A 5-Year Strategic Vision

The Elisha Yegal Bar-Ness Center for Machine Intelligence, Signal Processing, and Communications (MICS)
(formerly the Elisha Yegal Bar-Ness Center for Wireless Information Processing, CWiP)

New Jersey Institute of Technology

Dr. Joerg Kliewer, Director

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1 Executive Summary

The Elisha Yegal Bar-Ness Center for Machine Intelligence, Signal Processing, and Communications (MICS) is a recently reorganized research center at the New Jersey Institute of Technology (NJIT). As the successor to the Center for Wireless Information Processing (CWiP), MICS is strategically repositioned to address the growing importance of artificial intelligence and machine learning in modern information and communication systems.

This document outlines a five-year strategic vision for MICS. Our vision is to become a nationally recognized center of excellence that contributes to the theoretical foundations and practical applications of next-generation intelligent systems. Our mission is to conduct high-impact research, provide a high-quality educational environment for students, and build strong collaborative ties with industry and government partners.

The center's research will be focused on three synergistic pillars:

1. **Trustworthy AI and Machine Learning:** Developing robust, safe, and private learning algorithms, with a focus on safe reinforcement learning, privacy-preserving distributed learning, and causal inference.

2. **Intelligent Communication and Networking (6G & Beyond):** Researching AI-native networks, semantic communication, and the intelligent management of future wireless systems.

3. **Information, Learning, and System Dynamics:** Exploring the theoretical foundations of private learning and computation, information theory, the dynamics of information flow in complex systems, and modern signal processing.

With an experienced faculty, the addition of new researchers in critical AI fields, and a strong legacy of innovation, MICS is well-positioned to make significant contributions. This document details our strategic goals for research, education, and collaboration that will guide the center's growth.

2 Introduction

For decades, the Elisha Yegal Bar-Ness Center for Wireless Information Processing (CWiP) has been a key part of the research environment at NJIT, contributing to wireless communications and signal processing. The technological landscape is now experiencing a significant shift, driven by the advance of Artificial Intelligence (AI) and Machine Learning (ML). To address this, the center has been reorganized as the Elisha Yegal Bar-Ness Center for Machine Intelligence, Signal Processing, and Communications (MICS).

The motivation for this strategic shift is supported by clear economic and technological trends. The global economy is projected to see a significant impact from AI, with estimates suggesting a contribution of over $15 trillion by 2030 [1]. This growth is mirrored by an explosion in data generation and traffic. Global mobile data traffic alone is forecast to grow by about 20% per year through the end of the decade, reaching hundreds of exabytes per month [2]. These trends create both a challenge and an opportunity: a need for intelligent systems to manage this complexity and a demand for the foundational research that makes those systems possible.

This strategic plan serves as a roadmap for MICS for 2026–2030. It redefines our research focus to align with these challenges. Our core philosophy is that progress requires the holistic integration of learning, communication, and computation. This document articulates our strategy to contribute to these key emerging areas, educate the next generation of engineers, and translate our research into practice.

3 Vision and Mission

3.1 Vision Statement

To be a nationally recognized research center that makes significant contributions to the theory and application of intelligent information systems.

3.2 Mission Statement

The mission of MICS is to:

- **Advance Research:** Conduct fundamental and applied research at the intersection of machine learning, communications, and signal processing.
- **Educate Students:** Provide a high-quality educational experience for graduate students through advanced courses and hands-on research.
- **Foster Collaboration:** Build a collaborative network of faculty, students, industry, and government partners to support research and technology transfer.
- **Serve as a Resource:** Act as a center of expertise for NJIT and the broader technical community.

4 Core Research Areas

The research agenda of MICS is structured around three interconnected pillars. These pillars leverage our existing strengths in communications and information theory while focusing on the clear growth areas of AI and data science.

4.1 Pillar 1: Trustworthy AI and Machine Learning

The widespread adoption of AI is increasingly dependent on its trustworthiness. AI failures can lead to significant harm, financial loss, and erosion of public trust [3]. The market for AI trust, risk, and security management is projected to grow accordingly, reaching over $8 billion by 2032 [4]. Given these high stakes, a purely performance-driven approach to AI development is insufficient. To unlock the enormous economic and social benefits of AI, we must first ensure that it is reliable and safe. This pillar is therefore dedicated to developing the fundamental science and algorithmic frameworks for AI systems that are safe, robust, and private.

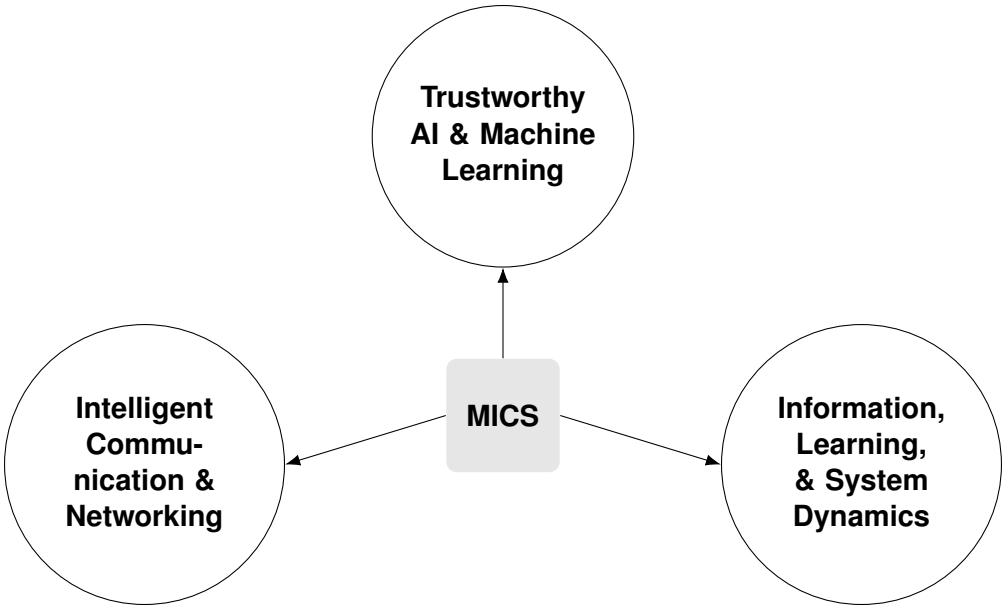


Figure 1: The research pillars of the MICS Center.

Research Thrusts:

- **Assured Autonomy with Safe and Interactive Learning:** We are developing the next generation of reinforcement learning (RL) algorithms that can operate safely in dynamic and uncertain environments. This includes designing RL systems with formal safety guarantees, enabling them to learn in high-stakes applications such as autonomous driving and robotic control without catastrophic failures. A key focus is on multi-agent learning and decision-making, where multiple AI agents must coordinate and compete, as well as on developing algorithms that are robust to unforeseen circumstances.

- **Privacy-Preserving Distributed Intelligence:** Our research focuses on designing federated and distributed learning frameworks that leverage principles from information theory and secure computation. This enables collaborative AI, where multiple parties can train models on their combined data without compromising the privacy of their individual datasets. We are creating algorithms that are resilient to data heterogeneity and adversarial attacks, ensuring both privacy and robustness in distributed settings.

- **Interpretable and Causal AI:** We are moving beyond models that only capture statistical correlations to build systems that understand causal relationships. This involves developing techniques for causal discovery from observational and interventional data, allowing us to build more robust and explainable AI systems. By understanding the "why" behind these systems, we can create models that are more reliable and less prone to spurious correlations, which is critical, for example, in healthcare, finance, and public policy.

4.2 Pillar 2: Intelligent Communication and Networking (6G & Beyond)

Future wireless networks must manage immense complexity. As noted above, mobile data traffic is expected to grow substantially through the end of the decade, with 5G networks forecast to carry about three quarters of it by the end of 2029 and 6G networks to follow [2]. This growth in scale and demand renders traditional, manually configured network management unsustainable. A new paradigm is required. This pillar is focused on developing intelligent and AI-native systems that can autonomously manage the complexity of these future networks, ensuring they are efficient, resilient, and responsive.

Research Thrusts:

- **AI-Native Network Fabrics:** Researching architectures where ML is a core component of the network stack for resource allocation, routing, and self-organization.
- **Semantic and Goal-Oriented Communication:** Investigating a paradigm shift from transmitting bits to transmitting meaning, allowing networks to discard irrelevant data at the source for significant efficiency gains.
- **Large-Scale Network Intelligence:** Developing AI-driven techniques for managing the complexity of future networks, including predictive quality-of-service and anomaly detection.

4.3 Pillar 3: Information, Learning, and System Dynamics

This pillar focuses on the theoretical foundations of information, learning, and complex systems. As engineered systems become more data-driven and interconnected, progress is often limited not by hardware capabilities but by our fundamental understanding of the principles governing these systems. A deep theoretical understanding is therefore a prerequisite for enabling the next generation of intelligent technologies. This research provides the essential tools, insights, and performance benchmarks that underpin the applied work in the other two pillars, creating a durable scientific foundation for the center's activities.

Research Thrusts:

- **The Fundamental Limits of Private Learning:** We investigate the theoretical trade-offs between privacy, accuracy, and efficiency in machine learning. This includes establishing fundamental limits on what is learnable under privacy constraints and developing algorithms that achieve these limits. Our work provides a rigorous foundation for the design of privacy-preserving machine learning systems, ensuring that they are both effective and secure.
- **The Dynamics of Information in Complex Systems:** We are developing novel models to understand the flow of information in complex, large-scale systems, including social, biological, and engineered networks. A key focus is on learning network structures from observational data, also known as causal graph discovery, which allows us to uncover hidden relationships and influence pathways. This research enables us to predict and control

the behavior of these systems, with applications ranging from understanding the spread of information in social networks to designing resilient communication systems.

- **Data Science and Modern Signal Processing:** This thrust is focused on the algorithmic core of signal processing, with an emphasis on developing novel, data-driven techniques for extracting meaningful information from high-dimensional and unstructured signals. We are creating new algorithms for problems such as blind signal separation, dictionary learning, and compressed sensing, with a focus on methods that are scalable, robust, and require minimal prior information. This work is critical for a wide range of applications, from wireless communications to medical imaging.

5 Strategic Goals (2026–2030)

To realize our vision, MICS will pursue the following strategic goals over the next five years:

5.1 Goal 1: Achieve National Research Leadership

- **Objectives:**
  - Increase publications in premier venues (e.g., NeurIPS, ICML, ICLR, IEEE Transactions and Journals).
  - Secure at least one large-scale, multi-PI, center-level grant from federal agencies such as NSF, DoD, and NIH.
  - Grow annual research expenditures to $1–1.5 million by 2030.
  - Establish a distinguished seminar series featuring leading researchers.

5.2 Goal 2: Foster Excellence in Education

- **Objectives:**
  - Increase the number of Ph.D. students affiliated with the center to 15–20.
  - Investigate opportunities to organize a Summer Research Institute for undergraduates as a potential pipeline for graduate studies.
  - Maintain a strong placement record for Ph.D. graduates in academic and industrial research positions.
- **Integrated Curriculum and Teaching Coordination:** A key goal is to create a more cohesive educational experience. We will explore opportunities to update our graduate curriculum to reflect the interdisciplinary nature of MICS. This could involve developing "MICS Research & Course Tracks" in our core research areas. We will also investigate possibilities for coordinating teaching schedules and cross-listing relevant courses to better serve our students.

5.3 Goal 3: Build Strong Industrial Partnerships

- **Objectives:**
  - Seek to establish a sustainable level of industry funding for joint research projects.
  - Host a biennial MICS Industrial Summit to showcase research and facilitate networking.
  - Increase the number of patents and technology licenses originating from the center.
- **Fostering Local Industrial Synergy:** MICS is located within a major industrial ecosystem. Our strategy includes strengthening our role as an academic partner for technology companies in the New York/New Jersey region. We will continue to build collaborative relationships with key sectors:
  - **Telecommunications:** Engaging with industry leaders such as **Verizon** and **Nokia Bell Labs** to contribute to the future of 6G and AI-native networking.
  - **Finance and FinTech:** Partnering with the NYC FinTech sector to develop AI for applications in financial services.
  - **Pharmaceuticals and Healthcare:** Collaborating with New Jersey's large pharmaceutical sector to apply ML and systems analysis to problems in computational biology and healthcare informatics.

6 Faculty and Expertise

The faculty of MICS provides the expertise to pursue the center's research agenda.

- **Dr. Joerg Kliewer (Director), Professor**: Dr. Kliewer's research is in the area of information theory, with a focus on privacy-preserving machine learning, secure computation, and channel coding. His work addresses the fundamental trade-offs between privacy, utility, and communication complexity in distributed learning and data analysis.
- **Dr. Ali Abdi, Professor**: Dr. Abdi's expertise is in wireless communications, signal processing, and the analysis of complex biological and communication systems. His research includes channel modeling, parameter estimation, and the application of signal processing techniques to biological networks.
- **Dr. Hongya Ge, Associate Professor**: Dr. Ge's research interests include statistical and array signal processing, wireless communications, and space-time multiuser detection. Her work focuses on developing advanced signal processing techniques for next-generation wireless systems.
- **Dr. Arnob Ghosh, Assistant Professor**: Dr. Ghosh is an expert in safe reinforcement learning, deep learning theory, and assured autonomy. His research focuses on developing learning algorithms that can operate safely and reliably in high-stakes, dynamic environments, with a particular emphasis on multi-agent systems and robust decision-making under uncertainty.

- **Dr. Alexander Haimovich, Distinguished Professor Emeritus**: Dr. Haimovich has made foundational contributions to radar systems, localization, and MIMO communications. His research focuses on statistical and array signal processing, with a particular emphasis on developing new techniques for target detection and tracking.

- **Dr. Anirudh Sridhar, Assistant Professor**: Dr. Sridhar's research interests are in network analysis, causal inference, and the dynamics of complex spreading processes. He develops novel methods for learning network structures from observational data, also known as causal graph discovery, which allows us to uncover hidden relationships and influence pathways. His work combines tools from information theory, probability, and statistics to analyze the flow of information in large-scale networks.

7 Conclusion

The reorganization of the center as MICS represents a strategic response to major trends in technology. By focusing on the integration of machine learning with communications and signal processing, MICS is positioned to contribute to key areas of innovation. The goals laid out in this plan provide a roadmap for increasing research output, training students, and building a lasting impact on technology and industry.

References

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