CNES involvement in simulation
Ter@tec 2008

By Stéphane Janichewski
Associate Director General
Director for Strategy, Programmes
And International Relations

CNES Missions

✓ **CNES is a state-owned but independently-managed commercial and industrial organisation. It is responsible for shaping and implementing France's Space policy to serve Europe.**

IJM3

✓**CNES is the French Space Agency in charge of Space programmes. Its technical centres in Toulouse, Evry and French Guiana cover all aspects of Space Technology and Techniques**

Diapositive 2

IJM3 ajout traducteur dans deuxième paragraphe, à valider ou faire modifier. Me contacter au besoin, Ian M

Ian; 26/05/2008

CNES Missions

CNES contributes its overall vision and expertise in Space systems to encourage innovation:

✓ by serving as a meeting-place between scientific and technical laboratories on the one hand and manufacturers and service providers on the other

✓ by stimulating research and progress in science, technology and industry for the benefit of public and private Space activities

CNES missions

CNES and its European partners

- CNES represents France in the European Space Agency (ESA)
- It leads a multinational programme as a complement to European programmes
- CNES follows the guidelines laid down by the French government for constructing European Space capability
- CNES and its European partners combine and coordinate their efforts to provide support for contracting authorities
- CNES contributes to changes in European institutions and constructs European Space capability

CNES Missions

CNES and its international partners:

CNES undertakes bilateral or multilateral cooperation with most European countries, either directly or jointly (direct bilateral cooperation or cooperation via ESA)

With the major Space nations: United States, Russia, Japan, India, China etc.

Via specific projects with several partners around the world: Israel, Thailand, Argentina, Algeria, Brazil, Korea, among others

CNES Missions

Organisation of the Space sector in France

IMPORTANCE OF SIMULATIONS IN CNES

3 main goals

1. To improve costs and delays (for instance by the reduction of the number of tests)
2. To improve the reliability and the performances of operational systems
3. To capitalize conception and expertise know-how

SIMULATIONS REQUIREMENTS REGARDING SYSTEMS CONCEPTION AND VALIDATION

- To validate mathematical and digital models of phenomena and to implement them to understand and anticipate these phenomena.
- To conceive and validate operational procedures allowing the operation of space systems (space and ground segment).
- To assist the conception of systems, components and equipments.
- To produce data (images, telemetry, …) of space systems test and qualification, on-board equipments, on-board processors and data processing ground facilities.
- To contribute to systems operators training.

FIELDS ISSUES (1)

1. **Launchers**

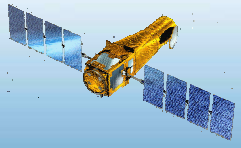
- ⇨ To develop tools in each discipline, in particular in the very complex propulsion domain
- ⇨ To integrate progressively these tools in a global simulation project (MINOS)

Objective : To predict tests outcomes and reduce their numbers
Examples of past achievements :

1) · 7 tests for Ariane 5 boosters
· Only 2 tests for P80 (more advanced solid propulsion booster)

2) Deletion of one stage test for Ariane 5 ECA

FIELDS ISSUES (2)

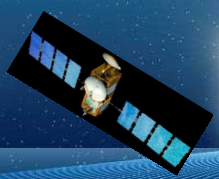


2- Orbital Systems

- To improve the efficiency of missions studies and conception, including systems, instruments, equipments and ground segments ;
- To develop knowledge in each expertise domain (for example : electromagnetics, structure mechanics, thermal engineering, trajectories, …) ;

3- Space Research

- To provide tools for those research which request simulation and computer high rated performances



EXAMPLES

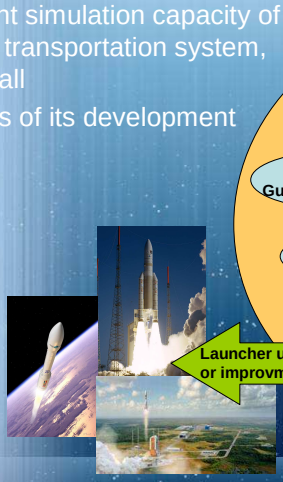
1. MINOS : Global Space Transportation Simulation
2. System engineering simulators
3. Antennae / satellites interactions models
4. Gaia : Astronomy data processing

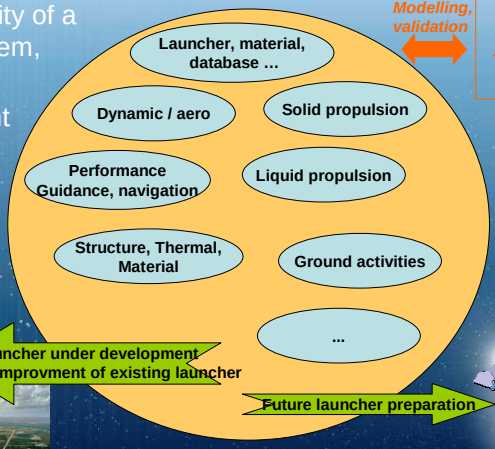
MINOS program:
global space transportation simulation

CENTRE NATIONAL D'ÉTUDES SPATIALES

What is MINOS program ?

MINOS aims giving a global and efficient simulation capacity of a space transportation system, along all phases of its development





Modelling, validation ⟷ Research and Technology activities

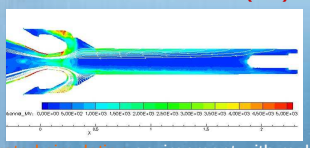
Launcher under development or improvment of existing launcher

Future launcher preparation

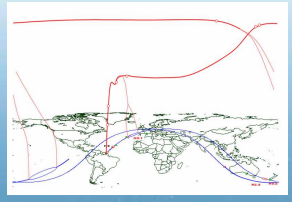
What kind of tools ?

- Dedicated tools for each technical discipline

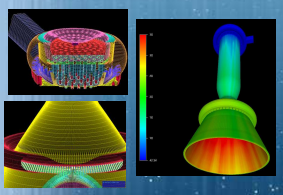
CALCUL ECOULEMENT INTERNE PROPULSEUR SOLIDE (Z9A)



TRAJECTOIRE A5ES-ATV

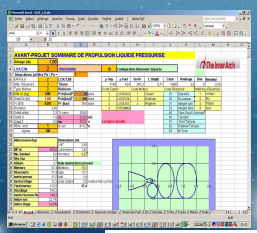


Integrated simulation environment with multidisciplinary optimisation (multi physics - multi scale)



CALCULS DE COMBUSTION MOTEUR VINCI

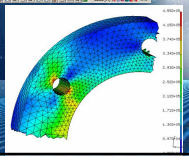
BOUCLE SYSTEME AVANT-PROJETS



DISPENSER GALILEO

- From global analysis (predevelopment) till very fine modelling (development, production phase)

CROSS-CHECKING CARDAN JOINT



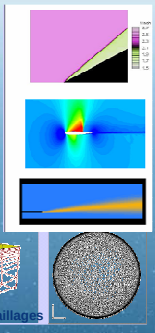
What kind of environment ?

- For dedicated tools environment allows:
  - To give all tools available for any engineer, and secure technical experts analysis
  - To build easily and quickly a specific computation loop, e.g. for flight anomaly treatment; to assure domain of validity of used loops and codes
  - To give access to databases (test results, material, thermodynamics, manufacturing) and to capitalize know-how
  - To give aid to decision, using graphical comprehensive presentation
- For integrated environment, analysis is under progress due to diversity of loops and codes
  - Analysis of the market, by privileging open source solution
  - Adaptation of existing solution to specifics Minos needs
  - Participation to “pole of competitiveness” System@tic
  - Building of a common project with ONERA

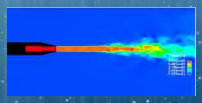
  Present evaluation concerns SALOME, ModeFrontier, ModelCenter and DAKOTA
- CNES computers resources :
  - Parallel Calculator at CST :12 IBM Power 4 processors, 28 Gb RAM.
  - Local PC cluster for pre and post treatment : 4 Xeon processors 16 Gb RAM
  - Evolution 2008 : increase RAM x 10 and increase by factor 6 the processor treatment capacity, in Linux cluster environment

Examples: dedicated CFD tool CEDRE

- CEDRE : new CFD code
  - **3D, multi species, reactive code**
  - **Multi domain and multi solver**
    - Navier Stokes solver and thermal solver
    - Lagrangian and Eulerian solver
  - **Unstructured grids**
  - **Common development with ONERA and DGA**
  - **Introduction of models developed within R&T activities**
  - **Partners: Onera, SNPE, Bertin**
  - **Applications :**

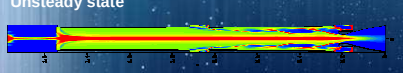


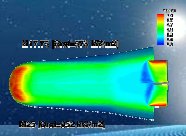
Jet noise



MPS : Ariane 5 solid rocket motor

Unsteady state

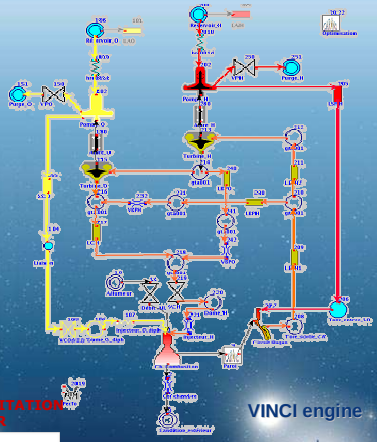


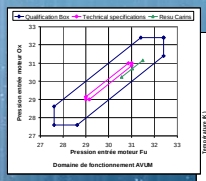


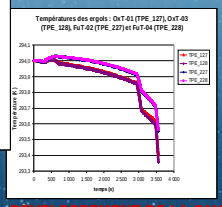
Examples: Liquid Propulsion tools

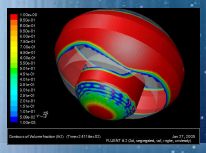
- CARMEN environment for engine and sub system definition + transient and steady state functional simulation.
- Dedicated tools for components (turbopump, valve, thrust chamber, mechanical, …

SCHEMA FONCTIONNEL CYCLE MOTEUR et TRANSITOIRES



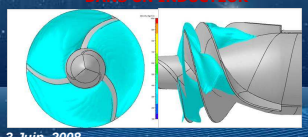






MOUVEMENT DES ERGOLS PASSIVATION ERCA

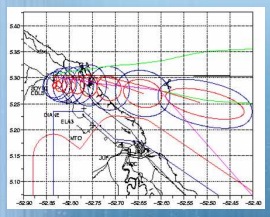
DEVELOPPEMENT DE LA CAVITATION DANS UN INDUCTEUR



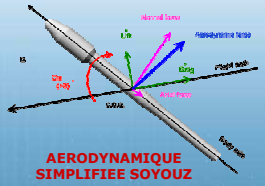
Russian inducer

VINCI engine

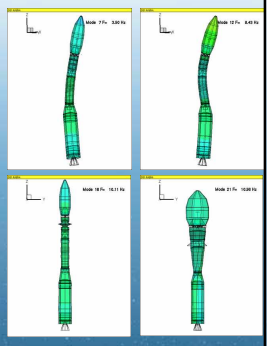
Examples: System tools



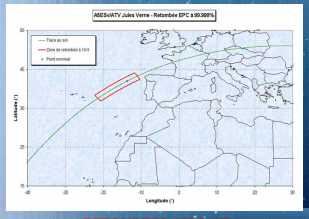
SAUVEGARDE EN CHAMP PROCHE



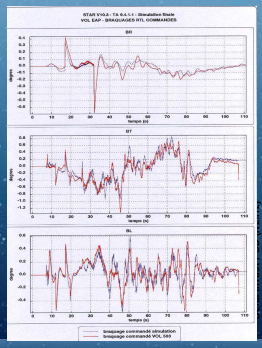
AERODYNAMIQUE SIMPLIFIEE SOYOUZ



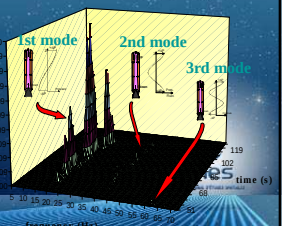
MODES DE FLEXION VEGA



RETOMBEES ASES ATV



GNC - RESTITUTION SIMULATION DE VOL V203



EXPLOITATION DDR VOL EAP AE

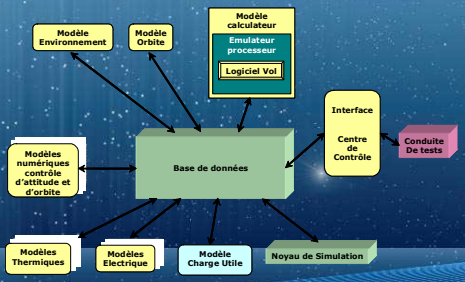
2. SYSTEM ENGINEERING SIMULATOR

- Simulators are necessary in each phase of a dedicated project
  - Example : Presto (Proteus Platform Digital Simulator)

Use for :

- Operational Ground Control segment procedures validation during system tests
- Command Control Operators training
- Expertise for flight events analysis

Architecture PRESTO



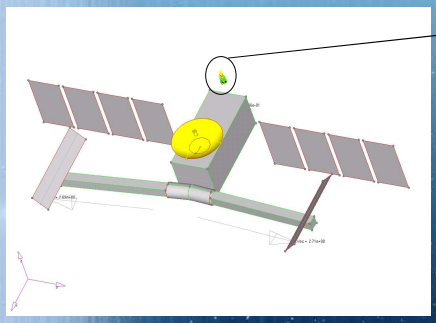
3. ANTENNAE – SATELLITES INTERACTION MODELS

- Objective : Prediction of antennae electromagnetic radiation perturbation due to satellite structure ;
- Until the end of the 90's, only "asymptotic methods" were used ;
- New methods (MoM), associated with the use of high performance Computer have led to solve these problems with a good level of accuracy
- Use of Cerfacs Electromagnetic Solver Codes
- N (Size of the matrix system) : $N \sim (\text{frequency})^2$

  $N \sim (\text{satellite surface})$

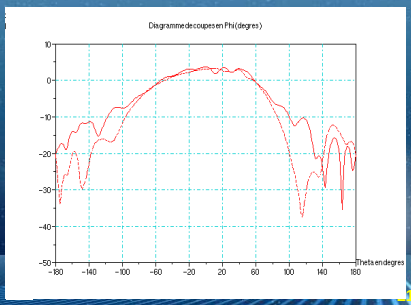
Exemple d'application

- 1er exemple d'application (FMM)
  - N = 61 000 degrés de liberté



MoM-LU
Temps CPU> 50 h
Mémoire >30 Go

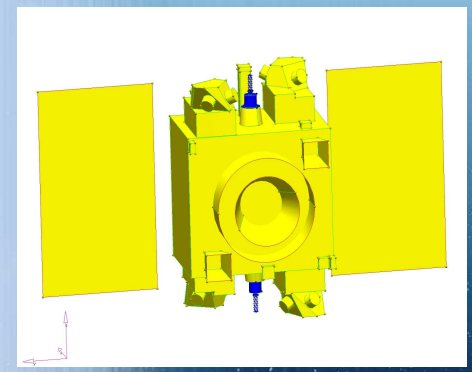
MoM-FMM
Temps CPU=15h 50 min
Mémoire=940 Mo



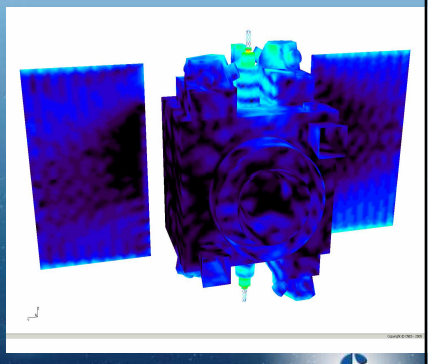
Exemple d'application

- 2ème exemple d'application (FMM)
  - N = 68 000 degrés de liberté

MoM-FMM
Temps CPU=16h 25 min
Mémoire=1200 Mo



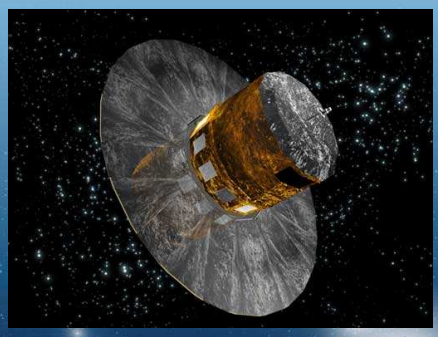
Géométrie du satellite MICROSCOPE



Simulation des courants électriques créés sur le satellite par le rayonnement des antennes

4- GAIA

- CNES in charge of the data processing Center of Gaïa Scientific ESA satellites.
- Gaia will map our galaxy in 3D, with an assessment of earth-stars distance and relative speed. It will also discover and register billions of unknown objects, with a good accuracy (7 to 300 µ arc / s for the position, speed accuracy, speed accuracy of 2 to 10 Km/s, spectral measurement).
- In 2012, data processing will request 6 Teraflops.
- Beyond 2017, all measures will be reprocessed : need of 30 Teraflops
- 1 Peta octets of Data will be required.



WAY AHEAD (1)

- Situation as of today
  - All simulation applications do not require emphasized computer performances
  - The fields requiring significative performance are emerging : Models based on detailed networks, requiring a lot of measurements or numerous iterations (e.g. meteo forecasts, thermo elastic structural engineering models)
  - Requirements for each application : hundreds of G Flops and Tera octets
  - Consistent with existing means
    - Cluster IBM AIX/Power (5 units) (48 processors, 224 G Octets, 364 Flops)
    - 2 clusters Linus/X 86 -64 (49 units in Toulouse, 4 units in Evry) (172 processors, 716 G octets, 928 G Flops)
    - Use of CERFACS expertise to optimize and parallelize codes

WAY AHEAD (2)

- Situation in the future

  - Requirement for enhanced simulation and data processing tools
    - Tens of Teraflops
    - Several Peta octets

  - CNES is interested by Teratec initiative in this context and would like to follow with attention its promising development