Multi-Vehicle and Assured Autonomous Control for Aerospace Applications

IEEE TCAC Workshop, 2021 CCTA
August 8, 2021, 8:30am-5:30pm (Pacific Time)

8:30 - 9:00 am Pacific Time Welcome, Introductions & Preliminaries: (11:30 am – 12:00 pm ET)

Chair: Dr. Richard A. Hull – Collins Aerospace Fellow, and Chair IEEE CSS TC on Aerospace Control (TCAC)
Co-Chair: Prof. Venanzio Cichella – University of Iowa, Dept. of Mechanical Engineering

7 Presentations approximately 45 minutes followed by 15 minutes for Q&A, Discussion or Personal Break

1 hour break for lunch at Noon Pacific Time

Attendees … Please Mute Your Microphone unless speaking!
Speakers … stop screen sharing when you are finished!

Presentation Files (.pdf only) will be uploaded to TCAC Website following workshop (allow 1-2 weeks)

TCAC Website: http://aerospace-controls.ieeecss.org/home

All Registrants – may contact me at: richard.hull@collins.com

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AGENDA

Pacific Time

8:30 – 9:00am **Welcome, Introductions & Preliminaries – Dr. Richard Hull,** Collins Aerospace, TCAC Chair

9:00 – 9:45am **Towards Trustworthy Autonomy: How AI can help address fundamental learning and adaptation challenges. - Prof. Gokhan Inalhan,** Cranfield University, UK
(15 Minutes for Q&A, Discussion … or Break)

10:00 –10:45am **An Optimal Kalman-Consensus Filter for Distributed Implementation over Dynamic Communication Network" – Matthew D. Howard**, Ph.D. Candidate, and **Prof. Zhihua Qu**, Pegasus Professor and Chair, Department of ECE, University of Central Florida, Orlando, Florida
(15 Minutes for Q&A, Discussion … or Break)

11:00 – 11:45am **Aerial Co-robots of the Future: Safety, Intelligence, Certification – Prof. Naira Hovakimyan,** W. Grafton and Lillian B. Wilkins Professor of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign
(15 Minutes for Q&A, Discussion … or Break)

12:00 – 1:00pm – **1 Hour Break for Lunch**

Pacific Time

AGENDA

1:00 – 1:45pm **Optimal Planning Strategies for Multiple UAV Missions** – **Prof. Venanzio Cichella**, Assistant Professor, Department of Mechanical Engineering, University of Iowa, Iowa City, Iowa and **Prof**. **Naira Hovakimyan**

(15 Minutes for Q&A, Discussion … or Break)

2:00 – 2:45pm **Autonomy in Aerospace at the Intersection of Machine Learning, Control and Physics – Dr. Evangelos Theodorou,** Associate Professor, Autonomous Control and Decision Systems Laboratory, School of Aerospace Engineering, Georgia Institute of Technology

(15 Minutes for Q&A, Discussion … or Break)

3:00 – 3:45pm **Defense Against Adversarial Swarms with Parameter Uncertainty– Prof. Isaac Kaminer,** Department of Mechanical and Aerospace Engineering, Naval Postgraduate School, Monterey CA, **and Prof. Venanzio Cichella**

(15 Minutes for Q&A, Discussion … or Break)

4:00 – 4:45pm **The intersection between Machine Learning & GNC" – Dr. Heather Hussain, Dr. Joseph Gaudio, and Dr. James Paduano,** The Boeing Company, Tukwila, Washington

(15 Minutes for Q&A, Discussion … or Break)

5:00 - 5:15pm **Final Questions, Comments, Wrap-Up - All**

Aerospace Control (60 members, chair: Richard Hull)

Scope: Through this Technical Committee (TC), members advance the technology and provide forums for the theoretical and practical consideration of techniques, devices, and systems for the control of flight vehicles and the control of related aerospace systems.

Membership:
- Open to any member of IEEE Control System Society (CSS) – contact Richard Hull
- 65% Academia, 20% Industry, 10% Government Labs - 25% International – 9 Fellows of the IEEE
- Please visit our website: http://aerospace-controls.ieeecss.org/home

Main activities:
- Chairmanship roles in Organizing Technical Conferences such as the ACC, CDC, CCTA
- Organize Special Sessions, Invited Sessions, Tutorials and Workshops
- Contributions to IEEE Control Systems Magazine – Jon How was prior technical editor
- Nominations to serve as Associated Editors on the IEEE Conference Editorial Board and for IEEE Journals
- TC Members sponsored and raised over $50K to endow the IEEE CSS Award for Excellence in Aerospace Control

Workshops on Aerospace Control
- 2021 CCTA (San Diego), 2020 ACC (Denver), 2019 ACC (Philadelphia), 2017 CCTA (Hawaii), 2012 CDC (Maui)

Many Distinguished Members and Awards (to name a few):
- Kevin Wise elected to National Academy of Engineering,
- Naira Hovakimyan was named recipient of 2019 Pendray Aerospace Literature Award
- Gokhan Inalhan received the IEEE Aerospace and Electronic Systems Society Exceptional Service Award
- Zhihua Qu named IEEE Distinguished Lecturer

Many Authors of Books (to name a few):
- L_1 Adaptive Control Theory, Guaranteed Robustness with Fast Adaptations, Naira Hovakimyan, Chengyu Cao,
- Robust and Adaptive Control with Aerospace Applications, Eugene Lavretsky, Kevin Wise
- Cooperative Control of Dynamical Systems, Zhihua Qu

IEEE CSS Technical Committees & Chairs

Jing Sun, U. of Michigan - VP Technical activities

1. Aerospace Controls
   Richard Hull (2018)
2. Automotive Controls
   Mara Tanelli (2021)
3. Control Education
   John Hedengren (2021)
4. Discrete Event Systems
   Kai Cai (2019)
5. Distributed Parameter Systems
   Thomas Meurer (2020)
6. Health and Medical Systems
   Alexander Medvedev (2018)
7. Hybrid Systems
   Majid Zamani (2020)
8. Intelligent Control
   Tansel Yucelen (2020)
9. Manufacturing Automation & Robotic Control
   Eloy Garcia (2020)
10. Networks and Communication Systems
    Giacomo Como (2019)
11. Nonlinear Systems and Control
    Andrea Serrani (2020)
12. Power Generation
    Jeffrey Scruggs (2020)
13. Process Control
    Ali Mesbah(2021)
14. Robust and Complex Systems
    Yoshio Ebihara (2020)
15. Smart Cities
    Andreas Malikopoulos (2020)
16. Smart Grid
    Ian Hiskens (2019)
17. Security and Privacy
    Quanyan Zhu (2021)
18. Systems and Synthetic Biology
    Steffen Waldherr (2019)
19. Systems Identification and Adaptive Control
    Simone Formentin (2020)
20. Variable Structure and Sliding Mode Control
    Christopher Edwards (2019)

Can Everyone See and Hear?

Questions or Problems?

Use the Chat Feature …

Welcome to the Virtual Workshop!

1. **9:00 - 9:45 am Pacific Time** **(12:00– 12:45 pm ET)**

Towards Trustworthy Autonomy: How AI can help address fundamental learning and adaptation challenges.

Gokhan Inalhan, Cranfield University, UK

- BAE Systems Chair and Professor of Autonomous Systems and Artificial Intelligence

- Gokhan leads the research theme on autonomous systems and artificial intelligence within the School of Aerospace, Transport and Manufacturing at Cranfield University. He and his research group focus on design, modeling, GNC, resilience, and security aspects of autonomy and artificial intelligence for air, defense, transportation and space systems.

- IEEE AESS Exceptional Service Award (2019), Boeing Faculty Fellowship(2018), Council of Higher Education Outstanding Achievement Award in Industrial Collaboration (2018)

- EEE Senior Member, AIAA Life-time member and Associate Fellow

(15 Minutes for Q&A, Discussion, or … Break)

15 Minutes for Q&A, Discussion,

or …

Break!

2. 10:00 – 10:45 am Pacific Time **(1:00 – 1:45pm ET)**

An Optimal Kalman-Consensus Filter for Distributed Implementation over Dynamic Communication Network

Dr. Zhihua Qu,

- Pegasus Professor, University of Central Florida
- Cyber-physical systems, energy systems, networked and cooperative controls, autonomous vehicles and robotics

- PhD from Georgia Institute of Technology
- Director of RISES, a university research center on energy systems
- Director of CPS Controls Lab and Robotics Lab at UCF
- Author of several books:
  - *Cooperative Control of Dynamical Systems* by Springer (2009)
  - *Robust Control of Nonlinear Uncertain Systems* by Wiley (1998)
  - *Robust Tracking Control of Robot Manipulators* by IEEE Press (1996)
- Fellow of IEEE and AAAS

(15 Minutes for Q&A, Discussion … or Break)

3. 11:00 – 11:45 am Pacific Time (2:00 – 2:45 pm ET)

Aerial Co-robots of the Future: Safety, Intelligence, Certification

Prof. Naira Hovakimyan, W. Grafton and Lillian B. Wilkins Professor of Mechanical Science and Engineering at University of Illinois at Urbana-Champaign (UIUC)

- Prof. Hovakimyan received her MS degree in Theoretical Mechanics and Applied Mathematics from Yerevan State University in Armenia. She got her Ph.D. in Physics and Mathematics from the Institute of Applied Mathematics of Russian Academy of Sciences in Moscow.

- She has co-authored two books, eleven patents and more than 450 refereed publications. She is the 2011 recipient of *AIAA Mechanics and Control of Flight Award*, the 2015 recipient of *SWE Achievement Award,* the 2017 recipient of *IEEE CSS Award for Technical Excellence in Aerospace Controls*, and the 2019 recipient of *AIAA Pendray Aerospace Literature Award*. In 2014 she was awarded the *Humboldt prize* for her lifetime achievements.

- She is Fellow and life member of AIAA, a Fellow of IEEE, and a member of SIAM, AMS, SWE, ASME and ISDG.

- She is cofounder and chief scientist of IntelinAir. Her work in robotics for elderly care was featured in the New York Times, on Fox TV and CNBC.

(15 Minutes for Q&A, Discussion … or Break)

12:00 – 1:00 pm Pacific Time **(3:00pm – 4:00pm ET)**

1 Hour Lunch!

4. 1:00 - 1:45 pm Pacific Time **(4:00 – 4:45 pm ET)**

Optimal Planning Strategies for Multiple UAV Missions

Prof. Venanzio Cichella, Assistant Professor, Department of Mechanical Engineering, University of Iowa, Iowa City, Iowa, and Prof. Naira Hovakimyan

Prof. Venanzio Cichella received his B.S. and M.S. in Automation Engineering in 2007 and 2011, respectively, from the University of Bologna, Italy. He got his Ph.D. in Mechanical Engineering in 2018 from the University of Illinois at Urbana-Champaign, majoring in planning and control of multiple autonomous systems.

He is currently an Assistant Professor at the Mechanical Engineering department at the University of Iowa. His research interests include cooperative control of autonomous systems, collision avoidance, optimal control, machine learning, and human-centered autonomous vehicle design.

(15 Minutes for Q&A, Discussion … or Break)

5. **2:00 – 2:45 pm Pacific Time** **(5:00 – 5:45 pm ET)**

Autonomy in Aerospace at the Intersection of Machine Learning, Control and Physics

Dr. Evangelos Theodorou

- Associate Professor, School of Aerospace Engineering, Georgia Institute of Technology
- Autonomous Control and Decision Systems Laboratory
- Institute of Robotics and Intelligent Machines
- Center for Machine Learning

(15 Minutes for Q&A, Discussion … or Break)

6. 3:00 pm – 3:45 pm Pacific Time (6:00 – 6:45 pm ET)

Defense Against Adversarial Swarms with Parameter Uncertainty

Prof. Isaac Kaminer, Department of Mechanical and Aerospace Engineering, Naval Postgraduate School, Monterey, CA,

and Prof. Venanzio Cichella, University of Iowa

- **Prof. Kaminer** received his PhD in Electrical Engineering from University of Michigan in 1992.

- Before that he spent four years working at Boeing Commercial first as a control engineer in 757/767/747-400 Flight Management Computer Group and then as an engineer in Flight Control Research Group. Since 1992 he has been with the Naval Postgraduate School first at the Aeronautics and Astronautics Department and currently at the Department of Mechanical and Aerospace Engineering where he is a Professor.

- He has a total of over 30+ years of experience in development and flight testing of guidance, navigation and control algorithms for both manned and unmanned aircraft. His more recent efforts have focused on the development of coordinated control strategies and of vision-based guidance laws UAVs as well as on the optimal defense strategies against a large-scale adversarial swarm. Professor Kaminer has co-authored a book and more than a hundred and fifty refereed journal and conference publications.

(15 Minutes for Q&A, Discussion … or Break)

7. 4:00 - 4:45 pm Pacific Time **(7:00 – 7:45 pm ET)**

The intersection between Machine Learning & GNC

Dr. Heather Hussain, Dr. Joseph Gaudio, and Dr. James Paduano,
The Boeing Company, Tukwila, Washington

- **Dr. Heather Hussain** received the B.S. degree and M.S. degree in Mechanical Engineering from the Rochester Institute of Technology, Rochester, NY, in 2012, and the Sc.D. degree in Mechanical Engineering at the Massachusetts Institute of Technology (MIT), Cambridge, MA, in 2017.

- Her work experience comprises several internships spanning the aerospace and consumer electronics industries–namely, in Product Design at Apple Inc., as a research Scholar at the Munitions Directorate of the Air Force Research Laboratory, and her work in the design and development of verifiable adaptive flight control systems at The Boeing Company.

- Ms. Hussain's doctoral research at MIT was sponsored by the Boeing Strategic University Initiative under the direction of Dr. EugeneLavretsky and Dr. Anuradha Annaswamy. Ms. Hussain joined BR&T's Guidance, Navigation, Control, and Autonomy (GNC&A) group in September 2017. Her research interests lie in adaptive control theory, particularly with applications in aerospace. Ms. Hussain is a member of AIAA and IEEE.

- Dr. Hussain is a member of AIAA and IEEE.

5:00 - 5:15 pm Pacific Time **(8:00 – 8:15 pm ET)**

Final Questions or Comments?

Thanks for attending today's workshop:

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IEEE TCAC Workshop, 2021 CCTA

Presented by members of the IEEE CSS Technical Committee on Aerospace Control

Contact info: richard.hull@collins.com **or** venanzio-cichella@uiowa.edu

.pdf files of today's presentations will be posted in the near future on the TCAC website at: http://aerospace-controls.ieeecss.org/home