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Center for Transformative Infrastructure Preservation and Sustainability (CTIPS)
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1. ACCOMPLISHMENTS: What was done? What was learned?

a. What are the major goals of the program?

The Center for Transformative Infrastructure Preservation and Sustainability (CTIPS) aims to revolutionize the preservation of existing transportation systems through the integration of advanced sensing technologies and automation in data collection and analysis. Our research aligns with the statutory priority area of Preserving the Existing Transportation System and USDOT's non-exclusive candidate topic area of "asset management – techniques and cost-effective inspection, preservation, and maintenance practices." In addition, CTIPS's research will address a lack of access to high-quality transportation options in some areas of the region stemming from the relatively poor condition of rural and Tribal roads. Infrastructure Preservation through Autonomous Inspection and Artificial Intelligence and Infrastructure Preservation through Pavement Resilience and Bridge Management form the two focus areas of the research portfolio. Overall, the proposed research portfolio represents a transformative approach to preserving the existing transportation system. By integrating advanced technologies, automation, IoT, and AI, the research will revolutionize infrastructure condition monitoring and assessment, leading to safer, more reliable, and more sustainable transportation infrastructure. The research aligns with the statutory priority of Preserving the Existing Transportation System and with USDOT's goal of innovation by expanding current practices and introducing transformative technologies into the transportation sector. By setting a new benchmark for the industry, the expected impacts of CTIPS's research will benefit the transportation system and its users.

The overall objectives are to: (1) conduct basic and applied research, the products of which are judged by peers or other experts in the field of transportation to advance the body of knowledge in transportation; (2) offer an education program in transportation that includes multidisciplinary course work and participation in research; (3) conduct workforce development activities and programs to expand the workforce of transportation professionals; and (4) provide an ongoing program of technology transfer to make transportation research results available to potential users in a form that can be readily used. Other program goals are to select projects and activities using peer review principles and procedures and client input that: (1) support the statutory priority area of Preserving the Existing Transportation System and USDOT's research priorities of Asset Management and Resilience to include techniques and cost-effective inspection, preservation, and maintenance practices and (2) leverage UTC funds with matching funds from state and local governments and private industry. The chief operational goal is a comprehensive approach to address the aforementioned research priorities and systemic issues. The proposal is targeted at a future vision of system preservation and asset management. and other supporting objectives while addressing critical issues of the region and stakeholder groups.

b. What was accomplished under these goals?

i. Project Selection

Research projects selection for years 1, 2 and 3 are undergoing a peer review process for possible selection. The projects reflect substantial input and matching resources from state departments of transportation, MPOs in the region, and industry. Collectively, this set of projects addresses all of the Secretary's strategic goals and several of USDOT's requested emphasis areas under State of Good Repair—e.g., (1) bridge condition monitoring, (2) locating critical infrastructure defects, (3) identifying tools to prevent and detect corrosion in transportation infrastructure, (4) analytical tools for infrastructure performance management, and (5) methods and criteria to measure performance of new materials and methods. Other research projects are related to the Secretary's strategic goals of Safety, Economic Strength and Global Competitiveness, and Transformation and other supporting objectives.

CTIPS projects CTIPS-001 through CTIPS-052 have been selected, peer reviewed, and posted to the CTIPS website and are listed in Appendix A.

ii. Programmatic Milestones

In addition to the programmatic milestones described below, several milestones embedded within individual projects will be achieved as projects proceed. Most of the research projects call for literature reviews. The literature reviews for those projects with the earliest starts are being completed. Interim reports are not required after the literature review stage. So, no publications have been produced at this time. At this time, all projects are on schedule to be completed as planned during the program period.

The accomplishments to date are summarized in Table 1 by reference to milestones.

Table 1: Program Milestones

Milestone Event	Description	Start Date	End Date
Call for Proposals	The solicitation of proposals occurred on each university campus, using proposal guidelines developed by the director.	12/01/2023	11/30/2025
Execution of Grant Agreement	The grant was received from RD&T and executed by NDSU's Sponsored Programs office. All of the necessary internal accounting and financial procedures were established, including subcontract agreements with consortium universities. Grant No. 69A3552348308. Modification No. 1	12/01/2023 006/01/2024	11/30/2029 11/30/2029
Center Directory	A directory of key center personnel was completed and published on the center's website.	12/01/2023	11/30/2029
Center Website	The CTIPS website was updated and is fully functional for the current grant period	12/01/2023	11/30/2029
Peer Review of Proposals	All project proposals were subjected to external and internal peer review.	03/01/2024	11/30/2025
Primary Focus	Our research aligns with the statutory priority area of Preserving the Existing Transportation System and USDOT's non-exclusive candidate topic area of "asset management – techniques and cost-effective inspection, preservation, and maintenance practices." In addition, CTIPS's research will address issues in the region, especially issues stemming from the relatively poor quality of Tribal and rural roads. Infrastructure Preservation through Autonomous Inspection and Artificial Intelligence and Infrastructure Preservation through Pavement Resilience and Bridge Management form the two focus areas of the research portfolio. The research aligns with the statutory priority of Preserving the Existing Transportation System and with USDOT's goal of innovation by expanding current practices and introducing transformative technologies into the transportation sector.	12/01/2023	11/30/2029

Selection of Projects	Projects are being selected from the proposals received and awards were made to principal investigators, based on the peer reviews of proposals, stakeholder commitments, and the overall availability of funds.	04/01/2024	11/30/2025
Posting of Projects	The selected projects will be posted on the CTIPS website and added to the Research in Progress database.	04/01/2024	11/30/2025
Site Visit	A site visit to all CTIPS Universities will be conducted annually.	12/01/2023	11/30/2030
UTC/CUTC Winter Meeting	The director and administrative staff will attend the UTC/CUTC meeting at TRB and received guidance from RD&T regarding the forthcoming grant.	01/07/2026	01/07/2026

iii. Educational Accomplishments

The transportation and transportation-related courses offered during Spring, Summer, and Fall 2025 are listed in Appendix B, organized by major subject area. In some cases, courses with the same titles were offered at more than one CTIPS university. In these cases, the number of courses offered is shown in parenthesis.

Altogether, **156 transportation and transportation-related courses** were offered this reporting period, for a total of **475 total transportation courses** offered this grant period. In addition to the courses listed above, foundational courses in engineering materials, mechanics, structural analysis, and geotechnical engineering were offered at most CTIPS universities.

iv. Workforce Development Accomplishments

Training: A list of **41 training events** were provided for transportation professionals during this reporting period and are listed in Appendix C. Dates following training, are development dates. In addition, CTIPS had **155 online training modules** and **123 recorded sessions** that **9,045 transportation professionals** utilized to strengthen their workforce skills.

c. How have the results been disseminated?

The results will be disseminated in a variety of ways, including: (1) workshops and conferences, (2) videoconferences, (3) online modules, (4) presentations at conferences, (5) publications, (6) website postings and displays, (7) Internet-based dissemination media, including broadcast emails and webinars, and (8) YouTube delivery.

d. What progress has been made this reporting period and also what do you plan to do during the next reporting period to accomplish the goals?

Projects will be selected and research will continue, along with implementation of plan and grant schedule.

Colorado State University (CSU) continues to advance research in transportation technology, materials, and workforce development. Current projects include developing unmanned aerial systems (UAS) for infrastructure inspection (CTIPS-020, CTIPS-025) and AI/ML frameworks (CTIPS-021, CTIPS-050) for pavement evaluation and asset management. Researchers have achieved milestones in creating snow-melting geopolymer concrete (CTIPS-024) to improve winter performance and sustainability. Additional efforts focus on evaluating cosmic ray neutron rovers (CTIPS-022) and predictive models for resuspension emissions (CTIPS-023) to enhance road condition monitoring and safety. CSU is also expanding educational capacity

through new curriculum resources (CTIPS-039) and AI modules in construction education (CTIPS-045). Next steps include UAS field testing, algorithm refinement, material performance validation, and broader implementation of training modules. Together, these efforts strengthen transportation infrastructure, promote innovation, and prepare a technology-driven workforce.

North Dakota State University (NDSU) continues to lead research that advances transportation innovation, safety, and economic competitiveness across Region 8. Two new projects focus on smart pavement distress monitoring using deep learning (CTIPS-051) and rural post-crash Emergency Management Services (EMS) coverage and responsiveness (CTIPS-044). Ongoing work includes the Advanced Air Mobility (AAM) project to enhance freight logistics and preserve road conditions (CTIPS-001) and pavement assessment using distributed fiber-optic sensors (CTIPS-002). The AAM project has produced several peer-reviewed publications and strengthened collaboration between NDSU and the University of North Dakota, supporting strategies for rural AAM integration. The Local Road Safety project (CTIPS-040) advances the use of low-cost tools and practitioner-engaged safety planning for local and Tribal communities. All projects remain on schedule and within budget, reinforcing NDSU's commitment to transportation system safety, sustainability, and regional innovation.

South Dakota State University (SDSU) currently manages five active research projects under this grant, all aligned with the strategic goal of transformation. Each project is progressing on schedule with no reported delays. SDSU's research portfolio emphasizes collaboration and innovation through strong partnerships with state and regional transportation agencies, including the South Dakota Department of Transportation (SDDOT) and Alaska Department of Transportation and Public Facilities (DOT&PF), as well as industry partners such as Facca Inc. and Chryso Saint-Gobain Inc. These collaborations enhance the practical application and regional impact of SDSU's research, advancing transportation system performance and supporting transformative solutions across various environments.

University of Colorado Denver (CU Denver) achieved significant progress toward its transportation research and education objectives across multiple CTIPS projects. Several initiatives advanced from data preparation to analytical and modeling phases, addressing key goals in safety, asset management, and infrastructure performance. Project CTIPS-026 is performing advanced statistical analyses using integrated 311 data, while CTIPS-027 has developed a national high-injury network dataset and is refining its analytical framework. Bridge modeling and optimization studies (CTIPS-028, CTIPS-029) continue to advance, and projects on worker access and roadway design vehicle impacts (CTIPS-046, CTIPS-047) are analyzing large datasets to inform design practices. CTIPS-048 is progressing toward statewide contractor training to improve traffic data collection. In the next phase, CU Denver will complete modeling and analysis tasks, expand its high-injury network framework, finalize bridge models, and implement the CTIPS-048 pilot program while disseminating research findings broadly.

University of Denver (DU) continues to advance its transportation research and outreach initiatives through two active CTIPS projects. Data collection and analysis have been completed for both projects, and results are being synthesized for publication. A research brief summarizing findings from CTIPS-004 has been prepared and distributed to key stakeholders to support data-driven decision-making. Under CTIPS-049, DU successfully delivered an outreach workshop focused on careers and innovation in the transportation industry, engaging students and professionals across sectors. Workshop data have been analyzed to inform future programming, and preparations are underway for a second workshop in the spring. These efforts strengthen workforce development and promote innovation within the transportation field.

University of Utah continues to make strong progress across multiple CTIPS projects advancing strategic goals in Economic Strength, Safety, and Transformation. Under the Economic Strength and Global Competitiveness goal, the project on data-driven culvert inspection using federated learning (FL) completed feasibility assessments, model comparisons, and benefit quantification for UDOT, positioning it for project completion next period. For the Safety goal, several projects are advancing: AI- and mobile-based pavement marking and litter detection tools have completed algorithm development; guardrail optimization studies finalized cost-effective placement modeling; and LiDAR-based pavement retro-reflectivity estimation has

produced a working automated tool now in testing. Additional progress includes research on bridge deck delamination repair, rail buckling prevention using low-cost monitoring technologies, and subsurface seismic imaging via physics-informed neural networks. Under Transformation, the high-modified asphalt field performance project is progressing, though slightly delayed due to construction scheduling.

University of Wyoming (UW) continues to make steady progress on all active CTIPS projects, each advancing according to plan. The Pavement Management System (PMS) study successfully identified the maintenance and rehabilitation needs of all county paved roads across Wyoming. Findings have been shared with county engineers and commissioners to support data-informed decision-making. In the next reporting period, these identified needs will be presented to the Wyoming Legislature to secure funding for implementation. UW's efforts contribute directly to improved asset management practices and long-term infrastructure sustainability throughout the state.

Utah State University (USU) has made strong progress on its three active CTIPS projects, each advancing the goals of the individual studies and the broader CTIPS mission. Under the Safety goal, artificial intelligence (AI) is being applied to develop adaptive evacuation planning tools capable of responding to real-time conditions and improving emergency management effectiveness. For Economic Strength and Global Competitiveness, USU researchers are evaluating advanced cementitious materials—such as Engineered Cementitious Composites (ECC), Ultra High-Performance Concrete (UHPC), and polymer mixtures—to assess the feasibility of thin overlays for extending bridge deck service life. In support of the Transformation goal, computer vision methods are being developed to provide more accurate and comprehensive bridge condition assessments than conventional inspection techniques. A computer vision–based framework was successfully developed during this reporting period. All projects are progressing as planned, with continued research, testing, and validation activities scheduled for the next reporting period.

Fort Lewis College has successfully developed a low-cost, autonomous sonar boat designed to map and monitor dangerous erosion, or scour, around bridge foundations. Through two design iterations, the research team produced a robust, field-tested prototype capable of autonomously navigating pre-set GPS routes, collecting depth data, and returning to its launch point. A complete data processing pipeline was established to convert raw sonar readings into detailed 2D and 3D riverbed maps, effectively identifying potential scour zones. Key technical challenges—such as power stability and complex software integration—were resolved, marking a successful transition from concept to operational system. The next phase will focus on adapting the system for real-world deployment in flowing rivers. Planned activities include river testing to refine navigation and stability, conducting bridge-site missions to validate scour detection performance, and enhancing system endurance through battery and reliability improvements. These efforts will advance the technology toward practical implementation for bridge safety monitoring.

United Tribes Technical College (UTTC) achieved certification through the North Dakota Department of Transportation as a certified third-party Commercial Driver's License (CDL) testing provider. This milestone enables UTTC to play a more active role in supporting both Tribal and local schools by offering timely, accessible CDL testing. The new certification reduces delays that trainees often face when scheduling tests, helping move qualified drivers into the workforce more efficiently. Beyond immediate program benefits, this effort strengthens regional training capacity by allowing local testing and minimizing the need for extended travel or wait times. It also enhances collaboration among Tribal colleges and community partners, building a stronger network to support individuals pursuing CDL licensure. Collectively, these advancements contribute to addressing workforce shortages in transportation and related sectors while reinforcing UTTC's commitment to delivering high-quality, accessible training and testing opportunities.

University of North Dakota successfully completed both of its active CTIPS projects, meeting all stated objectives and milestones. The first project (CTIPS-011) advanced technology for improved preservation of steel transportation infrastructure through early corrosion detection using hyperspectral imagery. This innovative approach enhances the ability to identify and address corrosion issues before significant deterioration occurs, improving long-term asset management. The second project (CTIPS-012) contributed to transportation safety by investigating the performance and impacts of connected and automated vehicles (CAV) on state

highways. Findings from both projects provide valuable insights to support the safe integration of emerging technologies and the proactive maintenance of critical transportation assets.

Executive Summary

During this reporting period, partner universities and colleges within the CTIPS consortium made substantial progress in advancing transportation research, technology innovation, and workforce development across Region 8. Collectively, these efforts contribute to the U.S. Department of Transportation's strategic goals of **Safety**, **Economic Strength and Global Competitiveness**, and **Transformation** by integrating emerging technologies, developing sustainable materials, improving infrastructure performance, and preparing a skilled workforce.

Research teams across eleven institutions are leading innovations in artificial intelligence (AI), machine learning (ML), unmanned aerial systems (UAS), autonomous sensing, and data analytics to enhance transportation safety and asset management. Universities such as **Colorado State University**, **University of Colorado Denver**, and **University of Utah** are advancing data-driven inspection and modeling tools, AI-enabled infrastructure monitoring, and smart material technologies. **North Dakota State University** and **University of North Dakota** are pioneering multimodal air mobility research and advanced sensing methods to improve safety and logistics, while **Utah State University** and **University of Wyoming** are applying AI and materials research to strengthen resilience and asset management in rural and statewide contexts.

Smaller institutions—including **Fort Lewis College**, **South Dakota State University**, **University of Denver**, and **United Tribes Technical College**—are contributing through practical, community-driven projects focused on workforce development, safety outreach, low-cost monitoring, and accessible testing and training programs. These initiatives build regional capacity, foster innovation, and ensure that transportation improvements benefit both urban and rural communities.

All projects are **progressing on schedule and within budget**, with several nearing completion or producing early peer-reviewed publications and field-tested prototypes. Together, these accomplishments demonstrate the consortium's collective impact in advancing the performance, safety, and sustainability of transportation systems across the region and the nation.

2. PARTICIPANTS AND OTHER COLLABORATING ORGANIZATIONS: Who has been involved?

a. What organizations have been involved as partners?

- Agricultural Research Service, Fort Collins, CO, financial and in-kind support, facilities, collaborative research
- Alaska Department of Transportation & Public Facilities, Juneau, AK, financial support
- Association of American Railroads, Pueblo, CO, financial support
- Cankdeska Cikana Coummuity College, Fort Totten, ND, subject matter experts, facilities
- Chryso Saint-Gobain Inc., Ontario, Canada, in-kind support
- City of Durango, Durango, CO, facilities
- Colorado Department of Transportation, Denver, CO, financial support
- Colorado State University, College of Engineering, Fort Collins, CO, financial support, educational support, subject matter experts
- Colorado State University, Drone Center, Fort Collins, CO, in-kind support
- ConGlobal, Chicago, IL, in-kind support
- Crow Tribe, Crow Agency, MT, collaborative research
- Denver International Airport, Denver, CO, subject matter experts and in-kind support with survey data
- Denver Regional Council of Governments, Denver, CO, subject matter experts
- Department of Transportation and Infrastructure, Denver, CO, subject matter experts

- Durango Community Recreation Center, Durango, CO, facilities
- Facca Incorporated, Ruscom Station, Ontario, Canada, in-kind support, subject matter experts
- Fort Lewis College, Durango, CO, in-kind support
- Gallegos Consulting Inc, Denver, CO, in-kind support
- Gerber Construction, Lehi, UT, in-kind support
- NDSU Department of Civil, Construction, and Environmental Engineering, Fargo, ND, financial support for travel, materials, and support to researchers
- North Dakota Department of Corrections and Rehabilitation, Bismarck, ND, collaborative research
- North Dakota Department of Transportation, Bismarck, ND, financial support, subject matter experts
- North Dakota Local Technical Assistance Program, Bismarck, ND, financial support
- North Dakota State University, Fargo, ND, facilities, subject matter experts, in-kind support
- Sika USA, Lyndhurst, NJ, in-kind support
- South Dakota Department of Transportation, Aberdeen, SD, in-kind support
- South Dakota State University, Brookings, SD, facilities, in-kind support, and financial
- Structural Technologies, Columbia, MD, in-kind support
- The Powerhouse, Durango, CO, in-kind support
- Transportation Learning Network, Fargo, ND, financial support
- Truckload Carrier Association, Alexandria, VA, financial support, in-kind support
- UDOT Maintenance & Facility Management Division, Salt Lake City, UT, subject matter experts, personnel exchanges
- United Parcel Service, Atlanta, GA, in-kind support
- United Tribes Technical College, Bismarck, ND, financial support, facilities
- University of Illinois Urbana-Champaign, Urbana, IL, collaborative research
- USDOT, Office of the Assistant Secretary for Research and Technology, Washington, DC, financial support
- Utah Department of Transportation, Materials and Structures Division, Salt Lake City, UT, subject matter experts
- Utah Department of Transportation, Salt Lake City, UT, financial support, subject matter experts
- Utah Systems of Higher Education, Salt Lake City, UT, financial support
- Utah Transit Authority, Salt Lake City, UT, in-kind support
- Wyoming Department of Transportation, Cheyenne, WY, financial support, data support, subject matter experts

b. Have other collaborators or contacts been involved?

USDOT's continued support with the award of this grant has allowed us to encourage and support **72 principal investigators, faculty, and administrators at 11 universities in Region 8.** In addition, we have been able to support, mentor, and develop research skills and knowledge in transportation for **75 students from the U.S. and countries around the world. These includes 1 post-doctoral, 34 doctoral students, 18 master's students, 15 undergraduate, and 7 certificate program students**. The following other collaborators have been identified and are working with our PIs on CTIPS projects that are outside of our consortium:

- Mostafa Tazarv, University of Nevada, Reno
- Anish Poudel, MxV Rail
- David Stevens, Utah Department of Transportation
- Hal Johnson, Utah Transit Authority
- Jim Ward, Truckload Carriers Association
- John Popovics, University of Illinois, Urbana-Champaign

- Jovan Tatar, University of Delaware
- Larry Gallegos, Private Engineering Consultant
- Nick Ferenchak, University of New Mexico
- Xinying Bi, Rice University

3. OUTPUTS: What new research, technology or process has the program produced?

a. Publications can be found in Appendix D

During this period CTIPS faculty and investigators have published **18 peer-reviewed articles or papers** in scientific, technical, or professional journals. Since the beginning of this grant, **we have published 47** different peer-reviewed articles or papers.

b. Conference papers can be found in Appendix D

This reporting period **we have published 25 conference papers and 40 total since the grant began**.

c. Presentations can be found in Appendix D

CTIPS faculty and investigators **have presented at 26 different** scientific, technical, or professional conference this period. In total, **we have had 55 presentations on CTIPS research**, results, and outcomes.

d. Other outputs to include but not limited to website(s) or other internet site(s).

i. The CTIPS website is fully operational with additional information added as needed at https://www.ctips.org/
ii. The CTIPS Key Personnel Directory can be found at https://www.ctips.org/personnel/executive-committee.php
iii. CTIPS project descriptions can be found at https://www.ctips.org/projects/
iv. Other outputs during this reporting period that are University specific:

University of Utah developed an enhanced Mixed Integer Programming (MIP) formulation and decomposition algorithms for optimizing guardrail placement along highways. These models integrate crash data with roadside features extracted using computer vision and are documented in the project's final report to support replication and future applications. Project methodologies and case studies have been incorporated into the undergraduate course CVEEN 3520, providing students with applied learning in optimization and transportation safety. A new methodology was also created to estimate pavement marking retro reflectivity by combining LiDAR and street-level imagery through automated image processing and machine learning techniques. A paper detailing this work was submitted to the Transportation Research Board Annual Meeting. Additionally, based on collaboration with the Utah Department of Transportation, the team developed a new epoxy injection repair process for bridge decks constructed with partial-depth precast concrete panels.

University of Wyoming developed a combined Clustering–Pareto Framework to improve cost estimation analysis in transportation projects. This hybrid approach integrates K-means clustering with Pareto analysis to detect systemic deviations in cost estimates and identify the most costly and impactful bid items across project categories. The framework provides a structured method for prioritizing problematic pay items, enhancing the accuracy of engineer's estimates, and supporting more efficient resource allocation. Findings and methodologies are being disseminated through conference papers and presentations, including a submission to the Construction Research Congress Joint Conference 2026**,** to engage both academic and industry audiences.

Utah State University advanced research in AI-driven safety and infrastructure assessment. The team developed Gemma-3 Evacuation, a fine-tuned large language model within the CTIPS-supported EvacuAIDi framework, trained on the Evacuation-Safety-QA Dataset to encode evacuation safety knowledge. In addition, a dual transformer–based deep learning method with late fusion was developed to enhance the accuracy of computer vision–based infrastructure inspection. This approach integrates two segmentation techniques to

provide detailed, element-level corrosion information, offering a significant advancement in automated condition assessment tools.

Fort Lewis College advanced its research on low-cost, open-source technologies for bridge safety monitoring. The team designed and built an autonomous surface vehicle (USV) for bridge inspection surveys and established a complete workflow for its assembly and data analysis. Results were presented at the FLC Fall Welcome Poster Symposium (September 2025). Seven undergraduate students were recruited to enhance and deploy the USV as part of their senior capstone project. To extend operational capability, the team also integrated an unmanned aerial vehicle (UAV) to complement the surface system under challenging environmental conditions. Both platforms will be refined and released as open-source tools via GitHub and associated publications by May 2026. A key outcome of this effort is the successful development and validation of a fully integrated system—from the autonomous vehicle to a functional data pipeline—capable of converting raw sensor data into clear 2D and 3D visual maps, demonstrating the viability of the approach.

United Tribes Technical College achieved certification from the Department of Transportation as a third-party Commercial Driver's License (CDL) testing center. This certification enables the institution to provide timely and accessible CDL testing for students and trainees, reducing delays associated with external scheduling and helping qualified drivers enter the workforce more efficiently. The initiative strengthens the college's transportation training program while expanding capacity for Tribal and local schools through locally available testing services. It also enhances collaboration with other Tribal colleges and community partners, building a regional support network for CDL training and licensure. By improving access to professional certification, United Tribes Technical College contributes directly to addressing workforce shortages in the transportation sector and reinforces its commitment to high-quality, education and training opportunities.

Executive Summary

During the reporting period, the multi-institution research team—comprising the **University of Utah**, **Utah State University**, **University of Wyoming**, **Fort Lewis College**, and **United Tribes Technical College**—achieved significant advances in transportation safety, infrastructure innovation, and workforce development.

The **University of Utah** developed improved optimization and computer vision models for guardrail placement and pavement marking retro reflectivity, alongside new bridge deck repair techniques. **Utah State University** advanced AI-driven safety systems through the Gemma-3 Evacuation model and introduced deep learning methods for corrosion detection. The **University of Wyoming** created a hybrid Clustering–Pareto Framework to enhance cost estimation accuracy and resource allocation across project categories. **Fort Lewis College** designed an integrated open-source system combining autonomous surface and aerial vehicles for bridge inspection and mapping, engaging undergraduate students in applied research. **United Tribes Technical College** became a certified Department of Transportation third-party CDL testing center, expanding regional workforce capacity and accessibility.

Together, these initiatives demonstrate a coordinated effort to apply cutting-edge technologies and collaborative education to improve transportation system safety, efficiency, and inclusivity.

4. OUTCOMES: What outcomes has the program produced? How are the research outputs described in section (3) above being used to create outcomes?

The Center for Transformative Infrastructure Preservation and Sustainability (CTIPS) consortium, comprising eleven partner universities, has generated a substantial body of project outcomes across its research, education, and technology transfer initiatives. Given the breadth and depth of these results, detailed summaries are presented in Appendix E, organized by university for clarity and ease of reference. Below is an **executive summary** highlighting the collective achievements and overarching outcomes of CTIPS as a whole.

a. Increased understanding and awareness of transportation issues.

The **Center for Transformative Infrastructure Preservation and Sustainability (CTIPS)** is advancing innovation in transportation research, education, and workforce development through a coordinated, multi-institutional effort. Its projects integrate artificial intelligence, robotics, sensing technologies, sustainable materials, and data-driven decision-making to address critical challenges in transportation infrastructure and safety. Collectively, CTIPS initiatives have expanded the scientific understanding of UAS-based inspection accuracy, gravel road moisture monitoring, emissions from vehicle resuspension, and the development of advanced, snow-melting geopolymer concretes. Research has also advanced sustainable materials science, AI-driven bridge inspection, and predictive maintenance methods that enhance infrastructure reliability and longevity.

CTIPS projects are modernizing transportation through data-centric tools for pavement assessment, distributed fiber optic sensors for real-time condition monitoring, and deep learning systems that unify distress detection and severity analysis. Studies on freight logistics, air mobility, and post-crash emergency response are providing data-driven insights that improve system performance and safety, particularly in rural and Tribal regions. Parallel research on bridge automation, wireless sensors, and cold-climate pavement materials is informing new design standards and accelerating adoption of durable, cost-effective construction practices.

AI applications are being successfully demonstrated in asset management, guardrail placement optimization, and litter detection, while federated learning frameworks are introducing secure data-sharing methods for state DOTs. Advances in non-contact corrosion detection, seismic imaging, and context-aware bridge inspection algorithms are setting new benchmarks for proactive maintenance and infrastructure intelligence.

Beyond technology, CTIPS is cultivating the next generation of transportation professionals through hands-on research, AI-integrated coursework, and cross-disciplinary education in robotics, materials, and data science. Simulation-based CDL training and collaborative workforce programs are addressing labor shortages and increasing access to high-quality, technology-enabled transportation careers.

Collectively, CTIPS research is transforming how infrastructure is designed, maintained, and managed. By linking emerging technologies with workforce readiness and sustainability principles, CTIPS is creating a safer, smarter, and a more reliable national transportation system that advances both scientific knowledge and practical application.

b. Passage of new policy, regulation, rulemaking, or legislation.

The **Center for Transformative Infrastructure Preservation and Sustainability (CTIPS)** is catalyzing policy, regulatory, and institutional change by translating research outcomes into actionable guidance for transportation agencies, legislators, and industry leaders. Across its multi-institutional portfolio, CTIPS research bridges scientific discovery with real-world governance, enabling data-driven decision-making that strengthens safety, sustainability, and infrastructure reliability.

Through projects focused on air mobility, autonomous systems, , and advanced materials, CTIPS is providing policymakers with evidence to shape emerging transportation standards.. Research on robotic inspection and UAS-based bridge assessment is contributing to the evolution of safety and certification frameworks for automated infrastructure evaluation, while work on concrete repair and advanced materials is guiding updates to structural and pavement specifications that improve long-term performance.

CTIPS projects are also redefining how transportation data is used in policymaking. Predictive analytics and AI-based asset management research are providing a scientific foundation for performance-based funding, maintenance prioritization, and equitable investment strategies. High-Injury Network analysis frameworks are

offering tools for agencies to better allocate safety resources, while emergency response studies are producing quantitative benchmarks for EMS performance and post-crash care in rural and Tribal regions.

Collectively, CTIPS research is strengthening collaboration between transportation agencies, health systems, and environmental regulators. By aligning engineering innovation with policy development, these projects are shaping new rulemaking efforts, influencing future design standards, and supporting the safe integration of connected, autonomous, and sustainable technologies. CTIPS continues to demonstrate that rigorous, applied research can serve as a catalyst for informed, adaptive policymaking—ensuring that transportation systems across the nation evolve toward greater safety, efficiency, and equity.

c. Increased in the body of knowledge.

The **Center for Transformative Infrastructure Preservation and Sustainability (CTIPS)** is advancing the national body of knowledge in transportation through applied, interdisciplinary research that bridges science, engineering, and technology. Across its university network, CTIPS projects are generating new insights into infrastructure monitoring, materials innovation, artificial intelligence, safety systems, and human factors—strengthening the theoretical and practical foundations that guide modern transportation research and implementation.

CTIPS-supported studies are contributing to measurable advances in transportation science. Research in unmanned aerial systems (UAS), robotics, and artificial intelligence is expanding understanding of infrastructure inspection, condition assessment, and asset management. Projects integrating machine learning and sensor fusion are establishing reproducible models for detecting bridge damage, evaluating pavement conditions, and automating data analysis—laying the groundwork for next-generation predictive maintenance systems. Work on vehicle emissions, road moisture monitoring, and neutron rover technology is producing validated datasets that refine environmental modeling and maintenance decision-making.

Parallel research in materials engineering is redefining transportation infrastructure. Investigations into graphene nanoplatelet dispersion, geopolymer concretes, and high-modified asphalt are generating scientific data that informs material design standards, and extending service life. Studies on freeze–thaw soil dynamics, salinity effects, and warm-mix asphalt performance are enhancing understanding of pavement durability in cold climates, while field validation of bridge deck overlays and epoxy repair methods provides practical frameworks for improved construction.

In the safety and mobility domains, CTIPS research is producing breakthrough insights that influence both practice and policy. Projects on advanced air mobility, connected and autonomous vehicles (CAVs), and emergency response systems are expanding the frontiers of transportation safety and intelligent mobility. The integration of physics-informed neural networks, federated learning, and behavioral AI is deepening the scientific understanding of risk modeling, decision-making, and system improvement across urban and rural environments.

CTIPS also advances the human and institutional aspects of transportation research. Studies on workforce recruitment, safety culture, and organizational behavior in commercial driving are informing a new understanding of human factors in transportation operations. At the same time, open-source frameworks, shared datasets, and reproducible algorithms are accelerating collaboration across academia, industry, and government.

Collectively, CTIPS projects are generating a diverse and enduring body of scientific knowledge—linking materials science, artificial intelligence, infrastructure management, and behavioral analysis into a cohesive foundation for future research. Through its interdisciplinary, data-driven approach, CTIPS continues to expand the frontiers of transportation science, empowering agencies, practitioners, and scholars to design, operate, and sustain safer, smarter, and more reliable transportation systems.

d. Improved processes, technologies, techniques and skills in addressing transportation issues.

The **Center for Transformative Infrastructure Preservation and Sustainability (CTIPS)** continues to advance the transportation field through innovations that improve how infrastructure is assessed, designed, and managed. Across its network of partner universities, CTIPS research is modernizing the processes, technologies, techniques, and professional skills essential for a reliable, data-driven transportation system. By combining applied research with hands-on training and interdisciplinary collaboration, CTIPS is strengthening both the technical foundations and human capacities that sustain national infrastructure innovation.

Projects supported by CTIPS are transforming infrastructure monitoring through automation, robotics, and sensing technologies. Unmanned aerial systems (UAS) and distributed fiber optic sensing (DFOS) are replacing time-intensive manual inspections with faster, more accurate methods, while AI-enabled models integrate distress detection, severity analysis, and predictive maintenance into single, streamlined workflows. Similar advances in computer vision, digital image correlation, and LiDAR-based retro reflectivity measurement are improving inspection precision and efficiency across bridges, pavements, and rail systems.

In materials and construction, CTIPS researchers are developing and validating advanced technologies—from ultra-high-performance concrete overlays to warm-mix asphalt additives and engineered cementitious composites—that extend service life, reduce costs, and enhance safety. The application of physics-informed models and field-tested methods ensures these innovations are ready for direct adoption by transportation agencies and contractors.

Data analytics and artificial intelligence are redefining transportation management processes. Projects on predictive infrastructure planning, cost estimation, and federated learning are providing agencies with new tools for evidence-based decision-making and resource optimization. These efforts foster transparency, improve performance forecasting, and strengthen institutional capacity for long-term infrastructure stewardship. Equally impactful are CTIPS's contributions to workforce and skill development. Through immersive coursework, multimedia educational materials, and simulation-based training, students and professionals are gaining expertise in AI, robotics, data science, and innovative construction. This integrated training approach ensures that the next generation of engineers, planners, and technicians is prepared to lead in an era of automation and advanced analytics.

Collectively, CTIPS's institutional advancements are transforming how infrastructure systems are monitored, maintained, and managed. By merging technological progress with education and process innovation, CTIPS is cultivating a more capable, efficient, and forward-looking transportation workforce—one equipped to deliver safer, smarter, and more sustainable solutions for the nation's evolving mobility challenges.

e. Enlargement of the pool of trained transportation professionals.

The **Center for Transformative Infrastructure Preservation and Sustainability (CTIPS)** is advancing national transportation capacity by cultivating a new generation of professionals equipped to lead in a rapidly evolving, technology-driven field. Through experiential learning, applied research, and interdisciplinary training, CTIPS projects are expanding both the technical expertise and professional readiness of students, educators, and practitioners across the transportation ecosystem. These initiatives emphasize the integration of emerging technologies—such as artificial intelligence, robotics, data analytics, unmanned aerial systems (UAS), and improved materials—into transportation research, education, and operations, ensuring that the workforce is prepared to meet the challenges of modern infrastructure management and mobility innovation.

Across participating institutions, CTIPS projects are strengthening the professional pipeline through hands-on, application-based learning. Programs in UAS-enabled inspection, AI-driven infrastructure management, and advanced materials testing are providing students with direct exposure to tools and techniques used by transportation agencies and industry partners. From drone pilot certification and distributed fiber optic

sensing to predictive modeling and digital image correlation, participants are gaining cutting-edge technical competencies that bridge theory and practice.

Workforce development extends beyond the classroom to agencies, contractors, and communities. Training modules and workshops developed under CTIPS projects are enhancing the skills of DOT staff and transportation practitioners in areas such as data-driven maintenance, safety analysis, cost estimation, and performance monitoring. At the same time, initiatives like simulation-based commercial driver training and Tribal college certification programs are addressing critical workforce shortages in the logistics and transit sectors, creating accessible pathways for diverse populations to enter and advance within the transportation industry.

By embedding education and workforce engagement into every stage of the research process, CTIPS is ensuring that innovation translates into human capital development. Students and professionals trained under these programs are not only contributing to immediate project outcomes but are also entering the field prepared to implement, adapt, and advance the next generation of transportation technologies. Collectively, these efforts are enlarging the nation's pool of highly skilled transportation professionals—empowering a resilient, data-savvy, and future-ready workforce capable of building and maintaining the infrastructure systems of tomorrow.

f. Adoption of new technologies or practices.

The **Center for Transformative Infrastructure Preservation and Sustainability (CTIPS)** is accelerating the adoption of next-generation technologies, techniques, and practices that bridge the gap between academic research and transportation implementation. Across its regional consortium, CTIPS projects emphasize practical application, user-centered design, and workforce readiness—ensuring that innovations in artificial intelligence, sensing technologies, materials science, and data analytics are transitioned from laboratories to real-world use. These efforts collectively empower transportation agencies to operate more efficiently, innovatively, and safely while positioning the U.S. transportation sector at the forefront of global infrastructure innovation.

CTIPS researchers are creating validated tools and frameworks that enable immediate adoption by practitioners. Automated inspection systems, distributed fiber-optic sensors, and AI-powered pavement and bridge monitoring platforms are transforming infrastructure assessment from reactive to predictive management. Through federated learning, data-sharing models, and sensor-based analytics, CTIPS projects are establishing scalable, privacy-preserving systems for collaborative asset management. Similar advances in LiDAR-based retro reflectivity measurement, mobile data collection, and intelligent guardrail placement are modernizing roadway monitoring and safety evaluation.

In construction and materials, CTIPS-funded work is introducing durable and reliable innovations such as engineered cementitious composites (ECC), ultra-high-performance concrete (UHPC) overlays, and highly modified asphalt mixtures. These technologies are supported by robust testing and implementation guidelines, enabling transportation agencies to adopt them with confidence. Projects further demonstrate how recycled materials, advanced geopolymers, and sustainable additives can improve performance while reducing costs and environmental impact.

Beyond technical innovation, CTIPS fosters adoption through education, training, and workforce engagement. Courses in UAS inspection, AI for infrastructure, and advanced materials engineering prepare professionals to integrate new technologies into their daily operations. Collaborative demonstrations and pilot deployments—such as low-cost robotic monitoring systems and autonomous vehicle applications—are equipping local, state, and tribal agencies with ready-to-use frameworks for modernization.

By combining research validation with direct implementation strategies, CTIPS ensures that innovation leads to measurable change in practice. The consortium's collaborative model—linking universities, government agencies, and industry—facilitates rapid technology transfer, ensuring that new ideas become standard tools in the field. Collectively, CTIPS projects are redefining the national approach to transportation

modernization by advancing automation, enhancing data-driven decision-making, and accelerating the widespread adoption of technologies that strengthen infrastructure performance, safety, and sustainability.

5. IMPACTS: What is the impact of the program? How has it contributed to improve the transportation system; enhance safety, reliability, durability, improve transportation education, and/or strengthen the workforce, etc.?

The Center for Transformative Infrastructure Preservation and Sustainability (CTIPS) consortium, comprising eleven partner universities, has generated a substantial body of project impacts across its research, education, and technology transfer initiatives. Given the breadth and depth of these results, detailed summaries are presented in Appendix E, organized by university for clarity and ease of reference. Below is an **executive summary** highlighting the collective achievements and overarching impacts of CTIPS as a whole.

a. What is the impact on the effectiveness of the transportation system?

The **Center for Transformative Infrastructure Preservation and Sustainability (CTIPS)** is strengthening the overall effectiveness of national transportation systems by integrating innovation into every layer of infrastructure design, management, and operation. Through applied research, advanced analytics, and workforce engagement, CTIPS projects are reducing maintenance costs, improving safety and durability, and increasing the innovation of transportation networks. Collectively, these efforts ensure that systems are not only more efficient and innovative but also better equipped to support future mobility demands.

Across the CTIPS consortium, research is demonstrating tangible improvements in transportation system performance. At the technical level, advances in unmanned aerial systems (UAS), distributed fiber-optic sensing (DFOS), and AI-based inspection have enabled faster, more accurate monitoring of bridges, pavements, and roads. Predictive maintenance tools and automated data analysis models are extending asset life cycles while cutting operational costs. Similarly, innovations in materials—such as warm-mix asphalt, ultra-high-performance concrete, and engineered cementitious composites—are producing more improved pavements and bridge structures capable of withstanding harsh environmental conditions.

CTIPS projects are also enhancing system safety through technology-enabled decision-making. Studies on rural crash response, emergency evacuation modeling, and guardrail optimization are improving response times, reducing fatalities, and guiding targeted infrastructure investments. Meanwhile, AI and federated learning applications are helping transportation agencies transition from reactive to predictive asset management, improving planning efficiency and resource allocation.

Beyond physical infrastructure, CTIPS initiatives are advancing the human and institutional dimensions of system effectiveness. Simulation-based training, AI-integrated curricula, and credentialing programs are preparing a highly skilled workforce capable of deploying advanced technologies in operational settings. These educational and professional development activities strengthen the alignment between research innovation and field implementation, ensuring sustainable improvements across transportation sectors.

By combining technical advancements with practical applications, CTIPS is demonstrating how innovation directly translates into measurable gains in transportation system effectiveness. The consortium's unified approach—linking universities, agencies, and industry partners—has resulted in safer roads, longer-lasting assets, reduced maintenance costs, and more efficient operations nationwide. Collectively, CTIPS research is enabling a transformation toward data-driven, reliable, and future-ready transportation networks that enhance both mobility and public safety for generations to come.

b. What is the impact of technology transfer on industry and government entities, on the adoption of new practices, or on research outcomes which have led to initiating a start-up company?

The **Center for Transformative Infrastructure Preservation and Sustainability (CTIPS)** is accelerating the nationwide adoption of advanced technologies, techniques, and practices that are redefining how transportation systems are designed, inspected, and maintained. Through targeted research and applied innovation, CTIPS projects bridge the gap between laboratory discovery and field implementation—delivering practical, ready-to-use solutions that strengthen infrastructure performance, improve operational efficiency, and enhance public safety. Collectively, these initiatives are driving measurable progress toward a more intelligent, reliable, and data-driven transportation system.

Across the CTIPS network, researchers are producing applied technologies that agencies can adopt directly into daily practice. Unmanned aerial systems (UAS), distributed fiber optic sensing (DFOS), and autonomous monitoring platforms are transforming inspection workflows by enabling faster, safer, and more accurate data collection. The integration of artificial intelligence and machine learning—seen in projects on automated pavement distress detection, bridge condition modeling, and predictive maintenance—reduces manual workload, improves decision accuracy, and extends the service life of infrastructure assets. These technologies are already being tested and refined with state departments of transportation, demonstrating their scalability and field readiness.

Materials research within CTIPS further supports adoption by providing proven, sustainable alternatives for construction and maintenance. Advances in ultra-high-performance concrete, engineered cementitious composites, and warm-mix asphalt are improving durability while reducing environmental impact and lifecycle costs. These materials innovations, coupled with new processes for bridge repair and overlay design, are enabling agencies to modernize specifications and transition toward more reliable construction practices.

Beyond technical implementation, CTIPS fosters adoption through workforce training, education, and demonstration. Courses in drone-based inspection, AI-enabled infrastructure management, and simulation-based training prepare engineers and technicians to deploy emerging technologies effectively. Partner institutions are collaborating with departments of transportation, Tribal colleges, and local agencies to test prototypes, conduct pilot deployments, and develop implementation guidelines—ensuring that innovations move efficiently from research environments to operational use.

By aligning technological innovation with workforce readiness and policy application, CTIPS is creating a comprehensive model for advancing transportation modernization. Its projects are equipping public agencies and industry professionals with validated tools, automated systems, and improved materials that are already influencing practice across the country. Together, these advancements represent a tangible transformation in how infrastructure is managed and maintained—delivering smarter, safer, and more innovative transportation networks for the future.

c. What is the impact on the body of scientific knowledge?

The **Center for Transformative Infrastructure Preservation and Sustainability (CTIPS)** is significantly advancing the scientific foundation of transportation research across the United States. Through cutting-edge studies in artificial intelligence, materials science, robotics, sensing, and safety analytics, CTIPS projects are generating new knowledge that is reshaping how infrastructure is designed, maintained, and managed. These contributions extend beyond academic inquiry, producing validated frameworks, datasets, and analytical tools that directly inform engineering practice, policy, and education.

Across the CTIPS consortium, researchers are breaking new ground in both fundamental and applied science. Projects exploring **machine learning and AI** are creating context-aware algorithms, multimodal deep learning frameworks, and federated learning systems that enhance predictive maintenance, asset management, and safety modeling. These advances demonstrate how artificial intelligence can improve infrastructure

performance while preserving data privacy and efficiency. In **materials science**, research on ultra-high-performance concrete (UHPC), engineered cementitious composites (ECC), graphene-infused geopolymers, and high-modified asphalt is generating empirical data on strength, sustainability, and long-term durability—contributing directly to more reliable and cost-effective infrastructure systems.

Innovations in **sensing and monitoring technologies**—including distributed fiber-optic systems, cosmic ray neutron rovers, and low-cost robotic scour monitoring—are transforming how infrastructure health is measured and predicted. These methods provide continuous, high-resolution data that enhance both scientific understanding and field application. CTIPS research in **automation and robotics** is likewise setting new standards for bridge and pavement inspection, replacing manual methods with adaptive, data-driven systems capable of real-time decision-making and performance evaluation. Beyond physical and computational advances, CTIPS projects are also contributing to the **social and behavioral sciences of transportation**. Studies on workforce safety, commercial driver retention, and human decision-making during emergency evacuations are yielding new insights into human factors, organizational culture, and safety system design. Educational innovations—such as AI-integrated curricula, simulation-based CDL training, and student research initiatives—are expanding the evidence base for effective transportation education and workforce development.

Collectively, CTIPS research outputs are enriching the global body of scientific knowledge that underpins modern transportation systems. Publications, open-source datasets, analytical models, and prototype tools are ensuring that discoveries translate into tangible benefits for agencies, practitioners, and communities. By advancing the frontiers of materials performance, sensing precision, data intelligence, and human-centered design, CTIPS is building the scientific foundation for a safer, smarter, and more sustainable transportation future.

d. What is the impact on transportation workforce development?

The **Center for Transformative Infrastructure Preservation and Sustainability (CTIPS)** continues to make measurable progress in advancing transportation research, workforce development, and the adoption of innovative technologies that enhance the durability, safety, and efficiency of the nation's infrastructure. Through its network of partner universities, CTIPS integrates artificial intelligence, advanced sensing, unmanned aerial systems (UAS), sustainable materials, and modernized education into a unified strategy for transportation innovation. Collectively, these projects are expanding the scientific foundation of the field, equipping future professionals with cutting-edge skills, and ensuring that research translates directly into practical improvements for transportation systems nationwide.

Across all partner institutions, CTIPS projects are producing substantial workforce and educational impacts. At **Colorado State University**, hands-on learning opportunities—such as the *Engineering with Drones* course and graduate-level AI and materials research—are directly preparing students for leadership in UAS inspection, sustainable construction, and infrastructure management. At **North Dakota State University**, students are gaining expertise in advanced sensing, data modeling, and rural safety analytics through projects in air mobility, fiber optic sensing, and post-crash response. **South Dakota State University** has integrated laboratory and field research on pavements, bridges, and cold-region materials into graduate and undergraduate instruction, ensuring long-term knowledge transfer to both students and practitioners.

The **University of Colorado Denver** is cultivating data-driven professionals through applied training in GIS, safety analysis, bridge management, and traffic sensor deployment. Similarly, the **University of Denver** is expanding the human dimension of transportation research through projects that address driver recruitment and retention, and that inspire the next generation of transportation professionals through undergraduate engagement and interdisciplinary collaboration.

At the **University of Utah**, projects span artificial intelligence, materials science, and infrastructure, training both students and state agency staff in predictive modeling, automated inspection, and emerging

transportation systems. The **University of Wyoming** provides experiential learning in pavement management and intelligent transportation systems, directly linking research outcomes with practitioner applications in local and county agencies. **Utah State University** continues to advance workforce skills in AI, materials innovation, and bridge engineering, cultivating expertise essential for the next generation of transportation leaders.

At **Fort Lewis College**, interdisciplinary training in robotics, civil engineering, and data science has created a new model for hands-on learning that supports safer and more efficient infrastructure monitoring. **United Tribes Technical College** has expanded workforce readiness through its *Driving Futures* program, integrating simulation-based CDL training and certification to address workforce shortages in tribal and rural regions. Finally, the **University of North Dakota** is developing professionals skilled in remote sensing, automation, and connected vehicle systems, preparing them for emerging challenges in infrastructure preservation and intelligent mobility.

Collectively, CTIPS projects are transforming how transportation professionals are educated, trained, and equipped. By embedding real-world research experiences, advanced analytics, and technology applications into the learning environment, CTIPS is building a workforce capable of implementing innovative, data-driven, and AI-enabled solutions that will strengthen the nation's infrastructure for decades to come.

6. CHANGES/PROBLEMS:

a. Changes in approach and reasons for change.

- A comprehensive review of the CTIPS website was completed, and updates were made to ensure full compliance with Federal requirements and Executive Orders 14148, 14153, and 14154.
- All CTIPS projects were reviewed, updated as necessary, reposted, and submitted to the grant manager for approval to confirm alignment with Federal requirements and the above Executive Orders.

b. Actual or anticipated problems or delays and actions or plans to resolve them.

Colorado State University – During this reporting period, several CTIPS projects encountered challenges such as scheduling delays, scope adjustments, and unexpected personnel changes. These included issues with field access and permitting, institutional transitions, and revisions to experimental designs. The project PIs have been responsive and proactive in identifying solutions to address the challenges, ensuring continued progress and the delivery of meaningful results. The projects that need NDSU's attention includes: CTIPS-024: The Principal Investigator's transition from Colorado State University to Boise State University necessitated a modification of scope, with the project focusing on the completion of Tasks 1 and 2 while Tasks 3 through 5 were removed to ensure meaningful results could still be achieved within available resources.

University of Colorado Denver – During this reporting period, the primary change to the CTIPS research approach occurred in CTIPS-026, where the team shifted from a cluster analysis method to a multilevel modeling framework. This adjustment allows for a more precise incorporation of area-level attributes and spatial variation within the analysis, improving the robustness of the results. The change does not affect project outputs, scope, or budget, but enhances the analytical depth and resolution of the study's findings. No other significant changes to the research approaches of CU Denver's CTIPS projects were reported during this period.

University of North Dakota – We are defining a new unified project; however, the review has been lengthy.

c. Changes that have a significant impact on expenditures.

- Nothing to Report.

d. Significant changes in use or car of human subjects, vertebrate animals, and/or biohazards.

- Nothing to Report.

e. Changes in primary performance site location from that originally proposed.

- Nothing to Report.

7. SPECIAL REPORTING REQUIREMENTS:

Nothing to Report.