Estimated deliverables (as per Addendum No. 7)	Deliverables completed
• Scientific and financial report	• completed 100%
• Project Website Update	• completed 100%
• 10 papers in ISI Q1 journals (open access) that have been published or are under review	• 17 papers in ISI Q1 journals (10 published papers with a cumulative impact factor of 51.5, 7 under review)
• 10 conference papers published or under review	• 29 conference papers (15 papers published and indexed in ISI proceedings, 1 international conference paper, 7 IEEE conference papers, 1 ISI proceedings paper currently being indexed, 5 ISI proceedings papers under review)
• Software application	• patient simulator, programs for digitizing disturbances, MATLAB programs for designing control algorithms, programs for estimating Hill parameters and dead time, programs for designing control algorithms, fully developed functional demonstrator (patient simulator), fully developed graphical user interface
• 2 special sessions	• 4 special sessions organized as part of the conferences: o ECC (22nd European Control Conference, June 25-28 2024, Stockholm, Sweden) o PID (4th IFAC Conference on Advances in Proportional-Integral-Derivative Control (PID 2024), June 12-14 2024, Almería, Spain) o ICSTCC (29th International Conference on System Theory, Control and Computing, October 9-11 2025, Cluj-Napoca, Romania) o AQTR (IEEE International Conference on Automation, Quality and Testing, Robotics, May 21-23 2026, Băile Felix, Romania)

• At least 2 research mobility periods	• Research mobility aimed at planning future project activities and resulting in a draft patent application: Mureșan Cristina Ioana, mobility from June 4–11, 2025, at Ghent University, Belgium. • Research mobility aimed at conducting collaborative research in the field of fractional-order controllers and comparing them with other methods, as well as presenting the developed simulator, networking, and participating in the ARCAI 2025 conference, resulting in a Best Oral Presentation Award
• 1 patent application	• A00544/20.11.2025 entitled "Experimental Stand: Synthetic Data Generator and Anesthesia Training Tool," filed with OSIM.
• 1 eligible Horizon project proposal	• 2 eligible Horizon project proposals (led by Clara Ionescu, led by Isabela Birs)
• 2 proposals for national research grants	• 2 research grant proposals (1 Innovation Grant led by Eva Dulf, 1 PED led by Cristina Muresan)

Dissemination of results - published papers:

1. A.R. Ynineb, D. Copot, E. Yumuk, R. De Keyser, H. Farbakhsh, G. Ben Othman, C. Muresan, I. Birs, S. Ladaci, M. Neckebroek, C.M. Ionescu (2025), Pharmacokinetic modelling during long term anesthesia: minimizing the gap, *Journal of Advanced Research*, doi: 10.1016/j.jare.2025.06.047 (**ISI Q1, impact factor 13.0)**
2. P.A. Pintea, E. Dulf (2024), Modelling Nonlinear Systems For Drug Administration Via Koopman Operator, *International Conference on Mathematical Analysis and Applications in Science and Engineering*, June 20-22 , Porto, Portugalia (conferință internațională, lucrarea urmează să fie publicată în editura Springer)
3. P.A. Pintea, E. Dulf (2024), Weight Matrix Syntheses Using the Controllability Gramian for LQR Anaesthesia Control, *IEEE International Conference on Automation, Quality and Testing, Robotics - AQTR 2024*, May 16-18, 2024, Cluj-Napoca, Romania, pp. 1-6, doi: 10.1109/AQTR61889.2024.10554112. (**ISI Proceedings**, WOS:001253157800012)
4. P.A. Pintea, E. H. Dulf, C.I. Muresan, C.M. Ionescu (2024), Inducing Anaesthesia via Exact Feedback Linearization control, *4th IFAC Conference on Advances in Proportional-Integral-Derivative Control (PID 2024)*, June 12-14, Almería, Spain, vol. 58 (7), pp.246-251, doi: 10.1016/j.ifacol.2024.08.069 (**ISI Proceedings,** WOS:001302114600042)

5. E. Hegedus, M.D. Mihai, I.R. Birs, H. Farbakhsh, E. Yumuk, D. Copot, E.H. Dulf, R. De Keyser, C.M. Ionescu, C.I. Muresan (2024), Analysis and Preliminary Results of a Feedback-Feedforward Controller for Depth of Anesthesia, *4th IFAC Conference on Advances in Proportional-Integral-Derivative Control (PID 2024)*, June 12-14, Almería, Spain, vol. 58 (7), pp.216-221, doi: 10.1016/j.ifacol.2024.08.037 (**ISI Proceedings**, WOS:001302114600037)
6. M.D. Mihai, I.R. Birs, E. Hegedus, D. Copot, M. Neckebroek, R. De Keyser, C.M. Ionescu, C.I. Muresan (2024), First-Hand Design of a Fractional order PID for Controlling the Depth of Hypnosis during Induction, *4th IFAC Conference on Advances in Proportional-Integral-Derivative Control (PID 2024)*, June 12-14, Almería, Spain, vol. 58 (7), pp.186-191, doi: 10.1016/j.ifacol.2024.08.032 (**ISI Proceedings**, WOS: 001302114600032)
7. A.R. Ynineb, M.D. Mihai, E. Yumuk, H. Farbakhsh, G. Ben Othman, R. De Keyser, C.I. Muresan, I.R. Birs, D. Copot, C. M. Ionescu (2024), Fractional Order PID Control of Propofol Dosage and Optimization in Lean and Obese Patients, *4th IFAC Conference on Advances in Proportional-Integral-Derivative Control (PID 2024)*, June 12-14, Almería, Spain, vol. 58 (7), pp. 228-233, doi: 10.1016/j.ifacol.2024.08.039 (**ISI Proceedings**, WOS:001302114600039)
8. E. Hegedus, M.D. Mihai, I.R. Birs, H. Farbakhsh, E. Yumuk, D. Copot, R. De Keyser, C.M. Ionescu, C.I. Muresan (2024), A Decoupled Fractional Order Control Strategy to Increase Patient Safety During Anesthesia-Hemodynamic Interactions, *22nd European Control Conference*, June 25-28, Stockholm, Sweden, pp. 3039-3044, doi: 10.23919/ECC64448.2024.10591046 (**ISI Proceedings**, WOS:001290216502129)
9. E.T. Hegedüs, I.R. Birs, C.M. Ionescu, C.I. Muresan (2024), A novel decentralized-decoupled fractional order control strategy for complete anesthesia-hemodynamic stabilization in patients undergoing surgical procedures, *Fractal and Fractional*, 8, 623. https://doi.org/10.3390/fractalfract8110623 (**ISI Q1, impact factor 3.3**)
10. P. A. Pintea, E. H. Dulf (2024), Disturbance modelling in Anaesthesia Control using Regression Models based on Gauss Processes, *2024 IEEE 22nd Jubilee International Symposium on Intelligent Systems and Informatics (SISY), Pula, Croatia,* pp. 000411-000414, doi: 10.1109/SISY62279.2024.10737550 (IEEE)
11. C.M. Ionescu, R. De Keyser, D. Copot, E. Yumuk, I.R. Birs, E. Hegedus, C.I. Muresan, M. Neckebroek (2024), Minimizing Epistemic Uncertainty for Predictive Control of General Anesthesia, *2th IFAC Symposium on Biological and Medical Systems*, IFAC-PapersOnLine, Vol. 58(24), pp. 490-495, https://doi.org/10.1016/j.ifacol.2024.11.086. (**ISI Proceedings**, WOS:001359709100085)
12. E. T. Hegedus, M.D. Mihai, G. Ben Othman, D. Copot, I.R. Birs, C.I. Muresan (2024), Comparative analysis for the maintenance phase of depth of anesthesia: decentralized or decoupled?, *The International Conference on Electrical, Computer, Communications and Mechatronics Engineering*, 4-6 November 2024, Male, Maldives, pp. 01-06, doi: 10.1109/ICECCME62383.2024.10797115. (IEEE)
13. T. Popescu, N. Badau, M. Mihai, E. Hegedus, I. Birs, D. Copot, E. H. Dulf, C.I. Muresan (2024), Advancing Anesthesia Education: Training on Modeling and Control for Enhanced Patient Care, *4th Workshop on Internet Based Control Education*, IFAC-PapersOnLine, Vol. 58(26), pp. 152-157, https://doi.org/10.1016/j.ifacol.2024.10.287 (**ISI Proceedings**, WOS: 001354678800027)

14. E.-H. Dulf, P. A. Pintea, C. I. Muresan (2024), Anesthesia Control using Fractional Order Controller, The IEEE 18th International Conference on Control, Automation, Robotics and Vision (ICARCV 2024), 12-15 December 2024, Dubai UAE, pp. 1178-1181, doi: 10.1109/ICARCV63323.2024.10821592 (**ISI Proceedings**, WOS:001435120000188)
15. M. D. Marcian, I. Birs, E. Hegedus, A. Ynineb, D. Copot, R. De Keyserb, C.M. Ionescu, S. Ladaci, C.I. Muresan, M. Neckebroek (2025), Online and Personalised Control of the Depth of Hypnosis during Induction using Fractional order PID, *Journal of Advanced Research,* https://doi.org/10.1016/j.jare.2025.03.05 (**ISI Q1, impact factor 13**)
16. E. Hegedus, A. Maxim, M. Mihai, I.R. Birs, N. Badau, C.I. Muresan (2025), Multivariable control in general anesthesia: A comparative study of model predictive control and fractional order control, *IEEE 12thInternational Joint Conference on Cybernetics and Computational Cybernetics, Cyber-Medical Systems (ICCC 2025)*, April 9-11 2025, Seychelle Islands, pp. 27-32, doi: 10.1109/ICCC64928.2025.10999109 (**ISI Proceedings**, WOS:001510286600005)
17. R. D. Keyser, I. R. Birs, C. I. Muresan and C. M. Ionescu (2025), A practical closed loop transfer function estimation method to enable better control performance, 2025 11th International Conference on Control, Decision and Information Technologies *(CoDIT)*, Split, Croatia, 2025, pp. 1-6, doi: 10.1109/CoDIT66093.2025.11321876 (IEEE)
18. C. I. Muresan, M. D. Mihai, E. Hegedus, N. Badau, I. R. Birs, R. De Keyser (2026), A Robust Fractional Order PI Controller for Time Constant Variations, Fractional Calculus and Applied Analysis, doi: 10.1007/s13540-026-00488-8 (**ISI Q1, impact factor 2.9**)
19. N. Badau, T. Popescu, M. Mihai, I. Birs and C. Muresan (2025), Personalized Control using Fractional Calculus for Patients Experiencing Surgical Stimuli, *2025 29th International Conference on System Theory, Control and Computing (ICSTCC)*, Cluj-Napoca, Romania, 2025, pp. 480-485, doi: 10.1109/ICSTCC66753.2025.11240297 (IEEE)
20. Mihai, M.D.; Birs, I.R.; Badau, N.E.; Hegedus, E.T.; Ynineb, A.; Muresan, C.I. Personalised Fractional-Order Autotuner for the Maintenance Phase of Anaesthesia Using Sine-Tests. Fractal Fract. 2025, 9, 317. https://doi.org/10.3390/fractalfract9050317 (**ISI Q1, impact factor 3.3**)
21. I. Birs, C. Rizel, M. Mihai, C. Muresan and R. De Keyser, Validation of a short relay test PID autotuner on a nonlinear process with stochastic disturbances, 2025 33rd Mediterranean Conference on Control and Automation (MED), Tangier, Morocco, 2025, pp. 305-310, doi: 10.1109/MED64031.2025.11073414 (**ISI Proceedings**, WOS:001556094800052)
22. A. C. Maliţa and C. I. Mureşan, Optimisation of Fractional Order Controllers using Genetic Algorithms for Bispectral Index Regulation, 2025 33rd Mediterranean Conference on Control and Automation (MED), Tangier, Morocco, 2025, pp. 126-131, doi: 10.1109/MED64031.2025.11073313 (**ISI Proceedings**, WOS:001556094800022)
23. A. M. Tudor and C. I. Muresan, Multi-objective genetic algorithm optimization applied on hemodynamic system control, 2025 33rd Mediterranean Conference on Control and

Automation (MED), Tangier, Morocco, 2025, pp. 417-422, doi: 10.1109/MED64031.2025.11073231 (**ISI Proceedings**, WOS:001556094800071)

24. C. I. Muresan, M. D. Mihai, E. Hegedus, N. Badau, T. Popescu and I. R. Birs, Robust Fractional Order Control of a Multivariable Hemodynamic System, 2025 33rd Mediterranean Conference on Control and Automation (MED), Tangier, Morocco, 2025, pp. 678-683, doi: 10.1109/MED64031.2025.11073354 (**ISI Proceedings**, WOS:001556094800115)
25. Malița, A.-C.; Muresan, C.I.; Duarte-Mermoud, M.A.; Ceballos Benavides, G. Adaptive Fractional Order Control for Bispectral Index Regulation During Anaesthesia. Fractal Fract. 2025, 9, 330. https://doi.org/10.3390/fractalfract9060330 (**ISI Q1, impact factor 3.3**)
26. M. D. Mihai, I. R. Birs, E. T. Hegedus and C. I. Muresan (2025), Event-Based PID Control for The Depth of Anesthesia System, 2025 5th International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME), Zanzibar, Tanzania, United Republic of, 2025, pp. 1-6, doi: 10.1109/ICECCME64568.2025.11277978 (IEEE)
27. E. Hegedüs, I. Birs, M. Mihai and C. Muresan (2025), Event-based fractional-order PI control for reduced computational load in decoupled Anesthesia-Hemodynamic systems, 2025 5th International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME), Zanzibar, Tanzania, United Republic of, 2025, pp. 1-5, doi: 10.1109/ICECCME64568.2025.11277760 (IEEE)
28. A. Berciu, L. Kovacs, E. Dulf, Hybrid Supervisory Control for Multi-Input General Anesthesia: Fuzzy PI vs. Rule-Based Control of Cardiac Output, 30th International Conference on System Theory, Control and Computing, Iași, Romania, on October 21st-24th, 2026, în recenzie (IEEE)
29. I. Birs, M. Mihai, E. Hegedus, N. Badau and C. Muresan (2025), Comparative Analysis of Hill-Based Interaction Models for Predicting BIS During General Anesthesia, 2025 5th International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME), Zanzibar, Tanzania, United Republic of, 2025, pp. 1-6, doi: 10.1109/ICECCME64568.2025.11277674 (IEEE)
30. M.D. Mihai, R. De Keyser, I.R. Birs, C.M. Ionescu, C.I. Muresan (2025), A Novel Fractional-Order PID Autotuning Method with Robustness to Time Constant Variation, IEEE/CAA Journal of Automatica Sinica, în recenzie (**ISI Q1**)
31. N.E. Badau, T.M. Popescu, M. D. Mihai, I.R. R. Birs, C. I. Muresan (2025), A robust fractional order controller for biomedical applications, Fractal and Fractional, 9, 597, doi: 10.3390/fractalfract9090597 (**ISI Q1, impact factor 3.3**)
32. T.M. Popescu, N.E. Badau, A.M. Tudor, A.C. Malita, I. R. Birs, C.I. Muresan (2025), Preliminaries on Mean Arterial Pressure Regulation Using Closed Loop Norepinephrine Infusion, Fractal and Fractional, 9(10):657, doi:10.3390/fractalfract9100657 (**ISI Q1, impact factor 3.3**)
33. R. De Keyser, I.R. Birs, C.I. Muresan, C.M. Ionescu (2025), Revisiting the impulse response creates an improved PID autotuner, Scientific Reports, 15, 36203, doi: 10.1038/s41598-025-20027-4 (**ISI Q1, impact factor 3.9**)
34. E. Hegedüs, I. Birs, C. Ionescu, M. Mihai, C.I. Muresan, Event-Based Fractional Order Control for Multi-Drug Anesthesia Systems: Improved Performance with

Computational Efficiency, Biomedical Signal Processing and Control, în recenzie (**ISI Q1**)

35. Nesrine Izemrane, Samir Ladaci, Erwin T. Hegedus, Cristina Muresan (2025), Fractional-order Model Predictive Control Design for Anesthesia–Hemodynamic Stabilization During Surgical Procedures, 13th IFAC Conference on Fractional Differentiation and its Applications, Algiers, Algeria, December 16-18, 2025, IFAC-Papers Online, Vol. 59 (37), pp: 256-261 (**ISI Proceedings**, WOS:001680117000045)
36. Cristina I. Muresan, Marcian D. Mihai, Erwin T. Hegedus, Isabela R. Birs, Clara M. Ionescu, Robin De Keyser (2025), A Simplified Robust Fractional Order PID for Dead Time Processes, The 2nd International Conference on Advanced Robotics, Control, and Artificial Intelligence (ARCAI 2025), November 24-27, 2025, Denarau, Nadi, Fiji, prezentat (**ISI Proceedings**, în curs de indexare)
37. Nicoleta E. Badau, Robin De Keyser, Ghada Ben Othman, Clara M. Ionescu, Marcian D. Mihai, Cristina I. Muresan (2026), A robust fractional order PID controller for FOPDT and SOPDT systems, 23rd IFAC World Congress, 23-26 August 2026, Busan, South Korea, in recenzie (**ISI Proceedings**, în curs de indexare)
38. Erwin Hegedüs, Isabela R. Birs, Bouchra Khoumeri, Ghada Ben Othman, Clara M. Ionescu, Marcian D. Mihai, Cristina I. Muresan (2026), Event-Based Control of Multivariable Anesthesia System: Reducing Dynamic Coupling Through Temporal Decorrelation, 23rd IFAC World Congress, 23-26 August 2026, Busan, South Korea, in recenzie (**ISI Proceedings**, în curs de indexare)
39. R. De Keyser, I. Birs, C. I. Muresan, C. M. Ionescu (2025), Process transient data from basic relay feedback test to autotune PID-controllers, Automatica, în recenzie (**ISI Q1**)
40. Robin De Keyser, Isabela R. Birs, Cristina I. Muresan and Clara M. Ionescu (2025), Transient Relay Test for Controller Tuning, IEEE/CAA Journal of Automatica Sinica, în recenzie (**ISI Q1**)
41. Paul A. Pintea, Eva-H. Dulf (2025), Robust Feedback Linearization for Anaesthesia Control, Journal of Process Control, în recenzie (**ISI Q1**)
42. Ada M. Tudor, Alin C. Malita, Marcian D. Mihai, Erwin T. Hegedus, Isabela R. Birs, Amani R. Ynineb, Clara M. Ionescu, Cristina I. Muresan (2026), A Digital Twin to Enable Personalised Control in Anaesthesia-Hemodynamics, 23rd IFAC World Congress, 23-26 August 2026, Busan, South Korea, in recenzie (**ISI Proceedings**, în curs de indexare)
43. N. Badau, C. Muresan, E. Yumuk (2026), A robust [FO-PID]λ controller for computer-controlled chemotherapy, IEEE International Conference on Automation, Quality and Testing, Robotics, AQTR 2026 (THETA 25), Băile Felix, Romania, on May 21-23, 2026, in recenzie (**ISI Proceedings**, în curs de indexare)
44. Badau, N.E.; Tudor, A.M.; Muresan, C.I. Experimental Validation of a Robust [FO-PID]$^{\lambda}$ Controller. Mathematics 2026, 14, 592. https://doi.org/10.3390/math14040592 (**ISI Q1, impact factor 2.2**)
45. A.M. Tudor, A.C. Malita, C. I. Muresan (2026), A Survey of Patient Simulators for Safe Anesthesia: Advancing Closed-Loop Control Systems, Annual Reviews in Control, in recenzie (**ISI Q1**)
46. E. Hegedus, I. Birs, M. Mihai, B. Khoumeri, C. Ionescu, C. Muresan (2026), Effective Dimensionality of Adaptive Anesthesia Depth Estimation, IEEE Journal Of Biomedical And Health Informatics, in recenzie (**ISI Q1**)

Special sessions organized:

1. C.M. Ionescu, A. Visioli, C.I. Muresan, Special session on "Drug dosing control in anesthesia", *4th IFAC Conference on Advances in Proportional-Integral-Derivative Control (PID 2024)*, June 12-14, Almería, Spain
2. C.I. Muresan, D. Copot, E. Yumuk. M. Neckebroek, Special session on "Multi-Drug Control and Optimization", *22nd European Control Conference*, June 25-28, Stockholm, Sweden
3. E. H. Dulf, C. I. Muresan, L. Kovacs, Special Session on "An Insight into Innovative Approaches In Biomedical Engineering", *29th International Conference on System Theory, Control and Computing*, October 9-11 2025, Cluj-Napoca, Romania
4. M. Mihai, A.G. Berciu, E. Yumuk, Special Session on „Intelligent Systems and Advanced Control Strategies in Biomedical Engineering", *IEEE International Conference on Automation, Quality and Testing, Robotics, AQTR 2026 (THETA 25)*, May 21-23 2026, Băile Felix, Romania

Patent application: A00544/20.11.2025, titled "Experimental stand. Synthetic data generator and training tool for anesthesia," filed with OSIM.

Horizon projects developed and submitted:

1. *Marie Skłodowska-Curie Actions, Doctoral Networks cod HORIZON-MSCA-2025-DN-01.* The proposal is titled *Resilient Tuning and Uncertainty Management in Next-Generation Control Systems* and acronym ReTUNE, ID 101311231, director: Prof.Dr.Ing. Clara Ionescu
2. *HORIZON-ERC, ERC Starting Grant, ERC-2026-STG.* The proposal is titled *Next Generation Anesthesia: Data Centric Patient Simulation Enables Fractional Order PK-PD Modeling on Large Scale Real-Life Data* and acronym AnestheSIM, ID 101303245, director: Sl.Dr.Ing. Isabela Bîrs

National projects developed (to be submitted when calls for proposals open):

1. Innovation voucher (grant). The proposal is titled HeartAI-5D: Automated Solution for Five-Dimensional Cardiovascular Magnetic Resonance (5D-Flow CMR), led by Prof. Dr. Ing. Eva Dulf
2. Experimental Demonstration Project (EDP). The proposal is titled "A cybermedical anesthesia-hemodynamic system for life support, tailored for sedated ICU patients," led by Prof. Dr. Ing. Cristina Muresan

Project website: https://control.utcluj.ro/projects/optimdrug/

Social media presence: https://www.facebook.com/optimdrug.research.project

https://www.linkedin.com/showcase/optimdrug-research-project