

Rahil Makadia

EDUCATION	University of Illinois at Urbana-Champaign (UIUC) Ph.D. in Aerospace Engineering Advisor: Siegfried Eggel 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)	Urbana, IL 01/21 - 12/25
	University of Illinois at Urbana-Champaign B.S. in Aerospace Engineering with Honors	Urbana, IL 08/17 - 12/20
WORK EXPERIENCE	NASA Jet Propulsion Laboratory (JPL) Visiting Technologist Advisors: Steven Chesley, Davide Farnocchia <ul style="list-style-type: none">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.	Pasadena, CA 09/25 - 12/25, 03/24 - 06/24, 05/23 - 08/23
	NASA Goddard Space Flight Center Visiting Technologist Advisors: Brent Barbee, Kenneth Getzandanner <ul style="list-style-type: none">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.	Greenbelt, MD 05/25 - 07/25
	NASA Goddard Space Flight Center OSIRIS-REx/OSIRIS-APEX CelNav Intern Advisors: Kenneth Getzandanner, Andrew Liounis <ul style="list-style-type: none">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.	Greenbelt, MD 06/22 - 08/22

RESEARCH EXPERIENCE	Astrodynamics and Planetary Exploration Group Advisor: Siegfried Eggl	Urbana, IL 01/21 - 12/25
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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 Advisor: Zachary Putnam Venus Aerogravity Assist Performance Assessment	Urbana, IL 08/22 - 01/23
	<ul style="list-style-type: none"> • 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	<p>Programming Languages: Fortran, Python, C/C++, MATLAB, Perl, SQL, R</p> <p>Software Tools: L^AT_EX, Git</p> <p>Prepackaged Tools: SPICE, Monte, FreeFlyer, GMAT</p> <p>Operating Systems: MacOS, Linux, Windows</p> <p>Languages: English, Gujarati, Hindi, French</p>	
HONORS AND AWARDS	<p>NASA Space Technology Graduate Research Fellow 08/22 - 12/25 NSTGRO fellowship from NASA Space Technology Mission Directorate</p> <p>ARCS Foundation Scholar Award 08/23 - 12/25 Achievement Rewards for College Scientists (ARCS) Illinois Chapter</p> <p>1st Place – Student Research Competition 05/25 9th IAA Planetary Defense Conference</p> <p>Alumni Advisory Board Fellowship 04/25 UIUC Aerospace Engineering Department</p> <p>Conference Presentation Award 04/25 UIUC Graduate College</p> <p>Best Visual Poster Award 02/24 UIUC Aerospace Engineering Department</p> <p>John C. Mather Nobel Scholar 07/22 - 06/23 National Space Grant Foundation</p> <p>Aerospace Excellence Award to DART Investigation Team 05/23 American Institute of Aeronautics and Astronautics (AIAA)</p> <p>Outstanding Academic and Research Achievement Fellowship 04/23 UIUC Aerospace Engineering Department</p> <p>President's Award 08/17 - 12/20 University of Illinois at Urbana-Champaign</p> <p>Dean's List 05/19, 05/20 University of Illinois at Urbana-Champaign</p>	
PUBLICATIONS	14 Journal Articles 28 Conference and Meeting Proceedings 5 Invited Seminars and Talks	

RESEARCH GRANTS	NASA Space Technology Graduate Research Fellowship	
	<ul style="list-style-type: none"> • 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 Eggel) • Period of Performance: 08/22 - 12/25 	
	LSST LINCC Frameworks Incubator	
	<ul style="list-style-type: none"> • 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 Eggel	08/21 - 12/21
	Teaching Assistant for AE 352: Aerospace Dynamical Systems	
	<ul style="list-style-type: none"> • 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. 	
PROFESSIONAL ACTIVITIES AND AFFILIATIONS	University of Illinois at Urbana-Champaign	Urbana, IL
	Instructor: Huy Tran	01/20 - 05/20
	Undergraduate Course Assistant for AE 199: Aerospace Computing	
	<ul style="list-style-type: none"> • 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. 	
Mission Participation		
ACTIVITIES AND AFFILIATIONS	<ul style="list-style-type: none"> • NASA Double Asteroid Redirection Test (DART) Mission Science Investigation Team Member • ESA Hera Mission Science Investigation Team Extended Member 	
Review Panel Activities		
	<ul style="list-style-type: none"> • NASA Yearly Opportunities for Research in Planetary Defense (YORPD) 	
Memberships (Current and Past)		
	<ul style="list-style-type: none"> • American Astronomical Society (AAS) 	

JOURNAL
ARTICLES

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

- 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).
- ¹³C. 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).
- ⁸M. Hirabayashi et al., “Elliptical ejecta of asteroid Dimorphos is due to its surface curvature”, *Nature Communications* **16**, 1602 (2025).
- ⁷D. C. Richardson et al., “The Dynamical State of the Didymos System before and after the DART Impact”, *The Planetary Science Journal* **5**, 182 (2024).
- ⁶N. 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).
- ⁴J.-Y. Li et al., “Ejecta from the DART-produced active asteroid Dimorphos”, *Nature* **616**, 452–456 (2023).
- ³T. 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).
- ¹D. 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).
- ²⁷C. 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. Egg, "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).
- ²⁴S. 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).
- ²³P. 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).
- ²²P. 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).
- ²⁰S. 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. Egg, "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).
- ¹³D. 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).

- ¹²R. 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. Eggel, "Heliocentric beta (β_{\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).
- ⁹D. 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).
- ⁷D. 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. Eggel, "Heliocentric beta (β_{\odot}) estimation", in November 2022 DART Investigation Team Meeting (Nov. 2022).
- ⁵**R. Makadia**, S. Eggel, and E. Farnestock, "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. Eggel, and E. Farnestock, "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. Eggel, and E. Farnestock, "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).