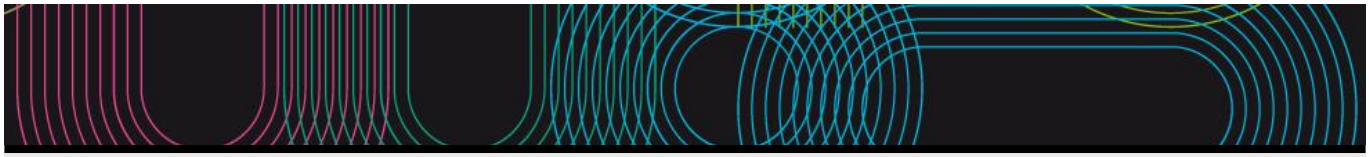

(*)Escola de Enxeñaría Aeronáutica e do Espazo

Presentation

The School of Aeronautic and Space Engineering (EEAE) of the University of Vigo at the Campus of Ourense offers the degrees of the University of Vigo that are related both to bachelor's and to master's level in the field of aeronautical or aerospace engineering.

More information about the Center and its degrees is found in this document or on the web page (http://aero.uvigo.es).

Address

Escola de Enxeñaría Aeronáutica e do Espazo

Pavillón Manuel Martínez-Risco
Campus universitario
32004 Ourense

Tel.: +34 988 368 823
Web: http://aero.uvigo.es

Regulations and legislation

The information is available on the Center's web site (http://aero.uvigo.es in the section: School -> Regulations).

Máster Universitario en Sistemas Aéreos no Tripulados

Subjects

Year 1st

Code	Name	Quadmester	Total Cr.
O07M189V01101	Fundamentals of unmanned aircraft systems	1st	6
O07M189V01102	Operations, legislation and certification	1st	6
O07M189V01103	Aerodynamics, flight mechanics and propulsion	1st	6
O07M189V01104	Observation systems	1st	6
O07M189V01201	Data analysis methods	2nd	6
O07M189V01202	Applications in the agroforestry and environment	2nd	6
O07M189V01203	Applications in engineering and architecture	2nd	6
O07M189V01204	Control systems	2nd	6

O07M189V01205	Navigation and communication systems	2nd	6
O07M189V01206	Critical software development	2nd	6
O07M189V01207		2nd	9
O07M189V01208		2nd	9

IDENTIFYING DATA				
Fundamentals of unmanned aircraft systems				
Subject	Fundamentals of unmanned aircraft systems			
Code	O07M189V01101			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Mandatory	1st	1st
Teaching language	#EnglishFriendly Spanish			
Department				
Coordinator	González Jorge, Higinio			
Lecturers	González Jorge, Higinio			
E-mail	higiniog@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	Course taught by USC professors			

Skills
Code

Learning outcomes	
Expected results from this subject	Training and Learning Results

Contents
Topic

Planning			
	Class hours	Hours outside the classroom	Total hours
*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.			

Methodologies
Description

Personalized assistance

Assessment		
Description	Qualification	Training and Learning Results

Other comments on the Evaluation

Sources of information
Basic Bibliography
Complementary Bibliography

Recommendations

IDENTIFYING DATA				
Operations, legislation and certification				
Subject	Operations, legislation and certification			
Code	O07M189V01102			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Mandatory	1st	1st
Teaching language	#EnglishFriendly Spanish			
Department				
Coordinator	González Jorge, Higinio			
Lecturers	González Jorge, Higinio			
E-mail	higiniog@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	Course taught by USC professors			

Skills
Code

Learning outcomes	
Expected results from this subject	Training and Learning Results

Contents
Topic

Planning			
	Class hours	Hours outside the classroom	Total hours
*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.			

Methodologies
Description

Personalized assistance

Assessment		
Description	Qualification	Training and Learning Results

Other comments on the Evaluation

Sources of information
Basic Bibliography
Complementary Bibliography

Recommendations

IDENTIFYING DATA				
Aerodynamics, flight mechanics and propulsion				
Subject	Aerodynamics, flight mechanics and propulsion			
Code	O07M189V01103			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Mandatory	1st	1st
Teaching language	#EnglishFriendly Spanish			
Department				
Coordinator	González Jorge, Higinio			
Lecturers	González Jorge, Higinio			
E-mail	higiniog@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	This subject aims to introduce the basic foundations that underlie the flight of any UAV: Aerodynamics, Flight Mechanics, and Propulsion. Its operating principles are described and the general concepts are reviewed. International students may request teachers: a) materials and bibliographic references to follow the subject in English, b) attend tutorials in English, c) tests and evaluations in English.			

Skills	
Code	
A1	Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context
A2	That students know how to apply their acquired knowledge and problem-solving skills in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study.
A3	That students are able to integrate knowledge and face the complexity of making judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
B1	That students acquire general knowledge in unmanned aerial systems engineering.
B5	That students are able to apply, in the field of unmanned aerial systems, the principles and methodologies of research such as literature searches, data collection, data analysis and interpretation, as well as the presentation of conclusions, in a clear, concise and rigorous manner.
C1	Knowledge about the main systems, on-board instruments and control station of an unmanned aircraft, as well as their influence on safety.
D8	Capacity for analysis and synthesis.
D9	Critical thinking skills and creativity.

Learning outcomes	
Expected results from this subject	Training and Learning Results
Understand the operation of a profile of flight, the basic performance of the aircraft and surfaces of control	A1 A2 A3 B1 B5 D8 D9
Learn which are the main systems of energy and propulsion	A1 A2 A3 B5 C1 D8 D9

Understand the basic principles of the mechanics of flight	A1 A2 A3 B1 B5 D8 D9

Contents	
Topic	
Introduction	Historical approximation to unmanned aerial vehicles. Ranking of the aircraft and his systems of propulsion. Terrestrial infrastructures. Management of aerial traffic. Legal environment.
Unmanned air vehicles	Principles of flight. Aircraft performance. General description of fixed wing aircraft . Controls of flight. Structure. Main instruments and systems. General description of helicopters. Controls of flight. Main instruments and systems. Multicopters.
Fluid mechanics priinciples	Compresivility. Viscosity. Limit layer and turbulence. Reynolds number. Mach number. Bernoulli's equation.. ISA.
Aerodynamics principles	Airfoils in incompresible flow. Flat plate. Cilinder. Kutta condition. Prandtl.
Introduction to the propulsion of aircraft.	Propellers: Theory of Froude; theory of the element of shovel. Propellerr adaptation. Aero jets. Push power, specific impulse and control of push in electric propulsion.
Flight mechanics	Basic flight equations. Cruisse flight, ascend, descent and gliding. Banking. Wind effect. Actuators. Stability and control.

Planning			
	Class hours	Hours outside the classroom	Total hours
Lecturing	21	40	61
Problem solving	21	45	66
Problem and/or exercise solving	3	0	3
Report of practices, practicum and external practices	0	20	20
*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.			

Methodologies	
	Description
Lecturing	Content presentation using audiovisual means. The contents will be upload to the e-learning platform.
Problem solving	Content presentation using audiovisual means. The contents will be upload to the e-learning platform.

Personalized assistance	
Methodologies	**Description**
Lecturing	e-mail and one-to-one tutorials
Problem solving	e-mail and one-to-one tutorials

Assessment

	Description	Qualification	Training and Learning Results			
Problem solving	.	80	A1 A2 A3	B1 B5	C1	D8 D9
Report of practices, practicum and external practices	.	20	A1 A2 A3	B1 B5	C1	D8 D9

Other comments on the Evaluation

Students will deliver all the required reports during the course. All have to reach at least a 5/10 score to pass.
In June evaluation, a 5/10 is needed for students to pass the exam.
In July evaluation, a 5/10 score is also needed in the exam, as well as having scored a 5/10 on required reports.

Sources of information

Basic Bibliography

Complementary Bibliography

Jeffrey D. Barton, **Fundamentals of small unmanned aircraft flight**,

Aviation Civil Aviation Organization, **Unmanned aircraft systems**,

Mouhamed Abdulla, Jaroslav V. Svoboda, Luis Rodrigues, **Avionics made simple**,

Bon Dewitt, **Unmanned aerial systems for mapping**,

Sergio Esteban Ronceso, **Fundamentos de Ingeniería Aeroespacial**,

John Anderson, **Fundamentos de aerodinámica**, 6, McGraw Hill, 2017

Miguel Ángel Gómez Tierno, **Mecánica de vuelo**, 2, Garceta, 2012

Antonio Esteban Oñate, **Conocimientos del avión**, 1, Paraninfo, 2007

Recommendations

Subjects that continue the syllabus

Radio communication and navigation systems/O07M174V01103

Subjects that are recommended to be taken simultaneously

Unmanned aerial systems operations/O07M174V01102

IDENTIFYING DATA				
Observation systems				
Subject	Observation systems			
Code	O07M189V01104			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Mandatory	1st	1st
Teaching language	#EnglishFriendly Spanish			
Department				
Coordinator	Salgueiro Piñeiro, Jose Ramon			
Lecturers	González Jorge, Higinio Salgueiro Piñeiro, Jose Ramon			
E-mail	jrs@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	This subject presents an overview of drone observation systems based on both active and passive sensors.			

Skills	
Code	
A1	Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context
A2	That students know how to apply their acquired knowledge and problem-solving skills in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study.
A3	That students are able to integrate knowledge and face the complexity of making judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
A5	That students possess the learning skills that will enable them to continue studying in a manner that will be largely self-directed or autonomous.
B4	That students acquire the knowledge to develop unmanned aerial systems and plan specific operations, depending on the existing needs and apply the existing technological tools.
B5	That students are able to apply, in the field of unmanned aerial systems, the principles and methodologies of research such as literature searches, data collection, data analysis and interpretation, as well as the presentation of conclusions, in a clear, concise and rigorous manner.
C2	Knowledge of geomatics, photogrammetric and cartographic principles, navigation, aerotriangulation, interpretation and digital image processing necessary in the operation of unmanned aerial systems and know how to apply the regulations in force.
C4	Ability to develop a technical project in the field of unmanned aerial systems engineering.
D2	Ability to communicate orally and in writing in Galician.
D6	Ability to work as part of a team.
D7	Organizational and planning skills.
D8	Capacity for analysis and synthesis.
D9	Critical thinking skills and creativity.

Learning outcomes	
Expected results from this subject	Training and Learning Results
NewTo know the different passive and active sensors existing in aerial applications.	A1 A2 A3 A5 B4 B5 C2 C4 D2 D6 D7 D8 D9

Understand sensor calibration procedures.	A1 A2 A3 A5 B4 B5 C2 C4 D2 D6 D7 D8 D9
Algoritmos básicos de procesamiento de imagen y procesamiento de datos LiDAR	A1 A2 A3 A5 B4 B5 C2 C4 D2 D6 D7 D8 D9

Contents	
Topic	
1. Introduction to observation systems	Motivation. Applications. Basic components of a sensor. Relevant spectral regions. Integration of sensors in UAVs
2. Radiation measurement	Ways to describe radiation propagation. Electromagnetic theory. Harmonic waves. Types of waves. Propagation of electromagnetic waves. Wave energy flow. Radiometric magnitudes and units. Photometric magnitudes and units.
3. Radiation sources	Types of radiation sources. Ratiative processes: emission and reflection. Thermal sources. Kirchhoff's law. Reflection types. Lambertian sources. Source-sensor radiation transfer. Atmospheric transmission.
4. Radiation detectors	Types of radiation detectors. Photon detectors. Architectures of photon detectors. Colour detectors. Thermal detectors. Microbolometers. Noise sources.
5. Optical systems	Centered systems. Perfect system. Abbe and Herschel conditions. Paraxial optics. Cardinal elements. Coupling of optical systems. Lenses and mirrors. Aberrations. Aperture and field stops. Resolution of optical systems.
6. Image sensors	Optical systems for cameras. Transversal and angular fields. Onjective basic design: telescope and wide angle. Image plane irradiance. Image resolution and sharpness. Image acquisition from UAVs. Responsivity and detectivity. Sensor sensitivity: figures of merit. Space resolution: PSF and MTF.
7. Thermal imaging	Types of thermographic systems. Output signal. Detector's general response. Image evaluation: figures of merit. Spatial resolution. Measuring instantaneous field of view. Applications.
8. Spectral imaging	Multiespectral and hyperespectral systems. Classification of hyperespectral systems. Spectral variables. Separation systems. Interference band filters. Diffraction gratings. Fourier transform spectrometers.
9. RADAR systems.	RADAR basics. Synthetic Aperture Radar (SAR). RADAR as an remote sensing system. Measurement of deformations with RADAR.
10. LiDAR systems.	Fundamentals. Time-of-flight LiDAR systems. Phase difference LiDAR systems. Solid state LiDAR systems. Calibration of LiDAR systems. Measurement procedures. Point clouds.
11. Integration of remote sensing and navigation system.	Fundamentals of navigation systems. GNSS and INS systems. Integration with passive optical systems. Integration with active optical systems
12. Data analysis and image processing	Metadata. Digital image. Image definition. Object recognition and tracking. Image processing. Photogrammetry. Point cloud processing

Planning

	Class hours	Hours outside the classroom	Total hours
Lecturing	21	21	42
Practices through ICT	21	87	108

*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.

Methodologies

	Description
Lecturing	The lecturer presents the contents of the subject using projection methods for the supporting graphic material and also attending questions formulated by the students during the presentation.
Practices through ICT	The lecturer explains the tasks to develop at the laboratory and help the students to handle the instruments and follow the necessary procedures.

Personalized assistance

Methodologies	Description
Lecturing	Mail. Videoconferencing.
Practices through ICT	Mail. Videoconferencing.

Assessment

	Description	Qualification	Training and Learning Results			
Lecturing	The theoretical contents of the subject will be evaluated by means of two partial exams.	50	A1 A2 A3 A5	B4 B5	C2 C4	D2 D6 D7 D8 D9
Practices through ICT	The practices will be evaluated on the basis of the solved exercises that the students will have to hand in to the teacher.	50	A1 A2 A3 A5	B4 B5	C2 C4	D2 D6 D7 D8 D9

Other comments on the Evaluation

Sources of information

Basic Bibliography

Complementary Bibliography

Grant, Barbara G., **Getting Started with UAV Imaging Systems**, SPIE, 2016

Holst, Gerald C., **Common Sense Approach to Thermal Imaging**, SPIE, 2000

Wolfe, William L., **Introduction to Imaging Spectrometers**, SPIE, 1997

Martínez-Corral, M., **Instrumentos ópticos y optométricos: teoría y prácticas**, Universidad de Valencia, 1998

Mejías Arias, P., Martínez Herrero, Rosario, **Óptica geométrica**, Síntesis, 1990

Hecht E., **Óptica**, Addison Wesley, 2000

Grant, Barbara G., **Field Guide to Radiometry**, SPIE, 2011

Palmer, James M. and Grant, Barbara G., **The Art of Radiometry**, SPIE, 2009

Slater, P. N., **Remote Sensing: Optics and optical systems**, Addison-Wesley, 1980

Willers, Cornelius J., **Electro-Optical System Analysis and Design: A Radiometry Perspective**, SPIE, 2013

Dereniak, Eustace L., **Optical radiation detectors**, John Wiley & Sons, 1984

Burbano de Ercilla, S., **Física General**, Mira, 1990

Born M., Wolf E., **Principles of optics: electromagnetic theory of propagation, interference and difraction of light**, Cabridge University Press, 1999

Muñoz-Rodríguez J. A., **Laser scanner technology**, InTech, 2012

Chen Z., **The application of airborne LiDAR data in the modelliing of 3D urban landscape ecology**, Cambridge Scholars Publishing, 2017

Clough D., **Earth observation systems for resource management and environmental control**, Springer, 2013

Fitch J. P., **Synthetic aperture RADAR**, Springer, 1988

Maitre H., **Processing of synthetic aperture RADAR images**, Wiley, 2008

Richards J. A., **Remote sensing with imaging RADAR**, Springer, 2009

Holvecz F., Pasquali P., **Land applications of RADAR remote sensing**, InTech, 2014

Recommendations

IDENTIFYING DATA				
Data analysis methods				
Subject	Data analysis methods			
Code	O07M189V01201			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Optional	1st	2nd
Teaching language	#EnglishFriendly Spanish			
Department				
Coordinator	González Jorge, Higinio			
Lecturers	González Jorge, Higinio			
E-mail	higiniog@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	Course taught by USC professors			

Skills
Code

Learning outcomes	
Expected results from this subject	Training and Learning Results

Contents
Topic

Planning			
	Class hours	Hours outside the classroom	Total hours
*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.			

Methodologies
Description

Personalized assistance

Assessment		
Description	Qualification	Training and Learning Results

Other comments on the Evaluation

Sources of information
Basic Bibliography
Complementary Bibliography

Recommendations

IDENTIFYING DATA				
Applications in the agroforestry and environment				
Subject	Applications in the agroforestry and environment			
Code	O07M189V01202			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Optional	1st	2nd
Teaching language	#EnglishFriendly Spanish			
Department				
Coordinator	González Jorge, Higinio			
Lecturers	González Jorge, Higinio			
E-mail	higiniog@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	Course taught by USC professors			

Skills
Code

Learning outcomes	
Expected results from this subject	Training and Learning Results

Contents
Topic

Planning			
	Class hours	Hours outside the classroom	Total hours
*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.			

Methodologies
Description

Personalized assistance

Assessment		
Description	Qualification	Training and Learning Results

Other comments on the Evaluation

Sources of information
Basic Bibliography
Complementary Bibliography

Recommendations

IDENTIFYING DATA				
Applications in engineering and architecture				
Subject	Applications in engineering and architecture			
Code	O07M189V01203			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Optional	1st	2nd
Teaching language	#EnglishFriendly Spanish			
Department				
Coordinator	González Jorge, Higinio			
Lecturers	González Jorge, Higinio			
E-mail	higiniog@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	Course taught by USC professors			

Skills
Code

Learning outcomes	
Expected results from this subject	Training and Learning Results

Contents
Topic

Planning			
	Class hours	Hours outside the classroom	Total hours
*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.			

Methodologies	
	Description

Personalized assistance

Assessment		
Description	Qualification	Training and Learning Results

Other comments on the Evaluation

Sources of information
Basic Bibliography
Complementary Bibliography

Recommendations

IDENTIFYING DATA				
Control systems				
Subject	Control systems			
Code	O07M189V01204			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Optional	1st	2nd
Teaching language	#EnglishFriendly Spanish Galician			
Department				
Coordinator	García Rivera, Matías			
Lecturers	García Rivera, Matías			
E-mail	mgrivera@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	This course describes fundamental concepts, principles and techniques about unmanned aerial vehicles: geometry, mechanics, hardware, control and navigation. English Friendly subject: International students may request from the teachers: a) materials and bibliographic references in English, b) tutoring sessions in English, c) exams and assessments in English.			

Skills	
Code	
A3	That students are able to integrate knowledge and face the complexity of making judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
A4	That students know how to communicate their conclusions -and the ultimate knowledge and reasons that support them- to specialized and non-specialized audiences in a clear and unambiguous manner.
A5	That students possess the learning skills that will enable them to continue studying in a manner that will be largely self-directed or autonomous.
B3	That students acquire the ability to analyze the needs of a company in the field of unmanned aerial systems and determine the best technological solution for it.
B4	That students acquire the knowledge to develop unmanned aerial systems and plan specific operations, depending on the existing needs and apply the existing technological tools.
B5	That students are able to apply, in the field of unmanned aerial systems, the principles and methodologies of research such as literature searches, data collection, data analysis and interpretation, as well as the presentation of conclusions, in a clear, concise and rigorous manner.
C1	Knowledge about the main systems, on-board instruments and control station of an unmanned aircraft, as well as their influence on safety.
C3	Ability to interact with other technical teams in the engineering field for the planning of operations with unmanned aerial systems.
C4	Ability to develop a technical project in the field of unmanned aerial systems engineering.
D6	Ability to work as part of a team.
D7	Organizational and planning skills.
D8	Capacity for analysis and synthesis.
D9	Critical thinking skills and creativity.

Learning outcomes	
Expected results from this subject	Training and Learning Results
RA01: Acquire knowledge about unmanned aerial robots, their key components, state estimation, basic mechanics, design considerations, agility and maneuverability.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9

RA02: Know the geometric and mechanical considerations of unmanned aerial vehicles, transformations, rotations, Euler angles, applicability of quaternions, angular velocity, equations of movement of a multi-rotor, linearization.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9
RA03: Understand the bases of the control and navigation system, PID controls, control in 1D, 2D and 3D of multirotor, generation of trajectories, Euler-Lagrange equations and Splines.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9
RA04: Understand the operation of multiple control systems.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9
RA05: Know the sense & avoid devices.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9
RA06: Understand the basics of embedded systems in real time.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9

RA07: Know the different existing open hardware controllers and their operation.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9

Contents	
Topic	
Introduction to unmanned aerial vehicles.	Multi-rotors.
Key components of autonomous flight.	Estimation of states. Basic mechanics Design considerations Agility and maneuverability Selection of components.
Geometry and mechanics.	Transformations Rotations Angles of Euler. Quaternions Angular velocity. Newton-Euler equations. Main axes and main moments of inertia. Equations of movement of a multi-rotor. Linearization
Control and navigation.	PID control. 1D, 2D and 3D control of multirotor. Paths. Euler-Lagrange equations. Splines.
Control of multiple systems.	
Sense & avoid devices.	
Fundamentals of embedded systems in real time.	
Open hardware controllers.	

Planning			
	Class hours	Hours outside the classroom	Total hours
Lecturing	10	0	10
ICT suppoted practices (Repeated, Dont Use)	10	15	25
Problem solving	10	15	25
Seminars	2	0	2
Mentored work	8	72	80
Problem and/or exercise solving	2	6	8
*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.			

Methodologies	
	Description
Lecturing	Exhibition by the teacher of the contents on the subject.
ICT suppoted practices (Repeated, Dont Use)	Activities of application of knowledge to concrete situations and acquisition of basic and procedural skills related to the subject. They are developed through ICT in an autonomous way.
Problem solving	Activity in which problems related to the subject are formulated. The students must develop the solutions. The objective is that the students apply the theoretical contents in the resolution of small programming problems.
Seminars	Orientation activity for students.
Mentored work	The student, individually or in groups, prepares a document on the topic of the subject or prepares seminars, investigations, reports, essays, summaries of readings, conferences, etc.

Personalized assistance

Methodologies	Description
Mentored work	Tutorials in the teacher's office. It is advisable to go to these tutorials when difficulties appear in the development of the supervised work, or when the time dedicated to the non-contact activities significantly exceeds the time set in the planning.
ICT suppoted practices (Repeated, Dont Use)	Tutorials in the teacher's office. It is advisable to attend these tutorials when difficulties arise in the development of autonomous practices through ICT, or when the time spent on non-contact activities significantly exceeds the time set in the planning.

Assessment						
	Description	Qualification	Training and Learning Results			
ICT suppoted practices (Repeated, Dont Use)	2 assignments of autonomous practices through ICT, each one will contribute 15% of the overall mark for this course	30	A3 A4 A5	B3 B4 B5	C1 C3 C4	D6 D7 D8 D9
Mentored work	1 assignment of supervised work, it will contribute 20% of the overall mark for this course	20	A3 A4 A5	B3 B4 B5	C1 C3 C4	D6 D7 D8 D9
Problem and/or exercise solving	2 written exams, short answer tests, about the contents and competences taught in the lectures and autonomous practices through ICT. These tests will be short answer, each one will contribute 25% of the overall mark for this course.	50	A3 A4 A5	B3 B4 B5	C1 C3 C4	D6 D7 D8 D9

Other comments on the Evaluation

ASSESSMENT FOR ASSISTANTS IN 1ST EDITION: CONTINUOUS EVALUATION.

For the students attending the 1st edition (continuous evaluation) the following tests and deliveries will be made:

- 1 assignment of supervised work, it will contribute 20% of the overall mark for this course;
- 2 assignments of autonomous practices through ICT, each one will contribute 15% of the overall mark for this course;
- 2 written exams, short answer tests, about the contents and competences taught in the lectures and autonomous practices through ICT. These tests will be short answer, each one will contribute 25% of the overall mark for this course.

To pass the subject it is mandatory that the student make all the assignments and all the written exams, and that in each assignment and written exam obtain a mark equal to or higher than 4.0.

In the case of not making any assignments or written exam, or obtain in any assignments or written exam a mark lower than 4.0, if the overall mark is higher than 5, the final mark in the minutes will be 4.9, fail.

ASSESSMENT FOR NON ASSISTANTS IN 1ST EDITION.

For the students attending the 1st edition (non continuous evaluation) the following tests and deliveries will be made:

- 1 assignment of supervised work, it will contribute 20% of the overall mark for this course;
- 2 assignments of autonomous practices through ICT, each one will contribute 15% of the overall mark for this course;
- 1 written exam about the contents and competences taught in the lectures and autonomous practices through ICT. This test will be short answer and it will contribute 50% of the overall mark for this course.

To pass the subject it is mandatory that the student make all the assignments and all the written exams, and that in each assignment and written exam obtain a mark equal to or higher than 4.0.

In the case of not making any assignments or written exam, or obtain in any assignments or written exam a mark lower than

4.0, if the overall mark is higher than 5, the final mark in the minutes will be 4.9, fail.

ASSESSMENT FOR 2ST EDITION AND OTHER EDITIONS

The same assessment for non assisstans in 1st edition

JUSTIFICATION OF ABSENCE

To be able to justify the absence to a exam is required a Certificate of Absence or a Consultation and Hospitalization Certificate (also called P10) issued by the SERGAS doctor, or a certificate issued by a doctor. A proof of the doctor's appointment will not be valid

Sources of information
Basic Bibliography
Randal Beard, Timothy McLain, **Small Unmanned Aircraft: Theory and Practice**, Princeton University Press, 2012
Complementary Bibliography
Michael Cook, **A Linear Systems Approach to Aircraft Stability and Control**, Butterworth-Heinemann, 2007
Katsuhiro Ogata, **Ingeniería de control moderna**, PRENTICE HALL, 2010
Hassan Gomaa, **Real-time software design for embedded systems**, Cambridge University Press, 2016
Plamen Angelov, **Sense and Avoid in UAS Research and Applications**, John Wiley & Sons, Ltd, 2012
https://px4.io/,

Recommendations

Subjects that it is recommended to have taken before
Unmanned aerial systems operations/O07M174V01102
On-board sensors/O07M174V01104

IDENTIFYING DATA				
Navigation and communication systems				
Subject	Navigation and communication systems			
Code	O07M189V01205			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Optional	1st	2nd
Teaching language	#EnglishFriendly Spanish			
Department				
Coordinator	González Jorge, Higinio			
Lecturers	Arias Acuña, Alberto Marcos González Jorge, Higinio González Valdés, Borja González de Santos, Luis Miguel Pino García, Antonio			
E-mail	higiniog@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	This subject shows the fundamentals of the main navigation and communication systems used in drones.			

Skills	
Code	
A1	Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context
A2	That students know how to apply their acquired knowledge and problem-solving skills in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study.
A3	That students are able to integrate knowledge and face the complexity of making judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
A4	That students know how to communicate their conclusions -and the ultimate knowledge and reasons that support them- to specialized and non-specialized audiences in a clear and unambiguous manner.
A5	That students possess the learning skills that will enable them to continue studying in a manner that will be largely self-directed or autonomous.
B3	That students acquire the ability to analyze the needs of a company in the field of unmanned aerial systems and determine the best technological solution for it.
B4	That students acquire the knowledge to develop unmanned aerial systems and plan specific operations, depending on the existing needs and apply the existing technological tools.
B5	That students are able to apply, in the field of unmanned aerial systems, the principles and methodologies of research such as literature searches, data collection, data analysis and interpretation, as well as the presentation of conclusions, in a clear, concise and rigorous manner.
C1	Knowledge about the main systems, on-board instruments and control station of an unmanned aircraft, as well as their influence on safety.
C3	Ability to interact with other technical teams in the engineering field for the planning of operations with unmanned aerial systems.
D6	Ability to work as part of a team.
D7	Organizational and planning skills.
D8	Capacity for analysis and synthesis.
D9	Critical thinking skills and creativity.

Learning outcomes	
Expected results from this subject	Training and Learning Results

To know the classic systems of communications and navigation.	A1 A2 A3 A4 A5 B3 B4 B5 C1 C3 D6 D7 D8 D9
To understand the operation of antennas and the range of the radio link.	A1 A2 A3 A4 A5 B3 B4 B5 C1 C3 D6 D7 D8 D9
To understand the operation of a positioning system based on ground aids.	A1 A2 A3 A4 A5 B3 B4 B5 C1 C3 D6 D7 D8 D9
To understand the operation of a satellite positioning system.	A1 A2 A3 A4 A5 B3 B4 B5 C1 C3 D6 D7 D8 D9

To learn the characteristics of automatic surveillance systems based on ADS-B.	A1 A2 A3 A4 A5 B3 B4 B5 C1 C3 D6 D7 D8 D9
Understand digital modulation systems.	A1 A2 A3 A4 A5 B3 B4 B5 C1 C3 D6 D7 D8 D9

Contents
Topic
1. Geodesy and aerial navigation.
2. Concept of frequency, wave and antenna. Wave propagation.
3. Navigation system based on ground aids.
4. Satellite-based navigation systems. ADS-B systems.
5. Inertial systems.
6. Complementary filter.
7. Kalman filter.
8. Friis formula. Noise, signal to noise ratio, BER and channel capacity.
9. Analog and digital modulations. Adaptive modulations.
10. MIMO techniques
11. Advanced satellite positioning. RTK

Planning			
	Class hours	Hours outside the classroom	Total hours
Lecturing	21	21	42
Practices through ICT	21	87	108
*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.			

Methodologies	
	Description
Lecturing	
Practices through ICT	

Personalized assistance	
Methodologies	**Description**
Lecturing	Attention by e-mail and videoconference.
Practices through ICT	Attention by e-mail and videoconference.

Assessment						
	Description	Qualification	Training and Learning Results			
Lecturing	Two multiple-choice tests.	50	A1 A2 A3 A4 A5	B3 B4 B5	C1 C3	D6 D7 D8 D9
Practices through ICT	Practical work deliverables.	50	A1 A2 A3 A4 A5	B3 B4 B5	C1 C3	D6 D7 D8 D9

Other comments on the Evaluation

Sources of information

Basic Bibliography

Complementary Bibliography

Mike Tooley, David Wyatt, **Aircarft communications and navigation systems**, Elsevier, 2007

Eduardo Huerta, Aldo Mangiaterra, Gustavo Noguera, **GPS. Posicionamiento satelital**, UNR Editora, 2005

Myron Kayton, WAlter R. Fried, **Avionics navigation systems**, Wiley, 1997

Robert Arán Escuer, J. R. Aragoneses Manso, **Sistemas de navegación aérea**, Paraningo, 1983

Recommendations

Subjects that it is recommended to have taken before

Aerodynamics, flight mechanics and propulsion/O07M189V01103

Fundamentals of unmanned aircraft systems/O07M189V01101

Operations, legislation and certification/O07M189V01102

Observation systems/O07M189V01104

IDENTIFYING DATA				
Critical software development				
Subject	Critical software development			
Code	O07M189V01206			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Optional	1st	2nd
Teaching language	#EnglishFriendly Spanish			
Department				
Coordinator	González Jorge, Higinio			
Lecturers	González Jorge, Higinio González de Santos, Luis Miguel			
E-mail	higiniog@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	This subject shows the fundamentals for software development in critical applications such as drone-autopilots.			

Skills	
Code	
A3	That students are able to integrate knowledge and face the complexity of making judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
A4	That students know how to communicate their conclusions -and the ultimate knowledge and reasons that support them- to specialized and non-specialized audiences in a clear and unambiguous manner.
A5	That students possess the learning skills that will enable them to continue studying in a manner that will be largely self-directed or autonomous.
B3	That students acquire the ability to analyze the needs of a company in the field of unmanned aerial systems and determine the best technological solution for it.
B4	That students acquire the knowledge to develop unmanned aerial systems and plan specific operations, depending on the existing needs and apply the existing technological tools.
B5	That students are able to apply, in the field of unmanned aerial systems, the principles and methodologies of research such as literature searches, data collection, data analysis and interpretation, as well as the presentation of conclusions, in a clear, concise and rigorous manner.
C1	Knowledge about the main systems, on-board instruments and control station of an unmanned aircraft, as well as their influence on safety.
C3	Ability to interact with other technical teams in the engineering field for the planning of operations with unmanned aerial systems.
C4	Ability to develop a technical project in the field of unmanned aerial systems engineering.
D2	Ability to communicate orally and in writing in Galician.
D6	Ability to work as part of a team.
D7	Organizational and planning skills.
D8	Capacity for analysis and synthesis.
D9	Critical thinking skills and creativity.

Learning outcomes	
Expected results from this subject	Training and Learning Results
To know, understand, analyze, evaluate and synthesize software development in aerospace projects.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D2 D6 D7 D8 D9

To know and analyze the importance of software in missions with unmanned systems.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D2 D6 D7 D8 D9
To know the main standards for software development.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D2 D6 D7 D8 D9
Know, understand, analyze, evaluate and synthesize the role of software in the systems engineering process.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D2 D6 D7 D8 D9
To know the main components for the operation of a software-based system.	A3 A4 B3 B4 B5 C1 C3 C4 D2 D6 D7 D8 D9

Contents
Topic
1. On board autopilot.
2. Real-time operating systems.
3. Concurrent systems.
4. Software engineering for unmanned aerial systems.
5. Software requirements for unmanned aerial systems.
6. Use of packages for telemetry and telecommand.
7. Verification and validation. Standards.

8. Simulation tools.

9. Autopilot design and implementation project

Planning

	Class hours	Hours outside the classroom	Total hours
Lecturing	14	14	28
Practices through ICT	28	94	122

*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.

Methodologies

	Description
Lecturing	
Practices through ICT	

Personalized assistance

Methodologies	Description
Lecturing	Tutorials by e-mail and videoconference.
Practices through ICT	Tutorials by e-mail and videoconference.

Assessment

	Description	Qualification	Training and Learning Results			
Lecturing	Multiple-choice tests.	50	A3 A4 A5	B3 B4 B5	C1 C3 C4	D2 D6 D7 D8 D9
Practices through ICT	Exercises deliveries.	50	A3 A4 A5	B3 B4 B5	C1 C3 C4	D2 D6 D7 D8 D9

Other comments on the Evaluation

Sources of information

Basic Bibliography

Complementary Bibliography

Castillo, Pedro, **Modelling and control of mini-flying machines**, Springer, 2005

Fahlstraom, Paul Gerin, **Introduction to UAV systems**, John Wiley & Sons, 2012

Recommendations

IDENTIFYING DATA				
(*)Prácticas externas				
Subject	(*)Prácticas externas			
Code	O07M189V01207			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	9	Mandatory	1st	2nd
Teaching language	#EnglishFriendly Spanish			
Department				
Coordinator	González Jorge, Higinio			
Lecturers	González Jorge, Higinio			
E-mail	higiniog@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	This subject allows students to receive practical training in companies in the drone sector.			

Skills	
Code	
A1	Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context
A2	That students know how to apply their acquired knowledge and problem-solving skills in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study.
A3	That students are able to integrate knowledge and face the complexity of making judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
A4	That students know how to communicate their conclusions -and the ultimate knowledge and reasons that support them- to specialized and non-specialized audiences in a clear and unambiguous manner.
A5	That students possess the learning skills that will enable them to continue studying in a manner that will be largely self-directed or autonomous.
B1	That students acquire general knowledge in unmanned aerial systems engineering.
B2	That students acquire general knowledge in the operation of unmanned aerial systems.
B3	That students acquire the ability to analyze the needs of a company in the field of unmanned aerial systems and determine the best technological solution for it.
B4	That students acquire the knowledge to develop unmanned aerial systems and plan specific operations, depending on the existing needs and apply the existing technological tools.
B5	That students are able to apply, in the field of unmanned aerial systems, the principles and methodologies of research such as literature searches, data collection, data analysis and interpretation, as well as the presentation of conclusions, in a clear, concise and rigorous manner.
C1	Knowledge about the main systems, on-board instruments and control station of an unmanned aircraft, as well as their influence on safety.
C2	Knowledge of geomatics, photogrammetric and cartographic principles, navigation, aerotriangulation, interpretation and digital image processing necessary in the operation of unmanned aerial systems and know how to apply the regulations in force.
C3	Ability to interact with other technical teams in the engineering field for the planning of operations with unmanned aerial systems.
C4	Ability to develop a technical project in the field of unmanned aerial systems engineering.
C5	Ability to apply data from unmanned aerial systems to obtain key information for natural resource and agroforestry management.
C6	Knowledge of existing good practices in the operation of unmanned aerial systems for use in the field of engineering, architecture and territory.
D1	Ability to understand the meaning and application of the gender perspective in the different fields of knowledge and in professional practice with the aim of achieving a more just and egalitarian society.
D2	Ability to communicate orally and in writing in Galician.
D3	Sustainability and environmental commitment. Equitable, responsible and efficient use of resources.
D4	Development of innovative and entrepreneurial spirit.
D5	Interpersonal relationship skills.
D6	Ability to work as part of a team.
D7	Organizational and planning skills.
D8	Capacity for analysis and synthesis.
D9	Critical thinking skills and creativity.

D10 Focus on quality and continuous improvement.

Learning outcomes	
Expected results from this subject	Training and Learning Results
To have completed an internship in a professional environment related to the subject matter of the master's degree.	A1 A2 A3 A4 A5 B1 B2 B3 B4 B5 C1 C2 C3 C4 C5 C6 D1 D2 D3 D4 D5 D6 D7 D8 D9 D10

Contents
Topic
Internship in a professional environment related to the subject matter of the master's program

Planning			
	Class hours	Hours outside the classroom	Total hours
Practicum, External practices and clinical practices	0	225	225
*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.			

Methodologies	
	Description
Practicum, External practices and clinical practices	

Personalized assistance	
Methodologies	**Description**
Practicum, External practices and clinical practices	Telematic tutoring

Assessment							
	Description	Qualification	Training and Learning Results				
Practicum, External practices and clinical practices	Internship report	100	A1 A2 A3 A4 A5	B1 B2 B3 B4 B5	C1 C2 C3 C4 C5 C6	D1 D2 D3 D4 D5 D6 D7 D8 D9 D10

Other comments on the Evaluation

Sources of information

Basic Bibliography

Complementary Bibliography

Recommendations

Subjects that continue the syllabus

(*)Traballo fin de máster/O07M189V01208

Subjects that it is recommended to have taken before

Aerodynamics, flight mechanics and propulsion/O07M189V01103
Fundamentals of unmanned aircraft systems/O07M189V01101
Data analysis methods/O07M189V01201
Observation systems/O07M189V01104

IDENTIFYING DATA				
(*)Traballo fin de máster				
Subject	(*)Traballo fin de máster			
Code	O07M189V01208			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	9	Mandatory	1st	2nd
Teaching language	#EnglishFriendly Spanish			
Department				
Coordinator	González Jorge, Higinio			
Lecturers	González Jorge, Higinio			
E-mail	higiniog@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	Subject that allows the development of an engineering project in the drone sector.			

Skills	
Code	
A1	Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context
A2	That students know how to apply their acquired knowledge and problem-solving skills in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study.
A3	That students are able to integrate knowledge and face the complexity of making judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
A4	That students know how to communicate their conclusions -and the ultimate knowledge and reasons that support them- to specialized and non-specialized audiences in a clear and unambiguous manner.
A5	That students possess the learning skills that will enable them to continue studying in a manner that will be largely self-directed or autonomous.
B1	That students acquire general knowledge in unmanned aerial systems engineering.
B2	That students acquire general knowledge in the operation of unmanned aerial systems.
B3	That students acquire the ability to analyze the needs of a company in the field of unmanned aerial systems and determine the best technological solution for it.
B4	That students acquire the knowledge to develop unmanned aerial systems and plan specific operations, depending on the existing needs and apply the existing technological tools.
B5	That students are able to apply, in the field of unmanned aerial systems, the principles and methodologies of research such as literature searches, data collection, data analysis and interpretation, as well as the presentation of conclusions, in a clear, concise and rigorous manner.
C1	Knowledge about the main systems, on-board instruments and control station of an unmanned aircraft, as well as their influence on safety.
C2	Knowledge of geomatics, photogrammetric and cartographic principles, navigation, aerotriangulation, interpretation and digital image processing necessary in the operation of unmanned aerial systems and know how to apply the regulations in force.
C3	Ability to interact with other technical teams in the engineering field for the planning of operations with unmanned aerial systems.
C4	Ability to develop a technical project in the field of unmanned aerial systems engineering.
C5	Ability to apply data from unmanned aerial systems to obtain key information for natural resource and agroforestry management.
C6	Knowledge of existing good practices in the operation of unmanned aerial systems for use in the field of engineering, architecture and territory.
D1	Ability to understand the meaning and application of the gender perspective in the different fields of knowledge and in professional practice with the aim of achieving a more just and egalitarian society.
D2	Ability to communicate orally and in writing in Galician.
D3	Sustainability and environmental commitment. Equitable, responsible and efficient use of resources.
D4	Development of innovative and entrepreneurial spirit.
D5	Interpersonal relationship skills.
D6	Ability to work as part of a team.
D7	Organizational and planning skills.
D8	Capacity for analysis and synthesis.
D9	Critical thinking skills and creativity.

D10 Focus on quality and continuous improvement.

Learning outcomes	
Expected results from this subject	Training and Learning Results
To be able to develop a technical project in the field of unmanned aerial systems.	A1 A2 A3 A4 A5 B1 B2 B3 B4 B5 C1 C2 C3 C4 C5 C6 D1 D2 D3 D4 D5 D6 D7 D8 D9 D10

Contents
Topic
Project in the field of unmanned aerial systems.

Planning			
	Class hours	Hours outside the classroom	Total hours
Mentored work	0	225	225
*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.			

Methodologies	
	Description
Mentored work	

Personalized assistance	
Methodologies	**Description**
Mentored work	Telematic tutoring

Assessment						
	Description	Qualification	Training and Learning Results			
Mentored work	Master thesis defense	100	A1 A2 A3 A4 A5	B1 B2 B3 B4 B5	C1 C2 C3 C4 C5 C6	D1 D2 D3 D4 D5 D6 D7 D8 D9 D10

Other comments on the Evaluation

Sources of information

Basic Bibliography

Complementary Bibliography

Recommendations

Subjects that it is recommended to have taken before

Aerodynamics, flight mechanics and propulsion/O07M189V01103
Fundamentals of unmanned aircraft systems/O07M189V01101
Data analysis methods/O07M189V01201
Observation systems/O07M189V01104