Module 4 – Lesson 1

Introduction to Flight Controllers

Lesson 1A — Introduction to Flight Controllers

Lesson 1B — IMU and GPS Sensors in the UAV Navigation System

Topic: Introduction to Flight Controllers and Basic UAV Sensors (IMU and GPS)

Duration: 2 hours (2 × 50 min)

Level: UAV Technician / 11th Grade Students – Applied Mechanics and Electronics

Type of Lesson: Theoretical–Practical (Explanatory + Applied + Demonstrative)

Resources: UAV flight controllers, IMU and GPS modules, configuration software (Betaflight, Mission Planner), UAV model, projector, laptops, worksheets, educational videos, flight simulator

Specific Competence: Understanding the operating principles and the role of the flight controller, identifying the main components and the data flow between sensors, controller, and actuators, as well as correctly applying the procedures for calibration and data interpretation from IMU and GPS sensors.

Lesson Plan

GENERAL INFORMATION

Learning Acquisitions

Lesson 1A — Introduction to Flight Controllers			
Objective code	**Desired behavior (What is required?)**	**The testing condition (What is offered?)**	**Success criterion (What is accepted?)**
O1A.1	Explain the role and functions of the air traffic controller.	Having at your disposal a video presentation and a worksheet with images of UAV components.	Correct description of functions in at least 3 examples related to flight stability.
O1A.2	Identify the main components of a flight controller	Based on a demonstration video and a real/virtual UAV mockup	Correct identification of at least 4 main components.
O1A.3	To differentiate the flight controller from the autopilot.	After watching a comparative video and guided group analysis	Correct formulation of at least 2 essential differences.

O1A.4	Describe the basic principles of UAV flight control.	With the support of a presentation and an interactive 3D model.	Correct explanation of the sensor–controller–motor data flow in 4 logical steps.

Lesson 1B — IMU and GPS Sensors in the UAV Navigation System

Objective code	Desired behavior (What is required?)	The testing condition (What is offered?)	Success criterion (What is accepted?)
O1B.1	Explain the functions and importance of IMU and GPS sensors.	After an explanation given by the teacher and an illustrative video clip.	Correctly mentioning at least 3 functions for each sensor.
O1B.2	Identify the main components of the IMU module.	Based on an image or an actual motherboard.	Correct recognition of gyroscope, accelerometer and magnetometer.
O1B.3	Explain how to guide a UAV using GPS.	After the teacher's demonstration and analysis of a simulated route.	Complete description of the localization and position correction process in at least 4 steps.

Table: Content structuring (areas, subareas, concepts and objective codes)

Content area	Content subarea	Key concepts	Corresponding objective code
UAV control systems	Flight controller architecture	processor, gyroscope, accelerometer, ESC, autopilot	O1A.1 – O1A.4
UAV Basic Sensors	IMU sensor	orientation, acceleration, angular motion, stabilization	O1B.1 – O1B.2
UAV Basic Sensors	GPS	positioning, coordinates, trajectory, correction	O1B.3
UAV control systems	Controller architecture	flight controller; processor; sensors; stabilization loop (PID)	O1A.1, O1A.4
Hardware components	Control board, connectors, power supply	microcontroller, IMU, I/O ports, ESC, BEC	O1A.2
Automatic functions	Autopilot vs FC	levels: control (low-level) vs planning/waypoints (high-level)	O1A.3
Inertial sensors	IMU	gyroscope (angular rate), accelerometer (specific acceleration), magnetometer (compass head)	O1B.1, O1B.2
Satellite location	GPS/GNSS	trilateration, 3D fix (≥4 satellites), update rates, errors (multipath, obstruction)	O1B.3
Sensor fusion	Attitude & position estimation	complementary filter, EKF (IMU+GPS fusion), rate & drift	O1A.4, O1B.1–B.3

Table: Educational resources used

No. of documents.	Name of educational institution	Content / use
1	Laptop + projector/screen	PowerPoint presentation, videos, demo software
2	Demonstration videos (4× short)	Controller role, components, autopilot vs FC, IMU calibration
3	UAV physical model / control board (1–2 pcs.)	Component identification, practical demonstrations
4	Flight simulator / telemetry logs	GPS loss demonstrations, flight behavior, sensor fusion
5	Worksheets / activity sheets	Schematization, component identification, practical exercises
6	Flight-config software (e.g. configuration tool) / phone with app	IMU calibration demonstration; sensor data visualization
7	Cleaning kits (work bench) + ESD tools	Safe handling, electrostatic discharge prevention
8	Board / marker / cards for groups	Discussion organization and visual synthesis

Time (min)	Pedagogical objective (code)	Stages of the learning cycle (lesson sequence)	Training content	Teaching methods	Organizational form	Educational resources	Evaluation form
Session 1 (50 minutes) Basic UAV sensors – IMU and GPS							
0–7	O1A.1 (introduction)	Obtaining information: 2–3 min video → oral survey	Short video: "The Controller in Action" + introduction: what it isFlight controller (FC), what is its importance	Video + guided questions	Frontal/collective	Projector, laptop, introductory sheet	Oral formative test (3 short questions). Criterion: coherent answer to at least 2 out of 3 questions
7–25	O1A.1, O1A.4	Information processing: explanation + diagrams → short exercise	FC architecture: sensors → attitude estimator (fusion) → control (PID) → actuators; concepts: loop control, role of sensors	Interactive presentation + questions	Frontal/collective	Slides (diagrams), marker	Mini-quiz (3 items—score ≥70% considered "understood")
25–40	O1A.2	Identifying component operations → Practice: identification by model/images	Components: IMU, UART/I2C ports, connectors, controller, LEDs, buttons; board layout	Demonstration + hands-on activity in pairs	Differentiated/group/directed	Physical model or images + worksheets	Identification sheet (rubric): 4+ components correctly identified = passed
40–50	O1A.3	Reverse connection/synthesis: autopilot vs FC comparison → discussion	Practical difference: FC = control & sensors (low-level); Autopilot = mission planning (high-level); examples	Guided discussion + feedback	Frontal/collective/directed	Summary slide	Students formulate 2 differences (written on the sheet). Criterion: 2 correct differences
Session 2 (50 mins) The most basic UAV sensors - IMU and GPS							
0–8	O1B.1 (recap)	Obtaining information: recap +	Short video about IMU and GPS (functions)	Video + questions	Frontal/collective/directed	Projector, video	Formative questions (oral) — min. 2 out of 3 correct

		IMU/GPS demo video					
8–25	O1B.1, O1B.2	Information processing: technical explanation & data interpretation	IMU: accelerometer (m/s^2; measures specific acceleration incl. gravity), gyroscope (°/s; measures angular velocity), magnetometer (heading); calibration — bias, drift; sampling rates (IMU: typical 100–1000 Hz)	Presentation + interpretation exercise (handout)	Frontal/ individual/ independent	Slides, handouts, example of sensor log	Exercise: data interpretation (sheet). Criterion: coherent answers to 3 items
25–38	O1B.3, O1B.1	Applying conclusions to new conditions: scenario simulation	GPS: principle (trilateration), minimum 4 satellites required for 3D fix; limitations (obstruction, multipath, 1–10 Hz update), RTK (corrections) + IMU+GPS fusion (ex: EKF)	Demonstration on simulator + group problem (what happens when GPS is lost)	Difference/ by groups/ independentl y	Simulator, telemetry logs	Group: short presentation (2 min). Criterion: correct identification of 2 possible solutions to GPS loss
38–48	O1B.2 (calibrat ion)	Identifying operations → Practice & correct: IMU calibration demo	Practical steps: flat position; running calibration procedure (gyro/acc self-calibration at stationary; magnetometer: 3-axis rotation); avoiding magnetic disturbances	Practical demonstration + activity (if equipment)	Differentiate d/in groups/inde pendently	Control board + configuration software (e.g. Mission Planner / Betaflight) or application	Direct observation (checklist): all steps followed = completed
48–50	O1A.4 / O1B.3 (conclus ion)	Reverse connection/final synthesis	Recap + theme: concept map + infographic / calibration checklist	Summary + homework instructions	Frontal/colle ctive/directe d	Homework sheets, rubrics	Checking assignment requirements; clarifying rubrics

Assessment forms and rubrics (suggested)

A. Formative assessment (during the lesson)

- **Oral questions / mini-quiz**— purpose: immediate verification of understanding; passing threshold 70% correct answers.
- **Identification sheets (hands-on)**— simple rubric: correct identification (1p / item) — 4 items required → 4p = good; ≥3p = satisfactory.

B. Summative assessment (homework + products)

1. **Conceptual map (mind map)**— criteria:
   - Scientific accuracy (40%) — correct information about roles / sensors;
   - Completeness (30%) — coverage of components + relationships;
   - Visual organization / clarity (20%);
   - Originality / references (10%).

   Success criterion:≥ 70% of the total score.
2. **Infographic (controller components + functions)**— heading:
   - Correctness (50%), Visual clarity (30%), Conciseness (20%).

   *Criterion:*contain at least 4 correctly explained components and 3 functions.
3. **Practical demonstration of calibration (if possible)**— observer checklist: compliance with steps (stationary, magnetometer rotation, saving settings), estimated time, ESD precautions. Criterion: all essential steps performed correctly = approved.
4. **Short written assessment (optional)**— 6–8 items (short questions / true/false / short explanations). Passing score 70%.

Scientific notes and best practices (succinct, rigorous)

- **IMU (Inertial Measurement Unit)**= combination of inertial sensors: accelerometer (measures specific acceleration, including gravity; units m/s^2), gyroscope (measures angular velocity, °/s), magnetometer (measures local magnetic field → heading).
  - The accelerometer does not differentiate inertial acceleration from gravity; to obtain attitude, the measurements are combined.
  - Gyros integrate over time to estimate orientation, but suffer from drift (cumulative error).
  - That is why sensor fusion (e.g. complementary filter, Extended Kalman Filter) is used to obtain stable and accurate estimates of attitude/position.
- **GPS/GNSS**
  - It works by trilateration: measuring distances from satellites (timing) to obtain the position. For 3D fix, a minimum of 4 satellites are required.

- Update rates typically between 1–10 Hz (consumers often 1 Hz; better GPS can be 5–10 Hz).
- Limitations: obstruction (buildings, forest), multipath (reflections), atmospheric errors; RTK / DGPS provides corrections (centimeter accuracy) but requires infrastructure.
- In practice, IMU provides fast (high frequency) but drifting estimates; GPS provides absolute position (no drift) but with lower latency/rates → their fusion gives optimal performance.

- **Autopilot vs Flight Controller**
  - **Flight controller**= low-level "brain": reads sensors, runs control (PID/add) and sends motor commands.
  - **Autopilot**(broadly) = high-level functionality (mission planning, waypoint tracking). In practice the terms overlap, but in teaching the distinction of responsibility is useful.
- **IMU calibration (best practices)**: positioning on a flat surface for accelerometer bias; rotation in the 3 axes for magnetometer; perform calibration away from magnetic sources (metal, phones, equipment). Check for ESD (electrostatic discharge) when working on the board.

Notes for the trainer

- If no physical hardware is available: use flight simulator and telemetry logs; hands-on activities can be adapted with detailed images and software interface.
- Follow ESD and work safety regulations (power off for work on the board).
- If time is limited, prioritize: 1) understanding FC functions + 2) recognizing components + 3) calibration procedure (demo).
- Encourage questions from practical experience (e.g., GPS loss situations, behavior in the wind).

Module 4 – Lesson 2

Maintenance and Repair of Flight Controllers & Sensors

Lesson 2A — Flight Controller Maintenance and Repair;
Lesson 2B — Sensors Maintenance and Repair

Topic: Maintenance and Repair of UAV Flight Controllers and Sensors

Duration: 2 hours (2 × 50 min)

Level: UAV Technician / 11th Grade Students – Applied Mechanics and Electronics

Type of Lesson: Theoretical–Practical (Explanatory + Applied + Demonstrative)

Resources: UAV flight controllers, sensor modules (IMU, GPS, barometer), configuration software (Betaflight, INAV, Mission Planner), ESD kits and diagnostic tools, laptops, worksheets, projector, demonstration videos, flight simulator, and telemetry logs

Specific Competence: Correct application of procedures for inspection, maintenance, and repair of UAV flight controllers and sensors, using measuring instruments, diagnostic software, and ESD safety techniques, with the aim of maintaining system performance and flight stability.

Lesson Plan

GENERAL INFORMATION

Learning Acquisitions

Lesson 2A — Flight Controller Maintenance and Repair			
Objective code	**Desired behavior (What is required?)**	**Trial condition (What is offered?)**	**Success criterion (What is accepted?)**
O2A.1	Identify and describe common faults that occur on the control board and preventive measures.	Based on a real board with simulated defects/defect images, diagrams and datasheets.	Correctly identifying at least 4 common defects and proposing a preventive measure for each (≥4/4).
O2A.2	Correctly apply firmware verification and update procedures.	Having a flight controller, a laptop with configuration software (e.g. Betaflight, INAV, Mission Planner) and version instructions.	Performing parameter backup, firmware checksum verification and error-free update; FC starts correctly after update (yes/no).
O2A.3	Calibrate the internal sensors (IMU) according to the recommended procedure.	With a flight controller connected to configuration software and a flat workspace.	Calibration followed correctly (steps followed) and values stabilized in log (stable orientation in static test).
O2A.4	Perform physical maintenance and diagnostic operations at the component level.	Equipped with ESD tool kit, compressed air, isopropanol and measuring instruments (multimeter).	Cleaning and inspection performed; correct measurements/diagnosis for the given problem (description & proof on the sheet).
O2A.5	Determine if a faulty component needs to be replaced or if the board needs to be replaced.	Case studies with repairable defects (solder, connector) vs. irreparable defects (burnt IC/severely affected trace).	Justified decision (repair/replace) with technical reasoning (criterion: correct justification in 80% of cases).

Lesson 2B — Sensors Maintenance and Repair			
Objective code	**Desired behavior (What is required?)**	**Trial condition (What is offered?)**	**Success criterion (What is accepted?)**
O2B.1	Explain the importance of sensor maintenance for flight performance and safety.	After presentation and observation of telemetry logs showing sensor errors.	Listing at least 3 negative effects (e.g. attitude drift, trajectory deviations, loss of GPS fix) and corrective measures.
O2B.2	Demonstrate cleaning and calibrating sensors (IMU, magnetometer, barometer) on a test unit.	Having a sensor/IMU, cleaning kit, and calibration software.	Correct cleaning without damage + calibration completed according to the procedure (checklist).
O2B.3	Perform diagnostic tests on UAV sensors and identify faulty sensors.	Using sensor logs, multimeter, and telemetry monitoring software.	Correct diagnosis of at least 2 simulated/real cases (sensor and cause identified).
O2B.4	Replace a damaged sensor and check its integration into the system.	With a replacement sensor and the appropriate replacement procedure; access to configuration software.	Replacement performed, sensor recognized by FC and values returned within accepted range (functional).
O2B.5	Monitor energy levels and explain how the autopilot uses this data in flight management.	Based on a set of telemetry (e.g. battery log) and flight scenario.	Proposal of at least 2 energy management actions (e.g.: Return-to-Home at specific %, speed reduction) and their technical justification.

Table: Content structuring (areas, subareas, concepts and objective codes)

Content area	Content subarea	Key concepts	Corresponding objective code
Fault diagnosis & prevention	Control board defects	weak connectors, cold solder joints, burnt capacitors, voltage regulator, traces of corrosion	O2A.1, O2A.4
Firmware & software	Firmware verification & update	backup parameters, firmware version, checksum, bootloader, update procedure	O2A.2
Calibration & sensors	IMU calibration	bias, offset, drift, gyroscope/accelerometer/magnetometer procedure	O2A.3, O2B.2
Component level maintenance	Physical maintenance	cleaning with isopropanol, compressed air, visual inspection, ESD	O2A.4, O2B.2
Sensor diagnostics	Sensor testing	telemetry logs, analog/digital signals, continuity, functionality test	O2B.3

Sensor replacement & integration	Replacing sensors	on-board soldering, connectors, firmware integration verification	O2B.4
Energy management	Power monitoring	battery telemetry, RTH threshold, autonomy estimation, energy protections	O2B.5

Table: Educational resources used

No. of documents.	**Name of educational institution**	**Content / use**
1	Laptop + projector/screen	Presentation, demonstration videos and configuration software interface
2	Demonstration videos (firmware update, diagnostics)	Examples of correct procedures and common mistakes
3	UAV model/control board (1–2 pcs.)	Hands-on practice: inspection, cleaning, connector replacement
4	ESD kit & tools (ESD bag, trumpets, pliers, microscope)	Working safely at the component level
5	Multimeter, oscilloscope (if available)	Voltage, continuity, I2C/SPI signal testing
6	Configuration software (Betaflight/Mission Planner/ArduPilot)	Firmware check, IMU calibration, telemetry log view
7	Worksheets / checklists (diagnostics, firmware, calibration)	Step-by-step guide to activities
8	**Resource 1 — Integrated Image**(see above)	Diagram/scheme for practical activities: identification of verification areas, activity flow, visual assessment rubrics
9	Compressed air, isopropanol, lint-free cleaning sticks	Electronic component cleaning
10	Flight simulator / telemetry logs	GPS loss simulation, behavior test for faulty sensors

Time (min)	Pedagogical objective (code)	Stages of the learning cycle (lesson sequence)	Training content	Teaching methods	Organizational form	Means	Evaluation form
Session 1 (50 min) — Flight controller maintenance and repair							
0–7	O2A.1 (introduction)	Obtaining information: 2–3 min video + oral survey	Video: real case of FC failure; the importance of preventive maintenance	Video + guided questions	Frontal/ Collective	Projector, laptop, Resource 1 (image)	Oral questions (min. 2/3 correct answers)
7–20	O2A.1, O2A.4	Information processing: technical explanation + example on images/board	Common faults: corroded connectors, cold junctions, burnt capacitors, voltage regulator; causes & prevention	Interactive exhibition + demonstrations	Front + demo	Slides, plate model, magnifying glass	Mini-quiz (3 items) — threshold 70%
20–30	O2A.2	Identification of operations: firmware procedure (verification & backup)	Steps: backup parameters, note version, download compatible firmware, checksum verification, stable power conditions	Step-by-step demonstration (software)	Front + demo	Laptop + software (Betaflight/Mission Planner), USB cable	Observation: backup performed (yes/no); complete checklist
30–42	O2A.2, O2A.5	Practice: students work in pairs to verify firmware (simulation)	Practice: connection, version reading, update simulation (no real writing unless required)	Guided hands-on	in pairs	Laptop, demo board, procedure sheets	Completed worksheet — rubric: correctly marked steps
42–50	O2A.4	Reverse connection / synthesis: cleaning & visual diagnosis	Cleaning demo: compressed air, isopropanol; visual check for cold junctions	Demonstration + discussion	Frontal/collective	Cleaning materials, plate model	Formative observation (checklist)
Session 2 (50 min) — Sensor Maintenance and Repair							

0–6	O2B.1	Getting information: recap + short video about sensor issues	Impact of uncalibrated/dirty sensors on flight (e.g. drift, loss of stability)	Video + questions	Front	Projector, video	Oral questions (2/3 correct)
6–20	O2B.2	Information processing: cleaning & calibration procedures	Cleaning methods (isopropanol, lint-free swabs), IMU calibration procedure (steps), magnetometer attention	Demonstration + explanation	Front + demo	Resource 1 (image) + procedure sheets, cleaning kit	Calibration checklist (steps to follow)
20–32	O2B.3	Applying conclusions: diagnostics through logs & measurements	Interpretation of telemetry logs; functional test (I2C signal, accelerometry/gyro values)	Practical exercise on logs (small groups)	In groups/independently	Simulator/logs, laptop	Group: short report (2–3 points) — criterion: correct diagnosis
32–42	O2B.4	Identifying component operations → practice & correction	Connector or sensor module replacement (demonstration); software integration and verification	Demonstration + hands-on (if possible)	Micro-groups	ESD tool kit, replacement sensor, software	Note: correct replacement or procedure description
42–48	O2B.5	Practicing the skill as a whole	Energy monitoring: battery telemetry reading, RTH threshold setting, autopilot responses	Demonstration + group problem	Small groups	Battery logs, simulator	Group: 2 energy management proposals (justified)
48–50	O2A.2 / O2B.2 (conclusion)	Back-connection & final synthesis	Recap + topic: maintenance checklist + short diagnostic report	Summary + homework instructions	Front	Homework sheets, rubrics	Rubric clarification; final questions

A. Formative assessment (during the lesson)

- Oral questions / mini-quiz — immediate verification; passing score 70%.
- Direct observation with checklist (cleaning, calibration, firmware update) — yes/no items.
- Completed worksheets — rubric: correctly listed steps (1p/item).

B. Summative assessment (homework + products)

1. **Maintenance checklist (homework)**— students submit a completed checklist for a real/simulated case (criteria: completeness & correctness; threshold 70%).
2. **Short diagnostic report (1 page)**— problem description, diagnostic steps, recommended solution; criteria: clarity and technical argumentation (≥70% score).
3. **Practical demonstration (optional)**— student performs calibration or replacement under observation; rubric: following steps (yes/no) + ESD safety.
4. **Short written test (6 items)**— 70% threshold.

SCIENTIFIC NOTES AND GOOD PRACTICES (RIGUROS)

- **ESD & safety:**work on antistatic surfaces; use an ESD wrist strap; disconnect the power before working; do not hold boards under voltage when soldering.
- **Firmware update:**always backup parameters before updating; use stable power source (regulator/USB) to avoid power loss during firmware writing. Check hardware–firmware compatibility.
- **Cleaning:**use 90%+ isopropanol and lint-free swabs; avoid damaging components; dry completely before refueling.
- **Soldering & component replacement:**requires competence; use appropriate temperatures and tips; avoid overheating components; if unsure, replace the entire module (cost–benefit).
- **IMU & magnetometer calibration:**The magnetometer calibration must be done away from metallic materials or magnetic sources; perform the procedure at a stable temperature; redo the calibration after any physical intervention.
- **Sensor diagnostics:**IMU provides high-frequency measurements but drifts over time; GPS provides absolute position but is vulnerable to obstruction. Fusion (EKF) corrects errors; telemetry logs are key to diagnostics — save them.
- **Energy management:**set RTH thresholds and battery alerts; test range estimation in real-world conditions (load, wind).

TRAINER NOTES

- If you don't have hardware for all learners, organize rotations: one group works hands-on, others analyze logs or go through worksheets.
- Use Resource 1 (integrated image) as a worksheet to identify critical areas on the control board and to guide the checklists. Ask students to make notes on the image (what to check / what to clean).
- Keep safety and ESD procedures in sight; check equipment before the session.
- Encourage documentation: any intervention is noted (firmware version, parameters, observations), for traceability.

Module 4 – Lesson 3

Maintenance and Repair of Sensors

Lesson 3A —Identification and operation of UAV sensors

Lesson 3B – Advanced Sensor Diagnostics and Maintenance

Topic: UAV sensor maintenance and repair – advanced diagnostics, calibration and system integration

Duration:2 hours (2 × 50 min)

Level: UAV technician / 11th grade students – applied mechanics / electronics field

Type of Lesson: mixed – theoretical-practical (demonstration + application + practical evaluation)

Main resources: sensor kit (IMU, GPS, barometer), laptops, configuration software, Resource 1 (practical diagram image)

Specific competence: applying UAV sensor maintenance and calibration procedures in safe conditions, using specific tools.

Lesson Plan

GENERAL INFORMATION

Learning Acquisitions

Objective code	Desired behavior (What is required?)	Trial condition (What is offered?)	Success criterion (What is accepted?)
O3A.1	Correctly identify the types of sensors used on board a UAV (IMU, GPS, magnetometer, barometer).	By analyzing a diagram and some real sensor modules.	Correct identification of at least 4 sensors and description of the function of each (≥4/4).
O3A.2	Explain the operating principles of the main sensors (IMU, GPS, barometer).	Based on a video presentation and illustrative materials (block diagrams).	Correct explanation of the principle of each sensor (3/3 correct).
O3A.3	Perform a complete calibration of the UAV sensor system.	Using dedicated software (e.g. Mission Planner / Betaflight) and a control unit.	Completion of error-free calibration and recording of stable values (bias < ±0.05).
O3A.4	Diagnose sensor malfunctions using flight logs and telemetry.	Having real or simulated logs with introduced errors available.	Correct identification of at least 2 faulty sensors and probable causes (≥80% accuracy).
O3A.5	Apply remedial measures and periodic maintenance of sensors.	Based on a standard maintenance plan and maintenance sheets.	Proposing at least 3 correct preventive actions (cleaning, periodic calibration, connection check).

Content structuring (areas, subareas, concepts and objective codes)

Content area	Content subarea	Key concepts	Corresponding objective code
Sensor systems	Types of UAV sensors	IMU, GPS, barometer, magnetometer	O3A.1
Sensor operating principles	Sensor operation	acceleration, gyroscope, drift, pressure, satellite positioning	O3A.2
Calibration & tuning	Full calibration	bias, offset, software procedure, post-calibration check	O3A.3
Sensor diagnostics	Log analysis and telemetry	drift, magnetic interference, GPS signal loss, barometer errors	O3A.4
Preventive maintenance	Periodic maintenance	cleaning, inspection, sensor firmware update	O3A.5

Educational resources used

No. of documents.	Name of educational institution	Content / use
1	Laptop + projector	Theoretical presentation and calibration software demonstration
2	Configuration software (Mission Planner, Betaflight)	Calibration and verification of sensor functionality
3	Real sensor modules (IMU, GPS, barometer)	Practical identification, analysis and cleaning
4	Educational videos	Explanation of operating principles and real error cases
5	Telemetry logs / UAV simulator	Sensor error diagnostics
6	Sensor cleaning kit	Isopropanol, lint-free swabs, compressed air
7	Calibration worksheets and checklist	Step-by-step guide to practical activities
8	**Resource 1 – Integrated Sensor Diagram**	Identifying sensor connections and routes
9	Multimeter / continuity tester	Check sensor connections
10	UAV maintenance manual	Technical reference for preventive actions

Time (min)	Pedagogical objective (code)	Stages of the learning cycle (lesson sequence)	Training content	Teaching methods	Organizational form	Means	Evaluation form
Lesson 3A —Identification and operation of UAV sensors							
0–8	O3A.1	Obtaining information	Introduction: the importance of sensors; types of sensors on board UAVs	Guided conversation + video	Front	Video + projector	Oral questions (3 correct answers)
8–20	O3A.1, O3A.2	Information processing	Analysis of the structure of an IMU and the GPS operating principle	Exhibition + demonstration	Front + demo	Sensor modules, Resource 1	Mini-test (3 items, 70% threshold)
20–35	O3A.2	Applying the conclusions	Comparing the operation of sensors (IMU, GPS, barometer)	Pair work	in pairs	Worksheets	Observation (complete the form correctly)
35–45	O3A.3	Practicing operations	Full IMU Calibration Demonstration	Guided demonstration	Front	Software, laptop, UAV module	Calibration checklist (error-free)
45–50	O3A.1–3	Reverse connection	Short summary: questions + clarifications	Discussion	Front	Flashcards, blackboard	Oral feedback
Lesson 3B – Advanced Sensor Diagnostics and Maintenance							
0–10	O3A.4	Obtaining information	Telemetry log analysis with sensor errors	Guided exercise	Front	Laptop, simulator	Oral questions (2/3 correct)

10–25	O3A.4	Information processing	Sensor diagnostics: interpretation of drift, GPS deviation, barometric pressure	Case study	Small groups	Logs, software	Short report (2 errors identified)
25–40	O3A.5	Applying the conclusions	Practical maintenance: cleaning, testing connections, checking sensors in the system	Hands-on practice	Individual / pairs	Cleaning kit, multimeter	Direct observation
40–48	O3A.5	Synthesis & reverse connection	Discussion: preventive maintenance plan	Guided debate	Collective	UAV maintenance manual	List of preventive actions (min. 3 correct)
48–50	O3A.1–5	end	Recap, feedback, announcement of the assignment (maintenance sheet)	Conversation + summary	Front	Sheets / evaluation rubric	Self-assessment 1–5

ASSESSMENT

A. Formative (during the lesson):

- Oral questions and mini-test (70% passing score);
- Direct observation during work (complete calibration checklist);
- Worksheets (sensor identification, error diagnosis);
- Group feedback (concluding discussion).

B. Summative:

1. **Sensor diagnostic report (topic):**students identify and describe causes of detected errors (≥70% correctness).
2. **Calibration and maintenance checklist:**completed during class, checked after the session.
3. **Final written test (6 items):**questions about sensor types, calibration and maintenance (70% threshold).
4. **Practical demonstration:**correct calibration of a real or virtual sensor.

TECHNICAL AND SCIENTIFIC NOTES

- **IMU sensors:**contain MEMS gyroscopes and accelerometers; typical errors include drift and random noise.
- **GPS:**sensitive to electromagnetic interference; weak signal = trajectory deviation.
- **Barometer:**measures static pressure; temperature variations affect altitude accuracy.
- **Correct calibration:**eliminates offsets; must be performed at a stable temperature, on a flat surface.
- **Preventive maintenance:**cleaning of sensors every 20 hours of flight, calibration after each change in mechanical structure.
- **ESD safety:**mandatory when handling electronic components (strap, antistatic surface).

TRAINER NOTES

- If there are few modules available, divide students into teams (rotating: log analysis / calibration / diagnostics).
- Encourage students to keep a UAV maintenance log – note down every intervention performed.
- Use Resource 1 (the embedded image from the previous lesson) as a basis for completing the sensor paths and checking the connections.
- End with a moment of reflection: “Which sensor is the most vulnerable and why?”

UAV Remote Controller Maintenance and Repair

Lesson 4A — Remote Control System Maintenance (Transmitter)

Lesson 4B — UAV Receiver Repair and Diagnosis (Receiver)

Topic: UAV Remote Control (Transmitter & Receiver Systems) Maintenance and Repair
Duration: 2 hours (2 × 50 min)
Level: UAV technician / 11th grade students – applied mechanics-electronics field
Lesson type: theoretical-practical (explanatory + applicative + demonstrative)
Resources: RC remote controls, UAV receivers, configuration software, ESD equipment, telemetry logs
Specific competence: performing verification, calibration, testing and preventive maintenance operations of RC UAV systems, under electrical and electromagnetic safety conditions.

Lesson Plan

GENERAL INFORMATION

Learning Acquisitions

Lesson 4A — Remote Control System Maintenance (Transmitter)			
Objective code	**Desired behavior (What is required?)**	**Trial condition (What is offered?)**	**Success criterion (What is accepted?)**
O4A.1	Describe the architecture and operating principles of an RC remote control.	By analyzing a real model and a RC UAV block diagram.	Complete description of the 3 functional blocks (transmission, encoding, power supply).
O4A.2	Perform channel and control stick calibration.	Using a remote control and RC configuration software (EdgeTX, OpenTX, Radiomaster, etc.).	Calibration completed without deviations >2% between channels.
O4A.3	To test the transmission signal and the RF link with the receiver.	Based on a range test and RSSI display.	The receiver responds in a stable range (RSSI > -70 dBm, no loss).
O4A.4	To perform cleaning and physical maintenance of the remote control.	Equipped with ESD kit, cleaning sticks and compressed air.	Complete cleaning, without traces of dust or oxidation on contacts and buttons.
Lesson 4B — UAV Receiver Repair and Diagnosis (Receiver)			
Objective code	**Desired behavior (What is required?)**	**Trial condition (What is offered?)**	**Success criterion (What is accepted?)**

O4B.1	Check the correct connections of the receiver to the flight controller.	With a UAV board, signal cables (PPM/SBUS/CRSF) and technical manual.	All connections made correctly (signal, power, GND).
O4B.2	Diagnose common RC receiver faults.	Based on simulated cases (loss of connection, weak signal, low voltage).	Correct identification of the cause in at least 2 cases (≥80% accuracy).
O4B.3	Update the receiver firmware and check protocol compatibility.	Using the manufacturer's software (e.g. ExpressLRS Configurator, Betaflight Configurator).	Update completed successfully and communication restored.
O4B.4	Test the distance and stability of the RC–RX connection after maintenance.	In a simulated or real flight test.	Stable connection within 90–100% of the nominal distance.

Content structuring (areas, subareas, concepts and objective codes)

Content area	Content subarea	Key concepts	Corresponding objective code
Remote control systems	RC UAV architecture	Transmitter, receiver, channels, PPM/SBUS encoding, RF module	O4A.1
Calibration procedures	Channel calibration	offset, endpoint, neutral, gimbal alignment	O4A.2
RF signal and diagnostics	RF signal test	RSSI, SNR, range test, interference, failsafe	O4A.3
Physical maintenance	Cleaning and inspection	connectors, oxidized contacts, switches, power supply	O4A.4
Receiver systems	Receiver–FC connection	PPM/SBUS/CRSF signal, power supply, wiring	O4B.1
Fault diagnosis	Receiver errors	lost signal, broken antenna, unstable power supply	O4B.2
Firmware integration	Receiver firmware update	protocol compatibility, binding, software version	O4B.3
Range and safety tests	Distance/stability test	RSSI, delay, RF redundancy, packet loss	O4B.4

Table: Educational resources used

No. of documents.	Name of educational institution	Content / use
1	UAV Remote Control (RC Transmitter)	Architecture analysis, stick calibration
2	RC receiver + flight controller	Connection testing, link diagnosis

3	Laptop + software (OpenTX, ExpressLRS, Betaflight)	Calibration, binding, signal test
4	Educational videos	Calibration demonstrations and common errors
5	Multimeter / oscilloscope	Check power supply and PWM/SBUS signal
6	Cleaning kit + ESD	Physical cleaning and handling safety
7	Flight simulator	RC–RX distance test and failsafe reaction
8	Diagnostic worksheets and checklist	Check calibration and maintenance steps
9	Radio control technical manual	Protocols and Configuration Reference

Time (min)	Pedagogical objective (code)	Stages of the learning cycle (lesson sequence)	Training content	Teaching methods	Organizational form	Means	Evaluation form
Session 1 (50 min) – Remote Control System Maintenance (Transmitter)							
0–7	O4A.1	Obtaining information	Introduction: the role of remote control in the UAV system	Conversation + video	Front	Video, projector	Questions (2/3 correct)
7–18	O4A.1	Information processing	RC architecture: functional blocks, protocols, frequencies	Exposure + image analysis	Front	Remote control, slides	Mini-test (3 items, 70%)
18–30	O4A.2	Practicing operations	Stick calibration procedure	Practical demonstration	Front + pairs	Remote control, laptop	Complete calibration checklist
30–40	O4A.3	Applying the conclusions	RF signal testing and receiver connection	Hands-on exercise	in pairs	Transmitter + Receiver	Stable RSSI measurement (yes/no)
40–50	O4A.4	Reverse connection	Physical cleaning of the remote control, maintenance	Demonstration	Collective	ESD kit, compressed air	Practical observation (without errors)
Session 2 (50 min) – UAV Receiver Repair and Diagnostics							
0–8	O4B.1	Obtaining information	Receiver–FC connections: types and signals	Presentation + real example	Front	Receiver, cables	Questions (2/3 correct)
8–20	O4B.2	Information processing	Error diagnosis: connection loss, weak signal	Case study + video	Groups	Logs + video	Short report (80% accuracy)
20–32	O4B.3	Practicing operations	Receiver firmware update (binding & test)	Demonstration + practice	in pairs	Laptop, RC software	Complete update checklist
32–45	O4B.4	Applying the conclusions	Distance test / failsafe	Simulation/group exercise	Small groups	Simulator, drone trainer	Stable result (RSSI > -70 dBm)
45–50	O4B.1–4	Reverse connection	Recap + topic: RC maintenance sheet	Conversation	Front	Homework sheets	Evaluation rubric clarification

ASSESSMENT

A. Formative:

- Quick mini-test (3 items, 70% threshold)
- Practical observation on calibration / signal test
- Completed forms (diagnostic, binding)
- Verbal feedback and review questions

B. Summative:

1. **RC maintenance checklist completed**– criterion: 100% completeness and correctness ≥ 70%.
2. 🎬 Receiver diagnostic report ⇔ cause and solution description (≥70% score).
3. 🎬 Written test (6 items) ⇔ RC protocols, calibration, diagnostics, failsafe (70% threshold).
4. 🎬 Practical demonstration (optional) ⇔ RC calibration + receiver binding.

TECHNICAL NOTES AND GOOD PRACTICES

- **UAV transmitter**operates in ISM bands (2.4 GHz, 868 MHz). Ensure antennas are clean and correctly oriented.
- **receiver**must be mounted away from EMI sources (ESC, power cables).
- **SIZING**RC sticks must be re-initialized after any firmware update.
- **Receiver firmware**must match the broadcast protocol (SBUS, CRSF, ExpressLRS).
- **Preventive maintenance:**cleaning the housing and checking the potentiometers after 50 hours of use.
- **Failsafe test:**mandatory before each flight – check reaction to signal loss.

TRAINER NOTES

- In the absence of complete equipment, use RC simulators (EdgeTX Companion).
- Encourage learners to document RC–RX firmware versions for traceability.
- Emphasize the importance of RF safety and signal verification before each flight.
- Suggest creating your own RC periodic maintenance sheet.