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Rahil Makadia

EDUCATION

University of Illinois at Urbana-Champaign (UIUC) — Urbana, IL
Ph.D. in Aerospace Engineering — 01/21 - 12/25
Advisor: Siegfried Eggl
Committee: Steven Chesley, Davide Farnocchia, Bruce Conway, Raluca Ilie
Dissertation: Design and Modeling of Kinetic Impact Missions for Deflecting Near-Earth Asteroids (Defended 22 July 2025)

University of Illinois at Urbana-Champaign — Urbana, IL
B.S. in Aerospace Engineering with Honors — 08/17 - 12/20

WORK EXPERIENCE

NASA Jet Propulsion Laboratory (JPL) — Pasadena, CA
Visiting Technologist — 09/25 - 12/25, 03/24 - 06/24, 05/23 - 08/23
Advisors: Steven Chesley, Davide Farnocchia

- Upgraded JPL's Scout, the short-term impact monitoring system for newly discovered near-Earth objects, making the system 300% faster.
- Implemented a novel adaptive method to perform initial orbit determination of solar system objects.
- Produced ability to compute locations of gravitational keyholes, which are predictors of future asteroid impacts with Earth.
- Wrote an efficient orbit propagator with sub-1 km position accuracy over 250 years compared to JPL's orbit software.
- Developed an orbit determination submodule around the propagator with sub-1σ agreement with JPL orbit solutions.
- Released a publicly available Python package, GRSS, to allow the planetary defense scientific community to study solar system objects.

NASA Goddard Space Flight Center — Greenbelt, MD
Visiting Technologist — 05/25 - 07/25
Advisors: Brent Barbee, Kenneth Getzandanner

- Leveraged proven mission analysis tools to design kinetic impact missions.
- Validated kinetic impact mission trajectories for mapping gravitational keyholes on the surface of (101955) Bennu.

NASA Goddard Space Flight Center — Greenbelt, MD
OSIRIS-REx/OSIRIS-APEX CelNav Intern — 06/22 - 08/22
Advisors: Kenneth Getzandanner, Andrew Liounis

- Developed simulations to assess performance of onboard Celestial Navigation (CelNav) during the cruise phase of NASA's OSIRIS-APEX mission.
- Simulated more than 8,000 planets/moons/asteroids to obtain optimal observation areas for the spacecraft on the celestial sphere.
- Performed covariance analyses using JPL's Monte library to study the spacecraft's state uncertainty on its way to asteroid (99942) Apophis.

Research Experience

Astrodynamics and Planetary Exploration Group — Urbana, IL
Advisor: Siegfried Eggl — 01/21 - 12/25

NASA's Double Asteroid Redirection Test (DART) Mission

- Analyzed high-fidelity ejecta dynamics simulation results from JPL for impacts in the (65803) Didymos binary asteroid system.
- Implemented a novel method to model momentum changes in the Didymos system after the DART impact.
- Generated updated B-plane maps to conclude that the Didymos system will not collide with the Earth after the DART impact.
- Built MATLAB and Python parameter estimation packages to assess measurability of the heliocentric momentum enhancement from the DART impact.
- Leveraged ultra-precision occultation measurements in 2024 and 2025 to detect heliocentric changes in an asteroid's orbit for the first time in human history.

Keyhole-aware Deflection Site Selection for Asteroids

- Developed a novel method to select deflection sites on asteroids while minimizing the probability of future Earth impacts.
- Modeled the effects of billions of kinetic impact deflections on an asteroid's orbit using Monte Carlo simulations with a Fortran foundation.
- Created impact probability maps on the surface of different asteroid shapes to directly compare the safety of available deflection sites.
- Applied the new method to a theoretical kinetic impactor mission design for asteroid (101955) Bennu that would avoid triggering future Earth impacts.

Gauss-Radau Small-body Simulator (GRSS)

- Implemented a high-accuracy propagator for asteroids and comets based on the `RADAU` and `IAS15` integrators.
- Developed an orbit determination code for estimating small body orbits using optical and radar observations.
- Released an open-source Python library with a C++ core codebase for use by the planetary defense community.
- Utilized this library to study the orbit of the newly discovered interstellar object 3I/ATLAS (C/2025 N1).

State Transition Matrices (STMs) via the Unscented Transform

- Extended the proven unscented transform formalism to compute the STM in addition to posterior distributions.
- Novel STMs do not require time-consuming partial derivatives or problem-specific finite difference steps, enabling more robust implementation.
- Unscented STMs are a new, easy, and reliable method to compute STMs with unbounded applications in dynamical systems.

Aerospace Mission Analysis Laboratory Urbana, IL
Advisor: Zachary Putnam 08/22 - 01/23
Venus Aerogravity Assist Performance Assessment

- Analyzed Venus aerogravity assist missions that enabled new trajectories to the outer solar system.
- Assessed the performance of blunt-body vehicles and waveriders using MATLAB for varying trajectories and vehicle configurations.

SKILLS

Programming Languages: Fortran, Python, C/C++, MATLAB, Perl, SQL, R

Software Tools: LaTeX, Git

Prepackaged Tools: SPICE, Monte, FreeFlyer, GMAT

Operating Systems: MacOS, Linux, Windows

Languages: English, Gujarati, Hindi, French

HONORS AND AWARDS

NASA Space Technology Graduate Research Fellow 08/22 - 12/25
NSTGRO fellowship from NASA Space Technology Mission Directorate

ARCS Foundation Scholar Award 08/23 - 12/25
Achievement Rewards for College Scientists (ARCS) Illinois Chapter

1st Place – Student Research Competition 05/25
9th IAA Planetary Defense Conference

Alumni Advisory Board Fellowship 04/25
UIUC Aerospace Engineering Department

Conference Presentation Award 04/25
UIUC Graduate College

Best Visual Poster Award 02/24
UIUC Aerospace Engineering Department

John C. Mather Nobel Scholar 07/22 - 06/23
National Space Grant Foundation

Aerospace Excellence Award to DART Investigation Team 05/23
American Institute of Aeronautics and Astronautics (AIAA)

Outstanding Academic and Research Achievement Fellowship 04/23
UIUC Aerospace Engineering Department

President's Award 08/17 - 12/20
University of Illinois at Urbana-Champaign

Dean's List 05/19, 05/20
University of Illinois at Urbana-Champaign

PUBLICATIONS

14 Journal Articles
28 Conference and Meeting Proceedings
5 Invited Seminars and Talks

Research Grants

NASA Space Technology Graduate Research Fellowship

- Title: Keyhole-Based Impact Site Selection and Post-Deflection Impact Risk Assessment for Near-Earth Objects
- Funding Institution: NASA Space Technology Mission Directorate
- Amount: $332,000
- Role: Co-Investigator (PI: Siegfried Eggl)
- Period of Performance: 08/22 - 12/25

LSST LINCC Frameworks Incubator

- Title: Orbit Fitting at LSST Scale
- Funding Institution: Vera C. Rubin Observatory
- Amount: $20,000
- Role: Co-Investigator (PI: Matthew Holman)
- Period of Performance: 02/25 - 05/25

Teaching Experience

University of Illinois at Urbana-Champaign Urbana, IL
Instructor: Siegfried Eggl 08/21 - 12/21
Teaching Assistant for AE 352: Aerospace Dynamical Systems

- Assisted in developing and teaching the curriculum's core dynamics course with aerospace applications.
- Covered Newtonian, Lagrangian, and Hamiltonian mechanics for rigid body motion.
- Advised 16 student teams with Project Clear Constellation, focusing on new methods to remove orbital debris.

University of Illinois at Urbana-Champaign Urbana, IL
Instructor: Huy Tran 01/20 - 05/20
Undergraduate Course Assistant for AE 199: Aerospace Computing

- Assisted with grading for a new course focused on using Python to solve problems such as analyzing air traffic data and designing Martian landers.
- Worked with instructor to augment course for a fully online learning environment without affecting students due to the COVID-19 pandemic.

Professional Activities and Affiliations

Mission Participation

- NASA Double Asteroid Redirection Test (DART) Mission Science Investigation Team Member
- ESA Hera Mission Science Investigation Team Extended Member

Review Panel Activities

- NASA Yearly Opportunities for Research in Planetary Defense (YORPD)

Memberships (Current and Past)

- American Astronomical Society (AAS)

- American Geophysical Union (AGU)
- American Astronautical Society (AAS)
- American Institute of Aeronautics and Astronautics (AIAA)

Journal Articles

[14] **R. Makadia**, S. R. Chesley, et al., "Direct detection of an asteroid's heliocentric deflection: The Didymos system after DART", Science Advances **Under review** (2026).

[13] C. O. Chandler et al., "NSF-DOE Vera C. Rubin Observatory Observations of Interstellar Comet 3I/ATLAS (C/2025 N1)", The Astrophysical Journal Letters **Under review** (2026).

[12] **R. Makadia** et al., "Keyhole-aware target site selection for kinetic impact missions to near-Earth asteroids", Icarus **447**, 116915 (2026).

[11] **R. Makadia** et al., "A novel method for computing state transition matrices due to the unscented transform", Celestial Mechanics and Dynamical Astronomy **137**, 18 (2025).

[10] **R. Makadia** et al., "Gauss-Radau Small-body Simulator (GRSS): An Open-source Library for Planetary Defense", The Planetary Science Journal **6**, 85 (2025).

[9] **R. Makadia** et al., "Gauss-Radau Small-body Simulator (GRSS): An Open-Source Library for Planetary Defense", Journal of Open Source Software **10**, 7861 (2025).

[8] M. Hirabayashi et al., "Elliptical ejecta of asteroid Dimorphos is due to its surface curvature", Nature Communications **16**, 1602 (2025).

[7] D. C. Richardson et al., "The Dynamical State of the Didymos System before and after the DART Impact", The Planetary Science Journal **5**, 182 (2024).

[6] N. L. Chabot et al., "Achievement of the Planetary Defense Investigations of the Double Asteroid Redirection Test (DART) Mission", The Planetary Science Journal **5**, 49 (2024).

[5] **R. Makadia** et al., "Measurability of the Heliocentric Momentum Enhancement from a Kinetic Impact: The Double Asteroid Redirection Test (DART) Mission", The Planetary Science Journal **5**, 38 (2024).

[4] J.-Y. Li et al., "Ejecta from the DART-produced active asteroid Dimorphos", Nature **616**, 452–456 (2023).

[3] T. S. Statler et al., "After DART: Using the First Full-scale Test of a Kinetic Impactor to Inform a Future Planetary Defense Mission", The Planetary Science Journal **3**, 244 (2022).

[2] **R. Makadia** et al., "Heliocentric Effects of the DART Mission on the (65803) Didymos Binary Asteroid System", The Planetary Science Journal **3**, 184 (2022).

[1] D. C. Richardson et al., "Predictions for the Dynamical States of the Didymos System before and after the Planned DART Impact", The Planetary Science Journal **3**, 157 (2022).

Conference and Meeting Proceedings

[28] **R. Makadia** et al., "Keyhole-Aware Target Site Selection for Kinetic Impact Missions to Near-Earth Asteroids", in 2025 AGU Annual Meeting, Invited (Dec. 2025).

[27] C. O. Chandler et al., "Solar System Science with the NSF-DOE Vera C. Rubin Observatory: Overview and Results", in 2025 AGU Annual Meeting (Dec. 2025).

[26] **R. Makadia**, S. R. Chesley, and S. Eggl, "Deflecting binary asteroids: Future considerations highlighted by the Didymos system's heliocentric deflection after DART", in Binaries in the Solar System VI (Sept. 2025).

[25] **R. Makadia** et al., "Keyhole-Based Site Selection for Kinetic Impact Deflection of Near-Earth Asteroids", in Europlanet Science Congress - Division of Planetary Sciences Joint Meeting 2025 (Sept. 2025).

[24] S. R. Chesley, **R. Makadia**, et al., "First detection of an asteroid's heliocentric deflection: The Didymos system after DART", in Europlanet Science Congress - Division of Planetary Sciences Joint Meeting 2025 (Sept. 2025).

[23] P. Tanga et al., "Stellar occultations by Near Earth Asteroids: challenges and results", in Europlanet Science Congress - Division of Planetary Sciences Joint Meeting 2025 (Sept. 2025).

[22] P. H. Bernardinelli et al., "Layup: Orbit fitting at LSST Scale", in Europlanet Science Congress - Division of Planetary Sciences Joint Meeting 2025 (Sept. 2025).

[21] **R. Makadia** et al., "Design constraints for asteroid deflection campaigns based on ΔV estimation timelines", in 9th IAA Planetary Defense Conference (May 2025).

[20] S. R. Chesley, **R. Makadia**, et al., "The post-DART heliocentric orbit of Didymos and implications for the effectiveness of the DART impact", in 9th IAA Planetary Defense Conference (May 2025).

[19] **R. Makadia** et al., "First detection of the Didymos system's heliocentric orbit changes after the DART impact", in April 2025 Hera Team Meeting (Apr. 2025).

[18] **R. Makadia** et al., "A novel method for computing state transition matrices using the unscented transform", in 35th AAS/AIAA Space Flight Mechanics Meeting (Jan. 2025).

[17] **R. Makadia** and S. Eggl, "GRSS: An open-source tool for high precision asteroid orbit determination and orbit propagation", in 32nd International Astronomical Union (IAU) General Assembly (Aug. 2024).

[16] **R. Makadia** et al., "A novel method for computing state transition matrices using the unscented transform", in Dynamics and Physics in the Solar System – The legacy of Paolo Farinella and Andrea Milani (June 2024).

[15] **R. Makadia** et al., "GRSS: An open-source small-body science tool for planetary defense", in 55th AAS Division for Planetary Sciences Meeting (Oct. 2023).

[14] **R. Makadia** et al., "The DART mission: Measurability of the heliocentric changes to the (65803) Didymos system", in 14th Asteroids, Comets, Meteors Conference (June 2023).

[13] D. C. Richardson et al., "The dynamical state of the Didymos System before and after the DART Impact", in 14th Asteroids, Comets, Meteors Conference (June 2023).

[12]R. Nakano et al., "Mutual orbit perturbations due to Dimorphos's deformation after the DART impact", in 14th Asteroids, Comets, Meteors Conference (June 2023).

[11]**R. Makadia** and S. Eggl, "Heliocentric beta ($\beta_\odot$) measurability", in May 2023 DART Investigation Team Meeting (May 2023).

[10]**R. Makadia** et al., "Measurability of the heliocentric momentum enhancement of the Didymos system from the DART impact", in 8th IAA Planetary Defense Conference (Apr. 2023).

[9]D. Engel, **R. Makadia**, and Z. Putnam, "Assessment of aerogravity assist at Venus using blunt-body vehicles", in 33rd AAS/AIAA Space Flight Mechanics Meeting (Jan. 2023).

[8]**R. Makadia** et al., "Post-impact prediction of changes to the heliocentric orbit of the (65803) Didymos system due to the DART mission", in 2022 AGU Fall Meeting (Dec. 2022).

[7]D. C. Richardson et al., "First Assessment of the Dynamical State of the Didymos Binary Asteroid System Before and After the DART Impact", in 2022 AGU Fall Meeting (Dec. 2022).

[6]**R. Makadia** and S. Eggl, "Heliocentric beta ($\beta_\odot$) estimation", in November 2022 DART Investigation Team Meeting (Nov. 2022).

[5]**R. Makadia**, S. Eggl, and E. Fahnestock, "The Double Asteroid Redirection Test (DART): Expected changes to the heliocentric orbit of (65803) Didymos", in 44th AAS Guidance, Navigation, and Control Conference (Feb. 2022).

[4]**R. Makadia**, S. Eggl, and E. Fahnestock, "Changes to the heliocentric orbit of (65803) Didymos system due to DART: Simulation and momentum enhancement estimation", in 53rd AAS Division for Planetary Sciences Meeting (Oct. 2021).

[3]**R. Makadia**, S. Eggl, and E. Fahnestock, "Changing the heliocentric orbit of the Didymos system with DART: Implications for β determination", in June 2021 DART Investigation Team Meeting (June 2021).

[2]**R. Makadia** et al., "Estimating β via the heliocentric orbit of Didymos", in June 2021 DART Investigation Team Meeting (June 2021).

[1]**R. Makadia** et al., "Changing the heliocentric orbit of the Didymos system with DART", in 7th IAA Planetary Defense Conference (Apr. 2021).

Invited Seminars and Talks

[5]**R. Makadia** et al., "Keyhole-Aware Target Site Selection for Kinetic Impact Missions to Near-Earth Asteroids", in 2025 AGU Annual Meeting (Dec. 2025).

[4]**R. Makadia**, "Didymos after DART: How the Binary Asteroid System Changed after the Deflection", in Johns Hopkins University Applied Physics Laboratory Asteroid Day Celebration (June 2025).

[3]**R. Makadia**, "Keyhole Mapping: The Next Step in Designing Kinetic Impact Missions for Near-Earth Asteroids", in Johns Hopkins University Applied Physics Laboratory Mission Design and Navigation Seminar (June 2025).

[2] **R. Makadia**, "Planetary Defense: A brief overview of the field and my research", in 1st Annual Illinois Space Society Day (Apr. 2025).

[1] **R. Makadia**, "Planetary Defense: How we (and I) got here, What we're doing, and Where we're going...", in ARCS Foundation Illinois Chapter Annual Holiday Luncheon (Dec. 2024).