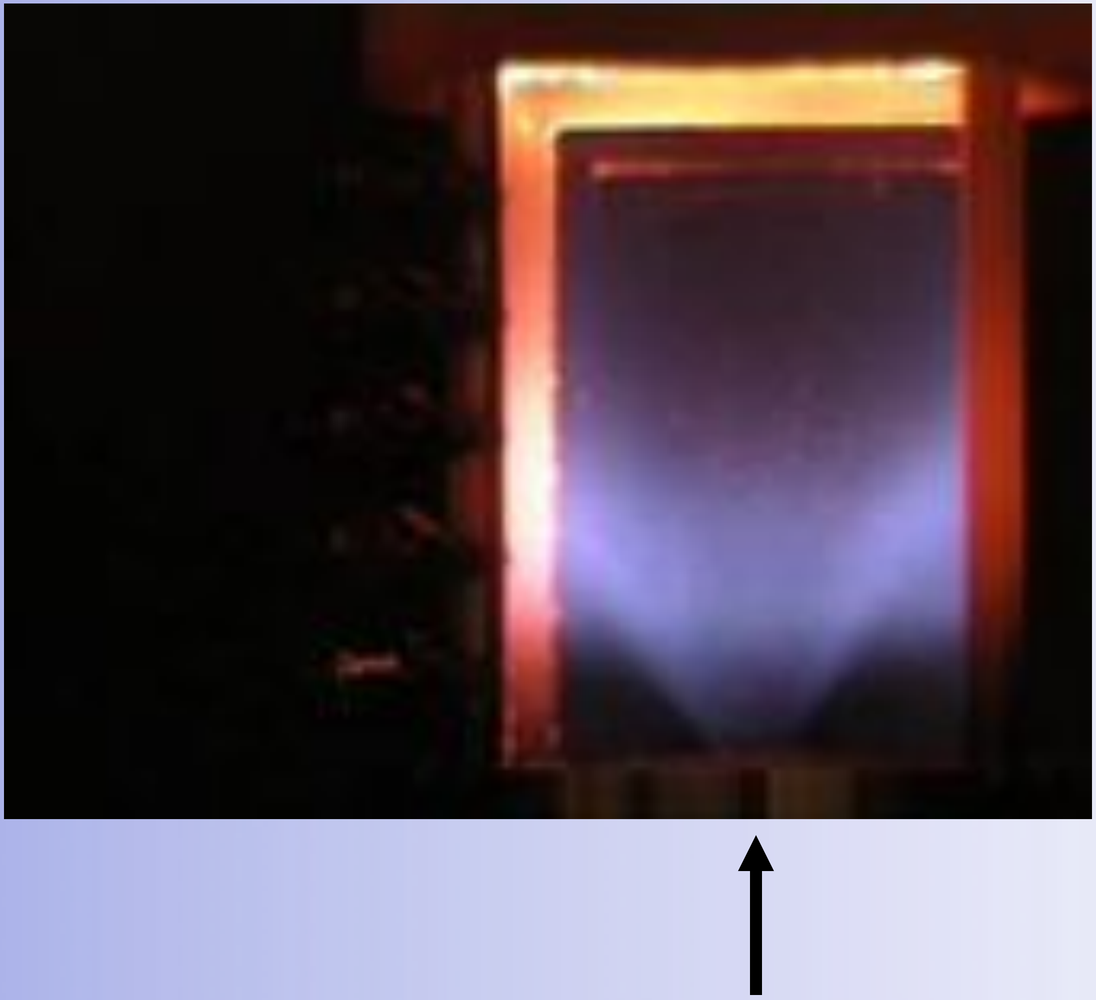

AIRCRAFTS
INJECTION DEVICES:

Good vibrations ?

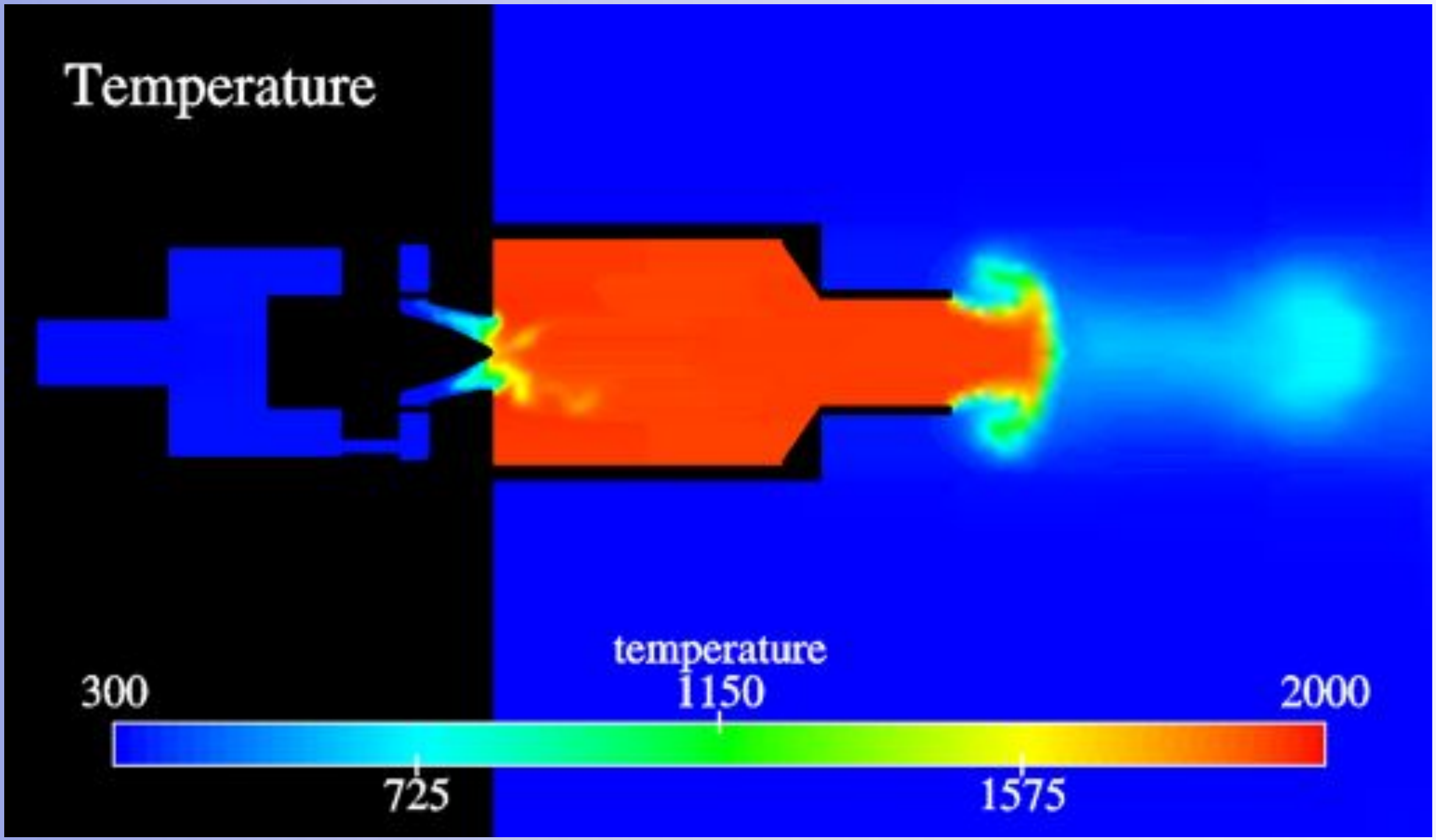


Shake it !

How does it look in a lab experiment ?



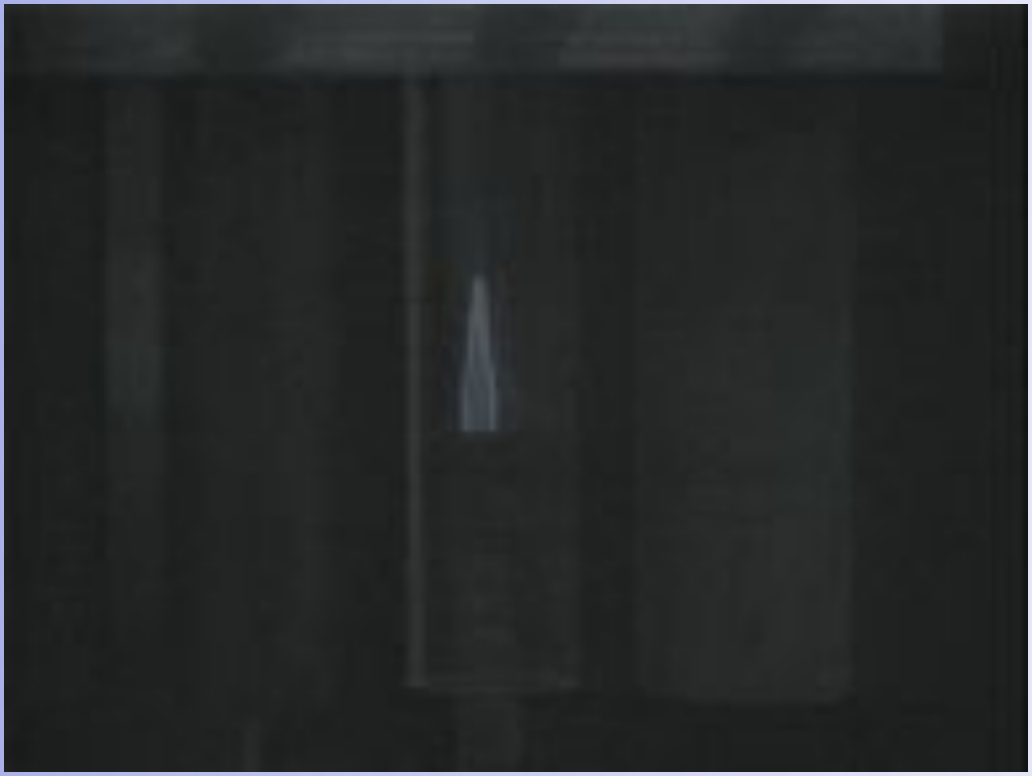
Today we can compute combustion instabilities !



PhD thesis S. Roux, CERFACS.

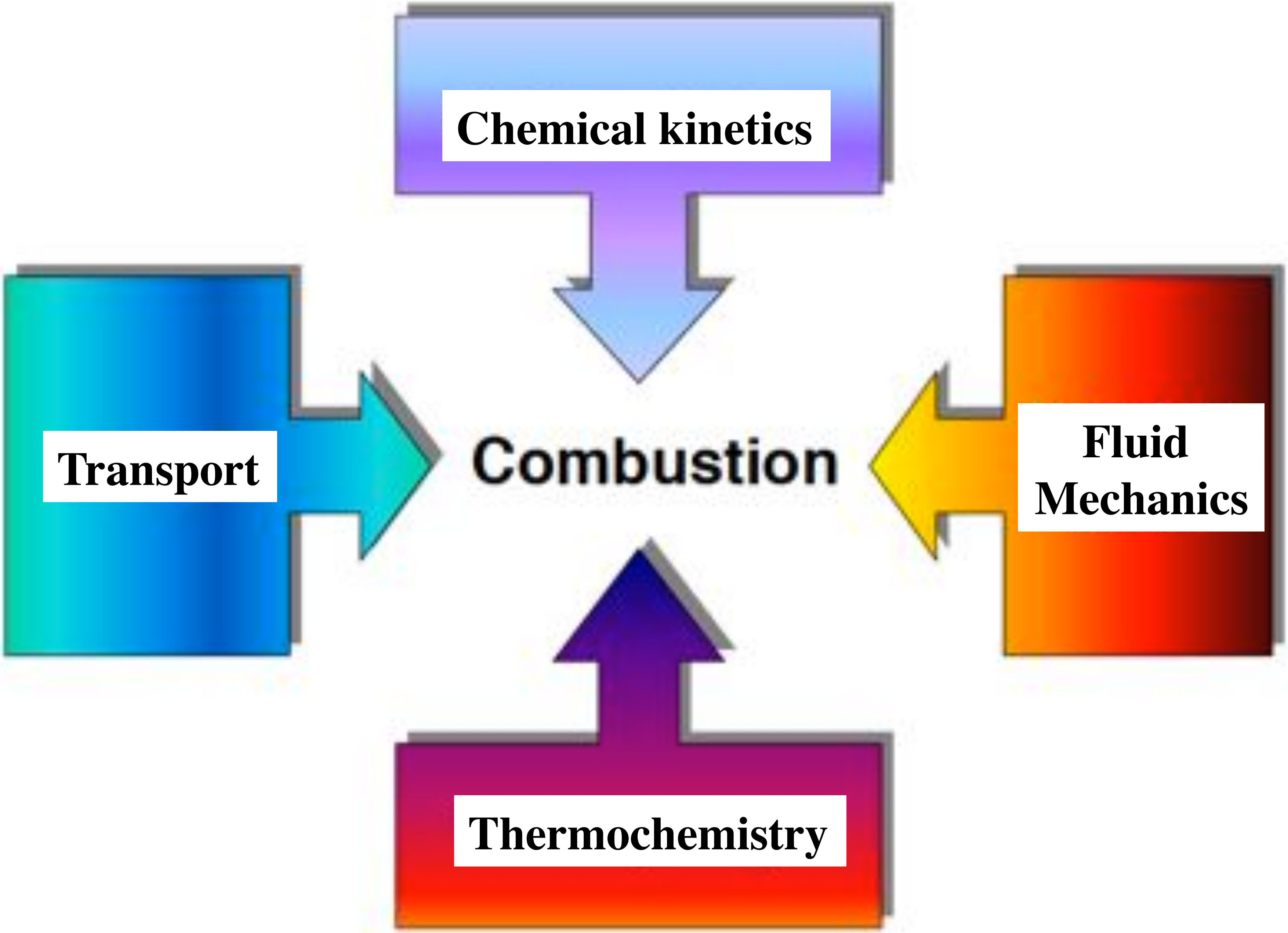
PRECCINSTA EC project.
Coordinator: Turbomeca/SNECMA.
Experiment: DLR

If you could look inside



Credit: Ecole Centrale Paris – Dr Durox

A little bit of science …



Source : Pr S. Candel

1/ Thermochemistry

- **Methane / air combustion:**

$CH_4 + 2(O_2+3.76\ N_2) \rightarrow CO_2 + 2H_20 + 2*3,76\ N_2$

Hydrocarbon fuels:

Most fuels are CnHm:

- **H_2: hydrogen** **--> gas**
- **CH_4: methane** **--> gas**
- **C_3H_8: propane** **--> gas**
- **C_8H_{18}: gasoline** **--> liquid**
- **$C_{10}H_{22}$: kerosene** **--> liquid**

Burnt with air or with oxygen only:

- **air = O_2+a N_2 with a=3.76 moles**
- **pure oxygen**

$C_nH_m + O_2$

OXYCOMBUSTION:

$C_nH_m + (n+m/4)\ O_2 \ \text{--->}\ n\ CO_2 + m/2\ H_2O$

WITH AIR:

$C_nH_m + (n+m/4)\ (O_2 + a\ N_2) \ \text{--->}\ n\ CO_2 + m/2\ H_2O + (n+m/4)\ a\ N_2$

Stoechiometry:

$CH_4 + 2(O_2+3.76\ N_2) \rightarrow CO_2 + 2H_20 + 2*3,76\ N_2$

This is stoechiometry (1 mole of CH_4 for 2 moles of O_2) BUT what if we have less (or more) than one mole of CH_4 for 2 moles of O_2:

$fCH_4 + 2(O_2+3.76\ N_2) \rightarrow\ ?\ CO_2 + ?H_20 +\ ?\ N_2$

If $f<1$: lean combustion

If $f>1$: rich combustion

Combustion : lean or rich

If f < 1: lean

f CH_4 + 2(O_2+3.76 N_2) -->

f CO_2 +2f H20+ 2*3.76 N_2+2(1-f) O_2

Oxygen is left

If f>1: rich

f CH_4 + 2(O_2+3.76 N_2) -->

CO_2 +2 H20+ 2*3.76 N_2+(f-1)CH_4

Unburnt hydrocarbons are left (CO too usually)

Application	Values of f
Gasoline engines	1
Direct Injection at idle	0.4
Gas turbine	0.3-1
Formula 1 engine	1.2
Motocycle engine (carburator)	1.1

2/ Chemical kinetics: speed at which chemistry proceeds:

CH4 + 2(O2+3.76 N2) --> CO2 +2H20+ 2*3,76 N2

INITIAL **FINAL**

This is the field of chemical kinetics: try to know how much time this reaction needs to proceed. In other words, what is the reaction speed ?

Chemical kinetics

$H_2 + 1/2\ O_2 \rightarrow H_2O$

Initial **Final**

Looks simple but never happens

H_2 never meets O_2…

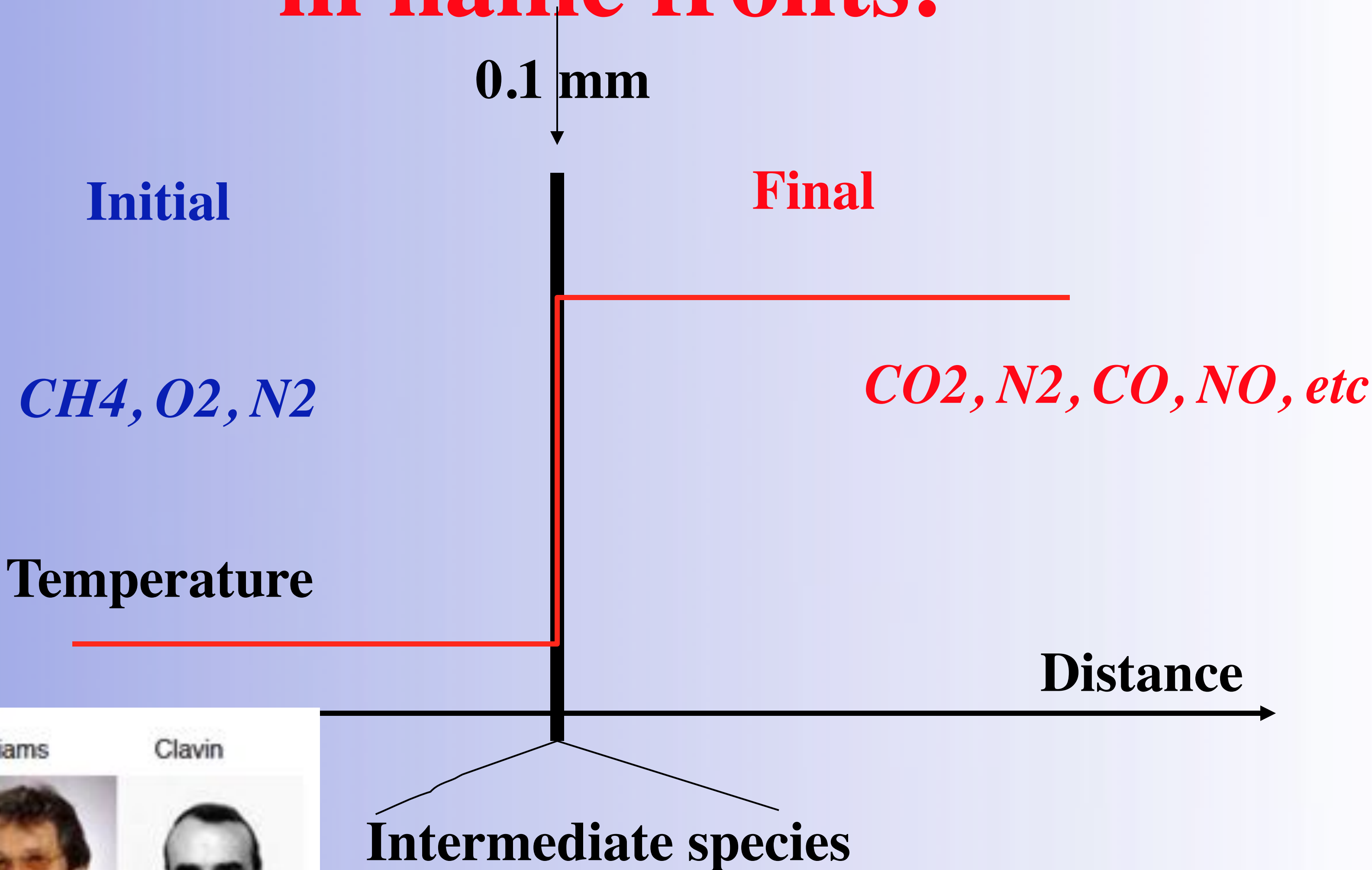
Chemical kinetics

```
ELEMENTS
 H  O   N
END
SPECIES
H2 O2 OH O H H2O HO2 H2O2 N N2 NO
END
REACTIONS
H2+O2=OH+OH                    1.700E13   0.0    47780.
H2+OH=H2O+H                    1.170E09   1.30    3626.
H+O2=OH+O                      5.130E16  -0.816  16507.
O+H2=OH+H                      1.800E10   1.0     8826.
H+O2+M=HO2+M                   2.100E18  -1.0       0.
  H2/3.3/ O2/0./ N2/0./  H2O/21.0/
H+O2+O2=HO2+O2                 6.700E19  -1.42      0.
H+O2+N2=HO2+N2                 6.700E19  -1.42      0.
OH+HO2=H2O+O2                  5.000E13   0.0    1000.
H+HO2=OH+OH                    2.500E14   0.0    1900.
O+HO2=O2+OH                    4.800E13   0.0    1000.
OH+OH=O+H2O                    6.000E08   1.3       0.
H2+M=H+H+M                     2.230E12   0.5   92600.
  H2/3./ H/2./  H2O/6.0/
O2+M=O+O+M                     1.850E11   0.5   95560.
H+OH+M=H2O+M                   7.500E23  -2.6       0.
  H2O/20.0/
HO2+H=H2+O2                    2.500E13   0.0     700.
HO2+HO2=H2O2+O2                2.000E12   0.0       0.
H2O2+M=OH+OH+M                 1.300E17   0.0   45500.
H2O2+H=H2+HO2                  1.600E12   0.0    3800.
H2O2+OH=H2O+HO2                1.000E13   0.0    1800.
END
```

Standard CHEMKIN

Sven August Arrhenius

Chemical kinetics happen in flame fronts:



Difference between thermochemistry and chemical kinetics

CH4 + 2(O2+3.76 N2) --> CO2 +2H20+ 2*3,76 N2

- Thermochemistry deals only initial and final states
- Totally independent of the speed at which one goes from initial to final state

APPLICATION: adiabatic flame temperature

-> see www.cerfacs.fr/elearning:

« Adiabatic flame computations »

Chemical kinetics:

- Gives the speed at which one goes from one state to the other !

- Need chemical schemes

3/ Transport and equation of state

Most of you know air as « $O2 + 3,76\ N2$ » in moles

AERODYNAMICS: for classical air

- **32 grammes of oxygen**
- **and 3.76*28= 105.3 grammes of N2**

Total = 32+105.3=137.3 grammes

The mass fraction of O2:

YO2= mass of O2/total mass = 32/137.3=0.233

And for N2:

YN2= 1-YO2=0.767

Molecular weight: W=(32+3,76*28)/(1+3,76)=28.8 g

State equation: $p=\rho\ r\ T$ with r=R/W=288 J/kg/K

Cp = Cp=5/2*R/W=5/2*8.315/0.0288=1004 J/kg/K

With combustion: it is more complex. We need to compute mass fractions of each species in a gas which contains many such species

INSTEAD OF:

O2+3.76 N2

WE NOW MUST TAKE INTO ACCOUNT:

CnHm, O2, CO2, H2O, OH, CO, OH2, H2O2,…

…………….. Usually 100 to 3000 species

The 'COMPOSITION' of the gas must be computed: mass fractions of the N species present in the gas:

$$Y_k = \frac{m_k}{m}$$

m_k: Mass of species k in V

m: Total mass in V

$$\frac{\partial \rho Y_k}{\partial t} + \frac{\partial}{\partial x_i}(\rho(u_i + V_{k,i})Y_k) = \dot{\omega}_k$$

$V_{k,i}$: Diffusion ← Transport

$\dot{\omega}_k$: Reaction ← Chemical kinetics

Chemical kinetics: flames are very sensitive to temperature

At which speed does the reaction A + B --> C proceed ?

$$\dot{\omega} = A Y_A^{\nu_A} Y_B^{\nu_B} exp(-T_a/T)$$

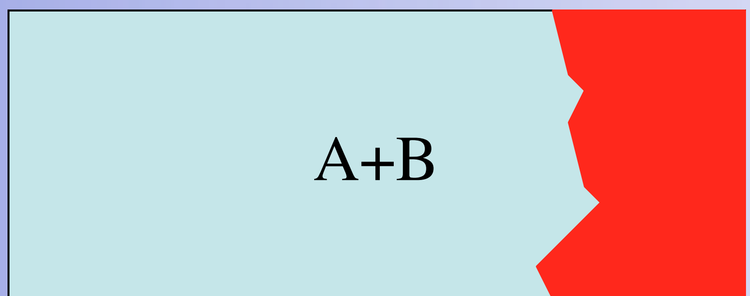
We need:

- **A**
- **B**
- **high temperature**

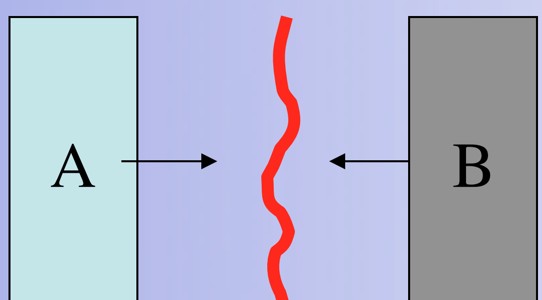
This expression is called 'Arrhenius' form

Having 3 ingredients together for combustion to occur leads to combustion 'regimes':

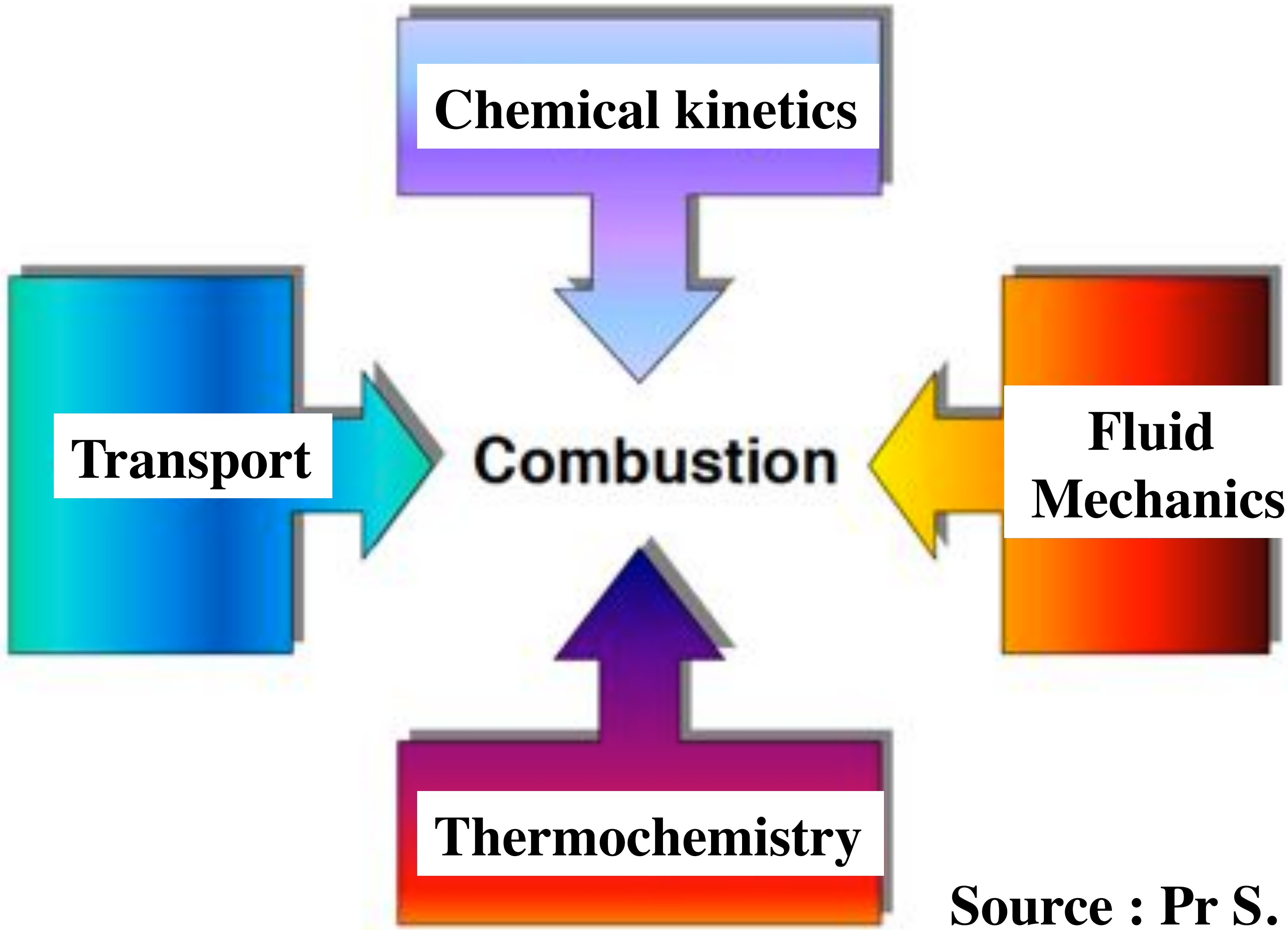
PREMIXED: First mix A and B, then bring T



DIFFUSION: A and B are mixed at the last instant and they burn at the same time



THIS IS WHERE FLUID MECHANICS GET INTO THE PICTURE. THE COMBUSTION REGIMES DEPEND ON THE FLOW ORGANIZATION: -> This is the last element we need to study !



Source : Pr S. Candel

FLUID MECHANICS AND MIXING:

PREMIXED:

The most efficient
The most dangerous

CH4 + Air

DIFFUSION (or NON-PREMIXED):

Less efficient
More pollution
Less dangerous

CH4

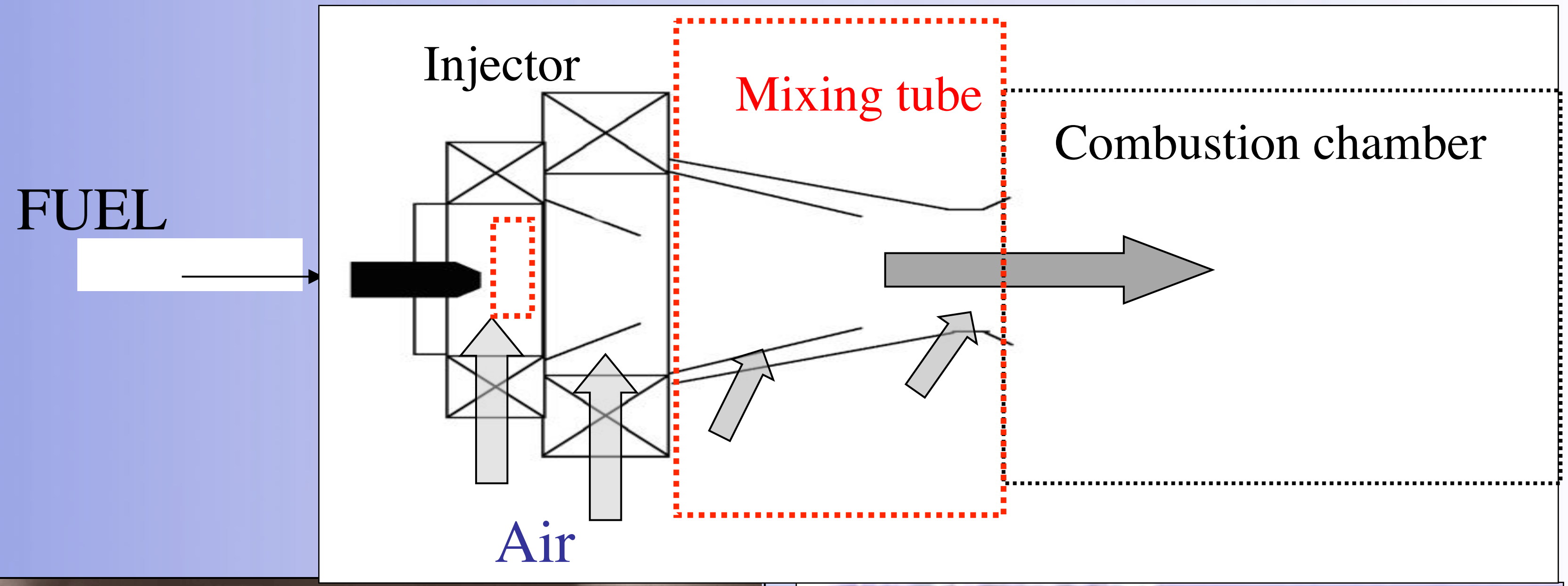
Air

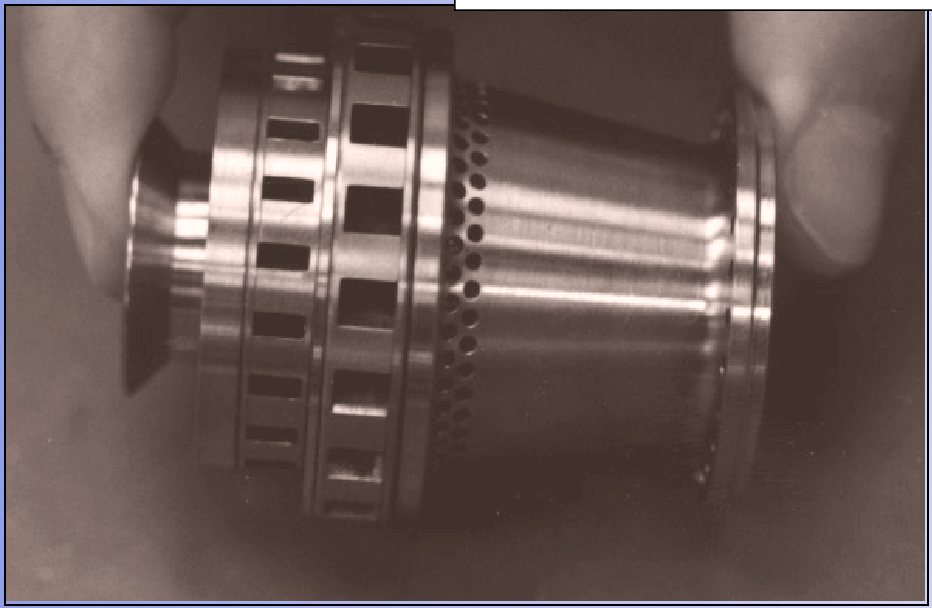
IN PRACTICE:

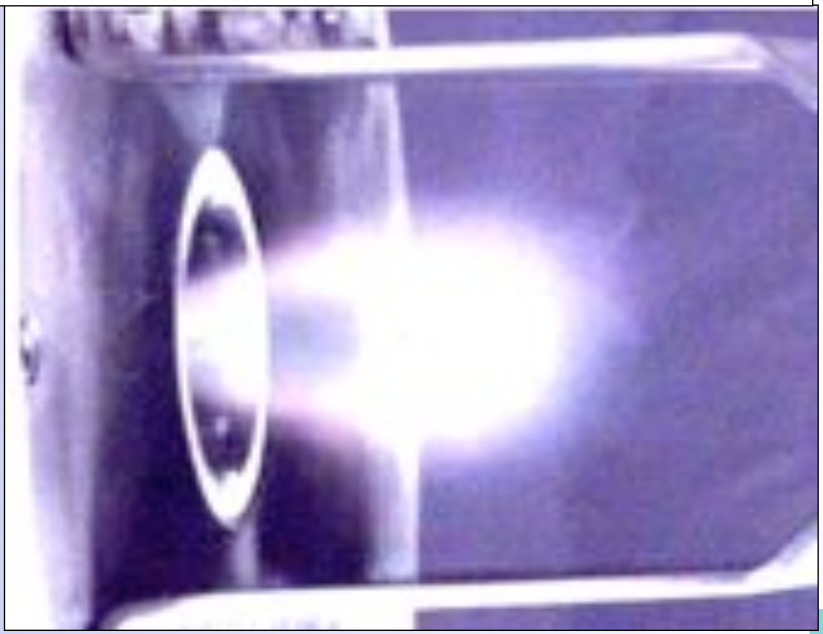
We can not use premixed systems for safety reasons (who wants a bomb at home or in your car ?) but we try to premix gases as much as possible within the combustor itself, just before we burn it.

Example: Lean Premixed Prevaporized systems in gas turbines

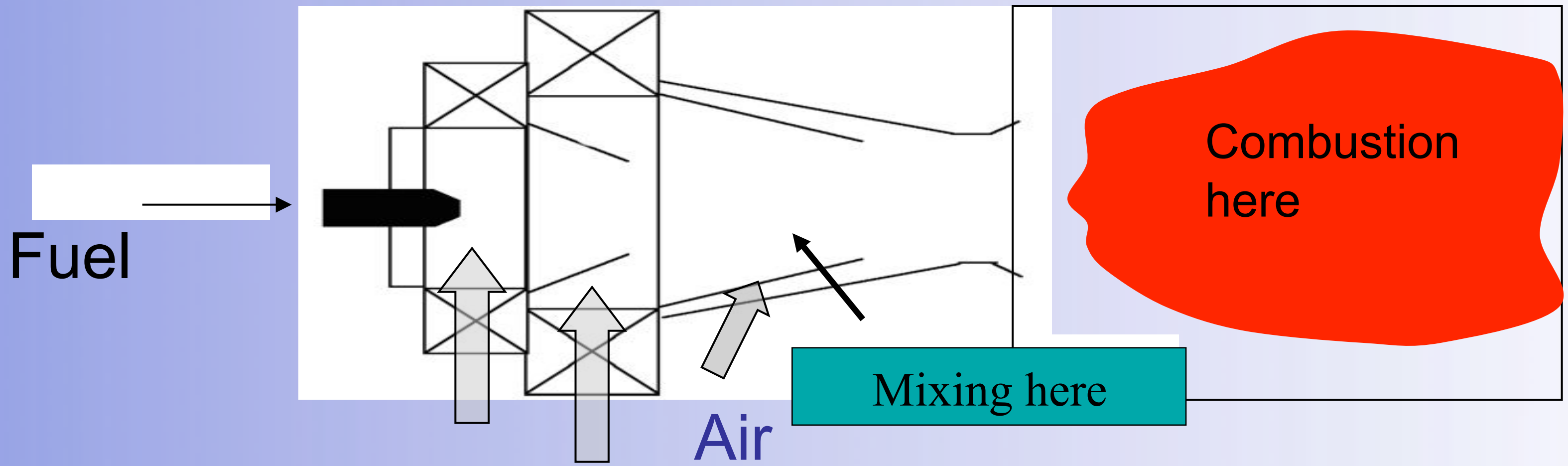
Manipulating combustion regimes with fluid mechanics:

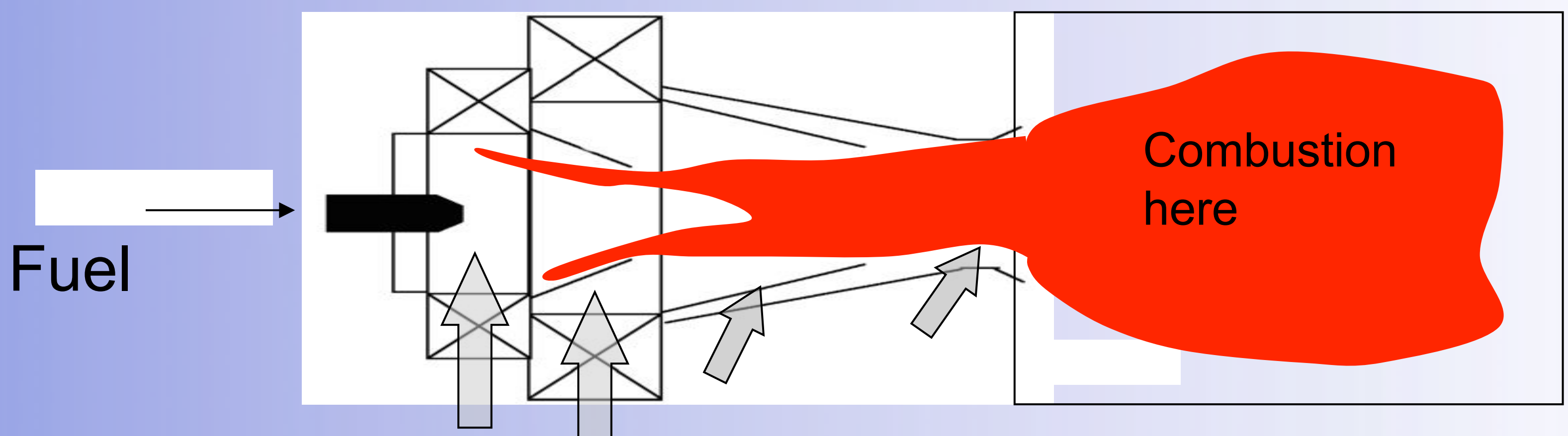






This is what we hope for:

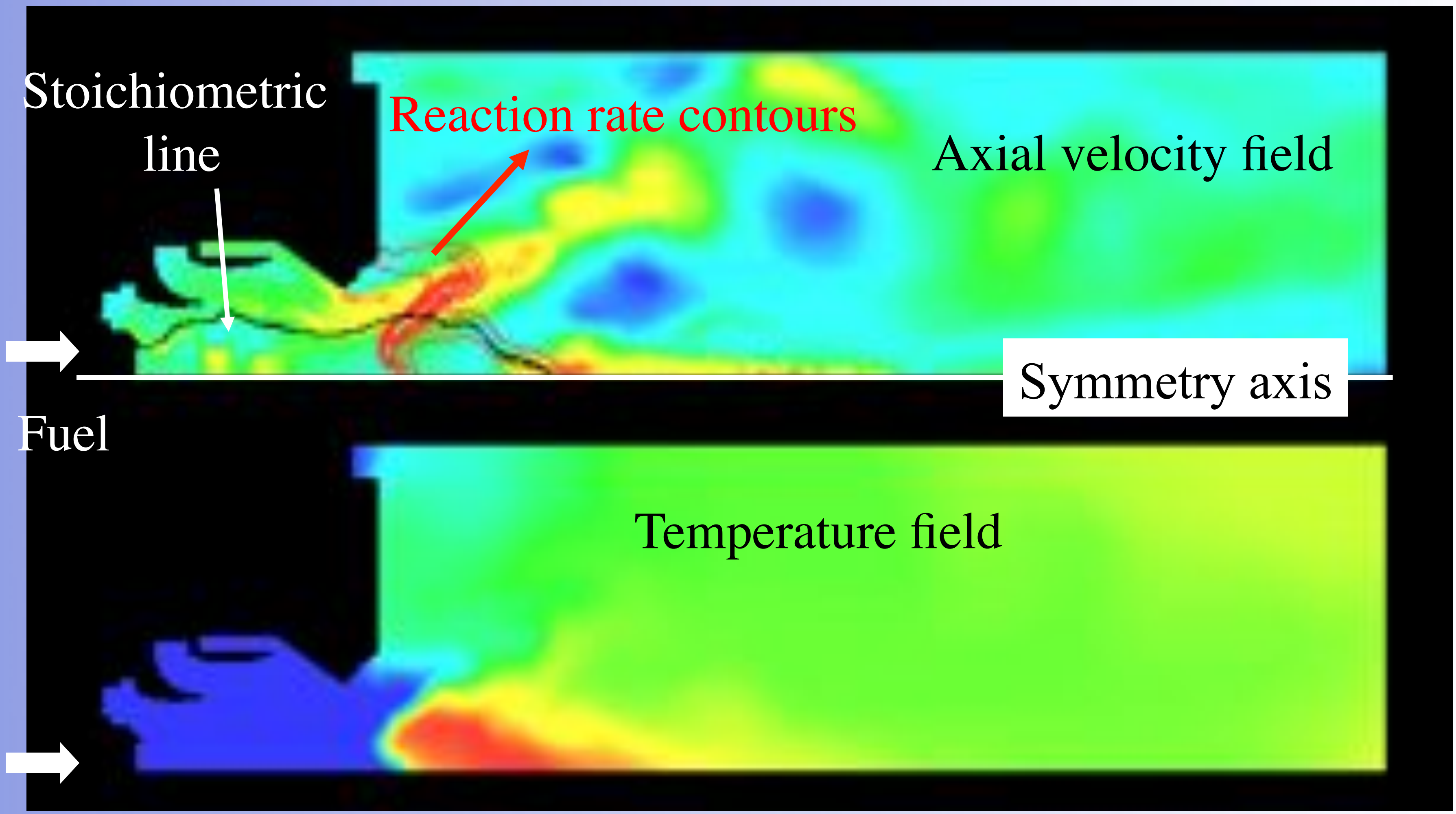




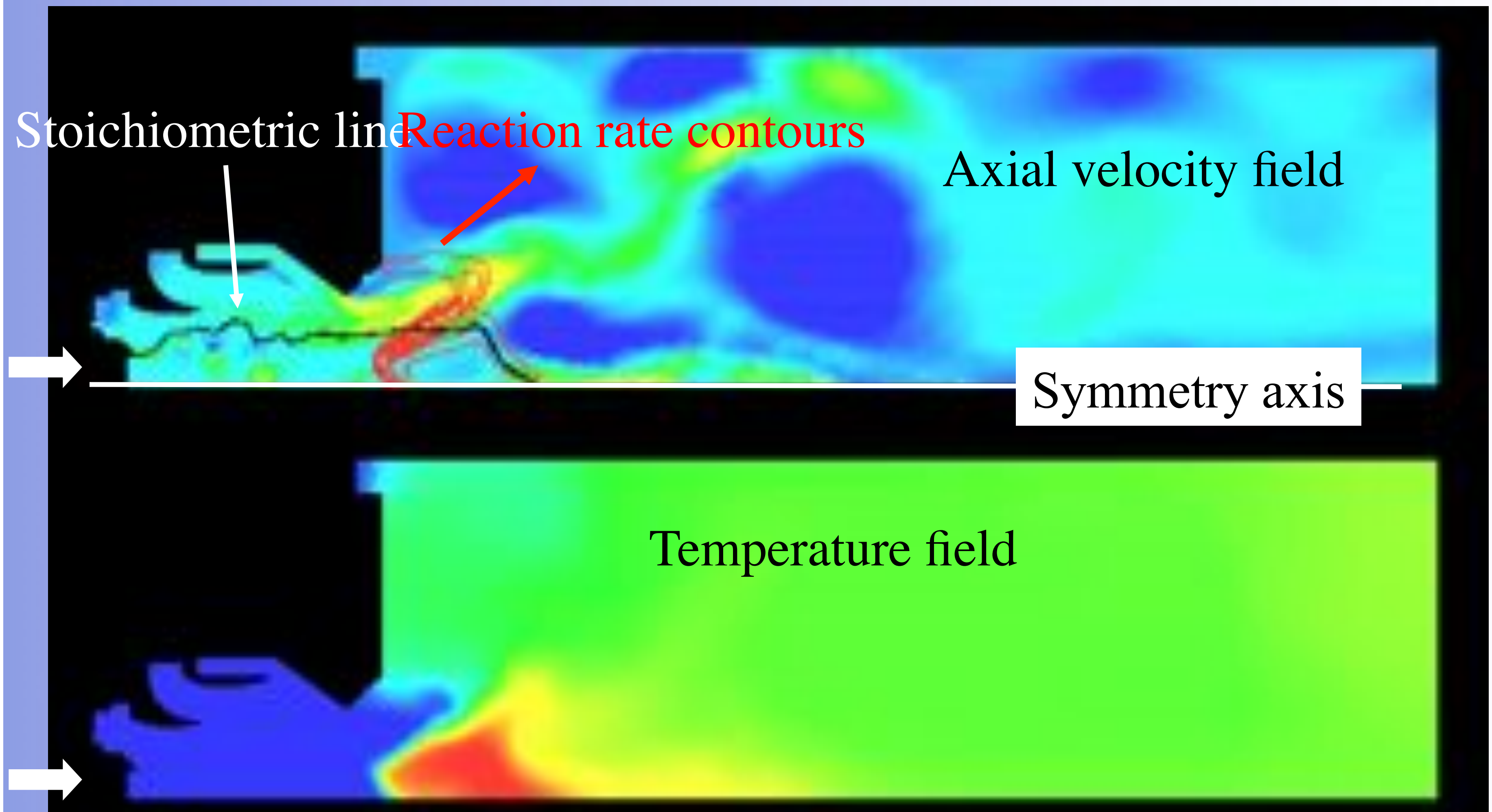
This is what can happen: flashback

Example of LPP after flashback:

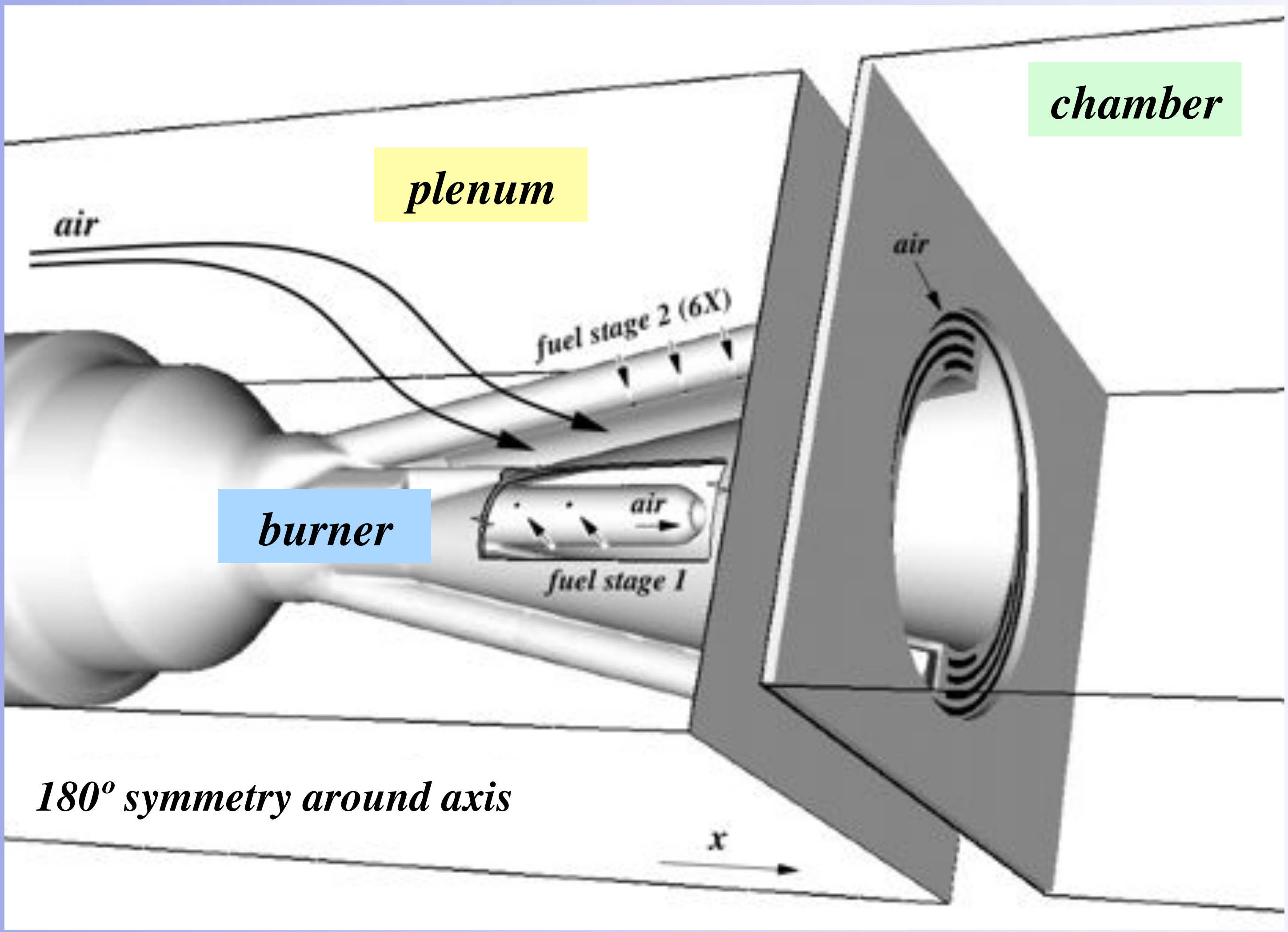
Illustration of the new capabilities offered by LES:
LES of a LPP nominal case (for this simulation, fuel is gaseous). The LES predicts that the flame stays near the dump plane



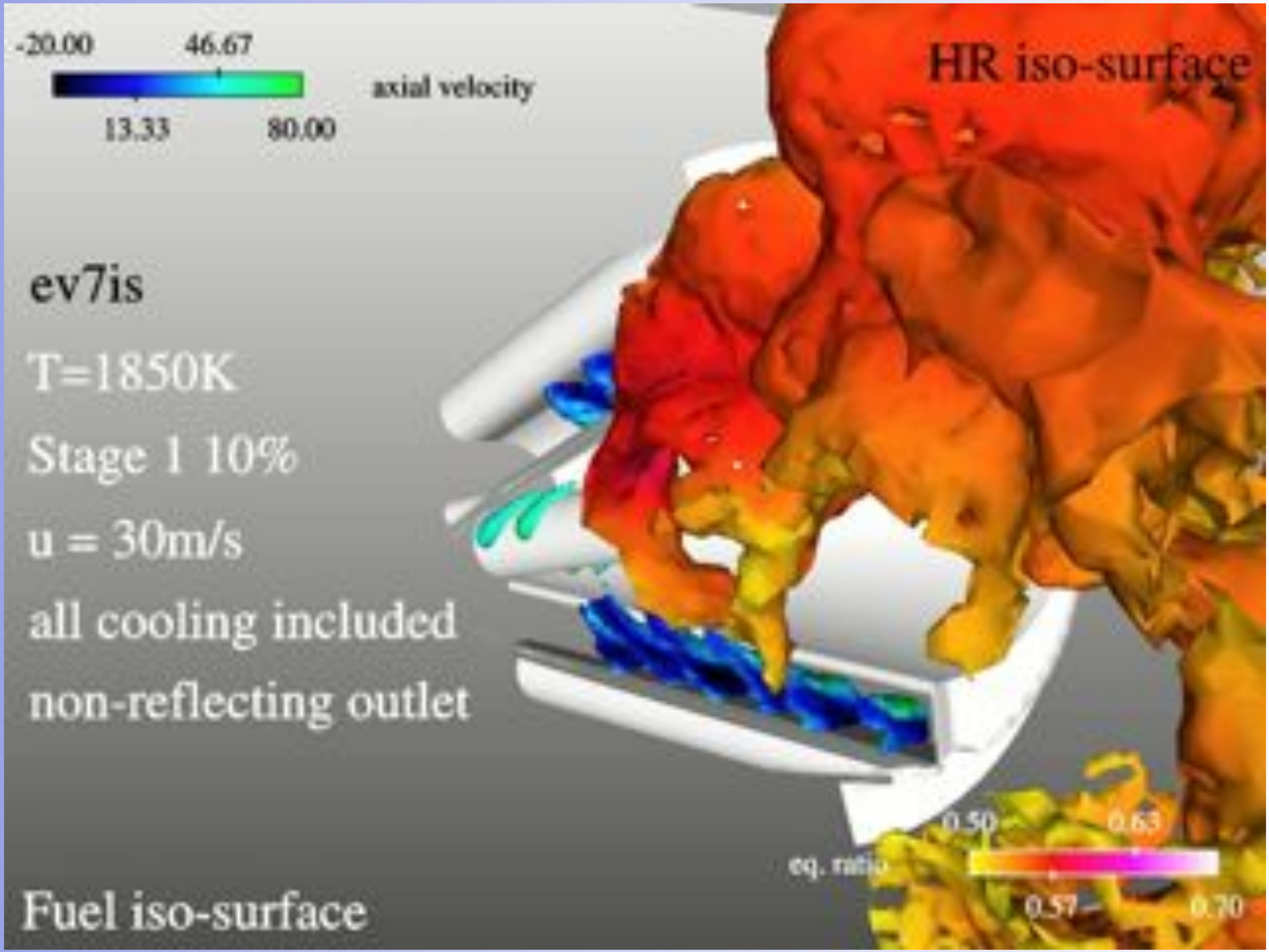
LES of flashback: the fuel and the air flow rate are divided by two during the simulation to mimic a change of regime: the flame flashes back...

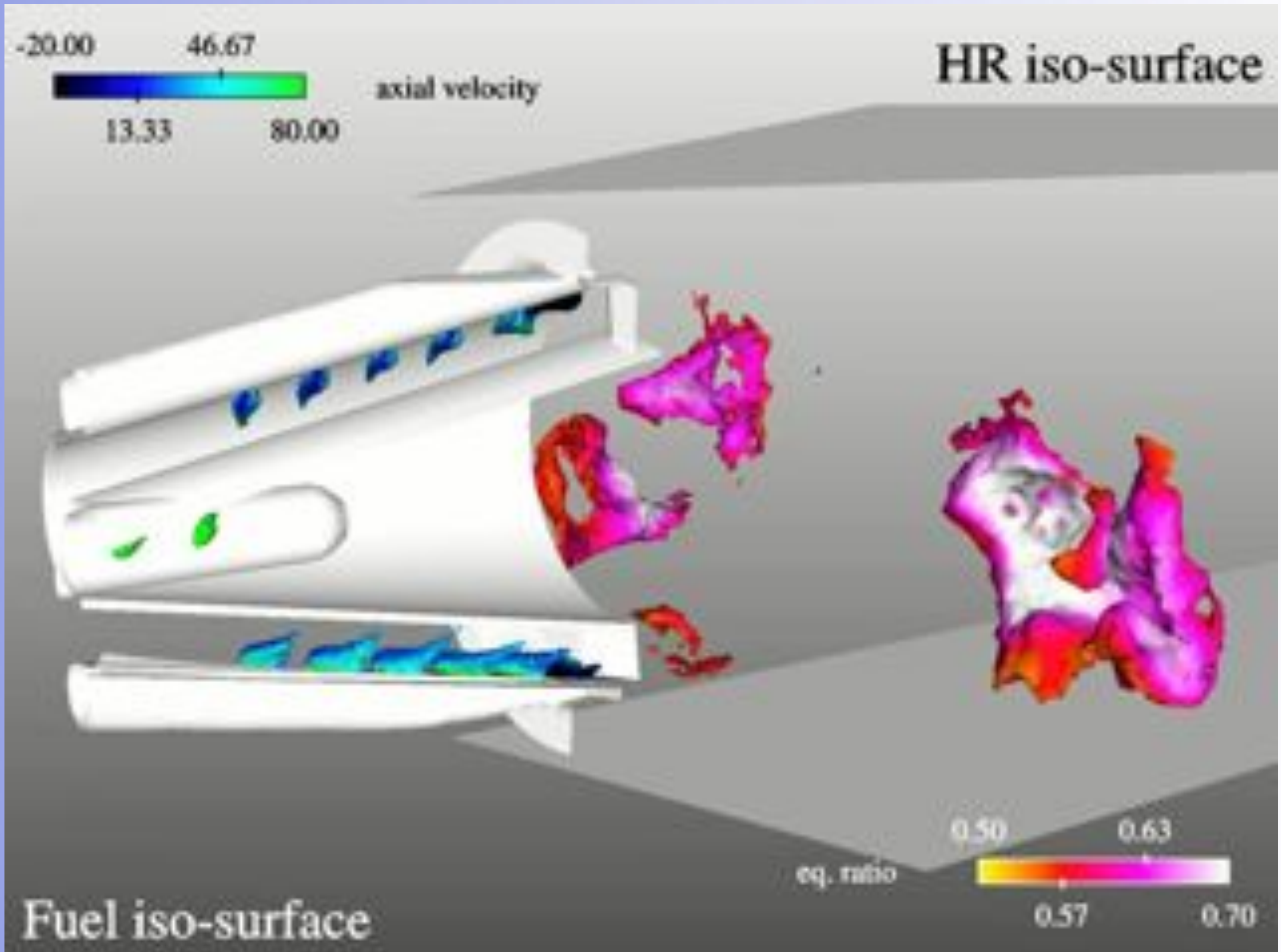


Detailed view of the **ev7is** **(Alstom)**



PhD P. Schmitt 29 June 2005

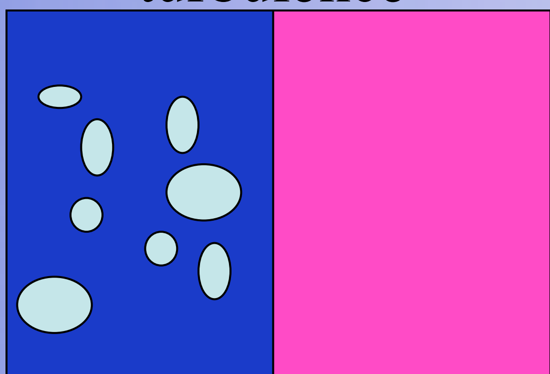

-20.00
46.67
13.33
80.00
axial velocity
HR iso-surface
ev7is
T=1850K
Stage 1 10%
u = 30m/s
all cooling included
non-reflecting outlet
0.50
0.63
eq. ratio
0.57
0.70
Fuel iso-surface


-20.00
46.67
13.33
80.00
axial velocity
HR iso-surface
0.50
0.63
eq. ratio
0.57
0.70
Fuel iso-surface

Influence of turbulence

If fresh gases are turbulent, the flame will be too !

Reactants + turbulence



This makes combustion science much more difficult

Laminar

Lighter
Candle

Turbulent

Rockets
Cars
Aircraft
Furnaces
Power plants
etc

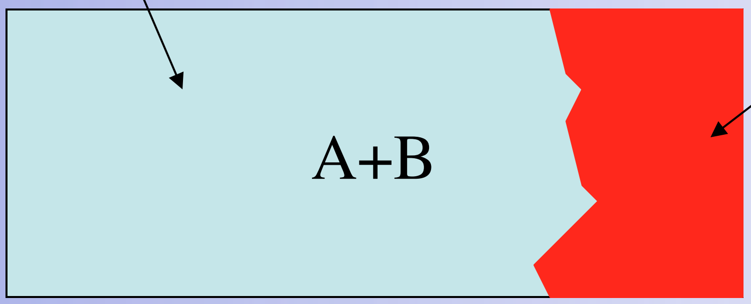
It gets hot

Chemical reactions release heat.

Temperature goes up and density goes down

T1 = 300 to 900 K
Rho1= 1 kg/m3 at P=1 bar

T2 = 1500 to 3000 K
Rho1= 0.2 kg/m3 at P=1 bar



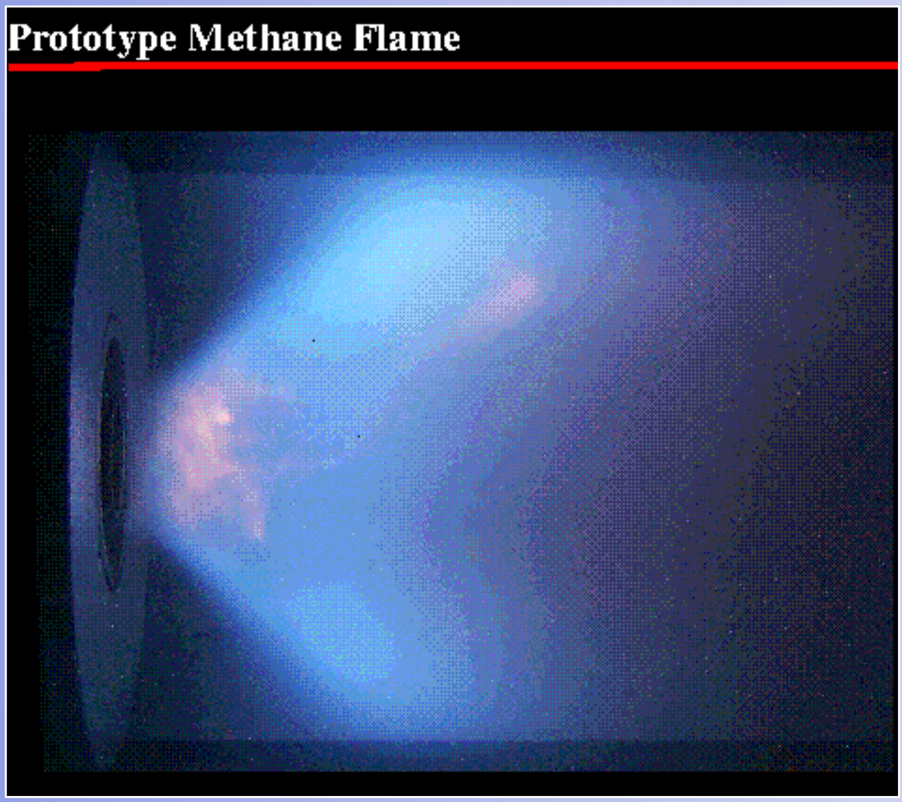
Less known: burnt gases become more viscous

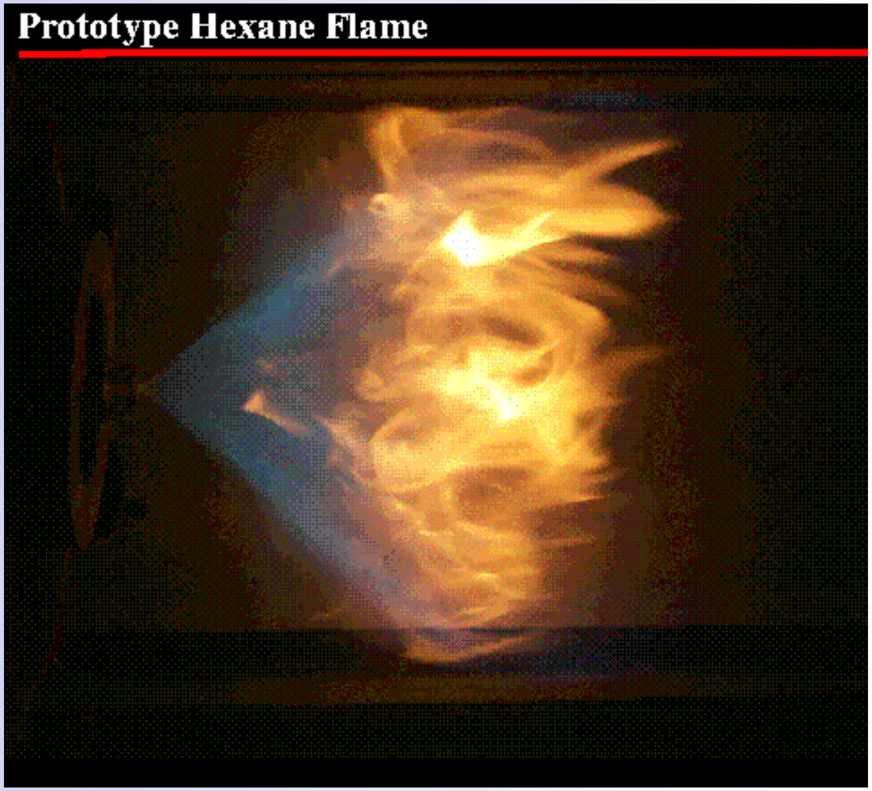
The kinematic viscosity changes like T^2

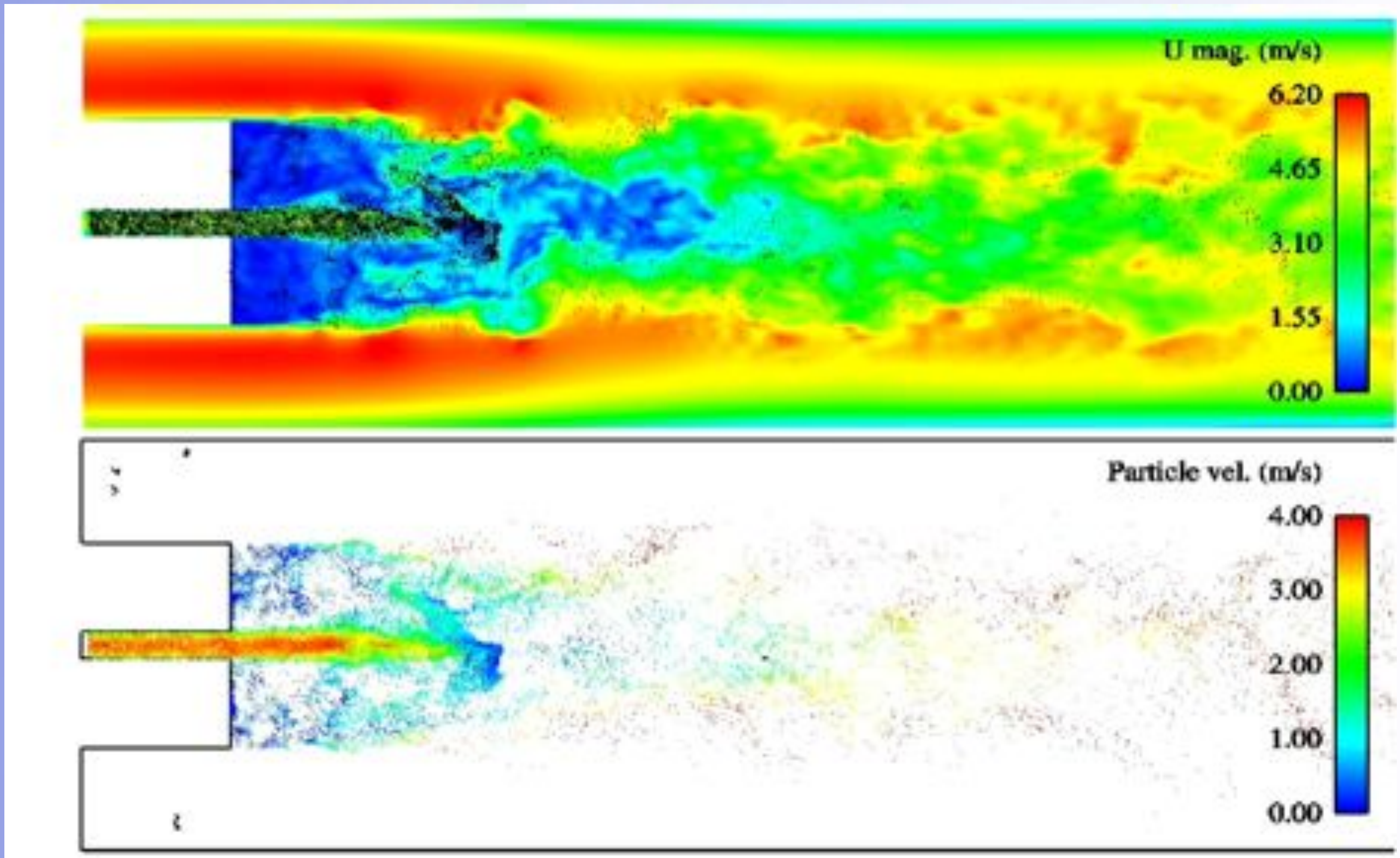
nu2/nu1 = 10 to 50

Now, what about droplets ?

The fuel is often liquid: gasoline, kerosene, Diesel fuel

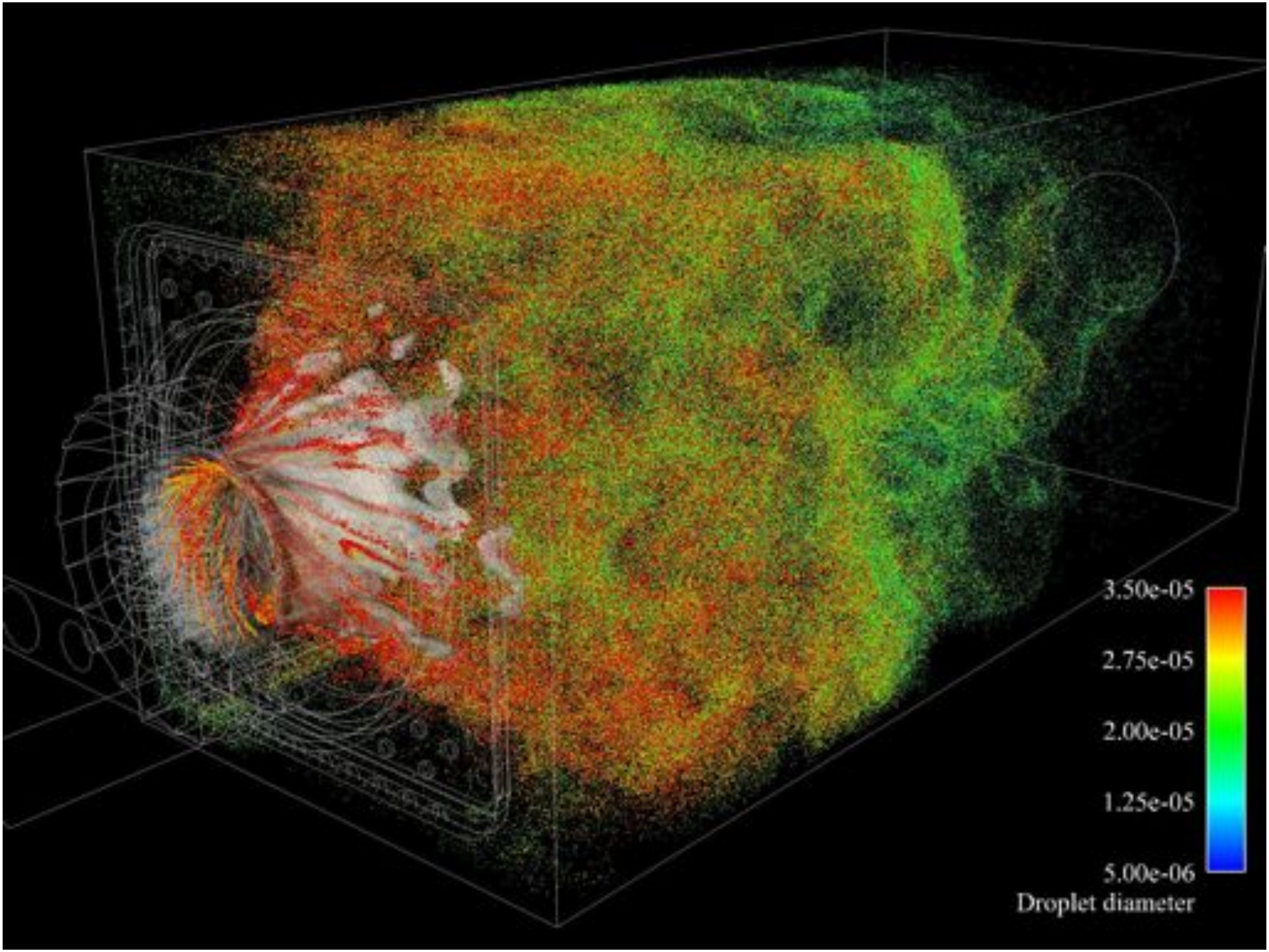




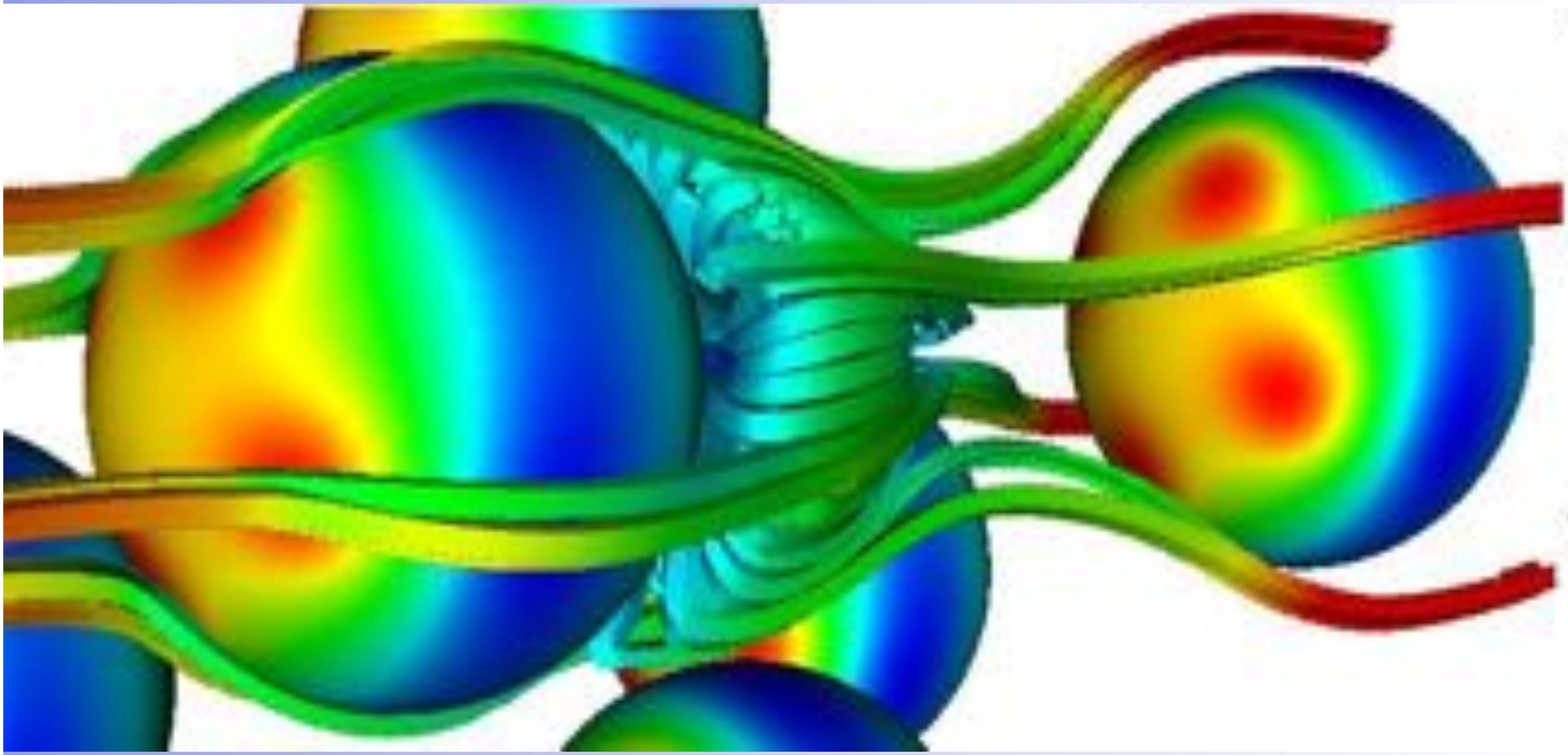


Credit: V. Moureau

1 m


3.50e-05
2.75e-05
2.00e-05
1.25e-05
5.00e-06
Droplet diameter

At the level of droplets, the flow also becomes complex



0.5 mm

PhD A. Massol CERFACS / IMFT

Ignition: how do we start it ?

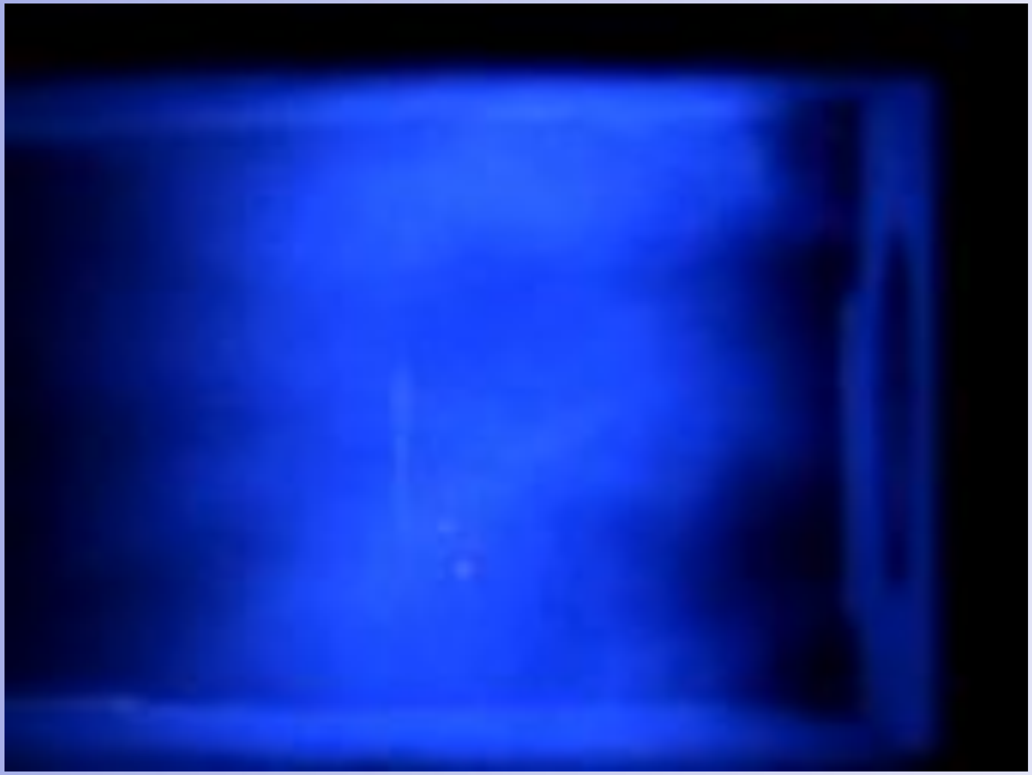
SPARK: gasoline engines (one ignition at each cycle), gas turbines (one ignition when you start the engine)

AUTOIGNITION: Diesel engine(each cycle), certain parts of certain gas turbines

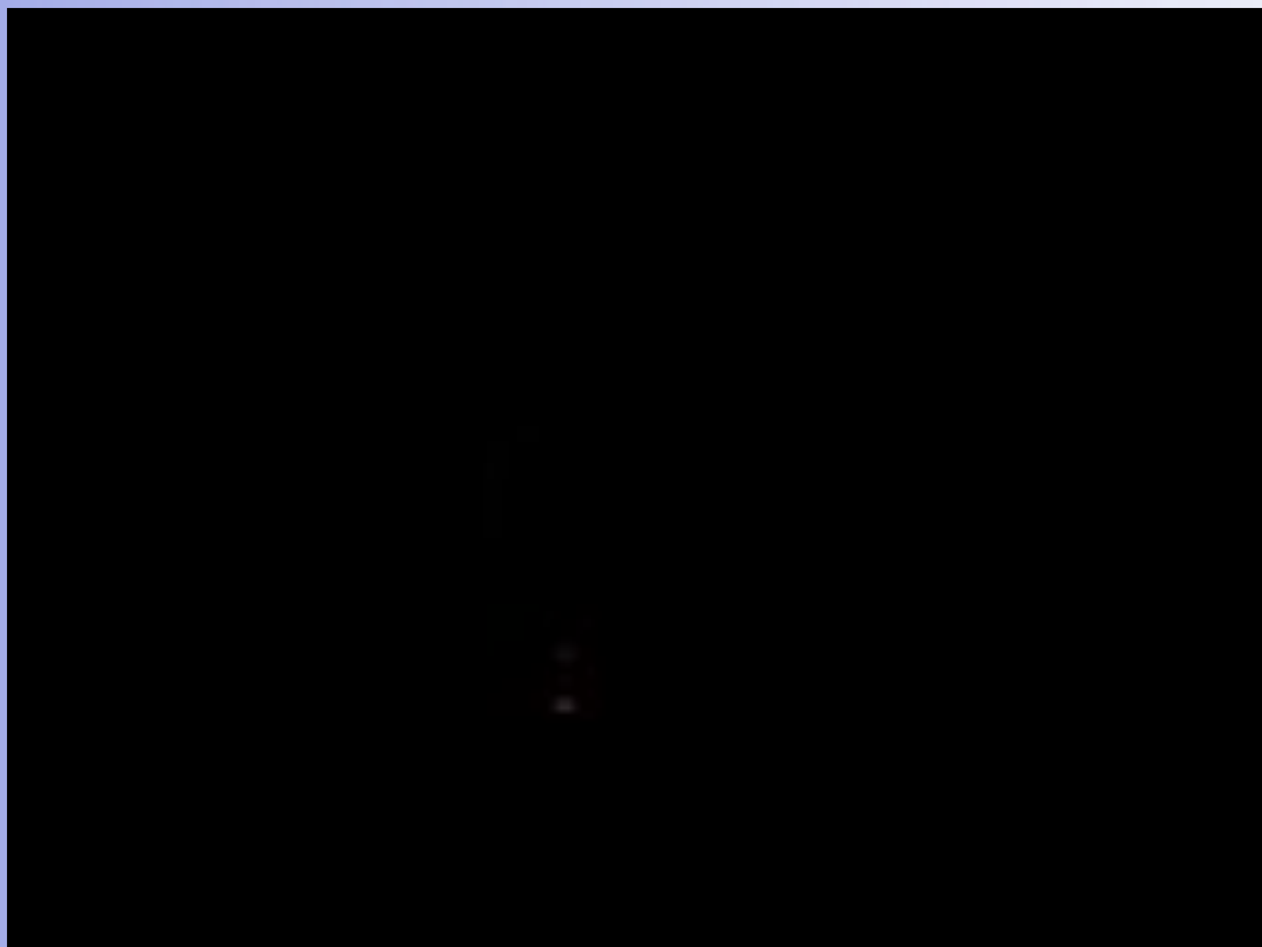
Ignition is also re-ignition: aircraft engine

Ignition is also… avoiding ignition -> safety issues !

DIRECT VIEW IN A LAB BURNER:



Air + fuel

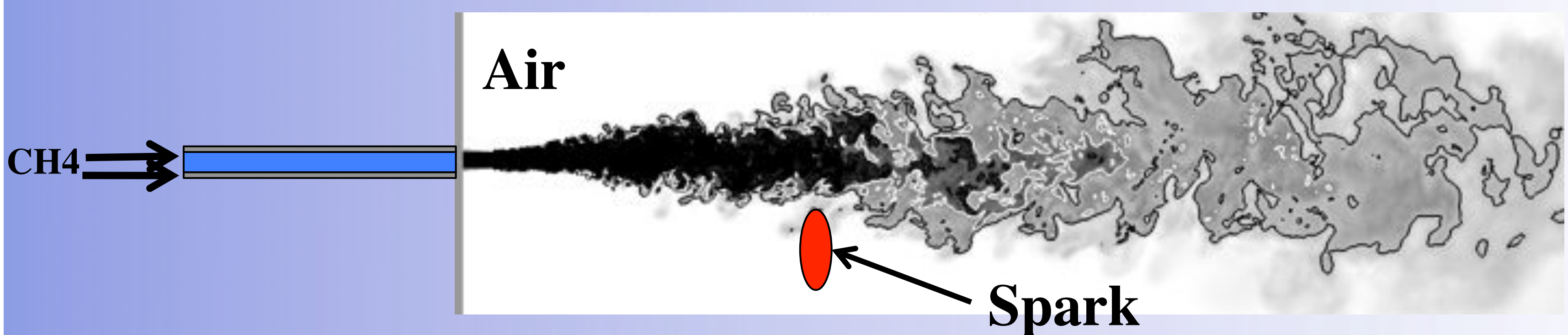


Air + fuel

Source: EM2C Paris

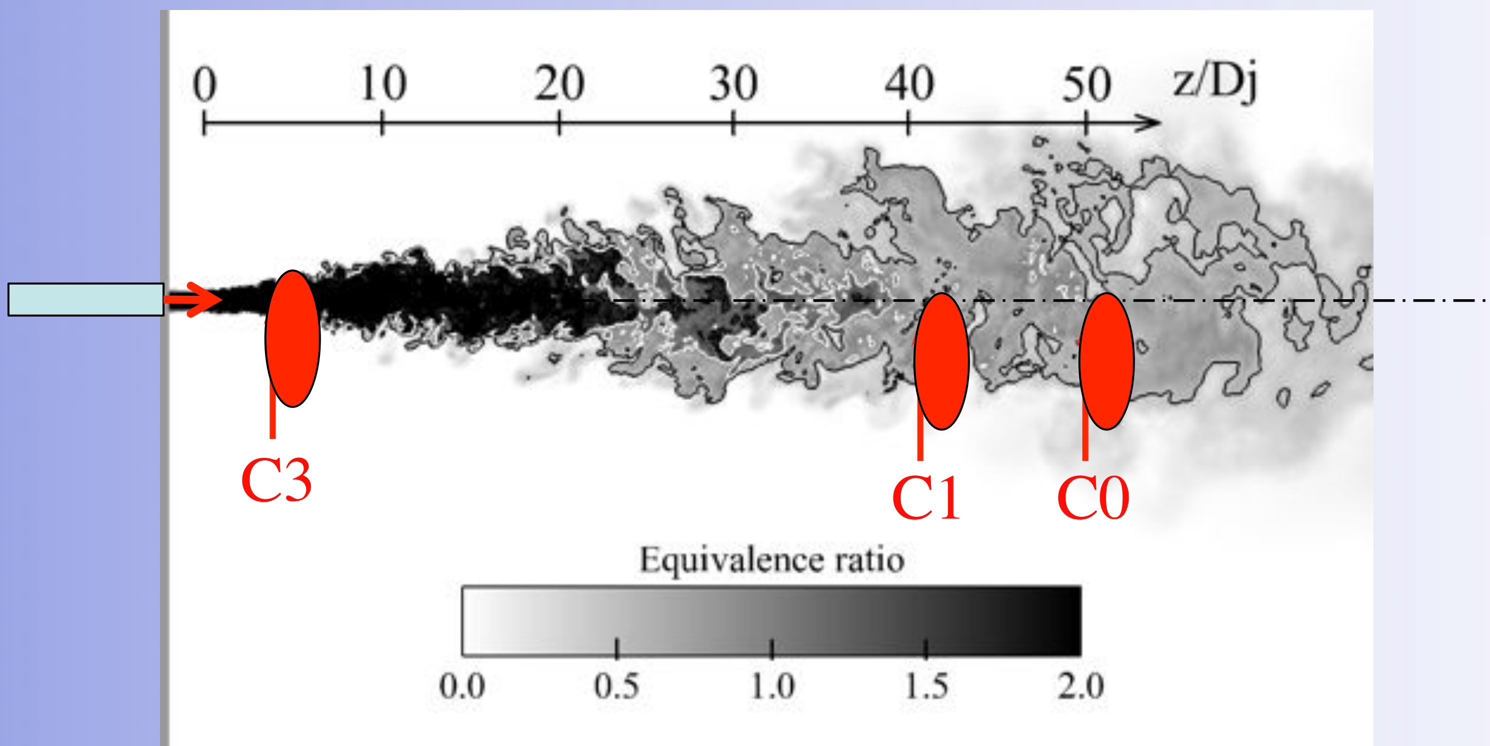
No need for expensive tests ?:

LES of ignition of a CH4 jet (Ahmed and Mastorakos)

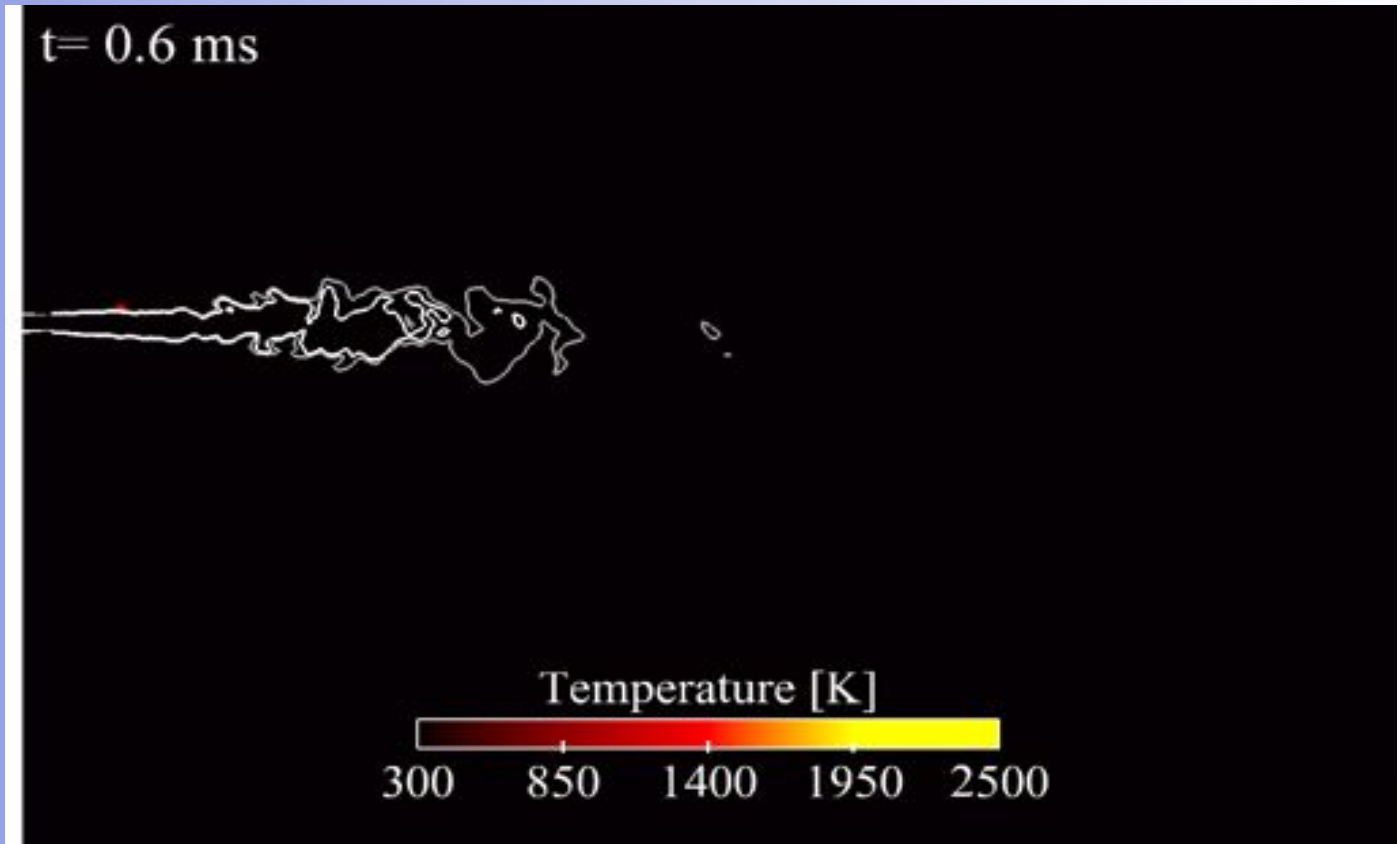


G. Lacaze, E. Richardsons and T. Poinsot. Large Eddy Simulation of spark ignition in a turbulent methane jet. *Combustion and Flame* 156, 6, 1993-2009.

Three examples with different locations for the spark:

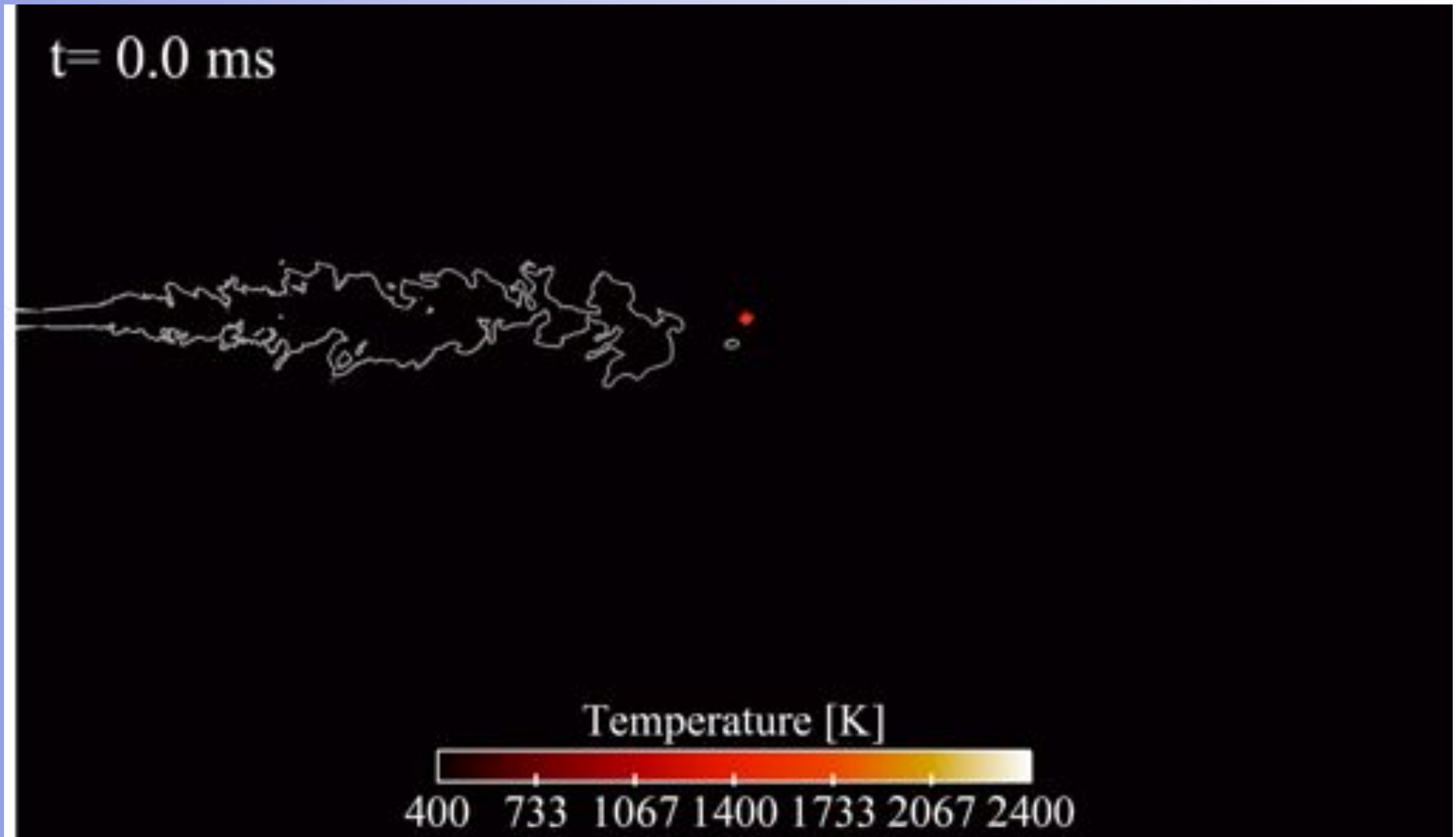


LES result for ignition at C3 (close to rim)



Isolines= mixture fraction (flammability limits)

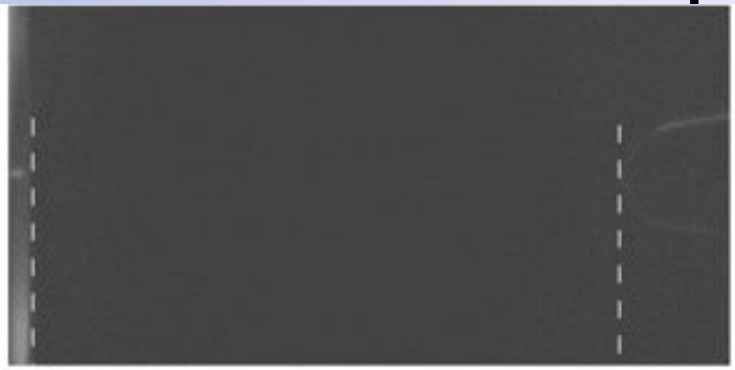
LES result for failed ignition at Co:



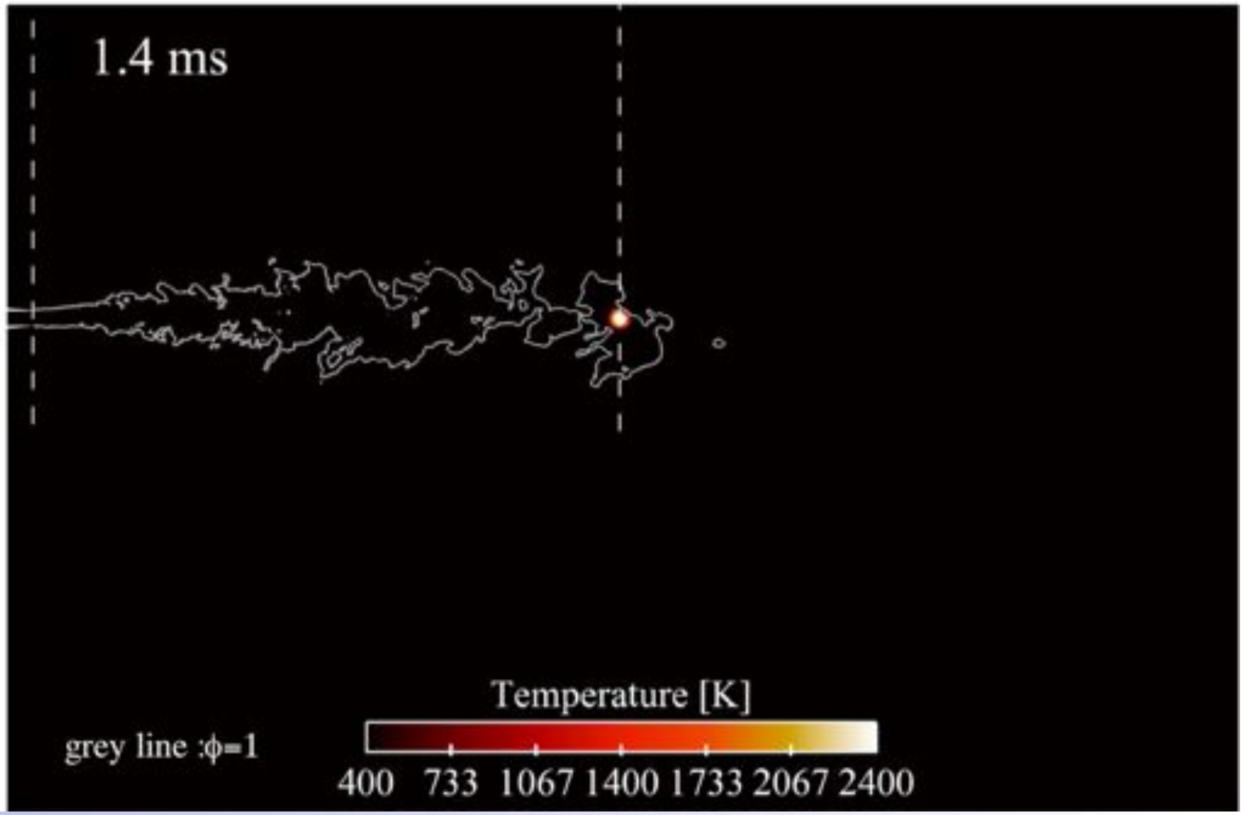
Isoline = stoechiometric line

Case C1: succesful but marginal ignition. Comparison of LES and experiment

Experiment

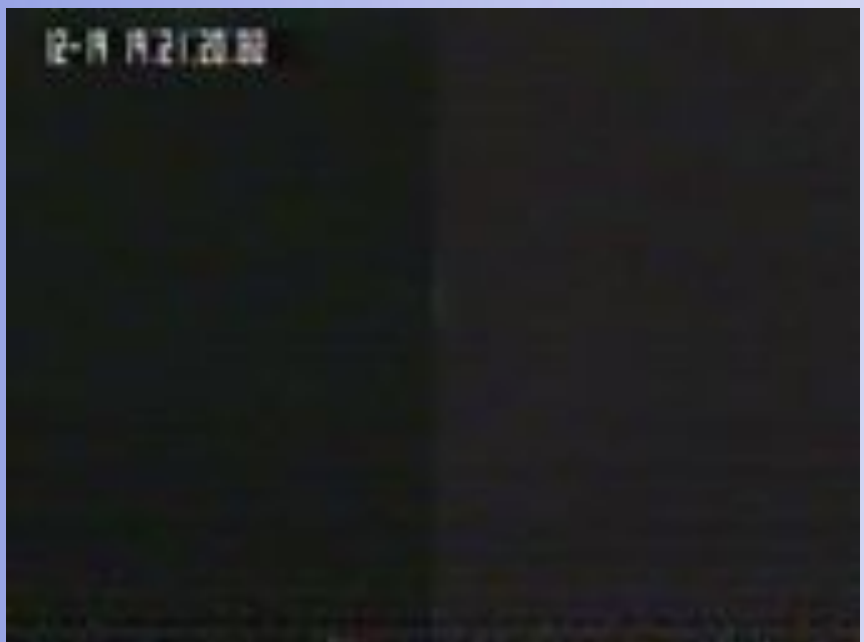


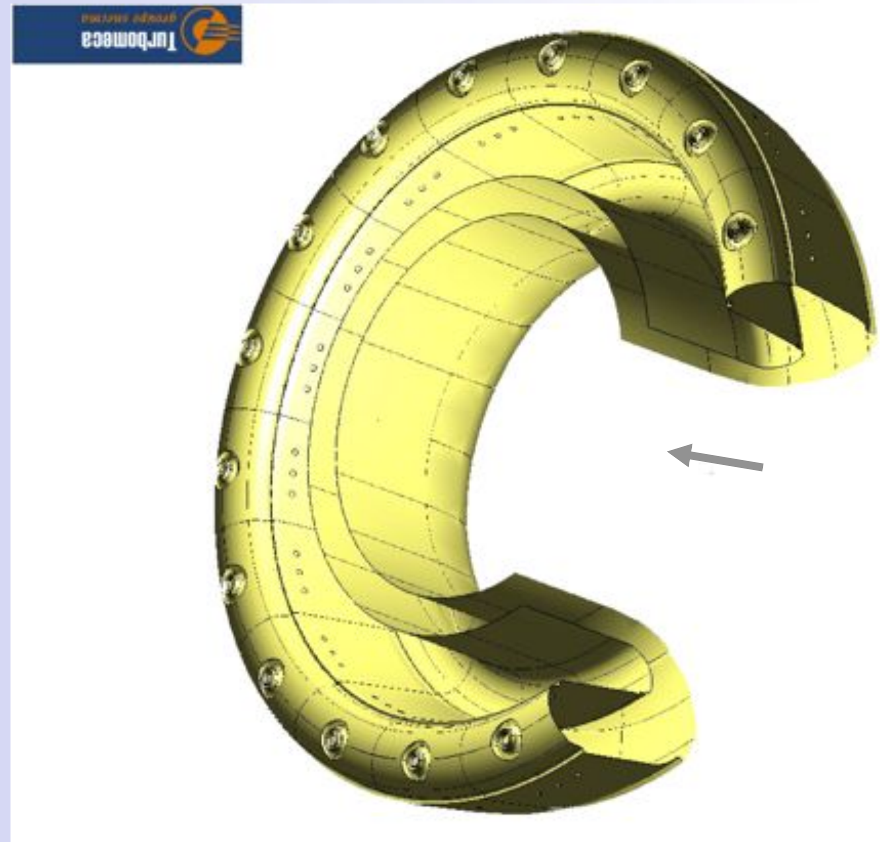
LES



2009

Example: how to ignite helicopters engines ?

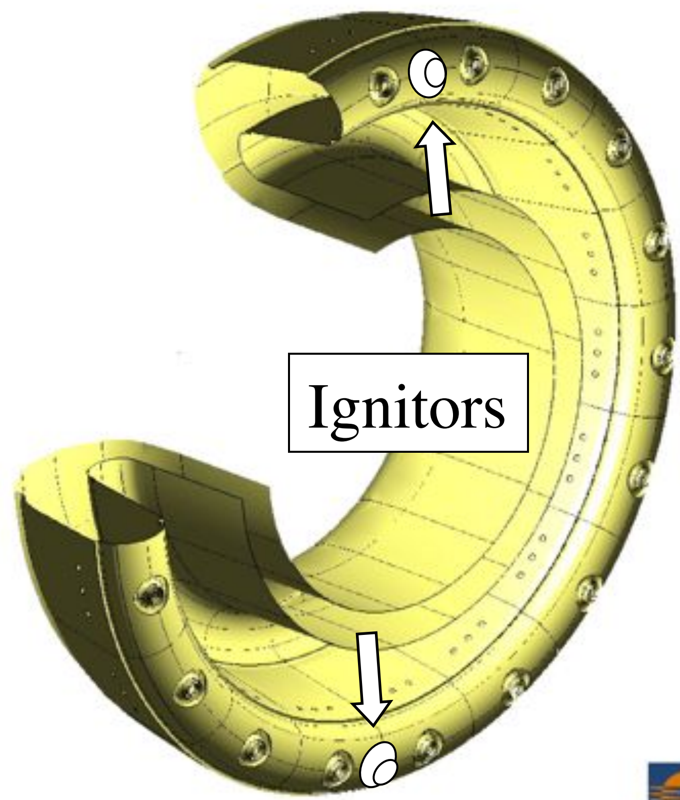


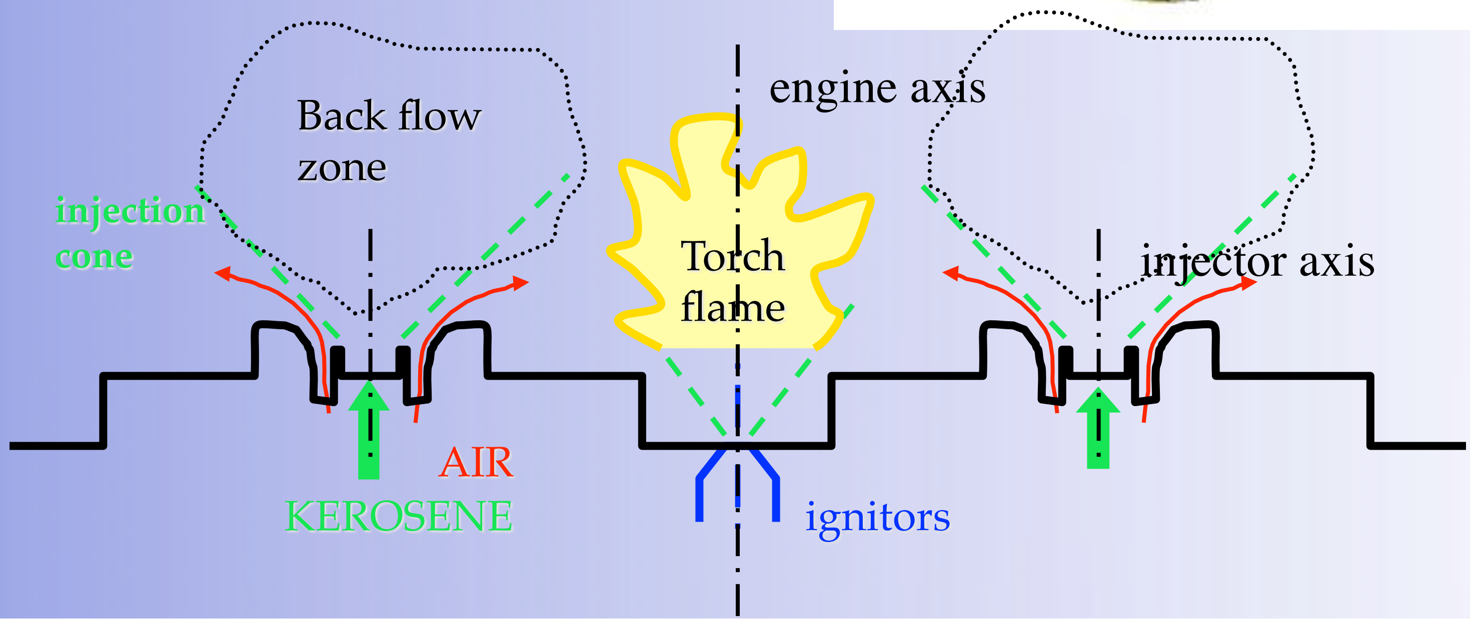


Experimental visualization of ignition in an helicopter engine

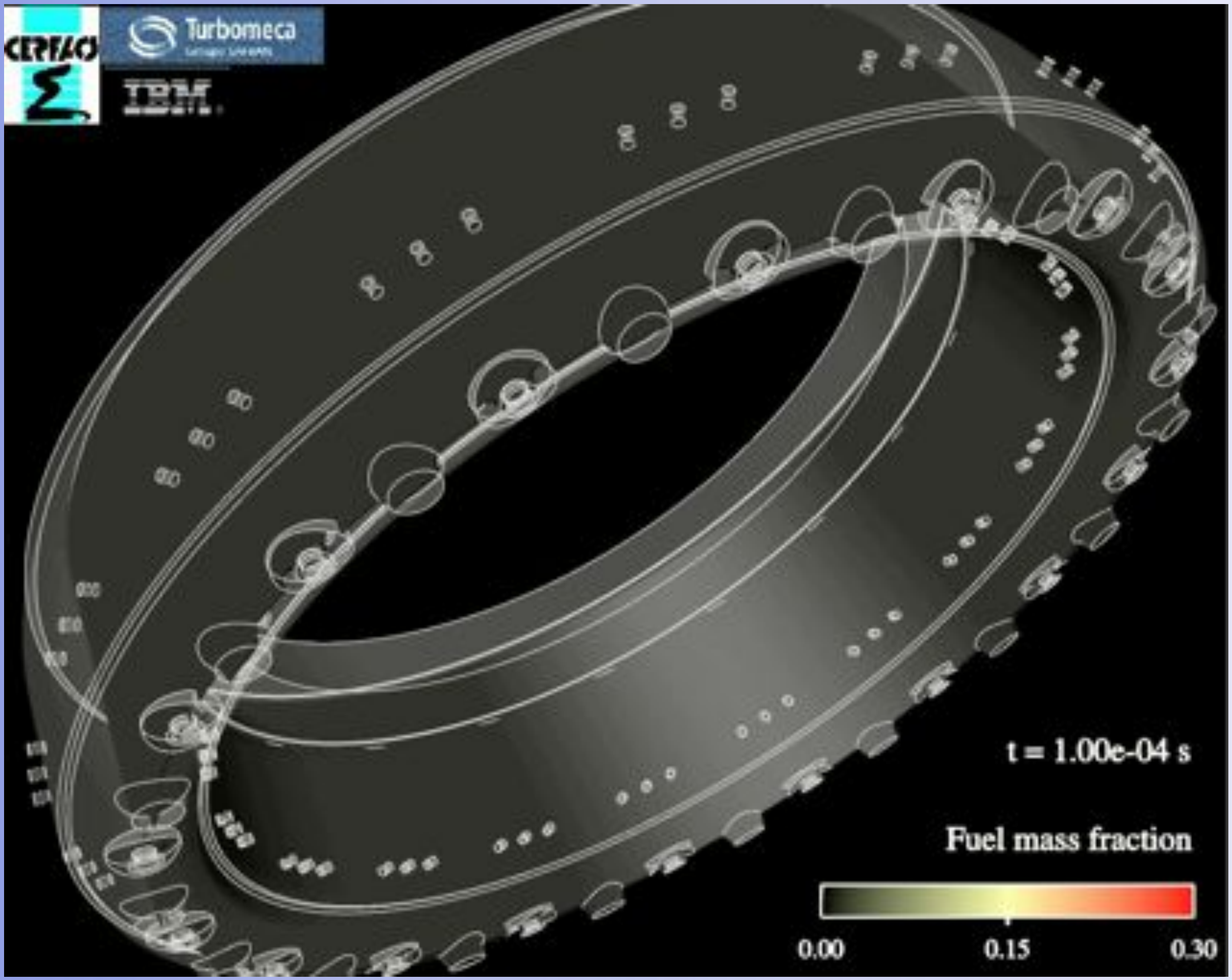
Ignition of helicopter engines:

not by spark but with hot jets produced by a separate ignitor



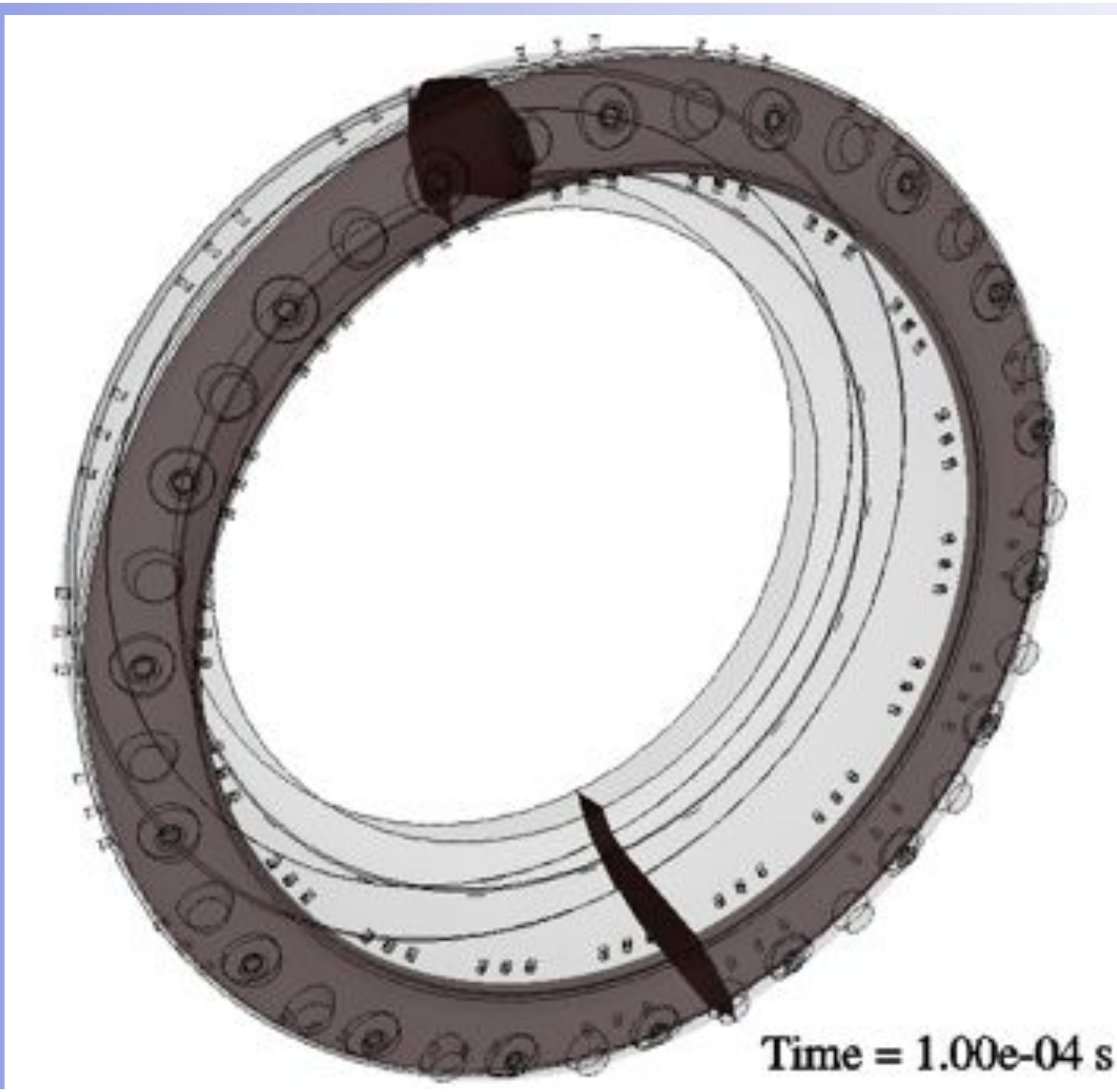


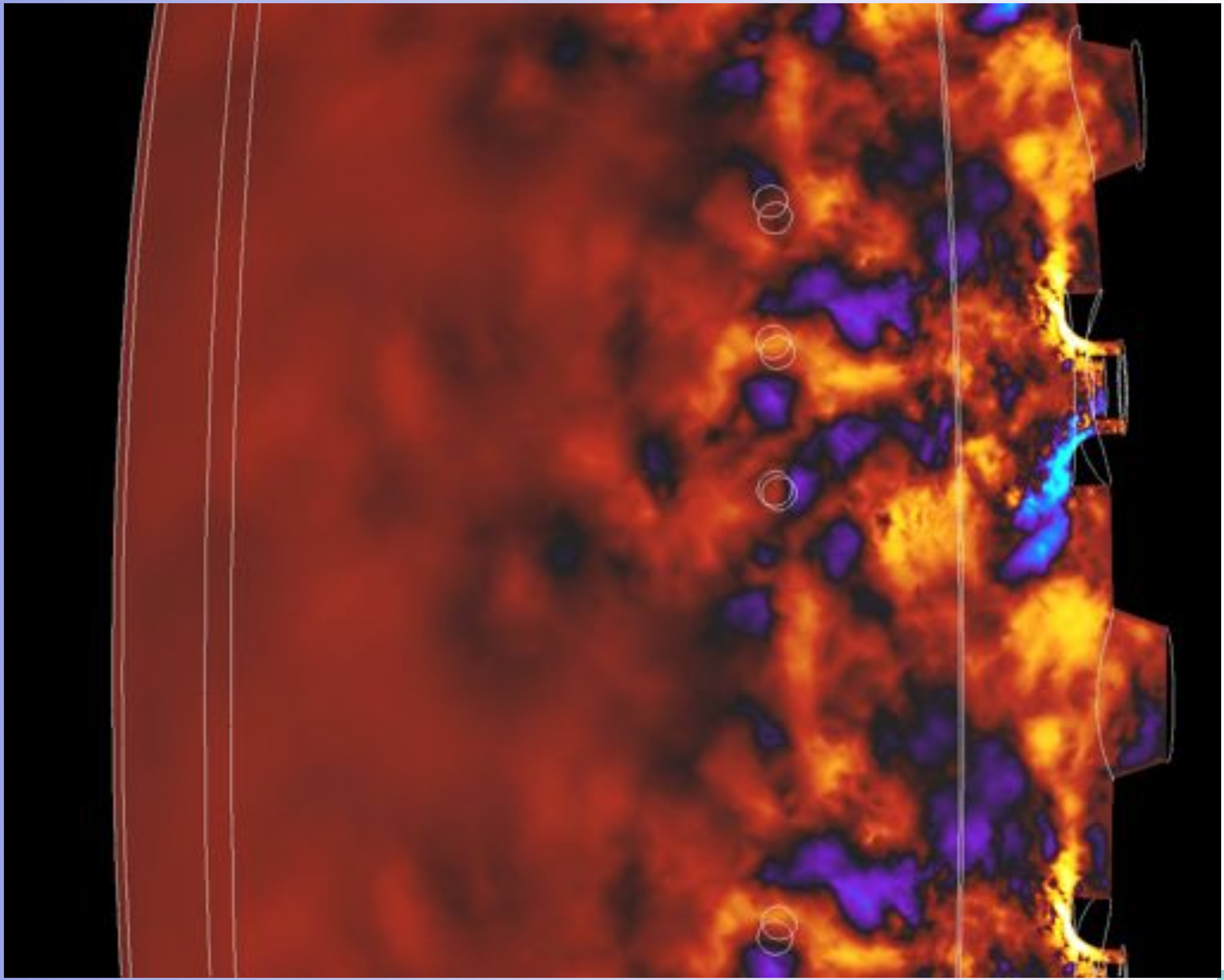
LES of full chambers ignition:



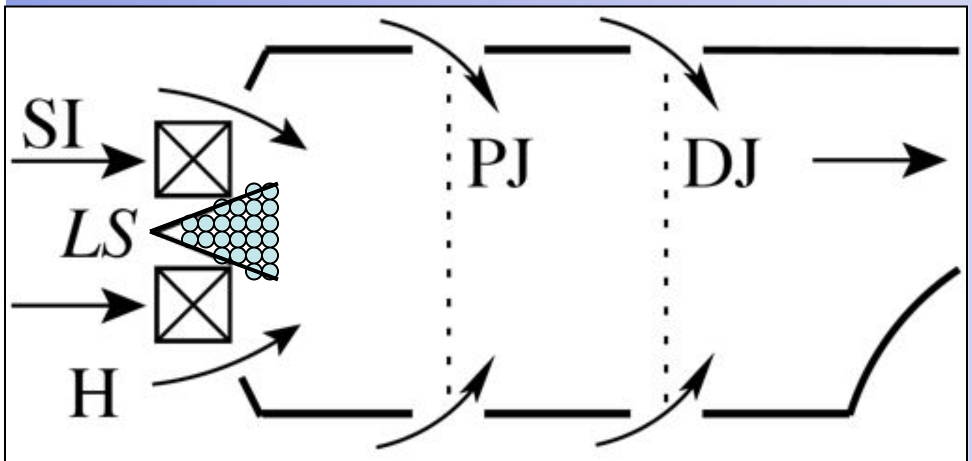
2000 processeurs
BlueGene (USA)

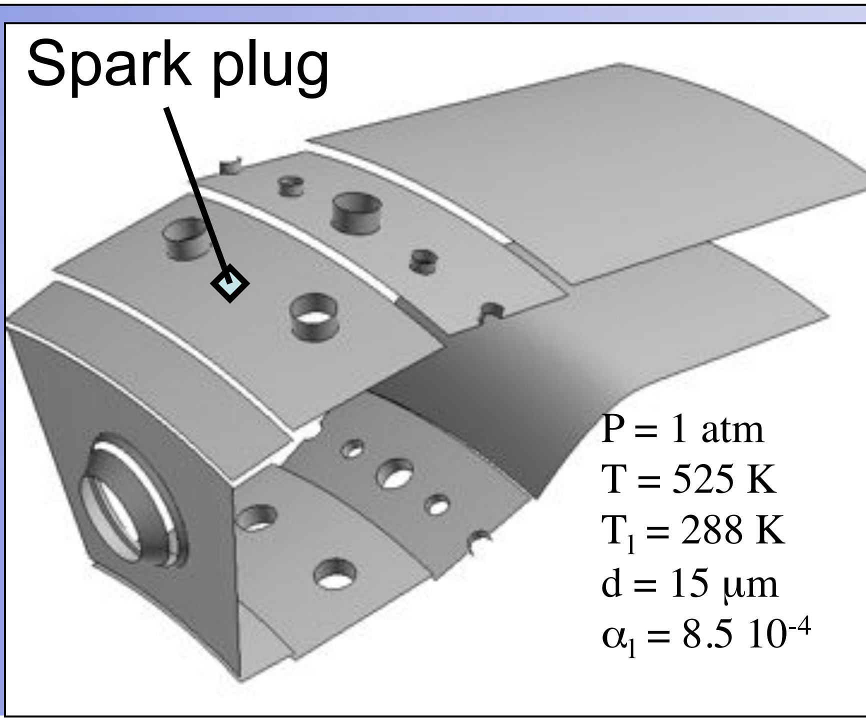
M. Boileau et al
Comb Flame


Time = 1.00e-04 s

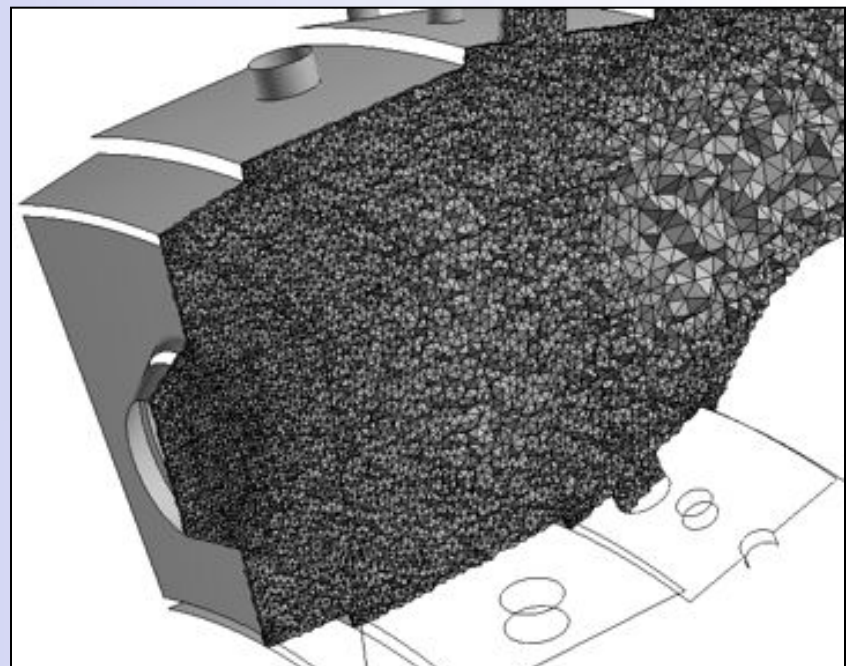


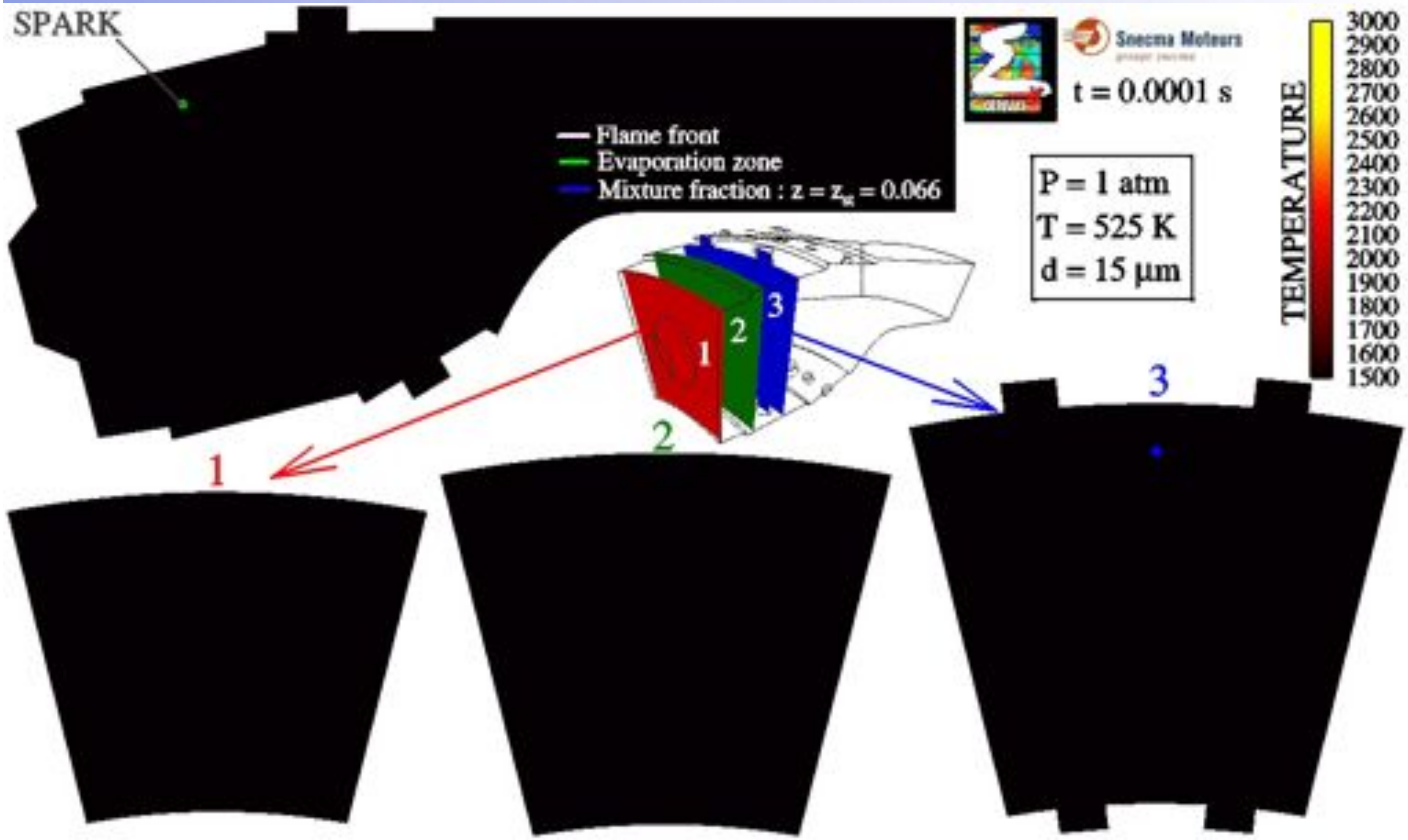
Aircraft engine: with spark





P = 1 atm
T = 525 K
T_l = 288 K
d = 15 μm
$\alpha_l = 8.5\ 10^{-4}$




SPARK
Flame front
Evaporation zone
Mixture fraction : $z = z_{st} = 0.066$
Snecma Moteurs
t = 0.0001 s
P = 1 atm
T = 525 K
d = 15 µm
TEMPERATURE
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1
2
3

Looking for more information ?:

- Get the textbook "Theoretical and numerical combustion" by Poinsot and Veynante at the library
- Buy it on amazon
- Get it free (or for 10 $ if you insist) on:

elearning.cerfacs.fr/combustion/index.php

- At the same place you will also find multiple tutorials and documents useful for this course:

Combustion

Online version of the Poinsot and Veynante book: "Theoretical And Numerical Combustion"

- Download the second edition of the book

University of Toulouse master courses

- Introduction ()
- Computation of adiabatic flame temperature
- Conservation equations for combustion
- Stabilisation, ignition and flame-wall interaction ()
- Past examinations ()

Tools

- Adiabatic Flame Temperature Calculator

Home

Courses

Combustion
Turbomachines
Environmental science
Advices for phD students

Online version of the Poinsot and Veynante book: "Theoretical And Numerical Combustion"

Download the second editi...

Mais tout cela se calcule !

Malgré leurs complexités apparentes:
- les flammes se calculent !
- elles suivent les équations de Navier Stokes réactives: rien de magique
- l’industrie manque cruellement d’experts dans ce domaine
- la recherche fondamentale sur ce thème va aussi bon train et la France est bien placée.

MAIS IL FAUT DES GENS INSTRUITS --> Thèses quasi-obligatoires et docteurs en combustion en nombre insuffisant en Europe

Apres une thèse ?

- Centrale, DEA, thèse MBDA missiles, ingénieur IFP
- Centrale, DEA, thèse ONERA, chef de projet Turboméca
- Centrale, DEA, thèse IFP, post doc Stanford, ingénieur Turbomeca
- N7, DEA, thèse pour Siemens, ingénieur IFP, responsable projet IFP
- Darmstadt, thèse moteurs à pistons, BMW, directeur du labo d'électronique de GM / Détroit
- N7, DEA, thèse CEE Turbines, Siemens Munich
- Centrale, thèse Toulouse PSA, chef de projet PSA
- N7, DEA, thèse Air Liquide, Transiciel, Airbus
- ENSICA, DEA, thèse Alstom, programme manager Mercedes
- N7, DEA, thèse CEE Turbomeca, ingénieur GDF
- N7, DEA, thèse CEE turbines, ingénieur PSA
- N7, DEA, thèse CEE turbines, ingénieur IFP
- N7, DEA, thèse Siemens turbines, post doc Caltech JPL, CNRS

Mais, m'sieur, moi, je ne veux pas faire de thèse !

Ben, c est ce que je disais aussi jusqu'à ce que j'aie vu ce qu'était l'industrie… Ne fermez pas trop vite les portes surtout si ça ne vous coûte rien ou presque.

Vous allez passer ~~37.5~~, ~~40~~, 42, ~~44~~ ans à bosser comme ingénieur. Pourquoi ne pas prendre 3 ans (bien payés…) pour faire un peu de recherche avant, tout en restant étudiant ?

Le PhD est LE diplôme mondial unique reconnu en R/D. Hors de France, il y a les PhD et les autres. Seule la France avec ses écoles d'ingénieurs est en marge de ce système mais y vient à cause entre autres des compagnies comme Airbus ou Siemens

La France est le pays où les thèses sont les plus rapides et les mieux payées.

ET l'ENSEEIHT ?

Beaucoup d'ingénieurs ENSEEIHT parmi les doctorants en mécanique des fluides et en combustion

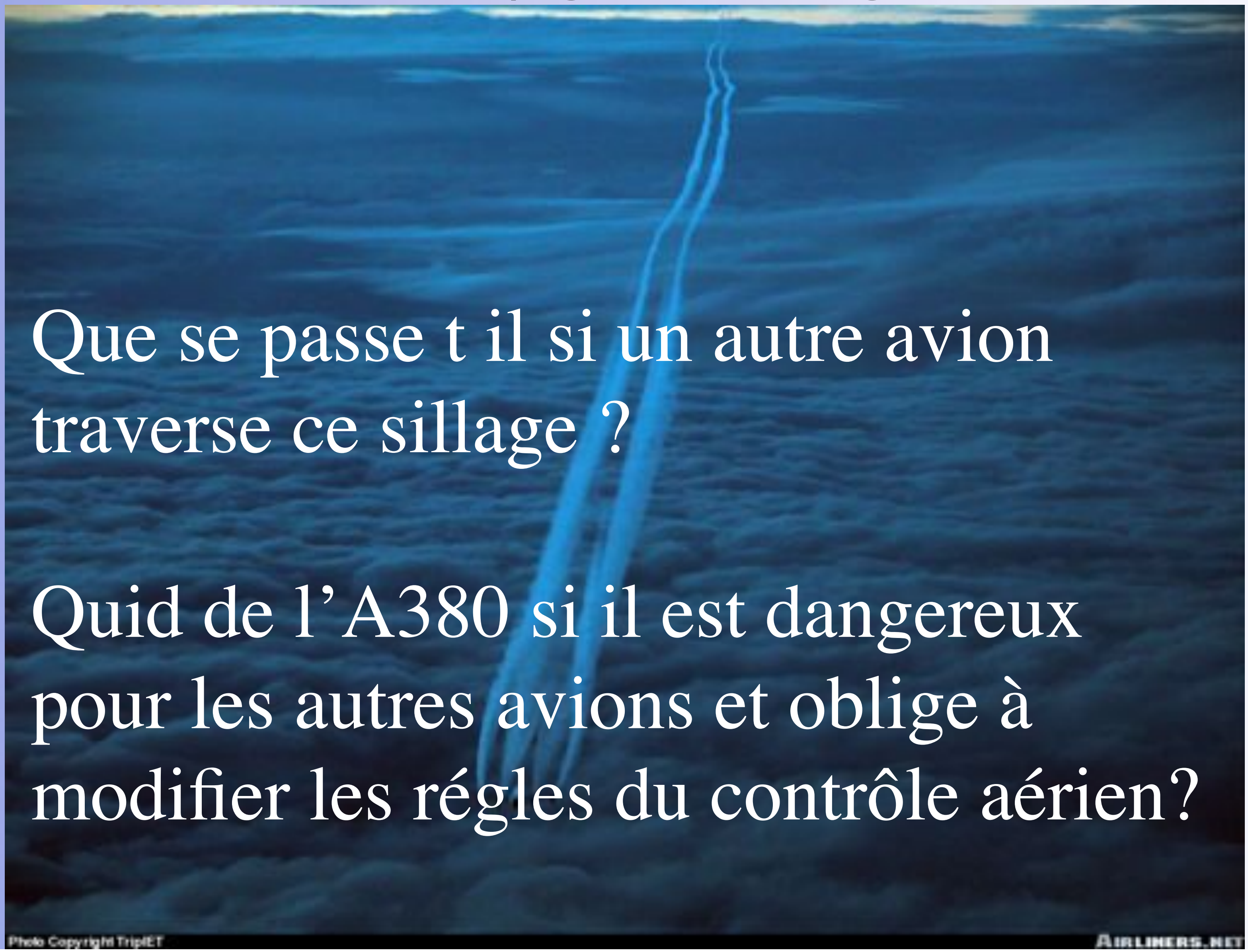
Energétique: point fort des N7

- nombreux cours de méca flu
- cours de thermodynamique
- 3ieme année Energétique ou MFN adaptés à la combustion
- BEI, BES

Contrairement à d'autres écoles, les N7 savent (d'habitude) faire autre chose que de l'aérodynamique

Dossiers étudiants N7 bien reçus par organismes distribuant les bourses: ADEME, ANRT, DGA, etc

Soyons plus précis: F. Laporte, thèse INPT/CERFACS 2002



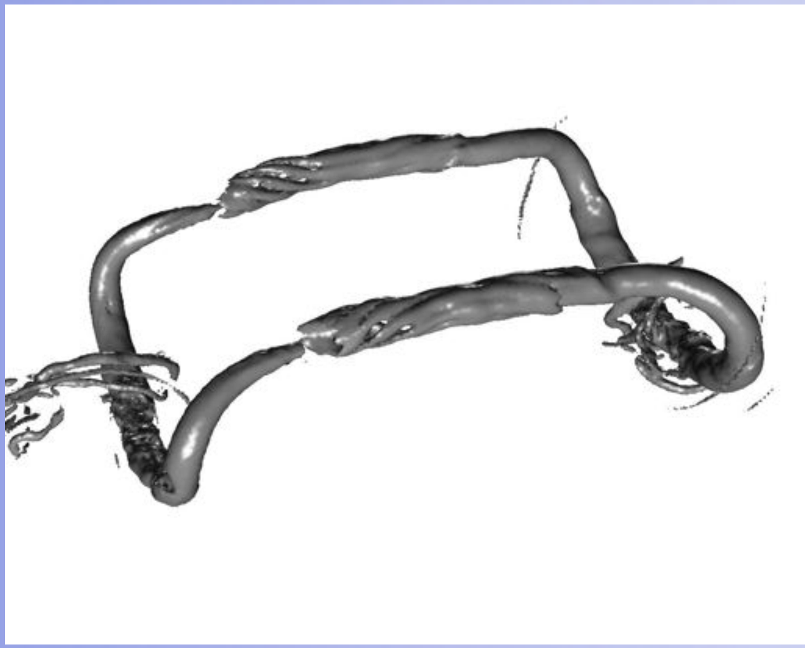
Que se passe t il si un autre avion traverse ce sillage ?

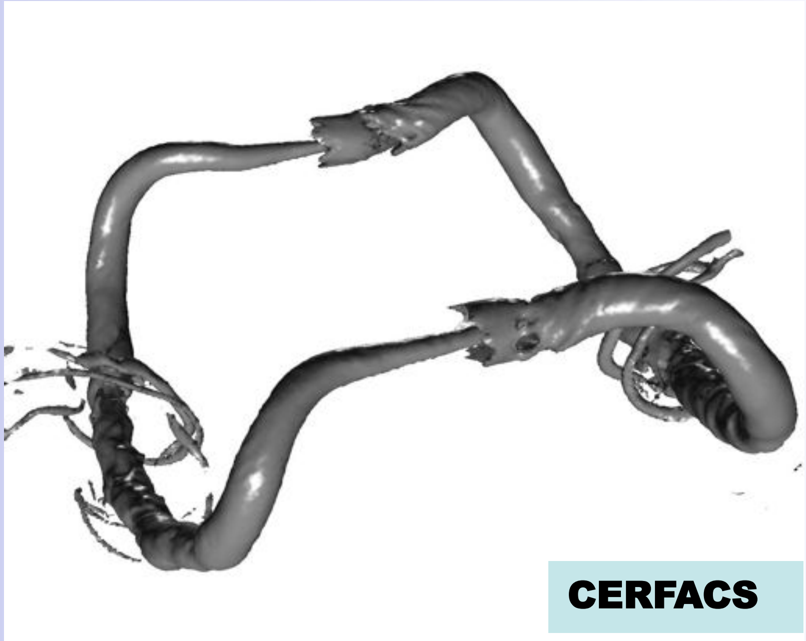
Quid de l'A380 si il est dangereux pour les autres avions et oblige à modifier les régles du contrôle aérien?

PhD thesis:
Theory
Large Eddy Simulations

Vortex reconnection

Vortex “bursting”





• Thèse au CERFACS sur les sillages d'avion
• Brevet avec Airbus déposé en fin de thèse
• Puis responsable du sillage de l'A380 (Hamburg/Toulouse) et des négociations avec les autorités aériennes

Coordination d’un ‘gros’ projet

Et de grosses manips:

Faire voler un A318 dans le sillage:
- d’un Boeing 747
- d’un A380

Mesurer juste avant le champ de vitesse avec un Falcon spécialement équipé

A380 Flight Tests - Cruise

A380 Flight Tests - Cruise


BETA :-0.3 DA MACH :0.69 HP1 :37608.FT
A318 1599
FLIGHT 0784
10:26:32:21
MOVIE:K
ALPHA:3.16 DA SLAT :-0.09 DA FLAP :0.0 DA LOG :0
AIRBUS ETT 04A

Autre exemple: P. Popp, thèse INPT 1996

Thèse à Toulouse

Embauche BMW: responsable centre de prospective BMW à Palo Alto (Californie)

Création Start up Munich

Embauche General Motors: directeur du laboratoire d'électronique à Détroit.

CONCLUSIONS

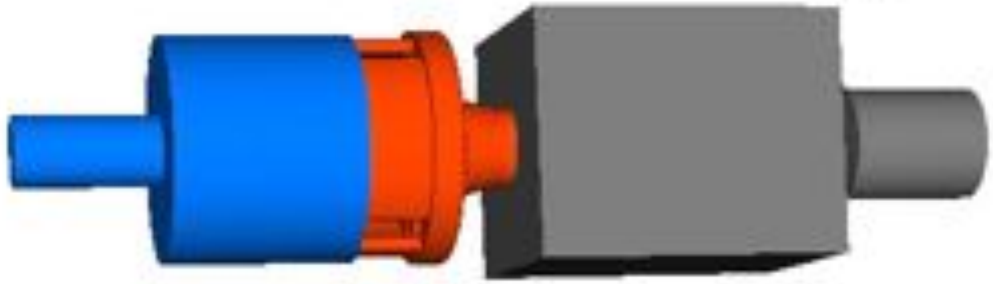
Vous cherchez un boulot d'avenir: faites de la combustion

Vous n'êtes pas absolument sûr de votre début de carrière: faites de la recherche, ou pas… en tous cas, faites un master à Toulouse ! Au pire vous ne vous en servirez pas !

Vous voulez aller à l'étranger mais pas en mangeant des nouilles tous les jours et pas en étant un simple étudiant: faites une thèse avec un séjour à l'étranger ou faites un post doc à l'étranger. Et d'abord un master

PS: euh… plus besoin de master d'ailleurs si vous avez été étourdis en 3ieme année.

PRECCINSTA EU project



Mesh | device fully meshed
3 million cells
3D unstructured

Measurement performed by DLR

Turbomeca
groupe snecma

Large Eddy Simulation of a gas turbine burner

CERFACS/SIEMENS

Experiments in Univ. Karlsruhe EBI and ITS