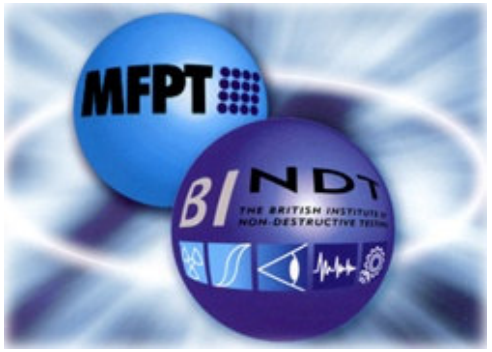
VITROCISET



CM2008 / MFPT2008 CONFERENCE

Vitrociset Activities in the Area of Health Management

Dr. Walter Matta (Vitrociset S.p.A) - CHAIRMAN

Vitrociset evolution toward PHM

- Vitrociset has large experience in the supply of MRO & ILS on very complex and critical systems in terms of performance and reliability.
- In the last year**, Vitrociset is evolving its preventive maintenance concepts from scheduled maintenance to predictive maintenance based on PHM**.
- This process is necessary to reduce the work process costs and consequently to improve its competitiveness on the MRO & ILS market.

R&D activities in the PHM field

- Vitrociset is participating in **international programs (e.g. JSF)** and various **R&D activities (auto-funded and co-funded)** in the field of **PHM of engines and mechanical aircraft structures.**
- In particular, Vitrociset constituted a **Focus Group** dedicated to the following main areas:
  - **Diagnostic & Prognostic System for Aircraft Engines based on vibration analysis**, in collaboration with **Cranfield University** (Prof. L. Gelman) and **Rolls Royce** (Dr. S. King)
  - **Prognostic of aircraft mechanical structures**, in collaboration with University of Cagliari.

Key Example n. 1:

Vibration Simulator Tool (VST)

Problem Statements

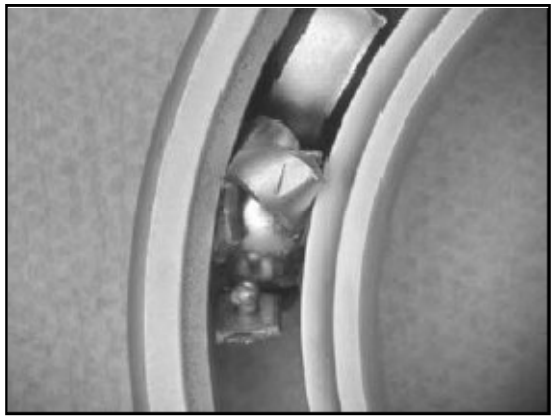
- The most common **health monitoring parameter** in the aerospace industry is **vibration**.
- The **validation and verification of prognostic capabilities** requires access to **quality data for both healthy and faulted systems**.
- While data for **healthy** systems is often readily available, **faulted data** is much more difficult to obtain.
- Seeded fault tests are **time consuming, expensive, and are not always representative of actual operation**.

Key Idea

- To implement an innovative and advanced system to reduce the **time & cost of PHM system development**:
  - **Vibration modeling** for healthy and faulted systems
  - **Dynamic simulating** of mechanical transmission paths, including the insertion of a realistic measurement noise

Scope of Project

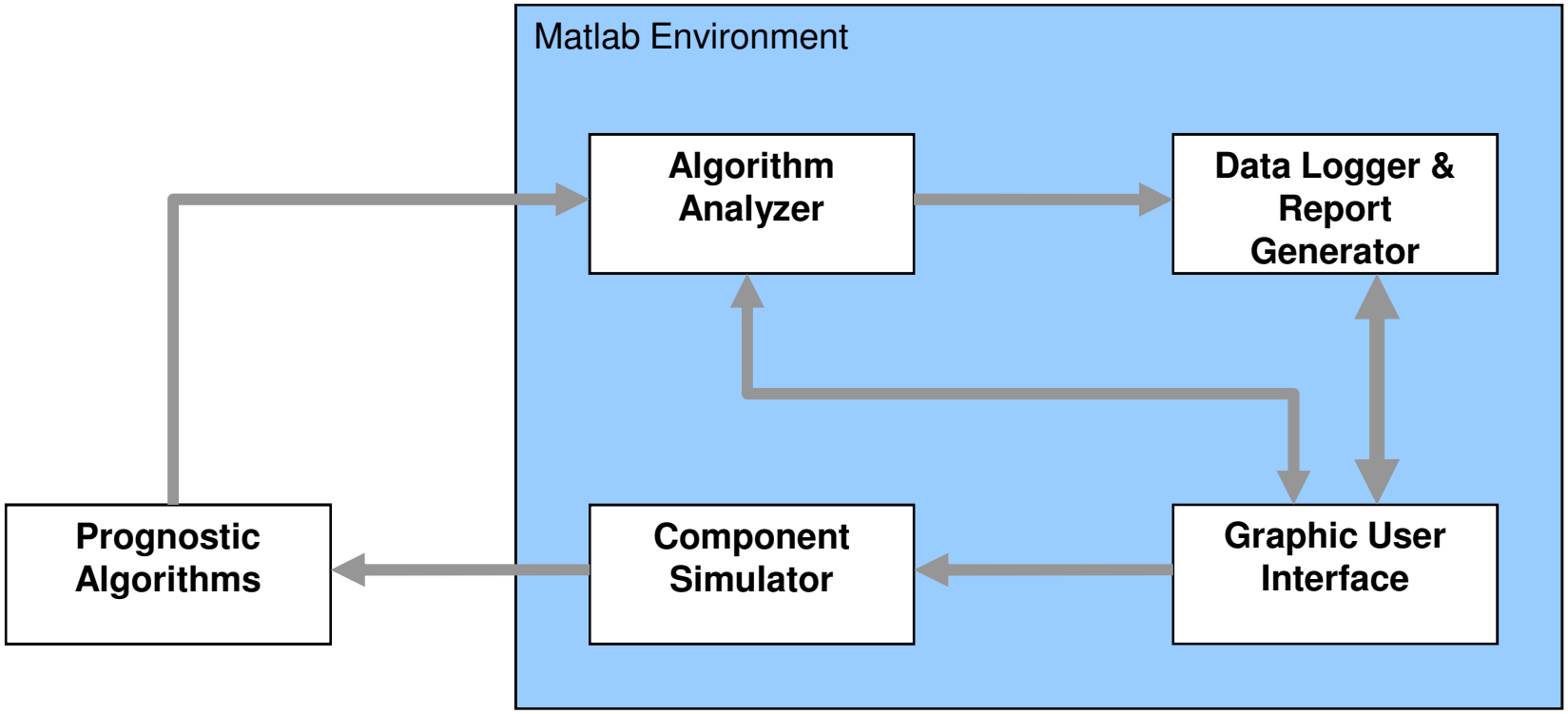
- **Generate** high-fidelity realistic vibration data
- **Populate** a database with faulted data
- **Augment or replace** physical testing
- **Validate** prognostic algorithms



Statement of Objectives

- **Simulating normal and faulted operation of the mechanical components** with emphasis on the dynamics and propagation of the mechanical vibrations induced by the fault(s).
- **Simulating the sensor mechanical transmission paths and the sensor dynamics**, including the insertion of a realistic measurement noise.
- **Interfacing** with the detection algorithms.
- **Testing and validating** the detection vibration analysis algorithms.
- Producing relevant validation **reports** and **statistics.**
- Interfacing with user by a **proper easy-to-use graphical user interface (GUI),** so that validation and verification simulation experiments can be set up from detection easily and results displayed efficiently.

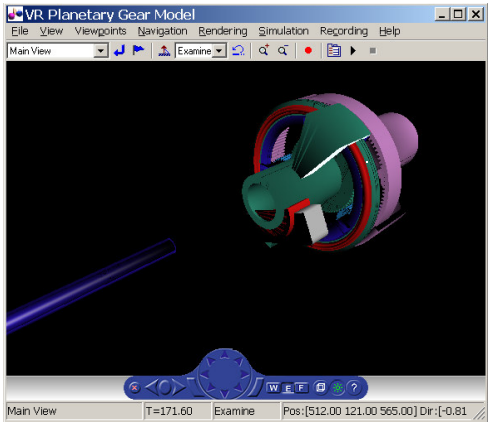
Architecture

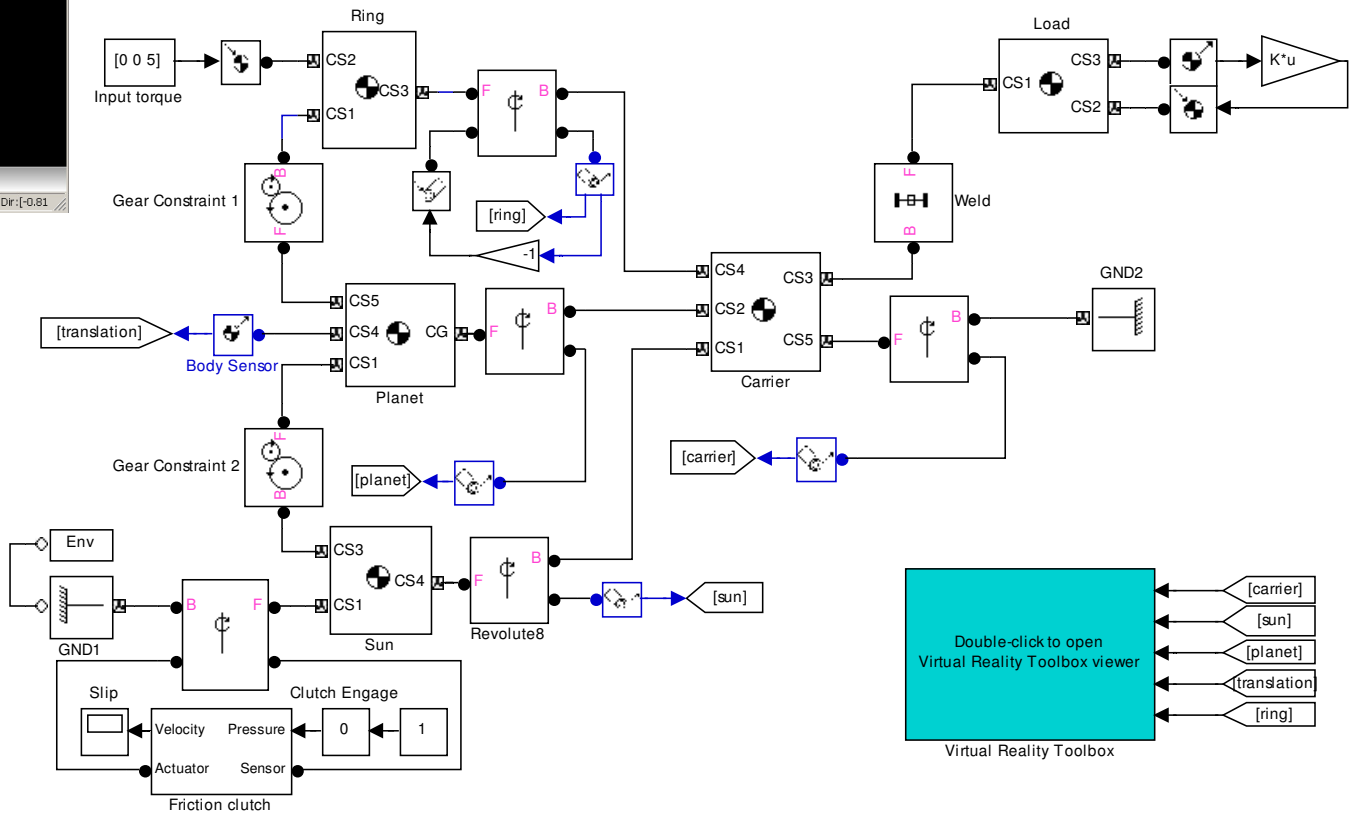


Components Simulator (cont'd)

- There are three main approaches for the systems modeling:
  - **Physics-based modeling**. The models should be targeted on capturing the mechanical interconnections of the components, the vibrations caused by the faults and the way the vibrations will propagate among the components of the engine and towards the sensor locations.
  - **Black-box modeling**. It uses real measurement data. At a first stage a candidate model with tunable parameters is identified. Then, its parameters are selected (parameter identification) in order to achieve a close matching between the model response and the measurements
  - "**Hybrid**" **modeling**. The candidate model is derived according to physics-based modeling, and its uncertain parameters are set via **parameter identification techniques** using measured data.

Components Simulator





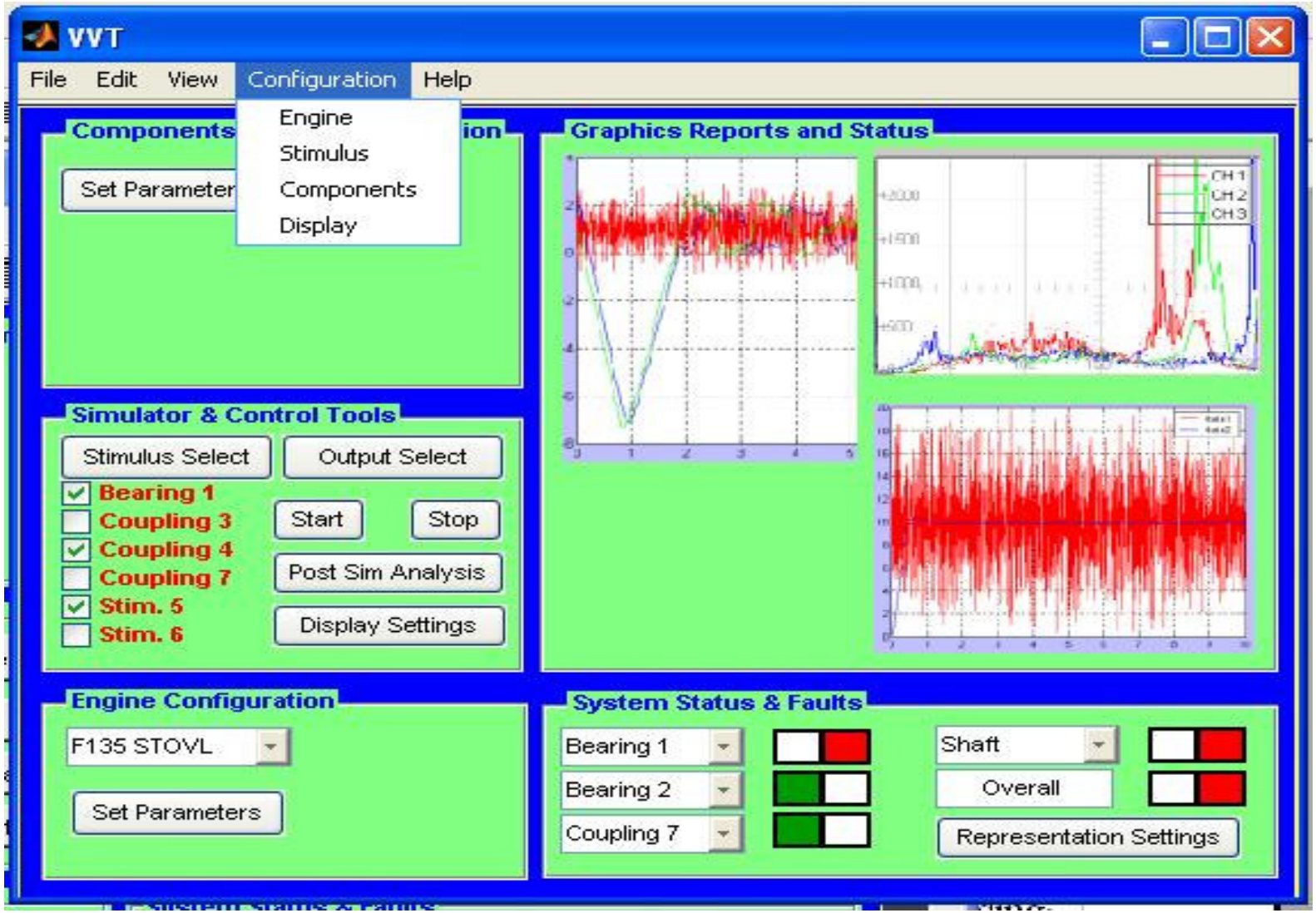
Detection Algorithms Analyzer

- **Processing of detection algorithms outputs** for extracting normal and faulted status of each mechanical components;
- **Generation of validation results** by comparing of computed status with the status selected by user;
- **Computing**, for each test, **of performance indexes of detection algorithm**, defined on the basis of **weighted function of missed detections and false alarms**, where each weight measures the relevance of each missed detection and each false alarm.
- **Computing and updating of statistical parameters**, such as:
  - Percentage of missed detections and false alarms of each detection algorithm
  - Percentage of missed detections and false alarms of each detection algorithm for each combination of faults
- **Statistical distribution of each performance index** of each detection algorithm

Graphic User Interface (cont'd)

- Main window
  - Menu Bar (File, Edit, View, etc)
  - Configuration & Setting Area/Window
  - Simulation & Control Area/Windows
  - Engine Configuration Area/Windows
  - Results Area/Windows

Graphic User Interface



Data Logger & Reports Generator

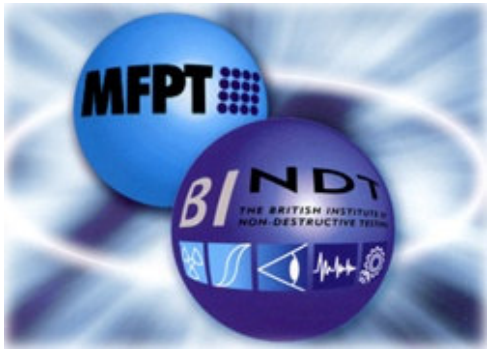
- For each trial, a **log file** containing the following data will be generated:
  - **Generality of the trial** (user name, denomination, date and hours of trial, synthetic description, etc.)
  - **Configuration and setting data** (engine type and configuration, parameter value of components and paths, selected faults, ..)
  - **Detection algorithm** to be analyzed (type and configuration)
  - **Simulation data** (type and properties of the mathematical solver, simulation start and stop times, external parameter to load, etc.).
  - **Final Results**
- Furthermore, for each detection algorithm, a **statistical report file** will be generated and update after each trial.

Applications

- In general, the **VST toolset can be used to benefit any industry using rotating machinery**.
- Military applications mainly include (but are not limited to) **jet/rotor aircraft and helicopters**.
- The **wind turbine power generation industry** is a rapidly growing industry that is actively pursuing PHM.
- Gearbox bearing failures are among the primary causes of wind turbine downtime; vibration analysis is the most commonly used method to detect **gearbox failure**.
- The VST toolset could be used in conjunction with operational data to **verify and validate** any diagnostic algorithm used by the PHM system.

Benefits

- Advanced modeling & simulation techniques.
- Reduction of validation algorithm time due to the study of quality indexes able to “measure” the tool performance of Customer’s detection algorithm.
- VST entirely designed and implemented to meet the Customer’s specific requirement.
- **Best cost-effective solution.**



Key Example n. 2:

PHM Analysis of Aircraft Components

Key Idea

To implement an innovative and advanced system for

fault diagnosis and prognosis

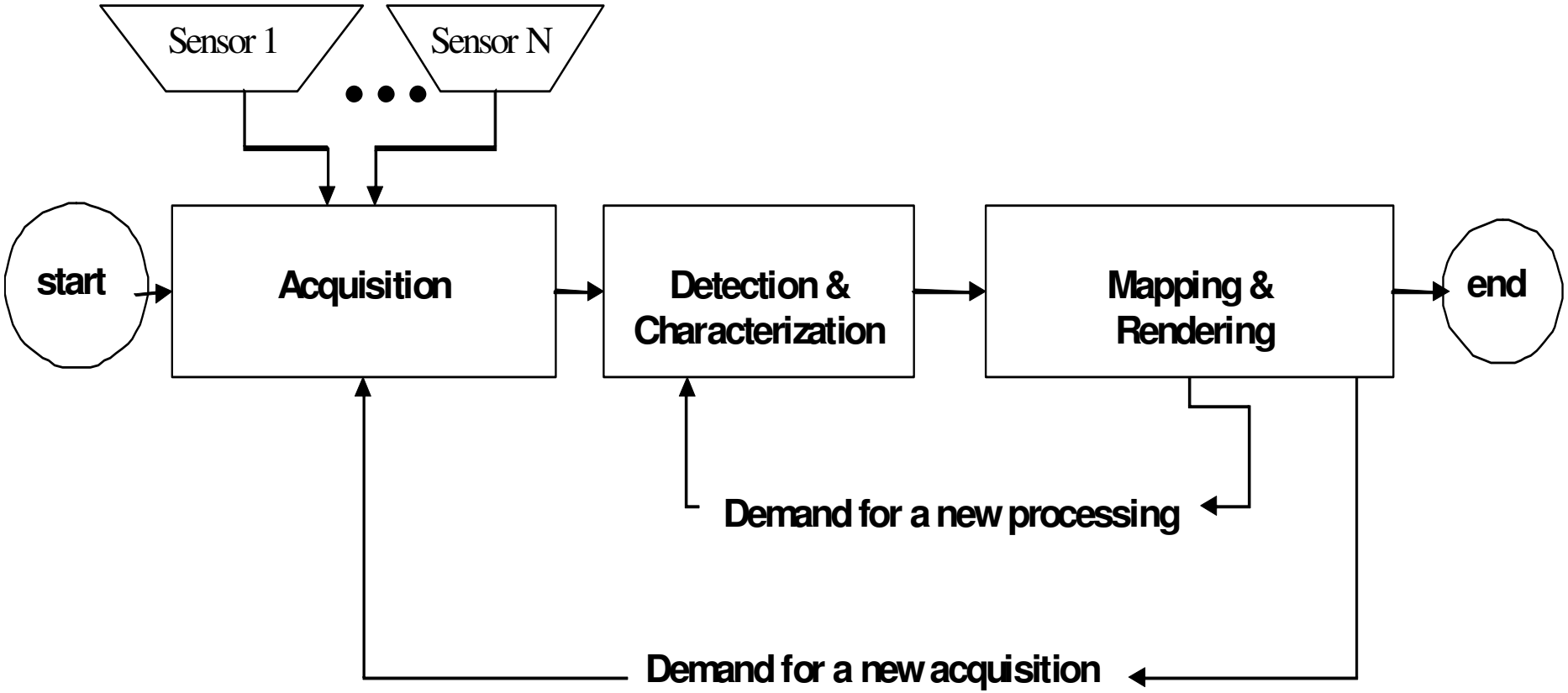
necessary for **monitoring and predictive maintenance** of aircraft structures (e.g. wings, nacelle, pipes and other components).

Scope of the Project

This innovative system will:

- locate **defects** in **aircraft components**
- predict the remaining life (**prognostic analysis**) of a component or a system

Logic Diagram

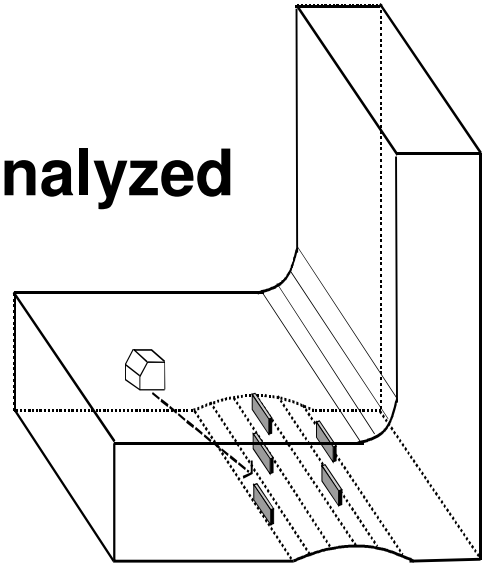


Input Data and Algorithms

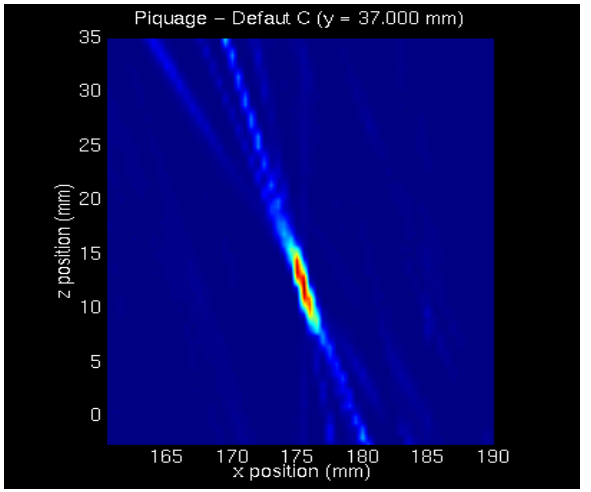
- Eddy Current (EC)
- Ultrasonic Techniques (UT)
- X-Ray (XR)
- Infrared (IR)

Acquisition

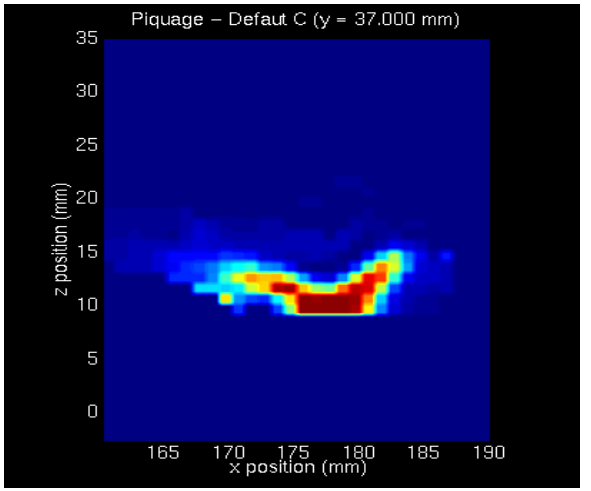
Object to be analyzed



X-Ray



UT



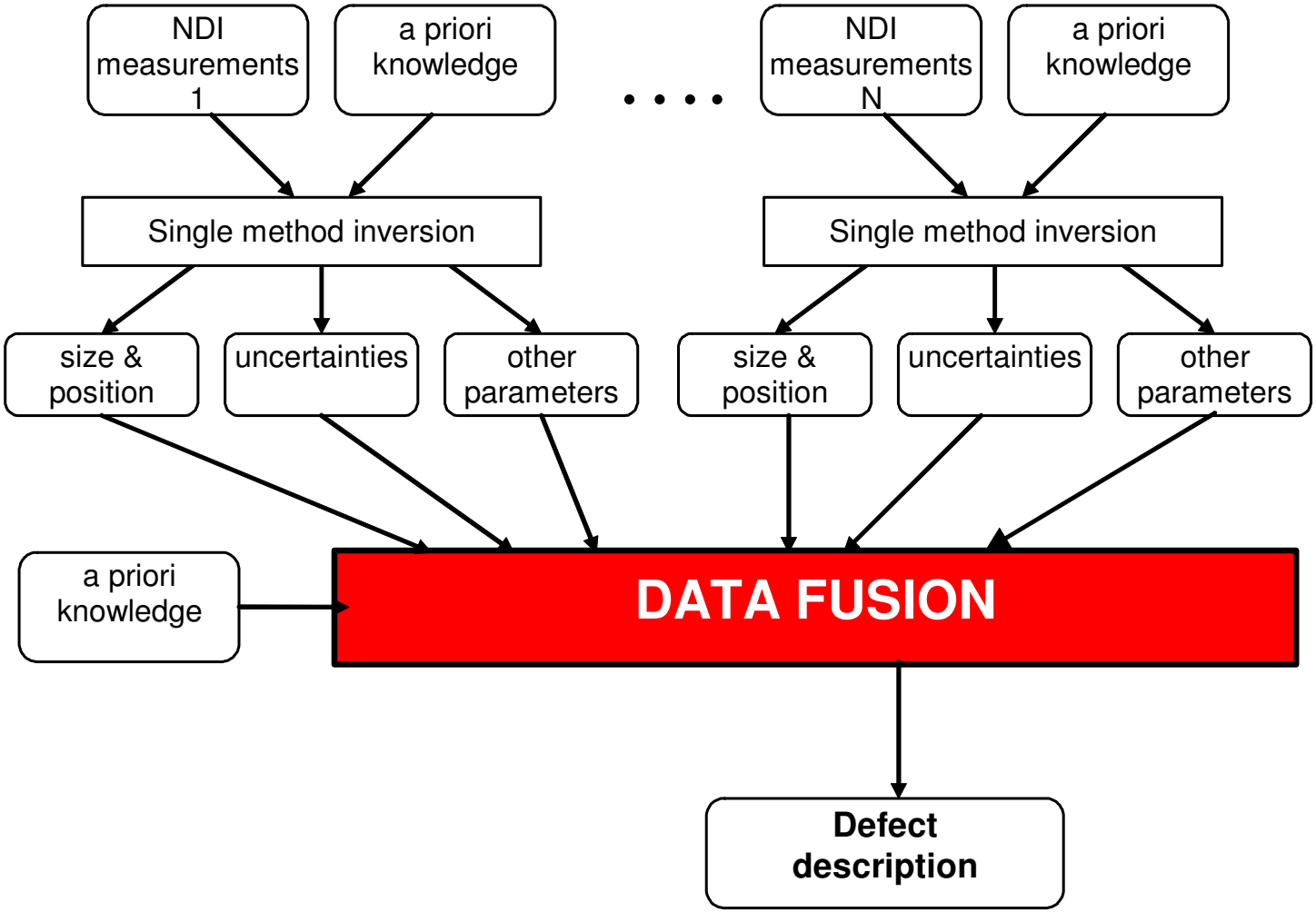
- **Acquisition** involves different sensors (e.g. X-rays, IR, UT), to exploit all their different capabilities

Detection & Characterization (1)

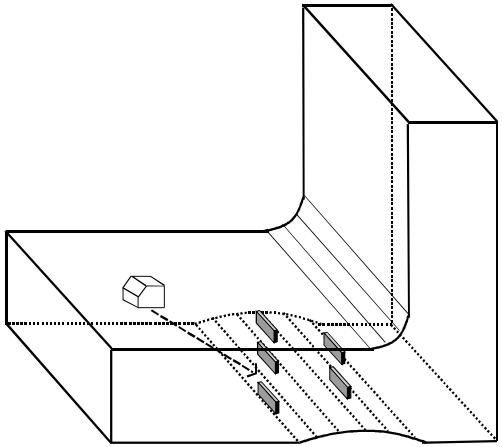
- The **defect detection** phase involves tools able to analyze quite in details all data, to minimize the non-detection probability

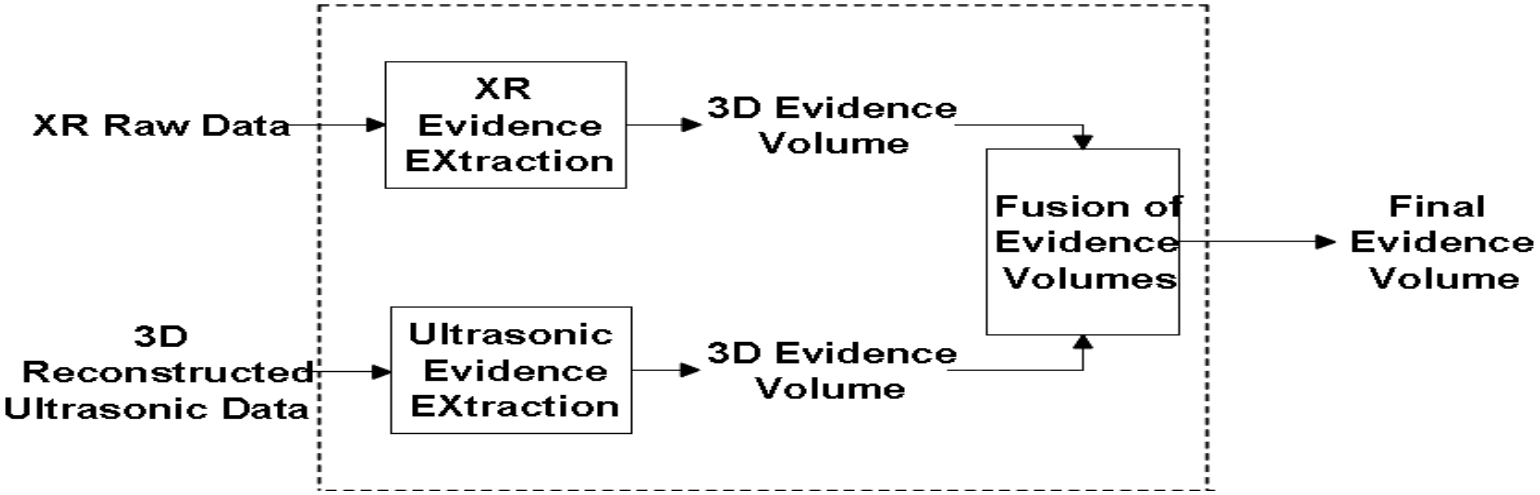
- The **defect characterization** phase involves automatic/semi-automatic tools for feature extraction able to reduce uncertainties regarding defects

Detection & Characterization (2)



Detection & Characterization (3)





Mapping & Rendering (1)

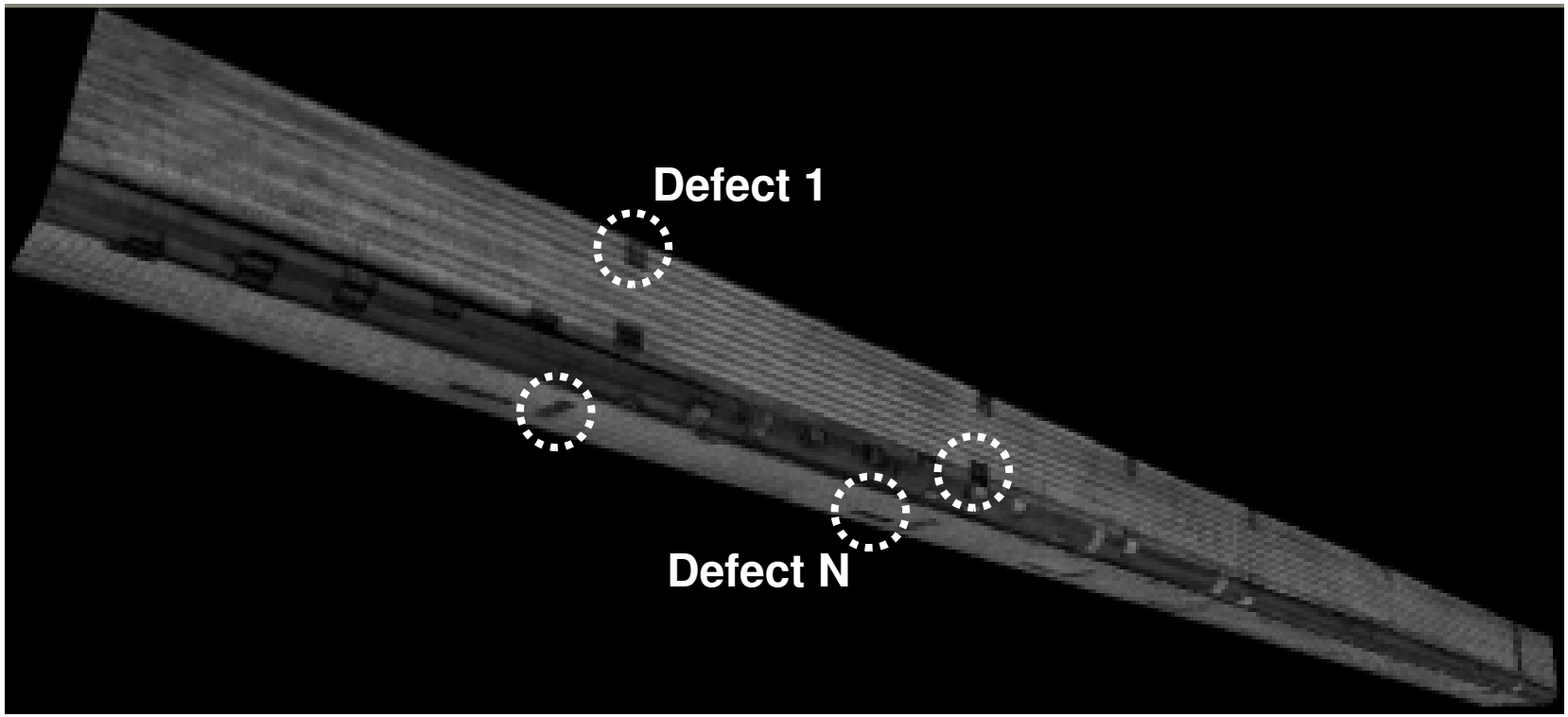
- **Mapping** involves CAD and automated tools for determining exact correspondences among NDI and 3D models of components under inspection

- **Rendering** involves a **virtual reality model,** to simplify the process of 3D model interaction, graphical defect visualization and localization, inspection monitoring, and annotation

Mapping & Rendering (2)

- The system allows for NDI inspectors to fuse together multi-sensor images and corresponding 3D CAD models
- Inspectors can visualize and analyze defects **in 3D** by mapping 2D NDI images onto a corresponding 3D CAD model surface
- **3D visualization provides a new paradigm for NDI: inspectors can locate defects more quickly, accurately and reliable than using traditional systems**

3D Multiple Rendering Result



Benefits

- Inspection time and defect uncertainty reduction, non-detection probability minimization
- Advanced and innovative prognostic analysis algorithms
- Easy 3D model interaction, graphical defect visualization and localization, inspection monitoring and annotation
- **Cost-effective solution that increases accuracy, reliability and speed of PHM analysis**

Thank You

for your attention