Statement of Purpose

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# Introduction

I am an aerospace engineer and scientific software developer who is passionate about computational dynamics. I have been fortunate to have had the opportunity to exercise this background to expand human space exploration at NASA. Now, I aspire to grow as a computational physicist, and expand astrophysical discovery through research.

As I continue to learn about open topics in astrophysics research, I am particularly drawn to research areas relating to galactic dynamics, large scale structure formation, and gravitational wave dynamics. I hope to be considered for graduate advisement by **Dr. Vogelsberger**, **Dr. Necib**, and **Dr. Hughes**. I am grateful for the opportunity to apply to the MIT Department of Physics’ PhD program; thank you for your consideration.

# Research Experience

My graduate research assistant experience under Dr. Dave Akin brought me into the weeds of constrained, performant software development. My final aerospace engineering course, Interplanetary Navigation & Guidance with Mr. Brent Barbee, introduced me to computational discovery and interdisciplinary research.

The University of Maryland’s Space Systems Lab ([SSL](https://ssl.umd.edu)) develops and maintains an 8DOF serial manipulator ([Ranger](https://ssl.umd.edu/ranger)) for satellite servicing and dexterous manipulation research. I independently developed interfaces (C++ templates) and implementations for kinematic solvers and Cartesian controllers. One [solver’s](https://onlinelibrary.wiley.com/doi/abs/10.1002/1097-4563(200009)17:9%3C453::AID-ROB1%3E3.0.CO;2-A) implementation introduced a small performance hurdle: the computation required several intermediate-Jacobian solutions, which I initially solved-for iteratively. After contributing the required [fixes](https://github.com/JuliaSymbolics/Symbolics.jl/pull/72), I used Julia’s [Symbolics.jl](https://symbolics.juliasymbolics.org/) to print analytical intermediate-Jacobian solutions to performant, non-allocating C++ functions; as a result, each intermediate-Jacobian solve’s performance improved by a factor of two. This experience at SSL, and others, taught me how to write performant software for high-speed computations. Graduate course projects, under Mr. Barbee’s guidance, showed me how computation extends to discovery across fields.

For my final M.S. course’s term project, I replicated halo orbit and invariant manifold computations as summarized by Megan Rund’s [thesis](https://digitalcommons.calpoly.edu/theses/1853/) on low-cost interplanetary transfer techniques. Multiple flavors of the halo orbit solver algorithm existed in literature, but I found no guidance in selecting one flavor over another. My project delivered a decision tree for selecting which flavor of the differential correction algorithm to use, depending on the desired orbit characteristics, alongside [open source Julia packages](https://github.com/cadojo/GeneralAstrodynamics.jl), and over 130k [initial conditions](https://github.com/cadojo/CR3BP-Manifold-Research) for periodic orbits in three-body dynamics.

Computation had revealed true low-energy paths in the solar system; I was exhilarated, and I sought out more opportunities to learn about computational research. After [presenting](https://youtu.be/WnvKaUsGv8w) the foundations of my project at JuliaCon 2021, I was added to the [JuliaSpace](https://github.com/JuliaSpace) GitHub organization. I was later invited to a [seminar](https://juliareach.github.io/juliareach-days-3/) on dynamical reachability. As I worked full-time at NASA, I continued to develop and release open source scientific software personally.

# Scientific Computing

In 2021, I released all of my astrodynamics research, and much of the functionality covered by my astrodynamics coursework, in a single Julia package: [GeneralAstrodynamics.jl](https://github.com/cadojo/GeneralAstrodynamics.jl). I have since corrected common beginner mistakes, such as over-relying on multiple dispatch. Throughout this effort, I have paused to develop new astrodynamics packages; of these, I have found [SPICEKernels.jl](https://github.com/cadojo/SPICEKernels.jl) to be the most useful. Professionally, scientific software has been critical to my role as an integrated GN&C analyst in the Artemis Program. I have developed several internal Python packages to assist with nonlinear analysis and verification, including a novel 6DOF kinematics simulator.

All of the scientific software I write personally is published on GitHub under the username [@cadojo](https://github.com/cadojo), and is linked-to and summarized by my personal website: [loopy.codes](https://loopy.codes/packages). I have enjoyed applying scientific software to human space exploration projects, and I am excited to apply these skills to physical discovery.

# Research Aspirations

Before my graduate astrodynamics coursework, I had not considered a career in astrophysics research. I was delighted to learn that astrophysical phenomena are studied in ways which align with my current technical skill set: dynamical analysis and scientific software development. Since graduation, I have missed formally learning about the universe through coursework and computation. I am eager to grow as a physicist, and work to advance discovery alongside scientists and research engineers.

# Future Plans

I am exploring general astrophysical concepts through the [Big Orange Book](https://www.cambridge.org/highereducation/books/an-introduction-to-modern-astrophysics), and galactic dynamics specifically through Dr. Body’s online [textbook](https://galaxiesbook.org) draft. Regardless of the path of my research career, I look forward to exploring concepts through computation, and sharing what I learn with others through open source scientific software.

I hope I have the opportunity to learn from the excellent scientists and software developers within MIT. Thank you for the opportunity to apply, your time, and your consideration.