

# Rahil Makadia

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CONTACT INFORMATION	104 S Wright St., 307 Talbot Lab Urbana, IL 61801	<a href="mailto:makadia2@illinois.edu">makadia2@illinois.edu</a> <a href="https://rahil-makadia.github.io">https://rahil-makadia.github.io</a>
OBJECTIVE STATEMENT	Imminent Ph.D. graduate in Aerospace Engineering from UIUC with a focus on solar system dynamics and planetary defense. Seeking the next professional chapter to leverage my skills in orbit determination and trajectory analysis.	
EDUCATION	<b>University of Illinois at Urbana-Champaign (UIUC)</b> Ph.D. in Aerospace Engineering Advisor: Siegfried Eggel Committee: Steven Chesley, Davide Farnocchia, Bruce Conway, Raluca Ilie Dissertation: Improvements to the Design and Modeling of Kinetic Impact Missions for Deflecting Near-Earth Asteroids	Urbana, IL 01/21 - 12/25
	<b>University of Illinois at Urbana-Champaign</b> B.S. in Aerospace Engineering with Honors	Urbana, IL 08/17 - 12/20
WORK EXPERIENCE	<b>NASA Goddard Space Flight Center</b> Visiting Technologist Advisors: Brent Barbee, Kenneth Getzandanner <ul style="list-style-type: none"><li>• Leveraged proven mission analysis tools to design kinetic impact missions.</li><li>• Validated kinetic impact mission trajectories for mapping gravitational keyholes on the surface of (101955) Benu.</li></ul>	Greenbelt, MD 05/25 - 07/25
	<b>NASA Jet Propulsion Laboratory (JPL)</b> Visiting Technologist Advisors: Steven Chesley, Davide Farnocchia <ul style="list-style-type: none"><li>• Validated an efficient orbit propagator with sub -1 km position accuracy over 250 years compared to JPL's internal software.</li><li>• Developed an orbit determination submodule around the propagator with sub - <math>1\sigma</math> agreement with JPL orbit solutions.</li><li>• 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.</li><li>• Implemented ability to compute locations of gravitational keyholes, which are predictors of future asteroid impacts with Earth.</li></ul>	Pasadena, CA 05/23 - 08/23, 03/24 - 06/24
	<b>NASA Goddard Space Flight Center</b> OSIRIS-REx/OSIRIS-APEX CelNav Intern Advisors: Kenneth Getzandanner, Andrew Liounis <ul style="list-style-type: none"><li>• Developed simulations to assess performance of onboard Celestial Navigation (CelNav) during the cruise phase of NASA's OSIRIS-APEX mission.</li></ul>	Greenbelt, MD 06/22 - 08/22

- 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 Eggel

01/21 - 12/25

**NASA's Double Asteroid Redirection Test (DART) Mission**

- Analyzed high-fidelity kinetic 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 high-precision stellar occultation measurements in 2024 and 2025 to measure the 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.

**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:** Python, C/C++, Fortran, MATLAB, R/RStudio, Perl

**Software Tools:** L<sup>A</sup>T<sub>E</sub>X, 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

**1<sup>st</sup> Place – Student Research Competition**

05/25

9<sup>th</sup> 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**

01/19 - 05/19, 01/20 - 05/20

University of Illinois at Urbana-Champaign

**Hans von Muldau Team Award for Best Project**

10/19

70<sup>th</sup> International Astronautical Congress

PUBLICATIONS	13 Journal Articles 26 Conference and Meeting Proceedings 4 Invited Seminars and/or Public Talks	
RESEARCH GRANTS	<b>NASA Space Technology Graduate Research Fellowship</b> <ul style="list-style-type: none"> <li>Title: <a href="#">Keyhole-Based Impact Site Selection and Post-Deflection Impact Risk Assessment for Near-Earth Objects</a></li> <li>Funding Institution: NASA Space Technology Mission Directorate</li> <li>Amount: \$332,000</li> <li>Role: Co-Investigator (PI: Siegfried Eggel)</li> <li>Period of Performance: 08/22 - 12/25</li> </ul> <b>LSST LINCC Frameworks Incubator</b> <ul style="list-style-type: none"> <li>Title: <a href="#">Orbit Fitting at LSST Scale</a></li> <li>Funding Institution: Vera C. Rubin Observatory</li> <li>Amount: \$20,000</li> <li>Role: Co-Investigator (PI: Matthew Holman)</li> <li>Period of Performance: 02/25 - 05/25</li> </ul>	
TEACHING EXPERIENCE	<b>University of Illinois at Urbana-Champaign</b> Instructor: Siegfried Eggel Teaching Assistant for AE 352: Aerospace Dynamical Systems	Urbana, IL 08/21 - 12/21
	<ul style="list-style-type: none"> <li>Assisted in developing and teaching the curriculum's core dynamics course with aerospace applications.</li> <li>Covered Newtonian, Lagrangian, and Hamiltonian mechanics for rigid body motion.</li> <li>Advised 16 student teams with Project Clear Constellation, focusing on new methods to remove orbital debris.</li> </ul>	
	<b>University of Illinois at Urbana-Champaign</b> Instructor: Huy Tran Undergraduate Course Assistant for AE 199: Aerospace Computing	Urbana, IL 01/20 - 05/20
	<ul style="list-style-type: none"> <li>Assisted with grading for a new course focused on using Python to solve problems such as analyzing air traffic data and designing Martian landers.</li> <li>Worked with instructor to augment course for a fully online learning environment without affecting students due to the COVID-19 pandemic.</li> </ul>	
PROFESSIONAL ACTIVITIES AND AFFILIATIONS	<b>Mission Participation</b> <ul style="list-style-type: none"> <li>NASA Double Asteroid Redirection Test (DART) Mission Science Investigation Team Member</li> <li>ESA Hera Mission Science Investigation Team Extended Member</li> </ul>	

#### 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)

#### JOURNAL ARTICLES

- <sup>13</sup>**R. Makadia** et al., “Keyhole-Aware Deflection Site Selection for Kinetic Impact Missions at Near-Earth Asteroids”, *Icarus* **Submitted** (2025).
- <sup>12</sup>**R. Makadia**, S. R. Chesley, et al., “First detection of an asteroid’s heliocentric deflection: The Didymos system after DART”, **Submitted** (2025).
- <sup>11</sup>**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).
- <sup>10</sup>**R. Makadia** et al., “Gauss-Radau Small-body Simulator (GRSS): An Open-source Library for Planetary Defense”, *The Planetary Science Journal* **6**, 85 (2025).
- <sup>9</sup>**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).
- <sup>8</sup>M. Hirabayashi et al., “Elliptical ejecta of asteroid Dimorphos is due to its surface curvature”, *Nature Communications* **16**, 1602 (2025).
- <sup>7</sup>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).
- <sup>6</sup>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).
- <sup>5</sup>**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).
- <sup>4</sup>J.-Y. Li et al., “Ejecta from the DART-produced active asteroid Dimorphos”, *Nature* **616**, 452–456 (2023).
- <sup>3</sup>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).
- <sup>2</sup>**R. Makadia** et al., “Heliocentric Effects of the DART Mission on the (65803) Didymos Binary Asteroid System”, *The Planetary Science Journal* **3**, 184 (2022).
- <sup>1</sup>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).

- <sup>26</sup>**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).
- <sup>25</sup>**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).
- <sup>24</sup>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).
- <sup>23</sup>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).
- <sup>22</sup>P. H. Bernardinelli et al., “Layup: Orbit fitting at LSST Scale”, in *Europlanet Science Congress - Division of Planetary Sciences Joint Meeting 2025* (Sept. 2025).
- <sup>21</sup>**R. Makadia** et al., “Design constraints for asteroid deflection campaigns based on  $\Delta V$  estimation timelines”, in [9th IAA Planetary Defense Conference](#) (May 2025).
- <sup>20</sup>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).
- <sup>19</sup>**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).
- <sup>18</sup>**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).
- <sup>17</sup>**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).
- <sup>16</sup>**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).
- <sup>15</sup>**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).
- <sup>14</sup>**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).
- <sup>13</sup>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).
- <sup>12</sup>R. Nakano et al., “Mutual orbit perturbations due to Dimorphos’s deformation after the DART impact”, in [14th Asteroids, Comets, Meteors Conference](#) (June 2023).

- <sup>11</sup>**R. Makadia** and S. Eggl, “Heliocentric beta ( $\beta_{\odot}$ ) measurability”, in May 2023 DART Investigation Team Meeting (May 2023).
- <sup>10</sup>**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).
- <sup>9</sup>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).
- <sup>8</sup>**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).
- <sup>7</sup>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).
- <sup>6</sup>**R. Makadia** and S. Eggl, “Heliocentric beta ( $\beta_{\odot}$ ) estimation”, in November 2022 DART Investigation Team Meeting (Nov. 2022).
- <sup>5</sup>**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).
- <sup>4</sup>**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).
- <sup>3</sup>**R. Makadia**, S. Eggl, and E. Fahnestock, “Changing the heliocentric orbit of the Didymos system with DART: Implications for  $\beta$  determination”, in June 2021 DART Investigation Team Meeting (June 2021).
- <sup>2</sup>**R. Makadia** et al., “Estimating  $\beta$  via the heliocentric orbit of Didymos”, in June 2021 DART Investigation Team Meeting (June 2021).
- <sup>1</sup>**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  
PUBLIC TALKS

- <sup>4</sup>**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).
- <sup>3</sup>**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).
- <sup>2</sup>**R. Makadia**, “Planetary Defense: A brief overview of the field and my research”, in 1st Annual Illinois Space Society Day (Apr. 2025).
- <sup>1</sup>**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).