Critical Grand Challenges
for
Technology Innovation Partnership

Atam P Dhawan, PhD

Interim Provost

Senior Vice Provost for Research

Distinguished Professor, Electrical and Computer Engineering

New Jersey Institute of Technology

United Nations 17 Sustainable Development Goals

United Nations 17 Sustainable Development Goals

- GOAL 1: No Poverty
- GOAL 2: Zero Hunger
- GOAL 3: Good Health and Well-being
- GOAL 4: Quality Education
- GOAL 5: Gender Equality
- GOAL 6: Clean Water and Sanitation
- GOAL 7: Affordable and Clean Energy
- GOAL 8: Decent Work and Economic Growth
- GOAL 9: Industry, Innovation and Infrastructure
- GOAL 10: Reduced Inequality
- GOAL 11: Sustainable Cities and Communities
- GOAL 12: Responsible Consumption and Production
- GOAL 13: Climate Action
- GOAL 14: Life Below Water
- GOAL 15: Life on Land
- GOAL 16: Peace and Justice Strong Institutions
- GOAL 17: Partnerships to achieve the Goal

https://www.un.org/sustainabledevelopment/sustainable-development-goals/

United Nations 17 Sustainable Development Goals

GOAL 1: NO POVERTY
GOAL 2: ZERO HUNGER
GOAL 4: QUALITY EDUCATION
GOAL 5: GENDER EQUALITY
GOAL 8: DECENT WORK AND ECONOMIC GROWTH
GOAL 10: REDUCED INEQUALITY
GOAL 16: PEACE AND JUSTICE STRONG INSTITUTIONS

SDG 6: CLEAN WATER AND SANITATION
SDG 7: AFFORDABLE AND CLEAN ENERGY
SDG 11: SUSTAINABLE CITIES AND COMMUNITIES
RENEWABLE ENERGY
SUSTAINABLE MODE OF TRANSPORTATION
SDG 13: CLIMATE ACTION
GREENHOUSE EMISSION

GOAL 3: GOOD HEALTH AND WELL-BEING
GOAL 14: LIFE BELOW WATER
GOAL 15: LIFE ON LAND

SDG 9: INDUSTRY, INNOVATION, AND INFRASTRUCTURE
GOAL 12: RESPONSIBLE CONSUMPTION AND PRODUCTION
GOAL 17: PARTNERSHIPS TO ACHIEVE THE GOAL

NAE Engineering Grand Challenges: 1-6

ADVANCE PERSONALIZED LEARNING

A growing appreciation of individual preferences and aptitudes has led toward more “personalized learning,” in which instruction is tailored to a student’s individual needs. Given the diversity of individual preferences, and the complexity of each human brain, developing teaching methods that optimize learning will require engineering solutions of the future.

MAKE SOLAR ENERGY ECONOMICAL

Currently, solar energy provides less than 1 percent of the world's total energy, but it has the potential to provide much, much more.

ENHANCE VIRTUAL REALITY

Within many specialized fields, from psychiatry to education, virtual reality is becoming a powerful new tool for training practitioners and treating patients, in addition to its growing use in various forms of entertainment.

REVERSE-ENGINEER THE BRAIN

A lot of research has been focused on creating thinking machines—computers capable of emulating human intelligence—however, reverse-engineering the brain could have multiple impacts that go far beyond artificial intelligence and will promise great advances in health care, manufacturing, and communication.

ENGINEER BETTER MEDICINES

Engineering can enable the development of new systems to use genetic information, sense small changes in the body, assess new drugs, and deliver vaccines to provide health care directly tailored to each person.

ADVANCE HEALTH INFORMATICS

As computers have become available for all aspects of human endeavors, there is now a consensus that a systematic approach to health informatics - the acquisition, management, and use of information in health - can greatly enhance the quality and efficiency of medical care and the response to widespread public health emergencies.

NAE Engineering Grand Challenges: 7-14

RESTORE AND IMPROVE URBAN INFRASTRUCTURE

Infrastructure is the combination of fundamental systems that support a community, region, or country. Society faces the formidable challenge of modernizing the fundamental structures that will support our civilization in centuries ahead.

SECURE CYBERSPACE

Computer systems are involved in the management of almost all areas of our lives; from electronic communications, and data systems, to controlling traffic lights to routing airplanes. It is clear that engineering needs to develop innovations for addressing a long list of cybersecurity priorities

PROVIDE ACCESS TO CLEAN WATER

The world's water supplies are facing new threats; affordable, advanced technologies could make a difference for millions of people around the world.

PROVIDE ENERGY FROM FUSION

Human-engineered fusion has been demonstrated on a small scale. The challenge is to scale up the process to commercial proportions, in an efficient, economical, and environmentally benign way.

PREVENT NUCLEAR TERROR

The need for technologies to prevent and respond to a nuclear attack is growing.

MANAGE THE NITROGEN CYCLE

Engineers can help restore balance to the nitrogen cycle with better fertilization technologies and by capturing and recycling waste.

DEVELOP CARBON SEQUESTRATION METHODS

Engineers are working on ways to capture and store excess carbon dioxide to prevent global warming.

ENGINEER THE TOOLS OF SCIENTIFIC DISCOVERY

In the century ahead, engineers will continue to be partners with scientists in the great quest for understanding many unanswered questions of nature.

MIT-Gates Foundation: Technology Review (2019)

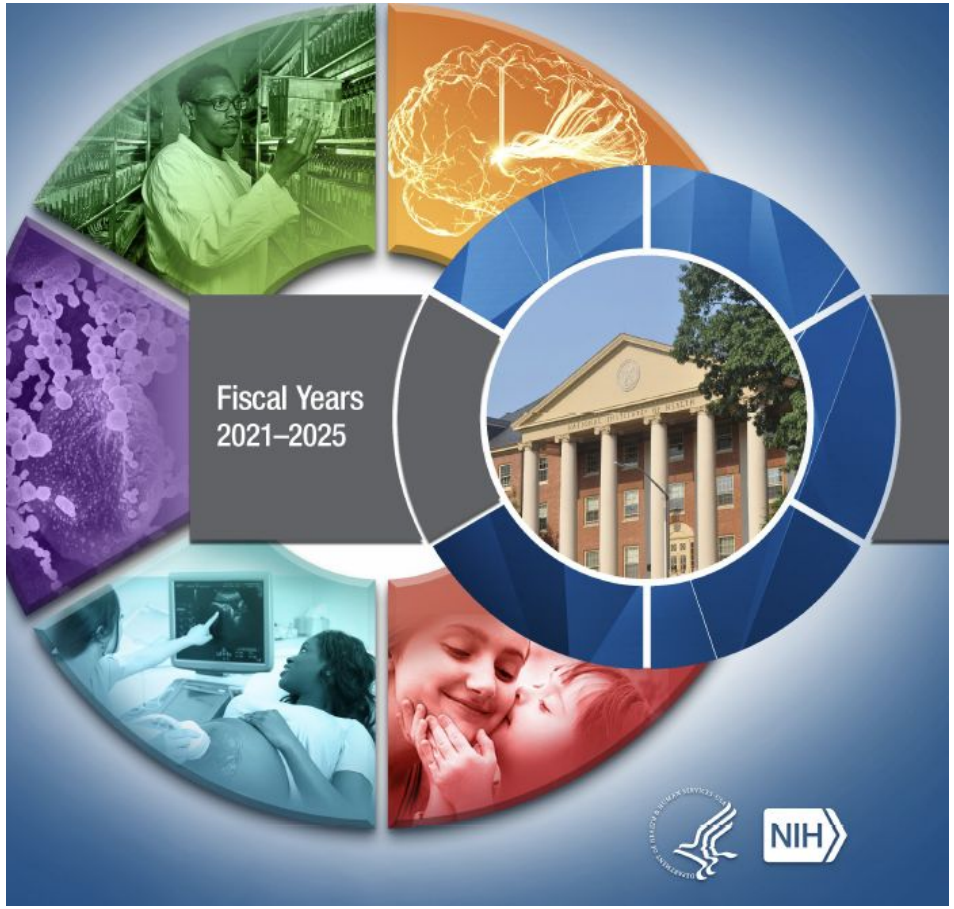
- Carbon sequestration (Environmental Sciences/Engineering)
- Grid-scale energy storage (Energy)
- Universal flu vaccine (Healthcare Pharma)
- Dementia treatment (Healthcare, Neuroscience)
- Ocean clean-up (Remediation, Environment)
- Energy-efficient desalination (Water)
- Safe driverless car (Automation, Data Analytics/AI)
- Embodied AI (AI; Machine Learning, Deep Learning)
- Earthquake prediction (Environmental Science; Data Analytics)
- Brain decoding (Neuroscience)

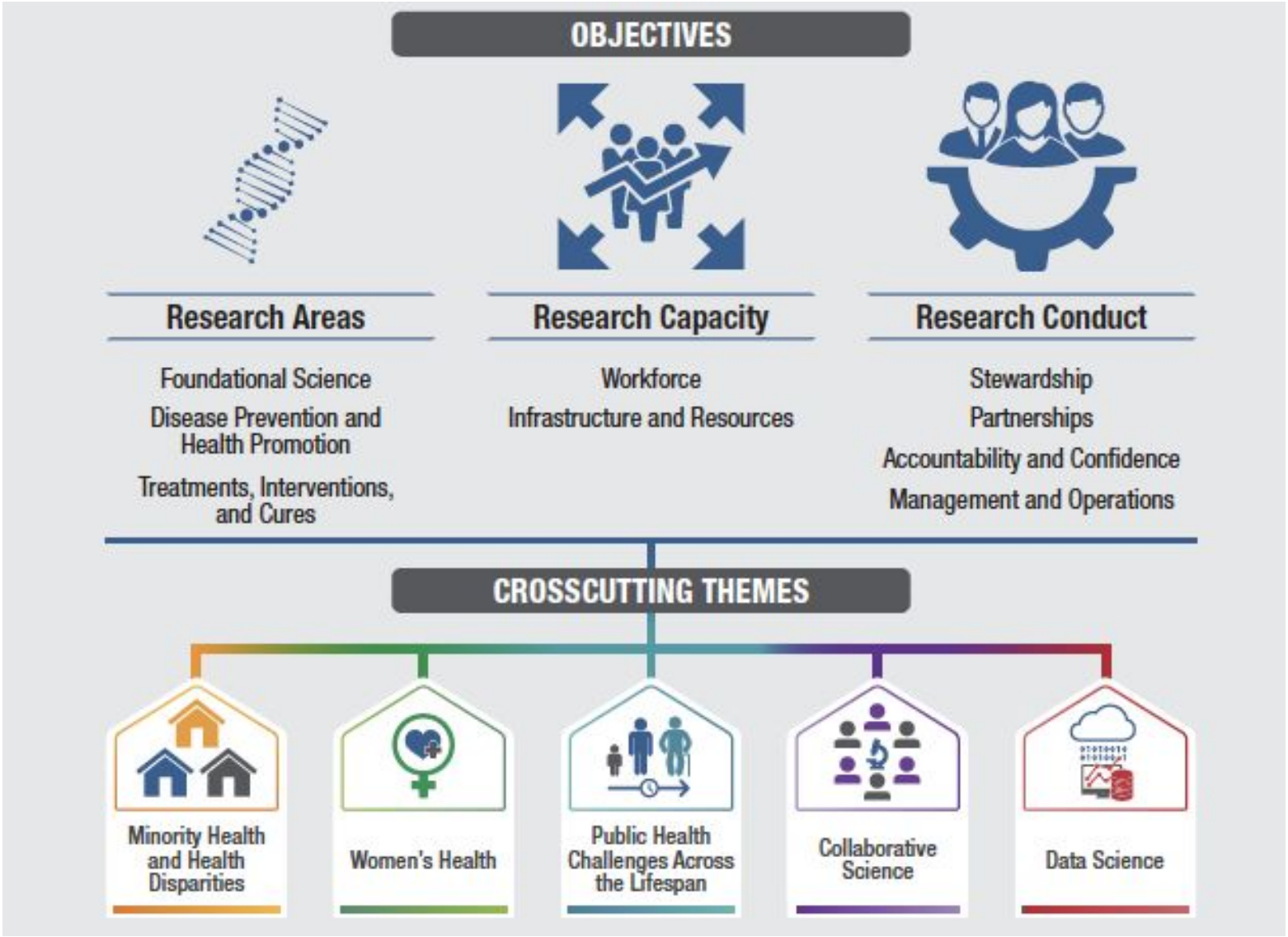
https://www.technologyreview.com/magazine/201

NSF 10 Big Ideas

- Harnessing the Data Revolution
- The Future of Work at the Human-Technology Frontier
- Navigating the New Arctic
- Windows on the Universe: The Era of Multi-Messenger Astrophysics
- The Quantum Leap: Leading the Next Quantum Revolution
- Understanding the Rules of Life: Predicting Phenotype
- Mid-scale Research Infrastructure
- NSF 2026: Seeding Innovation
- Growing Convergence Research at NSF
- NSF INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science): Enhancing STEM through Diversity and Inclusion

https://www.nsf.gov/news/special_reports/big_ideas/



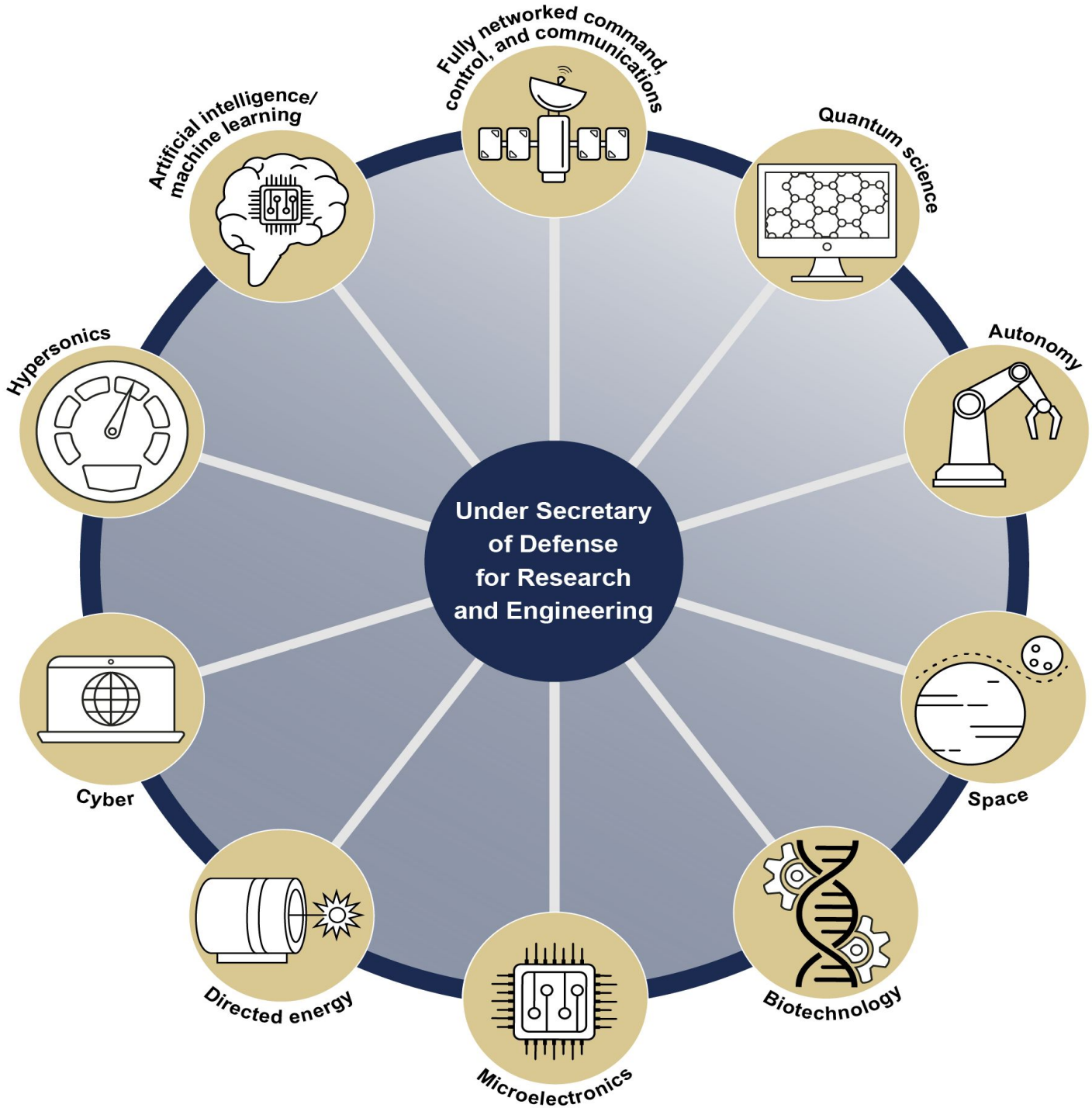


https://www.nih.gov/about-nih/nih-wide-strategic-plan

Defense Science and Technology: Opportunities to Better Integrate Industry Independent Research and Development into DOD Planning

Source: L3Harris. | GAO-20-578

https://www.gao.gov/assets/gao-20-578.pdf



NJIT New Jersey Institute of Technology

US Government R&D Priorities

- **American Connectivity and Autonomy:** advanced communications networks; autonomous driving systems and unmanned aircraft systems (UAS)
- **American Manufacturing:** smart and digital manufacturing, additive manufacturing, advanced industrial robotics, systems enabled by the industrial internet of things (IoT), machine learning, and AI
- **American Space Exploration & Commercialization:** in-space manufacturing, in-situ resource utilization, long-term cryogenic fuel storage and management, and advanced space-related power and propulsion capabilities. Micro-gravity research to advance biopharmaceuticals, optical communications, and machine learning.
- **American Energy Dominance:** Fueling America's greatness requires access to domestic sources of clean, affordable, and reliable energy
- **American Medical Innovation** basic research and translation, personalized medicine, disease prevention, addressing the opioid crisis, infectious disease, mental health, and public health threats
- **American Agriculture:** advanced and precision agriculture and aquaculture technologies, including the use of embedded sensors, data analytics, and machine learning techniques

Artificial Intelligence: an Administration Priority

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

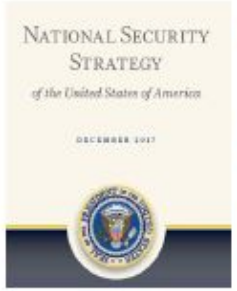
FROM: MICK MULVANEY
DIRECTOR, OFFICE OF MANAGEMENT AND BUDGET

MICHAEL KRATSIOS
DEPUTY ASSISTANT TO THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY

SUBJECT: FY 2019 Administration Research and Development Budget Priorities

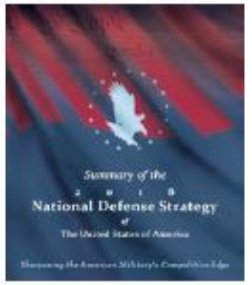
FY 2019 R&D Budget Priorities memo

"autonomous systems, … machine learning, and quantum computing ….. coordinated interagency initiatives, … STEM education, including computer science education "



National Security Strategy

"prioritize emerging technologies critical to economic growth and security, such as data science, encryption, autonomous technologies,… advanced computing technologies, and artificial intelligence. "



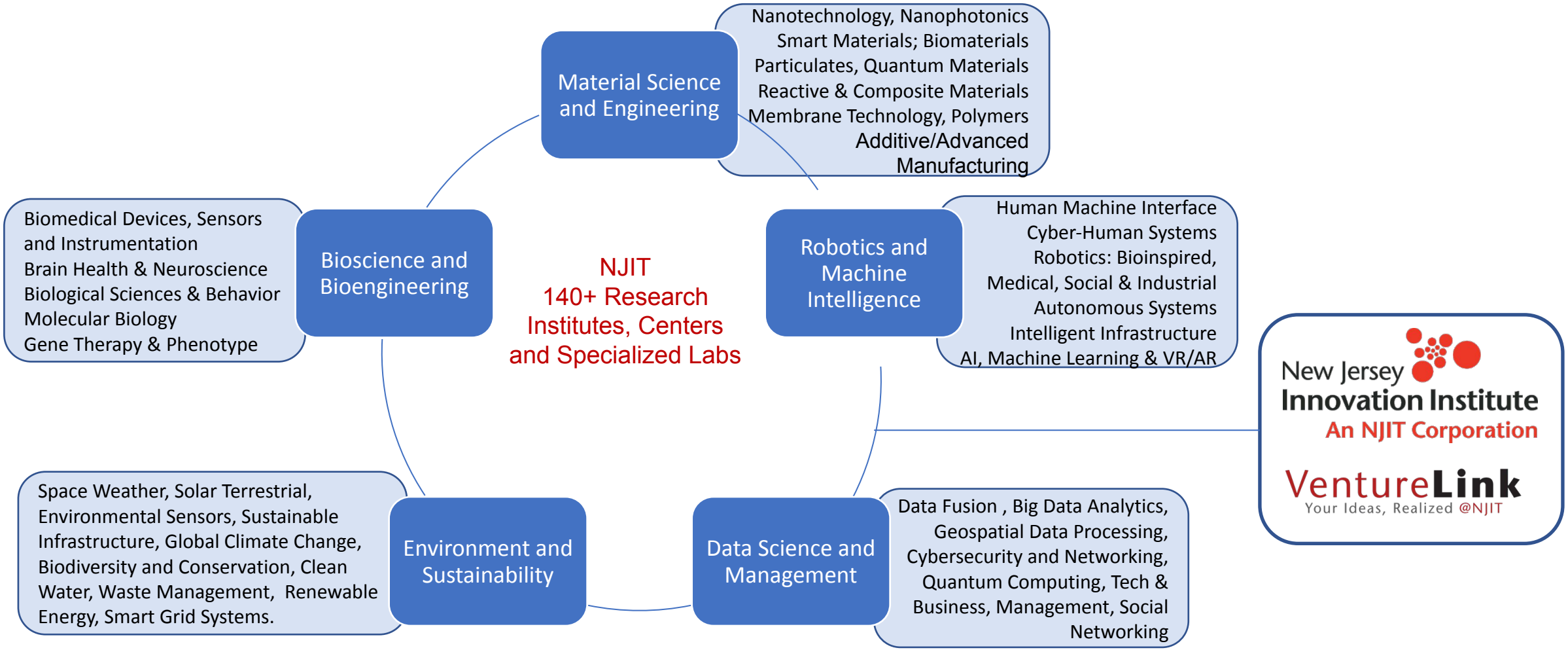
National Defense Strategy

".. invest broadly in military application of autonomy, artificial intelligence, and machine learning, including rapid application of commercial breakthroughs."

"Artificial intelligence holds tremendous potential as a tool to empower the American worker, drive growth in American industry, and improve the lives of the American people. Our free market approach to scientific discovery harnesses the combined strengths of government, industry, and academia, and uniquely positions us to leverage this technology for the betterment of our great nation."

- Michael Kratsios, Deputy Assistant to the President for Technology Policy

NJIT Research Clusters: 2025 Strategic Plan



NJIT Strategic Research Grand Challenge Areas of High Impact

- **Innovative Solutions for Sustainable Environment and Societies**
  - novel energy materials
  - water treatment and waste management
  - environment and climate resilience
  - space weather understanding
  - intelligent adaptive transportation
  - smart buildings and cities
  - additive manufacturing
  - Leadership workforce development with integrated educational, innovation and entrepreneurial programs
- **Healthcare Innovations**
  - wearable health-monitoring technologies
  - Personalized, preventive and precision medicine
  - cellular and tissue engineering-based therapeutic technologies
  - Traumatic Brain Injury (TBI) and brain health
  - human-robotic assistive devices
  - women's health
  - smart drug delivery systems
  - smart healthcare information management systems
- **Next-Generation Computing, Artificial intelligence and Cyber-infrastructure**
  - optimized system architectures for complex high-performance data analytics; edge computing
  - cybersecurity and adaptive networking
  - Quantum computing and information systems
  - artificial intelligence co-evolution of machine and human intelligence
  - smart robotics and assisted living
  - sustainable robust data management
  - data science for diverse workforce development

NAI-NJIT Workshop Series: Innovations to Global Solutions

Sustainable Societies: Global Drivers

- **Environment**
- **Healthcare**
- **Information (ITAIC)**

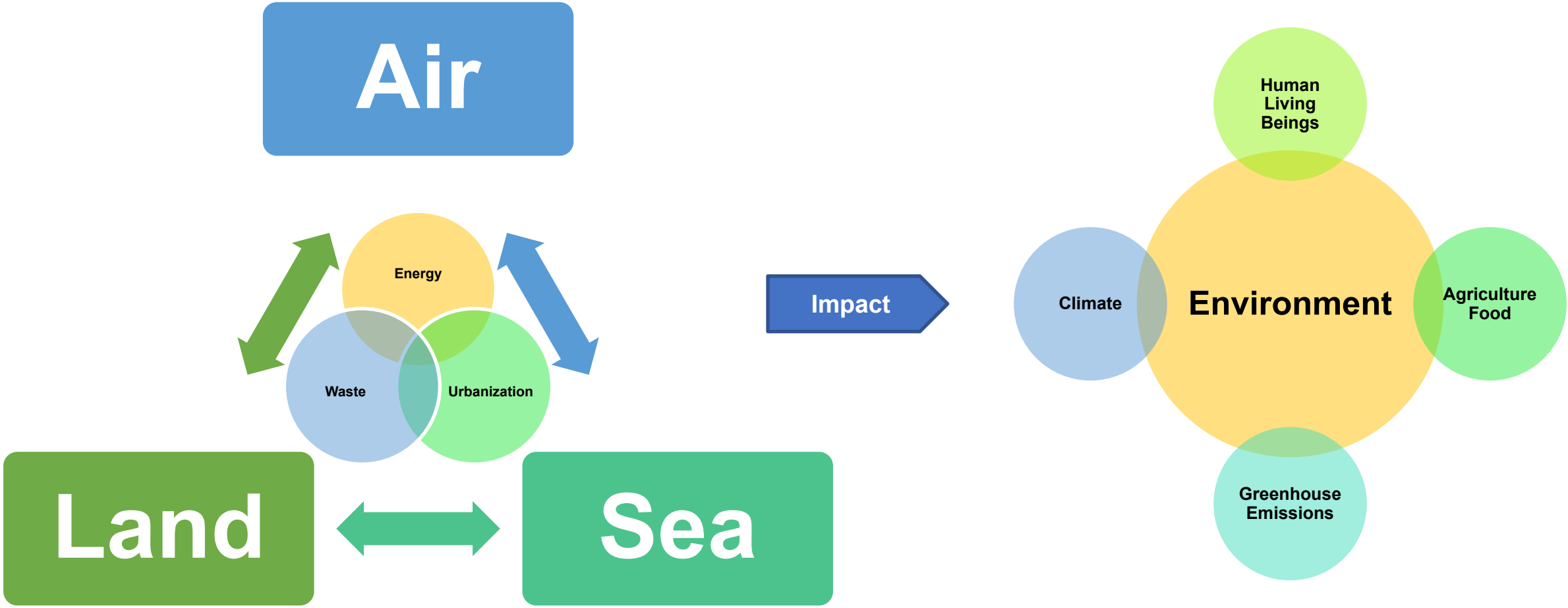
Infrastructure Enablers

- Technology Research and Innovation
- Resources and Infrastructure
- Governance and Policies

Growth Catalysts

- Communication
- Education
- Equality (socio-economic)

Sustainable Societies: Global Environment and Climate Change



Global Healthcare Challenges

- Rising Health Care Costs
- Rural Areas with No or Minimal Clinical Facilities
- Aging Population, Assisted Living and Quality Healthcare in the Global Society
- Management of Fast Health-Hazard Outbreaks
  - Infections
  - Disasters
  - Trauma

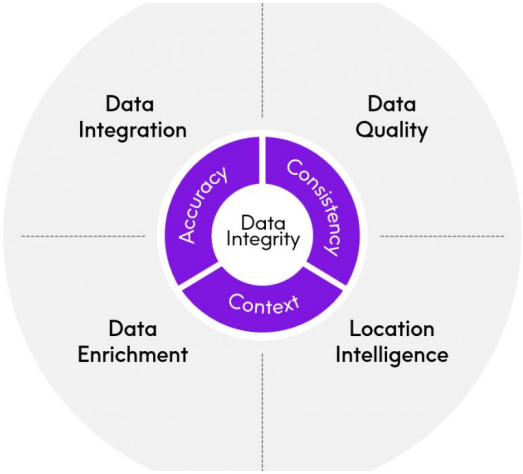
NJIT New Jersey Institute of Technology

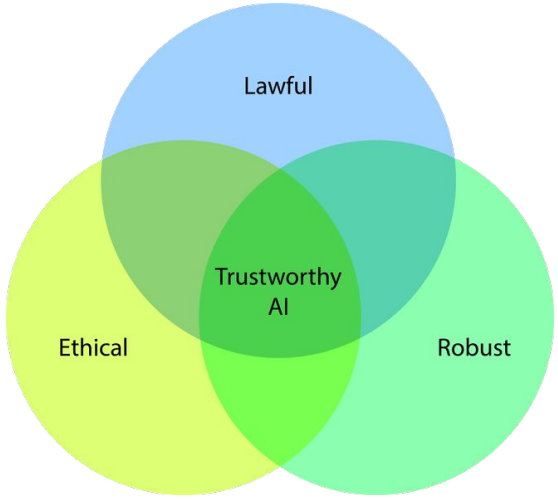
Personalized, Preventive and Precision Medicine

PAST	PRESENT	FUTURE
Intuition Medicine	Evidence-based Medicine	Precision Medicine
Signs and Symptoms	Clinical Trials	Algorithms

•https://www.scielo.br/j/clin/a/gBzbKRHWMMbjw4w9dLGxzrR/?lang=en#

Information Integrity and Trustworthy AI





- Information integrity is the dependability or trustworthiness of information.
- It is the accuracy, relevance, precision, consistency, and reliability of the information content, process, and system.
- Compromised data and information can lead to inaccurate and unreliable data analytics including AI based outcomes.
- The COVID-19 pandemic has been accompanied by a flood of misinformation and disinformation.

Cyber Grand Challenge

- The need for automated, scalable, machine-speed vulnerability detection and patching is large and growing fast as more and more systems—from household appliances to major military platforms—get connected to and become dependent upon the internet.
- Today, the process of finding and countering bugs, hacks, and other cyber infection vectors is still effectively artisanal.