NewFoS

The Magazine

THE UNIVERSITY OF ARIZONA

New Frontiers of Sound
Science and Technology Center

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OUR FIRST WAVE: MEET NEWFOS—WHO WE ARE, WHAT WE DO, AND WHY IT'S IMPORTANT

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At NewFoS, our four levels of industry engagement are designed to accelerate knowledge transfer (KT) and rapidly translate scientific breakthroughs into new technologies.

FROM THE DIRECTOR

Welcome to the first edition of the New Frontiers of Sound (NewFoS) Magazine—a celebration of our journey, a snapshot of our progress, and a testament to the transformative power of integration.

As we reflect on our inaugural year, I am proud to share that NewFoS has laid a strong foundation for the future of topological acoustics (TA). What began as a bold vision—to integrate researchers, educators, and stakeholders into a unified force—has quickly become a vibrant, collaborative community pushing the boundaries of science, technology, and education.

Integration has been our guiding principle, and it shows in every dimension of our work. We've united teams across institutions and disciplines, launched cross-cutting research efforts, initiated novel knowledge transfer pathways, and built educational bridges to train the next generation of acoustic innovators. From theoretical breakthroughs to experimental milestones, from interactive student experiences to dynamic stakeholder engagement—Year 1 has proven that we are stronger together.

The Annual Project Report—a core element of our accountability and sustainability—captures much of what we have accomplished. This magazine offers just a glimpse into the momentum we've built. You'll find snapshots of pioneering research, inspiring educational stories, and early examples of how NewFoS is already contributing to U.S. competitiveness and societal progress. We are creating new tools, new knowledge, and most importantly, new pathways for collaboration—all essential to realizing the 10-year vision of NewFoS.

Our strength lies in our people. To our students, postdocs, faculty, staff, stakeholders, and industry partners: thank you for investing your time, ideas, and energy. Together, we are building an enduring legacy—intellectual, technological, and human—that will echo far beyond the labs and classrooms of today.

On behalf of the NewFoS leadership team—Director of KT Dr. Keith Runge, Director of Education Dr. Sara Chavarria, and co-PIs Dr. Chiara Daraio, Dr. Massimo Ruzzene, and Dr. Andrea Alù—thank you for joining us in this extraordinary endeavor.

This magazine is for you, and because of you.

Welcome to the New Frontiers of Sound.
We're just getting started.

PIERRE DEYMIER
Director of NewFoS

MEET THE CENTER LEADERSHIP TEAM

ANDREA ALÙ, CUNY

Dr. Andrea Alù, Distinguished Professor and founding director of the Photonics Initiative at CUNY, is renowned for bridging physics and electrical engineering. As an Einstein Professor and co-PI of NewFoS, his groundbreaking work in photonic metamaterials has earned him the prestigious IEEE Photonics Society William Streifer Scientific Achievement Award, celebrating his transformative contributions and visionary leadership in advancing photonics.

CHIARA DARAIO, CALTECH

Dr. Chiara Daraio, G. Bradford Jones Professor of Mechanical Engineering and Applied Physics at Caltech and co-PI of NewFoS, develops advanced materials for medical devices, robotics, and aerospace. Her innovations in acoustic imaging and thermal sensing bridge mechanics, materials science, and nanofabrication.
Committed to STEM diversity, Chiara mentors future innovators and has led initiatives supporting women in science.

MASSIMO RUZZENE, CU BOULDER

Dr. Massimo Ruzzene, Slade Professor in Engineering, Vice Chancellor for Research and Innovation, and co-PI of NewFoS, leads research on smart materials and vibration reduction for applications in transportation and structural systems. His work on "metastructures" explores new ways to mitigate vibrations and direct waves for improved performance in noise isolation and stress wave mitigation.

Driving innovation, collaboration, and vision at the forefront of topological acoustics

KEITH RUNGE, UA

Dr. Keith Runge is the Knowledge Transfer (KT) Director at NewFoS. With a Ph.D. in Physics from the University of Florida and over 20 years of industry experience, he founded and operated BWD Associates, LLC. Now, he leads efforts to achieve NewFoS's three key KT objectives: integrating research and education among members, translating breakthroughs into technologies with industry, and informing society and policymakers to address critical needs.

SARA CHAVARRIA, UA

Dr. Sara Chavarria is one of the co-Principal Investigators of NewFoS. She directs NewFoS's education and broadening participation (E&BP) initiatives, drawing on extensive NSF-funded program experience to promote equitable STEM access. The NewFoS E&BP program integrates research with education and outreach through six activities, including a convergence education program and a mentoring ecosystem.

LYNN FRAZIER, UA

Lynn Frazier is the Center Manager at NewFoS. In this role, she serves as the administrative lead. Lynn is a Certified Research Administrator with over 35 years of experience in a variety of administrative positions including providing pre-award support as a Grants and Contracts Manager for the University of Arizona Cancer Center and the College of Agriculture, Life & Environmental Sciences.

The magazi

This magazine—and many of the photos featured throughout—are part of an **ongoing effort by the Knowledge Transfer (KT) team** to share what's happening across NewFoS with our broader community.

Led by **Keith Runge** and **Araceli Hernández Granados**, the KT team has been actively documenting key moments through photos, creative content, and writing that highlight the energy, collaboration, and innovation within NewFoS.

From student highlights to research spotlights, the content in this magazine was gathered directly through our engagement with teams across institutions. It's our way of bringing the sound science of NewFoS to life and sharing it with you, our extended community of researchers, industry partners, and stakeholders.

We hope you enjoy this first edition and join us as we continue to document and celebrate what's next.

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NEWFOS: ACCELERATING INNOVATION, EDUCATION, AND COLLABORATION TO UNLOCK THE FULL POTENTIAL OF TOPOLOGICAL ACOUSTICS FOR GLOBAL IMPACT

The New Frontiers of Sound (NewFoS) Science and Technology Center (STC) founded in 2023 with a $30 million grant from the National Science Foundation, NewFoS is at the forefront of innovation, bridging research in topological acoustics to revolutionize technology, enhance daily life, and foster sustainability. The center unites leading experts from partner institutions, including **the California Institute of Technology, the City University of New York, the Georgia Institute of Technology, Spelman College, the University of Alaska Fairbanks, the University of California, Los Angeles, the University of Colorado Boulder, and Wayne State University.**

Proudly based at the University of Arizona, NewFoS is where groundbreaking research and collaboration come to life.

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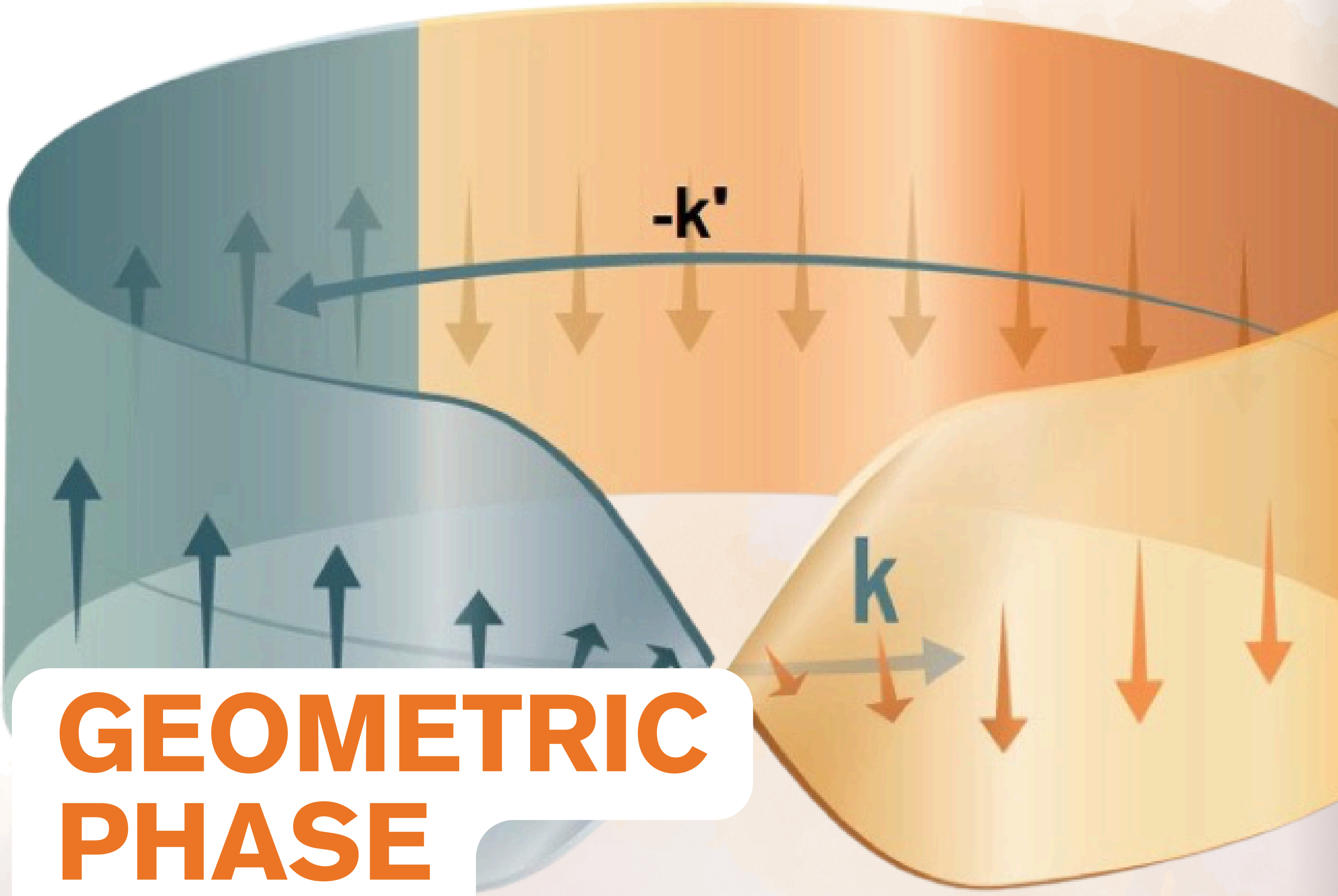


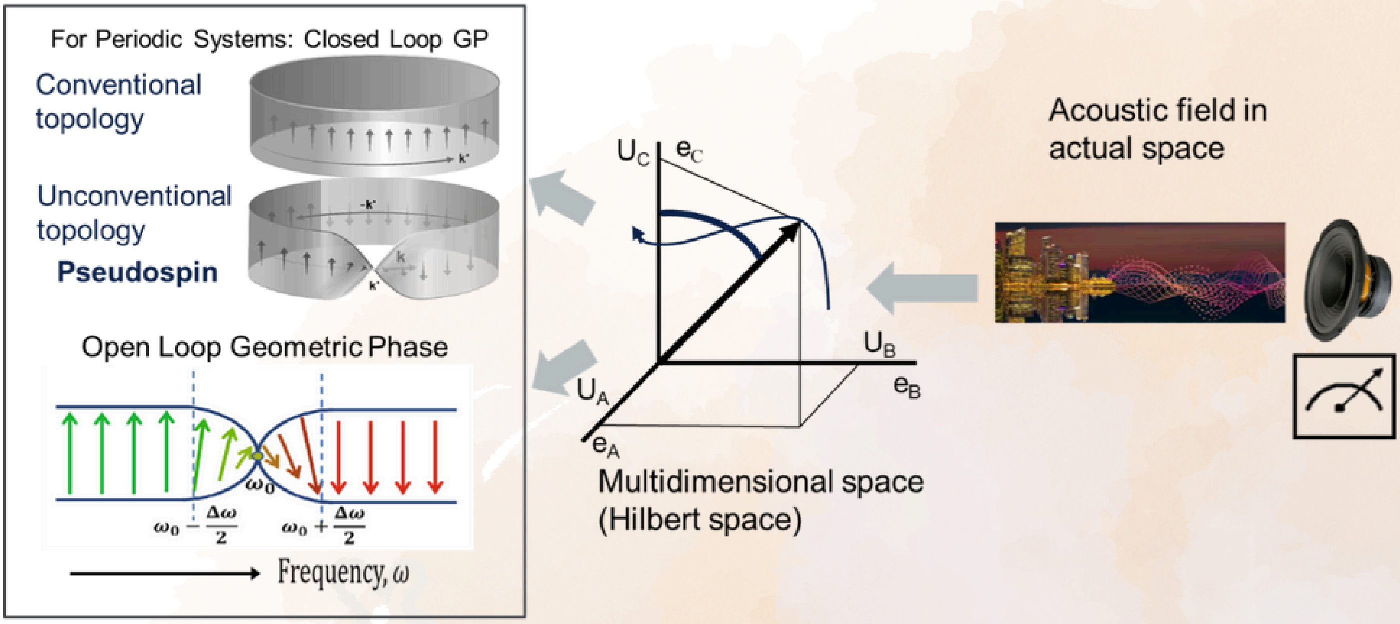
GEOMETRIC PHASE

By Keith Runge, KT director

For 150 years, sound science has given rise to indispensable technologies such as loudspeakers, microphones, radio frequency (RF) devices in smartphones, sonar, and medical ultrasound imaging.

Today, the emerging field of topological acoustics (TA) is revolutionizing sound science and advancing new frontiers. TA reveals that sound waves can now support quantum-like degrees of freedom—such as geometric phase or spin—that were previously "hidden".

NewFoS is dedicated to advancing this groundbreaking field, with applications ranging from next-generation telecommunications and medical devices to environmental sustainability. By harnessing the power of topological acoustics, NewFoS is driving technological innovation and creating a more sustainable, resilient future.



The experience of sound is ubiquitous and people easily distinguish well-known attributes of sound such as frequency (i.e., pitch) and intensity (i.e., volume). Yet while these attributes of sound or acoustic waves are familiar, sound still harbors some, as yet, underappreciated potential. Acoustic waves are always supported by a medium. For speech, the medium is air (in the vacuum of space no one can hear you speak), but acoustic waves are supported by metal rods called waveguides, acoustic devices in smartphones, airplane turbines and even the earth's crust. In the ground, acoustic waves are called seismic waves.

As waves, acoustic waves have crests and troughs, and sensors measure these waves the crest and troughs can align, they are in phase. They can be opposite each other, out of phase, or any phase arrangement in between. Changes in the shape or properties of the sound supporting medium will change these phase relationships and these changes are called changes in **geometric phase.** NewFoS researchers use the underappreciated aspect of sound, geometric phase, to fully exploit its full potential venturing into the new frontiers of sound.

LISTENING TO THE FUTURE: HOW TOPOLOGICAL ACOUSTICS IS TRANSFORMING OUR WORLD

By Samarjith Biswas, Research Scientist at NewFoS

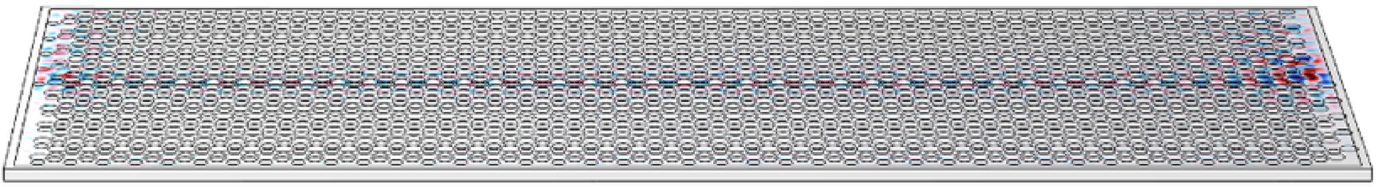
Imagine a world where sound waves can bend around corners without losing their power, where acoustic devices remain perfectly functional even when damaged, and where we can create "highways" for sound that are completely immune to interference. This isn't science fiction—it's the emerging reality of topological acoustics, a revolutionary field that's transforming how we understand and control sound.

Beyond Traditional Sound Control

For decades, engineers have struggled with a fundamental problem: sound waves are fragile. They scatter when they hit obstacles, reflect unpredictably from surfaces, and lose energy as they travel through imperfect materials[1]. Traditional acoustic devices—from concert hall designs to noise-canceling headphones—work around these limitations rather than solving them. Topological acoustics takes a radically different approach[2]. Instead of fighting the laws of physics, we're learning to bend them to our will by exploiting hidden mathematical properties of sound waves that remained invisible until recently. This field emerged from the intersection of quantum physics, materials science, and acoustic engineering, offering solutions that seemed impossible just a decade ago.

The Science Behind the Magic

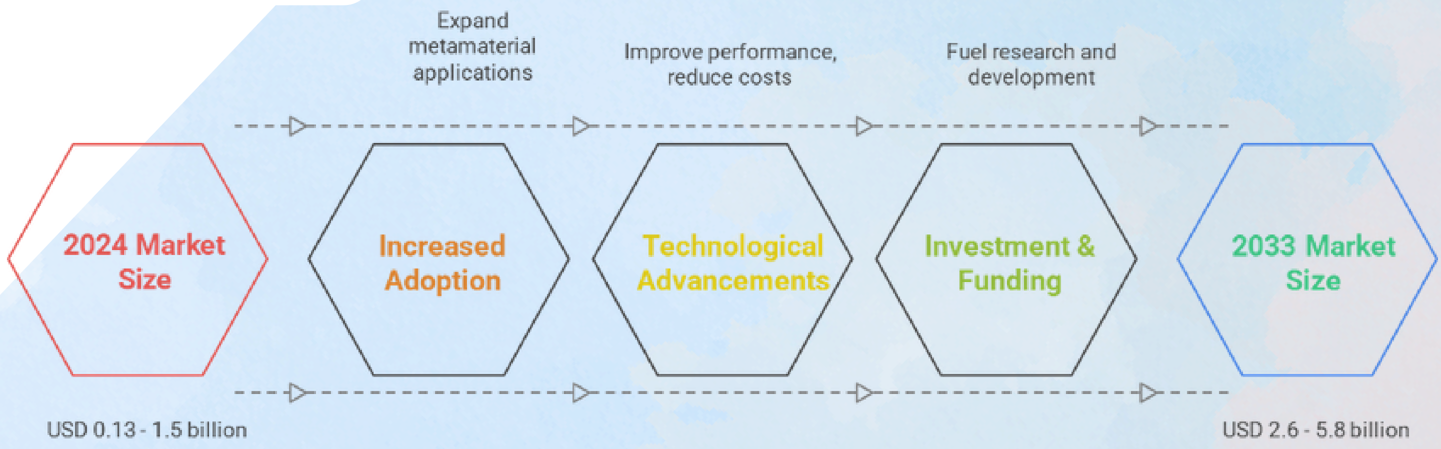
At its core, topological acoustics exploits the geometric properties of materials to create "protected" pathways for sound[3]. Think of it like building an invisible tunnel through which sound can travel, completely shielded from the chaos happening around it. These protected states aren't just theoretical curiosities—they're already being demonstrated in laboratories worldwide[4]. The fundamental mechanism relies on topological protection, where certain properties are preserved regardless of imperfections in the material structure[5]. In topological acoustic systems, sound waves can propagate along interfaces between different materials with inherent robustness against defects and disorder. This phenomenon, first demonstrated by researchers creating acoustic analogues of electronic topological insulators, enables one-way edge propagation of sound that is immune to backscattering[5].



Visualization of sound waves traveling along a topological interface in a phase-change material phononic crystal. Unlike conventional materials where sound scatters and reflects, topological acoustics creates "protected highways" for sound that maintain their integrity even when the surrounding material contains defects. The confined acoustic energy (shown in red and blue) propagates unidirectionally along the boundary between two different material regions, demonstrating the robust, backscattering-immune transport that makes topological acoustics revolutionary for next-generation communication and sensing technologies.

In my own research at NewFoS, we've been developing phononic crystals using advanced materials like phase-change glasses. These engineered structures can guide acoustic waves along specific paths with remarkable precision, maintaining their integrity even when the surrounding material is damaged or contains defects. Our recent work has shown that by carefully tuning the geometry of these crystals, we can create acoustic "switches" that route sound waves in different directions based on their frequency—like a sophisticated traffic control system for sound.

REAL-WORLD APPLICATIONS THAT MATTER



The acoustic metamaterials market shows explosive growth from 2024 to 2033, demonstrating the commercial potential of topological acoustics breakthroughs.

The applications of topological acoustics extend far beyond academic laboratories[6]. The global acoustic metamaterials market is projected to reach $5.8 billion by 2033, driven by revolutionary advances in noise control, communications, and sensing technologies[7]

REVOLUTIONARY NOISE CONTROL

Acoustic metamaterials can manipulate and control sound waves in ways that are not possible in conventional materials. These materials can selectively block specific frequencies while allowing air flow, solving long-standing challenges in automotive, aerospace, and building acoustics. Unlike traditional soundproofing that relies on bulk and weight, topological acoustic devices can achieve superior noise control in lightweight, compact formats[8] . Recent advances have demonstrated that acoustic metamaterials with periodic structures can break the mass law limit at certain frequencies, enabling high-performance sound insulation without the weight penalties of conventional materials. Companies are now commercializing metamaterial panels that control road noise and improve building acoustics using these principles.

Unbreakable Communication Systems

Researchers have successfully demonstrated acoustic topological insulators that support robust sound propagation along boundaries with inherent robustness against defects and disorders. This has profound implications for underwater communications, seismic monitoring, and even space exploration, where equipment must operate reliably in harsh, unpredictable environments[9]. Experimental work has shown that acoustic waveguide networks based on topological principles can maintain efficient and robust sound propagation even when structural components are damaged. These findings may offer unique applications for design of acoustic devices in guiding, switching, isolating, and filtering.

Climate and Environmental Monitoring

The Center's work extends to critical environmental applications using topological acoustic sensing techniques. These sensors can detect subtle changes in ground conditions that indicate climate-related infrastructure risks, potentially preventing disasters before they occur. Acoustic wave sensors are increasingly used for environmental monitoring, detecting and quantifying pollutants, gases, and substances in air, water, and soil[10].

The Quantum Connection

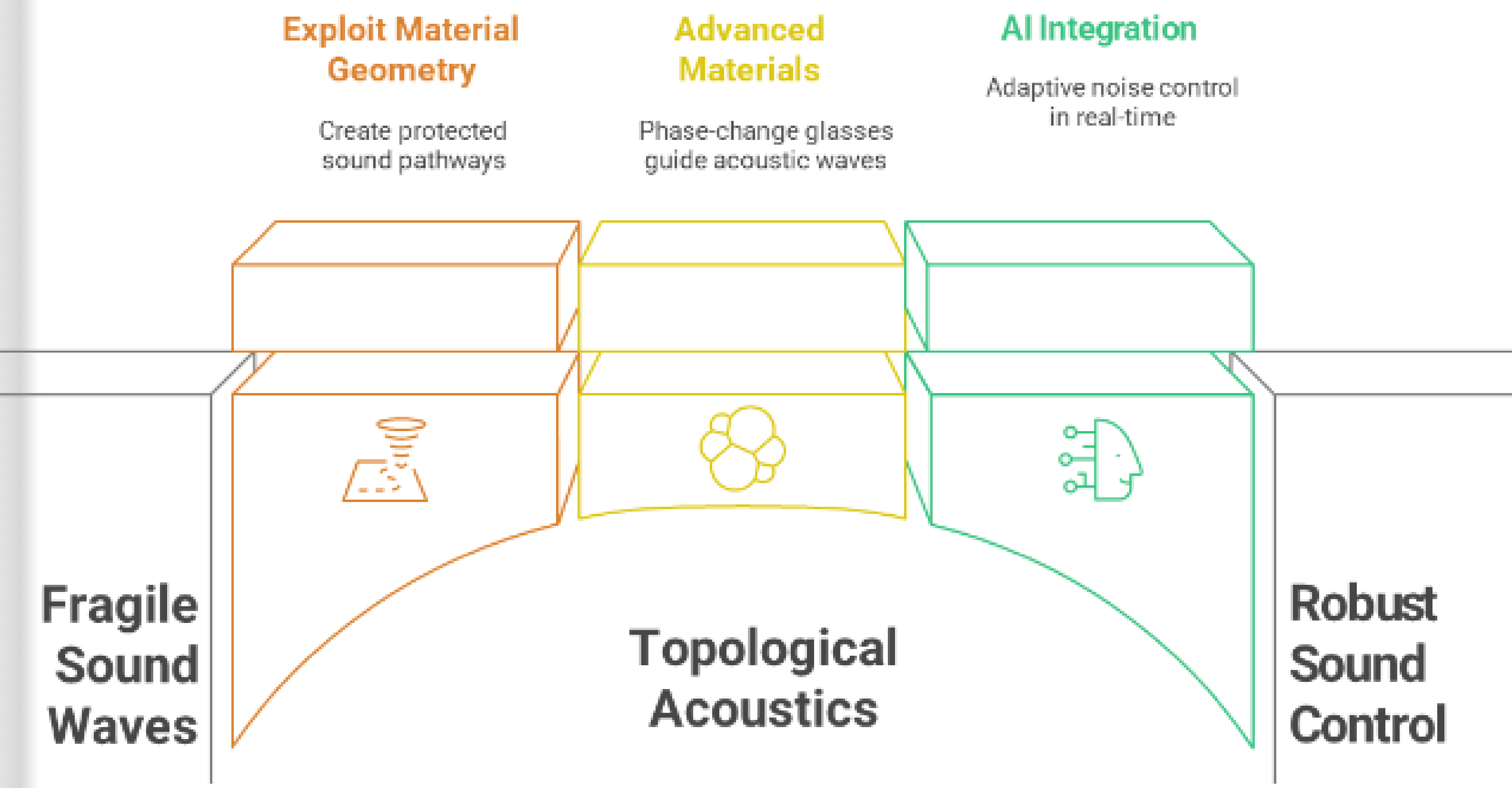
Perhaps most exciting is the potential for acoustic computing systems that rival quantum computers in processing power. NewFoS's Project 1 demonstrates how acoustic waves can do the work of quantum information processing without the time limitations and fragility of traditional quantum systems. Researchers have demonstrated the possibility for acoustic waves to do the work of quantum information processing without the time limitations and fragility of traditional quantum systems. Recent work has shown how acoustic metamaterials can support logical phi-bits, classical analogues of quantum bits, and opening pathways for digital quantum analogue computing platforms. This "quantum analogue" approach could provide the computational advantages of quantum systems without requiring the extreme conditions typically needed for quantum computers.

Breaking Down Barriers

What makes topological acoustics particularly exciting is its accessibility[11]. Unlike quantum computers that require temperatures near absolute zero, many topological acoustic devices operate at room temperature using conventional materials. This is where our phase-change material research provides a critical advantage - enabling room-temperature reconfigurability that was previously impossible. This means the technology can be deployed in everyday environments, from smartphones and hearing aids to building HVAC systems and automotive applications[12]. Recent breakthroughs have demonstrated acoustic metamaterial devices that can be 3D printed using standard materials, making customized acoustic solutions economically viable for small-scale applications. Researchers at MIT have developed new methods using 3D printing to produce metamaterials that are both strong and remarkably stretchable, utilizing microscopic double structures consisting of rigid support scaffolds and flexible networks. Topology optimization techniques are now being used to synthesize acoustic topological insulators through free material inverse design methods, with resulting structures showing high transmission and excellent field confinement. These advances democratize access to advanced acoustic technology and open possibilities we're only beginning to explore.

NewFoS's Three Transformative Projects

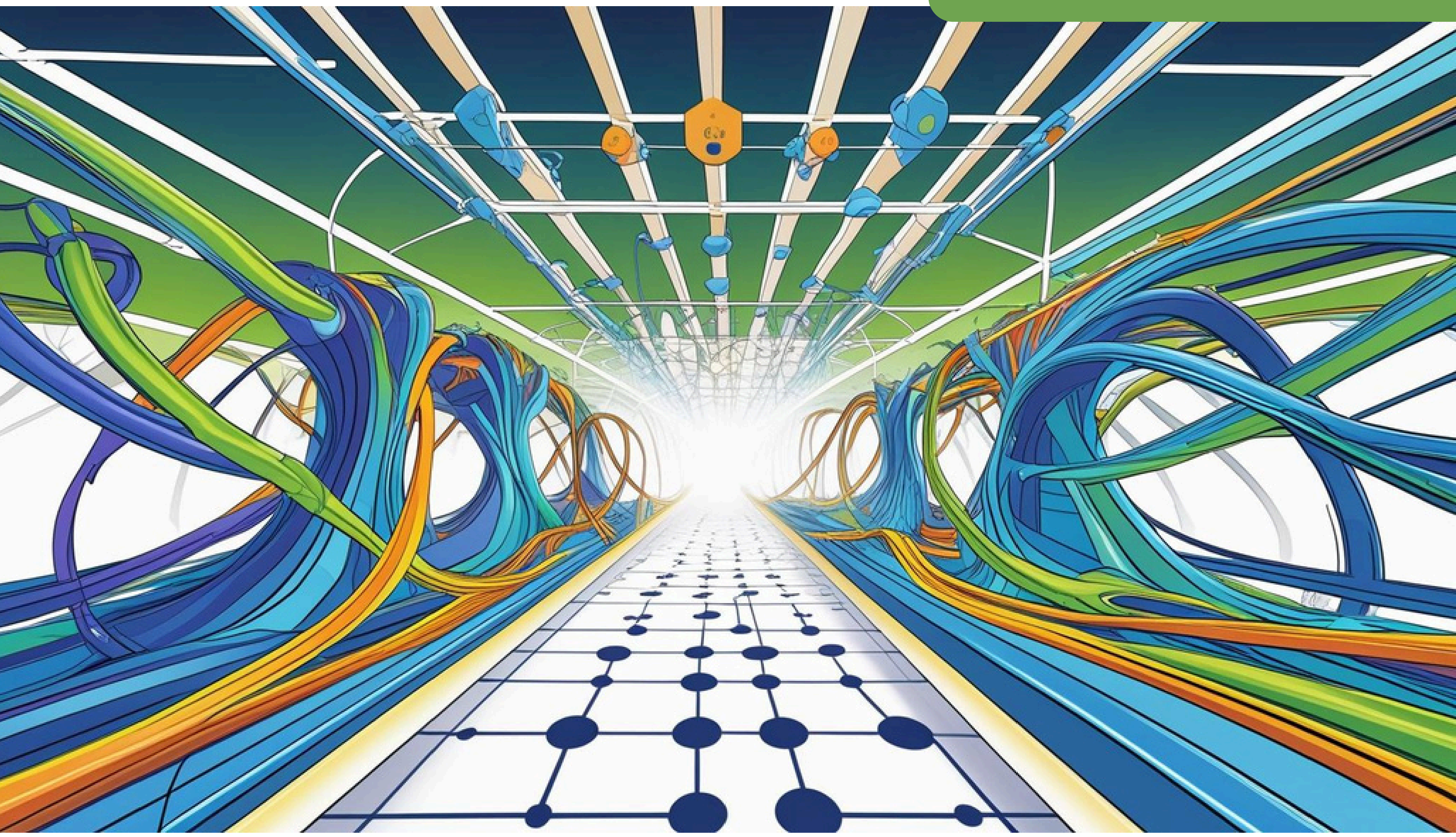
At NewFoS, we are pioneering the future of topological acoustics through three groundbreaking problem-driven projects that address grand challenges in quantum information science, telecommunications, and environmental sensing. Our research extends to advanced chalcogenide materials like Sb_2S_3 and $GeTe\text{-}Sb_2Te_3$ compounds for next-generation reconfigurable photonic and acoustic components. These materials demonstrate controllable crystallization behavior at the nanoscale, enabling switches from growth-driven to nucleation-driven crystallization in thin films. This provides more precise control essential for nonvolatile, energy-efficient acoustic integrated circuits.



How topological acoustics bridges fragile sound waves and robust sound control.

THE PATH FORWARD

The field is moving rapidly from theoretical co NewFoS's integrated approach combining qu development, and environmental sensin comprehensive effort to translate topologic real-world solutions



Academic-industry partnerships are accelerating development with researchers demonstrating free-form acoustic topological waveguides that can take arbitrary shapes and form open arcs within lattices. These advances enable more complicated functionalities such as beam splitting and provide exciting possibilities for controlling sound propagation with extraordinary robustness.

ncepts to practical devices. antum analogies, RF device g represents the most al acoustic principles into s.

Looking ahead, we envision acoustic devices that self-heal when damaged, communication systems that work reliably in any environment, and sensing technologies that can monitor everything from infrastructure health to climate change with unprecedented precision. The integration of artificial intelligence with topological acoustic systems promises even more sophisticated capabilities, including adaptive noise control that learns and responds to changing environments in real-time.

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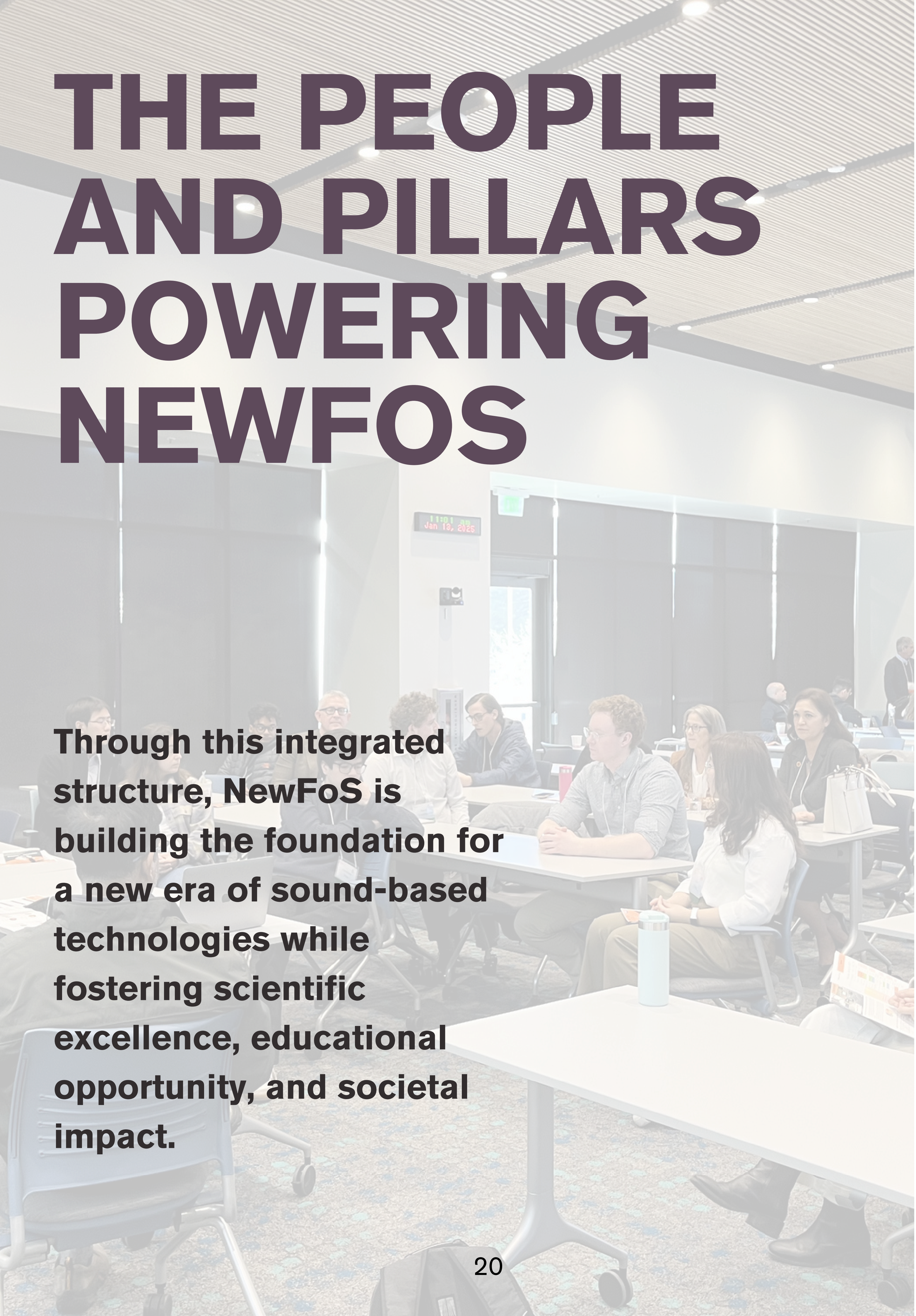

THE PEOPLE AND PILLARS POWERING NEWFOS

Through this integrated structure, NewFoS is building the foundation for a new era of sound-based technologies while fostering scientific excellence, educational opportunity, and societal impact.

The New Frontiers of Sound STC is pioneering next-generation technologies through cutting-edge research, inclusive education, and impactful knowledge transfer to industry and society.

Research is spearheaded by Center PI and Director Dr. Pierre Deymier, who leads pioneering investigations into the physics and engineering of sound with transformative potential for sensing, communication, and information processing.

- **Education and Broadening Participation efforts at NewFoS are led by Co-Principal Investigator Dr. Sara Chavarria**, who ensures that NewFoS cultivates a globally competitive next-generation workforce through innovative education, mentorship, and outreach programs.

- **Knowledge Transfer, under the leadership of Dr. Keith Runge**, bridges research and real-world application, translating scientific discoveries into technologies and practices that benefit industry and society at large.

Levels of Engagement

NewFoS is committed to fostering strong partnerships with industry through four progressive levels of engagement:

Level 1 – Stakeholder Meeting Participation

Companies can connect with NewFoS talent by attending the annual Stakeholder Meeting, beginning in Year 2. These meetings showcase the latest advances in Topological Acoustics (TA) science, with undergraduate students, graduate students, and post-docs presenting through elevator pitches, scientific talks, and poster sessions. Lightning talks within the poster session highlight the novelty and impact of research, while industry representatives provide coaching on resumes, interviews, and conducting research in industrial settings.

Level 2 – Two-Way Personnel Exchanges

NewFoS encourages knowledge transfer through personnel exchanges. A Faculty Fellow program allows NewFoS researchers to conduct R&D at partner companies, while industry researchers are invited to embed within the Center—such as through summer internships—to foster collaboration, germinate ideas, and accelerate innovation.

Level 3 – Access to Company Equipment and Facilities

While NewFoS maintains state-of-the-art facilities, some industrial partners offer unique tools and capabilities unavailable elsewhere. Examples include specialized laser-drilling machinery at AdValue Photonics, Inc., and access to 40 seismometers from the Earthscope Consortium for deployment at Murphy Dome, providing unprecedented research opportunities.

Level 4 – Industry-Funded Satellite Projects

At the highest level of engagement, industry partners can fund satellite projects that leverage NewFoS expertise for specific company interests, creating a direct avenue for innovation and applied research.

Through these structured engagement levels, NewFoS aims to create a dynamic ecosystem where academia and industry collaborate, innovate, and grow together.

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