Christopher Rabotin

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Summary

- Senior engineer skilled in astrodynamics and software engineering
- MSc. ESIEE Paris, MSc. CU Boulder
- Enjoys a proactive and rigorous team environment
- Passionate about interplanetary exploration
- Proficient technical writer and public speaker
- Thrives in research and development roles
- Swift learner and advocate of modern technologies
- Bi-national and bi-cultural, lived in five countries

Experience

GNC Engineer, XL-1 Lunar Lander — **Masten Space Systems**
Boulder, CO, USA — *Jan 2021 – Present*

- Mission design and orbit determination subject matter expert: reviewed trajectory requirements, Δv budget, sensor constraints, onboard guidance law targets, geometry assessments, quality of the orbit determination results.
- Implementation of guidance algorithms for lunar landing: Augmented Apollo Guidance (A2PDG), Fractional-Polynomial Powered Descent Guidance (FD2PG), and Universal Powered Guidance (UPG) from their respective papers all written by Dr. Ping Lu. These were implemented in our 6DOF simulation built on top of the Python/C++ Basilisk 6DOF framework.
- Comprehensive trade study of on-board guidance laws for on-orbit maneuvering in high fidelity: Powered Explicit Guidance, Ruggerio guidance, Q-Law. This was implemented on top of the Nyx 3DOF simulation framework which allowed running 2,000 simulations at 0.1 Hz in 7 hours. High fidelity included gravities of the Earth, Moon, Sun; solar radiation pressure with Earth and Moon eclipses; spherical harmonics of Earth (EGM2008 50x50) and the Moon (JGGRX 160x160).
- Development of high fidelity sensor models for our 6DOF simulation: star tracker model and fine sun sensor model. Both included a First Order Gauss Markov process (FOGM) for quaternions, derived by me starting from the scalar FOGM derived in the NASA Best Practices for Navigation Filters by D'Souza et al.
- Lead quality assurance engineer: designed and enforced a QA process, developed the CI/CD testing pipelines on Gitlab, including automatic execution of Monte Carlo simulation pipelines whose results are used for automatic requirement verification and reporting.
- Lead GNC flight software and simulation software reviewer: provided thorough review of each Python and C++ simulation model, the navigation filter, and their associated test suites; detailed reviews of the finite state machine for GNC scheduling and of the custom mathematical C++ library for the flight software.

Astrodynamicist, software engineer and enthusiastic advocate — **Nyx: open-source astrodynamics toolkit**
Boulder, CO, USA — *Jan. 2018 – Present*

- Nyx is a high-fidelity, extremely fast and validated astrodynamics toolkit for mission design and orbit determination. It is an open-source alternative to NASA GMAT and JPL MONTE, that I wrote from scratch and validated against GMAT.
- Nyx is used to run guidance law trade studies on XL-1, and was used for all trade studies for the Cislunar Autonomous Navigation System (CAPS), and for validating the CAPS flight software. It is also scheduled to be used for shadow navigation on the XL-1 lunar lander. Given all of the features and validation work, Nyx is by far my most accomplished software project.
- Mission Design features include multibody dynamics, spherical harmonics, solar radiation pressure with penumbra calculations, several drag models, finite burns, control laws for low thrust spacecraft, and CONOPS modeling (e.g. propagate until periapse, then execute burn).
- High fidelity time computations handled by my hifitime library, which support Barycentric Dynamical Time, Ephemeris Time, UTC, and TAI, and validated against SPICE. The hifitime library is currently used for timing computations by Murchison Widefield Array (MWA), a low-frequency radio telescope in Western Australia.
- Orbit Determination capabilities include classical and extended Kalman filters with state noise compensation, smoothing and iteration. All state transition matrices are computed using automatic differentiation enabling OD with any dynamical model supported in Nyx, cf. my conference paper on dual number theory and the hyperdual library.
- ANISE: a modern and FSW-ready replacement of NAIF SPICE. Currently in development, this framework includes a new data format that is ISO-certification ready (ASN1), and aims to provide formally validated and infallible methods for onboard GNC computations.

Aerospace and lead software engineer — **Advanced Space LLC.**
Boulder, CO, USA — *June 2017 – Dec. 2020*

- Lead engineer on the Cislunar Autonomous Position System (CAPS): filter configurations (CKF/EKF, SNC setups, dynamical models, etc.), system trade studies, flight software requirements, architecture (SysML), development (NASA Core Flight)

and automated testing (Docker); CAPS operations lead for the CAPSTONE mission (including coordination with spacecraft manufacturer, several mission operations and navigation teams).

- eXchange Binary (XB) files: a modern replacement for the NAIF SPICE DAF/SPK data format built with Google Protocol Buffers. Supports planetary and spacecraft ephemerides (with covariances), spherical harmonics, attitude frames & trajectories and navigation data. Tested on desktop and embedded software (PowerPC and ARM). Used onboard CAPSTONE.
- Lead/sole engineer on CAPSTONE Flight Dynamics System (Erebus): architected, developed and deployed all of the infrastructure (Kubernetes) and software (webapps, REST and gRPC APIs, Python scripts) which enable spacecraft navigation, maneuver design (via JPL MONTE), payload operations (via Nyx and MONTE), and secure communication with third parties.
- Astrodynamics engineer for the spacecraft deployment, orbit raising and orbit insertion of a low thrust megaconstellation.
- Wrote six proposals for NASA and the US Air Force, four of which received funding.

Lead backend software engineer and first employee **Sparrho**
London, UK *Nov. 2013 – Nov. 2015*
Responsible for the architecture, infrastructure, development and maintenance of the data-gathering and data-mining software (in Go and Python), and the search and recommendation algorithms (in Django, using Elastic Search and InfluxDB).

Engineer, Spacecraft Operations Architecture (via Amphinicy Technologies) **SES**
Betzdorf, Luxembourg *Nov. 2011 – Nov. 2013*
Designed and implemented spacecraft bus procedures for SES' Orbital Space Corporation Star 2 SES-8, and backported applicable procedures to SES-1/2/3 and NSS-9. Implemented payload procedures for Space Systems Loral's LS-1300 bus SES-5. Led redesign of payload procedures for all platforms. Included Ground Control System debugging. All coding work in Python on top of the SPELL-Sat procedure framework.

Publications & Patents

Hyperdual Numbers for Arbitrary Orbit Targeting **Rabotin**
American Astronautical Society - Astrodynamics Specialist Conference, AA-21-715 *Aug. 2021*

Masten XL-1 Lunar Lander Mission Design and GNC Architecture **Pettinato et al.**
American Astronautical Society - Astrodynamics Specialist Conference, AA-21-710 *Aug. 2021*

Application of Dual Number Theory to Statistical Orbit Determination **Rabotin**
American Astronautical Society - Astrodynamics Specialist Conference, AA-19-716 *Aug. 2019*

The Cislunar Autonomous Positioning System (CAPS) **Parker et al.**
American Astronautical Society - Guidance and Control Conference, AA-19-094 *Feb. 2019*

Decision-making process for elements in a distributed network **Rabotin & Valverde**
Patent WO2014108325 *Issued in Jul. 2014*

Method for maintaining a data stream from a cell site within a mobile communication network (...) **Gruet & Rabotin**
Patent EP2800446 *Issued in May 2013*

Education

University of Colorado Boulder **Boulder, CO, USA**
Master of Science, Astrodynamics and Spacecraft Navigation *2015 – 2017*
Aerospace engineering thesis student in the Autonomous Vehicle Systems (AVS) laboratory led by Dr. Schaub.

ESIEE Paris, Gustave Eiffel University **Noisy-le-Grand, France**
Master of Science, cum laude *2006 – 2011*
Electrical and computer science engineering, majored in telecommunications and signal processing.

Skills

Space related
- Spacecraft navigation (Kalman filters, SNC, smoothing)
- Trajectory optimization (control laws, multiple shooting)
- Flight dynamics systems (Adv. Space Erebus, GMV HiFly)
- Flight Software Reqs., Architecture & Dev. (NASA Core Flight)
- Spacecraft operational procedures and systems engineering
- Tools: NASA GMAT, JPL MONTE, NAIF SPICE

Programming
- Proficient: Rust, Python
- Competent: C, Golang, Web dev (REST, gRPC)
- Patterns: concurrency, borrow vs copy vs clone
- Cloud: AWS, GCP, Docker, Kubernetes (with certificate)
- Serialization: ASN1, Flatbuffers, Protocol buffers, HDF5
- Databases: Postgres, InfluxDB, Redis

Miscellaneous

Languages
- French (native)
- English (native)
- Spanish (basic conversational)

Sports
- Competitive freediver, SCUBA
- Climbing, Hiking (Kilimanjaro)
- Swimming, Running

Hobbies
- Traveling: 35 countries visited
- Reading: engineering, geopolitics
- Cooking, playing with my dog