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Structural In-Service Monitoring of Advanced Combat Aircraft: Operational Benefits

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CONTENTS

- Simple facts
- Structural Design Methodology
- The Rafale Health and Usage Monitoring System
- Operational Benefits

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SIMPLE FACTS

- Structural monitoring of previous generation aircraft

strain gauges + dedicated computer

poor ageing, drift, re-calibration

mass, power, reliability penalty

Emergence of the need for more advanced systems

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- Simple facts
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STRUCTURAL DESIGN METHODOLOGY

GENERAL

Continuous Follow-up of all Dassault Aircraft Programs

Initial Conditions Aerodynamic Loads
Fatigue Spectrum

Initial Design Loads
Durability & Damage Tolerance

Development Components Tests
Airframe Cell Test
Prototype Flights

Final Design
Structure Limit Loads
First Inspection & Maintenance Program

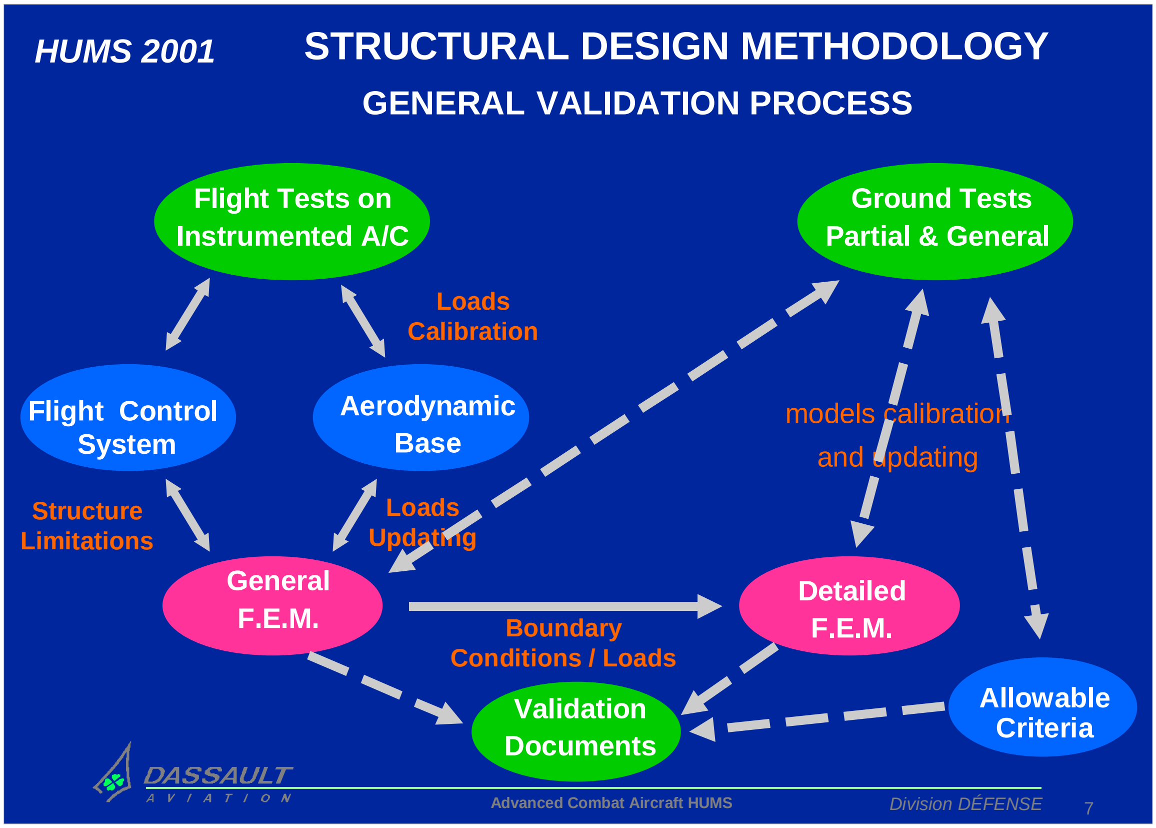
Operational Flights Structure Limit Loads

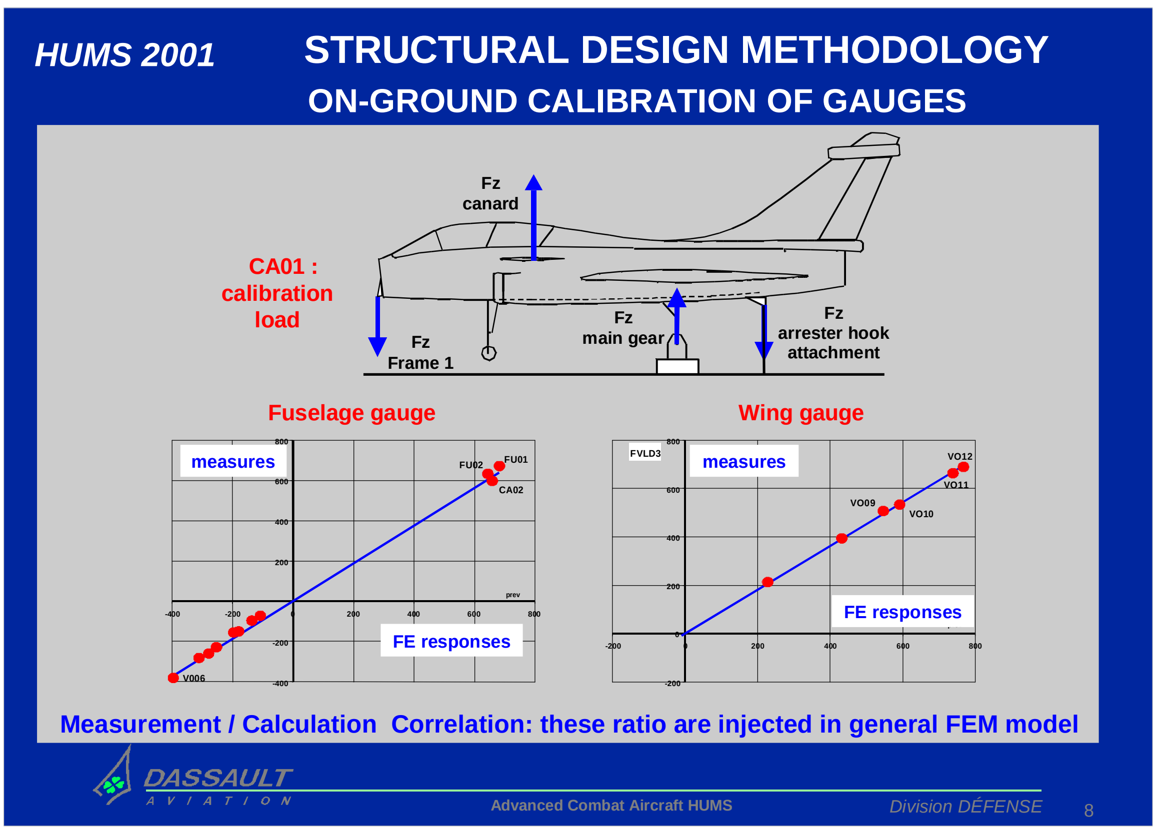
Fatigue Test on Aged Aircraft
from Fleet + Operational Loads

Inspection & Maintenance Program Updating

Fatigue Index Extension

TITRE DE LA PRESENTATION





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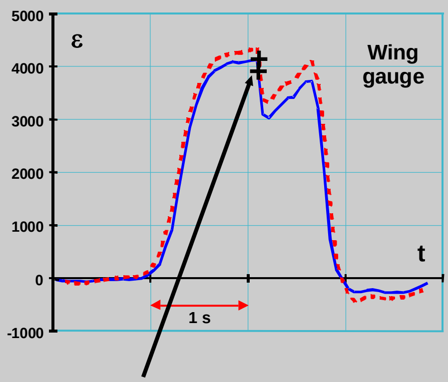
STRUCTURAL DESIGN METHODOLOGY

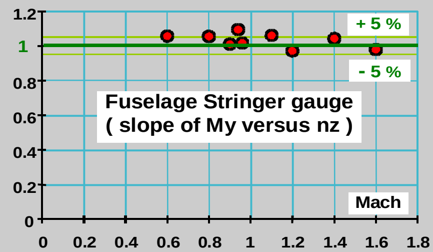
FLIGHT TEST EXPLOITATION

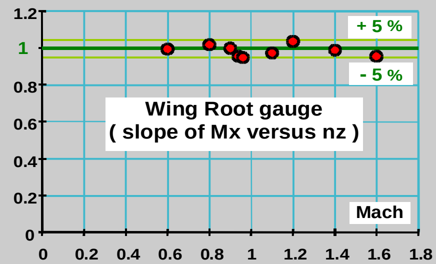
Samples of Flight/Computation Comparisons

Roll manoeuvre : strain response in time



If ratio "max measured/max. computed" is not # 1 then aeroelasticity database is re-calibrated by modifying aerodynamic database





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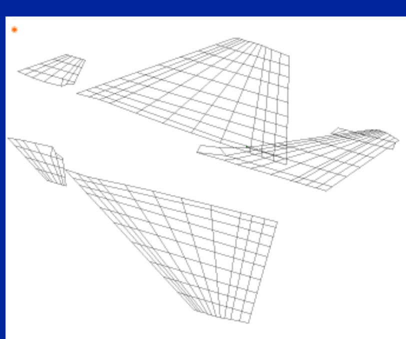
STRUCTURAL DESIGN METHODOLOGY

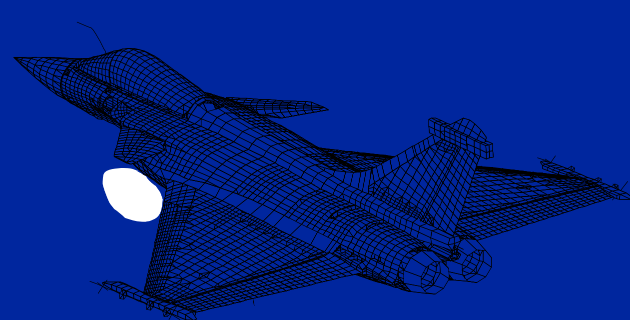
FLIGHT LOADS CONSTRUCTION

- Lifting surfaces grids
- Boxes (fuselage and external stores)

Manoeuvre conditions → Aeroelastic computation

General FE model with reference loads





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TITRE DE LA PRESENTATION

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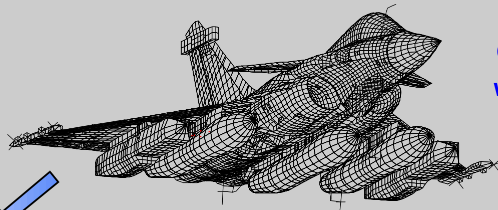
STRUCTURAL DESIGN METHODOLOGY

STATIC AND FATIGUE VALIDATION PROCESS

Procedures

Criteria

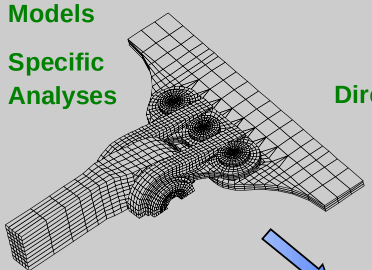
Allowables



Calibrated F.E. Model
with Reference Loads

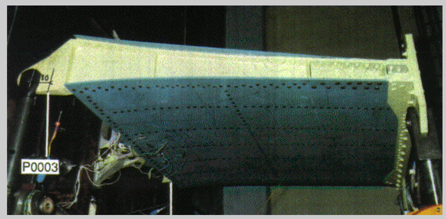
Detail
Models

Specific
Analyses



Direct Exploitation

Tests



Wing Box Attachment

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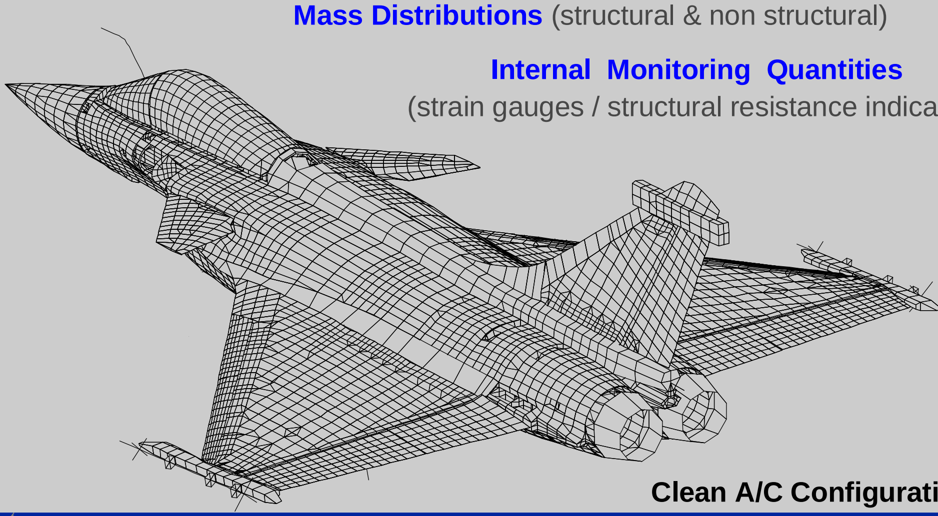
STRUCTURAL DESIGN METHODOLOGY

GENERAL FINITE ELEMENT MODEL

Creation with CATIA (geometrical & material characteristics)

Mass Distributions (structural & non structural)

Internal Monitoring Quantities
(strain gauges / structural resistance indicators)



Clean A/C Configuration

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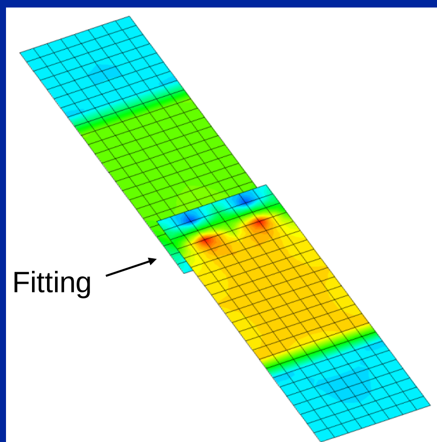
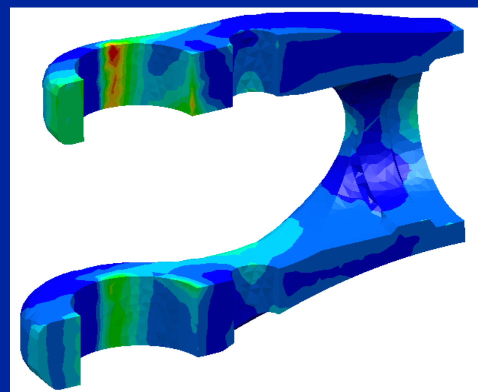
HUMS 2001 **STRUCTURAL DESIGN METHODOLOGY**

AIRFAME VALIDATION : DETAILED MODELS EXPLOITATION



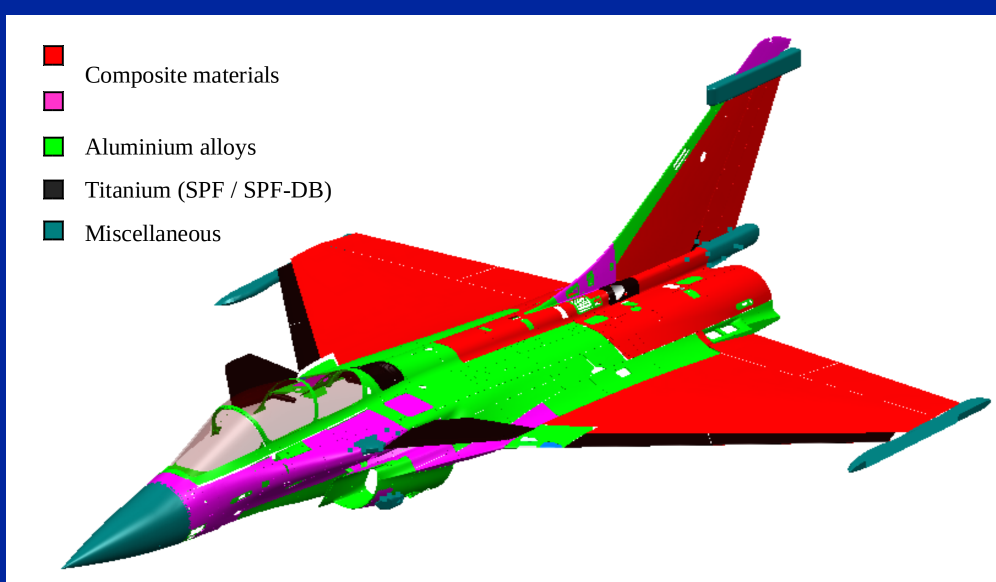


Elementary specimen (2.5D) **Arresting hook lug (3D)**

Type of Models especially used for Fatigue Calculations

HUMS 2001 **STRUCTURAL DESIGN METHODOLOGY**

RAFALE MATERIALS



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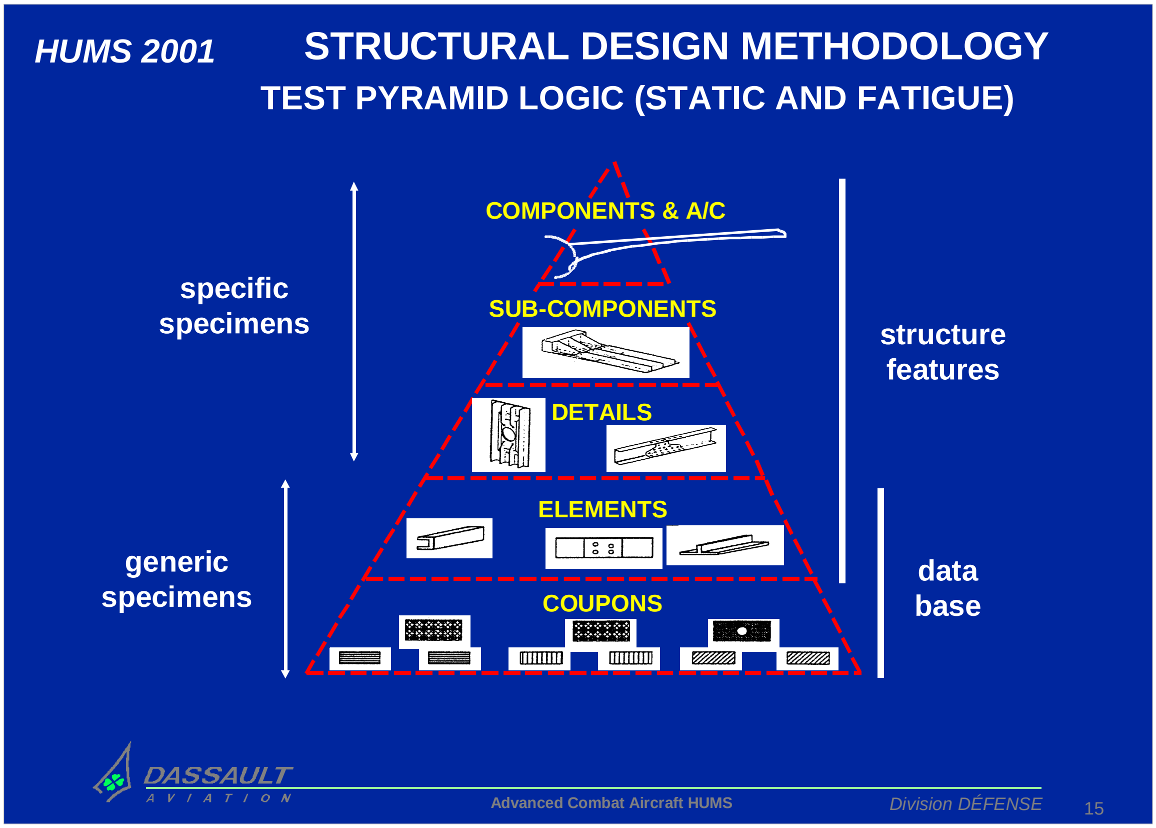

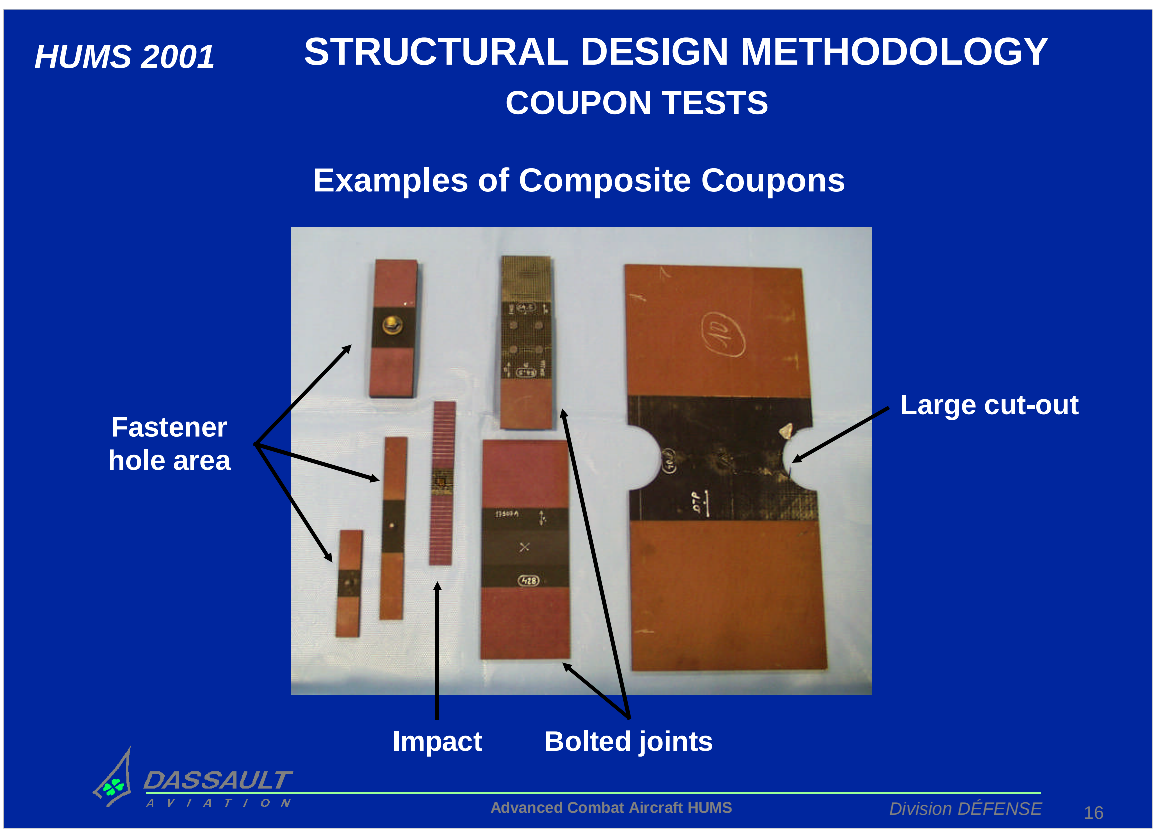

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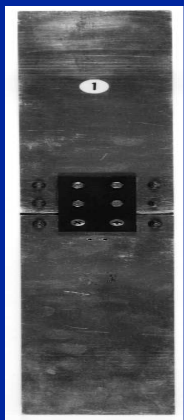
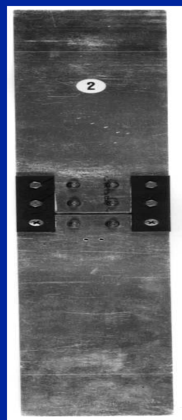
STRUCTURAL DESIGN METHODOLOGY

GENERIC ELEMENTS TESTS

Bolted Joint





Stiffeners

Used for Design Criteria & Allowable Construction

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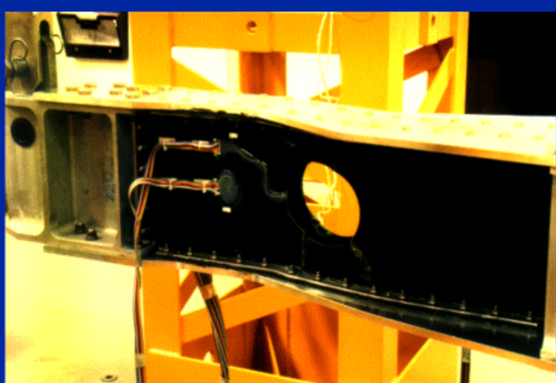
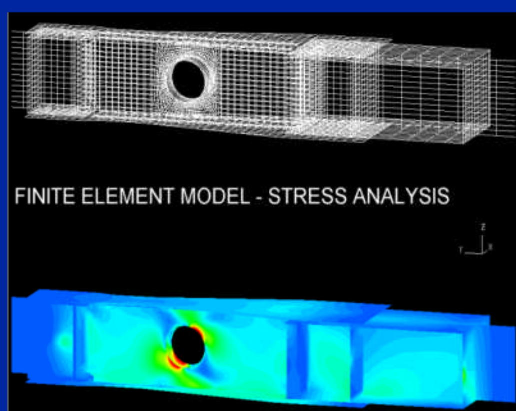
STRUCTURAL DESIGN METHODOLOGY

SUB -COMPONENT TEST





Simulation & Test of Wing Spar

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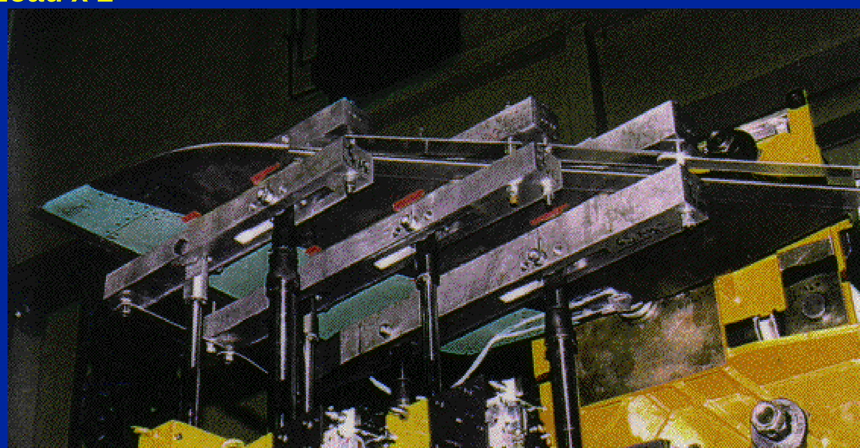
STRUCTURAL DESIGN METHODOLOGY

AIRCRAFT COMPONENT TESTING

Full Scale Test :

Fatigue (25 000 hours)

Static : Limit Load x 2



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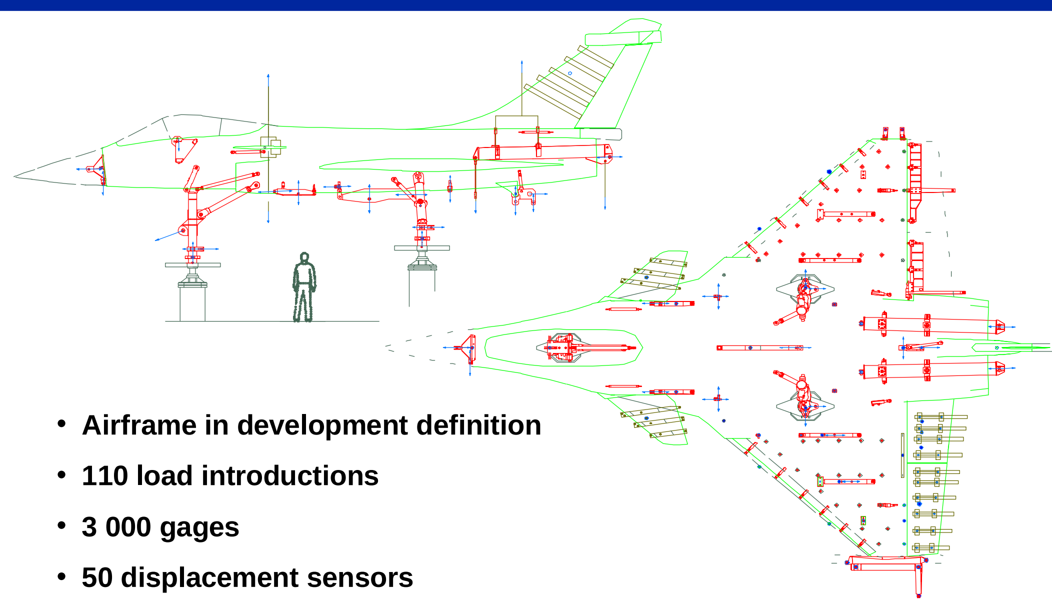
STRUCTURAL DESIGN METHODOLOGY

MECHANICAL TEST AIRFRAME



- **Airframe in development definition**
- **110 load introductions**
- **3 000 gages**
- **50 displacement sensors**

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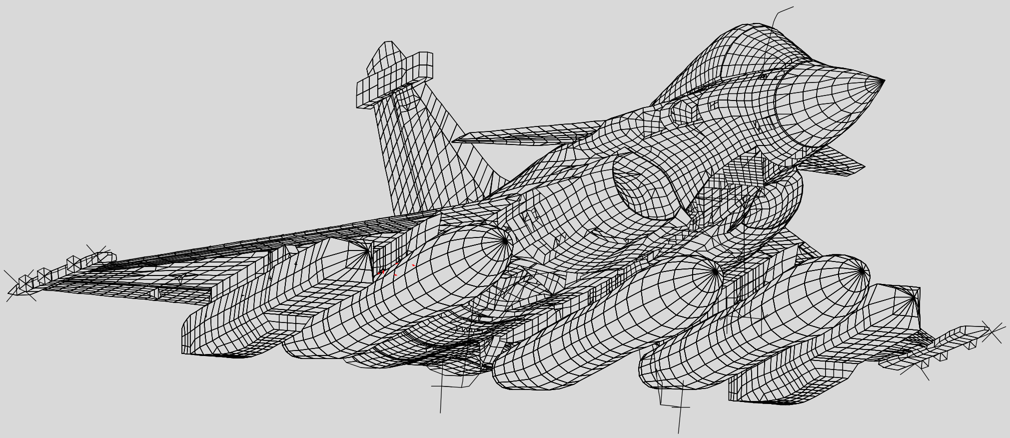
STRUCTURAL DESIGN METHODOLOGY
EXTERNAL STORES VALIDATION



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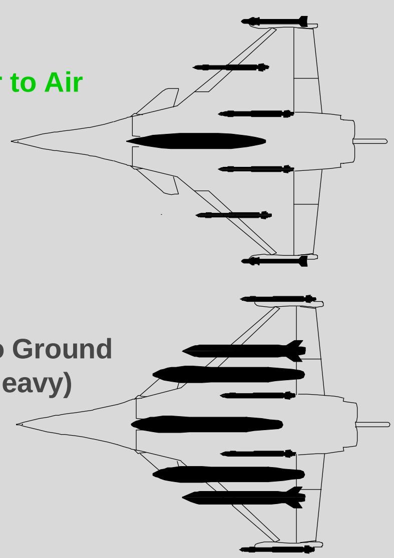
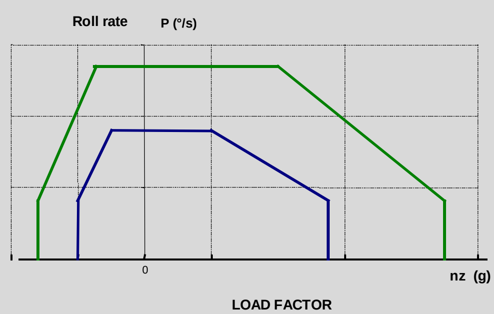
STRUCTURAL DESIGN METHODOLOGY
EXTERNAL STORES VALIDATION

Air to Air

Air to Ground (Heavy)



Design Envelope



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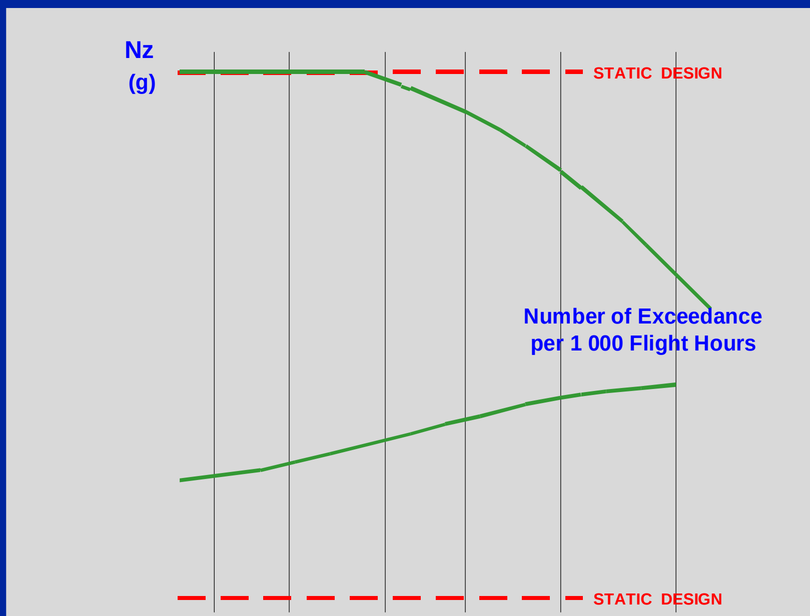
STRUCTURAL DESIGN METHODOLOGY

FATIGUE REFERENCE SPECTRUM



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STRUCTURAL DESIGN METHODOLOGY

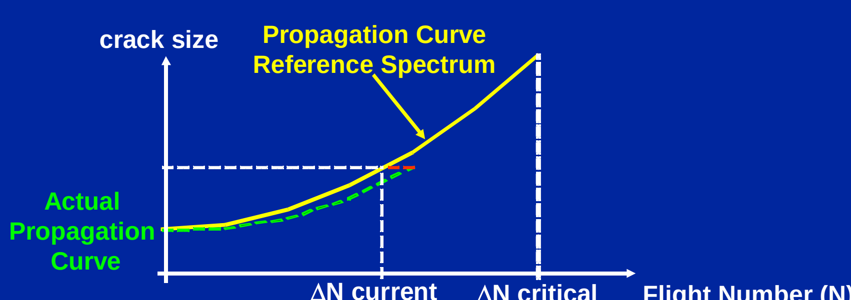
FATIGUE & PROPAGATION INDEXES

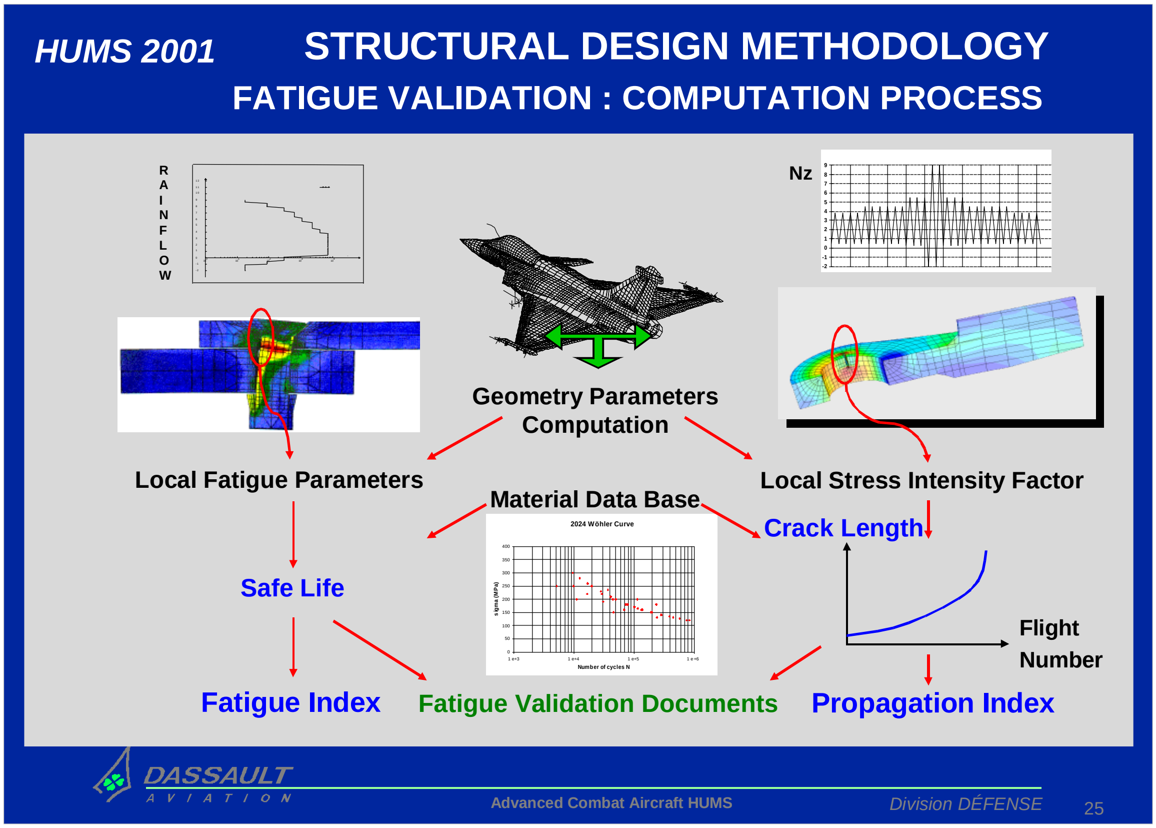
Reference Spectrum : XX Flight Hours equivalent to Indexes = 100

Structure Fatigue Strength calculated with Reference Spectrum

Fatigue Validation ⇔ Fatigue or Propagation Index > 100

In-Service Spectrum : Computation of F.I. & P.I. Actual Consumption





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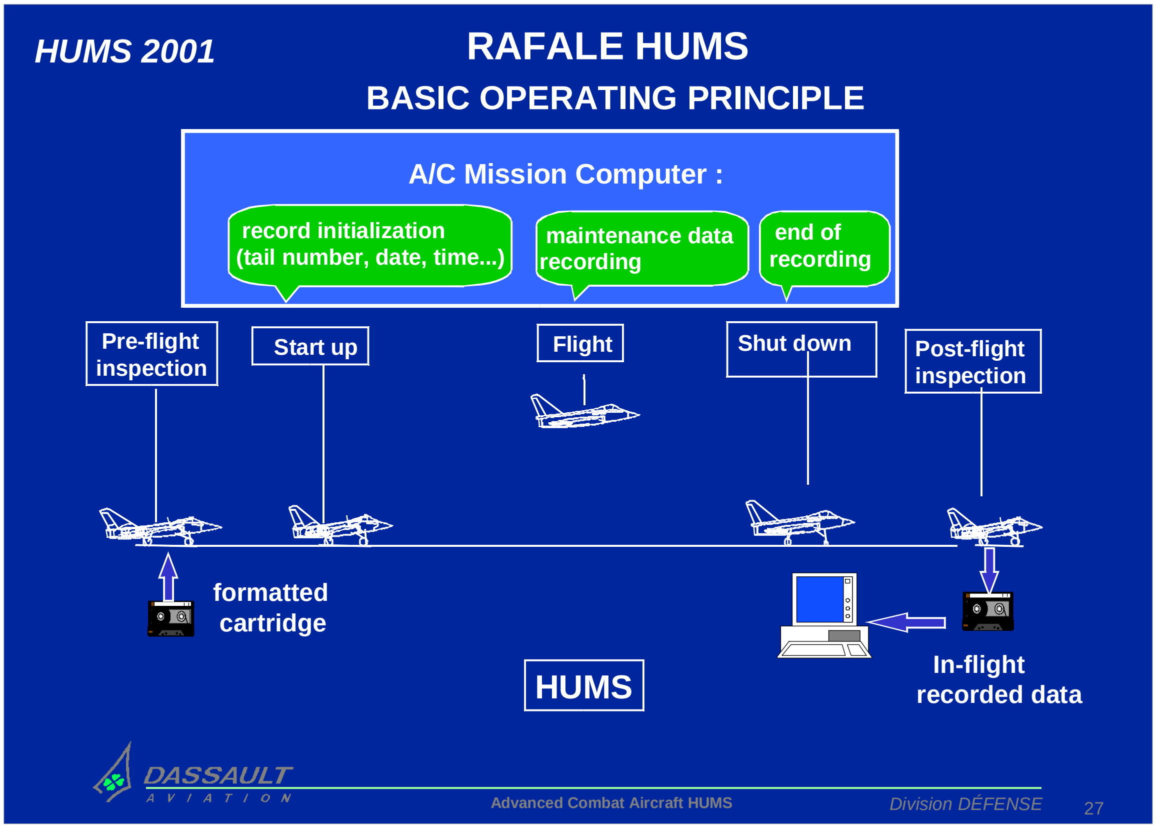
- Structural Design Methodology
- **The Rafale Health and Usage Monitoring System**
- Operational Benefits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RAFALE HUMS
BASIC OPERATING PRINCIPLE
A/C Mission Computer :
record initialization
(tail number, date, time...)
maintenance data recording
end of recording
Pre-flight inspection
Start up
Flight
Shut down
Post-flight inspection
formatted cartridge
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In-flight recorded data
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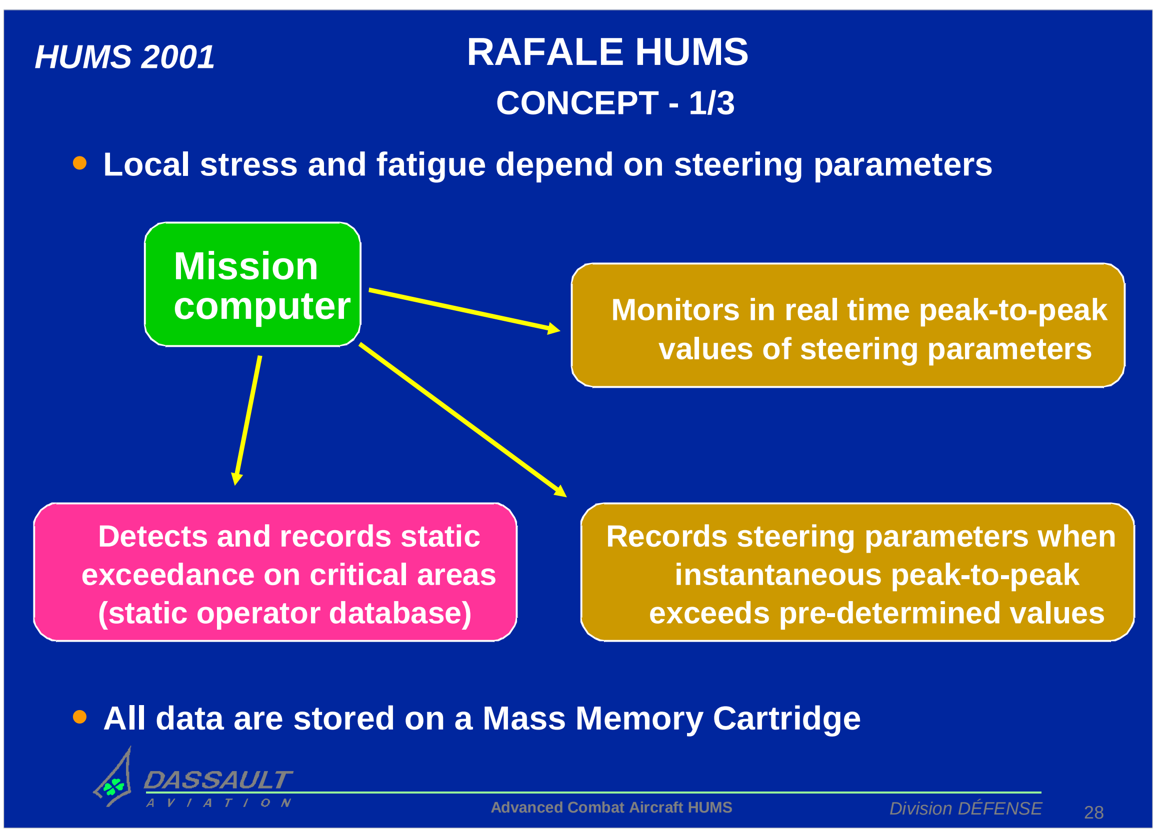
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RAFALE HUMS
CONCEPT - 1/3
• Local stress and fatigue depend on steering parameters
Mission computer
Monitors in real time peak-to-peak values of steering parameters
Detects and records static exceedance on critical areas (static operator database)
Records steering parameters when instantaneous peak-to-peak exceeds pre-determined values
• All data are stored on a Mass Memory Cartridge
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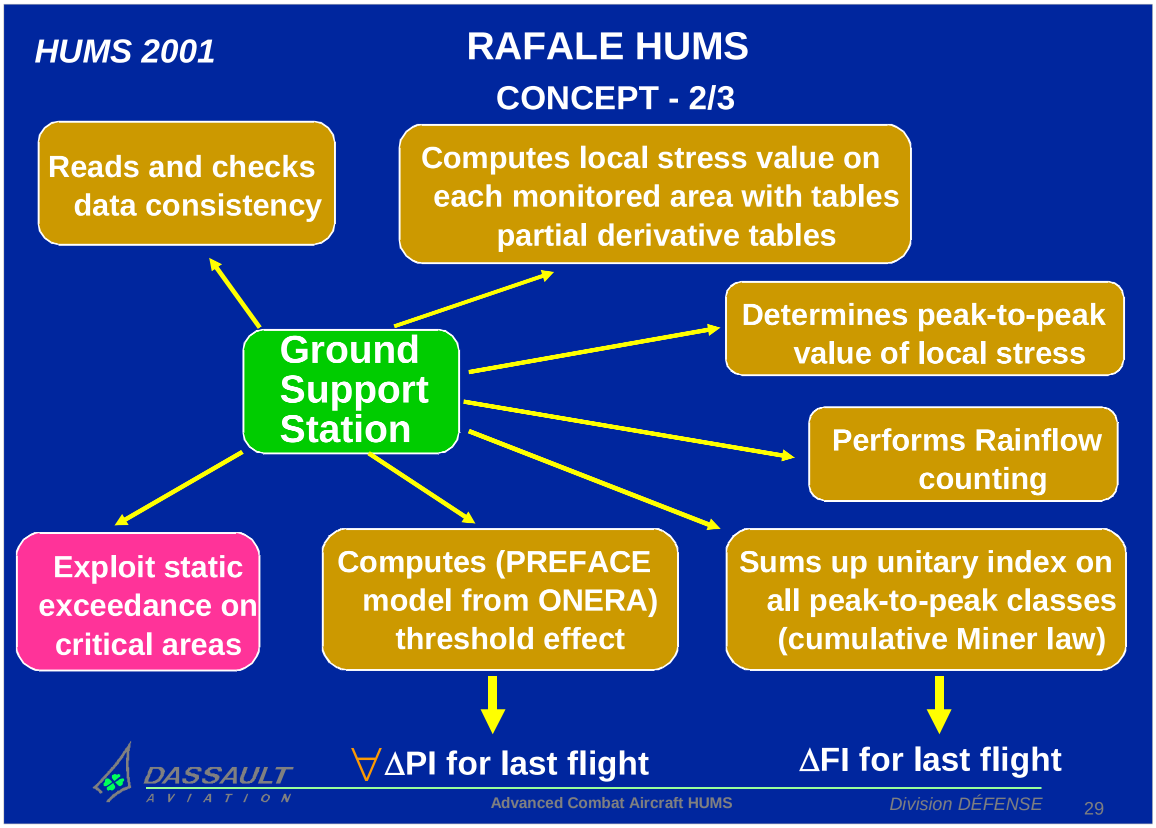
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RAFALE HUMS
CONCEPT - 2/3
Reads and checks data consistency
Computes local stress value on each monitored area with tables partial derivative tables
Determines peak-to-peak value of local stress
Ground Support Station
Performs Rainflow counting
Exploit static exceedance on critical areas
Computes (PREFACE model from ONERA) threshold effect
Sums up unitary index on all peak-to-peak classes (cumulative Miner law)
∀ΔPI for last flight
ΔFI for last flight
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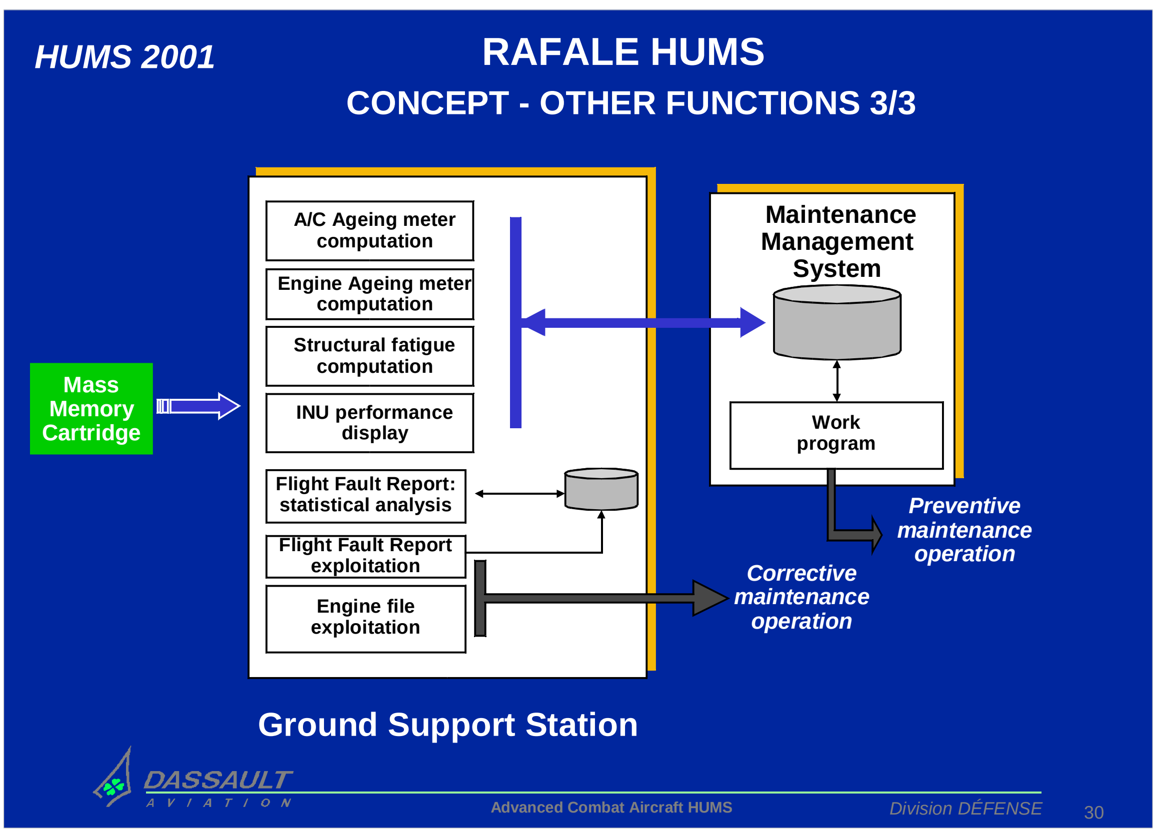
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RAFALE HUMS
CONCEPT - OTHER FUNCTIONS 3/3
A/C Ageing meter computation
Engine Ageing meter computation
Structural fatigue computation
INU performance display
Flight Fault Report: statistical analysis
Flight Fault Report exploitation
Engine file exploitation
Mass Memory Cartridge
Maintenance Management System
Work program
Preventive maintenance operation
Corrective maintenance operation
Ground Support Station
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TITRE DE LA PRESENTATION

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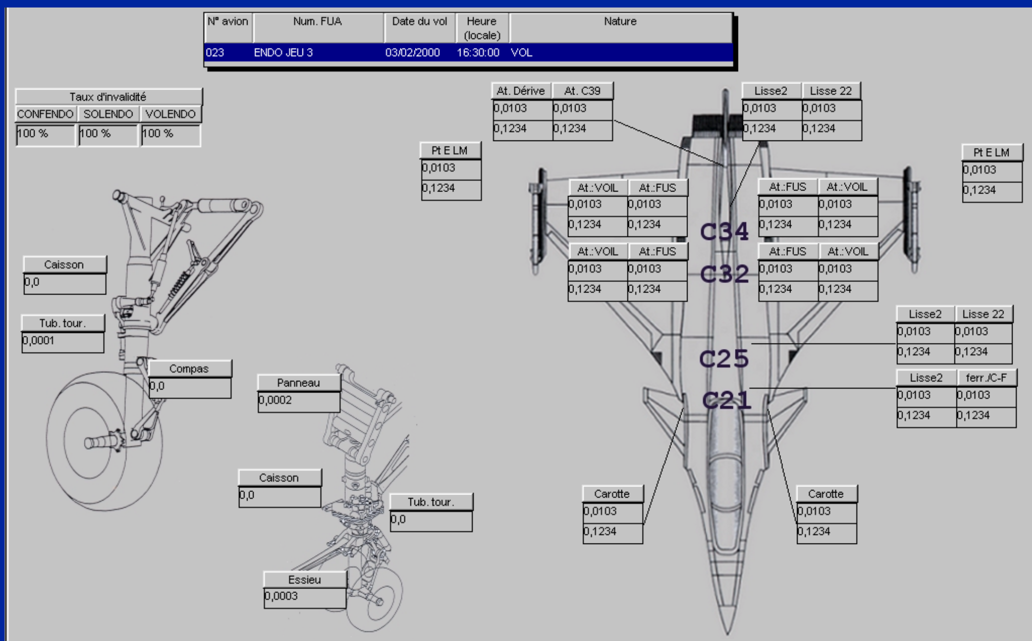
RAFALE HUMS

TYPICAL MAN-MACHINE INTERFACE



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Advanced Combat Aircraft HUMS

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- Simple facts
- Structural Design Methodology
- The Rafale Health and Usage Monitoring System
- **Operational Benefits**

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Advanced Combat Aircraft HUMS

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RAFALE HUMS

OPERATIONAL BENEFITS - 1/3

- On-ground computation of indexes enable to:
  - re-compute at any time the structural health of any area, in combination an accurate F.E. modelisation,
  - very easily support the software, since it is not flight-rated
  - save computing power on-board of the aircraft
  - monitor a high number of areas (# 30 on Rafale), thus providing for an itemised following of structurally significant elements

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RAFALE HUMS

OPERATIONAL BENEFITS - 2/3

- On-board monitoring of a limited set of non-dedicated steering parameters enable to:
  - save computing power on-board of the aircraft
  - devote this function to the mission computer only
  - save the mass, power, volume and reliability penalties generated by a dedicated system
  - record a high number of flights in the memory cartridge (10)

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TITRE DE LA PRESENTATION

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RAFALE HUMS
OPERATIONAL BENEFITS - 3/3

- Accurate modelisation enables to plan structural maintenance out of the actual use of the aircraft
- Fully automatic processing and clear language reduces training needs for structural life consumption assessment
- Simple inspection procedures associated with this index concept enable to support structural inspection at Intermediate Level throughout the aircraft life.