Countries	Institutions	Common Module	ECTS
Romania **Poland** **Greece** **France** **Bulgaria**	Military Technical Academy "Ferdinand I" Military University of Technology Hellenic Air Force Academy French Air Force Academy "Vasil Levski" National Military University	**Dynamic of Flight** *European Common Technical Semester for Defence and Security*	**3.0**

Service	**Minimum Qualification of Instructors**
Technical/ALL	• **Officers or civilian Lecturers:** ○ English: Common European Framework of Reference for Languages (CEFR) Level B2 or min. NATO STANAG 6001 Level 3. ○ Expertise in relevant topics. ○ Relevant academic publications.
Language **English**	

Prerequisites for international participants	**Goal of the Module**
• English: Common European Framework of Reference for Languages (CEFR) Level B1 or NATO STANAG Level 2. • At least 1 year of national (military) higher education. • Basic knowledge in technical systems for security and defence	• Discover and understand basic principles of the fluid mechanics, aerodynamics and of the dynamic of flight. • Learn about fluid mechanics, aerodynamics and dynamic of flight: boundary layer, laminar and turbulent flows, aerodynamic forces and moments, external ballistics, 6-DOF trajectory. • Deepen knowledge of the practical application using CFD tools and Matlab programming language.

Learning outcomes		
	Know-ledge	• Knows the basic concepts related to the fluid mechanics, aerodynamics and dynamic of flight used the in security and defence field. • Knowledge about the basic fluid mechanics, aerodynamics and dynamic of flight equations and explain the main principles relevant to aerodynamic forces, moment and aerodynamic coefficients, 6-DOF trajectories. • Demonstrates the necessary terminology allowing him/her to express opinion, arguments and feedbacks in the fluid mechanics, aerodynamic and dynamic of flight subjects.
	Skills	• Is able to use the CFD tools to compute the aerodynamic forces, moments and coefficients as well as the Matlab programming language to compute 6-DOF trajectories. • Give examples of real applications and practical problems to underline how the topics treated in the course are used within engineering activity.
	Respon-sibility and autonomy	• Understands the basic concept of the fluid mechanics, aerodynamics and dynamic of flight for defence and security systems. • Is able to argue the necessity of the fluid mechanics, aerodynamics and dynamic of flight support for describing the defence and security systems functionality. • Is able to analyse the trends in development of the new technologies in the security and defence and their potential future application.

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Verification of learning outcomes:

- **Observation**: Students are evaluated during each session in order to document their understanding of the basic concept of programming languages applied in defence and security technology applications
- **Project**: Teamwork project and project defence.
- **Test**: Final examination at the end of the module.

Module details

Main Topic	Recom-mended WH	Details
Basic Concepts and Laws of Fluid Mechanics	6	Basic problem of fluid mechanics. Properties of fluids. Forces acting in fluids. Methods of fluid motion analysis, local motion of a fluid element. Basic equations of fluid mechanics (Lec:2h, Lab:4h) • **Applications**: 1. Determination of the pressure resistance coefficient of a circular profile. Resistance of axisymmetric bodies 2. Determination of the pressure coefficient and total drag coefficient. Determination of differences in resistance for streamlined and non-streamlined bodies.
Dynamics of viscous fluids. Wave phenomena in the dynamics of gases, the influence of gas compressibility	**6**	• Dynamics of viscous fluids. Navier - Stokes equation. Boundary layer. The similarity of flows. Friction and pressure resistance, well-flown bodies. Resultant forces acting on the streamlined body - coefficients of aerodynamic forces and moments (Lec:2h, Lab:4h) • **Applications**: 1. Analytical solution of Navier - Stokes equations. Calculation of flow parameters using the equation of motion for selected specific flow cases. 2. First integrals of Euler's equation. Application of the Bernoulli equation in calculating the flow parameters using basic measuring instruments - Pitot tube and Ventouri. Bernoulli's equation in pressure form - static, dynamic and total pressure
Turbulence modelling	**6**	• Averaged Navier-Stokes equations (RANS). Turbulence modelling. • Average Navier-Stokes equations. Turbulent stress tensor, the so-called Reynolds. Application of turbulence models. An introduction to computational fluid dynamics (CFD). • Fluid Mechanics. Boundary layers. Stability, transition and turbulence. Heat transfer. (Lec:2h, Lab:4h)
Basic concepts of exterior ballistics and dynamic of flight. Basic definitions, forces and moments	6	• Exterior ballistics. Drag force, spin damping moment, lift and normal forces, overturning moment, Magnus force and moment. Center of pressure of the normal force and the magnus force. • External Ballistics. Forces acting on the projectile. Standard atmosphere. Stabilizing projectile during flight. Ballistic coefficients. Projectile drop. • Drag resistance. Transonic problem. Gyroscopic and Coriolis drift, Magnus and Poisson effect. Empirical and Doppler measurement methods. (Lec:2h, Lab:4h) • **Applications**: Description of flying objects motion. Reference systems applied in exterior ballistics.

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Point mass trajectory, modified point mass trajectory, 6-DOF trajectory	6	• Equations of motion. Constant Drag Coefficient, Drag coefficient inversely proportional to Mach number, and to the square root of Mach number. Change of independent variable from time to distance. Numerical solution of the equations of motions. Standard atmospheres for point-mass trajectories. Initial conditions for 6-DOF trajectories and MPM trajectories. Numerical solution for 6-DOF and MPM trajectories. Examples of 6-DOF and MPM trajectories. Generalized Missile Equations of Motion. Coordinate Systems. Rigid-Body Equations of Motion.(Lec:2h, Lab:4h) • **Applications**: Point mass trajectory, modified point mass trajectory, 6-DOF trajectory
Aircraft perfomance	6	• Physical nature of drag and classical drag measurements. Airflow regimes. Effect of projectile shape on drag, drag of smooth spheres. Effect of yaw on drag and minimum drag projectile shapes. Equations of motion. Firing uphill and downhill. .(Lec:2h, Lab:4h) • **Applications**: Measurement of aerodynamic forces and moments.
Basic Concepts of Navigation and Dynamic of guided missiles	6	• System Design and Missile Mathematical Model. The Missile Guidance System Model. Autopilots. Aerodynamics. Missile Guidance Laws. Guidance Intercept Techniques. Missile Equations of Motion. Fundamental Guidance Equations. Proportional Navigation. .(Lec:2h, Lab:4h)
Total WH	**42**	

Additional hours (WH) to increase the learning outcomes		
Self-Studies and syndicate work	33	• Enhancing knowledge by studying specific documents. • Preparation for the group project. • Teamwork for the group project. • Those hours comprise the work of students in laboratories and exercises to improve skills and consolidate knowledge.
Total WH	**75**	

List of Abbreviations:

B1, B2 ..... CEFR Levels

CEFR ..... Common European Framework of Reference for Languages

ECTS ..... European Credit Transfer and Accumulation System

GUI ..... Graphical User Interface

ODE ..... Ordinary Differential Equations

WH ..... Working Hour

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