



# Advanced Reduced Order Methods in Scientific Computing with Applications in CFD: Data, Models, HPC, Artificial Intelligence, Machine Learning and Digital Twin

ERC CoG AROMA-CFD; FARE-X-AROMA-CFD - MIUR FARE; H2020 EID ROMSOC; H2020 RISE ARIA; HE EID BLESSED; HE DN EARTH-SAFE; PRIN NA-FROM-PDEs; EURO-HPC E-FLOWS4HPC; ERC PoC 2022 ARGOS; POC ATLAS; PRIN 2022 FAROM and PRIN 2022 PNRR

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## Mission

- A team of international scientists at SISSA for the development of Advanced Reduced Order Modelling intrusive and non-intrusive techniques with a focus in Computational Fluid Dynamics (CFD) for incompressible and compressible flows, also with turbulence.
- To face and overcome many current limitations of the state of the art and improve the capabilities of reduced order methodologies for more demanding applications in industrial, medical, environmental and applied sciences contexts.
- AROMA-CFD, FARE, ROMSOC, ARIA, PRIN, E-FLOWS4HPC, BLESSED, EARTH-SAFE, ATLAS and ARGOS deal with strong methodological developments in numerical analysis, with special emphasis on mathematical modelling and an extensive exploitation of computational science and engineering as well as data science, machine learning and high performance computing.

## Tasks in reduced order modelling developments

- Study of bifurcations and instabilities in mechanics.
- Increase Reynolds number while guaranteeing the flow stability.
- Move towards parametric turbulent flows, also compressible.
- Consider complex geometrical parametrizations of shapes as computational domains, interfaces, as well as extended networks.
- Special focus on nonlinear inverse problems, focusing on optimal flow control, shape optimization, as well as uncertainty quantification.
- Multiphysics, fluid-structure interaction and multiphase flows, more general coupled phenomena involving inviscid, viscous and thermal flows, solids and porous media.
- Reduction in parameter space.
- Scientific and Physics Informed Machine Learning for advanced tasks (ANN, CNN, PINN, AI, DL), Artificial intelligence for image and/or object recognition, as well as for CSE within ROM.

## Industrial Collaborations

- Beneteau Group Italia
- Arcelor Mittal
- Bormioli Pharma
- Fincantieri
- Cetena
- Optimad
- Danieli
- Electrolux Professional
- Micad
- Danieli Automation
- Wartsila
- Electrolux
- SMACT
- Alfa Romeo Sauber Orlen
- Lombardi
- Volkswagen
- Dompè
- Cergol
- Galdi
- Toyota Motors Europe
- Indaco project
- Dofware
- Siemens
- EPS
- Engys
- MES

## Technology Transfer and Innovation from Research Valorisation

FAST computing ([www.fastcomputing.net](http://www.fastcomputing.net)) is a SISSA mathLab startup for real time computing and analytics. ODYSSEA is a digital twin live demo within SMACT, Competence Center for Industry 4.0 and iNEST is the interconnected innovation ecosystem (PNRR) in the North-East of Italy: Spoke 9 is hosted at SISSA and focused on digital twins.

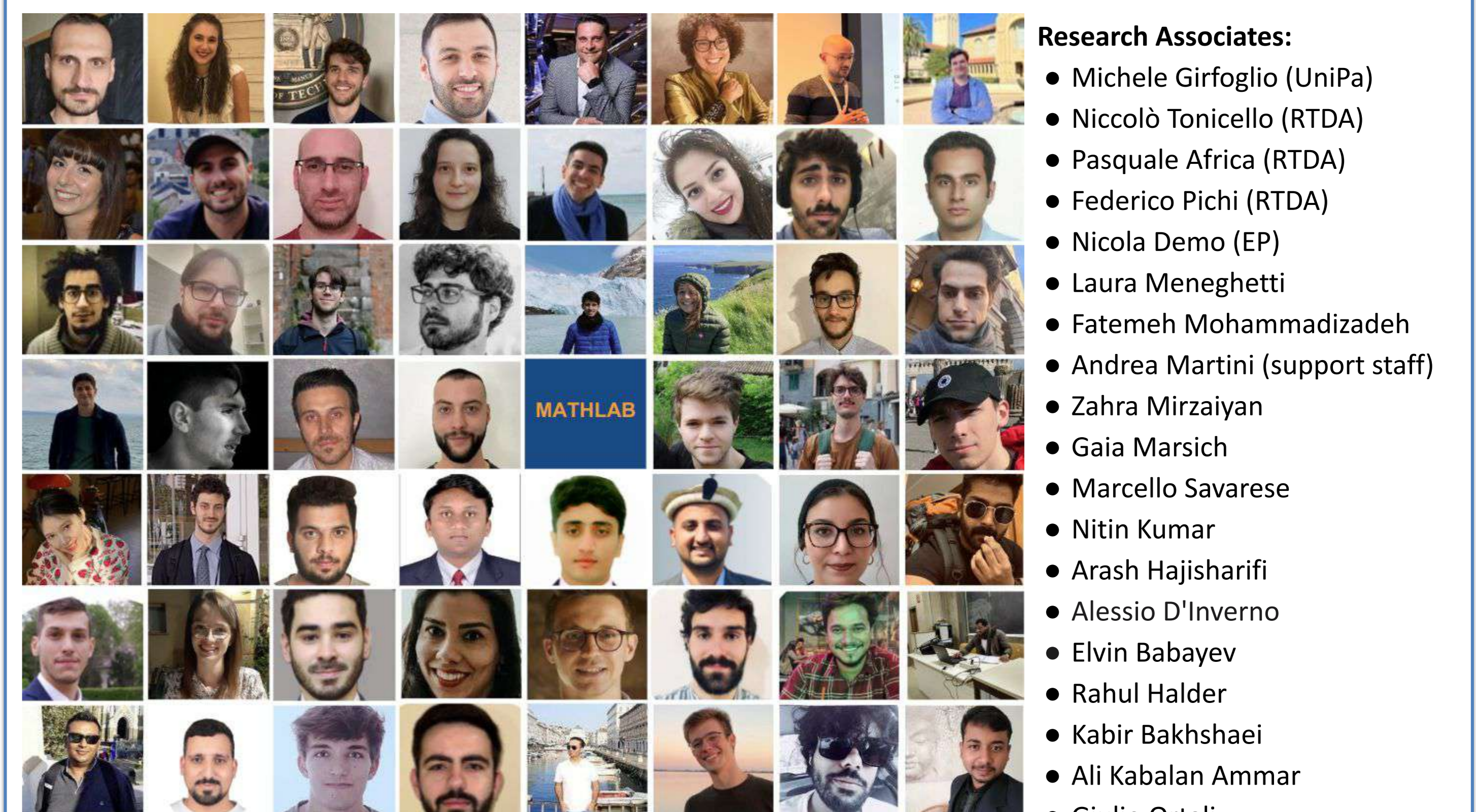


## National and International Collaborations

SISSA mathLab, MIT, University of Toronto, Houston, Harvard, Sevilla, Konstanz, Stuttgart, Ghent, Bordeaux, Santiago, Ulm, Muenster, Pavia, Trento, Milano, Trieste, Udine, Florida State University, RWTH Aachen, Sandia National Laboratories, Politecnico di Milano and Torino, Brescia, IMT, Padova, Paris Sorbonne LJLL, ParisTech, EPFL, ETHZ, Imperial College, TU/Eindhoven, Amsterdam UVA, Sapienza Roma, Duke University, Virginia Tech, Singapore NUS, INRIA, Max Planck Magdeburg, Ospedale L. Sacco, Ospedale San Camillo, Sunnybrook Hospital, TU Wien, TU/Delft, UPC and BSC Barcelona, Stanford, Sant'Anna Pisa, Emory.



## Rozza Group Research staff (2025)



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## Industrial, environmental and medical applications

- Aeronautical, mechanical, naval, nautical, civil, off-shore, wind, sport, biomedical, environmental engineering with a focus on cardiovascular surgery applications, and environmental sciences.



Towards real-time computing and visualization, through an offline-online computational paradigm combining high performance computing (in dedicated supercomputing centers), data analytics, artificial intelligence, uncertainty quantification and advanced reduced order modelling techniques (in common devices such as tablets and smartphones) for digital twins.



## Open Source Software Collection

New open source software libraries for AROMA-CFD have been created: ITHACA galaxy (FV, SEM, DG) In real Time Highly Advanced Computational Applications, enhancing current RBniCS and multiphenics educational and training capabilities based on FEM. Other support tools are developed in Python: PyGeM, BladeX, ATHENA, GRAPE, PINA, GEA. Our data driven ROM collection includes EZyRB, PyDMD and PINA. Computational web servers are under development, [argos-edu.sissa.it](http://argos-edu.sissa.it) and the twin [atlas.sissa.it](http://atlas.sissa.it).

