# Joe Hughes, PhD

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## Objective

Combine science and engineering to continue the exploration and utilization of space.

## Education

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|---|---|
| December 2018 | Ph.D., "Dynamics of Complex Spacecraft Subject to Forced and Environmental Charging," Aerospace Engineering, University of Colorado, Boulder (Advisor Dr. Hanspeter Schaub) |
| June 2014 | B.S in Physics, Walla Walla University |
| June 2014 | B.S. in Mechanical Engineering, Walla Walla University |

## Work Experience

4/2025 – Current
**Northwest Research Associates** , Boulder, Colorado
*Senior Research Scientist*

Leading projects to better understand the dynamics of earth's ionosphere and its interaction with radio frequencies.

7/2023 – 2/2025
**Orion Space Solutions**, Louisville, Colorado
*Senior Scientist*

Lead multiple projects as Primary Investigator (PI). Teams were typically between 3 and 8 scientists, engineers, and software developers. Directly managed 2-3 scientists. Regularly communicated results to external customers. Brought new work into my division through forming, shaping, and proposal writing.

2/2019 – 7/2023
**Orion Space Solutions**, Louisville, Colorado
*Research Scientist*

Grew from being a team member mostly communicating results internally to leading a large project as deputy PI and communicating results to external customers. Teams typically between 2 and 5 people. Beginning to write proposals as PI

6/2015 – 8/2015
**Air Force Research Laboratory**, Spacecraft Charging and Instrument Calibration Lab, Albuquerque, New Mexico
*Summer Scholar*

Designed and ran an experiment to investigate the causes of satellite solar panel arcing, a dangerous phenomenon which can cause mission-ending damage to satellites. This internship furthered my experimental aptitude with vacuum systems, detectors, experiment design, and data analysis.

6/2013 – 8/2013
**NASA Wallops Flight Facility**, GNC Division, Wallops Island, Virginia
*Intern*

Design of a passive stabilization system for a 6U CubeSat deployer using aerodynamic fins, gravity gradients, and hysteresis rods as dampers. This necessitated writing computational geometry algorithms to get aerodynamic characteristics of the satellite as well as integrating nonlinear ODE models of hysteresis behavior in a Matlab simulation.

## PROJECTS AND GRANTS

6/2023 – Current

*Title*: Space object IdeNtification and TRAcking (SINTRA)
*Prime Contractor*: Advanced Space, *Customer*: IARPA
*Role*: PI
*Description*: The SINTRA program will push the state of the art for detecting and tracking small space debris. I am leading the OSS effort to develop novel detection techniques based on debris interactions with their space environment.

6/2023 – Current

*Title*: Ouija
*Prime Contractor*: Science Technology Research, *Customer*: DARPA
*Role*: PI
*Description*: The Ouija program consists of a hardware and software component. I am leading the OSS piece of the software component. This piece will deliver a very accurate electron density 'nowcast' suitable for High Frequency (HF) propagation analysis. This is done by creating a novel dual-stage assimilator and using novel provisionally patented techniques for HF signals of opportunity data inversion.

9/2024 – Current

*Title*: CSDA New Vendor Onramp Evaluation (CNVOE)
*Prime Contractor*: Orion Space Solutions *Customer*: NASA
*Role*: PI
*Description*: NASA's Commercial Smallsat Data Acquisition (CSDA) program supplements existing NASA data with commercial providers. This evaluation assesses the quality, accuracy, and impact of the commercial data. We are evaluating the ionospheric scintillation data from the Radio Occultation (RO) provider PlanetiQ.

2/2023 – Current

*Title*: NSF GEM GIC
*Prime Contractor*: Catholic University of America *Customer*: NSF
*Role*: PI
*Description*: Geomagnetically Induced Currents (GICs) are harmful surges in amperage that can harm the power network among other things. Our role in this program is to investigate the connections between small-scale structures in field aligned currents (FACs) measured near $\sim$1,000 km in altitude to electric fields on the ground.

3/2022 – 3/2024

*Title*: Mars Data Analysis Program (MDAP)
*Prime Contractor*: Orion Space Solutions *Customer*: NASA
*Role*: Co-I
*Description*: We have analyzed data from the MAVEN mission to investigate non-linear coupling between global-scale waves in the martian thermosphere. We investigated the role of solar irradiance in thermospheric densities revealed by the NGIMS instrument, as well as coupling between kelvin waves and tides. This work resulted in three accepted journal articles, one of which I was first author on.

1/2023 – 1/2024

*Title*: CSDA New Vendor Onramp Evaluation (CNVOE)
*Prime Contractor*: Orion Space Solutions *Customer*: NASA
*Role*: PI
*Description*: NASA's Commercial Smallsat Data Acquisition (CSDA) program supplements existing NASA data with commercial providers. This evaluation assesses the quality, accuracy, and impact of the commercial data. We are evaluating the ionospheric total electron content (TEC) data from the Radio Occultation (RO) provider GeoOptics.

8/2023 – 12/2023

*Title*: Radio Occulation Sporadic E Studies (ROSES)
*Prime Contractor*: Orion Space Solutions *Customer*: Air Force Institute of Technology (AFIT)
*Role*: PI
*Description*: We are currently supporting AFIT in their investigations of mappings between radio occultation measurements and ionosonde-derived measurements of an ionospheric phenomena known as 'Sporadic E'. Sporadic E can dramatically impact HF propagation with impacts to HF communications and over the horizon surveillance. Our work used a machine learning model to predict what Sporadic E characteristics an ionosonde would measure.

8/2022 – 3/2024

*Title*: Polar Holes
*Prime Contractor*: Orion Space Solutions *Customer*: NSF
*Role*: Co-I
*Description*: Polar Holes are continental-scale depletions in plasma density. Despite their dramatic impact on HF and RF systems, little is known about their creation and evolution. My role in this project is to investigate whether we see backscatter from SuperDARN radars indicative of deca-meter scale structures on the leading edges of polar holes due to the gradient drift instability.

8/2023 – 2/2024

*Title*: ReflecTEC
*Prime Contractor*: Orion Space Solutions *Customer*: NASA
*Role*: PI
*Description*: This NASA SBIR developed a provisionally patented concept that I invented called 'ReflecTEC' where a LEO satellite broadcasts three VHF signals which reflect off the ocean and are collected with differential delays. These differential delays are used to calculate the total electron content of the ionosphere.

8/2023 – 2/2024

*Title*: Low Latitude Scintillation (LoLAS)
*Prime Contractor*: Orion Space Solutions *Customer*: NASA
*Role*: Co-I
*Description*: This NASA SBIR developed a machine learning method to predict ground-to-space scintillation using Radio Occultation (RO) measurements from the COSMIC-2 constellation. Results were compared to the climatological model WBMOD.

10/2022 – 6/2023

*Title*: Impacts of Ionospheric Irregularities (I3)
*Prime Contractor*: Orion Space Solutions *Customer*: AFRL
*Role*: PI
*Description*: This NRO-sponsored effort by AFRL analyzed the impact of ionospheric irregularities. Our work was to further validate the noisy truth model using oblique measurements, and to begin on any fixes or upgrades necessary. We found that the previous accounted for between 60 to 80% of the variability not captured in smooth truth models. This work also resulted in an extension of the Lomb-Scargle Periodogram into N dimensions, which in turn resulted in a journal manuscript.

9/2022– 9/2023

*Title*: LWS Ionospheric Electrodynamics
*Prime Contractor*: Orion Space Solutions *Customer*: NSF
*Role*: Co-I
*Description*: This project sought to improve models of high-latitude electrodynamics during solar storms by coupling the assimilation and physics-based models of IDA4D, AMIE, TIE-GCM, and CIMI. Results show improvement in electron density by using coupled models instead of stand alone models.

9/2022–
7/2023

*Title*: Ionospheric Scintillation Impact Prediction (ISIP)
*Prime Contractor*: Orion Space Solutions *Customer*: NASA
*Role*: Co-I
*Description*: This Research-to-Operations (R2O) project used physics-based modeling to predict ionospheric scintillation. This was done by coupling global runs of TIE-GCM with local high-fidelity runs of SAMI3 in sectors where equatorial plasma bubbles (EPBs) are likely to form. Rate of TEC Index (ROTI) was computed with the SAMI output and used to estimate $S_4$. Results were compared to the climatological model WBMOD.

11/2019 –
11/2022

*Title*: Commercial Weather Data Pilot (CWDP)
*Prime Contractor*: Orion Space Solutions *Customer*: USAF
*Role*: Deputy PI
*Description*: This project built on the success of the CSD project and expanded to evaluate commercial radio occultation from PlanetiQ. We assessed the accuracy and impact on operational systems in the 557$^{th}$ Weather Wing. This was done for both the ionosphere and troposphere. Northrup Grumman and STC assisted with the tropospheric work as subcontractors. The ionospheric data was assessed using both real data and simulation studies.

7/2020 –
1/2022

*Title*: Military Applications of the Space Environment (MASE)
*Prime Contractor*: Booz Allen Hamilton *Customer*: USAF
*Role*: Co-I
*Description*: My role in this project was to assess the impact of ingesting ionospheric data in different configurations to meet an operational outcome. To do this, I developed a novel truth model or nature run and performed multiple Observation System Simulation Experiments (OSSEs). This work resulted in one first-author journal publication.

4/2020 –
6/2021

*Title*: CHESS
*Prime Contractor*: Orion Space Solutions *Customer*: NSF
*Role*: Co-I
*Description*: This project sought to find connections between public magnetometer data and geomagnetically induced currents (GICs). We used Network Analysis among other tools to find connections across various scale sizes in the magnetometer data. This work resulted in multiple publications, and i am the first author on one of them.

5/2020 –
12/2020

*Title*: AOOS
*Prime Contractor*: Orion Space Solutions *Customer*: AOOS
*Role*: Co-I
*Description*: This project sought to use existing GNSS receivers to measure ocean tides. The interference pattern between direct and reflected GNSS can be used to calculate the height of a reflecting surface. Therefore, these receivers can be used to measure ocean tides. We performed a survey of numerous receivers and found three suitable for this type of measurement. We delivered code that does this calculation and provides the data which AOOS used on their dashboard.

3/2020 –
11/2020

*Title*: Clustered Multi-Ball Constellation (CMBC)
*Prime Contractor*: Leidos *Customer*: NRO
*Role*: PI
*Description*: This project applied novel synthetic aperture radar (ASR) techniques for a formation of 4 spacecraft. Our role was to design spacecraft and the complex Guidance, Navigation, and Control (GNC) algorithms required to control them. I modified quasi-j2 invariant orbit theory to account for the high inclination of the orbits and significantly reduced the $\Delta v$ required to maintain this spacecraft formation which increases its lifetime.

3/2021 – 11/2021

*Title*: PRISM
*Title*: Predictive Risk Investigation SysteM (PRISM)
*Prime Contractor*: University of Miami *Customer*: NSF
*Role*: Co-I
*Description*: This project sought to find connections between the fields of agriculture, ecology, finance, and space weather using novel machine learning methods. My role was to assess the impact of space weather and local ecology power outages. This was done using network analysis.

2/2019 – 2/2021

*Title*: R-MXAS
*Prime Contractor*: Leidos *Customer*: NASA NAIC
*Role*: PI
*Description*: This NASA NAIC Phase I and II project performed preliminary design of a novel rotating spacecraft with flexible $\sim$100 meter tethers kept taught by the centripetal acceleration. There were complex structures at the end of each tether which allowed for unprecedented array synthesis measurements of soil moisture. To control this structure, I designed a new Lyapunov-Stable non-linear control law that out performs the state of the art control law used by the Magnetic Multi Scale (MMS) mission. This work resulted in 1 first author journal publication.

7/2022 – 1/2023

*Title*: SORTIE
*Prime Contractor*: Orion Space Solutions *Customer*: AFRL
*Role*: Co - I
*Description*: The SORTIE mission was a 6U cubesat that measured ion density and drifts to better understand Traveling Ionospheric Disturbances (TIDs) and small-scale variabilities. My role was to compare the small-scale variability measured by SORTIE with other insitu measurements from COSMIC-2, and ICON. This work was presented at the American Meteorological Society conference.

9/2018 – 9/2020

*Title*: GAMMA
*Prime Contractor*: Orion Space Solutions *Customer*: AFRL
*Role*: Co - I
*Description*: This project was a feasibility study to assess whether ionospheric measurements of TEC and scintillation could be retrieved from a low cost GNSS receiver on a remote ocean buoy. The primary challenge is the rapidly changing multipath environment due to the motion of the waves and rocking of the buoy. The constructive and destructive interference causes rapid shifts in amplitude and phase which can be mistaken for ionospheric scintillation. I developed a provisionally patented algorithm to calculate the amplitude scintillation index ($S_4$) and it was deployed to the sensor via an Iridium connection.

9/2018 – 7/2019

*Title*: CSD
*Prime Contractor*: Orion Space Solutions *Customer*: USAF
*Role*: Co - I
*Description*: This project was a pathfinder to evaluate commercial radio occultation from Spire and GeoOptics. We assessed the accuracy and impact on operational systems in the 557$^{th}$ Weather Wing. This was done for both the ionosphere and troposphere. Northrup Grumman and STC assisted with the tropospheric work as subcontractors. The ionospheric data was assessed using both real data and simulation studies.

8/1/15– 8/1/18

*Title*: Faster-than-Realtime Electrostatic Force and Torque Modeling for SSA Applications
*PI*: Dr. H. Schaub
*Sponsor*: Air Force Office of Scientific Research
*Research*: Research faster-than-realtime electrostatic force and torque models for prototype GEO spacecraft shapes through continued development of the Multi-Sphere-Method.

## Software Skills

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| Software | Python, Matlab, LaTeX, Microsoft Office Suite, Linux Operating System |

## Journal Articles

1. **J. Hughes**, Ian Collett, Camella Nasr, Ana Newheart, Ryan Kelly, Scott Thaller, Raj Patel, Connor Johnstone, Elijah Vance, Houjun Wang, Nathan Re, Ben Tatman, Yoshiya Kasahara, Shoya Matsuda, Atsushi Kumamoto, Fuminori Tsuchiya, Tomoaki Hori, Atsuki Shinbori, Ayako Matsuoka, Mariko Teramoto, Kazuhiro Yamamoto, Yoshizumi Miyoshi, Iku Shinohara, "Observations and Statistical Studies of Orbit-Driven Plasma Waves in Low Earth Orbit at Very Low Frequencies" *in prep. for Advances in Space Research*

2. **J. Hughes**, Ian Collett, Anastasia Newheart, Connor Johnstone, Ethan Miller, Wesley Leong, Ryan Blay, "Relative Merits of Ionosondes, Ground GNSS TEC, and Radio Occultations for Ionospheric Data Assimilation" *submitted to AGU:Radio Science*

3. **J. Hughes**, Ian Collett, Anastasia Newheart, Walter 'Junk' Wilson, Ken Obenberger, Russell Landry, Jonah Colman, Joe Malins, "Analysis of Traveling Ionospheric Disturbances Using a N Dimensional Lomb Scargle Periodogram" *Frontiers in Astronomy and Space Science* 11, doi:10.3389/fspas.2024.1519436

4. **J. Hughes**, Ian Collett, Geoff Crowley, Adam Reynolds, Irfan Azeem "Evaluating the impact of commercial radio occultation data using the observation system simulation experiment tool for ionospheric electron density specification" *Frontiers in Astronomy and Space Science* 11, doi:10.3389/fspas.2024.1387941

5. F. Gasperini, **J. Hughes** , J. M. Forbes, and E. Thiemann, "Ultra-fast Kelvin wave packets in Mars' Atmosphere and their Interactions with Tides as Viewed by MAVEN/NGIMS and MRO/MCS " *JGR: Planets* 129, 2, doi:10.1029/2023JE008174

6. F. Gasperini, **J. Hughes** ,and E. Thiemann, "Solar Rotation Effects in Earth's and Mars' Thermospheric Densities as Revealed by Concurrent MAVEN, Swarm-C, and GOES Observations," *JGR:Planets* 128, e2022JE007431. doi:10.1029/2022JE00743

7. **J. Hughes**, V. Forsythe, R. Blay, I. Azeem, G. Crowley, W. Wilson, E. Dao, J. Colman, and R. Parris, "On Constructing a Realistic Truth Model Using Ionosonde Data for Observation System Simulation Experiments." *AGU: Radio Science* 57, e2022RS007508. doi:10.1029/2022RS007508

8. **J. Hughes**, F. Gasperini, and J. Forbes, "Solar rotation effects in Martian thermospheric density as revealed by five years of MAVEN observations." *JGR: Planets*, Vol. 127, No. e2021JE007036. 2022. doi:10.1029/2021JE007036

9. A. Kellerman, R. Mcgranaghan, J. Bortnik, B. Carter, **J. Hughes**, R. Arritt, et al. "Geomagnetically induced currents at middle latitudes: 1. Quiet-time variability." *AGU Space Weather* vol. 20, No. e2021SW002729, 2022. doi:10.1029/2021SW002729

10. **J. Hughes**, R. Mcgranaghan, A. Kellerman, J. Bortnik, R. Arrit, K. Venkataramani, et al. "Revealing novel connections between space weather and the power grid: Network analysis of ground-based magnetometer and Geomagnetically Induced Currents (GIC) measurements." *AGU Space Weather*, Vol. 20, No. e2021SW002727, 2022. doi:10.1029/2021SW002727

11. V. Forsythe, I. Azeem, R. Blay, G. Crowley, F. Gasperini, **J. Hughes**, et al. “Evaluation of the new background covariance model for the ionospheric data assimilation.” *AGU Radio Science*, Vol. 56, No. e2021RS007286, 2021.
doi:10.1029/2021RS007286

12. **J. Hughes**, R. Blay, J. Ziegler, P. Anderson, W. Armijo, J. Maxwell, J. Kendra, “Free-Space Dynamics and Control of the Rotary-Motion Extended Array Synthesis Spacecraft Concept,” *Journal of Spacecraft and Rockets* Vol. 59 No. 1, 2021, pp. 129 – 139
doi:10.2514/1.A35118

13. J. Maxwell, K. Wilson, **J. Hughes**, and H. Schaub, “Multi-Sphere Method for Flexible Conducting Space Objects: Modeling and Experiments,” *AIAA Journal of Guidance, Control, and Dynamics*, Vol. 57, No. 2, April 2020, pp. 225 – 234.
doi:10.2514/1.A34560

14. **J. Hughes**, and H. Schaub, “Electrostatic Tractor Analysis Using a Measured Flux Model,” *Journal of Spacecraft and Rockets*, Vol. 57, No. 2, April 2020, pp. 207 – 216.
doi:10.2514/1.A34359

15. **J. Hughes** and H. Schaub, “Heterogeneous Surface Multi-Sphere Models using Method of Moments Foundations,” *Journal of Spacecraft and Rockets*, Vol. 56 No. 4, August 2019, pp.1259 – 1266.
doi:10.2514/1.A34434

16. M. Bengtson, **J. Hughes**, and H. Schaub, “Prospects and Challenges for Touchless Sensing of Spacecraft Electrostatic Potential Using Electrons,” *IEEE Transactions on Plasma Science* Vol. 47 No. 8, August 2019, pp. 3858 – 3866
doi:10.1109/TPS.2019.2912057

17. **J. Hughes** and H. Schaub, “Rapid Modeling of Electrostatic Forces and Torques Considering Dielectrics,” *AIAA Journal of Spacecraft and Rockets* Vol. 56 No. 6, Dec 2019, pp. 1680 – 1688.
doi:10.2514/1.A34413

18. **J. Hughes**, and H. Schaub, “Space Weather Influence on Electromagnetic Geosynchronous Debris Perturbations Using Statistical Fluxes,” *AGU: Space Weather*, Vol. 16, No. 4, 2018, pp. 391–405.
doi:https://doi.org/10.1002/2017SW001768.

19. G. Ingram, **J. Hughes**, T. Bennett, C. Reilly and H. Schaub, “Volume Multi-Sphere-Model Development Using Electric Field Matching,” *Journal of Astronautical Sciences.*, Vol. 65, No. 4, 2018, pp. 377 – 399.
doi:10.1007/s40295-018-0136-x

20. M. Bengtson, K. Wilson, **J. Hughes**, and H. Schaub, “Survey of the electrostatic tractor research for reorbiting passive GEO space objects,” *Astrodynamics*, Vol. 2 No. 4, 2018, pp. 291 – 305.
doi:10.1007/s42064-018-0030-0

21. **J. Hughes** and H. Schaub, “Rapid Charged Geosynchronous Debris Perturbation Modeling of Electromagnetic Disturbances,” *Journal of Astronautical Sciences*, Vol. 65, No. 2, 2018, pp. 135 – 156.
doi:https://doi.org/10.1007/s40295-017-0127-3

22. **J. Hughes** and H. Schaub, “Spacecraft Electrostatic Force and Torque Expansions Yielding Appropriate Fidelity Measures,” *Journal of Astronautical Sciences* Vol. 66, No. 1, March 2019, pp 46-67.
doi:10.1007/s40295-019-00154-7

23. **J. Hughes** and H. Schaub, “Prospects of Using a Pulsed Electrostatic Tractor With Nominal Geosynchronous Conditions,” *IEEE Transactions on Plasma Science*, Vol. 45, No. 8, 2017, pp. 1887–1897.
doi:10.1109/TPS.2017.2684621

24. D.C. Ferguson and R.C. Hoffmann and R.J. Cooper and **J. Hughes**. “1997-2002 Solar Array String Failures Revisited” *Journal of Spacecraft and Rockets* Vol. 54, No. 3, 2017, pp. 542 – 553.
doi:10.2514/1.A33637

25. **J. Hughes** and F. Liebrand. “Conic Sections in the Double Slit Experiment,” *American Journal of Undergraduate Research*, Vol. 10, No 3, 2011, pp. 21–26