The NIST Measurement Science for Robotics and Autonomous Systems (MSRAS) Program

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https://www.nist.gov/el/robotics

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

Program Objective

To advance robotic system performance, collaboration, agility, autonomy, safety, and ease of implementation by developing and deploying the measurement science needed to enhance U.S. innovation and industrial competitiveness.

We work primarily in 3 domains/fields:

- Manufacturing
- Public Safety
  (air, ground, aquatic)
- On-road automated vehicles
  (perception and decision making)

Measurement Science for Robotics and Autonomous Systems Program

Unlock safe, agile, and collaborative robotics and physical AI, break barriers to adoption, and empower U.S. industrial competitiveness

Objective: To develop and deploy measurement science that advances robotic system performance, collaboration, agility, autonomy, safety, and ease of implementation to enhance U.S. innovation and industrial competitiveness.

Perception Performance of Robotic Systems

Assess and Assure Sensor & Perception Systems

Grasping and Manipulation Performance of Robotic Systems

Assess and Assure Dexterous Grasping & Manipulation

Mobility Performance of Robotic Systems

Assess & assure vehicles, mobile manipulators & wearables

Performance of Emergency Response Robots

Advance capabilities of emergency response robots

Measurement Science for Automated Vehicles

Assess and enhance the robustness of cooperative perception for AV

Physical AI and Data Generation for Robotics

Provide validated data & models for ML algorithms

Agility Performance of Robotic Systems

Easily and rapidly reconfigure and re-task robots

Performance of Human-Robot Interaction

Provide foundations for Intuitive and effective interaction methods

Performance of Emerging Technologies for Robotics

Reduce the technical barriers to adopting robots

Component projects work together to achieve the program objective

A few current robotics industry realities

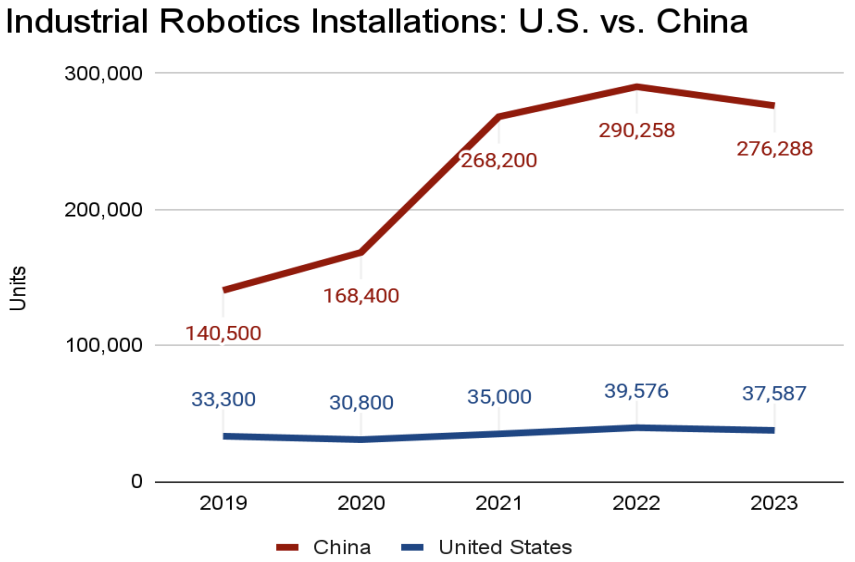
51% of global industrial robot installations in 2023 were in China. [1]

China deploys “nearly **10 times more** robots annually than the U.S.” [2]

~ 90% global humanoid robots are from China.

“Broad deployment of Physical AI is critical for advancing AI” [4]

$2.9 trillion in potential value could be unlocked in the U.S. by 2030 if people, AI agents, and robots are able to work together effectively. [5]



Source: World Robotics Reports, International Federation of Robotics (2020-2024).

1. “Record of 4 Million Robots Working in Factories Worldwide.” International Federation of Robotics, 24 Sept. 2024, ifr.org/ifr-press-releases/news/record-of-4-million-robots-working-in-factories-worldwide
2. “Robots Made in America: Advancing U.S. Leadership in Manufacturing and Automation.” YouTube, uploaded by House Science, Space, and Technology Committee, 22 Apr. 2026, www.youtube.com/watch?v=Lfh-EQ4OeOM
3. Omdia Market Radar: General-purpose Embodied Intelligent Robots 2026. Omdia, Jan. 2026, omdia.tech.informa.com/om143809/omdia-market-radar-generalpurpose-embodied-intelligent-robots-2026
4. Anonymous participant (under Chatham House rules) at the American AI Robotics Convening, U.S. Department of Commerce, Herbert C. Hoover Building Library, Washington, D.C., March 10, 2026, https://www.youtube.com/live/Lfh-EQ4OeOM?si=JVOJVDVT8_dvzMvz&t=2351
5. Yee, Lareina, et al. Agents, Robots, and Us: Skill Partnerships in the Age of AI. McKinsey Global Institute, 25 Nov. 2025, www.mckinsey.com/mgi/our-research/agents-robots-and-us-skill-partnerships-in-the-age-of-ai

Traditional vs. Advanced Robotics

Traditional Robotics

- Custom solutions
  (ad hoc, costly, fixtured, complex tooling, slow integration)
- Limited or no agility
- Separated for safety
- Not everyone can benefit
- "Dumb" machines

NIST OAM / MEP / NMI
National Strategy for CETs
America's AI Action Plan
NIST Strategy for American Technology Leadership in the 21st Century
National robotics strategy …

Measurement Science
metrics, protocols, benchmarks, models, testbeds, datasets, test methods, standards, ...

Other
Tax incentives
Trade policies
Regulations
…

Advanced Robotics

- Better productivity and higher quality
- More human-robot teaming
- Achievable by large *and* small and medium firms
- Dynamic safety
- Intelligent and agile agents

Applications of Robots and Autonomous Systems

(Blue = addressed by MSRAS program)

Defense and military
Exoskeletons

Emergency Response
Disaster response
Hazmat situations
Underwater rescue
Wildfire response

Infrastructure Inspection and Maintenance
Bridge and structural inspection
Nuclear inspection

Law enforcement and security
Bomb disposal
Surveillance and patrolling

Logistics and warehousing
Autonomous Mobile Robots (AMRs)
Automated Guided Vehicles (AGVs)
Picking and sorting

Manufacturing and industrial production
Assembly
Material handling
Machine tending
Cutting, grinding, and polishing

Mining
Exploration and mapping

Telecommunications
Tower climbing and maintenance

Transportation
AV

What domains/fields and application does the Program cover?

Industrial / Manufacturing

Assembly of small and medium parts (e.g., automotive)

Material handling in industrial settings

Assembly and inspection of aerospace components on/within large structures

Public Safety / Emergency Response

Response to natural and man-made disasters

Nuclear inspection / maintenance / remediation

Infrastructure inspection / maintenance

Automated driving on public roads

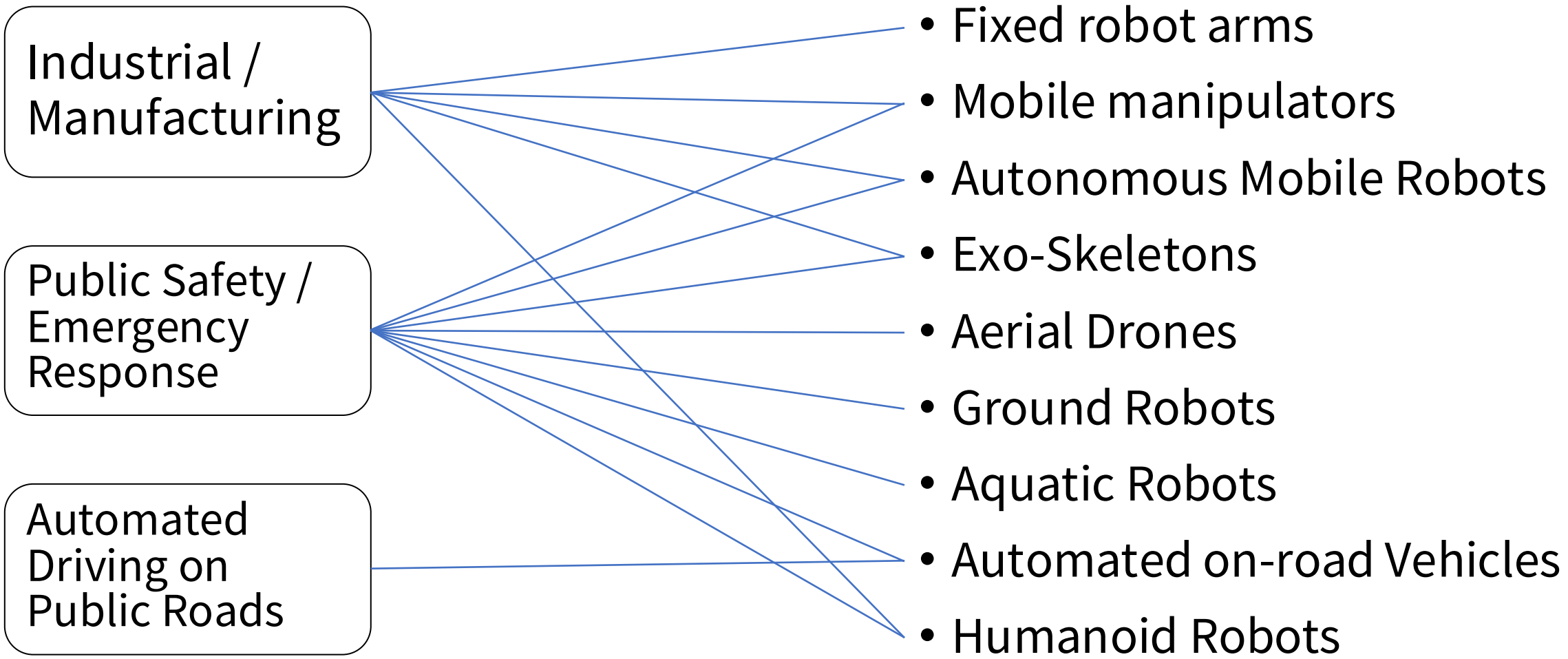
Historical (NIST)

- Space construction
- Ship building
- Airplane maintenance
- Construction
- Offroad autonomous vehicles
- Factory automation
- Welding

What types of robots and autonomous systems does the Program currently focus on?

- Fixed robot arms (industrial and collaborative applications)
- Mobile manipulators (wheeled and legged)
- Autonomous Mobile Robots (AMRs)
- Exo-Skeletons /Suits/Footwear (wearable robots)
- Aerial Drones
- Ground Robots
- Aquatic Robots (surface and underwater)
- Automated on-road Vehicles
- Humanoid Robots

What systems are involved in each domain?



Manufacturing

Some U.S. Manufacturing Realities

$2.94 Trillion value added (~10% of GDP)[1]

13 million employees[2]

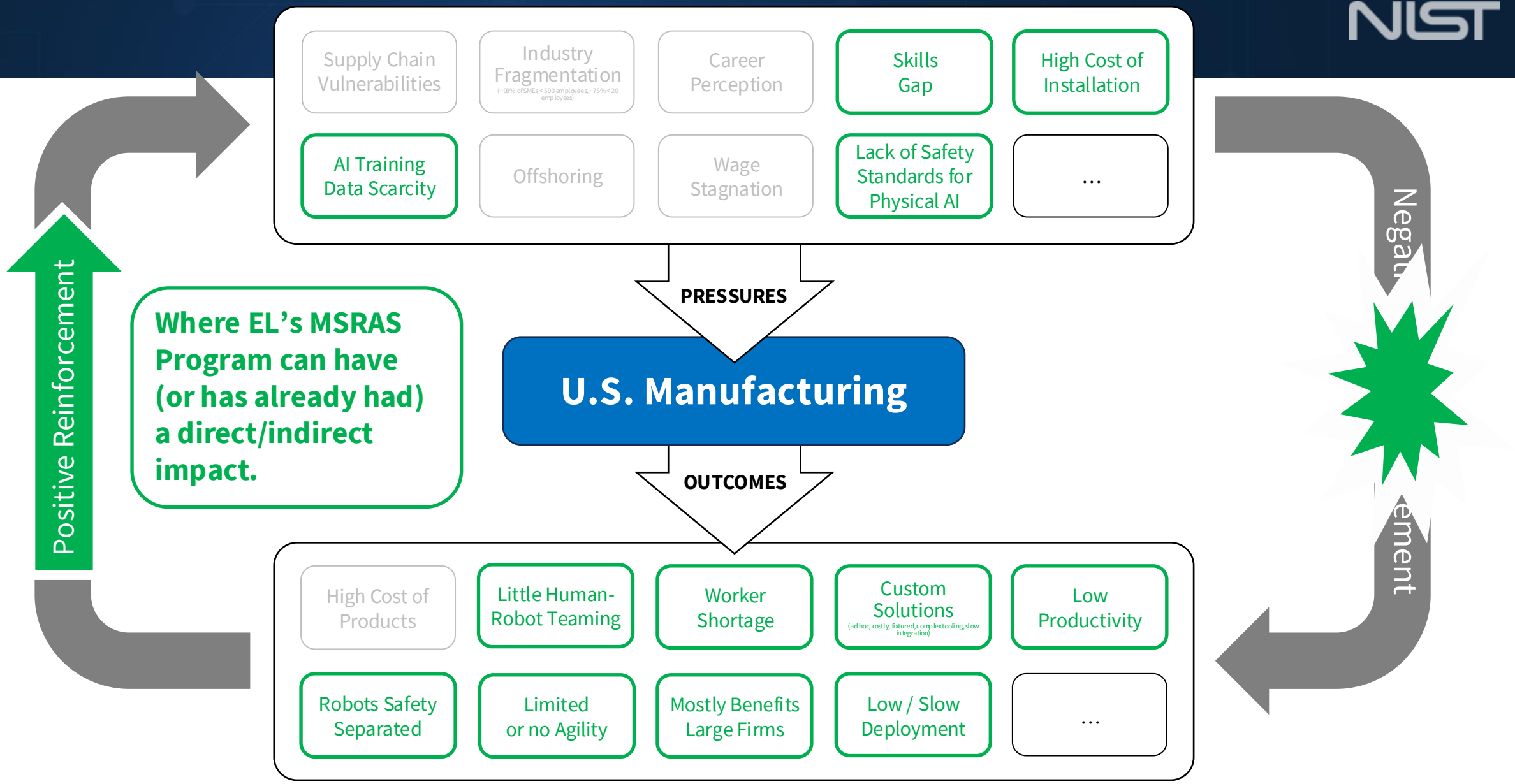
74% of manufacturers have fewer than 20 employees[3]
(many are family-owned businesses)

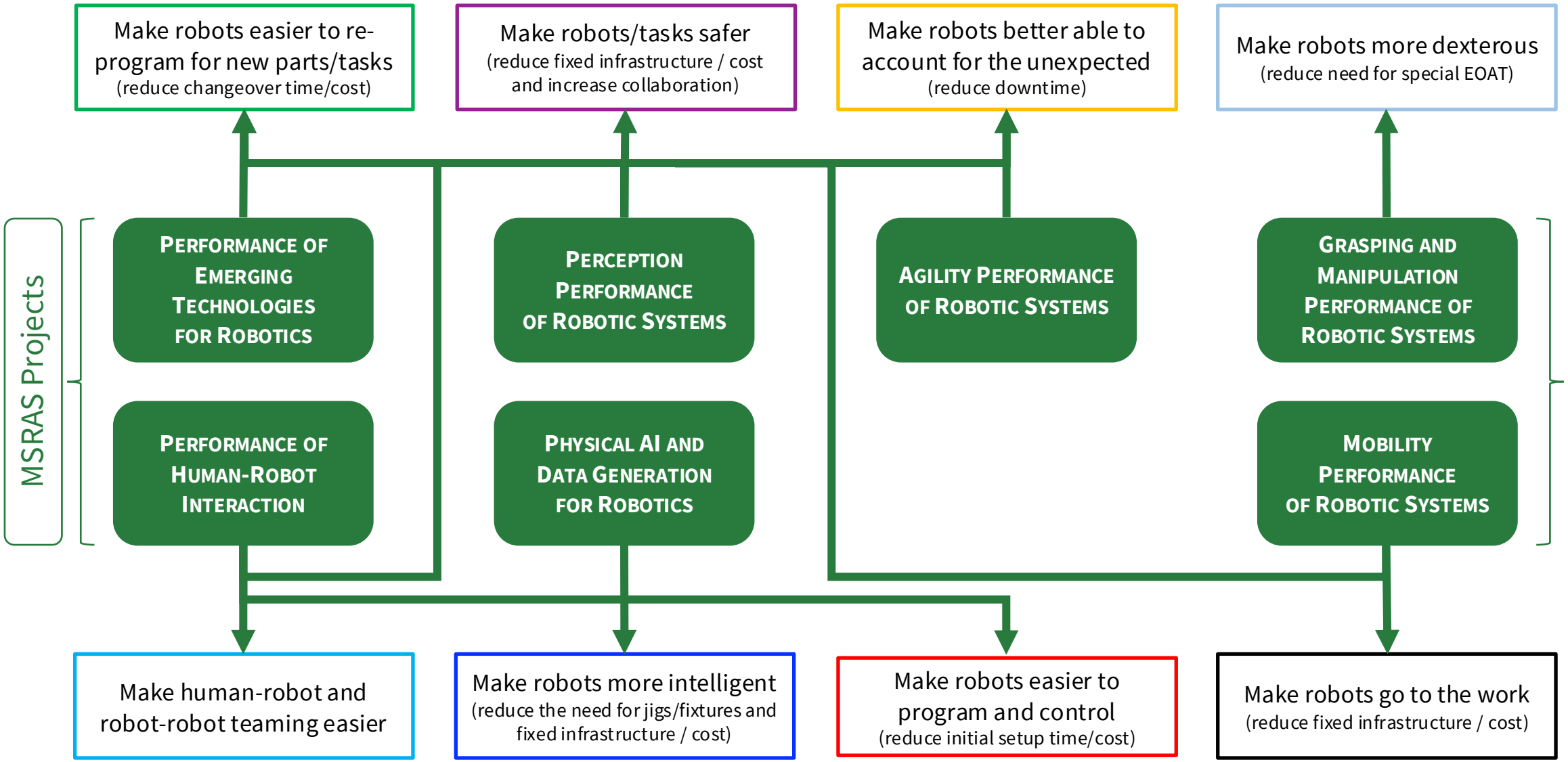
449,000 open manufacturing jobs (March 2025)[2]

3,800,000 new *unfilled* manufacturing jobs by 2033[4]

SMEs often think in the short term and have low tolerance for risk

1. *Bureau of Economic Analysis*
2. *Bureau of Labor Statistics*
3. *U.S. Census Bureau, Statistics of U.S. Businesses*
4. *Deloitte and the Manufacturing Institute*


Supply Chain Vulnerabilities
Industry Fragmentation
(~98% of SMEs < 500 employees, ~75% < 20 employees)
Career Perception
Skills Gap
High Cost of Installation
AI Training Data Scarcity
Offshoring
Wage Stagnation
Lack of Safety Standards for Physical AI
…
PRESSURES
U.S. Manufacturing
OUTCOMES
High Cost of Products
Little Human-Robot Teaming
Worker Shortage
Custom Solutions
(ad hoc, costly, fixtured, complex tooling, slow integration)
Low Productivity
Robots Safety Separated
Limited or no Agility
Mostly Benefits Large Firms
Low / Slow Deployment
…
Positive Reinforcement
Negat
ement
Where EL's MSRAS Program can have (or has already had) a direct/indirect impact.


Make robots easier to re-program for new parts/tasks
(reduce changeover time/cost)
Make robots/tasks safer
(reduce fixed infrastructure / cost and increase collaboration)
Make robots better able to account for the unexpected
(reduce downtime)
Make robots more dexterous
(reduce need for special EOAT)
MSRAS Projects
Performance of Emerging Technologies for Robotics
Perception Performance of Robotic Systems
Agility Performance of Robotic Systems
Grasping and Manipulation Performance of Robotic Systems
Performance of Human-Robot Interaction
Physical AI and Data Generation for Robotics
Mobility Performance of Robotic Systems
Make human-robot and robot-robot teaming easier
Make robots more intelligent
(reduce the need for jigs/fixtures and fixed infrastructure / cost)
Make robots easier to program and control
(reduce initial setup time/cost)
Make robots go to the work
(reduce fixed infrastructure / cost)

Manufacturing Impact Highlights

Industrial/Collaborative Robot Safety

Metrology for collaborative safety functions in ISO TS15066.

Collaborative robot application safety updates to OSHA Technical Manual.

Metrology for 1st safety standards for Industrial Mobile Robots (IMR).

Exoskeleton Performance

Founding member of ASTM F48.
15 published standards to date.

NIST Assembly Task Boards

Replicated worldwide in research and industry (e.g., NVIDIA and Google DeepMind).

Human-Robot Interaction

New HRI reporting criteria adopted by ACM/IEEE HRI conference templates.

Agility

"eagerly exploring and actively implementing the ARIAC outputs to make our robotics solutions more agile."
Amazon Robotics

"helped our team better understand industry-relevant challenges, while also preparing us to develop skills needed to work with industry."
GE Global Research

"ARIAC tests have helped us understand our weaknesses vis-à-vis the best and have enabled us to spur development and implementation."
Denbar Robotics

Public Safety / Emergency Response

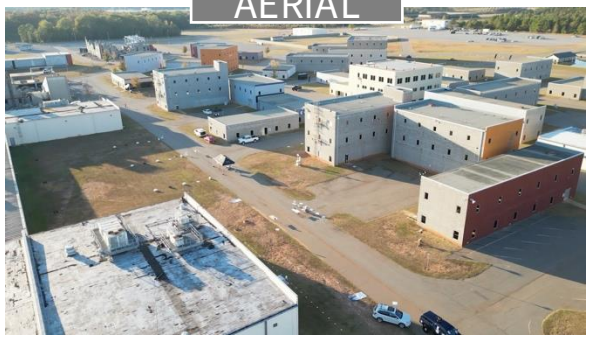
Performance of Emergency Response Robots Project

Performance of Emergency Response Robots Project

Objective: Develop the measurements and standards infrastructure necessary to quantitatively evaluate robotic system capabilities and remote operator/pilot proficiency for public safety operations.

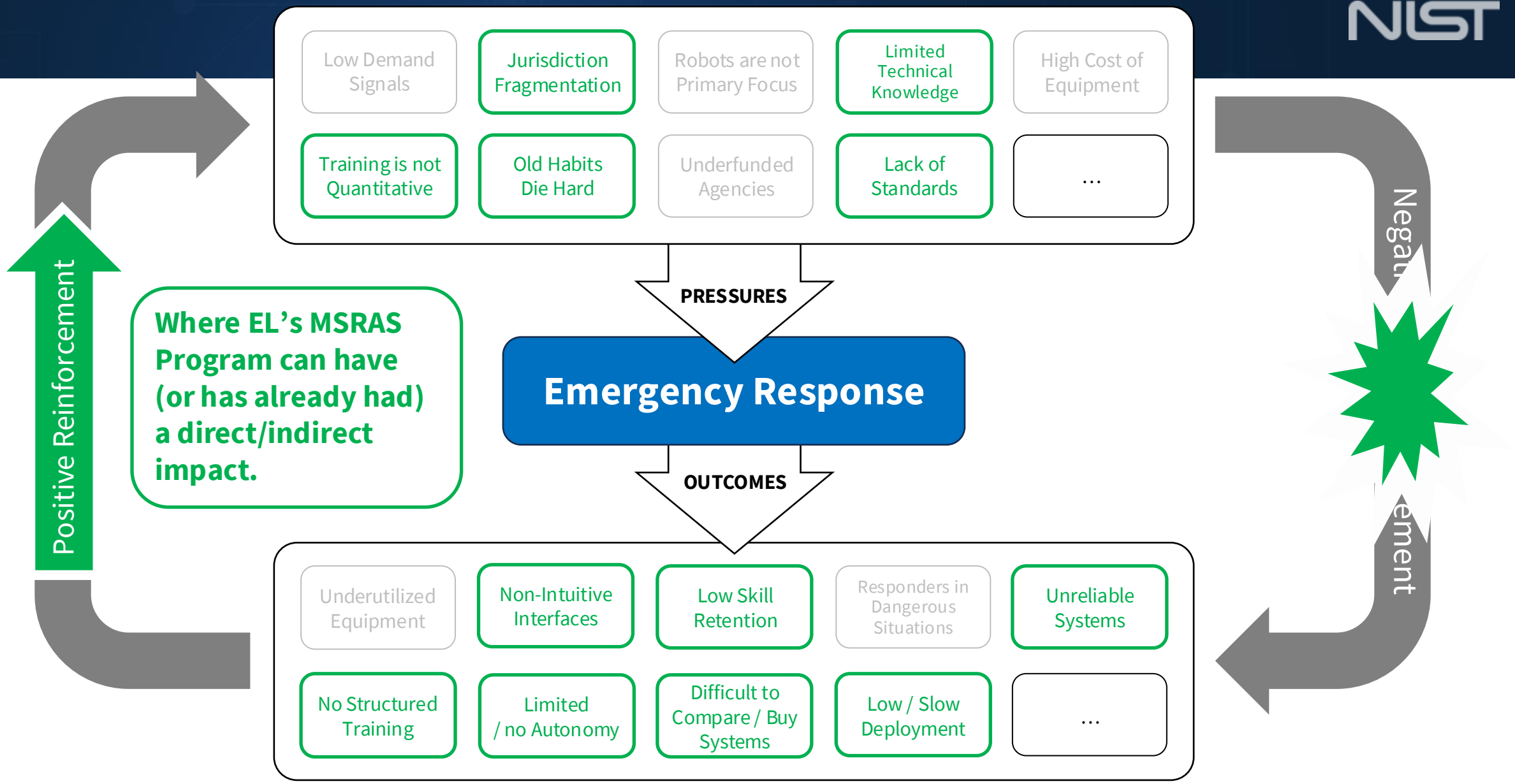
- Promote innovation within the research community
- Increase commercial competitiveness
- Improve the effectiveness and safety of emergency responders performing extremely hazardous tasks from safer standoff distances.

AERIAL



GROUND

AQUATIC


Low Demand Signals
Jurisdiction Fragmentation
Robots are not Primary Focus
Limited Technical Knowledge
High Cost of Equipment
Training is not Quantitative
Old Habits Die Hard
Underfunded Agencies
Lack of Standards
…
PRESSURES
Emergency Response
OUTCOMES
Underutilized Equipment
Non-Intuitive Interfaces
Low Skill Retention
Responders in Dangerous Situations
Unreliable Systems
No Structured Training
Limited / no Autonomy
Difficult to Compare / Buy Systems
Low / Slow Deployment
…
Positive Reinforcement
Negat
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Where EL's MSRAS Program can have (or has already had) a direct/indirect impact.

Training is not Quantitative

Jurisdiction Fragmentation

Old Habits Die Hard

Limited Technical Knowledge

Lack of Standards

Demonstrate the benefits of greater autonomy to guide development

Engage with national and international stakeholder communities

Develop quantitative measures of performance and operator proficiency

Communicate operational needs to robot developers

Focus training and measure proficiency for credentialing

Enable users to understand emerging robot capabilities

Support emerging technologies to facilitate commercialization

Guide robot purchasing, acceptance testing, and deployment

Unify terminology and democratize knowledge

Non-Intuitive Interfaces

No Structured Training

Limited / no Autonomy

Difficult to Compare / Buy Systems

Low / Slow Deployment

Unreliable Systems

Low Skill Retention

Project Impacts

Nationwide Aerial Drone Tests

Used to Purchase Drones and/or Train, Evaluate, and Credential Remote Pilots

Monthly courses hosted by the Airborne Public Safety Association (APSA), Regional Training Centers, Law Enforcement Drone Association, and others.

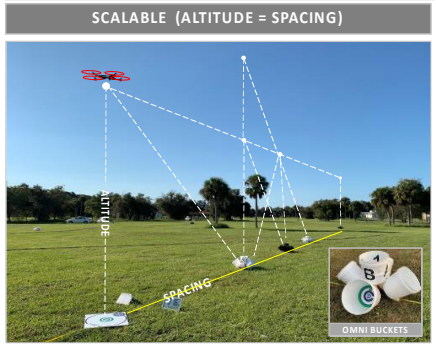
200+ in FY2025

LEVEL 1, 2, 3

OPEN Test Lane and Related Scenarios

- Position
- Traverse
- Orbit
- Inspect
- Recon

SCALABLE ALTITUDES

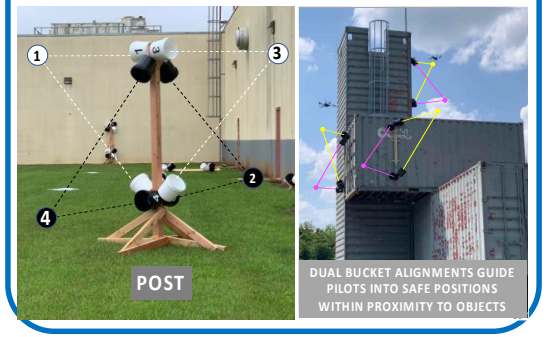


LEVEL 4

OBSTRUCTED Test Lane and Related Scenarios

- Perch
- Wall
- Ground
- Alley
- Post

CLOSE PROXIMITY

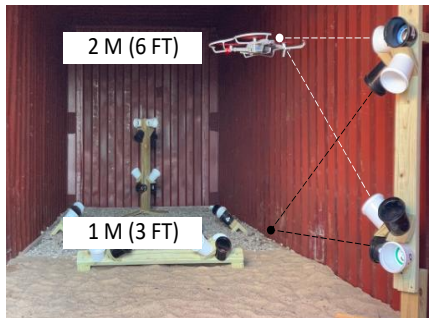


LEVEL 5

CONFINED Test Lane and Related Scenarios

- Perch
- Wall
- Ground
- Alley
- Post

GPS DENIED AND DARK



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Developed with funding form the ***Department of Homeland Security***. Being standardized through the ***ASTM International Standards Committee on Homeland Security Applications; Response Robots (E54.09).*** Already adopted and disseminated *internationally.*

Impacts Summary

- Over 20 published standards
- NIST Robotics Test Facility (207+209)
- Hosted dozens of companies
- Helped other agencies inform several robot procurement decisions ($300M+)
- Collaborate with 50+ public safety organizations, federal agencies, and national and international organizations.
- Aerial drone tests adopted by organizations such as NFPA, APSA, and LEDA to certify thousands of drone pilots.

Collaborating Organizations

(Validated and/or Integrated NIST Test Methods for their Own Purposes)

STANDARDS ORGANIZATIONS

- ASTM Homeland Security Applications (E54)
- ASTM Unmanned Aircraft Systems (F38)
- NFPA sUAS Used for Public Safety (NFPA 2400)

FEDERAL

- DHS Customs and Border Protection (CPB)
- DHS Secret Service (USSS)
- DHS Coast Guard (USCG)
- DHS Federal Emergency Management Agency (FEMA)

U.S. Air Force Auxiliary - Civil Air Patrol (CAP)

- DOJ Bureau of Alcohol, Tobacco and Firearms (ATF)
- DOJ U.S. Marshals Service

STATEWIDE

- Texas Department of Public Safety
- Colorado Aerial Technology Fire Fighting COE
- Virginia Department of Public Safety

OTHERS

SEE MAP OF CERTIFIED PROCTORS

- Airborne Public Safety Association (APSA)
- Drone Responders Public Safety UAS Alliance
- FAA ASSURE Center of Excellence for UAS
- Public Safety Aviation Accreditation Commission
- Transport Canada (their version of our FAA)
- International Rescue Systems Institute (Japan)
- International Emergency Drone Assoc. (Europe)

Automated On-road Vehicles

Measurement Science for Automated Vehicles Project

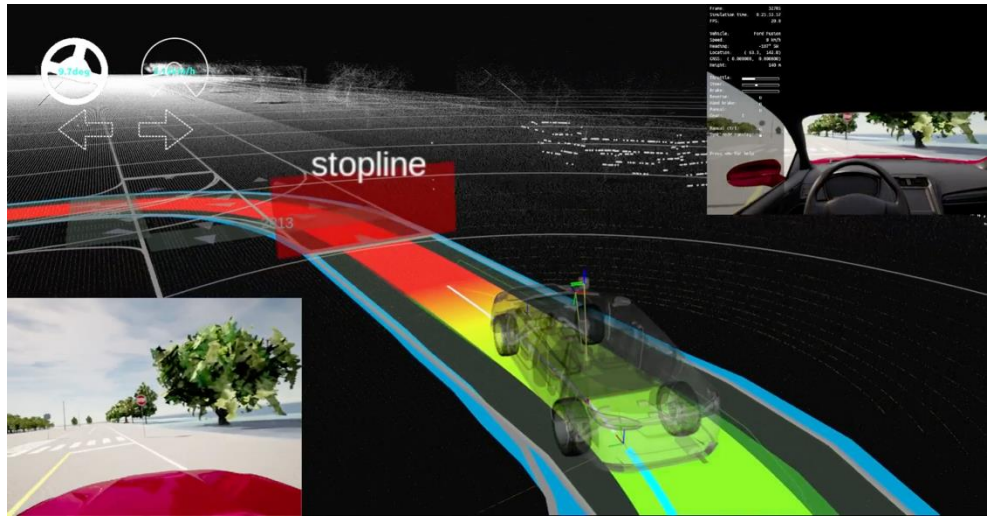
Objective: Develop measurement science for evaluating AI-based decision-making systems in automated vehicles.

What is the problem?

Regulators have no *independent* way to evaluate if an AV's AI makes safe driving decisions *before* the vehicle is deployed on public roads.

What is the technical idea?

Develop measurement methods, reference baselines, test tools, and scenario datasets to answer the question: "Did the decision-making system make the best available choice?"



COLLABORATORS

Michigan Technological University

MITRE

VIRGINIA TECH TRANSPORTATION INSTITUTE

Project Impacts (in collaboration with CTL/ITL)

Automotive Cybersecurity COI (2023)
17 gov, 20 academia, 320+ industry members. Monthly webinars with 60 to 100 attendees.

Two NIST AV workshops (2022, 2023)
NIST IR 8442 & NIST IR 8527 and 600+ attendees.

VTTI field testing campaign
Smart Road facility, 80 scenarios, data collections for perception, decision-making, and communications. Validated test protocols for research vehicle evaluation.

Cross-laboratory perception UQ Implemented and validated an ensemble-based approach using five state-of-the-art perception models to quantify uncertainty and identified critical failure modes where prediction probability dropped below safety thresholds.

Braking quality measurement
Developed test procedures capturing data from the NIST test vehicle across varied speeds and stopping distances and standardized driver response timing. Established quantitative metrics linking vehicle actions to measurable outcomes.

NIST test vehicle

Program Resources

MSRAS Program Standards Leadership & Participation

Robot Safety

Industrial Robots (arms): ANSI/A3 R15.06 (T),
ISO TC299/WG3 & WG8 (T), UL STP 1740 (T)

Industrial Vehicles: ANSI/ITSDF B56.5 (T), UL STP 3100 (T)

ISO 25785-1 Dynamically stable industrial mobile robots (T)

Industrial Mobile Robots

ANSI/A3 R15.08 (T)

Perception Systems

ASTM E57 3D Imaging Systems (L, T)

Industrial Vehicles

ASTM F45 (L, T)

Robot Agility and Knowledge Representation

IEEE RAS 1872 (.1, .2, .1.1) (L, T)

Robot Agility: IEEE RAS 2940 (L, T)

Wearable Robots/Exoskeletons

ASTM F48 (L, T)

Robotic Hand Grasping & Manipulation

ASTM F45.05 Grasp Performance Working Group (L, T)

Human-Robot Interaction

IEEE RAS Metrology for HRI Working Groups:
P3107, P3108 (L, T)

Robot Performance

Industrial Robots: ASME MAM on Robotic Arm Performance (L, T)

Service Robots: ISO TC299 WG4 (T)

Augmented Reality

AREA Committees on AR Requirements, Security, Safety, and Research (T)

Digital Twins

DT Use Cases: ISO/IEC 30172 (T)

DT Terminology: ISO/IEC 30173 (T)

Response Robots

ASTM E54.09 & NFPA 2400 (L, T)

Humanoid Robots

IEEE-RAS Humanoids Study Group (T)

ISO/WD 25785-1 - Part 1 (T)

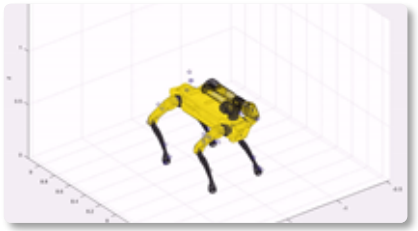
10+ SDOs
20+ Committees
80+ Published Standards

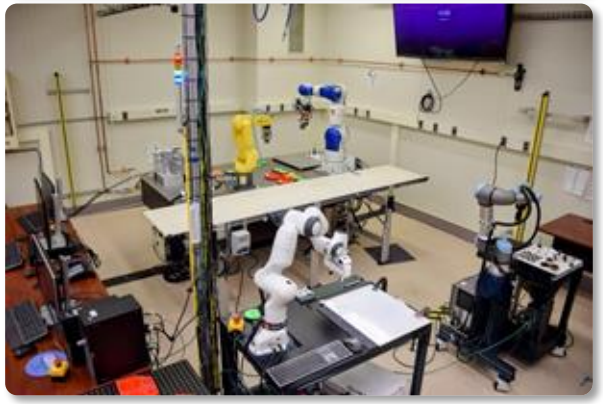
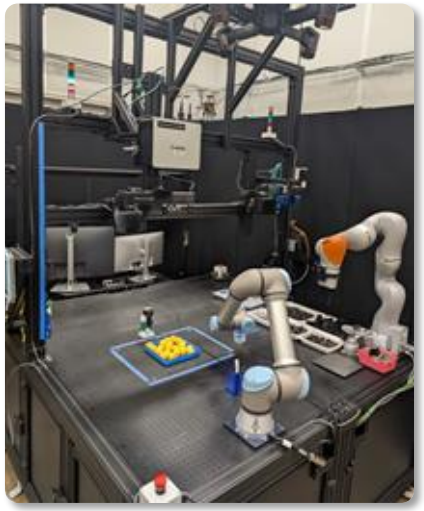
L = Leadership
T = Technical participation

Labs / Testbeds

Lab Name	Bldg/Rm
Human-Robot Interaction Lab	202/209-214
Response Robot Test Facility	207+209
ExoSkeleton Testbed	202/130
Grasping and Manipulation Lab	202/135
Mobile Robot Testing Lab	202/138
Robot Agility Lab	220/A126
Grasping and Manipulation	220/B025
MSRAS Manufacturing Testbed	202/A360
Robot PHM / Data Analysis Lab	220/A362
Sensing and Perception Systems Lab	202/130-1





Competitions

Robocup Federation, Robocup Rescue Competition (2000-present)

DARPA Robotics Challenge (2013-2014)

IEEE/RAS Quadruped Robot Challenge

NIST Agile Robotics for Industrial Automation Competition (2017-present)

IEEE/RAS Robotic Grasping and Manipulation Competition: Manufacturing Track (2019-present)

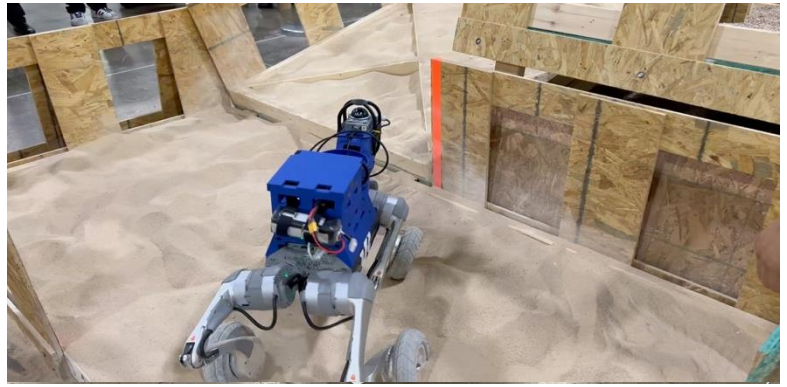
ASTM International ExoGames

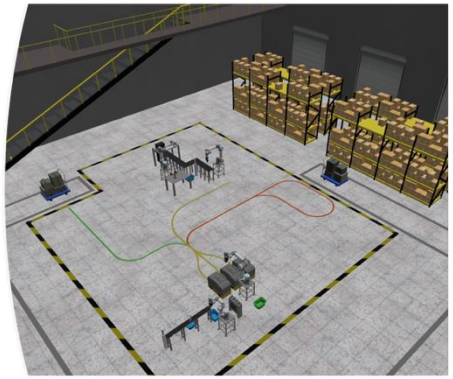
World Robot Summit Competition, Assembly Challenge

NIST First Responder UAS Challenges

World Robot Summit Competition, Disaster Robotics Category

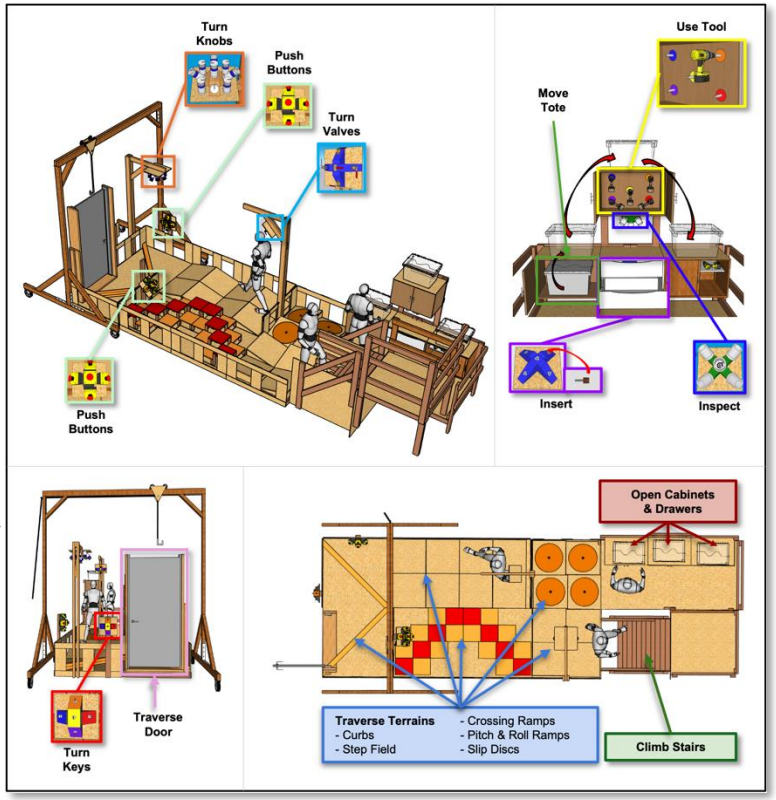
IEEE/RAS Humanoids 2026 Loco-Manipulation Challenge





Current & Future Activities

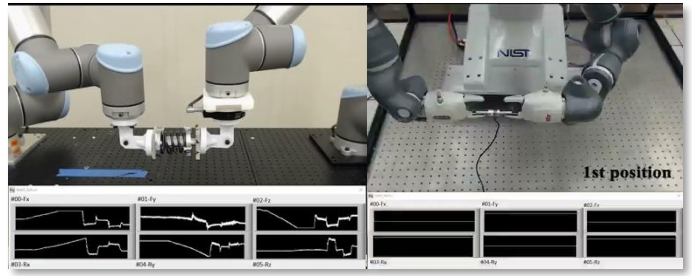
- Tactile sensing performance
- Assembly task boards for data centers
- Mobile manipulator performance
- Robotic bin picking selection guide



Humanoids Baseline Benchmark

U.S. Fire Administration
National Fire Academy

Drone pilot credentialing



Measuring pressure and force for bimanual manipulation

Allplan (ALLPLAN)	LixelStudio (Lixel)
ArchiCAD (Graphisoft)	Matterport (Matterport)
ATIS.cloud (ATIS.cloud)	MeshLab (Open-Source)
Inventor (Autodesk)	PDAL (Open-Source)
Navisworks (Autodesk)	QGIS (Open Source)
ReCap Pro (Autodesk)	Revizto (Revizto)
Benaco (Benaco)	Rhinoceros 3D (Robert McNeel)
MicroStation (Bentley Systems)	RIEGL RiSCAN Pro (RIEGL)
BricsCAD (Brics	(Solibri)
Cintoo Connec	Systèmes)
EdgeWise (Clea	
CloudCompare	
Cyclone FIELD	
Cyclone REGIS	
Dot3D (Dot Product)	Tekla Structures (Trimble)
Esri ArcGIS Pro (Esri)	Topcon Magnet Collage (Topcon)
FARO SCENE (FARO)	Trimble Business Center (Trimble)
FME Form (Safe Software)	Trimble Perspective (Trimble)
GDAL (Open-Source)	Trimble RealWorks (Trimble)
Geomagic Design X (3D Systems)	Vectorworks (Vectorworks, Inc.)
Global Mapper (Blue Marble)	Z+F LaserControl (Zoller + Fröhlich)
GstarCAD (Gstarsoft)	ZWCAD (ZWSOFT)

v2 of .e57 for mobile lidar?

Software that Supports .e57

Multi-Agent Synchronized Collaborative Assembly Testbed (MASCAR)

Thank you

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