

Morphing Wing Technologies

Large Commercial Aircraft and Civil Helicopters

Editors-in-Chief

Antonio Concilio, Ignazio Dimino

Adaptive Structures Division, The Italian
Aerospace Research Centre,
Capua (CE), Italy

Leonardo Lecce, Rosario Pecora

Department of Industrial Engineering, Aerospace Division,
University of Naples "Federico II",
Naples, Italy



Butterworth-Heinemann
An imprint of Elsevier

Contents

Contributors	xxi
Editor-in-Chief Biographies	xxvii
Biographies	xxxix
Foreword 1	xlix
Foreword 2	li
Preface	liii

SECTION 1 INTRODUCTION

CHAPTER 1 Historical Background and Current Scenario.....	3
1 Introduction	6
2 Components of a Wing Morphing Structural System	8
2.1 Structural Skeleton	9
2.2 Actuation Systems	10
2.3 Skin	10
2.4 Control System	11
2.5 Cabling.....	12
2.6 Assembly	13
3 The Main Challenges	13
3.1 Skins	13
3.2 Actuation Systems	15
3.3 Sensor Systems	17
4 Back to the Past.....	19
4.1 The Wright's Flyer	19
4.2 Plane and the Like for Aeroplanes	21
4.3 The Parker's Wing	22
5 Modern Times	24
5.1 NASA Studies	24
5.2 DGLR Studies	25
5.3 The Mission Adaptive Wing	28
5.4 Further NASA Studies	29
6 Recent Activities—United States.....	30
6.1 Adaptive Wing Reborn: SMAs	30
6.2 The DARPA Smart Wing Program	30
6.3 The DARPA Morphing Aircraft Structures Program	32

7	Recent Activities—Europe.....	34
7.1	ADIF.....	34
7.2	Clean Sky.....	35
8	Current Scenario.....	36
8.1	Airbus—SARISTU (Smart Intelligent Aircraft Structures).....	36
8.2	Boeing—Adaptive Wing.....	37
8.3	Flexsys and Gulfstream.....	39
9	The Tradition at the University of Napoli and CIRA.....	43
9.1	Adaptive Airfoil.....	44
9.2	The Hinge-Less Wing.....	45
9.3	Smartflap.....	47
9.4	SADE.....	49
9.5	Clean Sky—JTI-GRA—Low Noise.....	50
9.6	EU—SARISTU.....	51
9.7	The Adaptive Aileron.....	54
10	Future Perspectives.....	58
10.1	Safe Design.....	58
10.2	Skins and Fillers.....	59
10.3	Direct Actuation: The Use of Smart Materials.....	62
10.4	Wireless, Distributed Sensing.....	63
10.5	Control System Architecture.....	65
10.6	Cybernetics and Robotics.....	67
	Acknowledgments.....	69
	References.....	69
	University of Napoli and CIRA International Awards.....	84
CHAPTER 2	Aircraft Morphing—An Industry Vision.....	85
1	Introduction.....	86
2	Current Aircraft Capabilities.....	86
2.1	Interest of Industry.....	87
2.2	Some Considerations About Industry Aerodynamic Design Process.....	88
2.3	Expected Performance Targets.....	90
2.4	Manufacturing: New Materials and Controlled Industrial Processes.....	90
2.5	Assembly and Quality: Automation and Integrated Parts.....	91
2.6	Maintenance: Assessed Steps and Personnel Training.....	92
2.7	Safety: Assessed Methods for Standard Architectures.....	93
3	Current and Expected Needs.....	96
3.1	Technology Transition.....	96
3.2	A Mission Configurable Wing.....	97
3.3	Improved Flaps and Ailerons.....	98

4	Morphing as a Solution.....	99
4.1	Wing and Control Surface Feasible Solutions.....	99
4.2	Some Specific Requirements	99
5	Conclusions.....	100
	References	101
CHAPTER 3 The Development of Morphing Aircraft Benefit Assessment.....		103
1	Experiments as Basis for Morphing Progress.....	103
2	The Advent of Transonic Methods	105
3	Automated Methods as Enabler for Large Scale Studies.....	113
4	Reintroduction of Flexible Materials	114
5	The Final Step to Industrial Application	118
	References	119
SECTION 2 REQUIREMENTS AND PERFORMANCE		
CHAPTER 4 Span Morphing Concept: An Overview		125
1	Introduction	126
2	Effects of Span Increase.....	127
2.1	Aerodynamic Effects	127
2.2	Structural Effects.....	129
2.3	Stability and Control Effects.....	129
3	Span Morphing Concepts and Aircraft Performance	130
3.1	Symmetric Span Morphing	131
3.2	Asymmetric Span Morphing	136
4	Implementation Challenges.....	140
4.1	Telescopic Wings	140
4.2	Hinged Structures	141
4.3	Twin Spars.....	141
5	Conclusions.....	142
	Acknowledgments	143
	References	143
CHAPTER 5 Adjoint-Based Aerodynamic Shape Optimization Applied to Morphing Technology on a Regional Aircraft Wing		145
1	Introduction	146
2	Handling of Morphing Shape Changes in a CFD Context.....	147
2.1	Context of the Study	147
2.2	Discrete Model of Displacement Field at the Trailing Edge	148
2.3	3D CFD Mesh Deformation Technique.....	153

3	CFD Evaluation and Far-Field Drag Analysis Over a Wing Equipped with a Morphing System	154
3.1	Finite-Volume Solver for the RANS Equations in <i>elsA</i>	155
3.2	Far-Field Drag Extraction Tool	156
4	Sensitivity Analysis Using a Discrete Adjoint of the RANS Equations	157
4.1	Residual and Objective Function Dependencies	157
4.2	Discrete Adjoint Method in <i>elsA</i>	158
5	Local Shape Optimization Technique.....	159
5.1	Definition of the Problem	160
5.2	The Method of Feasible Directions	160
5.3	A 2D Example: The Rosenbrock's Function Constrained by a Disk	161
6	Aerodynamic Shape Optimization of Morphing System: An Application Within the EU Project SARISTU	162
6.1	Optimization Problem	163
6.2	Optimization Loop Presentation	164
6.3	First Optimization.....	164
6.4	Second Optimization	168
6.5	Expectations on Morphing Technology.....	172
7	Conclusion.....	172
	References	173
	Further Reading.....	174
CHAPTER 6	Expected Performances	175
1	Introduction	176
2	The Reference Aircraft.....	178
3	Active Camber Using Conventional Control Surfaces.....	179
3.1	Five Panels Over the Flap Region	180
4	Coupled Aerostructural Shape Optimization.....	181
4.1	Morphing Leading Edge	183
4.2	Morphing Trailing Edge.....	185
5	Fuel Savings	188
6	High-Fidelity Aerodynamic Analysis	190
6.1	Leading Edge Morphing	190
6.2	Trailing Edge Morphing.....	191
7	Weight Saving	195
7.1	Morphing Devices	196
8	Benefit Exploitation in the Transport Aircraft Design.....	199
9	Conclusions.....	201
	Acknowledgments	203
	References	203

SECTION 3 MORPHING SKINS

CHAPTER 7 Morphing Skin: Foams	207
1 Introduction	208
2 Design Principles.....	208
3 Low Temperature Elastomers	210
4 Material Properties of HYPERFLEX	215
5 Properties of Bonded Joints	218
6 Properties of Morphing Skin.....	222
7 Skin Manufacturing.....	225
8 Summary and Conclusions.....	228
References	229
CHAPTER 8 The Design of Skin Panels for Morphing Wings in Lattice Materials.....	231
1 Introduction	231
2 Requirements for the Skin of a Morphing Wing.....	232
3 A Methodology for Nonlinear Homogenization of Periodic Structures	234
4 Mechanical Properties of Skin Panels in Lattice Material.....	237
4.1 Analysis of Selected Lattice Topologies	237
4.2 The Design Space of the Chevron Lattice.....	242
5 Conclusions.....	245
References	245
CHAPTER 9 Composite Corrugated Laminates for Morphing Applications.....	247
1 Introduction	248
2 Types of Corrugated Laminates.....	250
3 Anisotropy and Stiffness Properties in Morphing Direction.....	252
3.1 Anisotropy Indices of Stiffness Properties	252
3.2 Compliance in Morphing Directions of Different Types of Composite Corrugated Laminates	254
4 Strength and Stiffness Contributions in Nonmorphing Directions	260
4.1 Failure Modes of Composite Corrugated Laminates and Strain Limits	260
4.2 Evaluation of Structural Stiffness Contribution in Nonmorphing Directions	261
5 Manufacturing of Composite Corrugated Laminates	267
6 Development of Aerodynamically Efficient Morphing Skins.....	269
6.1 Aerodynamic Issues in the Application of Composite Corrugated Laminates.....	269
6.2 Performance Index Based on Ratio Between Bending and Axial Compliance	270

6.3 Integration of an Elastomeric Cover on a Square-Shaped Corrugated Laminate	271
7 Conclusions.....	273
References	275

SECTION 4 SYSTEMS DESIGN

CHAPTER 10 Active Metal Structures	279
1 Introduction	280
2 Morphing Oriented Kinematic Chains: Working Principles and Design Approaches	281
2.1 Spar Caps Section Area at Generic Cross-section.....	287
2.2 Spars Webs, Skin Panels, Rib Plate Thickness at Generic Cross-Section.....	288
3 Compliant Mechanisms: Working Principles and Design Approaches	290
4 Applications of Morphing Oriented Kinematic Chains.....	292
4.1 Morphing Concept Overview	293
4.2 Structural Analyses.....	299
5 Applications of the Compliant Mechanism Approach	302
5.1 Arc-Based Flap, Actuated by SMA Active Elements	304
5.2 X-Cell Architecture for a Single Slotted Flap	311
6 Conclusions.....	317
References	319
CHAPTER 11 Sensor Systems for Smart Architectures	321
1 Introduction	323
2 Strain Sensors	323
2.1 Strain Gauge Foils	324
2.2 Piezoelectric Devices	324
2.3 Graphene-Based Polymers	325
2.4 Fiber Optics	325
3 Sensor Systems for Large Scale Integration.....	333
3.1 Wireless Technology	334
3.2 Sprayed Technology	335
3.3 Distributed Technology	335
3.4 Some Installation Issues	336
4 Case Studies.....	338
4.1 Shape Reconstruction of a Variable Camber Wing Trailing Edge.....	338
4.2 Damage and Load Monitoring	341
4.3 Rotation Angle Monitoring	343
5 Conclusions and Perspectives	347
References	348

CHAPTER 12 Control Techniques for a Smart Actuated Morphing Wing Model: Design, Numerical Simulation and Experimental Validation	351
1 Introduction	352
2 Project Background	353
3 General Structures of the Open Loop and Closed Loop Control Architectures...	357
4 Open Loop Controllers	362
4.1 Fuzzy Logic PD Controller	363
4.2 Combined On-Off and PID Fuzzy Logic Controller	371
4.3 Combined On-Off and Cascade PD-PI Fuzzy Logic Controller	377
4.4 Combined On-Off and Self-Tuning Fuzzy Logic Controller	386
5 Optimized Closed Loop Control Method	391
6 Conclusions	395
Acknowledgments	395
References	395

SECTION 5 NUMERICAL SIMULATION

CHAPTER 13 Influence of the Elastic Constraint on the Functionality of Integrated Morphing Devices	401
1 Introduction	402
2 Features of the FE Models	404
2.1 LE Modeling Strategy	406
2.2 TE Modeling Strategy	408
2.3 WL Modeling Strategy	409
3 Isolated Devices Behavior	410
4 Global Stiffness of the Outer Wing Box	410
5 Effects of the Actuation of the Morphing Devices	415
5.1 Cross Effects	417
5.2 Effects on the Wing Box	417
6 Conclusions and Further Steps	424
References	427

CHAPTER 14 Application of the Extra-Modes Method to the Aeroelastic Analysis of Morphing Wing Structures	429
1 Introduction	430
2 Aeroelastic Equilibrium Equation and Stability	431
3 Extra-Modes Formulation	434

4	Aeroelastic Analyses of Morphing Wings Using the Extra-Modes Method.....	437
4.1	Effectiveness of Wing Twist Morphing as Roll Control Strategy.....	437
4.2	Trade-Off Flutter Analysis of a Morphing Wing Trailing Edge.....	442
5	Conclusions.....	448
	Bibliography.....	449

CHAPTER 15	Stress Analysis of a Morphing System.....	451
1	Introduction.....	453
2	Design of a Morphing Structure.....	454
3	Finite Element Modeling of Morphing Structures.....	458
3.1	Rib and Spars.....	459
3.2	Fasteners.....	462
3.3	Skin.....	464
3.4	Actuation System.....	465
4	Design Loads and Constraints.....	467
5	Structural Design and Simulations.....	469
5.1	Static Analysis at Limit and Ultimate Loads: Linear and Nonlinear Analysis.....	470
5.2	Stress Analysis.....	470
5.3	Buckling Analysis.....	473
5.4	Modal Analysis.....	474
6	Stress Margins of Safety.....	476
6.1	Solid Parts.....	476
6.2	Internal Connections.....	478
7	Conclusions.....	486
	References.....	487
	Further Readings.....	488

SECTION 6 MORPHING WING SYSTEMS

CHAPTER 16	Morphing of the Leading Edge.....	491
1	Summary.....	492
2	Introduction.....	492
3	Conceptual Approach to the Morphing of the Leading Edge.....	495
4	Working Principle of the Architecture Selected to Produce the Drop Nose Effect.....	496
5	Architecture Design.....	497
5.1	Identification of the Kinematic Chain in the Rib Plane.....	498
5.2	Topologic Optimization of the In-Plane Rib Architecture.....	499
5.3	Spanwise Architecture and Actuation Design.....	500
5.4	Modelling and Working Simulation of the Complete Architecture.....	502

6	Prototyping	505
7	Experimental Campaign	505
	7.1 The Setup	505
	7.2 Experimental Results	508
	7.3 Numerical—Experimental Comparison	511
8	Conclusions and Further Steps	513
	References	514

CHAPTER 17 An Adaptive Trailing Edge 517

1	Introduction	519
2	The Concept	521
	2.1 Layout	522
3	Design	526
	3.1 Design Loads	526
	3.2 Structural Sizing	528
	3.3 Actuator Selection	530
	3.4 Results	533
4	Safety and Reliability Aspects	538
	4.1 Generalities	538
	4.2 Distributed Actuation	539
	4.3 The ATED Function	539
	4.4 Fault Hazard Assessment	539
	4.5 Functional Hazard Assessment	540
5	Discussion: Implementation on Real Aircraft	541
	5.1 System Development	541
	5.2 Operational Aspects	542
	5.3 Aeroelastic Issues	542
6	Conclusions and Future Developments	542
	Acknowledgments	543
	References	543
	Further Reading	545

CHAPTER 18 Morphing Aileron 547

1	Introduction	548
2	Conceptual Approach	549
3	Working Principle and T/A Architecture	550
4	Actuation System Design	553
5	Numerical Simulations	559
	5.1 Interface Load	567
6	Prototyping	568

7	Experimental Tests and Main Outcome	572
7.1	GVT and Numerical Correlation	572
7.2	Functionality Test.....	574
7.3	Experimental Shapes	575
8	Wind Tunnel Tests	577
9	Conclusions.....	580
	References	581

SECTION 7 FULL SCALE REALIZATION, SAFETY, AND RELIABILITY

CHAPTER 19	Morphing Technology for Advanced Future Commercial Aircrafts	585
1	Introduction	587
2	ATED Manufacturing.....	589
2.1	The Morphing System.....	589
2.2	Manufacturing	591
2.3	Assembly	593
2.4	Test Campaign.....	597
2.5	Conclusions.....	601
3	Other Experiences	601
3.1	3AS Project.....	601
3.2	CURVED Project	603
4	Future Studies—The Morphing Rudder	608
4.1	Synthesis.....	609
4.2	Manufacturing Challenges	611
4.3	Lateral Directional Stability Analysis.....	611
5	Conclusions.....	614
	References	615
	Further Reading.....	618
CHAPTER 20	Morphing Wing Integration	619
1	Introduction	620
2	Demonstrator Components.....	621
2.1	Wing Box Primary Structure.....	623
2.2	Leading Edge.....	624
2.3	Trailing Edge	627
2.4	Winglet	628
3	Conditions of Assembly	631
4	Jig.....	633
5	Equipment and Tooling.....	633
6	Demonstrator Assembly	636
6.1	The Assembly of the Wing Box	637

6.2 Morphing Systems Installation: The Leading Edge 639
 6.3 Morphing Systems Installation: The Trailing Edge 640
 6.4 Morphing Systems Installation: The Winglet..... 641
7 FBG Sensor Network 642
8 Conclusions..... 644
 Acknowledgments 644
 References 645

CHAPTER 21 Morphing Devices: Safety, Reliability, and Certification

Prospects 647
1 Introduction 648
2 System Level Approaches to the Certification of Morphing Wing Devices 650
 2.1 Adaptive Droop Nose..... 652
 2.2 Adaptive Trailing Edge Device 652
 2.3 Morphing Winglet 653
 2.4 Defining the System Level Functions of Morphing Devices..... 654
 2.5 Dual Level Safety..... 656
3 Functional Hazard Assessment 657
4 Dual-Level Approach for the FTA of a Morphing Wing 675
5 Common Cause Analyses..... 678
 5.1 Particular Risk Analysis..... 680
 5.2 Common Mode Analysis..... 680
 5.3 Zonal Safety Analysis 680
6 Conclusions..... 681
 References 681

CHAPTER 22 On the Experimental Characterization of Morphing Structures 683

1 Introduction 684
2 Testing Practices for Morphing Systems 686
 2.1 Morphing Trailing Edge Device 686
3 Unit Tests: From Component to Morphing System Verification..... 688
 3.1 Skin Over Dummy 690
 3.2 Actuators Over Dummy 692
 3.3 Control System Over Dummy..... 693
 3.4 Control System Over Skinned Dummy 694
 3.5 Complete System..... 695
4 System Integration Test Bench for Morphing Systems..... 698
5 Full-Scale Testing..... 700
 5.1 Shape Control of Adaptive Wings 700
 5.2 Wing Shape Controller Strategies and Experimental Verification 703

6	Conclusions.....	710
	References	711

CHAPTER 23 Wind Tunnel Testing of Adaptive Wing Structures 713

1	Introduction	715
1.1	General Test Procedure for the Morphing Item	716
2	3AS	716
2.1	Requirements for the EURAM and Experimental Facilities.....	717
2.2	Model Design and Manufacture.....	718
2.3	Laboratory Tests.....	718
2.4	Aeroelastic Wing Tip Controls Concept.....	723
2.5	All-Movable Vertical Tail Concept	725
2.6	Selective Deformable Structure Concept.....	730
3	SADE.....	732
3.1	Wing Demonstrator	732
3.2	Videogrammetry Method of Deformation Measuring.....	732
3.3	Test Object and Experimental Facility	734
3.4	Measuring Process and Data Handling	735
4	SARISTU.....	737
4.1	Objectives of the Wind Tunnel Test.....	738
4.2	Ground Vibration Test and Flutter Expansion Test	741
4.3	Load Measurements	744
4.4	Calculations of Wing Demo Aerodynamics in T-104 WT	748
4.5	Deformations Measurements of the Wing with Elastic Controls in WT T-104 Flow.....	752
5	Conclusions.....	752
	Acknowledgments	754
	References	754

SECTION 8 SMART HELICOPTERS

**CHAPTER 24 Rotary Wings Morphing Technologies: State of the Art
and Perspectives 759**

1	Introduction	761
2	Overview of Rotor Morphing Technologies.....	761
2.1	Trailing Edge Flaps.....	762
2.2	Active and Variable Twist	765
2.3	Variable Span	767
2.4	Emerging Rotor Morphing Technologies	769

3	Critical Review of Some Significant Efforts.....	771
3.1	Active Trailing and Leading Edge Devices.....	772
3.2	Individual Blade Control.....	774
3.3	Active Twist.....	779
3.4	Variable Span.....	782
3.5	Slowed/Stopped Rotor.....	783
4	Conclusions.....	784
	References.....	786
 CHAPTER 25 Aerodynamic Analyses of Tiltrotor Morphing Blades.....		799
1	Introduction.....	801
2	Aim and Structure of the Chapter.....	801
3	Research Context.....	802
4	Outline of Methods and Numerical Tools.....	803
4.1	Integration and Optimization Environment.....	804
4.2	MDA Procedures and Optimization Processes.....	804
4.3	BEMT Analysis.....	806
4.4	CFD Driven Analysis.....	809
4.5	Blade Parameterization.....	810
4.6	Airfoil Selection.....	815
4.7	Surface Grid Generation.....	816
4.8	Volume Grid Generation.....	817
5	Background.....	818
6	Case Study.....	820
6.1	Description of Activities.....	820
6.2	Baseline Geometry.....	821
6.3	Optimization Objectives and Strategy.....	821
7	Un-Morphed Blades.....	822
8	Morphing Blades.....	828
8.1	Blade Span Morphing and Variable Speed Rotor.....	828
8.2	Blade Section Morphing.....	829
9	Conclusions.....	836
	References.....	837
 CHAPTER 26 Synergic Effects of Passive and Active Ice Protection Systems....		841
1	Introduction.....	842
2	Pros and Cons of Considered IPS.....	843
2.1	Thermoelectric IPS.....	844
2.2	Low-Power Consuming Piezoelectric Deicing Systems.....	844
2.3	Hydrophobic Coatings.....	844
2.4	Alternative Strategy Based on a Hybrid Approach.....	845

3	Design and Realization of the IPS.....	845
3.1	Hydrophobic Coating Design and Process Assessment	846
3.2	Thermoelectric System Design and Ice Shedding Prediction	848
3.3	Piezoelectric IPS Sizing and Parameters Assessment	851
4	Experimental Validation	856
4.1	First WT Test Campaign.....	856
4.2	Second WT Test Campaign	859
5	Conclusions.....	861
	Acknowledgment.....	862
	References	863
	Further Reading.....	864
CHAPTER 27 Helicopter Vibration Reduction		865
1	Introduction	866
2	NextGen Vibration Levels	866
3	Vibration Specifications	866
4	Source of Helicopter Vibratory Loads.....	867
5	How Do Vibratory Loads Get Into the Fuselage?.....	869
6	What Is Used for Vibration Control Now?	869
6.1	Why Not Isolation?	870
6.2	The Venerable Frahm.....	871
6.3	Fuselage-Based Frahms.....	871
6.4	Rotor-Based Frahms.....	872
6.5	Frahms Are Heavy	874
6.6	Active Vibration Control.....	874
6.7	Dynamic Antiresonant Vibration Isolator.....	876
7	More Problems With Frahms	878
8	Active Counter-Force	879
8.1	Higher Harmonic Control	881
9	Individual Blade Control.....	882
9.1	Hydraulic IBC	883
9.2	Electrical IBC	883
9.3	On-Blade Flaps.....	885
10	The Path Forward.....	889
	Acknowledgments	889
	References	889
	Afterword.....	893
	Index	895

Contributors

Frederico Afonso

University of Lisbon, Lisbon, Portugal

Alessandro Airoidi

Politecnico di Milano, Milano, Italy

Salvatore Ameduri

The Italian Aerospace Research Centre, CIRA SCpA, Capua (CE), Italy

Gianluca Amendola

The Italian Aerospace Research Centre, CIRA SCpA, Capua (CE), Italy

Gennady A. Amiryants

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Francesco Amoroso

University of Naples “Federico II”, Naples, Italy

Alexandre Antunes

EMBRAER SA, Sao Jose dos Campos, Brazil

Alfonso Apicella

Leonardo S.p.A., Pomigliano D’Arco (NA), Italy

Gianvito Apuleo

Piaggio Aerospace, Villanova d’Albenga (SV), Italy

Maurizio Arena

University of Naples “Federico II”, Naples, Italy

Uwe T.P. Arnold

ZF Luftfahrttechnik GmbH, Calden, Germany

Silvestro Barbarino

Sikorsky, A Lockheed Martin Company, Stratford, CT, United States

Marco Bellucci

MARE Engineering, Napoli, Italy

Paolo Bettini

Politecnico di Milano, Milano, Italy

Robert Blackwell

Sikorsky, A Lockheed Martin Company, Stratford, CT, United States

Ruxandra M. Botez

École de Technologie Supérieure, ETS, Montreal, QC, Canada

Miguel Á. Castillo Acero

Aernnova Group, Madrid, Spain

Vasily Chedrik

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Alexander Chedrik

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Alexander Chevagin

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Monica Ciminello

The Italian Aerospace Research Centre, CIRA SCpA, Capua (CE), Italy

Antonio Concilio

The Italian Aerospace Research Centre, CIRA SCpA, Capua (CE), Italy

Alessandro De Gaspari

Politecnico di Milano, Milano, Italy

Federico Martín de la Escalera

Aernnova Engineering Division S.A., Madrid, Spain

Luca Angelo Di Landro

Politecnico di Milano, Milano, Italy

Ignazio Dimino

The Italian Aerospace Research Centre, CIRA SCpA, Capua (CE), Italy

José Lobo do Vale

University of Lisbon, Lisbon, Portugal

Antoine Dumont

ONERA, Meudon, France

Roman Efimov

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Sergio Esposito

Leonardo S.p.A., Pomigliano D'Arco (NA), Italy

Yasser Essa

Aernnova Engineering Division S.A., Madrid, Spain

Rolf Evenblij

Technobis Fibre Technologies, Alkmaar, The Netherlands

Alessandro Gilardelli

Politecnico di Milano, Milano, Italy

André Gratias

Fraunhofer ENAS, Chemnitz, Germany

Teodor L. Grigorie

École de Technologie Supérieure, ETS, Montreal, QC, Canada; University of Craiova, Craiova, Romania

Generoso Iannuzzo

Leonardo S.p.A., Pomigliano D'Arco (NA), Italy

Fanil Ishmuratov

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Vladimir Kulesh

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Innokentiy Kursakov

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Ksenia Kuruliuk

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Svetlana Kuzmina

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Fernando Lau

University of Lisbon, Lisbon, Portugal

Thomas H. Lawrence

Sikorsky, A Lockheed Martin Company, Stratford, CT, United States

Leonardo Lecce

University of Naples "Federico II", Naples, Italy

Grace Lima

EMBRAER SA, Sao Jose dos Campos, Brazil

Peter F. Lorber

Sikorsky, A Lockheed Martin Company, Stratford, CT, United States

Andreas Lühring

Fraunhofer IFAM, Bremen, Germany

Alexander Lysenkov

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Marco Magnifico

University of Naples "Federico II", Naples, Italy

Vladimir Malenko

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Victor Malyutin

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Mihir P. Mistry

The Boeing Company, Chicago, IL, United States

Christof Nagel

Fraunhofer IFAM, Bremen, Germany

Maria Chiara Noviello

University of Naples “Federico II”, Naples, Italy

Felipe Odaguil

EMBRAER SA, Sao Jose dos Campos, Brazil

Antonio Pagano

The Italian Aerospace Research Centre, CIRA SCpA, Capua (CE), Italy

Damiano Pasini

McGill University, Montreal, QC, Canada

Modesto Pecora

The Italian Aerospace Research Centre, CIRA SCpA, Capua (CE), Italy

Rosario Pecora

University of Naples “Federico II”, Naples, Italy

Fabian Peter

RWTH Aachen University, Aachen, Germany

Mikhail Pronin

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Francesco Rea

University of Naples “Federico II”, Naples, Italy

Sergio Ricci

Politecnico di Milano, Milano, Italy

Lorenzo Rossi

Leonardo S.p.A., Pomigliano D’Arco (NA), Italy

Salvatore Russo

Leonardo S.p.A., Pomigliano D’Arco (NA), Italy

Giuseppe Sala

Politecnico di Milano, Milano, Italy

Andrey Saprykin

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Oliver Schorsch

Fraunhofer IFAM, Bremen, Germany

Martin Schueller

Fraunhofer ENAS, Chemnitz, Germany

Sergey Shalaev

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Stefan Storm

Airbus Group Innovations, Ottobrunn, Germany

Tobias Strobl

3DSE Management Consultants, Muenchen, Germany

Eike Stumpf

RWTH Aachen University, Aachen, Germany

Afzal Suleman

University of Lisbon, Lisbon, Portugal; University of Victoria, Victoria, BC, Canada

Viktor Timokhin

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia

Maurizio Verrastro

Leonardo S.p.A., Caselle (TO), Italy

Andrea Vigliotti

The Italian Aerospace Research Centre, CIRA SCpA, Capua (CE), Italy

William A. Welsh

Sikorsky, A Lockheed Martin Company, Stratford, CT, United States

Matthew L. Wilbur

US Army Research Laboratory, Adelphi, MD, United States

Mikhail Zichenkov

Federal State Unitary Enterprise Central Aerohydrodynamic Institute Named After Professor N.E. Zhukovsky (TSAGI), Zhukovsky, Russia