NSF Science and Technology Center (STC)
Learning the Earth with Artificial Intelligence and Physics (LEAP)

Strategic and Implementation Plan 2021-2026

Context

Climate change poses unprecedented risk for human sustainability. This grand challenge threatens civil infrastructure, agriculture, public health, economic security, and international peace, with our world's most underserved communities disproportionately facing the greatest burden. Global adaptation, such as building sea walls, is projected to cost between $280B and $500B (USD) per year; early adaptation will maximize efficiency, resiliency, and cost-effectiveness. Scientific uncertainty is a challenge to t public and private climate adaptation decisions in two key ways:
1. Climate-forcing factors (population and economic growth, technology development, land use) cannot be precisely predicted, leading to *scenario uncertainties*. These uncertainties dominate climate estimates after ~40 years in the future.
2. Climate models, which project future climates, are *too imprecise*. For example, by 2055 and for moderate emission pathways, the likely range of global temperature increase lies between 0.9°C and 2.0°C and the likely range for global mean sea level rise is between 0.19m and 0.33m. Regional projections are even less precise. Model uncertainties exist across all timescales, but are dominant for the near-term (10 to 40 years), and thus are an impediment to today's decisions regarding adaptation, investment, security, and resiliency.

Climate projection uncertainties stem from climate *model deficiencies* in representing physical and biological processes because: 1) these processes occur at scales *too small* to be explicitly resolved on models' coarse (~100km) spatial grid; and 2) *basic scientific knowledge remains incomplete*. Overcoming these science and technology barriers is a grand challenge for climate scientists and policymakers alike. At the same time, the proliferation of observational technologies continuously monitoring the Earth's system components – the atmosphere, ocean, land, and cryosphere – provides an avalanche of new data that offer dramatic potential for placing observational constraints on physical and biological processes. Further, high-resolution models can now *simulate* key small-scale and fast processes (e.g., clouds, ocean eddies) with great accuracy, though only for brief periods of time and over small geographic areas due to their high computational cost. These timely revolutions combine to reveal a distinctive opportunity for harvesting data to improve *climate model projections*. Yet, only a small fraction of available climate data is currently used because they are extremely challenging to fully exploit. In comparably data-rich fields (e.g., health, security), modern data science has propelled efficient exploitation of big data. Similarly, data science is uniquely poised to reshape climate modeling, dramatically increasing its societal utility.

Three substantial challenges stand in the way of reaching this ambitious goal: 1) machine learning must transcend traditional methods that efficiently interpolate but do not extrapolate to unseen conditions, and that do not respect physical constraints; 2) the need for efficient data use and access will require reshaping modern climate data infrastructure; and 3) more accurate projection knowledge must be transferred to public and private stakeholders to enable informed adaptation strategies.

Such ambitious goals are only achievable through a large-scale and long-term effort covering research, education and knowledge transfer. In 2021, the National Science Foundation funded the Science and Technology Center (STC): *Learning the Earth through Artificial Intelligence and Physics (LEAP)* to address this challenge.

Strategic Vision
LEAP will revolutionize climate projections for informed climate adaptation.

Achieving this vision will ensure that a large and broad range of public and private stakeholders have the required tools necessary for informed decision making when facing climate change.

Mission
LEAP's mission is to increase the reliability, utility, and reach of climate projections through the integration of climate and data science.

Our Mission will be achieved through the following Center **Values**:

- *Innovation*: Integrate new knowledge and methods to explore, learn and create;
- *Diversity*: Connect across and respect varied perspectives to achieve shared goals;
- *Legacy*: Building lasting scientific knowledge and a new research community.
  These values will help us reach our final key value:
- *Impact*: our work should make a difference in the adaptation to climate change.

Strategic Priorities/**Goals**:

- 1. Harness data to improve the reliability of the Community Earth System Model [Research]
- 2. Establish and deploy a modern cloud computing infrastructure for climate data, LEAP-Pangeo, in support of research, education, and knowledge transfer [Research, Knowledge Transfer]
- 3. Create a new discipline: Climate Data Science [Education, Research]
- 4. Establish bidirectional knowledge transfer regarding climate projections with a broad range of public and private stakeholders [Knowledge Transfer]
- 5. Integrate diversity, equity and inclusion in LEAP research, education, and knowledge transfer efforts and activities [Diversity, Equity and Inclusion]

5-year **Goals and Objectives:**

- Goal 1: **Harness data to improve the reliability of the Community Earth System Model**

Earth System Models (ESMs) depend heavily on empirical relationships to represent unresolved processes, leading to limited grounding in the vast, and rapidly growing, archive of Earth system data. Machine learning (ML) can extract valuable knowledge from these large datasets. LEAP will use ML to advance the Community Earth System Model (CESM) which is maintained by the National Center for Atmospheric Research (NCAR). While these ML advances are targeted to the CESM, they will also be tested in the ESM of NASA's Goddard Institute for Space Science (GISS), ModelE, to ensure their broad applicability. LEAP will also emphasize development of new ML techniques that are constrained by physical laws and are therefore more appropriate for ESMs.

    - Objective 1.1: Accelerate CESM development with novel parameterizations enabled by ML and growing datasets

      Actions:
        - Action 1.1.1. Develop new parameterizations by mining high-fidelity simulations (e.g., turbulence, convection) and observations (e.g., satellite) with ML
        - Action 1.1.2. Implement ML-based parameterizations into the CESM component models to reduce model structural errors
        - Action 1.1.3. Integrate, validate, and deploy parameterizations into CESM development code, supported by a LEAP integration engineer and CESM domain scientists

        - Action 1.1.4. Ensure research portfolio maintains balance across data availability spectrum (rich, moderate, poor) and Earth system components (atmosphere, ocean, land, ice)
        - Action 1.1.5. Facilitate interoperability of ML-based parameterizations with the NASA GISS ModelE

    - Objective 1.2: Push the frontiers of ML to create algorithms that discover and leverage physical and causal knowledge

      Actions:
        - Action 1.2.1. Develop physical and causal algorithms across the data richness spectrum (rich, moderate, poor)
        - Action 1.2.2. Publish and deploy computational tools that implement algorithms integrating physical and causal knowledge
        - Action 1.2.3. Curate datasets and present climate science challenges to the ML community to accelerate advances
        - Action 1.2.4. Integrate LEAP research into data science curriculum to broaden talent pipeline (linked to action 3.2.4)

    - Objective 1.3 Establish systematic ML-based methodology for calibration of Earth System Model parameters

      Actions:
        - Action 1.3.1. Provide tools to enable systematic calibration of CESM component model parameters against diverse sets of observations and multiple calibration targets
        - Action 1.3.2. Develop automated approaches for tuning of the coupled (cryosphere-land-ocean-atmosphere) CESM
        - Action 1.3.3. Facilitate interoperability of parameter calibration methodologies with NASA GISS ModelE

    - Objective 1.4: Quantify CESM and component model improvement with advanced metrics

      Actions:
        - Action 1.4.1. Comprehensively assess LEAP-derived changes in CESM skill through comparison to existing and new data products
        - Action 1.4.2. Develop new data products for model validation that utilize ML to extrapolate from sparse data to wide area coverage, with quantified uncertainties
        - Action 1.4.3. Develop new approaches to compare CESM to complex and multivariate datasets; focus on Earth system components where such tools are underdeveloped

    - Objective 1.5: Produce ML-enabled CESM community simulations

      Actions:
        - Action 1.5.1. At regular intervals, freeze a version of the ML-enabled CESM and run historical and future simulations
        - Action 1.5.2. Disseminate new climate projections to research, public, and corporate stakeholders

Leading Indicators

- Development of novel ML-based parameterizations and physics-constrained ML approaches

- Implementation of ML-based parameterizations into CESM
- Observation-based calibration of CESM parameters aided by ML
- Production of ML-informed Earth system datasets
- Reduction in CESM error statistics based on standard evaluation packages (e.g., ESMValTool) and new tools
- Production and distribution of ML-enabled CESM community simulations, and adoption of these LEAP simulations by others outside of LEAP
- Balanced portfolio of projects across Earth system components, data richness, and LEAP maturity
- Peer-reviewed publications and conference papers
- Invited and conference presentations
- Publish codes and datasets on online open-source repositories
- Funding of complementary research grants
- Ensure research portfolio shifts in maturity from majority Level 1 (proof of concept) to majority Level 3 (implementation in CESM) over the LEAP STC lifetime

- **Goal 2: Establish and deploy a modern cloud computing infrastructure for climate data, LEAP-Pangeo, in support of research, education, and knowledge transfer**

The complexity and technical challenges of working with modern climate data and ML software could pose a barrier to LEAP's strategic vision. Datasets have tremendously grown in size, often exceeding petabytes, and cannot be analyzed on stand-alone computers. To overcome this barrier, accelerate progress, and support convergence, LEAP will pioneer an innovative cyberinfrastructure deployed in the cloud which will democratize access to and analysis of climate data through state-of-the-art computational tools for researchers, educators, and for Knowledge Transfer (KT).

- Objective 2.1: Establish a modern data cloud computing infrastructure, LEAP-Pangeo, for data climate science research
  Actions:
  - Action 2.1.1. Develop and publish open standards and best practices to guide the development of a cloud-native climate data platform
  - Action 2.1.2. Operate cloud-based Jupyter and Binder services in partnership
  - Action 2.1.3. Operate data library and data ingestion / cataloging service
  - Action 2.1.4. Host a user-driven, curated catalog of observational and model data
    - Satellite observations
    - In-situ measurements
    - Low and high resolution model data
  - Action 2.1.5. Develop a no-code data exploration web portal aimed at education and KT (with CarbonPlan)
  - Action 2.1.6. Develop and implement a training curriculum for onboarding new participants (with NCAR)
  - Action 2.1.7. Develop LEAP-Pangeo infrastructure for research and KT

- Objective 2.2: Use LEAP-Pangeo to empower LEAP research (linked to Objective 1.2)

  Actions:
  - Action 2.2.1. Ingest datasets relevant to LEAP research into the data library
  - Action 2.2.2. Provide LEAP students, postdocs, and researchers with the software tools they need to conduct exploratory ML research in the cloud
  - Action 2.2.3. Facilitate collaboration and sharing across research projects via shared data and computing environments

- Objective 2.3: Use LEAP-Pangeo to empower LEAP Education

  Actions:
  - Action 2.3.1. Integrate LEAP-Pangeo datasets and computing into courses (linked to Objective 3.1)
  - Action 2.3.2. Integrate LEAP-Pangeo datasets and computing into the certificate program classes (linked to Objective 3.1)
  - Action 2.3.3. Integrate LEAP-Pangeo datasets and computing into hackathons (linked to Action 3.3.2)

- Objective 2.4: Use LEAPango to empower LEAP Knowledge Transfer

  Actions:
  - Action 2.4.1. Provide direct access to data-proximate Jupyter notebook environment for data-proficient partners to directly leverage climate data
  - Action 2.4.2. Provide modern interactive web interface to manipulate LEAP-Pangeo climate data and visualize climate projections by a range of stakeholders

Leading Indicators
- Published documents, standards, and best practices for the operation of a cloud-native science platforms
- Datasets hosted and disseminated (LEAP-Pangeo, Zenodo)
- Researchers accessing LEAP-Pangeo
- Papers which acknowledge LEAP-Pangeo infrastructure
- Courses which use LEAP-Pangeo infrastructure
- Participants in hackathons who access LEAP-Pangeo
- Partner institutions who access JupyterHub, Data Library, and Climate Information Portal

- **Goal 3: Create a new discipline: Climate Data Science**

Collaboration between the climate science and data science communities has historically been limited because of different jargon, objectives, and training. To resolve this gap, LEAP will drive transdisciplinary convergence and create the *Climate Data Science* discipline through research-integrated curriculum, with immersive and transdisciplinary research experiences, while broadening talent pathways and building partnerships with partner universities and institutions.

- Objective 3.1: Develop multiple training entry-points into Climate Data Science

  Actions:
  - Action 3.1.1. Formal curriculum and training
    - Develop one semester-long course at Columbia: Climate Prediction Challenges
    - Develop two doctoral research seminars at Columbia
    - Launch a certificate program in Climate Data Science
  - Action 3.1.2. Researcher development
    - Hold “Train the trainer” faculty workshops
    - Develop short bootcamps focused on gaining targeted skills
  - Action 3.1.3. Broadening participation
    - Host Bridge-to-PhD scholars for post-baccalaureate students (also broadening participation)

- Objective 3.2: Converge data science and climate science communities through interdisciplinary and cross-institutional research

  Actions:
  - Action 3.2.1. Implement LEAP's research objectives via interdisciplinary research working groups
  - Action 3.2.2. Create and hold Convergence Luncheons, facilitating shared vocabulary development across traditional disciplines
  - Action 3.2.3. Require representation of PIs from different communities on projects funded through internal RFP process
  - Action 3.2.4. Convergent research training
    - Offer LEAP Research Experiences for Undergraduates (REU) Summer opportunities in LEAP's convergent research
    - Train a cohort of doctoral fellows (3-year GRAs) on new Climate Data Science, using LEAP's convergent research; use internal RFP research support to projects that train doctoral students
    - Train postdocs on LEAP's convergent research
  - Action 3.2.5. Develop and hold (convergent) LEAP seminars and journal clubs

- Objective 3.3: Disseminate LEAP's research-education integration approach to a broad community

  Actions:
  - Action 3.3.1. Create a Design studio for curriculum development and to disseminate research-integrated curriculum
  - Action 3.3.2. Develop and run public hackathons using curated LEAP-Pangeo datasets (linked to Action 2.3.3)
  - Action 3.3.3. Provide research experiences to K-12 teachers (RET) and support them in developing curriculum for their classrooms based on LEAP's research

- Objective 3.4: Critically evaluate and improve *climate data science* education programs

  Actions:
  - Action 3.4.1. Develop instruments to evaluate LEAP non-research programs
  - Action 3.4.2. Publish annual educational evaluation report
  - Action 3.4.3. Engage trainers in designing and improving LEAP education programs

<u>Leading Indicators</u>

- Infrastructure:
  - Introduction of LEAP courses
  - Introduction and development of LEAP REU program
  - Introduction of LEAP certificate program
- Participation:
  - Students participating in LEAP courses
  - Research trainees, faculty, and senior researchers participating in LEAP education programs
  - PhD GRAs
  - REU participants and RET participants
- Convergence:
  - Achieve a balance of disciplines in LEAP research and education programs
  - Active research working group meetings
  - Submission of interdisciplinary proposals
- Pathways and Broadening Participation:

- Recruitment of Bridge-to-PhD scholars
- Engagement with SOARS' Protégés
- Students' progression in LEAP research and education activities

- **Goal 4: Establish bidirectional knowledge transfer regarding climate projections with a broad range of public and private stakeholders**

Active climate change adaptation has been limited by the difficulty to access pertinent and informed climate data, especially on climate projections. In turn, scientists develop metrics to evaluate climate models that might not be entirely relevant to stakeholders. To ensure that LEAP science and products are relevant and broadly accessible, we must therefore establish mechanisms that support a bidirectional exchange of knowledge, expertise, and insight between LEAP data and a broad range of stakeholders.

- Objective 4.1: Solicit input from multiple corporate and public stakeholders regarding the most relevant climate metrics for climate adaptation, the accessibility and usefulness of LEAP resources input, and establish an exchange of information on climate metrics between LEAP and stakeholders

  Actions:
  - Action 4.1.1. Actively engage stakeholders to evaluate accessibility of LEAP resources
  - Action 4.1.2. Share and interact with a range of stakeholders on most important climate metrics for climate adaptation, which will then be used to evaluate climate models
  - Action 4.1.3. Evaluate how communication of climate information to corporate and other stakeholders influences perceptions and behavior
  - Action 4.1.4. Learn from knowledge in stakeholders communities: integrate bottom-up community knowledge into LEAP science and its climate metrics

- Objective 4.2: Disseminate information about LEAP resources to multiple corporate and public stakeholders

  Actions:
  - Action 4.2.1. Develop active outreach to inform stakeholders of LEAP activities and resources
  - Action 4.2.2. Adhere to an open-science model, making data and educational resources accessible for LEAP web platforms (linked to Objective 2.4)
  - Action 4.2.3. Engage stakeholder communities on the significance and utility of climate data science

- Objective 4.3: Foster an understanding of the importance of reliable data for climate adaptation

  Actions:
  - Action 4.3.1. Disseminate LEAP research findings to the public:
    - "Ask Me Anything"
    - Storytellers in Residence
    - "Translate-a-Thons"
    - Public Lectures
  - Action 4.3.2. Develop an annual Hackathon (linked to Action 3.3.2)
  - Action 4.3.3. Develop a semi-annual newsletter illustrating LEAP research and its implications for climate adaptation

- Objective 4.4: Make all LEAP research and existing CMIP data open-source and broadly accessible

  Actions:
  - Action 4.4.1. Use a modern data cloud infrastructure, LEAP-Pangeo, for broad climate data accessibility and associated computing (on the cloud) (linked to Objective 2.4)
  - Action 4.4.2. Curate and develop educational resources in partnership with Teachers College, related to climate data science for a range of public stakeholders

Leading Indicators
- Number of visits to the LEAP and LEAP-Pangeo interface websites
- Reoccuring stakeholder use of LEAP data and knowledge transfer resources
- Downloads of LEAP knowledge transfer resources
- References to LEAP and LEAP resources in public, private, and academic scholarship and practice
- LEAP climate models are enhanced as a result of stakeholder climate metrics' input
- Subscriptions and downloads of semi-annual newsletter
- Reoccuring stakeholder participation in LEAP events and activities
- Depth and diversity of corporate collaborations and engagement with LEAP
- Diverse and effective educational, non-profit, and government collaborations with LEAP
- Causal evidence of effective framing of LEAP and climate communications to key stakeholders
- Efficient and relevant partnerships with stakeholders working with communities vulnerable to climate change

- **Goal 5: Integrate diversity, equity and inclusion in LEAP research, education, and knowledge transfer efforts and activities**

Climate change impacts everyone, but underprivileged communities are being disproportionately affected. To adapt to climate change, the use of climate data has not reached its full reach and capacity because current climate projection data are not easily accessible or usable, thus limiting broader climate change adaptation. In parallel, the geosciences have historically suffered from a lack of racial diversity. LEAP aims to solve those two issues at once by significantly increasing the diversity of its community so the use of climate data can be dramatically broadened for more impactful and equitable climate adaptation.

- Objective 5.1: Promote and evaluate Diversity, Equity and Inclusion (DEI) efforts throughout the center

  Actions:
  - Action 5.1.1. Hold an annual DEI workshop to increase DEI awareness and competency Equity Literacy & Visioning (integrating diverse perspectives), Equity Planning (short- and long-term strategic plans for DEI integration), Critical Strategy Assessment; at all levels of LEAP (Center to lab)
  - Action 5.1.2. Track diversity progress throughout the years using LEAP Underrepresented Minorities data analysis to inform an iterative DEI strategy
  - Action 5.1.3. Offer on-going support to LEAP leadership via DEI "Office Hours", led by Chief Diversity Officer and aimed at improving DEI awareness and addressing questions on DEI implementation
  - Action 5.1.4. Review (annually) and enforce LEAP's code of conduct, available on LEAP GitHub

- Action 5.1.5. Review (annually) existing policies and procedures to ensure that they are aligned with LEAP's DEI effort
- Action 5.1.6. Recruit and track membership of a diverse (gender, race, seniority) External Advisory Board
- Action 5.1.7. Monitor the demographics and home institution of visitors and correct in following years if not aligned with DEI effort

- Objective 5.2: Recruit and train early career scientists from underrepresented groups

  Actions:
  - Action 5.2.1. Mentor and support Bridge-to-PhD programs (linked to Action 3.1.3)
  - Action 5.2.2. Mentor and support NCAR SOARS protégés
  - Action 5.2.3. Advertise scientific jobs via diverse avenues and expanded professional networks (e.g., Society for Advancement of Chicanos/Hispanics and Native Americans in Science) and actively encourage applicants from underrepresented groups
  - Action 5.2.4. Build and develop relationships with Minority-serving institutions (Historically Black Colleges and Universities, Hispanic-Serving Institutions, Tribal Colleges and Universities, and Asian American and Pacific Islander Serving Institutions) for graduate and postdoc recruiting as well as summer Research Experiences for Undergraduates (REU)
  - Action 5.2.5. Promote recruitment of underrepresented students in REU
  - Action 5.2.6. Emphasize social impact goals of LEAP as part of recruitment efforts

- Objective 5.3: Recruit, retain, and promote LEAP Staff through a DEI lens

  Actions:
  - Action 5.3.1. Apply anonymization and standardized interviews; any personnel involved in staff recruitment, retention, and promotion will participate in the annual DEI awareness and competency workshop
  - Action 5.3.2. Diversify and expand recruitment sources and only include key requirements in job postings to diversify searches
  - Action 5.3.3. Evaluate LEAP's DEI strategy implementation annually with Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis

- Objective 5.4: Promote inclusive access to LEAP data and research though a cloud-based platform (linked to Objective 2.1)

  Actions:
  - Action 5.4.1. Operate cloud-based Jupyter and Binder services to increase broader and more equitable use of climate data (linked to Action 2.1.2)
  - Action 5.4.2. Facilitate collaboration and sharing via shared data and computing environments
  - Action 5.4.3. Provide direct access to data-proximate Jupyter notebook environment for data-proficient partners to directly leverage climate data
  - Action 5.4.4. Provide modern interactive web interface to manipulate LEAP-Pangeo climate data and visualize climate projections by a range of stakeholders (linked to Action 2.1.5)
  - Action 5.4.5. Engage with public and private partners to develop broadly accessible and usable cloud infrastructure

- Action 5.4.6. Use cloud infrastructure to increase research and KT in underrepresented communities/regions and with small institutions in the public and private sector

Leading Indicators

- Supported cohort of Bridge-to-PhD scholars
- Supported cohort of NCAR SOARS protégés
- Supported cohort of underrepresented REUs
- Developed relationships with Minority serving institutions
- Distribution of gender and race in the LEAP community (scientists and staff) improving over time towards US population distribution
- Train participants in annual DEI workshop
- Provide support to attendees in DEI office hours
- Form a diverse External Advisory Board membership across indicators (gender, race, seniority)
- Active use of LEAP-Pangeo infrastructure use from underserved regions
- Active use of LEAP-Pangeo infrastructure use by small institutions (public and private)

Action *Research* *Research/KT* *Education/Research* *KT* *DEI*	Year 1	Year 2	Year 3	Year 4	Year 5
STC LEAP kick-off meeting					
Initiate Call for Research Project Proposals and award RFP funding					
Hire integration engineer					
Reporting on RFP projects					
Annual meeting, review research progress with whole LEAP community					
Annual RFP funding					
Working Groups meeting monthly					
Formal seminars bi-weekly					
Draft documentation, standards, and best practices for LEAP-Pangeo					
Deploy LEAP-Pangeo JupyterHub in the cloud					
Deploy LEAP-Pangeo data library					
Use LEAP-Pangeo JupyterHub in summer research experiences for undergraduates					
Train participants in using LEAP-Pangeo					
Infrastructure: ramping up curriculum development, identification of existing courses for research integration, designing and piloting a bootcamp, designing and pilot a REU program, engaging stakeholders for RET program and hackathons, planning for LEAP certificate program					
Participation: LEAP institutions					
Convergence: developing programs that aim to drive transdisciplinary convergence					
Pathways: initial engagement with SOARS and the Bridge-to-PhD program					
People: Communications Director and Postdoctoral Fellow hired					
Baseline assessment of LEAP communication effectiveness					
Strategic plan for key points of engagement					
Confirm initial set of corporate partnerships					
Begin internal (Columbia) engagement with climate, data, and social scientists					
Annual newsletter published					
Active DEI procedures in recruitment					

LEAP

Action *Research* *Research/KT* *Education/Research* *KT* *DEI*	Year 1	Year 2	Year 3	Year 4	Year 5
Implement hiring and recruitment strategy					
Establish integration of DEI with Education initiatives					
SWOT analysis / performance review					
Implement ML-enabled parameterizations					
Release first version of the climate data exploration portal					
Ingest datasets from research projects into data library					
Integrate LEAP-Pangeo into educational activities					
Integrate LEAP-Pangeo into outreach activities					
Continue to train participants in using LEAP-Pangeo					
Infrastructure: continuing curriculum development and research integration with existing courses, refining and offering bootcamp, refining and offering REU program, designing and piloting the RET program, designing and piloting the first hackathon, proposing and implementing a LEAP certificate program					
Convergence: continuing to develop and refine programs that aim to drive transdisciplinary convergence					
Implement research projects					
Begin to develop KT research strategy and design					
Assessment of LEAP communication (end of Y2)					
Curation and production of LEAP communication and educational products (website based)					
Confirm and clarify plan for corporate and community partnerships					
Initial reporting regarding Baseline - Y2 communications effectiveness/engagement					
Launch LEAP-Pangeo UX/UI (user experience/user interface) focus groups					
Engaging KT partners to assess and further develop communications products					
Storyteller in Residence project presentation and workshop					
LEAP Executive Committee and Leadership team DEI trainings (two) - focus: “Equity Literacy”					
SWOT analysis / performance review of DEI strategy (focus: hiring and recruitment)					
DEI training with EC and Leadership: Visioning and Short/Long-term Planning					

Action *Research* *Research/KT* *Education/Research* *KT* *DEI*	Year 1	Year 2	Year 3	Year 4	Year 5
Functioning cloud-based interactive data web interface for data usage					
Iteration of interactive data web interface prototype for LEAP-Pangeo data usage with broad range of public and private partners					
Participation: expanding beyond LEAP institutions					
Pathways: continuing engagement with SOARS and the Bridge-to-PhD program, recruiting participants of LEAP education programs into LEAP research activities					
Appoint Storyteller in Residence					
Discussion sessions and lectures with broader stakeholder community					
Host scientist communication workshop					
Semi-annual newsletter published					
Annual Hackathon					
Produce ML-enabled CESM climate change projection simulations					
Continue to ingest data into LEAP-Pangeo data library					
Continue to use LEAP-Pangeo for research, education, and outreach					
Refine climate data exploration portal based on feedback from LEAP participants					
Refine data library website based on feedback from LEAP participants					
Infrastructure: updating and offering all LEAP education programs in a steady state: LEAP's curricula and research integration, bootcamp, REU and RET programs, and hackathons					
Convergence: continuing driving and evaluating transdisciplinary convergence via LEAP education programs					
Continue to implement research projects					
Meaningful and diverse set of corporate and community partnerships					
Publish reports and manuscript related to KT initiatives and research					
Open-access reports on DEI strategy					
Digital educational resource to broaden public engagement (e.g., digital media, educational resources)					
SWOT analysis / performance review of DEI strategy (focus: research cohorts)					