Rahil Makadia

CONTACT INFORMATION
104 S Wright St., 307 Talbot Lab
Urbana, IL 61801
makadia2@illinois.edu
https://rahil-makadia.github.io

EDUCATION

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

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 / NSTGRO Fellow — 05/23 - 08/23, 03/24 - 06/24
Advisors: Steven Chesley, Davide Farnocchia

- Validated an efficient orbit propagator with sub-1 km position accuracy over 250 years compared to JPL's internal software.
- Developed an orbit determination submodule around the propagator with sub-1σ agreement with JPL orbit solutions.
- Tested a publicly available Python package, GRSS, to allow the scientific community to accurately propagate and compute the orbits of solar system objects such as asteroids and comets.
- Implemented ability to compute locations of gravitational keyholes, which are predictors of future asteroid impacts with Earth.

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

- Developed simulations to assess performance of Celestial Navigation (CelNav) using onboard cameras during the OSIRIS-APEX cruise phase.
- Simulated more than 8,000 planets/moons/asteroids to obtain optimal observable areas for the spacecraft.
- Performed covariance analyses using MONTE 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 kinetic impactor simulation results from NASA's Jet Propulsion Laboratory (JPL) for impacts in the (65803) Didymos binary asteroid system.

- Implemented a novel method to impart 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.
- Wrote MATLAB and Python parameter estimation packages to assess measurability of the heliocentric momentum enhancement from the DART impact.

Keyhole-aware Deflection Site Selection for Asteroids
- Developed a novel method to select deflection sites on asteroids that minimize the probability of future Earth impacts.
- Created impact probability maps on the surface of different asteroid shapes to directly compare the safety of available deflection sites.
- Applied new method to a theoretical kinetic impactor mission design for asteroid (101955) Bennu to avoid triggering keyholes between 2178-2200.

Gauss-Radau Small-body Simulator (GRSS)
- Developed a high-accuracy propagator for asteroids and comets based on the `RADAU` and `IAS15` integrators.
- Built an orbit determination code for estimating small body orbits using optical and radar observations.
- Released an open-source Python library with a C++ binding for use by the planetary defense community.

State Transition Matrices (STMs) using 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.

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.

Skills

Programming Languages: Python, C/C++, Fortran, MATLAB, R/RStudio

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

Alumni Advisory Board Fellowship 04/25
UIUC Aerospace Engineering Department

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 01/19 - 05/19, 01/20 - 05/20
University of Illinois at Urbana-Champaign

Hans von Muldau Team Award for Best Project 10/19
70th International Astronautical Congress

Professional Activities and Affiliations

DART Investigation Team Member
NASA Double Asteroid Redirection Test (DART) Mission Science Team

Hera Investigation Team Extended Member
ESA Hera Mission Science Team

Reviewer 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)

PUBLICATIONS
11 Journal Articles
21 Conference and Meeting Proceedings
1 Invited Public Talks and Seminars

JOURNAL ARTICLES

[11] **R. Makadia** et al., "A Novel Method for Computing State Transition Matrices due to the Unscented Transform", Celestial Mechanics and Dynamical Astronomy **Under review** (2025).

[10] **R. Makadia** et al., "Gauss-Radau Small-body Simulator (GRSS): An Open-Source Library for Planetary Defense", Journal of Open Source Software **Under review**, 1–3 (2025).

[9] **R. Makadia** et al., "Gauss-Radau Small-body Simulator (GRSS): An Open-Source Library for Planetary Defense", The Planetary Science Journal **In Press** (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

[21]S. R. Chesley 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).

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

[19]**R. Makadia** et al., "First estimate of the heliocentric changes in the Didymos system 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 Public Talks and Seminars

[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).