SHANNON MACKENZIE

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Dr. MacKenzie is a planetary scientist interested in processes that create and rework the surfaces of icy satellites. She has investigated sediments on Titan since 2012—working with data from Cassini's Visual and Infrared Mapping Spectrometer, RADAR, and Imaging Science Subsystem—with the aim of understanding how these sediments play a role in habitability and prebiotic chemistry. She also co-authored a spherical radiative transfer model and uses it to investigate how scattering in the atmosphere affects measurements of Titan's surface. As the Dragonfly Deputy Project Scientist, she assists in the definition and implementation of the science goals and objectives as a science theme lead. She recently served as Principal Investigator of a mission concept study of large-class missions to Saturn's moon Enceladus specifically to search for signs of life, the Enceladus Orbilander. The results of this study were delivered to the 2023-2032 Planetary Science and Astrobiology Decadal Survey and ranked as the second highest priority flagship for NASA to pursue in the coming decade. She joined the NOW Steering Committee as a Co-Lead in 2024 and served as a lead of the Life Detection module for the NOW 2023 Workshop.

EDUCATION

Ph.D. Physics University of Idaho	December 2017
M.Sc. Physics University of Idaho	August 2015
B.S. Physics University of Louisville	May 2012

PROFESSIONAL & MISSION EXPERIENCE

Network for Ocean Worlds Research Coordination Network Co-Lead	2024-present
Deputy Project Scientist, Dragonfly Mission Concept	2022-present
Senior Professional Staff II, Johns Hopkins University Applied Physics Lab (JHU APL)	1/2022-present
Senior Professional Staff I, JHU APL	1/2020-12/2021
Deputy Project Scientist, Dragonfly NF4 Mission	02/2022-present
Co-I, Dragonfly NF4 Mission	3/2016-present
Principal Investigator, Enceladus PMCS	10/2019-07/2020
Post-doctoral Fellow, JHU APL	1/2018-12/2019
Principal Investigator, JPL Planetary Science Summer School	5/2015- 8/2015

PUBLICATIONS

MacKenzie, S. M., Pontefract, A., Daly, R. T., Buffo, J. J., Osinski, G. R., Cline, C. J., ... & Vance, S. D. (2024). Impacts on Ocean Worlds Are Sufficiently Frequent and Energetic to Be of Astrobiological Importance. *The Planetary Science Journal*, 5(8), 176.

Pearce, B. K., Hörst, S. M., Cline, C. J., Cintala, M. J., He, C., Sebree, J. A., **MacKenzie, S.M.**, Daly, R.T., Pontefract, A.J., & Pesciotta, C. (2024). Toward Prebiotic Chemistry on Titan: Impact Experiments on Organic Haze Particles. *The Planetary Science Journal*, *5*(3), 68.

MacKenzie, S. M., Runyon, K. D., Yu, X., Kok, J. F., Newman, C., Lorenz, R. D., Comola, F. (2023). "Sediment-moving winds and abrasion on Titan: Implications for yardangs" *Icarus*, 394, (2023) 115433.

Es-sayeh, M., Rodriguez, S., Coutelier, M., Rannou, P., Bézard, B., Maltagliati, L., Cornet, T., Grieger, B., Karkoschka, E., Le Mouélic, S., Le Gall, A., Neish, C., **MacKenzie, S.**, Solomonidou, A., Sotin, C., Coustenis, A. (2023). "Updated Radiative Transfer Model for Titan in the Near-infrared Wavelength Range: Validation against Huygens Atmospheric and Surface Measurements and Application to the Cassini/VIMS Observations of the Dragonfly Landing Area" *The Planetary Science Journal*, 4, (2023) 44.

Choblet, G., Tobie, G., Buch, A., Čadek, O., Barge, L. M., BÄ`hounková, M., Camprubi, E., Freissinet, C., Hedman, M., Jones, G., Lainey, V., Le Gall, A., Lucchetti, A., **MacKenzie, S.**, Mitri, G., Neveu, M., Nimmo, F., Olsson-Francis, K., Panning, M., Postberg, F., Saur, J., Schmidt, J., Sekine, Y., Shibuya, T., Sotin, C., Soucek, O., Szopa, C., Usui, T., Vance, S., Van Hoolst, T. (2022). "Enceladus as a potential oasis for life: Science goals and investigations for future explorations" *Experimental Astronomy*, 54, (2022) 809.

Neveu, M., Coker, R. F., Lorenz, R. D., **MacKenzie, S. M.**, Lunine, J. I., Davila, A. F., Enceladus Orbilander Study Team (2022). "Planetary Protection Assessment of Radioisotope Thermoelectric Generator (RTG)–Powered Landed Missions to Ocean Worlds: Application to Enceladus" *Astrobiology*, 22, 1047.

Cohen, I. J., Beddingfield, C., Chancia, R., DiBraccio, G., Hedman, M., **MacKenzie, S. M.** et al. (2022). "The Case for a New Frontiers-Class Uranus Orbiter: System Science at an Underexplored and Unique World with a Mid-scale Mission" *The Planetary Science Journal*, 3, 58.

Rodriguez, S., Vinatier, S., Cordier, D., Tobie, G., Achterberg, R. K. et al. including **MacKenzie, S. M**. (2022). "Science goals and new mission concepts for future exploration of Titan's atmosphere, geology and habitability: titan POlar scout/orbitEr and in situ lake lander and DrONe explorer (POSEIDON)" *Experimental Astronomy*

MacKenzie, S. M., M. Neveu, A. F. Davila, J. I. Lunine, M. L. Cable, C. M. Phillips-Lander, J. L. Eigenbrode et al. (2022). "Science Objectives for Flagship-Class Mission Concepts for the Search for Evidence of Life at Enceladus." *Astrobiology*

MacKenzie, S. M., S. P. D. Birch, S. Hörst, C. Sotin, E. Barth, J. M. Lora, M. G. Trainer, P. Corlies, M. J. Malaska, E. Sciamma-O'Brien, et al. (2021). "Titan: Earth-like on the Outside, Ocean World on the Inside", *The Planetary Science Journal*, 2, 112.

MacKenzie, S. M., M. Neveu, A. F. Davila, J. I. Lunine, K. L. Craft, M. L. Cable, C. M. Phillips-Lander, J. D. Hofgartner, J. L. Eigenbrode, J. H. Waite, et al. (2021). "The Enceladus Orbilander Mission Concept: Balancing Return and Resources in the Search for Life", *The Planetary Science Journal*, 2, 77.

Perera, V., C. Mead, K. J. van der Hoeven Kraft, S. Stanley, R. Angappan, **S. M. MacKenzie**, A. Barik & S. Buxner (2021) Considering intergroup emotions to improve diversity and inclusion in the geosciences, *Journal of Geoscience Education*, doi: 10.1080/10899995.2021.1881863

Lorenz, R. D., **S. M. MacKenzie**, C. D. Neish, A. Le Gall, E. P. Turtle, J. W. Barnes, M. G. Trainer, A. Werynski, J. Hedgepeth, and E. Karkoschka (2021). "Selection and Characteristics of the Dragonfly Landing Site near Selk Crater, Titan", *The Planetary Science Journal* 2, 24, doi: 10.3847/PSJ/abd08f

Neveu, M., A. D. Anbar, A. F. Davila, D. P. Glavin, **S. M. MacKenzie**, C. M. Phillips-Lander, B. Sherwood, Y. Takano, P. Williams, and H. Yano (2020). "Returning Samples from Enceladus for Life Detection*", Frontiers in Astronomy and Space Sciences* 7, 26, doi: 10.3389/fspas.2020.00026

Barnes, J. W., **S. M. MacKenzie,** E. F. Young, J. M. Soderblom, A. G. Hayes, C. Sotin, R. H. Brown, and L. A. Soderblom (2020). "Diffraction-limited Titan Surface Imaging from Orbit Using Near-infrared Atmospheric Windows", *The Planetary Science Journal* 1, 24, doi: 10.3847/PSJ/ab91b6

Hofgartner, J. D., A. G. Hayes, D. B. Campbell, J. I. Lunine, G. J. Black, **S. M. MacKenzie**, S. P. D. Birch, C. Elachi, R. D. Kirk, A. Le Gall, R. D. Lorenz, and S. D. Wall (2020). "The root of anomalously specular reflections from solid surfaces on Saturn's moon Titan", *Nature Communications* 11, 2829, doi: 10.1038/s41467-020-16663-1

Martin, K. P., **S. M. MacKenzie**, J. W. Barnes, and F. M. Ytreberg (2020). "Protein Stability in Titan's Subsurface Water Ocean", *Astrobiology* 20, 190-198, doi: 10.1089/ast.2018.1972

Lucas, A., S. Rodriguez, F. Lemonnier, A. Le Gall, **S. MacKenzie**, C. Ferrari, P. Paillou, and C. Narteau (2019). "Texture and Composition of Titan's Equatorial Sand Seas Inferred From Cassini SAR Data: Implications for Aeolian Transport and Dune Morphodynamics", *Journal of Geophysical Research (Planets)* 124, 3140-3163, doi: 10.1029/2019JE005965

MacKenzie, S. M., J. M. Lora, and R. D. Lorenz (2019). "A Thermal Inertia Map of Titan", *Journal of Geophysical Research (Planets)* 124, 1728-1742, doi: 10.1029/2019JE005930

MacKenzie, S. M., J. W. Barnes, J. D. Hofgartner, S. P. D. Birch, M. M. Hedman, A. Lucas, S. Rodriguez, E. P. Turtle, and C. Sotin (2019). "The case for seasonal surface changes at Titan's lake district", *Nature Astronomy* 3, 506-510, doi: 10.1038/s41550-018-0687-6

Barnes, J. W., **S. M. MacKenzie**, R. D. Lorenz, and E. P. Turtle (2018). "Titan's Twilight and Sunset Solar Illumination", *The Astronomical Journal* 156, 247, doi: 10.3847/1538-3881/aae519

Birch, S. P. D., A. G. Hayes, P. Corlies, E. R. Stofan, J. D. Hofgartner, R. M. C. Lopes, R. D. Lorenz, J. I. Lunine, **S. M. MacKenzie**, M. J. Malaska, C. A. Wood, and Cassini Radar Team (2018). "Morphological evidence that Titan's southern hemisphere basins are paleoseas", *Icarus* 310, 140-148, doi: 10.1016/j.icarus.2017.12.016

Turtle, E. P., J. E. Perry, J. M. Barbara, A. D. Del Genio, S. Rodriguez, S. Le Mouélic, C. Sotin, J. M. Lora, S. Faulk, P. Corlies, J. Kelland, **S. M. MacKenzie**, R. A. West, A. S. McEwen, J. I. Lunine, J. Pitesky, T. L. Ray, and M. Roy (2018). "Titan's Meteorology Over the Cassini Mission: Evidence for Extensive Subsurface Methane Reservoirs", *Geophysical Research Letters* 45, 5320-5328, doi: 10.1029/2018GL078170

Barnes, J. W., **S. M. MacKenzie**, E. F. Young, L. E. Trouille, S. Rodriguez, T. Cornet, B. K. Jackson, M. Ádámkovics, C. Sotin, and J. M. Soderblom (2018). "Spherical Radiative Transfer in C++ (SRTC++): A Parallel Monte Carlo Radiative Transfer Model for Titan", *The Astronomical Journal* 155, 264, doi: 10.3847/1538-3881/aac2db

MacKenzie, S. M., T. E. Caswell, C. M. Phillips-Lander, E. N. Stavros, J. D. Hofgartner, V. Z. Sun, K. E. Powell, C. J. Steuer, J. G. O'Rourke, J. K. Dhaliwal, C. W. S. Leung, E. M. Petro, J. J. Wynne, S. Phan, M. Crismani, A. Krishnamurthy, K. K. John, K. DeBruin, C. J. Budney,

and K. L. Mitchell (2016). "THEO concept mission: Testing the Habitability of Enceladus's Ocean", *Advances in Space Research* 58, 1117-1137, doi: 10.1016/j.asr.2016.05.037

Cordier, D., T. Cornet, J. W. Barnes, **S. M. MacKenzie**, T. Le Bahers, D. Nna-Mvondo, P. Rannou, and A. G. Ferreira (2016). "Structure of Titan's evaporites", *Icarus* 270, 41-56, doi: 10.1016/j.icarus.2015.12.034

MacKenzie, S. M. and J. W. Barnes (2016). "Compositional Similarities and Distinctions between Titan's Evaporitic Terrains", *The Astrophysical Journal* 821, 17, doi: 10.3847/0004-637X/821/1/17

Vixie, G., J. W. Barnes, B. Jackson, S. Rodriguez, S. Le Mouélic, C. Sotin, **S. MacKenzie**, and P. Wilson (2015). "Possible temperate lakes on Titan", *Icarus* 257, 313-323, doi: 10.1016/j.icarus.2015.05.009

Neish, C. D., J. W. Barnes, C. Sotin, **S. MacKenzie**, J. M. Soderblom, S. Le Mouélic, R. L. Kirk, B. W. Stiles, M. J. Malaska, A. Le Gall, R. H. Brown, K. H. Baines, B. Buratti, R. N. Clark, and P. D. Nicholson (2015). "Spectral properties of Titan's impact craters imply chemical weathering of its surface", *Geophysical Research Letters* 42, 3746-3754, doi: 10.1002/2015GL063824

MacKenzie, S. M., J. W. Barnes, C. Sotin, J. M. Soderblom, S. Le Mouélic, S. Rodriguez, K. H. Baines, B. J. Buratti, R. N. Clark, P. D. Nicholson, and T. B. McCord (2014). "Evidence of Titan's climate history from evaporite distribution", *Icarus* 243, 191-207, doi: 10.1016/j.icarus.2014.08.022

Pipino, A., T. Szabo, E. Pierpaoli, **S. M. MacKenzie**, and F. Dong (2011). "The properties of brightest cluster galaxies in the Sloan Digital Sky Survey Data Release 6 adaptive matched filter cluster catalogue", *Monthly Notices of the Royal Astronomical Society* 417, 2817-2830, doi: 10.1111/j.1365-2966.2011.19444.x

FELLOWSHIPS AND PI'd GRANTS

Habitable Worlds Program	2024-2027
Solar System Workings Program	2024-2027
Scialog Fellow	2020-2023
Predecadal Mission Concept Studies Program	2019-2020
Habitable Worlds Program	2019-2020
Cassini Data Analysis Program	2019-2022
NASA Earth and Space Science Fellowship	2014-2017
Leonard Halland Centennial Scholarship	2015-2016
Glen E. and Jean K. Nielsen Science Scholarship	2014-2015
Idaho Space Grant Consortium Research Fellowship	2013
Barry M. Goldwater Scholarship	2011

FIRST AUTHOR CONFERENCE PRESENTATIONS

*Oral Presentations (*Invited)*

MacKenzie, S., Pontefract, A., Daly, R. T., Buffo, J., Pearce, B. K., Horst, S. M., ... & Hedgepeth, J. (2024). "Impacts on Ocean Worlds are sufficiently frequent and energetic to be of astrobiological importance." Astrobiology Science Conference.

MacKenzie, S.M., Davila, A., & Rodriguez, L. (2023) “Module 3: Life Detection” NOW Retreat

MacKenzie, S.M., Barnes, J., Miller W. (2023) “The Adjacency Effect at Kivu Lacus” Titan Through Time VI

MacKenzie, S., Turtle, E., Barnes, J., Trainer, M., Lorenz, R., Murchie, S., Hibbard, K., Bedini, P., The Dragonfly Team (2022). "Exploring Titan with Dragonfly" AAS/Division for Planetary Sciences Meeting Abstracts, 54,509.01.

MacKenzie, S. M., Runyon, K. D., Kok, J. F., Newman, C. E., Yu, X. (2022). "Simulating Abrasion Under Titan-Relevant Conditions" 53rd Lunar and Planetary Science Conference, 2678, 2085.

MacKenzie, S. M., Lorenz, R. D., Turtle, E. P., Neish, C. D. (2021). "Waqf As Suwaan as a Titan Crater Analog: The Role of Fluvial Erosion" Workshop on Terrestrial Analogs for Planetary Exploration, 2595, 8014.

***MacKenzie, S.,** Neveu, M., Lunine, J. I., Davila, A., Gold, R. E., Craft, K. L., Cable, M. L., Eigenbrode, J. L., Glein, C. R., Hofgartner, J. D., Phillips-Lander, C. M., Waite, J. H., McKay, C., Burton, D. (2020). "Enceladus Orbilander: A Flagship Mission Concept for the Planetary Decadal Survey" AGU Fall Meeting Abstracts, 2020, P001-08.

MacKenzie, S. M., Neveu, M., Davila, A., Craft, K., Lunine, J., Cable, M., Eigenbrode, J., Gold, R., Phillips-Lander, C., Hofgartner, J., Waite, J. H., Glein, C., McKay, C., Orbilander Team (2020). "Enceladus Orbilander" Outer Planets Assessment Group (Fall 2020), 2547, 6034.

MacKenzie, S. M., Lorenz, R. D., Lora, J. M. (2019). "A Thermal Inertia Map of Titan and the Effects on a Dry Climate" 50th Annual Lunar and Planetary Science Conference, 2999.

***MacKenzie, S.**, Turtle, E. P., Karkoschka, E. (2018). "Near-infrared characteristics of Titan's north polar cap" AGU Fall Meeting Abstracts, 2018, P34B-06.

MacKenzie, S., Turtle, E., Karkoschka, E. (2018). "On the nature of Titan's north polar cap" AAS/Division for Planetary Sciences Meeting Abstracts #50, 50, 203.08.

MacKenzie, S. M., Barnes, J. W. (2017). "A New Candidate Sand Source in Titan's Equatorial Region?" Fifth International Planetary Dunes Workshop`, 1961, 3062.

MacKenzie, S., Barnes, J. W., Sotin, C., Soderblom, J. M., Le Mouélic, S., Rodriguez, S., Baines, K., Buratti, B. J., Clark, R. N. (2016). "Compositional mapping of Titan's North Pole with VIMS" AAS/Division for Planetary Sciences Meeting Abstracts #48, 48, 412.04.

MacKenzie, S., Barnes, J. W., Brown, R., Sotin, C., Buratti, B. J., Clark, R., Baines, K. H., Nicholson, P. D., Le Mouelic, S., Rodriguez, S. (2013). "Evidence of Titan's Climate History from Evaporite Distribution" AAS/Division for Planetary Sciences Meeting Abstracts #45, 45, 302.04.

Poster

MacKenzie, S., Neveu, M., Lunine, J. I., Davila, A., Cable, M. L., Craft, K. L., Eigenbrode, J. L., Glein, C. R., Hofgartner, J. D., Phillips-Lander, C. M., Waite, J. H., Burton, D., Gold, R. E., McKay, C. (2023). “Enceladus Orbilander” Enceladus Focus Group Workshop

MacKenzie S. M., Barnes J. W., Miller W. J., Soderblom J. M. “Removing the Adjacency Effect from IR Spectra of Titan Lakes” LPSC 2023 Abstract #1641

MacKenzie, S., Neveu, M., Lunine, J. I., Davila, A., Cable, M. L., Craft, K. L., Eigenbrode, J. L., Glein, C. R., Hofgartner, J. D., Phillips-Lander, C. M., Waite, J. H., Burton, D., Gold, R. E., McKay, C. (2020). "Searching for life at Enceladus with the Orbilander mission concept" AGU Fall Meeting Abstracts, 2020, P077-0006.

MacKenzie, S. M., Nunez, J. I., Turtle, E. P., Lorenz, R. D., Horst, S. M., Le Gall, A., Radebaugh, J., Trainer, M. G., Barnes, J. W., Murchie, S., Dragonfly Team (2019). "Titan's Surface from Dragonfly: Bridging the Gap Between Composition and Environment" 50th Annual Lunar and Planetary Science Conference, 2885.

MacKenzie, S., Barnes, J. W., Rodriguez, S., Cornet, T., Brossier, J., Soderblom, J. M., Le Mouélic, S., Sotin, C., Brown, R. H., Buratti, B. J., Clark, R. N., Nicholson, P. D., Baines, K. (2017). "A bright intra-dune feature on Titan and its implications for sand formation and transport" AAS/Division for Planetary Sciences Meeting Abstracts #49, 49, 213.09.

MacKenzie, S., Caswell, T., Crismani, M., DeBruin, K., Dhaliwal, J., Hofgartner, J., Krishnamurthy, A., John, K., Phillips-Lander, C., Leung, C., O'Rourke, J., Petro, E., Phan, S., Powell, K., Stavros, E. N., Steuer, C., Sun, V., Wynne, J., Budney, C., Mitchell, K. (2015). "THEO: Testing the Habitability of Enceladus's Ocean" AAS/Division for Planetary Sciences Meeting Abstracts #47, 47, 312.24.

MacKenzie, S., Barnes, J. W. (2014). "Characteristics of the 5-μm-bright spectral unit from spectral analysis of Tui Regio" AAS/Division for Planetary Sciences Meeting Abstracts #46, 46, 211.09.

MacKenzie, S., Pipino, A. (2012). "Brightest Cluster Galaxy Formation: Models vs Observations" American Astronomical Society Meeting Abstracts #219, 219, 246.30.

MacKenzie, S., Pipino, A., Rich, R., Martin, C., GALEX Team (2011). "The Hoag's Object, UGC 4599 and NGC 6028: Other Examples of Star Forming Rings" American Astronomical Society Meeting Abstracts #217, 217, 149.09.

HONORS AND AWARDS

JHU APL Oscar Peer Recognition Award	September 2019
Walter G. Berl Award for Outstanding Paper in JHU APL Technical Digest	April 2018
JHU APL Bumblebee Award for Championing Revolutionary Capabilities	April 2018
University of Idaho Dean's Graduate	May 2017
Division for Planetary Sciences Hartmann Student Travel Award	October 2017
University of Idaho 3 Minute Thesis Competition 1st Place	April 2016
University of Idaho College of Science Innovation Showcase 3rd Place	April 2016
University of Idaho College of Science Video Competition 1st Place	April 2016
NSF Graduate Research Fellowship Program Honorable Mention	2012
University of Louisville College of Arts and Sciences Woodcock Medalist	2012
University of Louisville Honors Scholar Suma Cum Laude	2012
University of Louisville Dept. Physics and Astronomy Graduating Senior	2012
William Marshal Bullitt Award in Astronomy	2012
Barry M. Goldwater Scholarship	2011

COMMUNITY EXPERIENCE

Josep Comas i Solà International Astrobiology Summer School Lecturer July 2023
Member of Network for Life Detection Steering Committee 2021-present
Guest Editor of Ocean Worlds Focus Issue, *PSJ* 2020-present
Member of Network for Ocean Worlds Steering Committee 2019-present
Conference organizer
IPPW SOC 2023
Titan Through Time SOC 2020
DPS SOC 2018, 2020
Titan Surface Working Group Meeting 2015
Member of Roadmap to Ocean Worlds Committee 2016
Reviewer for *Icarus, JGRP, PSJ* 2017-present
Reviewer/Executive Secretary/ External Reviewer for NASA mission and grant proposals as 2015-present

MISSION & MISSION DEVELOPMENT EXPERIENCE

Enceladus Orbilander Predecadal Mission Concept Study May 2019-August 2020
Principal Investigator

Dragonfly New Frontiers 4 Proposal since March 2016
Co-Investigator: co-wrote the science section of the proposal, created maps for landing site selection, geomorphology science working group lead
Assistant Project Scientist (since 2021)

Oceanus New Frontiers 4 Proposal May - April 2016
Student collaborator: assisted in the design and writing of evaporite investigation, science section of the proposal, and STM development

Jet Propulsion Laboratory Planetary Science Summer School May - August 2015
Principal Investigator: led the design, planning, and execution of a mock mission; presented poster at several conferences; wrote manuscript

FIELD EXPERIENCE

Salton Sand Sea, California USA Sept 2021
Led expedition to collect sand for biological, chemical, and physical analyses; GPR, EC, and temperatures measurements taken
Veevers Crater, Western Australia July 2016
Assisted in OSL and photographic data collection
United Arab Emirates April 2014
Assisted in OSL, GPR, and photographic data collection

SHORT COURSES

Sensors & Software GPR short course at GSA November 2018
NASA Astrobiology Institute Astrobiology Summer School June 2018
JPL Planetary Science Summer School June – August 2015

TEACHING/MENTORING EXPERIENCE

NASA Here 2 Observe Dragonfly Liaison	May 2021-Jan 2023
Dragonfly Student & Early Career Investigator Program Mentor	May 2020 - present
Graduate Teaching Assistant	August - December 2015
University of Idaho Department of Physics	
Undergraduate Teaching Assistant	August - December 2011
University of Louisville Department of Physics and Astronomy	