HOST INSTITUTION,
UNIVERSITY OF CRAIOVA

Project no. 89/1.10.2015

Program:	**Human Resources**
Project type:	**Young Teams**
Project Cods:	**PN-II-RU-TE-2014-4-0849**

SYSNTHESYS OF THE WORK,

containing the activity and the obtained results in comparison with the objectives of the project

for

- Stage II (2016) -

Project title:

MODERN ARCHITECTURES FOR THE CONTROL OF AIRCRAFT LANDING

Stage II (2016), ***Design, validation and optimizing of the optimal Auto Landing System***, took 12 months (January - December); in this period, one has completely performed all the **8 activities**:

II.1. Design of the H_2/H_∞ control laws (longitudinal and lateral-directional planes).

II.2. Design of the blocks for the reference models, geometry of landing and the dynamic compensator (longitudinal and lateral-directional planes).

II.3. Design of the PCH blocks using classical or fuzzy methods (longitudinal and lateral-directional planes).

II.4. Design of the optimal landing control systems (longitudinal and lateral-directional planes).

II.5. Interconections of the two optimal subsystems and the obtaining of a new system for the control of aircraft landing.

II.6. Software implementation of the system for the landing optimal control.

II.7. Organizing of a special session within IEEE International Conference - ICATE'16.

II.8. Results' dissemination.

and one has also accomplished all the **6 specific objectives:**

OS5. To design a new optimal landing system (longitudinal plane) by using the H_2/H_∞ technique, the dynamic inversion approach, reference models, the geometry of landing, and dynamic compensators, taking into account the sensor errors, the wind shears, and the atmospheric turbulences (*innovative architecture*).

OS8. To interconnect the two automatic landing subsystems and to obtain a new and innovative ALS based on the H_2/H_∞

technique and the dynamic inversion approach (*innovative auto-pilot architecture*).

OS9. To software implement, test and validate the new optimal ALS (*software package*).

OS12. To design a Pseudo Control Hedging block (PCH), for aircraft motion in longitudinal plane, by using a new method based on fuzzy logic (*innovative architecture*).

OS21. To disseminate the results in the scientific, academic and socio-economic environment.

Beside the acomplish of the scientific activities, the members of **the team achieved administrative and management activities (elaboration of scientific rapports, tasks distribution, tracking deadlines etc.), which competed at the completion of this stage in good condition.** Also, there were **regular meetings** between team members of the team, especially given that the two PhD students involved in the project are PhD students of "Politehnica" University of Bucharest. Also, the research team was met in full in eight meetings to analyze activities and results so far achieved and to determine future actions of each member program. Funds allocated at this stage both for mobility, logistic and staff costs were managed successfully so that all objectives of the stage have been achieved.

Activitaty II.1. Design of the H_2/H_∞ control laws (longitudinal and lateral-directional planes).

This activity included **3 steps**:

- Establishment of aircraft dynamics in longitudinal and lateral-directional plane;
- Design of the control law (longitudinal plane)
- Design of the control law (lateral-directional plane)

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Activitaty II.2. Design of the blocks for the reference models, geometry of landing and the dynamic compensator (longitudinal and lateral-directional planes)

Because of the copyright rules, the detailed scientific issues and achievements can not be presented here; this information can be obtained only from the web platform of UEFISCDI with the acceptance of this institution and of the project manager.

Activitaty II.3. Design of the PCH blocks using classical or fuzzy methods (longitudinal and lateral-directional planes)

Because of the copyright rules, the detailed scientific issues and achievements can not be presented here; this information can be obtained only from the web platform of UEFISCDI with the acceptance of this institution and of the project manager.

Activitaty II.4. Design of the optimal landing control systems (longitudinal and lateral planes)

Because of the copyright rules, the detailed scientific issues and achievements can not be presented here; this information can be obtained only from the web platform of UEFISCDI with the acceptance of this institution and of the project manager.

Activitaty II.5. Interconections of the two optimal subsystems and the obtaining of a new system for the control of aircraft landing

Because of the copyright rules, the detailed scientific issues and achievements can not be presented here; this information can be obtained only from the web platform of UEFISCDI with the acceptance of this institution and of the project manager.

Activitaty II.6. Software implementation of the system for the landing optimal control

Because of the copyright rules, the detailed scientific issues and achievements can not be presented here; this information can be obtained only from the web platform of UEFISCDI with the acceptance of this institution and of the project manager.

Activitaty II.7. Organizing of a special session within IEEE International Conference - ICATE'16

The seventh activity during stage II of the project was the organizing of a special session for aircraft landing during a very good indexed international conference. This purpose has been achieved within the ***IEEE International Conference on Applied and Theoretical Electricity 2016 (ICATE 2016)*** – *ISI indexed conference*. Organized every two years starting with 1991, the International Conference on Applied and Theoretical Electricity has increased constantly in terms of organizational facilities, number of participants from Romania and abroad, scientific quality and visibility for academia and industry at regional and European level. The technical program committee was renewed over time with prominent specialists and the criteria of paper acceptance become more and more restrictive. As recognition of the increased scientific level, the two last editions (ICATE2012, ICATE2014) benefited by the IEEE technical co-sponsorship (IEEE Conference Record Numbers: #20803, #32678), and the conference proceedings were included in IEEEXplore database and Thomson Reuters ISI Conference Proceedings Citation Index. The web page of the conference is http://elth.ucv.ro/icate/icate16/.

The name of the special session organized within ICATE 2016 was „***Electrical Engineering in Transportation Systems (1) – Systems and equipment for aircraft landing***"; one of the session chairs was Prof. Romulus Lungu (member of our research team). A proof is presented below (Fig. 21 – list with regular sessions witin ICATE 2016; Fig. 22 – the list of papers accepeted for presentation in the special session).

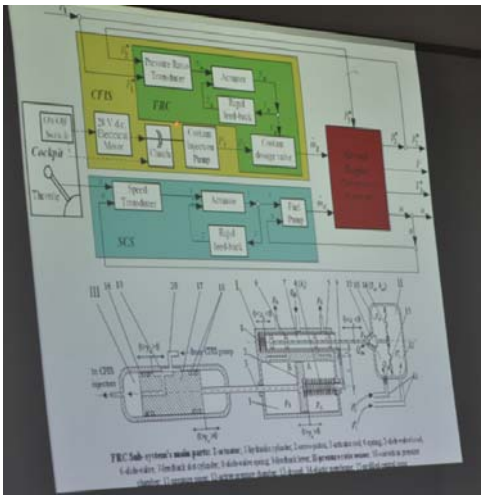
ICATE 2016 – *Conference program*

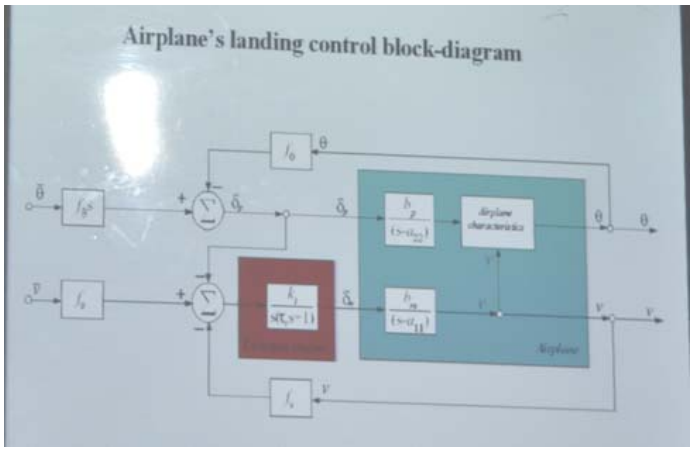
Location / Hours	University of Craiova, Faculty of Law Calea Bucuresti 107D, Craiova			
Thursday, October 6				
9:00-10:00	Registration			
10:00-10:30	**Opening ceremony / location Aula Magna**			
10:30-11:00	Coffee Break / location Aula Magna lobby			
11:00-12:30	**Plenary session – Keynote Speeches / location Aula Magna**			
13:00-14:00	Lunch / location Emma Est Hotel, Calea Bucuresti 82A, Craiova			
	Workshops and Regular sessions			
	Room A	Room B	Room C	Room D
15:00-17:00	RS3. Control Systems Chairs: Teodor Pana Viorel Stoian	RS5. Electrical Machines and Drives (1) Chairs: Aurel Campeanu Mircea Radulescu	RS4. Power and Energy Systems (1) Chairs: Leszek S. Czarnecki Leonardo Geo Manescu	RS8. Industrial Applications (1) Chairs: Alexandru Morega Maria Brojboiu
17:00-17:30	*Coffee Break*			
17:30-19:30	WS3. New trends in electrical drive for intelligent traction systems Chairs: Petre Marian Nicolae Sorin Enache	RS5. Electrical Machines and Drives (2) RS6. Power Electronics Chairs: Virgiuliu Fireteanu Sergiu Ivanov	RS1. Circuits and Systems RS2. Magnetics Chairs: Dragos Niculae Elena Helerea	RS8. Industrial Applications (2) Chairs: Petru Notingher Virginia Ivanov
Friday, October 7				
09:00-11:00	WS1. Safer EMF working environment in EU Chairs: Mihaela Morega Jolanta Karpowicz	WS2. Wireless Power Transfer Systems Chairs: Mihai Iordache Andrei Marinescu	RS4. Power and Energy Systems (2) Chairs: Florin Munteanu Stefan Gheorghe	RS10. Electrical Engineering in Transportation Systems (1) - Systems and equipment for aircraft landing Chairs: Romulus Lungu Stefan Luzica
11:00-11:30	*Coffee Break*			
11:30-13:30	WS1. Safer EMF working environment in EU RS7. Electromagnetic Compatibility and Engineering in Medicine and Biology Chairs: Calin Munteanu Lucian Mandache	RS8. Industrial Applications (3) RS9. Environment Engineering and Equipment Chairs: Constantin Bulac Dorin Lucache	RS4. Power and Energy Systems (3) Chairs: Mircea Chindris Denisa Rusinaru	RS10. Electrical Engineering in Transportation Systems (2) Chairs: Marius Minea Alexandru Tudosie
13:30-14:30	Lunch / location Emma Est Hotel, Calea Bucuresti 82A, Craiova			
15:00	Departure to Cetate – Culture Port for Gala Dinner. *Meeting point*: Emma Est Hotel, Calea Bucuresti 82A, Craiova			
17:00-23:00	Gala Dinner			
Saturday, October 8				
10:00-12:00	Research facilities in Electrical Engineering – Guided tour			
12:00-12:30	Closing Ceremony, Aula Marius Preda, Faculty of Electrical Engineering			

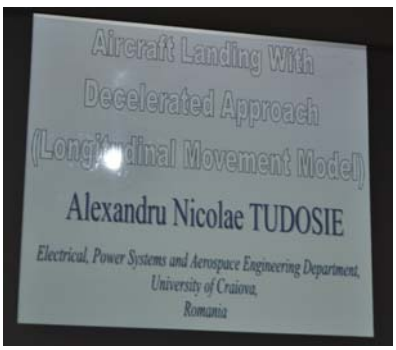
Fig. 21. List with regular sessions witin ICATE 2016 (conference program)

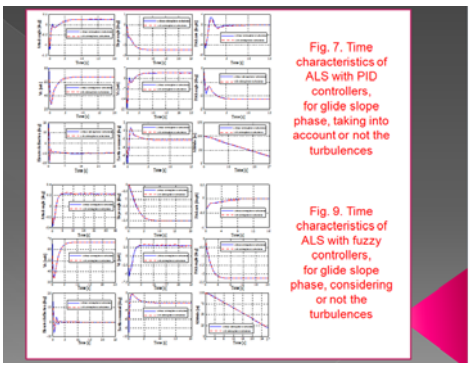
RS 10	**Electrical Engineering in Transportation Systems (1)**
10.1	George Cristian Calugaru, Elena Andreea Danisor: *Dynamic Matrix Control Used in Stabilizing Aircraft Landing*
10.2	Mihai Lungu, Romulus Lungu, Lucian Grigorie, Octavian Preotu: *The Influence of Atmospheric Turbulences on Aircraft Landing Process*
10.3	Stefan Luzica, Radim Bloudicek: *The Hyperbolic Time Difference of Arrival Passive Surveillance System Analysis and Its Application for Precision Approach and Landing*
10.4	Alexandru Nicolae Tudosie: *Aircraft Engine with Coolant Injection into Its Compressor and Flow Rate Controller as Controlled Object*
10.5	Liviu Dinca, Jenica Ileana Corcau, Eduard Ureche: *Mathematical Modeling for Buck Converter in Continuous Conduction Mode*
10.6	Alexandru Nicolae Tudosie, Florentin Alin Butu: *Aircraft Landing With Decelerated Approach (Longitudinal Movement Model)*

Fig. 22. List of papers accepeted for presentation in our special session









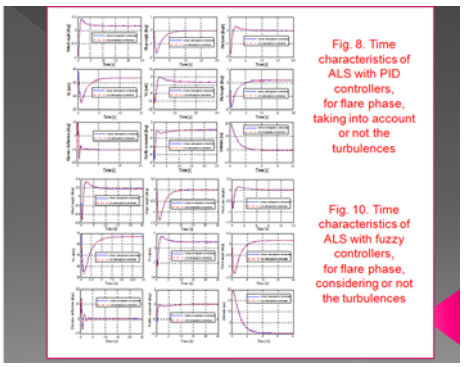


Fig. 23. Images from the session of papers' presenting

The special session included 6 papers (see Fig. 22); two of them (**papers 10.2 and 10.6**) have the Acknowledgment of our project (grant no. 89/1.10.2015 - Modern architectures for the control of aircraft landing). In the following pictures, we present images from the session of papers' oral presentation.

Activitaty II.8. Results' dissemination

The 8th activity of project's second stage (2016) was intended to carry out the objective ***OS21*** (*To disseminate the results in the scientific, academic and socio-economic environment*). It was conducted throughout the stage and materialized through a web page actualization with all the information regarding the achievements during Stage II and the accomplishment of the project's objectives. The links for the web page are:

- http://www.elth.ucv.ro/~mlungu/ro/TINERE_ECHIPE-48 (Romanian);
- http://www.elth.ucv.ro/~mlungu/en/YOUNG_TEAMS-50 (English)

From the expected results' point of view, the research team had the following targets during 2016:

1) *Design of a new optimal control system using the dynamic inversion and H_2/H_∞ techniques*. **This aim of the project has been acomplished by designing the automatic landing system from Fig. 8**.
2) *Software package for the automatic landing system*. This aim of the project has been acomplished by obtaining the **Matlab/Simulink programs from Appendix (landing in two planes: longitudinal and lateral) and the Simulink models from Figs. 9, 10 and 11**.
3) *Phase repport* (**the present document**).
4) *Publishing of 2 papers in ISI Journals and 4 papers in other databases*. In 2016, the members of the research team have published **2 papers in ISI Journals, 5 papers in international databases (ISI Web of Science and IEEE Xplore), and 1 chapter in an international book (ISI Web of Science)**. Thus, **the target related to the papers' publishing has been reached and even exceeded**. Below, we present the the 7 papers (with a short description) published in 2016 by the members of the research team.

4.1. Lungu, R., Lungu, M. *Design of Automatic Landing Systems using the H-inf Control and the Dynamic Inversion*. Journal of Dynamic Systems, Measurement and Control (Transactions of ASME), vol. 138, no. 2, 5 pp, 2016, ISSN: 0022-0434 (***ISI Journal***). *Databases: ISI Web of Science.*

4.2. Lungu, R., Lungu, M. *Adaptive Flight Control Law Based on Neural Networks and Dynamic Inversion for Micro Aerial Vehicles*. Neurocomputing Journal, vol. 199, pp. 40-49, 2016, ISSN: 0925-2312 (***ISI Journal***). *Databases: ISI Web of Science*.

4.3. Lungu, M., Lungu, R., Tutunea, D. *Control of Aircraft Landing using the Dynamic Inversion and the H-inf Control*. 17th International Carpathian Control Conference (ICCC 2016), Tatranská Lomnica, Slovak Republic, May 29 - June 1, 2016, pp. 461-466. *Databases: IEEE Xplore.*

4.4. Lungu, M., Lungu, R., Preotu, O. *Estimation of Aircraft State during Landing by means of Multiple Observers*. 23th International Conference on Systems, Signals and Image Processing (IWSSIP 2016), 23-25 May 2016, Bratislava, Slovakia. *Databases: IEEE Xplore*.

4.5. Lungu, M., Lungu, R. *Reduced-Order Multiple Observer for Aircraft State Estimation during Landing*. 11th edition of the International Conference on Trends in Aerospace, Robotics, Manufacturing Systems, Mechanical Engineering, Bioengineering, Power and Energy Engineering, Materials Engineering, Jupiter, 29 iunie - 2 iulie 2016; Applied Mechanics and Materials, vol. 841, 2014, pp. 253-259, 2016, DOI:10.4028/www.scientific.net/AMM.841.253 ISSN: 1660-9336 (***ISI Proceedings***). *In the indexing process in the databases: ISI Web of Science*.

4.6. Lungu, M., Lungu, R., Grigorie, L., Preotu, O. *The Influence of Atmospheric Turbulences on Aircraft Landing Process*. International Conference on Applied and Theoretical Electricity – ICATE 2016 (***ISI Proceedings***). *In the indexing process in the databases: ISI Web of Science, IEEE Xplore*.

4.7. Tudosie, A., Butu, A. *Aircraft Landing With Decelerated Approach (Longitudinal Movement Model)*. International Conference on Applied and Theoretical Electricity – ICATE 2016 (***ISI Proceedings***). *In the indexing process in the*

databases: ISI Web of Science, IEEE Xplore.

4.8. Lungu, R., Lungu, M. *Aircraft Landing Control Using the H-inf Control and the Dynamic Inversion Technique*. Chapter in the book „Automation and Control Trends", ISBN 978-953-51-2671-3 (editors: Pedro Ponce, Arturo Molina Gutierrez, Luis M. Ibarra). Intech Publisher, 2016, pp. 101-120. *In the indexing process in the databases: ISI Web of Science*.

Short description of the 7 published papers:

- Lungu, R., Lungu, M. *Design of Automatic Landing Systems using the H-inf Control and the Dynamic Inversion*. Journal of Dynamic Systems, Measurement and Control (Transactions of ASME), vol. 138, no. 2, 5 pp, 2016, ISSN: 0022-0434 (***ISI Journal***). *Databases: ISI Web of Science*.

The paper focuses on the automatic control of aircraft in the longitudinal plane, during landing, by using the linearized dynamics of aircraft, taking into consideration the wind shears and the errors of the sensors. A new robust automatic landing system is obtained by means of the H-inf control, the dynamic inversion, an optimal observer and two reference models providing the aircraft desired velocity and altitude. The theoretical results are validated by numerical simulations for a Boeing 747 landing; the simulation results are very good (Federal Aviation Administration accuracy requirements for Category III are met) and show the robustness of the system even in the presence of wind shears and sensor errors. Moreover, the designed control law has the ability to reject the sensor measurement noises and wind shears with low intensity.

- Lungu, R., Lungu, M. *Adaptive Flight Control Law Based on Neural Networks and Dynamic Inversion for Micro Aerial Vehicles*. Neurocomputing Journal, vol. 199, pp. 40-49, 2016, ISSN: 0925-2312 (***ISI Journal***). *Databases: ISI Web of Science.*

The paper presents two new adaptive systems, for the attitude's control of the micro aerial vehicles (MAVs) – insect type. The dynamic model describing the motion of MAVs with respect to the Earth tied frame is nonlinear and the design of the new adaptive control system is based on the dynamic inversion technique. The inversion error is calculated with respect to the control law and two matrices (inertia and dynamic damping matrices) which express the deviation of the estimated matrices relative to the calculated ones (the matrices from the nonlinear dynamics of MAVs) in conditions of absolute stability in closed loop system by using the Lyapunov theory. To completely compensate this error, an adaptive component (output of a neural network) is added in the control law. The system also includes a second order reference model which provides the desired attitude vector and its derivative. The two variants of the new adaptive control system are validated by complex numerical simulations.

- Lungu, M., Lungu, R., Tutunea, D. *Control of Aircraft Landing using the Dynamic Inversion and the H-inf Control*. 17th International Carpathian Control Conference (ICCC 2016), Tatranská Lomnica, Slovak Republic, May 29 - June 1, 2016, pp. 461-466. *Databases: IEEE Xplore.*

The paper focuses on the automatic control of aircraft in the longitudinal plane, during landing, by using the literalized dynamics of aircraft, taking into consideration the wind shears and the errors of the sensors. The H-inf control provides robust stability with respect to the uncertainties caused by different disturbances and noise type signals, while the dynamic inversion provides good precision tracking. A new robust automatic landing system (ALS) is obtained by means of the H-inf control, the dynamic inversion, optimal observers, a dynamic compensator and two reference models providing the aircraft desired velocity and altitude. The theoretical results are validated using numerical simulations for a light aircraft landing; the simulation results are very good (Federal Aviation Administration accuracy requirements for Category III are met) and show the robustness of the algorithm even in the presence of wind shears and sensor errors.

- Lungu, M., Lungu, R., Preotu, O. *Estimation of Aircraft State during Landing by means of Multiple Observers*. 23th International Conference on Systems, Signals and Image Processing (IWSSIP 2016), 23-25 May 2016, Bratislava,

Slovakia. *Databases: IEEE Xplore*.

The paper presents three multiple observers which are useful for the state reconstruction in the case of nonlinear systems characterized by unknown inputs. In the observers' design process, the Lyapunov and linear matriceal inequality theories are used. The paper inovation is related to the use of Takagi-Sugeno multiple-model and multiple observers to the estimation of an aircraft state during the landing process. The validation of the three observers' design algorithms is achieved through complex numerical simulations in Matlab/Simulink; the states and the unknown input vectors of the Takagi-Sugeno multiple-models are estimated and it is proved the proper functioning of the multiple observers as well as the very good estimation of the system's states.

- Lungu, M., Lungu, R. *Reduced-Order Multiple Observer for Aircraft State Estimation during Landing*. 11th edition of the International Conference on Trends in Aerospace, Robotics, Manufacturing Systems, Mechanical Engineering, Bioengineering, Power and Energy Engineering, Materials Engineering, Jupiter, 29 iunie - 2 iulie 2016; Applied Mechanics and Materials, vol. 841, 2014, pp. 253-259, 2016, DOI:10.4028/www.scientific.net/AMM.841.253 ISSN: 1660-9336 (***ISI Proceedings***). *In the indexing process in the databases: Google Scholar, ISI Web of Science*.

The paper presents a new reduced-order multiple observer which can achieve the finite-time reconstruction of the system's state associated to a multiple-model. This observer is a combination of a reduced-order observer and a full-order multiple observer. The design of the new observer involves the usage of the Lyapunov theory, the solving of a linear matriceal inequality, and a variables' change. The steps of the design procedure have been software implemented in order to validate the new reduced-order multiple observer for the case of an aircraft motion during landing.

- Lungu, M., Lungu, R., Grigorie, L., Preotu, O. *The Influence of Atmospheric Turbulences on Aircraft Landing Process*. International Conference on Applied and Theoretical Electricity – ICATE 2016 (***ISI Proceedings***). *In the indexing process in the databases: ISI Web of Science, IEEE Xplore*.

The paper presents the automatic control of aircraft in the longitudinal (vertical) plane during landing, taking into account the atmospheric turbulences. The presented structure of automatic landing system consists of two coupled automatic control systems: the former is used for the control of aircraft longitudinal velocity, while the latter performs the control of the flight altitude by means of a subsystem for the pitch angle control; these 2 subsystems are the parts of the same auto-pilot. The control laws are based on the dynamic inversion concept with proportional- integral-derivative controllers in conventional and fuzzy variants. The theoretical results are validated by numerical simulations in the absence or in the presence of atmospheric turbulences.

- Tudosie, A., Butu, A. *Aircraft Landing With Decelerated Approach (Longitudinal Movement Model)*. International Conference on Applied and Theoretical Electricity – ICATE 2016 (***ISI Proceedings***). *In the indexing process in the databases: ISI Web of Science, IEEE Xplore*.

The paper deals with a mathematical model for airplanes' longitudinal movement during the approach-stage of the landing. One has described an aerodynamic decelerated approach and has established the correlation between airplane's flight commands and thrust level (engines' commands). Airplane's command law was issued (a common law, for rudder and throttle positions), according to the approach law, which should be implemented into its board computer for the landing phase of the flight; system's mathematical model was used for some simulations concerning its quality.

- Lungu, R., Lungu, M. *Aircraft Landing Control Using the H-inf Control and the Dynamic Inversion Technique*. Chapter in the book „Automation and Control Trends", ISBN 978-953-51-2671-3 (editors: Pedro Ponce, Arturo Molina Gutierrez, Luis M. Ibarra). Intech Publisher, 2016, pp. 101-120. *In the indexing process in the databases: ISI Web of Science*.

The chapter presents the automatic control of aircraft during landing, taking into account the sensor errors and the wind shears. Both planes – longitudinal and lateral-directional are treated; the new obtained automatic landing system (ALS) will

consists of two subsystems – the first one controls aircraft motion in longitudinal plane, while the second one is for the control of aircraft motion in lateral-directional plane. These two systems can be treated separately but, in the same time, these can be put together to control all the parameters which interfere in the dynamics of aircraft landing. The two new automatic landing systems are designed by using the H-inf control, the dynamic inversion, optimal observers, and reference models. To validate the new obtained automatic landing system, one uses the dynamics associated to the landing of a Boeing 747, software implements the theoretical results and analyzes the accuracy of the results and the precision standards' achievement with respect to the requirements of the Federal Aviation Administration (FAA).

Also, in the last part of year 2016, other **four papers** have been sent for review and possible publish. ***Three of them have been sent to ISI Journals and one paper to an important international conference***. Below, we present their names and a short description of the papers.

- Lungu, R., Lungu, M. *Automatic Landing System using Neural Networks and Radio-technical Subsystems*. Chinese Journal of Aeronautics, ISSN: 1000-9361 (***ISI Journal***). Factor de impact relativ revista: 1.070.
- Lungu, M., Lungu, R. *Landing Auto-pilots for Aircraft Motion in Longitudinal Plane using Adaptive Control Laws Based on Neural Networks and Dynamic Inversion*. Asian Journal of Control, ISSN: 1561-8625 (***ISI Journal***). Journal relative impact factor:1.407.
- Lungu, R., Lungu, M. *Automatic control of the micro aerial vehicles' attitude and position*. International Journal of Micro Aerial Vehicles, ISSN: 1756-8293 (***ISI Journal***). Journal relative impact factor: 0.343.
- Lungu, M., Lungu, R. *Automatic Control of Aircraft Landing by using the H_2/H_∞ Control Technique*. The 36th IASTED International Conference on Modelling, Identification and Control (MIC 2017), February 20-22, 2017, Innsbruck, Austria.

Also it worth mentioning that some of the information obtained from this phase of the project were used to improve the Master course ***„Aircraft automatic flight control during landing"***, University of Craiova.

Taking into account all the issues presed above, for Phase II of the project (*Design, validation and optimizing of the optimal Auto Landing System*), we consider that all the eight specific activities were fully acomplished and all the 5 specific objectives of Phase II were achieved. Thus, the achievement of all the objectives originally set for this phase creates the premises to solve successfully the next stage of the project – *Design, validation and optimization of the adaptive ALS. Comparative studies between the two designed ALSs.* The first activity within Phase III - 2017 (*Acivity III.1. Optimization of the optimal ALS and robustness' improvement. Study of the sensor errors and atmospheric disturbances' influence*) will be a continuation of the work done in 2016; with other words, for the complete ALS designed in 2016, we will study the efect of sensor errors and atmospheric disturbances upon aircraft motion during landing and we will improve the robustness of the optimal automatic landing system with respect to these disturbances.

20.12.2015

Project Manager,
Associate Professor PhD. Eng. Mihai LUNGU
Universitatea din Craiova