Building Resilience to Climate Driven Extreme Events with Computing Innovations: A Convergence Accelerator Report

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December 2022

A Community Visioning Activity Organized By:

Elizabeth Bradley, University of Colorado - Boulder
Chandra Krintz, University of California - Santa Barbara
Melanie Moses, University of New Mexico

With Support From:

1.   Introduction

In 2022, the National Science Foundation (NSF) funded the Computing Research Association (CRA) to conduct a workshop to frame and scope a potential Convergence Accelerator research track on the topic of "Building Resilience to Climate-Driven Extreme Events with Computing Innovations." The CRA's research visioning committee, the Computing Community Consortium (CCC), took on this task, organizing a two-part community workshop series, beginning with a small, in-person brainstorming meeting in Denver CO on 27-28 October 2022, followed by a virtual event on 10 November 2022. The overall objective was to develop ideas to facilitate convergence research on this critical topic and encourage collaboration among researchers across disciplines.

Based on the CCC community white paper entitled *Computing Research for the Climate Crisis*[1], we initially focused on five impact areas (i.e. application domains that are both important to society and critically affected by climate change):

- Energy
- Agriculture
- Environmental justice
- Transportation
- Physical infrastructure

We used these impact areas as a framework to help us identify participants in the workshop series and to plan our initial discussions and activities.

We used the workshops to discuss these impact areas and to collaboratively identify the necessary *building blocks* and key use-inspired *research thrusts* that can be brought to bear to address the complex challenges surrounding climate change. *Building blocks* are new abstractions, methods, and systems that can be used to facilitate and expedite technological innovation. *Research thrusts* are specific research directions identified by the participants as having potential for effecting positive change in a particular impact area. Research thrusts become building blocks if the participants identify them as being broad in technical scope and capable of being leveraged and specialized by a broad and diverse community of innovators to address seemingly disparate challenges *across* impact areas. Finally, our overarching goal with this effort was to identify computing research opportunities that can be developed and deployed following the timelines, guidelines, and goals described by the Convergence Accelerator program model.

We selected participants for the first workshop, in consultation with cognizant NSF program officers. The second, virtual workshop, was open to everyone. Both workshops included those

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[1] Bliss, N., Bradley, E., Monteleoni, C. (2021) *Computing Research for the Climate Crisis 2021.* https://cra.org/ccc/wp-content/uploads/sites/2/2021/08/Computing-Research-and-Climate-Change-%E2%80%94-August-2021.pdf

with expertise in or across these impact areas. During the crafting of the participant list—which appears in the appendices of this report— we also paid attention to demonstrated ability for interdisciplinary thinking, as well as to attaining a diverse and broad representation of the computing research community (demographics, institution type, and career stage).

The goal of the in-person workshop was to refine the set of impact areas and identify research thrusts and building blocks. To enable this, we communicated with the participants in advance to establish the goals of the workshop: to brainstorm computational research that brings together collaborative multidisciplinary teams to create solutions with direct positive impact on climate change. In each impact area, we identified a "lead" (depicted in bold font in our participant list) who gave a brief presentation to define that area and frame some of the associated research challenges. The participants then went into breakout sessions to have focused discussions of research potential for that impact area, guided by three questions:

1. What are the key **building blocks** in computing research that are needed to expedite innovation in this impact area?
2. What use-inspired **research thrusts** can be brought to bear on this impact area to advance climate resilience?
3. What are the near-term **metrics** for success in this impact area?

Our intent with these questions was to build consensus around the climate crisis impact areas worthy of investment and building blocks that spanned areas (thus having potential for significant and potential near-term impact). We also asked the groups to construct an initial set of research thrusts for each area to indicate whether or not there is sufficient and necessary interest from the computing research community to pursue these thrusts as part of a Convergence Accelerator effort.

Following the breakout session, each group reported their findings to the whole group. These sequences (framing, breakout, report-back) were repeated for multiple impact areas. This was followed by a high-level synthesis discussion to review the topics and concepts that came up in multiple sessions, which culminated in a preliminary set of building blocks (listed below) and a concept matrix (depicted below) of research thrusts for the building blocks and the impact areas. Using this structure, we pursued a full-group brainstorming session in which participants used an electronic whiteboarding system (`mural.io`) to identify, discuss, and organize the research thrusts. This Mural represented the first major outcome of the brainstorming workshop.

Computing research building blocks
- ❖ Artificial intelligence (AI)
- ❖ Digital twins
- ❖ Cyberinfrastructure
- ❖ Optimization and planning
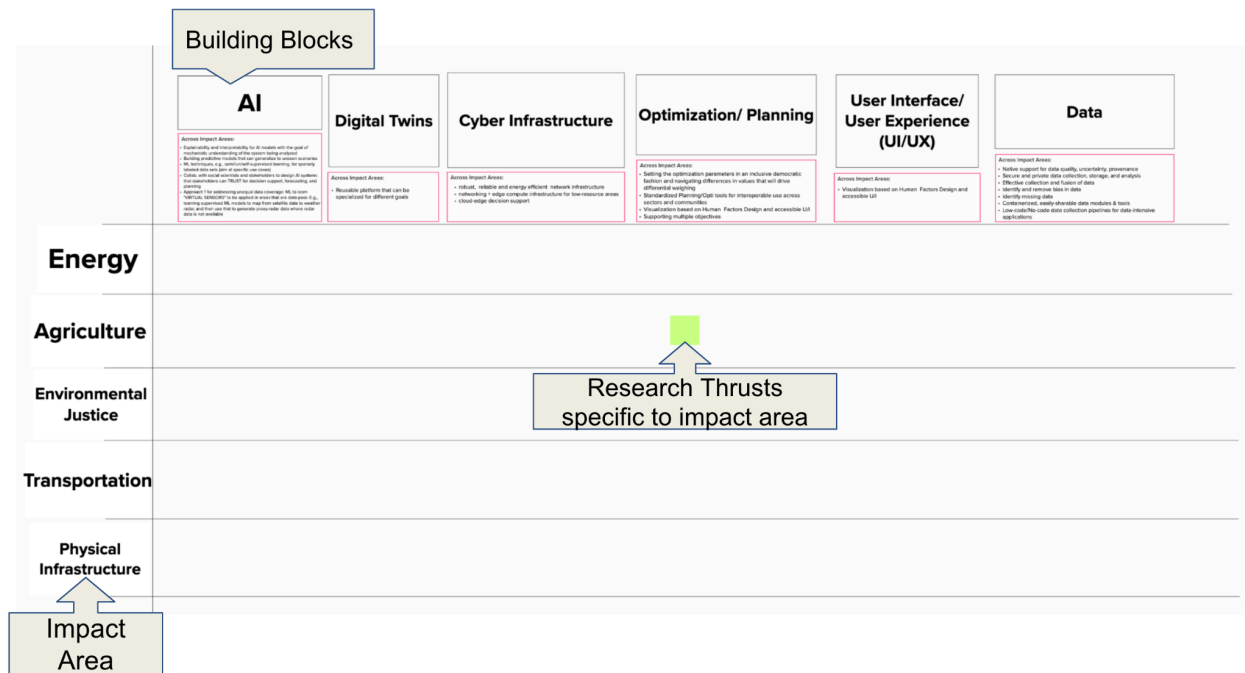- ❖ User Interface/User Experience (UI/UX)
- ❖ Data

Figure A-1. The skeleton of the concept matrix that was used in brainstorming during both workshops.

A second, unplanned, outcome of this capstone discussion was a set of *cross-cutting principles*. This set emerged from the group discussions and brainstorming and consisted of principles that the group felt should be addressed by any research project in this area, regardless of impact area, building block, or research thrust.

We used these outcomes as the starting point for collaboration, discussion, and feedback at the second, community-wide, virtual workshop. To publicize this workshop, we released announcements on the CCC blog and Twitter account, the CRA Facebook and LinkedIn accounts, the Computing Research News, the NSF listserv, the Climate Informatics Google group, the ACM website, and the University of Colorado-Boulder and University of New Mexico websites. Almost 300 people registered for the workshop, of whom 122 attended.

The virtual workshop was held using Zoom two weeks after the in-person meeting. After a short overview from the organizers and the cognizant NSF program officers, we reviewed the outcomes from the in-person workshop and offered participants the opportunity to join a one-hour breakout session for the impact area of their choice, which were facilitated by one of the attendees from the in-person workshop. Using a shared Google document and a copy of the Mural row for that impact area, the participants in each breakout room began by working through the cross-cutting principles, offering suggestions as to what should be added, deleted, or changed. Each breakout group then moved to updating the Mural row with their suggestions about research thrusts. (If participants were unable to find an appropriate building block for their suggestions, we encouraged them to add new ones). After a short break, all participants

returned to the main session and heard reports from each breakout room. This was followed by open discussion via the Zoom chat and Q&A channels and a wrap-up from the organizers. This second event produced revised and refined versions of the cross-cutting principles and the Mural.

The outcomes of this workshop series included a set of observations and recommendations that we document herein. We wish to note that the discussions at the meetings were very wide ranging. Given the timeline constraints of the Convergence Accelerator CFP, we distilled the community feedback and recommendations for those we thought were feasible, given these constraints. However, we want to emphasize that it became evident from these activities that the community feels strongly that significant and ongoing NSF investment is needed in this area to facilitate sustained progress, long-term impact, and societal benefits.

We next present these recommendations, together with supporting evidence from the workshop series. Slides for both the in-person and virtual events and the final concept matrix (in the form of a Mural) can be found in the appendix.

2. Recommendations for Building Resilience to Climate-Driven Extreme Events with Computing Innovations

We recommend that an NSF Convergence Accelerator (CA) track is warranted that focuses on computing advances that address the complex challenges surrounding climate change. Moreover, as part of the discussions and brainstorming in this community workshop series, we observed that there is tremendous opportunity for computing advances to be brought to bear on the climate crisis *across* impact areas. Both near-term and long-term computing research is needed to accomplish this. Since the Convergence Accelerator program focuses on the former, we identified key areas of overlap across impact areas and research thrusts to inform the recommendations in this report. Our recommendations include a set of:

- ❖ *Impact areas* – application domains that are both important to society and critically affected by climate change,
- ❖ *Research thrusts* with significant potential for addressing climate-induced challenges within and across impact areas,
- ❖ *Building blocks* – research advances that span impact areas and thus have potential for addressing multiple challenges concurrently, and
- ❖ *Cross-cutting principles* that all research projects should follow, regardless of impact area and technology.

2.1 Impact Areas

Our first recommendation is to integrate the *transportation* impact area into that of *physical infrastructure*, given the significant overlap in requirements, constraints, and climate impacts. Secondly, we recommend that environmental justice be a cross-cutting principle (described below) instead of an impact area, given the key role it plays across all of those areas.

Thus, the set of impact areas (our suggested application domain foci) that we recommend are:

- ❖ Energy – Energy system failures have economic impact as well as human costs. These harms are poised to worsen with the increased frequency and magnitude of extreme events due to climate change (hurricanes, heat waves, large rainfall events, etc.). At the same time, normal operating conditions for these systems are changing rapidly as renewables and other "edge" sources are added to the generation mix.
- ❖ Agriculture – Agriculture systems are sensitive to baseline shifts (e.g. changes in temperature and humidity, increased environmental variability, etc.) as well as to extreme events like droughts, floods, heat waves, and wildfires, which are projected to increase in both intensity and frequency as the climate changes.
- ❖ Physical infrastructure – Increased impacts of climate change and acceleration of frequency of extreme events stress regional power grids, transportation and communications networks, the manufacturing and financial services sectors and other aspects of the nation's critical infrastructure.

2.2 Research Thrusts and Building Blocks

The workshops enabled the research community to identify together a set of *building blocks* – areas of needed innovation that are key to combating the negative impacts of climate change across impact areas in the near term. The synthesized concept matrix that resulted from the workshops is depicted in this figure (a more readable version is available as an appendix). As described above, the columns in this matrix are the building blocks that the participants identified (AI, Digital Twins, Cyberinfrastructure, Optimization and Planning, UI/UX, and Data), and the rows are the climate crisis impact areas that we considered.

Figure A-2. *The final concept matrix, which combines all of the input from the in-person and virtual workshops.*

Within each cell (green box) in the concept matrix that was constructed with the Mural tool are the *research thrusts*—specific research directions identified by the participants as having potential for impact at the intersection of a particular impact area and a particular building block. The wide range of these thrusts clearly shows that our community sees many potential directions for addressing climate change impacts through the Convergence Accelerator program. Note that there are large clusters of research thrusts in some cells of the matrix. This is a direct reflection of opportunity and interest at these intersections.

Examples of research thrusts include:

- ❖ **Energy:**
    - ➢ Using digital twins to make energy infrastructure more robust and reslient
    - ➢ Utilizing a geographically-aware budget to reduce peak demand, allowing the minimization of rolling blackouts during heatwaves and cold snaps
    - ➢ Planning and optimization based on input from affected communities
- ❖ **Agriculture:**
    - ➢ AI tools for pest and invasive species detection
    - ➢ Edge computing on mobile platforms for labor shortage mitigation
    - ➢ Optimization advances for tailoring agriculture to climate change (e.g. what should crops look like in 2035, so that they are resilient to extreme events?)
    - ➢ Simple, intuitive UIs for precision agriculture tools which don't require the user to be an expert in computer or agricultural sciences.
- ❖ **Physical Infrastructure:**
    - ➢ A standardized platform for the recovery process for all disasters (FEMA, HUD CDBG, etc.)

➢ Real-time health monitoring for optimal repair schedules
➢ Cyber-physical systems: e.g., active structures that adapt stiffness for resilience to threats, such as high wind, etc.
➢ Resource efficient and privacy preserving analytics
➢ Eco-friendly decision support for travelers (e.g. directing a user to take a route that adds 9 minutes to their journey, but reduces their fuel consumption by 25%)
➢ Using data visualization as an educational tool to change behaviors

The PI team then performed extensive analysis of these research thrusts to identify those that occurred repeatedly across impact areas, and therefore are the major points of opportunity for near-term computing research to support climate adaptation. These building blocks, which are separated out into lists below each column header in Figure 1, are listed below:

AI

- Explainability and interpretability for AI models with the goal of mechanistic understanding of the system being analyzed
- Predictive models that can generalize to unseen scenarios
- Hybrid AI that combines physics-based with data-driven models
- Techniques that address spatially unequal data coverage/availability
- Physics-guided AI to generate and integrate theoretical & empirical data to improve modeling, analysis, and explainability
- Consideration of randomness, unmeasured, and unexpected factors
- Manage trade-offs to permit ML/AI at the edge/in-situ
- AI to design sustainable and resilient materials
- Trustworthy and robust AI

Digital Twins

- Clear definition of Digital Twins' purpose, goals, and validation
- Reusable cloud+edge platform that can be specialized for different goals
- Support for exploration of what-if scenarios
- Advances for interoperability (devices, models, services)
- Couple GIS + simulation into platform
- Probabilistic programming to build rich simulators & reason about possible trajectories
- Integrated data fusion from multiple sources, modalities, and scales
- Support for performance tuning and accuracy trade-offs

Cyberinfrastructure

- Robust, reliable, and energy efficient network infrastructure
- Networking + edge compute infrastructure for low-resource areas
- Cloud-edge decision support

- Service-ization (modularity) to enable maintainability/sustainability
- Support for metric collection & trade off management (power, size, performance)
- Biodegradable materials (or non-rare-earths) for computing devices and components

Optimization/Planning

- Setting the optimization parameters in an inclusive democratic fashion and navigating differences in values that drive differential weighting
- Standardized tools for interoperability across sectors & communities
- Support for multiple objectives
- Support for interactive visualization of decision support data and processes

UI/UX

- Visualization based on human factors design and accessible U/I
- Specialized for multiple, heterogeneous affected community targets & needs
- Decision-support tools that present a range of options and tradeoffs in an understandable way
- Psychology-grounded tools to help people think about risks and costs
- Tools to help people share information and tasks

Data

- Support for managing data quality, uncertainty, provenance
- Secure & private data collection, storage, protection, ownership management, and analysis
- Effective & efficient collection, storage compression, and fusion of data from multiple sources, modalities, & scales
- Identify and remove bias in data
- Identify missing data
- Containerized, easily-shareable, low-code/no-code data pipelines, modules & tools
- Data assimilation from sensors and/or crowd sourcing for rapid updating
- Statistical Design for responsive data collection and synthetic data generation
- Support for open knowledge networks

As described in the Convergence Accelerator program description, these building blocks represent research that is broad in technical scope, has far-reaching impact on society, builds upon foundational research, and requires a multidisciplinary, convergent research approach to be successful. Moreover, because they span impact areas, these building blocks have significant potential for affecting multiple use cases of societal import if pursued and invested in.

2.3 Cross-Cutting Principles

As mentioned in the first section of this report, the participants in this visioning activity identified an important set of cross cutting principles that Convergence Accelerators should address. For any research thrust or set of building blocks, projects should employ a systems-level approach, involving affected communities and addressing environmental justice. Projects should also develop an actionable set of outcomes and metrics. Details appear below.

- *Employ a systems-level approach that considers resilience, usability, trustworthiness, and explainability in the design.*

  The human/climate system is complicated, nonlinear, nonstationary, and highly coupled. Computational solutions need to respect this; addressing elements of the associated problems in isolation will not work because of uncertainties and couplings, both known and unknown, that may have unintended consequences. Finally, there is a need to consider socio-technical issues across all phases of the research. As mentioned in the recent National Academies report on responsible computing[2], "It is much easier to design a technology correctly from the start than it is to fix it later." This will require meaningful, operationalized partnerships between computer scientists on the project teams and experts in the social and behavioral sciences.

- *Include a plan for identifying and involving a wide range of affected communities, across all phases of the project, including design, deployment, and adoption.*

  In order to assure that the solutions are a deep match to all aspects of the associated problems, affected communities must be involved in meaningful ways in all phases of projects funded under this program, including those historically underserved. This will create many benefits: not only building support and facilitating adoption, but also avoiding data abuse/misuse issues and creating tools that the target audiences trust. A challenge here will be identifying those target audiences—e.g., end users, developers/innovators, students—and working with them to understand the associated usability issues. Ideally, there should be incentives and funding mechanisms in place to foster sustained engagement and continuous improvement: e.g., ongoing feedback loops between the researchers and the community members, all the way out to the field workers. This will, of course, be a tall order, given the constraints of the Convergence Accelerator program, but research funded under this program could provide effective nucleation points for the types of follow-on activities and sustained support and investment that will be necessary for real impact on these novel, difficult, and critical problems.

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[2] *Fostering Responsible Computing Research*. National Academies Press, Oct. 2022. *Crossref*, https://doi.org/10.17226/26507.

- *Provide a set of actionable outcomes for the project*

  These should include goals, milestones, and deliverables. Solutions must also be able to address a societal need and be capable of growing and adapting to achieve this in the long term.

- *Include well-defined metrics for success of the project that take into account not only **direct** climate impacts, but also an appropriate subset of the following considerations:*

  - *The impact of computing itself on the climate*

    Computation not only has a significant carbon footprint, but also major supply-chain and e-waste issues. Training a modern machine-learning model, for instance, can generate as much CO2 as five cars will produce over their lifetimes[3]. Mining of the rare earths used in computer electronics can be environmentally detrimental and disposing of that equipment properly is a real challenge. These factors must be identified and considered during all research funded by this program, across the full stack: hardware, software, cyberinfrastructure (e.g., the cloud), etc.

  - *Human impacts*

    Solutions to climate-change issues cannot have impact if they are not adopted, used, understood, and trusted by their target audiences. This requires effort to be devoted (again, throughout the design and deployment phases) to human-centered design thinking: satisfaction, inclusivity, cultural relevance.

  - *Tech transfer*

    Uptake by industry and spinoff of startups, perhaps catalyzed by academic-industry partnerships, could greatly leverage the impact of climate-change solutions developed under the auspices of this program.

  - *The complicated, often-conflicting nature of the goals that can arise in this assessment*

    A successful systems-level approach to climate-change problems will require multi-objective planning and optimization that takes into account risk and uncertainty, as well as differences in metrics across different affected and targeted groups, to give economical, environmental, and societal resiliences appropriate weight in decisions.

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[3] https://www.forbes.com/sites/robtoews/2020/06/17/deep-learnings-climate-change-problem

- *Consider and actively promote environmental justice*
    - *Any and all proposed technological advances to address climate change must simultaneously work to address, and ultimately overturn, unequal environmental legacies, as well as to assure equity going forward.*

Given the constraints of the Convergence Accelerator program, it will not be practical for every project to address every element of these cross-cutting principles in any comprehensive way, but all proposals should identify the critical subset of these principles that will guide their project, and **all** projects should include a meaningful set of metrics for their work.

2.4 Recommendations

In summary, given our experience with this workshop series, we recommend that NSF create a Convergence Accelerator track in support of computing advances that facilitate adaptation and build resilience to climate change. In collaboration with the research community, we have identified a set of cross-cutting principles that we believe all Convergence Accelerators should address. We have also identified key impact areas on which use-inspired research can focus, as well as computing research building blocks that build upon foundational research and require a multidisciplinary, convergent research approach in order to succeed in producing positive and far-reaching impacts for society. Finally, we recommend significant and ongoing NSF investment in climate-focused computing research in order to facilitate sustained progress, long-term impact, and societal benefits.

Appendix A. Workshop Materials
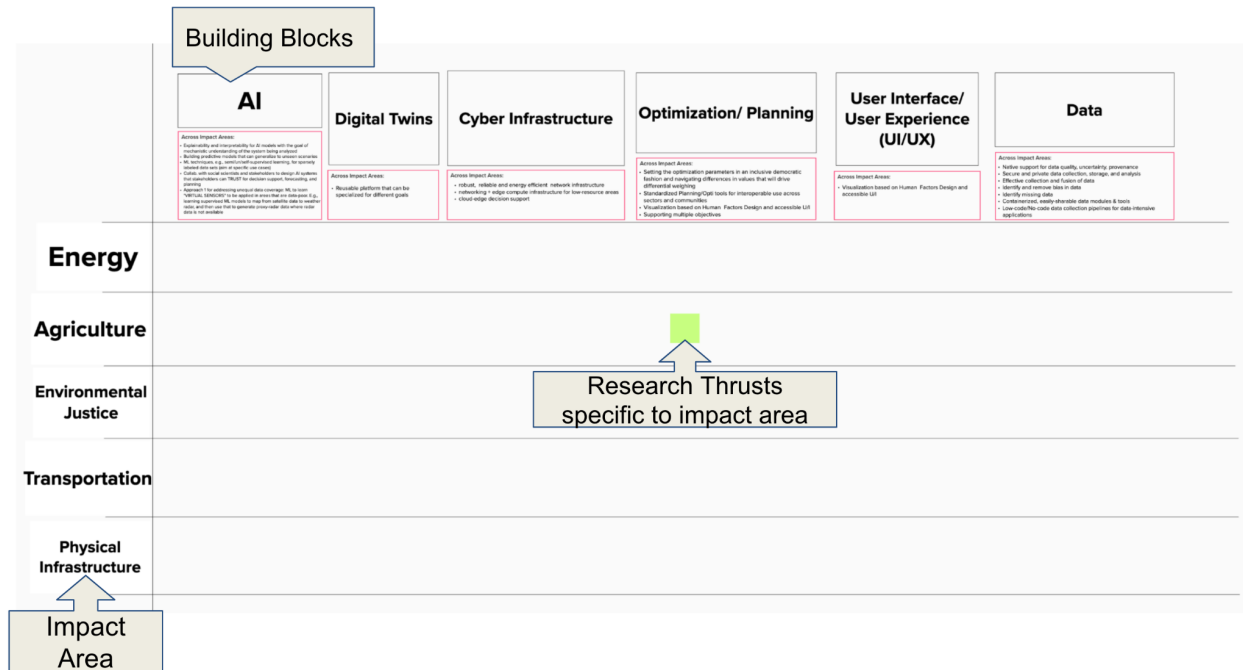
Figure A-1. Blank Mural

Figure A-1. A blank copy of the concept matrix that was used in brainstorming during both workshops. This copy has labels indicating the names we have chosen for the different categories in the matrix.
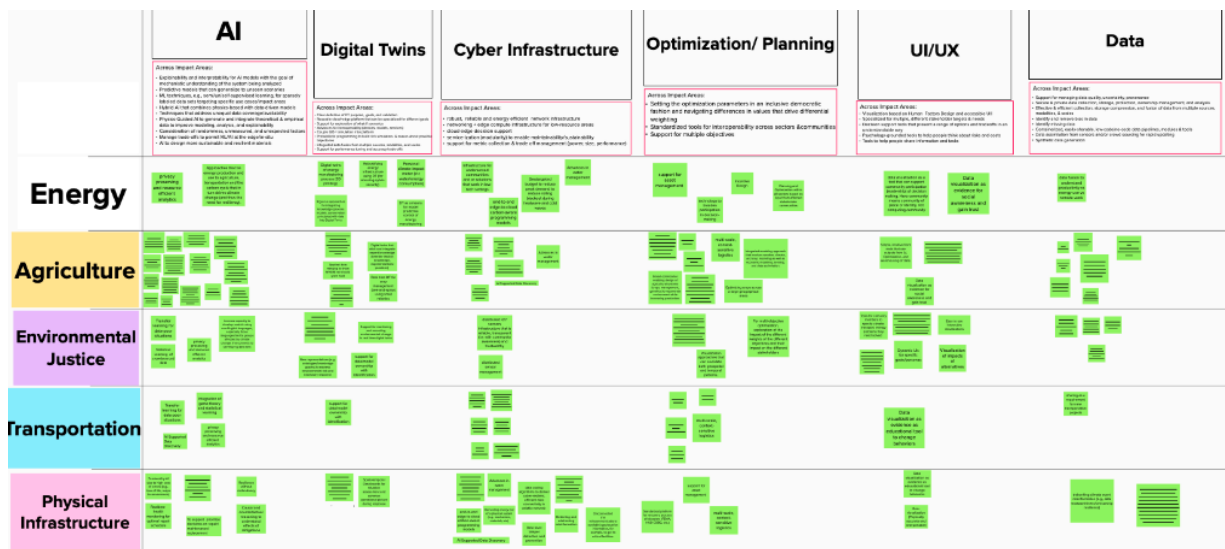
Figure A-2. Final Concept Matrix

Figure A-2. The final concept matrix, which combines all of the input from the in-person and virtual workshops.

Figure A-3. In-Person Workshop Slides

Building Resilience to Climate Driven Extreme Events with Computing Innovations: A Convergence Accelerator Workshop

October 27-28, 2022

Agenda Day 1

October 27, 2022 (Thursday)

12:00 PM	Lunch Available	Lodo
01:00 PM	Welcome and Introductions	Central City
01:30 PM	Topic 1: Energy	Central City
02:30 PM	Topic 2: Agriculture	Central City
03:30 PM	BREAK	Central City
04:00 PM	Topic 3: Transportation	Central City
05:00 PM	General/Cross-Cutting Discussion	Central City
05:30 PM	Wrap up	Central City
06:30 PM	Dinner	Lodo

Agenda Day 2

October 28, 2022 (Friday)

07:30 AM	Breakfast	Lodo Room
08:30 AM	Recap of Day 1	Central City Room
08:45 AM	Discussion: Building Blocks	Central City Room
09:15 AM	Panel 4: Environmental Justice	Central City Room. Breakouts in Leadville and Silverplume.
10:15 AM	BREAK	Central City Room
10:30 AM	Concluding Comments/Discussion	Central City Room
10:45 AM	What have we not discussed?	Central City Room
11:15 AM	Deliverable Muraling	Central City Room
12:00 PM	Lunch	Lodo Room
01:00 PM	End of Workshop

Welcome Remarks

Liz Bradley, University of Colorado-Boulder
Chandra Krintz, UC Santa Barbara/AppScale Systems Inc.

Lightning Introductions

Organizers

Chandra Krintz
University of California
Santa Barbara

Liz Bradley
University of
Colorado-Boulder

Melanie Moses
University of New Mexico

Aurali Dade
NSF (TIP/ITE)

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With Support From

Ann Schwartz
CCC

Catherine Gill
CCC

Haley Griffin
CCC

Maddy Hunter
CCC

Welcome from the NSF

NSF's Convergence Accelerator

NSF'S CONVERGENCE ACCELERATOR

2022 WORKSHOP POINTS OF EMPHASIS

Tuesday October 27, 2022

Aurali Dade, Program Director
Convergence Accelerator
Directorate for Technology, Innovation and Partnerships
National Science Foundation

ACCELERATING CONVERGENT SOLUTIONS FOR SOCIETAL IMPACT

A Pivotal Moment for the Nation
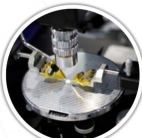
Climate change

Equitable access to education, health care

Critical and resilient infrastructure

2   NSF CONVERGENCE ACCELERATOR | 2022 WORKSHOP POINTS OF EMPHASIS

A Pivotal Moment for Science & Engineering

Pace of discovery accelerated by data, emerging technologies

Demand for societal impact

Opportunity to leverage partnerships

3   NSF CONVERGENCE ACCELERATOR | 2022 WORKSHOP POINTS OF EMPHASIS

MISSION:

To promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense; and for other purposes

VISION:

Envisions a nation that capitalizes on new concepts in science and engineering and provides global leadership in advancing research and education

4   NSF CONVERGENCE ACCELERATOR | 2022 WORKSHOP POINTS OF EMPHASIS

TIP Directorate for Technology, Innovation and Partnerships

Creates breakthrough technologies | Meets national needs | Empowers all

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CONVERGENCE RESEARCH

Today's grand challenges will **NOT** be solved by one discipline working alone.

Grand Challenges require **CONVERGENCE**: the merging of ideas, approaches, and technologies from widely diverse fields of knowledge to stimulate innovation and discovery.

6   NSF CONVERGENCE ACCELERATOR | 2022 WORKSHOP POINTS OF EMPHASIS

Slide 7

NSF Convergence Accelerator
Accelerating Solutions Toward Societal Impact

MISSION:
The Convergence Accelerator speeds the transition of convergence research into practice to address national-scale societal challenges

VISION:
Convergence research and multi-institutional teams that include users and other stakeholders will provide high-impact results to societies at scale

Slide 8

NSF Convergence Accelerator
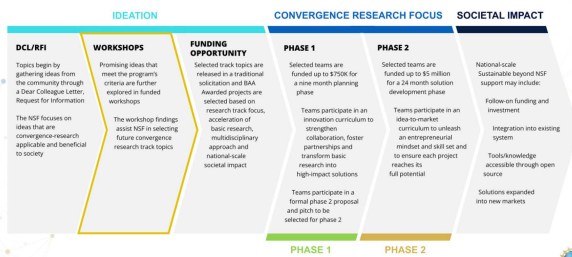*Accelerating Solutions Toward Societal Impact*

GOALS:
- Disrupt the usual way of NSF business through a new innovation model
- Expand and diversifies multidisciplinary teams and partnerships to include academia, industry, non-profits, government, and other sectors
- Deliver solutions that have a national societal impact

Characteristics	Proactively & Intentionally Managed
• Use-inspired research • Clear goals, milestones, high-impact deliverables • Leverages multidisciplinary teams • **Larger, national societal scale** • Requires **diverse partnerships** – industry, non-profits, academia • **Acceleration at speed and scale**	• Teams and Cohorts—"Tracks" • **Cooperation and Competition** • **Intensive education and mentorship—human-centered design thinking, team science, and customer discovery** • Mission-driven evaluation

Slide 9

CONVERGENCE ACCELERATOR PROGRAM

IDEATION | CONVERGENCE RESEARCH FOCUS | SOCIETAL IMPACT

DCL/RFI
Topics begin by gathering ideas from the community through a Dear Colleague Letter, Request for Information

The NSF focuses on ideas that are convergence-research applicable and beneficial to society

WORKSHOPS
Promising ideas that meet the program's criteria are further explored in funded workshops

The workshop findings assist NSF in selecting future convergence research track topics

FUNDING OPPORTUNITY
Selected track topics are released in a traditional solicitation and BAA
Awarded projects are selected based on research track focus, acceleration of basic research, multidisciplinary approach and national-scale societal impact

PHASE 1
Selected teams are funded up to $750K for a nine month planning phase

Teams participate in an innovation curriculum to strengthen collaboration, foster partnerships and transform basic research into high-impact solutions

Teams participate in a formal phase 2 proposal and pitch to be selected for phase 2

PHASE 2
Selected teams are funded up to $5 million for a 24 month solution development phase

Teams participate in a idea-to-market curriculum to unleash an entrepreneurial mindset and skill set and to ensure each project reaches its full potential

National-scale
Sustainable beyond NSF support may include:

Follow-on funding and investment

Integration into existing system

Tools/knowledge accessible through open source

Solutions expanded into new markets

PHASE 1 | PHASE 2

Slide 10

CONVERGENCE ACCELERATOR EXAMPLE
2021 Cohort: Ideation to Convergence Research

IDEATION | CONVERGENCE RESEARCH FOCUS | SOCIETAL IMPACT

DCL/RFI
NSF 20-061
Focused on gathering convergence research topics for FY 2021
NSF receives 180+ ideas

WORKSHOPS
Funded 12 workshops on a variety of topics to be further developed.
Two workshop topics were chosen for the 2021 solicitation:
•Track E: Networked Blue Economy
•Track F: Trust & Authenticity in Communication Systems

FUNDING OPPORTUNITY
NSF releases two solicitations in parallel:
• Traditional: NSF 21-572
• Broad Agency Announcement: NSFBAA-CA21-01
NSF receives 200+ proposals

PHASE 1
NSF awards 28 teams launching the 2021 Cohort:
• 16 Track E teams
• 12 Track F teams

Phase 1 teams:
•Participate in the innovation curriculum
•Develop the initial concept
•Identify new team members/partners
•Participate in a formal phase 1 proposal and pitch presentation
• Participate in EXPO 2022

PHASE 2
Begins October 2022

Begins Summer 2024

PHASE 1 | PHASE 2

Slide 11

PROGRAM STRUCTURE
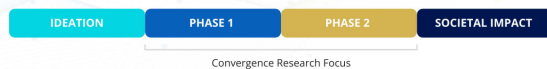
IDEATION (DCL/RFI, WORKSHOPS):
Selected by gathering input from the community. Identified topics must meet a societal need at scale, be built upon foundational research, and be suitable for a multidisciplinary, convergence research approach.

PHASE 1 (PLANNING):
Up to $750K over 9 months is provided to further develop the initial concept (building upon basic research), identify new team members/partners, participate in a hands-on innovation curriculum, and develop an initial/low-fidelity prototype.

PHASE 2 (IMPLEMENTATION):
Up to $5M over 24 months to develop solution prototypes and to build a sustainability model to continue impact beyond NSF support.

IDEATION | PHASE 1 | PHASE 2 | SOCIETAL IMPACT

Convergence Research Focus

Slide 12

Convergence Accelerator Portfolio

Track A
Open Knowledge Networks

Track B
AI and the Future of Work

Track C
Quantum Technology

Track D
AI-Innovation Data Sharing & Modeling

Track E
Networked Blue Economy

Track F
Trust & Authenticity in Communication Systems

2019 COHORT Phase 2 | **2020 COHORT** Phase 2 | **2021 COHORT** Phase 1

Track G
Securely Operating Through 5G Infrastructure

Track H
Enhancing Opportunities for Persons with Disabilities

Track I
Sustainable Materials for Global Challenges

Track J
Food & Nutrition Security

2022 COHORT

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Slide 13
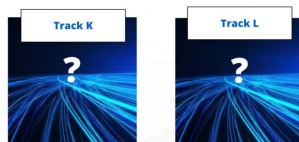
2023 Cohort Track Topics – TBD

If selected as a topic for the 2023 solicitation, this workshop report will be used as a reference for the community so make sure it's as clear, concise, and comprehensive as possible.

Track K
?

Track L
?

Slide 14

Convergence Accelerator Workshop Charge–Points of Emphasis

As you engage in the workshop discussion, keep in mind the following aspects of the Convergence Accelerator:

Convergence: Multiple disciplines with a focus on social science aspects; think big—don't just include experts from a single institution or discipline

Cross-cutting Partnerships: Multiple disciplines, organizations, and sectors; not just academia; must include industry, non-profits, government, and other communities of practice
- Diverse partnerships provide valuable expertise and insights to position the deliverable for success.
- Multidisciplinary approach (different sectors and expertise)
- Use-inspired research (end-user and prototyping research)

Broadening Participation: Must include the participation of underrepresented groups (e.g., expertise, partnerships, user groups, resource needs)

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Convergence Accelerator
Workshop Charge–Points of Emphasis Continued

As you engage in the workshop discussion, keep in mind the following aspects of the Convergence Accelerator:

Deliverables: What can be delivered to the American people in 3 years, (e.g., Prototypes); What impact will the solutions have on a national scale?

- Research papers are **not** sufficient.
- Deliverables do not have to result in commercialization, but they must be useful and needed tools, test beds, living labs, etc.
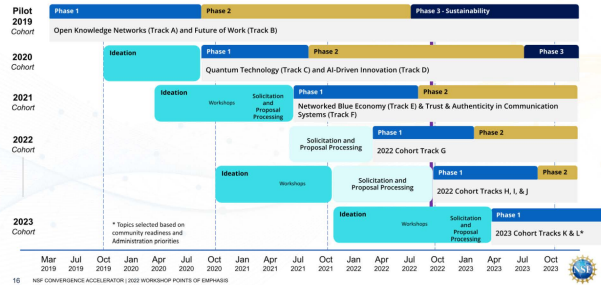
Track Alignment:

- How can multiple funded teams work together to solve a national-scale complex challenge?
- Each track funds a set of diverse teams focusing on different aspects of a national-scale societal challenge
- Teams are uniquely positioned to ensure the highest societal impact

Slide 16

CONVERGENCE ACCELERATOR PROGRAM TIMELINE
Overall Timeline – 2019-2023

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Workshop Themes for 2023 Track Topics

Topic	Workshop	Workshop Details
AI Safety	**Ethical Design of AIs**, led by University of Maryland, College Park, PI: Louiqa Raschid (Award ID: 2232404)	**Dates/Times:** September 29, October 6, and October 20, 2022 from 12 – 3:30 p.m. ET **Website:** go.umd.edu/EDAIs
AI Safety	**Provably Safe and Beneficial Artificial Intelligence Workshop (PSBAI)**, led by University of California, Berkeley, PI: Stuart Russell (Award ID: 2230996)	**Dates:** October 7-9, 2022 **Website:** humancompatible.ai/psbai-workshop-2022/
Bio-Informed Design/ Bioengineering	**Bio-inspired Design**, led by Syracuse University, PI: Lisa Manning (Award ID: 2232327)	**Dates:** October 3-4, 2022 **Website:** bioinspired.syr.edu/nsf-convergence-accelerator-workshop-bio-inspired-design
Chemical Sensing Innovation	**Chemical Sensing with an Olfaction Analogue: High-dimensional, Bio-inspired Sensing and Computation**, led by Texas A&M University, PI: Ricardo Gutierrez-Osuna, (Award ID: 2231512)	**Dates/Times:** October 7, 2022 from 8 – 10 a.m. CT, October 11, 2022 from 8 a.m. – 12 p.m. CT, October 13 from 8 a.m. – 12 p.m. CT, and October 14 from 8 a.m. – 12 p.m. CT. **Website:** psi.engr.tamu.edu/olfaction-workshop
Chemical Sensing Innovation	**Frontiers in Chemical Sensing: Synthetic, Neuromorphic and Cyborg Systems**, led by Washington University, PI: Barani Raman, (Award ID: 2231526)	**Dates/Times:** October 18 from 1 – 3 p.m. ET and October 24, October 26 and October 28 from 1 – 5 p.m. ET **Contact:** Baranidharan Raman (Principal Investigator) barani@wustl.edu
Citizen Science for Community Resilience	**Community Science and Resilience**, led by American Geophysical Union or AGU, PI: Raj Pandya (Award ID: 2231692)	**Dates/Times:** October 7, 2022 from 11 a.m. – 3 p.m. ET **Website:** resiliencethruscience.org

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Workshop Themes for 2023 Track Topics

Topic	Workshop	Website
Computing Solutions to Climate-Driven Extreme Events	**Building Resilience to Climate Driven Extreme Events with Computing Innovations**, led by University of Colorado, Boulder, PI: Elizabeth Bradley, (Award ID: 2232193)	**Dates/Times:** October 27, 2022 at 12 p.m. MDT, October 28, 2022 at 1 p.m. MDT and November 10, 2022 from 12 – 3:15 p.m. EST. **Website:** • In-Person workshop • Virtual event
Lifelong Learning / AI-Driven Innovation	**Personalized Adventures in Learning: The Future of AI in Education**, led by University of Massachusetts, PI: Beverly Woolf (Award ID: 2230697)	**Dates/Times:** Three afternoons between the dates of October 10 – 21, 2022 from 1 – 5, p.m. ET **Website:** humancompatible.ai/psbai-workshop-2022/
Lifelong Learning / AI-Driven Innovation	**Transforming Educational Technology Through Convergence**, led by the University of Pennsylvania, PI: Ryan Baker (Award ID: 2231524)	**Dates/Times:** October 3, 2022 from 1-3 p.m. ET, November 4, 2022 from 1-3 p.m. ET and mid-late October meeting scheduled by each sub-group **Website:** www.the-learning-agency.com/nsf-convergence-accelerator-virtual-conference-2022
Managing Water Resources	**Managing Water for a Changing Planet**, led by Oregon State University, PI: Pamela L. Sullivan, (Award ID: 2231723)	**Dates/Times:** October 25, 2022, October 31, 2022 and November 4, 2022 **Website:** sites.google.com/oregonstate.edu/managing-water-nsf-ca
Managing Water Resources	**Climate Resilience and Managing Water Resources**, led by the Indiana University, PI: Benjamin Kravitz (Award ID: 2231916)	**Dates/Times:** October 13, 2022 from 1 – 3 p.m. ET and October 17, 19, and 21, 2022 from 1 – 5 p.m. ET **Website:** https://earth.indiana.edu/research/workshops/water-resources.html

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NSF Convergence Accelerator Team

Doug Maughan — Head
Aurali Dade — Program Director
Pradeep Fulay — Program Director
Jemin George — Senior Advisor
Alex Loewi — AAAS Fellow

Ibrahim Mohedas — Program Director
Linda Molnar — Program Director
Michael Pozmantier — Program Director
Michael Reksulak — Program Director
Shelby Smith — Communications & Outreach Lead
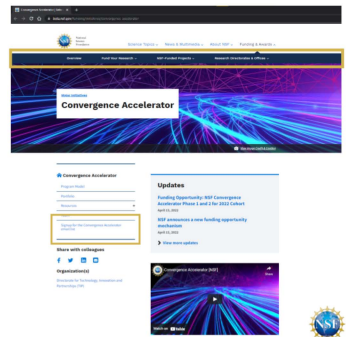**Nicole Tehrani** — Program Analyst

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LEARN ABOUT US.

- Unique Program Model
- Exciting Program Offerings
- Current Portfolio
- Ways to Connect into the Program and with the Team

BE THE FIRST TO KNOW.
Join our mailing list to learn about important program updates and new funding opportunities!

Slide 21

THANK YOU

beta.nsf.gov/funding/initiatives/convergence-accelerator
Convergence-Accelerator@nsf.gov

Aurali Dade, Program Director
NSF Convergence Accelerator
adade@nsf.gov

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TIP: Accelerating Research Toward Impact

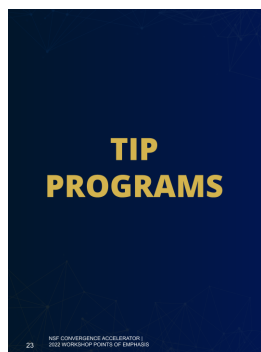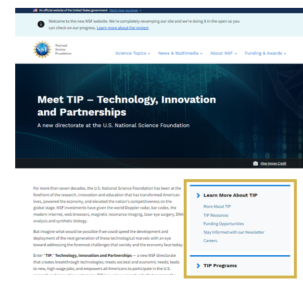| Fostering Innovation and Technology Ecosystems	Establishing Translation Pathways	Partnering to Engage the Nation's Diverse Talent
Nurtures regional and national innovation and technology ecosystems to support researchers and innovators to converge, develop and accelerate use-inspired research for societal impact.	Supports startups through a lab-to-market platform and establishes new pathways for translating research results for society.	Advances and deepens high-impact, public and private partnerships across all areas of science, engineering and education to cultivate innovation ecosystems, create technology solutions, and support future STEM leaders.

TIP PROGRAMS

- America's Seed Fund powered by NSF (SBIR/STTR)
- Convergence Accelerator
- Innovation Corps (I-Corps™)
- Partnerships for Innovation (PFI)
- Pathways to Enable Open-Source Ecosystems (POSE)
- Regional Innovation Engines (NSF Engines)

NSF CONVERGENCE ACCELERATOR | 2022 WORKSHOP POINTS OF EMPHASIS — 23

LEARN ABOUT TIP

- Mission and focus
- Innovation programs
- Funding opportunities
- Stay informed with our newsletter
- Resources and upcoming events

  Visit, beta.nsf.gov/tip/latest

Meet TIP – Technology, Innovation and Partnerships
A new directorate at the U.S. National Science Foundation

NSF CONVERGENCE ACCELERATOR | 2022 WORKSHOP POINTS OF EMPHASIS — 24

COMPUTING COMMUNITY CONSORTIUM

The mission of Computing Research Association's Computing Community Consortium (CCC) is to enable the pursuit of innovative, high-impact computing research that aligns with pressing national and global challenges.

Who
- **Council - 23 members**
- **CCC/CRA Staff**
- **Chair, VC, & Director**

Daniel Lopresti
CCC Chair

Inputs: Bottom-up, Internal, & Top-Down

What:
- **Workshops & Conf. Blue Sky Tracks**
- **Whitepapers & Social Media**
- **Reports Out (esp. to government)**
- **Symposium for DC'ers**

Nadya Bliss
CCC Vice Chair

Human Development
- **Early Career Workshops & Participation**
- **Council Membership**
- **Leadership w/ Gov't (LISPI)**

Elizabeth Bradley
CCC Chair Emerita

CCC VISIONING WORKSHOPS…

- Engage the community, together with relevant stakeholders, rapidly capturing and synthesizing the important ideas
- Facilitate broad thinking with compelling examples
- Create new avenues for (interdisciplinary) collaboration
- Frame future opportunities in a manner that energizes the community and engages potential funders
- Align with national and computing research priorities
- Articulate needs and barriers to research impact

CCC — Computing Community Consortium Catalyst

9

Goals & Expected Outcomes

- Develop and frame ideas to incorporate convergence research and encourage collaboration among stakeholders across disciplines/experiences
- Identify research tracks to include in next year's program solicitation
  - Research Focus: *Building Resilience to Climate Driven Extreme Events with Computing Innovations*
- This workshop: draft an outline for this focus and its tracks
  - Evolve/Improve with wider community at **virtual meetup on Nov 10**
- Identify key **computing research building blocks** that span impact areas
  - Energy, agriculture, transportation, environmental justice, infrastructure, and more…
  - To expedite innovation and near term demonstrable impact

CCC — Computing Community Consortium Catalyst

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Workshop Structure

- Four 1-hour sessions (5 + 35 + 5 + 15)
  - Area framed briefly by expert in the field (5mins)
    - Today: Energy (1:30), Agriculture (2:30), Transportation (4pm)
    - Tomorrow: Environmental Justice
  - Breakout rooms (35mins): Brainstorm computing advances (existing and new)
    - **Use inspired solutions** vs technologies
    - End-to-end, solutions themselves must be climate resilient
    - CCC staff will take shared notes
  - Regroup: Reporters summarize discussion from each breakout (15mins)

- Active participation in breakouts outside of your area of expertise
  - Get outside of your comfort zone

CCC — Computing Community Consortium Catalyst

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Figure A-3. In-Person Workshops Slides.

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Figure A-4. Virtual Workshop Slides

Slide 1

Building Resilience to Climate Driven Extreme Events with Computing Innovations: A Virtual Convergence Accelerator Workshop

12:00-3:00 pm EST

CCC Welcome

Chandra Krintz
University of California Santa Barbara

Liz Bradley
University of Colorado-Boulder

Melanie Moses
University of New Mexico

Ann Schwartz

Catherine Gill

Haley Griffin

Maddy Hunter

COMPUTING COMMUNITY CONSORTIUM

The mission of Computing Research Association's Computing Community Consortium (CCC) is to enable the pursuit of innovative, high-impact computing research that aligns with pressing national and global challenges.

Who
- Council - 23 members
- CCC/CRA Staff
- Chair, VC, & Director

Daniel Lopresti
CCC Chair

Inputs: Bottom-up, Internal, & Top-Down

What:
- Workshops & Conf. Blue Sky Tracks
- Whitepapers & Social Media
- Reports Out (esp. to government)
- Symposium for DC'ers

Nadya Bliss
CCC Vice Chair

Human Development
- Early Career Workshops & Participation
- Council Membership
- Leadership w/ Gov't (LISPI)

Elizabeth Bradley
CCC Chair Emerita

NSF Welcome and Overview

Aurali Dade
The National Science Foundation
TIP/ITE

Goals, Process, & Expected Outcomes

- Develop and frame ideas to incorporate convergence research and encourage collaboration among stakeholders across disciplines/experiences

- Identify research tracks for potential inclusion in next year's program solicitation
  - Research Focus: *Building Resilience to Climate Driven Extreme Events with Computing Innovations*

- Oct 27 "pre-workshop": Small in-person event to frame research focus
  - **Impact areas** (application domains)
  - Computing research **building blocks** that span impact areas
  - **Research thrusts** within impact areas
  - **Cross-cutting principles**

- **Today's event:** *Brainstorm and build upon framing to draft NSF report*

Pre-Workshop: When & Who

Participants
- Vikram Adve
- Sujata Banerjee
- David Begay
- Tracy Camp
- Michael Dunaway
- Tayo Fabusuyi
- Baskar Ganapathysubramanian
- Peter Harsha
- Raya Horesh
- Daniel Jacobson
- David Jensen
- Vipin Kumar
- Christine Lv
- Claudia Marin
- Charlie Messina
- Aditi Misra
- Claire Monteleoni
- Raj Pandya
- Shashi Shekhar
- Jiayang Sun

27-28 October 2022
Denver CO

Pre-Workshop: Impact Areas

- Energy
- Agriculture
- Transportation
- Environmental Justice
- Physical Infrastructure
- *Your impact area(s) here…*
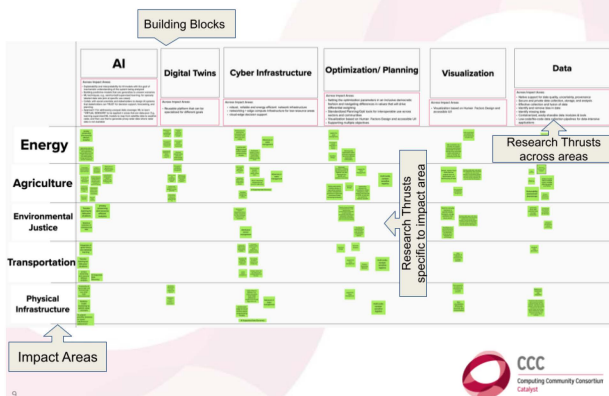

Pre-Workshop: Building Blocks

- Six broad computing research **building blocks across those impact areas**:

  - ➢ AI
  - ➢ Digital Twins
  - ➢ Cyberinfrastructure
  - ➢ Optimization/Planning
  - ➢ Visualization
  - ➢ Data
  - ➢ …?

Mural

Pre-Workshop: Building Blocks – Research Thrusts Across Impact Areas

AI
- explainable, interpretable, use inspired
- generalizable predictive models
- semi/un/supervised ML + sparse labeling
- stakeholder involvement to build trust
- transferable from data rich to data poor

Digital Twins
- uniform, reusable platform
- customizable for different goals

Cyberinfrastructure
- robust + easy of use and extend
- resource constrained, energy efficient
- edge-aware network, storage, compute

Optimization/Planning
- democratize parameterization & weighting
- standardization
- multi-objective support

Visualization
- human factors design & accessibility

Data
- quality, uncertainty, provenance
- sharing, security & privacy
- collection, fusion & bias removal
- tools & pipelines

Pre-Workshop: Cross-Cutting Principles

- Considers the impact of computing itself on the climate.

- Includes well defined metrics for success

- Employs a holistic, end-to-end systems-level approach that incorporates resilience considerations

- Addresses usability for different user targets

- Includes a plan for stakeholder involvement *and participation* (including those historically underserved)

- Integrated communication, outreach, and adoption plan

- …?

Agenda

- 12:00 - General Overview
  - CCC Welcome
  - NSF Welcome and overview of Convergence Accelerator Program
  - Overview of Part 1 of Workshop
  - Charge for Breakout Discussions
- 12:30 - Topical Breakouts
  - Energy, Agriculture, Environmental Justice, Transportation, Infrastructure
- 1:30 - Break
- 1:45 - General Session
  - Reports from Breakout Discussions
  - Wrap up

Instructions for Breakout Rooms

- Zoom room per impact area (1-2 breakouts created there on-demand)
- Identify "Reporter"
- Document discussion/ideas via shared google doc & mural row
- Discuss cross-cutting principles (15mins)
- Mural work: brainstorm research thrusts (30mins)
  - Select *Enter as a visitor*
- Refine report-out plan and identify what is missing (15mins)
- Break

Report-outs & discussion starts at 1:45pm ET at original webinar link

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Please join a breakout room! We will meet back here at 1:45 pm for reports and discussion

- Agriculture room: cra.org/ccc/Agriculture

- Energy room: cra.org/ccc/Energy

- Transportation room: cra.org/ccc/Transportation

- Environmental Justice room: cra.org/ccc/Environmental-Justice

- Infrastructure room: cra.org/ccc/Infrastructure

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Break

- 15 minute break; please be back by 1:45 pm EST to hear reports from each breakout room!

- Agriculture room: cra.org/ccc/Agriculture

- Energy room: cra.org/ccc/Energy

- Transportation room: cra.org/ccc/Transportation

- Environmental Justice room: cra.org/ccc/Environmental-Justice

- Infrastructure room: cra.org/ccc/Infrastructure

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Report out and discussion

- Three minutes per breakout room

- Grouped by impact area: first report(s), then discussion
  - Energy, Agriculture, Environmental Justice, Transportation, Infrastructure
  - Use zoom's chat feature for comments, questions, responses

- You can also put your comments and questions in the google doc from your breakout room

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Wrap-up

Grand Challenges require **CONVERGENCE**: the merging of ideas, approaches, and technologies from widely diverse fields of knowledge to stimulate innovation and discovery.

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THANK YOU!

Figure A-4. Virtual Workshop Slides

Appendix B. Participant Information

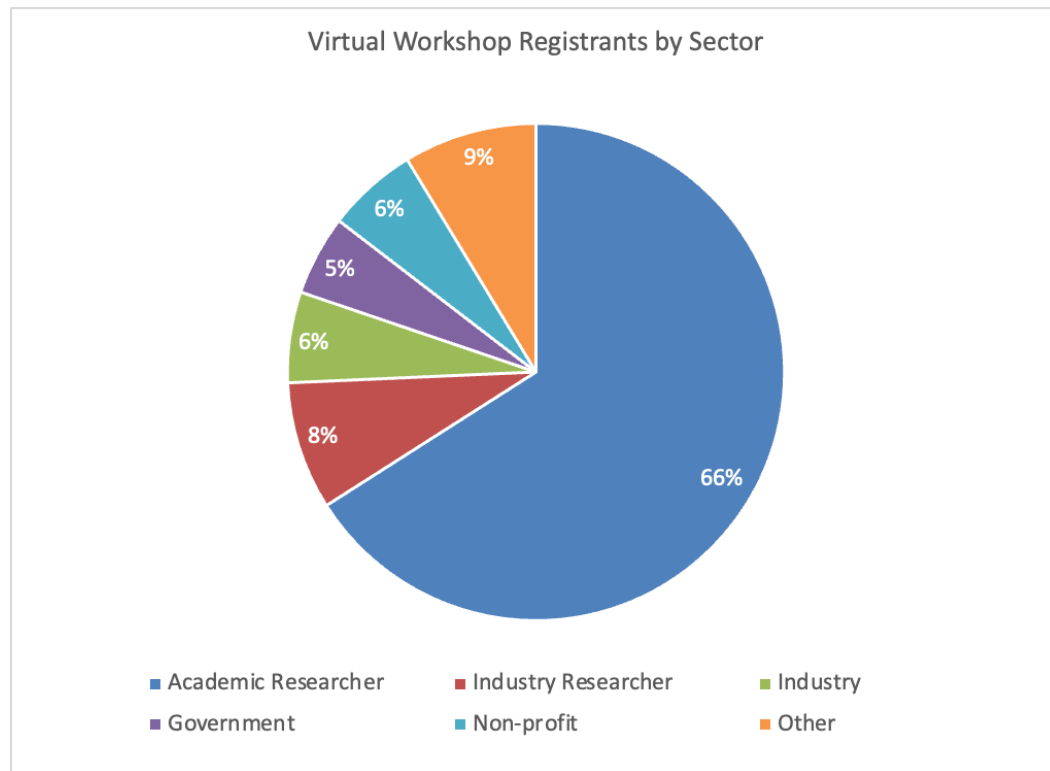**Figure B-1. Virtual Workshop Registrants by Sector**

Figure B-1. A graph of the virtual workshop registrants and the sector in which they work.

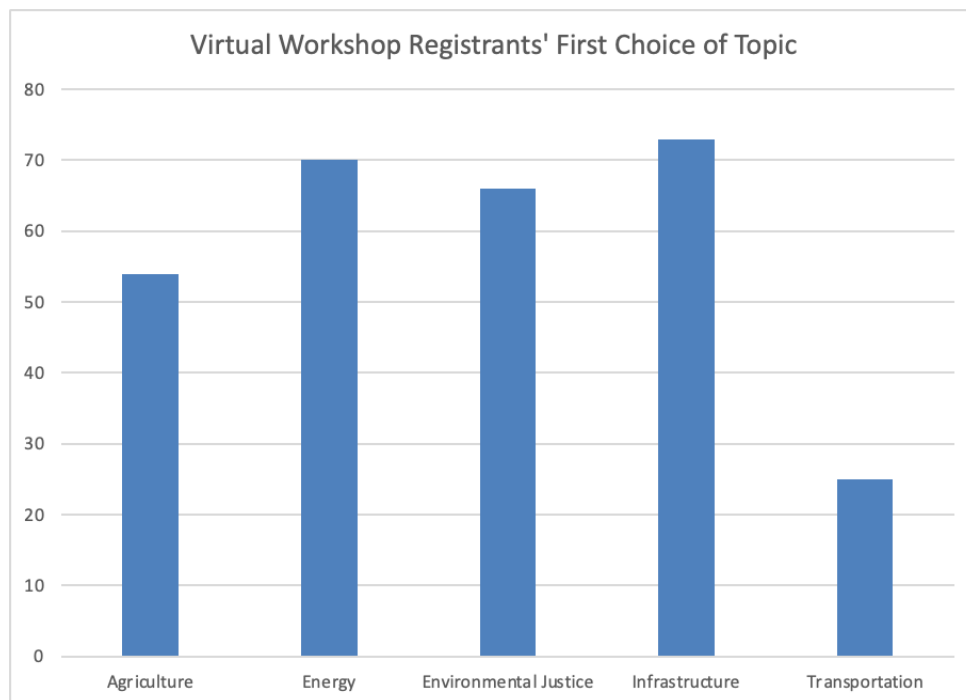**Figure B-2. Virtual Workshop Registrants' First Choice of Topic**

Figure B-2. A graph of the virtual workshop registrants' first choices of topics to discuss during the workshop.

Figure B-3. List of In-Person Workshop Attendees

First Name	Last Name	Institution
In-Person Workshop Attendees		
Vikram	**Adve**	University of Illinois at Urbana-Champaign
Sujata	Banerjee	VMware
David	Begay	University of New Mexico
Elizabeth	Bradley	University of Colorado - Boulder
Tracy	Camp	Computing Research Association
Aurali	Dade	National Science Foundation (ITE/TIP)
Michael	Dunaway	National Institute of Standards and Technology
Tayo	**Fabusuyi**	University of Michigan
Baskar	Ganapathysubramanian	Iowa State University
Catherine	Gill	Computing Community Consortium
Haley	Griffin	Computing Community Consortium
Peter	Harsha	Computing Research Association
Raya	**Horesh**	IBM Research
Daniel	**Jacobson**	Oak Ridge National Laboratory
David	Jensen	University of Massachusetts - Amherst
Chandra	Krintz	University of California - Santa Barbara
Vipin	Kumar	University of Minnesota
Christine	Qin	University of Colorado - Boulder
Claudia	Marin	Howard University
Charlie	Messina	University of Florida
Aditi	Misra	University of Colorado - Denver

Claire	Monteleoni	University of Colorado - Boulder
Melanie	Moses	University of New Mexico
Raj	Pandya	American Geophysical Union
Ann	Schwartz	Computing Community Consortium
Shashi	Shekhar	University of Minnesota
Jiayang	Sun	George Mason University

Figure B-3. In-Person Workshop Attendee list. Participants in bold gave short presentations at the beginning of our breakout discussions to help frame and focus our conversations.

Figure B-4. List of Virtual Workshop Attendees

Virtual Workshop Attendees		
First Name	**Last Name**	**Affiliation**
Mara	Alagic	Wichita State University
Ali	Alghamdi	King Saud University
Moussa	Ali Abdou	Wascal
Chid	Apte	IBM Research
Sujata	Banerjee	VMware
M. Mehdi	Bateni	International Union of Soil Sciences
Rachel	Bellamy	IBM
Nadya	Bliss	Arizona State University
Kit	Boone	The University of Memphis
Zourkalaini	Boubakar	
Salem	Boumediene	University of Illinois - Springfield
Salma	Boumediene	Naval Postgraduate School

Liz	Bradley	University of Colorado - Boulder
Matthew	Burke	Amazon Web Services
Randal	Burns	Johns Hopkins University
Matt	Campbell	Oregon State University
Zuri	Chavers	
Chin-Wei	Chen	University of Washington - Seattle
Aurali	Dade	National Science Foundation
Richard	Donovan	University of California - Irvine
Sean	Downey	Ohio State University
Ram	Durairajan	University of Oregon
Behzad	Esmaeili	Purdue University
Adriane	Fernandes Minori	Carnegie Mellon University
Shannon	Fitzsimmons-Doolan	Texas A&M University Corpus Christi
Trent	Ford	University of Illinois
Johannes	Friedrich	World Resources Institute
Annarita	Giani	GE Research
Catherine	Gill	Computing Research Association
Sharon	Gillett	Microsoft Research
Jared	**Goldman**	Charles River Analytics
TG	Goodael	
Roger	Grant	FbSI
Haley	Griffin	Computing Research Association
Greg	Hager	Johns Hopkins University

Youngjib	Ham	Texas A&M University
Peter	Harsha	Computing Research Association
Thomas	Hauser	NCAR
Robin	Hoard	Hoard & Support.CO
Seneca	**Holland**	Texas A&M University Corpus Christi
Kathleen	Holman	Bureau of Reclamation
Pengyu	Hong	Brandeis University
Raya	Horesh	IBM Research
Yu	Hou	Western New England University
Sudhir	Jain	
Vandana	Janeja	University of Maryland Baltimore County
Anne	Johansen	National Science Foundation
Nima	Kargah-Ostadi	Callentis Consulting Group
John	Kemeny	University of Arizona
Deborah	Khider	University of Southern California
Rabinder	Koul	Vega MX Inc
Chandra	Krintz	University of California - Santa Barbara
Yana	**Kucheva**	The City College of New York
Piotr	Kulczakowicz	Quantum Startup Foundry, University of Maryland
Michaela	Labriole	New York Hall of Science
Sophia	Laettner	Jacksonville Global Shapers
Justin	Lancaster	Hydrojoule LLC
Yongcheol	Lee	Louisiana State University

Guann Pyng	Li	University of California Irvine - Calit2
Gino	Lim	University of Houston
Asiyah	Lin	National Institute of Health
Dan	Lopresti	Lehigh University and CCC
Feng	luo	Clemson University
Christine	Lv	University of Colorado - Boulder
W John	MacMullen	University of Illinois
Candace	Major	National Science Foundation
Matthew	McGoffin	University of California - Berkeley
Amy	McGovern	University of Oklahoma
Yohan	Min	Dartmouth College
Aditi	Misra	University of Colorado - Denver
Claire	Monteleoni	University of Colorado - Boulder
Melanie	Moses	University of New Mexico
Ashley	Mueller	USDA NIFA
Philip	Murphy	InfoHarvest Inc.
Gwen	Nero	Columbia University
Karen	Olcott	T-Mobile
Andrew	Padilla	Datacequia LLC
Juan	Padilla	Social Solutions, LLC
Indrani	Pal	Columbia University / CUNY
Raj	Pandya	American Geophysical Union
Avi	**Pfeffer**	Charles River Analytics

Kristian	Poe	University of California - San Diego
Yi	Qiang	University of South Florida
Lauren	Quigley	IBM Research
Yuhan (Douglas)	Rao	North Carolina State University
Jon	**Rask**	NASA Ames Research Center
Glen	Romine	NCAR
Rayan	Sadeldin	Schmidt Futures
Abolfazl	Safikhani	George Mason University
Sumeet	Sandhu	Climate Data Hub
Manikandan	Sathiyanarayan	National Taiwan University
Johannes	Schmude	IBM
Ann	Schwartz	Computing Research Association
Noelle	Selin	Massachusetts Institute of Technology
Ram	Shetty	Opex Systems LLC
Farahnaz	Soleimani	Oregon State University
Jing	Song	Genesis Codes Inc.
Jiayang	Sun	George Mason University
Tara	Tasuji	Technology and Information Policy Institute at the University of Texas at Austin
Hailay Zeray	Tedla	Addis Ababa University
Mukul	Tewari	IBM
Theo	Theoharis	Agoge Ventures
Lloyd	Treinish	IBM Thomas J. Watson Research Center

Ardhendu	Tripathy	Missouri University of Science & Technology
Charles	Wang	University of Florida
Jun	Wang	University of Iowa
Weichao	Wang	University of North Carolina - Charlotte
Wenwen	Wang	University of Georgia
David	Watkins	Michigan Technological University
Quarshie	Wordu	Kwame Nkrumah University of Science and Technology
Kay	Worthington	Australian National Research Lab
Heather	Wright	Computing Research Association
Helen	Wright	Computing Research Association
Chen	Xia	Penn State University
Yang	Xiao	University of Kentucky
Jinding	Xing	Carnegie Mellon University
K.	Xiong	University of South Florida
Jie	Xu	George Mason University
Shouhuai	Xu	University of Colorado - Colorado Springs
Ellie	**Young**	Common Action
Kai	Zhang	University at Albany
Peter	Zhang	Carnegie Mellon University
Weihang	Zhu	University of Houston
Woody	Zhu	Carnegie Mellon University
Zhigang	Zhu	The CUNY City College

Figure B-4. Virtual Workshop Attendee list. Participants in bold gave short presentations after our breakout discussions to summarize the conversations held in each breakout session.