International Conference on Unmanned Aircraft Systems ICUAS 2026

June 15 - 18
Divani Corfu Palace
Corfu, Greece

Technical Program and Book of Abstracts

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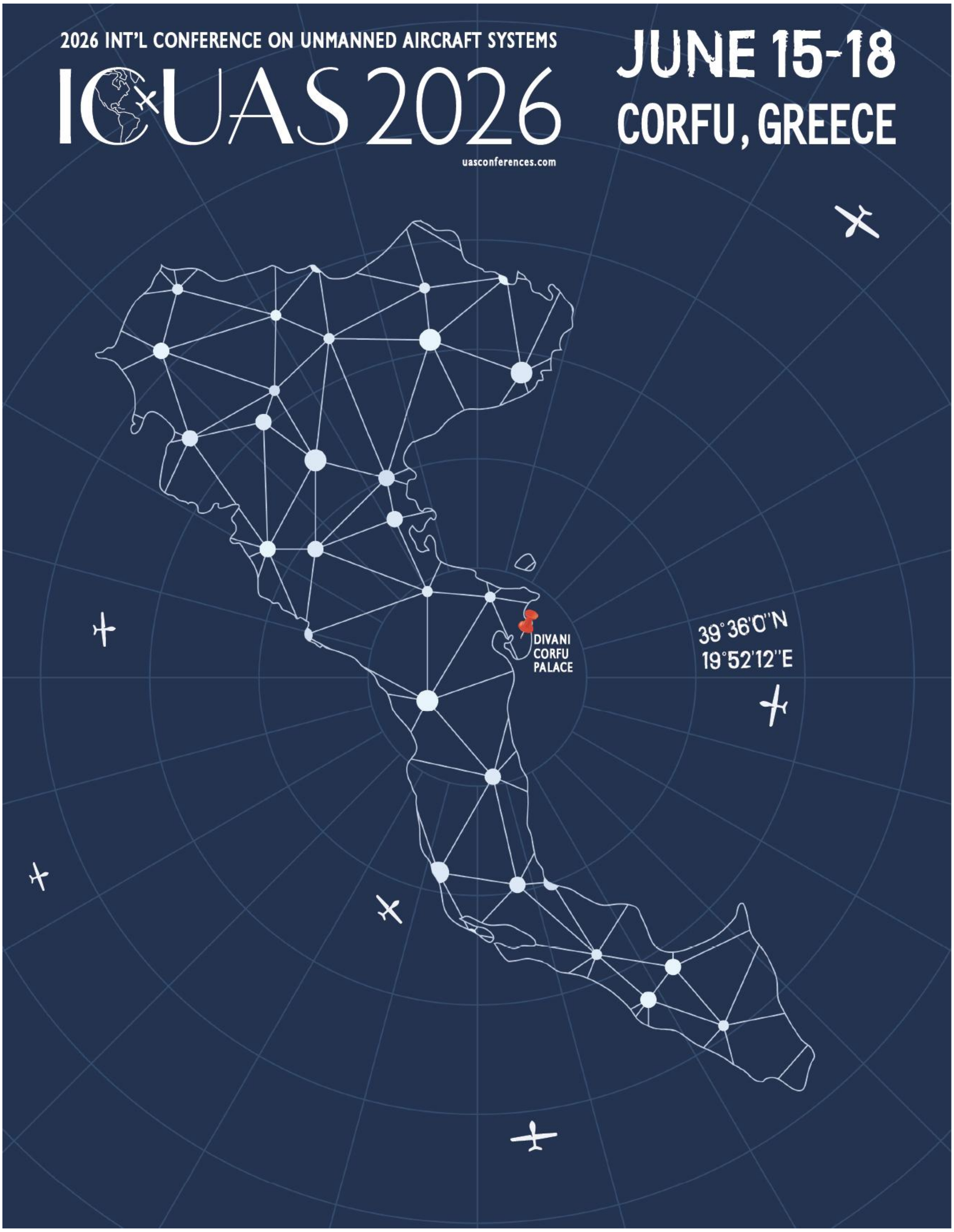
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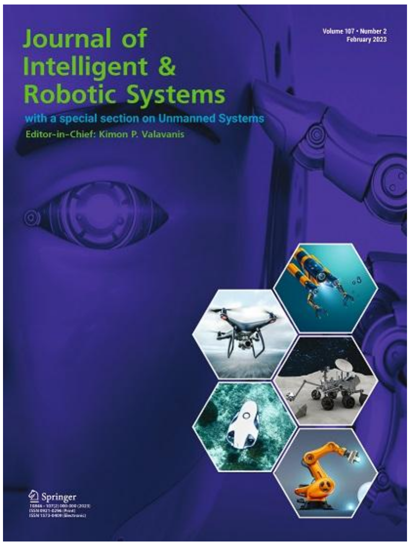

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Welcome Message from the ICUAS Association

Dear authors, colleagues, participants, and attendees:

On behalf of the ICUAS Association Inc., and in my capacity as the President of the Association, it is a privilege, a great pleasure and an honor to welcome you to the *2026 International Conference on Unmanned Aircraft Systems* (ICUAS'26). ICUAS'26 takes place in the island of Corfu, Greece, at the Divani Corfu Palace.

The Conference has returned to Europe. This decision was the correct one as evidenced by the record number of submissions: we received 336 contributions in all categories (contributed and invited papers, Tutorial and Workshop proposals) - this is a new record, and we certainly hope we can do even better in the very near future.

We look forward to your active involvement in the Association and in the annual Conference. We value your continuous support, and we look forward to your feedback. We welcome your participation, and we are open to your ideas and suggestions.

I offer my best wishes for a successful and productive event. I look forward to seeing all of you at the Conference, and I also look forward to continuing working with you.

Enjoy the Conference and explore beautiful Corfu.

Kimon P. Valavanis

Welcome Message from the ICUAS'26 General Chairs

Dear authors, colleagues, participants and attendees:

On behalf of the 2026 ICUAS Organizing Committee, it is a privilege and a great pleasure to welcome you to this year's Conference, which is organized in Corfu, Greece, at the Divani Corfu Palace. The Conference is a four-day event. June 15 is reserved for Tutorials and Workshops. The three-day technical Conference follows on June 16-18.

Conference participants represent academia, industry, government agencies, lawyers, policy makers, manufacturers, students, and end-users, all having deep interest in the state-of-the-art and future directions in UAS/RPAS, and in unmanned aviation. In response to the Call for Papers, we received 331 contributed and invited session papers, and 5 proposals for Workshops / Tutorials. The Technical Program includes 191 papers, which have been selected after a very thorough review process. As in previous years, all papers were also checked following the *iThenticate Document Viewer Guide* before the final decision was made.

We have assembled a three-day top-quality Technical Program. We also have five Plenary Lectures in which the keynote speakers address pressing and important issues related to several aspects of unmanned aviation. ICUAS'26 also includes the UAV Competition, which is student focused, offering unique opportunities for students to test and compare their skills with those of their peers, worldwide.

The Organizing Committee members, the Associate Editors and the reviewers have devoted an enormous amount of time and effort to assemble an exciting, informative, and educational Conference. We are thankful to all for their dedication and professionalism.

As already mentioned, the paper peer review process was very thorough and in-depth. It was coordinated by the Program Chairs, who assign groups of papers to the Associate Editors, and the Associate Editors choose qualified reviewers to review all papers. We thank all of them for their extremely valuable contributions and dedication. All papers were submitted through the PaperCept Conference Management System. Dr. Pradeep Misra is the 'glue' who keeps all Conference components together. We would not have been able to complete the paper review process without his help, and for this, we thank him wholeheartedly.

We thank all the authors for your participation and contributions. We hope you enjoy the Conference, as well as Corfu. Take this opportunity to mix business and pleasure; Corfu has a lot to offer.

With our warmest regards,

Anthony Tzes and Margarita Chli

Welcome Message from the ICUAS'26 Program Chairs

Dear authors, colleagues, participants and attendees:

Welcome to ICUAS'26. This year we received 336 contributed, invited session papers, and workshop and tutorial proposals from 43 different countries. 331 contributed and invited session papers went through a very detailed and rigorous review process. All papers were also checked for originality using the *iThenticate Document Viewer Guide*. Our goal was for each paper to have three reviews, in addition to the review by the corresponding Associate Editors and the Program Chairs. We met and achieved this goal; the aim was simply to make just and informed decisions and select the best papers for presentation and inclusion in the Conference Proceedings.

The Technical Program includes 173 contributed papers, 16 invited session papers, and 2 papers that have been accepted and will appear in the ICUAS Unmanned Aviation Magazine, eUAM. ***The acceptance rate is 57% - this marks an all-time low since launching the annual Conference***. The Table below shows the number of submitted and accepted papers per country.

COUNTRY	SUBMITTED	ACCEPTED
Argentina	3	3
Australia	7	4
Austria	1	1
Brazil	22	11
Canada	12	7
China	10	5
Colombia	1	1
Croatia	7	5
Cyprus	9	4
Czech Republic	4	2
Denmark	12	5
Ecuador	2	2
Finland	4	4
France	19	14
Germany	20	13
Greece	9	5
Hungary	2	0
India	14	2
Israel	3	2
Italy	24	14
Japan	1	1
Korea, South	2	1
Luxembourg	2	2
Mexico	3	2
Morocco	1	0
Netherlands	13	11
Norway	2	1
Poland	5	1
Portugal	7	3
Qatar	1	0
Romania	1	0
Russia	4	3
Saudi Arabia	3	1
Singapore	3	0
Slovakia	1	0
Spain	15	10

Sweden	3	2
Switzerland	2	0
Turkey	3	3
Ukraine	1	0
United Arab Emirates	9	6
United Kingdom	5	2
United States of America	59	38
Total	**331**	**191**

We would like to thank all the authors for their contributions. The rigorous review process would not have been possible if we did not have such a strong community of expert reviewers. We thank all reviewers for their professional service. Dr. Pradeep Misra helped us in working and effectively using the online paper submission and review system. This system is very sophisticated and yet very practical to use for both small- and large- scale Conferences. It is very hard to imagine how things would have been done without this excellent tool!

Last, but not least, we also thank all Associate Editors and reviewers for their professionalism and services in handling and reviewing all submitted papers.

We hope you enjoy the technical aspects of the Conference and Corfu.

We are looking forward to meeting all of you at the Conference!

Andrea Monteriu, Vinicius Goncalves, and Marija Popovic

ICUAS’26 General Information

The Venue

The Conference Venue is the ***Divani Corfu Palace*** located on the lush green hill of Kanoni. The venue offers an exceptional location just 3 km from Corfu Town and 1.5 km from the famous *Mon Repos* beach. Overlooking a serene lagoon and surrounded by pine-covered woods, it’s the perfect retreat for those seeking both easy access to the historic city center and a peaceful escape immersed in nature.

Each participant is responsible for making their own accommodation reservations.

View of the Divani Corfu Palace

Traveling to Corfu

Corfu is located north of the Ionian Sea, far away from the other Ionian islands. It is named ‘the countess of the Ionian Sea’, https://greeceinsiders.travel/corfu-the-countess-of-the-ionian-sea/, while others consider the island to be the ‘Queen of the Ionian’. Corfu attracts even the most demanding travelers and welcomes everybody with the amazing views it offers, in the middle of the sea and with the sun reflected in the clear blue waters, between the Old and the New Fortress, two of the jewels of the island. Corfu is the “gateway” of Greece to the West. It is a major touristic destination and is worth visiting for many reasons, see https://www.visitgreece.gr/islands/ionian-islands/corfu/ for details.

Athens may typically serve as a first stop when traveling to Corfu from international and non-Schengen destinations. Check with your local airlines for the most up to date flight schedules.

Corfu Airport (IATA code CFU), https://www.cfu-airport.gr, is located near Corfu Town and has a single terminal building. It operates domestic flights throughout the year, and international seasonal flights during the touristic period (April to end of October). Aegean Airlines (www.aegeanair.com) and SKY Express (https://www.skyexpress.gr) offer several flights each day from Athens International Airport (IATA code ATH), https://theathensairport.com/. In addition to these two airlines, the following airlines operate mostly seasonal flights to Corfu: Aer Lingus; Air Baltic; Air France; Air Serbia; Austrian Airlines; British Airways; Brussels Airlines; Condor; EasyJet; Edelweiss Air; Eurowings; Finnair; FlyDubai; Iberia; ITA Airways; Lot Polish Airlines; Lufthansa; LuxAir; Norwegian Air Shuttle; Norwegian Air Sweden; Ryanair; Scandinavia Airlines; Smartlynx Estonia; Smartwings; Sundair; Swiss; Transavia; TUI; TUS Airways; Volotea; Vueling, among several others.

Corfu may be reached by Ferry Boat from mainland Greece, mainly from the ports of Igoumenitsa and Patras, as well as from other Greek islands like Paxi and Lefkada. The Ferry Boat from Igoumenitsa takes about 1.5 hours, and it offers the most frequent and shortest daily route to Corfu. The trip from Patras takes about 7.5 hours. Igoumenitsa may be reached by car, driving from Athens, or any other city in Greece. Ferry Boat services are also available from Italian ports like Bari, Ancona, and Venice. These trips are longer, ranging from about 9 hours to over 25 hours.

Conference Activities

All Conference technical activities, Workshops / Tutorials and Technical Sessions (four parallel tracks) will take place in the venue. The UAV Competition will be in the semi-open space next to the Restaurant, while Coffee Breaks, Lunches, and the Welcome Reception will be in the restaurant veranda.

Visa Requirements

To find out whether you need a visa to travel to Greece, check the page on ***Visas for Foreigners travelling to Greece***. If you have trouble opening the link, follow the steps:
1. Go to the ***Hellenic Republic Ministry of Foreign Affairs*** web page.
2. In the menu, find ***Services***.
3. Click on ***Visas***.
4. Click on **Visas for Foreigners travelling to Greece** and follow instructions.

Conference Registration

All Conference attendees must register by using the online registration when they upload the final version of their papers. This is the preferred option. Late and onsite registration is also available for non-authors who want to attend the Conference. It is not required to present a paper in the Conference program to register and to attend the Conference. All registered participants must check in at the Registration Desk to pick up their registration packages. Personal badges will be provided for all registered participants and their Guests. Attendees must always wear their badges when attending any ICUAS'26 event (workshops, tutorials, technical sessions, and social functions). Conference details will be posted and updated daily in the registration area. To register, follow the steps:

- ✓ Go to https://controls.papercept.net
- ✓ Scroll down the list until you find ICUAS 2026 - Choose ICUAS 2026 (from the list of Conferences)
- ✓ Click on Register for ICUAS'26
- ✓ Login with your PIN and Password. *First time users must create a 'profile', to get a PIN and Password.*
- ✓ After you Log in, choose **Registree**.
- ✓ Follow the self-explained screens to register.

Alternatively, and especially if you have not authored a paper, you may register through www.icuas.com.

The registration desk will be open during the following hours:

Sunday, June 14:	5:00 PM–7:00 PM
Monday, June 15:	8:15 AM–10:00 AM, 1:00 PM–2:00 PM, 6:00 PM–7:30 PM
Tuesday, June 16:	8:15 AM – 4:00 PM
Wednesday, June 17:	8:15 AM – 13:00 PM
Thursday, June 18:	8:00 AM – 12:00 PM

Onsite Conference registration policy & fees

Attendees can register for the Conference under the following registration categories/rates:

Attendee Status	Onsite Registration
Regular Conference Registration	$740
Bundle Regular Conference and Workshop Registration	$840
Student Conference Registration	$425
Bundle Student Conference and Workshop Registration	$525
Retiree Conference Registration	$250
T1: Modeling, Navigation and Control of Multirotor UAVs: *A Comprehensive Framework*	$200
T2: When Robotics Meet Wireless Communications: A Tale of Two Interconnected Worlds	$200
T4: Aerial Soft Robotics	$200
Spouse/Guest Registration (Social Events)	$200
Extra Welcome Reception Ticket	$50
Extra Banquet Ticket	$100

Internet Access
All registered attendees will have complementary internet access.

Lunch for Registered Participants
Lunch will be served to registered Conference participants. Lunch tickets will be provided for Tuesday, Wednesday and Thursday, June 16-18.

Coffee Breaks with Snacks
There will be two coffee breaks per day for all registered participants, one in the morning and one in the afternoon.

Events and Receptions
The ICUAS'26 social agenda includes a *Welcome Reception* on Monday June 15, and the *Awards Luncheon* on Wednesday, June 17.

ICUAS'26 Tutorials and Workshops

ICUAS'26 offers three half-day Workshops/Tutorials addressing current and future topics in unmanned aircraft systems from experts in academia, national laboratories, and industry. Interested participants may find details on www.uasconferences.com, and they may use the online system for registration. Tutorials/Workshops will take place on Monday, June 15, from 09:00 AM - 1:00 PM, and 2:00 PM – 6:00 PM.

Calypso A	Calypso B
09:00-13:00 MoT2 **When Robotics Meet Wireless Communications: A Tale of Two Interconnected Worlds**	**09:00-13:00 MoT4** **Aerial Soft Robotics**
Calypso B	
14:00-18:00 MoT1 **Modeling Navigation and Control of Multirotor UAVs: A Comprehensive Framework**	

ICUAS'26 Plenary Lectures

ICUAS'26 includes five Plenary Lectures given by leading authorities in their fields. We are proud to include them in the Technical Program. The lecture sequence is shown next.

TUESDAY, JUNE 16

- ***Resilient Multi-UAS in Complex Missions***, *Prof. Dimitra Panagou, University of Michigan, USA*

WEDNESDAY, JUNE 17

- ***Integrating Advanced UTM Services into a Co-Simulation Environment***, *Prof. Antonios Tsourdos, Cranfield University, UK*
- ***Flying Robots That Touch the World: Are We There Yet?*** *Prof. Antonio Franchi, University of Twente, Netherlands and Sapienza University of Rome, Italy*
  Awards Luncheon
- ***CAT-A Ground Test to Class-A Miship: Case Study of an Uncrewed Military Helicopter with Lessons Learned for the R&D, T&E, and Academic Community***, *Prof. Donald Costello University of Maryland, USA*
- ***HERON - Hellenic Robotics Center of Excellence: Research Directions and Goals***, *Prof. Petros Maragos, HERON Director and Scientific Coordinator*

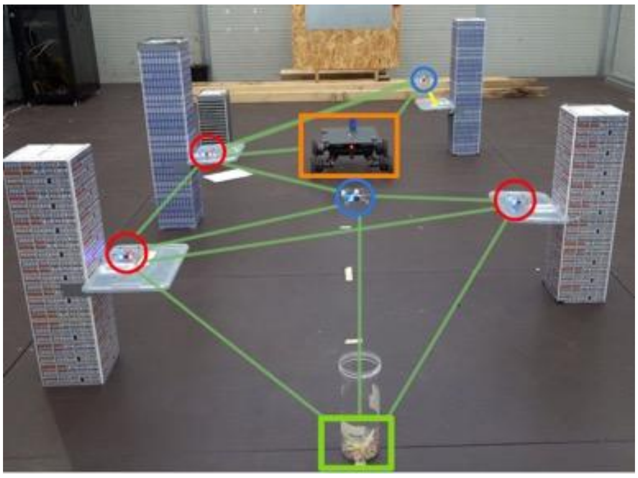
ICUAS 2026 UAV Competition

The ***2026 ICUAS UAV Competition*** is organized (as in previous years) by the Laboratory for Robotics and Intelligent Control Systems, **LARICS**, University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia, through the **CBRNe-HERO** project.

The competition will take place in two stages. The first stage is the qualifiers stage. Registered teams will develop their solution in a ROS-Gazebo environment. Submitted solutions will be evaluated and the 'top teams', up to six, will continue to the second and final stage. In the final stage, during the Conference, teams will present and will demonstrate their solution.

<u>*Competition Scenario*</u>: *Multi-UAV System for Communication Network Establishment and Maintenance during CBRNe Incidents in Urban Environments*

A team of UAVs is deployed in an urban environment to track a vehicle, which is tasked with resolving CBRNe threats (chemical, biological, radiological, nuclear, explosive). The UAV team deploys from a base and needs to track a ground vehicle and to maintain its connection with the base station. The ground vehicle is controlled externally, and the UAV team knows only its current location. Since some threats may interfere with communication links between agents, the UAV team is required to keep constant communication between the base and all agents in the system. The connection between neighboring agents in the system is maintained by keeping line of sight (see Figure) and by limiting the distance between agents. The team is assumed to be in a valid configuration if the underlying graph is connected.



Multi-robot team for search, identification and resolving CBRNe threats in urban environments. A team of Crazyflies is tasked with following a ground vehicle to maintain its connection to the base station, while also searching for threats or landing spots to use for energy conservation with the aim of extending the mission time.

The team of UAVs is also required to locate and identify an unknown number of CBRNe threats, which are simulated with ArUco markers, and to report the location of the threat to the base. While searching, the battery of each UAV is draining and each UAV can go back to the base to recharge, or land on available spots, which are also marked with ArUco markers. There are also decoy markers that do not denote nor CBRNe threat nor landing spot. When going back to the base, or landing, the system needs to remain connected even with one or more UAVs charging or grounded on landing spots. Each UAV can recharge only once but it is allowed to land multiple times on landing spots. The mission ends when the connection of the ground vehicle to the base is lost completely.

Evaluation

To evaluate the performance of the team of UAVs in such scenario, three benchmarks will be used:

- Benchmark-1: Threat localization and identification: The UAV ability to correctly identify all existing threats in the environment and report their location accurately.
- Benchmark-2: Connectivity: The team ability to remain connected throughout the mission.
- Benchmark-3: Time: The team ability to maximize the mission time of the ground vehicle.

The simulation phase environment is the Gazebo simulator (http://gazebosim.org/), in conjunction with ROS, https://www.ros.org/. Being realistic and modular, the combination of Gazebo and ROS enables simulations of both actuators and sensors through various plugins. For the UAV Competition, the supported versions for the simulation stage, and the versions that the solutions will be evaluated on, are Gazebo Garden and ROS2 Humble, running on Linux Ubuntu 22.04 LTS. Teams may opt to use different versions, in which case they take the risk of their code not running on the evaluation machine. The UAVs to be used are Bitcraze Crazyflies, running through SITL within CrazySim.

For the first phase of the UAV Competition, it is expected that a team's solution will be in the form of one or more ROS nodes. The developed node(s) will interface with the rest of the system via topics and services. List of topics, services and data types will be disseminated to the teams via the technical documentation accompanying the installation files. Subject to feedback from the teams, the organizing committee is open to revising these interfaces to streamline the integration of code developed by the teams. Teams are allowed to use ROS messages and services based on built-in ROS message types to communicate between nodes. The solution is to be submitted through Docker containers.

The List of Finalist Teams

Following a rigorous evaluation procedure, the following teams emerged as top contenders and qualified for the finals at the conference venue in Corfu, Greece.

1st Place Team: AGH Avader, AGH University of Krakow, Poland
Team Leader: Kamil Jędrzejko. Team Members: Remigiusz Mietła, Mateusz Gołąbek, Tymoteusz Domagała, Jan Jagodziński, Dominik Babiarczyk, Hubert Gąska, Krzysztof Jagiełło, Szymon Hołysz

2nd Place Team: QADT, Queen's University, Canada
Team leader: Ethan Milburn. Team Members: Abdullah Mohsin, Ashton Antony, Benjamin Cox, Cole Jowett, Erin Payne, Ethan Milburn, Gavin Tan, Kuzey Bilgin, Liam Shannon, Nishith Chowdary Ravuri, Purujit Kantiya, Visakan Makilrajah

3rd Place Team: ARRF, Kyungpook National University, South Korea
Team leader: Taeseung Woo. Team members: Seongjin Oh, Kangmin Kim, JinWan Kim, Jihyeong Ryu, Soyeon Park, Jiyoung Yoo

4th Place Team: CVRLs, Foundation for Research and Technology – Hellas (FORTH), Greece
Team leader: Michail Vangos. Team members: Michail Vangos, Iliana Platona, Michalis Savorianakis, Christos Trifinopoulos

5th Place Team: αeRAS, National Technical University of Athens, Greece
Team leader: Michalis Psychis. Team members: Zoi Tsouroufli, Maria-Rozina Bertou, Konstantinos Sarakis, Petros Pantazis, Elena Alevropoulou

6th Place Team: Aerial Robotics IITK, Indian Institute of Technology Kanpur, India
Team leader: Shivang Sonker. Team members: Ayush Goyal, Soumya Jhunjhunwala, Mansoju Vivekananda, Kritik Gupta, Krishna Agrawal

Special thanks go to LARICS (https://larics.fer.hr/) team for preparing and evaluating the ICUAS'26 UAV Competition simulation scenario. Support was provided by the project "Safe and Effective CBRNe Response with semiautonomous HEterogeneous RObotic System – CBRNe HERO", funded by the *European Union* – NextGeneration, Grant NPOO.C3.2.R3-I1.04.0075.

ICUAS' 26 TECHNICAL PROGRAM AT A GLANCE

Monday June 15, 2026

Calypso A	Calypso B
09:00-13:00 MoT2 **When Robotics Meet Wireless Communications: A Tale of Two Interconnected Worlds**	**09:00-13:00 MoT4** **Aerial Soft Robotics**

Calypso B
14:00-18:00 MoT1 **Modeling Navigation and Control of Multirotor UAVs: A Comprehensive Framework**

19:30 – 21:30 Welcome Reception

Tuesday, June 16, 2026

08:30-09:00 TuO1
Nafsika

ICUAS 2026 Opening Remarks

09:00-10:00, TuPL1
Nafsika

Resilient Multi-UAS in Complex Missions
Prof. Dimitra Panagou
University of Michigan, USA

10:00 – 10:20 Coffee Break

Nafsika	Lounge A	Calypso A	Calypso B
10:20-12:40 Regular Session TuA1 ***Control Architectures I***	10:20-12:40 Regular Session TuA2 ***Multirotor Design and Control I***	10:20-12:40 Regular Session TuA3 ***Path Planning I***	10:20-12:40 Regular Session TuA4 ***Perception and Cognition I***

12:40 – 14:00 Lunch

14:00-16:00 Regular Session TuB1 ***Best Paper Award Finalists***	14:00-16:00 Regular Session TuB2 ***Multirotor Design and Control II***	14:00-16:00 Regular Session TuB3 ***Path Planning II***	14:00-16:00 Regular Session TuB4 ***Perception and Cognition II***

16:00 – 16:20 Coffee Break

16:20-18:20 Regular Session TuC1 ***Control Architectures II***	16:20-18:20 Regular Session TuC2 ***Micro and Mini-UAS and Biologically Inspired UAS***	16:20-18:20 Regular Session TuC3 ***Navigation***	16:20-18:20 Regular Session TuC4 ***Airspace Operations and See-and-Avoid Systems***

Wednesday, June 17, 2026

09:00-10:00, WePL1
Nafsika

Integrating Advanced UTM Services into a Co-Simulation Environment
Prof. Antonios Tsourdos
Cranfield University, UK

10:00 – 10:20 Coffee Break

10:20-11:20, WePL2
Nafsika,

Flying Robots That Touch the World: Are We There Yet?
Prof. Antonio Franchi
University of Twente, Netherlands and Sapienza University of Rome, Italy

Nafsika	Lounge A	Calypso A	Calypso B
11:20-13:20 Regular Session WeA1 *Control Architectures III*	11:20-13:20 Regular Session WeA2 *Multirotor Design and Control III*	11:20-13:20 Regular Session WeA3 *UAS Testbeds*	11:20-13:20 Regular Session WeA4 *Autonomous Aerial Operations and Field Inspection*

13:30-16:00
AWARDS LUNCHEON

CAT-A Ground Test to Class-A Miship: Case Study of an Uncrewed Military Helicopter with Lessons Learned for the R&D, T&E, and Academic Community
Prof. Donald Costello
University of Maryland, USA

HERON - Hellenic Robotics Center of Excellence: Research Directions and Goals
Prof. Petros Maragos
HERON Director and Scientific Coordinator

16:00-18:00
UAV COMPETITION FINALS

Thursday, June 18, 2026

Nafsika	Lounge A	Calypso A	Calypso B
08:30-10:30 Regular Session ThA1 *Swarms*	08:30-10:30 Regular Session ThA2 *Autonomy*	08:30-10:30 Regular Session ThA3 *Energy Efficient UAS, Payloads and Aerial Delivery*	08:30-10:30 Regular Session ThA4 *Security, Regulations and Training*

10:30 – 10:50 Coffee Break

10:50-12:50 Regular Session ThB1 **_UAS Applications I: Detection, Tracking and Counter-UAS_**	10:50-12:50 Regular Session ThB2 **_Aerial Robotic Manipulation I_**	10:50-12:50 Regular Session ThB3 **_Sensor Fusion_**	10:50-12:50 Invited Session ThB4 **_Testing and Evaluation: Autonomy I_**

12:40 – 14:00 Lunch

14:00-16:00 Regular Session ThC1 **_UAS Applications II: Inspection and Monitoring_**	14:00-16:00 Regular Session ThC2 **_Aerial Robotic Manipulation II_**	14:00-16:00 Regular Session ThC3 **_Simulation and UAS Testbeds_**	14:00-16:00 Invited Session ThC4 **_Testing and Evaluation: Autonomy II_**

16:00 – 16:20 Coffee Break

16:20-18:20 Regular Session ThD1 **_UAS Communications and Networked Swarms_**	16:20-18:20 Regular Session ThD2 **_Risk Analysis and Manned/Unmanned Aviation_**	16:20-18:20 Regular Session ThD3 **_Reliability, Fail-Safe Systems and Airworthiness_**	16:20-18:20 Invited Session ThD4 **_Testing and Evaluation: Autonomy III_**

ICUAS '26 Technical Sessions

Tuesday June 16, 2026

TuA1	Nafsika
Control Architectures I (Regular Session)	
Chair: Tsetserukou, Dzmitry	Skolkovo Institute of Science and Technology
Co-Chair: Mizzoni, Mirko	University of Twente

10:20-10:40	TuA1.1
Robust Adaptive Sliding-Mode Control for Damaged Fixed-Wing UAVs, pp. 1-8.	
Spiller, Mark	German Aerospace Center
Kracke, Lennart	German Aerospace Center
Autenrieb, Johannes	German Aerospace Center

10:40-11:00	TuA1.2
Robust Co-Design Optimisation for Agile Fixed-Wing UAVs, pp. 9-17.	
Buda, Adrian Andrei	Imperial College London
Chen, Xiaorong	Imperial College London
Botteghi, Nicolò	Politecnico Di Milano
Fasel, Urban	Imperial College London

11:00-11:20	TuA1.3
A Comparative Study of INDI and NDI with Nonlinear Disturbance Observer for Aerial Robotics, pp. 18-25.	
Rota, Benedetta	Sapienza University of Rome
Mizzoni, Mirko	University of Twente
Afifi, Amr	University of Twente
van Goor, Pieter	University of Sydney
Franchi, Antonio	Univ. of Twente and Sapienza Univ. of Rome

11:20-11:40	TuA1.4
Adaptive SINDy: Residual Force System Identification Based UAV Disturbance Rejection, pp. 26-33.	
Mehboob, Fawad	Skolkovo Institute of Science and Technology
Habel, Amir Atef	Skolkovo Institute of Science and Technology
Khan, Roohan Ahmed	Skolkovo Institute of Science and Technology
Derevianchenko, Mikhail	Skolkovo Institute of Science and Technology
Fortin, Clement	Skolkovo Institute of Science and Technology
Tsetserukou, Dzmitry	Skolkovo Institute of Science and Technology

11:40-12:00	TuA1.5
GustPilot: A Hierarchical DRLINDI Framework for Wind-Resilient Quadrotor Navigation, pp. 34-41.	
Habel, Amir Atef	Skolkovo Institute of Science and Technology
Khan, Roohan Ahmed	Skolkovo Institute of Science and Technology
Mehboob, Fawad	Skolkovo Institute of Science and Technology
Fortin, Clement	Skolkovo Institute of Science and Technology
Tsetserukou, Dzmitry	Skolkovo Institute of Science and Technology

12:00-12:20	TuA1.6
Hybrid Adaptive Position Control for UAVs Subject to Mass-Variation and Aerodynamic Disturbances Via Frequency Decoupling, pp. 42-49.	
Millan, Alejandro	Université De Technologie De Compiègne
Tevera-Ruiz, Alejandro	Cinvestav-IPN Unidad Saltillo
Castillo, Pedro	Université De Technologie De Compiègne
Sanchez-Orta, Anand Eleazar	Cinvestav-IPN Unidad Saltillo
Lozano, Rogelio	Université De Technologie De Compiègne
Chazot, Jean-Daniel	Université De Technologie De Compiègne
Salazar, Sergio	Cinvestav-IPN Unidad Zacatenco

12:20-12:40	TuA1.7
Residual Koopman-Based Model Predictive Control of Quadrotors, pp. 50-56.	
Todde, Edoardo	Politecnico Di Torino

Martini, Simone	University of Denver
Rizzo, Alessandro	Politecnico Di Torino
Valavanis, Kimon P.	University of Denver

TuA2 | **Lounge A**

Multirotor Design and Control I (Regular Session)

Chair: Baldini, Alessandro	Università Politecnica Delle Marche
Co-Chair: Colombo, Leonardo, J	Centre for Automation and Robotics (CAR)

10:20-10:40 | TuA2.1

Mind the Gap: Online Control Allocation for Multirotors with Low-Speed Deadbands, pp. 57-64.

Ali, Ahmed	University of Twente
Romano, Fiorella Maria	Università Degli Studi Di Napoli Federico II
Gabellieri, Chiara	University of Twente
van Goor, Pieter	University of Sydney
Ruggiero, Fabio	Università Degli Studi Di Napoli Federico II
Franchi, Antonio	Univ. of Twente and Sapienza Univ. of Rome

10:40-11:00 | TuA2.2

Learning-Based Geometric Leader–Follower Control for Cooperative Rigid-Payload Transport with Aerial Manipulators, pp. 65-72.

Yago Nieto, Omayra	Universidad Politécnica De Madrid
Colombo, Leonardo, J	Centre for Automation and Robotics

11:00-11:20 | TuA2.3

Sensitivity-Based Tube NMPC for Cooperative Aerial Structures under Parametric Uncertainty, pp. 73-79.

Silano, Giuseppe	Czech Technical University in Prague
Sable, Quentin	University of Twente
Tognon, Marco	INRIA
Iannelli, Luigi	University of Sannio in Benevento
Franchi, Antonio	Univ. of Twente and Sapienza Univ. of Rome

11:20-11:40 | TuA2.4

Receding-Horizon Nullspace Optimization for Actuation-Aware Control Allocation in Omnidirectional UAVs, pp. 80-87.

Pretto, Riccardo	Tampere University
Hamandi, Mahmoud	New York University Abu Dhabi
Mohamed Ali, Abdullah	New York University Abu Dhabi
Alcan, Gokhan	Tampere University
Tzes, Anthony	New York University Abu Dhabi
Abu-Dakka, Fares	New York University Abu Dhabi

11:40-12:00 | TuA2.5

Geometric Adaptive Control on SE(3) for Fully-Actuated Aerial Vehicles with Online Parameter Estimation, pp. 88-95.

Olanrewaju, Farooq	King Fahd University of Petroleum & Minerals
Benyahia, Aymen	King Fahd University of Petroleum & Minerals
Rashad, Ramy	King Fahd University of Petroleum & Minerals
Sami, El-ferik	King Fahd University of Petroleum & Minerals

12:00-12:20 | TuA2.6

Control of Fully Actuated Aerial Vehicles: A Comparison of Model-Based and Sensor-Based Dynamic Inversion, pp. 96-103.

Yilmaz, Ali	Technical University of Munich
Turan, Buday	Technical University of Munich
Pries, Lukas	Technical University of Munich
Ryll, Markus	Technical University of Munich

12:20-12:40 | TuA2.7

Geometric Cascade Control for Thrust Vectoring Multirotors, pp. 104-111.

Baldini, Alessandro	Università Politecnica Delle Marche
Felicetti, Riccardo	Università Politecnica Delle Marche
Freddi, Alessandro	Università Politecnica Delle Marche
Monteriù, Andrea	Università Politecnica Delle Marche

TuA3	Calypso A
Path Planning I (Regular Session)	
Chair: Renzaglia, Alessandro	INRIA
Co-Chair: Kallies, Christian	German Aerospace Center

10:20-10:40	TuA3.1
Trajectory Planning for an Omnidirectional Drone in a GPS-Denied and Obstacle Cluttered Environment, pp. 112-119.	
Mohamed Ali, Abdullah	New York University Abu Dhabi
Hamandi, Mahmoud	New York University Abu Dhabi
Tzes, Anthony	New York University Abu Dhabi

10:40-11:00	TuA3.2
Multi-Agent Routing in Octree with Autonomous Waypoint Allocation, pp. 120-127.	
Karásek, Rostislav	German Aerospace Center
Kallies, Christian	German Aerospace Center
Gasche, Sebastian	German Aerospace Center

11:00-11:20	TuA3.3
Centralized vs Decentralized Multi-Agent Cooperative Trajectory Planning Via Model Predictive Control, pp. 128-136.	
Kallies, Christian	German Aerospace Center
Karásek, Rostislav	German Aerospace Center
Gasche, Sebastian	German Aerospace Center

11:20-11:40	TuA3.4
Plane-Based Spatial Partitioning Using Depth Sensors: Computationally Efficient Local Trajectory Planning for Multicopters Over Obstacles, pp. 137-142.	
Wang, Ting-Hao	University of California Berkeley
Mueller, Mark Wilfried	University of California Berkeley

11:40-12:00	TuA3.5
Quality-Guided UAV Surface Exploration for 3D Reconstruction, pp. 143-150.	
Sportich, Benjamin	INSA Lyon
Boubakri, Kenza Eléonore	INSA Lyon
Simonin, Olivier	INSA Lyon
Renzaglia, Alessandro	INSA Lyon

12:00-12:20	TuA3.6
C-3TO: Continuous 3D Trajectory Optimization on Neural Euclidean Signed Distance Fields, pp. 151-158.	
Gil Garcia, Guillermo	Universidad Pablo De Olavide
Cobano, Jose Antonio	Universidad Pablo De Olavide
Merino, Luis	Universidad Pablo De Olavide
Caballero, Fernando	Universidad Pablo De Olavide

12:20-12:40	TuA3.7
Controller-Aware Closed-Loop RRT for Real-Time Fixed-Wing UAV Navigation in Cluttered Airspace, pp. 159-166.	
Elo, Callahan	University of Kansas
Keshmiri, Shawn	University of Kansas

TuA4	Calypso B
Perception and Cognition I (Regular Session)	
Chair: Capello, Elisa	Politecnico Di Torino
Co-Chair: Sandino, Juan	Queensland University of Technology

10:20-10:40	TuA4.1
Towards Robust DEM-Based Monocular Depth Rescaling for UAVs: A Systematic Analysis, pp. 167-174.	
Musio, Maria Grazia	Politecnico Di Torino
Savian, Stefano	Leonardo S.p.A
Mohammadi, Seyedsaber	Leonardo S.p.A
Capello, Elisa	Politecnico Di Torino
Primatesta, Stefano	Politecnico Di Torino

10:40-11:00	TuA4.2
Geometry-Aware Onboard Perception for Powerline Conductor Estimation and Outside-FOV Tracking During Close-Range Flight, pp. 175-182.	

Nyboe, Frederik Falk — University of Southern Denmark
Ebeid, Emad Samuel Malki — University of Southern Denmark

11:00-11:20 — TuA4.3

Aerial Visual Place Recognition in Antarctica: Towards Robust Monitoring in Extreme Environments, pp. 183-190.

Fontan, Alejandro — Queensland University of Technology
Sandino, Juan — Queensland University of Technology
Civera, Javier — Universidad De Zaragoza
Fischer, Tobias — Queensland University of Technology
Gonzalez, Luis Felipe — Queensland University of Technology
Milford, Michael John — Queensland University of Technology

11:20-11:40 — TuA4.4

CPU-Optimized Real-Time Object Detection and Pose Estimation for UAVs, pp. 191-198.

Arash, Hashemi — Università Degli Studi Di Napoli Federico II
Scognamiglio, Vincenzo — Università Degli Studi Di Napoli Federico II
Caccavale, Riccardo — Università Degli Studi Di Napoli Federico II
Finzi, Alberto — Università Degli Studi Di Napoli Federico II
Lippiello, Vincenzo — Università Degli Studi Di Napoli Federico II

11:40-12:00 — TuA4.5

Adaptive Texture-Aware Pixel Selection for Robust Direct Visual Odometry in UAV Navigation, pp. 199-206.

Gaia, Jeremias — Universidad Nacional De San Juan
Alves Fagundes Junior, Leonardo — Universidade Federal De Viçosa
Soria, Carlos — Universidad Nacional De San Juan
Brandao, Alexandre Santos — Universidade Federal De Viçosa

12:00-12:20 — TuA4.6

Extended Model-Based Learned Inertial Odometry, pp. 207-212.

Kuruppu Arachchige, Sasanka — Tampere University
Kamarainen, Joni-Kristian — Tampere University

12:20-12:40 — TuA4.7

Robust Thermal Video Stabilization for Autonomous UAS: A Dynamic H-Infinity Approach with Covariance Persistence, pp. 213-220.

Ceron, Jose — Universidade Federal De São Carlos
Carmona Hernandes, Andre — Universidade Federal De São Carlos
Pazelli, Tatiana F.P.A.T. — Universidade Federal De São Carlos
Inoue, Roberto Santos — Universidade Federal De São Carlos

TuB1 — **Nafsika**

Best Paper Award Finalists (Regular Session)

Chair: Tzes, Anthony — New York University Abu Dhabi
Co-Chair: Monteriù, Andrea — Università Politecnica Delle Marche

14:00-14:20 — TuB1.1

An Autonomous Flight System for Small-Sized Drones Using Circular Buffered Hash Data Structure, pp. 221-226.

Lee, Dasol — Agency for Defense Development

14:20-14:40 — TuB1.2

Spinning Quadrotor: Hover Thrust Augmentation with Passive Lifting Surfaces, pp. 227-234.

Parkala, Aniketh — International Institute of Information Technology
Kandath, Harikumar — International Institute of Information Technology

14:40-15:00 — TuB1.3

Muscle Coactivation in the Sky: Geometry and Pareto Optimality of Energy vs. Aerodynamic Promptness and Multirotors as Variable Stiffness Actuators, pp. 235-242.

Franchi, Antonio — Univ. of Twente and Sapienza Univ. of Rome

15:00-15:20 — TuB1.4

Time-Constrained Coverage Path Planning for UAV Search Applications, pp. 243-250.

Luterman, Alec — University of Maryland
Bortoff, Zachary — University of Maryland
Nogar, Stephen — U.S. Army Research Laboratory

Paley, Derek — University of Maryland

15:20-15:40 — TuB1.5

A Robust Transfer Learning Cross-Dataset Generalization Approach for GNSS Spoofing Detection in Unmanned Aerial Vehicles: A Study on TEXBAT and OAKBAT Datasets, pp. 251-258.

Salles, Felipe — University of São Paulo
Ramos, Taiane Coelho — Federal Fluminense University
Branco, Kalinka Regina Lucas Jaquie Castelo — University of São Paulo

15:40-16:00 — TuB1.6

Dust-Resilient Autonomous Navigation and Mapping for UAVs in GNSS-Denied Underground Tunnels, pp. 259-264.

Montes-Grova, Marco Antonio — Center for Advanced Aerospace Technologies
González Marín, José Manuel — Center for Advanced Aerospace Technologies
Perez-Grau, Francisco Javier — Fundacion Andaluza Para El Desarrollo Aeroespacial
Viguria, Antidio — Fundacion Andaluza Para El Desarrollo Aeroespacial

TuB2 — **Lounge A**

Multirotor Design and Control II (Regular Session)

Chair: Arogeti, Shai — Ben-Gurion University of the Negev
Co-Chair: Loianno, Giuseppe — UC Berkeley

14:00-14:20 — TuB2.1

Disturbance-Aware Data-Driven Optimal Altitude Control of UAVs, pp. 265-272.

Gedj, Amit — Ben-Gurion University of the Negev
Taitler, Ayal — Ben-Gurion University of the Negev
Arogeti, Shai — Ben-Gurion University of the Negev

14:20-14:40 — TuB2.2

Adaptive Neural Attitude Control of a Quadcopter with Real-World Experimental Validation, pp. 273-280.

Kazakidis, Charalampos — University of West Attica
Protoulis, Teo — University of West Attica
Alexandridis, Alex — University of West Attica

14:40-15:00 — TuB2.3

Learning to Fly Using a Constant Reward Function, pp. 281-288.

Eschmann, Jonas — University of California Berkeley
Albani, Dario — Technology Innovation Institute
Loianno, Giuseppe — University of California Berkeley

15:00-15:20 — TuB2.4

Aggressiveness-Aware Learning-Based Control of Quadrotor UAVs with Safety Guarantees, pp. 289-296.

Colombo, Leonardo — Centre for Automation and Robotics
Beckers, Thomas — Vanderbilt University
Giribet, Juan Ignacio — University of San Andrés

15:20-15:40 — TuB2.5

Robust Attitude Tracking on Quadrotors Using Super-Twisting Sliding Mode Control, pp. 297-303.

Tavares, Luiz — Federal University of Espirito Santo
Bacheti, Vinícius Pacheco — Federal University of Espirito Santo
Sarcinelli-Filho, Mário — Federal University of Espirito Santo
Villa, Daniel Khede Dourado — Federal University of Espirito Santo

15:40-16:00 — TuB2.6

Adaptive Control for Off-The-Shelf Quadrotors Using a Simplified Dynamic Model, pp. 304-308.

Bacheti, Vinícius Pacheco — Federal University of Espirito Santo
Villa, Daniel Khede Dourado — Federal University of Espírito Santo
Sarcinelli-Filho, Mário — Federal University of Espirito Santo

TuB3 — **Calypso A**

Path Planning II (Regular Session)

Chair: Tzes, Anthony — New York University Abu Dhabi
Co-Chair: Bhandari, Subodh — California State Polytechnic University

14:00-14:20 — TuB3.1

Misfortunes Never Come Alone: Balancing Occupancy of UAM Alternate Landing Sites, pp. 309-316.

Hasan, Hardy	Lidingo Stad
Mori, Ryota	Kobe University
Polishchuk, Tatiana	Linkoping University
Polishchuk, Valentin	Linkoping University
Sedov, Leonid	Linkoping University

14:20-14:40 TuB3.2

Local Path Planning and Obstacle Avoidance for an Omnicopter Platform, pp. 317-324.

Helinski, Mikolaj	Delft University of Technology
Theodoulis, Spilios	Delft University of Technology
Hamandi, Mahmoud	New York University Abu Dhabi
Mohamed Ali, Abdullah	New York University Abu Dhabi
Tzes, Anthony	New York University Abu Dhabi
Popovic, Marija	Delft University of Technology

14:40-15:00 TuB3.3

Optimizing UAV Operations under Capacity and Distance Constraints: A Comparison of Routing Heuristics for Cerrado Restoration, pp. 325-332.

Nascimento, Flaviana	Universidade Federal De São Carlos
Guimarães, João Rafael	Universidade Federal De São Carlos
Sanglade, Lucas Dias	Universidade Federal De São Carlos
Boschi, Raquel	Universidade Federal De São Carlos
Pazelli, Tatiana F.P.A.T.	Universidade Federal De São Carlos
Kelen Cristiane, Teixeira Vivaldini	Universidade Federal De São Carlos

15:00-15:20 TuB3.4

Locally Optimal UAV Surveillance Evasion Via Sampling and Nonlinear Programming, pp. 333-340.

Kinerson, Joseph	Purdue University
Kim, Jaehyeok	Purdue University
Pant, Kartik	Purdue University
Sommer-Kohrt, Kylie	Purdue University
Goppert, James	Purdue University
Sun, Dengfeng	Purdue University

15:20-15:40 TuB3.5

3D Path Planning for Autonomous UAV Navigation in GPS-Denied Environments, pp. 341-348.

Thakkar, Tirth	California State Polytechnic University
Rick Ramirez, Rick Ramirez	California State Polytechnic University
Tsui, Rexley	California Polytechnic State University
Bhandari, Subodh	California State Polytechnic University
Raheja, Amar	California State Polytechnic University

15:40-16:00 TuB3.6

PSO-Based UAV Path Planning for Minimizing Tracking Probability in Bistatic Radar Networks, pp. 349-355.

Kahveci, Cemil	Istanbul Technical University
Inalhan, Gokhan	Cranfield University
Baspinar, Baris	Istanbul Technical University

TuB4 **Calypso B**

Perception and Cognition II (Regular Session)

Chair: Santiaguillo-Salinas, Jesús — Universidad Del Papaloapan

Co-Chair: Xu, Yan — Beihang University

14:00-14:20 TuB4.1

From Robust Perception to Conflict Detection: Res-Gated Fusion for Multi-UAV Collaborative Operations in Degraded Urban Airspace, pp. 356-364.

Wei, Yuxi	Beihang University
Xu, Yan	Beihang University
Cai, Kaiquan	Beihang University

14:20-14:40 TuB4.2

Learning-Based Perception of Cyber Anomalies in UAV Communication for Safe Autonomous Operations, pp. 365-372.

Ruseno, Neno	University of South-Eastern Norway
Mottaghi Tarom Sari, Fahimeh	University of South-Eastern Norway
Farina, Mauro	University of Trieste
Arntzen Bechina, Aurilla Aurelie	University of South-Eastern of Norway

14:40-15:00 TuB4.3

Enhancing Concealed Drone Detection with Attention Mechanisms in RT-DETR, pp. 373-380.

Obert, Luis	German Aerospace Center
da Silva Justino, Daniel Alexandre	German Aerospace Center
Gardi, Hamza A.A.	Karlsruhe Institute of Technology
Heizmann, Michael	Karlsruhe Institute of Technology

15:00-15:20 TuB4.4

Gesture-Based Natural User Interface for Formation Control of Multi-UAV Systems, pp. 381-388.

Flores Murcia, Zurisadai	Universidad Del Papaloapan
Lara Solís, Daly Yareth	Universidad Del Papaloapan
Santiaguillo-Salinas, Jesús	Universidad Del Papaloapan

15:20-15:40 TuB4.5

Temporally Consistent Multi-Plane Segmentation and Stable Semantic Classification for UAV-Based 3D Mapping in Irregular Terrain, pp. 389-395.

Alves, Werikson	Universidade Federal De Viçosa
Alves Fagundes Junior, Leonardo	Universidade Federal De Viçosa
Dias, Artur	Universidade Federal De Viçosa
Marcolino, Pablo	Universidade Federal De Viçosa
Brandao, Alexandre Santos	Universidade Federal De Viçosa

15:40-16:00 TuB4.6

Neural-Geometric Tunnel Traversal: Localization-Free UAV Flight with Tilted LiDARs, pp. 396-403.

Cano, Lorenzo	Universidad De Zaragoza
Tardioli, Danilo	Universidad De Zaragoza
Mosteo, Alejandro R.	Centro Universitario De La Defensa

TuC1 **Nafsika**

Control Architectures II (Regular Session)

Chair: Cenedese, Angelo	University of Padua
Co-Chair: Sarcinelli-Filho, Mário	Federal University of Espirito Santo

16:20-16:40 TuC1.1

A Coupled Stochastic Optimal Separation and Intercept Strategy for Dubins Vehicles, pp. 404-410.

Milutinovic, Dejan	University of California at Santa Cruz
Von Moll, Alexander	Air Force Research Laboratory
Weintraub, Isaac E.	Air Force Research Laboratory
Casbeer, David	Air Force Research Laboratory

16:40-17:00 TuC1.2

Trajectory Tracking Control Design for Autonomous Helicopters with Guaranteed Error Bounds, pp. 411-418.

Schitz, Philipp	German Aerospace Center
Dauer, Johann	German Aerospace Center
Mercorelli, Paolo	Leuphana University of Lueneburg

17:00-17:20 TuC1.3

Force Polytope-Based Cant-Angle Selection for Tilting Hexarotor UAVs, pp. 419-426.

Piccina, Alberto	University of Padua
Bertoni, Massimiliano	University of Padua
Cenedese, Angelo	University of Padua
Michieletto, Giulia	University of Padua

17:20-17:40 TuC1.4

Lyapunov-Driven Control Design for Quadrotors with Heading–Velocity Command Inputs: Further Insights towards a Digital Twin, pp. 427-434.

Malpica-Velasco, Esau	Centro De Investigación Y De Estudios Avanzados Del Instituto Politécnico Nacional

Rodriguez-Cortes, Hugo	Centro De Investigación Y De Estudios Avanzados Del Instituto Politécnico Nacional
Guerrero, Fermi	Benemerita Universidad Autonoma De Puebla
Amparan Estrada, Jesus Ramon	Centro De Investigación Y De Estudios Avanzados Del Instituto Politécnico Nacional

17:40-18:00 TuC1.5

Load Transportation by a Single Quadrotor Using the Null Space Behavioral Control Technique, pp. 435-441.

Spagnol, Felipe Andrade	Universidade Federal Do Espírito Santo
Cordeiro, Rafael	Universidade Federal Do Espírito Santo
Villa, Daniel Khede Dourado	Universidade Federal Do Espírito Santo
Sarcinelli-Filho, Mário	Universidade Federal Do Espírito Santo

18:00-18:20 TuC1.6

Speed-Based Trajectory Tracking Control for Fixed-Wing UAV, pp. 442-449.

Mendes Potes, André	Technology Innovation Institute
Retamal Guiberteau, Victor	Technology Innovation Institute
Wakode, Ashay	Technology Innovation Institute
Garcia, Jeison	Technology Innovation Institute
Barciś, Agata	Technology Innovation Institute
Nguyen, Hung	Technology Innovation Institute

TuC2 **Lounge A**

Micro and Mini-UAS and Biologically Inspired UAS (Regular Session)

Chair: Briñón Arranz, Lara	Université Grenoble Alpes
Co-Chair: Armanini, Sophie F.	Imperial College London

16:20-16:40 TuC2.1

Low-Compute Event-Based Navigation for Micro-Drones in Confined Subterranean Environments, pp. 450-457.

Arogeti, Shai	Ben-Gurion University of the Negev
Hen, Tal	Ben-Gurion University of the Negev

16:40-17:00 TuC2.2

RoboticsXR: Extended Reality for Robotics Visual Navigation, pp. 458-463.

Petre, Ricioppo	Politecnico Di Torino
Enrico, Riccardo	Politecnico Di Torino
Sarvadon, Jean-Luc	Politecnico Di Torino
Ruggiero, Dario	Politecnico Di Torino
Capello, Elisa	Politecnico Di Torino

17:00-17:20 TuC2.3

Evidence-Based Landing Site Selection and Vison-Based Landing for UAVs in Unstructured Environments, pp. 464-471.

Sajjadi, Sina	National Research Council Canada
Panerati, Jacopo	National Research Council Canada
Soleymanpour, Sina	National Research Council Canada
Mehta, Varun	National Research Council Canada
Janabi Sharifi, Farrokh	Toronto Metropolitan University
Mantegh, Iraj	National Research Council Canada

17:20-17:40 TuC2.4

Distributed Gradient-Based Control for Reconfigurable Regular Polygon Formations in Multi-UAV Systems, pp. 472-479.

Skantzikas, Kostas	Université Grenoble Alpes
Briñón Arranz, Lara	Université Grenoble Alpes
Susbielle, Pierre	Université Grenoble Alpes
Marchand, Nicolas	Université Grenoble Alpes

17:40-18:00 TuC2.5

Comparative Analysis of Different Polymer Membranes for Enhanced Aerodynamic Efficiency in FWMAVs, pp. 480-487.

Hammad, Ahmad	Technical University of Munich
Remakanthan, Devanarayanan	Technical University of Munich
Eldo, Joel	Technical University of Munich
Armanini, Sophie F.	Imperial College London

18:00-18:20 TuC2.6

TuC3 — **Calypso A**
Navigation (Regular Session)

Chair: Ollero, Anibal — Universidad De Sevilla
Co-Chair: Perez-Grau, Francisco Javier — Advanced Center for Aerospace Technologies

TuC4 — **Calypso B**
Airspace Operations and See-And-Avoid Systems (Regular Session)

Chair: Garbarino, Luca — Italian Aerospace Research Center CIRA
Co-Chair: Smeur, Ewoud — Delft University of Technology

Garbarino, Luca	Italian Aerospace Research Center
Gaudino, Maria	University of Naples
Vitale, Antonio	Italian Aerospace Research Center
Fasano, Giancarmine	University of Naples
Cuciniello, Giovanni	Italian Aerospace Research Center

16:40-17:00 TuC4.2

Visual Verification of UAV Location in Remote Identification Messages, pp. 553-560.

Obeid, Ahmad	Khalifa University
Saeed, Elyas	Khalifa University
Hejji, Dina	Khalifa University
Yohannes Woldegiorgish, Noah	Khalifa University
Rashid, M Ryyan	Khalifa University
Atrouz, Mohammad	Khalifa University
Shoufan, Abdulhadi	Khalifa University

17:00-17:20 TuC4.3

Robust H∞ Controller Design for INDI-Controlled Quadrotor Using Online Parameter Identification, pp. 561-568.

Aantjes, Tom	Delft University of Technology
Blaha, Till Martin	Delft University of Technology
Theodoulis, Spilios	Delft University of Technology
Smeur, Ewoud	Delft University of Technology

17:20-17:40 TuC4.4

INDI Control of Fixed-Wing Tilt-Rotor Applied to Tethered Flight, pp. 569-576.

Villanueva Aguado, Mauro	ENAC
Bronz, Murat	ENAC

17:40-18:00 TuC4.5

Obstacle Detection for Fixed-Wing UAVs Using a Digital Twin and Deep Learning, pp. 577-584.

Loyaga Carranza, Erick Steven	Escuela Politécnica Nacional
Chamorro Hernandez, William Oswaldo	Escuela Politecnica Nacional
Quinatoa Catota, Estefano Dario	Escuela Politécnica Nacional
Vandewalle, Patrick	KU Leuven
Valencia Torres, Esteban Alejandro	Escuela Politécnica Nacional

Wednesday, June 17, 2026

WeA1 **Nafsika**

Control Architectures III (Regular Session)

Chair: Cavone, Graziana	Università Degli Studi Roma Tre
Co-Chair: Rastgoftar, Hossein	University of Arizona

11:20-11:40 WeA1.1

Identification and Control of a Planar Quadrotor from Visual Data Using Koopman Representations, pp. 585-592.

Bongiovanni, Nicolas	Université Côte D'Azur
Mavkov, Bojan	Université Côte D'Azur
Martins, Renato	Université Bourgogne Europe
Allibert, Guillaume	Université Côte D'Azur

11:40-12:00 WeA1.2

Rule-Based High-Level Coaching for Goal-Conditioned Reinforcement Learning in Search-And-Rescue UAV Missions under Limited-Simulation Training, pp. 593-600.

Ramezani, Mahya	University of Luxembourg
Voos, Holger	University of Luxembourg

12:00-12:20 WeA1.3

Deep Q-Learning-Based Gain Scheduling for Nonlinear Quadcopter Dynamics, pp. 601-608.

Rastgoftar, Hossein	University of Arizona
Zahed, Muhammad Junayed Hasan	University of Arizona

12:20-12:40 WeA1.4

Neural PMP-NMPC for Adaptive and Stable Quadrotor Control in Perception-Driven Tasks, pp. 609-616.

Mukherjee, Pratik	Florida Atlantic University

12:40-13:00	WeA1.5

Adaptive and Predictive Control of UAS in Train-Drone Delivery System, pp. 617-624.

Cavone, Graziana	Università Degli Studi Roma Tre
Bardanzellu, Marco	Università Degli Studi Roma Tre
Pascucci, Federica	Università Degli Studi Roma Tre

13:00-13:20	WeA1.6

Full Actuator Nonlinear Dynamic Inversion for Enhanced Hybrid UAV Control, pp. 625-632.

Dubois, Justin Petrus G.	Delft University of Technology
Ntouros, Evangelos	Delft University of Technology
Smeur, Ewoud	Delft University of Technology

WeA2 — Lounge A

Multirotor Design and Control III (Regular Session)

Chair: Michieletto, Giulia	University of Padua
Co-Chair: Ciresola, Federico	University of Padua

11:20-11:40	WeA2.1

Geometric Inverse Flight Dynamics on SO(3) and Application to Tethered Fixed-Wing Aircraft, pp. 633-640.

Franchi, Antonio	Univ. of Twente and Sapienza Univ. of Rome
Gabellieri, Chiara	University of Twente

11:40-12:00	WeA2.2

Hardware-Aware SE(3) Control Barrier Functions for Counter-UAS Interceptors with Directed Energy Payloads, pp. 641-647.

Vlachos, Evangelos	ATHENA Research Center
Kolios, Panayiotis	University of Cyprus
Skliros, Christos	Hellenic Drones S.A

12:00-12:20	WeA2.3

Probabilistic Attainable Moment Sets for Uncertainty-Aware Design Optimization, pp. 648-655.

Tsagkaris, Michail	Technical University of Munich
Holzapfel, Florian	Technical University of Munich
Armanini, Sophie F.	Imperial College London
Ryll, Markus	Technical University of Munich

12:20-12:40	WeA2.4

Control Input Allocation for Tilting Multirotors - a Review, pp. 656-663.

Ciresola, Federico	University of Padua
Sorge, Marcello	University of Padua
Michieletto, Giulia	University of Padua
Cenedese, Angelo	University of Padua

12:40-13:00	WeA2.5

Hybrid Modeling of Multirotor UAVs with Learned Induced Velocity, pp. 664-671.

Laiche, Ibrahim	Sorbonne University
Boudaoud, Mokrane	Pierre and Marie Curie University
Gallinari, Patrick	Sorbonne University and Criteo AI Lab
Morin, Pascal	Mines Paris PSL

13:00-13:20	WeA2.6

Design and Aerodynamic Modeling of MetaMorpher: A Hybrid Rotary and Fixed-Wing Morphing UAV, pp. 672-679.

Bosak, Anja	University of Zagreb
Erić, Dorian	University of Zagreb
Milas, Ana	University of Zagreb
Bogdan, Stjepan	University of Zagreb

WeA3 — Calypso A

UAS Testbeds (Regular Session)

Co-Chair: Peti, Marijana	University of Zagreb, Faculty of Electrical Engineering and Computing

11:20-11:40	WeA3.1
Aerial-Autonomy-Stack---A Faster-Than-Real-Time, Autopilot-Agnostic, ROS2 Framework to Simulate and Deploy Perception-Based Drones, pp. 680-688.	
Panerati, Jacopo	National Research Council Canada
Sajjadi, Sina	National Research Council Canada
Soleymanpour, Sina	National Research Council Canada
Mehta, Varun	National Research Council Canada
Mantegh, Iraj	National Research Council Canada

11:40-12:00	WeA3.2
Development and Validation of an Instrumented Static Test Bench for Brushless Motors, pp. 689-695.	
Dudenko, Artur	Universidade Federal De Viçosa
Villibor, Geice Paula	Universidade Federal De Viçosa
Brandao, Alexandre Santos	Universidade Federal De Viçosa

12:00-12:20	WeA3.3
An Integrated Testbed for Mission-Level Autonomy Evaluation in Evolving Disaster Scenarios with Fixed-Wing Swarms, pp. 696-703.	
Bolz, Wolfgang	Austrian Institute of Technology
Faber, Filip	Austrian Institute of Technology
Lork, Julian	Austrian Institute of Technology
Cella, Marco	Austrian Institute of Technology
Zendel, Oliver	Austrian Institute of Technology
d'Apolito, Francesco	Austrian Institute of Technology

12:20-12:40	WeA3.4
Benchmarking Connectivity and Energy-Aware Algorithms Using Crazyflie UAVs: A Sim2Real Multi-Robot Framework, pp. 704-711.	
Peti, Marijana	University of Zagreb
Alamdar, Khawaja Ghulam	University of Zagreb
Kozlik, Marko	University of Zagreb
Ivanovic, Antun	University of Zagreb
Petric, Frano	University of Zagreb
Orsag, Matko	University of Zagreb
Bogdan, Stjepan	University of Zagreb

12:40-13:00	WeA3.5
ROScopter: A Multirotor Autopilot Based on ROSflight 2.0, pp. 712-719.	
Moore, Jacob	Brigham Young University
Reid, Ian	Brigham Young University
Tokumaru, Phillip	AeroVironment Inc
Beard, Randal W.	Brigham Young University
McLain, Tim	Brigham Young University

13:00-13:20	WeA3.6
ROSflight 2.0: Lean ROS 2-Based Autopilot for Unmanned Aerial Vehicles, pp. 720-728.	
Moore, Jacob	Brigham Young University
Tokumaru, Phillip	AeroVironment, Inc
Reid, Ian	Brigham Young University
Sutherland, Brandon	Brigham Young University
Ritchie, Joseph	Brigham Young University
Snow, Gabe	Brigham Young University
McLain, Tim	Brigham Young University

WeA4	**Calypso B**
Autonomous Aerial Operations and Field Inspection (Regular Session)	
Chair: Bechlioulis, Charalampos	University of Patras
Co-Chair: Karras, George	University of Thessaly

11:20-11:40	WeA4.1
Unmanned Aerial Vehicle Safe Autonomous Landing, pp. 729-736.	
Tsoukalas, Athanasios	New York University Abu Dhabi

Unlu, Halil Utku	New York University Abu Dhabi
Evangeliou, Nikolaos	New York University Abu Dhabi
Tzes, Anthony	New York University Abu Dhabi

11:40-12:00 WeA4.2

A Lightweight Toggleable Adhesion Prototype for Multirotor UAV Landing on Tilting Platforms, pp. 737-742.

Nordholt, Teighin	Queen's University
Greeff, Melissa	Queen's University

12:00-12:20 WeA4.3

Autonomous Exploration for Micro Aerial Vehicles with Sparse Sensing Using Harmonic Fields and Monte Carlo Integration, pp. 743-749.

Kotsinis, Dimitrios	University of Patras
Karras, George	University of Thessaly
Bechlioulis, Charalampos	University of Patras

12:20-12:40 WeA4.4

An Oceanic Small-UAS with Near-Surface Soaring Flight Sensory Design and Onboard Deep-Learned Meteorological Perception, pp. 750-758.

Carlson, Stephen	University of Nevada
Arora, Prateek	University of Nevada
Papachristos, Christos	University of Nevada

12:40-13:00 WeA4.5

Intercepting an Agile Target with Net-Carrying Drones Using Competitive Multi-Agent Reinforcement Learning, pp. 759-766.

Gavin, Timothée	Thales LAS
Bronz, Murat	ENAC

13:00-13:20 WeA4.6

System Identification and State-Space Control of a Small Unmanned Aerial Vehicle (UAV), pp. 767-773.

Zaraza Espinosa, Javier Mauricio	Universidad Industrial De Santander
Buitrago Galvan, Edgar Julian Farid	Universidad Industrial De Santander
Carreno Zagarra, Jose Jorge	Universidad Industrial De Santander
Esteban, Helio S	Universidad Industrial De Santander
Poveda, Diana Katheryn	Universidad Industrial De Santander

Thursday, June 18, 2026

ThA1 **Nafsika**

Swarms (Regular Session)

Chair: Artemiadis, Panagiotis	University of Delaware
Co-Chair: Wang, Liyang	Ecole Nationale De l'Aviation Civile

08:30-08:50 ThA1.1

Efficient Decentralized Multi-UAV Wildfire Monitoring Via MCTS-Distilled Diffusion Policies, pp. 774-781.

Wang, Liyang	Ecole Nationale De l'Aviation Civile
Bronz, Murat	Ecole Nationale De l'Aviation Civile

08:50-09:10 ThA1.2

Human Trust-Driven Adaptive Control for Unmanned Aerial Swarms, pp. 782-789.

Orozco, Jesus	University of Delaware
Walsh, Coleman	University of Delaware
Artemiadis, Panagiotis	University of Delaware

09:10-09:30 ThA1.3

Swarm-Steward: Scalable and Reliable Natural-Language Coordination of Autonomous Aerial and Ground Robots, pp. 790-798.

Jarabo-Peñas, Alejandro	University of Southern Denmark
Bravo-Arrabal, Juan	University of Southern Denmark
Rolland, Edouard George Alain	University of Southern Denmark
Christensen, Anders Lyhne	University of Southern Denmark

09:30-09:50	ThA1.4
Distributed Control of Disturbed Nonholonomic Aerial Robots with User-Defined Finite-Time Synchronization, pp. 799-804.	
Kurtoglu, Deniz	University of South Florida
Yucelen, Tansel	University of South Florida
Tran, Dzung	Air Force Research Laboratories
Garcia, Eloy	Air Force Research Laboratories
Casbeer, David	Air Force Research Laboratories

09:50-10:10	ThA1.5
Distributed Formation Control with Local Sensing Combining Bubble-Based Voronoi Tessellation and Consensus, pp. 805-812.	
Mendoza-Robles, Natalio	Université Grenoble Alpes and INSA Strasbourg
Briñón Arranz, Lara	Université Grenoble Alpes
Susbielle, Pierre	Université Grenoble Alpes
Skantzikas, Kostas	Université Grenoble Alpes
Durand, Sylvain	INSA Strasbourg
Marchand, Nicolas	Université Grenoble Alpes

10:10-10:30	ThA1.6
A Preliminary Study on Smoke Plume Observation with Drone Swarms, pp. 813-819.	
Chakraa, Hamza	ENAC
Verdoucq, Matthieu	ENAC
Machado, João	ENAC
Bronz, Murat	ENAC

ThA2	**Lounge A**
Autonomy (Regular Session)	
Chair: Kyriakopoulos, Kostas J.	New York University - Abu Dhabi
Co-Chair: Valencia Torres, Esteban Alejandro	Escuela Politécnica Nacional

08:30-08:50	ThA2.1
Safe Ergodic Exploration for Fixed-Wing UAVs, pp. 820-827.	
Kyriakopoulos, Kostas J.	New York University Abu Dhabi
Vavvas, Alexios	QUALCO

08:50-09:10	ThA2.2
Cooperative UAV Search and Rescue Via Multi-Agent Reinforcement Learning in Simulated Wildfire Environments, pp. 828-835.	
Sharma, Shivani	Kingston University London
Tsoumplekas, Georgios	Kingston University London
Spyridis, Yannis	Kingston University London
Vitzilaios, Nikolaos	University of South Carolina
Argyriou, Vasileios	Kingston University London

09:10-09:30	ThA2.3
Autonomous In-Operation Wind-Turbine Blade Inspection, pp. 836-843.	
Bosak, Anja	University of Zagreb
Peris, Stela	University of Zagreb
Markovic, Lovro	University of Zagreb
Ivanovic, Antun	University of Zagreb
Car, Marko	University of Zagreb
Orsag, Matko	University of Zagreb
Bogdan, Stjepan	University of Zagreb

09:30-09:50	ThA2.4
AgiPIX: Bridging Simulation and Reality in Indoor Aerial Inspection, pp. 844-852.	
Kuruppu Arachchige, Sasanka	Tampere University
Garcia-Cardenas, Juan José	ENSTA ParisTech
Tian, Changda	Foundation for Research and Technology - Hellas
Suomela, Lauri Aleksanteri	Tampere University
Trahanias, Panos	Foundation for Research and Technology - Hellas

Tapus, Adriana — ENSTA ParisTech
Kamarainen, Joni-Kristian — Tampere University

09:50-10:10 — ThA2.5

Prediction of Aerodynamic Coefficients Using Neural Network Based Reduced Order Models for Multiple Fixed-Wing UAV Configurations, pp. 853-860.

Ullaguari Chida, Nixon Sebastian — Escuela Politecnica Nacional
Alulema, Victor — Escuela Politécnica Nacional
Valencia Torres, Esteban Alejandro — Escuela Politécnica Nacional

10:10-10:30 — ThA2.6

Bearing-Only Target Localization Using Fixed-Wing UAV, pp. 861-867.

Koca, Muhammed Yasin — Turkish Aerospace
Bayram, Haluk — Istanbul Medeniyet University

ThA3 — Calypso A

Energy Efficient UAS, Payloads and Aerial Delivery (Regular Session)

Chair: Tatlicioglu, Enver — Ege University
Co-Chair: Kallies, Christian — German Aerospace Center

08:30-08:50 — ThA3.1

Energy-Aware Multicopter Modeling for Control and Planning Applications, pp. 868-877.

Gasche, Sebastian — German Aerospace Center
Kallies, Christian — German Aerospace Center
Himmel, Andreas — Technical University of Darmstadt
Findeisen, Rolf — Technical University of Darmstadt

08:50-09:10 — ThA3.2

Performance Analysis of Dynamic Soaring with Thrust and Regeneration, pp. 878-885.

Zhuo, Zihao — McGill University
Nahon, Meyer — McGill University
Sharf, Inna — McGill University

09:10-09:30 — ThA3.3

EAAE: Energy-Aware Autonomous Exploration for UAVs in Unknown 3D Environments, pp. 886-893.

Elskamp, Jacob — Delft University of Technology
Shi, Moji — Delft University of Technology
Bauersfeld, Leonard — University of Zurich
Scaramuzza, Davide — University of Zurich
Popovic, Marija — Delft University of Technology

09:30-09:50 — ThA3.4

Adaptive Prescribed Performance Control of Altitude of Agricultural UAVs, pp. 894-898.

Ozgun, Abdulkadir Sehmus — Ege University
Demirkol Ozgun, Serap — Ege University
Deniz, Meryem — IzmirKatip Celebi University
Tatlicioglu, Enver — Ege University

09:50-10:10 — ThA3.5

Deep Reinforcement Learning for Hexacopter Control under Payload Collection and Release, pp. 899-906.

Al Homsi, Mohammad — Università Degli Studi Di Palermo
Messaoudi, Sofiane — Università Degli Studi Di Palermo
Fagiolini, Adriano — Università Degli Studi Di Palermo
Cirrincione, Giansalvo — Université De Picardie Amiens
Valavanis, Kimon P. — University of Denver
Sopegno, Laura — University of Michigan

10:10-10:30 — ThA3.6

ADROP: Aerial Delivery Robot for Light-Parcel Operations, pp. 907-912.

Suarez, Alejandro — Universidad De Sevilla
Ollero, Anibal — Universidad De Sevilla

ThA4	Calypso B
Security, Regulations and Training (Regular Session)	
Chair: Ruggiero, Fabio	Università Degli Studi Di Napoli Federico II
Co-Chair: Pignaton de Freitas, Edison	Federal University of Rio Grande Do Sul

08:30-08:50 ThA4.1

A Theory of Mind Model for Proportionality Assessment in Military Operations, pp. 913-918.

Maathuis, Clara — Open University

08:50-09:10 ThA4.2

Secure UTM Infrastructure with Zero Trust: Design and Implementation for UAV Operations, pp. 919-926.

Pashchapur, Ravi Ashok — Technology Innovation Institute
Singh, Govind — Technology Innovation Institute
Royyan, Muhammad — Unikie

09:10-09:30 ThA4.3

A Comprehensive Evaluation of U-Space KPIs, pp. 927-934.

Nunez Portillo, Juan — University of Seville
Lundberg, Jonas — Linkoping University
Polishchuk, Tatiana — Linkoping University
Polishchuk, Valentin — Linkoping University
Sedov, Leonid — Linkoping University
Enea, Gabriele — MIT Lincoln Laboratory

09:30-09:50 ThA4.4

Addressing the Challenges of Autonomous Drone Swarms by Compliance-By-Design Regulations, pp. 935-942.

Kristoffersson, Eleonor — Örebro University
Kristoffersson, Magnus — Örebro University
Pignaton de Freitas, Edison — Federal University of Rio Grande Do Sul

09:50-10:10 ThA4.5

CA-AC-MPC: CUDA-Accelerated Actor-Critic Model Predictive Control, pp. 943-950.

Buo, Antonio — Università Degli Studi Di Napoli Federico II
Cammarota, Vittorio — Università Degli Studi Di Napoli Federico II
Avagnale, Michele — Università Degli Studi Di Napoli Federico II
Arpenti, Pierluigi — Università Degli Studi Di Napoli Federico II
Lippiello, Vincenzo — Università Degli Studi Di Napoli Federico II
Ruggiero, Fabio — Università Degli Studi Di Napoli Federico II

10:10-10:30 ThA4.6

Licensing of Drone Operators in the European Union: A Comparative Legal Analysis, pp. 951-960.

Konert, Anna — Lazarski University in Warsaw

ThB1	Nafsika
UAS Applications I: Detection, Tracking and Counter-UAS (Regular Session)	
Chair: Anastasiou, Andreas	KIOS Research and Innovation Center of Excellence, University of Cyprus
Co-Chair: Souli, N.	University of Cyprus

10:50-11:10 ThB1.1

Dynamic Encirclement Angle-Based Cooperative Guidance Law for Multi-Missile System against Maneuvering Target, pp. 961-967.

Wang, Mengmeng — Beijing Institute of Technology
Sun, Jingliang — Beijing Institute of Technology
Wang, Zihan — Beijing Institute of Technology
Zhong, Jianxin — Beijing Institute of Technology
Shi, Xianchao — Beijing Institute of Technology
Long, Teng — Beijing Institute of Technology

11:10-11:30 ThB1.2

Predictive Control with Integrated Target Estimation and Detection Probabilities for Coordinated Search and Track of Maritime Targets, pp. 968-975.

Anastasiou, Andreas — University of Cyprus
Papaioannou, Savvas — University of Cyprus

Kolios, Panayiotis	University of Cyprus
Panayiotou, Christos	University of Cyprus

11:30-11:50	ThB1.3

Small Object Detection in UAV Imagery Via Multimodal RGB-Thermal Fusion, pp. 976-983.

Galdelli, Alessandro	Università Politecnica Delle Marche
Brunella, Federico	Università Politecnica Delle Marche
Colletta, Matteo	Università Politecnica Delle Marche
Libofsha, Angjelo	Università Politecnica Delle Marche
Giano, Simone	Università Politecnica Delle Marche
Chiappini, Stefano	Università Politecnica Delle Marche
Bolognini, Luca	National Research Council
Mancini, Adriano	Università Politecnica Delle Marche

11:50-12:10	ThB1.4

A Topology-Aware Spatiotemporal Handover Framework for Continuous Multi-UAV Tracking, pp. 984-991.

Ye, Jianlin	University of Cyprus
Kyrkou, Christos	University of Cyprus
Kolios, Panayiotis	University of Cyprus

12:10-12:30	ThB1.5

High-Speed Drone Detection: Evaluating Ultra-Lightweight Custom Architectures for Deployment on Edge Devices, pp. 992-997.

Drimus, Alin	University of Southern Denmark
Jouffroy, Jerome	University of Southern Denmark

12:30-12:50	ThB1.6

Rogue Drone Detection and Tracking Using Vision and Range-Finder Measurements, pp. 998-1004.

Pettemeridis, Giorgos	University of Cyprus
Souli, Nicolas	University of Cyprus
Grigoriou, Yiannis	University of Cyprus
Ellinas, Georgios	University of Cyprus
Kolios, Panayiotis	University of Cyprus

ThB2	**Lounge A**
Aerial Robotic Manipulation I (Regular Session)	
Chair: Ghersin, Alejandro	Instituto Tecnológico De Buenos Aires
Co-Chair: Mas, Ignacio	Universidad De San Andrés

10:50-11:10	ThB2.1

Trajectory Control of the Suspended Load Pose Using Non-Stopping Flying Carriers, pp. 1005-1012.

Girardello, Sofia	University of Padua
Michieletto, Giulia	University of Padua
Cenedese, Angelo	University of Padua
Franchi, Antonio	Univ. of Twente and Sapienza Univ. of Rome
Gabellieri, Chiara	University of Twente

11:10-11:30	ThB2.2

Isotropic Force Generation in Tilting-Rotor Omnidirectional Multirotors, pp. 1013-1020.

Hernández-Rojo, Manuel	Universidad De Sevilla
Gonzalez-Morgado, Antonio	Universidad De Sevilla
Ollero, Anibal	Universidad De Sevilla
Heredia, Guillermo	Universidad De Sevilla

11:30-11:50	ThB2.3

Hierarchical Tracking Control of Multirotors under Saturation Constraints, pp. 1021-1028.

Stauder, Julien	Centre National De La Recherche Scientifique
Yigit, Arda	Centre National De La Recherche Scientifique
Viollet, Stephane	Centre National De La Recherche Scientifique
Fantoni, Isabelle	Centre National De La Recherche Scientifique

11:50-12:10	ThB2.4

Fault Tolerant Adaptive Control for Aerial Manipulators, pp. 1029-1036.

Pose, Claudio Daniel	Universidad De Buenos Aires
Ghersin, Alejandro	Instituto Tecnológico De Buenos Aires
Mas, Ignacio	Universidad De San Andrés
Giribet, Juan Ignacio	Universidad De San Andrés

12:10-12:30 ThB2.5

U-Joint CAAMS: Experimental Evaluation of a Universal-Joint Continuum Manipulator for Aerial Manipulation, pp. 1037-1044.

Uthayasooriyan, Anuraj	Queensland University of Technology
Alibrahim, Musab	Queensland University of Technology
Digumarti, Krishna Manaswi	Queensland University of Technology
Vanegas Alvarez, Fernando	Queensland University of Technology
Gonzalez, Luis Felipe	Queensland University of Technology

ThB3 **Calypso A**

Sensor Fusion (Regular Session)

Chair: Nyboe, Frederik F	University of Southern Denmark
Co-Chair: Amaral, Guilherme	INESC TEC - Institute for Systems and Computer Engineering, Technology and Science

10:50-11:10 ThB3.1

Distributed Multi-Station Data Fusion for UAV Tracking Combining Vision and mmWave Radar, pp. 1045-1053.

Amaral, Guilherme	Institute for Systems and Computer Engineering, Technology and Science
Fernandes, José Carlos	Institute for Systems and Computer Engineering, Technology and Science
Martins, João J.	Institute for Systems and Computer Engineering, Technology and Science
Dias, André	Institute for Systems and Computer Engineering, Technology and Science and Polytechnic of Porto
Lysak, Maksym	Institute for Systems and Computer Engineering, Technology and Science
Almeida, José Miguel	Institute for Systems and Computer Engineering, Technology and Science and Polytechnic of Porto
Silva, Eduardo	Institute for Systems and Computer Engineering, Technology and Science

11:10-11:30 ThB3.2

A Lightweight Framework for Neighborhood-Constrained UAV Localization Using Visual Embeddings, pp. 1054-1061.

Dimos, Alexandros	University of the Aegean
Skoutas, Dimitrios	University of the Aegean
Nomikos, Nikolaos	University of the Aegean
Skianis, Charalabos	University of the Aegean

11:30-11:50 ThB3.3

Drone-In-A-Box: A Precise Indoor Autonomous Docking System, pp. 1062-1069.

Godio, Simone	Technology Innovation Institute
Costa Fernandes, Rafael	Technology Innovation Institute
Montecchiari, Leonardo	Technology Innovation Institute
Al-Ali, Asraa	Technology Innovation Institute
Ashour, Reem	Technology Innovation Institute
Oliveira, Felipe	Technology Innovation Institute
Tortorici, Claudio	Technology Innovation Institute

11:50-12:10 ThB3.4

Conformal Aerial Geo-Localization through Visual Place Recognition, pp. 1070-1077.

Silva, Diogo	Academia Da Força Aérea
Bernardino, Alexandre	Instituto De Sistemas E Robótica, Instituto Superior Técnico
Cruz, Gonçalo	Portuguese Air Force Academy Research Center

12:10-12:30 ThB3.5

Towards Learning-Based Ground Velocity Estimation for UAVs Using Onboard Anemometer, pp. 1078-1085.

Gabrlik, Petr	Brno University of Technology
Cihlar, Milos	Brno University of Technology

12:30-12:50	ThB3.6

Event-Only Drone Trajectory Forecasting with RPM-Modulated Kalman Filtering, pp. 1086-1092.

Sundra Valli Muthumanickam, Hari Prasanth	Aalto University
Habibiroudkenar, Pejman	Aalto University
Alamikkotervo, Eerik	Aalto University
Bouzoulas, Dimitrios	Aalto University
Ojala, Risto	Aalto University

ThB4 — Calypso B

Testing and Evaluation: Autonomy I (Invited Session)

Chair: Costello, Donald	University of Maryland College Park
Co-Chair: Hwang, George	Naval Air Warfare Center Aircraft Division

10:50-11:10	ThB4.1

Benchmarking Geometric Monocular Ranging for Autonomous Aerial Refueling (I), pp. 1093-1100.

Lee, Kevin	United States Naval Academy
Lowe, Ryan	United States Naval Academy
Costello, Donald	University of Maryland
Mwaffo, Violet	United States Naval Academy

11:10-11:30	ThB4.2

Vision-Based Multi-Keypoint Relative Depth Estimation for Autonomous Aerial Refueling (I), pp. 1101-1108.

Smith, Seamus	United States Naval Academy
Andersen, James	United States Naval Academy
Costello, Donald	University of Maryland
Mwaffo, Violet	United States Naval Academy
Coleman, Bianca	United States Naval Academy

11:30-11:50	ThB4.3

Autonomous UAS Control Leveraging DNN-Based Monocular Camera Relative Position Estimation for Unmanned Aerial Refueling Systems (I), pp. 1109-1116.

Lowe, Ryan	United States Naval Academy
Torshizi, Kasra	University of Maryland
Wendland, Lucas	University of Maryland
Mwaffo, Violet	United States Naval Academy
Costello, Donald	University of Maryland

11:50-12:10	ThB4.4

February 2026 Development, Test & Evaluation, Verification & Validation (DTEVV) Workshop Summary (I), pp. 1117-1122.

Costello, Donald	University of Maryland

12:10-12:30	ThB4.5

Framing the Research Agenda for AI Agent Testing on Operational Platforms: Lessons and Open Questions from the X-62 VISTA (I), pp. 1123-1128.

Kinard, Rachel	USAF Test Pilot School
Zamot, Noel	USAF Test Pilot School

ThC1 — Nafsika

UAS Applications II: Inspection and Monitoring (Regular Session)

Chair: Franchi, Antonio	Univ. of Twente and Sapienza Univ. of Rome
Co-Chair: Fernandes, Manuel C.R M.	Universidade Do Porto

14:00-14:20	ThC1.1

Data Assisted Ground Truth Generation in Agricultural Orthomosaic, pp. 1129-1136.

Kiforenko, Lilita	University of Southern Denmark
Midtiby, Henrik Skov	University of Southern Denmark
Ladig, Robert	Ritsumeikan University

14:20-14:40	ThC1.2

Non-Contact Vibration-Based Damage Detection of Civil Structures Using a Cost-Effective Autonomous UAV, pp. 1137-1144.

Becerril, Javier	University of Texas Rio Grande Valley

Vargas, Maximiliano	University of Texas Rio Grande Valley
Herrera Solis, Jennifer	University of Texas Rio Grande Valley
Gutierrez, Joanna	University of Texas Rio Grande Valley
Rios, Jorge	University of Texas Rio Grande Valley
Amjadian, Mohsen	University of Texas Rio Grande Valley
Tarawneh, Constantine	University of Texas Rio Grande Valley
Yang, Jinghao	University of Texas Rio Grande Valley
Lu, Qi	University of Texas Rio Grande Valley

14:40-15:00 ThC1.3

UAV Sensor Payload Interface for Operator-In-The-Loop Target Geolocation and Live Map Mosaic Overlays, pp. 1145-1152.

Ashry, Ahmed	University of Maryland
Titus, Christopher	University of Maryland
Singal, Mudit	University of Maryland
Schmucki, Joshua	University of Maryland
Bortoff, Zachary	University of Maryland
Gaus, Joshua	University of Maryland
Paley, Derek	University of Maryland

15:00-15:20 ThC1.4

Autonomous Aerial Non-Destructive Testing: Ultrasound Inspection with a Commercial Quadrotor in an Unstructured Environment, pp. 1153-1160.

Veenstra, Ruben	University of Twente
Bazzana, Barbara	University of Twente
Smits, Sander	University of Twente
Franchi, Antonio	Univ. of Twente and Sapienza Univ. of Rome

15:20-15:40 ThC1.5

Geometric Look-Angle Shaping Strategy for Enclosed Inspection, pp. 1161-1168.

Shivam, Amit	Universidade Do Porto
Fernandes, Manuel C.R.M.	Universidade Do Porto
Vinha, Sérgio	Universidade Do Porto
Fontes, Fernando A.C.C.	Universidade Do Porto

15:40-16:00 ThC1.6

A4AWD: Augmenting Aerial Weed Detection Over Residential Lawns, pp. 1169-1176.

Du, Jiaxin	Purdue University
Xia, Shengqing	Purdue University
Peng, Chunyi	Purdue University

ThC2 **Lounge A**

Aerial Robotic Manipulation II (Regular Session)

Chair: Bronz, Murat	ENAC
Co-Chair: Verdoucq, Matthieu	ENAC

14:00-14:20 ThC2.1

Systematic Analysis of Coupling Effects on Closed-Loop and Open-Loop Performance in Aerial Continuum Manipulators, pp. 1177-1184.

Amiri, Niloufar	Toronto Metropolitan University
Sepahvand, Shayan	Toronto Metropolitan University
Mantegh, Iraj	National Research Council of Canada
Janabi Sharifi, Farrokh	Toronto Metropolitan University

14:20-14:40 ThC2.2

A Novel Lattice-Based Soft Gripper for Aerial Grasping, pp. 1185-1192.

Faraji, Pedram	University of Luxembourg
Bhandari, Aabhash	University of Luxembourg
Voos, Holger	University of Luxembourg

14:40-15:00 ThC2.3

A Fully Passive Rack and Pinion Based Gripper Mechanism for Cylindrical and Planar Landing, pp. 1193-1200.

Moslemi, Mohammad Erfan	Technical University of Munich

Hammad, Ahmad | Technical University of Munich
Tsagkaris, Michail | Technical University of Munich
Armanini, Sophie F. | Imperial College London

15:00-15:20 ThC2.4

Swarm Choreography Made Simple: Superposed Guiding Vector Fields for Rigid Formation Path Following, pp. 1201-1208.

Machado, João | ENAC
Verdoucq, Matthieu | ENAC
Jouffrais, Christophe | CNRS
Bronz, Murat | ENAC

15:20-15:40 ThC2.5

Autonomous Contact Inspection with Underactuated UAVs in Task-Space, pp. 1209-1215.

Greblo, Luka | University of Zagreb
Car, Marko | University of Zagreb
Ivanovic, Antun | University of Zagreb
Goricanec, Jurica | University of Zagreb
Markovic, Lovro | University of Zagreb
Orsag, Matko | University of Zagreb
Bogdan, Stjepan | University of Zagreb

ThC3 **Calypso A**

Simulation and UAS Testbeds (Regular Session)

Chair: Ollero, Anibal | Universidad De Sevilla

Co-Chair: Flores, Gerardo | Texas A&M International University

14:00-14:20 ThC3.1

High-Fidelity Antarctic UAV Simulation with Thermal Terrain Modelling, pp. 1216-1223.

Sandino, Juan | Queensland University of Technology
Boiteau, Sebastien | Queensland University of Technology
Brown, Daniel | Queensland University of Technology
Bollard, Barbara | University of Wollongong
Gonzalez, Luis Felipe | Queensland University of Technology

14:20-14:40 ThC3.2

CFD-Based Wind Turbulence Assessment Model for Urban UAV Path Planning, pp. 1224-1230.

Aldao Pensado, Enrique | University of Vigo
Veiga-Piñeiro, Gonzalo | University of Vigo
Martínez-Alonso, Gálata | University of Vigo
Veiga-López, Fernando | University of Vigo
Martin, Elena | University of Vigo
Gonzalez Jorge, Higinio | University of Vigo

14:40-15:00 ThC3.3

Low-Latency Quasi-Static Modeling of UAV Tether Aerodynamics, pp. 1231-1238.

Beffert, Max | University of Tübingen
Zell, Andreas | University of Tübingen

15:00-15:20 ThC3.4

Tutorial on Development of ROS2 Gazebo Simulator of Dual Arm Aerial Manipulator with PX4 for Parcel Delivery in Intra-Logistics, pp. 1239-1244.

Molina-Aguiar, Nelson | GRVC Robotics Lab
Suarez, Alejandro | Universidad De Sevilla
Gonzalez-Morgado, Antonio | Universidad De Sevilla
Ollero, Anibal | Universidad De Sevilla

15:20-15:40 ThC3.5

Controllability of the Soft-PVTOL under Tendon Failure: Analysis with Passive Elastic Arms, pp. 1245-1251.

Verdín, Rodolfo Isaac | Centro De Investigaciones En Òptica
Flores, Gerardo | Texas A&M International University

15:40-16:00 ThC3.6

ROSplane 2.0: A Fixed-Wing Autopilot for Research, pp. 1252-1259.

Reid, Ian	Brigham Young University
Ritchie, Joseph	Brigham Young University
Moore, Jacob	Brigham Young University
Sutherland, Brandon	Brigham Young University
Snow, Gabe	Brigham Young University
Tokumaru, Phillip	AeroVironment Inc
McLain, Tim	Brigham Young University

ThC4 **Calypso B**

Testing and Evaluation: Autonomy II (Invited Session)

Chair: Costello, Donald	University of Maryland College Park
Co-Chair: Hwang, George	Naval Air Warfare Center Aircraft Division

14:00-14:20 ThC4.1

Flight Test Evaluation of a Standardized Interface Framework for Autonomous Drone Functionality (I), pp. 1260-1267.

Costello, Donald	University of Maryland
Safeer, Jacob	University of Maryland

14:20-14:40 ThC4.2

From Language to Logic: A Theoretical Architecture for VLM-Grounded Safe Navigation (I), pp. 1268-1275.

Sakano, Kristy	University of Maryland
Harrington, Kalonji	University of Maryland
Xu, Huan	University of Maryland

14:40-15:00 ThC4.3

Evaluating Collision Risk of UAS in Proximity to Critical Infrastructure (I), pp. 1276-1283.

Snyder, Paul	University of North Dakota
Ullrich, Michael	University of North Dakota
Pothana, Prasad	University of North Dakota
Vidhyadharan, Sreejith	University of North Dakota

15:00-15:20 ThC4.4

Experimental Verification of Multi-Agent, Autonomous Search and Rescue Prototype (I), pp. 1284-1289.

Bopp, Autumn	United States Naval Academy
Farmer, Adam	United States Naval Academy
Frey, Christian	United States Naval Academy
Kruszczynski, Raquel	United States Naval Academy
Mccallum, Sage	United States Naval Academy
Van Dyk, Joe	United States Naval Academy
Feemster, Matthew	United States Naval Academy
O'Brien, Richard	United States Naval Academy

15:20-15:40 ThC4.5

LIFEGUARD: A Lightweight Intent-Focused Engine for Guidance in Unmanned Autonomous Rescue Deployments (I), pp. 1290-1297.

Seargeant, John	United States Naval Academy
Feemster, Matthew	United States Naval Academy
DeVries, Levi	United States Naval Academy
Kutzer, Michael	United States Naval Academy

ThD1 **Nafsika**

UAS Communications and Networked Swarms (Regular Session)

Chair: Fourlas, George K.	University of Thessaly
Co-Chair: Morbidi, Fabio	University of Picardie Jules Verne

16:20-16:40 ThD1.1

A Low-Complexity Distributed Adaptive Performance Formation Control Scheme for Multi-Quadrotor Systems with Input Constraints, pp. 1298-1305.

Gkesoulis, Athanasios	University of Patras
Fourlas, George K.	University of Thessaly
Bechlioulis, Charalampos	University of Patras
Karras, George	University of Thessaly

16:40-17:00	ThD1.2
Scalable Airborne Cellular Relay System for Emergency Communication Coverage, pp. 1306-1313.	
Kimura, Kiyoshi	SoftBank Corp
Park, Soekjun	SoftBank Corp
Nomachi, Masanori	SoftBank Corp

17:00-17:20	ThD1.3
Fast and Robust Event-Based Optical Communication for Aerial Robots Via Active LED Markers, pp. 1314-1321.	
Jabbari Tofighi, Nafiseh	University of Picardie Jules Verne
Robic, Maxime	Politecnico Di Milano
Caracotte, Jordan	University of Picardie Jules Verne
Vasseur, Pascal	University of Picardie Jules Verne
Morbidi, Fabio	University of Picardie Jules Verne

17:20-17:40	ThD1.4
SNR and Bandwidth-Aware Handover Strategy for UAV Monitoring in Urban Areas, pp. 1322-1329.	
Alves Fagundes Junior, Leonardo	Universidade Federal De Viçosa
Bonilla Licea, Daniel	Mohammed VI Polytechnic University
Brandao, Alexandre Santos	Universidade Federal De Viçosa

17:40-18:00	ThD1.5
The Swarming Project - Coordination and Guidance of Unmanned Swarms, pp. 1330-1338.	
Friedrich, Max	German Aerospace Center
Bethge, Johanna	German Aerospace Center
Lichtenheldt, Roy	German Aerospace Center
Lueken, Thomas	German Aerospace Center
Kallies, Christian	German Aerospace Center
Scharnweber, Alexander	German Aerospace Center
Krause, Stefan	German Aerospace Center
Donkels, Alexander	German Aerospace Center
Hellerer, Matthias	German Aerospace Center
Walko, Christian	German Aerospace Center
Gäde, Julius	German Aerospace Center
Winkler, Tobias Kurt Georg	German Aerospace Center
Felsch, Gerrit	German Aerospace Center
Laudien, Tim	German Aerospace Center
Franke, Dennis	German Aerospace Center
Paz Goncalves Martins, Ana	German Aerospace Center
Shutin, Dmitriy	German Aerospace Center
Mueller, Reiko	German Aerospace Center

18:00-18:20	ThD1.6
LLM-Enabled Human-In-The-Loop Control of Multi-UAV Teams under Communication Constraints, pp. 1339-1346.	
Alamdar, Khawaja Ghulam	University of Zagreb
Petric, Frano	University of Zagreb
Orsag, Matko	University of Zagreb

ThD2	**Lounge A**
Risk Analysis and Manned/Unmanned Aviation (Regular Session)	
Chair: Bertrand, Sylvain	ONERA

16:20-16:40	ThD2.1
Ground Risk Aware Path Planning for UAVs under Regulatory Criteria from SORA, pp. 1347-1354.	
Bertrand, Sylvain	Université Paris-Saclay
Lala, Stephanie	Université Paris-Saclay
Raballand, Nicolas	Université Paris-Saclay

16:40-17:00	ThD2.2
Collision Risk Analysis Near Airways Using Cluster-Based Air Traffic Models, pp. 1355-1362.	
Chiaratti, Anthony	Queensland University of Technology
Mcfadyen, Aaron	Queensland University of Technology
Mejias Alvarez, Luis	Queensland University of Technology

17:00-17:20	ThD2.3

From Bench to Flight: Translating Drone Impact Tests into Operational Safety Limits, pp. 1363-1370.

Mili, Mohamed Az	École De Technologie Supérieure
Gérard, Paul	École De Technologie Supérieure
Catar, Louis	École De Technologie Supérieure
Tabiai, Ilyass	École De Technologie Supérieure
St-Onge, David	École De Technologie Supérieure

17:20-17:40	ThD2.4

A Probability Collision Risk Assessment and Decision Support Framework for UAV Intrusion in Airport Terminal Airspace, pp. 1371-1379.

Lei, Xuming	Beihang University
Xu, Yan	Beihang University
Peng, Bo	Beihang University
Cai, Kaiquan	Beihang University

17:40-18:00	ThD2.5

Hybrid Trajectory Prediction for Non-Cooperative UAS Using Probabilistic LSTM-IMM Fusion, pp. 1380-1388.

Yu, Jinjiang	Beihang University
Xu, Yan	Beihang University
Chen, Ziang	Beihang University
Cai, Kaiquan	Beihang University

18:00-18:20	ThD2.6

Simulation-To-Flight Validation of Right of Way Requirements for Crewed–Uncrewed Encounters, pp. 1389-1396.

Clough, Justin	University of Kansas
Carlson, Megan	University of Kansas
Keshmiri, Shawn	University of Kansas
Ewing, Mark	University of Kansas

ThD3 — Calypso A

Reliability, Fail-Safe Systems and Airworthiness (Regular Session)

Chair: Giribet, Juan Ignacio	Universidad De San Andrés
Co-Chair: Fu, Wenxing	Northwestern Polytechnical University

16:20-16:40	ThD3.1

Budget-Aligned Epistemic Uncertainty for Onboard UAV Trajectory Prediction Via Regression-Adapted Deep Deterministic Uncertainty, pp. 1397-1404.

Jia, Weiyang	Northwestern Polytechnical University
Fu, Wenxing	Northwestern Polytechnical University
Li, Yang	Northwestern Polytechnical University
Zhai, Danfeng	Northwestern Polytechnical University

16:40-17:00	ThD3.2

Toward Real-Time Adaptive Dehazing for Drone-Embedded Object Detection, pp. 1405-1411.

Jayalath, Kasun Vimukthi	University of Southern Denmark
Drimus, Alin	University of Southern Denmark
Jouffroy, Jerome	University of Southern Denmark

17:00-17:20	ThD3.3

Cross-Platform Propeller Damage Regression in Multirotor UAVs Via Transfer Learning, pp. 1412-1419.

Torre, Gabriel	Universidad De San Andrés and Universidad De Buenos Aires
Pose, Claudio Daniel	Universidad De San Andrés and Universidad De Buenos Aires
Giribet, Juan Ignacio	Universidad De San Andrés

17:20-17:40	ThD3.4

An Onboard Transformer-Based Physics-Informed System for UAV Trajectory Prediction and State Classification in GNSS-Denied Environments, pp. 1420-1427.

Souli, Nicolas	University of Cyprus
Grigoriou, Yiannis	University of Cyprus
Chrysanthou, Panagiotis	University of Cyprus
Kolios, Panayiotis	University of Cyprus

Ellinas, Georgios	University of Cyprus

17:40-18:00	ThD3.5

Incremental Nonlinear Fault-Tolerant Control of the Variable Skew Quad Plane with Loss of Two Opposing Rotors, pp. 1428-1435.

De Ponti, Tomaso Maria Luigi	Delft University of Technology
Smeur, Ewoud	Delft University of Technology
Remes, Bart	Delft University of Technology

18:00-18:20	ThD3.6

Implementation of Computer Vision Models to Detect Propeller Damage During Pre-Flight Checks, pp. 1436-1442.

Schmidt, Immo	Technical University of Darmstadt
Sadineni, Dharma Shastha	Technical University of Darmstadt
Dhopavkar, Usama Hamid	Technical University of Darmstadt
Dietz, Yannick	Technical University of Darmstadt
Lingaraj, Dheeraj	Technical University of Darmstadt
Muddaiah Sreekantha, Shreyas	Technical University of Darmstadt

ThD4	**Calypso B**

Testing and Evaluation: Autonomy III (Invited Session)

Chair: Costello, Donald	University of Maryland College Park
Co-Chair: Hwang, George	Naval Air Warfare Center Aircraft Division

16:20-16:40	ThD4.1

Implementation of Ray-Ray Intersection for Sensor Constrained 3D Aerial Multi-Target Localization (I), pp. 1443-1450.

Titus, Christopher	University of Maryland
Ashry, Ahmed	University of Maryland
Baxevani, Kleio	University of Maryland
Gaus, Joshua	University of Maryland

16:40-17:00	ThD4.2

Feature 3D Gaussian Splatting for UAV-To-Ship Pose Estimation in GNSS-Denied Environments (I), pp. 1451-1458.

Bernas, Andrew	United States Naval Academy
McConnell, John	United States Naval Academy
Seargeant, John	United States Naval Academy
DeVries, Levi	United States Naval Academy

17:00-17:20	ThD4.3

Hardware and Vision-In-The-Loop Validation of Deep Monocular Pose Estimation for Autonomous Maritime UAV Flight (I), pp. 1459-1464.

Wickramasuriya, Maneesha	George Washington University
Yu, Beomyeol	George Washington University
Shin, Jaden	George Washington University
Huslig, Mason	George Washington University
Lee, Taeyoung	George Washington University
Snyder, Murray	George Washington University

17:20-17:40	ThD4.4

The Evolution of Methodologies for Estimating and Quantifying Risk for Mission-Level Autonomy (I), pp. 1465-1472.

Hwang, George	Naval Air Warfare Center Aircraft Division
Woods, Douglas	AM Pierce and Associates
Joyner, Jacob	Naval Air Warfare Center Aircraft Division
Marez, Matthew	Naval Air Warfare Center Aircraft Division
Brown, Michael	Naval Air Warfare Center Aircraft Division
Rickard, Kristina	Naval Air Warfare Center Aircraft Division
Johnson, Mark Anthony	Naval Air Warfare Center Aircraft Division
Johnson, Wanda Lowelyn	Naval Air Warfare Center Aircraft Division
Lay, Michael	Naval Air Warfare Center Aircraft Division
Rea, Charles	Naval Air Warfare Center Aircraft Division

17:40-18:00	ThD4.5

Visual-Inertial Odometry Robustness to Adverse Conditions in Proximity Flight (I), pp. 1473-1480.

Teacu, Alexander	University of Maryland

Paley, Derek | University of Maryland

18:00-18:20 | ThD4.6

Flying-Wing UAS Multi-Objective Design Optimization Via Cross-Entropy Method (I), pp. 1481-1488.

Richez, Adrien | Stanford University

Bostock, Nick | Stanford University

ICUAS '26 Paper Abstracts

Tuesday June 16, 2026

TuA1	Nafsika
Control Architectures I (Regular Session)	
Chair: Tsetserukou, Dzmitry	Skolkovo Institute of Science and Technology
Co-Chair: Mizzoni, Mirko	University of Twente

10:20-10:40 TuA1.1

Robust Adaptive Sliding-Mode Control for Damaged Fixed-Wing UAVs, pp. 1-8

Spiller, Mark — German Aerospace Center
Kracke, Lennart — German Aerospace Center
Autenrieb, Johannes — German Aerospace Center

Many unmanned aerial vehicles (UAVs) can remain aerodynamically flyable after sustaining structural or control surface damage, yet insufficient robustness in conventional autopilots often leads to mission failure. This paper proposes a robust adaptive sliding mode controller (RASMC) for fixed-wing UAVs subject to aerodynamic coefficient perturbations and partial loss of control surface effectiveness. A damage-aware flight dynamics model is developed to systematically analyze the impact of such impairments on the closed-loop behavior. The RASMC is designed to ensure reliable tracking and stabilization, while a gain adaptation law maintains low control effort under nominal conditions and increases the gains as needed in the presence of aerodynamic damage. Lyapunov-based stability guarantees are derived, and assumptions on admissible uncertainty bounds are formulated to characterize the limits within which closed-loop stability and performance can be ensured. The proposed controller is implemented within an existing UAV autopilot framework, where outer-loop guidance and speed control modules provide reference commands to the RASMC for attitude stabilization. Simulations demonstrate that, despite significant damage, all closed-loop states remain stable with bounded tracking errors.

10:40-11:00 TuA1.2

Robust Co-Design Optimisation for Agile Fixed-Wing UAVs, pp. 9-17

Buda, Adrian Andrei — Imperial College London
Chen, Xiaorong — Imperial College London
Botteghi, Nicolò — Politecnico Di Milano
Fasel, Urban — Imperial College London

Co-design optimisation of autonomous systems has emerged as a powerful alternative to sequential approaches by jointly optimising physical design and control strategies. However, existing frameworks often neglect the robustness required for autonomous systems navigating unstructured, real-world environments. For agile Unmanned Aerial Vehicles (UAVs) operating at the edge of the flight envelope, this lack of robustness yields designs that are sensitive to perturbations and model mismatch. To address this, we propose a robust co-design framework for agile fixed-wing UAVs that integrates parametric uncertainty and wind disturbances directly into the concurrent optimisation process. Our bi-level approach optimises physical design in a high-level loop while discovering nominal solutions via a constrained trajectory planner and evaluating performance across a stochastic Monte Carlo ensemble using feedback LQR control. Validated across three agile flight missions, our strategy consistently outperforms deterministic baselines. The results demonstrate that our robust co-design strategy inherently tailors aerodynamic features, such as wing placement and aspect ratio, to achieve an optimal trade-off between mission performance and disturbance rejection.

11:00-11:20 TuA1.3

A Comparative Study of INDI and NDI with Nonlinear Disturbance Observer for Aerial Robotics, pp. 18-25

Rota, Benedetta — Sapienza University of Rome
Mizzoni, Mirko — University of Twente
Afifi, Amr — University of Twente
van Goor, Pieter — University of Sydney
Franchi, Antonio — Univ. of Twente and Sapienza Univ. of Rome

This work presents a simulation-based comparative robustness analysis of Incremental Nonlinear Dynamic Inversion (INDI) and Nonlinear Dynamic Inversion augmented with a nonlinear disturbance observer (NDI+NDO) for fully actuated aerial robots. A systematic simulation campaign across representative operating scenarios is conducted, where we compare tracking performance, robustness, control effort, under parametric variations, external disturbances, and measurement noise. Results show that INDI demonstrates stronger robustness in several model-mismatch and combined-stress cases, while NDI+NDO primarily matches nominal performance but exhibits greater sensitivity under several non-ideal conditions. These findings provide practical guidance on the relative strengths and limitations of incremental and observer-based inversion strategies for aerial robotic applications.

11:20-11:40 TuA1.4

Adaptive SINDy: Residual Force System Identification Based UAV Disturbance Rejection, pp. 26-33

Mehboob, Fawad — Skolkovo Institute of Science and Technology
Habel, Amir Atef — Skolkovo Institute of Science and Technology
Khan, Roohan Ahmed — Skolkovo Institute of Science and Technology
Derevianchenko, Mikhail — Skolkovo Institute of Science and Technology

Fortin, Clement Skolkovo Institute of Science and Technology
Tsetserukou, Dzmitry Skolkovo Institute of Science and Technology

Unmanned Aerial Vehicles (UAVs) are susceptible to losing stability and crashes while operating in a turbulent environment, therefore the safety and reliability of UAV control in such environments is a matter of great concern. Devising a robust control algorithm to reject disturbances is challenging due to the highly nonlinear nature of wind dynamics, and modeling the dynamics using analytical techniques is not straightforward. While techniques using disturbance observers and classical adaptive control have shown some progress, they are mostly limited to relatively non-complex environments. On the other hand, learning-based approaches are increasingly being used for modeling of residual forces and disturbance rejection; however, their generalization and interpretability is a factor of concern. To this end, we propose a novel integration of data-driven system identification using Sparse Identification of Nonlinear Dynamics (SINDy) with a Recursive Least Square (RLS) adaptive control to adapt and reject wind disturbances in a turbulent environment. We tested and validated our approach on Gazebo harmonic environment and on real flights with wind speeds of up to 2 m/s from four directions, creating a highly dynamic and turbulent environment. The drone tracked complex trajectories like circular, lemniscate, and spiral with a speed of up to 0.89 m/s. Adaptive SINDy outperformed the baseline PID and INDI controllers on several trajectory tracking error metrics without crashing. A root mean square error (RMSE) as low as 17.6 cm and 12.2 cm, and a mean absolute error (MAE) of 13.7 cm and 10.5 cm were achieved on circular and lemniscate trajectories, respectively. The validation was performed on a very lightweight Crazyflie drone under a highly dynamic environment.

11:40-12:00 TuA1.5

GustPilot: A Hierarchical DRLINDI Framework for Wind-Resilient Quadrotor Navigation, pp. 34-41

Habel, Amir Atef Skolkovo Institute of Science and Technology
Khan, Roohan Ahmed Skolkovo Institute of Science and Technology
Mehboob, Fawad Skolkovo Institute of Science and Technology
Fortin, Clement Skolkovo Institute of Science and Technology
Tsetserukou, Dzmitry Skolkovo Institute of Science and Technology

Wind disturbances remain a key barrier to reliable autonomous navigation for lightweight quadrotors, where rapidly varying airflow can destabilize both planning and tracking. This paper introduces GustPilot, a hierarchical wind resilient navigation stack in which a deep reinforcement learning (DRL) policy generates inertial-frame velocity references for gate traversal, while a geometric Incremental Nonlinear Dynamic Inversion (INDI) controller provides low-level tracking with fast residual disturbance rejection. The INDI layer uses incremental feedback on both specific linear acceleration and angular acceleration/rate, relying on onboard sensor measurements to reject wind disturbances during execution. Robustness is achieved through a two-level strategy: wind-aware planning learned via fan-jet domain randomization during training and rapid execution-time disturbance rejection by the INDI tracking controller. We evaluate GustPilot in real flights on a 50 g quadrotor platform against a DRL–PID baseline across four scenarios ranging from no-wind to fully dynamic conditions with a moving gate and a moving disturbance source. Despite being trained only in a minimal single-gate/single-fan setup, the policy generalizes to more complex environments with up to six gates and four fans without retraining. Across 80 experiments, DRL–INDI achieves an average Overall Success Rate (OSR) of 94.6%, compared with 36.0% for DRL–PID, reduces tracking Root Mean Square Error (RMSE) by up to 50%, and sustains speeds up to 1.34 m/s under wind disturbances up to 3.5 m/s. These results demonstrate that combining DRL-based velocity planning with structured INDI disturbance rejection provides a practical approach to wind-resilient autonomous flight.

12:00-12:20 TuA1.6

Hybrid Adaptive Position Control for UAVs Subject to Mass-Variation and Aerodynamic Disturbances Via Frequency Decoupling, pp. 42-49

Millan, Alejandro Université De Technologie De Compiègne
Tevera-Ruiz, Alejandro Cinvestav-IPN Unidad Saltillo
Castillo, Pedro Université De Technologie De Compiègne
Sanchez-Orta, Anand Eleazar Cinvestav-IPN Unidad Saltillo
Lozano, Rogelio Université De Technologie De Compiègne
Chazot, Jean-Daniel Université De Technologie De Compiègne
Salazar, Sergio Cinvestav-IPN Unidad Zacatenco

Some aerial applications require controllers that are robust to system uncertainties and external disturbances. When an aircraft carries a mass/load that can vary over time, this can introduce or increase uncertainties in the system and affect its performance. Similarly, if this aircraft carrying a load is exposed to gusts of wind, this will also degrade its performance. In literature, robust controllers are proposed to mitigate these effects, nevertheless, their application in real-time experiments is sometimes hard and requires high-gain values to ensure the expected robustness. In this work, a hybrid robust control architecture based on a nominal controller with two compensation mechanisms is proposed. The compensation mechanism is composed of (i) an adaptive law proposal to compensate uncertainties into the system as mass variations and (ii) a Backpropagation Neural Network (BNN) to estimate the external disturbances during flight. The Lyapunov analysis is used to demonstrate that the errors of the system in closed loop are Uniformly Ultimately Bounded (UUB). To corroborate the performance of the proposed strategy, several real-time flight tests are carried out, comparing the nominal controller with the adaptive baseline against its BNN-augmented version.

12:20-12:40 TuA1.7

Residual Koopman-Based Model Predictive Control of Quadrotors, pp. 50-56

Todde, Edoardo Politecnico Di Torino
Martini, Simone University of Denver
Rizzo, Alessandro Politecnico Di Torino
Valavanis, Kimon P. University of Denver

This paper presents a residual-enhanced Koopman-based Model Predictive Control (RKMPC) framework for quadrotor trajectory tracking under parametric and unmodeled uncertainties. Building upon a quasi-linear lifted representation obtained through Koopman operator theory, a low-dimensional linear MPC formulation is preserved while augmenting the prediction model with a learned residual correction. The residual term is trained offline using simulation data and evaluated outside the quadratic program at each sampling instant, where it is injected as a measured disturbance. This strategy maintains the convex QP structure and computational efficiency of the baseline Koopman MPC while compensating prediction bias induced by modeling errors. Closed-loop simulations are conducted under both nominal conditions and uncertain plant parameters. The proposed RKMPC significantly improves tracking performance and robustness against parameter mismatches between the true and simulated quadrotor plant. The results highlight the robustness–optimality trade-off between nominal model-based control and residual-enhanced predictive control, demonstrating that learned residual compensation enhances robustness without increasing online computational complexity.

TuA2	**Lounge A**
Multirotor Design and Control I (Regular Session)	
Chair: Baldini, Alessandro	Università Politecnica Delle Marche
Co-Chair: Colombo, Leonardo, J	Centre for Automation and Robotics (CAR)

10:20-10:40 TuA2.1

Mind the Gap: Online Control Allocation for Multirotors with Low-Speed Deadbands, pp. 57-64

Ali, Ahmed — University of Twente
Romano, Fiorella Maria — Università Degli Studi Di Napoli Federico II
Gabellieri, Chiara — University of Twente
van Goor, Pieter — University of Sydney
Ruggiero, Fabio — Università Degli Studi Di Napoli Federico II
Franchi, Antonio — Univ. of Twente and Sapienza Univ. of Rome

In this work, we present a novel optimization-based input allocation strategy for fully actuated multirotor aerial vehicles with N propellers that explicitly respects box constraints on the control inputs in both positive and negative actuation values while accounting for a deadband around zero. The resulting optimization problem belongs to the fundamental class of NP-hard global optimization problems, which can be recast as a Mixed-Integer Linear Program (MILP). We show that feasible solutions to this formulated MILP can efficiently be computed using a standard branch-and-bound algorithm. Building on that algorithm, the proposed method also robustly handles cases in which the desired allocation is infeasible by introducing several fallback instances. The method is experimentally validated on an octo-rotor platform, demonstrating the effectiveness of the proposed approach and its superior performance compared to the conventional QP-based allocation method.

10:40-11:00 TuA2.2

Learning-Based Geometric Leader–Follower Control for Cooperative Rigid-Payload Transport with Aerial Manipulators, pp. 65-72

Yago Nieto, Omayra — Universidad Politécnica De Madrid
Colombo, Leonardo, J — Centre for Automation and Robotics

This paper develops a learning-based tracking controller for cooperative transport of a rigid payload by multiple aerial manipulators under rigid grasp constraints. A unified geometric model yields a coupled agent–payload differential–algebraic system capturing contact wrenches and internal-force redundancy. A leader generates a desired payload wrench from geometric tracking errors, and follower agents realize it via constraint-consistent wrench allocation.

Model uncertainties and disturbances are compensated using Gaussian Process (GP) regression. High-probability GP error bounds are embedded in the controller through a GP feedforward term and geometric feedback. A Lyapunov analysis guarantees uniform ultimate boundedness of the payload tracking errors with high probability, with a bound that scales with the GP predictive uncertainty.

11:00-11:20 TuA2.3

Sensitivity-Based Tube NMPC for Cooperative Aerial Structures under Parametric Uncertainty, pp. 73-79

Silano, Giuseppe — Czech Technical University in Prague
Sable, Quentin — University of Twente
Tognon, Marco — INRIA
Iannelli, Luigi — University of Sannio in Benevento
Franchi, Antonio — Univ. of Twente and Sapienza Univ. of Rome

This paper presents a sensitivity-based tube Nonlinear Model Predictive Control (NMPC) framework for cooperative aerial chains under bounded parametric uncertainty. We consider a planar two-vehicle chain connected by rigid links, modeled with input-rate actuation to enforce slew-rate and magnitude limits on thrust and torque. Robustness to uncertainty in link mass, length, and inertia is achieved by propagating first-order parametric state sensitivities along the horizon and using them to compute online constraint-tightening margins. We robustify an inter-link separation constraint, implemented via smooth cosine embedding, and thrust-magnitude bounds. The method is implemented in MATLAB and evaluated with boundary-hugging maneuvers and Monte-Carlo uncertainty sampling. Results show improved constraint margins under uncertainty with tracking performance comparable to nominal NMPC.

11:20-11:40 TuA2.4

Receding-Horizon Nullspace Optimization for Actuation-Aware Control Allocation in Omnidirectional UAVs, pp. 80-87

Pretto, Riccardo — Tampere University
Hamandi, Mahmoud — New York University Abu Dhabi

Mohamed Ali, Abdullah New York University Abu Dhabi
Alcan, Gokhan Tampere University
Tzes, Anthony New York University Abu Dhabi
Abu-Dakka, Fares New York University Abu Dhabi

Fully actuated omnidirectional UAVs enable independent control of forces and torques along all six degrees of freedom, broadening the operational envelope for agile flight and aerial interaction tasks. However, conventional control allocation methods neglect the asymmetric dynamics of the onboard actuators, which can induce oscillatory motor commands and degrade trajectory tracking during dynamic maneuvers. This work proposes a receding-horizon, actuation-aware allocation strategy that explicitly incorporates asymmetric motor dynamics and exploits the redundancy of over-actuated platforms through nullspace optimization. By forward-simulating the closed-loop system over a prediction horizon, the method anticipates actuator-induced oscillations and suppresses them through smooth redistribution of motor commands, while preserving the desired body wrench exactly. The approach is formulated as a constrained optimal control problem solved online via Constrained iterative LQR. Simulation results on the OmniOcta platform demonstrate that the proposed method significantly reduces motor command oscillations compared to a conventional single-step quadratic programming allocator, yielding improved trajectory tracking in both position and orientation.

11:40-12:00 TuA2.5

Geometric Adaptive Control on SE(3) for Fully-Actuated Aerial Vehicles with Online Parameter Estimation, pp. 88-95

Olanrewaju, Farooq King Fahd University of Petroleum & Minerals
Benyahia, Aymen King Fahd University of Petroleum & Minerals
Rashad, Ramy King Fahd University of Petroleum & Minerals
Sami, El-ferik King Fahd University of Petroleum & Minerals

This paper presents a geometric adaptive control framework to control fully actuated aerial vehicles that are subjected to variations in mass, CoG and moment of inertia due to unknown payload events. The controller is formulated on SE(3) and uses Lie-algebra errors in SE(3) to achieve global, coordinate-free pose tracking. An adaptation law is derived for online estimation of the generalized inertia parameters with Lyapunov stability guarantees. The approach is validated in MATLAB simulations over multiple trajectories with an unknown initial payload and an abrupt payload drop. Results demonstrate consistently high SE(3) tracking performance, rapid recovery after parameter changes, and substantial improvement over a non-adaptive baseline. Mass estimation is reliable, CoG estimation achieves partial convergence and improves with higher CoG adaptation gains, while inertia parameters show poor convergence due to insufficient regressor excitation, although this does not cause any system instability.

12:00-12:20 TuA2.6

Control of Fully Actuated Aerial Vehicles: A Comparison of Model-Based and Sensor-Based Dynamic Inversion, pp. 96-103

Yilmaz, Ali Technical University of Munich
Turan, Buday Technical University of Munich
Pries, Lukas Technical University of Munich
Ryll, Markus Technical University of Munich

Fully actuated multirotor platforms decouple translational force generation from vehicle attitude, enabling independent control of position and orientation and shifting performance limitations from attitude authority to actuator dynamics and control effectiveness. This paper compares a model-based nonlinear dynamic inversion controller (geometric NDI) with a sensor-based incremental dynamic inversion controller (INDI) on a fixed-tilt fully actuated hexarotor. Both controllers share an identical outer-loop structure and are both executed at 500~Hz; therefore, performance differences can be attributed primarily to the inversion strategy. Controller performance is evaluated in five experiments covering attitude step tracking under nominal conditions and under a 50% mismatch in the rotor force coefficient, hover disturbance rejection under an external lateral load, waypoint tracking in the presence of wind gust disturbances, reduced control frequency, and injected sensor degradation. The results show that INDI offers clear advantages under parameter mismatch, gust disturbances, and sensor degradation, and maintains lower position errors across the controller-frequency sweep. However, its advantages are not universal: geometric NDI yields better attitude tracking at reduced control frequencies. To the authors' best knowledge, this work presents the first experimental validation of a full pose tracking INDI controller with decoupled translational and rotational dynamics. These findings highlight the trade-off between measurement-based and model-based inversion for robust control and rapid deployment of fully actuated UAVs.

12:20-12:40 TuA2.7

Geometric Cascade Control for Thrust Vectoring Multirotors, pp. 104-111

Baldini, Alessandro Università Politecnica Delle Marche
Felicetti, Riccardo Università Politecnica Delle Marche
Freddi, Alessandro Università Politecnica Delle Marche
Monteriù, Andrea Università Politecnica Delle Marche

In this paper, we propose a geometric control scheme for multirotors with tiltable rotors. The control scheme is based on the well-known inner-outer loop structure, allowing the system to track both position and orientation references while avoiding local coordinate parameterizations, thereby preventing singularity issues. Moreover, it leverages thrust vectoring to enable level flight during trajectory tracking without requiring the entire vehicle to tilt to generate lateral forces, providing advantages for passenger transportation, infrastructure inspection, and, more generally, tasks involving interaction with the environment. Simulations conducted on a hexarotor show that the proposed control scheme enables level flight, is robust with respect to constant external disturbances such as steady wind and can easily be tuned to accommodate rotor inefficiencies at allocation level.

TuA3	Calypso A
Path Planning I (Regular Session)	
Chair: Renzaglia, Alessandro	INRIA
Co-Chair: Kallies, Christian	German Aerospace Center

10:20-10:40 TuA3.1

Trajectory Planning for an Omnidirectional Drone in a GPS-Denied and Obstacle Cluttered Environment, pp. 112-119

Mohamed Ali, Abdullah — New York University Abu Dhabi
Hamandi, Mahmoud — New York University Abu Dhabi
Tzes, Anthony — New York University Abu Dhabi

Omnidirectional drones offer a unique advantage over classical multirotor UAVs by enabling independent tracking of both three-dimensional position and orientation. This added flexibility makes trajectory planning significantly more challenging than planning for classical drones. In this paper, we present a trajectory planning framework tailored for omnidirectional UAVs operating in unknown, cluttered environments. The vehicle is equipped with a forward-facing RGB-D camera and an IMU and builds an RTAB-Map with loop closures during flight. Our method incrementally identifies feasible subgoals from the explored free space and generates full-pose safe trajectories—covering both position and orientation—to reach them. This process is repeated until the global target becomes accessible. The proposed approach is validated in a high-fidelity physics simulator, using our omnidirectional drone, within an environment that requires precise navigation through tight passages and complex orientations. The planner's effectiveness is demonstrated in scenarios that are otherwise infeasible for conventional UAVs.

10:40-11:00 TuA3.2

Multi-Agent Routing in Octree with Autonomous Waypoint Allocation, pp. 120-127

Karásek, Rostislav — German Aerospace Center
Kallies, Christian — German Aerospace Center
Gasche, Sebastian — German Aerospace Center

The multi-agent routing is the first stage of an ensemble mission planning and execution pipeline required to control a multi-agent system in an environment filled with obstacles while ensuring deconfliction between the agents. The concept of the presented multi-agent routing aims at allocating mission goals in an optimized order to the agents. Moreover, it plans obstacle-free corridors through the environment represented by an n-dimensional tree. The multi-agent routing obtains the corridors using A* search algorithm. We propose a new approach to calculating the edge weights for the A* search algorithm that significantly shortens the overall corridor length and improves flight safety. The advantage of the proposed method is studied in a realistic urban environment, and its performance is compared with that of the standard approach, which uses Euclidean distance between the node center points as the edge weight.

11:00-11:20 TuA3.3

Centralized vs Decentralized Multi-Agent Cooperative Trajectory Planning Via Model Predictive Control, pp. 128-136

Kallies, Christian — German Aerospace Center
Karásek, Rostislav — German Aerospace Center
Gasche, Sebastian — German Aerospace Center

Path and trajectory planning for multi-agent systems is computationally heavy when vehicle dynamics are involved. If a centralized setup is used, the computational burden scales exponentially with the number of agents due to dependent decisions and interactions between them. To dampen this effect the classical idea is decentralization. However, optimality gets lost and, in a model predictive control setup major replanning effects occur if no consensus is enforced. To overcome these issues, we propose another planning layer providing decisions and additional information to significantly simplify the dynamics based lower-level optimization.

11:20-11:40 TuA3.4

Plane-Based Spatial Partitioning Using Depth Sensors: Computationally Efficient Local Trajectory Planning for Multicopters Over Obstacles, pp. 137-142

Wang, Ting-Hao — University of California Berkeley
Mueller, Mark Wilfried — University of California Berkeley

The agility of quadcopters enables diverse autonomous applications, but rapid trajectory planning in cluttered environments remains challenging due to strict payload constraints on sensing and computation. This paper presents a computationally efficient, memoryless local path planner for navigating quadcopters over obstacles using limited onboard resources. Operating at 20Hz in a receding horizon fashion, the planner relies solely on the current vehicle state and the latest depth measurements. We introduce a plane-based spatial partitioning method that accelerates trajectory collision checking and selects optimal motion primitives to maximize mission velocity. Our algorithm reduces collision-checking duration to approximately 25% of the prior pyramid-based method while maintaining comparable mission completion behavior. The system is validated through simulation and physical experiments, demonstrating safe and efficient navigation toward designated goals above obstacles.

11:40-12:00 TuA3.5

Quality-Guided UAV Surface Exploration for 3D Reconstruction, pp. 143-150

Sportich, Benjamin — INSA Lyon
Boubakri, Kenza Eléonore — INSA Lyon
Simonin, Olivier — INSA Lyon
Renzaglia, Alessandro — INSA Lyon

Reasons for mapping an unknown environment with autonomous robots are wide-ranging, but in practice, they are often overlooked

when developing planning strategies. Rapid information gathering and comprehensive structural assessment of buildings have different requirements and therefore necessitate distinct methodologies. In this paper, we propose a novel modular Next-Best-View (NBV) planning framework for aerial robots that explicitly uses an explicit reconstruction quality objective to guide the exploration planning. Our approach introduces new and efficient methods for view generation and selection of viewpoint candidates that are adaptive to the user-defined confidence objectives, exploiting the uncertainty encoded in a Truncated Signed Distance field (TSDF) representation of the environment. This results in informed and efficient exploration decisions tailored towards the predetermined objective. Finally, we validate our method via extensive simulations in realistic environments. We demonstrate that it successfully adjusts its behavior to the user goal while consistently outperforming conventional NBV strategies in terms of coverage, quality of the final 3D map and path efficiency.

12:00-12:20 TuA3.6

C-3TO: Continuous 3D Trajectory Optimization on Neural Euclidean Signed Distance Fields, pp. 151-158

Gil Garcia, Guillermo — Universidad Pablo De Olavide
Cobano, Jose Antonio — Universidad Pablo De Olavide
Merino, Luis — Universidad Pablo De Olavide
Caballero, Fernando — Universidad Pablo De Olavide

This paper introduces a novel framework for continuous 3D trajectory optimization (C-3TO) in cluttered environments, leveraging online neural Euclidean Signed Distance Fields (ESDFs). Unlike prior approaches that rely on discretized ESDF grids with interpolation, our method directly optimizes smooth trajectories represented by fifth-order polynomials over continuous neural ESDF, ensuring precise gradient information throughout the entire trajectory. The framework integrates a two-stage nonlinear optimization pipeline that balances efficiency, safety and smoothness. Experimental results demonstrate that C-3TO produces collision-aware and dynamically feasible trajectories. Moreover, its flexibility in defining local window sizes and optimization parameters enables straightforward adaptation to diverse users' needs without compromising performance. By combining continuous trajectory parameterization with a continuously updated neural ESDF, C-3TO establishes a robust and generalizable foundation for safe and efficient local replanning in aerial robotics.

12:20-12:40 TuA3.7

Controller-Aware Closed-Loop RRT for Real-Time Fixed-Wing UAV Navigation in Cluttered Airspace, pp. 159-166

Elo, Callahan — University of Kansas
Keshmiri, Shawn — University of Kansas

Real-time planning for fixed-wing unmanned aerial vehicles (UAVs) requires both rapid generation of dynamically feasible trajectories and the ability to reliably track those trajectories. Closed-loop rapidly exploring random trees (CL-RRT) provide a promising framework by embedding vehicle dynamics and feedback control within rapid tree expansion; however, their application to fixed-wing aircraft remains limited. This work quantifies the impact of aircraft guidance and control architecture on both closed-loop node propagation and reference path tracking in real-time CL-RRT planning. Planning and tracking are first analyzed independently in simulation to isolate architectural effects. Results indicate that controller dynamics shape the short-horizon assessed reachable set during propagation, thereby constraining planner performance and computational robustness. Moreover, fixed-lookahead tracking assumptions break down under the nonuniform spacing and curvature of RRT waypoints. A Total Energy Control System (TECS) scheme and a modified Multi-Segment Adaptive Arc-Length Guidance (MS-AALG) law are proposed to address these shortcomings. Real-time CL-RRT simulations demonstrate improved reliability relative to conventional linear architectures.

TuA4 **Calypso B**

Perception and Cognition I (Regular Session)

Chair: Capello, Elisa — Politecnico Di Torino
Co-Chair: Sandino, Juan — Queensland University of Technology

10:20-10:40 TuA4.1

Towards Robust DEM-Based Monocular Depth Rescaling for UAVs: A Systematic Analysis, pp. 167-174

Musio, Maria Grazia — Politecnico Di Torino
Savian, Stefano — Leonardo S.p.A
Mohammadi, Seyedsaber — Leonardo S.p.A
Capello, Elisa — Politecnico Di Torino
Primatesta, Stefano — Politecnico Di Torino

Monocular depth estimation suffers from inherent scale ambiguity, limiting its real-world applicability. While recent foundation models produce high-quality relative depth maps, their predictions lack metric consistency, which becomes critical in aerial environments. Recent rescaling approaches address this limitation by leveraging Digital Elevation Maps (DEM) as absolute references, yet existing DEM-based methods remain difficult to deploy due to their reliance on offline ground segmentation techniques and the absence of standardized validation frameworks. To overcome these challenges, we introduce a Synthetic-to-Geo-Real simulation framework that jointly models realistic flight dynamics and real georeferenced terrain, enabling a novel, systematic, and controlled evaluation of DEM-based rescaling across diverse operational conditions. The framework provides a unified benchmarking setting to compare multiple state-of-the-art depth models and alternative ground segmentation strategies under consistent assumptions. Our results show that semantic segmentation provides more consistent performance across models, altitudes, and environments, achieving up to a 60% reduction in error over geometric segmentation. We further observe that decoupling segmentation from depth estimation and selectively sampling ground points can improve scale recovery. These findings support the practical viability of DEM-based metric depth rescaling for Unmanned Aerial Navigation.

10:40-11:00 TuA4.2

Geometry-Aware Onboard Perception for Powerline Conductor Estimation and Outside-FOV Tracking During Close-Range Flight, pp. 175-182

Nyboe, Frederik Falk University of Southern Denmark
Ebeid, Emad Samuel Malki University of Southern Denmark

Autonomous drone flight within powerline corridors requires reliable onboard perception that can estimate and track the poses of conductors, even when individual cables temporarily leave the sensors' field of view. In this work, we present an onboard perception system for mid-span corridor powerline pose estimation and tracking, building on previous research that combines mmWave radar and RGB camera measurements with flight controller odometry. First, we introduce a transformation of the cable direction that enables consistent estimation of the global powerline orientation regardless of the drone's attitude by compensating for the mismatch between the camera and sensor planes. Second, we propose the Relative Cable Positions algorithm, which exploits the fixed geometric relationships between conductors to estimate the positions of cables outside the mmWave radar field of view based on measurements from cables that remain visible. The system is implemented onboard a drone and evaluated through real-world flight experiments conducted at a dedicated powerline test facility. The results show a clear reduction in position estimation error for conductors outside the radar field of view compared to odometry-only tracking under non-RTK conditions. Overall, the proposed methods improve the robustness of drone-based tracking and pose estimation of conductor geometry without relying on RTK, supporting safer and more reliable autonomous flight within mid-span powerline corridors.

11:00-11:20 TuA4.3

Aerial Visual Place Recognition in Antarctica: Towards Robust Monitoring in Extreme Environments, pp. 183-190

Fontan, Alejandro Queensland University of Technology
Sandino, Juan Queensland University of Technology
Civera, Javier Universidad De Zaragoza
Fischer, Tobias Queensland University of Technology
Gonzalez, Luis Felipe Queensland University of Technology
Milford, Michael John Queensland University of Technology

Visual Place Recognition is widely considered a mature field, yet most benchmarks are constrained to visually similar environments, predominantly urban or road scenes, leaving its performance in extreme environments largely unexplored. We address this gap by introducing a challenging benchmark built from Antarctic imagery, characterized by vast textureless areas covered by snow and ice, severe visual aliasing, and aerial perspectives from downward-facing drone cameras. We curate a GNSS-based ground truth refined with feature matching to establish a reliable evaluation. Additionally, we propose several adaptations to VPR methods to operate effectively under such conditions: rotation-robust VPR to accommodate aerial downward-facing viewpoints and a proxy to discard visually uninformative images. Finally, we present VPR-LAB, the most comprehensive pipeline to date for VPR benchmarking, enabling systematic evaluation across both conventional and unconventional datasets. Experiments demonstrate significant improvements for VPR in polar environments, directly enabling autonomous monitoring essential for Antarctic ecosystem conservation and multi-season ecological surveys.

11:20-11:40 TuA4.4

CPU-Optimized Real-Time Object Detection and Pose Estimation for UAVs, pp. 191-198

Arash, Hashemi Università Degli Studi Di Napoli Federico II
Scognamiglio, Vincenzo Università Degli Studi Di Napoli Federico II
Caccavale, Riccardo Università Degli Studi Di Napoli Federico II
Finzi, Alberto Università Degli Studi Di Napoli Federico II
Lippiello, Vincenzo Università Degli Studi Di Napoli Federico II

The use of mobile robots is becoming increasingly common, especially for surveillance and search and rescue operations in disaster areas. During these operations, robots need to perceive the environment, detecting and estimating the pose of specific targets leveraging their on-board capabilities. Specifically, Unmanned Aerial Vehicles (UAVs), due to the limited payload, energy supply, and costs are often provided with low-cost and energy-efficient CPU-based companion computers, which may cause degraded performance, especially regarding vision applications. In this view, this work aims to present a CPU-based optimization of a real-time object position estimation suited for UAVs companion computers. The proposed pipeline, which implements quantization and inference optimization, has been tested over six state-of-the-art models for object detection on CPU-based hardware mounted on a drone. The validation has been carried out with real flights for estimating objects' positions.

11:40-12:00 TuA4.5

Adaptive Texture-Aware Pixel Selection for Robust Direct Visual Odometry in UAV Navigation, pp. 199-206

Gaia, Jeremias Universidad Nacional De San Juan
Alves Fagundes Junior, Leonardo Universidade Federal De Viçosa
Soria, Carlos Universidad Nacional De San Juan
Brandao, Alexandre Santos Universidade Federal De Viçosa

Direct visual odometry (DVO) is becoming widely used to estimate camera ego-motion and simultaneously reconstruct/map the environment from image sequences, particularly due to its efficient use of photometric information and strong performance in weak-texture scenarios. However, since DVO relies directly on pixel intensity patterns for frame-to-frame alignment, it is inherently sensitive to brightness inconsistencies and illumination changes, which can degrade pose estimation, particularly in aerial robotics scenarios involving motion blur, illumination variations, and texture-poor environments. This paper proposes an adaptive pixel selection mechanism for DVO systems. The proposed approach prioritizes regions with strong structural content, ensuring that the pose estimate remains constrained by meaningful image gradients, even in low-texture or highly homogeneous scenarios. By integrating image texture descriptors, the system dynamically adjusts selection parameters, according to the scene complexity. This enables the operation across structured, semi-structured, and unstructured environments without introducing significant computational overhead. Experimental validation in both indoor and outdoor scenarios demonstrates that the proposed method preserves uniform spatial coverage while

suppressing low-gradient and photometrically unstable regions. The results demonstrate enhanced trajectory consistency and greater robustness under challenging visual conditions, confirming the algorithm effectiveness for UAV navigation in GPS-denied environments.

12:00-12:20 TuA4.6

Extended Model-Based Learned Inertial Odometry, pp. 207-212

Kuruppu Arachchige, Sasanka — Tampere University
Kamarainen, Joni-Kristian — Tampere University

Inertial odometry is a compelling approach to state estimation for agile quadrotor flight due to its affordability, low weight, and robustness to perceptual degradation. However, relying only on integrated inertial measurements is impractical, as sensor errors and time-varying biases lead to significant pose drift. Although recent advances have enabled inertial odometry for drone racing, existing approaches show limited generalization to trajectories not seen during training. This work improves generalization by adopting a body-frame representation and incorporating body-frame torque dynamics into the learning pipeline. The learned model predicts short-horizon relative displacements, which are fused with IMU measurements in an Extended Kalman Filter. Experimental results show that the proposed method outperforms the previous state-of-the-art learned inertial odometry approach for quadrotor pose estimation on unseen trajectories.

12:20-12:40 TuA4.7

Robust Thermal Video Stabilization for Autonomous UAS: A Dynamic H-Infinity Approach with Covariance Persistence, pp. 213-220

Ceron, Jose — Universidade Federal De São Carlos
Carmona Hernandes, Andre — Universidade Federal De São Carlos
Pazelli, Tatiana F.P.A.T. — Universidade Federal De São Carlos
Inoue, Roberto Santos — Universidade Federal De São Carlos

The deployment of Unmanned Aerial Systems (UAS) in degraded visual environments relies heavily on Long-Wave Infrared (LWIR) sensors. However, thermal visual odometry is frequently compromised by high-frequency aerodynamic jitter and radiometric contrast loss. This paper presents a purely causal, real-time stabilization framework for 640x480 LWIR video at 30 fps, addressing the critical issue of "over smoothing" inherent in standard Gaussian estimators. We identify a severe "Cold-Start Anomaly" in the classical Kalman Filter (KF), which, during turbulent initialization, suffers from numerical gain explosion and discards up to 16.31% of the useful frame area (Crop Ratio). To overcome this, we propose a spectrally- bounded $H\infty$ minimax formulation that enforces strict numerical stability through an attenuator derived from the spectral radius of the observation-weighted information term. Furthermore, we validate a Covariance Persistence (Warm-Start) strategy that eliminates transient initialization penalties entirely. Evaluated across stable cruise, turbulent landing, and thermal crossover scenarios, the proposed $H\infty$ framework demonstrated superior geometric preservation, restricting spatial loss to just 3.63% under cold-start turbulence, while matching the Kalman baseline in Inter-frame Transformation Fidelity (ITF). These results prove that spectrally bounded robust filtering is essential for maintaining zero-latency, high-fidelity perception in autonomous UAS operations.

TuB1 **Nafsika**

Best Paper Award Finalists (Regular Session)

Chair: Tzes, Anthony — New York University Abu Dhabi
Co-Chair: Monteriù, Andrea — Università Politecnica Delle Marche

14:00-14:20 TuB1.1

An Autonomous Flight System for Small-Sized Drones Using Circular Buffered Hash Data Structure, pp. 221-226

Lee, Dasol — Agency for Defense Development

This paper proposes an autonomous flight system for small-sized drones using an efficient data structure based on circular buffered hash mechanism and presents its flight experiment results. The proposed circular buffered hash data structure can be utilized in various algorithms handling voxel-like data, and it possesses the favorable characteristic of automatically maintaining a maximum number of the most recent data, thereby preventing a continuous increase in memory usage. The practical feasibility of the proposed data structure and the autonomous flight system have been verified by conducting flight experiments using a small-sized drone platform equipped with a Livox Mid-360 LiDAR, confirming the capability of achieving precise autonomous flight in GNSS-denied and cluttered environments.

14:20-14:40 TuB1.2

Spinning Quadrotor: Hover Thrust Augmentation with Passive Lifting Surfaces, pp. 227-234

Parkala, Aniketh — International Institute of Information Technology
Kandath, Harikumar — International Institute of Information Technology

Conventional multirotor aerial vehicles actively suppress yaw rotation during hover, expending power to maintain a fixed heading even though yaw regulation is not required for force balance or altitude control. This paper challenges that paradigm by proposing a spinning quadrotor architecture that intentionally operates at a sustained yaw rate, converting power traditionally spent on yaw regulation into useful aerodynamic effects. A dynamic model of the spinning quadrotor is developed, analysis for low Re range is conducted to choose an airfoil for lifting surfaces. Preliminary hardware tests show a 22% reduction in thrust required. These findings suggest that intentional yaw rotation, rather than being suppressed, can be exploited as a design mechanism for efficient and robust multirotor flight.

14:40-15:00 TuB1.3

Muscle Coactivation in the Sky: Geometry and Pareto Optimality of Energy vs. Aerodynamic Promptness and Multirotors as Variable Stiffness Actuators, pp. 235-242

Franchi, Antonio — Univ. of Twente and Sapienza Univ. of Rome

In robotics and biomechanics, trading metabolic cost for kinematic readiness is a well-established principle. This paper formalizes this concept for aerial multirotors through the introduction of aerodynamic promptness--a dynamic metric analogous to dynamic manipulability in robotics. By formulating redundancy resolution as a geometric multi-objective optimization along task fibers, we rigorously characterize the topological trade-off between energy consumption and promptness. We demonstrate that this interplay is fundamentally governed by fiber geometry. Cooperative actuation regime yields compact fibers with bounded, compatible Pareto fronts. Conversely, antagonistic actuation regime unlocks unbounded fibers, enabling aerodynamic co-contraction that drives promptness to hardware limits at the expense of flight endurance. We establish a structural isomorphism between aerodynamic co-contraction and biologically inspired variable stiffness actuators, introducing a dynamic ``flying muscle'' paradigm. Ultimately, this framework transitions multirotor allocation from heuristic energy minimization to principled, geometry-aware Pareto navigation, laying foundational theory for the design and control of highly agile aerial platforms.

15:00-15:20 TuB1.4

Time-Constrained Coverage Path Planning for UAV Search Applications, pp. 243-250

Luterman, Alec — University of Maryland
Bortoff, Zachary — University of Maryland
Nogar, Stephen — U.S. Army Research Laboratory
Paley, Derek — University of Maryland

Traditional coverage path planning methods for unmanned aerial vehicles (UAVs) take an overly simplistic look at the sensor footprint of the camera, resulting in inefficient path plans that waste significant coverage and are not optimal in travel time. We propose a coverage path planning algorithm based on generating and sequencing a set of stationary vantage points that the UAV will travel to and capture imagery. These vantage points ensure that the coverage path plan achieves a spatial resolution threshold throughout the entire search domain while minimizing the amount of unnecessary excess coverage both inside and outside of the search domain. We also propose a routing method for maximizing the portion of the search domain we can cover when faced with a maximum mission time constraint. Simulation testing shows the improvement of our method in both coverage efficiency and total travel time compared to lawnmower-based coverage path plans. Experimental testing details how coverage path plans based on stationary coverage can degrade when the UAV's onboard camera does not have a level attitude.

15:20-15:40 TuB1.5

A Robust Transfer Learning Cross-Dataset Generalization Approach for GNSS Spoofing Detection in Unmanned Aerial Vehicles: A Study on TEXBAT and OAKBAT Datasets, pp. 251-258

Salles, Felipe — University of São Paulo
Ramos, Taiane Coelho — Federal Fluminense University
Branco, Kalinka Regina Lucas Jaquie Castelo — University of São Paulo

Given the increasing use of Unmanned Aerial Vehicles (UAVs), cyberattacks targeting them have caused significant financial and operational losses, highlighting the need for effective security solutions. Despite advances in Machine Learning (ML) approaches, literature still lacks investigations into the generalizability of results across datasets for detecting Global Navigation Satellite Systems (GNSS) Spoofing. The main contribution of this study is to show that different collection conditions, experiments, receptors, and even the collection location itself can prevent an ML-trained model from generalizing to another dataset. On the TEXBAT and OAKBAT datasets, we propose a Transfer Learning (TL) approach that uses a model trained on TEXBAT and fine-tuned on OAKBAT, demonstrating strong cross-dataset generalization. In contrast, when evaluated without fine-tuning (FT), we observed a substantial performance drop, highlighting a fundamental gap in approaches that rely on single-dataset evaluation or on independent models for each dataset. Such practices limit real-world applicability, particularly for UAV systems operating in heterogeneous and complex environments. Our approach was tested across six distinct OAKBAT scenarios, achieving accuracy above 99% in four of the six cases, indicating potential for practical deployment in real-world UAV applications.

15:40-16:00 TuB1.6

Dust-Resilient Autonomous Navigation and Mapping for UAVs in GNSS-Denied Underground Tunnels, pp. 259-264

Montes-Grova, Marco Antonio — Center for Advanced Aerospace Technologies
González Marín, José Manuel — Center for Advanced Aerospace Technologies
Perez-Grau, Francisco Javier — Fundacion Andaluza Para El Desarrollo Aeroespacial
Viguria, Antidio — Fundacion Andaluza Para El Desarrollo Aeroespacial

Autonomous UAVs enable safe inspection of hazardous underground environments, but simultaneous GNSS denial and visibility degradation from airborne dust present critical navigation challenges. Conventional visual odometry fails under feature scarcity, while LiDAR-based methods suffer from noise artifacts as suspended particles are misinterpreted as obstacles. This paper presents a UAV system for autonomous mapping in dust-laden, GNSS-Denied tunnels. LiDAR-Inertial odometry was integrated with IMU pre-integration to achieve 100~Hz state estimation for responsive control in confined spaces. An intensity-based dust filtering algorithm removes point cloud contamination in real-time, enabling autonomous capabilities despite visibility degradation. Experimental validation in a real mining tunnel under controlled visually degraded conditions demonstrates autonomous operation. The system completes exploration and mapping in 480 seconds, achieving 0.19 m mean mapping accuracy and 0.60 m RMS error against Total Station ground truth. Results establish quantitative benchmarks for UAV deployment in underground construction and emergency response scenarios where human access is restricted.

TuB2	Lounge A
Multirotor Design and Control II (Regular Session)	
Chair: Arogeti, Shai	Ben-Gurion University of the Negev
Co-Chair: Loianno, Giuseppe	UC Berkeley

14:00-14:20 TuB2.1

Disturbance-Aware Data-Driven Optimal Altitude Control of UAVs, pp. 265-272

Gedj, Amit — Ben-Gurion University of the Negev
Taitler, Ayal — Ben-Gurion University of the Negev
Arogeti, Shai — Ben-Gurion University of the Negev

Adaptive dynamic programming (ADP) and policy iteration (PI) algorithms are powerful tools for data-driven optimal control. When using the linear-quadratic regulator (LQR) in the ADP framework, most existing approaches assume disturbance-free system dynamics. Data-driven design eliminates the need for a dynamical model by utilizing data from the system state and input. If the system is disturbed by an unknown disturbance, the system input is not fully known, which makes standard ADP and PI approaches impractical. In this study, a novel PI-based ADP framework is proposed to explicitly handle constant unknown disturbances by integrating frequency-domain filtering with the classical ADP approach. High-pass filtering of input-output trajectories suppresses the effects of disturbances on the design, allowing the use of established PI techniques, while a low-pass filter extracts the required steady-state feed-forward term. The resulting control law preserves the LQR structure but improves steady-state accuracy and robustness. The process is experimentally validated using a quadcopter altitude control design with unknown mass and motor dynamics. The unknown gravitational force is assumed to be a constant unknown disturbance input. The results show that the proposed approach eliminates steady-state altitude errors compared to baseline controller gains. These findings demonstrate that disturbance-aware ADP provides a practical and effective framework for robust data-driven control in systems with unknown dynamics.

14:20-14:40 TuB2.2

Adaptive Neural Attitude Control of a Quadcopter with Real-World Experimental Validation, pp. 273-280

Kazakidis, Charalampos — University of West Attica
Protoulis, Teo — University of West Attica
Alexandridis, Alex — University of West Attica

This paper presents a robust adaptive attitude control framework for quadcopters subject to parametric uncertainty and unmodeled nonlinear dynamics. The control design is based on a backstepping approach, where the uncertain moments of inertia and the synaptic weights of a radial basis function neural network (RBFNN) that is employed to approximate the unknown dynamics, are estimated online through dedicated adaptive laws. Projection operators are incorporated to ensure strict positivity of the inertia estimates, thereby preserving physical consistency and controllability, and ultimate boundedness of the RBFNN weights. Moreover, through rigorous analysis, uniform ultimate boundedness of the tracking errors and boundedness of all closed-loop signals is formally established. The proposed controller is experimentally validated on a real-world quadcopter platform directly utilizing measurements from onboard sensors, in contrast to most of the existing literature that relies on high-precision motion capture systems. Finally, comparison results against alternative controllers validate the superiority of the proposed control protocol.

14:40-15:00 TuB2.3

Learning to Fly Using a Constant Reward Function, pp. 281-288

Eschmann, Jonas — University of California Berkeley
Albani, Dario — Technology Innovation Institute
Loianno, Giuseppe — University of California Berkeley

Recently, Reinforcement Learning (RL) has been applied to numerous robotics domains, including end-to-end quadrotor control. The training of useful policies using RL usually involves the time-consuming and often unprincipled, tuning-based design of a reward function. In this work, we present a novel alternative method to train an end-to-end quadrotor control policy using a constant reward function r(s,a)=1. Since a constant reward function cannot carry information, we show that end-to-end policies can learn to fly solely through the feedback of the termination signal. Furthermore, we show that encoding additional objectives into the termination signal leads to robust end-to-end policies with low-level RPM outputs. We demonstrate that these policies can be directly transferred to a real quadrotor and even generalize to new tasks, such as trajectory tracking. Finally, we compare the trajectory-tracking performance of our policy to other classical and RL-based methods and find that our policies can achieve similar performance to other RL-based approaches while eliminating the need for hand-tuned reward functions. We open-source our implementation for the benefit of the community and to advance research in this area.

15:00-15:20 TuB2.4

Aggressiveness-Aware Learning-Based Control of Quadrotor UAVs with Safety Guarantees, pp. 289-296

Colombo, Leonardo — Centre for Automation and Robotics
Beckers, Thomas — Vanderbilt University
Giribet, Juan Ignacio — University of San Andrés

This paper presents an aggressiveness-aware control framework for quadrotor UAVs that integrates learning-based oracles to mitigate the effects of unknown disturbances. Starting from a nominal tracking controller on SE(3), unmodeled generalized forces and moments are estimated using a learning-based oracle and compensated in the control inputs. An aggressiveness-aware gain scheduling mechanism adapts the feedback gains based on probabilistic model-error bounds, enabling reduced feedback-induced aggressiveness while guaranteeing prescribed practical exponential tracking performance. The proposed approach makes explicit the trade-off between model accuracy, robustness, and control aggressiveness, and provides a principled way to exploit learning for safer and less aggressive quadrotor maneuvers.

15:20-15:40	TuB2.5

Robust Attitude Tracking on Quadrotors Using Super-Twisting Sliding Mode Control, pp. 297-303

Tavares, Luiz	Federal University of Espirito Santo
Bacheti, Vinícius Pacheco	Federal University of Espirito Santo
Sarcinelli-Filho, Mário	Federal University of Espirito Santo
Villa, Daniel Khede Dourado	Federal University of Espirito Santo

Reference accelerations are tracked by the action of the inner-loop attitude control of quadrotors. While conventional PID controllers are widely utilized, they often lack the robustness required to handle modeling mismatches and aggressive maneuvers. This work proposes a cascaded control architecture where the inner-loop attitude rate control is governed by a Super-Twisting Sliding Mode Controller (ST-SMC). This high-order sliding mode control strategy enhances robustness while mitigating the chattering typically associated with first order sliding mode controllers. Experimental validation on a Crazyflie platform under stress scenarios, including carrying an unmodeled payload from an offset from the center of mass and navigating with damaged propellers, demonstrates that ST-SMC significantly outperforms the industry-standard PID, achieving a 15.58% reduction in position-tracking RMSE and a 22.93% reduction in velocity-tracking error. Furthermore, the ST-SMC demonstrated reduced control effort and superior reliability, leading to fewer crashes during agile flights.

15:40-16:00	TuB2.6

Adaptive Control for Off-The-Shelf Quadrotors Using a Simplified Dynamic Model, pp. 304-308

Bacheti, Vinícius Pacheco	Federal University of Espirito Santo
Villa, Daniel Khede Dourado	Federal University of Espírito Santo
Sarcinelli-Filho, Mário	Federal University of Espirito Santo

Linearization around the near-hover condition is a common approach in modeling quadrotors, assuming small pitch and roll angles to yield a fully actuated dynamic model. Such linearized models are particularly useful because they can be readily applied to control off-the-shelf quadrotors, enabling their use in commercial applications and academic research. For the control of translational motion and heading angle, most models reported in the literature require eight parameters to be identified via a black-box procedure. In this paper, we revisit a recently proposed simplified model that requires identifying only four parameters while still achieving good performance. Based on this model structure, a model reference adaptive controller is proposed to handle parameter variations and improve tracking performance during more aggressive navigation. Experimental results obtained with a quadrotor platform validate the proposed approach by comparing the trajectory-tracking performance of the model requiring the identification of four parameters against that of the model requiring the identification of eight parameters and a purely analytical model. The obtained results show that the proposed model is not only simpler and easier to implement but also capable of delivering superior performance, thus providing an interesting framework for researchers working with off-the-shelf quadrotors.

TuB3	**Calypso A**
Path Planning II (Regular Session)	
Chair: Tzes, Anthony	New York University Abu Dhabi
Co-Chair: Bhandari, Subodh	California State Polytechnic University

14:00-14:20	TuB3.1

Misfortunes Never Come Alone: Balancing Occupancy of UAM Alternate Landing Sites, pp. 309-316

Hasan, Hardy	Lidingö Stad
Mori, Ryota	Kobe University
Polishchuk, Tatiana	Linkoping University
Polishchuk, Valentin	Linkoping University
Sedov, Leonid	Linkoping University

We study routing of Urban Air Mobility (UAM) flights while ensuring robustness to large-scale disruptions during which many aircraft may need to initiate contingency maneuvers at the same time. We propose algorithmic solutions for routing drones so that they always stay sufficiently close to potential alternate landing locations, while preventing the situations when too many drones rely on a single landing site at once. The performance of our algorithms is evaluated on simulated urban scenarios.

14:20-14:40	TuB3.2

Local Path Planning and Obstacle Avoidance for an Omnicopter Platform, pp. 317-324

Helinski, Mikolaj	Delft University of Technology
Theodoulis, Spilios	Delft University of Technology
Hamandi, Mahmoud	New York University Abu Dhabi
Mohamed Ali, Abdullah	New York University Abu Dhabi
Tzes, Anthony	New York University Abu Dhabi
Popovic, Marija	Delft University of Technology

Autonomous unmanned aerial vehicles (UAVs) increasingly operate in cluttered environments where global planners such as RRT* are not directly deployable at control rates. This paper presents a real-time local planning and obstacle avoidance module for an omnidirectional multirotor (Omnicopter) by extending the Dynamic Window Approach to six degrees of freedom (6D-DWA). Our method achieves real- time feasibility through (i) local-map voxelisation, (ii) a compact sphere-based approximation of the vehicle geometry, and (iii) adaptive velocity sampling in the 6D search space. To improve reactivity to unknown obstacles, we introduce a context-aware “Agile Mode” that adjusts scoring weights online to trade- off between goal progress, clearance, and heading/facing constraints during evasive

manoeuvres. We evaluate our approach in simulation across computational stress tests, dense-waypoint path tracking, and static/unknown obstacle scenarios. Our planner runs consistently within a 0.2 s control loop, tracks waypoint-dense global paths with < 0.1 m average cross-track error and ~ 13◦ average heading error and avoids collisions in static environments. For unknown obstacle avoidance, Agile Mode achieves 79.3% success for an off-center obstacle and 41.4% for a centred obstacle, highlighting both the effectiveness of adaptive weighting and remaining limitations in highly constrained geometries.

14:40-15:00 TuB3.3

Optimizing UAV Operations under Capacity and Distance Constraints: A Comparison of Routing Heuristics for Cerrado Restoration, pp. 325-332

Nascimento, Flaviana	Universidade Federal De São Carlos
Guimarães, João Rafael	Universidade Federal De São Carlos
Sanglade, Lucas Dias	Universidade Federal De São Carlos
Boschi, Raquel	Universidade Federal De São Carlos
Pazelli, Tatiana F.P.A.T.	Universidade Federal De São Carlos
Kelen Cristiane, Teixeira Vivaldini	Universidade Federal De São Carlos

This work addresses the seed dispersal planning problem as a Commodity-Constrained Split Delivery Vehicle Routing Problem (C-SDVRP), in which the UAV must repeatedly return to a depot for reloading and recharging. We benchmark five routing algorithms across field sizes from 25 × 25 m to 150 × 150 m: Nearest-Neighbor (NN), two variants of Lin- Kernighan with split (LKH-Split), Discrete Artificial Hummingbird Algorithm (D-AHA), and Hybrid Genetic Search (HGS). Results highlight trade-offs between computational efficiency, solution quality, and scalability. LKH-Split achieves sub-second planning times but incurs relatively high trajectory costs, with optimality gaps ranging from 41.6% to 47.2%. D-AHA shows competitive performance on small-to-medium instances, achieving low optimality gaps (1.4%–6.2%), but its performance degrades significantly in large fields (46.9%–57.0% optimality gap). Notably, the simple NN heuristic outperforms more complex metaheuristics in the largest instance (150 × 150 m), reaching a near-optimal solution with a 0.2% optimality gap and sub-millisecond computation time. These results provide practical guidelines for selecting routing algorithms based on field scale and mission constraints in UAV-based aerial seeding operations.

15:00-15:20 TuB3.4

Locally Optimal UAV Surveillance Evasion Via Sampling and Nonlinear Programming, pp. 333-340

Kinerson, Joseph	Purdue University
Kim, Jaehyeok	Purdue University
Pant, Kartik	Purdue University
Sommer-Kohrt, Kylie	Purdue University
Goppert, James	Purdue University
Sun, Dengfeng	Purdue University

The defense of civil and military airspace is increasingly challenged by low-cost, small Unmanned Aerial Vehicles (UAVs) with high maneuverability, enabling them to evade modern detection systems, disrupting the airspace, or even leading to a catastrophe. Contrary to existing counter UAS (cUAS) methods that focus on optimal sensor placement or control, this paper identifies vulnerabilities in existing sensor deployments by formulating the problem as a zero-sum differential surveillance–evasion game between an intruding UAV and the detection system. In this formulation, intruders seek paths that minimize detection probability while reaching their goal. Our focus is on identifying optimal intruder best response trajectories given the knowledge of the detection system to evaluate its performance and vulnerabilities. However, planning such trajectories is challenging due to the high dimensionality of the space–time domain and the non-convex visibility regions of panning sensors. To address this, we propose a hybrid approach that combines sampling-based planning with a non- linear program (NLP) to obtain a locally optimal solution. The sampling solution provides an initial guess, thereby alleviating the computational burden of the NLP and refining the solution to obtain locally optimal paths. Finally, we use a Monte Carlo simulation to demonstrate that our proposed attacker's best response approach reduces the detection probability by 49.6% on average relative to purely sampling-based methods, with an additional average cost of 53.8 seconds per trial.

15:20-15:40 TuB3.5

3D Path Planning for Autonomous UAV Navigation in GPS-Denied Environments, pp. 341-348

Thakkar, Tirth	California State Polytechnic University
Rick Ramirez, Rick Ramirez	California State Polytechnic University
Tsui, Rexley	California Polytechnic State University
Bhandari, Subodh	California State Polytechnic University
Raheja, Amar	California State Polytechnic University

This paper presents a UAV path planning framework designed to enable smooth, collision-free autonomous navigation in static, GPS-denied environments. The framework relies on point cloud data collected by a primary, pilot UAV, which uses onboard sensing, SLAM, and object detection to incrementally map an unknown environment and identify waypoints. Path planning is performed in a bounded SE(3) state space using sampling-based algorithms with a multi-objective formulation that balances path length, obstacle clearance, and orientation smoothness. Safety is ensured through tight integration with a dedicated collision detection and proximity query engine, enabling efficient collision and distance queries against the octree-based environment representation. Planned paths are further refined through shortcutting and B-spline smoothing to produce dynamically feasible trajectories, which are executed via a MAVROS–PX4 control pipeline. The enhanced collision validation approach for global path planning incorporates 6-DOF vehicle motion to facilitate accurate navigation. Simulation and flight test results demonstrate the effectiveness of the proposed framework for reliable UAV autonomous navigation in complex and GPS-denied environments.

15:40-16:00 TuB3.6

PSO-Based UAV Path Planning for Minimizing Tracking Probability in Bistatic Radar Networks, pp. 349-355

Kahveci, Cemil — Istanbul Technical University
Inalhan, Gokhan — Cranfield University
Baspinar, Baris — Istanbul Technical University

Route planning for Unmanned Aerial Vehicles (UAVs) in hostile surveillance environments requires trajectory optimization frameworks that incorporate realistic radar detection physics beyond simple geometric avoidance. This study proposes a novel route planning framework for bistatic and multi static radar environments using Segmented Particle Swarm Optimization (PSO). Unlike traditional approaches that rely on monostatic radar models, we formulate a high-fidelity observability metric based on bistatic range-rate sum physics and continuous Doppler-notch attenuation. This formulation enables the planner to exploit “blind speeds” and clutter rejection filters inherent in Pulse-Doppler radars. We demonstrate the effectiveness of the proposed method across four scenarios, ranging from canonical iso-range validation to complex multistatic environments with strict time-of-arrival constraints. The results show that the planner autonomously discovers low-observability maneuvers, such as iso-range loitering and bistatic weaving with low RCS, significantly reducing the tracking probability while satisfying kinematic limits and mission timing requirements.

TuB4	**Calypso B**
Perception and Cognition II (Regular Session)	
Chair: Santiaguillo-Salinas, Jesús	Universidad Del Papaloapan
Co-Chair: Xu, Yan	Beihang University

14:00-14:20 — TuB4.1

From Robust Perception to Conflict Detection: Res-Gated Fusion for Multi-UAV Collaborative Operations in Degraded Urban Airspace, pp. 356-364

Wei, Yuxi — Beihang University
Xu, Yan — Beihang University
Cai, Kaiquan — Beihang University

Multi-UAV collaborative perception is essential for maintaining safe operations in complex urban environments, where single-agent vision often suffers from instability and the resulting localization drift in adverse weather conditions. This paper presents a Res-Gated Fusion framework that integrates residual structures with a dynamic gating mechanism to dynamically prioritize reliable geometric attributes when visual cues are degraded, thereby enhancing perception robustness. Building upon this, we introduce a risk representation that transforms geometric predictions into conflict indicators for collaborative decision support. Extensive evaluations on the customized CityUAV-3D benchmark demonstrate that multi-UAV collaborative perception consistently outperforms individual sensing in both perception accuracy and conflict detection by leveraging multi-view complementarity. Furthermore, strong zero-shot cross-scene transfer results in unseen complex scenarios underscores the framework's robustness and its potential for deployment in diverse urban airspace.

14:20-14:40 — TuB4.2

Learning-Based Perception of Cyber Anomalies in UAV Communication for Safe Autonomous Operations, pp. 365-372

Ruseno, Neno — University of South-Eastern Norway
Mottaghi Tarom Sari, Fahimeh — University of South-Eastern Norway
Farina, Mauro — University of Trieste
Arntzen Bechina, Aurilla Aurelie — University of South-Eastern of Norway

Unmanned Aerial Vehicles (UAVs) increasingly rely on wireless communication links for command, control, and data exchange, making them vulnerable to cyber-attacks that may compromise operational safety. This paper presents a learning-based perception framework for detecting anomalous UAV communication behavior using the UAV-NIDD dataset. The proposed approach treats network traffic analysis as a cyber-perception problem, where machine learning models infer deviations from normal communication patterns in real time, and includes a mitigation strategy based on explainable AI to define suitable mitigation actions. Supervised algorithms including Random Forest, XGBoost, Support Vector Machine, and Logistic Regression are evaluated for both binary (normal vs. attack) and multi-class (attack types) intrusion detection. Experimental results demonstrate near-perfect performance in binary classification and high macro-F1 scores in multi-class scenarios, highlighting the effectiveness of tree-based ensemble models in capturing non-linear packet-level patterns. Feature importance analysis and SHAP-based explainability reveal that transport-layer attributes (e.g., UDP packet length and source port), together with wireless-layer indicators, provide strong discriminative signals for identifying malicious activity. The findings show that UAV cyber-attacks exhibit structured statistical signatures that can be effectively perceived through data-driven learning models. This work contributes toward enhancing cyber-situational awareness and strengthening safety assurance in increasingly autonomous aerial operations.

14:40-15:00 — TuB4.3

Enhancing Concealed Drone Detection with Attention Mechanisms in RT-DETR, pp. 373-380

Obert, Luis — German Aerospace Center
da Silva Justino, Daniel Alexandre — German Aerospace Center
Gardi, Hamza A.A. — Karlsruhe Institute of Technology
Heizmann, Michael — Karlsruhe Institute of Technology

The detection of concealed drones in complex environments, such as urban areas or forests, remains a significant challenge for computer vision systems. While the Real-Time Detection Transformer (RT-DETR) achieves state-of-the-art performance in general object detection, its reliance on global self-attention may limit its effectiveness for targets that blend into the background. This work investigates the impact of integrating alternative attention mechanisms into the RT-DETR architecture to enhance the detection of concealed drones. We evaluate four distinct attention modules—Multi-Head Self-Attention (MHSA), Convolutional Block Attention Module (CBAM), Window Attention (WA), and Local-Global Attention (LGA) - prior to the encoder, as well as Efficient Channel Attention (ECA) prior to the decoder.

Using a test set biased towards camouflaged drones, we demonstrate that the placement and type of attention are critical to performance. Specifically, applying Window Attention to lower-level feature maps improves Average Precision (AP) by 1.5%, while the implementation of ECA at the encoder output yields a gain of 2.0% in AP. These findings suggest that for concealed drone detection, local and channel-selective attention mechanisms are superior to global self-attention, provided they are applied at semantically rich feature levels.

15:00-15:20 TuB4.4

Gesture-Based Natural User Interface for Formation Control of Multi-UAV Systems, pp. 381-388

Flores Murcia, Zurisadai — Universidad Del Papaloapan
Lara Solís, Daly Yareth — Universidad Del Papaloapan
Santiaguillo-Salinas, Jesús — Universidad Del Papaloapan

This paper presents the experimental implementation of a gesture-based formation control framework for a multi-UAV system using a Natural User Interface (NUI). Hand gestures are recognized through a Multilayer Perceptron (MLP) trained on skeletal hand features extracted with MediaPipe Hands, enabling intuitive high-level command generation. The recognized gestures define both formation configurations and motion references for a leader–follower architecture, while low-level control is achieved through input–output linearization and consensus-based formation strategies. Experimental validation with three Crazyflie quadrotors and an OptiTrack motion capture system demonstrates stable formation transitions and coordinated collective motion generated through natural human interaction. Results show convergence toward desired formations and successful trajectory tracking under dynamic gesture commands, highlighting the feasibility of integrating vision-based human interaction with cooperative aerial robotics.

15:20-15:40 TuB4.5

Temporally Consistent Multi-Plane Segmentation and Stable Semantic Classification for UAV-Based 3D Mapping in Irregular Terrain, pp. 389-395

Alves, Werikson — Universidade Federal De Viçosa
Alves Fagundes Junior, Leonardo — Universidade Federal De Viçosa
Dias, Artur — Universidade Federal De Viçosa
Marcolino, Pablo — Universidade Federal De Viçosa
Brandao, Alexandre Santos — Universidade Federal De Viçosa

Plane structures such as floors, ravines, and surfaces play a fundamental role in robotic navigation, perception, and mapping. Although single-frame plane segmentation is well established, ensuring temporal consistency and geometric stability across sequential observations remains a challenging problem. In this work, we propose a stability-driven pipeline for multi-plane segmentation, temporal tracking, and semantic classification in 3D point clouds. The method first extracts dominant planes using iterative RANSAC, followed by a geometry-aware association strategy that tracks planes over time based on orientation, centroid, and offset constraints. To evaluate temporal robustness, we introduce a comprehensive stability analysis framework that measures global angular deviation, frame-to-frame variation, metric offset evolution, and inlier support over time. Experiments on real-world irregular terrain demonstrate that the proposed approach maintains consistent plane orientation and parameterization despite altitude and viewpoint changes or partial occlusions. The results show bounded angular drift, smooth metric evolution, and sustained geometric support, confirming the robustness of the proposed temporal modeling strategy.

15:40-16:00 TuB4.6

Neural-Geometric Tunnel Traversal: Localization-Free UAV Flight with Tilted LiDARs, pp. 396-403

Cano, Lorenzo — Universidad De Zaragoza
Tardioli, Danilo — Universidad De Zaragoza
Mosteo, Alejandro R. — Centro Universitario De La Defensa

Navigating UAVs in environments like tunnels or mines is a complex task due to unavailable GNSS for localization, uneven or absent lighting, and likely scarce wall features, especially at high speeds. In this paper we propose a novel proof-of-concept reactive UAV navigation technique using only LiDAR data that combines geometric and machine-learning algorithms. 2D range information is processed by a deep neural network to establish the UAV's yaw relative to the tunnel's longitudinal axis for navigation directions. Additionally, a geometric method computes the safest location inside the tunnel that maximizes distance to the closest obstacle. This information proves to be sufficient for simple yet effective navigation in straight and curved environments at speeds of up to 6m/s in simulation.

TuC1 **Nafsika**

Control Architectures II (Regular Session)

Chair: Cenedese, Angelo — University of Padua
Co-Chair: Sarcinelli-Filho, Mário — Federal University of Espirito Santo

16:20-16:40 TuC1.1

A Coupled Stochastic Optimal Separation and Intercept Strategy for Dubins Vehicles, pp. 404-410

Milutinovic, Dejan — University of California at Santa Cruz
Von Moll, Alexander — Air Force Research Laboratory
Weintraub, Isaac E. — Air Force Research Laboratory
Casbeer, David — Air Force Research Laboratory

In this paper, we study a navigation problem composed of two distinctive phases required to perform a task. Navigation in the first phase and the decision to transition to the second phase directly influence the chance of success of the second phase and, consequently, the entire task. Specifically, we consider an intercept task involving two Dubins vehicles and two target sets. We demonstrate that the

problem can be solved by a set of interdependent stochastic Hamilton-Jacobi-Bellman and Backward Kolmogorov equations. To enable the use of these equations, we exploit an exponential utility function and Cantelli's inequality for probabilities. Finally, we compute the solution and validate it through numerical simulations.

16:40-17:00	TuC1.2

Trajectory Tracking Control Design for Autonomous Helicopters with Guaranteed Error Bounds, pp. 411-418

Schitz, Philipp	German Aerospace Center
Dauer, Johann	German Aerospace Center
Mercorelli, Paolo	Leuphana University of Lueneburg

This paper presents a systematic framework for computing formally guaranteed trajectory tracking error bounds for autonomous helicopters based on Robust Positive Invariant (RPI) sets. The approach establishes a closed-loop translational error dynamics which is cast into polytopic linear parameter-varying form with bounded additive and state-dependent disturbances. Ellipsoidal RPI sets are computed, yielding explicit position error bounds suitable as certified buffer zones in upper-level trajectory planning. Three controller architectures are compared with respect to the conservatism of their error bounds and tracking performance. Simulation results on a nonlinear helicopter model demonstrate that all architectures satisfy the derived bounds, while highlighting trade-offs between performance and the conservatism of the computed invariant set.

17:00-17:20	TuC1.3

Force Polytope-Based Cant-Angle Selection for Tilting Hexarotor UAVs, pp. 419-426

Piccina, Alberto	University of Padua
Bertoni, Massimiliano	University of Padua
Cenedese, Angelo	University of Padua
Michieletto, Giulia	University of Padua

From a maneuverability perspective, the main advantage of tilting multirotor UAVs lies in the dynamic variability of the feasible executable wrench, which represents a key asset for physical interaction tasks. Accordingly, cant-angle selection should be optimized to ensure high performance while avoiding abrupt variations and preserving real-world feasibility. In this context, this work proposes a lightweight control framework for star-shaped interdependent cant-tilting hexarotor UAVs performing interaction tasks. The method uses an offline-computed look-up table of zero-moment force polytopes to identify feasible cant angles for a desired control force and select the optimal one by balancing efficiency and smoothness. The framework is integrated with a geometric full-pose controller and validated through Monte Carlo simulations in MATLAB/Simulink and compared against a baseline strategy. The results show a significant reduction in computation time, together with improved pose-tracking performance and competitive actuation efficiency. A final physics-based simulation of a complete wall inspection task in Simscape further confirms the feasibility of the proposed strategy in interacting scenarios.

17:20-17:40	TuC1.4

Lyapunov-Driven Control Design for Quadrotors with Heading–Velocity Command Inputs: Further Insights towards a Digital Twin, pp. 427-434

Malpica-Velasco, Esau	Centro De Investigación Y De Estudios Avanzados Del Instituto Politécnico Nacional
Rodriguez-Cortes, Hugo	Centro De Investigación Y De Estudios Avanzados Del Instituto Politécnico Nacional
Guerrero, Fermi	Benemerita Universidad Autonoma De Puebla
Amparan Estrada, Jesus Ramon	Centro De Investigación Y De Estudios Avanzados Del Instituto Politécnico Nacional

Commercial quadrotors typically expose to the pilot a reduced set of control inputs that correspond to intuitive first-order motion commands, such as the desired translational velocity expressed in a heading-aligned frame and the desired yaw rate. The underlying onboard autopilot is responsible for mapping these pilot commands into thrust and moment references that command the full nonlinear quadrotor dynamics. Motivated by this industrial practice, this paper formulates the problem of designing an onboard controller that emulates the closed-loop behavior of commercial velocity-commanded quadrotors. A pilot-level kinematic reference model is introduced, in which the commanded heading frame directly drives the translational position, yaw dynamics, velocity, and yaw rate. Using the standard rigid-body quadrotor model, it is shown, via Lyapunov stability analysis, that this behavior can be emulated by regulating a velocity-tracking error defined in the heading frame. This formulation naturally leads to a cascaded control architecture, consistent with commercial autopilot implementations, and provides a principled framework for reproducing commercial flight behavior on custom quadrotor platforms. Software-in-the-loop (SIL) simulations with X-Plane providing the flight dynamics model and MATLAB/Simulink executing the control algorithm, along with experimental results, validating the proposed controller.

17:40-18:00	TuC1.5

Load Transportation by a Single Quadrotor Using the Null Space Behavioral Control Technique, pp. 435-441

Spagnol, Felipe Andrade	Universidade Federal Do Espírito Santo
Cordeiro, Rafael	Universidade Federal Do Espírito Santo
Villa, Daniel Khede Dourado	Universidade Federal Do Espírito Santo
Sarcinelli-Filho, Mário	Universidade Federal Do Espírito Santo

This work addresses the use of the null-space-based behavioral control technique to design a controller for guiding a single quadrotor during the transport of a cable-suspended load. The adopted control paradigm is the virtual structure one, for which the virtual structure is the imaginary vertical line connecting the drone and the load. The control objective is to maintain the virtual structure in the vertical position during task execution, thereby minimizing load swing. The designed controller is discussed in detail, and experimental results from a quadrotor equipped with this controller to transport a cable-suspended load in an indoor environment are presented and analyzed, thereby validating the approach adopted for the application. To obtain the necessary feedback, namely the position and velocity of the

quadrotor and the load, a motion capture system is used, enabling accurate measurements.

18:00-18:20	TuC1.6

Speed-Based Trajectory Tracking Control for Fixed-Wing UAV, pp. 442-449

Mendes Potes, André	Technology Innovation Institute
Retamal Guiberteau, Victor	Technology Innovation Institute
Wakode, Ashay	Technology Innovation Institute
Garcia, Jeison	Technology Innovation Institute
Barciś, Agata	Technology Innovation Institute
Nguyen, Hung	Technology Innovation Institute

Reliable and safe trajectory tracking control is critical for many missions involving fixed-wing unmanned aerial vehicles (FW-UAVs). This paper presents a simple, safe, and practical solution to the trajectory tracking problem for FW-UAVs, where the vehicle is required to track a time-parameterized curve defined by a sequence of waypoints. By leveraging the built-in path-following capabilities already available in widely used autopilot systems such as PX4, the proposed approach reduces the trajectory tracking problem to speed command regulation. Instead of redesigning low-level controllers, the method achieves time coordination along the trajectory by appropriately commanding the vehicle's air speed, while relying on the autopilot's internal guidance and stabilization loops for lateral and altitude tracking. The proposed solution is validated through extensive Monte Carlo simulations in the Gazebo simulator, as well as real flight experiments with both single and multiple (Vertical Take-Off and Landing) VTOL UAVs. The experimental scenarios include missions requiring precise trajectory tracking to achieve simultaneous destination arrival, both along the path and at the final waypoint. Simulation and flight test results demonstrate that the proposed method provides reliable, safe, and accurate trajectory tracking performance.

TuC2	**Lounge A**
Micro and Mini-UAS and Biologically Inspired UAS (Regular Session)	
Chair: Briñón Arranz, Lara	Université Grenoble Alpes
Co-Chair: Armanini, Sophie F.	Imperial College London

16:20-16:40	TuC2.1

Low-Compute Event-Based Navigation for Micro-Drones in Confined Subterranean Environments, pp. 450-457

Arogeti, Shai	Ben-Gurion University of the Negev
Hen, Tal	Ben-Gurion University of the Negev

Micro-drones under 250g offer unique potential for exploring confined subterranean environments such as mines, tunnels, and caves, where larger robots cannot operate. However, complete autonomous explore-and-return navigation in such GPS-denied spaces remains highly challenging for these platforms: existing topological and metric SLAM methods require lidar-class sensors or GPU-class compute, exceeding strict size-weight-power budgets. We present a novel topological navigation pipeline designed from the ground up for sparse depth sensing and CPU-only compute. Our approach builds confidence-aware radial profiles from sparse ToF arrays, applies potential-based stabilization to filter transient junction detections, and adapts landmark matching to accumulated odometry drift through covariance-scaled search gates. Rotation-invariant Fourier descriptors enable re-identification during return navigation despite different approach headings. We validate the system using hardware-in-the-loop simulation on the target embedded platform (RADXA Zero 2 Pro, ARM Cortex-A55), achieving, 2 Hz perception cycles. To our knowledge, this is the first complete explore-and-return pipeline for sub-250g platforms using sparse ToF-based event perception and lightweight onboard odometry.

16:40-17:00	TuC2.2

RoboticsXR: Extended Reality for Robotics Visual Navigation, pp. 458-463

Petre, Ricioppo	Politecnico Di Torino
Enrico, Riccardo	Politecnico Di Torino
Sarvadon, Jean-Luc	Politecnico Di Torino
Ruggiero, Dario	Politecnico Di Torino
Capello, Elisa	Politecnico Di Torino

Virtual Environments and Extended Reality (XR) have transformed artificial intelligence and robotics research by enabling realistic simulations for training and testing. XR enables the seamless integration of digital and physical spaces, offering new opportunities for training and testing autonomous systems. In this work, we propose RoboticsXR, an XR-based framework where a robot operates in a physical lab while images are captured from a virtual environment. This approach fuses real-world motion with synthetic visual data to develop and validate visual navigation algorithms efficiently. RoboticsXR feasibility is assessed using a convolutional neural network trained on synthetic images from NVIDIA Isaac. Performance is compared across different hardware platforms and using virtual and real camera images. Real-time performance is evaluated for a UAV moving in a confined test area, while virtual images from a synthetic mountain environment are shared with the robotic platform. Results highlight RoboticsXR's potential to extend laboratory testing capabilities, reduce costs, and improve the reliability of vision-based navigation in autonomous robotics systems.

17:00-17:20	TuC2.3

Evidence-Based Landing Site Selection and Vison-Based Landing for UAVs in Unstructured Environments, pp. 464-471

Sajjadi, Sina	National Research Council Canada
Panerati, Jacopo	National Research Council Canada
Soleymanpour, Sina	National Research Council Canada
Mehta, Varun	National Research Council Canada

Janabi Sharifi, Farrokh — Toronto Metropolitan University
Mantegh, Iraj — National Research Council Canada

Autonomous landing in cluttered or unstructured environments remains a safety-critical challenge for unmanned aerial vehicles (UAVs), particularly under noisy perception caused by sensor uncertainty and platform-induced disturbances such as vibration. This paper presents an evidence-based probabilistic framework for autonomous UAV landing that explicitly separates decision-making under uncertainty from execution via visual servoing. Landing safety is modeled as a latent variable and inferred through recursive accumulation of frame-wise visual likelihoods derived from flatness, slope, and obstacle cues, yielding a temporally consistent belief map that is robust to transient perception errors. Physical feasibility is enforced through a hard geometric constraint based on the minimum required landing radius of the UAV, ensuring that undersized but visually appealing regions are rejected. The final landing site is selected using constrained maximum a posteriori estimation. Once selected, the UAV locks onto the target region using ORB feature tracking and performs precise alignment and descent via image-based visual servoing (IBVS). The proposed approach is validated through both real-world laboratory experiments and high-fidelity simulations in Nvidia Isaac Sim, demonstrating consistent, cautious, and stable landing behavior across domains.

17:20-17:40 — TuC2.4

Distributed Gradient-Based Control for Reconfigurable Regular Polygon Formations in Multi-UAV Systems, pp. 472-479

Skantzikas, Kostas — Université Grenoble Alpes
Briñón Arranz, Lara — Université Grenoble Alpes
Susbielle, Pierre — Université Grenoble Alpes
Marchand, Nicolas — Université Grenoble Alpes

This paper addresses distributed formation control for multiple aerial robots. We design a new distance-based control strategy to steer a team of UAVs toward equally spaced planar configurations, with particular focus on regular polygon-shaped formations. The distributed controller, based on attractive-repulsive potential fields, does not require prescribed desired distances and enables real-time formation reconfiguration when the team composition changes, preserving equal spacing. The Lyapunov/LaSalle framework is used to analyze the stability of the proposed control, and equilibrium configurations are investigated via Hessian-based analysis. Real-world experiments with a team of UAVs validate the efficacy of the proposed gradient-based control and demonstrate convergence to stable reconfigurable polygon formations.

17:40-18:00 — TuC2.5

Comparative Analysis of Different Polymer Membranes for Enhanced Aerodynamic Efficiency in FWMAVs, pp. 480-487

Hammad, Ahmad — Technical University of Munich
Remakanthan, Devanarayanan — Technical University of Munich
Eldo, Joel — Technical University of Munich
Armanini, Sophie F. — Imperial College London

Flapping-Wing Micro Aerial Vehicles (FWMAVs) have advanced considerably in recent years due to their versatility and ability to operate in cluttered environments. However, their real-world use remains limited by endurance constraints and the inability to carry heavy payloads. The unsteady aerodynamics governing these vehicles also significantly determine their performance, driven by their flapping motion and flexible wing membrane. This makes the material selection for the wing membrane a key aspect in the design of these vehicles. However, a systematic comparative analysis of membrane material properties remains a gap in the literature, especially for larger bird-like FWMAVs. This study presents an experimental investigation of the aerodynamic characteristics of FWMAV with wings made from different flexible materials. Systematic testing has been conducted using a load cell to evaluate their performance and the influence of the wing membrane material. Wings were tested for lift and thrust generation across a range of flapping frequencies and at a constant 25% throttle setting. Mylar (PET) wing yielded the highest averaged lift over one flapping cycle and demonstrated a lift-to-weight ratio of 0.747 at a flapping frequency of 3.75 Hz, outperforming Ripstop Nylon by a factor of 4.7. Whereas Nylon showed better thrust performance, especially at higher flapping frequencies, producing 1.170~N net thrust at 3.75 Hz, nearly 180% higher than the 0.420 recorded for Ripstop Nylon. Results indicate that the wing membrane significantly influences the vehicle's performance, and that a systematic selection is crucial given the mission requirements. This work provides insight into the wing membrane effect on performance and enhances current knowledge of FWMAV wing design.

18:00-18:20 — TuC2.6

A Bi-Level Optimization Framework Based Conceptual Design of Flapping Wing UAV, pp. 488-495

Bhamidipati, Srinath Dhatre — International Institute of Information Technology Hyderabad
Mavurapu, Akshith Reddy — International Institute of Information Technology Hyderabad
Joseph, Jonish Abisheck — Birla Institute of Technology and Science Pilani
Kandath, Harikumar — International Institute of Information Technology Hyderabad

The conceptual design of Flapping-Wing Uncrewed Aerial Vehicles (FWUAVs) is currently constrained by the trade-off between computational cost and modeling fidelity. While high-fidelity solvers like Unsteady Vortex Lattice Methods (UVLM) capture the complex physics of flapping flight, they are too computationally expensive for iterative design optimization. To address this gap, this paper introduces a novel automated inverse-design methodology that directly translates high-level mission requirements into optimized physical hardware specifications. We propose a bi-level optimization framework coupled with a Gaussian Process Regression (GPR) aerodynamic surrogate model, enabling instantaneous force predictions across the design space. The architecture's outer level performs a global search over wing geometry, while the inner level solves trim-feasible flight kinematics to ensure every candidate design is physically viable. To ensure the reliability of the proposed designs, the underlying aerodynamic and power models are validated against experimental data from three ornithopter prototypes, achieving endurance predictions with a low margin of error relative to the observed values across scales.

TuC3	**Calypso A**
Navigation (Regular Session)	

Chair: Ollero, Anibal	Universidad De Sevilla
Co-Chair: Perez-Grau, Francisco Javier	Advanced Center for Aerospace Technologies

16:20-16:40 TuC3.1

Temporal-Augmented Observation for Navigation of Unmanned Aerial Vehicles: A Recurrent Reinforcement Learning Architecture, pp. 496-502

Gemignani, Gabriele — University of Pisa
Perrusquía, Adolfo — Cranfield University
Tsourdos, Antonios — Cranfield University
Pollini, Lorenzo — University of Pisa

In aerial robotics, data-driven Reinforcement Learning (RL) approaches have proven highly effective for obstacle avoidance and goal-directed navigation, especially when operating on high-dimensional sensor data that provide only partial, local information about the environment. Such limited observability, combined with irregularly shaped obstacles, poses significant challenges for reactive control policies that rely solely on instantaneous observations. To address these issues, this paper introduces a Twin Deep Deterministic Policy Gradient (TD3)-based algorithm that leverages explicit Temporal Augmentation of the Observation space (TAO-TD3). The proposed method preserves the simplicity of the original TD3 framework by augmenting the observation with a short history of past states and incorporating a lightweight recurrent network, without requiring changes to the TD3 training paradigm. Extensive simulations across diverse environmental topographies and irregular obstacle shapes demonstrate that the proposed approach nearly halves the collision rate and improves overall navigation success compared to feedforward RL-based architectures.

16:40-17:00 TuC3.2

Conservative Cost-Aware SAC-Lagrangian for Safe UAV Autonomous Navigation, pp. 503-510

Liu, Jinlun — University of Denver
Valavanis, Kimon P. — University of Denver

Autonomous navigation of multi-rotor unmanned aerial vehicles (UAVs) in confined and cluttered three-dimensional (3D) environments requires balancing goal reaching efficiency with safety constraints related to obstacle avoidance and workspace boundaries. Conventional navigation methods can be limited by model dependence, replanning cost, and reduced adaptability when obstacle configurations vary. Deep reinforcement learning (DRL) provides a flexible closed-loop decision-making framework, but standard reward-based methods do not explicitly constrain safety violations. To address this issue, this paper proposes Conservative Cost-Aware Soft Actor-Critic Lagrangian (CCSAC-Lag), a safe DRL framework that combines Soft Actor-Critic (SAC) with a Lagrangian cost-constraint mechanism. The navigation task is formulated as a constrained Markov decision process (CMDP), where safety violations are represented by an independent indicator cost rather than being merged into the reward. To reduce cost underestimation under sparse safety events, CCSAC-Lag employs twin cost critics with a conservative maximum backup over cost estimates. The proposed method is evaluated in a physics-based ROS-Gazebo simulation environment with randomized obstacle configurations. Experimental results show that CCSAC-Lag reduces safety violations and improves the success rate compared with standard SAC, while maintaining reasonable navigation efficiency. These results suggest that conservative cost-aware learning can improve safety compliance for multi-rotor navigation in bounded 3D environments.

17:00-17:20 TuC3.3

Efficient Goal-Conditioned Deep Reinforcement Learning for UAV Navigation: Zero-Shot Transfer from Static Goals to Dynamic Targets, pp. 511-518

Abellan-Galiana, Pablo — Advanced Center for Aerospace Technologies
Perez-Grau, Francisco Javier — Advanced Center for Aerospace Technologies
Viguria, Antidio — Advanced Center for Aerospace Technologies
Ollero, Anibal — Universidad De Sevilla

This work presents a lightweight, high-level planner for UAV navigation based on a Soft Actor-Critic (SAC) reinforcement learning policy. Trained in a simplified 3D simulation, the policy generates velocity commands to reach static goals and generalizes zero-shot to dynamic tasks, including trajectory tracking and pursuit of moving targets. A parallelized PyTorch implementation accelerates training, enabling convergence in under five minutes on accessible computing hardware. The policy was validated in SITL and controlled indoor flight experiments using a real UAV with Vicon-based localization. Results demonstrate that a policy trained under simplified assumptions can generalize to multiple navigation-related tasks while requiring modest onboard computational resources. A video demonstration of the main experiments can be found at https://youtu.be/R2PkxlgmO74.

17:20-17:40 TuC3.4

A Unified Error-State Kalman Filtering Framework for Multi-Sensor Navigation of Fixed-Wing UAVs in GNSS-Denied Scenarios, pp. 519-528

Villalobos Hernandez, Guillermo — Technology Innovation Institute
Costa Fernandes, Rafael — Technology Innovation Institute
Sorokin, Artem — Technology Innovation Institute
Korimi, Maheedhar — Technology Innovation Institute
Oliveira e Silva, Felipe — Federal University of Lavras

Reliable navigation in Global Navigation Satellite System (GNSS)-denied environments remains a critical challenge for fixed-wing Unmanned Aerial Vehicles (UAVs). In such conditions, Inertial Navigation Systems (INSs) must be aided by heterogeneous sensors to

mitigate drift and ensure long-term accuracy. This paper presents the development, implementation, and experimental validation of a unified Error-State Extended Kalman Filter (ESEKF) designed for fixed-wing UAV navigation under GNSS-denied and GNSS-degraded scenarios. The proposed framework integrates an INS with magnetometer, barometer, pitot tube with pseudovanes, Visual-Inertial Odometry (VIO), and Computer Vision (CV) Convolutional Neural Network (CNN)-based position estimates within a unified estimation architecture. A comprehensive mathematical description of the ESEKF is provided, with special attention given to the modeling of sensor systematic errors, which are explicitly included in the augmented error-state vector. The estimator performance is evaluated through a flight experiment using a custom fixed-wing UAV platform, where the contribution of each aiding sensor is assessed via systematic sensor deactivation under GNSS outage conditions. Experimental results demonstrate the robustness and modularity of the proposed ESEKF architecture, highlighting its ability to maintain navigation accuracy despite the loss of individual aiding sensors (except barometer and CV). The presented framework consolidates previously fragmented sensor fusion approaches into a single, self-consistent navigation solution, providing both a practical implementation reference and a foundation for future extensions and tuning strategies.

17:40-18:00 TuC3.5

Lights Out: A Nighttime UAV Localization Framework Using Thermal Imagery and Semantic 3D Maps, pp. 529-536

Allen, Ryan Cooper — Queen's University
Greeff, Melissa — Queen's University

Reliable backup localization for unmanned aerial vehicles (UAVs) operating in GNSS-denied nighttime conditions remains an open challenge due to the severe modality gap between daytime RGB maps and nighttime thermal imagery. This work presents a semantic reprojection framework for map-relative nighttime UAV localization by aligning segmented thermal observations with a globally referenced, semantically labeled 3D map constructed from daytime RGB data. Rather than relying on appearance-based correspondence, localization is formulated in a shared semantic domain and solved via a symmetric bidirectional reprojection objective with confusion-aware weighting to improve robustness under segmentation uncertainty. The approach is evaluated offline across 6.5 km of nighttime, real-world UAV flight trajectories in urban and semi-structured environments. Relative to RTK ground truth, the system achieves a bias-corrected RMSE_2D of 2.18 m and a median RMSE_2D of 1.52 m. Results show that localization performance is strongly correlated with the availability of semantic edge evidence and that large-error events are spatially localized to semantically ambiguous areas rather than uniformly distributed. These findings indicate that semantic reprojection offers a promising pathway toward globally referenced nighttime UAV localization using thermal imagery alone.

18:00-18:20 TuC3.6

Impedance Diffusion: Diffusion-Based Global Path Planning for UAV Swarm Navigation with Generative Impedance Control, pp. 537-544

Batool, Faryal — Skolkovo Institute of Science and Technology
Yaqoot, Yasheerah — Skolkovo Institute of Science and Technology
Mustafa, Muhammad Ahsan — Skolkovo Institute of Science and Technology
Khan, Roohan Ahmed — Skolkovo Institute of Science and Technology
Fedoseev, Aleksey — Skolkovo Institute of Science and Technology
Tsetserukou, Dzmitry — Skolkovo Institute of Science and Technology

Safe swarm navigation in cluttered indoor environment requires long-horizon planning, reactive obstacle avoidance, and adaptive compliance. We propose Impedance Diffusion, a hierarchical framework that leverages image-conditioned diffusion-based global path planning with Artificial Potential Field (APF) tracking and semantic-aware variable impedance control for aerial drone swarms. The diffusion model generates geometric global trajectories directly from RGB images. These trajectories are tracked by an APF-based reactive layer, while a VLM-RAG module performs semantic obstacle classification with 90 % retrieval accuracy to adapt impedance parameters for mixed obstacle environments during execution. Two diffusion planners are evaluated: (i) a top-view long-horizon planner using single-pass inference and (ii) a first person-view (FPV) short-horizon planner deployed via a two-stage inference pipeline on top view. Both planners achieve a 100 % trajectory generation rate across twenty static and dynamic experimental configurations and are validated via zero-shot sim-to-real deployment on Crazyflie 2.1 drones through the hierarchical APF-impedance control stack. The top-view planner produces smoother trajectories that yield conservative tracking speeds of 1.0-1.2 m/s near hard obstacles and 0.6-1.0 m/s near soft obstacles. In contrast, the FPV planner generates trajectories with greater local clearance and typically higher speeds, reaching 1.4-2.0 m/s near hard obstacles and up to 1.6 m/s near soft obstacles. Across 20 experimental configurations (100 total runs), the framework achieved a 92% success rate while maintaining stable impedance-based formation control with bounded oscillations and no in-flight collisions demonstrating reliable and adaptive swarm navigation.

TuC4 **Calypso B**

Airspace Operations and See-And-Avoid Systems (Regular Session)

Chair: Garbarino, Luca — Italian Aerospace Research Center CIRA
Co-Chair: Smeur, Ewoud — Delft University of Technology

16:20-16:40 TuC4.1

A Digital Twin Framework for Multi-UAV and U-Space Operations with Real-Time Testing Integration, pp. 545-552

Garbarino, Luca — Italian Aerospace Research Center
Gaudino, Maria — University of Naples
Vitale, Antonio — Italian Aerospace Research Center
Fasano, Giancarmine — University of Naples
Cuciniello, Giovanni — Italian Aerospace Research Center

The digital twin paradigm is increasingly recognized as a key enabler for advancing autonomy, safety, and operational reliability in unmanned aviation. This paper presents a digital twin-based simulation framework designed for single and multi-UAV operations, integrating offline and real-time execution modes within a unified environment. The system combines high-fidelity dynamic models of multiple UAV platforms with a MAVLink-based communication layer that ensures seamless interoperability with ground control stations such as QGroundControl and Mission Planner. In addition, the framework incorporates an interface to a U-Space Service Provider (USSP), enabling the evaluation of U-Space services and procedures in realistic operational scenarios. This integration supports real-time testing, hardware-in-the-loop experiments, and the assessment of cooperative mission behaviors under varying traffic and airspace conditions. By providing a controllable and risk-free environment, the digital twin reduces development time, cost, and safety concerns associated with real flight testing, while enabling both technical and operational performance evaluations. The paper describes the system architecture, key functionalities, and experimental capabilities, and outlines future research directions for enhancing digital-twin-enabled UAV and U-Space operations.

16:40-17:00 TuC4.2

Visual Verification of UAV Location in Remote Identification Messages, pp. 553-560

Obeid, Ahmad — Khalifa University
Saeed, Elyas — Khalifa University
Hejji, Dina — Khalifa University
Yohannes Woldegiorgish, Noah — Khalifa University
Rashid, M Ryyan — Khalifa University
Atrouz, Mohammad — Khalifa University
Shoufan, Abdulhadi — Khalifa University

Remote Identification (RID) is increasingly mandated to enhance drone traceability by broadcasting a UAV's identity, position, and other metadata for ground-based monitoring. However, the transmitted location can be falsified by operators to conceal restricted-area violations or compromised by GPS spoofing, causing ground observers to receive deceptive positional data. To address this, we propose a ground-based cross-modal verification system that validates RID-reported locations using visual data from a calibrated RGB camera. Given the camera's known position and the UAV's physical dimensions (retrieved via drone ID or inferred in real time) the system infers the UAV's range and compares it to the GPS-derived distance. Discrepancies exceeding an adaptive threshold are flagged as potential spoofing or manipulation events. For reproducibility, we release DroneR, a public dataset of UAV frames annotated with ground-truth range information. DroneR contains 208 images across two drone platforms, spanning distances of 3–50 m under varied lighting and background conditions, and includes scripted distance-error profiles that emulate spoofing scenarios. Experiments on DroneR demonstrate that the proposed verification system reliably detects both large and minor location falsifications, achieving a true positive rate of 0.8–0.91 with a corresponding false positive rate between 0.25 and 0.05. This performance supports consistent operational accuracy and practical deployability. The approach provides a complementary verification layer that strengthens cryptographic RID protection and enhances the security of UTM ecosystems. The code and dataset are publicly available at github.com/KU-USL/visual-location-authentication.

17:00-17:20 TuC4.3

Robust H∞ Controller Design for INDI-Controlled Quadrotor Using Online Parameter Identification, pp. 561-568

Aantjes, Tom — Delft University of Technology
Blaha, Till Martin — Delft University of Technology
Theodoulis, Spilios — Delft University of Technology
Smeur, Ewoud — Delft University of Technology

It has recently been shown that all physical parameters of an Incremental Nonlinear Dynamic Inversion (INDI) controller can be estimated onboard a multirotor within half a second, which is fast enough to do the full identification during a throw in the air. However, a robust method to tune outer loop gains for this feedback-linearizing INDI controller depending on the model parameters is still missing. This work presents the design of a robust gain-scheduled controller for attitude control of quadrotor, using an INDI-based inner loop with online identification of its system parameters. A gain-scheduled cascaded attitude controller with a feedforward filter is synthesized for a symmetric quadrotor using signal-based H∞ closed-loop shaping. The resulting controller exhibits good stability margins, with nonlinear simulations confirming effective tracking performance under uncertainty. Experimental evaluation is also conducted through flight tests with full online parameter identification. Even though the identified parameters during these tests are far outside the defined uncertainty range, acceptable flight performance comparable to simulation results is maintained for actuator time constants below 40 ms.

17:20-17:40 TuC4.4

INDI Control of Fixed-Wing Tilt-Rotor Applied to Tethered Flight, pp. 569-576

Villanueva Aguado, Mauro — ENAC
Bronz, Murat — ENAC

The use of unmanned aerial vehicles (UAVs) for physical interaction and aerial manipulation introduces significant technical challenges. While quadrotors are widely adopted for these tasks, their reliance on purely vertical thrust fundamentally limits their energy efficiency during sustained transport missions. Hybrid tilt-rotor configurations decouple thrust vectoring from attitude control, at the cost of tightly coupled, nonlinear aerodynamics during transition. The fixed-wing tilt-rotor configuration investigated in this paper features independently tiltable left and right rotor pairs, decoupling pitch from forward acceleration, so the wing can operate at its optimal angle of attack. This paper presents a unified control architecture based on Incremental Nonlinear Dynamic Inversion (INDI) for this platform, specifically applied to tethered flight. Simulation results on a circular trajectory demonstrate both the controller's tracking accuracy and the efficiency of the platform: compared to a baseline quadrotor, the tiltrotor reduces specific power consumption by 47%, and the tethered configuration by 38% while maintaining precise tracking through transition under the tether disturbances.

17:40-18:00 TuC4.5

Obstacle Detection for Fixed-Wing UAVs Using a Digital Twin and Deep Learning, pp. 577-584

Loyaga Carranza, Erick Steven — Escuela Politécnica Nacional
Chamorro Hernandez, William Oswaldo — Escuela Politecnica Nacional

Quinatoa Catota, Estefano Dario | Escuela Politécnica Nacional
Vandewalle, Patrick | KU Leuven
Valencia Torres, Esteban Alejandro | Escuela Politécnica Nacional

High-Andean wetlands are critical for water supply in Ecuador, but their monitoring requires beyond-visual-line-of-sight (BVLOS) UAV operations in harsh, obstacle-rich environments. Fixed-wing and VTOL platforms are suitable for large-area monitoring but lack affordable obstacle avoidance systems adapted to high-speed flight. This work proposes a deep-learning-based obstacle detection framework for high-speed VTOL UAVs operating at up to 20 m/s. The proposed network, based on an enhanced SSD architecture with binary mask segmentation, estimates obstacle dimensions (height and width) and distance at ranges up to 200 m, enabling early detection compatible with aerodynamic maneuvering constraints. For safe development and validation, a high-fidelity digital twin was implemented in ROS and Gazebo, integrating a five-motor VTOL model with ArduPilot and QGroundControl. The digital twin enables controlled simulation, dataset generation, and algorithm evaluation without operational risk. Results show reliable long-range obstacle detection across multiple distance intervals, supporting future integration with collision avoidance systems for high-speed environmental-monitoring UAVs.

Wednesday, June 17, 2026

WeA1 | **Nafsika**
Control Architectures III (Regular Session)

Chair: Cavone, Graziana | Università Degli Studi Roma Tre
Co-Chair: Rastgoftar, Hossein | University of Arizona

11:20-11:40 | WeA1.1

Identification and Control of a Planar Quadrotor from Visual Data Using Koopman Representations, pp. 585-592

Bongiovanni, Nicolas | Université Côte D'Azur
Mavkov, Bojan | Université Côte D'Azur
Martins, Renato | Université Bourgogne Europe
Allibert, Guillaume | Université Côte D'Azur

Identifying predictive models of nonlinear dynamical systems directly from visual observations remains a fundamental challenge, particularly in the context of control. In this paper, we propose a deep learning–based Koopman identification framework that learns control-oriented models of nonlinear dynamical systems from visual data. In contrast to existing Koopman-based approaches, our method incorporates additional geometric consistency losses and represents the lifted system dynamics using both linear and bilinear model formulations. Closed-loop trajectory-tracking simulations of a quadrotor observed by an external camera demonstrate the model's capacity to accurately capture the underlying system dynamics, enabling reliable visual predictions and effective visual control.

11:40-12:00 | WeA1.2

Rule-Based High-Level Coaching for Goal-Conditioned Reinforcement Learning in Search-And-Rescue UAV Missions under Limited-Simulation Training, pp. 593-600

Ramezani, Mahya | University of Luxembourg
Voos, Holger | University of Luxembourg

This paper presents a hierarchical decision-making framework for unmanned aerial vehicle (UAV) missions motivated by search-and-rescue (SAR) scenarios under limited simulation training. The framework combines a fixed rule-based high-level advisor with an online goal-conditioned low-level reinforcement learning (RL) controller. To stress-test early adaptation, we also consider a strict no-pretraining deployment regime. The high-level advisor is defined offline from a structured task specification and compiled into deterministic rules. It provides interpretable mission- and safety-aware guidance through recommended actions, avoided actions, and regime-dependent arbitration weights. The low-level controller learns online from task-defined dense rewards and reuses experience through a mode-aware prioritized replay mechanism augmented with rule-derived metadata. We evaluate the framework on two tasks: battery-aware multi-goal delivery and moving-target delivery in obstacle-rich environments. Across both tasks, the proposed method improves early safety and sample efficiency primarily by reducing collision terminations, while preserving the ability to adapt online to scenario-specific dynamics.

12:00-12:20 | WeA1.3

Deep Q-Learning-Based Gain Scheduling for Nonlinear Quadcopter Dynamics, pp. 601-608

Rastgoftar, Hossein | University of Arizona
Zahed, Muhammad Junayed Hasan | University of Arizona

This paper presents a deep Q-network (DQN)–based gain-scheduling framework for safety-critical quadcopter trajectory tracking. Instead of directly learning control inputs, the proposed approach selects from a finite set of pre-certified stabilizing gain vectors, enabling reinforcement learning to operate within a structured and stability-preserving control architecture. By exploiting the isotropic structure of the translational dynamics, feedback gains are shared across spatial axes to reduce dimensionality while preserving performance. The learned policy adapts feedback aggressiveness in real time, applying high authority during large transients and reducing gains near convergence to limit control effort. Simulation results using a high-fidelity nonlinear quadcopter model demonstrate accurate trajectory tracking, bounded attitude excursions, smooth transition to hover after the final time, and consistent reward improvement, validating the effectiveness and robustness of the proposed learning-based gain scheduling strategy.

12:20-12:40 | WeA1.4

Neural PMP-NMPC for Adaptive and Stable Quadrotor Control in Perception-Driven Tasks, pp. 609-616

Mukherjee, Pratik | Florida Atlantic University

This paper presents a learning-based optimal control framework for stable and perception-aware quadrotor flight in near-ground, obstacle-adjacent, and close-proximity multi-robot environments central to Active Information Acquisition (AIA) tasks. In these regimes, quadrotors experience poorly modeled aerodynamic disturbances from propeller downwash and inter-vehicle interactions that degrade tracking and stability. We develop a Pontryagin-based Nonlinear Model Predictive Control (PMP-NMPC) framework that integrates optimal trajectory planning with online disturbance compensation. A spectrally normalized Deep Neural Network (DNN) learns residual downwash and interaction-induced dynamics and is embedded within the control loop to preserve boundedness and stability. A Lyapunov analysis establishes local finite-time practical stability under bounded disturbance approximation error. Simulations on Gym-PyBullet, a physics-based rigid-body simulation environment, demonstrate stable flight, effective disturbance rejection, and improved perception performance in disturbance-rich close-proximity scenarios.

12:40-13:00	WeA1.5

Adaptive and Predictive Control of UAS in Train-Drone Delivery System, pp. 617-624

Cavone, Graziana	Università Degli Studi Roma Tre
Bardanzellu, Marco	Università Degli Studi Roma Tre
Pascucci, Federica	Università Degli Studi Roma Tre

This paper addresses the control of a quadrotor operating in a hybrid train–drone delivery system, focusing on payload uncertainty and landing on a moving railway platform. The considered mission includes take-off from a train entering a logistics terminal, cruise flight to a delivery location, and dynamic re-landing on the departing train. A hierarchical control architecture based on Model Predictive Control (MPC) is presented. It integrates trajectory generation, constrained MPC trajectory tracking, and an online parameter adaptation scheme based on recursive least squares for mass estimation. The adaptive model is embedded in the MPC prediction model, allowing real-time compensation of payload variations without direct payload measurements. Dynamic landing is formulated as a time-varying constrained tracking problem where the landing target evolves according to the train kinematic model. Simulation results validate the proposed architecture across the mission phases, showing accurate trajectory tracking, robustness to payload mismatch, and reliable landing on a moving platform.

13:00-13:20	WeA1.6

Full Actuator Nonlinear Dynamic Inversion for Enhanced Hybrid UAV Control, pp. 625-632

Dubois, Justin Petrus G.	Delft University of Technology
Ntouros, Evangelos	Delft University of Technology
Smeur, Ewoud	Delft University of Technology

Expanding the operational capabilities of Micro Air Vehicles (MAVs) hinges on control systems that manage highly nonlinear dynamics across broad flight envelopes. Incremental Nonlinear Dynamic Inversion (INDI) is popular for its simplicity and modest modeling needs, but its assumption of infinitely fast actuators and neglect of state-dependent effects limit performance when actuators have slow or heterogeneous dynamics or when aerodynamic effects are significant. Actuator Nonlinear Dynamic Inversion (ANDI) overcomes these limitations by explicitly incorporating state-dependent dynamics and finite actuator bandwidth into the control law, enabling improved tracking performance across diverse actuator configurations. This work implements the full ANDI stabilization controller on the Cyclone, a hybrid MAV tail-sitter, using cascaded complementary filtering for state estimation. Simulation and flight experiments validate the approach and assess whether this compensation yields practical performance gains, establishing ANDI as a viable, generic control solution for MAVs. Code is available at https://github.com/tudelft/paparazzi/.

WeA2	**Lounge A**
Multirotor Design and Control III (Regular Session)	
Chair: Michieletto, Giulia	University of Padua
Co-Chair: Ciresola, Federico	University of Padua

11:20-11:40	WeA2.1

Geometric Inverse Flight Dynamics on SO(3) and Application to Tethered Fixed-Wing Aircraft, pp. 633-640

Franchi, Antonio	Univ. of Twente and Sapienza Univ. of Rome
Gabellieri, Chiara	University of Twente

We present a robotics-oriented, coordinate-free formulation of inverse flight dynamics for fixed-wing aircraft on SO(3). Translational force balance is written in the world frame and rotational dynamics in the body frame; aerodynamic directions (drag, lift, side) are defined geometrically, avoiding local attitude coordinates. Enforcing coordinated flight (no sideslip), we derive a closed-form trajectory-to-input map yielding the attitude, angular velocity, and thrust–angle-of-attack pair, and we recover the aerodynamic moment coefficients component-wise. Applying such a map to tethered flight on spherical parallels, we obtain analytic expressions for the required bank angle and identify a specific zero-bank locus where the tether tension exactly balances centrifugal effects, highlighting the decoupling between aerodynamic coordination and the apparent gravity vector. Under a simple lift/drag law, the minimal-thrust angle of attack admits a closed form. These pointwise quasi-steady inversion solutions become steady-flight trim when the trajectory and rotational dynamics are time-invariant. The framework bridges inverse simulation in aeronautics with geometric modeling in robotics, providing a rigorous building block for trajectory design and feasibility checks.

11:40-12:00	WeA2.2

Hardware-Aware SE(3) Control Barrier Functions for Counter-UAS Interceptors with Directed Energy Payloads, pp. 641-647

Vlachos, Evangelos	ATHENA Research Center
Kolios, Panayiotis	University of Cyprus

Skliros, Christos Hellenic Drones S.A

Strict power limits on small drone interceptors constrain the use of reusable directed energy payloads such as RF jammers and High-Power Microwave (HPM) sources. High-gain beams can close the engagement link budget with minimal transmit power, but their required tight Field of View (FoV) conflicts with the aggressive maneuvers of pursuing multi-rotor. This paper resolves this conflict with a hardware-aware safety filter using Control Barrier Functions (CBFs) on the SE(3) manifold. The filter provides formal pointing guarantees, enabling highly directional antennas whose gain would otherwise be sacrificed for pointing tolerance. We formulate a phased array's electronic steering limits as a relative-degree-two safety constraint with analytically verified Lie derivatives and solve the resulting Quadratic Program (QP) via ADMM with a constant-time core factorization. Validation in a nonlinear SE(3) simulation and a custom 6-DOF Software-in-the-Loop (SITL) environment demonstrates the proposed CBF eliminates all FoV violations and recovers up to 12.0 dB of antenna gain by tightening the beam. The approach also reveals conventional pitch clamping provides negligible benefit against FoV violations, avoids the severe actuator-saturation failure modes of multi-step Model Predictive Control (MPC)-CBF architectures, and executes reliably in under 350 μs.

12:00-12:20 WeA2.3

Probabilistic Attainable Moment Sets for Uncertainty-Aware Design Optimization, pp. 648-655

Tsagkaris, Michail Technical University of Munich
Holzapfel, Florian Technical University of Munich
Armanini, Sophie F. Imperial College London
Ryll, Markus Technical University of Munich

This paper introduces Probabilistic Attainable Moment Sets for uncertainty-aware aircraft design optimization as an extension of the classical Attainable Moment Set concept to account for parametric uncertainty in actuator effectiveness. A computational method based on first-order parametric linearization of actuator models is proposed to propagate uncertainty through the control effectiveness mapping. The resulting probabilistic formulation enables the evaluation of control authority in terms of the likelihood of moment-space constraint violations rather than deterministic feasibility. Building on this framework, design optimization problems are formulated using a probabilistic metric that quantifies the probability of violating prescribed moment-space constraints. Two multirotor case studies are presented in which rotor tilt angles are optimized under actuator uncertainty, demonstrating the effectiveness of the proposed approach to uncertainty-aware aircraft design optimization.

12:20-12:40 WeA2.4

Control Input Allocation for Tilting Multirotors - a Review, pp. 656-663

Ciresola, Federico University of Padua
Sorge, Marcello University of Padua
Michieletto, Giulia University of Padua
Cenedese, Angelo University of Padua

Tilting multirotor platforms have gained significant attention in the research community due to their over-actuation and input redundancy capabilities. However, these features introduce complex challenges, such as the design of new nonlinear controllers and the use of control input allocation to fully exploit the redundancy of these platforms. A cascaded architecture comprising a high-level controller, a control allocation layer, and a low-level controller to command the actuators and rotors, offers great flexibility and space for co-design. This allows ad-hoc control allocation approaches to be defined without requiring modifications to the high-level controller. This review analyzes different methods of allocating control inputs presented in the literature and discusses their respective advantages and disadvantages. Furthermore, it categorizes these methods into three distinct classes based on their fundamental characteristics.

12:40-13:00 WeA2.5

Hybrid Modeling of Multirotor UAVs with Learned Induced Velocity, pp. 664-671

Laiche, Ibrahim Sorbonne University
Boudaoud, Mokrane Pierre and Marie Curie University
Gallinari, Patrick Sorbonne University and Criteo AI Lab
Morin, Pascal Mines Paris PSL

This paper proposes a new hybrid (i.e., physics-based and data-driven) modeling approach for multirotor UAVs. The model favors the physics component to promote simplicity, physical consistency, and suitability for control and estimation tasks. It relies on a physics-based dynamic formulation derived from Blade Element Theory and Momentum Theory, while restricting learning to the induced velocity of each rotor. We study the impact of rotor flow interactions by comparing models with and without interaction terms. We also propose a velocity-based learning procedure and compare it with a force-based alternative. The proposed approach is evaluated on a real-world dataset. Results show that significant improvements in velocity prediction are obtained when rotor flow interactions are included. In addition, velocity-based training yields more accurate velocity prediction than force-based learning.

13:00-13:20 WeA2.6

Design and Aerodynamic Modeling of MetaMorpher: A Hybrid Rotary and Fixed-Wing Morphing UAV, pp. 672-679

Bosak, Anja University of Zagreb
Erić, Dorian University of Zagreb
Milas, Ana University of Zagreb
Bogdan, Stjepan University of Zagreb

In this paper, we present a generalized, comprehensive nonlinear mathematical model and conceptual design for the MetaMorpher, a metamorphic Unmanned Aerial Vehicle (UAV) designed to bridge the gap between vertical takeoff and landing agility and fixed-wing cruising efficiency. Building on the successful design of the spincopter platform, this work introduces simplified mechanical architecture using lightweight materials and a novel wing-folding strategy. Unlike traditional rigid-body approximations, we derive a nonlinear flight

dynamics model that enables arbitrary force distributions across a segmented wing structure. This modularity allows testing different airfoils, mass distributions, and chord lengths in a single environment. As part of this work, various flight modes were specifically tested and analyzed in the Simulink environment. The results show that the model behaves predictably under different structural configurations, demonstrating its reliability as a tool for rapid design evaluation.

WeA3	**Calypso A**
UAS Testbeds (Regular Session)	
Chair: d'Apolito, Francesco	Austrian Institute of Technology
Co-Chair: Peti, Marijana	University of Zagreb, Faculty of Electrical Engineering and Computing

11:20-11:40 WeA3.1

Aerial-Autonomy-Stack---A Faster-Than-Real-Time, Autopilot-Agnostic, ROS2 Framework to Simulate and Deploy Perception-Based Drones, pp. 680-688

Panerati, Jacopo — National Research Council Canada
Sajjadi, Sina — National Research Council Canada
Soleymanpour, Sina — National Research Council Canada
Mehta, Varun — National Research Council Canada
Mantegh, Iraj — National Research Council Canada

Unmanned aerial vehicles are rapidly transforming multiple applications, from agricultural and infrastructure monitoring to logistics and defense. Introducing greater autonomy to these systems can simultaneously make them more effective as well as reliable. Thus, the ability to rapidly engineer and deploy autonomous aerial systems has become of strategic importance. In the 2010s, a combination of high-performance computing, data, and open-source software led to the current deep learning and AI boom, unlocking decades of prior theoretical work. Robotics is on the cusp of a similar transformation. However, physical AI faces unique hurdles, often combined under the umbrella term “simulation-to-reality gap”. These span from modeling shortcomings to the complexity of vertically integrating the highly heterogeneous hardware and software systems typically found in field robots. To address the latter, we introduce aerial-autonomy-stack, an open-source, end-to-end framework designed to streamline the pipeline from (GPU-accelerated) perception to (flight controller-based) action. Our stack allows the development of aerial autonomy using ROS2 and provides a common interface for two of the most popular autopilots: PX4 and ArduPilot. We show that it supports over 20x faster-than-real-time, end-to-end simulation of a complete development and deployment stack---including edge compute and networking---significantly compressing the build-test-release cycle of perception-based autonomy.

11:40-12:00 WeA3.2

Development and Validation of an Instrumented Static Test Bench for Brushless Motors, pp. 689-695

Dudenko, Artur — Universidade Federal De Viçosa
Villibor, Geice Paula — Universidade Federal De Viçosa
Brandao, Alexandre Santos — Universidade Federal De Viçosa

The characterization of UAV propulsion systems requires reliable measurements of thrust and electrical performance, which are not always available from manufacturer datasheets under practical operating conditions. This paper presents the development and experimental validation of a low-cost instrumented static test bench for brushless motors used in UAV propulsion systems. The platform measures thrust, rotational speed, voltage, and current, enabling the analysis of propulsion performance and electrical power consumption. The mechanical structure was designed in CAD and fabricated using 3D printing with linear guides to reduce friction during thrust measurement. Sensor data are acquired using an Arduino-based system and processed in MATLAB for real-time visualization and analysis. Experimental validation was conducted using a Holybro motor–propeller assembly with reference data provided by the manufacturer. The results showed strong agreement with the expected propulsion behavior, confirming the quadratic relationship between thrust and RPM and the cubic trend between current and rotational speed. The proposed platform provides a reliable and accessible tool for propulsion testing and comparison of UAV motor–propeller configurations.

12:00-12:20 WeA3.3

An Integrated Testbed for Mission-Level Autonomy Evaluation in Evolving Disaster Scenarios with Fixed-Wing Swarms, pp. 696-703

Bolz, Wolfgang — Austrian Institute of Technology
Faber, Filip — Austrian Institute of Technology
Lork, Julian — Austrian Institute of Technology
Cella, Marco — Austrian Institute of Technology
Zendel, Oliver — Austrian Institute of Technology
d'Apolito, Francesco — Austrian Institute of Technology

Crisis and disaster response increasingly depends on persistent situational awareness over fast-changing hazards such as wildfires and floods. Fixed-wing UAV swarms are a promising enabler due to their wide-area coverage and endurance. Evaluating swarm mission supervision in these settings requires closed-loop scenarios that couple evolving environments to realistic vehicle dynamics and multi-agent execution. We present an integrated testbed for fixed-wing swarm supervision architectures that combine centralized mission reasoning with decentralized onboard behavior execution. The testbed integrates (i) a dynamic disaster scenario generator producing time-evolving hazard state and mission context, (ii) a multi-aircraft JSBSim-based flight dynamics simulation with control and energy modeling, and (iii) a decentralized guidance layer that executes a library of behavior primitives through a common interface and multi-rate updates. The framework supports deterministic seeding, synchronized replay, and logging of mission effectiveness and safety metrics for controlled comparisons. We validate the executability of primitives under calm and windy conditions within a bounded flight envelope and demonstrate end-to-end closed-loop operation on generated scenarios. An LLM-based supervisor is used as an example

client to exercise the mission interface and behavior primitives.

12:20-12:40 WeA3.4

Benchmarking Connectivity and Energy-Aware Algorithms Using Crazyflie UAVs: A Sim2Real Multi-Robot Framework, pp. 704-711

Peti, Marijana	University of Zagreb
Alamdar, Khawaja Ghulam	University of Zagreb
Kozlik, Marko	University of Zagreb
Ivanovic, Antun	University of Zagreb
Petric, Frano	University of Zagreb
Orsag, Matko	University of Zagreb
Bogdan, Stjepan	University of Zagreb

Maintaining network connectivity while managing limited battery resources is a real challenge in missions with multiple Unmanned Aerial Vehicles operating in cluttered environments. Although numerous connectivity-aware and energy-aware control strategies exist, they are often evaluated independently, limiting insight into their coupled effect. This paper presents a sim2real benchmarking framework for multi-robot UAV systems that enables systematic evaluation of connectivity preservation, battery management, and search mission performance under unified constraints. The framework integrates a Software-in-the-Loop Crazyflie simulator, a procedural world-generation pipeline, and a ROS 2-based interface and evaluation stack to ensure consistent deployment in both simulation and physical experiments. Communication constraints are modeled using range and line-of-sight–based connectivity graphs, while energy limitations require periodic returns to a charging base. Metrics quantify connectivity loss, recharging events, mission duration, and detection performance. In addition to that, several examples of benchmark worlds are provided. The platform was validated through deployment in the UAV Competition as a part of the 2025 International Conference on Unmanned Aircraft Systems, featuring simulation-based qualifications and real-world finals. Experimental insights highlight remaining sim2real gaps in battery dynamics, communication robustness, and middleware configuration.

12:40-13:00 WeA3.5

ROScopter: A Multirotor Autopilot Based on ROSflight 2.0, pp. 712-719

Moore, Jacob	Brigham Young University
Reid, Ian	Brigham Young University
Tokumaru, Phillip	AeroVironment Inc
Beard, Randal W.	Brigham Young University
McLain, Tim	Brigham Young University

ROScopter is a lean multirotor autopilot built for researchers. ROScopter seeks to accelerate simulation and hardware testing of research code with an architecture that is both easy to understand and simple to modify. ROScopter is designed to interface with ROSflight 2.0 and runs entirely on an onboard flight computer, leveraging the features of ROS 2 to improve modularity. This work describes the architecture of ROScopter and how it can be used to test application code in both simulated and hardware environments. Hardware results of the default ROScopter behavior are presented, showing that ROScopter achieves similar performance to another state-of-the-art autopilot for basic waypoint-following maneuvers, but with a significantly reduced and more modular codebase.

13:00-13:20 WeA3.6

ROSflight 2.0: Lean ROS 2-Based Autopilot for Unmanned Aerial Vehicles, pp. 720-728

Moore, Jacob	Brigham Young University
Tokumaru, Phillip	AeroVironment, Inc
Reid, Ian	Brigham Young University
Sutherland, Brandon	Brigham Young University
Ritchie, Joseph	Brigham Young University
Snow, Gabe	Brigham Young University
McLain, Tim	Brigham Young University

ROSflight is a lean, open-source autopilot ecosystem for unmanned aerial vehicles (UAVs). Designed by researchers for researchers, it is built to lower the barrier to entry to UAV research and accelerate the transition from simulation to hardware experiments by maintaining a lean (not full featured), well-documented, and modular codebase. This publication builds on previous treatments and describes significant additions to the architecture that improve the modularity and usability of ROSflight, including the transition from ROS1 to ROS2, supported hardware, low-level actuator mixing, and the simulation environment. We believe that these changes improve the usability of ROSflight and enable ROSflight to accelerate research in areas like advanced-air mobility. Hardware results are provided, showing that ROSflight can control a multirotor over a serial connection at 400 Hz while closing all control loops on the companion computer.

WeA4 **Calypso B**

Autonomous Aerial Operations and Field Inspection (Regular Session)

Chair: Bechlioulis, Charalampos	University of Patras
Co-Chair: Karras, George	University of Thessaly

11:20-11:40 WeA4.1

Unmanned Aerial Vehicle Safe Autonomous Landing, pp. 729-736

Tsoukalas, Athanasios	New York University Abu Dhabi

Unlu, Halil Utku New York University Abu Dhabi
Evangeliou, Nikolaos New York University Abu Dhabi
Tzes, Anthony New York University Abu Dhabi

The secure landing of an Unmanned Aerial Vehicle (UAV) in a cluttered environment is considered. Using a downward-facing depth sensor, the UAV detects obstacles by taking depth point-cloud measurements. These measurements are rectified depending on the UAV's roll and pitch angles provided by its autopilot. The planes of the obstacles are then extracted from the normal vectors using an agglomerative clustering technique. Planes with normal directions perpendicular to the gravity vector are subsequently excluded. The remaining planes are feasible candidates for landing. Using a UAV-centered circular convex hull, areas within those non-convex planes are sought within which the UAV can safely land. Using a variation of the poles of inaccessibility algorithm, the maximum area-wise inscribed circle is computed in each plane. If more than one circle is computed containing the UAV's hull, the farthest one is selected depending on the average depth value. Experimental studies using a quadrotor are offered to highlight the efficiency of this real-time landing scheme.

11:40-12:00 WeA4.2

A Lightweight Toggleable Adhesion Prototype for Multirotor UAV Landing on Tilting Platforms, pp. 737-742

Nordholt, Teighin Queen's University
Greeff, Melissa Queen's University

Autonomous multirotor landings on uncrewed surface vessels (USVs) are critical for persistent maritime operations but remain challenging due to wave-induced tilt, wind disturbances, and limited landing area. Many existing approaches exhibit small pose tolerance for reliable landing. This paper presents a lightweight toggleable adhesion mechanism to improve landing reliability. The system uses a motor-driven corkscrew that engages hook-and-loop material on the landing surface, enabling active adhesion during landing and controlled release during takeoff. We evaluate a prototype using a modified Crazyflie 2.0 and a custom tilting platform at fixed angles representative of extreme wave conditions. Using only a simple vertical PID controller, the proposed approach increases landing success from an average of 40% (baseline) to 80% across platform tilts up to 43 degrees using appropriately selected actuation settings.

12:00-12:20 WeA4.3

Autonomous Exploration for Micro Aerial Vehicles with Sparse Sensing Using Harmonic Fields and Monte Carlo Integration, pp. 743-749

Kotsinis, Dimitrios University of Patras
Karras, George University of Thessaly
Bechlioulis, Charalampos University of Patras

Efficient autonomous exploration in unknown, obstacle-cluttered environments remains a significant challenge in the robotic field. Building on our previous Partial Differential Equation-based navigation for ground vehicles, this paper extends the framework to Micro Aerial Vehicles operating under severe sensing constraints. Using a Crazyflie 2.1 quadrotor equipped with a sparse four-beam range sensor, we propose a continuous exploration policy that simultaneously optimizes translation and rotation to maximize information gain. We generate these velocity commands by solving an elliptic Partial Differential Equation with Dirichlet boundary conditions. To overcome flat gradient deadlocks, we solve a Poisson equation with source values dynamically derived from a Hybrid Visibility Graph. Crucially, we enhance the grid-free Walk on Spheres algorithm by reducing solution variance, significantly lowering computational overhead. Validated through comparative simulations and real-world ROS2-MATLAB experiments, our approach efficiently calculates the navigation gradient directly at the agent's position, ensuring smooth, deadlock-free exploration in complex 2D spaces.

12:20-12:40 WeA4.4

An Oceanic Small-UAS with Near-Surface Soaring Flight Sensory Design and Onboard Deep-Learned Meteorological Perception, pp. 750-758

Carlson, Stephen University of Nevada
Arora, Prateek University of Nevada
Papachristos, Christos University of Nevada

This work describes the design features and systems of the Laysan, a small UAS with VTOL capability, waterproof environmental resilience, and solar energy-harvesting with dynamic soaring augmentation for migratory cross-ocean missions. Key innovations include a radar-based altimetry system, a self-cleaning pitot-static airspeed sensing system, and a unique camera-based meteorological perception system running in a real-time on-board Neural Processing Unit. The radar altimeter and air speed are used for dynamic soaring maneuvering, and the outputs from the perception system can be leveraged for path-planning avoidance of clouds and other hazardous weather. Experiments with these systems are demonstrated, such as the behavior of the radar altimeter mounted to the aircraft in a real-world over-water dynamic soaring cycle, and the performance of the trained cloud instance segmentation system.

12:40-13:00 WeA4.5

Intercepting an Agile Target with Net-Carrying Drones Using Competitive Multi-Agent Reinforcement Learning, pp. 759-766

Gavin, Timothée Thales LAS
Bronz, Murat ENAC

This article presents a solution to intercept an agile drone by a team of agile drone carrying catching nets. We formulate the problem as a competitive Multi-Agent Reinforcement Learning (MARL) task. To address the problem of non-stationarity and catastrophic forgetting of agents overfitting to the current opponent strategy, we train the pursuers and the evader using Multi-Agent Proximal Policy Optimization (MAPPO) with Prioritized Fictitious Self Play (PFSP). We train the agents in a high-fidelity simulator using low-level control commands, collective thrust and body rates (CTBR), to achieve agile flights for both the pursuers and the evader. We compare the performance of the trained policies in terms of catch rate, time to catch and crash rates, against heuristic baselines and show that our solution outperforms them. Ablation studies show that PFSP leads to more robust policies that can adapt to different opponent strategies, and that a low-level

control command is crucial for learning performing strategies in the pursuit-evasion task. Finally, a qualitative analysis of the learned behaviors highlights the emergence of cooperative tactics among the pursuers.

13:00-13:20 WeA4.6

System Identification and State-Space Control of a Small Unmanned Aerial Vehicle (UAV), pp. 767-773

Zaraza Espinosa, Javier Mauricio	Universidad Industrial De Santander
Buitrago Galvan, Edgar Julian Farid	Universidad Industrial De Santander
Carreno Zagarra, Jose Jorge	Universidad Industrial De Santander
Esteban, Helio S	Universidad Industrial De Santander
Poveda, Diana Katheryn	Universidad Industrial De Santander

This paper presents the modeling, identification, and experimental control of a Parrot Mambo micro–Unmanned Aerial Vehicle (UAV) using a Linear Quadratic Gaussian (LQG) control framework. A dynamic model of the quadrotor is developed by combining physical inspection with experimental system identification to estimate key parameters such as inertial properties, thrust coefficients, and geometric characteristics. The resulting model is expressed in state-space form and used to design an optimal state-feedback controller coupled with Kalman filtering for state estimation. The control architecture follows a cascade structure that separates position and attitude control loops, enabling stable and reliable trajectory tracking under sensor noise and modeling uncertainties. Controller performance is evaluated through both simulation and real flight experiments using representative square and circular trajectories. Experimental results show accurate trajectory tracking and improved transient behavior compared with a conventional PID baseline. In addition, the study provides an experimentally validated dynamic model of the Parrot Mambo platform, highlighting the importance of parameter identification and state estimation in achieving reliable control of micro-UAV systems.

Thursday, June 18, 2026

ThA1 **Nafsika**
Swarms (Regular Session)

Chair: Artemiadis, Panagiotis	University of Delaware
Co-Chair: Wang, Liyang	Ecole Nationale De l'Aviation Civile

08:30-08:50 ThA1.1

Efficient Decentralized Multi-UAV Wildfire Monitoring Via MCTS-Distilled Diffusion Policies, pp. 774-781

Wang, Liyang	Ecole Nationale De l'Aviation Civile
Bronz, Murat	Ecole Nationale De l'Aviation Civile

We address decentralized multi-UAV wildfire monitoring as a long-horizon active state estimation problem under partial observability. UAVs integrate local observations into global belief maps for fire and fuel, while an uncertainty map identifies unobserved regions. We propose an information-driven objective combining uncertainty reduction, fire-front tracking, and fuel-aware exploration using a conservative no-fuel map. A decentralized MCTS planner provides high-quality decisions but is computationally costly online. We distill its behavior into a diffusion-based trajectory policy, amortizing planning into learned conditional sampling of future poses. Experiments over multiple scales and team sizes show that the diffusion policy surpasses random and greedy baselines and closely matches MCTS in estimation accuracy. Its runtime is comparable to MCTS at small scales, but it scales more favorably and delivers a better accuracy–latency trade-off in larger environments.

08:50-09:10 ThA1.2

Human Trust-Driven Adaptive Control for Unmanned Aerial Swarms, pp. 782-789

Orozco, Jesus	University of Delaware
Walsh, Coleman	University of Delaware
Artemiadis, Panagiotis	University of Delaware

This paper introduces an innovative Human-Swarm Interaction (HSI) architecture leveraging a Brain-Computer Interface (BCI) to evaluate operator trust in real-time during collaborative multi-UAV navigation. While Electroencephalography (EEG)-based trust detection is well-documented, its implementation remains predominantly restricted to offline assessments. Addressing the critical need for online, adaptive control in aerial robotics, we propose a k-Nearest Neighbors (k-NN) classifier that differentiates trusting from distrusting cognitive states with over 90% accuracy. Integrated into a closed-loop BCI, this model dynamically adjusts aerial swarm formations. Experimental validations demonstrate the system's capacity to swiftly identify operator distrust, prompted by sub-optimal UAV behaviors, and autonomously revert the swarm to a stable, trusted configuration. These findings highlight that higher-order human factors, particularly trust, can effectively govern adaptive controllers in unmanned aerial systems, facilitating hands-free operations for complex missions.

09:10-09:30 ThA1.3

Swarm-Steward: Scalable and Reliable Natural-Language Coordination of Autonomous Aerial and Ground Robots, pp. 790-798

Jarabo-Peñas, Alejandro	University of Southern Denmark
Bravo-Arrabal, Juan	University of Southern Denmark
Rolland, Edouard George Alain	University of Southern Denmark
Christensen, Anders Lyhne	University of Southern Denmark

We present Swarm-Steward, a platform-agnostic system for natural-language multi-robot control that enables a non-expert operator to coordinate many drones by creating and commanding groups, bridging high-level intent to reliable, low-level execution. Swarm-Steward uses a hierarchical LLM-based multi-agent design where planning and context gathering are separated from actuation: specialized agents ground requests in map features and telemetry, while a dedicated action-execution stage composes group actions and dispatches only deterministic, schema-constrained commands through a safety gate (e.g., geofencing, altitude and separation limits), with optional operator preview before execution. To keep grounding scalable, Swarm-Steward applies dual retrieval-augmented generation over both map features (Feature RAG) and telemetry variables (State RAG), injecting only relevant candidates at each step. In scalability tests, Feature RAG remains effective with up to 10,000 features, and end-to-end sessions from 5 to 500 drones maintain near-constant LLM token cost with 92.9% task success across 280 prompts. The observed failures arise from prompt-specific scaling limits at larger swarm sizes, rather than from incorrect coordinator planning. Finally, we validate sim-to-real transfer by executing the same mission script in simulation and on a real-world DJI Mini 4 Pro swarm, demonstrating consistent behavior across comparable mission phases without modifying the LLM multi-agent system layer.

09:30-09:50 ThA1.4

Distributed Control of Disturbed Nonholonomic Aerial Robots with User-Defined Finite-Time Synchronization, pp. 799-804

Kurtoglu, Deniz — University of South Florida
Yucelen, Tansel — University of South Florida
Tran, Dzung — Air Force Research Laboratories
Garcia, Eloy — Air Force Research Laboratories
Casbeer, David — Air Force Research Laboratories

Nonholonomic motion constraints fundamentally limit maneuverability in many aerial robots, particularly fixed-wing vehicles that cannot generate instantaneous lateral motion. These limitations become even more pronounced in the presence of exogenous disturbances. Motivated by these challenges, this paper develops a new distributed control framework for disturbed nonholonomic aerial robots consisting of two integrated steps. Specifically, the first step employs feedback linearization to represent each aerial robot with single-integrator dynamics. The second step introduces a switching distributed control protocol that guarantees finite-time synchronization at a user-defined time horizon T and preserves synchronization for all t >= T. Stability of the proposed protocol is rigorously established using methods from time transformation, input-to-state stability, and Lyapunov analysis. In addition to the theoretical developments, an illustrative numerical example is also provided to demonstrate the effectiveness of the proposed control framework.

09:50-10:10 ThA1.5

Distributed Formation Control with Local Sensing Combining Bubble-Based Voronoi Tessellation and Consensus, pp. 805-812

Mendoza-Robles, Natalio — Université Grenoble Alpes and INSA Strasbourg
Briñón Arranz, Lara — Université Grenoble Alpes
Susbielle, Pierre — Université Grenoble Alpes
Skantzikas, Kostas — Université Grenoble Alpes
Durand, Sylvain — INSA Strasbourg
Marchand, Nicolas — Université Grenoble Alpes

This work proposes a distributed formation control strategy for a multi-robot system, addressing local sensing constraints and the rigidity of classic methods. By combining a Voronoi-based controller for separation and a consensus algorithm for cohesion, the proposed approach ensures flocking-inspired behaviors using only the relative positions of close neighbors. Each Voronoi cell is enclosed in a circular convex region, called bubble, enabling distributed Centroidal Voronoi Tessellation for safe separation. The strategy requires no global knowledge of the size of the swarm and autonomously adapts to changes in the number of robots. The stability of the system is theoretically proven through the separation scale principle between Voronoi tessellation computation and formation control. Simulation and experimental results highlight the effectiveness of the proposal on a group of Unmanned Aerial Vehicles.

10:10-10:30 ThA1.6

A Preliminary Study on Smoke Plume Observation with Drone Swarms, pp. 813-819

Chakraa, Hamza — ENAC
Verdoucq, Matthieu — ENAC
Machado, João — ENAC
Bronz, Murat — ENAC

Smoke plumes provide critical information for assessing wildfire behavior, spread dynamics, and atmospheric impact. To observe such phenomena, single-UAV observations are often limited by restricted viewpoints and insufficient coverage of evolving plume structures. This paper presents a perception-guided coordination framework for UAV swarms that integrates object detection with adaptive motion primitives to enable structured, multi-view observation of smoke plumes. Upon detecting a target of interest, the swarm autonomously executes a sequence of behaviors: a safe straight-line approach, circular orbiting for various lateral perspectives, and vertical sweeps with altitude-dependent radius scaling to capture elevation-dependent plume morphology. The system is implemented on DJI Mini-3 quadrotors, where a designated leader performs YOLO-based detection and relative target pose estimation, and the follower UAVs maintain a collision-avoiding formation around the estimated target position. Outdoor experiments using a visually distinctive vertical column as a surrogate target demonstrate reliable detection, rapid alignment, and stable coordinated orbiting with inward-facing yaw tracking. This work establishes a foundation for perception-driven adaptive UAV swarm systems to enhance smoke observation and reconstruction strategies in wildfire monitoring scenarios.

ThA2	Lounge A
Autonomy (Regular Session)	
Chair: Kyriakopoulos, Kostas J.	New York University - Abu Dhabi
Co-Chair: Valencia Torres, Esteban Alejandro	Escuela Politécnica Nacional

08:30-08:50 ThA2.1

Safe Ergodic Exploration for Fixed-Wing UAVs, pp. 820-827

Kyriakopoulos, Kostas J. — New York University Abu Dhabi

Vavvas, Alexios — QUALCO

Enabling fixed-wing UAVs to maneuver aggressively through cluttered environments—while respecting stall and actuator limits—remains an active area of research. This paper presents an Integral High-Order Control Barrier Function (IHOCBF) safety filter for a 12-DOF nonlinear fixed-wing model that enables such maneuvers without explicit trajectory planning. By treating actuator deflections as states and optimizing their rates, we obtain a control-affine augmented system that naturally accommodates actuator constraints. The safety filter is posed as a quadratic program that minimally modifies inputs from a nominal controller (in this case an ergodic exploration one) to enforce obstacle avoidance, stall prevention, and geofence limits. Simulations demonstrate emergent aggressive behaviors—including "bank and yank" coordinated turns, reactive wall avoidance near stall limits, and sustained loitering over multiple regions of interest—with computation times below the simulation timestep.

08:50-09:10 ThA2.2

Cooperative UAV Search and Rescue Via Multi-Agent Reinforcement Learning in Simulated Wildfire Environments, pp. 828-835

Sharma, Shivani — Kingston University London

Tsoumplekas, Georgios — Kingston University London

Spyridis, Yannis — Kingston University London

Vitzilaios, Nikolaos — University of South Carolina

Argyriou, Vasileios — Kingston University London

Wildfire poses an increasing global threat, endangering both human and animal lives. Rapid and coordinated search and rescue (SAR) operations are critical to minimizing casualties in such emergencies. This paper investigates the use of Multi-Agent Reinforcement Learning (MARL) to train autonomous unmanned aerial vehicles (UAVs) capable of cooperative SAR in simulated wildfire environments. The task is modeled as a decentralized partially observable Markov decision process (Dec-POMDP) and trained under a Centralized Training with Decentralized Execution (CTDE) paradigm. Two learning configurations are compared: a single-agent baseline using Proximal Policy Optimization (PPO) and a cooperative multi-agent framework based on Multi-Agent Policy Optimization with Credit Assignment (MA-POCA) incorporating posthumous credit assignment. Training employs a three-stage curriculum to progressively increase environmental complexity and enhance policy generalization. Simulations across one to six UAVs demonstrate that multi-agent coordination significantly improves mission efficiency and consistency. Specifically, teams of four to five UAVs achieved the lowest average completion times while maintaining high stability and reliability across trials. These results confirm that MARL-based cooperative control improves scalability, robustness and overall mission performance in UAV-based SAR operations, especially under optimal team sizing, underscoring the potential of decentralized learning for real-world disaster response scenarios.

09:10-09:30 ThA2.3

Autonomous In-Operation Wind-Turbine Blade Inspection, pp. 836-843

Bosak, Anja — University of Zagreb

Peris, Stela — University of Zagreb

Markovic, Lovro — University of Zagreb

Ivanovic, Antun — University of Zagreb

Car, Marko — University of Zagreb

Orsag, Matko — University of Zagreb

Bogdan, Stjepan — University of Zagreb

This paper presents a method for the autonomous inspection of rotating wind turbines using an unmanned aerial vehicle (UAV). To address the challenges of a dynamic environment, the proposed approach tightly couples LiDAR-based wind turbine poses estimation and blade tracking with illumination-aware path planning. Using onboard GPS, IMU and LiDAR sensors, the proposed approach determines the position of the wind turbine relative to the UAV. A multi-objective optimization framework then generates an inspection path which ensures complete blade coverage while maximizing image quality by accounting for environmental constraints. During the inspection flight, a camera mounted on a gimbal is used together with a range-finder sensor to capture high-resolution blade images. Simultaneously, the blade tracking algorithm ensures the correct association between obtained images and specific blades. The proposed approach is validated in a realistic simulation environment, while the wind turbine pose estimation is further analyzed on real-world aerial datasets of operational wind turbines.

09:30-09:50 ThA2.4

AgiPIX: Bridging Simulation and Reality in Indoor Aerial Inspection, pp. 844-852

Kuruppu Arachchige, Sasanka — Tampere University

Garcia-Cardenas, Juan José — ENSTA ParisTech

Tian, Changda — Foundation for Research and Technology - Hellas

Suomela, Lauri Aleksanteri — Tampere University

Trahanias, Panos — Foundation for Research and Technology - Hellas

Tapus, Adriana ENSTA ParisTech
Kamarainen, Joni-Kristian Tampere University

Autonomous indoor flight for critical asset inspection presents fundamental challenges in perception, planning, control, and learning. Despite rapid progress, there is still a lack of a compact, active-sensing, open-source platform that is reproducible across simulation and real-world operation. To address this gap, we present AgiPIX, a co-designed open hardware and software platform for indoor aerial autonomy and critical asset inspection. AgiPIX features a compact, hardware-synchronized active-sensing platform with onboard GPU-accelerated compute that is capable of agile flight; a containerized ROS2-based modular autonomy stack; and a photorealistic digital twin of the hardware platform together with a reliable UI. These elements enable rapid iteration via zero-shot transfer of containerized autonomy components between simulation and real flights. We demonstrate trajectory tracking and exploration performance using onboard sensing in industrial indoor environments. All hardware designs, simulation assets, and containerized software are released openly together with documentation.

09:50-10:10 ThA2.5

Prediction of Aerodynamic Coefficients Using Neural Network Based Reduced Order Models for Multiple Fixed-Wing UAV Configurations, pp. 853-860

Ullaguari Chida, Nixon Sebastian Escuela Politecnica Nacional
Alulema, Victor Escuela Politécnica Nacional
Valencia Torres, Esteban Alejandro Escuela Politécnica Nacional

The conceptual design of fixed-wing unmanned aerial vehicles (UAVs) demands aerodynamic evaluation tools that balance physical fidelity with computational efficiency. This work presents a set of multilayer perceptron (MLP) based reduced-order models (ROMs) for predicting lift and drag coefficients across eight conventional and non-conventional fixed-wing configurations, including canard, tandem, joined-wing, and box-wing layouts. Training data were generated using a hybrid low-fidelity methodology combining the Vortex Lattice Method and empirical drag correlations, targeting small- to medium-scale UAVs operating in the low subsonic regime. The developed ROMs achieve mean R^2 values of 0.9995 and 0.9940 for lift and drag prediction across all evaluated configurations, respectively, while requiring less than 10% of the computational time of the underlying low-fidelity solver. Although predictive fidelity is bounded by the low-fidelity training data, the ROMs provide near real-time aerodynamic evaluation suitable for integration into conceptual design and multidisciplinary design optimization (MDO) workflows. Configurations with strong geometric coupling at wing tips, specifically joined-wing and box-wing layouts, exhibited higher prediction errors, a limitation discussed in the context of VLM solver assumptions.

10:10-10:30 ThA2.6

Bearing-Only Target Localization Using Fixed-Wing UAV, pp. 861-867

Koca, Muhammed Yasin Turkish Aerospace
Bayram, Haluk Istanbul Medeniyet University

Target localization is a fundamental problem for unmanned aerial vehicle (UAV) missions. While existing bearing-only localization methods achieve high accuracy, they often rely on multi-UAV setups or computationally intensive estimation filters that are not suitable for resource-constrained platforms. This paper proposes a novel, low-complexity geometric localization method specifically designed for a single fixed-wing UAV. The proposed approach estimates the target position by iteratively intersecting measurement triangles derived from bearing observations subject to bounded noise. Furthermore, an adaptive doubling-halving trajectory planning algorithm is employed to guide the UAV toward the target while reducing localization uncertainty and ensuring continuous motion. Extensive simulations demonstrate that the proposed method successfully balances localization accuracy with operational cost under varying bounded-noise levels and desired uncertainty thresholds.

ThA3 **Calypso A**

Energy Efficient UAS, Payloads and Aerial Delivery (Regular Session)

Chair: Tatlicioglu, Enver Ege University
Co-Chair: Kallies, Christian German Aerospace Center

08:30-08:50 ThA3.1

Energy-Aware Multicopter Modeling for Control and Planning Applications, pp. 868-877

Gasche, Sebastian German Aerospace Center
Kallies, Christian German Aerospace Center
Himmel, Andreas Technical University of Darmstadt
Findeisen, Rolf Technical University of Darmstadt

Today, unmanned aerial vehicles, especially multicopters, are utilized in environmental monitoring, infrastructure assessment, logistics, and disaster response due to their flexibility, maneuverability, and ability to operate in complex environments. However, autonomous coordination, planning, and control of these systems require accurate yet computationally efficient modeling of the employed vehicles and their capabilities. This paper presents a modeling approach that considers vehicle dynamics and energy consumption. The power train model provides a detailed representation of key components, such as lithium-ion batteries, electronic speed controllers, and brushless direct current motors, validated using real flight data. Since most of the model parameters are directly taken from data sheet information, the proposed model only requires few calibration flights. The proposed energy-aware multicopter model serves as a foundation for planning, control, and coordination of unmanned aircraft systems in dynamic environments.

08:50-09:10 ThA3.2

Performance Analysis of Dynamic Soaring with Thrust and Regeneration, pp. 878-885

Zhuo, Zihao McGill University
Nahon, Meyer McGill University

Sharf, Inna McGill University

Inspired by the flight behavior of albatrosses, dynamic soaring has emerged as a promising technique for energy-efficient flight with unmanned aerial vehicles. However, the current implementation of dynamic soaring is restricted by the minimum wind shear requirement and makes limited use of the harvested energy. In this work, we investigate the combined use of thrust and regeneration in dynamic soaring, which gives UAVs more flexibility in energy management, allowing them to operate in a wider range of wind conditions and with higher energy-harvesting efficiency. In addition, we explore the effect of drive train losses on the use of thrust and regeneration during dynamic soaring, providing insights into the deployment of such a strategy in practice. The results demonstrate the significant benefits of using both thrust and regeneration during dynamic soaring, especially in conditions with strong wind shear.

09:10-09:30 ThA3.3

EAAE: Energy-Aware Autonomous Exploration for UAVs in Unknown 3D Environments, pp. 886-893

Elskamp, Jacob Delft University of Technology
Shi, Moji Delft University of Technology
Bauersfeld, Leonard University of Zurich
Scaramuzza, Davide University of Zurich
Popovic, Marija Delft University of Technology

Battery-powered multirotor unmanned aerial vehicles (UAVs) can rapidly map unknown environments, but mission performance is often limited by energy rather than geometry alone. Standard exploration policies that optimize for coverage or time can therefore waste energy through manoeuvre-heavy trajectories. In this paper, we address energy-aware autonomous 3D exploration for multirotor UAVs in initially unknown environments. We propose Energy-Aware Autonomous Exploration (EAAE), a modular frontier-based framework that makes energy an explicit decision variable during frontier selection. EAAE clusters frontiers into view-consistent regions, plans dynamically feasible candidate trajectories to the most informative clusters, and predicts their execution energy using an offline power estimation loop. The next target is then selected by minimising predicted trajectory energy while preserving exploration progress through a dual-layer planning architecture for safe execution. We evaluate EAAE in a full exploration pipeline with a rotor-speed-based power model across simulated 3D environments of increasing complexity. Compared to representative distance-based and information gain-based frontier baselines, EAAE consistently reduces total energy consumption while maintaining competitive exploration time and comparable map quality, providing a practical drop-in energy-aware layer for frontier exploration.

09:30-09:50 ThA3.4

Adaptive Prescribed Performance Control of Altitude of Agricultural UAVs, pp. 894-898

Ozgun, Abdulkadir Sehmus Ege University
Demirkol Ozgun, Serap Ege University
Deniz, Meryem IzmirKatip Celebi University
Tatlicioglu, Enver Ege University

This work addresses the altitude tracking control problem for agricultural Unmanned Aerial Vehicles (UAVs) subject to time-varying mass due to liquid payload depletion. The continuous change in system inertia and gravitational forces can significantly degrade the tracking performance of conventional fixed-gain controllers. To ensure robust performance, an adaptive prescribed performance control scheme is proposed for the vertical dynamics of the UAV. By utilizing a logarithmic error transformation, the proposed method guarantees that the altitude tracking error evolves strictly within a user-defined, decaying performance funnel, thereby ensuring the pre-specified transient and steady-state characteristics. An adaptive update law is employed to compensate for parametric uncertainties and the effects of mass variation. Numerical validations, performed in a physics-based environment, demonstrate that the controller achieves precise altitude tracking without violating the user-defined performance constraints, despite significant weight loss.

09:50-10:10 ThA3.5

Deep Reinforcement Learning for Hexacopter Control under Payload Collection and Release, pp. 899-906

Al Homsi, Mohammad Università Degli Studi Di Palermo
Messaoudi, Sofiane Università Degli Studi Di Palermo
Fagiolini, Adriano Università Degli Studi Di Palermo
Cirrincione, Giansalvo Université De Picardie Amiens
Valavanis, Kimon P. University of Denver
Sopegno, Laura University of Michigan

Unmanned Aerial Vehicles (UAVs), particularly multirotor platforms, are widely used in civil and public applications. Many missions require payload (P/L) transportation and release, causing significant variations in the system dynamic. These changes, combined with external disturbances, introduce time-varying dynamics that challenge conventional control methods and often require separate controllers for different flight configurations. This work investigates Deep Reinforcement Learning (DRL) strategies for a hexacopter control under dynamic regime transitions. A robust thrust control strategy is developed using probabilistic actor–critic algorithms, both on-policy (PPO, TRPO, RPO) and off-policy (SAC). The control problem is formulated under partial observability: the policy does not receive explicit information about P/L mass, attachment state, or release timing. The DRL agent implicitly infers dynamic changes from onboard observations. The policy is assessed during two different phases: P/L transport–release P/L and collection–release. To enhance generalization across varying operating conditions, domain randomization and adaptive learning strategies are incorporated during training. The approach is systematically assessed under continuous external disturbances in the form of steady wind. The results obtained show that all policies maintain bounded trajectory tracking despite P/L variations and wind disturbances. Stochastic on-policy methods effectively handle dynamic transitions, with PPO and TRPO achieving the highest tracking accuracy and robustness and ensuring stable performance during regime changes, while RPO and SAC exhibit slower convergence and reduced stability in flight validation, consistent with the characteristics of their respective learning frameworks.

10:10-10:30 ThA3.6

ADROP: Aerial Delivery Robot for Light-Parcel Operations, pp. 907-912

Suarez, Alejandro — Universidad De Sevilla
Ollero, Anibal — Universidad De Sevilla

This paper describes the design, development, and validation of a 40 by 40 cm size, 2.2 kg weight autonomous aerial delivery robot intended to conduct intra-logistics operations with light parcels (under 250 grams) that can be safely delivered directly to the people on flight. The aerial robot is fed by power cables to overcome the limitations of batteries while increasing the payload-to-weight ratio, covering the propellers with the carbon fiber frame structure and foam protection to avoid potential damage in case of collision with the people or the environment. A comparison of the proposed design with respect to our previous prototypes is presented along with the related works to motivate the design choices. The aerial robot implements and compares two onboard localization and mapping methods: RTAB-Map with RGB-D camera and 2D LiDAR, and FAST-LIO2 with 3D LiDAR. The platform is validated in two indoor mockup scenarios executing two different tasks. In the first one, the aerial robot is equipped with a hook for retrieving a parcel from a shelf, whereas in the second scenario a parcel is delivered through the window of a user's home.

ThA4 — **Calypso B**

Security, Regulations and Training (Regular Session)

Chair: Ruggiero, Fabio — Università Degli Studi Di Napoli Federico II
Co-Chair: Pignaton de Freitas, Edison — Federal University of Rio Grande Do Sul

08:30-08:50 — ThA4.1

A Theory of Mind Model for Proportionality Assessment in Military Operations, pp. 913-918

Maathuis, Clara — Open University

This article introduces a Theory of Mind (ToM) model for proportionality assessment in military operations that captures how civilian and adversary beliefs and behaviors modulate collateral damage and military advantage across alternative CoAs (Courses of Action. To this end, the proportionality assessment is formalized as a dual-lens decision problem in which collateral damage is evaluated under two perspectives. First, a physical harm only lens, and second, an expanded lens that includes psychological harm in addition to physical harm, while preserving a common rule-based classifier mapping categorical results. Furthermore, to demonstrate and evaluate the model proposed, a counter-UAV (Unmanned Aerial Vehicle) engagement use case is considered where a comparison between kinetic, non-kinetic, delay/reposition, warning, and abort CoAs is conducted. The results show that the ToM model provides a transparent, distributional, and policy-relevant approach to proportionality assessment while capturing behavioral feedback loops and clarifying when assessment results depend critically on the chosen collateral harm perspective.

08:50-09:10 — ThA4.2

Secure UTM Infrastructure with Zero Trust: Design and Implementation for UAV Operations, pp. 919-926

Pashchapur, Ravi Ashok — Technology Innovation Institute
Singh, Govind — Technology Innovation Institute
Royyan, Muhammad — Unikie

Secure Unmanned Traffic Management (UTM) is critical as Unmanned Aerial Vehicles (UAVs) integrate into shared airspace; perimeter-based security is insufficient for UTM's decentralized, multi-stakeholder setting. We implement and evaluate a Zero Trust UTM framework [19] that applies to the National Institute of Standards and Technology (NIST) Zero Trust Architecture (ZTA) to UAV, ground station, and UTM interactions. A four-component testbed is used: QGroundControl (QGC) with UTM Adapter, Flight Blender with Policy Enforcement Point (PEP) and Policy Decision Point (PDP) and Zero Trust layers, a custom quadrotor platform, and a Technology Innovation Institute (TII) Security Verifier. We address four problems: unauthorized access (P1), Man-in-the-Middle (MitM) on links (P2), lack of per-request authorization and audit (P3), and integrity and non-repudiation (P4). Evaluation shows that with Zero Trust enabled, all tested attack types (invalid token, wrong scope, MitM fake response, MitM modify payload, replay) are blocked and logged; MitM-injected flight plan responses are rejected by signature verification using the Elliptic Curve Digital Signature Algorithm (ECDSA). Latency overhead is 25–40% versus baseline, with success rate above 99% under peak load. The framework is implementable and effective in a concrete test environment with full auditability.

09:10-09:30 — ThA4.3

A Comprehensive Evaluation of U-Space KPIs, pp. 927-934

Nunez Portillo, Juan — University of Seville
Lundberg, Jonas — Linkoping University
Polishchuk, Tatiana — Linkoping University
Polishchuk, Valentin — Linkoping University
Sedov, Leonid — Linkoping University
Enea, Gabriele — MIT Lincoln Laboratory

EASA's Acceptable Means of Compliance and Guidance Material (AMC/GM) to Regulation (EU) 2021/664 on a regulatory framework for the U-space put into writing the obvious fact (obvious to U-space stakeholders) that U-space airspaces must be regularly assessed based on a well worked out set of performance metrics. This paper reports on a probabilistic analysis of a variety of Key Performance Indicators (KPIs) for UAV (Unmanned Aerial Vehicle) Traffic Management (UTM). The KPIs belong to the Key Performance Areas (KPAs) of Access and Equity, Capacity, Efficiency, and Safety. The metrics are evaluated on a variety of simulated demand scenarios in very low level (VLL) metropolitan airspace over European cities. In particular, we study the dependence of the UTM KPIs on the lookahead time of strategic deconfliction of U-plans; the length of this time interval, between the deconfliction and the desired takeoff time of the drone operation, is called Reasonable Time to Act (RTTA) in the European Concept of Operations for U-space (CORUS) and its Urban Air Mobility (UAM) extension (CORUS-XUAM). In view of the stochastic nature of VLL UAV traffic, we present not only the average values of the KPIs, but also their probability distributions.

09:30-09:50	ThA4.4

Addressing the Challenges of Autonomous Drone Swarms by Compliance-By-Design Regulations, pp. 935-942

Kristoffersson, Eleonor	Örebro University
Kristoffersson, Magnus	Örebro University
Pignaton de Freitas, Edison	Federal University of Rio Grande Do Sul

Autonomous drone swarms offer significant potential for civil applications such as search and rescue, disaster response, and infrastructure monitoring, yet they challenge regulatory frameworks originally designed for single unmanned aircraft under direct human control. This paper analyzes key regulatory and safety issues arising from civil autonomous drone swarms, focusing on accountability, autonomy governance, airspace integration, and public safety and privacy. Using European Union law as the primary reference, complemented by a Swedish national case study and comparative insights from selected non-EU jurisdictions, the paper identifies structural gaps in aviation, AI, and data protection regulation. It argues that compliance-by-design—embedding legal and safety requirements directly into swarm architectures and operational concepts—is essential for enabling safe, lawful, and publicly acceptable deployment of autonomous drone swarms in civil airspace.

09:50-10:10	ThA4.5

CA-AC-MPC: CUDA-Accelerated Actor-Critic Model Predictive Control, pp. 943-950

Buo, Antonio	Università Degli Studi Di Napoli Federico II
Cammarota, Vittorio	Università Degli Studi Di Napoli Federico II
Avagnale, Michele	Università Degli Studi Di Napoli Federico II
Arpenti, Pierluigi	Università Degli Studi Di Napoli Federico II
Lippiello, Vincenzo	Università Degli Studi Di Napoli Federico II
Ruggiero, Fabio	Università Degli Studi Di Napoli Federico II

In the literature, actor-critic model predictive control (AC-MPC) integrates MPC with reinforcement learning to enable high-performance control of complex dynamical systems. However, its differentiable MPC layer requires repeatedly solving an optimization problem in both the forward and backward passes, leading to substantial training and inference latency. This paper tackles this bottleneck introducing a CUDA-accelerated variant that significantly reduces end-to-end execution time while preserving the control performance of the baseline formulation. Simulation results on an agile drone racing task show that our approach achieves state-of-the-art lap times and near-limit dynamic behaviour with markedly reduced training and inference time.

10:10-10:30	ThA4.6

Licensing of Drone Operators in the European Union: A Comparative Legal Analysis, pp. 951-960

Konert, Anna	Lazarski University in Warsaw

The paper conducts a multi-dimensional analysis of licensing systems for unmanned aircraft (drone) operators in selected Member States of the European Union. The research includes a legal analysis of national regulations implementing the EU regulatory framework, in particular Regulations (EU) 2019/947 and 2019/945, as well as an assessment of the practical functioning of these systems, with particular emphasis on the degree of their harmonization with EU regulations and their impact on operational safety and the development of the drone services market. The study also seeks to identify similarities and differences between the solutions adopted in individual Member States and to assess their impact on the development of the drone services market, the level of operational safety, and the mobility of operators within the EU internal market.

ThB1	**Nafsika**
UAS Applications I: Detection, Tracking and Counter-UAS (Regular Session)	
Chair: Anastasiou, Andreas	KIOS Research and Innovation Center of Excellence, University of Cyprus
Co-Chair: Souli, N.	University of Cyprus

10:50-11:10	ThB1.1

Dynamic Encirclement Angle-Based Cooperative Guidance Law for Multi-Missile System against Maneuvering Target, pp. 961-967

Wang, Mengmeng	Beijing Institute of Technology
Sun, Jingliang	Beijing Institute of Technology
Wang, Zihan	Beijing Institute of Technology
Zhong, Jianxin	Beijing Institute of Technology
Shi, Xianchao	Beijing Institute of Technology
Long, Teng	Beijing Institute of Technology

In this paper, a novel cooperative encirclement guidance method is proposed for multiple missiles against the maneuvering target. By covering the target's reachable domain with the missiles' combined detection range, the ideal missile number and dynamic encirclement angles are designed to improve the capture probability and block escape directions of the target. Moreover, the desired positions of missiles are calculated in real-time within the leader-follower framework. Then, considering the non-adjustability of speed, a cooperative guidance law is constructed without chattering based on the continuous finite-time stabilizing control scheme to eliminate tracking errors. The finite-time stability of the system is proved theoretically. Finally, the effectiveness and feasibility are verified by numerical simulation under the constraint of balanced maneuverability.

11:10-11:30	ThB1.2

Predictive Control with Integrated Target Estimation and Detection Probabilities for Coordinated Search and Track of Maritime Targets, pp. 968-975

Anastasiou, Andreas	University of Cyprus
Papaioannou, Savvas	University of Cyprus
Kolios, Panayiotis	University of Cyprus
Panayiotou, Christos	University of Cyprus

This paper introduces a novel Model Predictive Control (MPC) framework for multi-UAV Search and Track in maritime environments. Unlike existing approaches that treat detection and estimation as separate processes, our method embeds probabilistic target detection models and estimation uncertainty directly within the MPC formulation. This enables adaptive control decisions based on detection confidence and estimation quality. The framework addresses cooperative guidance of a UAV swarm for simultaneous search and tracking of multiple moving targets with altitude-dependent sensing, where detection probability varies with flight height. By integrating target detection probabilities as decision variables, the MPC controller generates trajectories that balance search coverage and tracking accuracy while accounting for environmental uncertainties. Quantitative simulations demonstrate improved target acquisition rates and tracking precision under maritime conditions. Real-world prototype validation confirms both computational feasibility and practical effectiveness, establishing the transition from theoretical framework to operational autonomous UAV systems for maritime surveillance.

11:30-11:50 ThB1.3

Small Object Detection in UAV Imagery Via Multimodal RGB-Thermal Fusion, pp. 976-983

Galdelli, Alessandro	Università Politecnica Delle Marche
Brunella, Federico	Università Politecnica Delle Marche
Colletta, Matteo	Università Politecnica Delle Marche
Libofsha, Angjelo	Università Politecnica Delle Marche
Giano, Simone	Università Politecnica Delle Marche
Chiappini, Stefano	Università Politecnica Delle Marche
Bolognini, Luca	National Research Council
Mancini, Adriano	Università Politecnica Delle Marche

Aerial surveillance using Unmanned Aerial Vehicles (UAVs) faces challenges in detecting small targets, particularly under varying illumination conditions. Single-modality detectors degrade in performance when targets are visually camouflaged or when lighting is poor. To improve robustness across day/night and reduced-visibility scenarios, this paper introduces multimodal RGB–thermal perception, leveraging the complementary information provided by visible-spectrum and thermal infrared imagery. The work introduces enhanced multimodal architecture based on DEYOLO (Dual-Feature-Enhancement YOLO), specifically optimized for small object detection in high-altitude imagery. The model employs dual RGB and thermal backbones and integrates lightweight architectural refinements aimed at improving multi-scale representation and cross-modal alignment. In particular, the feature pyramid is extended toward higher-resolution levels to better capture small targets, with SPDConv introduced as an additional module in the backbone. The neck is modified with SPANet to enhance the capture of fine-grained details, while attention-based fusion modules adaptively weight spatial and channel information across modalities. The approach is evaluated on public RGB–thermal UAV datasets and a custom dual-sensor aerial dataset. Ablation tests validate the effectiveness of these enhancements. Experimental results show that the proposed multimodal configuration improves detection accuracy and robustness compared to single-modality baselines while maintaining computational efficiency compatible with near-real-time deployment.

11:50-12:10 ThB1.4

A Topology-Aware Spatiotemporal Handover Framework for Continuous Multi-UAV Tracking, pp. 984-991

Ye, Jianlin	University of Cyprus
Kyrkou, Christos	University of Cyprus
Kolios, Panayiotis	University of Cyprus

The integration of Unmanned Aerial Vehicles (UAVs) into Intelligent Transportation Systems (ITS) offers synoptic visibility for traffic monitoring, yet scalable deployment is hindered by trajectory fragmentation, where vehicle identity persistence is lost across multi-UAV Fields of View (FOV). While state-of-the-art frameworks excel in optimizing local trajectory extraction and stability for single-drone imagery, they often function as isolated data silos that generate disjointed trajectories, thereby precluding network-level analysis such as Origin-Destination estimation. This paper presents a real-time Multi-Camera Multi-Vehicle Tracking (MCMT) system designed to handle global identity persistence. Addressing the visual ambiguity and computational cost of appearance-based Re-Identification (Re-ID) in nadir views, we introduce a lightweight Topology-Based Spatiotemporal Handover mechanism. We implement a high-throughput parallel pipeline leveraging YOLO11 and ByteTrack to process concurrent 4K streams. Our core contribution is a deterministic queue-based matching algorithm that utilizes geometric overlaps and virtual lane discretization to predictively manage identity handover via FIFO queues. Experimental results on complex urban environments, including intersections and merging traffic, demonstrate a Handover Success Rate (HOSR) of 99.8% in continuous traffic flows, significantly outperforming Re-ID baselines (74.1%) while validating edge deployment feasibility. The source code is available at https://github.com/JYe9/multi-camera-multi-vehicle-tracking -system.

12:10-12:30 ThB1.5

High-Speed Drone Detection: Evaluating Ultra-Lightweight Custom Architectures for Deployment on Edge Devices, pp. 992-997

Drimus, Alin	University of Southern Denmark
Jouffroy, Jerome	University of Southern Denmark

Reliable detection of consumer-grade quadcopters is necessary for aerial security and collision avoidance. Deploying high-frequency detectors on edge platforms with strict Size, Weight, and Power (SWaP) budgets, however, remains difficult. This paper presents DroNet, an ultra-lightweight drone detector (0.07M parameters) inspired by the YOLOX architecture, built entirely with depth wise separable

convolutions and a simplified Feature Pyramid Network backbone. DroNet achieves mAP@.5-.95 scores of 0.50--0.55 depending on input resolution and delivers inference speeds above 130 FPS on the Luxonis OAK VPU. Across resolutions (192x192 to 320x320) we observe an empirical resolution-invariance regime for the chosen sensor and target: the 192x192 variant detects 7-inch quadcopters at the same 40 m range as higher resolutions while delivering 2.1x higher throughput. Against YOLOX-Nano and YOLOX-ShuffleNetV2 at 256x256, DroNet matches long-range detection at 3–4x the speed, making it suitable for real-time drone surveillance on companion edge computers.

12:30-12:50	ThB1.6

Rogue Drone Detection and Tracking Using Vision and Range-Finder Measurements, pp. 998-1004

Pettemeridis, Giorgos	University of Cyprus
Souli, Nicolas	University of Cyprus
Grigoriou, Yiannis	University of Cyprus
Ellinas, Georgios	University of Cyprus
Kolios, Panayiotis	University of Cyprus

Advancements and the widespread availability of unmanned aircraft systems (UASs) have contributed to a rise in unauthorized operations over critical infrastructure and public spaces, making the investigation of techniques for detection and tracking of rogue drones a necessity. This work presents a real-time framework for rogue drone detection, tracking, and localization by combining vision-based drone detection with laser range-finder measurements and camera gimbal state (roll, pitch, yaw). Specifically, a measurement and validation stage rejects inconsistent detections using range and camera-position geometry, while an extended Kalman filter (EKF) with a constant-velocity model fuses the validated observations to produce rogue drone tracks and to mitigate the effects of noise, outliers, and intermittent missed detections. The rogue drone estimates are then converted into geographic coordinates using the proposed system's Global Positioning System (GPS), altitude, yaw, and pitch angles, which are then exchanged with a custom-designed web-based platform for real-time map visualization and logging. A prototype system is implemented in hardware and software and extensively tested in numerous outdoor experiments, demonstrating that the proposed filtering and sensor fusion framework significantly improves detection and tracking accuracy of rogue drones inside a designated area.

ThB2	**Lounge A**
Aerial Robotic Manipulation I (Regular Session)	
Chair: Ghersin, Alejandro	Instituto Tecnológico De Buenos Aires
Co-Chair: Mas, Ignacio	Universidad De San Andrés

10:50-11:10	ThB2.1

Trajectory Control of the Suspended Load Pose Using Non-Stopping Flying Carriers, pp. 1005-1012

Girardello, Sofia	University of Padua
Michieletto, Giulia	University of Padua
Cenedese, Angelo	University of Padua
Franchi, Antonio	Univ. of Twente and Sapienza Univ. of Rome
Gabellieri, Chiara	University of Twente

This work presents the first closed-loop control framework for cooperative payload transportation with non-stopping flying carriers. The proposed method includes a feedback wrench controller that actively regulates the load's pose by computing the wrench required for tracking its desired pose trajectory. Building upon grasp-matrix formulation and internal force redundancy, an optimization layer dynamically shapes internal-force parameters to guarantee persistent carrier motion, while not altering the desired load wrench. The desired non-stopping carrier's trajectories are computed using the system's kinematics and desired cable forces. Numerical simulations demonstrate that the method successfully prevents the carriers from stopping, while achieving a successful tracking of the desired load trajectory.

11:10-11:30	ThB2.2

Isotropic Force Generation in Tilting-Rotor Omnidirectional Multirotors, pp. 1013-1020

Hernández-Rojo, Manuel	Universidad De Sevilla
Gonzalez-Morgado, Antonio	Universidad De Sevilla
Ollero, Anibal	Universidad De Sevilla
Heredia, Guillermo	Universidad De Sevilla

Omnidirectional multirotor aerial vehicles enable independent force and moment generation in arbitrary orientations. This capability makes them particularly attractive for aerial physical interaction tasks, as they can exert forces in any direction. However, the maximum achievable force typically depends on the direction, resulting in anisotropic force capabilities and preferred interaction directions. This paper presents design insights for single-axis tilting-rotor omnidirectional multirotors aimed at generating isotropic force sets, i.e., configurations in which the maximum achievable force is independent of direction, thereby eliminating preferred interaction axes. To this end, we introduce the Isotropic Force Space Index (IFSI) to quantify the degree of force isotropy of a platform. To avoid solving a high-dimensional optimization problem, the motor placement problem is analyzed as a composition of individual motor thrust sets. Based on this geometric interpretation, we propose the use of the Fibonacci lattice for motor placement, ensuring that the motors are evenly distributed around the platform. The proposed methodology is validated for different numbers of motors, demonstrating that the resulting platforms achieve higher force isotropy compared to state-of-the-art omnidirectional designs.

11:30-11:50	ThB2.3

Hierarchical Tracking Control of Multirotors under Saturation Constraints, pp. 1021-1028

Stauder, Julien	Centre National De La Recherche Scientifique

Yigit, Arda — Centre National De La Recherche Scientifique
Viollet, Stephane — Centre National De La Recherche Scientifique
Fantoni, Isabelle — Centre National De La Recherche Scientifique

Thrust saturations limit the wrench that multirotor aerial vehicles can develop. Geometric control on SE(3) can be adapted to account for actuator saturations by prioritizing the position tracking with respect to attitude control. When the pose tracking requires an unfeasible force to be generated by the actuators, the proposed controller modifies the orientation of the multirotor to preserve position tracking. This controller is also compatible with reconfigurable and morphing multirotors that can switch smoothly between under-actuation and full actuation. Simulations and experiments validate the proposed approach for multiple platforms.

11:50-12:10 — ThB2.4

Fault Tolerant Adaptive Control for Aerial Manipulators, pp. 1029-1036

Pose, Claudio Daniel — Universidad De Buenos Aires
Ghersin, Alejandro — Instituto Tecnológico De Buenos Aires
Mas, Ignacio — Universidad De San Andrés
Giribet, Juan Ignacio — Universidad De San Andrés

This work addresses the problem of fault tolerance in aerial manipulators, focusing on maintaining maneuverability after the failure of a single rotor without adding any extra hardware. Instead, the proposed approach exploits the ability to reposition the onboard manipulator or payload, thereby modifying the vehicle's center of mass (CoM) and moments of inertia to recover controllability. This study develops a Gain Scheduled (GS) adaptive controller that explicitly adapts to variations in the vehicle's moment of inertia induced by payload repositioning. The controller is implemented on a resource-constrained autopilot, which requires a design that balances computational efficiency with robustness. Simulations and experimental flight tests validate the proposed method, comparing the Gain Scheduled controller to a conventional PID controller under similar maneuvering scenarios.

12:10-12:30 — ThB2.5

U-Joint CAAMS: Experimental Evaluation of a Universal-Joint Continuum Manipulator for Aerial Manipulation, pp. 1037-1044

Uthayasooriyan, Anuraj — Queensland University of Technology
Alibrahim, Musab — Queensland University of Technology
Digumarti, Krishna Manaswi — Queensland University of Technology
Vanegas Alvarez, Fernando — Queensland University of Technology
Gonzalez, Luis Felipe — Queensland University of Technology

Continuum manipulators mounted on multi-rotor UAVs enable compliant aerial manipulation, but payloads and propeller downwash amplify out-of-plane bending and twisting that degrade end-effector pose accuracy. To address this problem, we present a universal-joint-based continuum manipulator designed to improve resistance to out-of-plane deformation during aerial manipulation. The proposed design uses a tubular backbone with spring-reinforced universal joints and an integrated conduit for internal routing and fluid delivery. We evaluate the design in still air and under peak propeller downwash across varying payloads, and benchmark it against a prior Nitinol-backbone CM. Bench tests show improved resistance to out-of-plane deformation across all conditions. Under peak downwash, the proposed design reduces mean error by 2.5–4× in yaw, 2–45× in y-axis, and up to 5× in roll compared to the NiTi-backbone design. We further analyze hover stability through in-flight coupled-disturbance tests over varying payloads and actuation speeds, and demonstrate the system in water sampling, spot spraying, and object transport.

ThB3 — Calypso A

Sensor Fusion (Regular Session)

Chair: Nyboe, Frederik F — University of Southern Denmark
Co-Chair: Amaral, Guilherme — INESC TEC - Institute for Systems and Computer Engineering, Technology and Science

10:50-11:10 — ThB3.1

Distributed Multi-Station Data Fusion for UAV Tracking Combining Vision and mmWave Radar, pp. 1045-1053

Amaral, Guilherme — Institute for Systems and Computer Engineering, Technology and Science
Fernandes, José Carlos — Institute for Systems and Computer Engineering, Technology and Science
Martins, João J. — Institute for Systems and Computer Engineering, Technology and Science
Dias, André — Institute for Systems and Computer Engineering, Technology and Science and Polytechnic of Porto
Lysak, Maksym — Institute for Systems and Computer Engineering, Technology and Science
Almeida, José Miguel — Institute for Systems and Computer Engineering, Technology and Science and Polytechnic of Porto
Silva, Eduardo — Institute for Systems and Computer Engineering, Technology and Science

Accurate infrastructure-based UAV localization remains challenging in the presence of occlusions, clutter, and limited observability from single sensing modalities. We present a distributed multi-station tracking framework that fuses mmWave radar and monocular vision to

achieve robust 3D position and velocity estimation. Building upon a prior single-station radar–vision tracker, we extend the approach to a network of three portable observation stations, each performing local multi-hypothesis tracking with uncertainty-aware Kalman filtering. Vision measurements provide angular constraints that improve radar data association and mitigate clutter-induced artifacts. Instead of transmitting raw detections, each station communicates a compact state estimate and covariance to a central fusion node, where an information-form filter produces a globally consistent estimate. The system is validated in indoor flight experiments using motion capture ground truth, while remaining fully independent of it during estimation. The fused solution achieves a 3D RMSE of 0.2342 m and improves robustness against degraded individual station estimates. These results highlight the potential of distributed radar–vision sensor networks for scalable and reliable infrastructure-based UAV localization.

11:10-11:30 ThB3.2

A Lightweight Framework for Neighborhood-Constrained UAV Localization Using Visual Embeddings, pp. 1054-1061

Dimos, Alexandros — University of the Aegean
Skoutas, Dimitrios — University of the Aegean
Nomikos, Nikolaos — University of the Aegean
Skianis, Charalabos — University of the Aegean

One of the most crucial functionalities of a UAV is to always be aware of its location, which is usually provided by an established navigation system, such as GNSS. However, there is no fallback mechanism in the case where GNSS is denied. For this reason, we propose a framework that acts as a fallback system for such occasions and relies mainly on the visual input from the UAV's camera. At its core, our framework uses this visual input and tries to match the drone's current POV with the correct area of a pre-loaded satellite map. Instead of using raw images, our approach relies on high-dimensional image embedding vectors generated using transformer neural networks and, more specifically, DINOv2. For matching, we utilize a codebook trained on samples from the satellite map, where we aggregate local image features using the VLAD algorithm and create image descriptors. Localization is then achieved by comparing the similarity between the UAV's live visual descriptor and the stored descriptors of the map. Our framework yielded promising results, and our analysis indicates that it is lightweight enough to operate on a UAV.

11:30-11:50 ThB3.3

Drone-In-A-Box: A Precise Indoor Autonomous Docking System, pp. 1062-1069

Godio, Simone — Technology Innovation Institute
Costa Fernandes, Rafael — Technology Innovation Institute
Montecchiari, Leonardo — Technology Innovation Institute
Al-Ali, Asraa — Technology Innovation Institute
Ashour, Reem — Technology Innovation Institute
Oliveira, Felipe — Technology Innovation Institute
Tortorici, Claudio — Technology Innovation Institute

Indoor autonomous drones are increasingly adopted for inspection, monitoring, and inventory tasks in GNSS-denied facilities, where reliable global positioning is essential to automate repeatable takeoff, navigation, and landing. A key challenge is enabling accurate relocalization to a global reference frame when the docking station can be placed arbitrarily, without relying on visual markers or infrastructure-intensive site modifications. To address this problem, we present a global localization system for indoor Unmanned Aerial Vehicles (UAVs) that enables takeoff and landing operations from a portable docking station ('drone-in-a-box'). Our approach fuses Ultra-Wideband (UWB) ranging and Light Detection and Ranging (LiDAR) measurements within an Error-State Extended Kalman Filter (ES-EKF), and is sensor-model agnostic, supporting Inertial Measurement Unit (IMU), LiDAR, and different hardware configurations. A UWB tag mounted on the drone interacts with anchors installed in the environment and additional tags on the docking box to provide robust range-based measurements; these enable an initial pose estimate computed via Particle Swarm Optimization (PSO), which is subsequently refined through LiDAR scan matching to refine localization. Experimental results in real-world indoor scenarios validate the proposed system, demonstrating accurate and repeatable autonomous deployment and recovery in indoor environments.

11:50-12:10 ThB3.4

Conformal Aerial Geo-Localization through Visual Place Recognition, pp. 1070-1077

Silva, Diogo — Academia Da Força Aérea
Bernardino, Alexandre — Instituto De Sistemas E Robótica, Instituto Superior Técnico
Cruz, Gonçalo — Portuguese Air Force Academy Research Center

Visual place recognition (VPR) can be used for aerial geo-localization (VG), by matching aerial images against a database of geo-referenced satellite images. VG can be a valuable replacement or complement for navigation within environments where the use of Global Navigation Satellite Systems (GNSS) is denied. While deep learning methods have significantly advanced VPR performance, most provide point estimates without statistical guarantees. We apply the Conformal Prediction (CP) framework to retrieval-based VPR, formulating distance-based and cumulative similarity-based nonconformity measures that generate retrieval sets guaranteed to contain the true location with a user-specified probability. While prior conformal retrieval work requires uncertainty-aware feature extractors, limiting applicability to specific model families, we propose model-agnostic formulations that operate directly on metric space, enabling the use of any pretrained backbone. We further propose a novel uncertainty measure for fixed-size retrieval sets, based on CP, enabling uncertainty-aware decision making under fixed computational budgets. Experiments on two cross-view aerial/satellite datasets validate coverage guarantees and compare the efficiency of standard CP, Adaptive Prediction Sets, and calibrated fixed-k retrieval.

12:10-12:30 ThB3.5

Towards Learning-Based Ground Velocity Estimation for UAVs Using Onboard Anemometer, pp. 1078-1085

Gabrlik, Petr — Brno University of Technology
Cihlar, Milos — Brno University of Technology

This paper investigates the feasibility of using an onboard ultrasonic anemometer for ground velocity estimation on a multirotor Unmanned Aircraft System (UAS), framed as a proof-of-concept study. The sensor is considered as an additional sensing modality that may complement conventional navigation sources, particularly in Global Navigation Satellite System (GNSS)-degraded environments. While anemometers directly measure air speed rather than ground speed and are affected by rotor-induced airflow disturbances, they offer attractive properties such as immunity to lighting conditions and resistance to external radio interference. A data-driven approach is proposed to compensate for aerodynamic effects and wind influence. A compact multilayer perceptron with a sliding temporal window is trained to map measured signals to reference ground velocity. The study includes the design and integration of a dedicated hardware setup and the collection of a real-flight dataset comprising numerous data collection missions and almost one hundred thousand samples. Experimental evaluation demonstrates a consistent reduction of bias and root mean square error compared to raw air speed measurements, confirming the viability of the proposed concept. The estimator remains computationally lightweight, with very low inference time on standard CPU hardware, supporting real-time onboard deployment.

12:30-12:50	ThB3.6

Event-Only Drone Trajectory Forecasting with RPM-Modulated Kalman Filtering, pp. 1086-1092

Sundra Valli Muthumanickam, Hari Prasanth	Aalto University
Habibiroudkenar, Pejman	Aalto University
Alamikkotervo, Eerik	Aalto University
Bouzoulas, Dimitrios	Aalto University
Ojala, Risto	Aalto University

Event cameras provide high-temporal-resolution visual sensing that is well suited for observing fast-moving aerial objects; however, their use for drone trajectory prediction remains limited. This work introduces an event-only drone forecasting method that exploits propeller-induced motion cues. Propeller rotational speed is extracted directly from raw event data and fused within an RPM-aware Kalman filtering framework. Evaluations on the FRED dataset show that the proposed method outperforms learning-based approaches and vanilla Kalman filter in terms of average distance error and final distance error at 0.4s and 0.8s forecasting horizons. The results demonstrate robust and accurate short- and medium-horizon trajectory forecasting without reliance on RGB imagery or training data.

ThB4	**Calypso B**
Testing and Evaluation: Autonomy I (Invited Session)	
Chair: Costello, Donald	University of Maryland College Park
Co-Chair: Hwang, George	Naval Air Warfare Center Aircraft Division

10:50-11:10	ThB4.1

Benchmarking Geometric Monocular Ranging for Autonomous Aerial Refueling (I), pp. 1093-1100

Lee, Kevin	United States Naval Academy
Lowe, Ryan	United States Naval Academy
Costello, Donald	University of Maryland
Mwaffo, Violet	United States Naval Academy

Reliable monocular ranging is a critical capability for autonomous probe-and-drogue aerial refueling under size, weight, power, and certification constraints. Reported performance across monocular ranging approaches is often difficult to compare due to differences in datasets, calibration, ground truth, and metrics. This paper presents a fair benchmark of two geometric methods: (i) a DNN detection pipeline that estimates 3D relative position from bounding-box geometry using calibrated similar-triangle relationships with weighted fusion, and (ii) a segmentation-driven pipeline that estimates 3D relative position by fitting an ellipse to the drogue rim and applying pinhole projection. Both approaches are evaluated on the same dataset with identical calibration, shared motion-capture ground truth, and unified error definitions. Performance is assessed using signed-error box plots and RMSE curves across a 7–22 ft envelope, along with normalized error distributions to support comparison across distance. Results show complementary behavior: the bounding-box method exhibits range-dependent bias drift, increasing RMSE with distance, and more frequent long-range outliers, whereas the segmentation/ellipse method maintains more uniform mid-range performance with a consistent overestimation bias but shows an abrupt far-field degradation where rim pixel support is reduced. These findings clarify accuracy–robustness tradeoffs and guide method selection for embedded AAR systems.

11:10-11:30	ThB4.2

Vision-Based Multi-Keypoint Relative Depth Estimation for Autonomous Aerial Refueling (I), pp. 1101-1108

Smith, Seamus	United States Naval Academy
Andersen, James	United States Naval Academy
Costello, Donald	University of Maryland
Mwaffo, Violet	United States Naval Academy
Coleman, Bianca	United States Naval Academy

Autonomous aerial refueling (AAR) can substantially extend the endurance and operational reach of uncrewed aerial systems (UAS), but many approach-phase concepts still rely on GPS-aided cues for join-up and deconfliction. Since GPS availability is not assured in contested environments, this paper evaluates a monocular, geometry-based alternative for relative navigation using multi-landmark pose recovery. A YOLO26 detector localizes six physically marked landmarks on a scaled aircraft surrogate, providing 2D image measurements paired with known 3D landmark coordinates. Camera-to-target pose is recovered via Perspective-n-Point (PnP) using OpenCV solvePnP, and the reported range is the optical-axis depth extracted from the estimated translation vector. Experiments are conducted in the USNA VIPER Laboratory with motion-capture ground truth, enabling repeatable evaluation across stand-off distance and centerline/$pm 15^{circ}$ viewing angles. Detector performance is reported using precision-recall behavior and mean average precision (mAP), while ranging accuracy is quantified using mean absolute error (MAE) and RMSE. Results show an approximately

linear depth-to-truth relationship with perspective-dependent systematic bias in the raw estimates; a simple per-perspective affine calibration reduces aggregate error from 24.77~mm MAE to 7.52~mm MAE (27.85~mm to 10.01~mm RMSE) over 1-16~ft in-lab distances. These findings provide measurement-driven evidence for the viability of multi-keypoint monocular ranging and clarify dominant error modes relevant to scaling toward longer equivalent stand-off distances under controlled conditions.

11:30-11:50 ThB4.3

Autonomous UAS Control Leveraging DNN-Based Monocular Camera Relative Position Estimation for Unmanned Aerial Refueling Systems (I), pp. 1109-1116

Lowe, Ryan — United States Naval Academy
Torshizi, Kasra — University of Maryland
Wendland, Lucas — University of Maryland
Mwaffo, Violet — United States Naval Academy
Costello, Donald — University of Maryland

The United States Navy plans to increase the number of uncrewed aerial systems (UASs) within its carrier air wings. These UASs are expected to operate in GPS-denied and RF-denied environments, requiring fully autonomous capabilities. A key enabler is the ability to perform autonomous aerial refueling without reliance on external positioning systems. This research investigates the viability of using relative position information from a single camera to autonomously control an UAS for aerial refueling docking. A deep neural network (DNN)-based monocular ranging system was adapted and evaluated in the University of Maryland's Omni-domain Autonomous Systems Integration Space (OASIS), a 4,800 square foot motion capture environment. A YOLO11m DNN was trained to identify the aerial refueling coupler and drogue basket at ranges from 5–50 ft. A similar-triangles ranging algorithm produced real-time position estimates of the coupler relative to the UAS that were utilized for navigation control and compared against truth data. The UAS used the position estimations and a bang-bang control architecture to align itself to an F/A-18 refueling drogue and approach the docking position. Across four test flights starting with 20 feet of range, the UAS successfully navigated to the coupler docking position. Mean error values between the estimated and true position of the drogue coupler relative to the UAS were less than 2.75 inches in the X, Z, and Range components, and less than 4.75 inches in the Y component. These results demonstrate that a single monocular optical payload can be used as a closed-loop control input for autonomous docking during AAR.

11:50-12:10 ThB4.4

February 2026 Development, Test & Evaluation, Verification & Validation (DTEVV) Workshop Summary (I), pp. 1117-1122

Costello, Donald — University of Maryland

The future of transportation is uncrewed and ultimately autonomous. Yet, a clear pathway does not exist on how to get there. The 4 February 2026 Development, Test & Evaluation, Verification & Validation (DTEVV) of Autonomous Systems Workshop focused on mapping out the priority research and workforce challenges that need to be addressed before it will be possible to field truly autonomous technology. The DTEVV Workshop brought together more than 100 technology and operations experts, faculty, students, members of the DTEVV workforce, and policymakers from academia, industry, and government to help define the gaps and offer strategies that may enable the fielding of autonomous systems. The morning focused on research gaps that need to be filled to enable the fielding of an autonomous system. The afternoon focused on the needs of the DTEVV workforce as they are tasked with evaluating the risks associated with fielding these systems. Both the morning and afternoon consisted of a keynote address, an interactive panel, and a proctored road map development activity. In total, 44 road maps were developed by the workshop attendees, and they are currently being analyzed to help guide future decisions on pathways for fielding autonomous systems.

12:10-12:30 ThB4.5

Framing the Research Agenda for AI Agent Testing on Operational Platforms: Lessons and Open Questions from the X-62 VISTA (I), pp. 1123-1128

Kinard, Rachel — USAF Test Pilot School
Zamot, Noel — USAF Test Pilot School

The integration of artificial intelligence agents into operational aerospace platforms presents a set of testing, trust, and interoperability challenges that existing certification and validation frameworks were not designed to address. This paper examines the X-62 VISTA (Variable Inflight Simulator Test Aircraft) as a case study in transitioning AI from laboratory demonstration to flight-ready operation. Rather than proposing definitive solutions, this work frames three interrelated research questions that demand attention as AI technologies mature toward fielded systems: (1) how to define and validate acceptable operational envelopes for nondeterministic AI systems, (2) how human operators should calibrate trust in agents that process information beyond human perceptual bandwidth, and (3) how networked intelligent systems will behave when operating within shared, contested airspace. Drawing on recent X-62 program milestones and the broader landscape of autonomous systems research, the paper argues that the X-62 VISTA offers a uniquely suitable platform for exploring these questions within a safe, bounded, and operationally relevant flight-test environment.

ThC1 **Nafsika**

UAS Applications II: Inspection and Monitoring (Regular Session)

Chair: Franchi, Antonio — Univ. of Twente and Sapienza Univ. of Rome
Co-Chair: Fernandes, Manuel C.R.M. — Universidade Do Porto

14:00-14:20 ThC1.1

Data Assisted Ground Truth Generation in Agricultural Orthomosaic, pp. 1129-1136

Kiforenko, Lilita — University of Southern Denmark
Midtiby, Henrik Skov — University of Southern Denmark
Ladig, Robert — Ritsumeikan University

The lack of reliable annotated datasets remains a major obstacle to applying deep learning in agriculture. This issue is particularly pronounced for large-scale orthomosaics, where manual labeling is impractical. In many agricultural settings, initial annotations are derived from available domain knowledge, such as planned crop layouts. While this information provides useful structural guidance, it often results in labels with substantial noise when actual plant emergence deviates from expectations. In this work, we investigate whether existing label-noise handling techniques can be adapted to generate usable training labels under such conditions. We propose a practical annotation pipeline for agricultural orthomosaics that combines prior planting information, unsupervised clustering, and iterative refinement using Co-teaching and Co-teaching+. The resulting Iterative Co-teaching+ pipeline progressively reduces the proportion of incorrect labels through domain-informed corrections and iterative training. On a newly introduced Oilseed Radish and Winter Rapeseed (OR--WR) dataset, initial labels with an estimated noise level exceeding 80% are refined to below 6%. Rather than proposing a new learning algorithm, this work examines the limits of existing methods under extreme label noise and demonstrates how domain knowledge can be used to stabilize label refinement in practice. To assess the practical impact of label quality, we train commonly used classifiers (YOLOv11n and ResNet-50) using labels obtained at different stages of the pipeline. This enables an analysis of how residual label noise affects downstream performance and the extent to which it can be tolerated. In addition to the proposed pipeline, we released the OR-WR dataset and a QGIS plugin to support efficient orthomosaic processing and annotation.

14:20-14:40 ThC1.2

Non-Contact Vibration-Based Damage Detection of Civil Structures Using a Cost-Effective Autonomous UAV, pp. 1137-1144

Becerril, Javier	University of Texas Rio Grande Valley
Vargas, Maximiliano	University of Texas Rio Grande Valley
Herrera Solis, Jennifer	University of Texas Rio Grande Valley
Gutierrez, Joanna	University of Texas Rio Grande Valley
Rios, Jorge	University of Texas Rio Grande Valley
Amjadian, Mohsen	University of Texas Rio Grande Valley
Tarawneh, Constantine	University of Texas Rio Grande Valley
Yang, Jinghao	University of Texas Rio Grande Valley
Lu, Qi	University of Texas Rio Grande Valley

This paper presents a non-contact approach for vibration-based structural damage detection using an autonomous and customized cost-effective unmanned aerial vehicle (UAV). The developed UAV integrates a lightweight onboard camera, embedded processing, and a visual positioning algorithm to enable stable operation and target tracking in indoor environments. Vibration signals are extracted from video recordings through vision-based motion tracking to identify shifts in natural frequencies indicative of structural degradation. A laboratory-scale frame structure is evaluated under healthy and simulated-damage conditions, where damage is introduced via an added mass. The proposed system is validated through a multi-platform experimental study involving two high-resolution smartphones, a USB camera, and a custom-built low-cost UAV equipped with an onboard camera and an AprilTag-based autonomous alignment system for operation in GPS-denied environments. The displacement time is extracted and analyzed in the frequency domain and compared to reference measurements from contact accelerometers and a finite element model. Experimental results from two contemporary mobile devices, a USB camera, and a custom-developed UAV show that all platforms successfully capture the fundamental frequency and its shift due to damage. Although the UAV exhibits slightly higher errors (approximately 5–6%) due to platform-induced disturbances and sensing limitations, it reliably detects damage-induced frequency changes. Compared to commercial UAV systems, the proposed platform achieves comparable inspection performance at significantly lower cost. These results demonstrate that low-cost autonomous UAVs provide a practical, flexible, and scalable solution for structural health monitoring.

14:40-15:00 ThC1.3

UAV Sensor Payload Interface for Operator-In-The-Loop Target Geolocation and Live Map Mosaic Overlays, pp. 1145-1152

Ashry, Ahmed	University of Maryland
Titus, Christopher	University of Maryland
Singal, Mudit	University of Maryland
Schmucki, Joshua	University of Maryland
Bortoff, Zachary	University of Maryland
Gaus, Joshua	University of Maryland
Paley, Derek	University of Maryland

Time-critical response missions require rapid geolocated target reports and scene context to support fast decisions. Unmanned aerial vehicles (UAVs) are well suited for wide-area scanning and target search, but aerial video can be difficult to interpret reliably under clutter, occlusions, and time pressure. To address this, we present USPI, a modular ROS~2 UAV Sensor Payload Interface that supports operator-in-the-loop use of live RGB/thermal streams. USPI enables click-to-center gimbal pointing and a pause-and-annotate workflow to localize one or more targets from image clicks, and it maintains a map-aligned mosaic overlay that updates scene context in real time. We evaluate USPI in controlled 15~m AGL field tests and in a timed mock mass-casualty scenario at 30~m AGL, showing sub-meter localization accuracy in the controlled tests and a median error of 1.3~m (RMSE 1.7~m) in the mock scenario.

15:00-15:20 ThC1.4

Autonomous Aerial Non-Destructive Testing: Ultrasound Inspection with a Commercial Quadrotor in an Unstructured Environment, pp. 1153-1160

Veenstra, Ruben	University of Twente
Bazzana, Barbara	University of Twente
Smits, Sander	University of Twente
Franchi, Antonio	Univ. of Twente and Sapienza Univ. of Rome

This work presents an integrated control and software architecture that enables arguably the first fully autonomous, contact-based non-destructive testing (NDT) using a commercial multirotor originally restricted to remotely piloted operations. To allow autonomous operation with an off-the-shelf platform, we developed a real-time framework that interfaces directly with its onboard sensor suite. The architecture features a multi-rate control scheme: low-level control is executed at 200 Hz, force estimation at 100 Hz, while an admittance filter and trajectory planner operate at 50 Hz, ultimately supplying acceleration and yaw rate commands to the internal flight controller. We validate the system through physical experiments on a Flyability Elios 3 quadrotor equipped with an ultrasound payload. Relying exclusively on onboard sensing, the vehicle successfully performs autonomous NDT measurements within an unstructured, industrial-like environment. This work demonstrates the viability of retrofitting off-the-shelf platforms for autonomous physical interaction, paving the way for safe, contact-based inspection of hazardous and confined infrastructure.

15:20-15:40 ThC1.5

Geometric Look-Angle Shaping Strategy for Enclosed Inspection, pp. 1161-1168

Shivam, Amit — Universidade Do Porto
Fernandes, Manuel C.R.M. — Universidade Do Porto
Vinha, Sérgio — Universidade Do Porto
Fontes, Fernando A.C.C. — Universidade Do Porto

This paper introduces inspection through GLASS, a Geometric Look-Angle Shaping Strategy for enclosed regions using unmanned aerial vehicles. In doing so, the vehicle's guidance command is constructed through a bounded, look-angle shaping function relative to a desired standoff path. By embedding a smooth, hyperbolic-tangent-type shaping function within a polar geometric framework, GLASS ensures global existence of the guidance dynamics while avoiding the far-field limitations inherent to conventional formulations. Lyapunov stability analysis establishes asymptotic convergence to a prescribed inspection standoff under explicit curvature feasibility conditions, along with analytical settling-time characteristics. The proposed strategy incorporates maximum turn-rate constraints without inducing singularities throughout the workspace. High-fidelity six-degree-of-freedom quadrotor simulations demonstrate the effectiveness of GLASS in representative enclosed inspection scenarios, highlighting a practically viable guidance framework for autonomous enclosed inspection missions.

15:40-16:00 ThC1.6

A4AWD: Augmenting Aerial Weed Detection Over Residential Lawns, pp. 1169-1176

Du, Jiaxin — Purdue University
Xia, Shengqing — Purdue University
Peng, Chunyi — Purdue University

In this paper, we conduct the first work to revolutionize weed detection in residential lawns using unmanned aerial vehicles (UAVs). Compared with prior weed detection studies, our target scenario is much harder. Weeds become extremely small (from near-ground cameras to UAVs) and visually like surrounding turfgrass (from crop fields to residential lawns), making them difficult to distinguish. Moreover, the lack of annotated aerial lawn weed datasets forces detectors to be trained on public ground-level datasets, introducing a ground-to-aerial domain shift that significantly degrades detection accuracy. To address these challenges, we propose A4AWD, a lightweight inference-time augmentation tailored for aerial weed detection. A4AWD devises a new weed-specific augmentation method tailored for green-on-green detection, where weeds are extremely tiny, irregular, and visually like the surrounding turfgrass. Our field test over 165 residential houses shows that A4AWD outperforms three SOTA approaches and achieves high precision in both healthy and weedy lawns, roughly 1.7x-2.5x higher than the second best. Our dataset is released at Github [1].

ThC2 **Lounge A**

Aerial Robotic Manipulation II (Regular Session)

Chair: Bronz, Murat — ENAC
Co-Chair: Verdoucq, Matthieu — ENAC

14:00-14:20 ThC2.1

Systematic Analysis of Coupling Effects on Closed-Loop and Open-Loop Performance in Aerial Continuum Manipulators, pp. 1177-1184

Amiri, Niloufar — Toronto Metropolitan University
Sepahvand, Shayan — Toronto Metropolitan University
Mantegh, Iraj — National Research Council of Canada
Janabi Sharifi, Farrokh — Toronto Metropolitan University

This paper investigates two distinct approaches to the dynamic modeling of aerial continuum manipulators (ACMs): the decoupled and coupled formulations. Both open-loop and closed-loop behaviors of a representative ACM are analyzed. The primary objective is to determine the conditions under which the decoupled model attains accuracy comparable to the coupled model while offering reduced computational cost under identical numerical conditions. The system dynamics are first formulated using the Euler–Lagrange method under the piecewise constant curvature (PCC) assumption, with explicit treatment of the near-zero curvature singularity. A decoupled model is then obtained by neglecting the coupling terms in the ACM dynamics, enabling systematic evaluation of open-loop responses under diverse actuation profiles and external wrenches. To extend the analysis to closed-loop performance, a novel dynamics-based proportional-derivative sliding mode image-based visual servoing (DPD-SM-IBVS) controller is developed to regulate image feature errors in the presence of a moving target. The controller is implemented with both the decoupled and coupled models, allowing a direct comparison of their effectiveness. Open-loop simulations reveal pronounced discrepancies between the two modeling approaches, particularly under varying torque inputs and continuum arm parameters. Conversely, closed-loop experiments demonstrate that the decoupled model achieves tracking accuracy on par with the coupled model (within subpixel error) while incurring lower computational cost.

14:20-14:40	ThC2.2

A Novel Lattice-Based Soft Gripper for Aerial Grasping, pp. 1185-1192

Faraji, Pedram	University of Luxembourg
Bhandari, Aabhash	University of Luxembourg
Voos, Holger	University of Luxembourg

Soft aerial manipulation is often hindered by structural gripper mass and payload-induced sway, which makes UAV flight control difficult. This paper introduces a monolithic, tendon-driven soft gripper utilizing Functionally Graded Lattices (FGL) 3D-printed from TPU. By modulating unit-cell geometry in fingers, we achieve localized mechanical properties programming while eliminating the pneumatic complexity of state-of-the-art alternatives. A systematic parametric study on a single soft finger identified a 10 mm hexagonal lattice finger as the optimal architecture, yielding a 75% mass reduction and an approximately 100% improvement in vibration damping (1.0s vs. 2.0s settling time) compared to silicone benchmarks. Integrated via a modular mechatronic system, the 150 g soft gripper assembly successfully transported payloads up to 650 g. Our results demonstrate that architected metamaterials provide a robust, lightweight, and rapidly manufacturable pathway for stable, high-speed soft aerial grasping in complex UAV applications.

14:40-15:00	ThC2.3

A Fully Passive Rack and Pinion Based Gripper Mechanism for Cylindrical and Planar Landing, pp. 1193-1200

Moslemi, Mohammad Erfan	Technical University of Munich
Hammad, Ahmad	Technical University of Munich
Tsagkaris, Michail	Technical University of Munich
Armanini, Sophie F.	Imperial College London

Micro Aerial Vehicles (MAVs) have advanced considerably in recent years due to their versatility and ability to operate in cluttered environments. However, their real-world use remains limited by endurance constraints and the difficulty of carrying large batteries. Existing solutions include perching, which often rely on motors, sensors, or complex actuation, adding weight, consuming energy, being surface-specific, and limiting integration on small MAVs. In contrast, this study presents a lightweight, fully passive perching mechanism that enables both planar and cylindrical landings without energy consumption, instead leveraging the vehicle's own weight for secure, reliable engagement. The gripper uses a rack-and-pinion mechanism for simplified actuation, and it disengages once the weight is lifted. This design ensures stable perching with minimal energy loss during perching and takeoff. With a single gripper weighing just 33 g, capable of being integrated on vehicles more than 20 times its weight, the mechanism provides perching on both cylindrical and planar surfaces, thus significantly enhancing the current capabilities of aerial robots. Testing was done on three different platforms: a 1.3 kg DJI drone, a 102 g entomopter, and a 450 g ornithopter. Tests showed the adaptability of the mechanism to different vehicles and its effectiveness in increasing the overall mission duration in each case.

15:00-15:20	ThC2.4

Swarm Choreography Made Simple: Superposed Guiding Vector Fields for Rigid Formation Path Following, pp. 1201-1208

Machado, João	ENAC
Verdoucq, Matthieu	ENAC
Jouffrais, Christophe	CNRS
Bronz, Murat	ENAC

This paper presents a decentralized guiding vector field framework for rigid formation path following multi-UAV systems based on the superposition of simple rule-driven vector fields. Each control objective is encoded as a dedicated vector-field component: a normalized tangential term to ensure progression along a prescribed geometric path at a desired speed, a convergence term driving the formation toward the path, a local coordination term that preserves the desired formation shape through a pseudo-path parameter, and a local separation term for inter-agent collision avoidance. The coordination mechanism requires the exchange of only a single scalar per agent, resulting in low communication bandwidth. Partial theoretical results establish convergence of the swarm to the desired path and formation in the absence of the separation term, while collision avoidance is formally guaranteed. The approach is experimentally validated using a swarm of five quadrotors executing two 3D choreographies. The first experiment involves tracking a helical path while maintaining a rigid V-shaped formation. The second demonstrates a spiral-like motion obtained by a rotating circular formation tracking a vertical line. The experimental results support the effectiveness and practical applicability of the proposed framework.

15:20-15:40	ThC2.5

Autonomous Contact Inspection with Underactuated UAVs in Task-Space, pp. 1209-1215

Greblo, Luka	University of Zagreb
Car, Marko	University of Zagreb
Ivanovic, Antun	University of Zagreb
Goricanec, Jurica	University of Zagreb
Markovic, Lovro	University of Zagreb
Orsag, Matko	University of Zagreb
Bogdan, Stjepan	University of Zagreb

This paper presents a novel framework for autonomous inspection of metallic infrastructure leveraging real- time stiffness estimation, surface-aligned impedance adaptation in underactuated aerial unmanned aerial vehicle (UAV) and unactuated manipulator, addressing the pervasive challenge of underactuation-induced sliding during contact tasks. Simulation results in Gazebo demonstrate suppression of lateral sliding and precise force regulation on inclined planes, enabled by real-time stiffness adaptation through a Lyapunov-derived impedance law. Field trials confirm robust contact maintenance, accurate adaptive stiffness convergence, and reliable inspection under variable surface geometries and wind disturbances. A LiDAR-based surface detection and RANSAC pipeline aligns the UAV control frame with the local surface normal, de- coupling normal-force regulation from underactuated lateral dynamics. Together with a compliant

end-effector integrating a load cell and passive adhesion, this design cushions impacts while preserving accurate force sensing. The integration of surface-aligned impedance adaptation, online stiffness estimation, and lightweight mechanical compliance yields an unmodified, cost-effective underactuated UAV platform capable of autonomous and stable surface interaction, paving the way for rapid, safe, and high-quality industrial inspection workflows.

ThC3	**Calypso A**
Simulation and UAS Testbeds (Regular Session)	
Chair: Ollero, Anibal	Universidad De Sevilla
Co-Chair: Flores, Gerardo	Texas A&M International University

14:00-14:20 ThC3.1

High-Fidelity Antarctic UAV Simulation with Thermal Terrain Modelling, pp. 1216-1223

Sandino, Juan — Queensland University of Technology
Boiteau, Sebastien — Queensland University of Technology
Brown, Daniel — Queensland University of Technology
Bollard, Barbara — University of Wollongong
Gonzalez, Luis Felipe — Queensland University of Technology

Developing and testing UAV algorithms for Antarctic operations is constrained by brief summer field windows, sub-zero equipment failures, and the high cost of remote deployments. We integrate real-world terrain data from three East Antarctic sites (ASPA~135, Robinson Ridge, and Bunger Hills) into Gazebo simulation environments with accurate terrain geometry, RGB textures, and thermal signatures derived from field sensor data. The pipeline introduces a thermal terrain modelling method that compensates for Gazebo's lack of thermal heightmap support by generating transparent mesh overlays from digital elevation models with embedded thermal properties, enabling thermal search and rescue simulations over varied Antarctic terrain. The pipeline processes field-collected imagery through automated orthomosaicking, raster alignment, and texture generation stages, producing simulation-ready assets at ground sampling distances from 0.25 to 10.8~cm/pixel. A thermal search and rescue case study validates the pipeline: a YOLOv8 detector trained entirely on simulated thermal imagery achieved 0.995 mAP@0.5 and 1.0 recall for human target detection across all three terrains. The framework integrates ROS2 Humble, PX4 Software-in-the-Loop autopilot, and real-time object detection, supporting applications including autonomous navigation and environmental monitoring. All simulation environments and tools are designed for reproducible Antarctic UAV research, reducing reliance on costly and logistically constrained field campaigns.

14:20-14:40 ThC3.2

CFD-Based Wind Turbulence Assessment Model for Urban UAV Path Planning, pp. 1224-1230

Aldao Pensado, Enrique — University of Vigo
Veiga-Piñeiro, Gonzalo — University of Vigo
Martínez-Alonso, Gálata — University of Vigo
Veiga-López, Fernando — University of Vigo
Martin, Elena — University of Vigo
Gonzalez Jorge, Higinio — University of Vigo

The use of Unmanned Aerial Vehicles (UAVs) has grown substantially in recent years, owing to their efficiency and versatility. These advantages have led to their widespread adoption in applications such as logistics, infrastructure inspection, and environmental monitoring. However, such operations entail a high level of risk, as UAVs are particularly sensitive to adverse environmental conditions, especially wind gusts and turbulence, which can compromise flight stability and safety. This issue is especially relevant in urban areas, where the interaction between wind and built structures generates complex flow patterns, including instabilities and wake regions. These phenomena occur at spatial scales of only a few meters, requiring high-resolution tools such as Computational Fluid Dynamics (CFD) models to anticipate their formation. Consequently, recent studies have integrated CFD simulations into UAV path-planning tools to avoid flight through highly turbulent regions. Typically, these approaches analyse fluid variables such as wind speed or turbulent kinetic energy and restrict UAV access in areas exceeding predefined turbulence thresholds. However, such threshold-based methods are often arbitrary and do not account for the specific characteristics of the UAV when assessing the impact of turbulence on controllability. In this work, a turbulence assessment model is proposed to characterize UAV controllability under varying wind conditions. The proposed approach employs CFD simulation results and conducts a statistical analysis based on Dryden turbulence models. This information is then integrated into an efficient path-planning framework, enabling the computation of safe UAV trajectories in complex urban environments.

14:40-15:00 ThC3.3

Low-Latency Quasi-Static Modeling of UAV Tether Aerodynamics, pp. 1231-1238

Beffert, Max — University of Tübingen
Zell, Andreas — University of Tübingen

One of the main limitations of multirotor UAVs is their short flight time due to battery constraints. A practical solution for continuous operation is to power the drone from the ground via a tether. While this approach has been demonstrated for stationary systems, scenarios with a fast-moving base vehicle or strong wind conditions require modeling the tether forces, including aerodynamic effects. In this work, we propose two complementary approaches for low-latency quasi-static tether modeling with aerodynamics. The first is an analytical method based on catenary theory with a uniform drag assumption, achieving very fast solve times below 1~ms. The second is a numerical method that discretizes the tether into segments and lumped masses, solving the equilibrium equations using CasADi and IPOPT. By leveraging initialization strategies, such as warm starting and analytical initialization, low-latency performance was achieved with a solve time of 5~ms, while allowing for flexible force formulations. Both approaches were validated in real-world tests using a load cell to measure the tether force. The results show that the analytical method provides sufficient accuracy for most tethered UAV

applications with minimal computational cost, while the numerical method offers higher flexibility and physical accuracy when required. These approaches form a lightweight and extensible framework for low-latency tether simulation, applicable to both offline optimization and online tasks such as simulation, control, and trajectory planning.

15:00-15:20 ThC3.4

Tutorial on Development of ROS2 Gazebo Simulator of Dual Arm Aerial Manipulator with PX4 for Parcel Delivery in Intra-Logistics, pp. 1239-1244

Molina-Aguiar, Nelson	GRVC Robotics Lab
Suarez, Alejandro	Universidad De Sevilla
Gonzalez-Morgado, Antonio	Universidad De Sevilla
Ollero, Anibal	Universidad De Sevilla

This tutorial paper explains how to develop a ROS2 Gazebo simulator of a dual arm aerial manipulation robot intended to conduct parcel delivery operations in a representative intra-logistics scenario. This work follows a real-to-sim approach in the sense that the simulator replicates the aerial robot, scenario, and operation carried out by a fully autonomous dual arm aerial delivery robot cite{suarez2025fully} during the euROBIN Project Cooperative Competition. The aerial robot consists of a quad-rotor platform controlled with the PX4 flight control software, equipped with a lightweight and human-size dual arm manipulator providing two joints per arm (shoulder and elbow pitch flexion/extension), integrating a camera for parcel detection and localization with Aruco markers, and a 2D LiDAR for localization and mapping. The paper outlines the process of creating the ROS2 simulator package from the 3D model and physical parameters of the robot and the objects in the scenario relying on the examples from PX4, including a 3D mesh of the flying arena scanned from the real scenario. The purpose of this work is to serve as guidelines for students and young researchers in the development of an aerial robot simulator.

15:20-15:40 ThC3.5

Controllability of the Soft-PVTOL under Tendon Failure: Analysis with Passive Elastic Arms, pp. 1245-1251

Verdín, Rodolfo Isaac	Centro De Investigaciones En Òptica
Flores, Gerardo	Texas A&M International University

The Soft-PVTOL is a planar vertical take-off and landing aircraft with soft continuum arms actuated by tendons. In its nominal configuration, the system has four control inputs two thrusts and two tendon torques and five degrees of freedom. This paper investigates the behavior of the Soft-PVTOL when the tendon actuation is lost, as may occur due to tendon failure, hysteresis, fixed tendons, or mechanical faults. In this degraded mode, the only available control inputs are the two thrust forces at the arm tips, while the arm curvatures evolve passively under the combined effect of elastic restoring forces, damping, gravity, and a thrust-induced bending torque $T_i cdot l_i cdot sinc(q_i)$. We show that this passive-arm configuration remains locally controllable at hover for all positive values of the arm stiffness, despite losing two of its four actuators. However, the degree of controllability measured by the minimum singular value of the controllability matrix depends critically on the stiffness parameter, with a pronounced weakening near a critical threshold. Simulation results demonstrate successful takeoff and hover stabilization using a simple PD-based controller. Experimental results on a constrained test stand validate pitch tracking and passive arm dynamics under realistic operating conditions.

15:40-16:00 ThC3.6

ROSplane 2.0: A Fixed-Wing Autopilot for Research, pp. 1252-1259

Reid, Ian	Brigham Young University
Ritchie, Joseph	Brigham Young University
Moore, Jacob	Brigham Young University
Sutherland, Brandon	Brigham Young University
Snow, Gabe	Brigham Young University
Tokumaru, Phillip	AeroVironment Inc
McLain, Tim	Brigham Young University

Unmanned aerial vehicles (UAV) research requires the integration of cutting-edge technology into existing autopilot frameworks. This process can be arduous, requiring extensive resources, time, and detailed knowledge of the existing system. ROSplane is a lean, open-source fixed-wing autonomy stack built by researchers for researchers. It is designed to accelerate research by providing clearly defined interfaces with an easily modifiable framework. Built around ROS 2, ROSplane allows for rapid integration of low or high-level control, path planning, or estimation algorithms. A focus on lean, easily understood code and extensive documentation lowers the barrier to entry for researchers. Recent developments to ROSplane improved its capacity to accelerate UAV research, including the transition from ROS 1 to ROS 2, enhanced estimation and control algorithms, increased modularity, and an aerodynamic modeling pipeline. This aerodynamic modeling pipeline can reduce the effort of transitioning from simulation to real-world testing by not requiring costly system identification or computational fluid dynamics tools. ROSplane's architecture reduces the effort required to integrate new research tools and methods, expediting hardware experimentation.

ThC4 **Calypso B**

Testing and Evaluation: Autonomy II (Invited Session)

Chair: Costello, Donald	University of Maryland College Park
Co-Chair: Hwang, George	Naval Air Warfare Center Aircraft Division

14:00-14:20 ThC4.1

Flight Test Evaluation of a Standardized Interface Framework for Autonomous Drone Functionality (I), pp. 1260-1267

Costello, Donald	University of Maryland
Safeer, Jacob	University of Maryland

Autonomous uncrewed aerial systems (UAS) research increasingly relies on perception-driven navigation and control, yet transitioning autonomy algorithms from simulation and bench testing to repeatable flight testing remains hindered by fragile integration paths and a lack of reusable interfaces between autonomy software and flight controllers. This paper presents a flight-tested evaluation of a standardized autonomy-to-flight-controller interface implemented on a modular quadrotor research platform, extending prior work on a portable ROS~2-to-PX4 software stack. In addition, informed by a survey of comparable autonomy-capable quadrotor platforms, the paper proposes an NDAA-compliant electronics architecture that prioritizes robust offboard communication, sufficient onboard vision computing, and manageable mass/power for repeatable perception-driven experiments. An incremental indoor flight-test campaign was conducted to assess end-to-end command execution fidelity, mode-transition predictability, and operational reliability factors that emerge only in flight. Tests progressed from bench-level verification and single-setpoint offboard control to multi-setpoint trajectories and perception-driven visual navigation using fiducial marker tracking to generate closed-loop velocity commands. Results demonstrate stable and consistent tracking of autonomy-generated velocity setpoints during autonomous target approaches, with reliable engagement and disengagement of offboard mode and no observed interface-related faults under nominal conditions. The paper further documents flight-specific failure cases—including low-altitude optical-flow estimation degradation, vibration sensitivity, and companion-computer communication bottlenecks—and the mitigations applied to restore reliable test.

14:20-14:40 ThC4.2

From Language to Logic: A Theoretical Architecture for VLM-Grounded Safe Navigation (I), pp. 1268-1275

Sakano, Kristy University of Maryland
Harrington, Kalonji University of Maryland
Xu, Huan University of Maryland

We propose an architecture for integrating high-level, human-provided safety rules and operator-aligned semantic preferences into autonomous robot navigation in unstructured outdoor environments. In our approach, natural-language rules are translated into Signal Temporal Logic (STL) specifications that guide planning and navigation during runtime. Persistent, environment-centric rules and terrain preferences are grounded into a 2D cost map, while temporally dynamic requirements are expressed as STL specifications to be monitored during runtime. We hypothesize the use of Vision-Language Models (VLMs) for zero-shot scene understanding, enabling mapping between human instructions, semantic features, and environmental constraints. Within this framework, we construct an illustrative navigation model that is designed to satisfy a set of STL-encoded specifications and soft operator preferences through formal satisfaction metrics embedded into environmental properties and runtime monitoring.

14:40-15:00 ThC4.3

Evaluating Collision Risk of UAS in Proximity to Critical Infrastructure (I), pp. 1276-1283

Snyder, Paul University of North Dakota
Ullrich, Michael University of North Dakota
Pothana, Prasad University of North Dakota
Vidhyadharan, Sreejith University of North Dakota

Uncrewed Aerial Systems (UAS) operations present a growing risk to critical infrastructure due to unexpected anomalies in navigation systems or failure of critical components. This risk is particularly elevated when operations occur in complex airspace environments near critical infrastructure. According to the Department of Homeland Security (DHS), airports and associated facilities such as air traffic control towers are classified as critical infrastructure within the transportation sector. As UAS operations become increasingly prevalent, it is essential to address the associated collision risks when critical infrastructure is present within the operational environment. Unintended UAS intrusions into restricted zones can result from flight control or subsystem failures, posing a serious threat to airport operations and human life. In this paper, we examine the collision risk of UAS operating near critical infrastructure in beyond visual line of sight (BVLOS) conditions in and around airport environments. The analysis presented is based on an air traffic control tower located at Grand Forks International Airport. Risk assessment was conducted using a digital replica of the infrastructure and surrounding airspace within a simulation environment, with risk analysis focused on loss-of-control scenarios.

15:00-15:20 ThC4.4

Experimental Verification of Multi-Agent, Autonomous Search and Rescue Prototype (I), pp. 1284-1289

Bopp, Autumn United States Naval Academy
Farmer, Adam United States Naval Academy
Frey, Christian United States Naval Academy
Kruszczynski, Raquel United States Naval Academy
Mccallum, Sage United States Naval Academy
Van Dyk, Joe United States Naval Academy
Feemster, Matthew United States Naval Academy
O'Brien, Richard United States Naval Academy

Using commercially available, off-the-shelf equipment, a multi-agent autonomous search and rescue (SAR) system is developed to locate, identify, and maneuver to a target representing a person lost at sea. The system includes an Apache3 uncrewed surface vessel (USV) and Hexsoon EDU-650 uncrewed aerial vehicle (UAV). The UAV uses received signal strength indicator (RSSI) data to localize a radio frequency (RF) source mounted on the target and communicates the target's GPS coordinate to the USV. A combined steering and heading control is developed for the USV to navigate towards the transmitted GPS waypoint. Once near the waypoint, the USV navigates to the target using its on-board camera and a computer vision model trained on the target, an orange life ring. All aspects of the autonomous SAR system have been tested, evaluated, and verified in an outdoor environment and this experimental data is presented and analyzed.

15:20-15:40 ThC4.5

LIFEGUARD: A Lightweight Intent-Focused Engine for Guidance in Unmanned Autonomous Rescue Deployments (I), pp.

1290-1297

Seargeant, John — United States Naval Academy
Feemster, Matthew — United States Naval Academy
DeVries, Levi — United States Naval Academy
Kutzer, Michael — United States Naval Academy

Creating and executing missions for autonomous vehicles during search-and-rescue (SAR) operations is challenging for inexperienced operators and can become impossible under degraded communication conditions. Traditional ground control stations (GCS) require extensive workflows, mission changes can be slow to plan, and reliable internet connectivity cannot be assumed in certain field environments. The Lightweight Intent-Focused Engine for Guidance in Unmanned Autonomous Rescue Deployments (LIFEGUARD) is a self-contained, offline-capable GCS that converts spoken natural language intent into executable MAVLink missions for one or more autonomous agents. The system couples an offline speech-to-text (STT) engine (Vosk), a compact spaCy-based natural language understanding (NLU) stack with number normalization and GPS coordinate parsing, and a robust mission execution module built on PyMAVLink. Operators can issue voice commands, and LIFEGUARD extracts entities, generates and executes flight paths, and coordinates agents, all while including confirmation dialogs. We demonstrate software-in-the-loop (SITL) validation, showing multi-agent coordination in a multi-vehicle experiment executed without internet connectivity. The system achieves an end-to-end latency of <2 seconds from the push-to-talk (PTT) release to the initiation of mission upload, enabling responsive voice control of unmanned systems in time-critical SAR scenarios.

ThD1	**Nafsika**
UAS Communications and Networked Swarms (Regular Session)	
Chair: Fourlas, George K.	University of Thessaly
Co-Chair: Morbidi, Fabio	University of Picardie Jules Verne

16:20-16:40 — ThD1.1

A Low-Complexity Distributed Adaptive Performance Formation Control Scheme for Multi-Quadrotor Systems with Input Constraints, pp. 1298-1305

Gkesoulis, Athanasios — University of Patras
Fourlas, George K. — University of Thessaly
Bechlioulis, Charalampos — University of Patras
Karras, George — University of Thessaly

In this paper, we address the distributed leader–follower formation control problem for multiple quadrotor aerial vehicles subject to hard amplitude constraints on the commanded translational velocities and yaw rate. Using a consensus-based formulation on the augmented pose, we design a low-complexity kinematic-level controller that enforces prescribed transient and steady-state performance for all local formation errors using only local neighbor information. To explicitly account for saturation in the embedded low-level flight controller, we introduce an adaptive prescribed performance mechanism that relaxes the performance bounds during saturation and recovers the nominal performance once feasibility is restored, thereby avoiding infeasible control demands and ensuring bounded closed-loop behavior. All closed-loop signals remain bounded and prescribed performance for the formation errors is guaranteed to the extent permitted by the imposed input constraints. Simulation results validate the effectiveness of the proposed approach.

16:40-17:00 — ThD1.2

Scalable Airborne Cellular Relay System for Emergency Communication Coverage, pp. 1306-1313

Kimura, Kiyoshi — SoftBank Corp
Park, Soekjun — SoftBank Corp
Nomachi, Masanori — SoftBank Corp

This paper presents a scalable airborne cellular relay system for emergency communication coverage, focusing on simulation-based coverage characterization and control-oriented system design. The proposed architecture adopts a control-oriented framework in which RF-IQ–based uplink sensing and multi-aircraft redundancy are defined as future extensions for adaptive and resilient operation in disaster scenarios. The relay payload is integrated into a certified Super SPIDI pod and is designed for integration with long-endurance aerial platforms. A dual-link architecture decouples the feeder link and service link, enabling frequency reuse and flexible backhaul configuration. Multi-gateway interference suppression using zero-forcing (ZF) was experimentally validated in an SDR environment, demonstrating significant error vector magnitude (EVM) improvement under cochannel interference conditions. Simulation-based evaluations were conducted to characterize reference signal received power (RSRP) distributions under helicopter-assisted deployment geometries and to identify practical deployment constraints, including antenna actuation limits. The results establish quantitative coverage trends with respect to altitude and horizontal distance and provide a structured validation framework toward future field experiments. The proposed system emphasizes practical airborne integration and provides a foundation for the deployment of resilient airborne communication systems in large-scale disaster response scenarios.

17:00-17:20 — ThD1.3

Fast and Robust Event-Based Optical Communication for Aerial Robots Via Active LED Markers, pp. 1314-1321

Jabbari Tofighi, Nafiseh — University of Picardie Jules Verne
Robic, Maxime — Politecnico Di Milano
Caracotte, Jordan — University of Picardie Jules Verne
Vasseur, Pascal — University of Picardie Jules Verne
Morbidi, Fabio — University of Picardie Jules Verne

Unmanned Aerial Vehicles (UAVs) are popular robotic platforms nowadays and they are gradually entering our everyday lives. For normal operation, a two-way communication link between a UAV and a ground station, has to be established. While radio-frequency communication is a simple and common option, it suffers from major drawbacks, such as interference and multi-path errors. Moreover, it is prone to spoofing/jamming attacks which might have catastrophic consequences in densely populated or sensitive areas. To overcome these limitations, in this paper, we propose a compact LED-event camera system for fast optical communication via a new optimized dynamic N-pulse protocol. A learning-based method guarantees the robust detection and tracking of the active markers and it makes the application of standard 3D pose estimation algorithms possible. The effectiveness of the proposed system is demonstrated via hardware experiments with a DJI Matrice 600 Pro hexarotor and a Prophesee Gen. 4.1 HD camera.

17:20-17:40 ThD1.4

SNR and Bandwidth-Aware Handover Strategy for UAV Monitoring in Urban Areas, pp. 1322-1329

Alves Fagundes Junior, Leonardo — Universidade Federal De Viçosa
Bonilla Licea, Daniel — Mohammed VI Polytechnic University
Brandao, Alexandre Santos — Universidade Federal De Viçosa

Unmanned Aerial Vehicles (UAVs) are increasingly employed in long-distance urban monitoring and inspection missions that require reliable high-throughput wireless connectivity for real-time video transmission. Evaluating such communication strategies in large-scale urban environments is costly and difficult to reproduce experimentally, making simulation a fundamental tool. However, many existing platforms treat UAV mobility and wireless communication independently, neglecting their strong coupling under frequent handovers and data-intensive traffic. This work presents the modeling and evaluation of an SNR- and bandwidth-aware handover strategy for UAV-based urban monitoring. The proposed approach prioritizes throughput while preserving link robustness by triggering handovers only when the received SNR falls below a predefined threshold. Simulation results in representative urban scenarios demonstrate improved link stability, controlled packet loss, and sustained data rates during mission execution.

17:40-18:00 ThD1.5

The Swarming Project - Coordination and Guidance of Unmanned Swarms, pp. 1330-1338

Friedrich, Max — German Aerospace Center
Bethge, Johanna — German Aerospace Center
Lichtenheldt, Roy — German Aerospace Center
Lueken, Thomas — German Aerospace Center
Kallies, Christian — German Aerospace Center
Scharnweber, Alexander — German Aerospace Center
Krause, Stefan — German Aerospace Center
Donkels, Alexander — German Aerospace Center
Hellerer, Matthias — German Aerospace Center
Walko, Christian — German Aerospace Center
Gäde, Julius — German Aerospace Center
Winkler, Tobias Kurt Georg — German Aerospace Center
Felsch, Gerrit — German Aerospace Center
Laudien, Tim — German Aerospace Center
Franke, Dennis — German Aerospace Center
Paz Goncalves Martins, Ana — German Aerospace Center
Shutin, Dmitriy — German Aerospace Center
Mueller, Reiko — German Aerospace Center

Rapid acquisition of situation awareness and the execution of complex, multi domain missions are critical in disaster response operations. The Swarming project, a research effort at the German Aerospace Center (DLR), addresses this challenge, where a fleet of heterogeneous unmanned aircraft and ground systems operated in swarms provide critical information from a disaster site in real-time. The swarms are coordinated in a task-based manner from one central ground control station. Furthermore, a manned helicopter serves as a mothership for unmanned aircraft that can be dropped in flight and autonomously integrated into a swarm. This paper describes the components that were developed, integrated into a system-of-systems and demonstrated within the scope of a simulation campaign using a multi-agent simulation system. An outlook on the next steps for further exploitation of the Swarming platform is given.

18:00-18:20 ThD1.6

LLM-Enabled Human-In-The-Loop Control of Multi-UAV Teams under Communication Constraints, pp. 1339-1346

Alamdar, Khawaja Ghulam — University of Zagreb
Petric, Frano — University of Zagreb
Orsag, Matko — University of Zagreb

This work presents a human-in-the-loop framework for coordinating multi-UAV teams in disaster environments, where a large language model serves as a natural-language interface between a human operator and a swarm of UAVs operating under short-range communication constraints. The system is demonstrated in a mission scenario in which a ground robot explores an environment while UAVs act as communication relays to maintain connectivity between the robot and a base station. The operator provides high-level guidance that complements an autonomous connectivity-and-perching controller. The framework is evaluated in multiple simulated environments using connectivity and mission-duration metrics, together with interaction measures such as command-to-execution delay. Experiments show that trained user interaction can outperform the fully autonomous baseline in multiple environments.

ThD2	Lounge A
Risk Analysis and Manned/Unmanned Aviation (Regular Session)	
Chair: Bertrand, Sylvain	ONERA
Co-Chair: Carlson, Megan	University of Kansas

16:20-16:40 ThD2.1

Ground Risk Aware Path Planning for UAVs under Regulatory Criteria from SORA, pp. 1347-1354

Bertrand, Sylvain — Université Paris-Saclay
Lala, Stephanie — Université Paris-Saclay
Raballand, Nicolas — Université Paris-Saclay

This paper proposes a path planning algorithm that explicitly accounts for ground risk constraints as directly expressed by the SORA risk assessment method, considered in UE regulations on UAVs. Two criteria are handled: one related to the Ground Risk Class of the operation, and another on containment requirements related to the risk of fly-away and crash over the Adjacent Area of the operation. A filtering process of the population density map is proposed along with a path planning algorithm that automatically and iteratively adjusts the trade-off between the length of the path and the ground risk criterion. The proposed algorithm is illustrated on an UAV operation close to areas with high population densities.

16:40-17:00 ThD2.2

Collision Risk Analysis Near Airways Using Cluster-Based Air Traffic Models, pp. 1355-1362

Chiaratti, Anthony — Queensland University of Technology
Mcfadyen, Aaron — Queensland University of Technology
Mejias Alvarez, Luis — Queensland University of Technology

The integration of Uncrewed Aerial Vehicles (UAVs) into non-segregated airspace presents a critical safety challenge, requiring approval mechanisms that are both rigorous and operationally flexible. This paper proposes a hybrid risk assessment framework for operations near airways that synthesizes deterministic geometric constraints with probabilistic collision risk modeling. The assessment logic operates on a two-tier hierarchy: first, a strict geometric veto prohibits operations within the 3 sigma deviation safety bounds of crewed airways; second, it evaluates the quantitative collision (NMAC) risk against a Target Level of Safety (TLS) threshold. We assess this framework using a cluster-based air traffic model derived from real-world traffic data in a terminal area. The results validate that while geometric conflicts require spatial replanning, risk-based conflicts can often be resolved through temporal scheduling, maximizing airspace access without compromising safety.

17:00-17:20 ThD2.3

From Bench to Flight: Translating Drone Impact Tests into Operational Safety Limits, pp. 1363-1370

Mili, Mohamed Az — École De Technologie Supérieure
Gérard, Paul — École De Technologie Supérieure
Catar, Louis — École De Technologie Supérieure
Tabiai, Ilyass — École De Technologie Supérieure
St-Onge, David — École De Technologie Supérieure

Indoor micro-aerial vehicles (MAVs) are increasingly considered for tasks that bring them near people, yet practitioners lack a practical way to tune motion limits to measured impact risk. We present an end-to-end, open tool chain that turns benchtop impact tests into deployable safety governors for drones. First, we detail a compact, replicable impact rig and protocol that captures force–time profiles across drone classes and contact surfaces. Second, we provide data-driven fits that map pre-impact speed to impulse and contact duration, enabling direct computation of speed bounds for a target force limit. Third, we release scripts and a ROS2 node that enforce these bounds online and log compliance, with hooks for facility-specific policies. We target indoor MAV platforms with protective cages, focusing on bounding blunt contact forces of the airframe rather than propeller-strike hazards. We validate runtime enforcement in a closed-loop PX4-SITL/Gazebo setup (rotor-on dynamics), while physical rotor-on impact testing is left for future work. The contribution is a practical bridge: from measured impacts to runtime limits, with sharing datasets, code, and a repeatable process that teams can adopt to certify indoor MAV operations near humans.

17:20-17:40 ThD2.4

A Probability Collision Risk Assessment and Decision Support Framework for UAV Intrusion in Airport Terminal Airspace, pp. 1371-1379

Lei, Xuming — Beihang University
Xu, Yan — Beihang University
Peng, Bo — Beihang University
Cai, Kaiquan — Beihang University

UAV intrusion events pose significant safety risks to airport operation due to their high uncertainty, limited observability and potential operational disruptions. This paper proposes an integrated trajectory uncertainty prediction and collision risk assessment framework for UAV intrusion scenarios in airport terminal airspace. A probabilistic trajectory prediction model is developed to estimate both UAVs and manned aircraft future positions and their associated uncertainties. Based on these heterogeneous trajectory predictions, a collision risk assessment method is established to derive the lower bound of time-to-collision and upper bound of collision probability in both nominal and worst-case intrusion scenarios. Quantitative risk indicators are also provided to support maneuvering and countermeasure decisions during critical flight phases. Results demonstrate that the proposed framework can provide accurate collision risk estimates, supporting timely decision-making under representative UAV intrusion events.

17:40-18:00 ThD2.5

Hybrid Trajectory Prediction for Non-Cooperative UAS Using Probabilistic LSTM-IMM Fusion, pp. 1380-1388

Yu, Jinjiang	Beihang University
Xu, Yan	Beihang University
Chen, Ziang	Beihang University
Cai, Kaiquan	Beihang University

With the widespread application of unmanned aircraft systems (UAS) across various fields, non-cooperative UAS, characterized by frequent maneuvers and strong motion uncertainty, pose potential risks to airspace safety, making their trajectory prediction particularly challenging. To address these challenges, this paper proposes a hybrid trajectory prediction framework for non-cooperative UAS, which integrates LSTM-Gaussian with an interacting multiple model (IMM). By introducing a Gaussian loss function, the LSTM-Gaussian model is able to characterize prediction uncertainty while outputting trajectory mean estimates, thereby enabling confidence interval estimation for future states. To effectively handle diverse flight motion patterns, the IMM structure models three typical motion modes, including constant velocity, constant acceleration, and coordinated turn. An adaptive fusion strategy is designed to organically combine the nonlinear modeling capability of LSTM with the numerical stability and physical interpretability of IMM. Experimental results demonstrate that the proposed method achieves higher prediction accuracy and robustness across different motion scenarios, with advantages in short-term prediction, providing a reliable and effective solution for trajectory prediction of non-cooperative UAS under complex maneuvering conditions.

18:00-18:20	ThD2.6

Simulation-To-Flight Validation of Right of Way Requirements for Crewed–Uncrewed Encounters, pp. 1389-1396

Clough, Justin	University of Kansas
Carlson, Megan	University of Kansas
Keshmiri, Shawn	University of Kansas
Ewing, Mark	University of Kansas

Various probabilistic and deterministic methods have been developed and extensively validated in simulation environments to enhance safety in hybrid manned-unmanned airspace. However, reliance on simulation alone limits real-world assessment of algorithm reliability. This work closes a critical simulation-to-flight validation gap for right-of-way (RoW) logic by experimentally evaluating a morphing potential field algorithm in representative encounters and quantifying the minimum detection distance required for a fixed-wing UAS to maintain well-clear from a crewed aircraft. Flight tests were conducted using a general aviation Cessna 172 Skyhawk and a fixed-wing UAS, both instrumented with ADS-B to enable cooperative DAA functionality. Seventeen flight test scenarios were conducted, systematically varying the relative heading and speed to generate a diverse set of encounters and to map well-clear outcomes as a function of detection range. Results indicate that simulations accurately predicted the UAS's ability to maintain the required 2000-ft right-of-way separation in most cases, with 88% of flight test outcomes aligning with simulation-based well-clear classifications. Taken together, the experimentally observed detection range thresholds and the measured simulation-to-flight mismatch demonstrate that high-fidelity nonlinear simulation provides strong predictive capability for DAA performance and can effectively guide design and pre-flight screening. However, the observed sensitivity to nonlinear right-of-way logic, encounter phasing, and unmitigated collision distance highlights the necessity of at least a detection range of 3,962-m or greater in the tested ranges to meet well-clear requirements when utilizing the morphing potential field algorithm.

ThD3	**Calypso A**
Reliability, Fail-Safe Systems and Airworthiness (Regular Session)	

Chair: Giribet, Juan Ignacio	Universidad De San Andrés
Co-Chair: Fu, Wenxing	Northwestern Polytechnical University

16:20-16:40	ThD3.1

Budget-Aligned Epistemic Uncertainty for Onboard UAV Trajectory Prediction Via Regression-Adapted Deep Deterministic Uncertainty, pp. 1397-1404

Jia, Weiyang	Northwestern Polytechnical University
Fu, Wenxing	Northwestern Polytechnical University
Li, Yang	Northwestern Polytechnical University
Zhai, Danfeng	Northwestern Polytechnical University

Onboard UAV trajectory prediction for safety- critical missions requires not only accurate forecasts but also deployment-oriented epistemic uncertainty under strict millisecond-level inference budgets. Existing evaluations are often budget-misaligned, comparing single-forward predictors with multi-forward baselines without normalizing inference cost. In this paper, a budget-aligned evaluation protocol is established based on the forward-pass budget, floating-point operations (FLOPs), and CPU-proxy latency. Outage-segment trajectory- level survival is introduced to assess system-level safety. Under the strict single-forward constraint, deep deterministic uncertainty (DDU) is adapted to time-series regression by stabilizing the feature space with spectral normalization, modeling feature density via a Gaussian mixture model (GMM), and mapping density scores to continuous epistemic variance through isotonic calibration. Stress tests on a physics-intensity grid demonstrate that the proposed approach retains safety under severe runtime drift. In the HighDyn_LongOut scenario, a trajectory-level survival probability of 0.92 is achieved, while a five-member deep ensemble baseline yields 0.45. The proposed post-processing introduces only about 8.5% overhead and provides approximately 4.6 times speedup relative to the ensemble baseline under CPU- proxy evaluation, supporting onboard-feasible epistemic uncertainty estimation within a millisecond-level budget under the evaluated simulation setting.

16:40-17:00	ThD3.2

Toward Real-Time Adaptive Dehazing for Drone-Embedded Object Detection, pp. 1405-1411

Jayalath, Kasun Vimukthi	University of Southern Denmark

Drimus, Alin University of Southern Denmark
Jouffroy, Jerome University of Southern Denmark

Autonomous drones are used in a wide range of applications such as package delivery, search and rescue, surveillance, and other special operations. Most autonomous drones are equipped with object detection models to identify generic objects or models specially trained for objects such as humans, vehicles, or other drones in a swarm. One of the main challenges of detecting objects during adverse weather conditions is when the drone cannot acquire undistorted images under the glare haze produced. As object detection is paramount in drone vision, the ability to use pretrained detection models with its full potential even during such conditions is indispensable for full autonomy. To improve visibility in bad weather, there are various kinds of approaches that have been taken, including physically grounded statistical methods and deep learning-based techniques. However, adding heavy processing to the detection pipeline is undesirable, as it adds substantial latency to every frame. To address this, we developed methods to gauge the extent of the real-time haze and adjust the de-hazing magnitude without distorting the image, or bypass de-hazing altogether when unnecessary. Our method consists of analyzing the light and dark channels immediately after the image acquisition or right after the object detection to produce a reliable estimate of the haze level providing a critical foundation for controlled de-hazing, adaptive decision making, and safe autonomous drone operation across varying haze conditions.

17:00-17:20 ThD3.3

Cross-Platform Propeller Damage Regression in Multirotor UAVs Via Transfer Learning, pp. 1412-1419

Torre, Gabriel Universidad De San Andrés and Universidad De Buenos Aires
Pose, Claudio Daniel Universidad De San Andrés and Universidad De Buenos Aires
Giribet, Juan Ignacio Universidad De San Andrés

This paper presents a transfer learning framework for cross-platform propeller damage regression in multirotor UAVs. A neural network is trained in a source domain to estimate asymmetric propeller tip damage from spectral features extracted from inertial and control signals. The model is then deployed on a target vehicle with different size and propulsion characteristics, introducing domain shifts. We evaluate three adaptation strategies under realistic deployment constraints: physics-based spectral scaling (zero-shot), affine output calibration, and few-shot fine-tuning. Experiments on two quadrotor platforms show that spectral scaling provides modest gains in strictly zero-shot settings, while few-shot fine-tuning substantially reduces estimation error. Interpolation and extrapolation analyses indicate that fine-tuning improves accuracy near supervised damage levels, whereas spectral scaling produces more uniform behavior across unseen magnitudes. These results characterize practical trade-offs when deploying regression-based fault estimation models across heterogeneous UAV platforms under limited supervision.

17:20-17:40 ThD3.4

An Onboard Transformer-Based Physics-Informed System for UAV Trajectory Prediction and State Classification in GNSS-Denied Environments, pp. 1420-1427

Souli, Nicolas University of Cyprus
Grigoriou, Yiannis University of Cyprus
Chrysanthou, Panagiotis University of Cyprus
Kolios, Panayiotis University of Cyprus
Ellinas, Georgios University of Cyprus

This work introduces a real-time, lightweight system deployed onboard unmanned aerial vehicles (UAVs) that achieves the two-fold objective of state classification and trajectory prediction by integrating a Transformer-based physics-informed learning model with an extended Kalman filter (EKF). The proposed framework employs a two-stage sensor fusion mechanism that combines a physics-informed Transformer with an EKF-based measurement augmentation. In the first stage, an EKF fuses onboard sensor readings together with vision-derived measurements (optical flow measurements) and external sensor information (such as weather station data of wind speed and direction) to construct an augmented and denoised input measurement vector. In the second stage, the resulting filtered state estimates are fed into a physics-informed Transformer network that exploits shared feature learning to jointly enhance robustness and improve state classification and trajectory forecasting performance in Global Navigation Satellite System (GNSS)-denied environments. The proposed EKF-assisted AI framework is trained and validated on a custom dataset of UAV trajectories collected across various outdoor environments, and its prototype implementation is thoroughly assessed and validated in real-world outdoor experiments.

17:40-18:00 ThD3.5

Incremental Nonlinear Fault-Tolerant Control of the Variable Skew Quad Plane with Loss of Two Opposing Rotors, pp. 1428-1435

De Ponti, Tomaso Maria Luigi Delft University of Technology
Smeur, Ewoud Delft University of Technology
Remes, Bart Delft University of Technology

The operation of heavy hybrid Unmanned Aerial Vehicles (UAVs) in populated areas demands robust Fault Tolerant Control (FTC) strategies to ensure safe landings following actuator failures. This paper presents the first successful real-life demonstration of stable relaxed hover on a large hybrid drone, the Variable Skew Quad Plane (VSQP), subject to the total loss of control authority in two opposing multirotor motors while in forward-flight mode. A modified Incremental Nonlinear Dynamic Inversion (INDI) controller is derived to regulate the vehicle's principal axis of rotation. The framework is extended to actively incorporate aerodynamic control surfaces (flaperons), which are shown to significantly improve the rejection of unmodelled aerodynamic and reaction moments. Furthermore, alongside a standard position controller, a novel pusher-motor guidance strategy is proposed and flight-tested. By exploiting the pusher motor the control-authority requirements on the primary stabilization actuators are reduced. The controller achieves fully autonomous tracking of a square trajectory. These results confirm the efficacy of INDI for executing relaxed hover on large quad-planes equipped with aerodynamic surfaces and demonstrate the benefits of leveraging the full suite of hybrid UAV actuators.

18:00-18:20 ThD3.6

Implementation of Computer Vision Models to Detect Propeller Damage During Pre-Flight Checks, pp. 1436-1442

Schmidt, Immo Technical University of Darmstadt
Sadineni, Dharma Shastha Technical University of Darmstadt
Dhopavkar, Usama Hamid Technical University of Darmstadt
Dietz, Yannick Technical University of Darmstadt
Lingaraj, Dheeraj Technical University of Darmstadt
Muddaiah Sreekantha, Shreyas Technical University of Darmstadt

Propeller damages can have a substantial impact on the performance of the powertrains of unmanned aerial vehicles (UAVs). In the case of significant damage, the consequences may be critical regarding flight safety. To prevent taking off with damaged propellers, the integrity of the installed propellers is assessed during pre-flight checks. This paper explores the potential for automating this inspection by using computer vision models trained on UAV image data. Following an initial data collection phase, computer vision models are implemented and their performance is assessed. The approach demonstrates that the implemented models successfully detect damaged propellers with high accuracy, especially in the case of severely damaged propellers, which are most safety critical.

ThD4 **Calypso B**

Testing and Evaluation: Autonomy III (Invited Session)

Chair: Costello, Donald University of Maryland College Park
Co-Chair: Hwang, George Naval Air Warfare Center Aircraft Division

16:20-16:40 ThD4.1

Implementation of Ray-Ray Intersection for Sensor Constrained 3D Aerial Multi-Target Localization (I), pp. 1443-1450

Titus, Christopher University of Maryland
Ashry, Ahmed University of Maryland
Baxevani, Kleio University of Maryland
Gaus, Joshua University of Maryland

With the rapid proliferation of unmanned aerial systems (UAS) and growing interest in onboard computation, 3D target localization has emerged as a fundamental challenge across many applications. This work demonstrates the feasibility of a lightweight method for estimating the 3D locations of stationary targets using ray-ray intersections combined with efficient filtering techniques. The proposed approach enables localization of multiple targets from asynchronous and noisy observations, even in the presence of false positives, using data from a single UAS. The method relies only on sensors commonly available on autonomous UAS, namely a monocular camera and a position estimate, making it well-suited for smaller, low-cost platforms. Experimental results showcase localization accuracy comparable to, and in some cases exceeding, existing approaches, while maintaining low computational complexity.

16:40-17:00 ThD4.2

Feature 3D Gaussian Splatting for UAV-To-Ship Pose Estimation in GNSS-Denied Environments (I), pp. 1451-1458

Bernas, Andrew United States Naval Academy
McConnell, John United States Naval Academy
Seargeant, John United States Naval Academy
DeVries, Levi United States Naval Academy

Autonomous recovery of Unmanned Aerial Vehicles (UAVs) in maritime environments is challenged by dynamic ship motion, texture-poor surroundings, and vulnerabilities inherent to Global Navigation Satellite Systems (GNSS). To enable robust UAV state estimation relative to a naval vessel in GNSS-denied environments, this paper presents a novel vision-based pose estimation framework leveraging Feature 3D Gaussian Splatting (3DGS). Adopting STDLoc's sparse pose estimation framework, our approach bypasses computationally expensive dense rendering in favor of direct sparse 2D-3D matching. We extract 2D features from live monocular imagery using SuperPoint and match them against a compact set of view-consistent 3D Gaussian landmarks distilled via a Matching-Oriented Sampling strategy. The 6-DoF camera pose is then robustly recovered using a Perspective-n-Point (PnP) solver augmented with Locally Optimized RANSAC (LO-RANSAC). Experimental validation on a 1/24-scale naval Yard Patrol (YP) craft demonstrates centimeter-level translational accuracy (1.66 cm lateral, 2.28 cm vertical mean absolute errors) and near-degree rotational accuracy (0.90° roll, 1.17° yaw). This method eliminates the need for physical fiducial markers or precise CAD models, offering a scalable and highly accurate relative localization solution for autonomous maritime operations.

17:00-17:20 ThD4.3

Hardware and Vision-In-The-Loop Validation of Deep Monocular Pose Estimation for Autonomous Maritime UAV Flight (I), pp. 1459-1464

Wickramasuriya, Maneesha George Washington University
Yu, Beomyeol George Washington University
Shin, Jaden George Washington University
Huslig, Mason George Washington University
Lee, Taeyoung George Washington University
Snyder, Murray George Washington University

Autonomous UAV operations on ships require reliable vision-based relative pose estimation, yet at-sea validation is costly, weather-dependent, and risky. This paper presents a hardware-validated vision-in-the-loop framework that enables fully autonomous indoor flight while emulating photorealistic maritime environments. Rendered maritime views are processed onboard by a deep transformer-based monocular pose estimator. Delayed vision measurements are fused with high-rate IMU data using a delayed Kalman filter to provide consistent state estimates for geometric control. The system captures critical embedded effects, including perception latency,

asynchronous updates, and computational constraints, that are absent in pure simulation. Autonomous takeoff, trajectory tracking, and landing experiments demonstrate stable closed-loop flight. The results establish a safe and hardware-realistic intermediate stage for developing maritime UAV autonomy prior to shipboard deployment.

17:20-17:40 ThD4.4

The Evolution of Methodologies for Estimating and Quantifying Risk for Mission-Level Autonomy (I), pp. 1465-1472

Hwang, George — Naval Air Warfare Center Aircraft Division
Woods, Douglas — AM Pierce and Associates
Joyner, Jacob — Naval Air Warfare Center Aircraft Division
Marez, Matthew — Naval Air Warfare Center Aircraft Division
Brown, Michael — Naval Air Warfare Center Aircraft Division
Rickard, Kristina — Naval Air Warfare Center Aircraft Division
Johnson, Mark Anthony — Naval Air Warfare Center Aircraft Division
Johnson, Wanda Lowelyn — Naval Air Warfare Center Aircraft Division
Lay, Michael — Naval Air Warfare Center Aircraft Division
Rea, Charles — Naval Air Warfare Center Aircraft Division

As Mission-Level Autonomous Systems (MAS) for aviation systems become ready for deployment, safety is of paramount importance, especially in conditions where these systems interact with humans. Compounding this general challenge is the need for rigorous certification and safety guarantees that are hallmarks of the aviation community; namely, the exploration of an intractably large sample space is an important consideration when characterizing likelihood of hazards. This brings up the question of how can aviation safety practitioners capture and characterize risk when the computational budget for computer simulation is limited, and the real-world data is sparse while still ensuring mission success? One approach in the computer simulation literature is the development of surrogate models trained on limited datasets to perform large state exploration. This work expands on that approach by using Gaussian Process Regression, a supervised learning approach, to build a surrogate for further safety analysis and Operational Design Domains to precisely define the sampling space. This paper presents a methodology to build a model specifically to estimate risk for MAS by using a large computer simulation in support of safety certification.

17:40-18:00 ThD4.5

Visual-Inertial Odometry Robustness to Adverse Conditions in Proximity Flight (I), pp. 1473-1480

Teacu, Alexander — University of Maryland
Paley, Derek — University of Maryland

This paper tests and evaluates the performance of visual-inertial odometry (VIO) under adverse visual factors within the context of autonomous proximity flight. VIO is widely used in UAV autonomy for micro air vehicles (MAVs) due to its cost-effectiveness and the small size of required sensor. Since VIO relies on a camera, visual factors can significantly impact its performance; however, there is a general lack of public VIO flight datasets that contain adverse visual factors. Here we describe the use of a MAV platform to collect real-world visual-inertial datasets that contain adverse visual factors– for example, moving objects, reflections, low light, featureless environments, and lens contamination, along with the ground truth pose of the MAV. However, some visual factors, such as fire, dust, and smoke, are challenging or hazardous to reproduce in a controlled environment. To produce datasets containing these visual factors, we combine and augment the real-world images with a computational simulation. The real and augmented datasets along with ground-truth data are used to evaluate VIO robustness through a combination of practical performance metrics.

18:00-18:20 ThD4.6

Flying-Wing UAS Multi-Objective Design Optimization Via Cross-Entropy Method (I), pp. 1481-1488

Richez, Adrien — Stanford University
Bostock, Nick — Stanford University

This project investigates the aerodynamic optimization of a flying-wing design using the Cross Entropy Method (CEM), a global stochastic optimization technique. The objective was to identify an optimal planform that maximizes aerodynamic performance, defined as a weighted combination of lift and lift-to-drag ratio, while satisfying stability constraints for multi-role intelligence, surveillance and reconnaissance (ISR) and strike applications. A vortex lattice method (VLM) was used to compute aerodynamic forces in inviscid flow, and Trefftz-plane analysis was employed to calculate induced drag. Design variables included local sweep, twist, taper ratio, and dihedral angles of both the main wing and tip segment. Constraints were enforced via a quadratic penalty formulation to maintain a minimum static margin, ensuring longitudinal stability. The CEM iteratively refined a probability distribution over the design space, converging to a planform that demonstrated theoretically improved aerodynamic performance over baseline and compliance with geometric and stability constraints. The final design indicated reduced induced drag and enhanced mission-specific aerodynamic efficiency. Flight test validation attempts resulted in rapid-unscheduled disassembly. Further flight test validation is required.

ICUAS '26 Key Word Index

ICUAS '26 Author Index

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