



# **DIGITAL MATHEMATICS APPLIED IN DEFENCE AND SECURITY EDUCATION (DIMAS)**

**KA220-HED - Cooperation Partnerships in Higher Education**

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## **DIMAS**

**International Olympiad in  
Applied Mathematics for Defence and Security  
Individual Competition**

## **REGULATION**

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## 1. Aim and Purpose of the Regulation

### 1.1 Aim of the Regulation

The aim of this regulation is to establish the organisation, participation conditions, evaluation criteria and award procedures for the DIMAS “Olympiad in Applied Mathematics for Defence and Security” - *Individual Competition*, organised within the Erasmus+ project “Digital Mathematics Applied in Defence and Security Education (DIMAS)”.

### 1.2 Objectives of the DIMAS Olympiad - Individual Competition

The aim of the DIMAS “Olympiad in Applied Mathematics for Defence and Security” - *Individual Competition* is to promote the practical application of mathematics and digital technologies in defence and security education by engaging international students in solving interdisciplinary problems based on real-life scenarios.

The objectives of the Olympiad are:

- to increase students’ interest in mathematics and its applications in defence and security.
- to develop students’ skills in using digital mathematical tools and specialised software.
- to improve problem-solving, analytical thinking and decision-making competencies.
- to stimulate creativity and innovation in solving practical problems related to defence and security systems.
- to promote the exchange of good practices between students, teachers and researchers from the participating institutions.

## 2. Concept of the DIMAS Olympiad – Individual Competition

### 2.1 Selection of Scenarios for the Individual Competition

For the individual competition of the DIMAS Olympiad, a set of representative scenarios shall be prepared by the Scientific Committee and selected for each of the main competition directions. The scenarios shall be based on real or realistic situations from the field of defence and security and shall require the use of mathematical models, analytical methods and/or specialised digital tools.

The scenarios should be designed to assess not only the students’ theoretical knowledge but also their ability to apply mathematics in practice, use software tools, and formulate justified conclusions. For each direction, several alternative scenarios may be prepared. The final selection of scenarios for a given edition of the Olympiad shall be made by the Scientific Committee.

The Scientific Committee may decide to include an additional competition direction, in addition to the five basic directions, if it is considered relevant to the objectives of the DIMAS Olympiad and to current developments in defence and security education. An additional direction may be introduced based on the expertise of the participating institutions, students' interests, or emerging topics in defence and security.

## ***2.2 Registration for the Individual Competition***

The first phase for students represents the registration for the individual competition of the DIMAS Olympiad. Within this phase, students individually register for one of the main directions of the competition:

- Technical Systems for Defence and Security.
- Electronic Warfare and Cybersecurity.
- Logistics in Defence and Security.
- Military Leadership.
- Artificial Intelligence in Defence and Security.

## ***2.3 Written evaluation phase***

After registration, all students participating in the Individual Competition shall receive the common scenario assigned for each competition field, together with the evaluation criteria. After solving the assigned scenario within the time limit established and communicated by the Organising Committee, the students shall submit both a PDF version and an editable Word version of their solution, together with a PowerPoint presentation.

The written document and the presentation shall include at least the following elements:

- the scientific background of the student and the connection with the chosen field/received scenario.
- a brief presentation of the requirements of the scenario.
- the proposed solution.
- the conclusions and the student's personal contributions.
- a detailed explanation of the solving process, including the mathematical models used and the manner in which digital tools, including Artificial Intelligence tools where applicable, were employed.

The documents (PDF, DOCX and PPTX) submitted during the Individual Competition of the DIMAS Olympiad shall be evaluated by an international panel composed of teachers and experts from the partner institutions. Each student's submission shall be evaluated independently by at least two evaluators, using a common evaluation grid established by the Scientific Committee.

The evaluation shall consist of:

- the assessment of the written solution (PDF/DOCX), awarded a maximum of 50 points.
- the assessment of the PPTX presentation, awarded a maximum of 50 points.

Therefore, in this phase of the evaluation, each participant may obtain a maximum total score of 100 points.

The evaluation of the Individual Competition shall be based on the following criteria:

- correctness, completeness, and scientific quality of the solution to the common scenario.
- appropriate use of mathematical models, specialised software, and digital tools.
- quality of interpretation and validation of the obtained results.
- clarity, structure, visual quality, and scientific rigour of the PowerPoint presentation.
- ability to clearly explain and justify the methods and solutions used.
- originality and individuality of the overall approach.
- quality, applicability, and relevance of the conclusions and recommendations.
- correct and appropriate use of bibliographical references.

Given that the Individual Competition is conducted independently and within a limited timeframe, particular importance shall be placed on the originality of each participant's solutions, as well as on the use of various digital tools and on the detailed explanation of the manner in which these tools have been used, including Artificial Intelligence tools, where applicable. If several submissions are found to contain substantially similar approaches or solutions, the Scientific Committee may reduce the corresponding scores or invalidate the submissions.

After the evaluation process is complete, the students shall be ranked according to their final scores. The minimum quality threshold for a submission to be considered acceptable shall be 60 points out of 100.

#### ***2.4 Synchronous Presentation of the Solution***

After the written evaluation phase, the highest-ranked students in each competition direction whose submissions meet the minimum quality threshold shall be invited to participate in a synchronous presentation session organised online or in a hybrid format.

During this phase, each student shall present his or her solution to the common scenario before the international evaluation panel within a time limit set by the Organising Committee.

The presentation shall be based on the PPTX file previously submitted and shall include, at least:

- a short reminder of the assigned scenario and its objectives.
- the main elements of the proposed solution.
- the mathematical models, software applications and digital tools used.
- the personal contribution of the student and the originality of the approach.
- the main conclusions and recommendations resulting from the analysis.

Following the presentation, the members of the evaluation panel will ask questions in order to clarify the proposed solution, verify the student's understanding of the mathematical methods and digital tools employed, and assess the degree of personal contribution.

The synchronous presentation shall be evaluated separately, using a common evaluation grid established by the Scientific Committee. The evaluation may include the following criteria:

- clarity and coherence of the oral presentation.
- ability to explain and justify the proposed solution.
- quality of answers to the questions asked by the evaluators.
- demonstrated understanding of the mathematical models and digital tools used.
- evidence of the student's own contribution and originality.
- correct and appropriate use of bibliographical references.

The synchronous presentation may be awarded up to 100 additional points. Therefore, the final score of a participant in the Individual Competition, including both the written evaluation and the synchronous presentation, may reach a maximum of 200 points.

The Scientific Committee shall establish the detailed schedule, the duration of presentations, and the technical conditions for this phase, and shall communicate them to all qualified participants in due time.

### 3. Guidelines for the Elaboration of the Scenario

Each scenario developed for the DIMAS Olympiad shall follow a common structure to ensure coherence, comparability, and a similar level of complexity across all competition fields. The scenario shall be based on a realistic situation in the field of defence and security, and shall require the use of mathematical models and digital tools to solve it.

#### 3.1 Selection of the direction and of the general topics

The author of the scenario shall first identify the main defence and security topic and the real-life context in which the problem appears.

The scenario should belong to one of the main DIMAS direction:

- Military Leadership.
- Logistics in Defence and Security.
- Technical Systems for Defence and Security.
- Electronic Warfare and Cybersecurity.
- Artificial Intelligence in Defence and Security.
- or another direction approved by the Scientific Committee.

The selected topic should correspond to a realistic operational, technical or organisational situation and should allow the application of mathematics and digital technologies. Typical examples include projectile trajectory modelling, route optimisation, cybersecurity data analysis, machine learning for defence applications, and electronic warfare signal processing.

#### 3.2 Definition of the Scenario Title

The scenario shall have a short, clear, and attractive title that expresses both the topic and the main mathematical or technological aspect addressed.

Examples: “Modelling Projectile Trajectory with Aerodynamic Drag”

#### 3.3 Preparation of the Short Description

The short description shall briefly explain the scenario's context, its defence or security relevance, the main challenge for the student, and the expected practical application. The description should normally contain 100–200 words and answer the following questions: What is the problem? Why is it important? What is the role of the student? What is expected from the student? The scenario shall be written as a realistic mission, assignment or case study.

### ***3.4 Identification of the Topics involved***

The author shall define the main scientific, technical and operational topics involved in the scenario. This section should include 5–10 short topics. The topics shall clearly indicate the scenario's interdisciplinary nature. Examples: projectile motion; drag coefficient; neural networks; data preprocessing; logistics optimisation; radio signal detection; route planning; target identification, etc.

### ***3.5 Identification of the Mathematical Areas***

The scenario shall explicitly identify the mathematical branches required to solve it. The author should specify the name of the mathematical branch and the role of that branch in solving the problem. Possible mathematical areas include: Algebra, Geometry, Trigonometry, Differential Equations, Partial Differential Equations, Numerical Analysis, Probability and Statistics, Linear Algebra, Optimisation, Vector Calculus, Mathematical Modelling, etc. For each mathematical area, a short explanation shall be included.

Example:

Differential Equations – used to describe the variation of the projectile velocity over time.

### ***3.6 Selection of the Digital Mathematics Tools***

The scenario shall include at least one digital mathematical tool or specialised software package required to solve the problem. Possible tools include MATLAB, Python, Excel, Mathematica, Simulink, and Maple. The selected tool shall be adapted to the scenario's difficulty and objectives.

### ***3.7 Formulation of the Learning Objectives***

The learning objectives shall be grouped into knowledge, abilities, responsibility and autonomy. The objectives should be formulated using action verbs derived from Bloom's Taxonomy. Each category should contain 2–3 objectives.

### ***3.8 Definition of the Methodologies Adopted***

The author shall describe the methodologies that students are expected to use during the solution process. Typical methodologies may include analytical and mathematical modelling, numerical integration, optimisation methods, machine learning, simulation, data analysis, parameter estimation, and project-based learning. Each methodology should be briefly described and related to the scenario.

### ***3.9 Definition of the Prerequisites***

The scenario shall indicate the minimum background required from the students. The prerequisites may be grouped into mathematical, software and programming, and technical or domain-specific categories.

Examples: knowledge of ordinary differential equations.

### ***3.10 Estimation of the Time Required***

For each scenario, the author shall estimate the time required for a student or a team to complete the different parts of the task. The estimated time shall be clearly indicated in the scenario description. The estimated time shall be validated during the testing phase of the scenario and, if necessary, adjusted in order to ensure that the scenario can be solved within the official duration of the competition.

### ***3.11 Elaboration of the Tasks***

Each scenario shall contain several tasks of increasing complexity. It is recommended to include an understanding and description of the problem, the development of the mathematical model, implementation using digital tools, analysis and interpretation of the results. The tasks should encourage both technical correctness and creativity.

### ***3.12 Definition of the Specific Evaluation Criteria***

For each scenario, the author shall prepare an evaluation grid indicating the criteria to be assessed as the solution, the number of points allocated to each criterion, and the expected level of performance.

### ***3.13 Preparation of Supporting Materials***

The scenario may also include tables, diagrams, maps, formulas, datasets, software files, screenshots, or images. The supporting materials should help the students understand the context without directly providing the solution.

### ***3.14 Verification and Validation of the Scenario***

Before being approved, each scenario shall be reviewed, tested, and checked for clarity, difficulty, realism, and expected solution time. The final scenario should be solvable within the established competition time, have a clearly justifiable solution, and be of comparable difficulty to the other scenarios.

The scenarios developed within DIMAS are expected to create a clear connection between real-life situations in defence and security and the mathematical branches and digital tools used to analyse them.

## Annex. Example of a Scenario

Title	Modelling Projectile Trajectory with Aerodynamic Drag
Short description	This scenario provides military engineering students with a practical simulation of projectile motion under realistic battlefield conditions. It models the trajectory of a projectile while accounting for aerodynamic drag, gravity, and launch parameters such as muzzle velocity and firing angle. The exercise helps students understand the influence of aerodynamic forces on range, accuracy, and impact point—key factors in the design, testing, and operational use of modern weapon systems.
Topics Involved	<ul style="list-style-type: none"> <li>- Fundamentals of projectile motion</li> <li>- Aerodynamic drag and drag coefficient</li> <li>- Ballistic equations of motion</li> <li>- Numerical modelling and simulation techniques</li> <li>- Effects of launch parameters (velocity, angle, mass)</li> <li>- External forces: gravity and air resistance</li> <li>- Computational tools for trajectory prediction</li> <li>- Application of physics in weapon system design</li> <li>- Data analysis and visualisation of projectile paths</li> <li>- Accuracy and range optimisation in military ballistics</li> </ul>
Areas of Mathematics	<ul style="list-style-type: none"> <li>- Differential Equations – to describe the projectile’s velocity and position over time</li> <li>- Numerical Analysis – for solving nonlinear equations that lack analytical solutions</li> <li>- Vector Calculus – to represent motion and forces in two or three dimensions</li> <li>- Algebra and Trigonometry – for resolving components of velocity and angle relationships</li> <li>- Applied Mathematics – integrating physical models with computational simulation</li> <li>- Statistics and Data Analysis – for evaluating trajectory data and error estimation</li> </ul>
Digital mathematics tools	MATLAB
Learning objectives (knowledge, abilities, competencies)	<p><b>Knowledge:</b></p> <ul style="list-style-type: none"> <li>- Understand the physical principles governing projectile motion with and without aerodynamic drag.</li> <li>- Explain how drag coefficients, air density, and launch parameters influence trajectory behaviour.</li> <li>- Identify the mathematical models used to describe projectile dynamics in military applications.</li> </ul> <p><b>Abilities:</b></p> <ul style="list-style-type: none"> <li>- Apply differential equations to simulate projectile trajectories under real-world conditions.</li> <li>- Use computational tools to model and visualise projectile flight paths.</li> <li>- Analyse and interpret simulation results to assess range, accuracy, and impact energy.</li> </ul> <p><b>Competencies:</b></p> <ul style="list-style-type: none"> <li>- Develop the capability to integrate mathematical modelling with engineering judgment in ballistic analysis.</li> <li>- Demonstrate critical thinking in optimizing projectile performance considering aerodynamic effects.</li> <li>- Collaborate effectively in technical problem-solving related to weapon system design and testing.</li> </ul>

<p>Methodologies adopted</p>	<ol style="list-style-type: none"> <li>1. Analytical modelling - Derive closed-form relationships where possible (ideal projectile without drag; small-angle approximations). Use these solutions to build intuition, set initial conditions, and provide benchmarks for numerical results.</li> <li>2. Derivation of governing equations- Formulate the full equations of motion including gravity, quadratic (or other) aerodynamic drag, and optionally lift and Coriolis force. Express in vector form and split into components for 2-D or 3-D analysis.</li> <li>3. Dimensional analysis - Introduce characteristic scales (length, time, velocity) and no dimensional numbers (e.g., ballistic coefficient, Reynolds number) to identify dominating effects and simplify parameter studies.</li> <li>4. Numerical integration of ODEs - Solve the nonlinear equations of motion using reliable time-stepping ODE solvers (e.g., Runge–Kutta 4(5), adaptive step solvers). Implement event detection (impact, max altitude) and ensure solver stability and error control.</li> <li>5. Aerodynamic modelling Use empirical drag laws (constant <math>C_d</math>, speed-dependent <math>C_d(V)</math>, piecewise regimes) and tabulated ballistic coefficient data.</li> <li>6. Numerical methods - Apply step-size control, stiffness detection, and convergence testing. Perform grid/sensitivity refinement and compare multiple integrators to quantify numerical error.</li> <li>7. Parameter estimation and calibration - Fit drag coefficients or ballistic coefficients to experimental or published trajectory data using least-squares or Bayesian estimation to improve model fidelity.</li> <li>8. Sensitivity and uncertainty analysis - Perform one-factor-at-a-time and global sensitivity analyses (Sobol, Morris) and Monte Carlo simulations to quantify how uncertainties in initial conditions, mass, drag, or atmospheric parameters affect range and impact point.</li> <li>9. Environmental modelling - Include air density variation with altitude, wind profiles, temperature, and humidity. Model Coriolis and geodetic effects for long-range trajectories when relevant.</li> <li>10. Validation and verification - Verify numerical code against analytical solutions and published ballistic tables. Validate models against experimental firing data or trusted simulations. Document test cases and discrepancies.</li> <li>11. Optimization studies - Use optimization algorithms (gradient-based or heuristic) to find launch parameters (angle, velocity) or design parameters (mass, shape) that maximize range, minimize dispersion, or meet mission constraints.</li> <li>12. Visualization and data analysis -Plot trajectories, phase-space diagrams, range vs. angle curves, and error bands. Use statistical summaries and reporting to interpret results and support engineering decisions.</li> <li>13. Software engineering practices - Adopt version control, modular code structure, unit tests for physics routines, and reproducible notebooks/scripts to ensure transparency and repeatability.</li> </ol>
<p>Prerequisites</p>	<p>Mathematics &amp; numerical skills</p> <ul style="list-style-type: none"> <li>- Numerical methods for ODEs (Runge–Kutta family, stability concepts).</li> <li>- Basic error analysis and numerical convergence testing.</li> <li>- Familiarity with statistics (mean, variance, basic Monte Carlo concepts) for uncertainty analysis.</li> </ul> <p>Programming &amp; software</p> <ul style="list-style-type: none"> <li>- Proficient in a scientific scripting language (MATLAB).</li> <li>- Ability to implement numerical integrators, read/write data files, and produce plots.</li> </ul>
<p>Estimated time</p>	<p>8 hours (including self-studies and teamwork)</p>

Task for students

### Mission Brief

As part of your military engineering training, you are assigned to simulate the trajectory of a projectile under realistic battlefield conditions. The mission involves developing a computational model that accounts for aerodynamic drag, gravity, and launch parameters to predict the projectile's flight path, range, and impact characteristics. Your analysis will support decision-making in weapon system design, targeting accuracy, and operational planning.

- Define initial conditions and projectile parameters
- Formulate the system of ordinary differential equations (ODEs)
- Perform numerical integration and detect the impact point
- Extract trajectory features (maximum height, range)
- Visualize the results

Task 1. For each function write a one-paragraph summary (“What it does, inputs & outputs, key steps”).

Task 2. Trace the data flow: draw a simple block diagram showing how data moves from *initial conditions* → *trajectory\_animation*.

Task 3. Write a script called *parameter\_variation* in which you:

- Vary one parameter at a time (Launch angle  $\theta_0$ , mass  $m$ , or frontal area  $S$ ; Keep the other two parameters constant).
- For each variation: compute the range and the apex (maximum height) and plot how each output (range, height) depends on the chosen parameter.
- Write a short report in which interpret the observed trends (for example, how increasing mass alters the effect of drag).