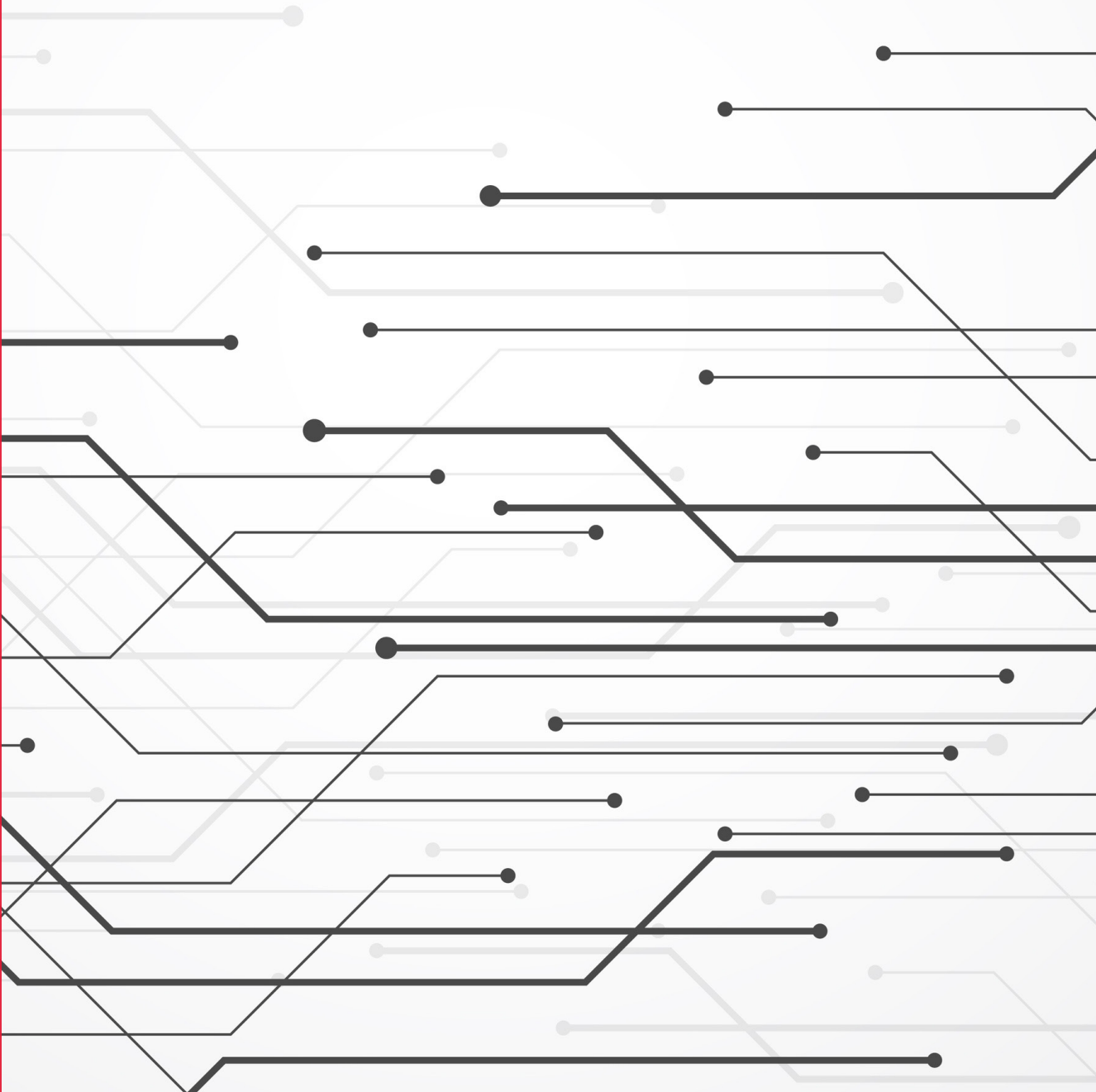




INSTITUTE FOR SYSTEMS RESEARCH

2027 - 2032 Strategic Plan



Institute for Systems Research (ISR) Strategic Plan 2027–2032

Introduction

The Institute for Systems Research (ISR) has long been recognized as a pioneering force in systems science and engineering, advancing the theoretical and methodological foundations of control, communications, networks, and autonomy, and translating these advances to address some of the most complex challenges of our time. As engineered systems grow in scale and complexity, and are increasingly shaped by advances in artificial intelligence and autonomy, semiconductor technologies, biotechnology, and quantum technologies, ISR enters its next chapter focused on advancing intelligent, data-informed, and human-centered systems with principled guarantees of performance, robustness, security, trust, and resilience. Grounded in a tradition of interdisciplinary excellence, ISR’s strategy builds on strengths across engineering, the natural sciences, computer and mathematical sciences, business, policy, and the social sciences to integrate rigorous theory with real-world system design, deployment, and impact. As the University’s engine for interdisciplinary systems research and innovation, ISR will launch strategic cross-cutting clusters, flagship interdisciplinary initiatives, and entrepreneurial pathways to accelerate impact and create a self-reinforcing flywheel of talent, partnerships, and resources.

Vision

The Institute for Systems Research aspires to be a global leader in the science and engineering of intelligent and autonomous systems. ISR advances interdisciplinary research that integrates engineering domain expertise with control, systems theory, and machine learning to enable the principled design and realization of robust, resilient, secure, trustworthy, and transformative systems.

Context and Direction

The Institute for Systems Research (ISR) drives discovery and innovation at the intersection of systems science, engineering, and intelligent computation to advance robust and resilient systems. ISR brings together interdisciplinary expertise across engineering, the natural sciences, mathematical and computer sciences, business, policy, and the social sciences. It integrates engineering domain knowledge with AI and systems theory, combining data-driven methods with algorithmic reasoning and engineering models. These capabilities enable the principled design, analysis, deployment, and scaling of complex and autonomous systems.

Operating at a time of rapid technological change and growing systemic risk, including challenges in security, trust, semiconductor systems, and biological complexity, ISR emphasizes a rigorous systems perspective spanning design, simulation, validation, and real-world deployment. Building on strengths in systems theory, control, communications, autonomy, and robotics, ISR is expanding toward next-generation intelligent systems enabled by AI, computational modeling, and human–system collaboration. Leveraging world-class experimental facilities, including the Maryland Robotics Center (MRC), the Brin Aerial Robotics Lab, the Embodied AI and Robotics Lab, the Neural Systems Lab, and cross-campus platforms such as MATRIX, AIM, and ARLIS, together with strategic partnerships and proximity to federal agencies and national laboratories in the Washington, D.C. region, ISR serves as a cross-cutting research hub. Through foundational and use-inspired research, flagship interdisciplinary initiatives, entrepreneurial pathways, and education, as described below, ISR translates rigorous theory into real-world systems with measurable societal and technological impact.

Strategic Research Domains (2027–2032)

ISR’s strategic research agenda builds on its historic strengths in systems theory, control, optimization, communications, networks, autonomy, and robotics while addressing the growing complexity, scale, and uncertainty of modern technologies. In an era shaped by rapid advances in cyber-physical systems,

semiconductor technologies, biotechnology, artificial intelligence and autonomy, quantum technologies, mobility, and global interconnectivity, ISR will lead transformative interdisciplinary research by integrating systems theory, engineering expertise, and data-driven methods to create robust, scalable systems capable of operating at national and global scale.

While expanding into new interdisciplinary frontiers listed below, ISR continues to advance cutting-edge research in its core foundational areas, including systems theory, control, optimization, communications, and network and information theory. These foundations define ISR’s intellectual core and serve as the engine for innovation across the following strategic research domains, enabling ISR to address critical challenges across technology, defense, health, infrastructure, manufacturing, sustainability, policy, and economic resilience.

1. Systems Security, Trust, and Resilience

ISR will advance the science and engineering of secure and trustworthy systems operating reliably under uncertainty, adversarial conditions, and large-scale deployment. Research includes secure system design, verification and validation, adversarial robustness, privacy-preserving systems, and resilience to cascading failures. It also includes hardware security through secure chip design, semiconductor-level protections, and hardware–software co-design. ISR will develop principled frameworks that embed trust and security as foundational properties of engineered systems.

2. Semiconductor Systems and Microelectronics Ecosystems

ISR will address system-level challenges in semiconductor technologies and microelectronics ecosystems that underpin modern computing, communications, and sensing infrastructures. The domain spans integration across devices, circuits, architectures, and systems, including heterogeneous integration and co-design. Research includes scalable architectures, manufacturing-aware system design, supply chain resilience, and emerging technologies such as AI hardware, photonic computing, and analog computing.

3. Cyber-Physical, Network, and Communication Systems

This domain addresses the design of next-generation cyber-physical, networked and communication systems that tightly integrate computation, communication, and control. Research includes resilience, scalability, and real-time adaptability, addressing cyber threats, cascading failures, and interdependent networks across energy, mobility, defense, aerospace, supply chain, and critical infrastructure. This domain will also advance next-generation communication systems (including 5G/6G and beyond), multi-agent communication, and their system-level implications, including latency, efficiency, coordination, distributed command and control, spectrum sharing, and large-scale networked operations.

4. Neuroscience and Systems Biology

This domain advances the understanding and engineering of complex biological systems through systems-level modeling, analysis, and design. This domain focuses on neural systems, systems biology, and the interaction between engineered systems and biological processes. Research includes multi-scale modeling, sensing and actuation in biological environments, and closed-loop systems for monitoring and intervention.

5. Intelligent Autonomous Systems, Robotics & Agentic AI

ISR will lead research on intelligent and autonomous systems that sense, learn, reason, and act in complex and uncertain environments. Research spans agentic AI, embodied intelligence, physical AI, robotics, multi-agent coordination, learning-enabled control, and human–machine interaction. Through real-world experimentation and system-level rigor, ISR will establish new foundations for safe, trustworthy, and human-aligned autonomy across physical and digital domains.

6. Human-Centered & Socio-Technical Systems

ISR will advance research on systems that integrate humans, machines, and complex organizations. Research includes trust, transparency, human–machine teaming, decision-making, and policy and governance considerations to ensure intelligent systems augment human expertise and agency. ISR will advance responsible, interpretable, and human-aligned socio-technical systems across healthcare, security, education, and emergency response.

7. Sustainable and Resilient Systems: Energy Efficiency, Power Delivery Solutions, and Infrastructure Technologies

ISR will pioneer systems-level approaches to sustainability, resilience, and energy efficiency across infrastructure, energy, computing, and environmental systems. Research includes resilient infrastructure, semiconductor technologies, energy management, and secure power delivery aligned with national priorities. This domain will further emphasize advanced computing hardware systems, packaging innovations and heterogeneous integration, power delivery and thermal management, and system-level design methodologies.

8. Robust AI Engineering & Foundations

This domain advances the science and engineering of reliable, controllable, and scalable AI systems grounded in systems theory and engineering principles. This domain focuses on accuracy, generalizability, robustness, efficiency, verification, safety, and lifecycle assurance, as well as on domain-aware foundation models and generative AI methods that accelerate scientific discovery and engineering innovation. Robust AI engineering will serve as a cross-cutting capability supporting all ISR research domains.

Innovation Strategy Recommendations and Next Steps

The Institute for Systems Research (ISR) positions itself as the engine of interdisciplinary systems research and innovation across the University of Maryland and its partners. Building on its research strengths, ISR will expand its role as a cross-campus catalyst by integrating engineering and scientific rigor with human-centered, societal, and policy perspectives to deliver meaningful, high-impact outcomes. ISR will drive impact through four complementary and interrelated mechanisms.

(1) Cross-cutting research clusters connect faculty across disciplines into agile teams aligned with ISR’s strategic research domains listed above and evolve dynamically as resources and opportunities emerge. Each cluster serves as an innovation incubator, generating pilot projects, domain-specific strategic plans, publications, and competitive proposals. As clusters mature, they will pursue center-level funding to support collaborative research and platform development.

(2) Flagship interdisciplinary research initiatives that operate as open-innovation platforms for system-level experimentation and demonstration. Built on ISR’s strategic research domains and supported by targeted seed funding and ISR PhD fellowships, these initiatives are designed to address emerging industry and societal needs, build momentum, and scale impact through a self-reinforcing cycle of success, partnerships, and resources. They position ISR to pursue and secure large-scale, center-level funding from federal agencies, industry, and philanthropic partners.

(3) Infrastructure and research execution capacity strengthened by leveraging world-class facilities, cross-campus platforms, and external partnerships to enable rapid prototyping, integrated experimentation, and technology translation;

(4) Entrepreneurial and translational pathways that support the transition from research to practice through industry engagement, venture creation, and validated deployment pathways.

As a strategic enabler across ISR and the College of Engineering, ISR will establish the AI Engineering initiative as a shared institutional capability for building AI engineering capacity across the College of

Engineering. The initiative will advance the rigor, reliability, and scalability of AI-enabled systems by providing shared expertise, platforms, and best practices that support the integration of AI into diverse engineering research agendas. Operating collaboratively with other campus AI efforts, including the Artificial Intelligence Interdisciplinary Institute at Maryland (AIM) and the Center for AI in Business at the UMD Smith School of Business, the initiative will align and amplify complementary strengths across campus. Through these collaborations, the initiative will help scale individual research efforts into large, coordinated, cross-disciplinary sponsored programs and strengthen UMD's leadership in AI engineering.

Together, these mechanisms establish a dynamic innovation ecosystem that accelerates the translation of discovery into durable societal and economic impact.

Flagship Interdisciplinary Initiatives

ISR will launch several flagship cross-cutting initiatives as long-term research and experimentation platforms that unite faculty, students, and external partners across its strategic research domains. These initiatives will demonstrate how advances in autonomy, robotics, control, communications, optimization, machine learning, power electronics, and systems theory translate into real-world impact across healthcare, defense, energy, infrastructure, manufacturing, sustainability, finance, and advanced computing with increasing emphasis on security, trust, and scalable system integration. Each initiative will operate as an open research and innovation ecosystem, centered on shared research platforms, real-world experimentation, and integrated system prototypes and demonstrations, enabling sustained, collaborative, and cumulative research and serving as anchors for funding, partnerships, and translation, while also advancing scientific discovery, workforce development, and ISR's national leadership in systems science and engineering.

1. Healthcare Assistive & Intelligent Systems

This initiative will advance networked, assistive, autonomous, and intelligent systems for healthcare and biomedical applications, including physical and virtual assistants. It will integrate ISR strengths in sensing, signal processing, robotics, autonomy, communications, control, neuroscience, systems biology and human-machine interaction, leveraging partnerships with the Maryland Robotics Center (MRC), AIM, the Institute for Health Computing (IHC), and collaborations with the School of Medicine (UMSOM) and the Clark School of Engineering. The platform will emphasize safe, practical assistance in home and clinical settings while serving as a training ground for interdisciplinary teams at the intersection of engineering, AI, and healthcare. It will also incorporate systems-level approaches to biological modeling, sensing, and intervention, aligned with emerging directions in neuroscience and systems biology.

2. Agentic AI & Multi-Agent Autonomy

This initiative will advance agentic AI, embodied intelligence, robotics, and multi-agent systems to enable coordinated and resilient autonomy across cyber-physical and virtual environments. Building on ISR leadership in control, distributed AI, robotics, and autonomy, and leveraging MATRIX Lab, ARLIS, AIM, MRC, and aerospace research labs, the platform will address large-scale coordination, human-agent teaming, system security, trust, verification, and resilience in contested environments, as well as the role of next-generation communication systems in enabling distributed autonomy. The initiative will serve as a national research resource through collaborations with DoD, NASA, DHS, and national laboratories.

3. Resilient Infrastructure Systems: Extreme Systems Design

This initiative will pursue extreme systems thinking to design high-performance, energy-efficient, and resilient national-scale infrastructures spanning computing, energy, mobility, logistics, supply chains, and communications. ISR will integrate strengths across networking, distributed systems, power and energy, and systems engineering, leveraging partnerships with CALCE, CATT Lab, the UMD Power Electronics Lab, the Quantum Computing Center, the Chips and Semiconductor Initiatives, the Industrial AI Lab,

civil and environmental engineering labs, and the Smith School of Business. Emphasis includes extreme co-design for AI factories; resilience and lifecycle optimization of national-scale infrastructure; advanced semiconductor systems, packaging and heterogeneous integration, and power-delivery technologies; digital twins; and hybrid quantum–classical computing.

4. Robust AI Engineering for Science & Engineering Innovation

This initiative will advance robust, controllable, and scalable AI systems, **including considerations of system security, trust, and lifecycle assurance**, for engineering innovation, scientific discovery, and industry-relevant applications. Grounded in systems theory and engineering rigor, and leveraging AIM, CML, MATRIX Lab, ARLIS, MRC, and cross-campus partnerships, the platform will develop domain-aware foundation models, robust generative AI methods, and human–AI collaboration and decision-support capabilities. The initiative will establish principled pathways from foundational research to validated, high-impact AI-enabled systems and technologies at scale.

Implementation and Impact

ISR’s initiatives will be led by interdisciplinary faculty teams and ISR Graduate Fellows spanning multiple departments, colleges, and research centers, supported by dedicated graduate and postdoctoral cohorts focused on shared research platforms, real-world experimentation, and integrated system prototypes. These initiatives will leverage ISR’s shared infrastructure, including robotics and autonomy laboratories, AI computing resources, and integration testbeds, together with cross-campus and external partnerships, to pursue joint funding from federal agencies, industry, and philanthropic organizations. Annual progress and impact reports will track advances in research excellence, technology translation, partnerships, talent development, and educational innovation, ensuring sustained and measurable impact.

Education, Training, and Workforce Development

ISR will expand its educational impact by strengthening degree and certificate programs and developing interdisciplinary curricula, hands-on research experiences, and workforce pathways that prepare students to design and deploy intelligent and autonomous systems in real-world environments. Leveraging ISR facilities through project-based learning in flagship initiatives and industry collaboration, ISR will equip students to invent, prototype, and engineer the next generation of intelligent systems and technologies.

Conclusion

As the scale, complexity, and societal significance of engineered systems continue to grow, further amplified by advances in artificial intelligence and autonomy, semiconductor technologies, and biotechnology, the Institute for Systems Research is well positioned to lead the development of the scientific, engineering, and methodological foundations required to design, analyze, and deploy complex and autonomous systems at scale. By advancing foundational systems science, pioneering interdisciplinary research platforms, and cultivating the next generation of systems thinkers and innovators, ISR will address both the opportunities and challenges of these systems, with a focus on robustness, resilience, security, human alignment, and trust. Through principled engineering, responsible innovation, and deep collaboration across disciplines and sectors, ISR will strengthen the University of Maryland’s position as a global leader in shaping advanced systems and technologies that address critical technological and societal needs at national and global scale.