

## **Cosmo Nazzareno Santoni**

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Links: [GitHub](#) | [Google Scholar](#) | [Personal Website](#) | [LinkedIn](#)

Location: London, UK (Available to relocate)

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Machine learning researcher, engineer and PhD candidate in Applied Mathematics at Imperial College London specialising in sequence models, state-space architectures, and simulation-based inference for decision-making and large language models (LLMs), LLM robustness and safety, with 125,000× speed-ups over traditional simulators while maintaining calibrated uncertainty estimates. Deployed in production for World Health Organisation (WHO) malaria programme planning and UK government crisis response; publications include Nature and The Lancet with work presented at a NeurIPS 2025 workshop and manuscripts targeting ICML 2026 and KDD 2026. Creator of mamba2-jax, a JAX/Flax Mamba-2 implementation merged by Google's JAX team into Google's official jax-ml/bonsai models repository, as part of an open-source collaboration with Google.

### **SELECTED IMPACT**

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- *Mamba2-jax – Merged JAX/Flax Mamba-2 implementation for language modelling and time-series. Referred by Xavi Amatriain (Google VP, AI Products) to Google's JAX team; [PR merged into jax-ml/bonsai](#). Ongoing contributor.*
- Developed **state-space and RNN neural surrogate architectures** for large-scale agent-based models, achieving **125,000× speedups with 99.8% fidelity**, deployed in production for WHO malaria intervention planning and international government decision support.
- Received **SAGE Award** from **Sir Patrick Vallance & Professor Chris Whitty, UK Government Chief Scientific & Medical Officers** for modelling and data support enabling evidence-based COVID-19 policy.
- Released **LLM safety tooling prototypes**, including a metacognitive study of Claude; transcripts shared with **Anthropic Trust & Safety** at their request.

### **PROFESSIONAL EXPERIENCE**

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#### **Machine Learning Researcher / Technical Analyst – Imperial College London, U.K., 2023 – Present**

- Led end-to-end design and research of state-space neural surrogate architectures for large-scale contextual agent-based simulators, replacing 24-minute HPC computations with sub-10.5ms inference (>125,000× speedup, 99.8% fidelity) and cut compute from ~22–43 MWh on consumer HPCs (≈£5.9k–£11.3k) to ~0.13 kWh for ~1M scenarios.
- Lead MINTverse production; MLOps / ML platform processing 100+ scenarios per second on a consumer GPU. Designed a modular neural multi-task emulation architecture with hot-swappable RNN / Mamba-2 sequence-model heads (PyTorch + CUDA + AMP), built synthetic data generation and analytics infrastructure over 6.89B+ data points (DuckDB, sub-second queries), and deployed model serving APIs with deterministic versioning—enabling millisecond-latency policy queries where hours would have previously been required.
- Built open-source modular ML infrastructure that reduced teams' model development cycles from months to days.
- Partnered with WHO to translate neural emulator outputs into deployment, bridging ML model performance and policy requirements for international malaria intervention programmes.

#### **Machine Learning Researcher – University of Cambridge, Department of Computer Science, UK., & German Centre for Artificial Intelligence (DFKI), DE., 2022 – 2023**

- Engineered neural ODE architectures with hard physical constraints for complex dynamical systems. Implemented physics-informed loss functions and automatic differentiation in PyTorch / Julia, achieving strong performance on irregular sparse time-series while maintaining clinical interpretability.
- Designed training and deployment infrastructure for multi-scale dynamical systems, building pipelines supporting multiple optimisation algorithms (Adam, Levenberg-Marquardt), Bayesian uncertainty quantification, and sensitivity analysis suitable for safety-critical settings.
- Drove architecture decisions for Neural Universal Differential Equations, balancing expressiveness vs interpretability. Developed 1D/2D neural ODE architectures that enabled previously intractable dynamical systems where unconstrained data-driven baselines failed physical consistency checks.

#### **Research Assistant – COVID-19 Real-time Modelling, Imperial College London, U.K., 2021 – 2023**

- Owned real-time inference pipeline for national-scale epidemic time-series, delivering <24hr from raw data to policy recommendations. Outputs directly informed UK lockdown policy during the national emergency.
- Maintained open-source inference libraries under active use by UK SAGE during the pandemic. Managed breaking changes, backward compatibility, and emergency bug fixes while ensuring reproducibility across distributed teams.
- Engineered automated reporting infrastructure generating statistical analyses, visualisations, and forecasts for systems running continuously for 18+ months, supplying weekly briefings to UK Chief Scientific Advisors.
- Received SAGE Award for contributions to UK national-scale epidemic modelling and data pipelines.

## TECHNICAL SKILLS & LANGUAGES

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- **Languages:** Python, R, Julia, C++ (familiar), SQL, Bash (Linux)
- **ML / DL:** JAX, PyTorch, JAX-CFD, **Transformers**, Mamba2, RNNs/LSTMs, XGBoost, Optuna, NumPy, Pandas
- **Data & Storage:** DuckDB, HDF5
- **HPC & Acceleration:** CUDA, MPS, Automatic Mixed Precision (AMP); CPU/GPU clusters; Google Cloud TPUs / GCP (familiar); Triton kernels (familiar), distributed training (DeepSpeed, ZeRO, TP/PP/DDP)
- **Tooling:** Git / GitHub, CI/CD (GitHub Actions), Linux, Docker (deployment exposure)
- **Research focus:** RNNs/LSTMs, sequence models & state-space models (Mamba-2), Transformers and large language models (LLMs), generative modelling (flow matching), neural ODEs, simulation-based inference (SBI), Bayesian modelling, probabilistic modelling, conformal prediction, calibration and uncertainty quantification (UQ).

## EDUCATION

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- **Full-time PhD in Applied Mathematics**, Imperial College London, U.K., January 2025 – December 2027  
Thesis: “Towards State Space and Graph Neural World Models for Large-Scale Agent-Based Simulators”
- **MSc. Epidemiology (Merit)**, Imperial College London, U.K., 2020 – 2021
- **BSc. (Hons.) Mathematics with Economics**, Aston University, U.K., 2015 – 2019

## SYSTEMS, OPEN SOURCE & RESEARCH SOFTWARE

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### Production ML Systems & Flagship Libraries

- [mamba2-jax](#): Pure JAX/Flax Mamba-2 implementation for language modelling and time-series forecasting, designing the NNX Mamba-2 architecture for Google’s JAX/Bonsai ecosystem (Google [jax-ml/bonsai](#) model zoo, ongoing open-source collaboration with the Google JAX team).
- [MINTverse](#): production orchestration (R/Python) delivering neural emulation for WHO operational decision-support.

### Robustness, Uncertainty Quantification, LLMs

- [Metacognitive Prompting of Claude](#) - systematic behavioural analysis of non-uniform helpfulness; shared transcripts with Anthropic Trust & Safety at their request.
- [RADAR](#): risk-aware UQ and calibration for SSMS, learning residual-based risk scores and adaptive conformal prediction under distribution shift, designed for time-series, LLM token, sequence, and reasoning-head outputs.

### Open-source libraries & tooling

- [mamba2-triton-guard](#): Lightweight patcher that stubs Triton and guards version checks so mamba2\_torch imports cleanly on macOS M1–M5 (CPU / MPS), enabling SSM experimentation without GPU triton-only constraints.
- [mamba2-torch contribution](#) (PR under review): Added import guard for MPS, gated fast-path, and fixed a padding edge case to improve stability on Apple silicon and avoid silent shape errors.
- [Epireview](#): production data extraction and automated figures / tables for WHO [PERG](#); used by international teams
- [Sircovid](#), [Spimalot](#), [MCState](#): UK COVID-19 Bayesian toolkit (adaptive PMCMC, inference, forecasting).

## PUBLICATIONS & RESEARCH OUTPUT

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### Selected Publications:

- Perez-Guzman, P. N., Knock, E., et al. “[Epidemiological drivers of transmissibility and severity of SARS-CoV-2 in England](#).” **Nature Communications (co-author)**
- Imai, N., Rawson, T., et al. “[Quantifying the impact of delaying the second COVID-19 vaccine dose in England: a mathematical modelling study](#)” **The Lancet Public Health (co-author)**
- Multiple publications under [PERG](#) including **Lancet Infectious Disease**, **Lancet Global Health** & **Lancet Microbe**

### Manuscripts under Preparation/Review:

- Charles, G., Santoni, N. C., et al. “Tokenised Flow Matching for Hierarchical Simulation Based Inference” **International Conference on Machine Learning, ICML, 2026 (target venue; co-author)**
- Santoni, N. C., et al. “State-Space Neural Emulators for Real-Time Policy Decision Support” **ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, KDD, 2026. (target venue; first-author)**

### Conferences, Workshops & Presentations:

- **Tokenised Flow Matching for Hierarchical Simulation-Based Inference**, NeurIPS 2025 Workshop on Frontiers in Probabilistic Inference: Sampling Meets Learning, San Diego, USA (co-author; presented by Charles, G.)
- **Applying Neural Network Emulation to Assess the Impact of Pyrethroid-Pyrrole Bed Nets on Malaria in Africa**, 9th International Conference on Infectious Disease Dynamics, Bologna, Italy, November 2023

## ACADEMIC SERVICE & VOLUNTARY WORK

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- **Curator, Amphibian & Malaria Collections**, Museum of Life Sciences, King’s College London, U.K., 2025 –
- **Departmental MRC GIDA Seminar Series Co-Organiser**, Imperial College London, U.K., 2023 –