



Strategic and Implementation Plan

Center for Oldest Ice Exploration
NSF Science and Technology Centers Class of 2021

Updated January 2024

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1. Introduction

The Center for Oldest Ice Exploration (COLDEX) is an NSF Science and Technology Center (STC) funded in 2021. COLDEX is a multi-institution collaboration to find and analyze the oldest ice preserved in the Antarctic ice sheet. The overarching goal is to understand how Earth’s climate system functions under warmer than present conditions – conditions humanity very likely faces in the near future. COLDEX is headquartered in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University.

COLDEX research goals are underpinned by several decades of research on cores drilled through the polar ice sheets. This work has revealed how the composition of Earth’s atmosphere and climate are linked on many time scales, from ice-age cycles to abrupt climate changes, and provides the groundwork for our understanding of human impacts on climate and the environment. However, the existing ice core data do not extend far enough back in time to reveal how the Earth system behaves under warmer than present conditions. Reaching these time periods is critical for understanding our future, and is also a significant challenge, requiring a coordinated approach and sustained collaboration of numerous research groups. COLDEX also addresses challenges in making polar science more equitable for people from diverse backgrounds and perspectives, and in making scientific knowledge from our work relevant, useful, and accessible to educators, policymakers, students, and a broad range of communities.

The initial participating institutions involved in COLDEX and their primary roles are outlined in Table 1A.

Table 1A. COLDEX institutions.

Institution	Role	Lead Representative
Oregon State University (OSU)	Lead Institution	Ed Brook
American Meteorological Society (AMS)	Teacher Professional Development	Beth Mills
Amherst College	Exploration	Nick Holschuh
Brown University	Early Career Researcher Leadership	Meredith Hastings
Dartmouth College, Ice Drilling Program	MSI Faculty Professional Development	Mary Albert
Princeton University	Ice Coring; Ice Analysis	John Higgins

University of California, Berkeley (UCB)	Exploration	Ryan Bay
University of California, Irvine (UCI)	Ice Analysis	Eric Saltzman
University of California, San Diego, Scripps Institution of Oceanography (UCSD)	Exploration; Ice Analysis; Ice Coring	Jeff Severinghaus
University of Kansas, Center for Remote Sensing of Ice Sheets (KU)	Exploration	John Paden
University of Maine, Climate Change Research Institute (UMaine)	Ice Coring; Ice Analysis	Andrei Kurbatov
University of Minnesota, Duluth (UMD)	Exploration	John Goodge
University of Minnesota, Twin Cities (UMN)	Knowledge Transfer; Field Research and Data	Heidi Roop
University of Texas, Institute of Geophysics (UTIG)	Exploration	Duncan Young
University of Washington (UW)	Modeling and Ice Dynamics; Ice Analysis; Exploration	Michelle Koutnik

This strategic and implementation plan outlines the guiding principles for COLDEX, the Center’s vision, mission, and values, and a roadmap for how the work of the Center will progress. The plan will be updated at least annually and has been developed with input from all participants.

Several terms are used to describe elements of this strategic and implementation plan. *Optimal outcomes* are high-level statements about what COLDEX aspires to accomplish. *Objectives* describe Center strategies for achieving those outcomes. *Milestones* are specific achievements required to meet objectives. *Activities* are defined actions taken to reach milestones, with specific responsible COLDEX participants or groups and time frames for completion indicated.

This document will be reviewed and updated on an annual basis. Updates will include identifying activities and milestones that have been completed, adding new activities and milestones, revising activities to reflect changes that have happened over the course of the past year, or deleting activities that have been found to be beyond the current capacity of the Center to take on. Blue text indicates that an activity has been completed, and a completion date is noted for each.

2. COLDEX Vision, Mission, and Values

Vision: COLDEX will advance our understanding of the controls on Earth's climate by obtaining and synthesizing new knowledge of climate and atmospheric composition beyond the ice age cycles of the Pleistocene, into the Pliocene, and possibly beyond. COLDEX will help create a more diverse and inclusive polar and earth science community.

Mission: COLDEX will use geophysical imaging, modeling, and novel exploration tools to identify a site for a deep ice core in the Antarctic interior that extends to at least 1.5 million years. Ice coring near the ice sheet margin will provide records of Antarctic climate and atmospheric composition extending even further back in time.

COLDEX will create a national sample archive, recruit, and mentor the next generation of polar researchers, and increase participation of underrepresented groups in polar science. It will provide education, professional development, and field experiences for early career scientists, undergraduates, graduate students, and K-20 educators. COLDEX will also facilitate knowledge transfer within the scientific community and to external stakeholders.

Values: COLDEX values the open, honest exchange of ideas, data, and technology. All participants are expected to engage in improving equity, diversity, and inclusion. The COLDEX leadership team commits to transparent, inclusive leadership, organization, and management.

3. Guiding Principles and Decision Making

The following general principles will guide COLDEX decision-making.

- Alignment of actions with the Center vision, mission, and values.
- Commitment to creating a welcoming, inclusive, diverse, and engaged community across career levels, institutions, and activities.
- Integration between all components of the Center.
- A healthy tolerance for risk in pursuit of Center goals.
- A high standard of scientific ethics, behavior, and leadership.
- Accessibility of scientific discoveries, information, and educational opportunities.
- Willingness to involve new partners and participants who will extend and enhance the science.
- Transparency in decision making, sharing information, and outcomes.

4. Research

4a. Exploration and Ice Sheet Modeling

Optimal Outcomes

- I. Optimal Outcome I: Identify sites for a continuous 1.5 million year ice core in the East Antarctic interior capable of at least resolving orbital cycles in climate variables including water isotopes, dust, and trapped gases.
- II. Optimal Outcome II: Provide exploration data sets, models, instrumentation, and relevant metadata from COLDEX useful for, and used by, the wider scientific community.

Objectives and Milestones

- I. Objective 1: Find site or sites for a 1.5 million year ice core through acquisition and interpretation of new airborne and ground based geophysical data and *in situ* information from Ice Diver, integrated with ice sheet modeling.
 - A. Milestone 1A: Develop a comprehensive and traceable workflow that plans for interdependencies between instrument development, data collection, and modeling in order to clarify how multiple instruments and activities contribute to achieving the objectives. This workflow will include relevant science-defined instrument requirements, a timeline for deliverables, and responsibilities for each component of work. The workflow document will also be used to identify critical impacts of weather and other delays on the work and potential mitigation strategies.
Completed
 - B. Milestone 1B: Acquire, process, and interpret airborne geophysical data in COLDEX survey region of East Antarctica and identify regions for more detailed ground-based surveys to follow.
 - C. Milestone 1C: Acquire, process, and interpret ground-based radar and geophysical data in regions of interest.
 - D. Milestone 1D: Construct, test and deploy Ice Diver vehicle for age vs. depth information in ground-based survey regions.
 - E. Milestone 1E: Conduct glaciological modeling that integrates geophysical and Ice Diver information to assess possible ice core sites.
 - F. Milestone 1F: Maintain connection with Rapid Access Ice Drill (RAID) project to identify possible use of RAID in COLDEX site selection.
 - G. Milestone 1G: Integrate all available information to choose a site or sites for a deep ice core.

Table 4A. Exploration and ice sheet modeling timeline.

Objectives	Milestones	Year 1	Year 2	Year 3	Year 4	Year 5
	Antarctic field season within Center-year	21/22	22/23	23/24	24/25	25/26
1. Find site or sites for a 1.5 million year ice core	1A. Develop a comprehensive and traceable workflow.	Develop	Update	Update	Update	Update
	1B. Acquire, process, and interpret airborne geophysical data in COLDEX survey region of East Antarctica.	Planning and testing	Broad survey	Targeted surveys	Data processing & interp.	Data processing & interp.
	1C. Acquire, process, and interpret ground-based radar and geophysical data in regions of interest.	Planning	Planning	Saddle Site	Interior 1	Interior 2
	1D. Construct, test and deploy Ice Diver vehicle for age vs. depth information in ground-based survey regions.	Design/ Construct	Greenland Test	Prep.	Interior 1	Interior 2
	1E. Conduct glaciological modeling that integrates geophysical and Ice Diver information to assess possible ice core sites.	Per workflow	Per workflow	Per workflow	Per workflow	Per workflow
	1F. Maintain connection with Rapid Access Ice Drill (RAID) project to identify possible use of RAID in COLDEX activities.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
	1G. Integrate all available information to choose a site or sites.	Planning	Form selection committee	Review progress	Review progress	Decision
<p><i>Orange=planning/development; blue=includes field work; green=does not include field work. See appendix for detailed activities for each milestone.</i></p>						

Table 4B. Potential barriers to success and strategies to overcome barriers.

Potential Barriers	Mitigating Strategies
Delays in building and testing new technology including supply chain issues, shipping delays and problems.	Frequent communication with Center leadership about possible delays; develop alternative suppliers. One identified risk factor which we do not have a mitigation plan for is not getting the modified antenna fairing for the KU accumulation radar certified by Transport Canada in time for the first season. The impact is that we would not be able to fly the Accumulation Radar in the first season. Based on positive discussions with Kenn Borek Air and their experience with aircraft certifications, we believe the probability is low and that our plan to certify by comparison using the previous supplemental type certificate (STC) will satisfy Transport Canada's requirements to certify the modified antenna fairing. We estimate the overall risk factor as medium risk since we rate the probability as low and the impact as high.
Delays in aircraft certification.	Develop back up plans that deploy a more limited set of instruments. Monitor timing with respect to shipping equipment to Antarctica; advance planning for commercial air shipping if needed.
Delays due to field logistics constraints (weather, COVID, other events).	Develop alternative plans that use more limited airborne and surface-based radar. Maintain dual focus on ice margin and deep interior sites.
Short time for model-data integration.	As possible, develop codes in advance of new data collection and define model-relevant aspects of processed data products in advance.
Instrument failure in field work.	Field and bench testing. Identify back up instruments.
Industry pirating faculty and staff.	Cross training within groups to avoid dependence on one person.
Field participants not physically qualifying for field work.	Cross training within groups to avoid dependence on one person; identification of alternate participants.
Student wages may not be competitive.	Prioritize access to professional development opportunities, conference travel funds, field opportunities, research seed funding, lab resources, and other grad-program enrichment opportunities.
UTIG's gravimeter (jointly owned by Transparent Earth Geophysics) has Russian origins, leading to issues of support and sustainability going forward given the ongoing conflict in Ukraine.	We are working with Transparent Earth Geophysics on identifying paths forward.

<p>Quality and reliability of the Basler autopilot as a limitation on the likely success of the repeat interferometry technique.</p>	<p>We are working with KBA, NSF and other contacts on ways to mitigate this problem.</p>
<p>USAP has released their FY23 Continental Acquisition plan - which puts the need date for cargo for our field season very close to our test flight in Canada.</p>	<p>May require more equipment being added to the COMAIR request list due to limited time for rework after the test flights.</p>

4b. Ice Coring and Ice Analysis

Optimal Outcomes

- I. Optimal Outcome I: Recover ice cores from the Antarctic ice sheet margin with discontinuous ice sections dating to 3 million years or older.
- II. Optimal Outcome II: Develop a robust and flexible workflow for identifying and characterizing ice age and stratigraphic orientation in disturbed ice.
- III. Optimal Outcome III: Obtain atmospheric gas and ice chemistry data to understand the role of greenhouse gases in warmer climates and the nature of the transition to the late Pleistocene ice age cycles.
- IV. Optimal Outcome IV: Create a well-documented ice sample archive for the broader scientific community.

Objectives and Milestones

- I. Objective 1: Collect shallow ice cores at ice margin sites.
 - A. Milestone 1A: Develop a set of site selection criteria for the Allan Hills and Elephant Moraine shallow drill sites, drill, and return ice cores.
 - B. Milestone 1B: Intermediate depth core drilled at Allan Hills (scope contingency in logistics planning as of April 2022).
- II. Objective 2: Establish a workflow for building paleoclimate records in disturbed basal and ice margin samples.
 - A. Milestone 2A: Create centralized COLDEX laboratory for analyzing chemical parameters in COLDEX cores.
 - B. Milestone 2B: Develop initial ice core chronologies using argon and krypton isotope dating.
 - C. Milestone 2C: Develop hyperspectral imaging capabilities at NSF ICF with new camera equipment acquired by COLDEX. *Completed.*
 - D. Milestone 2D: Refine ice core chronology and assess the stratigraphic orientation of ice samples using a suite of analytical techniques.
 - E. Milestone 2E: Increase throughput of dry extraction ice core CO₂ measurements.
- III. Objective 3: Develop paleoenvironmental records and document sample archive for wider scientific community.
 - A. Milestone 3A: Develop publicly available metadata and data about core sites, analyses, and archived ice core samples.
 - B. Milestone 3B: Develop schedule of ice analysis, including technical and sample requirements for different labs, measurement plan, preliminary data availability, archive plan.

- C. Milestone 3C: Acquire basic chemical and imagery data for all COLDEX cores (stable isotopes, dust, soluble chemistry).
- D. Milestone 3D: Acquire records of greenhouse gases, other atmospheric constituents, dust, and radiogenic isotopes for COLDEX cores.

Table 4C. Ice coring and ice analysis timeline.

Objectives	Milestones	Year 1	Year 2	Year 3	Year 4	Year 5
	Antarctic field season within Center-year□	21/22	22/23	23/24	24/25	25/26
1. Collect ice cores at ice margin sites.	1A. Site selection criteria for shallow cores, drilling and sample return.	Criteria	Select sites; coring under I-165	Drill cores; return ice; explore other tools	Drill cores; return ice; explore other tools	Drill cores; return ice; explore other tools
	1B. Intermediate depth core at Allan Hills.	Planning	Locate site, perform radar survey	Staging	Drill cores; return ice	Drill cores; return ice
2. Establish a workflow for building paleoclimate archives in disturbed basal and ice margin samples	2A. Centralized laboratory at OSU.	Build and integrate equip.; recruit students & postdoc	Upgrade, acquire equip.; Analysis	Laboratory fully operating by summer 2024; Analysis	Analysis	Analysis
	2B. Krypton and argon isotope chronologies.	Develop/improve	Develop/improve	Analysis	Analysis	Analysis
	2C. Hyperspectral imagery development.	Acquire equip.	Develop protocols			
	2D. Refine chronologies and assess stratigraphic orientation.	Planning	Planning	Analysis	Analysis	Analysis

	2E. Increase CO2 measurement throughput.	Planning	Design and test system	Analysis		
3. Develop paleoenvironmental records	3A. Data and meta data publicly available.	Develop protocols and policies	COLDEX reports available	COLDEX reports available	COLDEX reports available	COLDEX reports available
	3B. Ice analysis schedule and technical requirements.	Survey needs; develop policies	Update	Update	Update	Update
	3C. Acquire basic chemical data and imagery for COLDEX cores.	Planning	Processing and analysis	Processing and analysis	Processing and analysis	Processing and analysis
	3D. Acquire records of greenhouse gases, other atmospheric constituents, dust, and radiogenic isotopes.		Analysis	Analysis	Analysis	Analysis
<i>Orange=planning/development; blue=includes field work; green=does not include field work. See appendix for detailed activities for each milestone.</i>						

Table 4D. Potential barriers to success and strategies to overcome barriers.

Potential Barriers	Mitigating Strategies
Delays due to field logistics constraints (weather, COVID, other events).	Shift analysis to existing samples. Prioritize coring sites within seasons. Maintain communication with field teams. We are developing core site priorities for year 1 field work.
Poor ice core quality from margin sites.	Discrete sampling and analysis (water isotopes, chemistry, gas analysis). Attempt drilling with small column of drill liquid. Experiment with different types of cutters in drilling systems. Work with US Ice Drilling Program to experiment with drilling methods to improve quality. Ongoing discussions about preparations for discrete measurements.
Stratigraphic disturbances are too severe to decipher.	Perform “paired” discrete analyses of ages, gas concentrations, and water isotopes.
Lack of redundancy in analytical techniques required to develop paleoclimate archives.	Identify colleagues outside and within COLDEX with comparable analytical capabilities. Maintain older equipment to use as back up instruments.
Instrument failure.	Develop clear priority protocol for continuous flow analysis that determines when and how to proceed in case of instrument failure. Identify colleagues with comparable analytical capabilities.

5. Diversity, Equity, and Inclusion

Optimal Outcomes

- I. Optimal Outcome I: Welcoming Community. A COLDEX community that is open and welcoming to people from historically marginalized identities and that is viewed by the polar science community as an example.
- II. Optimal Outcome II: Inclusive Leadership and Mentoring. Individuals within COLDEX at all career stages will gain leadership skills for safe, equitable, and inclusive team science (in the lab, field, and meetings).
- III. Optimal Outcome III: Diversity of Polar Science Community. The polar science community will be more diverse, as COLDEX will support career pathways and minimize attrition for students and early career scientists from historically marginalized identities.
- IV. Optimal Outcome IV: Communication. COLDEX internal and external communication will be sensitive to and challenge the exclusive aspects of historical narratives in polar science.

Objectives

- I. Objective 1. Creating a welcoming culture within COLDEX.
 - A. Milestone 1A: Set expectation of open, welcoming community in all team interactions. *Completed.*
 - B. Milestone 1B: Create a COLDEX Diversity, Equity, and Inclusion Committee of 4-6 people across career stages and institutions to provide guidance to the Executive Committee on all equity and inclusion issues. *Completed.*
 - C. Milestone 1C: Create a COLDEX DEI Ambassador Team to encourage conversations and listening. *Completed.*
 - D. Milestone 1D: Maintain and promote culture of open, welcoming community within COLDEX, and add new actions as needed.
 - E. Milestone 1E: Implement an actionable anti-racism plan, as described in Ali et al 2021 *Nature Communications*.
- II. Objective 2. Provide, and encourage practice of, inclusive leadership skills.
 - A. Milestone 2A: Develop and implement workshops and seminars to help all participants improve their leadership skills with emphasis on inclusive leadership.
 - B. Milestone 2B: Define mechanisms for feedback, mediation, and accountability for issues among COLDEX participants (during meetings,

field work, or time at home institution) that are codified in COLDEX Integrity and Professional Ethics Plan. *Completed.*

- C. Milestone 2C: Monitor feedback and engage in mediation when necessary for issues among COLDEX participants.
 - D. Milestone 2D: Create an inclusive leadership award within COLDEX.
- III. Objective 3. Increasing diversity in polar sciences.
- A. Milestone 3A: Increase recruitment of participants from historically marginalized identities into COLDEX.
 - B. Milestone 3B: Build relationships with faculty at MSIs to 1) provide connections to students for REU or graduate programs, 2) explore expanding COLDEX community by directly collaborating with MSI faculty, 3) help COLDEX refine strategic planning goals.
 - C. Milestone 3C: Support career development of participants from historically marginalized identities including appropriate mentoring and career planning.
- IV. Objective 4. Broaden the reach of polar science content/messaging to the public and other audiences, especially to previously excluded identities and communities.
- A. Milestone 4A: Assess communication to avoid presenting exclusive narratives in our external and internal communication.

Table 5A. Diversity, equity, and inclusion timeline.

Objectives	Milestones	Year 1	Year 2	Year 3	Year 4	Year 5
	Antarctic field season within Center-year□	21/22	22/23	23/24	24/25	25/26
1. Create a welcoming culture within COLDEX	1A. Set expectation of open, welcoming community in all team interactions.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
	1B. Create a COLDEX Equity and Inclusion Committee.	Create initial committee	Update and rotate	Update and rotate	Update and rotate	Update and rotate
	1C. Create a COLDEX DEI Ambassador Team to encourage conversations and listening.	Appoint initial team; define	Update and rotate	Update and rotate	Update and rotate	Update and rotate
2. Provide and encourage practice of Inclusive Leadership skills	2A. Develop and implement workshops and seminars to help all participants improve their leadership skills with emphasis on inclusive leadership.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
	2B. Define mechanisms for feedback, mediation, and accountability for issues among COLDEX participants.	Develop	Update plan	Update plan	Update plan	Update plan
	2C. Create an inclusive leadership award within COLDEX.	Define criteria	Award	Award	Award	Award
3. Increasing diversity in polar sciences	3A. Increase recruitment of students and collaborators from historically marginalized identities into COLDEX. Build relationships with faculty at MSIs.	Develop	Ongoing	Ongoing	Ongoing	Ongoing

	3B. Provide supported career pathways (retention) for participants from historically marginalized identities including appropriate mentoring and career planning.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
4. Broaden the reach of polar science content/messaging to the public and other audiences, especially to previously excluded identities and communities	4A. Assess communication to avoid presenting exclusive narratives in our external (and internal) communication.	Assess and develop	Ongoing	Ongoing	Ongoing	Ongoing
	4B. Create structure for assessing educational and other workshop material to encourage inclusive content and pedagogy.	Develop	Assess	Assess	Assess	Assess
<p><i>Orange=planning/development; blue=includes field work; green=does not include field work. See appendix for detailed activities for each milestone.</i></p>						

Table 5B. Potential barriers to success and strategies to overcome barriers.

Potential Barriers	Mitigating Strategies
<p>The white male “Hero” narrative is deeply embedded in the media culture and within the science culture (even beyond polar science). Changing this narrative will not happen quickly. This narrative sends an exclusive message to students - anyone who doesn’t fit the media’s view of who is a polar scientist will be hesitant to apply for REU or grad school.</p>	<p>Be consistent with our alternative narratives, build individual relationships with prospective applicants well before they have to decide to apply.</p>
<p>All of us (COLDEX participants) have implicit bias and limited self-awareness of our own strengths and weaknesses with respect to our ability to practice inclusive mentoring and leadership. Some may be resistant to feedback and change.</p>	<p>Patience. Repeated messaging through ongoing conversations and modeling appropriate behavior can inspire evolving ideas. Discuss empirical evidence that implicit bias exists.</p>
<p>Power dynamics exist, despite our best effort to want earlier career participants or those from historically marginalized identities (at any career level) to feel “included.”</p>	<p>Be intentional in addressing this and discuss during leadership workshops.</p> <p>Create “brave spaces” for anyone to voice their ideas (either through a DEI ambassador or through a confidential form).</p>
<p>Research is taking place at many different institutions and in the field. Any issues within a research group must be brought forward by people within that research group in order to be able to mediate and support.</p>	<p>Create a feedback portal on the member website where members can submit suggestions, ideas, concerns, and information related to Diversity, Equity, and Inclusion (DEI) in the Center and to any aspect of the Center structure and community. DEI Ambassadors will be from all research groups and will do their best to keep conversations going within each group.</p>
<p>MSI faculty and partners can feel “used” if they sense our desire to partner with them is not genuine, but instead to fulfill a requirement from NSF.</p>	<p>Relationship building, through consistent communication, visits to institutions by COLDEX representatives, DEI Ambassadors, and through attending conferences.</p>
<p>Mentors may believe there is too much risk in taking particular actions, such as accepting a student that doesn’t fit the image of a perfect graduate student.</p>	<p>Provide guidance through activities such as a discussion group at the annual COLDEX meeting, where people can share success stories.</p>

6. Education and Leadership Opportunities

Optimal Outcomes

- I. Optimal Outcome I: Increased awareness and appreciation of ice core and polar sciences through the engagement of K-12 through graduate students, postdocs, teachers, and professors in COLDEX research goals. Engagement with these groups will increase diversity of participants in ice core and polar sciences.
- II. Optimal Outcome II: A well-trained group of students and postdoctoral researchers contributing to the COLDEX mission who obtain skills and experience relevant to their future work and through development of professional skills.
- III. Optimal Outcome III: A well-trained group of students and postdoctoral researchers who successfully incorporate education, outreach, and science communication to science and non-science audiences throughout their careers.
- IV. Optimal Outcome IV: Successful implementation of inclusive education opportunities that are developed through incorporation of diverse perspectives, particularly those that have not historically taken part in and may challenge the “status quo” of ice core and polar science activities.

Objectives and Milestones

- I. Objective 1: Develop the next generation of ice core and climate scientists.
 - A. Milestone 1A: Develop and implement a new Research Experiences for Undergraduates (REU) program that engages a diverse group of undergraduate students in COLDEX sponsored research projects, advertising widely across listservs, at conferences, and through School of Ice alumni at Minority Serving Institutions with target applicant pool that has at least the same percentage of students from historically minoritized identities as national baseline.
 - B. Milestone 1B: Create graduate student and postdoc positions at individual COLDEX institutions, successfully recruit and mentor students and postdocs, particularly from underrepresented groups.
 - C. Milestone 1C: Create and implement a leadership and career development workshop program for early career scientists, open to participants from COLDEX institutions and outside groups, advertised widely including within the Association of Early Career Polar Scientists, Ice Core Young Scientists, and other similar groups.

- D. Milestone 1D: Develop and maintain an inclusive student/postdoc culture that promotes participation in COLDEX activities.
- E. Milestone 1E: Provide scholarship funds for graduate student and postdoc research related to COLDEX goals (at COLDEX and non-COLDEX institutions).
- II. Objective 2: Bring ice core and climate science to K-12 and university curricula.
 - A. Milestone 2A: Incorporate COLDEX research and participants into Ice Drilling Program “School of Ice” (SOI) for faculty at Minority Serving Institutions.
 - B. Milestone 2B: Develop and implement “Project Ice” K-12 teacher education program with the American Meteorological Society, incorporating COLDEX research and scientists.
 - C. Milestone 2C: Provide opportunities to involve COLDEX students, postdocs, and faculty in formal and informal K-12 outreach.
- III. Objective 3: Evaluate all COLDEX educational programs.
 - A. Milestone 3A: Create and implement an evaluation framework allowing for summative and formative feedback.

Table 6A. Education and leadership opportunities timeline.

Objectives	Milestones	Year 1	Year 2	Year 3	Year 4	Year 5
	Antarctic field season within Center-year□	21/22	22/23	23/24	24/25	25/26
1. Bring ice core and climate science to K-12 and university curricula	1A. Incorporate COLDEX research and participants into Ice Drilling Program “School of Ice” (SOI) for faculty at Minority Serving Institutions.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
	1B. Develop and implement “Project Ice” K-12 teacher education program with the American Meteorological Society.	Planning	Ongoing	Ongoing	Ongoing	Ongoing
	1C. Provide opportunities to involve COLDEX students, postdocs, and faculty in formal and informal K-12 outreach.	Planning	Ongoing	Ongoing	Ongoing	Ongoing
2. Develop the next generation of ice core and climate scientists	2A. Develop and implement a new Research Experiences for Undergraduates (REU) program.	Planning	Ongoing	Ongoing	Ongoing	Ongoing
	2B. Create graduate student and postdoc positions at individual COLDEX institutions, successfully recruit and mentor students and postdocs, particularly from underrepresented groups.	Initial cohort	Ongoing	Ongoing	Ongoing	Ongoing
	2C. Create and implement a leadership and career development workshop program for early career scientists.	Planning	Delivery	Delivery	Delivery	Delivery

	2D. Develop and maintain an inclusive student/postdoc culture that promotes participation in COLDEX activities.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
	2E. Provide scholarship funds for graduate student and postdoc research related to COLDEX goals.	Planning	Ongoing	Ongoing	Ongoing	Ongoing
3. Evaluate all COLDEX educational programs	3A. Create and implement an evaluation framework allowing for summative and formative feedback.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
<p><i>Orange=planning/development; blue=includes field work; green=does not include field work. See appendix for detailed activities for each milestone.</i></p>						

Table 6B. Potential barriers to success and strategies to overcome barriers.

Potential Barriers	Mitigating Strategies
Lack of applicants from historically marginalized identities in science and engineering.	Target recruitment from Minority Serving Institutions, programs in COLDEX institutions, and Community Colleges through School of Ice faculty alumni network and current COLDEX MSI partner institutions.
	Recruit teacher participants with high student populations percentages of those underrepresented in STEM and polar science.
	Recruit at a variety of professional meetings.
	Advertise student and postdoc positions through national and international listservs, particularly those representing underrepresented groups.
Difficulty maintaining strong student and postdoc community across multiple COLDEX and non-COLDEX institutions.	Build REU cohort before, during, and after annual summer research program using remote and in-person team building efforts.
	Develop a multi-tiered network of undergraduate-graduate students, postdocs, and faculty.
	Offer multiple “listening sessions” for current graduate students and postdocs with COLDEX staff and science leadership.
	Include undergraduate, graduate students, and postdocs in COLDEX Center annual meetings with options for in-person and virtual attendance.
Lack of training around mentorship/instruction to encourage participation, success, and persistence of audiences of target.	Provide collaborative opportunities for mentor growth among all COLDEX participants.
	Use outside resources for mentorship growth of COLDEX participants, including the Center for the Improvement of Mentored Experiences in Research (CIMER).
	Open mentoring and leadership workshops to all COLDEX participants (not just students and postdocs) so that mentoring across COLDEX is consistently based in research on best practices.

7. Knowledge Transfer

Optimal Outcomes

- I. Optimal Outcome I: New partnerships, collaborations, and mentoring relationships are established across the COLDEX team, including across and within participating institutions, participant career stages, and disciplinary expertise.
- II. Optimal Outcome II: New partnerships, collaborations, and knowledge exchange opportunities are established between the COLDEX team, other researchers, and industry partners.
- III. Optimal Outcome III: COLDEX successfully leverages our disciplinary expertise and perspectives, knowledge transfer, education, and evaluation approaches to deepen public engagement in Earth and climate sciences.

Objectives and Milestones

- I. Objective 1. Expand and facilitate connections across the current network of those who engage with COLDEX research, education, and knowledge transfer activities.
 - A. Milestone 1A: Conduct and maintain network mapping research and social network analysis of COLDEX participants over the duration of the Center.
 - B. Milestone 1B: Establish mutual working relationships with contacts from government, industry, non-profit, and for-profit sectors. Build a collective culture of knowledge sharing and exchange across the COLDEX network.
 - C. Milestone 1C: Establish a protocol for addressing external COLDEX inquiries and related communication and knowledge needs. *Completed.*
 - D. Milestone 1D: Lead and contribute each year to sessions and presentations at professional society gatherings (e.g., workshops, meetings, town halls, webinars) to share COLDEX approaches and outcomes related to our research, education, knowledge transfer, diversity, equity and inclusion activities, and key findings.
 - E. Milestone 1E: Develop and maintain monthly remote seminar series with internal and external speakers from diverse research fields and practice areas, made available to collaborators and colleagues outside of COLDEX.
- II. Objective 2. Support effective, consistent communication of polar and climate-related knowledge to diverse audiences.
 - A. Milestone 2A: Develop and execute a Center-wide strategic communications plan with priority external audiences reviewed and updated annually.

- III. Objective 3. Expand expertise of COLDEX participants on applied climate science, science communication best practices and actionable science.
 - A. Milestone 3A: Provide annual professional development opportunities for Center participants to engage with applied scientists, practitioners, and communication professionals. *Director for KT and Director for FRD: years 3-4.*
 - B. Milestone 3B: Create communication materials and assets to increase COLDEX Center participants' knowledge of COLDEX-related climate, education, knowledge transfer and other key research approaches and findings.
 - C. Milestone 3C: Support development of a graduate student cohort with experience in multidisciplinary research and provide consistent engagement of social and communications-focused graduate students in all COLDEX activities, including field work.

Table 7A. Knowledge transfer timeline.

Objectives	Milestones	Year 1	Year 2	Year 3	Year 4	Year 5
	Antarctic field season within Center-year□	21/22	22/23	23/24	24/25	25/26
1. Expand and facilitate connections across the current network of those who engage with COLDEX research, education, and knowledge transfer activities	1A. Conduct and maintain network mapping research and social network analysis of COLDEX participants.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
	1B. Establish mutual working relationships with contacts from government, industry, non-profit, and for-profit sectors. Build a collective culture of knowledge sharing and exchange across the COLDEX network.	Planning	Ongoing	Ongoing	Ongoing	Ongoing
	1C. Establish a protocol for addressing external COLDEX inquiries and related communication and knowledge needs.	Develop	Update as needed	Update as needed	Update as needed	Update as needed
	1D. Lead and contribute each year to sessions and presentations at professional society gatherings.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
	1E. Develop monthly remote seminar series with internal and external speakers from diverse research fields and practice areas.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
2. Support effective, consistent communication	2A. Develop and execute a Center-wide strategic communications plan with priority external audiences reviewed and updated annually.	Develop	Ongoing	Ongoing	Ongoing	Ongoing

of polar and climate-related knowledge to diverse audiences						
3. Expand impact of COLDEX participants on applied climate science, science communication best practices and actionable science	3A. Provide annual opportunities for Center participants to engage with applied scientists, practitioners, and communication professionals.	Planning	Planning	Delivery	Delivery	Delivery
	3B. Create communication materials and assets to increase COLDEX Center participants' knowledge of COLDEX-related climate, education, knowledge transfer and other key research approaches and findings.	Planning	Develop	Ongoing	Ongoing	Ongoing
	3C. Support development of a graduate student cohort with experience in multidisciplinary research and provide consistent engagement of social and communications-focused graduate students in all COLDEX activities, including field work.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
<i>Orange=planning/development; blue=includes field work; green=does not include field work. See appendix for detailed activities for each milestone.</i>						

Table 7B. Potential barriers to success and strategies to overcome barriers.

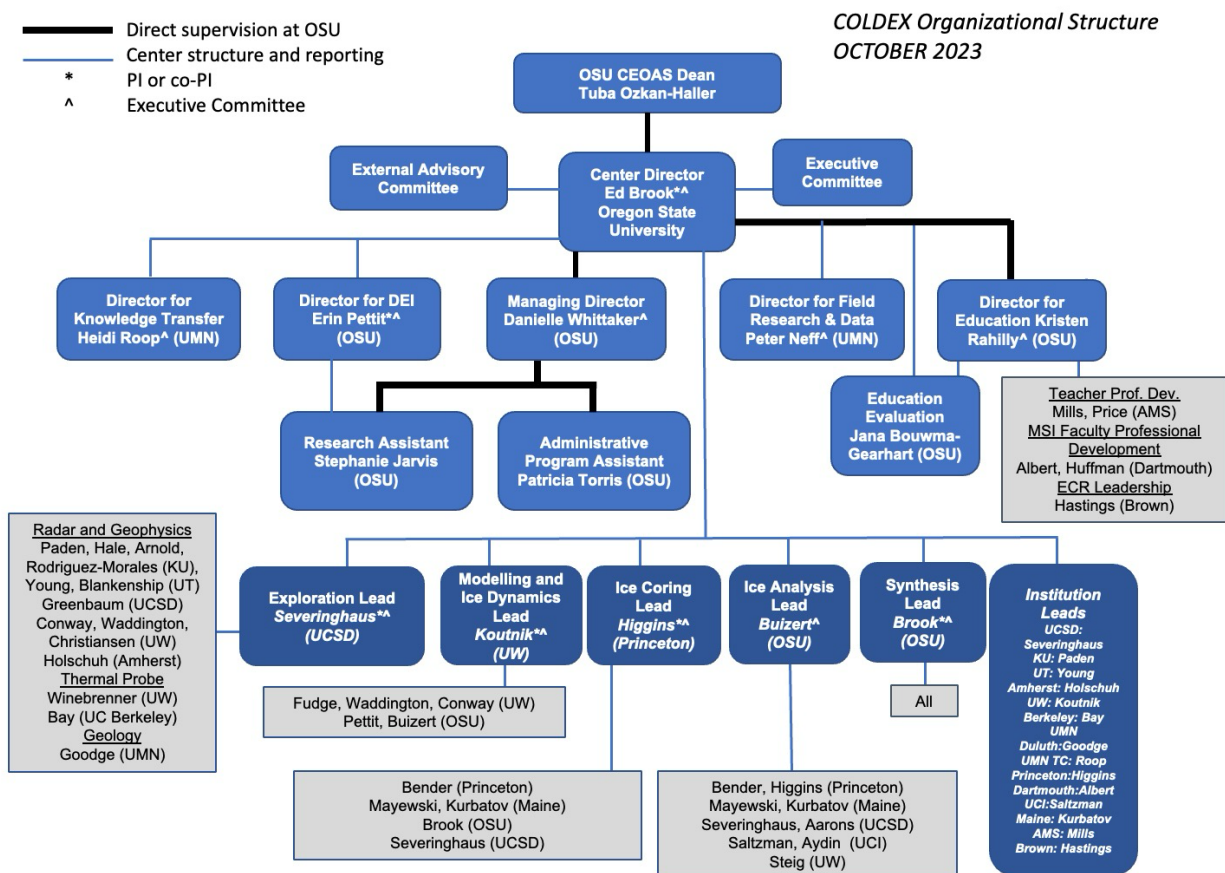
Potential Barriers	Mitigating Strategies
<p>Inconsistent or incomplete participation by Center participants in activities tracking and network analysis reporting that will be collected through biannual surveys.</p>	<p>COLDEX leadership sets clear expectations that participation in Center evaluation and tracking activities is required.</p>
	<p>Incentivize participation and ensure people can see and understand the value of the evaluation and tracking activities.</p>
<p>Communications plan and approaches lack specificity and attempt to reach too many audiences across too many channels.</p>	<p>Maintain clearly defined priority audiences informed through audience segmentation and message testing.</p>
	<p>Update and evaluate communications plan using analytics and network analysis research to inform gaps and narrow target audiences over the duration of the Center.</p>
	<p>Remain nimble and be willing to add or limit scope where needed to ensure impact for priority audiences and messages.</p>
<p>Inconsistent or insufficient support for implementation of communication plan priorities.</p>	<p>Secure additional resources for dedicated communications capacity.</p>
	<p>Leverage existing Public Relations offices and Communications professionals at COLDEX institutions to help amplify COLDEX messages and materials. Ensure the culture of Center supports and empowers all participants to feel responsibility for the success of the communications, engagement, and knowledge transfer work of the Center.</p>

8. Management and Integration

Optimal Outcomes

- I. Optimal Outcome I: COLDEX management will operate effectively in a transparent manner, enabling COLDEX members to achieve their research, education, DEI, and knowledge transfer goals.
- II. Optimal Outcome II: COLDEX members will perceive themselves as belonging to a cohesive, welcoming community with shared goals and values.
- III. Optimal Outcome III: Research, education, knowledge transfer, and diversity, equity, and inclusion activities and values will be integrated across all aspects of the Center.

Figure 8A. COLDEX organizational structure.



Objectives and Milestones

- I. Objective 1: Establish and maintain Center leadership and management. The current COLDEX organizational structure is shown in Figure 8A. Overall leadership is provided by the Center Director, who reports to the Dean of the College of Earth, Ocean, and Atmospheric Sciences. The Managing Director oversees and facilitates all aspects of Center management, including internal communications, budgeting, financial management, meeting organization, and reporting. The Director for Education oversees and facilitates all aspects of COLDEX educational programs and plays a key role in diversity, equity, and inclusion. Directors for Knowledge Transfer, Diversity, Equity and Inclusion, and Field Research and Data, are faculty members in COLDEX institutions, who oversee these cross-cutting activities. Leads for individual components of COLDEX (Figure 8A) oversee those areas, and monitor progress and facilitate exchange of information with the rest of the Center. Institutional leads provide points of contact for administrative matters, recruiting and other institutional issues.
 - A. Milestone 1A: Hire staff and implement effective Center management structures. *Completed.*
 - B. Milestone 1B: Establish Executive Committee role in governance and oversight of COLDEX, including written committee charter. *Completed.*
 - C. Milestone 1C: Maintain effective management systems through regular communication, assessment, and improvements.
- II. Objective 2: Establish effective communication with participants to establish and maintain integration of Center activities and goals. Maintain communication as a key mechanism for maintaining transparency in decision-making and supporting inclusivity among the COLDEX community.
 - A. Milestone 2A: Establish internal facing communications. *Completed.*
 - B. Milestone 2B: Establish regular COLDEX monthly seminar series featuring both internal and external speakers.
 - C. Milestone 2C: Create and maintain internal COLDEX data repository.
 - D. Milestone 2D: Maintain regular COLDEX communications and seminar offerings.
- III. Objective 3: Facilitate external communications with the media, policymakers, and the general public about COLDEX activities.
 - A. Milestone 3A: Establish ongoing communication, allocate responsibilities, and set standards and policies. *Completed.*
 - B. Milestone 3B: Maintain communication between Management team and Knowledge Transfer team.
- IV. Objective 4: Integrate Center science, education, knowledge transfer, and diversity, equity, and inclusion efforts into an enduring Center culture.

- A. Milestone 4A: Ensure potential new members can easily find information about how to get involved in COLDEX and access resources.
 - B. Milestone 4B: Create opportunities to exchange information internally.
 - C. Milestone 4C: Create opportunities for participants to work across COLDEX themes.
 - D. Milestone 4D: Organize Annual Center meetings that integrate all COLDEX themes and provide opportunities for participant connections.
 - E. Milestone 4E: Ensure diversity, equity, and inclusion activities are valued by COLDEX members and enrich careers.
- V. Objective 5: Provide support to COLDEX participants investigating new funding streams and collaborations for COLDEX-related activities.
- A. Milestone 5A: Serve as a point of contact for COLDEX participants wishing to approach potential donors or funders.
 - B. Milestone 5B: Communicate funding opportunities to participants and encourage/facilitate proposals.
 - C. Milestone 5C: Seek new research partners who can take advantage of COLDEX samples, data, or programs.
- VI. Objective 6: Ensure oversight and evaluation of COLDEX by seeking feedback from the External Advisory Committee on an annual basis, as well as from the annual NSF site visits, and regularly assess progress towards management and integration goals.
- A. Milestone 6A: *Appoint External Advisory Committee (EAC) and develop EAC Charter including roles, responsibilities, and length of service. Completed.*
 - B. Milestone 6B: *Initiate formal evaluation of educational programs (see education section). Director for Education and Jana Bouwma-Gearhart: Completed.*
 - C. Milestone 6C: Initiate internal and external evaluation of non-education components of COLDEX.
 - D. Milestone 6D: Review participant activity on a quarterly basis.
- VII. Objective 7: Manage and facilitate field and ice core logistics planning with participants, NSF and USAP logistics providers.
- A. Milestone 7A: The Director for Field Research and Data will act as primary liaison between COLDEX and National Science Foundation (NSF) / United States Antarctic Program (USAP) for field logistics and the Ice Drilling Program for drilling, supporting the individual teams simultaneously carrying out COLDEX field research programs.
- VIII. Objective 8: Make COLDEX data and technology openly and widely available within and outside of COLDEX.
- A. Milestone 8A: Finalize and maintain COLDEX Data Management policy.

- B. Milestone 8B: Develop and track internal data sharing mechanism.
 - C. Milestone 8C: Create centralized location for long-term public archive of COLDEX data, metadata, model results and engineering designs.
 - D. Milestone 8D: Investigate how new concepts of Open Science can be incorporated in COLDEX data streams and management.
- IX. Objective 9: Implement and maintain program of ethics training.
- A. Milestone 9A: Establish an ethics policy and engage all members of COLDEX in ethics training. *Completed.*
 - B. Milestone 9B: Deliver first training module on ethical behavior during field research before first COLDEX field season. *Completed.*
 - C. Milestone 9C: Maintain ethics policy and engage all members of COLDEX in annual ethics training.
- X. Objective 10: Create and maintain COLDEX Intellectual Property Plan.
- A. Milestone 10A: Engage OSU IP and Licensing Office for assistance.

Table 8A. Management and integration timeline.

Objectives	Milestones	Year 1	Year 2	Year 3	Year 4	Year 5
	Antarctic field season within Center-year□	21/22	22/23	23/24	24/25	25/26
1. Establish Center leadership and management	1A. Hire staff and implement effective Center management structures.	Initial hiring and develop	Update	Update	Update	Update
	1B. Establish Executive Committee role in governance and oversight of COLDEX, including written committee charter.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
2. Establish effective communication with participants	2A. Establish internal facing communications.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
	2B. Establish regular COLDEX seminar series featuring both internal and external speakers.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
	2C. Create COLDEX data repository linked to website.	Develop	Update	Update	Update	Update
3. Facilitate external communication with media, policymakers, and public about COLDEX activities	3A. Maintain ongoing communication, allocate responsibilities, and set standards and policies.	Develop	Ongoing	Ongoing	Ongoing	Ongoing

4. Integration of Center science, education, knowledge transfer, and diversity, equity, and inclusion efforts into an enduring Center culture	4A. Potential new members can easily find information about how to get involved in COLDEX and access resources.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
	4B. Opportunities to exchange information internally.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
	4C. Create opportunities for participants to work across COLDEX themes.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
	4D. Annual Center meetings that integrate all COLDEX themes and provide opportunities for participant connections.	Annually	Annually	Annually	Annually	Annually
	4E. Diversity, equity, and inclusion activities are valued by COLDEX members and enrich careers.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
5. Provide support to COLDEX participants investigating new funding streams and collaborations for COLDEX-related activities	5A. Serve as a point of contact for COLDEX participants wishing to approach potential donors.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
	5B. Communicate funding opportunities to participants and encourage/facilitate proposals.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
	5C. Seek new research partners who can take advantage of COLDEX samples or data.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
6. Ensure oversight and	6A. Appoint External Advisory Committee (EAC) and develop EAC Charter including roles, responsibilities, and length of service.	Initial appointment	Update as needed	Update as needed	Update as needed	Update as needed

evaluation of COLDEX	6B. Initiate formal evaluation of educational programs.	Initiation	Evaluate	Evaluate	Evaluate	Evaluate
	6C. Initiate internal and external evaluation of non-education components of COLDEX.	Develop	Annually	Annually	Annually	Annually
	6D. Quarterly review of participant activity.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
7. Manage and facilitate field and ice core logistics planning with participants, NSF and USAP logistics providers	7A. The Director for Field Research and Data will act as primary liaison between COLDEX and National Science Foundation (NSF) / United States Antarctic Program (USAP) for field logistics and the Ice Drilling Program for drilling, supporting the individual teams simultaneously carrying out COLDEX field research programs.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
8. Make COLDEX data and technology openly and widely available within and outside of COLDEX	8A. Finalize and maintain COLDEX Data Management policy.	Finalize	Maintain and monitor	Maintain and monitor	Maintain and monitor	Maintain and monitor
	8B. Develop and track internal data sharing mechanism.	Develop	Ongoing	Ongoing	Ongoing	Ongoing
	8C. Create centralized location for long-term public archive of COLDEX data, metadata, model results and engineering designs.	Develop	Update as needed	Update as needed	Update as needed	Update as needed
	8D. Investigate how new concepts of Open Science can be incorporated in COLDEX data streams and management.	Prelim summary				
	9A. Implement program of ethics training.	Develop	Ongoing	Ongoing	Ongoing	Ongoing

9. Implement and continue program of ethics training	9B. Deliver training module on ethical behavior during field research before first COLDEX field season.	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
10. Create and maintain COLDEX Intellectual Property Plan	10A. Engage OSU IP and Licensing Office for assistance.	Initial plan created	Update as needed	Update as needed	Update as needed	Update as needed
<p><i>Orange=planning/development; blue=includes field work; green=does not include field work. See appendix for detailed activities for each milestone.</i></p>						

Table 8B. Potential barriers to success and strategies to overcome barriers.

Potential Barriers	Mitigating Strategies
Large number of institutions and participants makes communication and progress reporting challenging.	Make communication a high priority.
	Develop internal survey on effectiveness.
Staff resources must match workload.	Review staff workload and responsibilities regularly.
Reconciling early career researcher research plans across the Center, given the academic community's expectations for individual productivity.	Identify overlap, conflicts, and potential opportunities, and facilitate communication and cooperation in cooperation with institutional leads.
	Create a community authorship policy.
	Create a policy of distributing abstracts of papers and talks on COLDEX topics to the entire COLDEX group prior to submission.
	Communicate early on high impact papers in progress.
Unanticipated changes in logistics landscape.	Identify possibilities and refine existing contingency plans.
Leadership unavailability.	Codify temporary leadership policy and succession plan.
Nonconformance with Center policies in Ethics, Data Management, Mentoring or other areas.	Monitor critical activities.
	Publicize methods for reporting and resolving problems.
	Ensure all participants are aware of policies and consequences of violation.