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## Advances in Product Modelling and Simulation at Dassault Aviation

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### ABSTRACT

Aerospace industry has always been in the forefront in relying as much as possible on modelling and simulation to continuously increase global efficiency of product development and realization. A comprehensive combination of partial tests and simulation stands as a low-cost approach to limit the number of necessary prototypes to design, develop and qualify a new product.

For more than 30 years Dassault Aviation has invested large efforts in the field of product modelling and simulation, as it has always been considered as an essential asset in the sustained competitiveness of the company. The best known offspring of this policy is the CATIA software initially developed by Dassault Aviation for its own needs, and now a world standard marketed by Dassault Systèmes.

Another significant example of systematic resorting to simulation is given by the RAFALE program : the number of prototypes has been drastically reduced to only 4, for an airplane in 3 different versions and due to replace 7 existing different aircraft of French Forces.

Dassault Aviation field of activity includes both Military Air Systems (manned aircraft and UAV) and Civil Aircraft (the FALCON line of business jets), and for both the company acts as an architect of complex systems and an aircraft designer.

The presentation will lay out what today's Dassault Aviation specific answers are in terms of processes and tools as well as the

future challenges to be taken up considering future combat air systems.

Four main objectives drive the effort to improve the overall efficiency of every new product development :

- Initialize the design from valid requirements.
- Reduce time spent in each elementary task.
- Parallelize as much as possible the workflow.
- Set up dynamic risk management

Each one will fully benefit from Dassault's modelling expertise from preliminary upstream studies to comprehensive simulation of the whole life cycle costs.

The overall process developed today is a "multisimulation process" :

- Multilevel : from the overall design to the detailed design
- Multidisciplinary : integrated and based on the same reference
- Multipartner/Multisite : developing global models including coherent and relevant models produced by partner companies.

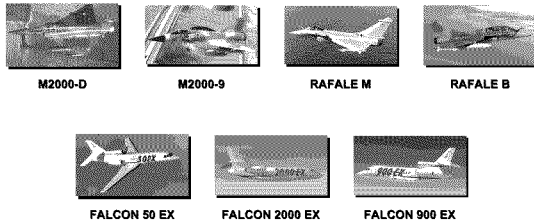
Specific emphasis will be brought on associated scientific, information technology and management challenges. The key issues leading to efficient development of appropriate simulations in a cooperative environment will be discussed.

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# 1. CONTEXT

The Dassault Aviation company field of activity covers both military and civil aircraft :

## PRODUCTION AIRPLANES



CUSTOMERS BENEFIT FROM BEST PRICE / PERFORMANCE RATIO

- Military aircraft :
  - manned fighter, maritime patrol and trainer aircraft. Today the MIRAGE 2000 and RAFALE are in production in several versions, offering optimised solutions to specific requirements and a dramatic decrease in operating cost.
  - UAV : studies on UAV and UCAV are in progress, specifically directed to meet new emerging needs with a stealthy UAV demonstrator already flying.
- Civil Aircraft : the very successful line of Falcon business jets. Today several types are in production using improved methodologies from basic layout to 3D completion work. The brand new type, FALCON 7X, is developed taking into account major advances in cooperative design.
- Space : Dassault extends its expertise in reentry vehicle aerothermodynamics and is producing pyrotechnical systems for launchers and a wide range of customers.

The Dassault Company is acting both as an architect of complex systems and as an expert in the challenging field of aircraft design and development.

Since the sixties Dassault Aviation has devoted a considerable in-house effort in

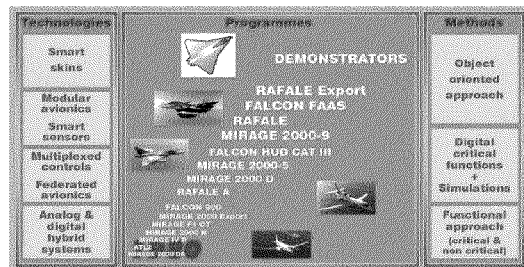
modelling the aircraft components and its physical behaviour ; the company has steadily considered as mandatory for its competitiveness to be able to use the best possible tools to fulfill two objectives :

- get the best product by way of a better optimization,
- reduce the development time and cost by streamlining the design to manufacturing process and by reducing the amount of required tests.

These efforts led to the development of very efficient codes for Aerodynamics, Structure design (CATIA and ELFINI), Flight controls and Performances, and more lately on Electromagnetic and Thermal signatures.

In parallel to these developments Dassault has also invested in Avionics - Flight Control Systems - Mission and Weapons Systems modelling, with simultaneous development of technologies, for example modular avionics, and methods, taking advantage of object oriented technologies.

## SYSTEMS DEVELOPMENT : CONTINUOUS IMPROVEMENT



Two obviously successful examples of the results of this policy must be highlighted :

### PRODUCT MODELLING AND SIMULATION A LONG STANDING METHODOLOGY

#### OUTSTANDING SUCESS STORIES :

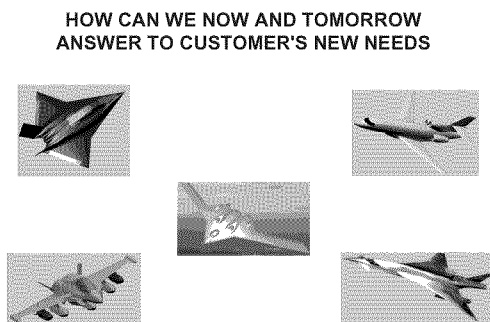
- **CATIA SOFTWARE FAMILY:**  
INITIALLY DEVELOPED IN HOUSE BY DASSAULT AVIATION  
NOW A WORLD REFERENCE PROSPERING UNDER  
DASSAULT SYSTEMES' BANNER
- **DEVELOPMENT OF RAFALE :**  
INTENSIVE USE OF ADVANCED PRODUCT MODELLING AND SIMULATION  
A SUCCESSFUL DEVELOPMENT OF THREE DIFFERENT VERSIONS :

C : Air, single seater  
B : Air, twin seater  
M : Carrier based, single seater } With only 4 prototypes

- The CATIA software : firstly developed in-house by Dassault Aviation in the late seventies for its own needs. This tool set has been then developed by Dassault Systèmes and became a world standard.
- Rafale Fighter : systematic use of advanced product modelling and simulation did allow to develop the aircraft with only 4 prototypes. Compared to other fighter programs facing cost overruns and delays, this has to be markedly pointed up for an aircraft with a fully integrated "omnirole mission system", developed in three versions : C = Air single seater, B = Air twin seater and the very demanding M = Naval single seater.

## 2. TODAY'S DASSAULT ANSWERS

In a customer driven market, customer needs are fast evolving and the improvements in product modelling and simulation must enable the timely and economic development of potential future products such as illustrated in this figure :



- Rafale mid life update
- UAVs and UCAVs
- Extended Falcon family
- Supersonic business jet

Four main objectives drive the effort to improve the overall efficiency of every new product development :

### ACQUISITION TIME REDUCTION PRAGMATIC APPROACH

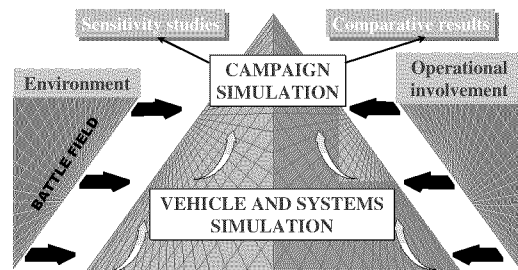
- START FROM VALID REQUIREMENTS , INCLUDING ECONOMICAL FEASIBILITY
- REDUCE DURATION OF ELEMENTARY TASKS :
- INTRODUCE STATE OF THE ART RULES INTO SPECIFIC DESIGN TOOLS FOR EACH DISCIPLINE
- PARALLELIZE AS MUCH AS POSSIBLE THE WORKFLOW, TAKING INTO ACCOUNT TRUSTABLE SIMULATIONS OR COHERENT CROSSCHECKS WITH PHYSICAL RESULTS
- SET UP DYNAMIC RISK MANAGEMENT USING "RED TEAMS" SKILLS AND TREATING DRIFTS AS SOON AS THEY OCCUR

➡ REDUCE DRASTICALLY REWORK

- Initialize design from valid requirements : this represents a major (and often underestimated) ingredient of a successful design. Product effective performance simulation is a way to let the customer test the use of a future system and better define its requirement, with an adequate balance between cost and performance.

An example is the technical-economical-operational simulation

### START FROM VALID REQUIREMENTS : TECHNICAL-ECONOMICAL-OPERATIONAL SIMULATIONS



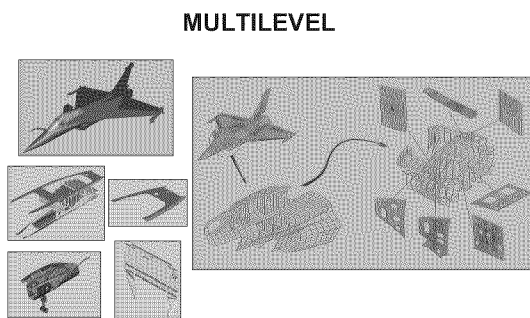
allowing to show the customer the global efficiency of the future product for different uses and different design hypotheses.

- Reduce the duration of elementary tasks : a classical application of product modelling. This is being notably done introducing state of the art rules and automated checks into specific design tools needed by each discipline.

- Parallelize as much as possible the workflow : to reduce time to market, it is necessary to allow some overlapping between the different development phases without incurring excessive risk. This can only be done by using high quality simulations including maturity criteria.
- Set up dynamic risk management :
  - Using the experience and skills of "Red Teams" formed with senior managers.
  - Treating drifts, delays and discrepancies as soon as they occur

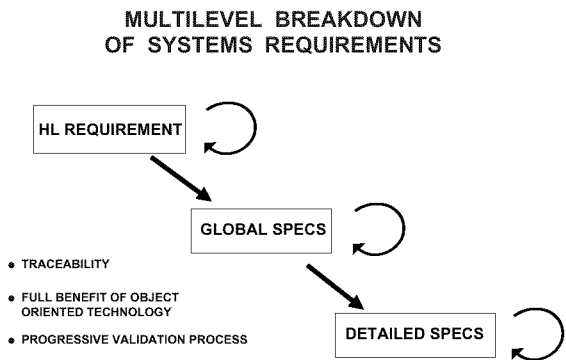
Today's improvements are focused on a "multisimulation" process :

- Multilevel
  - Multidisciplinary
  - Multipartners/Multisites
- Multilevel**
- The modelisation of the product is at different levels, for example for airframe in the following figure :



from complete airframe to detailed design of subcomponents and primary parts, keeping in memory associativity rules and parametric adjustments. It goes also from product design to manufacturing in a seamless process.

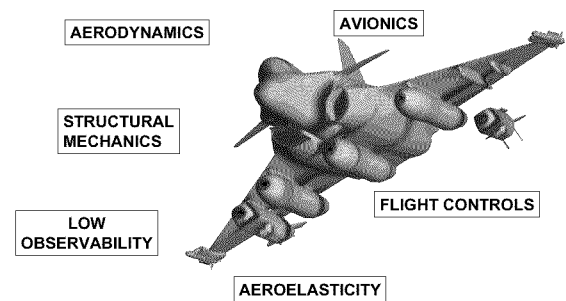
For mission systems (in this figure)



a proper breakdown of high level requirement to global specification and detailed specifications is necessary, enabling impact analysis of changes to the very end of elementary software components.

- **Multidisciplinary**
- Modelisation must integrate the models produced by the different technical disciplines, and this based on common product definition.
- Two significant examples of present results :

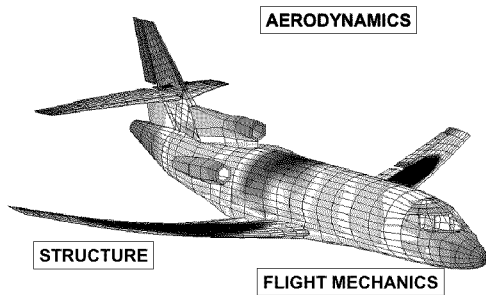
**MULTIDISCIPLINARY : WEAPON INTEGRATION**



- One military : weapon integration : The figure above shows the launch of an Apache/Scalp cruise missile from a Rafale with three drop tanks. Weapons integration is a skilful combination of six disciplines : Aerodynamics, Structural mechanics, Low observability, Aeroelasticity, Flight controls and Avionics.

- Another example of multidisciplinary modelisation is a Falcon in manoeuver with a combination of structures, aerodynamics, flight mechanics and aeroelasticity.

**MULTIDISCIPLINARY : FALCON IN MANOEUEVER**



Two examples of current significant strides :

**STIMULATING MULTIDISCIPLINARY CHALLENGE**  
DEVELOPMENT OF FUTURE RAFALE NAVY TWIN SEATER

- DIRECT TRANSPOSITION OF EXTERNAL STORES INTEGRATION



- INTENSIVE USE OF DYNAMIC SIMULATION AND SHOCK MODELLING ALLOW DIRECT TESTS ON CHARLES de GAULLE CARRIER WITH A PRODUCTION AIRCRAFT
- SUPPRESSION OF GROUND AND FLIGHT TEST ON DEDICATED CATAPULTING AND ARRESTING FACILITIES

- The Rafale N : this new version of Rafale twin seater for the French Navy will be directly developed as a production aircraft. This is only possible by virtue of the quality of the modelisation, particularly the multidisciplinary modelisation of catapult launching and arrested landing.

- Cabin noise reduction :

**MULTIDISCIPLINARY**  
NOISE REDUCTION IN A/C CABIN : A NEW DESIGN DRIVER

- VIBRO-ACOUSTICS
- AERODYNAMICS
- STRUCTURAL PROPAGATIONS
- ADAPTED INSULATION MATERIALS



**➡ FULL APPLICATION TO F7X PROGRAM**

A low noise level in cabins of business jets is a customer demand.

Traditionally this was done mostly experimentally by adding phonic insulations on existing airframe. That was both heavy and costly.

A new multidisciplinary design method allows introduction of noise level as a design driver in a new global optimization of structure and acoustic insulation.

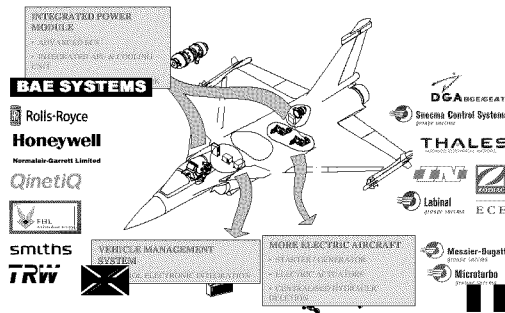
**Multipartner/Multisite**

The aircraft being a global product and not the simple sum of independent subsystems, product modeling and simulation must allow to integrate in global models coherent and relevant models developed by partnering companies. Both to verify the behaviour of the subsystem in its environment, and to check overall behaviour of the complete system.

Two examples :

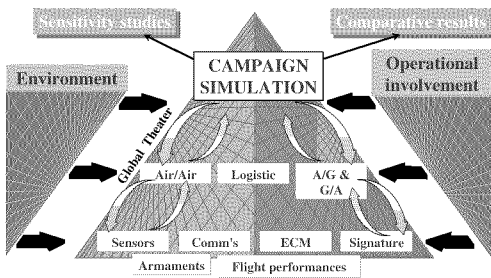
- Optimization of on board energy system. An example of multipartner studies is given in the next figure .

**MULTIPARTNER : FRANCE-UK PARTNERSHIP  
OPTIMIZED ENERGY MANAGEMENT**



- This study is not only multipartner but also multiobjective as the results have to be applicable to different programs : existing combat A/C, UAV/UCAV and future European Combat Aircraft.
- Technical-operational simulation

**MULTIPARTNER :  
TECHNICAL-ECONOMICAL-OPERATIONAL SIMULATIONS**



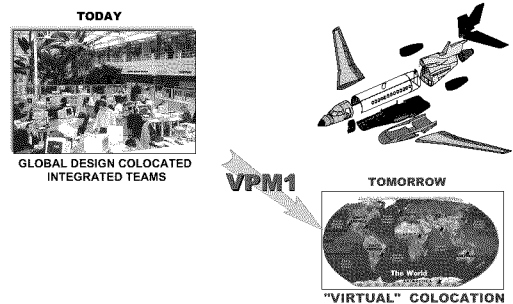
The combination of aircraft system models from different origins, environment model (theater) and operational involvement models permit very high level campaign simulation as well as more detailed simulation of operational phases (example Air to Air) and detailed modelization (for example for a sensor in its environment)

Today's developments including several companies in several countries force to rethink IT architecture and develop new systems enabling several actors, initially "physically" colocated for preliminary

design phases, to work efficiently in their own sites "virtually" colocated. Process commonality is also necessary to continue "concurrent engineering" between design offices as well as production teams in their plants. The need is there to insure a universal sharing of up to date data.

Development of the FALCON 7X

**MULTIPARTNER :  
F7X " IN CONTEXT AIRCRAFT DESIGN "**



is at present being done by an integrated design team gathering in St Cloud representatives of 18 participating companies, then is to transition during this summer to "virtual" cooperative work, using latest technological development of VPM1 tools suite.

In the field of systems and software development, Dassault Aviation has also set up a wide range of "System and software workshops" for new developments of embedded systems : Flight Control System, Navigation and Weapon Systems, Utilities Systems.

Systematic use of object oriented technology among partnering companies allowed significant benefits and cost effectiveness derived from generic architecture and optimised commonality.

**3 - TOMORROW CHALLENGES**

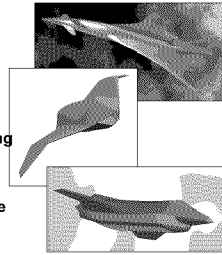
To continue progression in the field of product modelling and simulation several challenges have to be considered :

- Scientific challenges,
- Information technology challenges,
- Management challenges, and pragmatic limits.

## – Scientific Challenges

### SCIENTIFIC CHALLENGES

- Generalized automatic shape optimization
- Non-linear coupling
  - ex.: transonic aeroelasticity
- Distributed control
- Low-cost high-performance computing
  - metacomputing
- Formal verification of large finite state software modules



A number of subjects have still to be improved ; and will benefit from a coherent long-term investment plan :

- generalized automatic shape optimization,
- non linear coupling (a typical example is transonic aeroelasticity),
- distributed control,
- low-cost high performance computing,
- formal verification of large finite state software modules.

## – Information Technology Challenge

### IT CHALLENGES

- **OPEN ARCHITECTURES**  
TO TAKE FULL ADVANTAGE OF COTS PROGRESS AND EMERGING TECHNOLOGIES
  - ⇒ Avionics
  - ⇒ Engineering and manufacturing frameworks
- **TOOLS AND DATA PERENNITY**  
ALONG THE LIFE-CYCLE (30 TO 50 YEARS)
  - ⇒ Intensive data reuse
  - ⇒ Seamless re-engineering process
- **KNOWLEDGE MANAGEMENT**
  - ⇒ To cope with up to 20 years gaps between major programs
  - ⇒ To capitalize safety critical information

Three axes emerge :

- Open architectures to maximise use of COTS and be able to integrate new technologies
- Tests and data perennity

As the life cycle of the product may be 30 to 50 years, it is mandatory to be able to migrate

and reuse data with a limited effort.

In the same vein, the company must be able to easily reengineer or modify parts of the product and replace without rupture engineering, manufacturing and support tools.

## – Knowledge management

There also the timespan between major programs must be considered with the problem of maintaining expertise of the design team ; a typical example is the capitalization of safety critical information for continuous improvement of crew and passenger safety.

## – Management challenge

### MANAGEMENT CHALLENGES NEW DESIGN MANAGER'S COMPETENCIES

- DEVELOPMENT OF FINAL PRODUCT'S VISION INCLUDING PERFORMANCES AND COSTS MODELLING : MAIN SYSTEM AND SUPPORT SYSTEM
- CREATE INTERDISCIPLINARY SYNERGIES TO TIME AND COST REDUCTION VIA GENERALIZATION OF CONCURRENT ENGINEERING
- ANALYSE MASTER AND IMPLEMENT COMPLEX PROCESSES : BE ABLE TO SPECIFY NEW INFORMATION SYSTEMS TAKING INTO ACCOUNT CLOSE PARTNERSHIP WITH OTHER COMPANIES

To cope with the demands of the development of more and more complex and closely integrated products, managers with a new set of competences are needed.

They must be able to :

- Develop a final product's vision (performances and costs) both for the main system, and support system.
- Create interdisciplinary synergies to time and cost reduction via generalization of concurrent engineering ; these managers must especially have enough multidisciplinary knowledge to be able to remove "fences" between disciplines.
- Analyse, master and implement complex processes, and specify new information systems taking into

account close partnership with other companies.

– **Pragmatic limits**

**MANAGEMENT CHALLENGES**  
COMMITTING TO BEST PRACTICES

- SET UP SIMULATIONS AND MODELLING SUPERVISION USING FORMALIZED AND STEADILY UPDATED PROCESSES
- INSIST ON ACCURACY AND RELIABILITY TO EVALUATE TECHNOLOGICAL RISKS → IDENTIFY MATURITY LEVEL
- CREATE A FULLY REUSABLE DATA BASE AND ASSOCIATED TOOL SET
- KEEP HIGH LEVEL SYNTHESIS REALLY ACTIVE, USING SIMPLIFIED MODELS

In addition to the limits resulting from constraints of the scientific tools, a more fundamental problem is the limitation of human understanding of the behaviour of a very complex system. It is still a dream to believe that a "true" and consequently detailed representation of highly integrated complex systems of systems can be understood and fully mastered by the engineering team. Tomorrow as yesterday, high level synthesis will still be carried out using also simplified behavioural models.

## 4 - CONCLUSION

Three factors can be summarized as key points to steadily improve design, manufacturing and support processes, permitting an effective enhancement of methodologies and an advanced risk management of new projects :

1. Intensive use of technical-economical-operational simulation
2. Smooth communication and parallel teamwork
3. Implication of the customer from end to end, starting with preliminary specifications and including Life Cycle Cost.

### *Paper Keynote #2*

Discussor's name John Martin

Author L. de Jessey

**Q:** In my company we have a problem with level of detail between manufacturing detail and visualization detail, particularly for parts provided by third parties. Your presentation suggested that the digital mock-up is not complete until you have all data captured. How do you address the level of detail issue for a complete aircraft?

**A:** We have a common problem. For example, we buy engines for our aircraft so we can use a simple version of engine model in the mockup. Also our supplier information is often not of correct quality and we have a team to create suitable levels of model for our mock up from the design data