EUROPEAN
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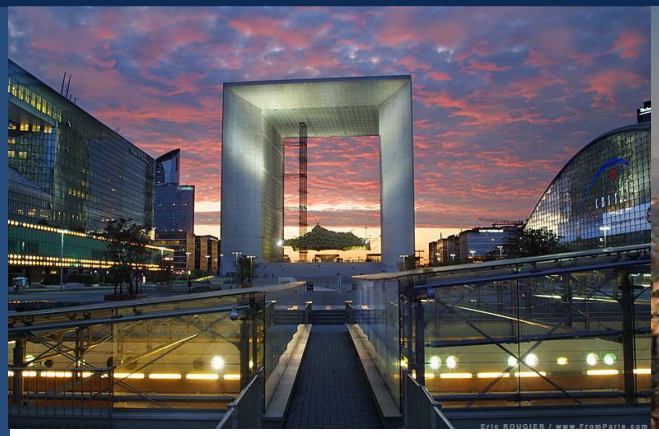

ETN AGM & WORKSHOP

2-3 April, Paris La Defense, France

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Condition Based Maintenance & Related GT modeling aspects

Dr. Christoforos Romesis

National Technical University of Athens (NTUA)
Laboratory of Thermal Turbomachines

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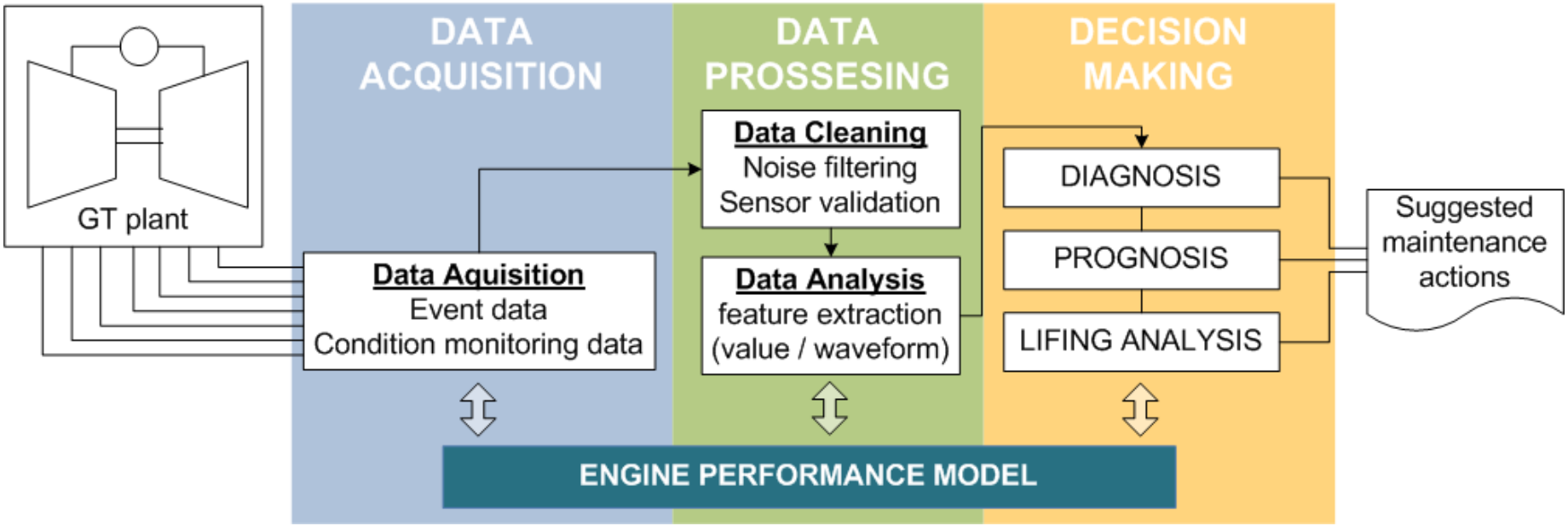
Overview of the CBM approach



CBM is a maintenance approach, where maintenance actions are suggested, based on information collected through condition monitoring

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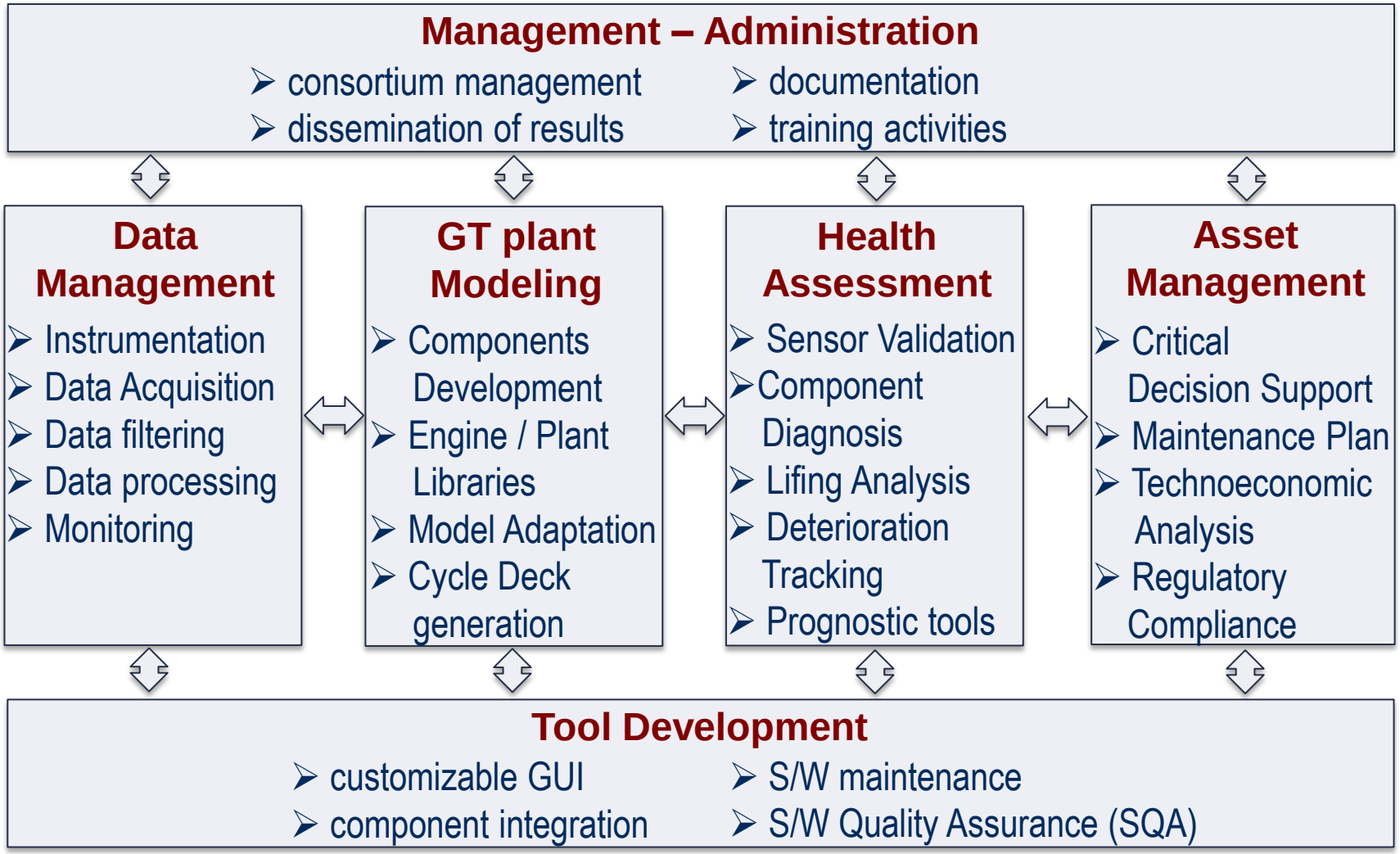
Proposed Project Structure

– initial approach –



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Questions Raised

- The development of a tool following the complete CBM sequence is a huge task to be covered by a single project, in terms of both required effort and cost
- Some condition monitoring features, related to CBM, may be of little interest to users or is already covered by existing tools

- Need of mapping current practices and available tools for GT plants condition monitoring
- Identify any technological gap and CBM related issues of interest

Questionnaires

created by NTUA and CU, towards ETN partners

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Questionnaires structure

GT users and O&G industry

Current Maintenance Approach
Breakdown | Preventive | Predictive

Software related questions
How is developed?
How is currently used?
How data can be exported?

Condition Monitoring features
Features currently available?
Desired features?
How to be integrated?

Concerns
Additional Comments

OEMs, R&D, suppliers & service providers

Condition Monitoring activities
software | tools | services

Condition Monitoring features
currently available

Condition Monitoring features
to be developed within the frame of a CBM project

Concerns
Additional Comments

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Questionnaires Responses

In total, 19 questionnaires feedback were received by partners

Oil&Gas (2) – Utilities (3) – OEM (1)

R&D institutes (5) – Suppliers & Service providers (8)

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Questionnaires Responses

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Questionnaires Responses
– GT users and O&G industry –

Current Maintenance Approaches

Breakdown Maintenance
maintenance actions are taken only after breakdown / when fault occurs.

Preventive Maintenance
maintenance actions are taken after specific time intervals of operation, regardless of the condition of the engines, unless a machinery issue occur in the meantime.

EDF, Statoil, VATTENFALL

Predictive Maintenance
maintenance actions are planned and taken according to the actual condition of the operating engines, which is assessed through appropriate condition monitoring procedures.

Shell, Statoil

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Questionnaires Responses
– GT users and O&G industry –

Software related questions

	Shell	Statoil		E.ON	EDF
In-house developed software	■			■	■
Software developed by GT manufacturer		■	■		■
Software developed by third party					■

- In 80% of users, available software allows real-time data exports
- Users are either consulted their condition monitoring software, for maintenance planning, to detect an event at an early stage, or when an event has already occurred.

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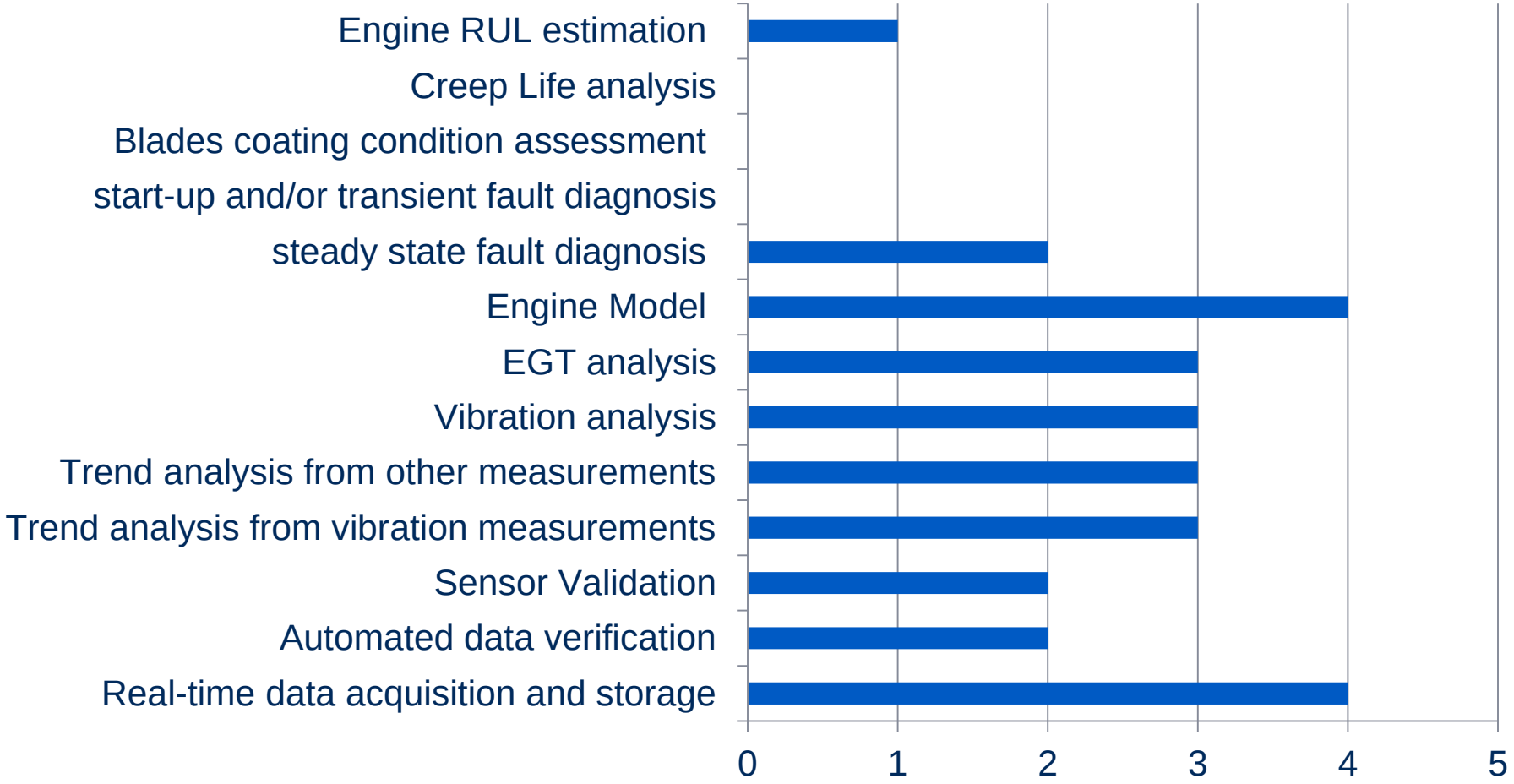
Questionnaires Responses
– GT users and O&G industry –

Current Condition Monitoring features



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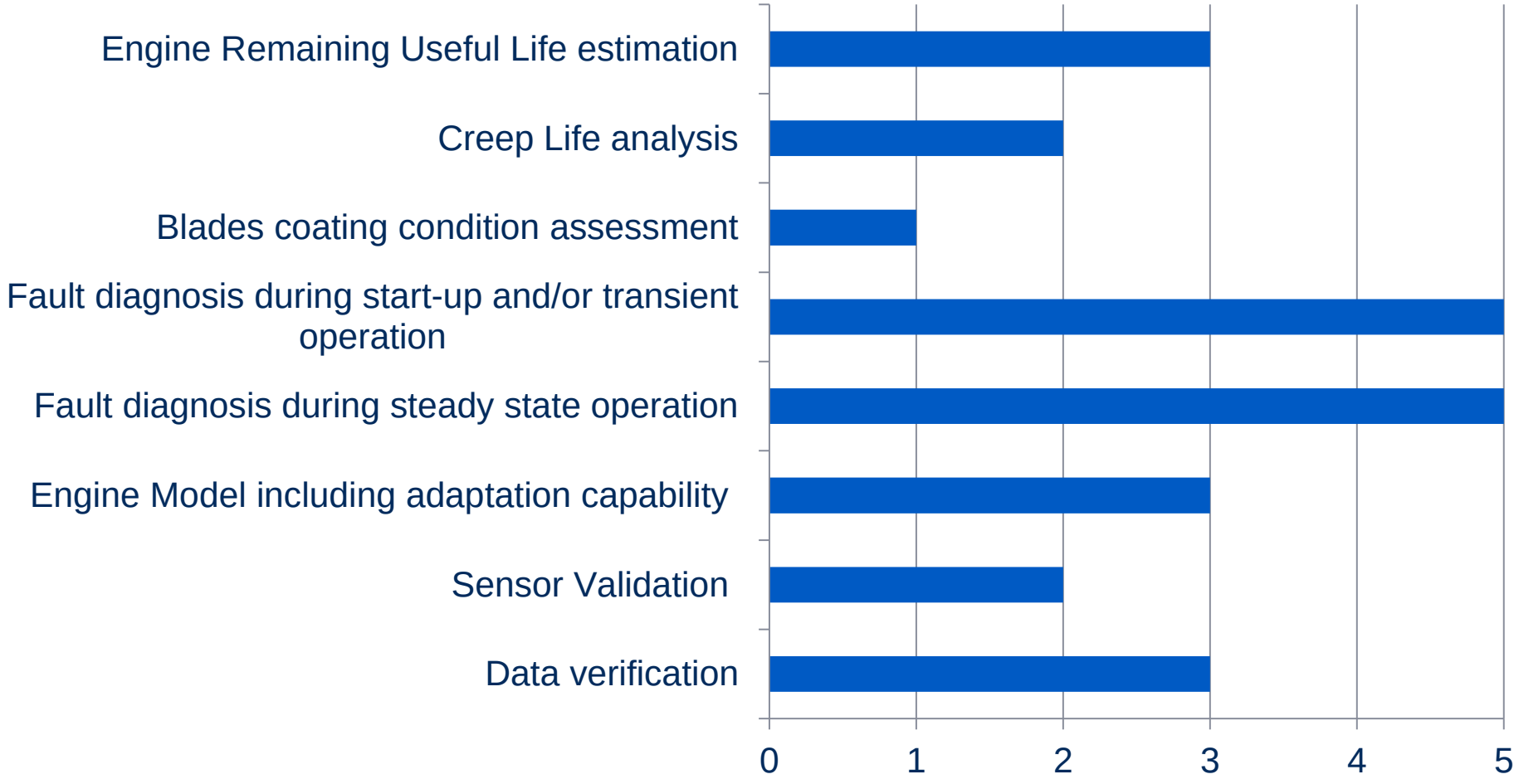
Questionnaires Responses

– GT users and O&G industry –

Desired Condition Monitoring features



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Questionnaires Responses

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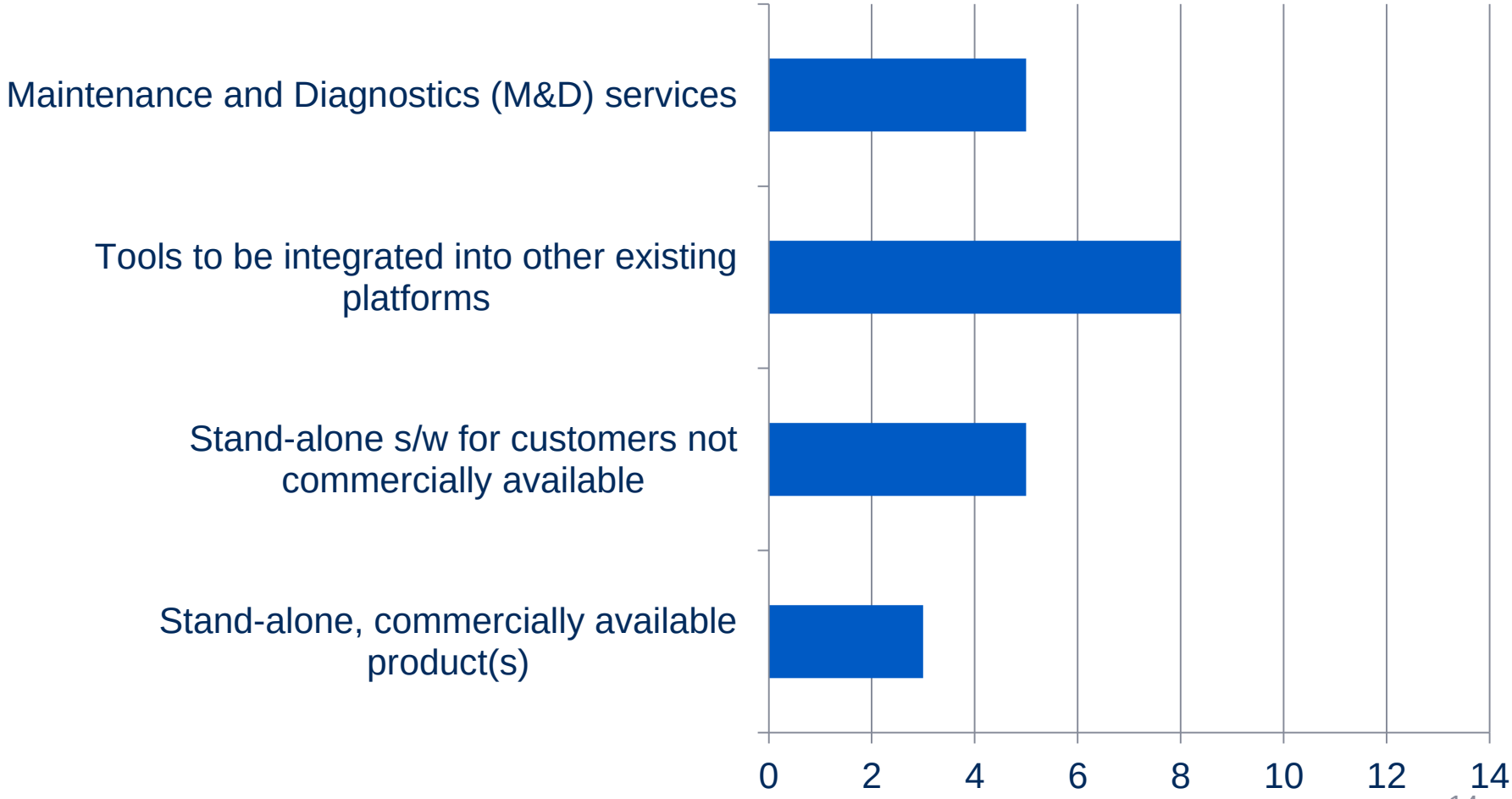
Additional Comments

Questionnaires Responses

– OEMs, R&D, suppliers & service providers –

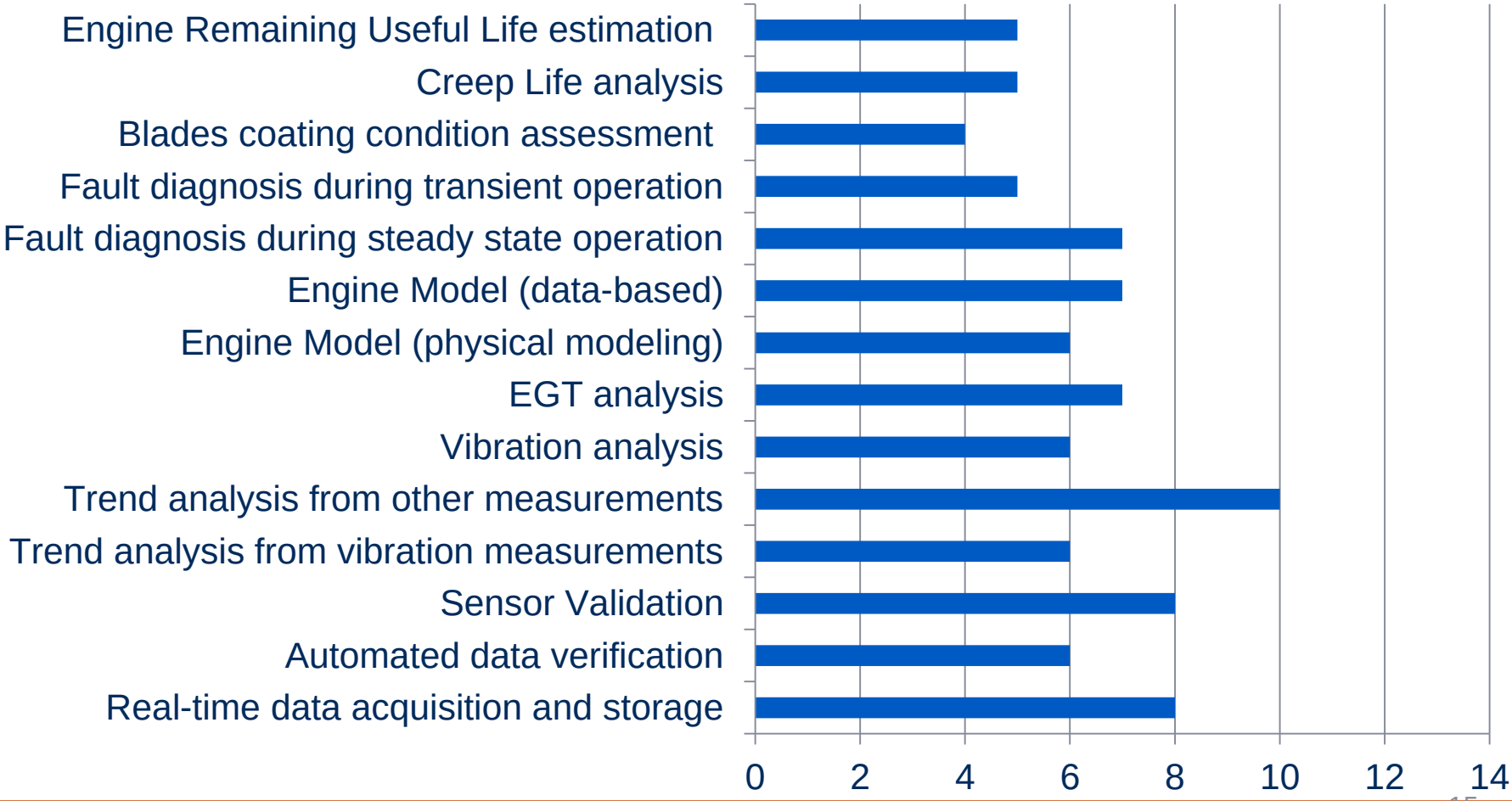
Provided Condition Monitoring Activities



Questionnaires Responses

– OEMs, R&D, suppliers & service providers –

Available Condition Monitoring features



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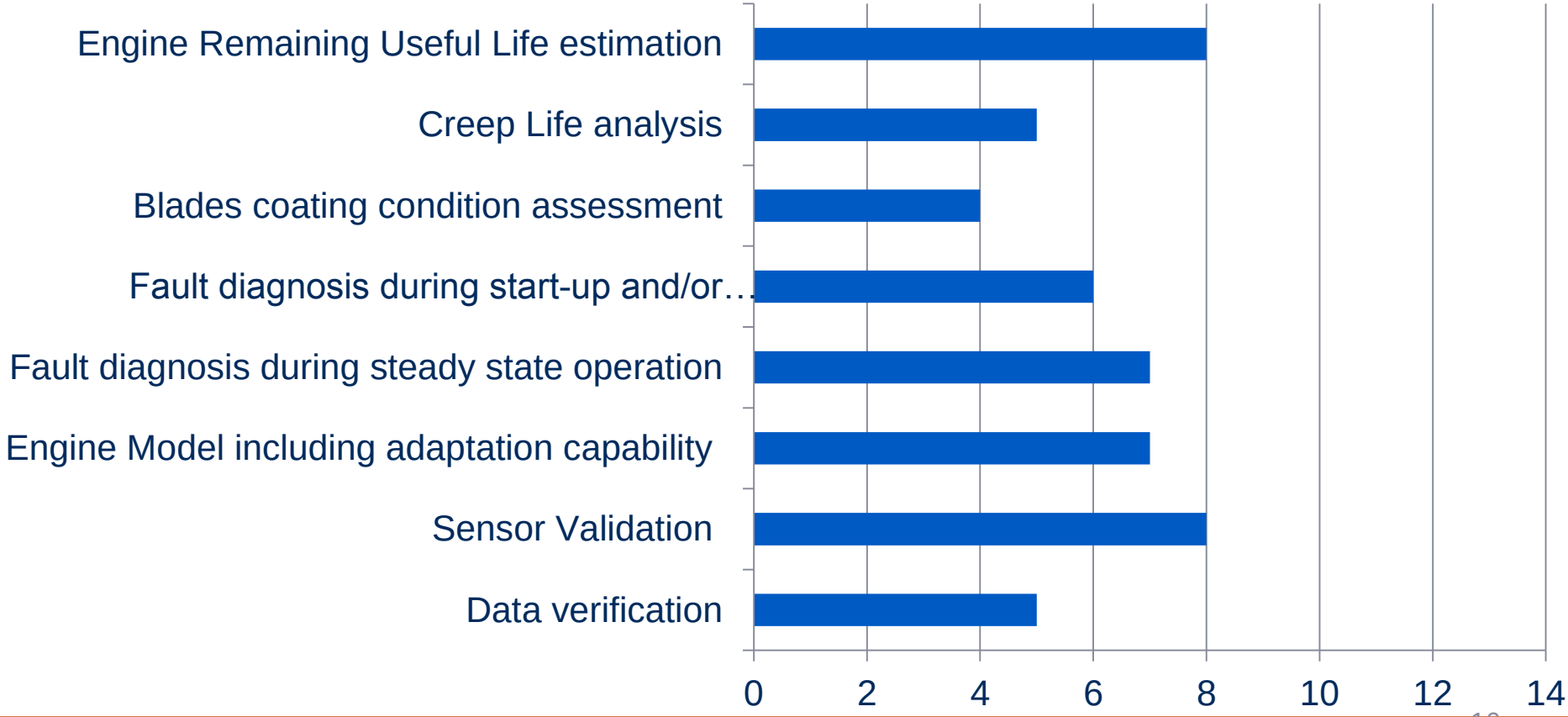
Questionnaires Responses

– OEMs, R&D, suppliers & service providers –

Condition Monitoring features partners could contribute



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Concerns & Comments

- **Confidentiality issues**
  Important, but cannot be addressed at the moment, since the project structure and the consortium are not yet defined
- **Usefulness of the outcome**
  Tools already exist, but users are missing condition monitoring features. Also OEM expresses the interest in incorporating advanced methods & techniques
- **Required OEM participation – Service providing**
  Output of the project will be a decision-support tool. Whether this is a stand-alone tool for users or integrated to OEMs' and service providers systems, depends on the consortium.

- distinction should be made between fault detection (short term, quick actions) and maintenance considerations (long term)
- Additional measurements would improve the capabilities of condition monitoring techniques

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Questionnaires conclusions

- ETN partners form a pool of developers that can cover all aspects of a CBM tool
- Users on the other hand are interested in seeing the considered features, either incorporated into their existing systems, or as a stand-alone tool
- OEM is also interested in the project idea:
  "In case that the commercial issues mentioned below (in the questionnaire, Ed.) can be resolved there is considerable interest in supporting all the mentioned areas"
- A realistic output would be the development of a Decision Support tool, focused on Diagnosis (steady-state, transient) and Prognosis
- Consortium scheme is still open
- Confidentiality issues must be addressed

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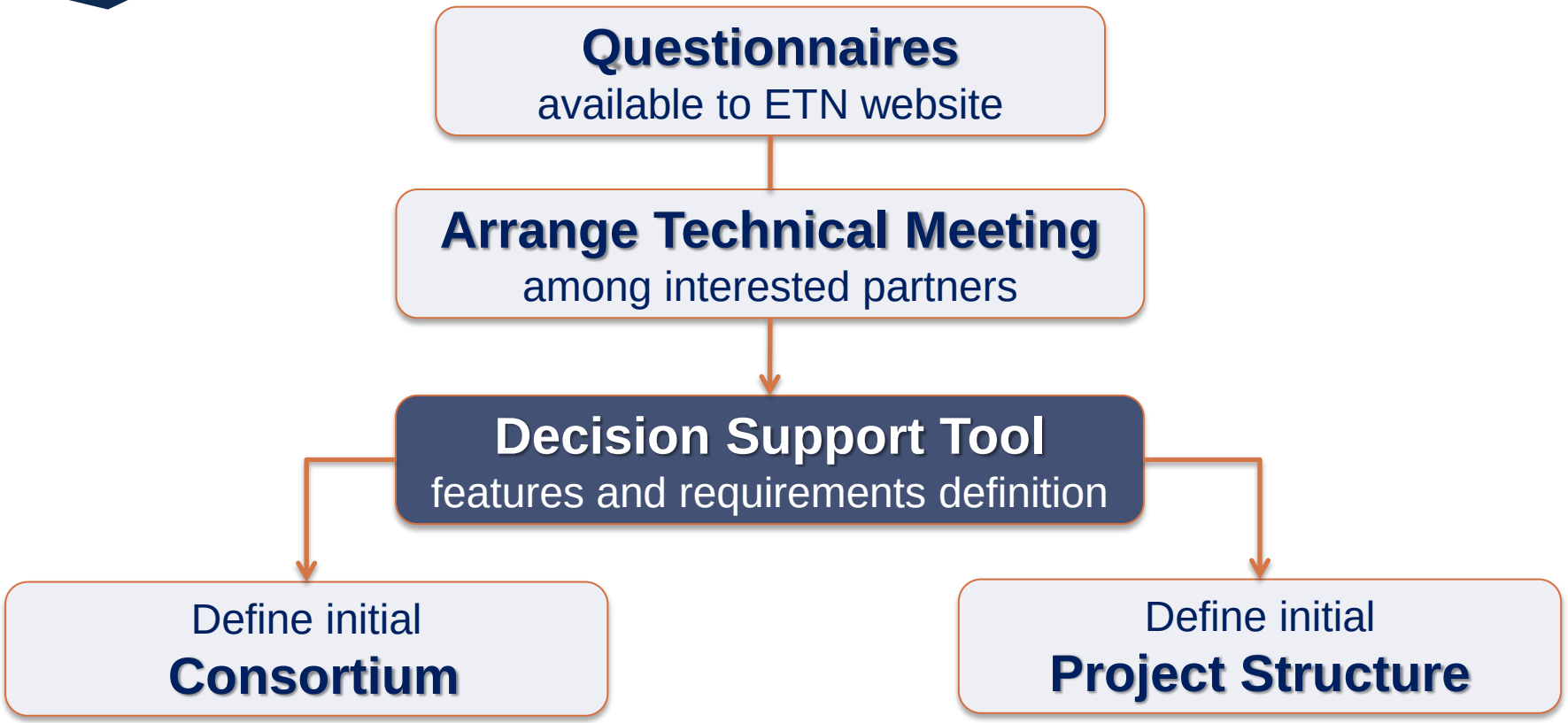
Way forward



We need to move into more technical details, to clarify final product features. This would allow partners to express their particular interest and us to propose a project structure

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Gas Turbine modeling aspects related to CBM

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Engine Performance Modeling
current state-of-the-art

There is currently a multitude of commercial and in-house codes across Europe

Current state-of-the-art will be presented using PROOSIS,
a tool developed in Europe for the European Gas Turbine Industry

PROOSIS

Developed in European Research Project **VIVACE** (2004-2007) by a consortium of European Universities (NTUA, CU & USTUTT), Research Institutes and corporate companies (Empresarios Agrupados Int., Snecma, MTU, AVIO, ITP, Turbomeca, Airbus France)

The ultimate goal for PROOSIS is to reduce development time and costs in all types of gas turbine or propulsive systems by becoming a **common simulation environment**, providing shared standards and methodologies for everybody involved in European gas turbine engine research and development programs.

Current users include Airbus, SAFRAN (Snecma, Turbomeca, TechSpace Aero), European Universities & Research Institutes

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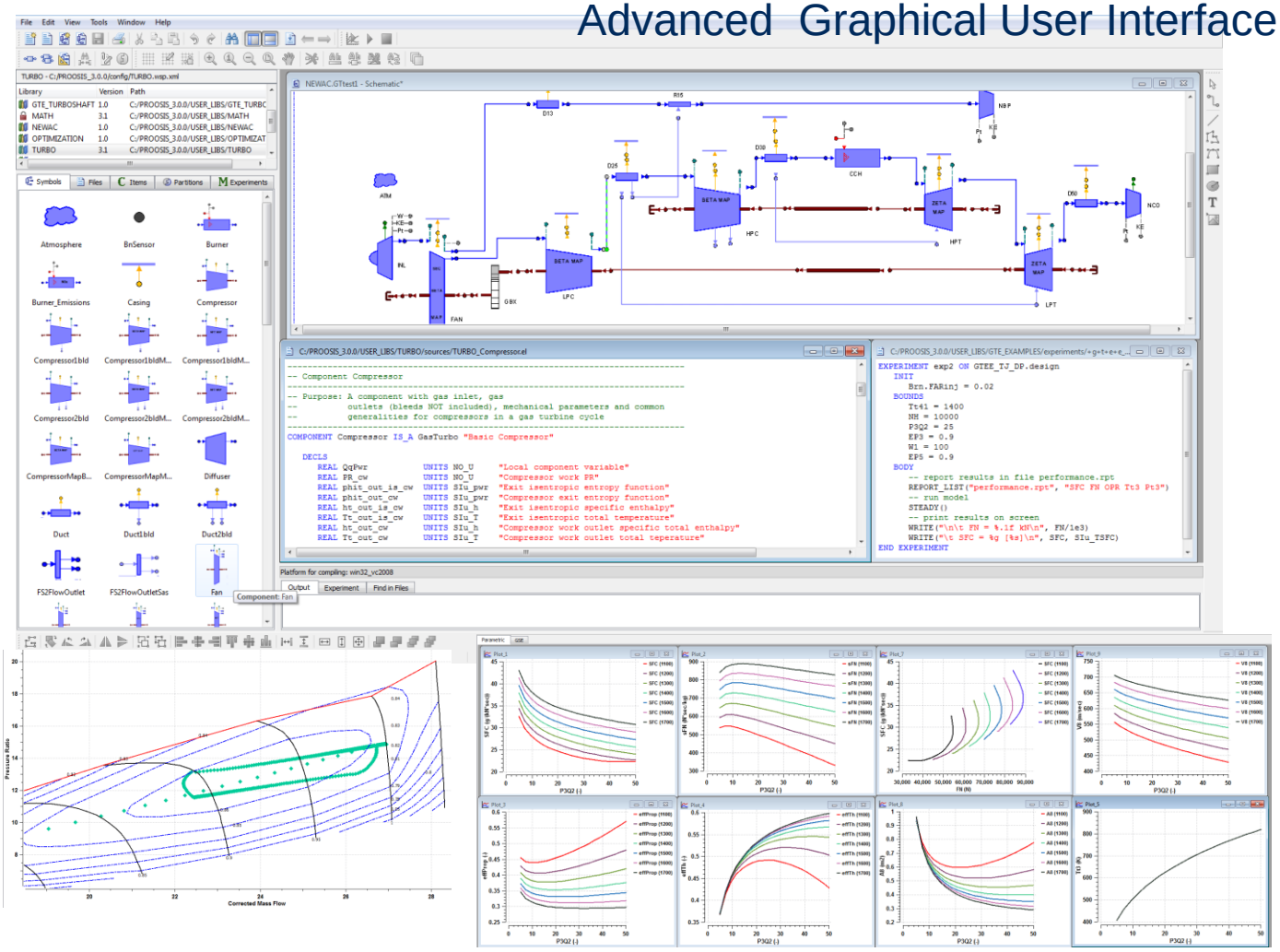
PROOSIS

(PRopulsion Object-Oriented Simulation Software)

- Object-Oriented
- Steady State
- Transient
- Mixed-Fidelity
- Multi-Disciplinary
- Distributed
- Multi-point Design
- Off-Design
- Test Analysis
- Diagnostics
- Sensitivity
- Optimisation
- Deck Generation
- Connection with Excel & Matlab
- Integration of FORTRAN, C, C++

Advanced Graphical User Interface



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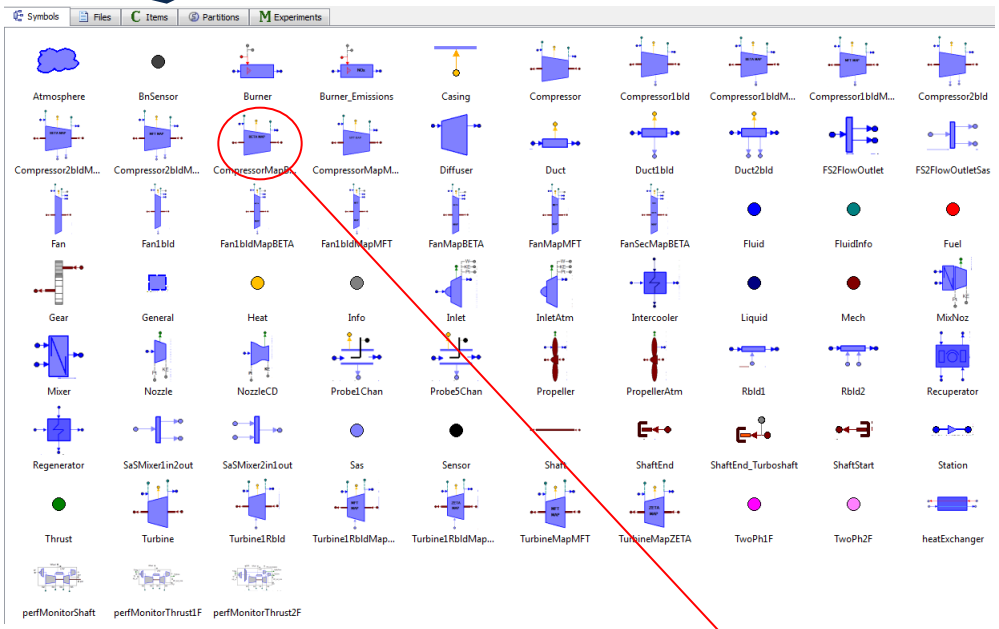
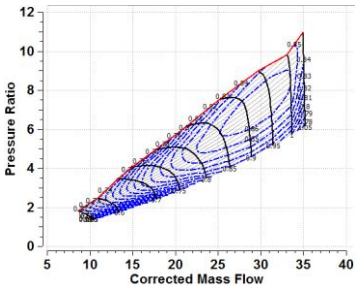
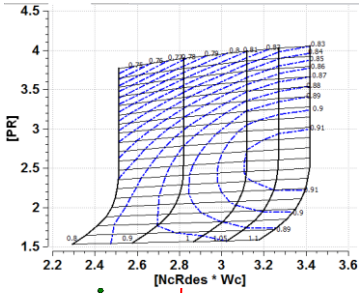
TURBO library of gas turbine components

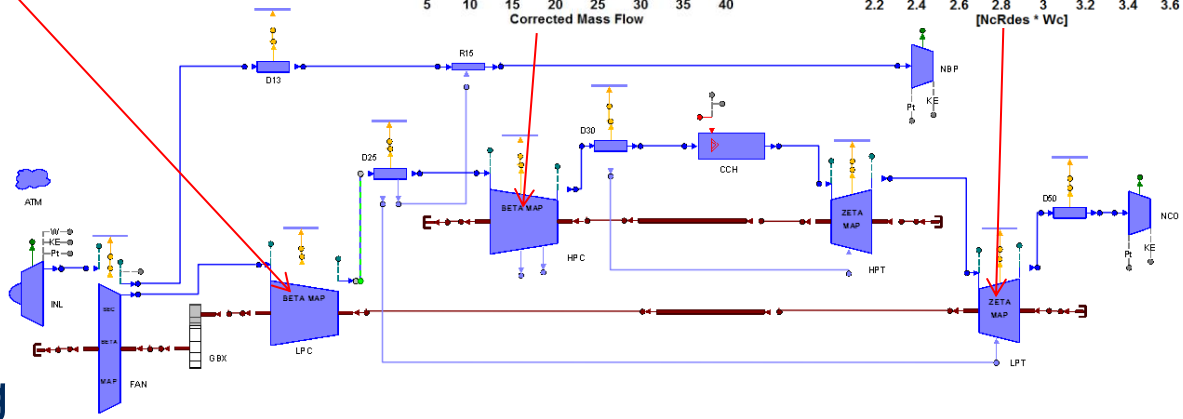


Compressor map



Turbine map





- **Industry-accepted** performance modelling techniques
- Respects international **standards** in nomenclature, interface & OO programming

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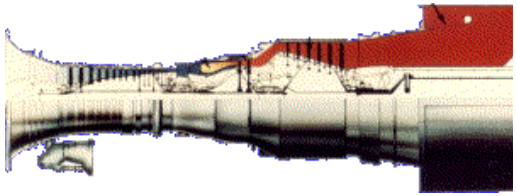
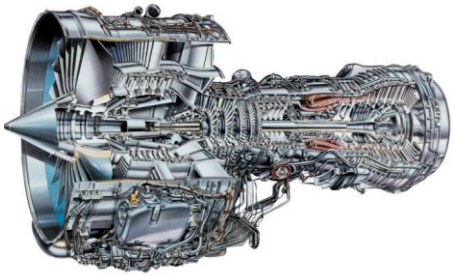
Generic and Existing Engines library

Turbomeca Makila-1A1

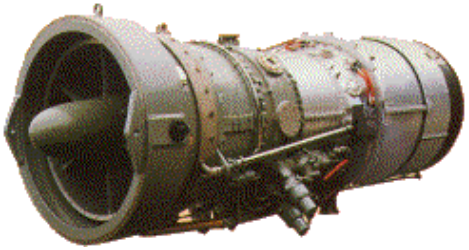


GE LM2500-30

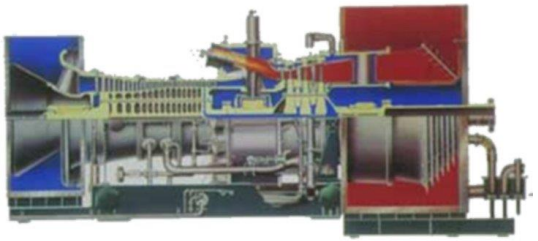
Siemens V64.3



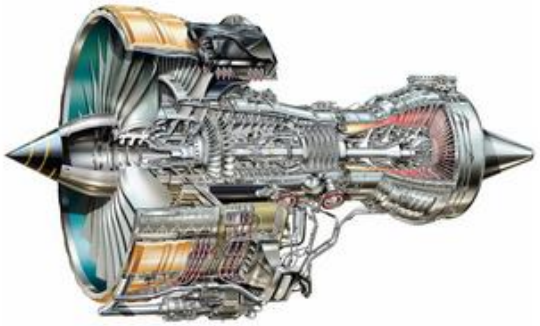
IAE-V2500-A1



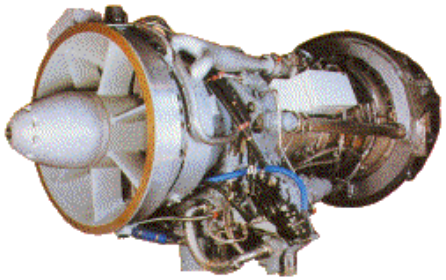
Rolls-Royce Olympus



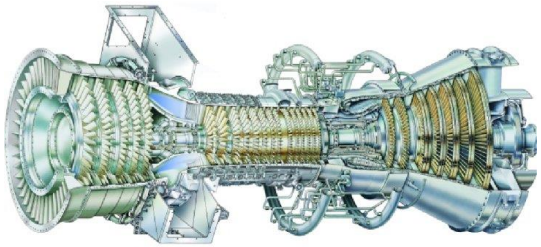
GE PG9171E



Rolls-Royce TRENT-772B



Rolls-Royce Tyne



GE LM6000

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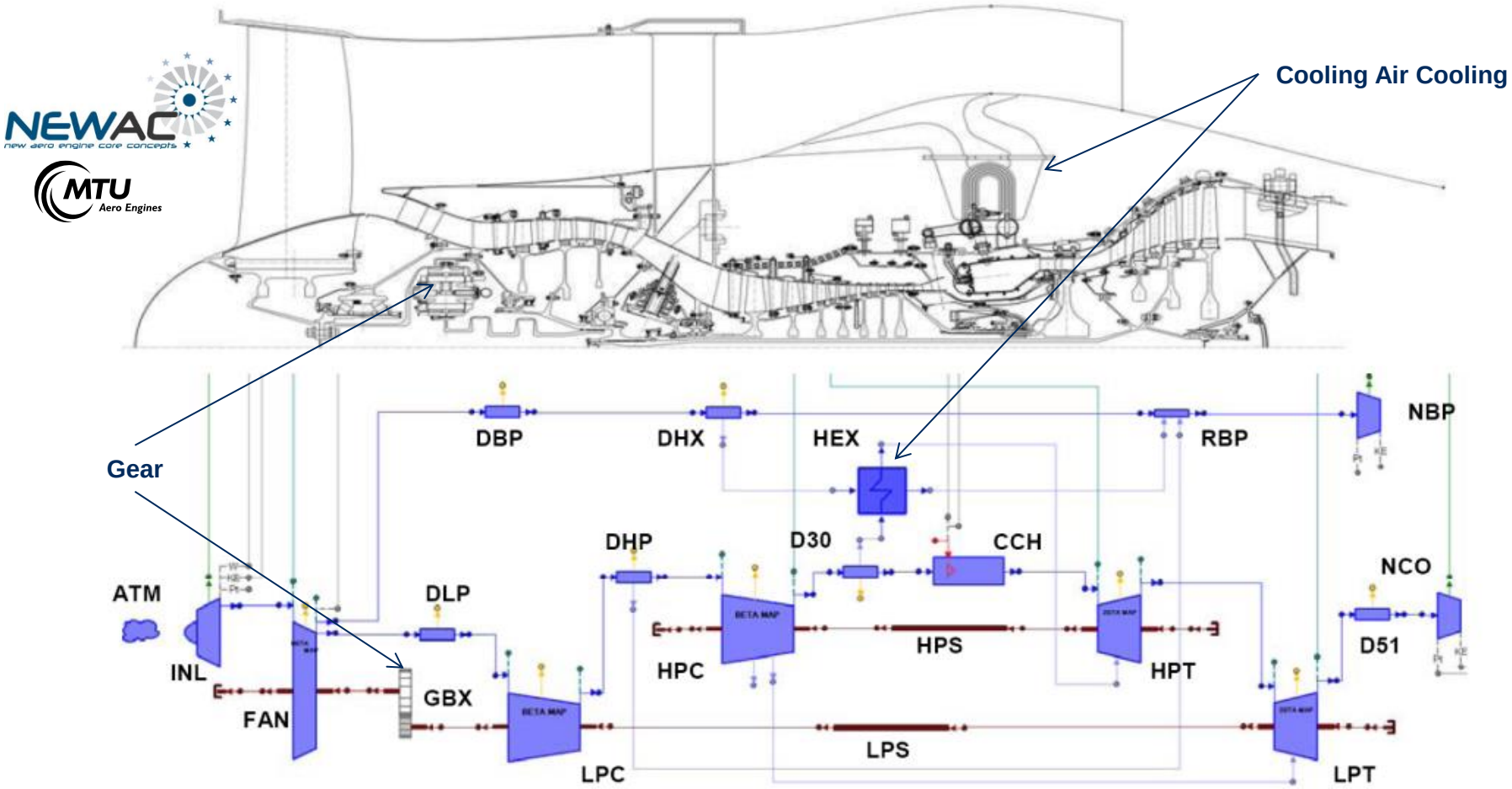
Modeling Concept GT Configurations

Geared Turbofan with Active Core Technologies



Active Cooling Air Cooling (ACAC) aim:
reduce HP turbine cooling air consumption at cruise while maintaining its cooling potential at take-off

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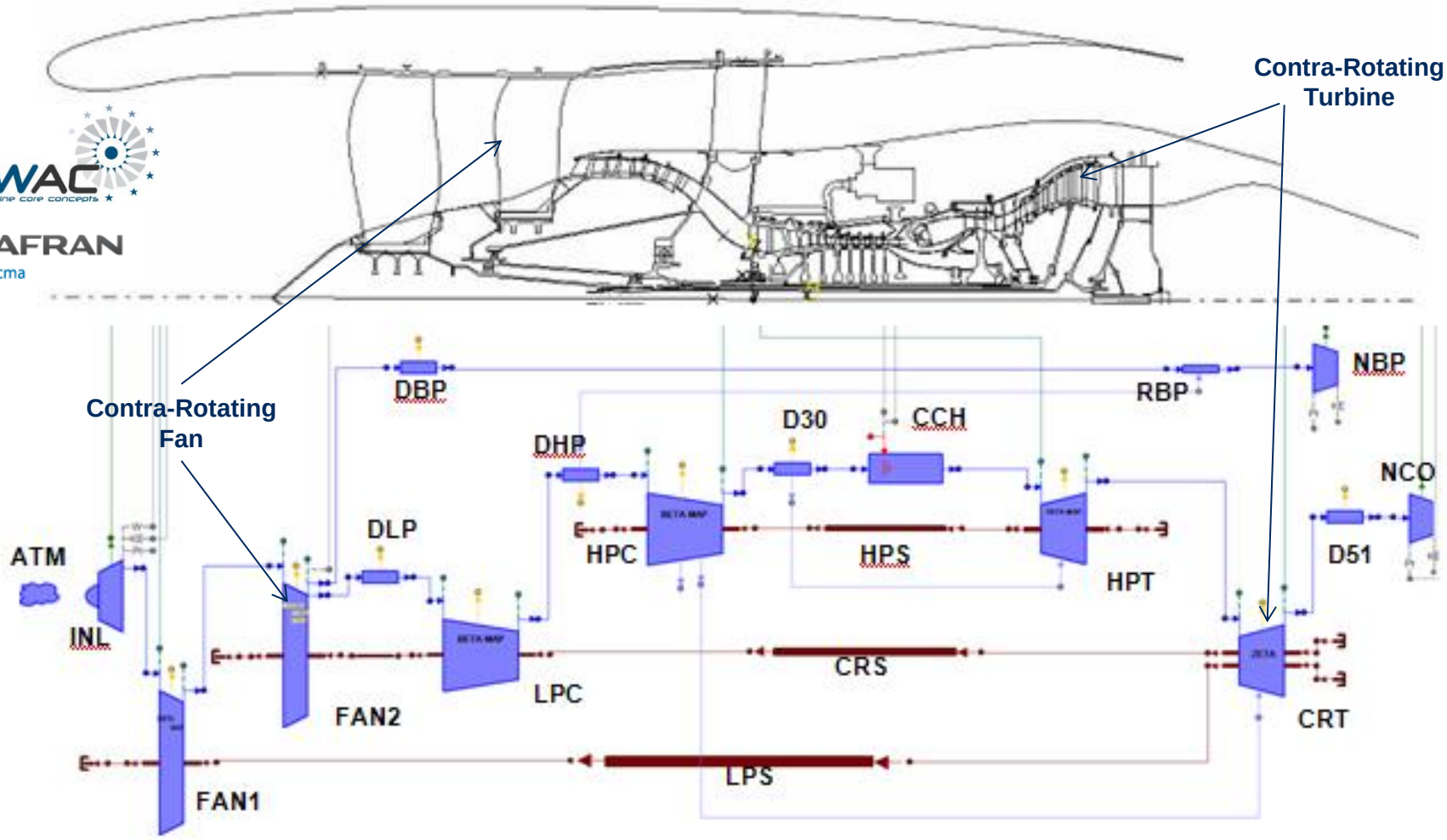
Modeling Concept GT Configurations

Contra-Rotating Turbofan

NEWAC new aero engine core concepts

SAFRAN Snecma



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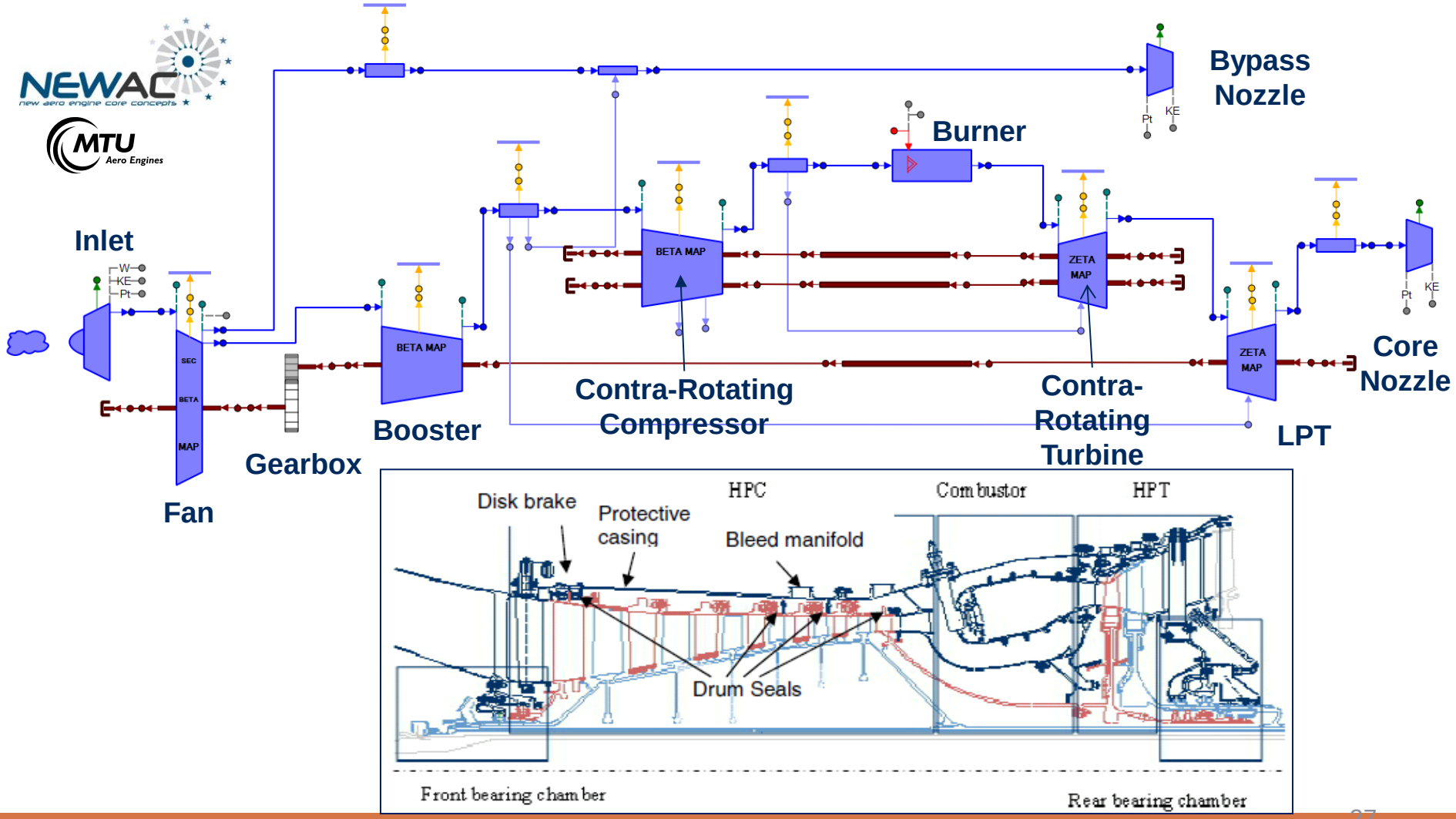
Modeling Concept GT Configurations

Contra-Rotating Core Geared Turbofan



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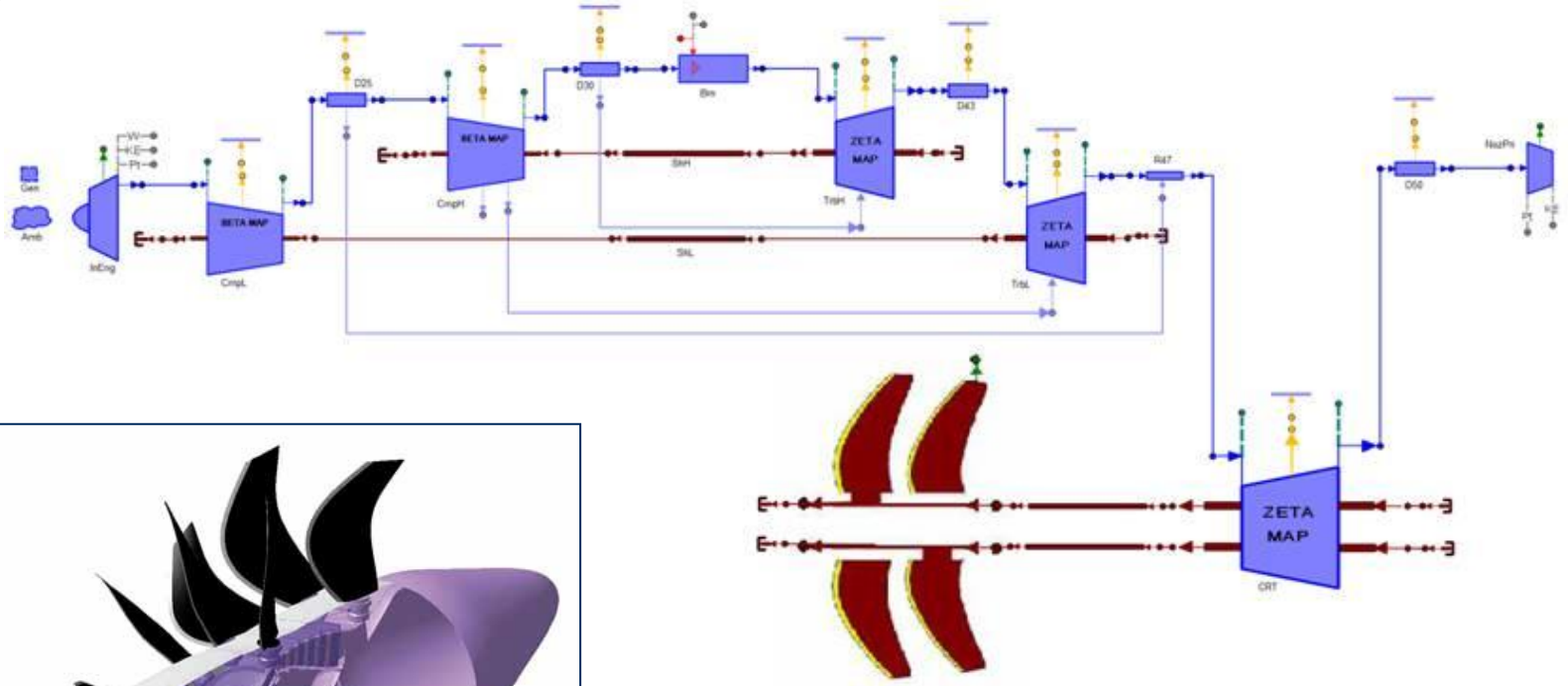
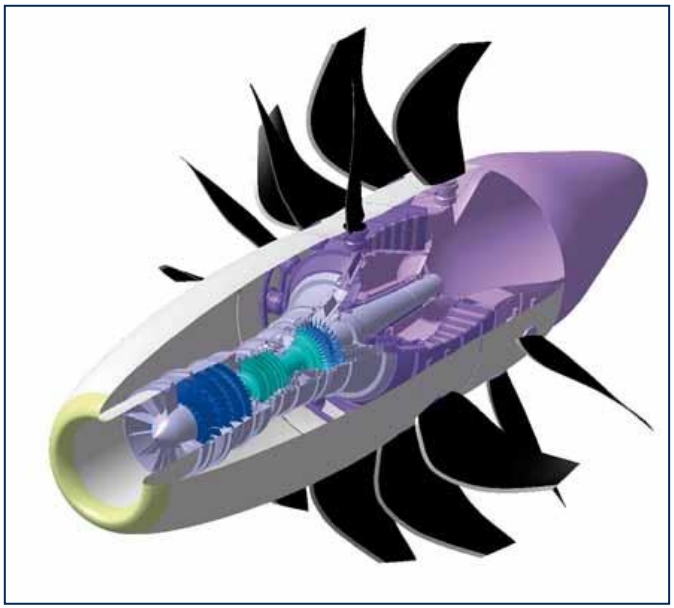
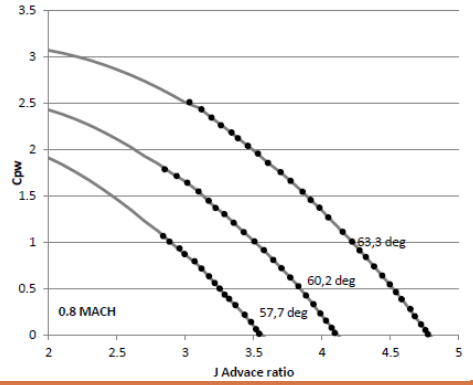
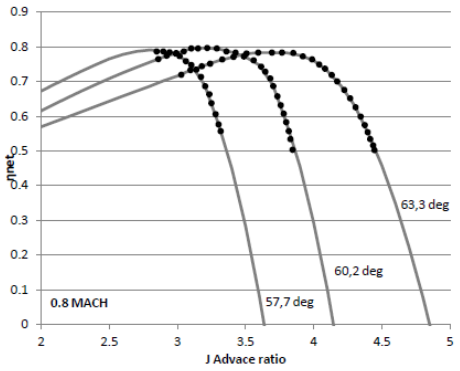
Modeling Concept GT Configurations

Open Rotor









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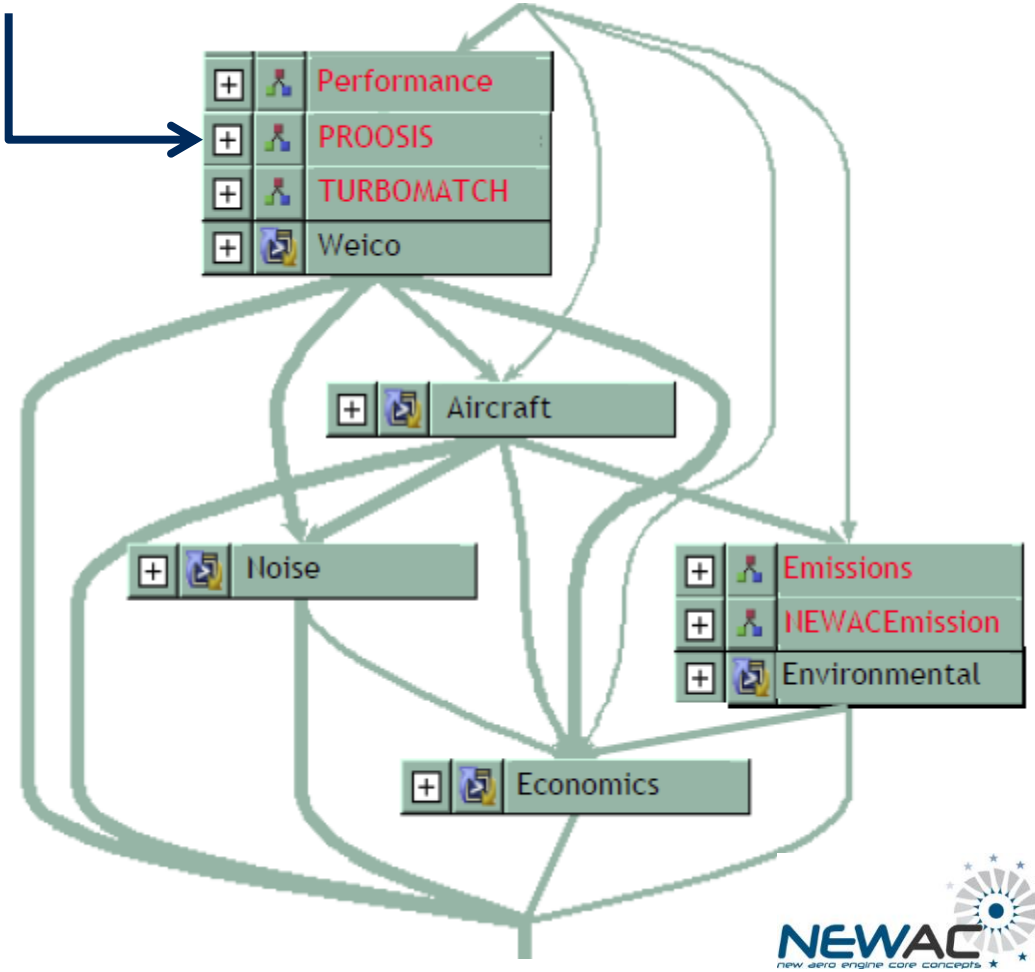
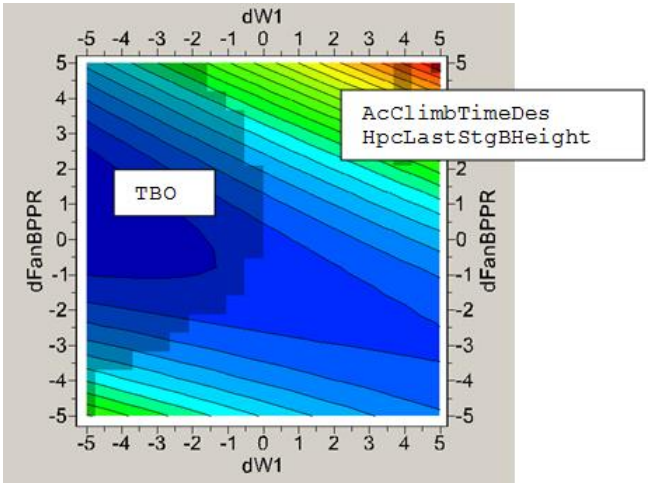
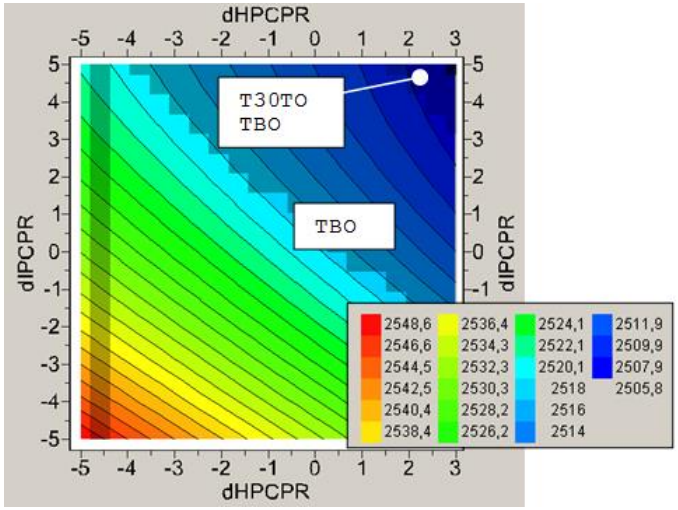
Multi-Disciplinary Design Optimization

PROOSIS executable deck in iSIGHT





Fuel Burn Contour Plots



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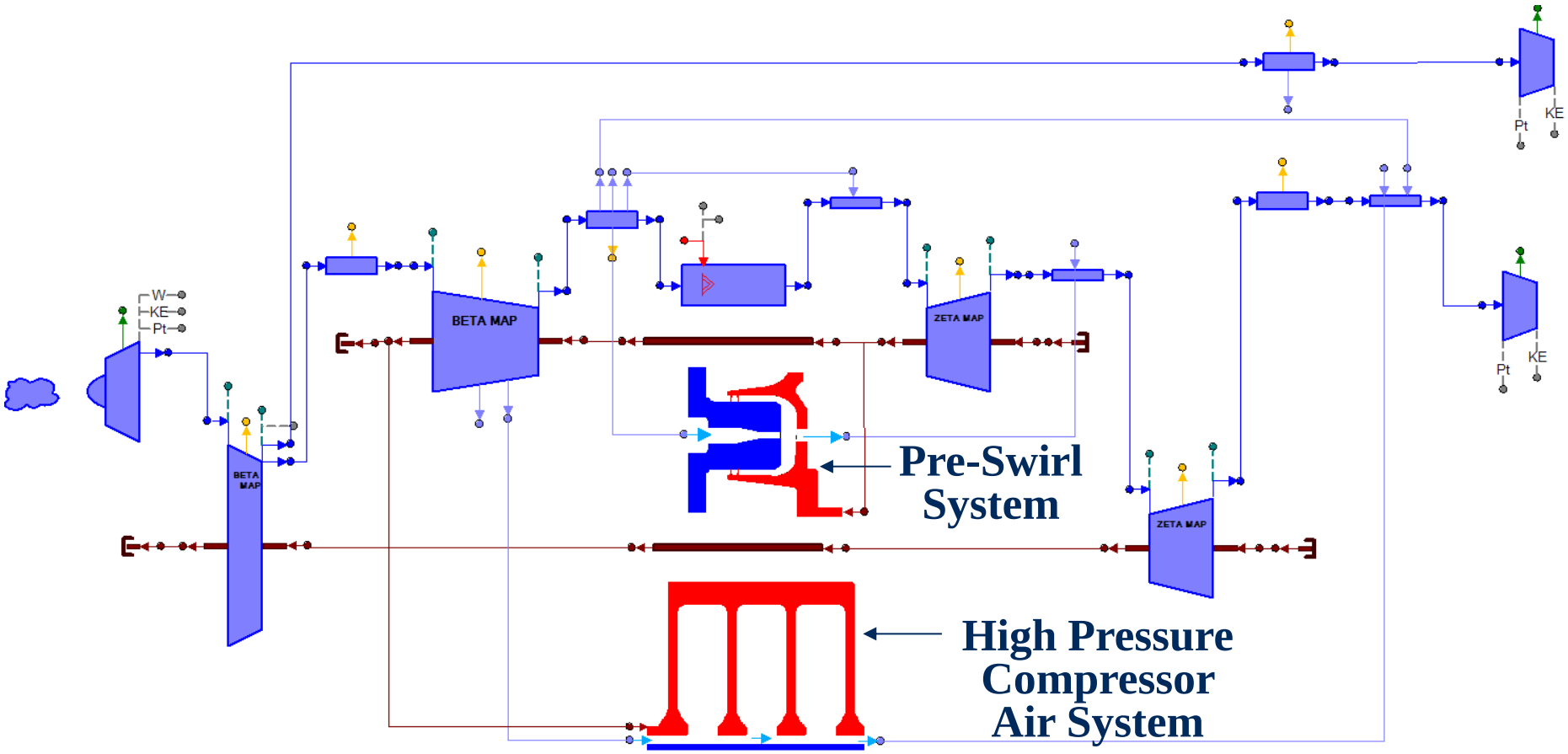
Secondary Air System Modeling & Integration in Engine Model



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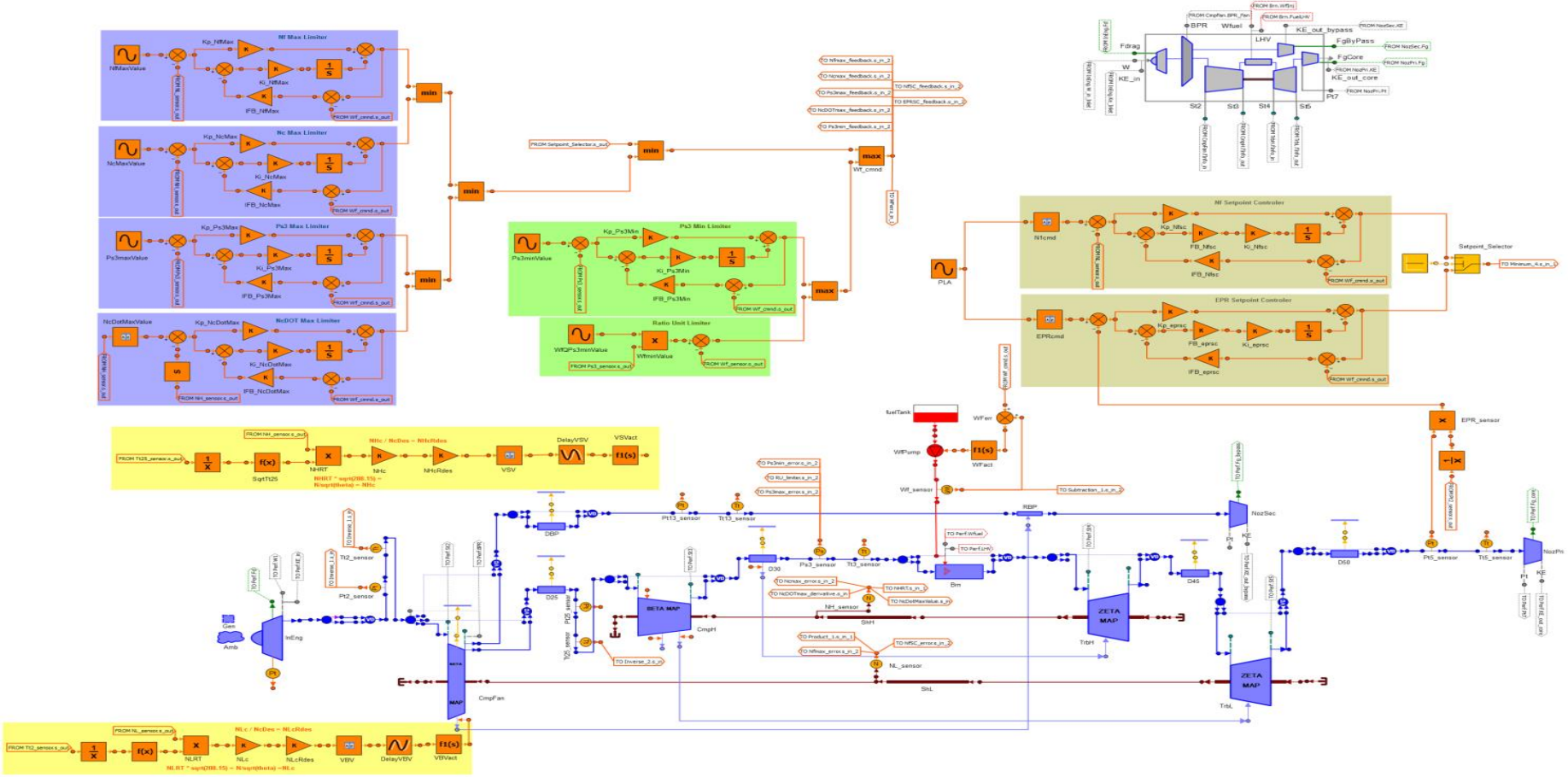
Transient Simulations

Full transient simulation capability including: Shaft dynamics, Heat soakage, Volume dynamics, Sensor & actuator dynamics, Control system



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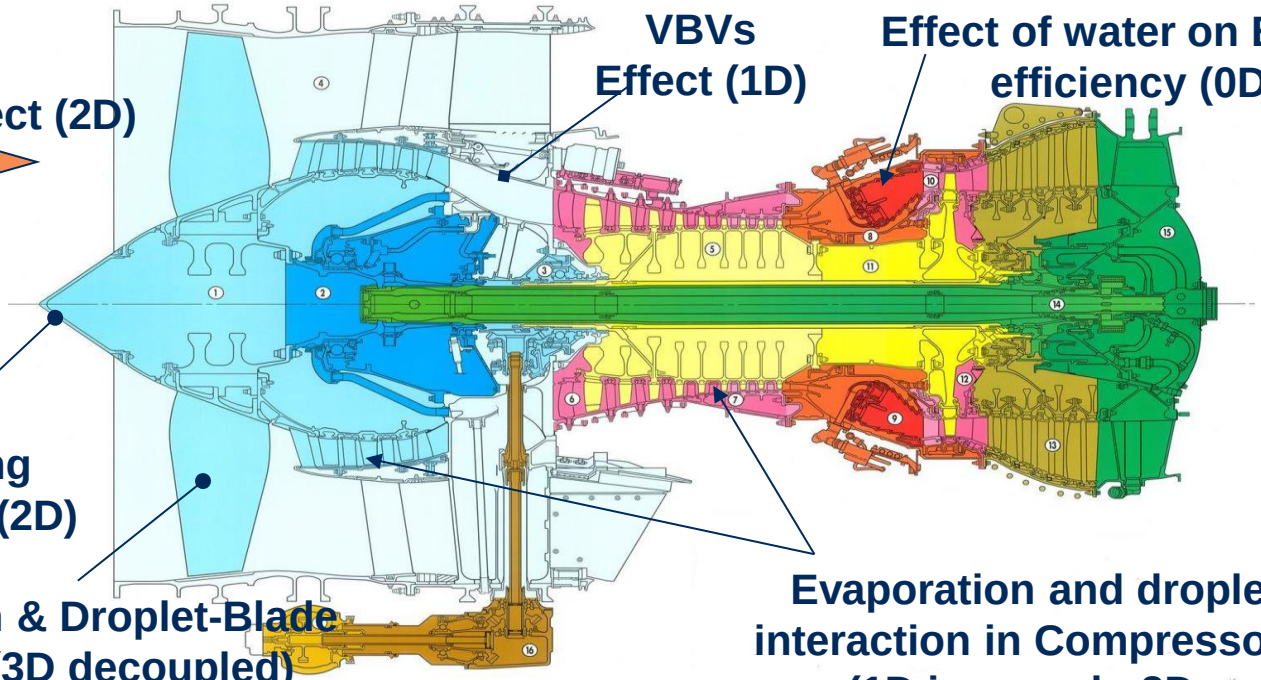
Mixed-fidelity modeling

Rain Ingestion Simulation Example

Scoop Effect (2D)

VBVs Effect (1D)

Effect of water on Burner efficiency (0D)



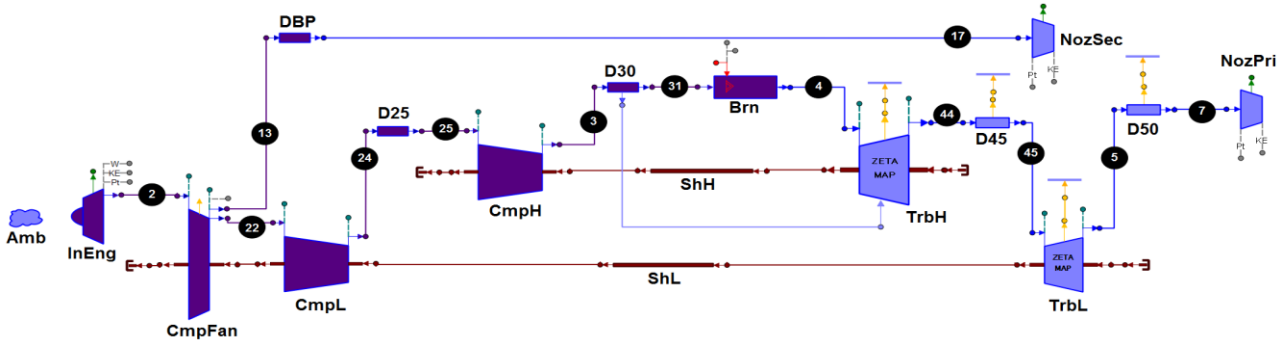
Bouncing Fan Cone (2D)

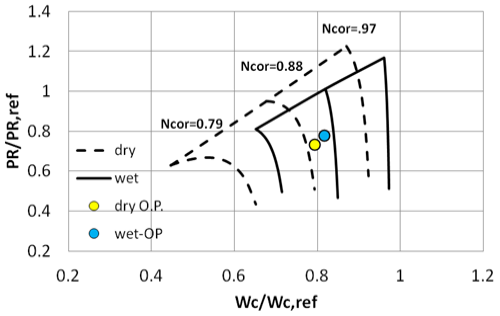
Centrifugation & Droplet-Blade Interaction (3D decoupled)

Evaporation and droplet surface interaction in Compressors & Ducts (1D in pseudo 3D analysis)

CRESCENDO

SAFRAN Snecma





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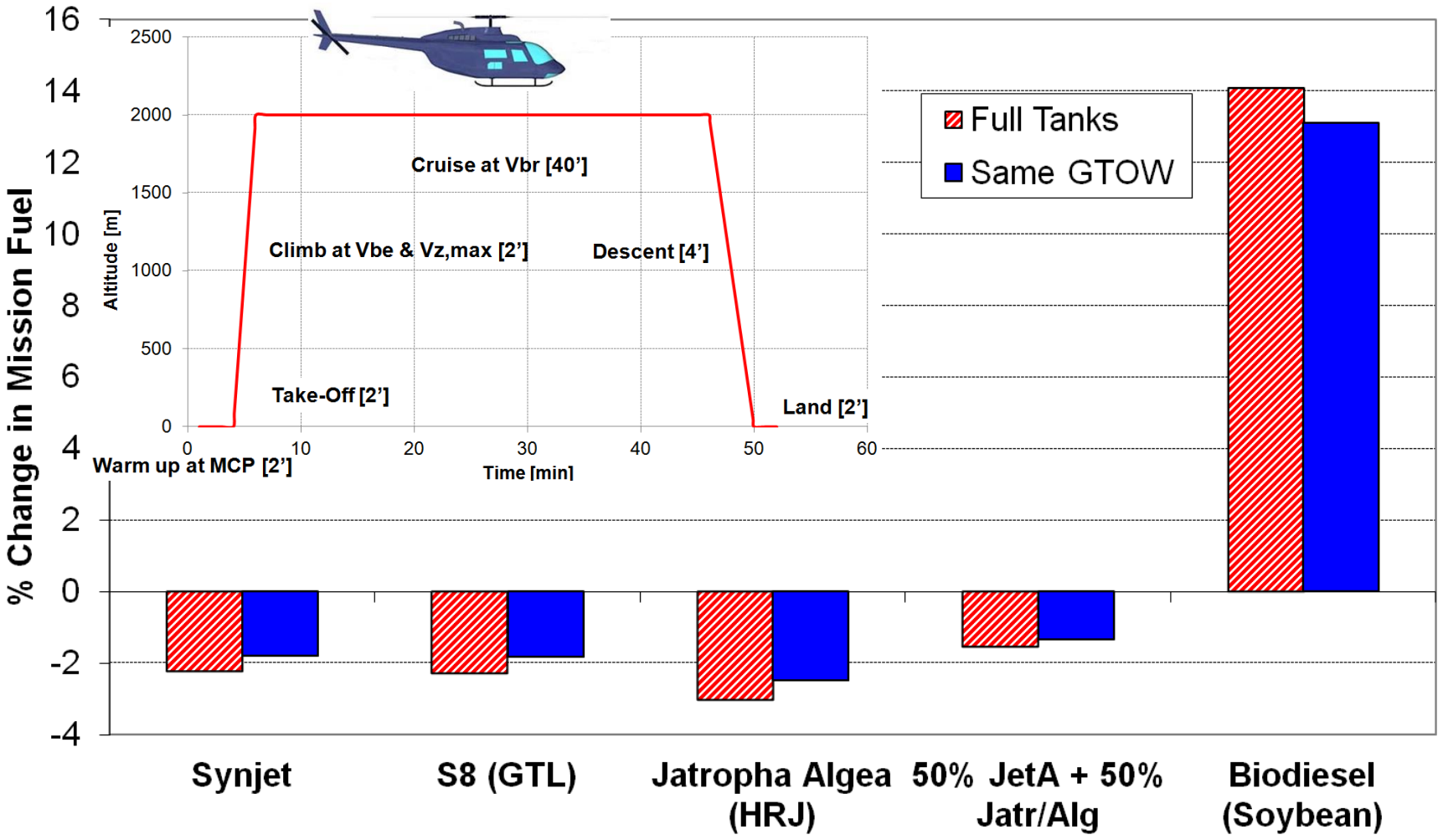
Operation with Alternative Fuels

Effects on Helicopter Mission



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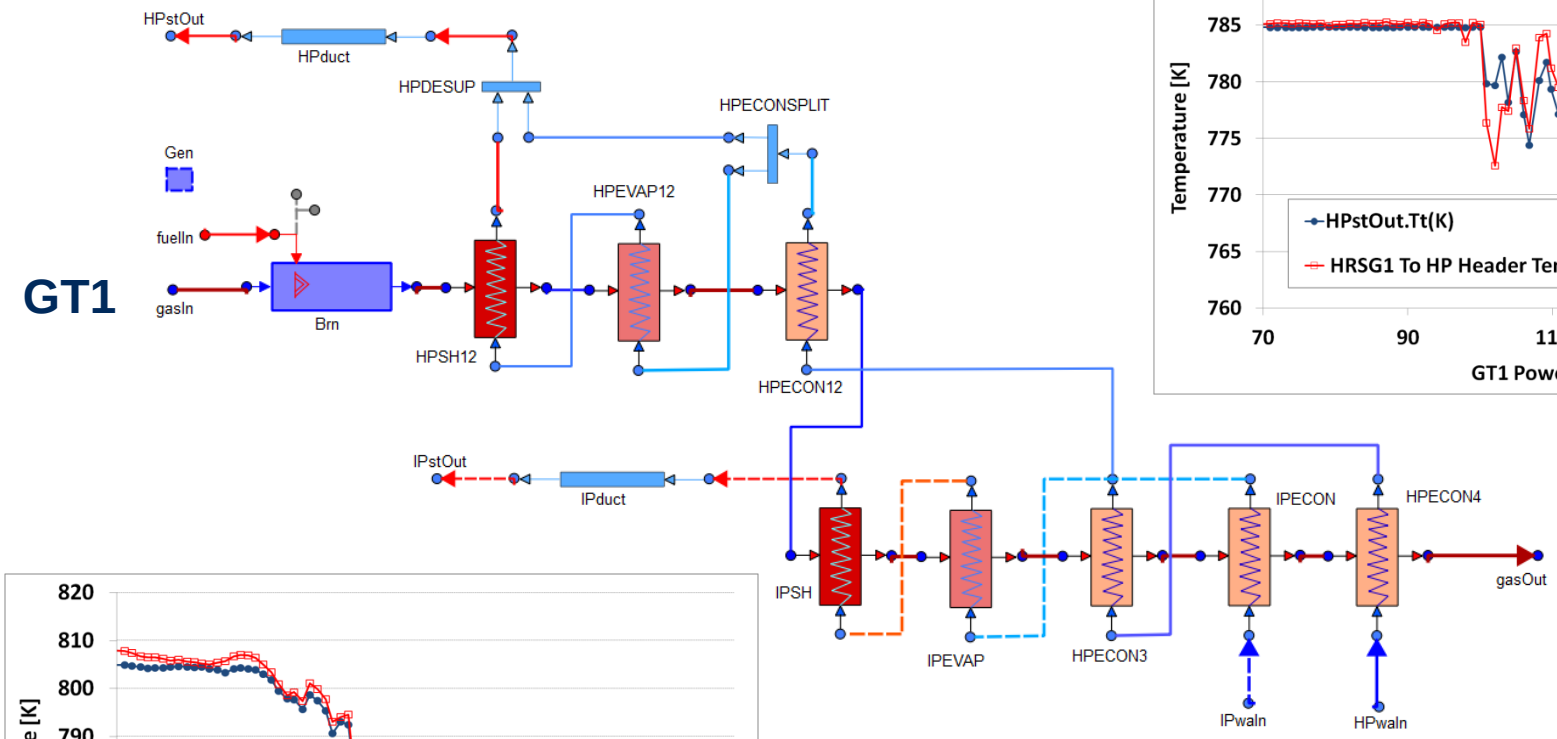
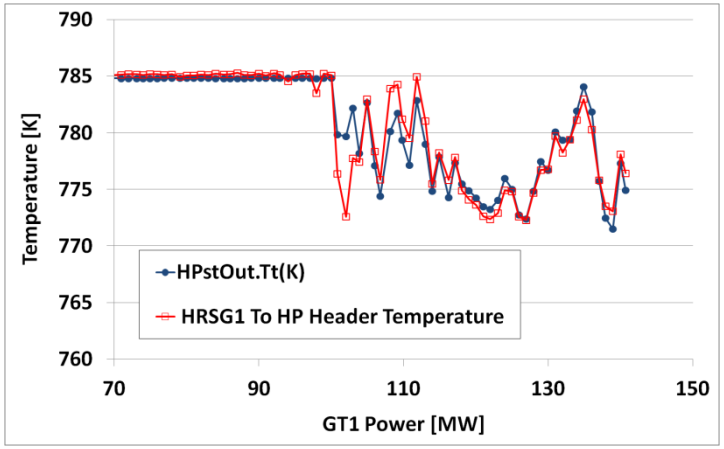
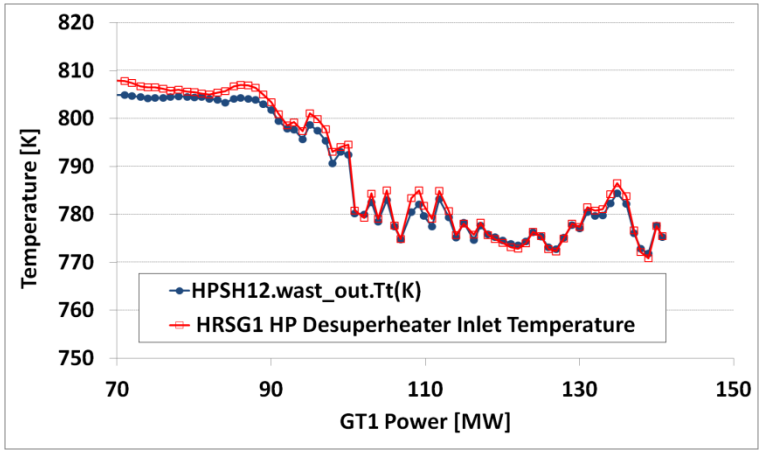
Combined Cycle
HRSG Simulation

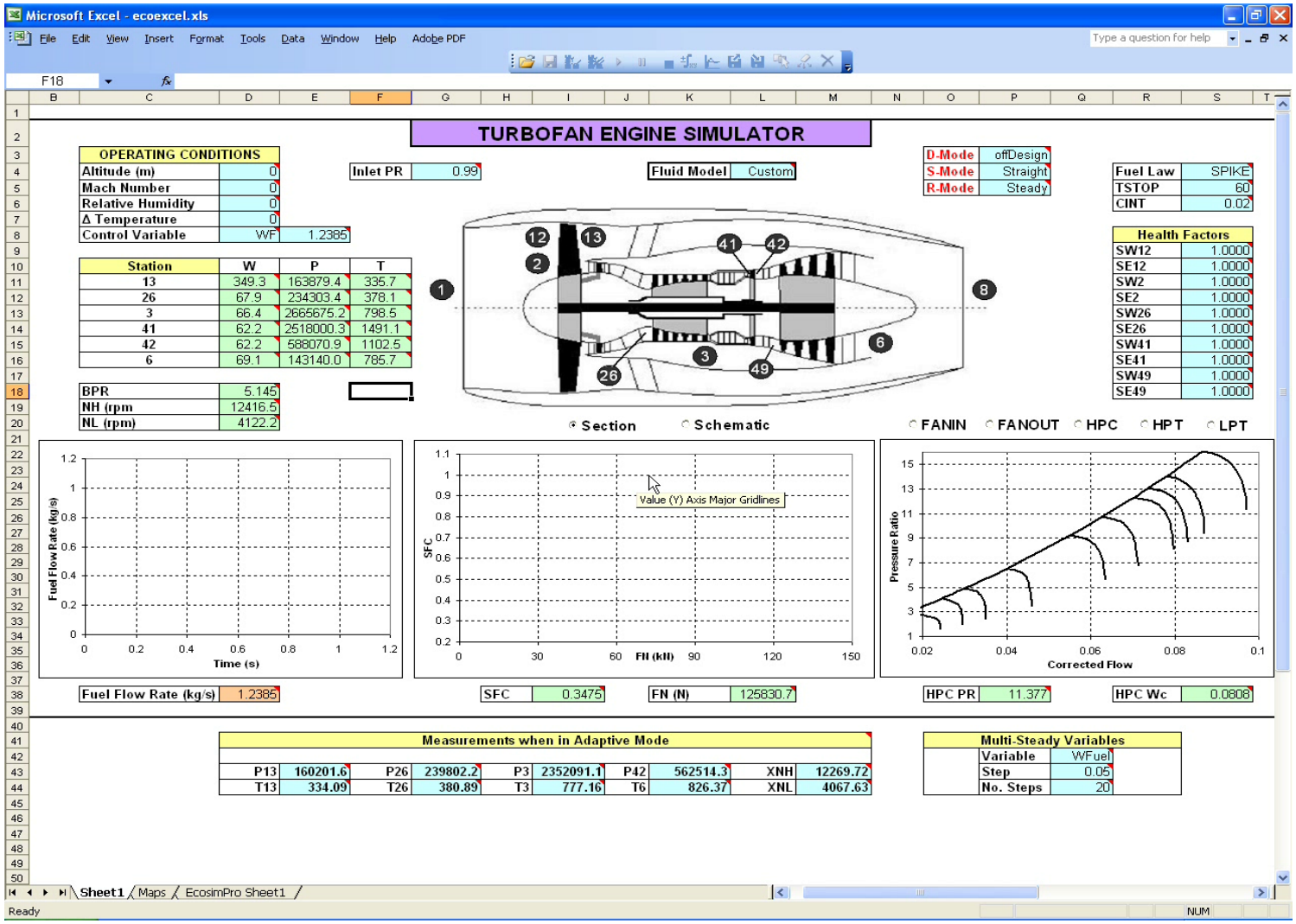




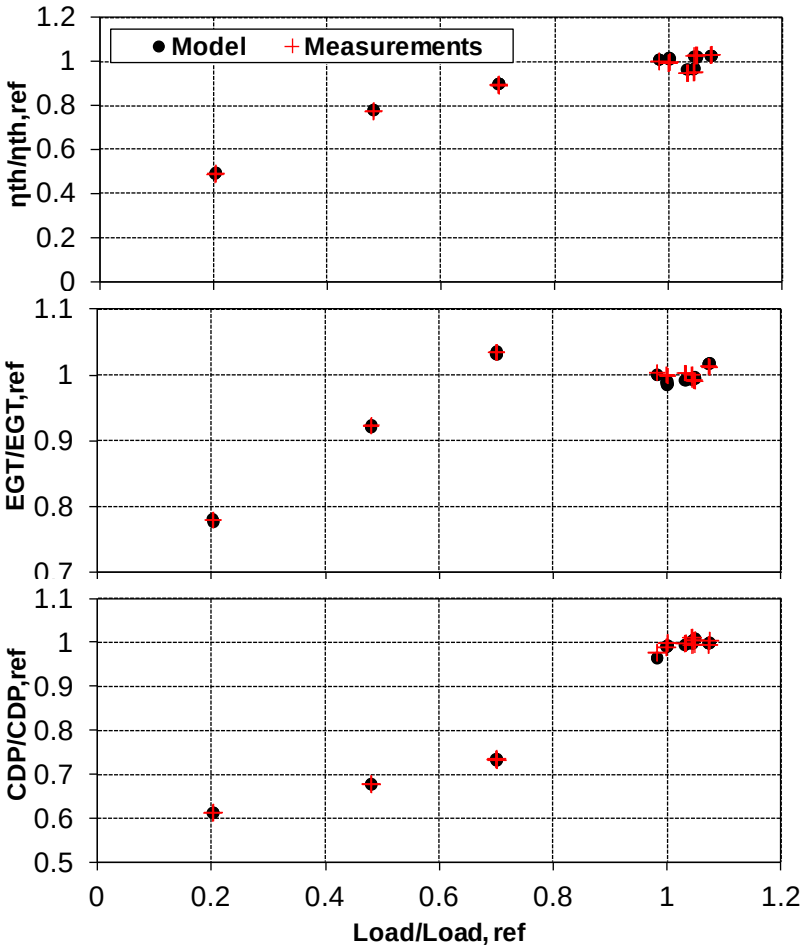


EUROPEAN TURBINE NETWORK

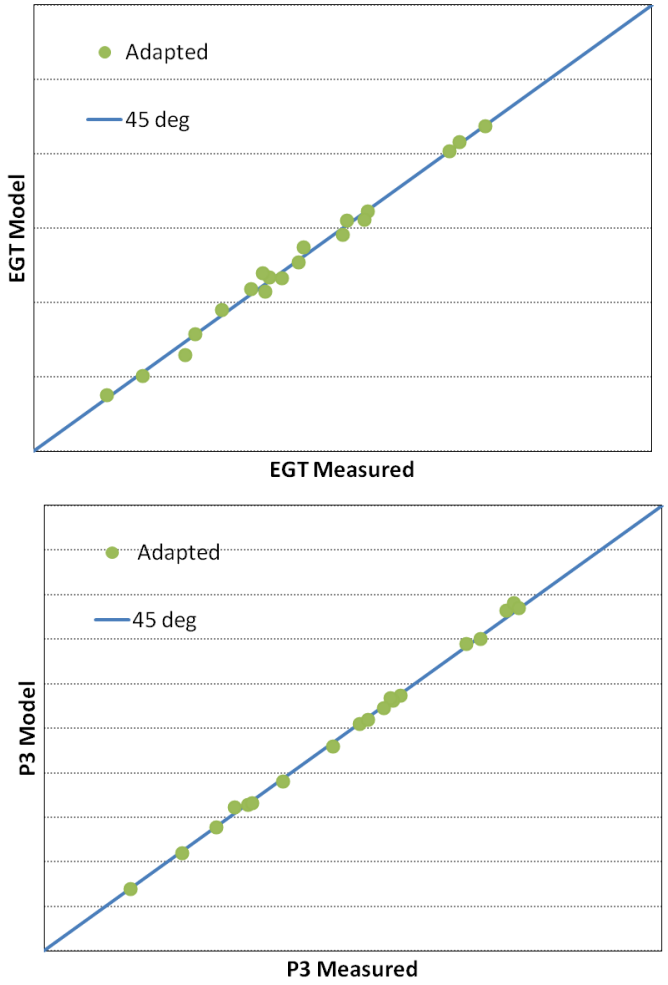
Simulation in Excel



Models Adapted to Engine Specific Data Using Built-In Parameter Estimation Wizard



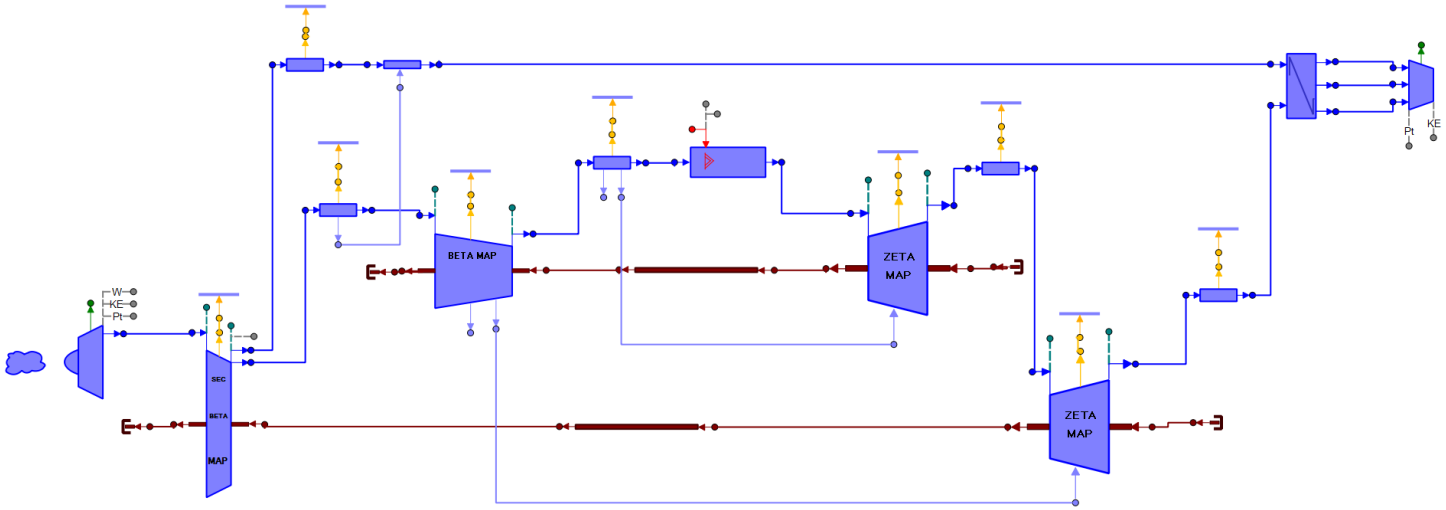
Adapted Industrial GT

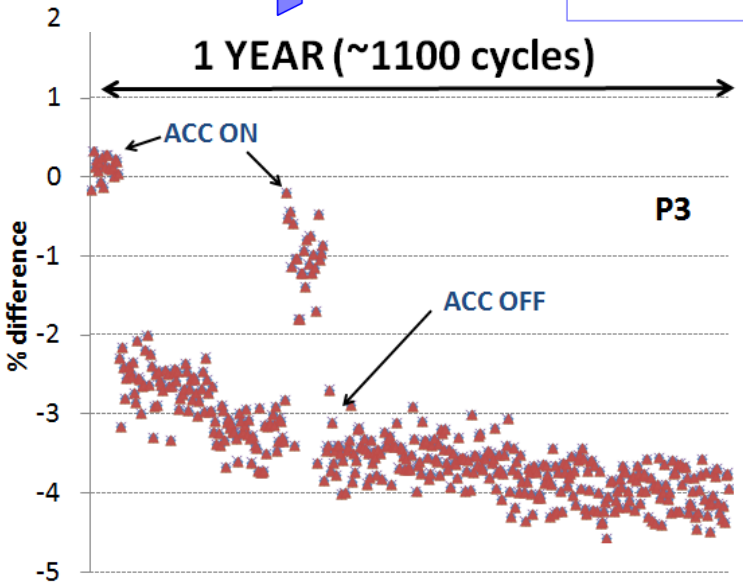


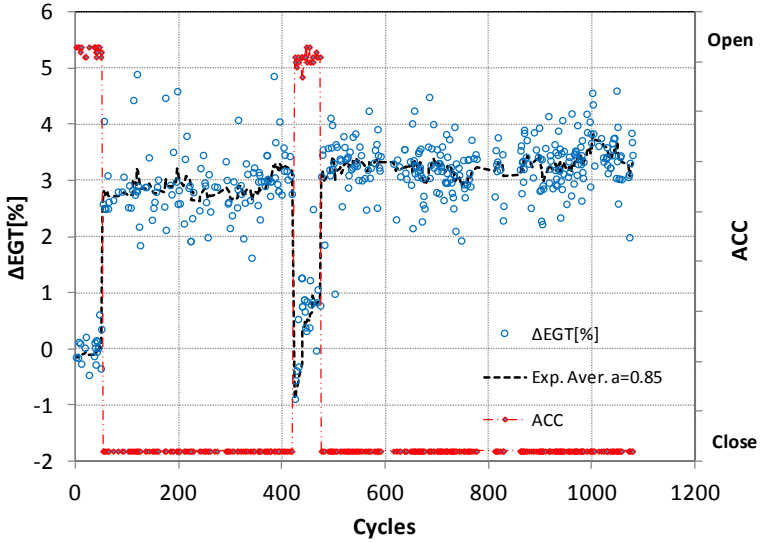
Adapted Civil Aero-Engine

EUROPEAN TURBINE NETWORK

From adapted model to diagnosis

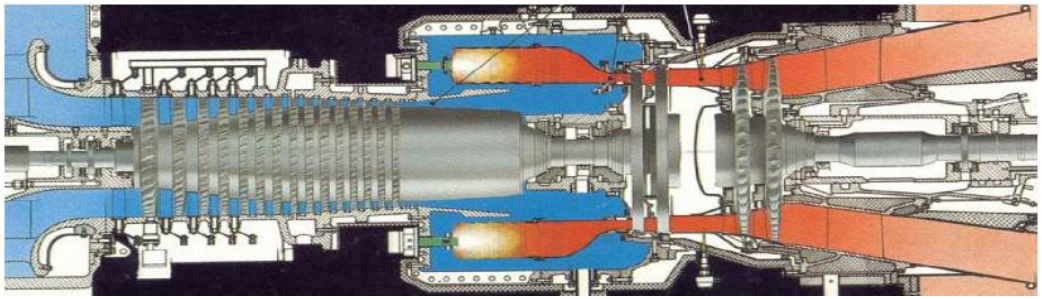






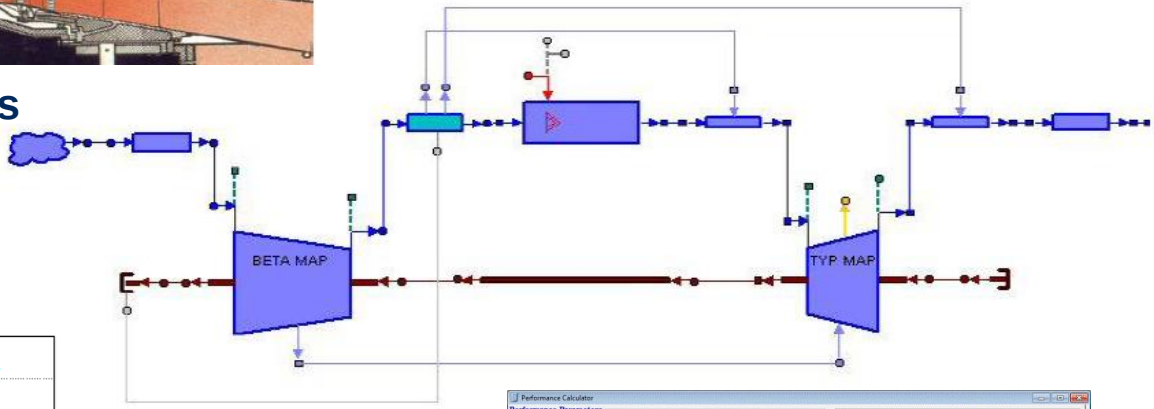
EUROPEAN TURBINE NETWORK

Diagnostic Systems

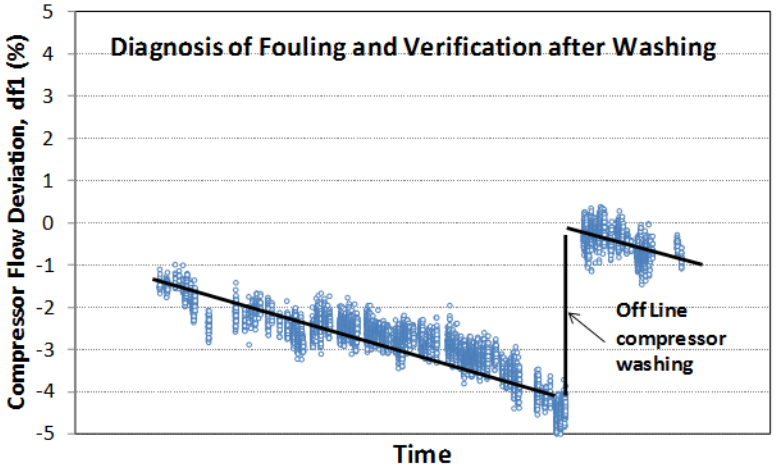


On engine Measurements

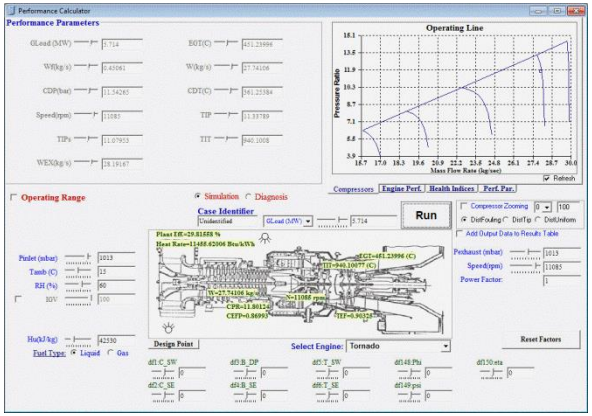
PROOSIS Engine Model



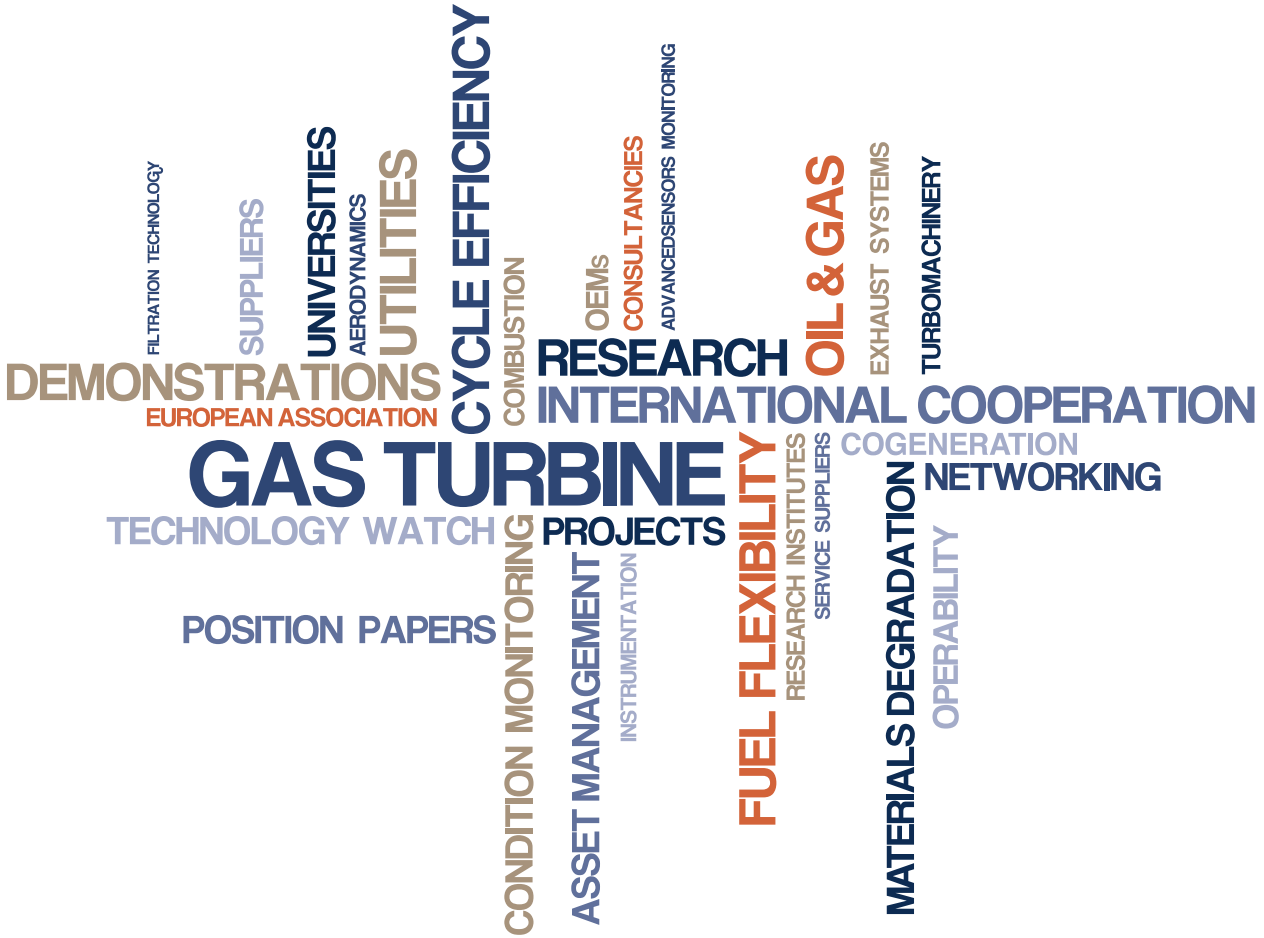
Diagnosis



Monitoring System



Thank you!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