Patrick McKeen

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Research Interests

I develop control, estimation, and autonomy methods that change what spacecraft can do and what hardware they need. My research spans precision pointing with fewer actuators, control of flexible spacecraft, close-proximity formation flight, and adaptable mission operations, connecting mathematical methods with open-source software and spacecraft design.

Education

2025 **Ph.D., Massachusetts Institute of Technology**
Dissertation: *Computational Methods to Improve Satellite Attitude Determination and Control with a Focus on Autonomy, Generalizability, and Underactuation.*
Advisor: Kerri Cahoy. Degree conferred February 2025.

2019 **S.M., Massachusetts Institute of Technology**
Thesis: *Modeling and Tradespace Exploration of a Space Suit Hip Bearing Assembly using Multi-Degree-of-Freedom Range of Motion Analysis.*
Advisor: Leia Stirling. Degree conferred September 2019.

2017 **B.S. in Engineering, Harvey Mudd College**
Graduated with High Distinction.

Academic Appointments and Research Experience

2026–present **Postdoctoral Associate, MIT AeroAstro, REx Lab**
With Zac Manchester. Led development of the WiggleSat mission concept. Developed formation control using drag, lift, and solar radiation pressure. Organized the MIT–FOI/FMV collaboration. Evaluated onboard AI for mission planning.

2019–2025 **Graduate Research and Teaching Assistant, MIT STAR Lab**
With Kerri Cahoy. Originated Generalized ACS for transferring control laws across spacecraft and actuator configurations. Developed the research code and methods underlying the full GenADCS framework. Originated the underactuated attitude-planning methods underlying SALTRO. Led BeaverCube ADCS development.

2022–2024 **Doctoral Research, MIT – Orbit Propagation**
With Richard Linares. Developed orbit-propagation tools for Monte Carlo studies of space debris, including THALASSA integration and a DSST-based propagator for MOCAT.

2017–2019 **Graduate Research Assistant, MIT Human Systems Lab**
With Leia Stirling. Built computational models to study how spacesuit hip-bearing geometry affects joint dynamics and range of motion.

Honors and Fellowships

2020 **Matthew Isakowitz Fellowship Program**

2016–2017 **Eugene H. Kopp Scholarship**

Publications

Peer-Reviewed Journal Articles

J2 **McKeen, P.**, and Cahoy, K. "Method for Pointing Spacecraft While Minimizing Change in Orientation." *Journal of Guidance, Control, and Dynamics*, 45(8), 1554–1557, 2022. doi: 10.2514/1.G006429.

J1 **McKeen, P.**, Cullinane, C., Rhodes, R., and Stirling, L. "Analysis of the relationship between hip joint flexion/extension and torques in the mark III space suit using a computational dynamics model." *Computer Methods in Biomechanics and Biomedical Engineering*, 24(8), 831–843, 2021. doi: 10.1080/10255842.2020.1853708.

Conference Papers

C12 **McKeen, P.**, and Manchester, Z. "Autonomous Mission Planning with an Onboard Vision-Language Model: What a Small Model Can and Cannot Do for a CubeSat, Measured." *Joint i-SAIRAS & iSpaRo*, Cologne, 2026. *Accepted.*

C11 Zhang, J., Verhagen, J. P. M., Vega, F., **McKeen, P.**, and Manchester, Z. "Mjorbit: A Simulation Framework for Space Robotics." *International Conference on Space Robotics (iSpaRo)*, Cologne, 2026. *Accepted.*

C10 **McKeen, P.**, and Manchester, Z. "Decentralized Formation Control with Differential Drag for Close-Proximity Satellite Clusters." *77th International Astronautical Congress*, Antalya, 2026. Paper IAC-26-C1.3.2.

C9 Scheuer, N., **McKeen, P.**, and Cahoy, K. "One Wheel Is Enough: Control Strategies for the 3+1 Actuator Architecture Across Small Satellite Mission Profiles." *77th International Astronautical Congress*, Antalya, 2026. Paper IAC-26,B4,6A,2,x109468.

C8 **McKeen, P.**, Scheuer, N., and Cahoy, K. "A Feasibility-Aware Attitude Trajectory Planner for Small Satellites." *40th Annual Small Satellite Conference*, Salt Lake City, 2026. Paper SSC26-FT-34. doi: 10.26077/0cet-hr57.

C7 **McKeen, P.**, Scheuer, N., and Cahoy, K. "Generalized Attitude Control for Small Spacecraft." *40th Annual Small Satellite Conference*, Salt Lake City, 2026. Paper SSC26-P2-54. doi: 10.26077/6a3x-dk30.

C6 **McKeen, P.**, Scheuer, N., and Cahoy, K. "A Modular Open-Source ADCS Framework for Small Satellite Development and Testing." *SmallSat Europe*, Amsterdam, 2026. Conference record.

C5 **McKeen, P.**, and Cahoy, K. "Generalized Attitude Estimation for Spacecraft." *38th Annual Small Satellite Conference*, 2024. doi: 10.26077/vgd0-7e57.

C4 **McKeen, P.**, Meredith, A., and Cahoy, K. "Trajectory-Planning Attitude Control System for Satellites with Magnetic Attitude Control and One Reaction Wheel." *AAS/AIAA Astrodynamics Specialist Conference*, Charlotte, NC, 2022. Paper 22-810.

Publications (continued)

Conference Papers (continued)

C3 do Vale Pereira, P., Garcia, M., Schroeder, M., Caldelas, H., Lindsay, C., Choi, A., Pfrang, K., Gagnon, A., Meredith, A., **McKeen, P.**, Clark, J., Murphy, T. J., Baber, S., Khan, S., Miller, A., Velez, G., Campbell, M., Coray, J., Koldada, J., Tran, T., Austin, S., Louthain, A., Wells, T., Kabir, M., Sit, E., Haughwout, C., and Cahoy, K. "BeaverCube: Coastal Imaging with VIS/LWIR CubeSats." *34th Annual Small Satellite Conference*, 2020. Paper SSC20-V-03. Proceedings record.

C2 **McKeen, P.**, and Stirling, L. "Tradespace Exploration of Geometry for a Spacesuit Hip Bearing Assembly." *IEEE Aerospace Conference*, 2020. doi: 10.1109/AERO47225.2020.9172433.

C1 Aguilar, A., Butler, P., Collins, J., Guerster, M., Kristinsson, B., **McKeen, P.**, Cahoy, K., and Crawley, E. F. "Tradespace Exploration of the Next Generation Communication Satellites." *AIAA Scitech Forum*, San Diego, 2019. Paper 2019-0768. doi: 10.2514/6.2019-0768.

Submitted Manuscripts

S1 Scheuer, N., **McKeen, P.**, and Milojevic, D. "Reinforcement Learning for Fast Magnetorquer-Only Spacecraft Detumbling and Pointing." Submitted to the *2027 IEEE Aerospace Conference*.

Manuscripts in Preparation

Journal manuscripts extending the conference papers cited below; working titles.

M6 **McKeen, P.**, and Manchester, Z. "Formation Flying of Orbital Data Centers Using Drag and Solar Radiation Pressure." Additional analysis underway; extends the control methods in C10.

M5 **McKeen, P.**, and Manchester, Z. "Passive Safety of Close Proximity Orbital Data Centers." Additional analysis underway; extends the systems analysis in C10.

M4 Scheuer, N., **McKeen, P.**, and Cahoy, K. "Control Strategies for a Satellite with One Reaction Wheel and Three Magnetorquers." Manuscript substantially complete; extends C9.

M3 **McKeen, P.**, Scheuer, N., and Cahoy, K. "Onboard Planning-Based Attitude Control." Manuscript substantially complete; extends C4 and C8.

M2 **McKeen, P.**, Scheuer, N., and Cahoy, K. "Generalized ADCS: An Open-Source Python Framework for ADCS Architecture." Draft in progress; extends C5 and C6.

M1 **McKeen, P.**, Scheuer, N., and Cahoy, K. "Adapting Attitude Control Laws across Missions, Spacecraft, and Actuators." Draft in progress; extends C7.

Abstracts Under Consideration

A1 **McKeen, P.**, and Manchester, Z. "Grown in Orbit: Soft Robotic for Shape-Programmable Attitude Control." Abstract submitted to the *2027 IEEE Aerospace Conference*; decision pending.

Research Software

2026–present **Generalized ADCS (GenADCS)**
Developed the research code and methods that became the basis of GenADCS. Led method development for the open-source package and co-maintained it with Niclas Scheuer, who led software implementation. The Python framework provides interchangeable estimation, control, dynamics, sensor, and actuator models. Used for simulation and ADCS development by small-satellite teams at MIT, Tufts, ETH Zurich, and other institutions. Related papers: C5, C6.
github.com/nscheuer/Generalized_ADCS | PyPI: generalized-adcs

2026–present **SALTRO (Satellite Augmented Lagrangian Trajectory Optimizer)**
Conceived and developed the spacecraft attitude-planning methods implemented in SALTRO. Led development of the ALTRO-based C++ implementation and Python interface with Niclas Scheuer. Raspberry Pi 4 benchmarks achieved sub-second cold-start solves for 500 s planning horizons across three tested actuator configurations. Related papers: C4, C8.
github.com/nscheuer/SALTRO

2024 **DSST Orbit Propagator for MOCAT**
Developed and tested a DSST-based propagator for Richard Linares's space-debris modeling tool. Internal research software.

2022–2023 **THALASSA Propagator Integration**
Adapted the THALASSA numerical orbit propagator for Monte Carlo studies of space debris. Modified its Fortran implementation for repeated multi-satellite propagation.

2022 **Quaternion Pointing Methods**
Released companion code for analytical reduced-attitude pointing methods, including minimum-slew goal selection and keep-out-zone avoidance. Related paper: J2.
github.com/patrickmckeen/quaternion-pointing

Research Collaboration

EarthTraq

Contributed spacecraft attitude estimation and control expertise through an academic collaboration.

MIT–FOI/FMV Collaboration

Organized an MIT collaboration with Sweden's FOI and FMV, including an October 2026 visit to MIT by Swedish researchers. Contributed technical expertise in differential-drag formation flying and optimization combining differential drag with thruster control.

Proposal Development

2020 **In-Space Manufacturing of Large, Stiff, and Thermally Stable Structures**
Developed the research approach for Objective 3, adapting construction to compensate for manufacturing errors and improve structural performance. Contributed substantial technical writing incorporated by PI Zachary Cordero into the interdisciplinary NRO proposal.

Selected Research Contributions

Generalizable Attitude Control and Reduced Actuation

Originated and developed Generalized ACS to transfer existing control laws across spacecraft, pointing goals, and actuator configurations. Demonstrated precision pointing with three magnetorquers and one reaction wheel: disturbance-inclusive 6U simulations achieved median final pointing errors of 0.51–0.74°, versus 0.47–0.61° with three wheels. Related papers: C7, C9. Journal extensions in preparation: M1, M4.

Predictive Attitude Planning for Underactuated Spacecraft

Conceived and developed the attitude-planning approach underlying SALTRO, incorporating anticipatory slews, disturbances, and wheel-momentum management. Demonstrated emergent spin stabilization without prescribing a spin maneuver. In 100 paired magnetorquer-only simulations, 84% of planner runs reached less than 5° final boresight error at 1000 s, versus 27% for magnetic PD feedback. Related papers: C4, C8. Journal extension in preparation: M3.

Close-Proximity Formation Control

Conceived a decentralized formation-control strategy using drag, lift, and solar radiation pressure for in-plane formation-keeping without thrust. Achieved approximately 3 m RMS slot error for 81 satellites at 100 m nominal spacing in nonlinear simulations with navigation and pointing errors. The simulations used orbit-normal thrust to maintain inclination. Characterized trades between formation geometry, passive safety, and propellant use. Related paper: C10. Journal extensions in preparation: M6, M5.

Joint Attitude, Bias, and Disturbance Estimation

Developed dynamics-based extended and unscented Kalman filters for joint estimation of attitude, angular velocity, sensor and actuator biases, and disturbance parameters. Used the estimates to support bias and disturbance compensation in spacecraft control and planning. Developed these methods into the configurable estimation framework within GenADCS. Related papers: C5, C6. Journal extension in preparation: M2.

Evaluation of Onboard AI

Developed and applied an evaluation framework for vision-language models in autonomous CubeSat mission planning. Measured task performance and failure modes to assess practical capabilities and readiness for reliable onboard use. Related paper: C12.

Selected Mission Contributions

2026–present **WiggleSat**
Led a team developing a CubeSat mission concept for arcsecond-level pointing without reaction wheels. Investigated variable-shape actuation, building on prior research by Zac Manchester.

c. 2021–2023 **BeaverCube II**
Designed the attitude actuation architecture using three magnetorquers and one reaction wheel. Developed the control methods underlying the mission's control stack. Launch planned for spring 2027.

2019–2022 **BeaverCube**
Led ADCS development, including flight-code implementation. Advised student teams through launch and ISS deployment in 2022.

2021 **SEASALT Mission Concept Study**
Evaluated optics and ADCS for an MIT–WHOI–University of Arizona ocean-color CubeSat concept. Compared 6U and 12U designs against a 15 m ground-sampling requirement.

Invited Talks, Panels, and Institutional Presentations

Nov. 10, 2026 **Invited Talk on Modern ADCS, ETH Zurich I Space**
Scheduled. Introduction to ADCS concepts and current research for master's students and controls researchers.

Nov. 4, 2026 **Invited Panelist, AI in Space**
Scheduled, Joint i-SAIRAS & iSpaRo Conference, Cologne. Discussion of onboard decision-making, autonomy, and operational trust.

Feb. 22, 2021 **Research Presentation, MIT Small Satellite Center**

Conference Oral Presentations

Nov. 3, 2026 **Autonomous Mission Planning with an Onboard Vision-Language Model: What a Small Model Can and Cannot Do for a CubeSat, Measured**
Joint i-SAIRAS & iSpaRo, Cologne. Scheduled. Related paper: C12.

Oct. 8, 2026 **One Wheel Is Enough: Control Strategies for the 3+1 Actuator Architecture Across Small Satellite Mission Profiles**
77th International Astronautical Congress, Antalya. Related paper: C9.

Oct. 6, 2026 **Decentralized Formation Control with Differential Drag for Close-Proximity Satellite Clusters**
77th International Astronautical Congress, Antalya. Related paper: C10.

Aug. 25, 2026 **A Feasibility-Aware Attitude Trajectory Planner for Small Satellites**
40th Annual Small Satellite Conference, Salt Lake City. Flash talk. Related paper: C8.

Aug. 2024 **Generalized Attitude Estimation for Spacecraft**
38th Annual Small Satellite Conference. Related paper: C5.

Aug. 11, 2022 **Trajectory-Planning Attitude Control System for Satellites with Magnetic Attitude Control and One Reaction Wheel**
AAS/AIAA Astrodynamics Specialist Conference, Charlotte, NC. Related paper: C4.

2020 **Tradespace Exploration of Geometry for a Spacesuit Hip Bearing Assembly**
IEEE Aerospace Conference. Related paper: C2.

Poster Presentations

Aug. 24, 2026 **Generalized Attitude Control for Small Spacecraft**
40th Annual Small Satellite Conference, Salt Lake City. Jointly presented with Niclas Scheuer. Related paper: C7.

July 9, 2018 **Analysis of Human Postural Control in the Demonstrator Spacesuit**
With C. Jacobs and L. Stirling. Student poster, 48th International Conference on Environmental Systems, Albuquerque, NM.

Teaching and Curriculum Development

Guest Lectures and Laboratory Development

Fall 2026 **MIT 16.07 Dynamics – Laboratory Development**
Primary designer of three laboratories on bifilar pendulums, double pendulums, and stick-slip friction. Developed the hardware, supporting code, and laboratory procedures for a class of approximately 50 students.

Oct. 15, 2026 **MIT 16.07 Dynamics – Guest Lecturer**
Delivered a lecture on attitude representations to approximately 50 students.

Spring 2026 **MIT 16.346 Astrodynamics – Guest Lecturer**
Developed and delivered five lectures on Lagrange's planetary equations, indirect optimal control, and periodic orbits and stability in the three-body problem for approximately 30 students. Student evaluations: overall mean 6.6/7; median 7/7 on all four rated items.

Teaching Assistantships

Fall 2020 **MIT 16.851 Satellite Engineering**
Primary designer of DemoSat laboratories on remote sensing, attitude control, power, thermal systems, and communications, used by 33 students. Wrote the exercises and supporting code. Guided students through experiments and graded their work.

Spring 2020 **MIT 16.831 Space Systems Development**
Developed laboratories for the BeaverCube capstone, serving approximately 30 students. Advised students on spacecraft and ADCS development. Graded laboratory work.

Fall 2019 **MIT 16.83 Space Systems Engineering**
Developed multiple laboratories as part of the teaching team for approximately 30 capstone students. Designed hardware, supporting code, and procedures. Guided students through the exercises and graded their work.

Peer Teaching and Professional Development

2026 **MIT Research Mentoring Certificate**
Completed the CIMER research mentoring curriculum.

Spring 2026 **Graduate Qualifying-Exam Tutoring**
Tutored a graduate student in preparation for mechanical engineering qualifying examinations.

2023 **STAR Lab Controls Office Hours and Reading Group**
Organized and taught a peer learning series on controls and ADCS, covering Kalman filtering from its foundations through extended and unscented formulations.

Research Mentoring and Advising

2025–present **Niclas Scheuer – Master's Student, ETH Zurich**
Mentored research on generalized ADCS, attitude planning, and underactuated control, including an ETH semester project on reinforcement learning for magnetorquer detumbling. The collaboration produced multiple conference papers and the GenADCS and SALTRO software packages.

2020–2022 **Alex Meredith Rose – Undergraduate, then Master's Student, MIT**
Mentored research on BeaverCube ADCS flight code and trajectory planning. Coauthored the resulting AAS/AIAA paper (C4).

Professional Service and Leadership

Peer Review

2026 **International Conference on Space Robotics (iSpaRo) – Manuscript Reviewer**
Reviewed two manuscripts.

2025–2026 **Journal of Spacecraft and Rockets – Manuscript Reviewer**

2025 **Advances in Space Research – Manuscript Reviewer**

2023 **Journal of Aerospace Information Systems – Manuscript Reviewer**

Maker Education and Engineering Leadership

2018–2023 **MIT MakerWorkshop – Electronics Team Lead Mentor and Executive Member**
Built and led the electronics team. Trained users in electronics and supervised safe equipment use as a mentor and Electronics Team Machine Master. Now an emeritus mentor.

2018–c. 2020 **MIT ProtoWorks – Shop Guardian**
Supervised shop sessions and safe equipment use. Mentored users on their projects.

Harvey Mudd College
Class of 2017 president; Honor Board.

2015–2017 **Harvey Mudd College Machine Shop – Proctor**
Supervised machine-shop users and monitored safe equipment use.

2015–2017 **Hyperloop Competition, Harvey Mudd College**
Led HMC's contributions to a six-institution collaboration. Served as controls team captain in 2017. Developed motion simulation, sensor fusion, and control software. Designed sensor hardware.

Industry and Consulting Experience

2019–present **Zenith Consulting – Sole Proprietor**
Provided space-systems and rocketry consulting, including spacecraft attitude determination and control. Clients included Venturi Astrolab and others under NDA.

Summer 2020 **Venturi Astrolab – Engineering Intern and Matthew Isakowitz Fellow**
Developed lunar-rover simulations for dynamics, sensing, and control, including articulated limbs and terrain contact. Advised the engineering team on rover human factors. Manhattan Beach, CA.

Summer 2016 **Blue Origin – Mechanical Engineering Intern**
Compared New Shepard crew-capsule separation concepts through simulation and trade studies. Developed component approval, qualification, and acceptance-test procedures. Kent, WA.

Summer 2015 **Millennium Space Systems – Engineering Intern**
Designed an autonomous marine platform to test satellite power, sensing, and navigation hardware. Wrote manufacturing procedures for the platform. El Segundo, CA.

Professional Memberships and Outside Activities

Tau Beta Pi: Member, 2016–present.
Tripoli Rocketry Association: Member, 2015–present; Level 2 high-power rocketry certification.
BattleBots SawBlaze Team: Machinist, Spring–Summer 2019.