# THE CONCEPT OF MORPHING ADAPTED STRUCTURES TO UAVS

**Vasile PRISACARIU*, Cătălin CIOACĂ*, Mircea BOŞCOIANU****

*"Transilvania" University, Brasov, Romania, **"Henri Coandă" Air Force Academy, Brasov, Romania

***Abstract**: The article is a review of the research concept of UAV morphing covering areas involved in shaping the final product (smart materials, adaptive structures, optimization and control, aerodynamics and flight mechanics). Morphing concept objectives are the development and implementation of advanced technologies, integrating multi-point adaptive structures. This aviation project attracts many risks, so a project risk analysis is developed to identify as many potential risks as possible and to decide how to prevent or mitigate risk impact.*

***Keywords**: morphing, UAV, adaptive structures, smart materials, piezoelectric actuators, risk.*

## 1. INTRODUCTION

An aircraft that has implemented the concept of morphing is defined as an aircraft whose shape changes during flight to optimize its performance. Form changes include scale, chord and volume, bearing surface, thickness profile, elongation and plan shape modification. Morphing can be used as a control element by changing the aircraft shape for flight dynamics. The morphing project objectives include the development and implementation of advanced technologies, in order to integrate the concept of adaptive multi-point structure. The concept is focused on four directions (figure 1) adaptive structural morphing, adaptive control, and biologically inspired flight system and smart materials.

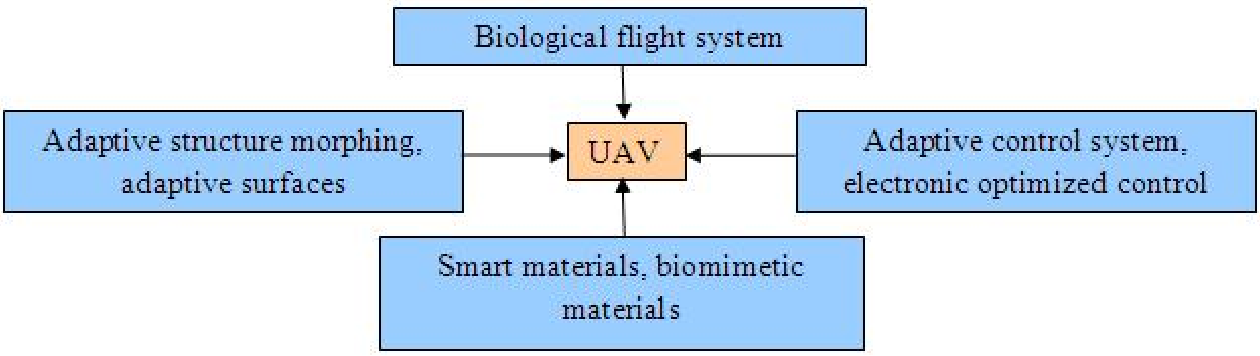


Fig. 1. Morphing structure concept

The project benefits are extended versatility to adapt to multiple in-flight requirements, adaptability to unforeseen safety situations, significant features improvements by reducing weight and drag, the performance of new missions that were previously considered impossible. Morphing software is applicable to almost all classes and sizes of civil and military UAVs. Complex systems, such as this aviation project, must be designed to remain operational and to be able to adapt-recovery in case of failures (Amin, 2002:28). Thus, systemic risk analysis is present in the systems engineering process at all stages.

## 2. THE FLIGHT - A BIOLOGICAL INSPIRATION

Birds in flight are able to change and modify wingspan bearing surface, thus changing forward speed. String wing can be modified and wing twist can be transformed in order to alter the aerodynamic performance (figure 2). Nature provides many examples of integrated multifunction systems in optimized design.

These natural systems are optimized for a set of requirements that may be different from engineering needs, so a direct imitation is not always appropriate. However, the concept of morphing vehicles, inspired by a multitude of examples of natural systems, has resulted in biologically inspired research areas. (Evers, 2005:15)

Fig. 2 Biological morphing

## 3. ADAPTIVE STRUCTURAL MORPHING – ASM

Adaptive Structural Morphing aims at developing, evaluating and demonstrating the multifunctional adaptive wing concepts that can adapt effectively to different flight conditions to improve future versatility, safety, handling and efficiency of airspace vehicles. Research is focused on approaches beyond the conventional control surfaces.

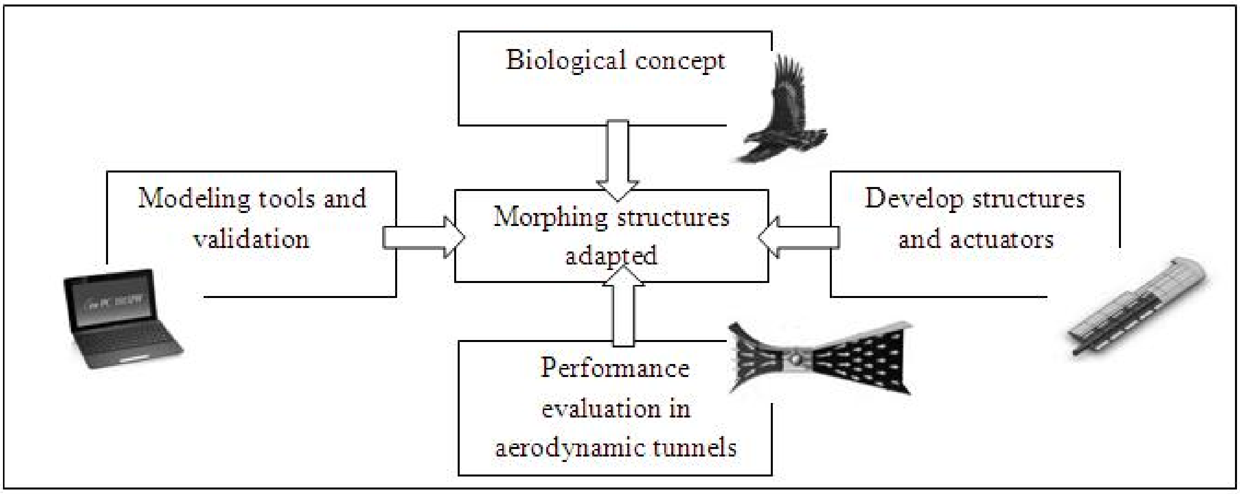


Fig. 3 The main activities at NASA Langley Research Center

Multipurpose adaptive wing concept may enable new surface forms and new types of transportation. (Florance, 2003:3).

NASA Langley Research Center ASM area is divided into four main activities: structural concepts inspired by biology, modeling and data validation tools, development of technology regarding structures and actuators, and evaluation of wind tunnel performance (figure 3). These areas are organized in order to develop technologies from concepts to wind tunnel testing. In the biological field, nature is the provider of guidance for structural concepts and mechanisms for wing structure with a range of movements while supporting aerodynamic loads. In parallel with the design work, comes the development of structures with shape memory alloy and piezoelectric actuators, sensors, manufacturing and production of components to demonstrate new capabilities of aerospace structures.

To exploit the full potential of these concepts, modeling, validation and design tools are still being developed to be used in designing and engineering technologies to accelerate the migration of applications in this field. As technology evolves, performance evaluations are performed to determine the feasibility and technological differences. (McGowan, 2003:2).

The next step in technology development cycle is the evaluation of system performance under real conditions, both in wind tunnels and in actual flight conditions. Performance evaluation effort is an essential part of the research cycle as they provide vital feedback to other areas of research related to technology integration, feasibility and implementation issues.

## 4. ADAPTIVE CONTROL SYSTEM

**Adaptive control with piezoelectric actuators**. NASA Dryden design and testing was done on a wing with piezoelectric actuators to evaluate the phenomenon of fluttering in the equipment and to improve electromechanical coupling effects.

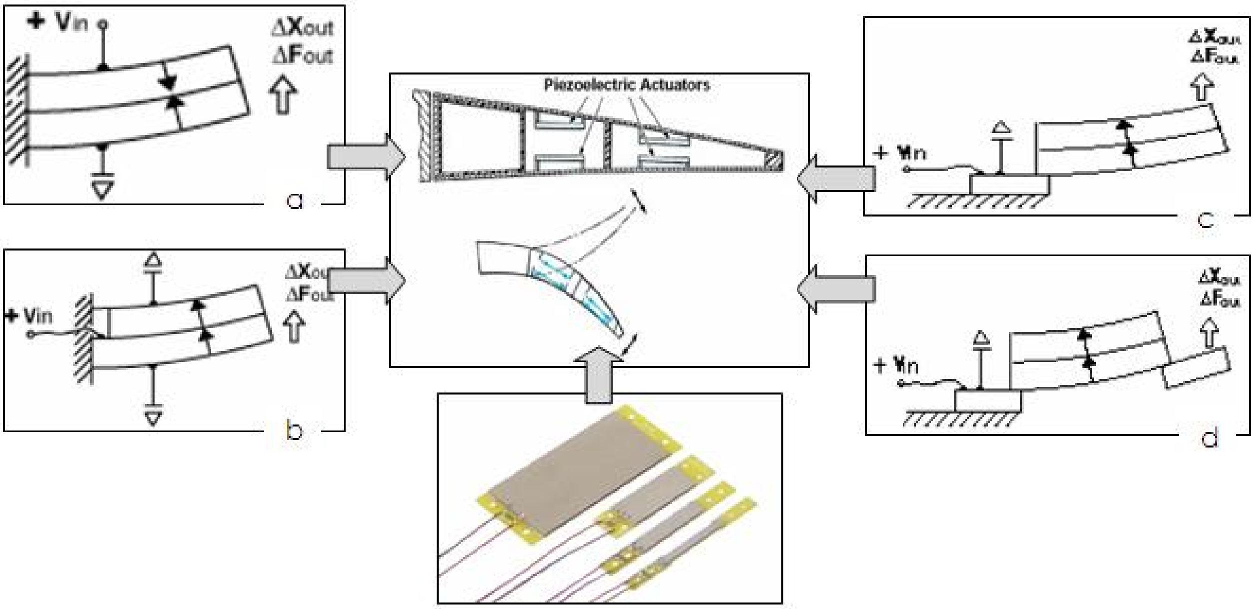


Fig. 4 Piezoelectric Models for controlling strain surfaces (a-2-wire serial, parallel b-3 wire, c-mounted at one end, d-mounted to 2 heads)

Figure 4 illustrates the piezoelectric actuator control models of surface deformation with 2 laminated layers (rectangular or circular). (Roberson 2002/2)Adaptive control (figure 5) is mainly concentrated in four general areas: development of fundamental tools, improved performance, handling and noise attenuation control.

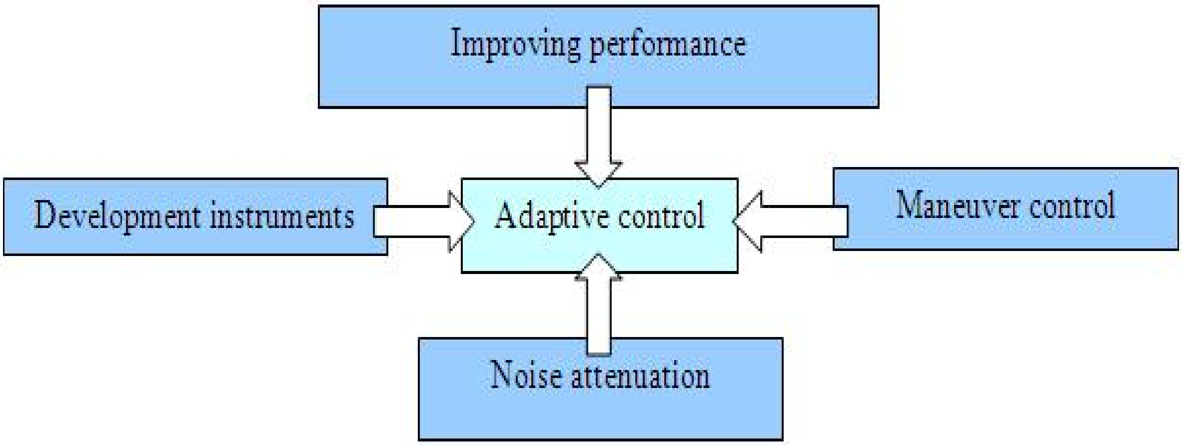


Fig. 5 Adaptive control areas

## 5. BIOLOGICALLY INSPIRED INTELLIGENT BIO-MIMETIC MATERIALS

**Smart materials and actuators.** Research of Intelligent materials constituted the starting point for the morphing concept, for a long time. In this context "smart" means the ability to respond to an external stimulus in a predictable and reproducible manner. This class of unspecific materials - Smart materials - is known as adaptive, active and multi-purposes materials. The unique capabilities of these materials inspired many important innovative concepts for adaptive structures for morphing flight and flow control.

Development of active polymers provided new materials with improved levels of deformation energy within an interval of higher temperatures that allows the development of electro-active films. These materials will lead to the development of thin elastic smart surfaces containing sensors and embedded dimensional components in the morphing architecture. (McGowan, 2003:11).

**Biologically inspired materials.** BIOS Research Area (BIOlogically -Inspired Smart Nanotechnology) was initiated in January 2000. It was designed to cover the research focused on developing materials in bio-mimetics and nanotechnology fields. The purpose of BIOS is to work on the interface of biotechnology and nanotechnology in order to create future revolutionary materials. Substantial progress has been made in the area of MAV flapping wings which try to decipher the resonant flight dynamics, as part of morphing (Figure 6) (Swanberg, 2008:5).

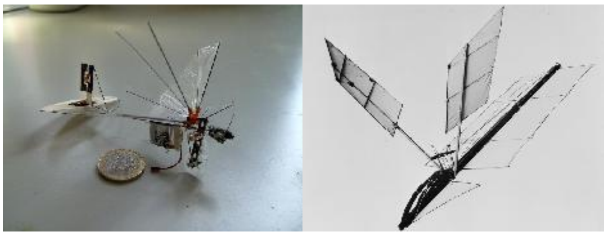

Fig. 6 MAV with flapping wing

BIOS program's contribution was the manufacturing of a lightweight material with tendon-like electro-contractile capacities for command and of a flexible wing material – skin for the dynamic control of the wing (fiber thickness of 200-400 nm). The Tendon was achieved by twisting several fibers, resulting in a material that is responsive to a sinusoidal wave with a certain amount of voltage and frequency.

## 6. OPTIMIZATION AND CONTROL TECHNOLOGIES

Two important technologies within the morphing concept are the optimization of multidisciplinary design and optimal control (Figure 7).

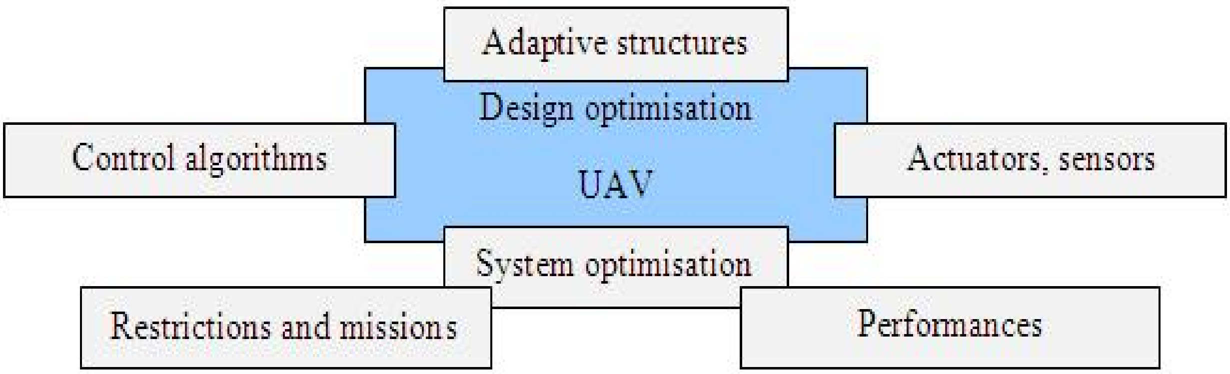


Fig. 7 Design optimization and optimal control

Design optimization is fundamental to the design and operation of future morphing vehicle, for several reasons: 1) during the conceptual design, the optimization of design requires compromises between different fields and it is crucial for the achievement of maximum potential in areas such as active flow control structures adaptive and biologically inspired flight, 2) during the preliminary design, optimal placement of numerous actuators and sensors in vehicles provide efficiency in vehicle design and efficiency in operation, and 3) during detailed design, design optimization allows for efficient flight control algorithms determining the best set of sensors and actuators for various vehicle functions.Optimal control using shape change devices in future aerospace vehicles can use hundreds of distributed matrices for stabilization and maneuver control, thus replacing conventional systems (ailerons, rudder, steering). This approach can reduce fuel consumption, improve maneuverability, adaptability and tolerance to failure. (Weisshaar, 2006:18).

## 7. APPLICATION OF SYSTEMS ENGINEERING IN MITIGATING RISKS PROCESS

Risk management is an ongoing process that provides the basic structure for detection and risk assessment, risk analysis and control

Systems engineering process is essential in the total system life cycle and specific core challenge for the system (Maloş, 2005:47), in a creative way in order to meet the original goal (figure 8).

To perform the analysis it has to identify the risk, including a thorough description of the risk and risk triggers, it can be characterized in terms of probability of occurrence and the consequence if it does occur (Cioacă, 2011:78).

Each stage is a base for the following and it is important to go through each of them before going to the next step. For example, if the risk identification phase is interrupted in order to focus on a specific risk before identifying every possible hazard and other most important dangerous situations may be omitted, the risk management process can be distorted. Until risk identification is complete, it is not possible to rank risks and control measures related to each.

Advantages are not limited to reducing the rate of occurrence of events, but also to of aviation projects, offering as a result the improvement of the performances and the maximize of the operational capacity of the system.

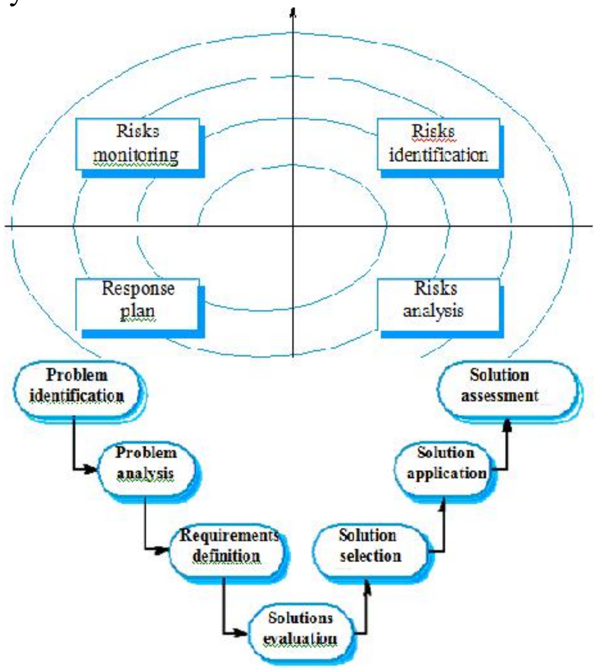


Fig. 8 Engineering systems in risk decision making process

activities must be repeated every time there is a new requirement / increasing the actual effectiveness of the system. Services involving a high degree of risk can be undertaken when the benefits were carefully evaluated versus probability and severity of losses; the analysis of the current practices can reduce the risks currently accepted, decisions are based on a rational and repeatable process rather than intuition; a proper understanding of risks ensures a clear picture of the strengths and weaknesses of the system.

## 8. CONCLUSIONS & ACKNOWLEDGMENT

Morphing UAV projects are under investigation with regard to a number of technologies that will enable adaptability of aircraft, they are focusing on adaptive smart materials, active control structures and biologically inspired technologies.

Currently there are still barriers in terms of flow control on morphing surfaces from the energy use perspective, energy providing control actuators. Therefore, it is desirable that miniaturized sensors and robust actuators with low energy consumption be used.

Basic principles of structural design must be revised to open new approaches generated by the properties of materials used and the operating capacity of systems within the concept of morphing. In addition there are issues to be considered, such as non-invasive electronics, reliability and maintenance of morphing systems.

Disciplinary interaction of advanced structures, smart materials, flow control and biologically inspired technologies will provide multidisciplinary research approaches, applications of advanced adaptive technologies that lead inevitably to further progress.

Cyclic application of risk management process refers to the supervision and review of the feedback early in the process. It is a cyclical feature that generates a continuous improvement of the process features. When determining that certain risks have been significantly reduced, the hazard identification step is repeated to identify new threats. In this way, risk management process continuously reassesses risks.

The authors wish to thank the “Transilvania” University Braşov and ”Henri Coandă” Air Force Academy.

**BIBLIOGRAPHY**

1. Amin, M. (2002). Restructuring the Electric Enterprise. Simulating the Evaluation of the Electric Power Industry with Intelligent Adaptive Agents, in *Electricity Pricing in Transition.* Boston: Kluwer Academic Publisher..
2. Cioacă, C. (2011). Qualitative Risk Analysis Methods in Aviation Projects. in *Journal of Defense Resources Management.* No. 1(2). 77-84.
3. Evers, J.H. (2007). Biological inspiration for agile autonomous air vehicles. *Meeting Proceedings RTO-MP-AVT-146*, Paper 15. Neuilly-sur-Seine, France.
4. Florance, J.P., Burner, A.W., Fleming, G.A., Hunter, C.A., Graves, S.S. (2003) Contributions of the NASA Langley Research Center to the RPA/AFRL/NASA/ Northrop Grumman Smart Wing Program. *AIAA Dynamics Specialists Conference*. April 9-10.
5. Malos, G. (2005). *Ingineria sistemelor în managementul achiziţiilor pentru apărare*. Bucharest: The National Defense University Publishing House.
6. McGowan, A.R., Cox, D.E., Lazos, B.S., Waszak, M.R., Raney, D.L., Siochi E.J., Pao, S.P. (2003). Biologicaly-inspired technologies in NASA’s morphing project. *Smart structures and materials, proceedings of SPIE*, vol. 50-51.
7. Roberson P.C., Bockman, J.F. (2002). Miniaturized High Voltage Amplifiers for Piezoelectric Actuators. *Actuator 2002*, Paper 23. Bremen, Germany.
8. Swanberg, C.E. (2008). *Biomimetic micro air vehicle testing development and small scale flapping-wing analysis.* PhD thesis. Wright-Patterson Air Force Base, Ohio: Air force Institute of technology, Department of the Air Force University.
9. Weisshaar, T.A. (2006). Morphing Aircraft Technology – New Shapes for Aircraft Design. *NATO unclassified documents. Meeting Proceedings RTO-MP-AVT-141*.