first european conference of the prognostics
and health management society 2012

July 3-5, 2012

Tutorial 3
State-of-the-art Realization of Prognostics in Industry

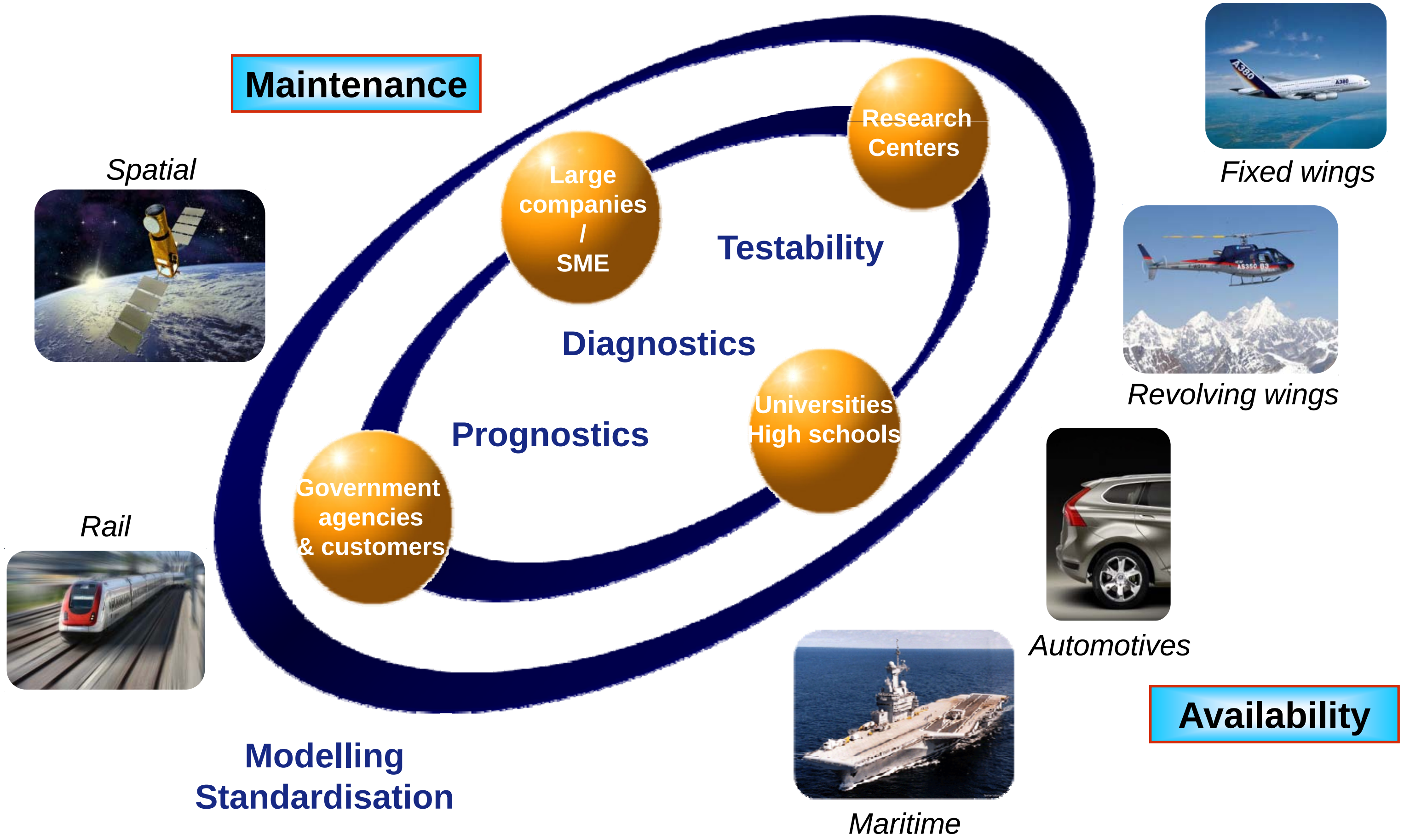
Presenters: Michel SCHIEBER (Cassidian T&S)
Jean Baptiste LEGER (Predict)
Benoit IUNG (Lorraine University, CRAN)

FOREWORD: Why diag 21 ?

- **The main problematic met**
  - *Divergences between requirements and the state of the art;*
  - *Discrepancies between policies and methods;*
  - *Divergences of interests from actors;*
  - *Hardware / Software validation realized at the end of the design process.*
- **Have for consequences…**
  - ***No optimized embedded systems maintenance;***
  - *Late re-design in the development phase which results in project risk with high cost;*
  - ***No optimized maintenance cycle;***
  - *Full life cycle cost factors are not understood.*
- **A worldwide status**
  - *By contract only safety aspects are considered;*
  - *Platform of exchanges and services on these disciplines in France … in Europe Europe do not exist;*
  - *Increasing interest (European projects) but no federate actions.*

diag 21 is a challenge

FOREWORD: towards Health Monitoring Management



Eurocopter
MBDA
Cassidian ...

Diag 21 main objective is to boost synergies between all actors involved in common problematic in these domains

FOREWORD: diag 21 objectives

- ***diag 21*** **is an exchange platform which:**
  - actively ***participate*** to the writing of the future testability, diagnostic, prognostic standards,
  - ***share*** the knowledge between testability, diagnosis and prognosis experts in order move a step further,
  - ***improve*** methods, processes and means to reduce costs and delays in development, production and support phases,
  - ***establish*** a network of excellence between customers, system designer, suppliers and research centers,
  - ***create*** strong partnership between industries and universities and Research Centers

diag 21 is an exchange center

diag 21

FOREWORD: Structure of the Association

7 COLLEGES

- GOVERNMENTAL ORGANISATIONS → 1
- LARGE COMPANIES → 5
- SMALL AND MEDIUM-SIZED FIRM (ECC) SME → 3
- High Schools → 1
- Laboratories → 2
- Universities → 2
- Individual Members → 1

General Assembly

Governing Body

20 members
+ the 5 members of the association board

→ 5

Association Board

- President
- Vice-President
- Secretary
- Finance
- President scientific committee

Scientific Committee

5 Working Groups

International Board
(M. Schieber)

diag 21

FOREWORD: Expected benefices

- Standards Improvement
- Methods and processes improvement in order to promote exchanges between different technical fields
- Customer relationships / system designer / supplier development & improvement
- Quality and diagnostic of failure relevance improvement
- **New services definition** triggers new technical and economical interests

diag 21 a contributor of customer satisfaction improvement

To be in contact

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TUTORIAL OVERVIEW

- From conventional considerations of Prognostics … to system considerations more in phase with decision making requirements in industrial context … UNIVERSITÉ DE LORRAINE
- … What are actually the prognostics vision from industrial viewpoint: dream, reality, something else ? UNIVERSITÉ DE LORRAINE
- Towards a reality: Illustration in the case of industry and defence sector (needs, techniques used, results obtained) PREDICT
- Towards a reality: International standardisation initiatives diag 21
- Conclusions

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- Towards a reality: International standardisation initiatives
- Conclusions

Prognostics … mainly component oriented

- PHM definition phmsociety
  - Estimation of remaining life of a **component** or **subsystem**
- Prognostics evaluate the current health of a **component**, and conditional on future load and environmental exposure, estimates at what time the **component** (or **subsystem**) will no longer operate within its stated specifications
- Prognostic is the ability to perform a reliable and sufficiently accurate prediction of the remaining useful life of **equipment** in service. The primary function of the prognostic is to project the current health state of **equipment** into the future taking into account estimates of future usage profiles [Lebold et al. 2001]

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A. Saxena, "Prognostics: The science of Prediction", Tutorial, Annual Conference of the PHM Society (PHM2010), Portland, October 10 - 14, 2010

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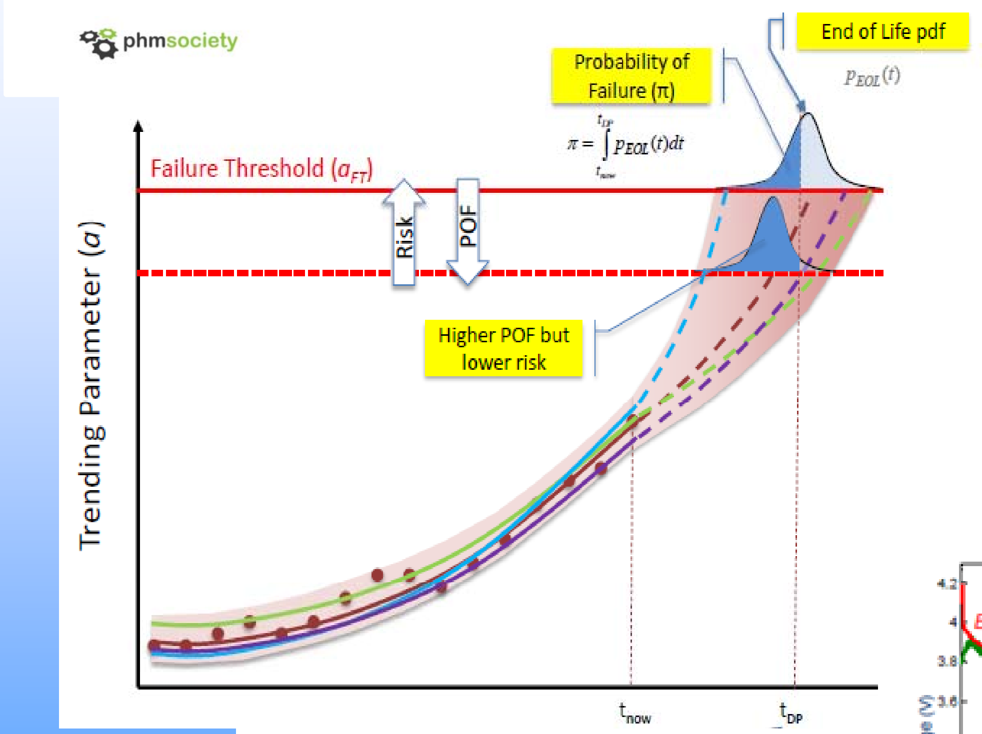
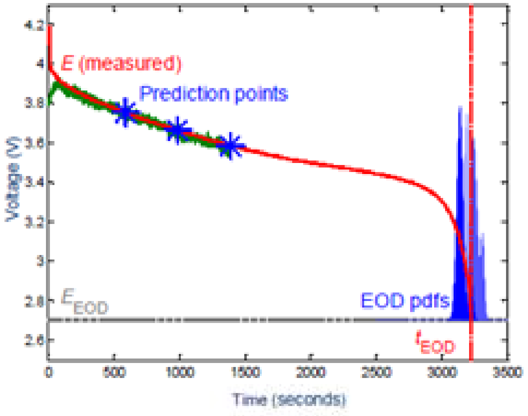
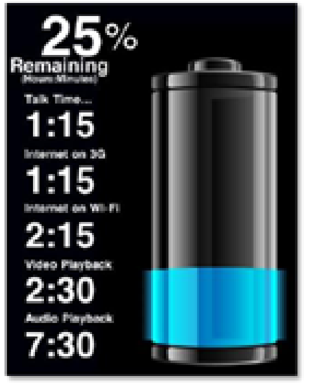
Prognostics … mainly component oriented



Prognostics for
Battery, Bearing, Engine …

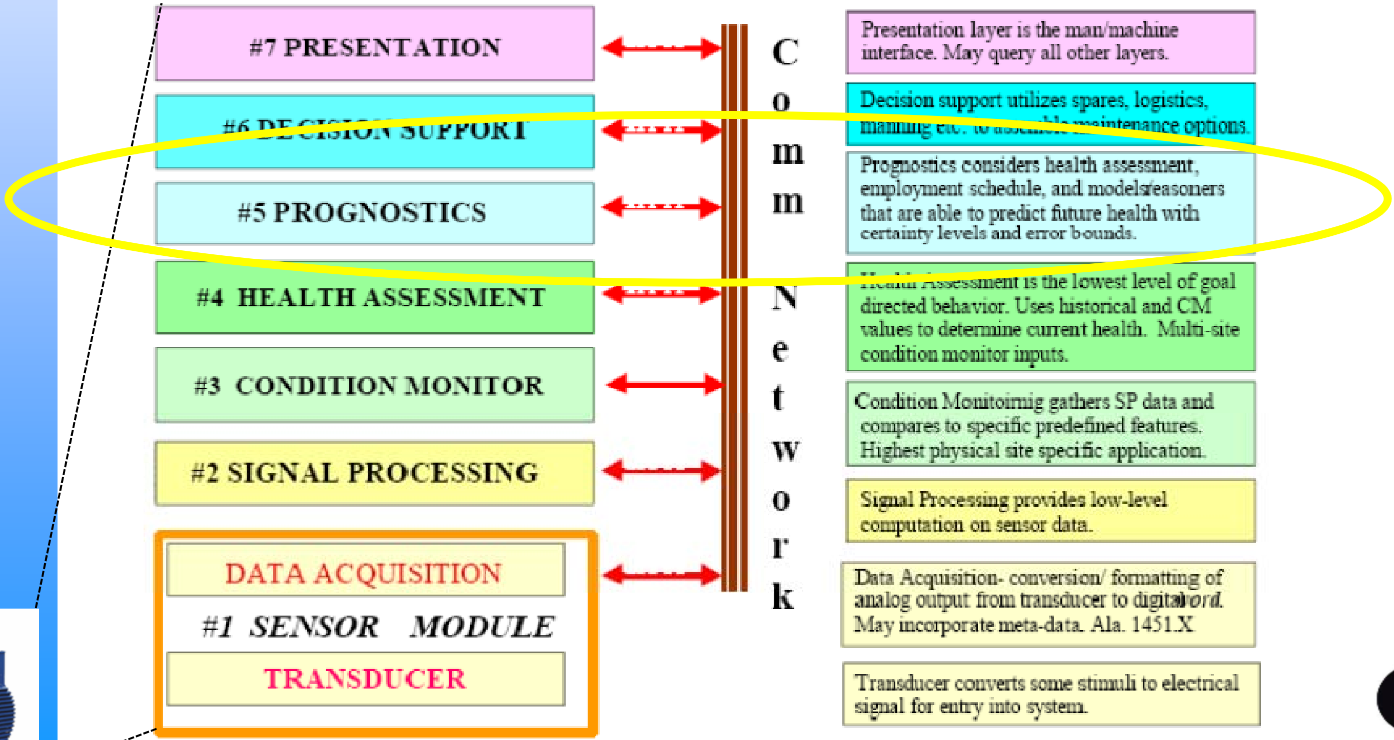




N. Scott Clements, "Introduction to Prognostics", Tutorial, Annual Conference of the PHM Society, Montreal, Canada September 25 – 29, 2011

Prognostics … mainly component oriented

- Component instrumentation (mainly for Control purpose)
- Components follow different rates and failures modes with behavior varying all its life cycle phases (impacting maintenance)
- Component supports PHM processes to move to CBM by considering both Information & its support Software application



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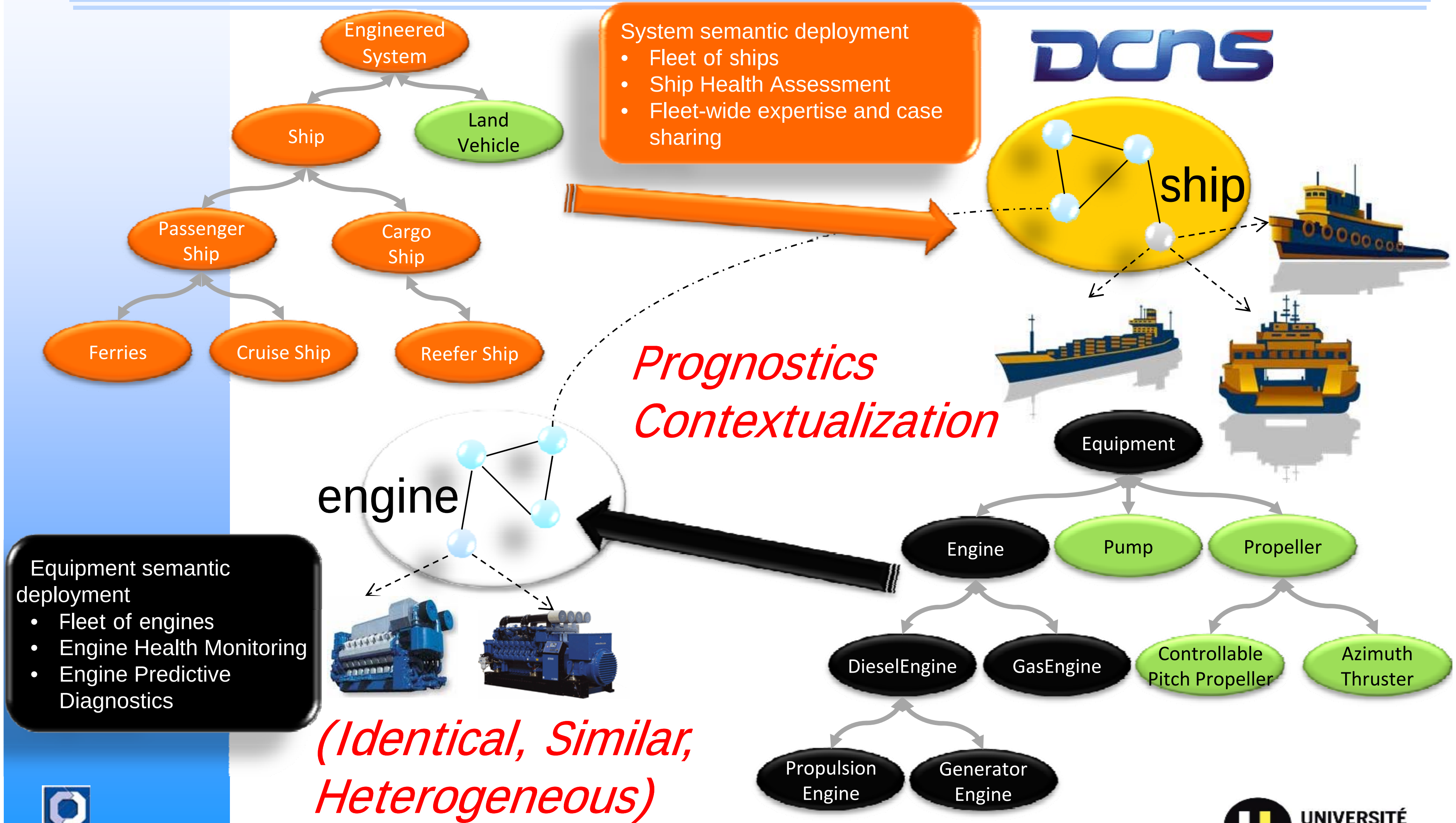
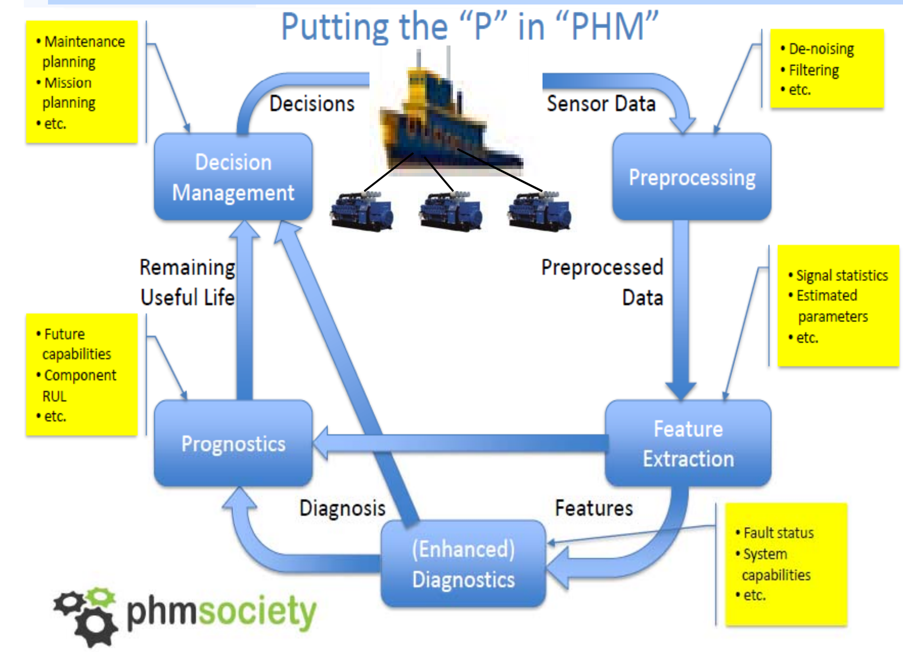
Prognostics … but the context is mainly system oriented (CBM+)



B. Iung, JB Léger, M. Monnin, "PHM Applications for fleet management: A summary", PHM Applications Panel, IEEE PHM conference 2012, Denver, USA

Prognostics … but the context is mainly system oriented (CBM+)



DoDI 4151.22

- "The application and integration of appropriate processes, technologies, and knowledge based capabilities to improve the reliability and maintenance effectiveness of DoD systems and components."

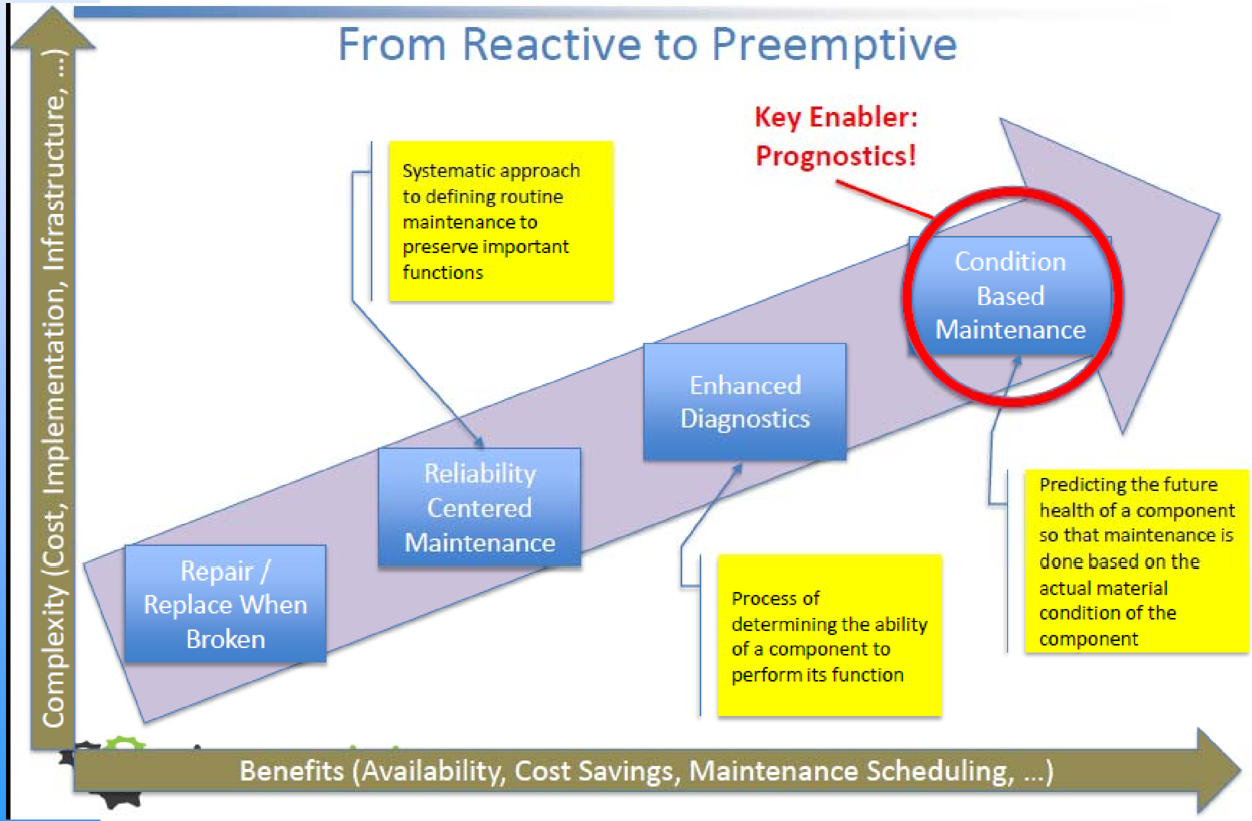
Vision	• Establish predictive maintenance and anticipatory logistics through automated data collection, analysis, & integration
Objectives	• Decrease maintenance burden on the users • Increase platform availability & readiness • Enhance safety • Reduce life cycle costs
Enablers	• Digital source collectors (embedded sensors, diagnostics, prognostics) • Data warehousing • Data fusion/analysis tools

- **Decision at "System" – "Fleet" levels … using Component PHM processes**
  - Increasing the system control performance vs. services with regards to operational conditions, missions, strategic requirements (i.e. availability) … while increasing maintenance considerations (drift observation …)
  - … Towards **a proactive vision of the system functioning** to make dynamic decision and by considering the principle of fleet not only at system level but also as "system-of-system" level (Population, Aggre./Consolidation)

M Monnin, J-B Léger, D. Morel, Proactive facility fleet/plant monitoring and management, 24th International Congress on Condition Monitoring and Diagnostics Engineering Management, 2011.

Prognostics … as main process for supporting System Pro-activity

- Evolution on the Maintenance practices: from conventional to Predictive strategies (Condition-Based + Prediction) … and finally Proactive one (E-maintenance) … because anticipation is required (**opportunity space**)

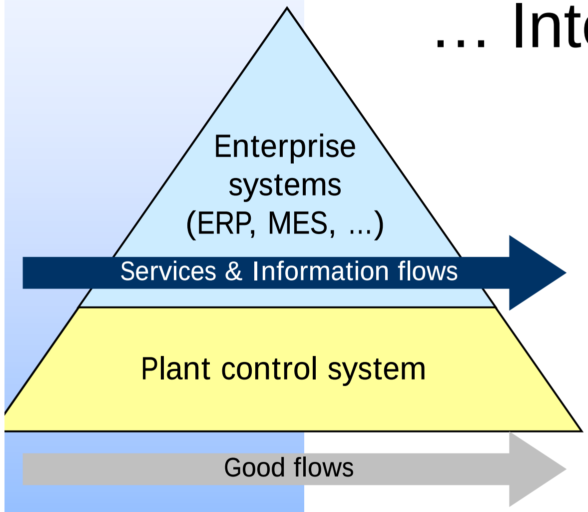


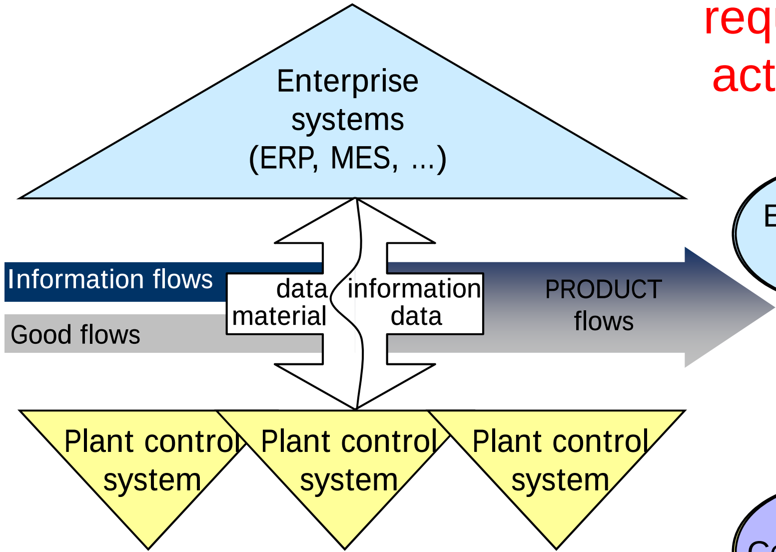
N. Scott Clements, "Introduction to Prognostics", Tutorial, Annual Conference of the PHM Society, Montreal, Canada September 25 – 29, 2011

Prognostics … as main process for supporting System Pro-activity

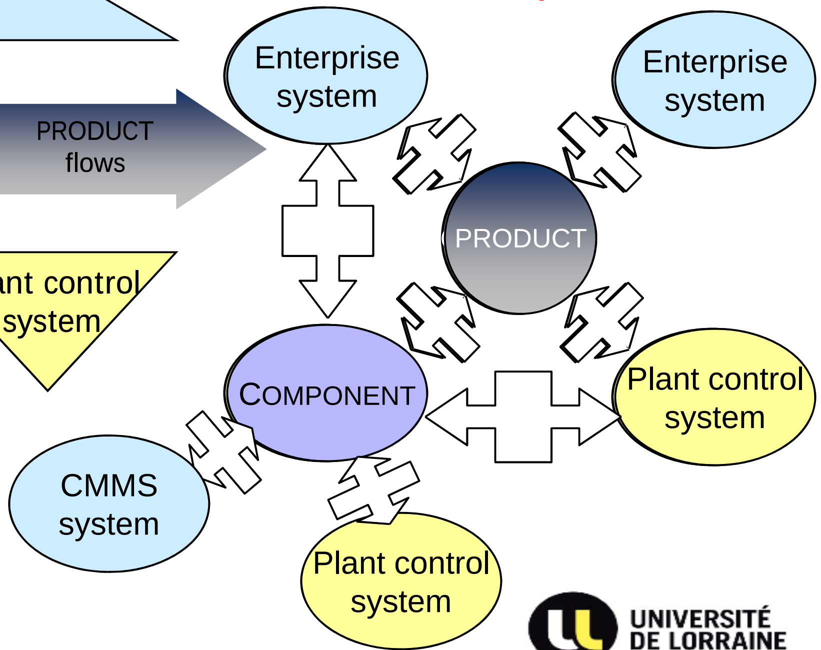
IMS : Intelligent Manufacturing System

… Intelligent Maintenance System (E-Maintenance)





Main Change: « Component is requesting maintenance action » (/itself;/product deviation)



Reconsidering Automation Paradigm …

Prognostics … as main process for supporting System Pro-activity

- **MOBILITY concept** ... leading to offer new capacities for supporting maintenance actions
  - “on-line” diagnostic based on “mobile” sensors (MEMS with wireless communication) – Plug and Play principle
  - Tools localisation based on RFID Tags ...
- **PROACTIVITY concept** ... leading to make decision by integrating new factors
  - **“on-line” prognostics ... to PHM**
  - From Predictive Maintenance (CBM) to Opportunistic maintenance ... then to Pro-active Maintenance (LCC approach)

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Prognostics … as main process for supporting System Pro-activity

Using e-technologies to increase maintenance efficiency, velocity, PROACTIVITY, MOBILITY .. and to optimise maintenance related workflow

- … To support the m[…]m "fail and fix" maintenance practice[…]o "**predict and prevent**" strategies vs. **Proactivity concept** [Lee et al. 2006] [Iung, 2003] [Blann, 2003]… while keeping Maintenanc[…]s an Enterprise process

Carrying out global **system-of-interest** objectives which imposes to the maintenance area: Openness, Integration, Collaboration with the other e-enterprise services

A. Muller, A. Crespo Marquez, B. Iung, On the concept of e-maintenance. Review and current research, Reliability Engineering and System Safety (RESS). Volume 93, Issue 8, Pages 1165-1187, 2008

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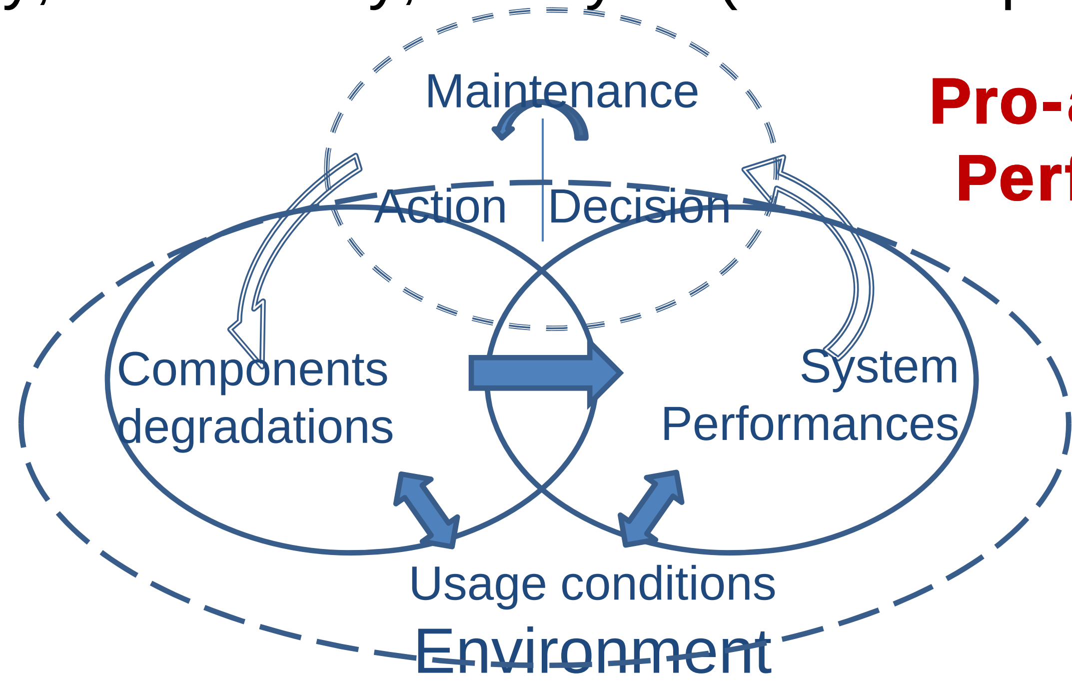
Prognostics … as main process for supporting System Pro-activity

- The maintenance action is done on the **component** … but the maintenance decision aims at maintaining or restoring a **Performance,** a **Service**
  - ROI, OEE, LCC …
  - Quality, Productivity, Safety … (Metric of performances)

Holonic View



Pro-actvity vs. Performance

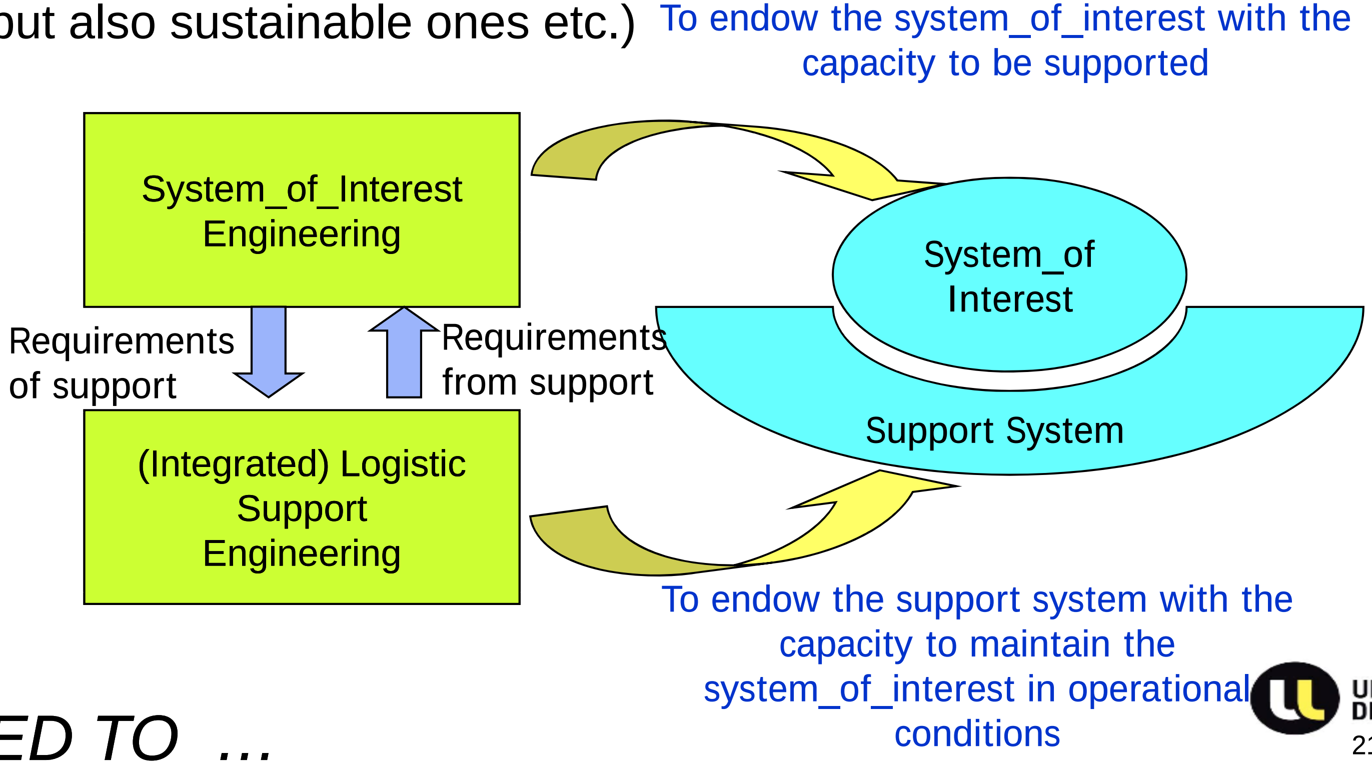
Levrat E., Iung B., A. Crespo Marquez, E-maintenance : Overview and Conceptual Framework ; Journal PP&C, special issue on Maintenance and Facility Management organised by Pr. M. Garetti, Vol. 19, No. 4, June 2008, pp 1–22

Prognostics … within System Engineering consideration

INCOSE Systems Engineering Handbook v. 3.2; ISO/IEC 15288:2008

Prognostics … within System Engineering consideration

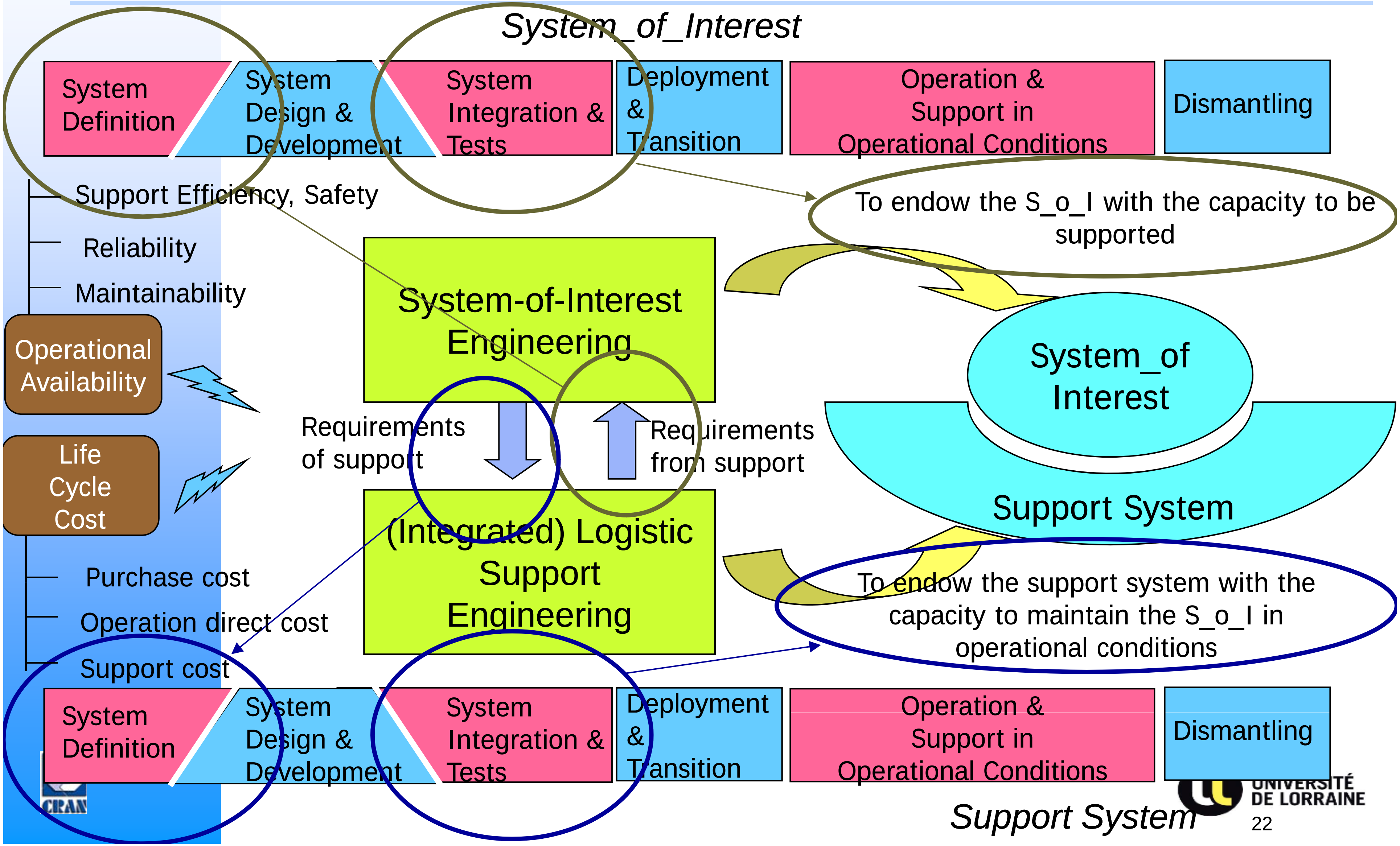
- Evolution on the engineering practices: towards System Engineering (Collaborative Dimension – System Thinking – Life Cycle consideration)
  - From component layer (action level) to system layer (strategy level)
  - New way for performance and requirement controlling (conventional ones … but also sustainable ones etc.)



INTEGRATION

RELATED TO …

Prognostics … within System Engineering consideration



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Prognostics … within System Engineering consideration

"Needs and Requirements" View

- Purpose (Final Goal) = Why the system does exist ?
- Mission = What it does (transforms) ?
- Objectives = How many inputs it transforms? …

"Functional/Logical Architecture" View

- A structure of functions that allows the system to perform all the identified operational scenarios throughout its life-cycle
- Includes exchanged flows between functions and external world (interface)

"Organic/Physical Architecture" View

- A set of concrete components that support both functions and interactions between the components
- Includes physical connexions

Also for the prognostics engineering ...

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M Monnin, A Voisin, J-B Léger, B Iung, Fleet-wide health management architecture, Annual Conference of the Prognostics and Health Management Society, PHM 2011, Montreal, Canada, 2011

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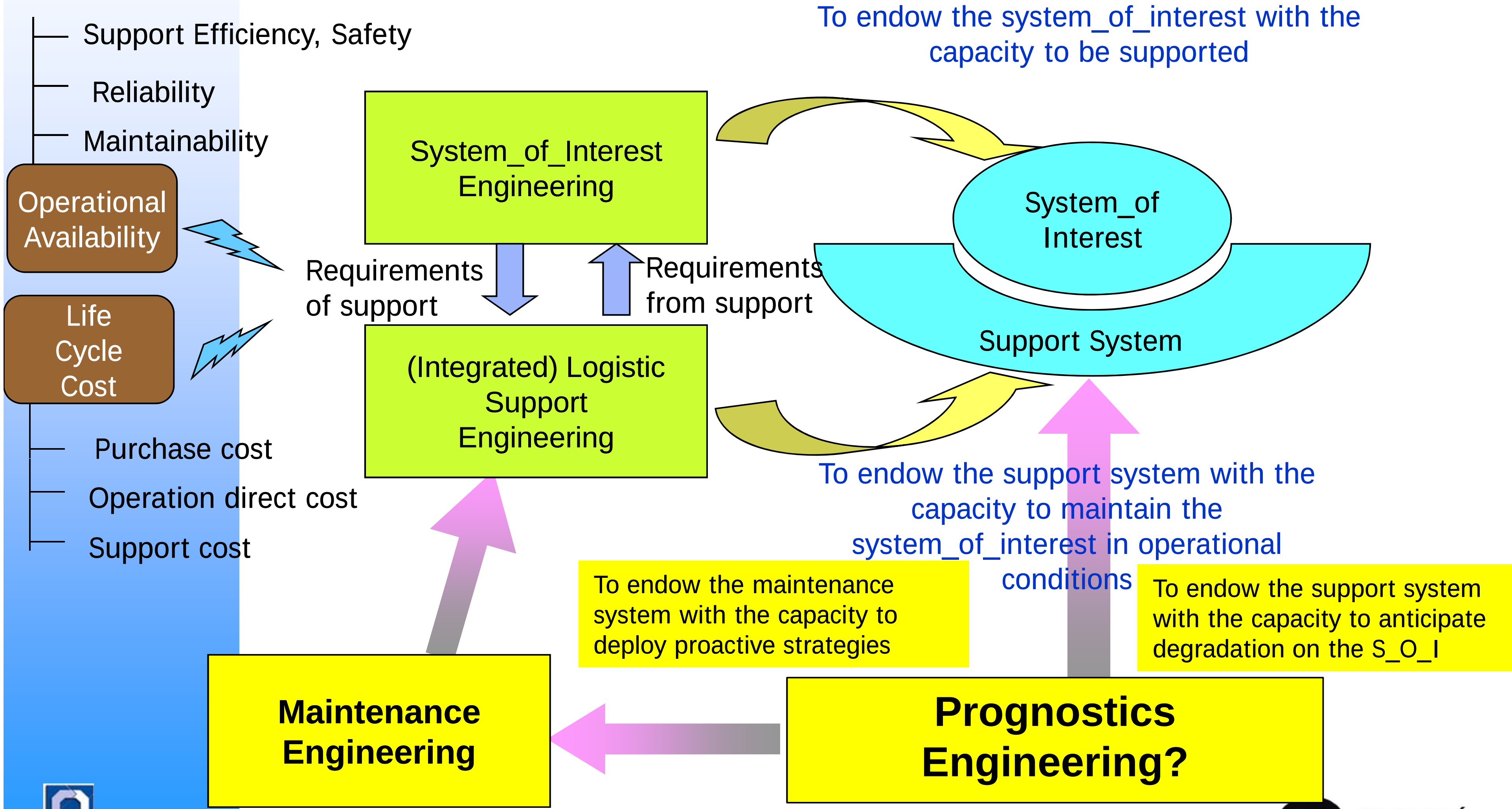
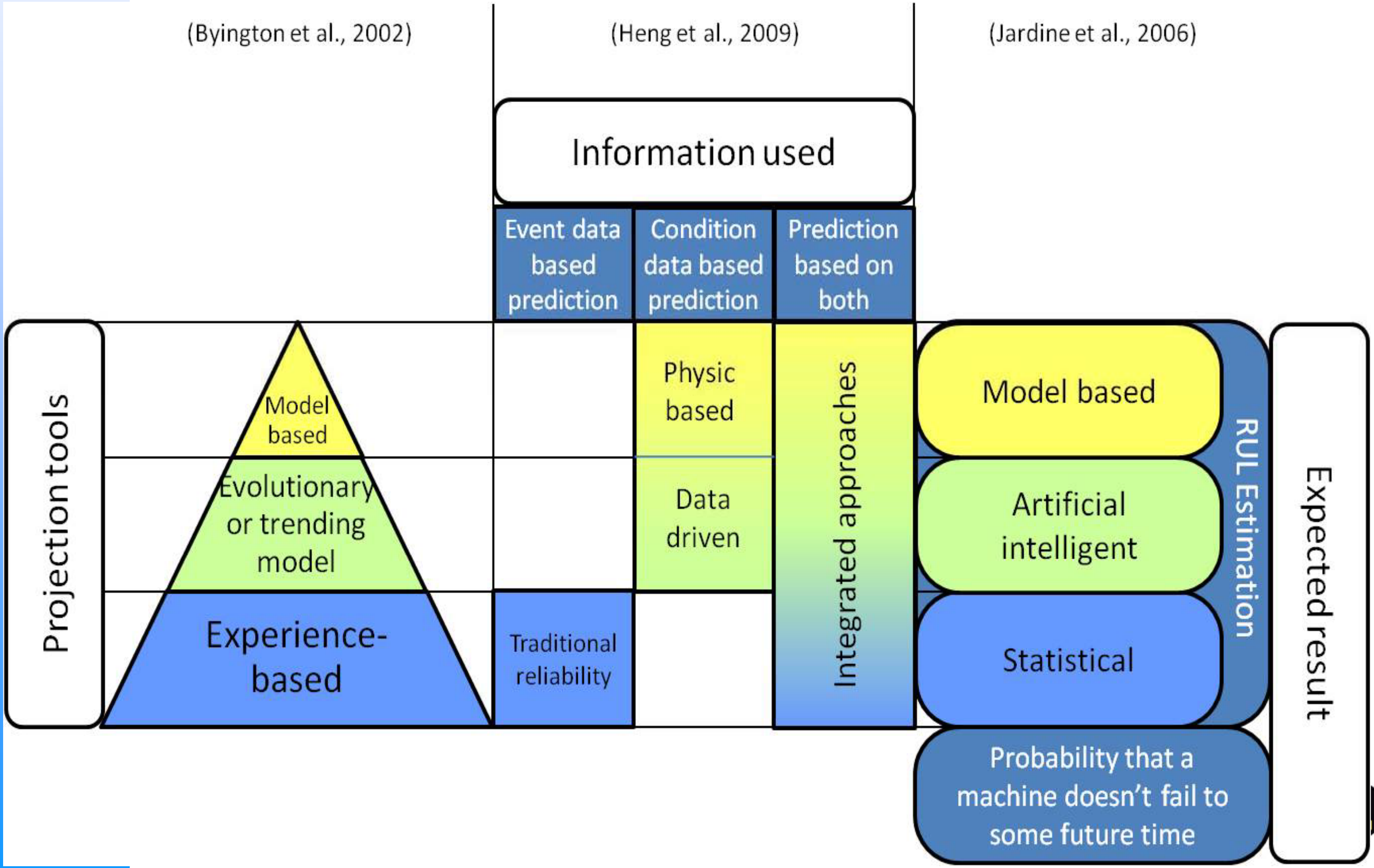
Prognostics … within System Engineering consideration



A. Muller, M-C. Suhner, B. Iung, Proactive Maintenance for industrial system operation based on a formalised prognosis process, Reliability Engineering and System Safety (RESS) – Volume 93, Issue 2, February 2008, Pages 234-253

Prognostics … within System Engineering consideration

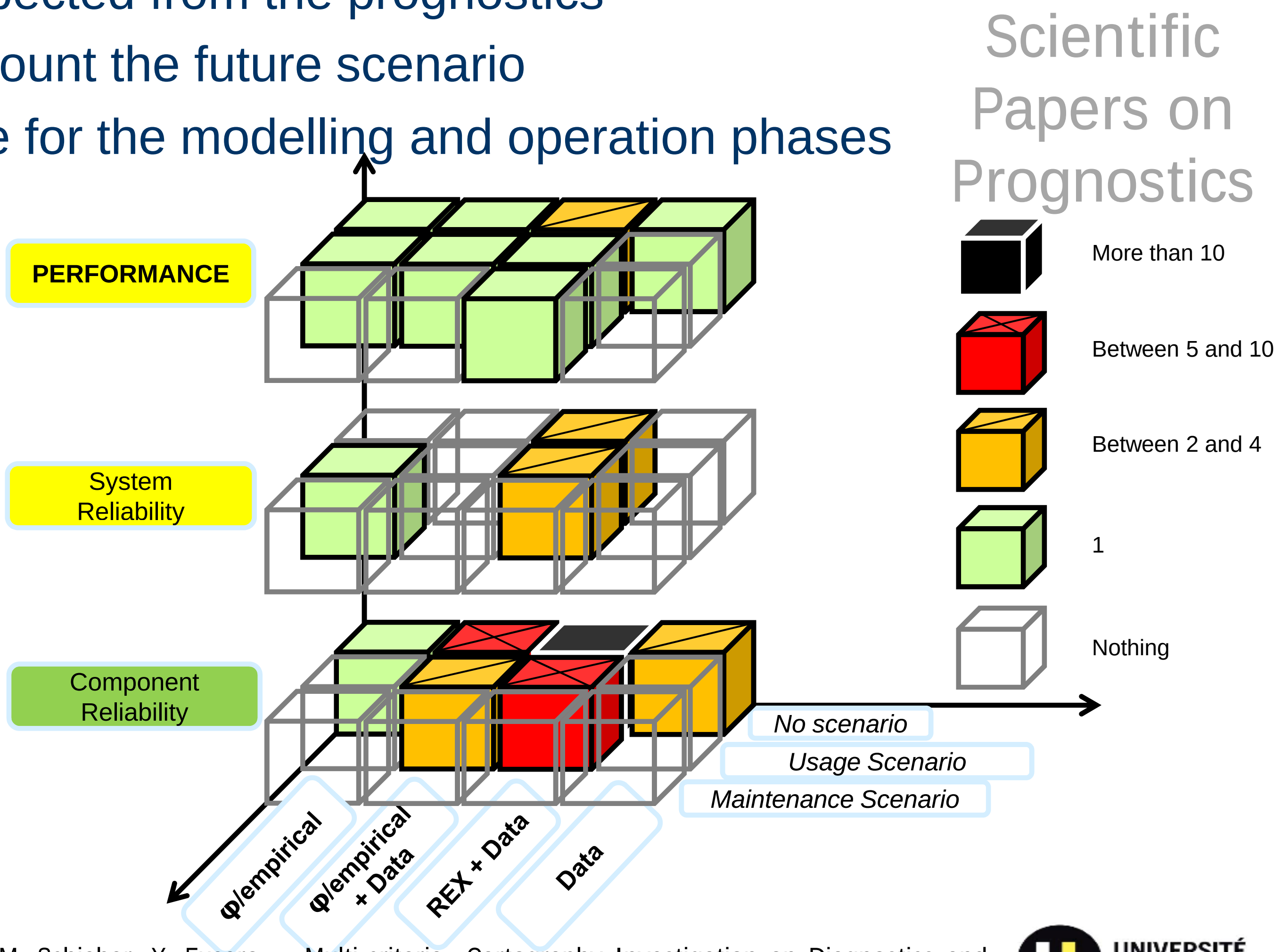
Conventional Prognostics Classifications based on forecasting techniques …



Prognostics … within System Engineering consideration

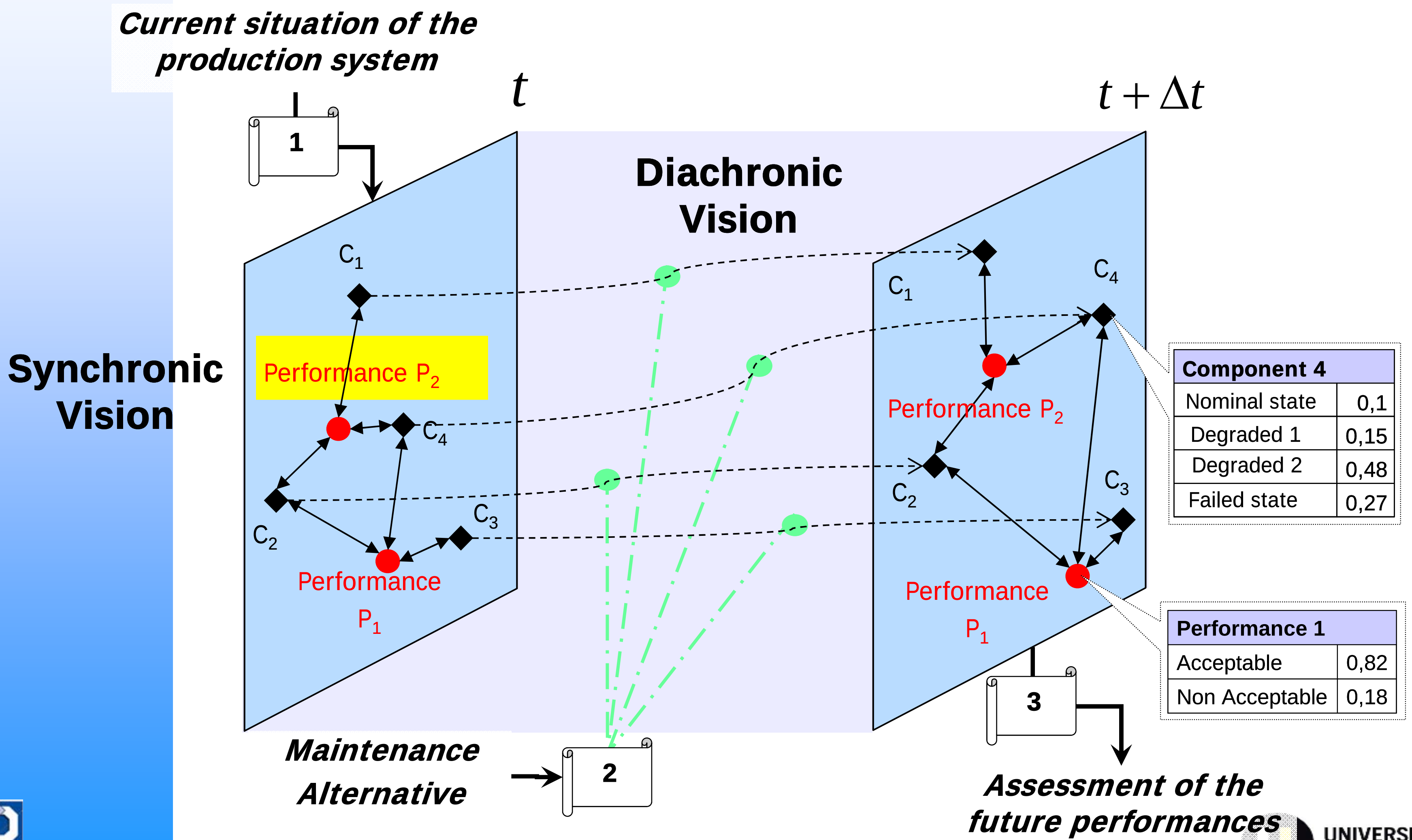
- The criteria expected from the prognostics
- Taking into account the future scenario
- Knowledge use for the modelling and operation phases

… towards Prognostics Classification based on **system considerations**

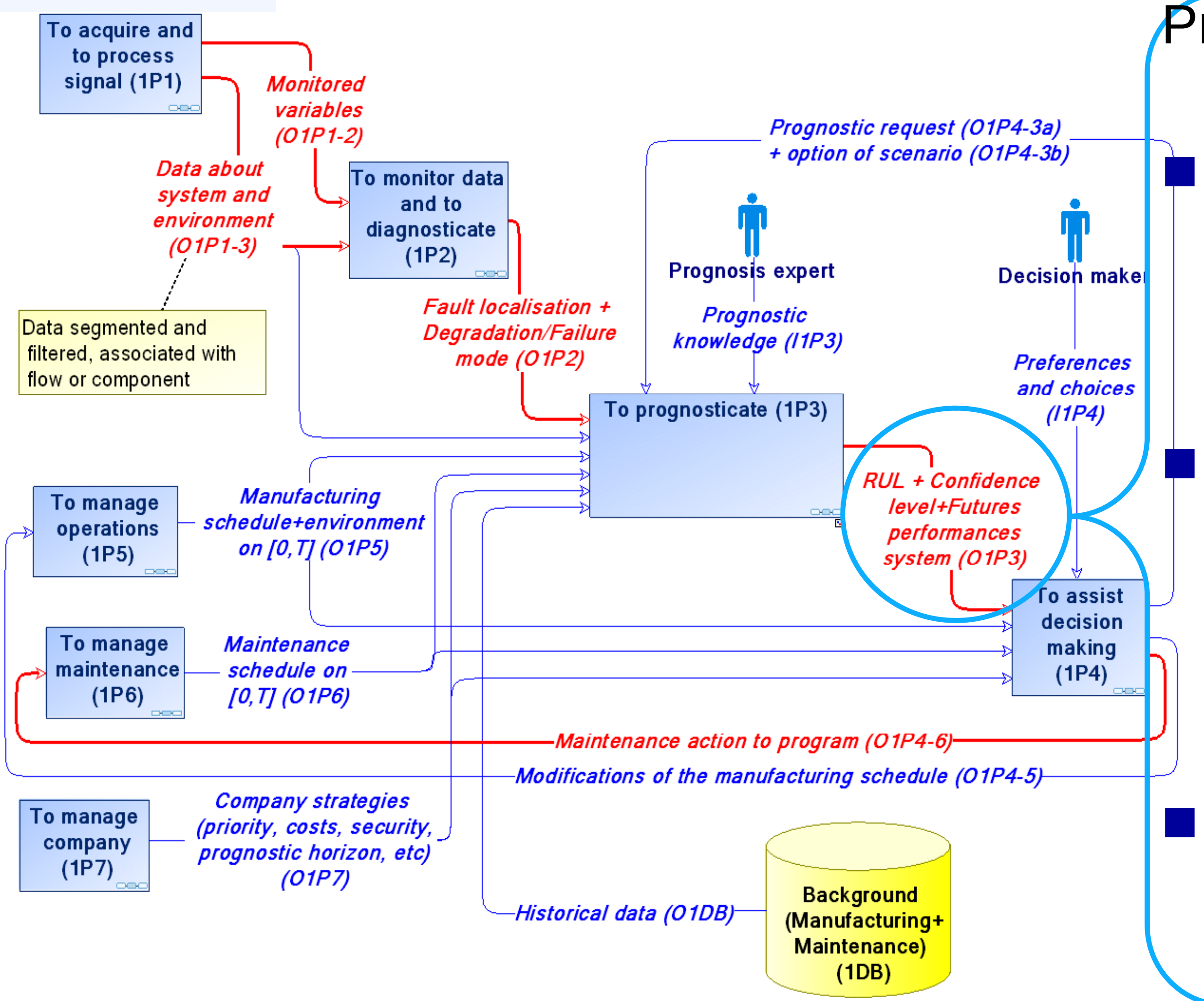


I. Geanta, D. Theilliol, B. Iung, M. Schieber, Y. Fusero, « Multi-criteria Cartography Investigation on Diagnostics and Prognostics Techniques Suited for System and Vehicle Health Maintenance « , Conference IEEE AutoTestCon, Anaheim,CA U.S.A, 2012

Prognostics formalization



Prognostics formalization



Predict future system health:

- Components' conditions AND performances
- Remaining Useful lives (RULs) of the system, sub-system or components
- Associated confidence level

Voisin A., Levrat E., Cocheteux P., Iung B., Generic prognosis model for proactive maintenance decision support: application to pre-industrial e-maintenance test-bed; International Journal of Intelligent Manufacturing. Vol. 21, 2, pp 177-193 April 2010

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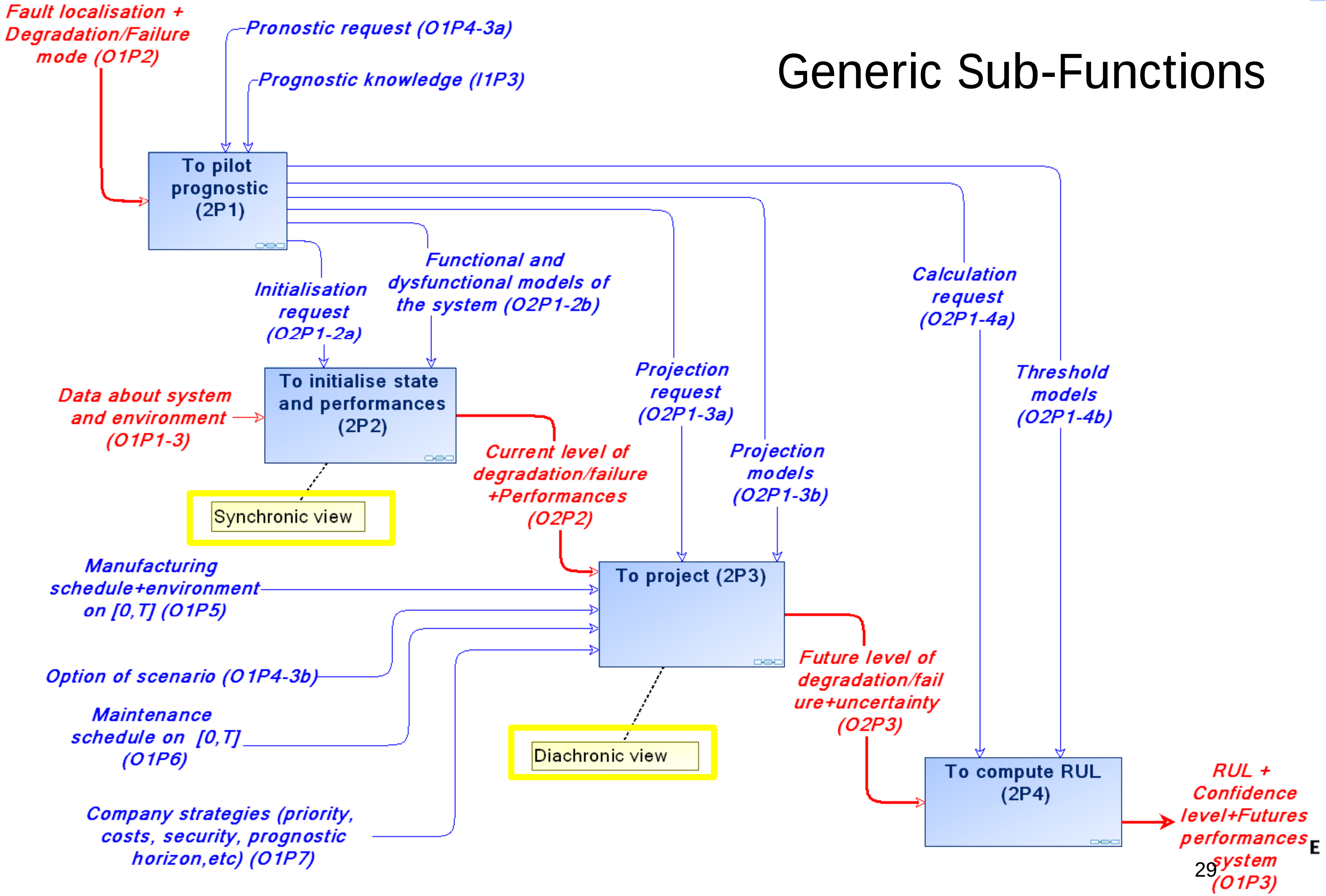
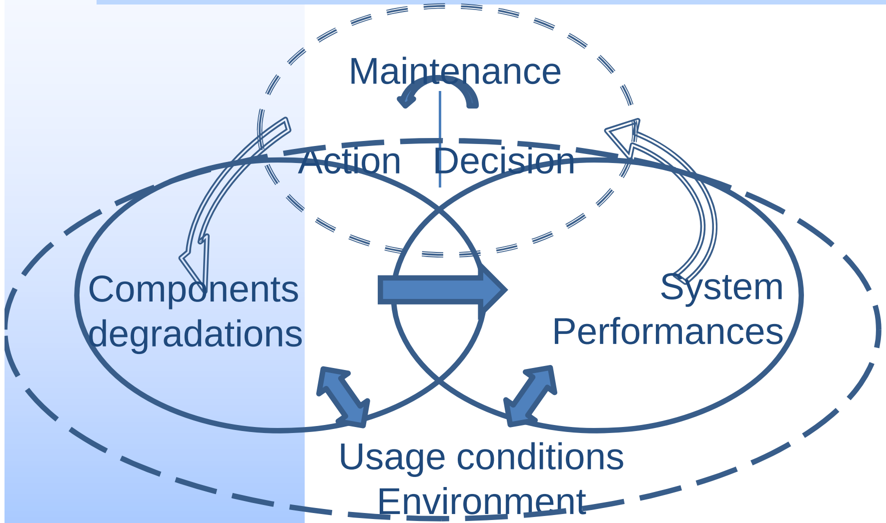
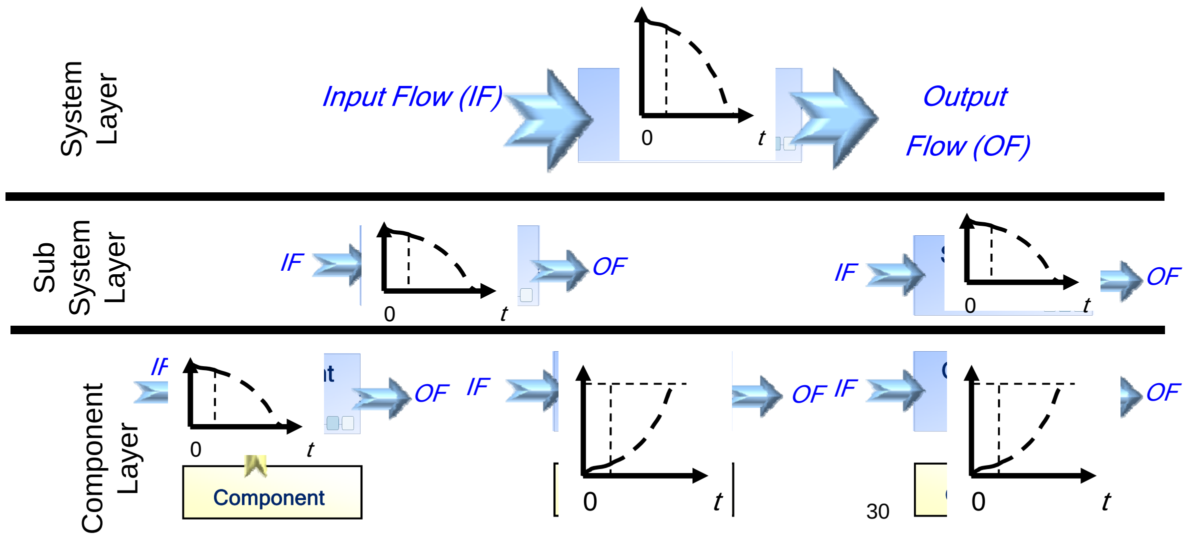
Prognostics formalization



Prognostics
Formalization … at system level



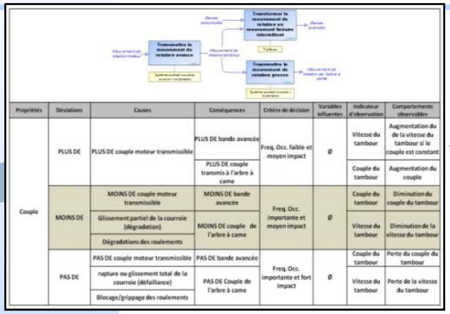
System multi-layers/multi components



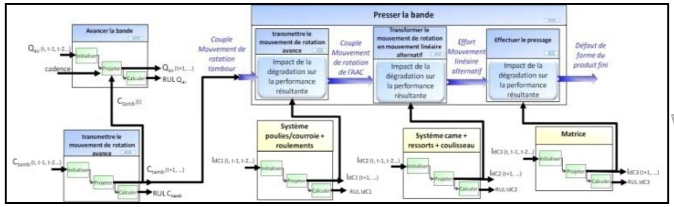
Prognostics
Formalization … at system level

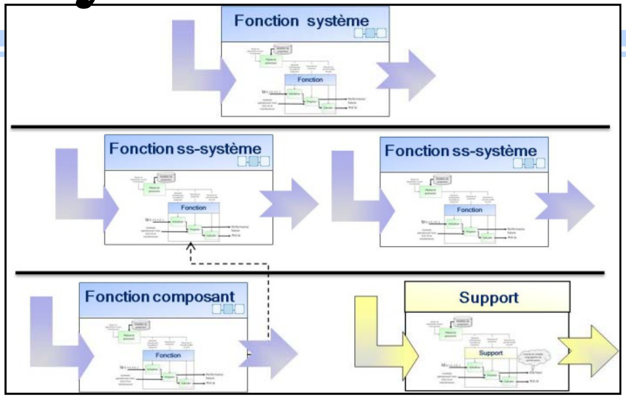
Degradation-Failure-Flow Analysis

①



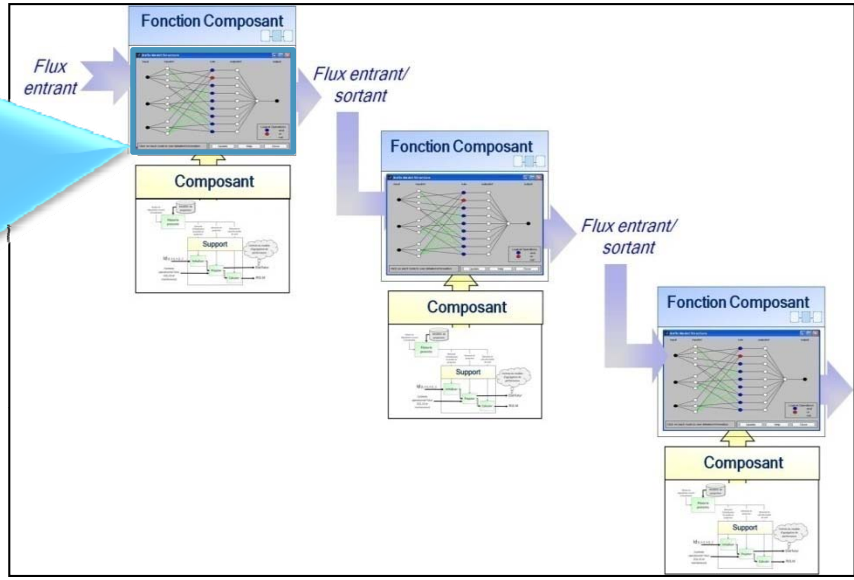
② Selection of the indicators and the architecture



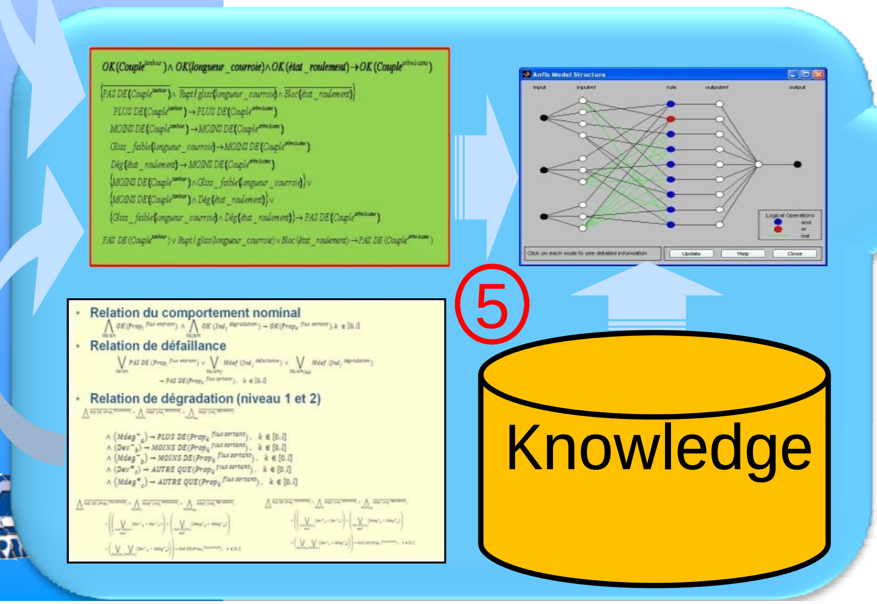


« Layered » Architecture ③

Cumulated Architecture ④



⑤



Prognostics
Formalization … at system level

- **Functional analysis**
  - Process approach
  - Flow based performance assessment
  - Causality (physical laws)
- **Dysfunctional analysis**
  - Component degradation
  - Flow deviation
- **Event-Driven Indicators**
- **Inference mechanisms** (degradation propagation)
  - Causal (in time throughout components)
  - Temporal (throughout time)

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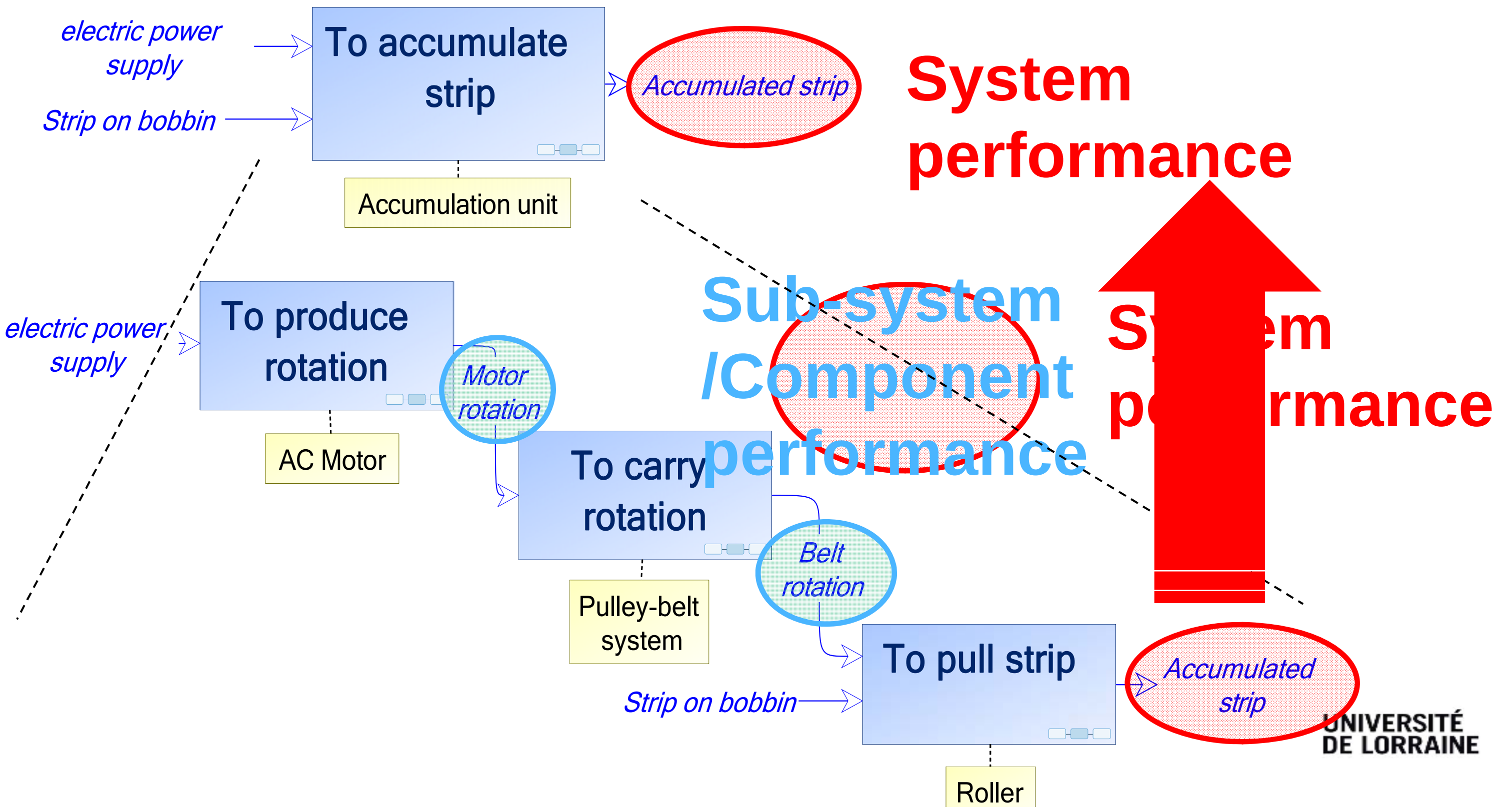
Prognostics
Formalization … at system level

- System performance has to modeled in a generic way
  - Performances-Requirements definition: performances represent the finality fulfillment (objectives) which are modeled through **output flows**.
    - Performance indicator: output flow's properties
  - Functional point of view: multi-level hierarchical decomposition



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Prognostics
Formalization … at system level

Dysfunctional point of view : performance loss arises from the deviation of output flow properties

- Dysfunctional causality modeled by generic causal relations. They model the causes of output flow deviation:
  - The deviation of an input flow property
  - The support degradation

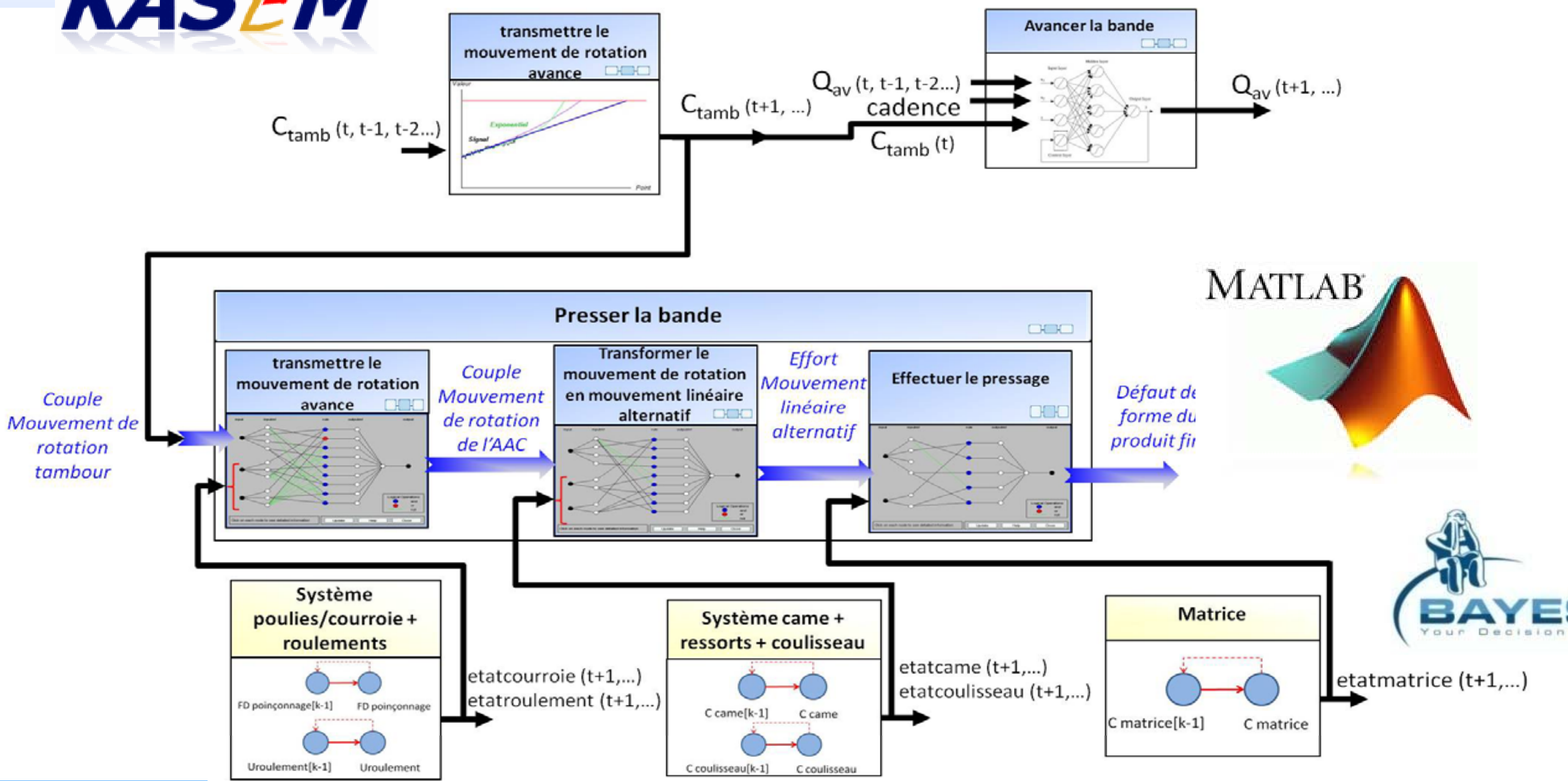
$$Dev\,\mathrm{Prop}_{Input\ flow} \vee Deg_{component} \rightarrow Dev\,\mathrm{Prop}_{Output\ flow}$$

- Knowledge from particularizing relationships extracted from FMECA and HAZOP analyses

Belt rotation		
Attribute	**Deviation**	**Cause**
Angular Velocity (Wob)	NO	NO Angular Velocity (AC motor rotation)
		Slip (belt)
	LESS	LESS Angular Velocity (AC motor rotation)
		lengthening (belt)
	MORE	MORE Angular Velocity (AC motor rotation)

Léger J-B., Iung B.; Methodological approach to modelling of degradation detection and failure diagnosis in complex production system. In: Proceedings of the 9th workshop on Principles of Diagnosis DX98,, pp. 209-216, May 24-27, 1998, Cap Cod, Massachusetts, USA

Prognostics Execution… at system level: test case for deployment



Iung B, Levrat E, Crespo Marquez A, Erbe H. Conceptual framework for e-maintenance: Illustration by e-maintenance technologies and platform. Annual Review in Control, vol.33, issue 2, pp220-229, 2009

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- … What are actually the prognostics vision from industrial viewpoint: dream, reality, something else ? UNIVERSITÉ DE LORRAINE
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- Towards a reality: International standardisation initiatives
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DIAG 21 Industrial Survey on Prognostics: Context and objective

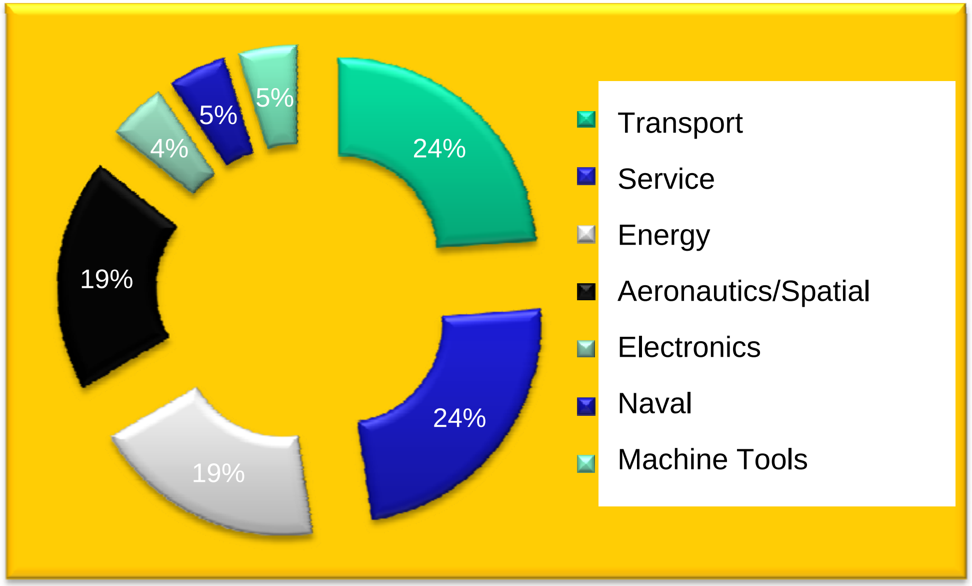
- DIAG21 Prognostics Working Group objective
  - To identify the industrial considerations (i.e. needs, issues, challenges, interests) on Prognostics
  - To compare the academic Prognostics vision with the industrial one in accordance to the previous considerations
  - To contribute by a joint industrial – academic work to the formalisation and engineering of the Prognostics to face with considerations
- DIAG21 Prognostics WG main statement
  - Prognostics is understood differently by industry and academia
  - Prognostics is a “emergent field” (not well known) for most of industrial people
- DIAG21 Prognostics WG first challenge
  - To collect the industrial vision on Prognostics (considerations-based)
  - To develop a “white paper”
  - To promote the Prognostics in industry

DIAG 21 Industrial Survey on Prognostics: Context and objective

- Development of Interviews based on a specific questionnaire
  - What are the objectives of the questionnaire but also of the interview?
  - What are the professional profile of the interviewee industrial?
  - What are the main issues – challenges related to the application domain in which the interviewee is working on (but also the main criterion characterising these issues - challenges) ?
  - What are the levers for change but also the areas of progress in relation these issues – challenges ?
  - How the interviewee industrial is considering Prognostics with regards to these issues – challenges ?
    - ✓ Is it already implemented ?
      - Yes : Prognostics definition, Prognostics added-value ...
      - No: Why ? What are the obstacles? ...
  - What the interviewee is expecting from Prognostics academic community ?

DIAG 21 Industrial Survey on Prognostics: Who are provided fulfilled questionnaires in a first step of procedure ?

- About 20 answers directly from individual interviews
- About 15 answers from exchanges issued of the industrial panel on Prognostics developed during DIAG21 Forum (November 2011 in Paris)



- Industrial representative of Design, Manufacturing, Integration, Operation, Maintenance areas

DIAG 21 Industrial Survey on Prognostics: What are the main reports?

- Industrial Prognostics vision is not totally in phase with the scientific one (i.e. Prognostics is an item within a decision loop such as PHM, CBM+ not a finality by itself)
- Only some of the interviewees use Prognostics capacities. For the others, it is a long-term project, a dream or a danger (with regards to the investment, the benefits, the ROI)
  - Some industrial refused to communicate on this subject
- Prognostics development thinking is similar to the historical way of deciding (i.e. the difficulty) to evolve from corrective to preventive maintenance
- Prognostics is often associated to the issues – challenges related to **SERVICES**

DIAG 21 Industrial Survey on Prognostics: What are the main reports?

- Services with regards to:
  - Product/System Life Cycle consideration
    - Prognostics capacities could be integrated from Design phase (PHM Engineering)
    - Prognostics can take advantage of the Return of Experience data
    - Prognostics can serve to prove delivery of expected performances in normal functioning
    - Prognostics can impact the product quality by mastering the component degradation and its evolution ...
  - Circular Economy paradigm
  - Economical considerations
    - Prognostics capacities to support maintenance cost control
    - Prognostics metrics to assess its impact on CoO, OEE, ROI

DIAG 21 Industrial Survey on Prognostics: What are the prognostics key vision with regards to industrial requirements ?

- Component availability vision: Prognostics can be a support to anticipate a component failure by controlling its actual and future degradation according to its “operational context”
- System productivity vision: Prognostics can be a support to adapt the maintenance planning (dynamic change) with regards not only of the components availability but also of the global requirements/performances expected
- Mission vision
- Safety-Risk vision

DIAG 21 Industrial Survey on Prognostics: What are the prognostics key vision with regards to industrial requirements ?

- Operation - Business vision

DIAG 21 Industrial Survey on Prognostics: What are the facts and obstacles to face with for Prognostics deployment?

- Prognostics in general is based on the RUL principle ... but it is very different in relation to the technologies considered due to the degradation to be observed (i.e. Prognostics restricted to well known components such as Engine, Bearings)
- Prognostics starts from the current situation (i.e. Indicators) leading to consider Condition Monitoring and Health Management as two main up-stream processes
  - Relevance of the CM, HM, HUMS systems ? Consideration of these systems in the whole engineering.
    - ✓ Sources of knowledge in general
  - Indicators definition? Information system standardisation and interoperability (i.e. OSA/CBM)
  - How the indicators aggregation is solved to supply “current situation” at different abstraction levels?

DIAG 21 Industrial Survey on Prognostics: What are the facts and obstacles to face with for Prognostics deployment?

- ❑ Prognostics and uncertainties on the input data, the results (degree of confidence). What is the forecasting horizon well adapted to minimise the uncertainties (i.e. 1 hour, 1 day)? Is it realistic to consider Prognostics at system level taking into account the sum of all the uncertainties at each level?

- ❑ The importance of the forecasting model (method) to be used and depending on the system data, the system knowledge, the context data, ... Is the model selected the most appropriated taking into account the available data, the technologies, the horizon ...? Verification/Validation phases of the model

- ❑ Prognostics engineering in general ? Without integration of Prognostics at design phase, the Prognostics added value is very limited (towards a System thinking based PHM Engineering)

DIAG 21 Industrial Survey on Prognostics: What are the facts and obstacles to face with for Prognostics deployment?

- Prognostics and metrics [A. Saxena, 2008] required to be able to assess the impact of Prognostics not only on “internal” considerations but also on “external” ones (i.e. ROI, OEE, maintenance cost decreasing) in relation to temporal scale
- Prognostics deployment requires to use sometimes emergent ICT ... which are not yet necessary reliable
  - Not to be intrusive (i.e. certification issue for IVHM)
  - Effort quantification (on all the Prognostics life cycle)

TUTORIAL OVERVIEW

- From conventional considerations of Prognostics … to system considerations more in phase with decision making requirements in industrial context …
- … What are actually the prognostics vision from industrial viewpoint: dream, reality, something else ?
- Towards a reality: Illustration in the case of industry and defence sector (needs, techniques used, results obtained)
- Towards a reality: International standardisation initiatives
- Conclusions

Prognostics in Industry

Process Industry
- ✓ Oil refinery
- ✓ Steel industry
- ✓ Chemical
- ✓ Pulp & paper
- ✓ Nuclear fuel recycling
- ✓ ...

Power Energy
- ✓ Hydropower plant
- ✓ Gas turbine/steam turbine
- ✓ Nuclear power plant
- ✓ Wind farm
- ✓ ...

Manufacturing
- ✓ Milling machine
- ✓ Automotive manufacturing
- ✓ Nuclear fuel manufacturing
- ✓ ...

Defense
- ✓ Frigates, aircraft carriers...
- ✓ Ground vehicle
- ✓ UAV
- ✓ ...

...

Why Prognostic?

For all industry

- ✓ Anticipate failure and breakdown
  - ⇨ Increase uptime
- ✓ Dynamic planning for maintenance
  - ⇨ Decrease maintenance costs
- ✓ Decrease energy consumption

In Process industry

- ✓ Anticipate performances and product quality
  - ⇨ Increase competitiveness

In Power energy

- ✓ Anticipate 2 years main shutdown/outage
  - ⇨ Maintenance optimisation
- ✓ Anticipate safety impact
  - ⇨ Decrease nuclear risk

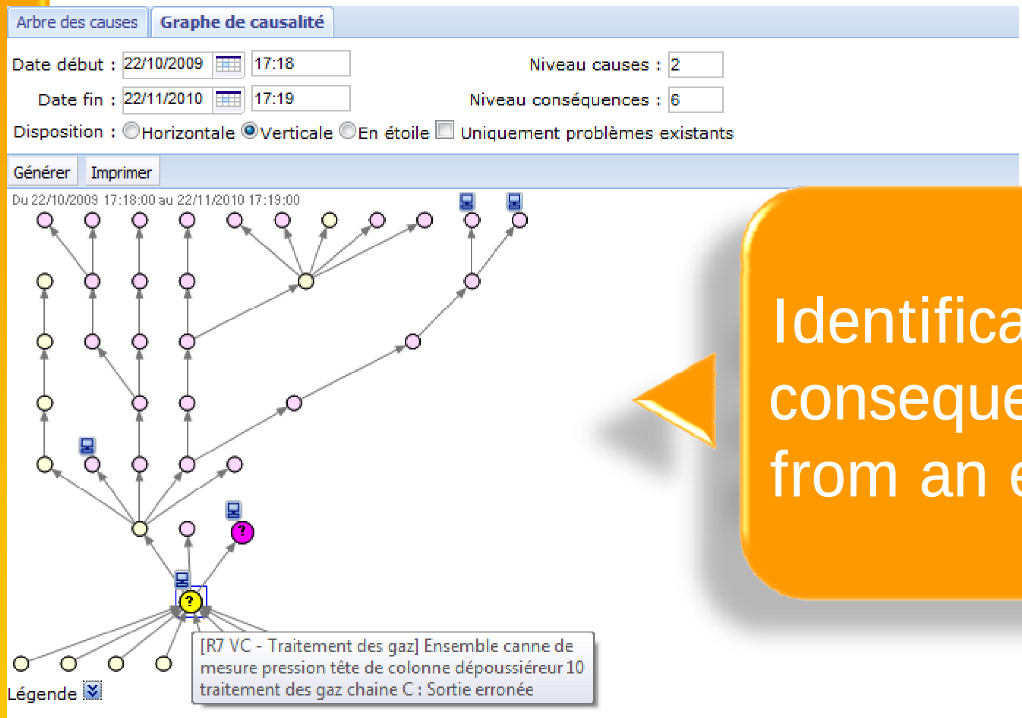
In Manufacturing

- ✓ Anticipate decrease of product quality
  - ⇨ Decrease waste or product defect
- ✓ Optimal change of tools
  - ⇨ Decrease product costs

In Defence

- ✓ Anticipate mission impact
  - ⇨ Decrease mission abort
  - ⇨ Increase survivability

Prognostics based on effect impacts

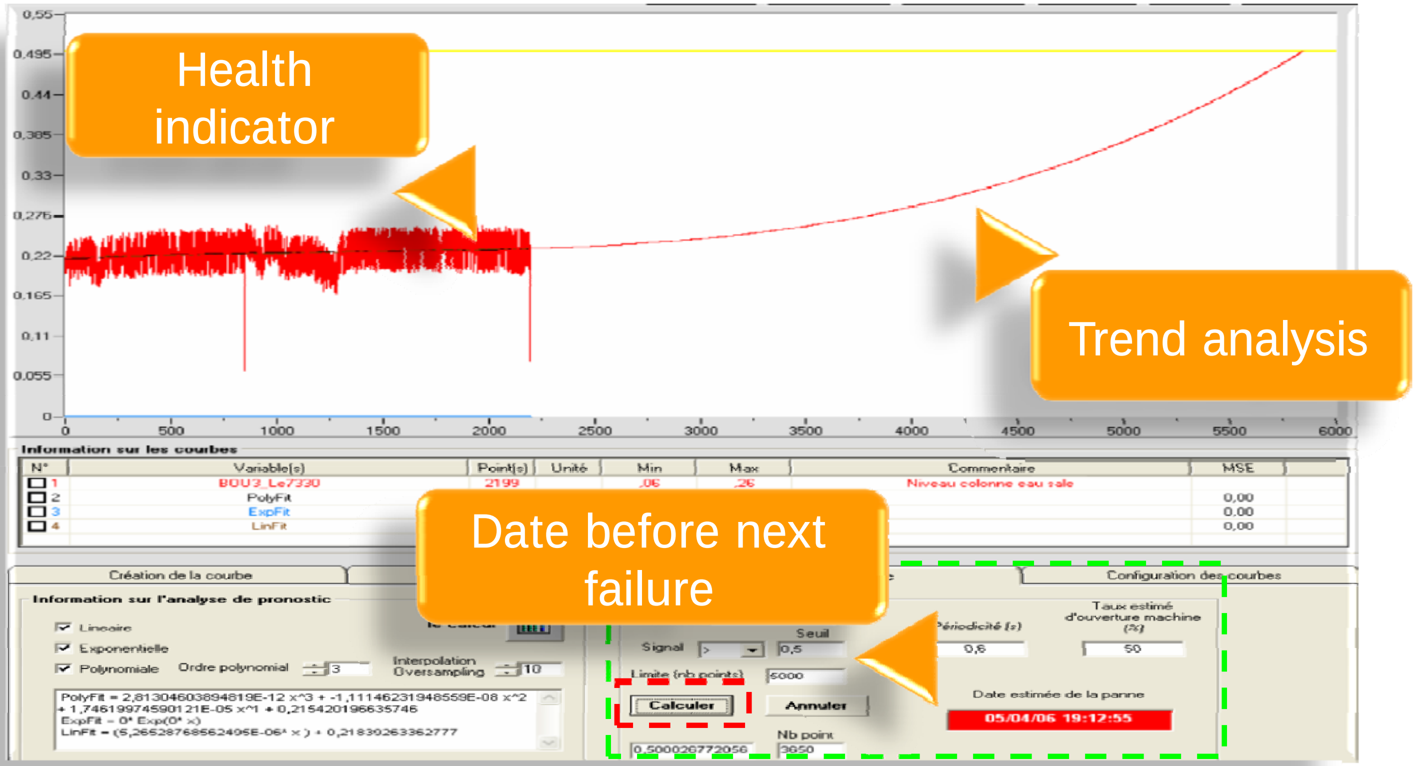


Identification of consequences from an event

Applicable to all Industry

PREDICT

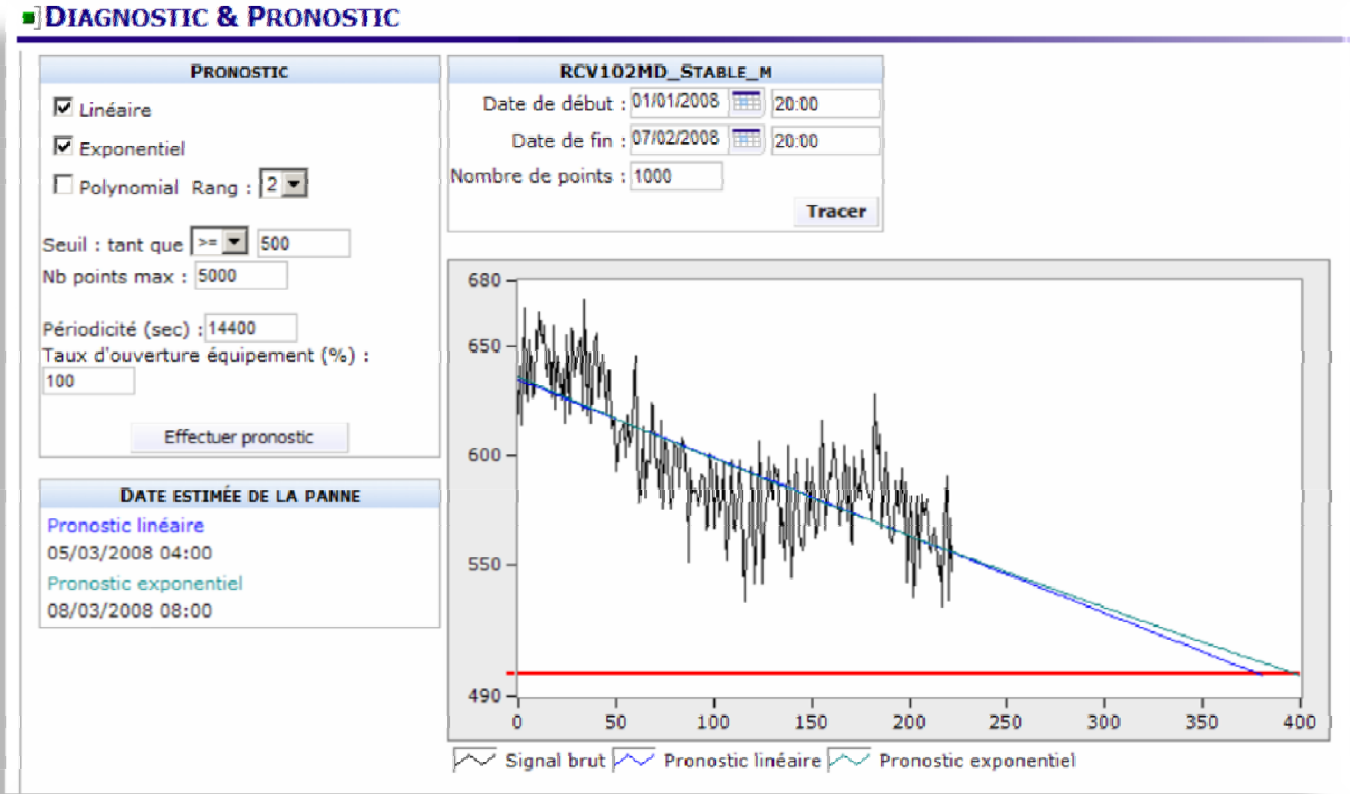
Prognostics based on Trend



Applicable to Process parts of any Industry

PREDICT

Prognostic based on multi-trends

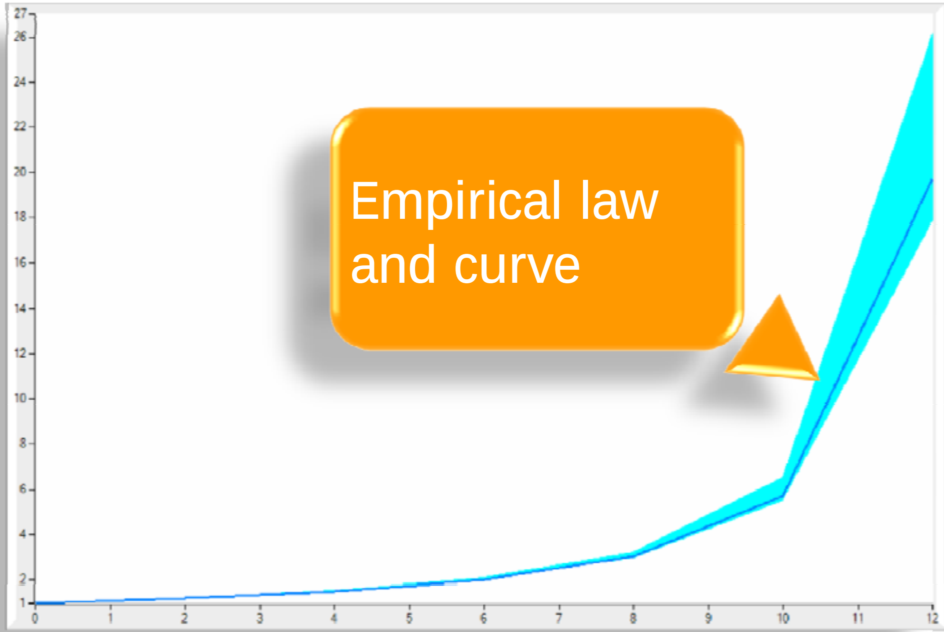


Applicable to Process parts of any Industry

PREDICT

Empirical prognostic

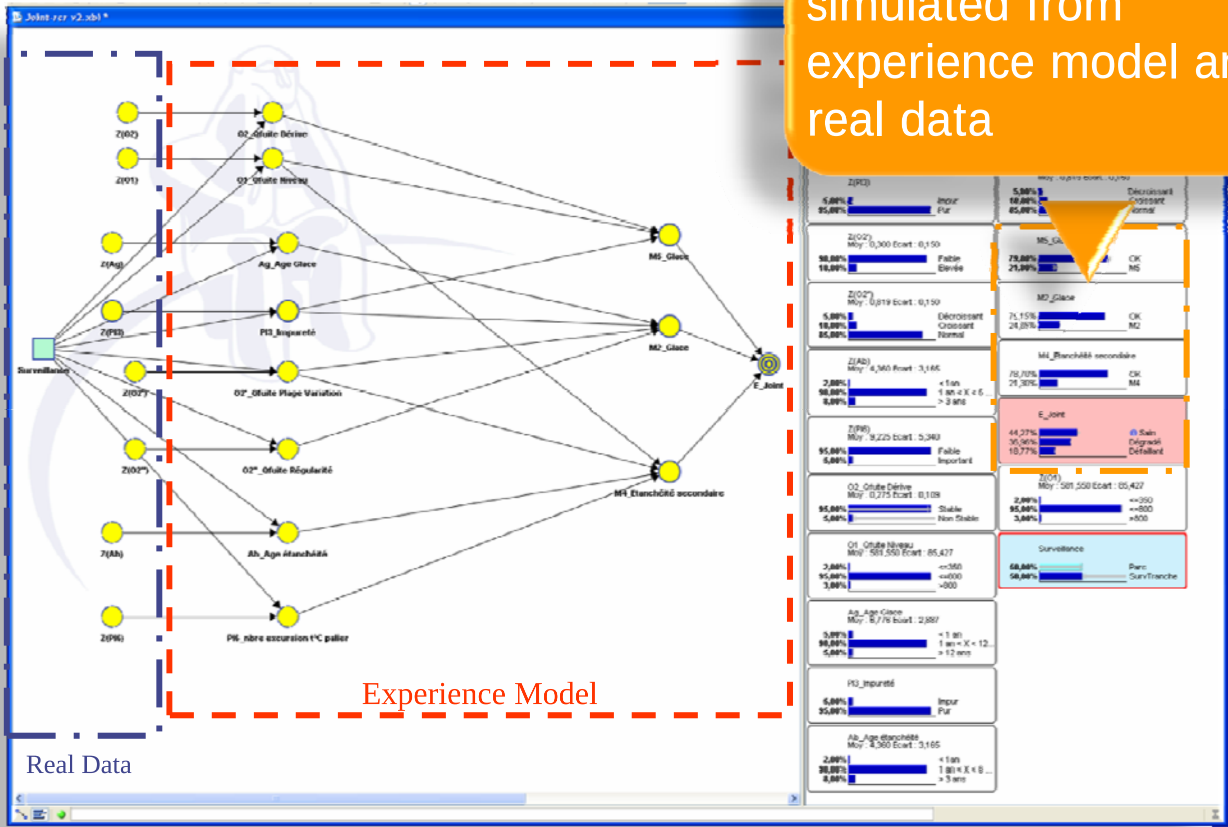
Based on empirical law and table



Applicable to Industry having long time record system or long time experimental tests

Prognostic based on conditional probability

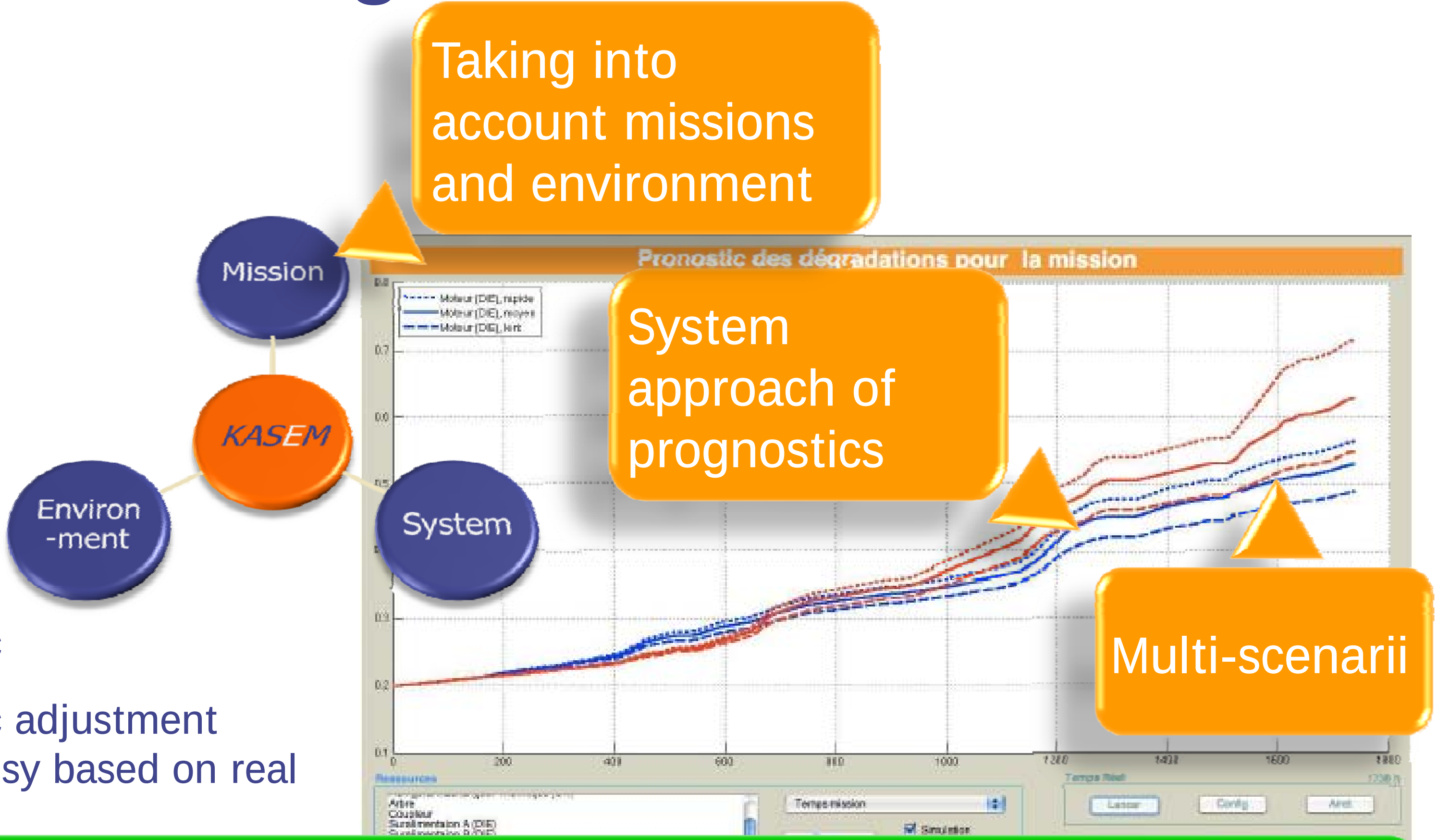
Failures and states simulated from experience model and real data



Applicable to Industry having long experience or fleet-wide systems

PREDICT

Systemic Prognostic



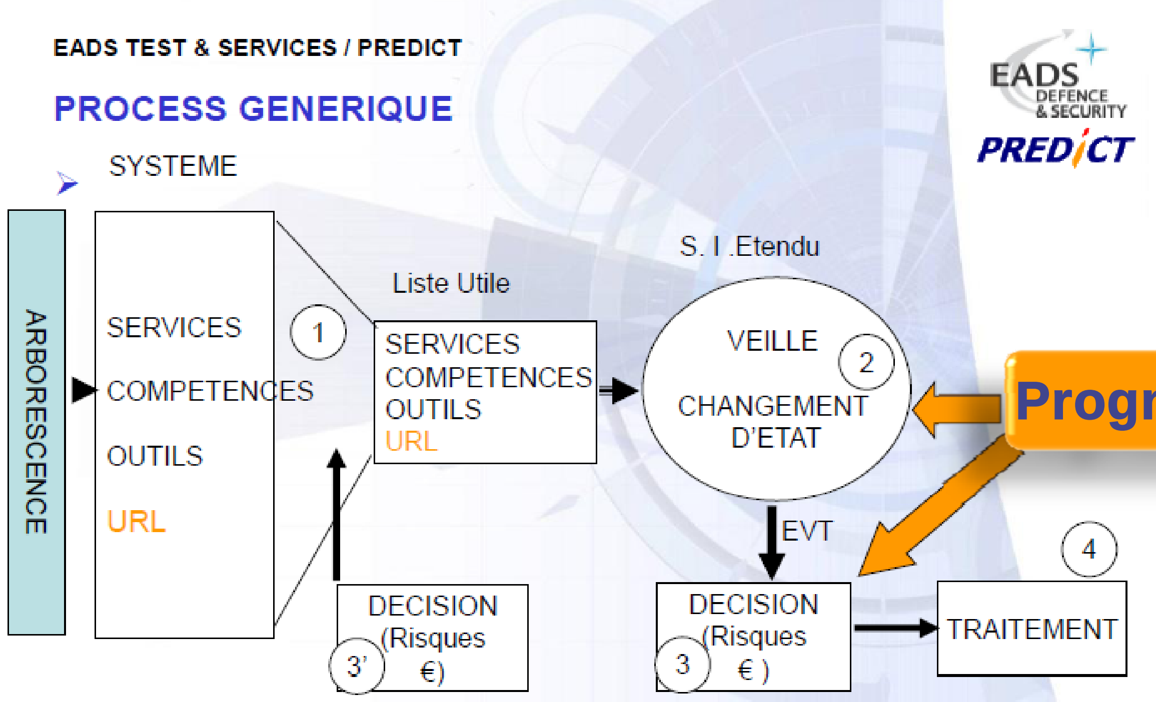
Prognostic

Prognostic adjustment continuoulsy based on real data

Applicable to Defense, Maritime and Wind Offshore

Prognostic for ageing mngt.

Big Picture with CASSIDIAN T&S



Applicable to Industry having long life-cycle

Some examples

Nuclear Fuel Recycling

Prognostic: 6 months

- ✓ Prognostic of bearing failure on a rotational furnace based on speed analysis

Nuclear Fuel Manufacturing

Prognostic: 3 months

- ✓ Prognostic of motor failure on a milling machine based on current analysis

Nuclear Power Energy

Prognostic: 3 months

- ✓ Prognostic of pump failure on a coolant system based on pressure and flow-rate analysis

Navy

Prognostic : 2 months

- ✓ Prognostic of diesel engine failures on embedded power plant and on propulsion system based on stress real-time evaluation

Power Energy

Prognostic : 1 month

- ✓ Prognostic of main condensers fouling on a sea water cooling system based on pressure/flowrate balance drift

Main pre-requirements

- Prognostics based on effect impacts
  - ✓ System approach
  - ✓ Dysfunctional analysis
    - ⇨ FMEA, HAZOP, FTA, RCA...
- Prognostics based on trend analysis
  - ✓ Identification of relevant indicators
    - ⇨ Indicator isn't direct measure from sensors
  - ✓ Data cleaning and conditioning
  - ✓ Reconciliation of data when sensor faults
- Empirical prognostics
  - ✓ Long experience or experimentation
- Prognostics based on conditional probabilities
  - ✓ System approach
  - ✓ Dysfunctional analysis
  - ✓ Long experience with statistics coupled with real data
- Systemic prognostics
  - ✓ Mission modelling
  - ✓ System approach
  - ✓ Experience on impact factors and corroboration
- Prognostics for ageing management
  - ✓ Ageing modelling
  - ✓ Long experience or experimentation
  - ✓ Continuous improvement

Prognostics ROI

- ✓Return on investment: **10 times**
- ✓Benefits starting between **3 to 6 months** after solutions commissioning
- ✓Reduction in maintenance costs: **25% to 30%**
  - ▪Proactive maintenance program can provide a cost saving of 8% to 12% over a program utilizing preventive maintenance strategies
  - ▪Cost saving opportunities of 30% to 40% could easily be realized regarding a reactive maintenance approach and material condition.
- ✓Elimination of breakdowns: **70% to 75%**
- ✓Reduction in downtime: **35% to 45%**
- ✓Increase in production: **20% to 25%**
- ✓Maintenance planning postponed from 30% to 40% -> **only 3 maintenance cycles to save one**

Predictive

- •67% OEE
- •74% plant throughput
- •34% asset downtime

Reliability Centred

- •86% OEE
- •91% plant throughput
- •13% downtime

Proactive

- •93% OEE
- •97% plant throughput
- •3% downtime

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Towards a reality: International standardisation initiatives

Actual state

The fault detection calculus methods are multiples and each new standards bring some new ways to calculate (ex: IEEE 1522),

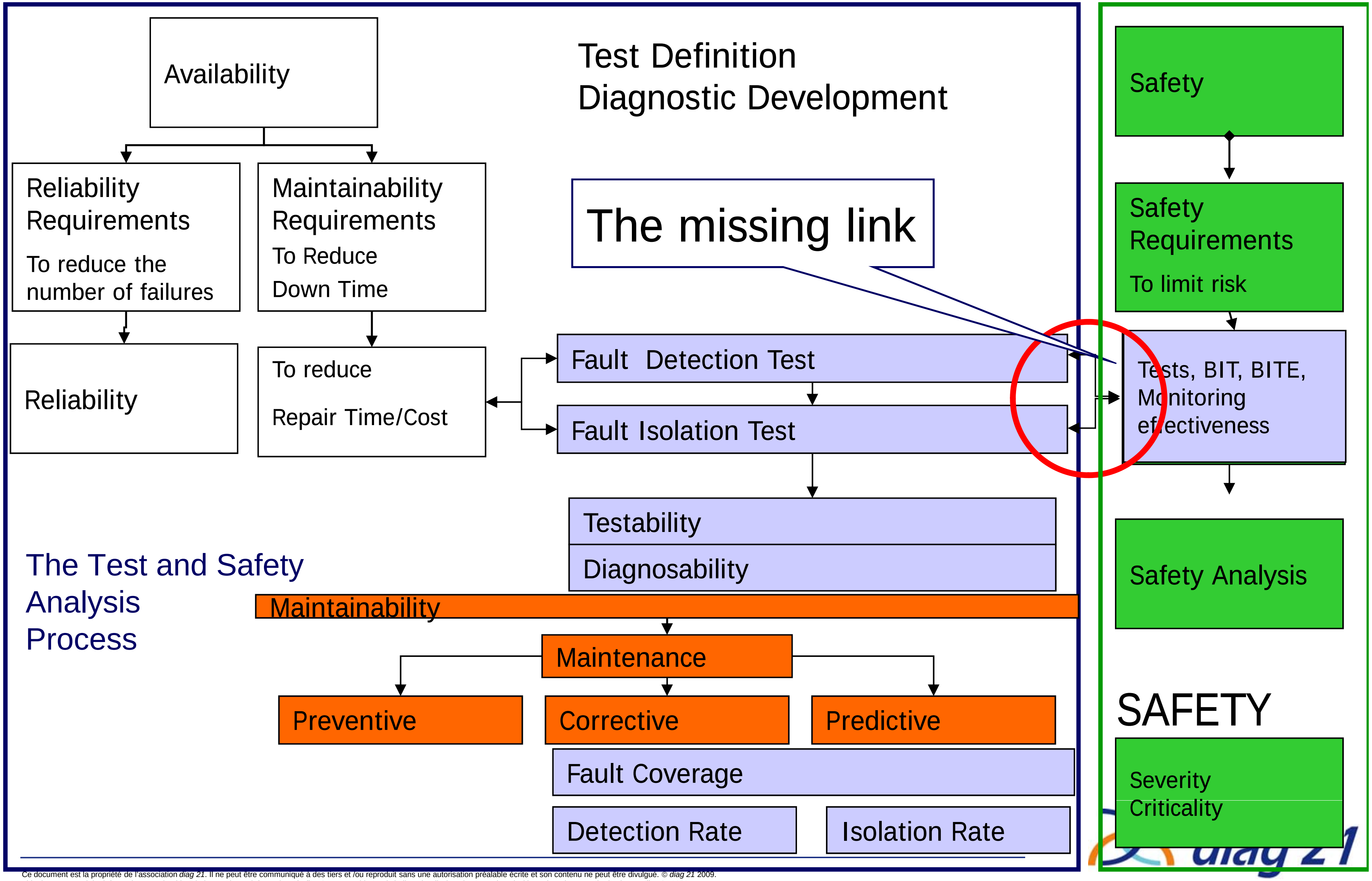
Their used is still base on a fuzzy definition of the faults catalog which is the base of the proposed calculus.

- No or not precise fault catalog based on function or Failure modes
- The fault catalog is defined between the supplier and the client (No standards)
- The notion of fault catalog for software is not existing or not proven

Many (or too many >20) norms standard industrial and military which concern testability. Most of them are not applicable or obsolete

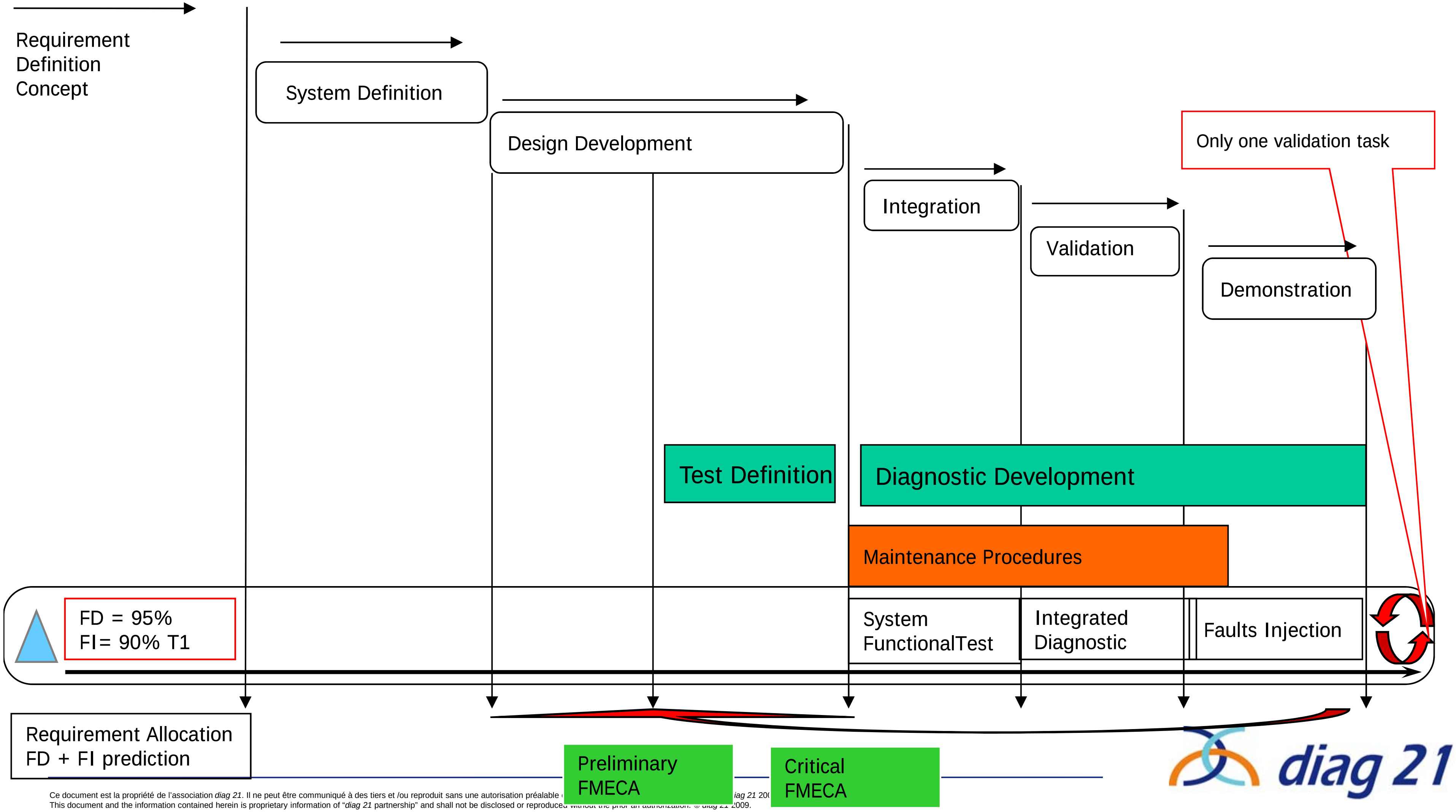
- MIL HDBK 472 (1984)
- IEEE 1522 (2004): remove 2010

Some results show that the calculated results of isolation and localization of faults are different from the real found in field during return of experience. Even more the results attached to the embedded fault isolation algorithms bring uncertainty of isolation even during support and maintenance.

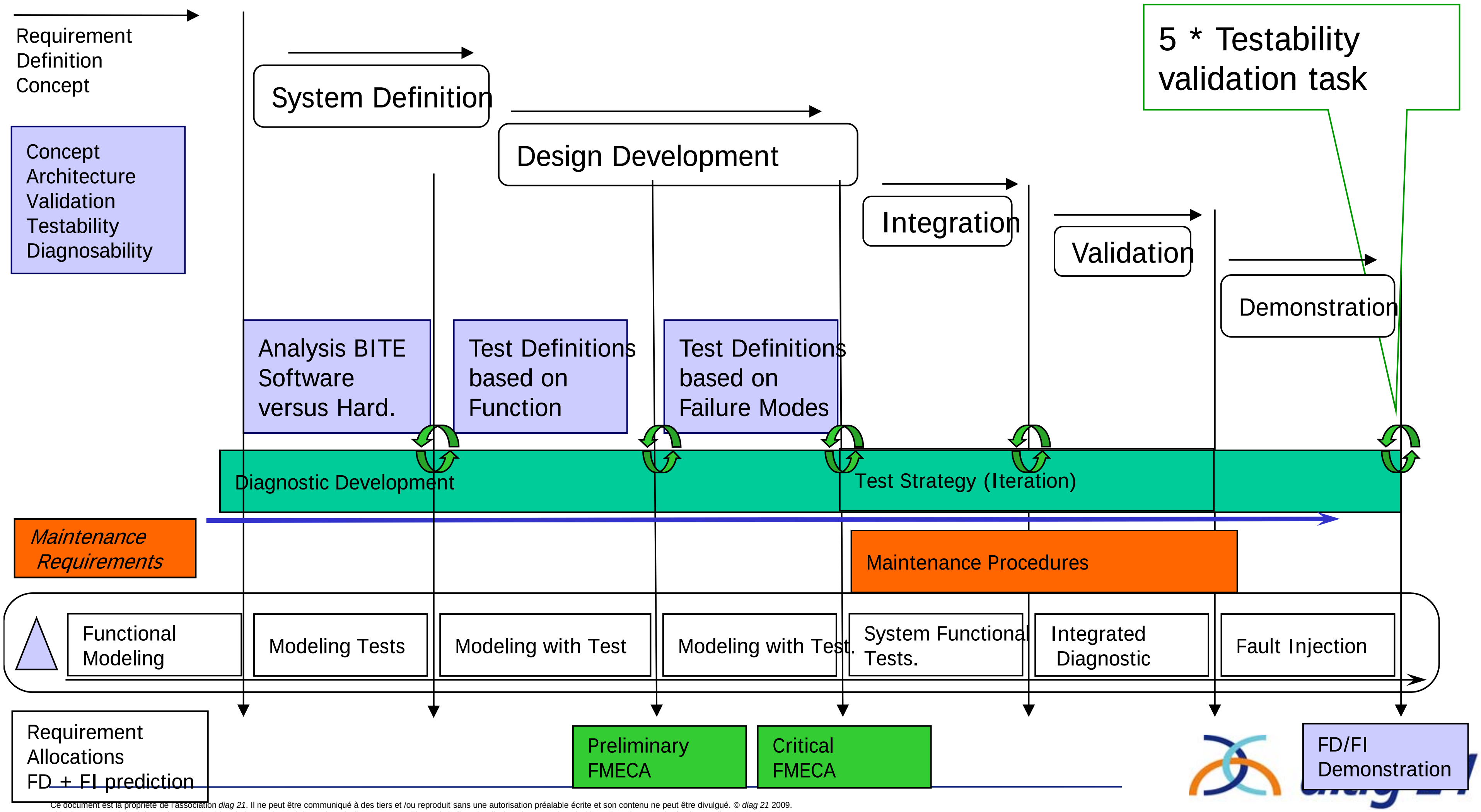

Availability
Test Definition
Diagnostic Development
Reliability Requirements
To reduce the number of failures
Maintainability Requirements
To Reduce Down Time
The missing link
Reliability
To reduce
Repair Time/Cost
Fault Detection Test
Fault Isolation Test
Testability
Diagnosability
The Test and Safety Analysis Process
Maintainability
Maintenance
Preventive
Corrective
Predictive
Fault Coverage
Detection Rate
Isolation Rate
Safety
Safety Requirements
To limit risk
Tests, BIT, BITE, Monitoring effectiveness
Safety Analysis
SAFETY
Severity
Criticality

Actual engineering process

No validation milestone.



Model driven Engineering process



Standards Support Interoperability

- ISO Standards
  - ISO 13374-1 Condition Monitoring and diagnostics of machines – Data processing, communication and presentation – Part 1: General guidelines (OSACBM-based)
  - ISO 13374-2 Condition monitoring and diagnostics of machines – Data processing, communication and presentation – Part 2: Data processing
  - PLCS (Product Life Cycle Support) – An ISO standard being developed within the STEP community focusing on information exchange for the life cycle support
  - OASI PLCS DEX on Aviation Maintenance
    - Historical Maintenance activities (similar to MAI)
    - Non maintenance activities that may affect future maintenance
    - Estimation of system state
    - Activities affecting product inventories

Reference Diagnostic Modeling and Application Development (John Sheppard Montana State University, TIM Wilmering, The Boeing Company)

Standards Support Interoperability

- IEEE Standards SCC20 DMC
  - IEEE P1232 Artificial Intelligence Exchange and Tie to All Test Environments (AI-ESTATE)
  - IEEE P1636 Software Interface for Maintenance Information Collection and Analysis (SIMICA)
  - IEEE P1636.1 Exchanging Test Results and Session Information via the Extensible Markup Languuage (XML)
  - IEEE 1636.2 Exchanging Maintenance Action Information via the Extensible Markup Language (XML)
- Machinery Information Management Open System Alliance (MIMOSA)
  - OSA-EAI V3.2.1..
  - OSA-CBM V3.2.1 ..

Standards

Ministry of Defence - Defence Standard 25-24 Health and Usage Monitoring Capability for Land Platforms (HUMS) Issue 1 Publication Date 24 December 2004

MoD STAN 23-09 Generic Vehicle Architecture

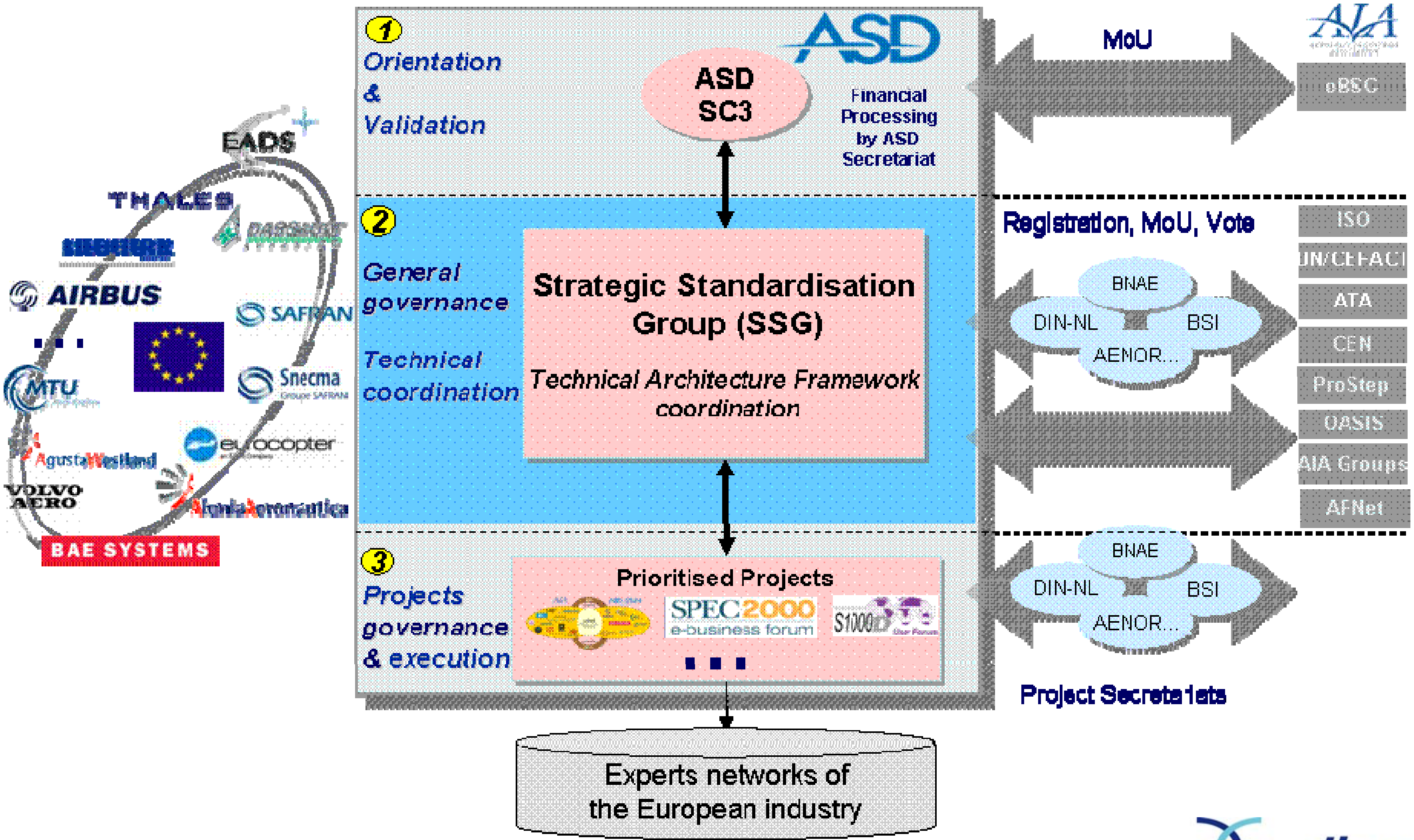
Working group SAE HM-1

- Design (Andy Hess, Tim Wilmering)
- Architecture (Emmanuel Nwadiogbu, Sonia Vohnout)
- V&V, Certification (Ravi Rajamani)
- Data & Information Management (Bob Hess)

HM-1 Design Processes (Wilmering, Timothy J timothy.j.wilmering@boeing.com)

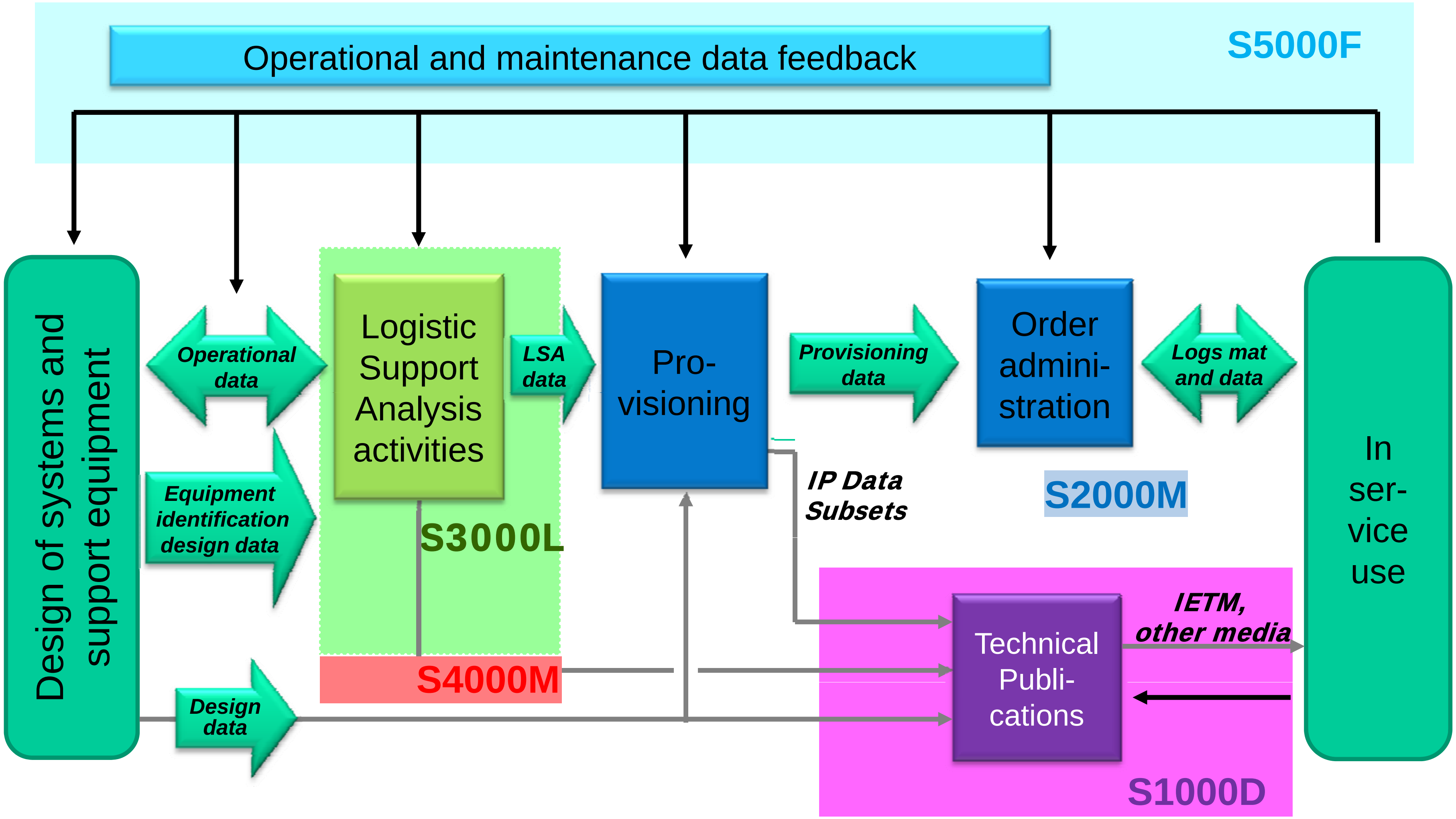
VHM design

ASD governance structure for e-Business Standards



diag 21

ASD Network



Source: EADS - Saab

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CONCLUSION

- Prognostics – A emergent process within PHM context ... but with potential great added value
- Prognostics – Towards its required integration within decision-making loop ... thus considering not only the component level but also the requirements/services/performances one (CBM+ vision)
- Prognostics – System Engineering thinking ... thus PHM Engineering has to be considered within System Engineering
- A lot of issues and challenges
  - Uncertainty Management and Degree of Confidence
  - Performance assessment with regards to Prognostics metrics
  - Dependable ICT to support Prognostics deployment
  - Synergy between industry and academia to develop methods, models, tools ...

first european conference of the prognostics
and health management society 2012

July 3-5, 2012

Tutorial 3
State-of-the-art Realization of Prognostics in Industry

Presenters: Michel SCHIEBER (Cassidian T&S)
Jean Baptiste LEGER (Predict)
Benoit IUNG (Lorraine University, CRAN)