GARTEUR

AD-EG77

GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

Machine learning and data-driven approaches for aerodynamic analysis and uncertainty quantification

(Acronym: ML4AERO)

AG52 & EG77 overview to GARTEUR Council

3rd November, 2020

Outline

Previous AG52: Surrogate-based global optimization methods in preliminary aerodynamic design

- Motivation
- AG objectives & challenges
- Membership
- Main results & Conclusions

EG77: Machine learning and data-driven approaches for aerodynamic analysis and uncertainty quantification

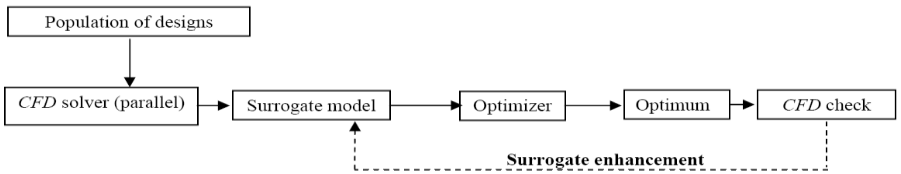
- Objectives
- Partners
- Workplan

AG52 overview

- Motivation
- AG objectives & challenges
- Membership
- Main results
- Dissemination & Conclusions

Motivation

KEY CAPABILITIES



SBGO methods in aerodynamic shape design:

- **broad design space** exploration
- high potential to find the **global optimum**
- inherent **parallelization**
- **independence** from initial configuration
- feasibility in **MDO, complementary to adjoint**

But **open issues** to be further studied:

- **Complex physics require high-fidelity (CFD) simulations, computational cost must be taken into account**
- **Efficient investigation of a large design space**
- **accuracy of the model when reduced number of samples**
- **efficient constraints handling**

OPEN ISSUES

AG52 OBJECTIVES

Deep assessment of SBGO methods for aerodynamic shape optimization

Application-driven EU collaborative research

AG objectives & challenges (1/2)

OBJECTIVES

Assessment vs. Design exercise

- **Assessment of surrogate modeling techniques** for fast computation of the fitness function
- **Assessment of surrogate-based global optimization strategies** for shape design
- **Evaluation of DoE techniques** given a certain geometry parameterization. Analysis of the cost/accuracy trade-off for different DoE plans and strategies
- Demonstration of the applicability and **CPU time savings** by the use of surrogate-based global optimization

- **Provision of "best practice" guidelines for the industrial use** of SBGO methods in shape optimization
- Simplification of the **use of SBGO methods in aeronautic industries**

AG objectives & challenges (2/2)

CHALLENGES FACED

- Deal with the **"curse of dimensionality".** Assessment of the surrogate modeling techniques to deal with **high dimensionality problems (n>10)**

- Model **validation strategies**, assessment of the overall **computational time** required to build and train the surrogate
- Assessment of the **proper error metrics** for comparison (RMSE, ME ....)
- Handling **constraints** with surrogates, possible formulations of constraints
- **Accuracy** of the model on **large database** (more than 200 samples)
- Improvement of **surrogate accuracy** at fixed computational budget
- Efficient DoE techniques, adaptive **DoE strategies** for "optimal" selection of training points towards validation error mitigation

Membership

- **9 organizations** from 5 **GARTEUR state members** (ESP, FRA, ITA, SWE, UK) and 1 **non-GARTEUR country** (CZE)
  - **2 industries** (AIRBUS Military, SAAB)
  - **4 research establishments** (INTA, CIRA, FOI, ONERA)
  - **3 universities** (UAH, UNIS, VUT)

- **Chairmanship: INTA** (Esther Andrés)
- **Vice-chairmanship: CIRA** (Emiliano Iuliano)
- Monitoring Responsible: Fernando Monge, INTA

INTA
CIRA
AIRBUS MILITARY
ONERA
THE FRENCH AEROSPACE LAB
SAAB
FOI
UNIVERSITY OF SURREY
Universidad de Alcalá
BRNO UNIVERSITY OF TECHNOLOGY

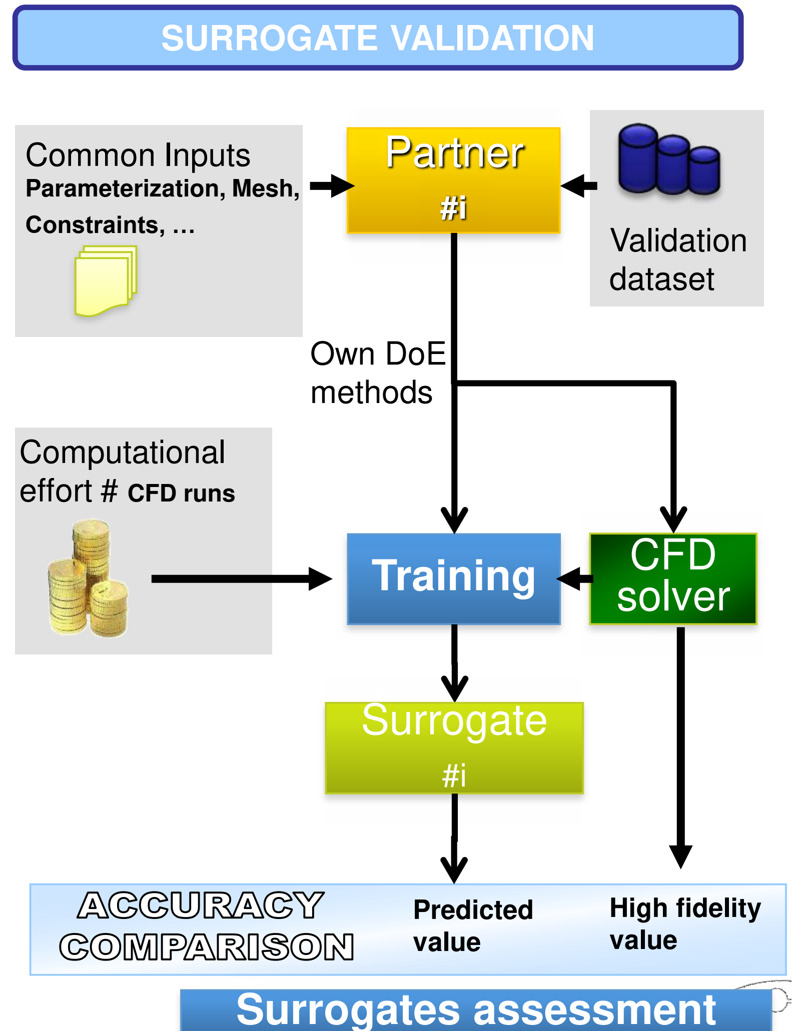
Main results (1/6)

- An upper limit in the **computational effort** was agreed for sampling the design space and training the surrogate in terms of **high-fidelity CFD runs (5xDV)**
- Each partner was free to decide how to sample the design space (DoE)

SURROGATE TRAINING

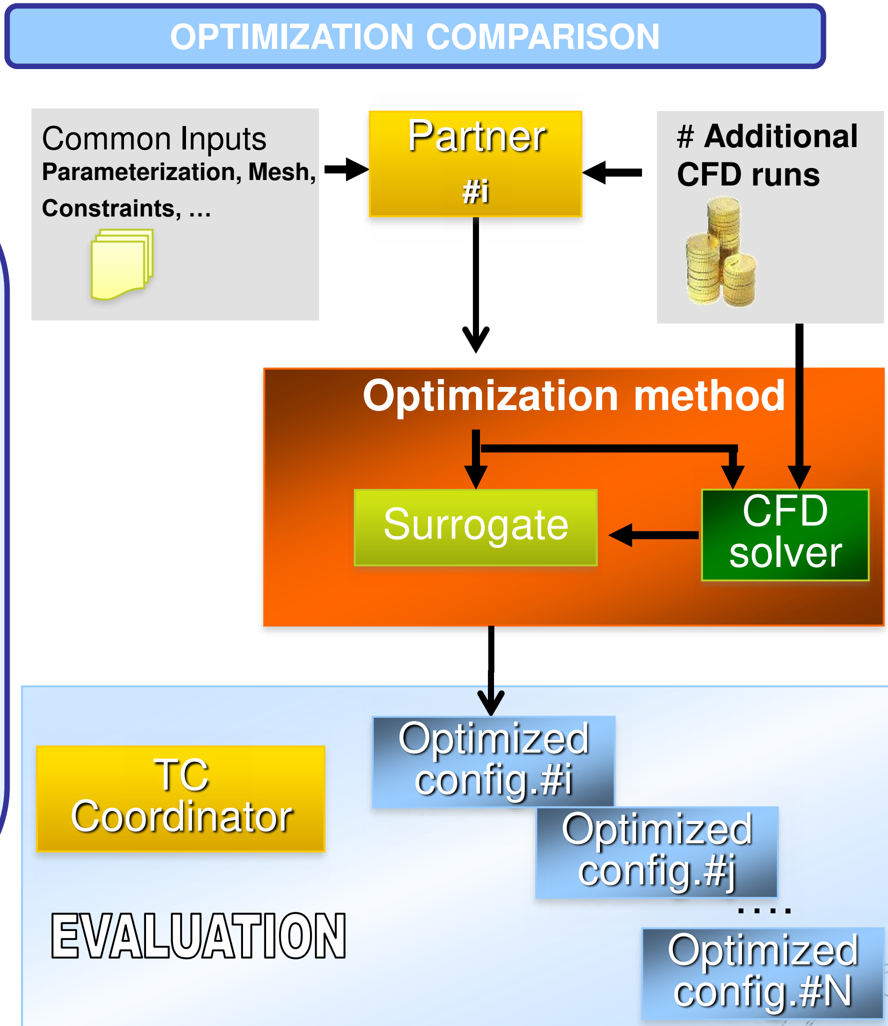
- Once the surrogate was trained, the validation plan was performed
- The selected validation strategy was a **10-fold cross validation.**
- Each partner provided **two values** at each point of the validation dataset: the **high-fidelity** & **surrogate prediction** (different solvers)
- Error metrics were derived and a final comparison was made to assess each surrogate.

SURROGATE COMPARISON



Main results (2/6)

- Each partner applied its own **optimization method** coupled with the shared tools (parameterization, mesh, ….) and his own surrogate model
- It was up to each partner to **decide whether to update the surrogate** during the optimization, but the **number of additional CFD computations** to update the model **was fixed** a priori
- The **optimal candidates obtained by each partner were evaluated** by a single partner (TC coordinator) in order to fairly compare the results of the optimization

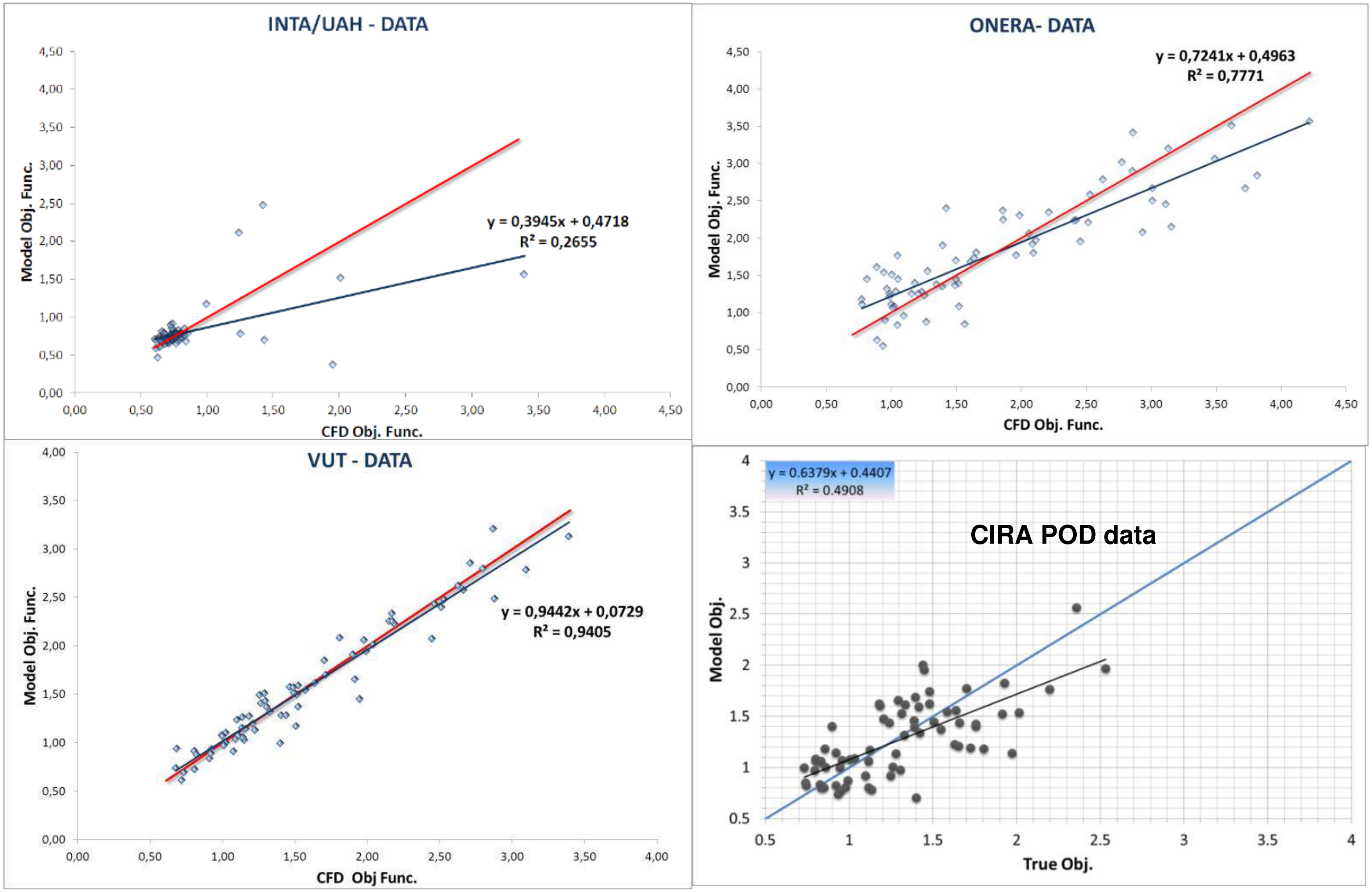


Main results (3/6)

COMPARISON:

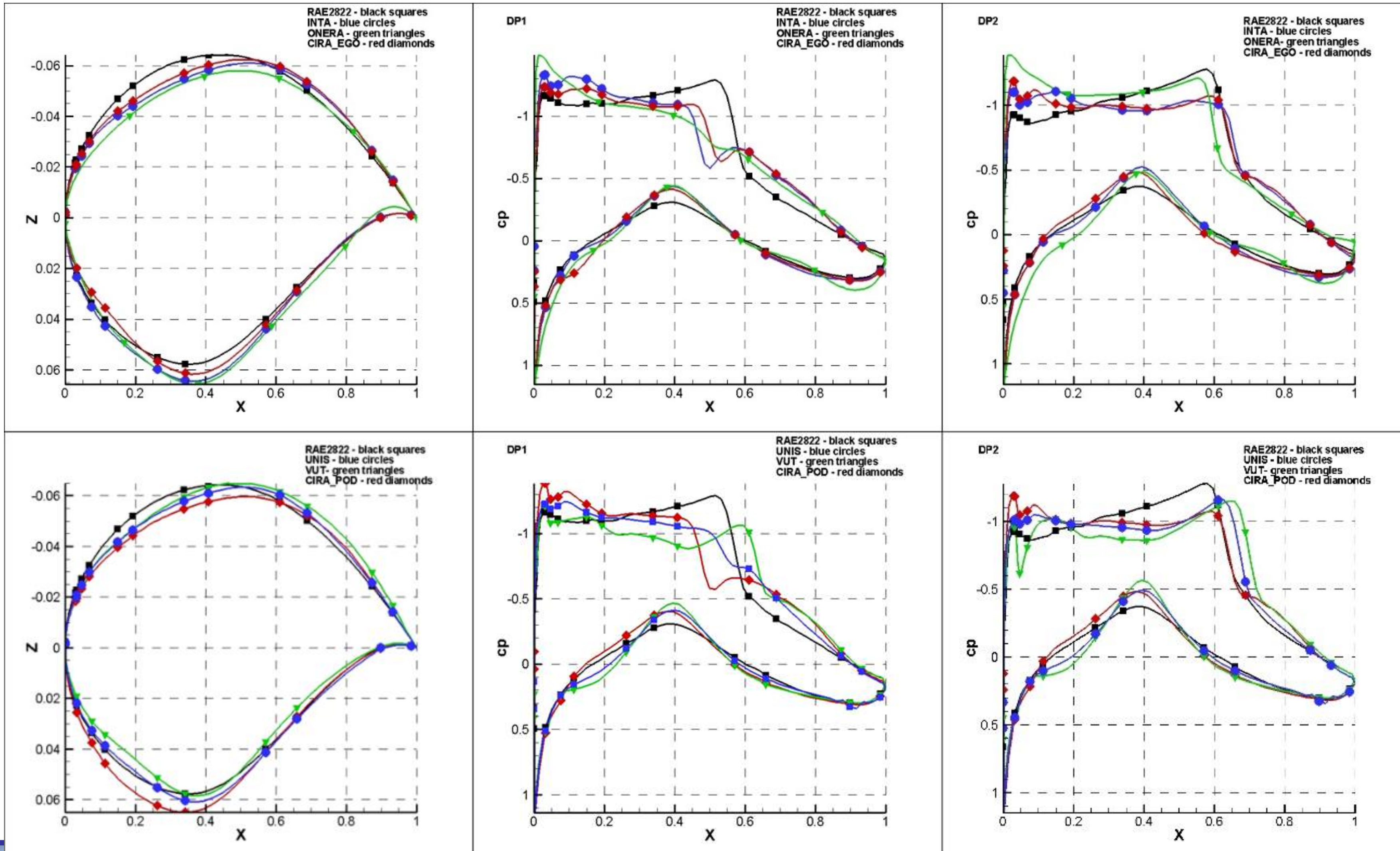
- INTA/UAH, **SVM model with mixed a-priori (4 samples)** / **adaptive sampling (66 samples)** using the Intelligent Estimation Search with Sequential Learning (IES-SL) infill criteria
- ONERA, **Kriging model with a-priori LHS sampling**
- VUT, **ANN model (12 LHS + 58 LOLA-Voronoi) with mixed a-priori (12 samples)** / **adaptive (58 samples) LOLA-Voronoi sampling**
- CIRA**, POD/RBF model with mixed a-priori (24 samples)** / **adaptive (46 samples) sampling** through ad-hoc in-fill criteria
- CIRA, **Kriging model with mixed a-priori (24 samples)** / **adaptive (46 samples)** sampling through Expected Improvement maximization
- UNIS, Gaussian Process + Radial Basis Function Network **ensemble with a-priori samples**

Main results (4/6)



RAE 2822 Test Case: Approx. vs true obj. function correlation plot

Main results (5/6)



Main results (6/6)

	Objective Function
RAE2822	1
CIRA-POD	0.6266
CIRA-EGO	0.6236
INTA/UAH	0.6211
ONERA	0.6498
UNIS	0.6338
VUT	0.7063

Cross-validation of the optimized geometries
(using TAU and ZEN, 3 mesh levels)

Conclusions

The following surrogate models have been tested:

- Kriging
- Support Vector Machines for Regression
- Radial Basis Functions
- Proper Orthogonal Decomposition
- Artificial Neural Networks
- Ensemble methods

1. The accuracy of the surrogate models **strongly depends on the sampling and the objective of the surrogate**:

- If the objective is to provide general predictions, an a-priori LHS sampling in combination or not with Lola-Voronoi sampling seems to be a good option (as concluded from VUT, UNIS and ONERA results).
- If the objective is to better predict those regions of the design space where the optimum is located, then a mixed a-priori and adaptive sampling is recommended, as can be concluded from INTA and CIRA results.

Conclusions

2. Best results were achieved by the **adaptive Kriging and SVMr optimization** approaches. Ensemble methods showed poor performance on the performed tests, probably due to a not optimal sampling for the training phase.

3. **Surrogate-based global optimization** has been demonstrated to be **feasible** for aerodynamic design in case of high number of design variables (tested on **36 DVs**).

4. The **selection of the number and location of the control points in a volumetric NURBS parameterization (design parameters) is a crucial step**, and strongly determines the range of solutions and performance of the optimization algorithm. In particular, for the RAE 2822 case, the improvement in the OF was 15% higher when using an appropriate number of control points

Consult the complete AG52 report

Participation in congresses (1/3)

Organization of 4 Minisymposiums:

- **EUROGEN 2013: International Conference on Evolutionary and Deterministic Methods for Design, Optimization and Control**. 7-9 October 2013, Las Palmas de Gran Canaria (Spain). http://www.eurogen2013.ulpgc.es/

16:30: Minisymposia 4

Surrogate-Based Optimization Methods in Aerodynamic Design.
Session Chairman: D. Quagliarella, CIRA, Italy
Organizers: E. Andrés, INTA, Spain and E. Iuliano, CIRA, Italy, eandres@isdefe.es, e.iuliano@cira.it
Main Room.

MS4	Philipp Amtsfeld, Dieter Bestle and Marcus Meyer. Direct 3D Aerodynamic Optimization of Turbine Blades with GPU-accelerated CFD
MS4	Gianluca Badjan, Carlo Poloni, Andrew W. Pike and Nadir Z. Ince. Evaluation of Surrogate Modelling Methods for Turbo-machinery Component Design Optimization
MS4	Emiliano Iuliano and Domenico Quagliarella. Wing shape optimization by surrogate modeling
MS4	Jorge Muñoz, Javier García and Antonio Crespo. Multi-objective aerodynamic optimization of high-speed trains in tunnels
MS4	Konstantinos Tsiakas, Xenofon Trompoukis, Varvara Asouti and Kyriakos Giannakoglou. Design-Optimization of a Compressor Blading on a GPU Cluster

- **ECFD 2014: ECCOMAS European Conference on Computational Fluid Dynamics.** July 2014, Barcelona (Spain). http://www.wccm-eccm-ecfd2014.org/frontal/Dates.asp

WCCM XI - ECCM V - ECFD VI BARCELONA 2014

22/07/2014 16:30 - 18:30 **Surrogate-based Global Optimization Methods in Preliminary Aerodynamic Design I** *Minisymposium organized by Esther Andrés and Emiliano Iuliano*	Room: Tramuntana 1 MS102A Chair: Esther Andrés CoChair: Emiliano Iuliano

Adaptive sampling strategies for surrogate-based aerodynamic optimization
Emiliano Iuliano and Domenico Quagliarella

PCA-enhanced metamodel-assisted evolutionary algorithms for aerodynamic optimization
Varvara G. Asouti, Stylianos A. Kyriacou and Kyriakos C. Giannakoglou

Surrogate-based Optimization of the Nose Shape of a Train subjected to Cross-wind
Jorge Munoz-Paniagua, Javier Garcia and Antonio Crespo

Fast aerodynamic coefficients prediction using SVMS for global shape optimization
Esther Andrés-Pérez, Leopoldo Carro-Calvo and Sancho Salcedo-Sanz

Multi-objective surrogate based optimization of gas cyclones using support vector machines and CFD simulations
Khairy Elsayed and Chris Lacor

An automatic aerodynamic design process in a multi-disciplinary context
Davide Di Pasquale, Carren Holden, Timoleon Kipouros and Mark Savill

Participation in congresses (2/3)

ECFD 2016: ECCOMAS European Conference on Computational Fluid Dynamics. June 5-10, Greece

Friday, June 10 — **Room 23**
9:00-11:00

MS 1011 - 1: SURROGATE-ASSISTED EVOLUTIONARY ALGORITHMS IN AERODYNAMIC DESIGN/OPTIMIZATION

MS Organizers: Varvara Asouti, Esther Andrés, Emiliano Iuliano
Chair: Varvara Asouti

8857 A NOVEL IMPLEMENTATION OF COMPUTATIONAL AERODYNAMIC SHAPE OPTIMISATION USING MODIFIED CUCKOO SEARCH AND REDUCED ORDER MODELLING
***David Stefan Naumann**, Ben Evans, Oubay Hassan*

6765 MULTIOBJECTIVE OPTIMIZATION WITH GAUSSIAN PROCESS FOR DISTRIBUTED COMPUTING
***Jonathan Guerra**, Patricia Klotz, Fabrice Gamboa, Patrick Cattiaux, Nicolas Dolin*

8407 ON THE INFLUENCE OF A PRIORI SAMPLING METHODS ON SURROGATE MODELS ACCURACY IN AIRCRAFT AERODYNAMIC DESIGN OPTIMIZATION
***Raul Yondo**, Esther Andrés, Eusebio Valero*

9174 MULTI-FIDELITY EXTENSION TO NON-INTRUSIVE PROPER ORTHOGONAL DECOMPOSITION BASED SURROGATES
***Tariq Benamara**, Piotr Breitkopf, I. Lepot, Caroline Sainvitu*

11229 THE RBF4AERO BENCHMARK TECHNOLOGY PLATFORM
*Massimo Bernaschi, **Alessandro Sabellico**, Giorgio Urso, Emiliano Costa, Stefano Porziani, Fabrizio Lagasco, Corrado Groth, Ubaldo Cella, Marco Evangelos Biancolini, Dimitrios H.Kapsoulis, Varvara G. Asouti, Kyriakos C. Giannakoglou*

EUROGEN 2017: International Conference on Evolutionary and Deterministic Methods for Design, Optimization and Control. September 2017, Madrid (Spain).

http://eurogen2017.etsiae.upm.es

15:10-17:30	**MS session – "Surrogate-assisted Optimization of Real World problems I/II"**

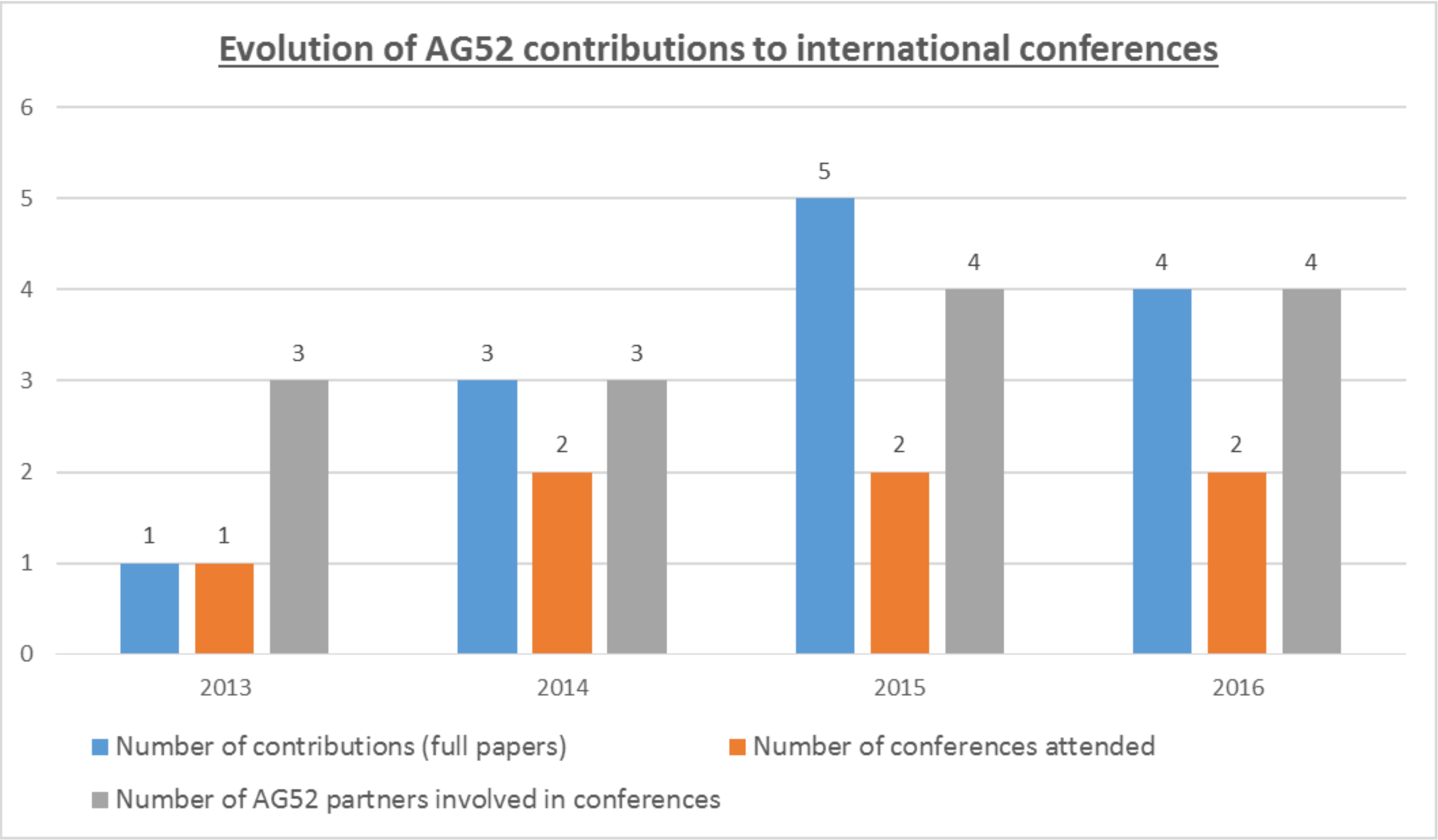
Organized by D. González (AIRBUS) and E. Iuliano (CIRA)
Room: Auditorio

003. Daniel González Juárez and Esther Andrés. Study of the influence of the initial a-priori training dataset size in the efficiency and convergence of surrogate-based evolutionary optimization
006. Dmitrij Ivanov, Dieter Bestle and Christian Janke. A Response Surface Based Strategy for Accelerated Compressor Map Computation
012. Jorge Munoz Paniagua and Javier Garcia. Surrogate-based optimization of the nose shape of a high-speed train for lateral stability.
015. Charlotte Beauthier, Paul Beaucaire and Caroline Sainvitu. Surrogate-based evolutionary algorithm for highly constrained design problems
027. Luca Miretti, Enrico Ribaldone, Laura Lorefice, Giuseppe Scantamburlo and Renzo Arina. POD Based Reduced Order Model for CFD Optimization of Vehicle Aerodynamics.
038. Remo De Donno and Stefano Rebay. Surrogate-Based Shape Optimization of the ERCOFTAC Centrifugal Pump Impeller
041. Tobias Keßler, Christian Kunde, Nick Mertens, Dennis Michaels and Achim Kienle. Global Optimization of Distillation Columns using Surrogate Models.

Participation in congresses (3/3)

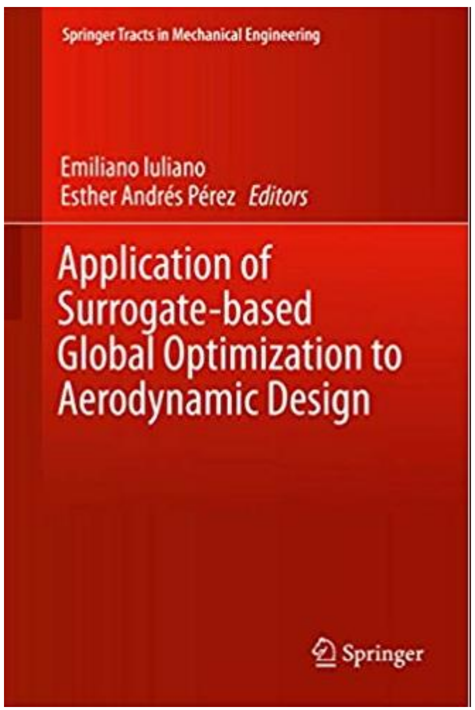
Participation (full papers) at:

EUROGEN 2013, 2015, 2017
ECCOMAS 2014, 2016
EUCASS 2015



Springer books

Emiliano Iuliano, Esther Andrés. *Application of surrogate-based global optimization to aerodynamic design*. **Springer Tracts in Mechanical Engineering**. ISBN 978-3-319-21505- 1. 2016.



Esther Andrés, Leo González, Jaques Periaux, Nicolas Gauger, Domenico Quagliarella, Kyriakos Giannakoglou. *Evolutionary and Deterministic Methods for Design Optimization and Control With Applications to Industrial and Societal Problems*. **Springer Computational Methods in Applied Sciences.** ISBN 978-3-319-89890-2. January 2019.

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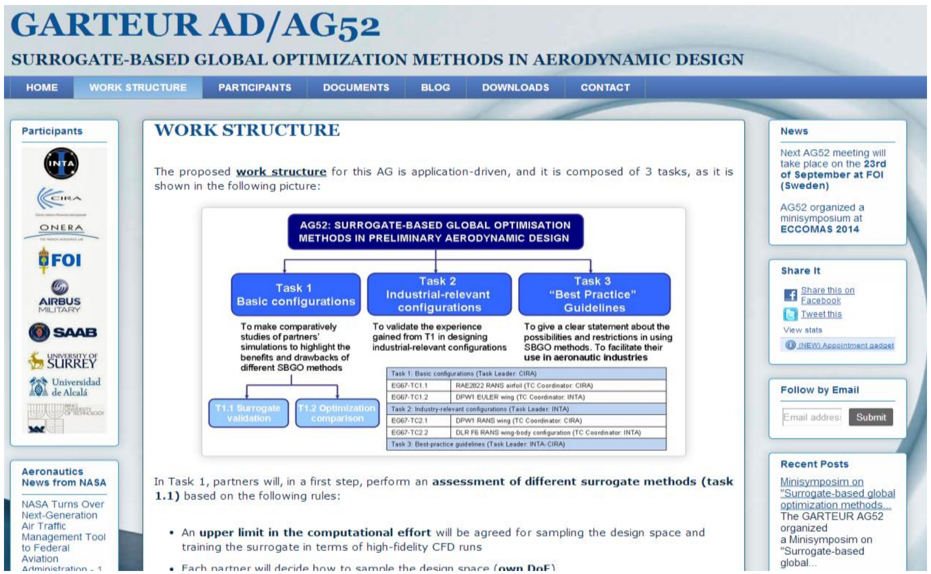
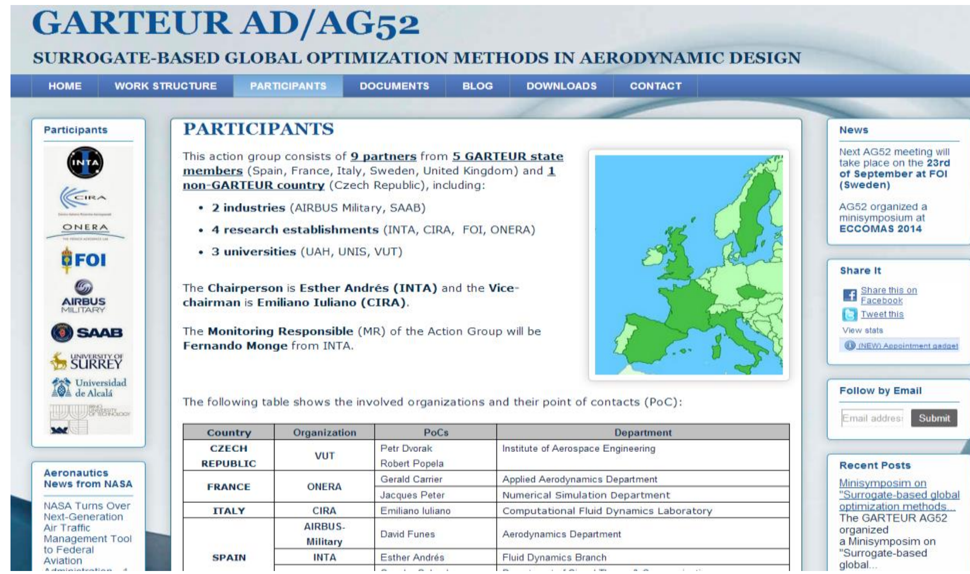
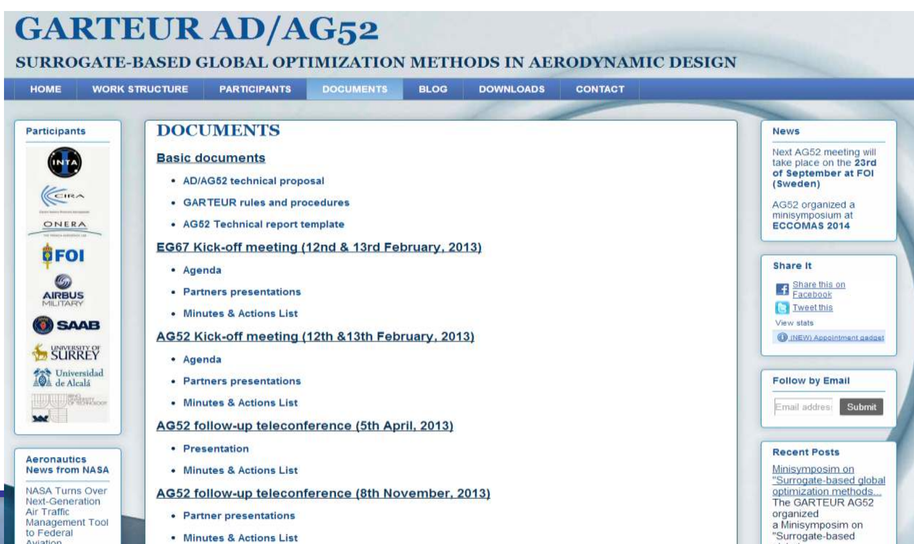
AG52 blog/website

AG52 overview → Technical Progress → **Dissemination & Others**







EU Funding attempts: GANDIA

GANDIA

Global AerodyNamic Design for Innovative Aircraft

Work Programme topics addressed:

MG-1.5-2014 (Breakthrough innovation for European Aviation)

MG-1.1-2014 (Competitiveness of European Aviation through cost efficiency and innovation)

Duration: 36 months

Coordinator: Dr. Esther Andrés (Fluid Dynamics Branch – INTA), eandres@isdefe.es, +34.91.520.20.30

List of participants

Participant No	Participant organisation name	Country
1*	**INTA** - INSTITUTO NACIONAL DE TECNICA AEROESPACIAL	Spain
2	**UNIS** - UNIVERSITY OF SURREY	United Kingdom
3	**JYU** - JYVASKYLAN YLIOPISTO	Finland
4	**NTUA** - NATIONAL TECHNICAL UNIVERSITY OF ATHENS	Greece
5	**USTL** - UNIVERSITE DES SCIENCES ET TECHNOLOGIES DE LILLE - LILLE I	France
6	**ONERA** - OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES	France
7	**CIRA** - CENTRO ITALIANO RICERCHE AEROSPAZIALI SCPA	Italy
8	**NLR** - STICHTING NATIONAAL LUCHT- EN RUIMTEVAARTLABORATORIUM	The Netherlands
9	**EADS–CASA** - CONSTRUCCIONES AERONAUTICAS	Spain
10	**NUMECA** - NUMERICAL MECHANICS APPLICATIONS INTERNATIONAL SA	Belgium
11	**PAI** - PIAGGIO AERO INDUSTRIES S.P.A.	Italy
12	**FOI** - SWEDISH DEFENCE RESEARCH AGENCY	Sweden
13	**USOL** - UNMANNED SOLUTIONS, S.L.	Spain
14	**AGI** - **AIRBUS** GROUP INNOVATIONS	France

MULTI-FIDELITY, MULTI-DISCIPLINARY ROBUST INTEGRATED FRAMEWORK FOR HIGH PERFORMANCE AIRCRAFT DESIGN

List of participants

Participant No.	Participant organisation name	Short name	Country
1 (Coordinator)	CENTRO ITALIANO RICERCHE AEROSPAZIALI SCPA	CIRA	IT
2	UNIVERSITY OF STRATHCLYDE	SU	UK
3	OPTIMAD ENGINEERING S.R.L.	OPT	IT
4	DEUTSCHES ZENTRUM FUER LUFT UND RAUMFAHRT	DLR	DE
5	AIRBUS DEFENCE AND SPACE GMBH	ADS	DE
6	DASSAULT AVIATION	DAV	FR
7	INSTITUTO NACIONAL DE TECNICA AEROESPACIAL ESTEBAN TERRADAS	INTA	ES
8	OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES	ONR	FR
9	INSTITUT DE RECHERCHE ET TECHNOLOGIES ANTOINE DE SAINT EXUPERY	IRT	FR

1. Excellence

The future of the aerospace sector is facing the enormous challenges of being able to respond effectively and efficiently to increased volumes, increased demand for performance, increased need for sustainability and safety. It is therefore crucial ensuring that the aerospace industry is able to generate innovation and introduce disruptive technologies in a consistent manner. To this end, being capable to access more knowledge, systematically assess the level of uncertainty and make use of such knowledge along the design process in a timely and cost-effective manner[1] is emerging as an unavoidable necessity to design of the next generation aircraft.

The currently adopted approach to aircraft design is based on the paradigm of a series of different stages, starting from conceptual, preliminary and progressing up to the final detailed design phases. Within this framework, the adoption of fast approximate methods (commonly referred to as surrogates) for the evaluation of the design solutions is predominant. Early stages of the design are almost exclusively relying on various types of surrogates and the use of expensive (in terms of time and cost) but very accurate methods is allowed only when the final detailed design stages are reached.

One major concern with this approach is the limited ability to explore confidently non-classical design solutions (e.g. radically different configurations and/or aircraft performance over extended flight envelopes) due to the potentially high inaccuracy of existing surrogates. Not being able to confidently introduce and evaluate "black sheep" solutions in the early phases will make it unlikely that these will emerge in later stages and the design process will very likely be evolutionary other than revolutionary.

EG77 overview

Machine learning and data-driven approaches for aerodynamic analysis and uncertainty quantification

(Acronym: ML4AERO)

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EG77: ML4AERO

ML4AERO main objective:

Machine learning techniques commonly used in the area of Artificial Intelligence (AI) and Data Mining (DM) can represent a valuable support to reduce the computational cost required for UQ analysis: given the big amount of data produced during optimization under uncertainty, the adoption of data-driven models and their continuous updating may help to save computational time in later design stages.

The objective of this proposal is to **research in the application of machine learning and data-driven approaches for aerodynamic optimization and uncertainty quantification**.

EG77 delivered the full AG proposal on March 2020

Duration:

- AG Kick-off (webex): November 2020
- End date: November 2022

Chairpersons:

- Chairperson: Esther Andrés (INTA)
- Vice-Chair: Emiliano Iuliano (CIRA) → Emiliano will leave CIRA, probably Domenico Quagliarella (to be confirmed)
- Monitoring Responsable: Fernando Monge (INTA)

EG77: ML4AERO

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ML4AERO partners:

- 12 organizations from 6 GARTEUR state members (ESP, FRA, DEU, ITA, NLD, SWE)
- 2 industries (AIRBUS D&S and AIRBUS) and 1 SME (OPTIMAD)
- 9 research establishments (CIRA, NLR, UT, INTA, DLR, FOI, ONERA, IRT and INRIA)

Country	Organization	PoC	E-mail
THE NETHERLANDS	NLR	Robert Maas	Robert.Maas@nlr.nl
	UT	Bojana Rosic	b.rosic@utwente.nl
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	AIRBUS	Daniel Redondo Marta Gonzalez	daniel.redondo@airbus.com
	INTA	Esther Andrés	eandres@isdefe.es

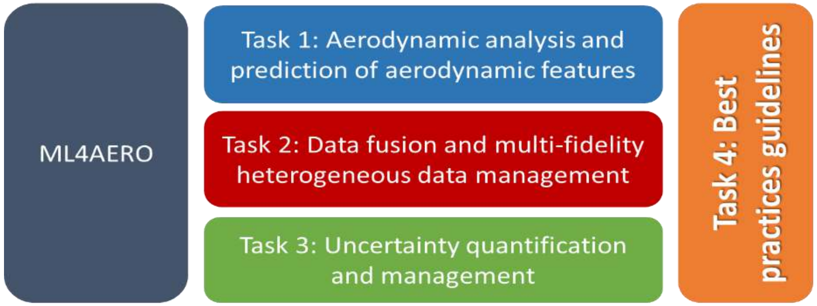
Most of the partners in this proposal (INTA, CIRA, ONERA and AIRBUS-Military) have previous experience in the surrogate modelling field. In particular, they contributed to a previous GARTEUR AD/AG52.

EG77: ML4AERO

Objectives:

- ❑ **O1:** Extensive comparison of **deep learning, surrogate models and machine learning techniques** → for prediction (Cp plots, etc.)
- ❑ **O2:** Exploit the potential of data fusion (**Multi-fidelity**). Heterogeneous data from different sources (CFD with different precision, wind-tunnel, flight test data, etc.)
- ❑ **O3: Uncertainty quantification and management**

- ○ Explore different techniques (e.g. clustering, dimensionality reduction, neural networks, SVM, deep learning, etc.) on big datasets (e.g., flow fields, past/ongoing optimization data,…) for knowledge extraction & prediction
- ○ Main focus not on techniques, but rather on which data should be fed to ML to really improve the whole process performance



EG77: ML4AERO

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Use of **common test cases and data bases to be provided by AIRBUS:**

- ❑ **TC1:** XRF1 geometry + CFD + wind tunnel data (Airbus will support the EG77 application as a part of XRF1 research consortium).

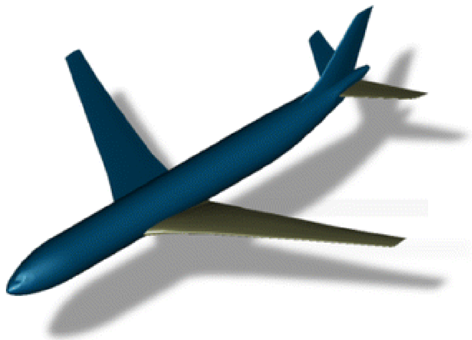
- ❑ **TC2:** Large database of approx. 7000 aircraft points (simulated with RapidCFD) representing different aircraft configurations for internal use on AI/DL topics based on Airbus internal geometries (including geometry variations). It is possible that an equivalent database based on geometry of lower sensitivity could be created and provided → parameterization could be also provided.

Link between objectives and test cases:

- ❑ O2 and O3 will use TC1
- ❑ O1 and O3 will use TC2 (maybe also O2 if XRF1 is included in TC2, or if the group runs extra CFD RANS simulations)

The Airbus XRF-1 configuration will be used as the reference geometry to demonstrate the capabilities of the machine learning in a realistic application. This figure shows the XRF1 geometry as a wing/fuselage/tail configuration.

Source: DLR project Kroll, N., Abu-Zurayk, M., Dimitrov, D. et al. Digital-X: towards virtual aircraft design and flight testing based on high-fidelity methods. CEAS Aeronaut J (2016) 7: 3.



EG77: ML4AERO

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Technical Details:

	Task 1: Aerodynamic analysis	Task 2: Data fusion	Task 3: Uncertainty quantification
INTA	Surrogate model based on SVRs to predict aerodynamic features	Research on SVRs to exploit and manage multi-fidelity data (database 2)	-
CIRA	KPLS, Surrogate models Mixture of Experts (MOE) to predict aero-data	Additive and multiplicative variable-fidelity model, multi-fidelity Kriging and Co-Kriging	PCA + Kriging surrogate for predicting the statistical moments and risk measures of the full model outputs
NLR	ML/DL autoencoders with neural networks	-	Bayesian methods combined with ML/DL
ONERA	From basic machine-learning surrogates to deep learning neural networks for approximation of aerodynamic data	-	Polynomial chaos & compressed sensing to efficiently predict statistical moments
IRT	Mixtures Of Experts based on Kriging and/or Polynomial Chaos Expansion	-	Statistical moments and risk measures estimated by PCA + Polynomial Chaos Expansion
AIRBUS	Generation of the DB2 database	-	Generation of the DB2 database
AIRBUS-Military	Surrogate model based on HOSVD, POD, Kriging to predict aerodynamic features	Research on HOSVD to exploit and manage multifidelity, Kriging and Co-Kriging	-
FOI	Auto-encoder + GPR vs POD+GPR for aerodata prediction	-	PCE (Polynomial Chaos Expansions)

	SVM	Neural Networks	Kriging	HOSVD	Polynomial Chaos Expansion	Mixture Of Experts
INTA	Scikit-learn Support Vector Regressor (SVR)	MLP + TensorFlow	-	-	-	-
CIRA	Scikit-learn Support Vector Regressor (SVR)	Scikit-learn MLP, Keras + TensorFlow	In-house SUITE Scikit-Learn GaussianProcess Regressor	-	-	-
NLR		Scikit-learn, Keras, TensorFlow	-	-	-	-
ONERA	Scikit-learn & In-house	Scikit-learn	SMT tool-box & In-house	-	-	-
IRT	-	-	OpenTurns, Scikit-Learn, GEMS	-	OpenTurns, GEMS	OpenTurns, Scikit-Learn, GEMS
AIRBUS	-	-	-	-	-	-
AIRBUS-Military		Caret library in R	In-house tools development	In-house tools development.	-	-
FOI	Scikit SVM & SVR	Scikit-Learn, Tensorflow	Scikit-Learn GaussianProcess Regressor	-	-	-

EG77: ML4AERO

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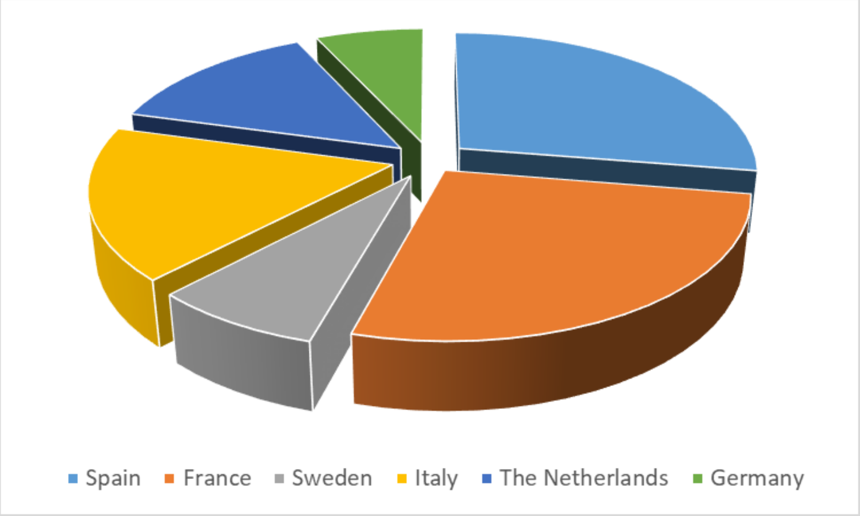
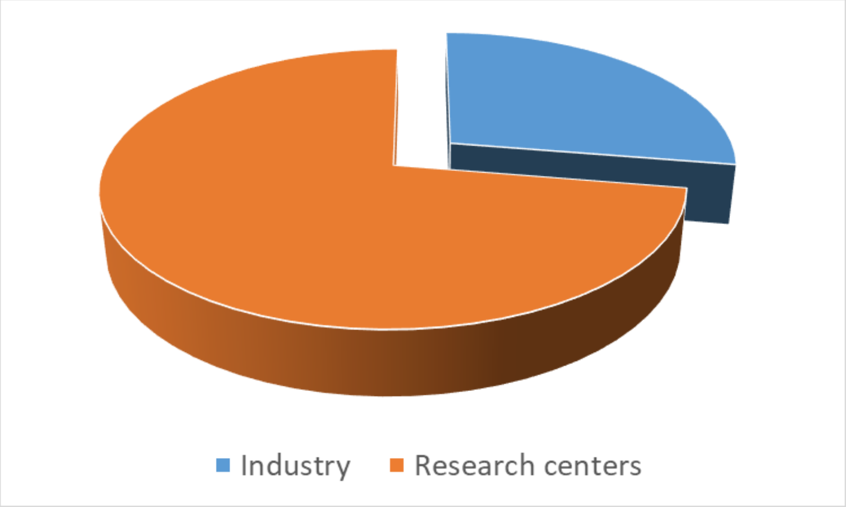
Proposal info.:

Participant	2020		2021		2022	
Data preparation						
Task 1						
Task 2						
Task 3						
Final report						
Meeting		1 (kick-off)	2	3	4 (final)	

Participant	2020			2021			2022			TOTAL		
	PM	CC	TC	PM	CC	TC	PM	CC	TC	PM	CC	TC
INTA	1,5	5	1	3	10	2	1,5	5	1	6	20	4
CIRA	1	0	1	2	0	2	1	0	1	4	0	4
NLR	1	0	1	2	0	2	1	0	1	4	0	4
UT	1	0	1	2	0	2	1	0	1	4	0	4
ONERA	1.5	5	1	1.5	5	1	1.5	5	1	4.5	15	3
IRT	4	-	1	1	-	1	1	-	1	6	-	3
INRIA	1	1	1	2	2	2	2	2	1	5	5	5
FOI	1,5	5	1	1,5	10	2	1,5	5	1	4,5	20	4
AIRBUS	2	8	1	1.5	1	2	1.5	1	1	5	10	4
AIRBUS-Military	1.5	0	1	3	0	1	0.5	0	0	5	0	2
OPTIMAD	2	3	1	3	3	2	1	3	1	6	9	4
DLR	1	0	1	2	0	2	1	0	1	4	0	4
TOTAL										58	79	45



PM distribution by country (note that AIRBUS has been included in Spain effort, although it is a European Consortium)



PM distribution by sector

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GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY IN EUROPE

FRANCE GERMANY ITALY THE NETHERLANDS SPAIN SWEDEN UNITED KINGDOM

Machine learning and data-driven approaches for aerodynamic analysis and uncertainty quantification

(Acronym: ML4AERO)

INTA CIRA ONERA THE FRENCH AEROSPACE LAB FOI DLR OPTIMAD

AIRBUS MILITARY AIRBUS IRT SAINT EXUPERY Inria UNIVERSITY OF TWENTE. nlr

EG77 overview to GARTEUR Council

3rd November, 2020