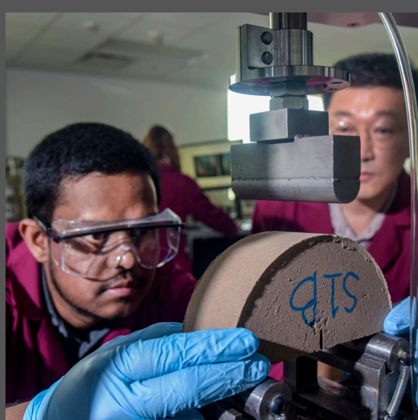
CIR | CENTER FOR **Infrastructure Renewal**



Strategic Plan

2021-2026

Texas A&M Transportation Institute

TEES | Texas A&M Engineering Experiment Station

cir.tamu.edu

CIR Facts

Texas A&M Engineering Experiment Station

Texas A&M Transportation Institute

CIR Center for Infrastructure Renewal

Partnership

60+ Staff Researchers & PhDs

$20M+ in active projects

The Center for Infrastructure Renewal

The Center for Infrastructure Renewal (CIR) has a vision to be the national leader in the development of transformative infrastructure solutions for Texas, the nation, and global partners. The center's mission to facilitate the creation of state-of-the-art methods, technologies, and solutions for accelerating infrastructure renewal rests on a unique partnership between the Texas A&M Engineering Experiment Station (TEES), the Texas A&M Transportation Institute (TTI), the Texas A&M College of Engineering (CoE), and the State of Texas. The Texas Legislature funded the construction of the CIR in 2015, and the building opened its doors in April 2018. Researchers, staff members, and funding either come from or are shared across TEES, TTI, and CoE, creating tremendous opportunities and a few challenges to leverage the best talent and processes among all three entities. Importantly, the CIR is integral to TEES and TTI executing their strategic plans and visions for the future.

For more than 100 years, TEES has improved lives through basic and applied engineering research and development in the state of Texas and the nation. As one of eight state agencies within The Texas A&M University System, TEES was established in 1914 as part of the Texas land-grant university system (under State Statute Chapter 88, Subchapter E, Texas Education Code). TEES performs cutting-edge research, advances the workforce through education and technology transfer, and offers solutions to improve quality of life and foster economic development. TEES's structure maximizes research and educational partnerships across the state and nation by forming networks that bring together subject matter expertise from universities, national laboratories, state and federal agencies, and industry. For more information about TEES, see https://tees.tamu.edu.

TEES Facts

- **1,000+ Projects**
- **600+ Industry Partnerships**
- **$241M External Research**

TTI, like TEES, is a state agency with a decades-long and storied history of great impact in Texas and across the nation. Established in 1955, TTI researchers pursue better ways to develop and maintain safe and efficient transportation—saving lives, time, and resources. Today's TTI vision is to "lead in the creation of knowledge that transforms transportation for the benefit of society." Its mission statement, "TTI delivers practical, innovative and sustainable solutions to improve the movement of people, data and goods through research, education and technology transfer," reflects its history of developing practical and impactful solutions we see and experience every day as we move about our cities and country. For more information and the latest about TTI, see https://tti.tamu.edu.

The great advantage of the CIR is working within our parent organizations and bringing into the facility itself a history and culture of service to the state and nation. By focusing on the outcomes and benefits more than the brands, we are all a part of discoveries with impact.

TTI Facts

- $66.9M Annual Research Expenditures
- 200+ Students
- 400+ Professional Researchers
- 200+ Public and Private Sponsors
- 700+ Annual Projects

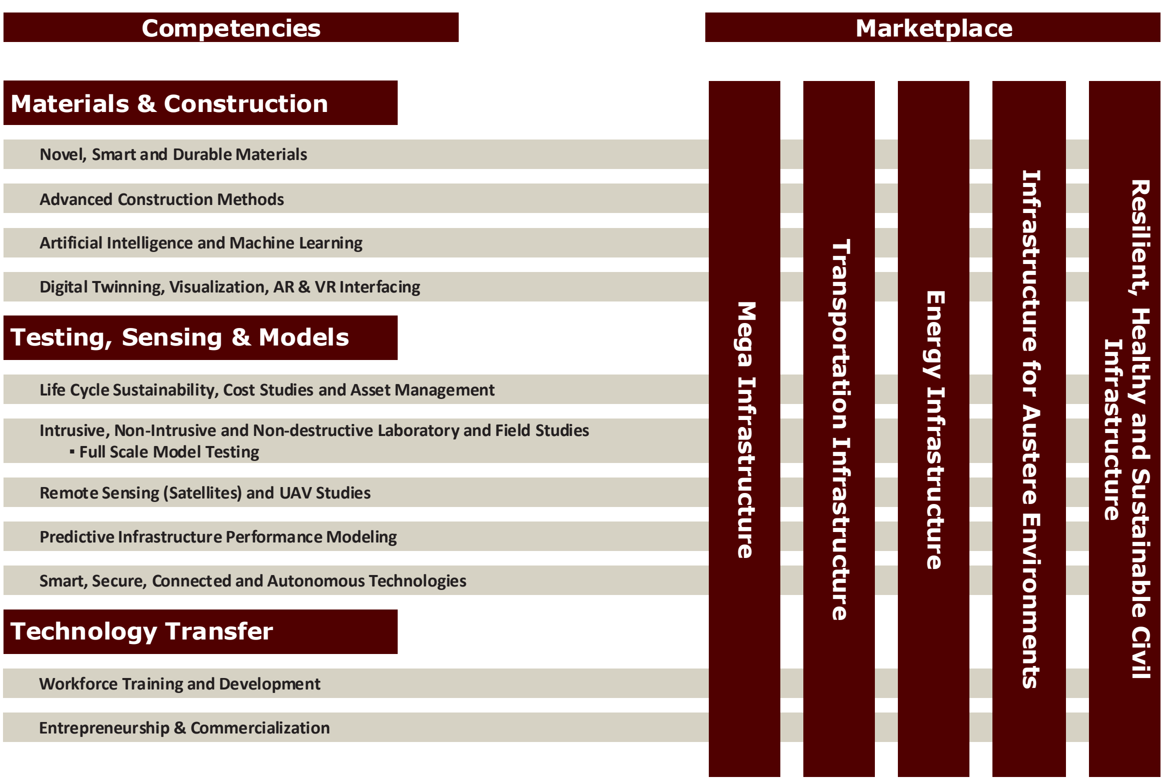
Focus on Markets and Competencies

Our strong relationship with TEES and TTI enables CIR leadership and research teams to firmly focus on infrastructure markets and competencies. TEES and TTI are built to discover and apply infrastructure design, fabrication, and construction techniques to engineering problems and have historically served as national leaders in this area.

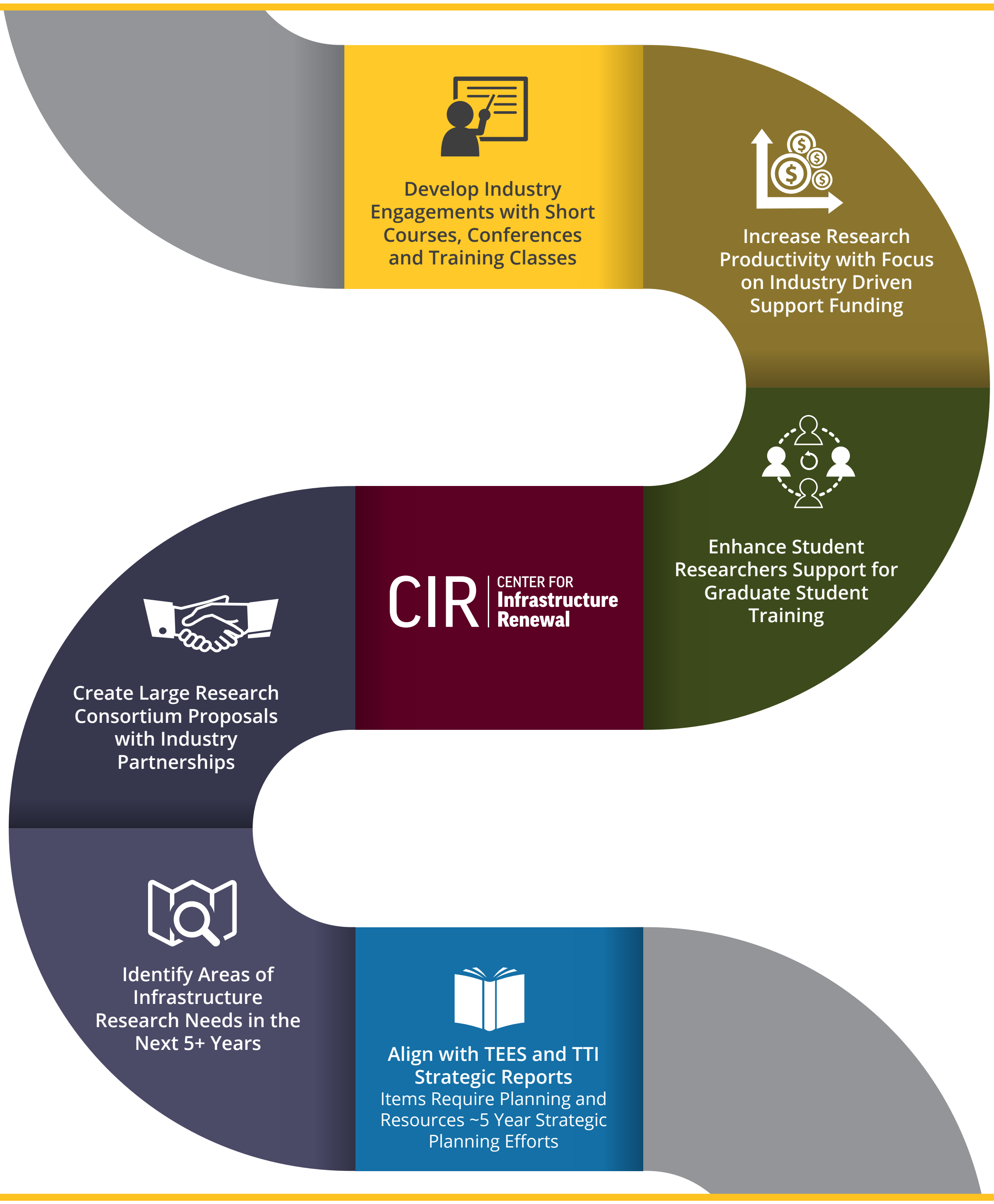
Markets are those sectors of infrastructure that (1) we believe will be important to the state and the nation over the next 5+ years, and (2) we currently are highly competitive in or have the potential to be highly competitive in within 5 years. The identification of these markets was based on a combination of projected state, national, and global infrastructure needs over the coming decade; areas of emphasized federal and state investment; and industry insights into future focus areas. We believe CIR researchers can make a concerted effort to remain or become competitive and relevant in these growing areas.

Competencies are those capabilities and resources associated with the CIR necessary to be highly competitive in the identified marketplaces. Competencies are often cross cutting and apply to multiple markets. For example, having expertise, facilities, equipment, and students that enable research into the use of artificial intelligence and machine learning applied to infrastructure-related design, construction, maintenance, and operation will be important in each marketplace. Also, emerging fields such as remote-sensing and photogrammetry operations, novel and sustainable materials, and data-centric connected infrastructure will offer many challenging multi- and transdisciplinary opportunities in various application areas, including infrastructure asset management, resilient and smart-built infrastructure, and others.

We oriented the development of this strategic plan around this construct to understand what differentiates the CIR from our peers and determine where we should invest our time, money, and talent. Over the course of several months, CIR leadership met with TEES, TTI, CIR, and industry leaders and researchers to identify the markets we see as being critical to our contributions today and into the future. Similarly, we worked with those same groups to identify the areas of competency essential for our short- and long-term differentiation from our peers. Based on these discussions, we developed markets and competencies of this CIR strategic plan, which are presented in the figure below.

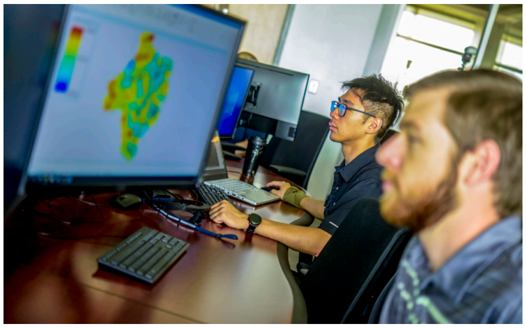


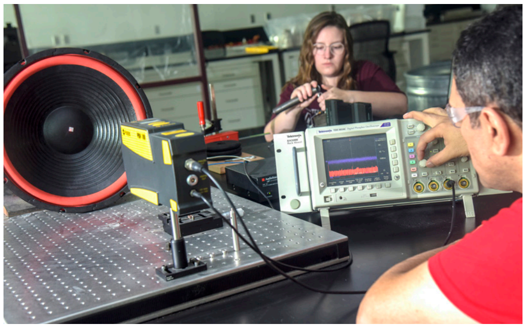
Focus on Markets and Competencies



Certainly, the marketplace and competency lists are not exhaustive of our expertise, capabilities, or research interests. Texas A&M is home to the largest civil engineering department in the country, and the College of Engineering ranks second in undergraduate enrollment, ninth in graduate enrollment, and second in research expenditures.

As a result, we have the intellect and laboratories to address demands across all technical areas related to infrastructure, either directly in the CIR or within other labs associated with Texas A&M, TEES, or TTI. Marketplaces and competencies represent areas we believe warrant special emphasis to best position our CIR researchers and labs to meet the demands of our nation and industries and to keep us at the forefront of the highest-priority infrastructure research and development in the next decade.





Focus on Markets and Competencies

Markets

Resilient, healthy, and sustainable civil infrastructure is a broad area with a title reflective of important and often overlapping terms that describe infrastructure characteristics valued by the public and industry. Resilience in infrastructure refers to the ability to recover from an adverse event, whether it be the elasticity of a material to return to its original shape, a power grid to be restarted, the electric load to be shifted to available circuits, or something similar.

Healthy refers to materials and methods that will make our workspaces, communities, or climate healthier. Safer construction methods, community considerations, and improved indoor air quality are examples of healthy infrastructure initiatives. Sustainable refers to using materials in a way that does not deplete or damage our future and current resources. Specific methods of coastal and urban infrastructure designs integrated with reliability-based design against various hazards and use of recycling materials along with novel low-carbon cementitious materials for infrastructure are prime examples of sustainable infrastructure.

Infrastructure for austere environments considers construction in remote or desolate locations. Applications include construction in space and on the moon; support for military operations overseas or in challenging domains like the arctic and extreme cold regions; and construction response following manmade or natural disasters. Important design goals in this market space include utilization of local materials (soils, sea water, dredging); rapid, simple, inexpensive, and safe construction; unique design life—some for use until permanent construction or repairs can be completed; and use of automation in construction practice.

Energy infrastructure for both production and distribution of energy is critical to the Texas and U.S. economies. The crippling winter storm in February of 2021 highlighted the urgency of research and discovery related to robust and resilient electrical grids, including microgrids. Researchers can lower construction and operational costs of offshore and onshore wind power production using composite and corrosion-free materials and construction methods, such as additive manufacturing and offshore concrete production, as well as improved structural design. Another area of interest is the integration of the electrical grid with the transportation network.

Transportation infrastructure has always been a central marketplace for TTI and TEES researchers. The CIR currently supports much-needed research to develop more durable and resilient roadways; increase the use of recycled materials in construction; and create innovative road, rail, bridge, and port designs and rapid construction techniques. Consistent feedback is needed for more effective material modeling to underpin design and construction across all transportation network components. As the population in Texas continues to rapidly grow, the need for low-cost, long-lasting, sustainable transportation infrastructure will continue. Furthermore, there is a national need—backed by legislation—to improve and modernize the national transportation infrastructure.

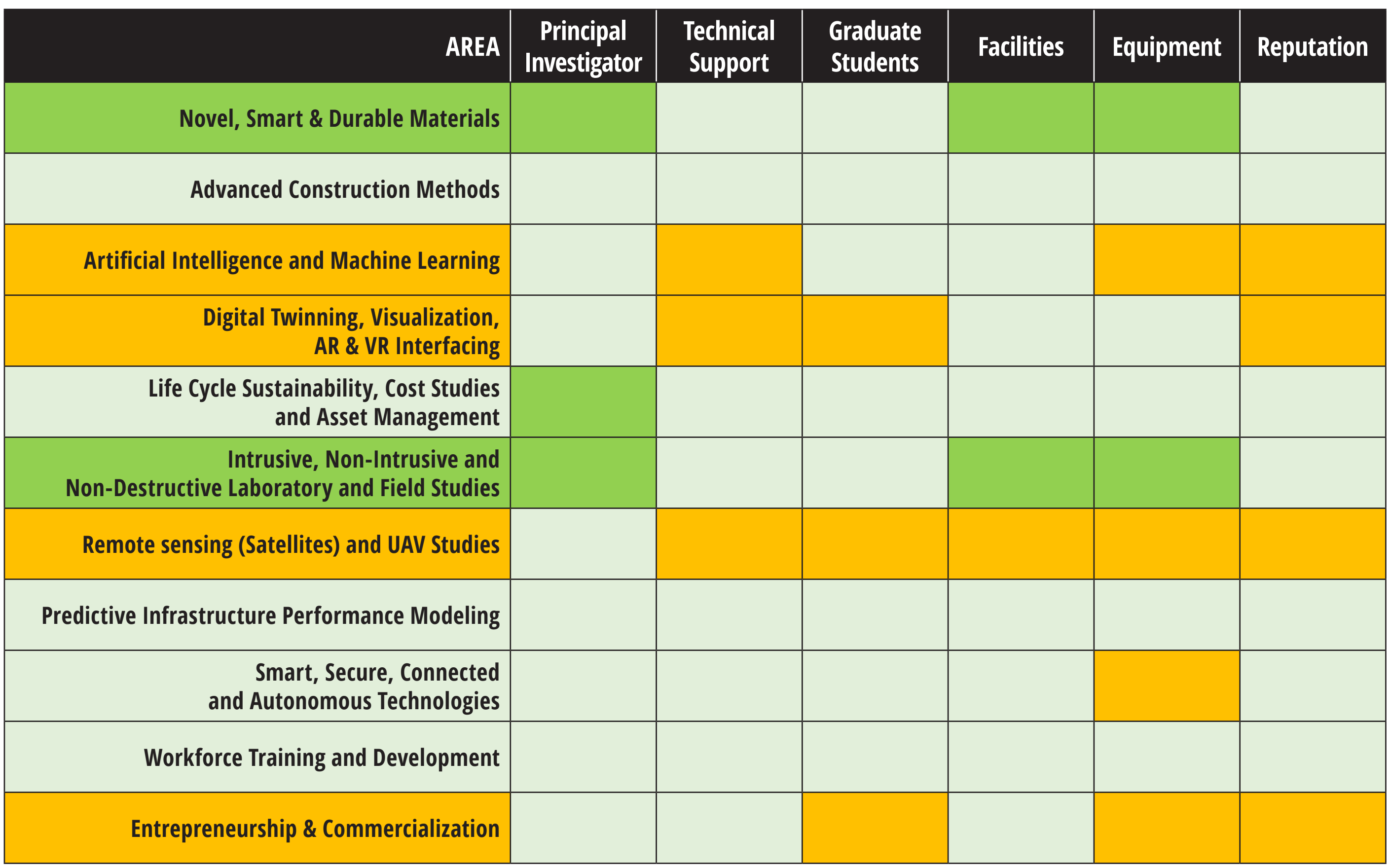
Mega infrastructure involves long, multiyear, multidecade design and construction programs, such as building infrastructure of a country or a city to host the Olympics or World Cup, that can benefit from applied research early in the design and construction programs that can then be implemented over the course of the program. The research outcomes should be focused on areas such as improving safety, construction, or facility operating efficiency; lowering construction, operational, and life-cycle costs; and increasing the lifespan while bringing technology, materials, and techniques to bear in the program. Large and long-duration programs provide incentives for sponsors to partner with researchers in ways that routine and lower-cost projects do not. This market is not a traditional space in which academic researchers often participate, but one in which there is a clear potential for added value.

Focus on Markets and Competencies

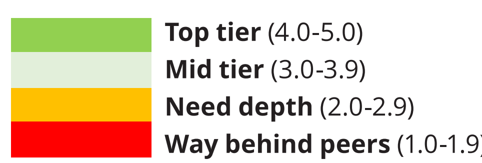
Competencies

An essential step in building our strategic plan is to honestly assess where we are today regarding our competencies—the capabilities that our research clients and partners see in the CIR and affiliated researchers that drive relevance in the marketplace. What are our strengths that differentiate us from our peers and drive the scale of our current research program? What areas do we need to grow to ensure our teams remain relevant and competitive in the future? One thing that is clear is that multi- and transdisciplinary engineering—the need to apply multiple engineering disciplines to effectively solve challenges and enable discovery—will only grow in importance in the future. So our assessment is not about “either this or that” but rather “this and that.”

Based on internal self-assessments that included a critical review of where we stand with our peer institutions, short surveys, and meetings with CIR researchers, technicians, students, and selected TEES and TTI leadership team members, we have identified several competency areas that rank our researchers, reputation, laboratory and equipment facilities, technical support, and graduate student involvement.



This figure captures how reserachers, technical staff, graduate students and TEES/TTI/CIR leaders assess areas critical to each competency area.



What We Found

Competency Strengths to Leverage and Reinforce

Strategic growth and partnerships are built on foundations of strength. It is requisite that the CIR leverage and expand its areas of strength to grow in effectiveness and impact across the country. Two competency areas are clear strengths and differentiate the CIR from our peers. The first is research and discovery related to novel, smart, and durable materials. The second is our ability to understand what occurs in materials and infrastructure using intrusive, nonintrusive, and nondestructive laboratory testing, often combined with field studies. Going forward, the CIR will continue to deliver great materials research, testing, and discovery. It is in our DNA and arguably THE essential competency going forward.

Opportunities

Opportunities describe those technical competency areas that are growing in importance to our industries and profession. These are not niche areas of expertise but reflect the digitalization and direction of our profession across virtually all marketplaces. The CIR team needs to deliberately strengthen these competencies to meet growing demands and expectations of our clients and research partners. Our goal is to lead into the future, and the time is now.

The three areas that we **need to strengthen** are artificial intelligence (AI) and machine learning; digital twinning, visualization, and augmented reality (AR) and virtual reality (VR) interfacing; and remote-sensing (satellites, air vehicles) and unmanned aerial vehicle (UAV) studies.

Artificial intelligence and machine learning is becoming integral to infrastructure and facility operations, and manufacturing processes and research need to both take advantage of AI in research activities and also build AI and machine learning components, such as automated algorithms for operations, into research outcomes.

Digital twinning, visualization, and AR and VR interfacing are becoming standard techniques across industry, from electrical grids to all mechanical systems within a single building or campus-like setting. Improving the quality of these tools for designers and operators over the coming decades is a key market area for industry and potentially research.

Remote-sensing (satellites, air vehicles) and UAV studies are driving more efficient, safer, and less time intensive assessments of infrastructure systems. By improving these developing tools, CIR researchers can lower life-cycle and operational costs for infrastructure owners through improved efficiency and effectiveness in asset management strategies.

Entrepreneurship and Commercialization—Deliberate Development

Entrepreneurship and commercialization are two competency areas that reflect development opportunities across the entire CIR research team and mirror the path of both TEES and TTI. The two are related, yet slightly different. Researchers can be entrepreneurial in setting up their research programs and specialties without pursuing commercialization of their research outcomes and ideas. We want our researchers to be entrepreneurial—treating their research as a business—in all their specialty areas.

Additionally, we want to intentionally increase applied research and the commercialization of viable outcomes, whether algorithms, models, or physical products. Our researchers have achieved great discoveries, and we need to help them reap appropriate financial rewards for their intellectual property (IP)—their discoveries. By identifying and protecting IPs through patents and commercializing products, our researchers achieve greater recognition and long-term financial stability. As our researchers thrive and receive recognition, so too will the CIR.

Strategies, Goals, and Measures

How we will enhance strengths and pursue opportunities

Since our researchers and center are part of TEES and TTI, our strategies and goals are consistent with and directly support the strategies and goals of these two parent organizations. In general terms, when we achieve CIR goals, we help TEES and TTI achieve their goals and metrics. Our strategy is to strengthen or grow key competency areas, targeting the previously identified markets where possible. We will work closely with leadership from TEES, the CoE (in particular Civil and Environmental Engineering), other departments, and TTI to strengthen these areas so that we will be competitive with future and national infrastructure initiatives, including major centers of excellence.

The four elements for strategic emphasis are partnerships, human capital, facilities and equipment, and training and technology transfer. Our measures are often lifted directly from the TEES and TTI strategic plans and have an identified CIR-specific target. Selecting measures already in place with our parent organizations ensures full alignment with their priorities and measures the CIR similarly.

Partnerships

As an organization, we exist to partner with others to solve some of the world's most challenging and practical problems. Without partners and sponsors, we have no purpose. One of our most important strategies is to grow our partnerships in the key markets we identified. We will evaluate our growth using one broad and several targeted measures. The CIR's overarching partnership goal is to obtain $25 million per year in sponsored research at the center within 5 years (2026). We will do this by:

- **TEES, TTI, other TEES centers, and College of Engineering partnerships:**
  - **Metric 1:** Increase the number of multicenter-related research projects to 2 by 2026, with one focused on materials and construction, and one on testing, sensing and models..
- **Cross-industry partnerships:**
  - **Metric 2:** Increase the number of industry partnerships to 3 by 2026.
  - **Metric 3:** Have 5 industry partners active in funding research in CIR labs and using CIR facilities by 2026.
  - **Metric 4:** Increase the number of industry partners using CIR services for testing/proving of technology and products to 10 by 2026.
- **Governmental agency partnerships:**
  - **Metric 5:** Increase the number of strategic partnerships to 3 by 2026.
  - **Metric 6:** Increase the number of state-sponsored research projects from inside and outside of the State of Texas to 15 by 2026.
  - **Metric 7:** Have at least 8 federal research projects by 2026.

Strategies, Goals, and Measures
How we will enhance strengths and pursue opportunities

Our Team—Human Capital

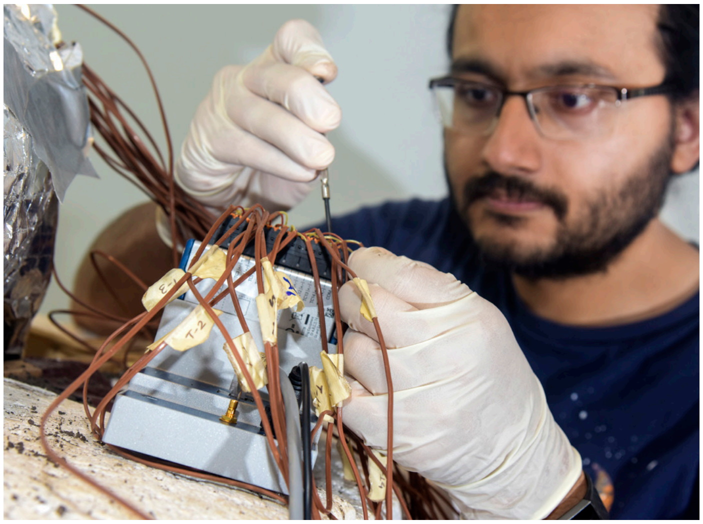
Our team of principal investigators (PIs), full- and part-time researchers, research technicians, and staff is the critical element in conducting world-class applied and basic research. Our goal is to work with TEES and TTI leadership to recruit, retain, and grow exceptional teammates.

- **Metric 1:** Increase full-time research staff in the CIR to 10 by 2026.
- **Metric 2:** increase the number of PIs actively using CIR facilities to 25 by 2026.

Facilities and Equipment

The CIR will house and provide state-of-the-art spaces and equipment to accelerate new infrastructure research and innovation.

- **Metric 1:** Improve provision and/or access to remote-sensing and UAV research-related equipment to enable 20% increase in infrastructure-related remote-sensing research.
- **Metric 2:** Acquire new laboratory and field equipment and nondestructive testing capabilities in various infrastructure tracks, such as additive manufacturing and unmanned aerial vehicles.
- **Metric 3:** Develop stronger computing capabilities for modeling and simulation.



Training and Technology Transfer

CIR researchers, technicians, and staff will place technology and skill sets into practice through our commercialization and the use of our training/classroom spaces.

- **Metric 1:** Increase the number of patents granted to CIR researchers to 1 per year by 2026.
- **Metric 2:** Increase the number of startups and established companies maturing and bringing CIR discoveries to market to 7 by 2026.
- **Metric 3:** Host 2 conferences or symposia per year sponsored by CIR researchers.
- **Metric 4:** Host 10 continuing education classes in our spaces per year by 2026.

Appendix:
Strategic Plan Development Methodology

A strategic plan typically describes how an organization will achieve its ambitions. It is a roadmap of investments, activities, and decision points along a multiyear journey. As the strategic plan authors and CIR team considered our journey and studied strategic planning books and guides, it became clear that strategic planning is often set aside or fails because the plan either does not help the leaders make strategic choices between multiple options after the plan is published or they simply elect not to make choices. This is a fundamental challenge for everyone involved—how do we make the best future choices and stick to our plan?

This challenge is certainly found in academia and the CIR. We hope to move broadly in key technology and research areas, yet individual researchers have earned the autonomy to operate successfully in important niche environments. This plan is not about forcing a choice between niche and broad area research. It is about how we consider time and resource investment choices in the years ahead to maximize the opportunities to grow the research portfolio in a manner that is beneficial to everyone, including the niche researcher.

Fundamentally, we believe in the adage a rising tide lifts all boats. In other words, by growing the research portfolio through serving key markets and developing/maturing needed competencies with our researchers, the opportunities and support for everyone will improve as the reputations of CIR and Texas A&M rise.

The CIR leadership team used a deliberate process to consider the current and future marketplace of infrastructure-related research and testing. By beginning with a small team, expanding to multiple center directors, and ultimately including all the CIR researchers in a series of meetings, the team received the broadest possible views on the future direction of research and the areas that will provide the greatest opportunities in the next decade.

An essential step in building our strategic plan is to honestly assess where we are today regarding our competencies—the capabilities that our research clients and partners see in the CIR and affiliated researchers. We completed a self-assessment of our research teams, facilities, equipment, and reputation to identify the strengths that differentiate us from our peers and the areas we need to grow to ensure our teams remain relevant in the future. Our assessment is not about "either this or that" but rather "this and that."

Figure Y presents the results of a survey sent to all CIR researchers, technicians, a sampling of graduate students, and selected TEES and TTI leaders. We asked respondents to compare CIR capabilities and expertise with those of peer institutions and centers, such as the University of Illinois and Purdue University. The responses used a 5-point Likert scale, with a 3 representing the average of peer institutions and centers. The questions addressed each competency area and focused on the expertise or equipment capabilities and depth of principal investigators, technical support (staff), graduate students, facilities, equipment, and CIR/TEES/TTI reputation. The full questionnaire can be found in Appendix B.

Appendix:
Strategic Plan Development Methodology

AREA	Principal Investigator	Technical Support	Graduate Students	Facilities	Equipment	Reputation
Novel, Smart & Durable Materials	✓	●	●	✓	✓	●
Advanced Construction Methods	●	●	●	●	●	●
Artificial Intelligence and Machine Learning	●	⊖	●	●	⊖	⊖
Digital Twinning, Visualization, AR & VR Interfacing	●	⊖	⊖	●	●	⊖
Life Cycle Sustainability, Cost Studies and Asset Management	✓	●	●	●	●	●
Intrusive, Non-Intrusive and Non-Destructive Laboratory and Field Studies	✓	●	●	●	✓	●
Remote sensing (Satellites) and UAV Studies	●	⊖	⊖	⊖	⊖	⊖
Predictive Infrastructure Performance Modeling	●	●	●	●	●	●
Smart, Secure, Connected and Autonomous Technologies	●	●	●	●	⊖	●
Workforce Training and Development	●	●	●	●	●	●
Entrepreneurship & Commercialization	●	●	⊖	●	⊖	⊖

This figure captures how reserachers, technical staff, graduate students and TEES/TTI/CIR leaders assess areas critical to each competency area.

✓	**Top tier** (4.0-5.0)
●	**Mid tier** (3.0-3.9)
⊖	**Need depth** (2.0-2.9)
✕	**Way behind peers** (1.0-1.9)

Instructions:

Please rank the investment need on each competency listed below, using 1-5 with 1 needing the most investment and 5 needing the least. If you are unsure of a ranking to use, feel free to leave a ranking blank. See detailed value explanations below.

- **Collective Tech Area PI Expertise (PIs):** (Note: this is not about a single PI, but the team of PIs across the CoE, TEES, and TTI) 5 = extreme breadth and depth of knowledge (multiple PIs published in impactful journals, research/grants), 4 = PIs are above average in either breadth or depth, 3 = PIs are in need of either depth and breadth to be above average, 2 = PIs need either depth and breadth to be average, 1 = PIs need both depth and breadth to be average (in respect to peer universities)

- **Technical Support:** 5 = sufficient capacity in both expertise and availability of technician support, 4 = sufficient but lacking either expertise depth or availability, 3 = moderate capacity but lacking in both expertise and availability to be sufficient, 2 = lack capacity and expertise, 1 = no technical support available

- **Graduate Students:** 5 = Students with strong skillset (experimental, computational, and analytical areas) and can perform their duties with no supervision, 4 = Students with very good or above average skillset (experimental, computational and analytical areas) and can perform their duties with limited supervision, 3 = Students with above average skill set and require moderate training to perform their duties under supervision, 2 = Students with average skill set and require considerable training to perform their duties under supervision, 1 = Students with average skill set and require significant training to perform their duties under supervision

- **Facilities:** (Facilities below addresses testing labs, and/or computational equipment and servers that are needed for areas such as tools/models, AI/ML and other fields) 5 = Wet/Dry/computational/IT-servers labs with all basic operational equipment needs including excellent electrical connections, access to air, water, vacuum as well as clean room conditions and hardware and software for lab operations, 4 = Wet/Dry/computational/IT-servers labs with majority of the basic equipment support systems and IT support systems, 3 = Wet/Dry/computational/IT-servers labs with above average basic equipment support systems and IT support systems, 2 = Wet/Dry/computational/IT-servers labs with average basic support systems and IT support systems, 1 = Wet/Dry/computational/IT-servers labs with below average basic support systems and IT support systems

- **Equipment:** (Equipment below addresses labs, tools/models, AI/ML and other fields that may need computational equipment and servers) 5 = Excellent - state-of-the-art laboratory and/or computational equipment with full software and hardware support, 4 = Very Good - majority of state-of-the-art laboratory and/or computational equipment with full software and hardware support with some pieces missing here and there, 3 = Good – Most of state-of-the-art laboratory and/or computational equipment with full software and hardware support with some a few important pieces missing here and there, 2 = Average - Adequate state-of-the-art laboratory and/or computational equipment with full software and hardware support with several important pieces missing here and there, 1 = Poor – Limited state-of-the-art laboratory and/or computational equipment and in a major need of many equipment and computational equipment and servers

- **TAMU Reputation:** 5 = recognized as top 5 program nationally in that particular concentration, 4 = above average in comparison to peer institutions (Georgia Tech, Illinois, Purdue), 3 = average in comparison to peer institutions, 2 = below average in that particular concentration, 1 = not nationally recognized in that particular concentration.

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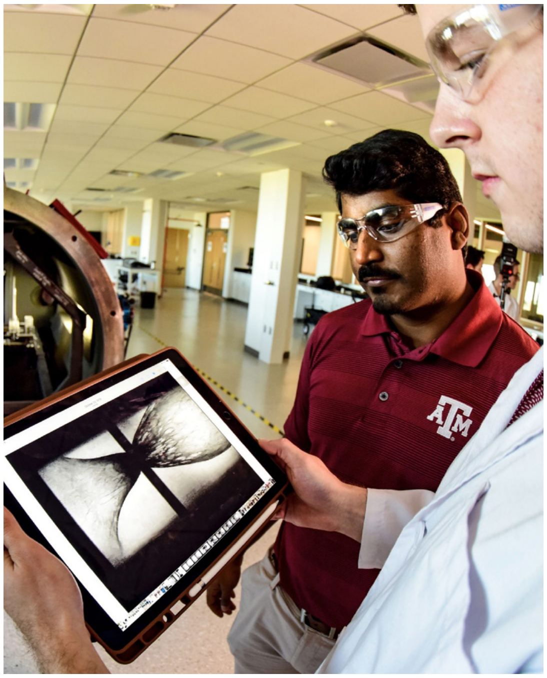

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