

# Zachary Nolan Sunberg

Ann and H. J. Smead Aerospace Engineering Sciences  
University of Colorado Boulder

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## Academic Appointments

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### Assistant Professor

[January 2020 – Present]

University of Colorado, Boulder, CO

Ann and H. J. Smead Aerospace Engineering Sciences Department

### Postdoctoral Research Scholar

[October 2018 – October 2019]

University of California, Berkeley, CA

Supervisor: Claire Tomlin, Hybrid Systems Laboratory

## Education

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### Doctor of Philosophy in Aeronautics and Astronautics

[2018]

Stanford University, Stanford, CA

Advisor: Mykel Kochenderfer | Thesis: "Safety and Efficiency in Autonomous Vehicles through Planning with Uncertainty"

### Master of Science in Aerospace Engineering

[2013]

Texas A&M University, College Station, TX

Advisor: Jonathan Rogers | Thesis: "A Real Time Expert Control System for Helicopter Autorotation"

### Bachelor of Science in Aerospace Engineering

[2011]

Texas A&M University, College Station, TX

Summa cum Laude, Minor in Mathematics

## Peer Reviewed Journal Publications

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- [1] **Michael H. Lim, Tyler J. Becker, Mykel J. Kochenderfer, Claire J. Tomlin, and Zachary N. Sunberg.** "Optimality Guarantees for Particle Belief Approximation of POMDPs". In: *Journal of Artificial Intelligence Research* (2023). Accepted, awaiting publication. URL: [🔗](#).
- [2] **Prashin Sharma, Benjamin Kraske, Joseph Kim, Zakariya Laouar, Ella Atkins, and Zachary Sunberg.** "Investigation of risk-aware MDP and POMDP contingency management autonomy for UAS". In: *AIAA Journal of Aerospace Information Systems (JAIS)* (2023). Under review.
- [3] **Benjamin W. Blonder, Michael H. Lim, Zachary Sunberg, and Claire Tomlin.** "Navigation between initial and desired community states using shortcuts". In: *Ecology Letters* (2023). URL: [🔗](#).
- [4] **Zachary Sunberg and Mykel Kochenderfer.** "Improving Automated Driving through Planning with Human Internal States". In: *IEEE Transactions on Intelligent Transportation Systems* (2022). URL: [🔗](#).
- [5] **Shakeeb Ahmad, Zachary N. Sunberg, and J. Sean Humbert.** "End-to-End Probabilistic Depth Perception and 3D Obstacle Avoidance using POMDP". In: *Journal of Intelligent & Robotic Systems* 103.2 (2021).
- [6] **Patrick Slade, Zachary Sunberg, and Mykel J. Kochenderfer.** "Estimation and Control Using Sampling-Based Bayesian Reinforcement Learning". In: *IET Cyber-Physical Systems: Theory and Applications* 5 (1 2020). URL: [🔗](#).
- [7] **Maxim Egorov, Zachary N. Sunberg, Edward Balaban, Tim A. Wheeler, Jayesh K. Gupta, and Mykel J. Kochenderfer.** "POMDPs.jl: A Framework for Sequential Decision Making under Uncertainty". In: *Journal of Machine Learning Research* 18.26 (2017). URL: [🔗](#).

- [8] **Zachary Sunberg**, Suman Chakravorty, and Richard Scott Erwin. "Information Space Receding Horizon Control for Multisensor Tasking Problems". In: *IEEE Transactions on Cybernetics* 46.6 (2016). URL: [↗](#).
- [9] **Zachary N. Sunberg**, Nathaniel R. Miller, and Jonathan D. Rogers. "A Real-Time Expert Control System For Helicopter Autorotation". In: *Journal of the American Helicopter Society* 60.2 (2015). DOI: 10.4050/JAHS.60.022008. URL: [↗](#).
- [10] **Zachary Sunberg**, Suman Chakravorty, and Richard Scott Erwin. "Information Space Receding Horizon Control". In: *IEEE Transactions on Cybernetics* 43.6 (2013). URL: [↗](#).
- [11] **Zachary Sunberg** and Jonathan Rogers. "A Belief Function Distance Metric for Orderable Sets". In: *Information Fusion* 14.4 (2013). DOI: 10.1016/J.INFFUS.2013.03.003. URL: [↗](#).

## Journal-Equivalent Peer Reviewed Conference Publications

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- [12] **Himanshu Gupta**, Bradley Hayes, and **Zachary Sunberg**. "Intention-Aware Navigation in Crowds with Extended-Space POMDP Planning". In: *Autonomous Agents and Multi-Agent Systems (AAMAS)*. 2022. URL: [↗](#).
- [13] John Mern, Anil Yildiz, **Zachary Sunberg**, Tapan Mukerji, and Mykel J. Kochenderfer. "Bayesian Optimized Monte Carlo Planning". In: *AAAI Conference on Artificial Intelligence (AAAI)*. 2021.
- [14] **Michael H. Lim**, Claire J. Tomlin, and **Zachary N. Sunberg**. "Sparse Tree Search Optimality Guarantees in POMDPs with Continuous Observation Spaces". In: *International Joint Conference on Artificial Intelligence (IJCAI)*. 2020.
- [15] **Lasse Peters**, David Fridovich-Keil, Claire Tomlin, and **Zachary Sunberg**. "Inference-Based Strategy Alignment for General-Sum Differential Games". In: *International Conference on Autonomous Agents and Multiagent Systems (AAMAS)*. 2020. URL: [↗](#).
- [16] **Zachary N. Sunberg** and Mykel J. Kochenderfer. "Online Algorithms for POMDPs with Continuous State, Action, and Observation Spaces". In: *International Conference on Automated Planning and Scheduling (ICAPS)*. 2018. URL: [↗](#).

## Peer Reviewed Conference Publications

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- [17] Sampada Deglurkar, **Michael H. Lim**, **Johnathan Tucker**, **Zachary N. Sunberg**, Aleksandra Faust, and Claire J. Tomlin. "Compositional Learning-based Planning for Vision POMDPs". In: *Learning for Dynamics & Control (L4DC)*. 2023. URL: [↗](#).
- [18] **Qi Heng Ho**, Roland B. Ilyes, **Zachary Sunberg**, and Morteza Lahijanian. "Automaton-Guided Control Synthesis for Signal Temporal Logic Specifications". In: *IEEE Conference on Decision and Control (CDC)*. 2022. URL: [↗](#).
- [19] **Qi Heng Ho**, **Zachary N. Sunberg**, and Morteza Lahijanian. "Gaussian Belief Trees for Chance Constrained Asymptotically Optimal Motion Planning". In: *2022 International Conference on Robotics and Automation (ICRA)*. 2022. DOI: 10.1109/ICRA46639.2022.9812343.
- [20] **Zachary Nolan Sunberg**, Kathryn Anne Wingate, and Lara Buri. "Fair Senior Capstone Project Teaming based on Skills, Preferences, and Friend Groups". In: *ASEE Annual Conference*. 2021. URL: [↗](#).
- [21] **Michael H. Lim**, Claire J. Tomlin, and **Zachary N. Sunberg**. "Voronoi Progressive Widening: Efficient Online Solvers for Continuous Space MDPs and POMDPs with Provably Optimal Components". In: *Conference on Decision and Control (CDC)*. 2021. URL: [↗](#).
- [22] Shakeeb G. Ahmad, **Zachary Sunberg**, and Sean Humbert. "APF-PF: Probabilistic Depth Perception for 3D Reactive Obstacle Avoidance". In: *American Control Conference (ACC)*. 2021.
- [23] Ekhlas Sonu, **Zachary Sunberg**, and Mykel J. Kochenderfer. "Exploiting Hierarchy for Scalable Decision Making in Autonomous Driving". In: *Intelligent Vehicles Symposium*. 2018.
- [24] **Zachary N. Sunberg**, Christopher J. Ho, and Mykel J. Kochenderfer. "The Value of Inferring the Internal State of Traffic Participants for Autonomous Freeway Driving". In: *American Control Conference (ACC)*. 2017. URL: [↗](#).

- [25] Patrick Slade, Preston Culbertson, **Zachary Sunberg**, and Mykel J. Kochenderfer. “Simultaneous Active Parameter Estimation and Control using Sampling-based Bayesian Reinforcement Learning”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2017. URL: [↗](#).
- [26] **Zachary Sunberg**, Mykel J. Kochenderfer, and Marco Pavone. “Optimized and Trusted Collision Avoidance for Unmanned Aerial Vehicles using Approximate Dynamic Programming”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2016. URL: [↗](#).
- [27] **Zachary Sunberg**, Suman Chakravorty, and Richard Erwin. “Information space sensor tasking for Space Situational Awareness”. In: *American Control Conference (ACC)*. June 2014. doi: 10.1109/ACC.2014.6858922.
- [28] **Zachary Sunberg**, Nathaniel Miller, and Jonathan Rogers. “A Real Time Expert Control System for Helicopter Autorotation”. In: *70th Forum of the American Helicopter Society*. 2014.
- [29] **Zachary Sunberg**, Suman Chakravorty, and Richard Erwin. “Information Space Receding Horizon Control for MultiAgent Systems”. In: *American Control Conference (ACC)*. 2012. URL: [↗](#).

## Conference Publications with Abstract-only Review

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- [30] Johnathan Tucker, Jackson Wagner, and **Zachary Sunberg**. “Adaptive Stress Testing Applied To Space Domain Awareness Systems”. In: *Advanced Maui Optical and Space Surveillance Technologies (AMOS)*. 2022. URL: [↗](#).
- [31] **Tyler Becker** and **Zachary Sunberg**. “Imperfect Information Games and Counterfactual Regret Minimization in Space Domain Awareness”. In: *Advanced Maui Optical and Space Surveillance Technologies (AMOS)*. 2022. URL: [↗](#).
- [32] Hunter M. Ray, Nicholas Conlon, **Zachary Sunberg**, and Nisar R. Ahmed. “User Preference Elicitation for Unmanned Aircraft System Collaborative Search”. In: *AIAA SCITECH Forum*. 2022.
- [33] **Zachary Sunberg** and Jonathan Rogers. “A Fuzzy Logic-Based Controller for Helicopter Autorotation”. In: *AIAA Aerospace Sciences Meeting*. 2013.

## Open Source Software

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**POMDPs.jl** [2015 – present]

<https://github.com/JuliaPOMDP/POMDPs.jl>

Interface for defining continuous and discrete, fully and partially observable Markov decision processes along with a suite of state-of-the-art solvers written in Julia and C++.

**ProjectAssigner.jl** [2020]

<https://github.com/zsunberg/ProjectAssigner.jl>

Software for optimally assigning student teams to projects based on preferences, friend groups, and skills [20]. Used to assign senior project groups in the AES department since 2020.

## Research Funding

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**Co-I: IUCRC Phase I: Center for Autonomous Air Mobility and Sensing (CAAMS)** [2022 – 2027]

*National Science Foundation*

\$2,210,225 (PI: Eric Frew) | Co-Is: Nisar Ahmed, Morteza Lahijanian, Sriram Sankaranarayanan | This grant establishes the IUCRC and pays for administrative costs; sub-awards funded through industry contributions will be listed separately.

**Co-I: Dispersed Autonomy for Marsupial Aerial Robot Teams** [2022 – 2025]

*National Science Foundation | National Robotics Institute (Collaborative Research)*

\$1,045,429 (PI: Eric Frew) | My share: \$300,000 (approx.) | Co-Is: Brian Argrow, Adam Houston (University of Nebraska, Lincoln)

**PI: HIPPO (Human-Informed Planning with Probabilistic Observations)** [2022-2023]

*NSF Center for Autonomous Air Mobility and Sensing (CAAMS) Sub-award*

\$68,000 | PI share: full amount

<b>Co-I: SURP: Fast planning under uncertainty with operational and safety guarantees</b> <i>NASA Jet Propulsion Laboratory</i> \$60,000 (PI: Federico Rossi, JPL)   My share: \$50,000   Co-Is: Martin Feather (JPL), Morteza Lahijanian	[2022-2023]
<b>PI: Elektra: Naval Defensive Resource Allocation through POMDP Optimization</b> <i>Office of Naval Research (Subcontract of Johns Hopkins University Applied Physics Lab)</i> \$169,805   PI share: full amount	[2021 – 2023]
<b>Co-I: L3Harris Modern Analytics for Mission Applications (LMA2)</b> <i>L3-Harris Technologies</i> \$1,495,048 (PI: Marcus Holzinger)   My share: \$350,000 (approx.)	[2021-2023]
<b>Co-PI: Full Stack Planning and Control under Uncertainty</b> <i>NSF Center for Unmanned Aircraft Systems (C-UAS) Sub-award</i> \$130,000 (with Co-PI Ella Atkins, Univ. of Michigan)   My share: \$65,000	[2021 – 2022]
<b>PI: POMDP Algorithms for In-flight Learning in Emergencies</b> <i>NSF Center for Unmanned Aircraft Systems (C-UAS) Sub-award</i> \$60,000   PI share: full amount	[2020 – 2021]

## Research Positions

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<b>Autonomous Decision and Control Laboratory (ADCL)</b> <i>Director</i> University of Colorado, Boulder, CO	[January 2020 – Present]
<b>Hybrid Systems Laboratory</b> <i>Postdoctoral Research Scholar</i> University of California, Berkeley, CA	[October 2018 – October 2019]
<b>Stanford Intelligent Systems Laboratory (SISL)</b> <i>Graduate Research Assistant</i> Stanford University, Stanford, CA	[2015 – 2018]
<b>Autonomous Systems Laboratory (ASL)</b> <i>Graduate Research Assistant</i> Stanford University, Stanford, CA	[2014 – 2016]
<b>Hansen Experimental Physics Lab</b> <i>Graduate Research Assistant</i> Stanford University, Stanford, CA	[2013 – 2014]
<b>Helicopters and Unmanned Systems Laboratory (HUSL)</b> <i>Graduate Research Assistant</i> Texas A&M University, College Station, TX	[2011 – 2013]
<b>Air Force Research Lab Summer Faculty Program</b> <i>Research Assistant</i> Kirtland AFB, Albuquerque, NM	[Summer 2011]

## Industry Experience

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<b>Google, Inc., Mountain View, CA</b> <i>Software Engineering Intern</i> Wrote software to evaluate and optimize a NASA collision avoidance program for use with Google self-piloted air vehicles.	[Summer 2014]
<b>Lockheed Martin Autonomous Systems, Littleton, CO</b> <i>Intern</i> Helped in testing of autonomous SMSS allterrain military transport vehicle navigation system; wrote rough terrain navigation program in C++ based on the A* search algorithm; wrote software in C++ for analyzing the performance of an advanced video analysis tool.	[Summer 2009]

## Invited and Contributed Talks and Panels

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### 2022

**University of Illinois Urbana-Champaign (UIUC):** Safe and efficient autonomy in the face of uncertainty.

**University of Texas at Austin:** Safe and efficient autonomy in the face of uncertainty.

**Korea Advanced Institute of Science and Technology (KAIST):** Safe and efficient autonomy in the face of state and interaction uncertainty.

### 2021

**AIAA Rocky Mountain Annual Technical Symposium:** “Machine Learning in Aerospace Systems” (panel)

**JuliaCon 2021:** POMDPs.jl and Interactive Assignments in Julia

**NASA Jet Propulsion Lab, Pasadena, CA:** Scalable online POMDP planning for safe and efficient autonomy

**Johns Hopkins University Applied Physics Lab, Laurel, MD:** Some Recent Advances in Online POMDP Algorithms

### 2019

**SRI International, Palo Alto, CA:** Safety and Efficiency for Autonomous Vehicles through Online Learning

**Washington State University, Pullman, WA:** Safety and Efficiency for Autonomous Vehicles through Online Learning

**University of Colorado, Boulder, CO:** Safety and Efficiency for Autonomous Vehicles through Online Learning

### 2018

**Renault-Nissan Research, Sunnyvale, CA:** Safety and Efficiency in Autonomous Vehicles through POMDP Planning

**Lyft Level 5, Palo Alto, CA:** Safety and Efficiency in Autonomous Vehicles through Planning with Uncertainty

**Makani, Alameda, CA:** Algorithms for Uncertain, Non-convex Control Problems in the Real World

**Indeed, San Francisco, CA:** Safety and Efficiency in Autonomous Vehicles through Planning with Uncertainty

### 2017

**Julia in Controls Workshop, ACC, Seattle, WA:** POMDPs.jl

**Open Source Software for Decision Making (OSS4DM), Stanford, CA:** POMDPs.jl - Challenges and Lessons Learned

## Teaching

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**ASEN 3128 Aircraft Dynamics** [2022 – Present]

*University of Colorado Boulder*

**ASEN 5264 Decision Making under Uncertainty** [2020 – present]

*University of Colorado Boulder*

Developed new entry-level graduate course about decision making under uncertainty.

Open-source course materials: <https://github.com/zsunberg/CU-DMU-Materials>

Open-source companion software package: <https://github.com/zsunberg/DMUStudent.jl>

**ASEN 6519 Advanced Survey of Sequential Decision Making** [2021]

*University of Colorado Boulder*

Developed new advanced graduate course that surveys recent advances in decision making under uncertainty.

**ASEN 4018/4028 Senior Design Project** [2020 – 2021]

*University of Colorado Boulder*

Advised senior design project teams, created new optimization-based approach (see Open Source Software) for fairly creating teams based on student preferences [20].

**Army High Performance Computing Summer Institute** [June 2017]

*Stanford University, Stanford, CA*

Developed and taught a 5 lecture course about decision making under uncertainty for college students.

**Stanford Artificial Intelligence Lab OutReach Summer (SAILORS, now AI4ALL)** [2015-2017]

*Stanford University, Stanford, CA*

Developed and taught a 2 week course and project for high school students that included programming robots for optical line following and using Dijkstra’s algorithm to find the shortest path on a road network; only project mentor to serve all three years of the program. <http://ai-4-all.org/>

## AA-228/CS-238 Decision Making Under Uncertainty

[Autumn 2016]

Stanford University, Stanford, CA

Head course assistant for a class of around 200; developed problems for midterm project; gave guest lectures on the POMDPs.jl framework and autonomous driving research; project software was reused in a course at Iowa State University.

## Advising and Mentoring

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### Ph.D. Thesis Advisees.....

Hyun Jae (Michael) Lim (Co-advised with Claire Tomlin at U.C. Berkeley)	[Spring 2020 – Present]
Tyler Becker	[Fall 2020 – Present]
Qi Heng Ho	[Fall 2020 – Present]
Ben Kraske (Received NSF GRFP under my direction)	[Fall 2020 – Present]
Himanshu Gupta	[Fall 2020 – Present]
Zakariya Laouar	[Fall 2021 – Present]

### M.S. Thesis Advisees.....

William Pope	[Spring 2022 – Fall 2022]
Jackson Wagner	[Summer 2022 – Present]

### Independent Study Advisees.....

Johnathan Tucker (Received NSF GRFP under my direction)	[Fall 2020 – Summer 2022]
Saurabh Mishra	[Spring 2020]

### Ph.D. Comprehensive Exam and Defense Committees.....

Sangwoo Moon	John Jackson
Charles (Luke) Burks	Prashin Sharma (Univ. of Michigan)
Neha Garg (Nat. Univ. of Singapore, External Examiner)	Shakeeb Ahmad
Ramya Kanlapuli	John Mern (Stanford Univ.)
Katherine Glasheen	Aastha Acharya
Andrew Mills	Shohei Wakayama
Chandranth Venigalla	Marcus Lapeyrolerie (Univ. of California, Berkeley, Qualls)
Sam Fedeler	

### M.S. Thesis Committees.....

Lasse Peters (TU Hamburg)	Akash Ratheesh
Wyatt Raich	Jamison McGinley
Cody Charland	Rio McMahon

## Department Service and Outreach

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### Graduate Program Committee

[2020–present]

*Autonomous Systems Lead*

Served on Preliminary Exam Subcommittee

Rising Stars in Aerospace organizing committee member

[2022]

Speaker for Tuskegee Airmen outreach event at CU

[2021, 2022]

Invited Speaker for AIAA Movie Night & Technical Discussion: 2001: A Space Odyssey

[2021]

## Conference and Workshop Organization

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**Strategic multi-agent interactions: game theory for robot learning and decision making** [2022]  
*Workshop at the Conference on Robotic Learning (CoRL)*  
Co-organizer with David Fridovich-Keil (Univ. of Texas) and Negar Mehr (Univ. of Illinois)

## Academic Peer Review and Editing

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**Guest editor for the AIAA Journal of Aerospace Information Systems** [2020 – 2022]

**Reviewer:** I have reviewed manuscripts for the following journals and conferences:

Journal of Artificial Intelligence Research	International Symposium on Robotics Research
AIAA Journal of Guidance, Control, and Dynamics	Intl. Conference on Robotics and Automation (ICRA)
IEEE Robotics and Automation Letters	Intl. Joint Conference on Artificial Intelligence (IJCAI)
IEEE Transactions on Cybernetics	AAAI Conference on Artificial Intelligence
IEEE Transactions on Intelligent Transportation Systems	American Control Conference (ACC)
IEEE Transactions on Intelligent Vehicles	Intelligent Transportation Systems Conference (ITSC)
Journal of Aerospace Information Systems	Robotics, Science and Systems (RSS)
Autonomous Robots	Learning for Decision and Control Conference (L4DC)
Intl. Journal of Robotics Research	
Journal of the American Helicopter Society	

## Fellowships and Awards

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<b>AIAA Journal of Guidance, Control, and Dynamics Excellent Reviewer</b>	[2021,2022]
<b>Association for the Advancement of Artificial Intelligence Doctoral Consortium</b>	[February 2018]
<b>IJCAI 2019 Distinguished Program Committee member</b>	[2019]
<b>American Control Conference Student Travel Award</b>	[May 2017]
<b>National Science Foundation Graduate Research Fellowship</b>	[2012-2016]