

**COURSE OFFERED IN THE DOCTORAL SCHOOL**

|                                |                                                   |                                      |                                                                                               |                                                |            |                |
|--------------------------------|---------------------------------------------------|--------------------------------------|-----------------------------------------------------------------------------------------------|------------------------------------------------|------------|----------------|
| Code of the course             | 4606-ES-00000BH-0016                              | Name of the course                   | Polish                                                                                        | Identyfikacja systemów w inżynierii lotniczej  |            |                |
|                                |                                                   |                                      | English                                                                                       | System identification in aerospace engineering |            |                |
| Type of the course             | specialized                                       |                                      |                                                                                               |                                                |            |                |
| Course coordinator             | Piotr Lichota, PhD, DSc                           |                                      |                                                                                               |                                                |            |                |
| Implementing unit              | The Faculty of Power and Aeronautical Engineering | Scientific discipline / disciplines* | Mechanical Engineering/ Automation, electronic, electrical engineering and space technologies |                                                |            |                |
| Level of education             | PhD                                               | Semester                             | winter                                                                                        |                                                |            |                |
| Language of the course         | english                                           |                                      |                                                                                               |                                                |            |                |
| Type of assessment:            | Credit with a grade                               | Number of hours in a semester        | 30                                                                                            | ECTS credits                                   |            | 2              |
| Minimum number of participants | 10                                                | Maximum number of participants       | 20                                                                                            | Available for students (BSc, MSc)              |            | <u>Yes</u> /No |
| Type of classes                |                                                   | Lecture                              | Auditory classes                                                                              | Project classes                                | Laboratory | Seminar        |
| Number of hours                | in a week                                         | 1                                    |                                                                                               |                                                | 1          |                |
|                                | in a semester                                     | 15                                   |                                                                                               |                                                | 15         |                |

\* does not apply to the Researcher's Workshop

**1. Prerequisites**

Basic knowledge of flight mechanics, mathematical analysis, automation and control.

**2. Course objectives**

The course aims to familiarize the course participants with system identification methods used in aeronautical engineering. After completing the study, the participant can plan identification experiments and define the requirements for measurement data adequate for aircraft motion modeling. The course participant can choose the appropriate estimation method, carry out the system identification for typical flight dynamics problems and validate the results.

**3. Course content (separate for each type of classes)**

**Lecture**

Experiment planning, measurement and data compatibility check, equation error methods, output error methods, filter error methods, identification from frequency responses, artificial neural networks, online identification, dynamically unstable aircraft identification, mathematical models, model validation.

**Laboratory**

Basic systems identification methods, equation error method, maximum likelihood principle, designing system identification experiments.

**4. Learning outcomes**

|           | Learning outcomes description                                                                                                                                           | Reference to the learning outcomes of the WUT DS | Learning outcomes verification methods* |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|-----------------------------------------|
| Knowledge |                                                                                                                                                                         |                                                  |                                         |
| K01       | The course participant has basic knowledge of system identification and flight mechanics for identifying mathematical models describing aircraft movement.              | SD_W2, SD_W3                                     | Written test                            |
| K02       | The course participant knows the types of signals used to identify models that are describing the aircraft motion and can determine their capabilities and limitations. | SD_W2, SD_W3                                     | Written test, report evaluation         |

|                    |                                                                                                                                                                                                                                        |                    |                                 |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|---------------------------------|
| K03                | The course participant knows the basic assumptions of carrying out measurements, mathematical models of the measurement sensors used, and data validation methods used to identify mathematical models describing the aircraft motion. | SD_W2, SD_W3       | Written test                    |
| K04                | The course participant knows the basic estimation methods used to identify mathematical models describing the aircraft motion and their applicability range.                                                                           | SD_W2              | Written test, report evaluation |
| K05                | The course participant knows modifications of the primary identification methods used to describe the aircraft motion for near real-time estimation and dynamically unstable aircraft.                                                 | SD_W2, SD_W3       | Written test                    |
| K06                | The course participant knows how to determine the form and structure of the mathematical model describing the aircraft's motion under test.                                                                                            | SD_W2              | Written test, report evaluation |
| K07                | Uczestnik kursu ma wiedzę w zakresie określania formy i struktury modelu matematycznego opisującego ruch badanego statku powietrznego.                                                                                                 | SD_W2, SD_W3       | Written test, report evaluation |
| Skills             |                                                                                                                                                                                                                                        |                    |                                 |
| S01                | The course participant can plan the identification experiment by themselves.                                                                                                                                                           | SD_U1              | Written test, report evaluation |
| S02                | The course participant can select the appropriate estimation method for the identified aircraft at given flight conditions.                                                                                                            | SD_U1              | Written test                    |
| S03                | The course participant can choose a method for the identification task and carry out the parametric or non-parametric identification process for simple problems.                                                                      | SD_U1, SD_U2, SD_4 | Written test, report evaluation |
| S04                | The course participant can determine the structure of the mathematical model of the identified aircraft and update it.                                                                                                                 | SD_U1, SD_U2       | Report evaluation               |
| S05                | The course participant can use validation methods to analyze the result.                                                                                                                                                               | SD_U2              | Written test, report evaluation |
| Social competences |                                                                                                                                                                                                                                        |                    |                                 |
| SC01               | The course participant formulates priorities in the investigated problems and independently works in searching for information and achieving the assumed goal.                                                                         | SD_K4              | Report evaluation               |
| SC02               | The course participant is aware of their knowledge and skills and understands the need for further professional improvement and personal development.                                                                                  | SD_K1, SD_K2       | Report evaluation               |

\*Allowed learning outcomes verification methods: exam; oral exam; written test; oral test; project evaluation; report evaluation; presentation evaluation; active participation during classes; homework; tests

#### 5. Assessment criteria

During the semester, one test is planned (max. 20 points), laboratory work is assessed (max. 4 points in total), and the presence and activity in the laboratory are monitored (max. 1 point). The student receives a final grade based on the number of points obtained.

#### 6. Literature

Primary literature:

- [1] Jategaonkar, R. V.: "Flight Vehicle System Identification: A Time Domain Methodology," Progress in Astronautics and Aeronautics, AIAA, Reston, VA, 2006.
- [2] Klein, V., Morelli, E. A.: "Aircraft System Identification: Theory and Practice," AIAA Education Series, AIAA, Reston, VA, 2006.
- [3] Tischler, M.B., Rempke, R. K., "Aircraft and Rotorcraft System Identification: Engineering Methods with Flight Test Examples", AIAA Education Series, AIAA, Reston, VA, 2006.

Secondary Literature:

- [1] Goodwin, G. C. , Payne, R. L. : "Dynamic system identification Experiment design and data analysis," Academic Press, New York, 1977
- [2] Ljung L.: "System Identification: Theory for the User", Prentice Hall, Upper Saddle River, 1998
- [4] Soedersroem T., Stoica P.: Identyfikacja systemów, PWN, Warsaw, 1997.

**7. PhD student's workload necessary to achieve the learning outcomes\*\***

| No.                          | Description                                                                                                      | Number of hours |
|------------------------------|------------------------------------------------------------------------------------------------------------------|-----------------|
| 1                            | Hours of scheduled instruction given by the academic teacher in the classroom                                    | 30              |
| 2                            | Hours of consultations with the academic teacher, exams, tests, etc.                                             | 5               |
| 3                            | Amount of time devoted to the preparation for classes, preparation of presentations, reports, projects, homework | 20              |
| 4                            | Amount of time devoted to the preparation for exams, test, assessments                                           | 5               |
| <b>Total number of hours</b> |                                                                                                                  | <b>60</b>       |
| <b>ECTS credits</b>          |                                                                                                                  | <b>2</b>        |

\*\* 1 ECTS = 25-30 hours of the PhD students work (2 ECTS = 60 hours; 4 ECTS = 110 hours, etc.)