

The Journey So Far, and The Path Ahead

Annual Report
September 2022





“ I am optimistic, inspired, and very privileged to support Topos Institute in its mission to shape technology through the sciences of connection so that the systems that surround us benefit us all. This work offers a different and better way of embracing change while being accountable. ”

Ilyas Khan, Chair, Topos Institute

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Welcome

How do we build a world where the systems that surround us benefit us all?

This is the question we begin with at Topos.

As we look out around us, many of our urgent challenges are about systems out of balance: the climate, pandemics, misinformation and mistrust, runaway AI. These problems have become urgent this century largely because of technology—both tangible, such as power grids and social media, and conceptual, such as markets and trade. While these technologies scale powerfully, they often fail to account for key, systemic consequences.

How do we collectively understand and cooperate around this evolving pandemic, or engineer planetary-scale AI systems that improve society for all? Through science and technology, humanity is more powerful than ever before, but we must use this power wisely. How do we build systems that honour our human values?

We believe that these are problems of communication and cooperation, language and translation, trust and vulnerability, power and relationships. Traditional mathematics, the foundational language of our technologies, cannot capture the complexity that interweaves us all. At Topos, we pioneer new mathematical



The team already hard at work in our Berkeley offices



Topos launched in early 2021

tools with this fundamental purpose of connecting and coordinating. We dedicate ourselves to advancing this knowledge and putting it into practice to serve society.

We opened our doors on January 1st last year. I'm proud and thrilled to note our rate of progress: in a bit over a year we have pioneered new software for collaborative scientific modelling, designed with tools from the cutting edge of pure mathematics, and in pilot use by communities of epidemiologists. An important case study is complex disease interactions, such as influenza and COVID-19 here in California this winter.

More generally, we've built a proof of concept of a new model for scientific research, which integrates fundamental, mathematical

inquiry, tool-building, and ethical social impact. Beginning with just three people, we have grown rapidly to a team of ten, and seek to double in size again over the coming year. Our vision is an international, diverse community of scientists, technologists, ethicists, and policy-makers, working together to serve society.

Topos' greatest strength has always been this team of passionate people across diverse expertise, all invested in using their talents to benefit our communities, and humanity as a whole. Our research staff has trained and taught at MIT, Stanford, Oxford, Cambridge, and other leading research centers. And we're honored to have a stellar team of directors and advisors, with our board led by Ilyas Khan, CEO of Quantinuum and previously chairman of the Stephen Hawking Foundation, and with senior advisors such as Dana Scott, Turing Award laureate.

In both our organisational design and our community, we're laying a strong foundation with a real potential to change the world.

We invite you to join us in this revolutionary journey to build a world where the systems that surround us benefit us all.



Brendan Fong
CEO, Topos Institute



What we do

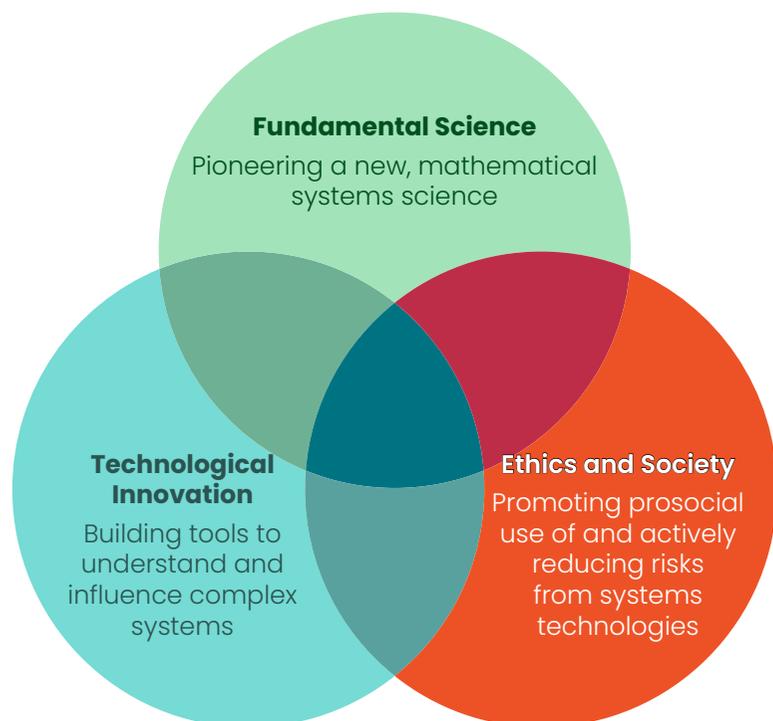
Our Vision

A world where the systems that surround us benefit us all.

Our Mission

To shape technology for public benefit by advancing sciences of connection and integration.

Topos achieves this mission through three interdependent pillars of activity:



These pillars together pioneer a new model of the practice of science for societal good. This integrated combination of basic inquiry, guided by ethical engagement, and expressed in groundbreaking tools, is essential for facing the great, systemic challenges of our times.

Over the past year, we have focussed on four themes, addressing the following key questions:

- **Tools for Collaborative Decision-Making:** What tools allow collaboration between diverse experts on scientific modelling? How can tools build trust and consensus, unveiling implications of shared perspectives?
- **Practices for Ethically-Engaged Fundamental Research:** How does fundamental research impact society? How do we ensure new technologies are designed in a safe way, that will help all of humanity flourish both today and long into the future?
- **Mathematics of Connected Intelligence:** How do we collectively make sense of the world? With mathematical precision, can we describe how cooperation and intelligence emerge from interactions between people, corporations, technologies, and their environments?
- **Community Building and Public Engagement:** Systems technologies affect everyone. How can we ensure everyone has a voice in their construction?

Programme Highlights

Tools for Collaborative Decision-Making

Through both AlgebraicJulia and our Networked Mathematics project, we research open-source software for collaborative scientific modelling, project and data management, and policy-making.

Highlights:

- Designed in collaboration with epidemiologists, our **Algebraic-Dynamics.jl**¹ research software tool allows rapid, visual, and collaborative epidemic modelling by diverse teams with different viewpoints and objectives, facilitating clearer communication and improving trust.²
- **Rewriting individual-based models for epidemiology using graph rewriting**³ provides a novel modelling method in pilot use at the *Institute for Health Metrics and Evaluation* to create complex, next-generation malaria transmission and evolution models.
- Researchers at the *California Department of Public Health* have reached out with interest in using AlgebraicJulia to model influenza and COVID-19 interactions this coming winter.
- Our **Diagrammatic differential equations in physics** paper⁴ and **Decapodes.jl** research software adapts these methods to engineering, merging models across electrical, mechanical, and aeronautical systems.
- We have launched a two-year collaboration with the *US National Institute of Standards and Technologies (NIST)*, *Carnegie Mellon University*, and *Chevron* to research adapting AlgebraicJulia for systems engineering project management, showing its flexibility for effective shared decision-making in all types of complex systems.

- With collaborators at *NIST*, **Extracting Mathematical Concepts from Text**⁵ provides a preliminary study into organising mathematical knowledge with AI, in order to make cutting-edge research more accessible.



A lecture by Topos Chief Scientist David Spivak at our Berkeley offices

Programme Highlights

Mathematics of Connected Intelligence

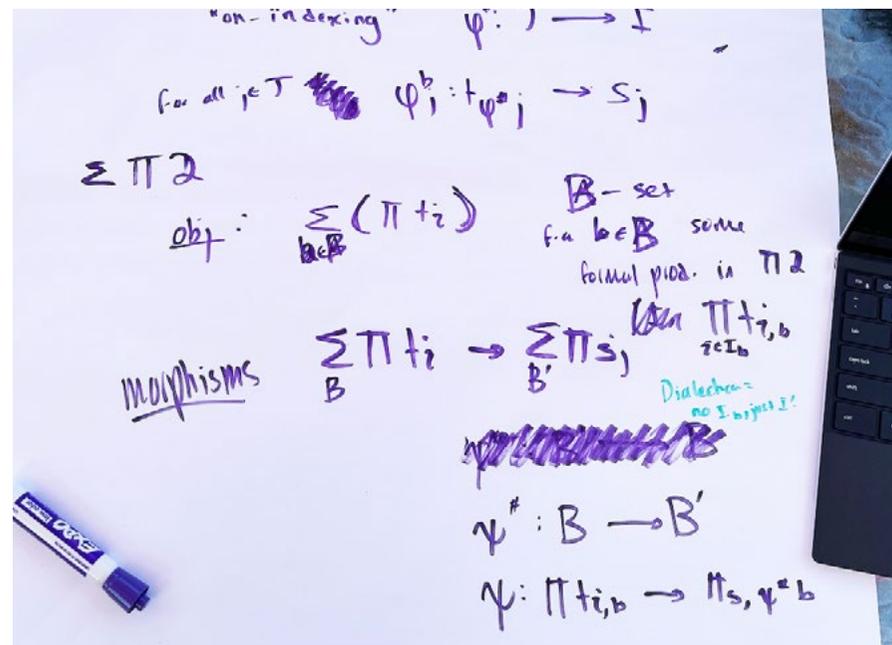
Our Connected Intelligence theme develops precise mathematics for understanding systems through exploring concepts of relationship, process, interaction, and communication.

Highlights:

- **Polynomial Functors: A General Theory of Interaction**⁶ is an open-access textbook and 15 lecture course on polynomial functors, a mathematical framework for describing interaction, dynamical systems, and decision-making. This provides the foundation for much of our work on intelligence and cooperation, and was presented as a keynote at Artificial General Intelligence 2022.
- **Dynamic categories, dynamic operads: From deep learning to prediction markets**⁷ studies how organizations adapt to internal and external pressures, with applications to deep learning and prediction markets.
- **Collectives: Compositional protocols for contributions and returns**⁸ studies protocols for aggregating contributions and distributing returns. Through such a protocol, many members may participate in a mutual endeavor; one goal is to describe fair economic systems.
- **Compositional active inference I and II**⁹ give a systematic account of active inference and the free energy principle, a leading neuroscience theory characterizing perception, planning, and action, and ultimately general intelligence.
- **Categorical Systems Theory**¹⁰ is an open-access book on using category theory to model complex systems, focussing on new ways of describing rich interfaces between individual people and parts.

“ The most advanced technology is not that which is fastest or most outlandish; it is that which harmoniously coordinates the living world. By clarifying the ways by which technical, social, and biological systems are formed and sustained, Topos provides a foundation to both develop transformational new technologies and maintain our alignment with them. ”

David Spivak, Topos Chief Scientist



Research in action!

Programme Highlights

Practices for Ethically-Engaged Fundamental Research

Topos' unique model integrates social impacts and ethics of science and technology as a key pillar in our research process. This growing part of our team researches the impacts of our work, how to reduce risks and improve prosocial outcomes, and ways to better align our internal processes and culture with these goals.

Highlights:

- In **Strategies for ethically-oriented pursuit of research and technology**¹¹ we review four governance strategies employed by technology research institutes to help research be responsive and accountable to the public good, as part of our work to implement effective processes at Topos.
- Topos Colloquium talks **Ethics in AI, not Ethics of AI** by David Danks, and **Ethics Washing in AI** by Moshe Vardi provided a venue for conversation amongst leading computer scientists and ethicists about positive ways forward for AI and related technology-driven research.
- Our chair Ilyas Khan, together with Lord Rees, The Astronomer Royal and founder of the *Centre for the Study of Existential Risk*, hosted leading figures in science, technology, and society for a conversation on **Ethics, Technology, and Embracing the 21st Century** at the Royal Society, London.
- The **Topos AI Safety Strategy Summit** brought together leaders at Topos and in the AI safety community for a 5 day retreat to discuss how our work on intelligence and cooperation can be used to ensure AI does not threaten human flourishing.

“Who, as a society, do we want to become?’ and ‘Who is this technology benefiting and who does it have the power to oppress?’. Topos is asking these questions and trying to approach them sensibly, within the actual mechanics by which work at Topos might be relevant, and with recognition of the potential issues on the table.”

Alejandra Arciniegas, PhD student in Technology Ethics at Carnegie Mellon University, and Topos Summer Research Associate



The 2022 cohort of Summer Research Associates

Programme Highlights

Community Building and Public Engagement

We believe that technology research must be open to all for it to benefit all. Our public seminars, workshops, blog, and community support efforts help us build a diverse, international, and inclusive community.

Seminars

Our four public seminar series include:

- Our flagship **Topos Colloquium**, held online over Zoom and broadcast live on YouTube, has hosted leading figures in mathematics, computer science, and technology ethics, including John Baez (“Mathematics in the 21st Century”), Bob Coecke (“Compositional Intelligence”), David Danks (“Ethics in AI, not Ethics of AI”), and Emily Riehl (“Contractibility as Uniqueness”).
- Our **Emerging Researchers in Category Theory (Em-Cats)** series gives graduate students the chance to learn the craft of speaking from expert Eugenia Cheng, and aims to increase diversity and inclusivity in category theory research.

Community support

Topos assists with the administration of many community projects, including:

- **The nLab**: a critically important research wiki for collaborative work on Mathematics, Physics, and Philosophy through a category theory lens, with over 18,000 pages.
- **The Adjoint School**: an annual research school for new researchers in applied category theory, attracting over 100 applicants each year.
- **Women in Logic**: a forum that brings together women conducting research in logic and closely related areas, including a blog and annual workshop.

Workshops

- The **Category Theory for Epidemiology Summer School** funded by the Canadian Network for Modelling Infectious Disease, taught 20 epidemiologists how to use AlgebraicJulia to predict disease spread.
- The **Intelligence, Modularity, and Dynamics Retreat** brought together neuroscience and mathematics researchers from Topos and Stanford University to study how computation emerges from simple dynamics.
- The **Finding the Right Abstractions for AI Safety Workshop** facilitated collaboration between Topos and AI researchers on topics related to AI safety.
- The **First and Second Workshops on Polynomial Functors** gathered leading researchers in polynomial functors for a week of discussions.

/// *Topos is a novel, innovative experiment in interdisciplinary research that has inspired my students and shown them the true potential of academic study. ///*

Ted Theodosopoulos, high school teacher at The Nueva School



The Finding the Right Abstractions for AI Safety Workshop began with a fireside chat between leading AI researchers David A Dalrymple and Jaan Tallinn



Outputs at a glance

37 open-access papers published or submitted for publication at top-tier scientific journals/conferences

56 talks by Topos scientists, at international top-tier venues including Johns Hopkins University, University of Cambridge, and the National Autonomous University of Mexico

5 open-source research software tools and **2** open-access data sets released, with initial users including researchers at Georgia Tech, Institute for Health Metrics and Evaluation, and the US National Institute of Standards and Technologies

More than **150** hours of scientific content, **6,000** subscribers, and **12,000** views per month freely available on our YouTube channel

49 blog posts, opening up the research process at Topos to the public in real-time

For details see: <https://topos.site/output/>



Team

Our community is our greatest asset.

Board

Ilyas Khan (chair) – CEO of Quantinuum; Leader-in-Residence, Judge Business School and Fellow of St Edmund’s College, University of Cambridge

David Spivak (secretary and treasurer) – Chief Scientist, Topos Institute

Edward Kmett – Head of Software and Fellow, Groq

Wesley Phoa – Portfolio Manager, Capital Group

Advisory Council

John Baez – Professor of Mathematics, University of California, Riverside

Eugenia Cheng – Author and Scientist-in-Residence, School of the Art Institute of Chicago

David Danks – Professor of Data Science and Philosophy, University of California, San Diego

Grace Lyo – Assistant Dean and Director of Teaching and Learning, Stanford Graduate School of Business

Lisa Raphals – Distinguished Professor of Chinese and Comparative Literature, University of California, Riverside

Dana Scott – Turing Award Laureate; Emeritus Hillman University Professor of Computer Science, Philosophy, and Mathematical Logic, Carnegie Mellon University



A picnic lunch during our all-staff retreat in April 2022

Staff

Nancy Derbish
Brendan Fong
Tim Hosgood
Sophie Libkind
Owen Lynch
Valeria de Paiva

Evan Patterson
Brandon Shapiro
Toby Smithe
David Spivak
Juliet Szatko
Patricia Tanski

Visiting Researchers

Angeline Aguinaldo
Anthony Agwu
Alejandra Arciniegas
Harrison Grodin

Michael Lambert
Joshua Meyers
David Jaz Myers
Nelson Niu

Supporters

We are grateful for the generosity, insight, and partnership of all our supporters in our shared pursuit of the Topos vision.

Donors

Founding Circle

Jaan Tallinn
Ilyas Khan
Jed McCaleb
Margaret Morgan and Wesley Phoa
—
Mark and Carrie Casey
Brendan Fong
Edward Kmett
Alan Longley
Lee Mondshein
Laura O'Brien
Daniele Palombi
Adam Pingle
Dana Scott
David Spivak
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Max Wall

Foundations and Grants

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Centre for Effective Altruism
Chevron Corporation
Defense Advanced Research Projects Agency
Foundational Questions Institute
FTX Foundation
National Science Foundation (USA)
Stanhill Foundation
Survival and Flourishing Fund

Financials

The Topos Institute was incorporated as a 501(c)(3) non-profit organization in the State of California, USA in November 2019. We have raised over USD5M since that date, with approximately 65% from competitive research grants, largely from the US Federal Government, and 35% from generous private donors. Expenses totalled USD1.2M in our 2022 financial year.

For further information, our annual Form 990 tax returns can be found on our website, or are available upon request.

Our vision at Topos is transformative: to help humanity navigate the tidal wave of complex interconnection that characterises today's world.

If we are to realize this vision, we must be ambitious. The progress this report shares is only the beginning.

The scientific community has responded to our call for collaborators across domains who can help transform our current systems, and are committed to doing so in order to enable us all to thrive. We have been able to attract some of the best minds to join us at Topos itself. At the same time, our small but committed group of donors has provided the seed funding to launch our ambitious new initiative.

We must now grow the team and the organisation purposefully, bringing in new expertise to complement our existing strengths. In the next year, we have already secured funding to bring in a new, experienced senior scientific administrator, and launch a dedicated education and outreach division.

We wish to share two further, important aspects of our vision, that we hope to build out as soon as funds allow.

First, we must grow our strengths in the humanities and public policy. The question of how to define public benefit extends beyond the realm of scientists alone: it concerns the people our work impacts, our values, and how we live them in society.

To help answer this question we have carved a role for a PhD researcher in technology ethics, to both study the ethical implications of fundamental technological research, and help form Topos' nascent culture. This is supported by world-leading ex-

pertise on our advisory council. Crucially, this additional role will ensure that our concern for ethical action and our drive to serve society are built into the core of Topos.

Second, in order to shape technologies and ultimately systems to truly benefit all, our community must represent the diverse voices and perspectives across all of society. This means Topos must be an international project: the impacts of new technology aren't limited by national borders; thus neither can our work and community.

With our strong links in the UK, including representation on our board and key staff members, the UK is the natural location for a European base for Topos. We have secured office space in Oxford, UK and, over the coming years, aim to grow this to be an active research centre alongside our Berkeley, USA office.

It is the support of the wider community that both makes this financially possible, and inspires us in our work. These initiatives have a yet-to-be-raised funding need of USD0.5M over the next year. Concurrent with these pilot initiatives, we seek to raise USD10M over the next three years to ensure Topos can grow with stability and guided only by our long-term vision and mission.

If you look toward the future, and share our vision of a world in which we are surrounded by healthy systems rather than broken ones, we invite you to join us.

Brendan Fong, CEO would be happy to discuss your involvement. He can be reached at info@topos.institute

Notes

1. *The AlgebraicJulia Project*. <https://www.algebraicjulia.org>
2. John Baez, Xiaoyan Li, Sophie Libkind, Nathaniel Osgood, Evan Patterson, *Compositional Modeling with Stock and Flow Diagrams, 5th International Conference on Applied Category Theory*. https://msp.cis.strath.ac.uk/act2022/papers/ACT2022_paper_8631.pdf
3. Sean L. Wu, Sophie Libkind, Kristopher Brown, Evan Patterson, and James Fairbanks, *Individual.jl: Rewriting individual-based models for epidemiology using graph rewriting, 5th International Conference on Applied Category Theory*. https://msp.cis.strath.ac.uk/act2022/papers/ACT2022_paper_3642.pdf
4. Evan Patterson, Andrew Baas, Timothy Hosgood, and James Fairbanks, *A diagrammatic view of differential equations in physics, Mathematics in Engineering Volume 5 Issue 2*. DOI:10.3934/mine.2023036
5. Jacob Collard, Valeria de Paiva, Brendan Fong, Eswaran Subrahmanian, *Extracting Mathematical Concepts from Text, The 8th Workshop on Noisy User-generated Text*. <https://arxiv.org/abs/2208.13830>
6. Nelson Niu, David I. Spivak, *Polynomial Functors: A General Theory of Interaction*. <https://topos.site/poly-course/>
7. Brandon Shapiro, David I. Spivak, *Dynamic categories, dynamic operads: From deep learning to prediction markets*. <https://arxiv.org/abs/2205.03906>
8. Nelson Niu and David I. Spivak, *Collectives: Compositional protocols for contributions and returns*. <https://arxiv.org/abs/2112.11518>
9. Toby St. Clere Smithe, *Compositional Active Inference I: Bayesian Lenses. Statistical Games and Compositional Active Inference II: Polynomial Dynamics. Approximate Inference Doctrines*. <https://arxiv.org/abs/2109.04461> and <https://arxiv.org/abs/2208.12173>
10. David Jaz Myers, *Categorical Systems Theory*. <http://davidjaz.com/Papers/DynamicalBook.pdf>
11. Alejandra Arciniegas and Brendan Fong, *Strategies for ethically-oriented pursuit of research and technology*. <https://topos.site/blog/2022/08/strategies-for-ethically-oriented-pursuit-of-research-and-technology/>

■ ■ A very exciting initiative at Topos Institute is its commitment to become a novel “proof of concept” for finding ways to “crack” the ethics nut. This grand vision will require funding and the right talent, but I am personally convinced that Topos Institute is the right place to make it happen. ■ ■

Dana Scott, Turing Award Laureate and Topos Senior Advisor



Topos Institute is a new independent, international, non-profit research institute.

This report highlights its activities from its launch in January 2021 until September 2022.

Topos Homepage: topos.institute

Research Homepage: topos.site