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Cover

Federal Agency and Organization Element to Which Report is Submitted:	**4900**
Federal Grant or Other Identifying Number Assigned by Agency:	**1901712**
Project Title:	**Unidata: Next-generation Data Services and Workflows to Advance Geoscience Research and Education**
PD/PI Name:	**Mohan K Ramamurthy, Principal Investigator**
Recipient Organization:	**University Corporation For Atmospheric Res**
Project/Grant Period:	**05/01/2019 - 04/30/2024**
Reporting Period:	**05/01/2020 - 04/30/2021**
Submitting Official (if other than PD\PI):	**Mohan K Ramamurthy Principal Investigator**
Submission Date:	**03/27/2021**
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	**Mohan K Ramamurthy**

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Accomplishments

* What are the major goals of the project?

This report details activities that took place under the five-year core-funding award "Unidata: Next-generation Data Services and Workflows to Advance Geoscience Research and Education" (NSF 1901712). The proposal for that funding award grouped the Unidata program's activities into the following focus areas identified in the Unidata Strategic Plan:

Managing Geoscience Data

Providing Useful Tools

Supporting People

Note: While Unidata has identified a number of different initiatives that fall under these broad categories of service, the activities and results described below share a continuing focus on adapting Unidata technologies to take advantage of new capabilities emerging from the cloud computing paradigm.

The following sections detail the program's activities and results during the period April 2020 – March 2021.

* What was accomplished under these goals and objectives (you must provide information for at least one of the 4 categories below)?

Major Activities:

This section summarizes Unidata's main activities during the second year of the five-year grant. Additional information on the outcome of these activities can be found under "Significant Results," below.

Data Distribution

Helping researchers and educators acquire and use real-time meteorological data was one of the Unidata program's founding goals, and continues to be one of the core activities of the program. By participating in Unidata's Internet Data Distribution (IDD) system, educators and researchers can subscribe to one or more of the 35 streams of current data that interest them. The IDD system comprises nearly 600 machines at roughly 220 sites running Unidata's Local Data Manager (LDM) software to receive (and in many cases retransmit to "downstream" institutions) real-time weather data.

(Note that a number of organizations use the LDM to move substantial amounts of data but do not report statistics to Unidata. Among these organizations are NOAA, NASA, USGS, USACE, the national weather services of Spain and South Korea, private companies, universities, and others.)

Unidata also facilitates data distribution by developing and supporting remote data access server technologies. While we do not require licensing or registration of the THREDDS Data Server (TDS), we have received information from tens of thousands of unique IP addresses running the server. Of these, 194 are publicly accessible and providing data to other community members.

Finally, many community members connect directly to remote access servers managed directly by the Unidata Program Center. Unidata's TDS, McIDAS ADDE, and AWIPS EDEX servers together provide terabytes of data to remote users every day.

Cloud Technology Experiments

Continuing to find ways to leverage the strengths of the cloud computing environment to enhance universities' access to geoscience data and tools is one of Unidata's highest priorities during the period of this award. During the second year of the award, UPC staff have made significant progress toward these goals, most notably through the expansion of the Unidata Science Gateway on NSF's Jetstream Cloud. The Gateway collects Unidata-related technologies and demonstrates a workflow involving combining cloud-based resources to create end-to-end scientific workflows. One of the most exciting tools in the Unidata Science Gateway is a JupyterHub server, which allows students and educators to access Unidata-provided Jupyter notebooks illustrating atmospheric science concepts. During the 2020-2021 academic year, when many universities have transitioned to remote-learning during the COVID-19 outbreak, Unidata has offered to set up JupyterHub systems to support atmospheric and related science courses. Courses serving nearly 600 students at 15 universities have now taken advantage of this Unidata resource.

As part of the Science Gateway, Unidata also operates cloud-based data distribution mechanisms (notably AWIPS EDEX servers and THREDDS Data Servers). Additionally, Unidata continues to work with cloud service providers to enable access to historical and real-time data, and create demonstrations of cloud-based application services (most notably for remote access to the IDV visualization software).

Software Development

Developing free, open-source software to help researchers and educators manage their access to and use of geoscience

data is one of Unidata's primary activities. During the second year of this award, Unidata's development staff has mixed ongoing work toward well-defined, long-term development goals for existing technologies with newer technologies and initiatives aimed at addressing our community's evolving technology needs. The MetPy team released a "stable API" version 1.0 of the package this year, with significant community development support. At the same time, use of MetPy as an alternative to the GEMPAK meteorological analysis package continues to grow.

Community Building

Unidata sponsors or participates in a wide variety of events and activities that bring community members together to share ideas and techniques, aids in participation, or enlarges the existing community. In addition, in the second year of this award, the Program has enhanced its focus on outreach and provision of services to underserved communities within the atmospheric and related sciences.

In order to build better relationships with underserved communities, Unidata staff have begun participating in the Society for Advancement of Chicanos/Hispanics & Native Americans in Science (SACNAS) National Diversity in STEM Conference and the American Indian Science and Engineering Society (AISES) National Conference. Participation in the AISES 2020 conference has already borne fruit in the form of a collaborative effort between the Southwestern Indian Polytechnic Institute, Navajo Technical University, Tohono O'odham Community College, and Unidata. This group is working together to apply for an NSF CISE Community Research Infrastructure grant (with Unidata as an unfunded collaborator). In addition, as a result of this collaboration, Unidata will be welcoming a representative from Tohono O'odham Community College in Arizona to the Unidata Users Committee this spring.

This year, some of Unidata's more traditional venues for community interaction and outreach have been affected by COVID-19 travel restrictions. Staff members generally engage with community members at the American Meteorological Society (AMS) and American Geophysical Union (AGU) annual meetings, spending time talking about Program activities at UCAR's booth in both conferences' exhibition halls. The number of conversations we were able to have at these conferences was certainly reduced by their remote nature; we are looking forward to meeting in person with community members at future conferences.

We maintain an online presence via the News@Unidata weblog and a variety of social media channels. All of these forms of interaction allow us to hear directly from community members about their data access and cyberinfrastructure issues and concerns.

We attribute the ongoing success of the Unidata program, in large part, to our community-based governance structure. Unidata calls on members of its core academic community to serve on its two governing committees: the Unidata Users Committee and the Unidata Strategic Advisory Committee. Users Committee members are charged with serving as an interface between the Unidata Program Center and individuals and organizations who use Unidata data streams and services, reporting on challenges they face and shedding light on the scientific and technical environment in which they work. Members of the Strategic Advisory Committee are asked to weigh in on the larger, longer-term trends and issues they see evolving in the geosciences, guiding the program to areas where community leadership is needed and valuable. These stable avenues of communication between the UPC and the community it serves have been instrumental in helping the program meet its members evolving cyberinfrastructure needs.

Additionally, UPC staff members participate actively in scientific societies and other organizations that serve our community members. Unidata participates actively in the American Meteorological Society, the American Geophysical Union, the European Geosciences Union, the ESIP Federation, the Open Geospatial Consortium, Research Data Alliance, and the NSF EarthCube initiative, among others. Staff activities in association with these groups range from highly technical work with scientific data formats and software development issues, to member assistance and support, to capacity-building for other organizations. Of special interest has been the UPC technical staff's active involvement in the Eleventh Symposium on Advances in Modeling and Analysis Using Python at the 101st AMS Annual Meeting in New Orleans, LA in January 2021.

Specific Objectives:	
Significant Results:	This section lists some of the most significant results attained as a result of the work described in the "Major Activities" section above.

Data Distribution

The volume of observational data and model output delivered to Unidata community members and institutions in near real-time continues to grow. As of March 2021, Unidata's Internet Data Distribution (IDD) clusters deliver roughly 57 Terabytes per day to downstream systems, up from roughly 54 Terabytes per day in 2020. The volume of data served via remote access methods (most notably ADDE) has increased by roughly 30 percent in the past year, now averaging approximately 2.5 Terabytes per day

Unidata's collaboration with the University of Wisconsin's Space Science and Engineering Center (SSEC) continues to be productive and beneficial for the atmospheric science community. Unidata receives data from SSEC's GOES-16/17 fanout servers, and SSEC feeds from Unidata's GOES Rebroadcast (GRB) ingest system. This sharing of the feed streams has allowed SSEC and Unidata to minimize the effects of solar and terrestrial interference on our satellite data reception.

Cloud Technologies

Cloud-computing related activities during the first year of this award have focused on making Unidata Science Gateway resources available to university courses and workshops as a remote computing environment. The Unidata JupyterHub server has proven to be the most popular feature of the Science Gateway; it has been deployed for workshops and courses including:

> Ongoing semester-long data science classes at Southern Arkansas University

> Summer 2020 workshops at the University of California, Santa Barbara, the University of Oklahoma, and City University of New York

> A Python workshop at the Annual Student Conference for the American Meteorological Society 2021 annual meeting, supporting 82 student participants

Unidata Science Gateway resources have been used in UCAR's Significant Opportunities in Atmospheric Research and Science (SOARS) for several years now. In the summer of 2020, we were able to help SOARS protégé Angelie Nieves-Jiménez gain access to data and WRF model output on UCAR servers to which she would not have had access as a "remote" intern. (See UCAR Mentorship and Remote Computing Resources Boost Remote Research for SOARS Student https://www.unidata.ucar.edu/blogs/news/entry/ucar-mentorship-and-remote-computing for details)

In addition, as a response to the COVID-19 outbreak and the resulting move by many universities to conduct all classes online, Unidata began offering to provide Science Gateway JupyterHub resources to schools beginning in the spring semester of 2020. So far for the 2020-2021 academic year, nine different instructors at seven U.S. universities have taken advantage of Unidata Science Gateway resources for fall 2020 and spring 2021 classes.

Technical staff have continued to employ Docker container technology to streamline building, deploying, and running Unidata technology offerings in cloud-based environments. A containerized version of the Common AWIPS Visualization Environment (CAVE) client is now available for testing and debugging.

Of special interest has been the operation of a community-accessible cloud-based AWIPS Environmental Data EXchange (EDEX) server. Unidata's distribution of the CAVE client points to this EDEX server by default, allowing university users to get up and running quickly without the need to configure a local data server. In the second year of this award, Unidata's cloud-based EDEX server provided roughly 28 Gigabytes per day to remote access users. A separate cloud-based EDEX server is used for development and testing, and is available as a failover replacement for the primary hosted EDEX in the event o f technical difficulties.

Software Development

MetPy:

The MetPy project, which is a collection of Python tools for reading, visualizing, and performing calculations with weather data, made its version 1.0 release at the beginning of 2021. MetPy version 1.0 is an important milestone because it marks a commitment by the developers to keep the software's Application Programming Interface (API) stable over a longer time period — ideally until development advances to the level of a version 2 release.

As of the fall of 2020, MetPy's project and documentation pages were averaging almost 24k page views per month, a 45% increase over the previous year. Over the past year at least 22 new scholarly publications have cited MetPy, a large increase over the total count of 19 publications prior to 2020.

AWIPS and GEMPAK:

In May 2020, an experienced lead developer joined the Program Center's AWIPS development team. AWIPS

development efforts over the past year have focused on user support and on performance enhancements to Unidata's public EDEX server. A number of new radar products including Spectrum Width, Hail Index, and Tornado Vortex Signature have also been added to the data served by Unidata's EDEX server. In addition, the Graphical Forecast Editor (GFE), a component of the AWIPS Interactive Forecast Preparation System (IFPS), was added to Unidata's distribution of the CAVE client in order to support a COMET forecaster workshop in the summer of 2020. We believe the GFE functionality will be of interest to the broader university community as well.

In early 2021, in consultation with the Unidata Users Committee, the Program Center initiated a process for transitioning Unidata's GEMPAK distribution into a community supported and maintained open source project. Program Center staff are working with volunteers from the GEMPAK-using community to provide access to Unidata's GEMPAK repository on Github, with the goal of having the community group assume responsibility for future updates to the code base. In the near term, Unidata will continue to support the GEMPAK community by hosting the repository, providing online documentation, and continuing to operate the gembud e-mail list. Future arrangements will be determined in coordination with the community group.

IDV:

The most recent version of Unidata's Integrated Data Viewer, version 5.7, was released in the spring of 2020. Work on version 5.7 update 1 is under way.

LDM:

Local Data Manager versions 6.13.12 and 6.13.13 were released in the past year. Work on a "multicast" version of the LDM employing virtual circuit technology continues activities begun in collaboration with the University of Virginia.

NetCDF:

The netCDF-C library version 4.7.4 was released during the second year of the award. This release added compatibility features with HDF5 and furthered work aimed at making the netCDF libraries compatible with widely used key-value pair cloud storage systems (such as Amazon's S3, for example). Work continues on the implementation of a netCDF-ZARR (NCZarr) data model to support this functionality.

In addition, version 4.5.3 of the netCDF FORTRAN library was released, building on features in netCDF-C version 4.7.4.

Siphon:

The Siphon project is a collection of Python utilities for accessing data from Unidata data technologies such as the THREDDS Data Server. Siphon development has slowed as Program Center staff have been allocated to other projects, but the package continues to gain functionality slowly as when requirements are revealed in the course of MetPy development.

Rosetta:

Rosetta development has slowed as Program Center staff have been allocated to other projects.

TDS:

The THREDDS Data Server (TDS) version 5.0 is currently in a beta-testing phase, but is currently deployed at 55 non-Unidata sites. Progress toward an official TDS 5.0 release was slowed by the departure of key development staff, but a new THREDDS developer has joined the UPC staff in the second year of the award.

The NetCDF-Java library that underlies the TDS has seen releases 5.3.2 through 5.4.1 in the second year of the award.

Key outcomes or Other achievements:

This section briefly notes some Unidata activities and achievements not listed in the "Significant Results" section, above.

Outreach to Underserved Communities

In order to build better relationships with underserved communities, in the second year of the award Unidata staff have continued participation in the Society for Advancement of Chicanos/Hispanics & Native Americans in Science (SACNAS) National Diversity in STEM Conference and the American Indian Science and Engineering Society (AISES) National Conference, as well as engaging with UCAR's Rising Voices program for Climate Resilience through Indigenous and Earth Sciences. Participation in the AISES 2020 conference has already borne fruit in the form of a collaborative effort between the Southwestern Indian Polytechnic Institute, Navajo Technical University, Tohono O'odham Community College, and Unidata. This group is working together to apply for an NSF CISE Community Research Infrastructure grant

(with Unidata as an unfunded collaborator). In addition, as a result of this collaboration, Unidata will be welcoming a representative from Tohono O'odham Community College in Arizona to the Unidata Users Committee this spring.

Initial structural changes have been made to some Unidata programs, including modifications to how equipment awards, internships, workshops, and committee placements are announced and selected.

Unidata Users Workshops

Unidata Users Workshops gather participants from across the community to discuss topics such as useful tools to access data and strategies for teaching computational concepts. The workshops bring together geoscience educators, pedagogical experts, and Unidata staff to discuss and share best practices for helping students engage in data-enabled science.

Traditionally, workshops are held every three years; planning for a 2021 event would, under normal circumstances, be in full swing at the time of this report. Due to COVD-19 related uncertainty about prospects for a workshop in the summer of 2021, the Unidata Users Committee made the decision to delay the next Users Workshop until the summer of 2022. Interested members of the Users Committee have formed a planning subcommittee for the 2022 workshop, and plans are beginning to take shape.

Note that a follow-on to the 2018 Users Workshop, scheduled to be held at the University of Alaska, Fairbanks in early 2020, was postponed due COVID-19 travel restrictions as well. We hope to be able to reschedule that workshop.

DeSouza Award

Each year, the Unidata Users Committee presents the Russell L. DeSouza award to a community member whose energy, expertise, and active involvement enable the Unidata Program to better serve geoscience. Honorees personify Unidata's ideal of a community that shares data, software, and ideas through computing and networking technologies. The 2020 award was given to Mike Zuranski from the College of DuPage, in Glen Ellyn, IL. Mr Zuranski has been an integral part of the team maintaining the College of DuPage's widely used Nexlab weather site since 2011.

EarthCube Projects

UPC staff are involved in the following ongoing EarthCube projects:

> Pangeo: An Open Source Big Data Climate Science Platform (collaboration with NCAR/CISL, and Columbia University-Lamont-Doherty Earth Observatory)

> Project Pythia: A Community Learning Resource for Geoscientists (collaboration with NCAR/CISL, NCAR/CGD, and the University at Albany, SUNY)

Scientific Conferences

Participation by Program Center staff at scientific conferences in the second year of the award was somewhat reduced by COVID-19 travel restrictions. Staff members were able to participate virtually in a range of conferences, including:

> American Meteorological Society summer and annual meetings

> American Geophysical Union annual meeting

> European Geosciences Union annual meeting

> ESIP Federation summer and winter meetings

> EarthCube Annual meeting

> Research Data Alliance Plenary meetings

> National Data Service meetings

> Open Geospatial Consortium Technical Committee meetings

Software Training

UPC staff conducts workshops focused on building skills with Unidata software packages in the context of the atmospheric sciences. During the second year of this award, COVID-19 travel restrictions severely limited our ability to hold interactive software training workshops. Workshops we were able to conduct virtually included:

> A week-long asynchronous Python Workshop, held as part of the AMS 2021 Annual Meeting Student Conference.

The workshop attracted 82 student attendees.

An AMS Short Course titled "Python for Climate and Meteorology." UCP developers led one of the four sessions associated with this course, and assisted with the other three. A total of 48 participants were enrolled, roughly half of whom were associated with U.S. educational institutions.

A total of six virtual IDV training sessions for Millersville University and the Florida Institute of Technology.

UPC staff have also begun producing a series of weekly postings on Python topics, centered on the use of MetPy. The "MetPy Mondays" series, which has continued uninterrupted since 2018, brings a short discussion of a MetPy related topic to the Unidata developer's blog every Monday, most often with an accompanying short video tutorial. The series now has more than 170 installments on a wide range of MetPy related topics, and has been viewed more than 50,000 times in the past year. A similar series of AWIPS-focused postings are currently in preparation.

As a result of the addition of an educational designer to the UPC staff in early 2021, we are actively working to increase our capability to conduct productive remote training events.

Committee Membership Changes

Each fall, a portion of the membership of each of Unidata's advisory committees "turns over," with members who have served a three-year term rotating off and new members joining the mix. In 2020, the committees changed as follows:

Shawn Riley from the University of Oklahoma finished his term on the Users Committee.

Alex Haberlie from Louisiana State University joined the Users Committee. Tim Foster from Tohono O'odham Community College joined the Users Committee in the Spring of 2021.

Gretchen Mulledore from the University of North Dakota joined the Strategic Advisory Committee, but resigned after leaving the university to take a position as Director of MMM at NCAR.

Charles Graves from Saint Louis University and James Potemra from the University of Hawaii joined the Strategic Advisory Committee.

Program Center Staffing

As a result of new development initiatives, new non-core funding, and normal staff turnover, the Unidata Program Center has added six new members to our technical staff over the course of the second year of this award. New technical staff members are focused on the AWIPS, Python, THREDDS, and IDD projects, with additional new efforts in online training and machine learning.

The Program Center continues to work to foster diversity in our technical staff. As of spring 2021, our technical team includes five women, four of whom have joined the program since August 2019.

* What opportunities for training and professional development has the project provided?

In a year when Unidata's traditional training venues were significantly curtailed by travel restrictions, we were able to conduct our summer internship program as an entirely virtual experience. The program invited three students to spend the summer working "at" the Unidata Program Center in 2020. Russell Manser came to Unidata this summer from Texas Tech University with the goal of integrating support for Dask Arrays into Unidata's MetPy package; to make progress toward this goal, Russell ended up contributing code to some of the other Open Source projects that MetPy relies upon. He also spent time extending MetPy's code-testing suite, making improvements that will be especially beneficial as the effort to support Dask Arrays proceeds. Caitlyn McAllister from Embry-Riddle Aeronautical University made excellent use of her internship time by building her Python coding skills and getting familiar with the tools and processes used by developers in the Open Source community. Having honed her skills a bit, she began to lay the groundwork for adding a Wet Bulb Globe Temperature (WBGT) calculation to add to Unidata's MetPy package. Lauren Prox from George Mason University focused her time as an intern on improving user documentation for several of Unidata's Open Source projects. After building skills with the Git and GitHub tools used to manage most of Unidata's software projects, Lauren set about updating topics in the netCDF, MetPy, and Siphon user assistance materials.

The 2020 interns — along with interns from previous years — were instrumental in creating the week-long asynchronous Python workshop that drew 82 students as part of the 2021 American Meteorological Society Student Conference.

* Have the results been disseminated to communities of interest? If so, please provide details.

Unidata communicates with community members in a variety of ways, both electronic and otherwise. The most important channels of communication for the Program during the proposal period have been:

Participation in scientific organizations, conferences, and meetings, including the American Meteorological Society, the American Geophysical Union, European Geosciences Union, the Open Geospatial Consortium, and the Earth Science Information Partners (ESIP) Federation.

Meetings of Unidata's two governing committees. The governing committees are made up of representatives of Unidata's academic community, and serve a three-year term to enhance two-way communication between the Program and the geoscience educators who form our core community. This year's committee meetings have been virtual; as a result, in an effort to combat "Zoom Fatigue," we have shifted to a meeting schedule that consists of shorter meetings (2-4 hours maximum) held over the course of several days or weeks.

Unidata staff members conducted virtual training sessions and workshops over the course of the year, with varying levels of formality.

In addition to in-person forums like these, Unidata staff publish their results and discuss ongoing research in academic journals, and through Unidata's own web site and News@Unidata blog. Both the UPC and individual staff members also communicate with the community via social media channels including Facebook and Twitter.

* What do you plan to do during the next reporting period to accomplish the goals?

During the third year of this award, the Unidata program will continue to undertake the activities described in the "Plan of Action" section of the grant proposal. For reference, this document is available on the Unidata web site:

http://www.unidata.ucar.edu/publications/Unidata_2024.pdf

An Operating Plan for the next reporting period has been submitted separately, along with a budget justification.

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Products

Books

Book Chapters

Inventions

Journals or Juried Conference Papers

View all journal publications currently available in the NSF Public Access Repository ☐ for this award.

The results in the NSF Public Access Repository will include a comprehensive listing of all journal publications recorded to date that are associated with this award.

Arms, Sean and Chastang, Julien and Grover, Maxwell and Thielen, Jon and Wilson, Matthew and Dirks, Douglas. (2020). Introducing Students to Scientific Python for Atmospheric Science. *Bulletin of the American Meteorological Society*. 101 (9) E1492 to E1496. Status = Deposited in NSF-PAR doi:https://doi.org/10.1175/BAMS-D-20-0069.1 ☐ ; Federal Government's License = Acknowledged. (Completed by Ramamurthy, null on 03/22/2021) Full text ☐ Citation details ☐

Snowden, Derrick and Tsontos, Vardis M. and Handegard, Nils Olav and Zarate, Marcos and O' Brien, Kevin and Casey, Kenneth S. and Smith, Neville and Sagen, Helge and Bailey, Kathleen and Lewis, Mirtha N. and Arms, Sean C.. (2019). Data Interoperability Between Elements of the Global Ocean Observing System. *Frontiers in Marine Science*. 6 . Status = Deposited in NSF-PAR   doi:10.3389/fmars.2019.00442 ▯ ; Federal Government's License = Acknowledged. (Completed by Ramamurthy, Mohan on 03/31/2020) Full text ▯   Citation details ▯

Licenses

Other Conference Presentations / Papers

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Trujillo, Joseph Enrique and Kyong Lee, S. and Berry, K. and Obermeier, H. and Klockow-McClain, K. and Campbell, P.A. and Meyer, T. C. and Williams, S. S. and Ernst, S. and Landeros, E. (2021). *Applying Social Science Concepts to Enhance R2O: Analysis of 2018 and 2019 NOAA Hazardous Weather Testbed Probabilistic Hazard Information Experiments*. Proceedings,101st AMS Annual Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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Bates, Alyssa V. and Stumpf, G. and Ling, C. and Klockow-McClain, K. and LaDue, J. and Hyland, P. and James, J. and Manross, K. L. and Guo, Y. and Golden, C. and Meyer, T. C. and Monroe, J. and Gerard, A. and Kingfield, D. (2021). *Envisioning NWS Interoffice Collaboration during FACETs-Era Warning Operations within the NOAA Hazardous Weather Testbed (HWT)*. Proceedings, 101st AMS Annual Meeting. New Orleans, LA. Status

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Camron, Drew and May, R. and Goebbert, K. H. (2021). *How Unidata Taught Python in 2020*. Proceedings, 101st AMS Annual Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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Calhoun, Kristin M. and Berry, K. and Campbell, P. A. and Gerard, A. and Hyland, P. and Meyer, T. C. and Ortega, K. L. and Reinhart, A. E. and Sandmael, T. and Satrio, C. and Smith, T. M. and Steeves, R. B. and Stumpf, G. and Williams, S. S. (2021). *Probabilistic Hazard Information (PHI): Integrating Multiple Machine Learning Algorithms for Forecaster and End User Decision-Making during Severe and Hazardous Weather*. Proceedings, 101st AMS Annual Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Clyne, John and Long, M. and May, R. and Paul, K. and Rose, B. and Tyle, K. (2021). *Project Pythia: A Community Learning Resource for Geoscientists*. Proceedings, 101st AMS Annual Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Arms, S. and Chastang, J (2021). *Python Workshop*. Proceedings, 101st AMS Annual Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hyland, Patrick and Klockkow-McClain, K. and Ling, C. and James, J. and Stumpf, G. and Bates, A. and LaDue, J. and Manross, K. L. and Guo, Y. and Golden, C. and Meyer, T. C. and Monroe, J. and Kingfield, D. and Gerard, A. (2021). *Stop, Collaborate, and Listen: A Survey and HWT Experimental Analysis of Inter-/Intraoffice National Weather Service (NWS) Collaboration and Impacts for the FACETs Paradigm*. Proceedings, 101st AMS Annual Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Prox, Lauren (2021). *The Intersection of Software Development: A Review of my Software Development Internship*. Proceedings, 101st AMS Annual Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Meyer, Tiffany C. and Carter, S. (2021). *Unidata AWIPS Update*. Proceedings, 101st AMS Annual Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Manross, Kevin L. and Guo, Y. and Stumpf, G. and Meyer, T. C. and Monroe, J. and Bates, A. V. and Nietfeld, D. and Kingfield, D. and Berry K. (2021). *Updates on Hazard Service - Probabilistic Hazard Information (HS-PHI)*. Proceedings, 101st AMS Annual Meeting. New Orleans, LA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Other Products

Other Publications

Patent Applications

Technologies or Techniques

Thesis/Dissertations

Websites or Other Internet Sites

Unidata Website
https://www.unidata.ucar.edu/

The Unidata website serves as a primary mechanism for Unidata Program Center staff to provide information about the program to community members and the general public. The site provides information about the program overall provides descriptions of individual projects that are currently underway, along with summaries of completed projects describes data available via the Internet Data Distribution system, and provides information on how to access that data collects historical documents including funding proposals, annual and final project reports, and archives of governing committee records serves as a gateway to Unidata's technical support system, and provides access to archived support information allows community members to download software developed by the program links to current program information and community news via the News@Unidata weblog.

Unidata YouTube Channel
https://www.youtube.com/user/unidatanews

The Unidata YouTube channel serves as a conduit for video tutorials for Unidata software packages. While many of the video tutorials are created by Unidata Program Center staff, we also publish tutorials created by community members. The YouTube channel also makes available video recordings of talks and presentations that are part of the Unidata Seminar Series.

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Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Ramamurthy, Mohan	PD/PI	12
Davis, Ethan	Co-Investigator	12
Arms, Sean	Other Professional	12
Camron, Michael	Other Professional	12
Carter, Shaylina	Other Professional	12
Chastang, Julien	Other Professional	12
Corbin, Nicole	Other Professional	3
Dirks, Doug	Other Professional	12
Emmerson, Steve	Other Professional	12
Fisher, Ward	Other Professional	12
Heimbigner, Dennis	Other Professional	12
Ho, Yuan	Other Professional	12
ILES, Mustapha	Other Professional	5

Johnson, Hailey	Other Professional	8
May, Ryan	Other Professional	12
Meyer, Tiffany	Other Professional	12
Mitchell-Sur, Terry	Other Professional	12
Oxelson, Jennifer	Other Professional	12
Perna, Matthew	Other Professional	12
Purvis, Inken	Other Professional	12
Ruscetta, Sheri	Other Professional	12
Schmidt, Mike	Other Professional	12
Weber, Jeff	Other Professional	12
Yoksas, Tom	Other Professional	12
Young, Joshua	Other Professional	12

Full details of individuals who have worked on the project:

Mohan K Ramamurthy
Email: mohan@ucar.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 12

Contribution to the Project: Program Director - Administration and Management

Funding Support: NSF Grant via Indiana University - 8716UCAR

Change in active other support: Yes C&P_Ramamurthy_Annual Award Project Report_4-2021.pdf

International Collaboration: No
International Travel: No

Ethan Davis
Email: edavis@ucar.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer & Technical Manager - program development & project management

Funding Support: NSF Grant 1541031 EarthCube netCDF-CF 2.0, 140G0120F0217 DOI-GS/Geological - USGS-HyTEST

International Collaboration: Yes, Germany, Spain, United Kingdom
International Travel: No

Sean Arms
Email: sarms@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: IOOS Model Data - NA18NOS0120157 NSF Grant via Indiana University - 8617UCAR 140G0120F0217 DOI-GS/Geological - USGS-HyTEST

International Collaboration: No
International Travel: No

Michael Camron
Email: dcamron@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant 1740315 NSF Grant 2026899

International Collaboration: No
International Travel: No

Shaylina Carter
Email: scarter@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Julien Chastang
Email: chastang@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant via Indiana University - 8716UCAR

International Collaboration: No
International Travel: No

Nicole Corbin
Email: ncorbin@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 3

Contribution to the Project: Software Engineer - program development

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Doug Dirks
Email: ddirks@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Program Editor/Writer - community service outreach

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Steve Emmerson

Email: emmerson@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: 39154765 Univ VA - University of VA LDM7 Enhancement

International Collaboration: No
International Travel: No

Ward Fisher
Email: wfisher@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Enginner - program development

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Dennis Heimbigner
Email: dmh@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Yuan Ho
Email: yuanho@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: NSF Grant 1639648

International Collaboration: No
International Travel: No

Mustapha ILES
Email: mustapha@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 5

Contribution to the Project: Software Engineer - program development

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Hailey Johnson
Email: hajohns@ucar.edu
Most Senior Project Role: Other Professional

Nearest Person Month Worked: 8

Contribution to the Project: Software Engineer - program development

Funding Support: 140G0120F0217 DOI-GS/Geological - USGS-HyTEST

International Collaboration: No
International Travel: No

Ryan May
Email: rmay@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer & Technical Manager - program development & project management

Funding Support: NSF Grant 1740633 NSF Grant 1740315 NSF Grant 2026899

International Collaboration: No
International Travel: No

Tiffany Meyer
Email: tiffanym@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Terry Mitchell-Sur
Email: tmitchel@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Program Manager - program administration and management

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Jennifer Oxelson
Email: oxelson@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Matthew Perna
Email: mperna@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Systems Administration

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Inken Purvis
Email: ipurvis@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Administrative Support

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Sheri Ruscetta
Email: ruscetta@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Administrative Support

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Mike Schmidt
Email: mschmidt@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Systems Administration

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Jeff Weber
Email: jweber@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Project Manger - project management

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Tom Yoksas
Email: yoksas@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Software Engineer - program development

Funding Support: No additional funding

International Collaboration: No
International Travel: No

Joshua Young

Email: jwyoung@ucar.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12

Contribution to the Project: Community Services Manager - community outreach & management

Funding Support: No additional funding

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Leeman Geophysical LLC	Other Organizations (foreign or domestic)	Siloam Springs, AR
University of Wisconsin	Academic Institution	Madison, WI

Full details of organizations that have been involved as partners:

Leeman Geophysical LLC

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Siloam Springs, AR

Partner's Contribution to the Project:
Other: Production of MetPy Monday videos

More Detail on Partner and Contribution: John Leeman with Leeman Geophysical LLC was the originator of MetPy Mondays while he was at Unidata and has taught many of the Python workshops with us. He is continuing the MetPy Monday videos and keeping up their regular releases and growing success to continue growing our Python portfolio.

University of Wisconsin

Organization Type: Academic Institution
Organization Location: Madison, WI

Partner's Contribution to the Project:
Financial support
In-Kind Support
Facilities
Collaborative Research

More Detail on Partner and Contribution:

Were other collaborators or contacts involved? If so, please provide details.

Mariella Liberti, CNR-IIA – Florence Division

Institute of Atmospheric Pollution Research - National Research Council of Italy, Sesto Fiorentino (FI) - Italy

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Impacts

What is the impact on the development of the principal discipline(s) of the project?

A survey of papers published in 2020 in journals of the American Meteorological Society shows 73 articles containing citations of Unidata software and data services. (Of these, 50 refer to Unidata software packages but make no mention of the Unidata program itself.) In the same period, an additional 176 papers published in journals of the American Geophysical Union cited Unidata software and data services.

What is the impact on other disciplines?

A review of citations reported by the Google Scholar search engine in 2020 indicated that Unidata software and data services were cited 3595 times in the full range of scholarly literature encompassed by the search engine. Of these, 3112 refer to Unidata software packages but make no mention of the Unidata program itself. This correlates with anecdotal evidence of widespread use of Unidata products (especially netCDF) beyond the communities traditionally served by Unidata.

What is the impact on the development of human resources?

Unidata's efforts to provide software training contribute directly to levels of computational and data science literacy among geoscience students and educators.

What was the impact on teaching and educational experiences?

bulk of the program's activities can be thought of as helping improve teaching and educational experiences in the geosciences. Of special note are the following metrics, collected in late 2020:

> Number of U.S. universities receiving software: 258

> Number of universities outside the U.S.: 677

What is the impact on physical resources that form infrastructure?

Community Equipment Awards

Each year, the UPC sets aside $100,000 to fund the Unidata Community Equipment Awards program. The program provides funds to encourage new geoscience departments to join the Unidata community and to allow existing members to continue and enhance their participation.

Projects funded in 2020 include:

University/PI	Project Title
College of Charleston Gabriel J. Williams, Jr.	Acquisition of AWIPS II CAVE Client Computing Infrastructure at the College of Charleston
Mississippi State University Kimberly M. Wood	Advancing Weather Visualization at Mississippi State University through a Dedicated AWIPS Server
Texas A&M University Christopher J. Nowotarski	Building a Real-Time Running Archive EDEX Server for Meteorology Instruction
University of Buenos Aires	

Moira Doyle   Upgrading LDM server at DAOC University of Buenos Aires

University of Hawaii at Manoa

Jennifer D. Small Griswold   Enhancing Education in Atmospheric Sciences using AWIPS II and CAVE at the University of Hawaii at Manoa

A complete list of projects funded under the Community Equipment Awards program and the many creative applications of Unidata software and systems by the recipient universities to advance education and research is available online at http://www.unidata.ucar.edu/community/equipaward/.

What is the impact on institutional resources that form infrastructure?

Unidata community members look to the UPC not only for technological solutions, but for guidance on emerging trends in cyberinfrastructure and to represent their interests in collaborations with standards bodies and organizations that work across scientific disciplines. As standards-based solutions have become increasingly important to the conduct of international science, Unidata has assumed a central role in identifying and articulating standards, conventions, and data formats. Unidata's standards efforts have enabled ongoing collaboration with dozens of international organizations – especially those represented in the OGC MetOceans, Earth System Science, and Hydrology Domain Working Groups. Unidata undertakes a variety of activities with the goal of building a vibrant community in the geosciences and beyond. The following are a sampling of these activities:

Unidata Science Gateway

The Unidata Science Gateway on NSF's Jetstream Cloud collects Unidata-related technologies and demonstrates a workflow involving combining cloud-based resources to create end-to-end scientific workflows. One of the most exciting tools in the Unidata Science Gateway is a JupyterHub server, which allows students and educators to access Unidata-provided Jupyter notebooks illustrating atmospheric science concepts. To assist universities that have transitioned to remote-learning during the COVID-19 pandemic, Unidata has offered to set up JupyterHub systems to support atmospheric and related science courses. Over the course of the second year of this award, nine universities have taken advantage of custom JupyterHubs for this purpose. In addition, a week-long workshop associated with the AMS 2021 Student Conference provided resources for 82 students.

Scientific Society Meetings

Unidata staff are active in convening sessions and making presentations at AGU, AMS, and EGU meetings as well as at other national and international conferences and workshops. UPC staff members helped create AGU's Earth and Space Science Informatics session in 2004, and the EGU ESSI Division was formally launched in 2008 with the active involvement of UPC staff. Both sessions have grown significantly. While travel restrictions during the past year have reduced conference attendance somewhat, UPC staff members have remained involved in the above areas through virtual participation.

National Water Center

The National Water Model (NWM) is a hydrologic model that simulates observed and forecast streamflow over the entire continental United States. Based in large part on the community-developed Weather Research and Forecasting Model Hydrologic modeling extension package (WRF-Hydro), the NWM integrates terrestrial hydrology and atmospheric conditions to provide streamflow predictions for approximately 2.7 million river reaches. Several Unidata technologies are in use in connection with the NWM and at the National Water Center (NWC) in Tuscaloosa, Alabama:

> Output from the NWM is delivered in netCDF format, making it easy to analyze and visualize the model output using a variety of standard software tools, from coding-focused workflows in Python or R to full-featured applications such as the IDV and ESRI's ArcGIS.

> NWM output is made available via NOAA's National Operational Model Archive and Distribution System (NOMADS) project, which incorporates the TDS and lists Unidata as a "Core Collaborator."

> LDM software is used for data transfer at the NWC, both to acquire data for NWM initialization and to transfer the model output to NOMADS.

EarthCube Activities

Unidata's director (Dr. Mohan Ramamurthy) represents Unidata on the EarthCube Council of Data Facilities.

Unidata participates in a variety of EarthCube activities, including collaboration on several awarded "Building Blocks" proposals. Currently, Unidata is teaming with Columbia University, NCAR, and Continuum Analytics on *Pangeo: An Open Source Big Data Climate Science Platform*, and with NCAR and the University at Albany, SUNY on *Project Pythia: A Community Learning Resource for Geoscientists*.

What is the impact on information resources that form infrastructure?

The UPC created and continues to coordinate the Internet Data Distribution system (IDD), in which hundreds of universities, government agencies, and others cooperate to disseminate earth observations via the Internet in near real time. As of early 2021, the traffic handled by servers operated by the

UPC itself — a fraction of the total IDD system — was more than 57 Tbytes/day, or an average of more than 20 petabytes over the course of a year.

While the "push" data services provided by the IDD system are the backbone of Unidata's data distribution services, the UPC also provides on-demand "pull" data services via THREDDS, ADDE, and RAMADDA data servers. With the inclusion of image data from the GOES-16 and GOES-17 satellites, the UPC now provides more than 2.5 Tbytes of data per day to the community via remote access mechanisms.

The UPC's data servers are not classified as "operational" resources, but they nonetheless have a 99.96% uptime record and are used heavily by educational sites that lack the resources to store IDD-provided data locally, or to operate their own data servers. UPC's servers are housed in a UCAR co-location computer facility for reliability, and share UCAR's Internet2/National Lambda Rail connectivity, which provides access to ample bandwidth for Unidata's needs.

The Unidata Local Data Manager (LDM) system includes network client and server programs designed for event-driven data distribution. It is the fundamental component of the IDD system. The LDM is used by hundreds of sites worldwide, and is integrated into the National Weather Service's AWIPS package.

Unidata's Network Common Data Form (netCDF) is a set of freely-available, open-source technologies for efficiently storing scientific data. Ongoing development of netCDF has led to its wide adoption by the atmospheric sciences community, and it is especially popular among climate and ocean modelers. For example, model output datasets for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change must be submitted in netCDF format, using the associated Climate and Forecast (CF) metadata conventions. The resulting large base of netCDF users and data has led to support for the format in more than 80 open source packages and many commercial applications including ArcGIS, MATLAB, and IDL.

Unidata's THREDDS Data Server (TDS) allows for browsing and accessing collections of scientific data via electronic networks. Data published on a TDS are accessible through a variety of remote data access protocols including OPeNDAP, OGC Web Map Service (WMS) and Web Coverage Service (WCS), NetCDF Subset Service (NCSS), and HTTP. The TDS is widely used in the United States (by NOAA, USGS, NASA, and the Earth System Grid, for example) and internationally, and are part of the deep infrastructure on which next generation capabilities are being built by other organizations. Additionally, many other tools build on the TDS (NOAA PMEL's LAS and Ferret-TDS, for example), and on Unidata's Common Data Model (CDM) on which the TDS is built.

Unidata's MetPy project is aimed at bringing GEMPAK-like meteorology functionality to the Python environment. The package has seen strong adoption within the atmospheric sciences research and education community, with hundreds of students and faculty attending MeyPy-focused workshops in the past year. In addition, the number of community contributors to the open source project has also grown significantly, with more than thirty contributors who are not UPC staff members.

Unidata's Integrated Data Viewer (IDV) is a 3D geoscience visualization and analysis tool that gives users the ability to view and analyze a rich set of geoscience data in an integrated fashion. The IDV brings together the ability to display and analyze satellite imagery, gridded data (such as numerical weather prediction model output), surface observations (METARs), upper air soundings, NWS NEXRAD Level II and Level III RADAR data, NOAA National Profiler Network data, and GIS data, all within a unified interface. The IDV integrates tightly with common scientific data servers (including Unidata's TDS) to provide easy access to many real-time and archive datasets. It also provides collaborative features that enable users to easily share their own data holdings and analysis products with others.

Unidata works closely with the National Weather Service and the National Centers for Environmental Prediction to create a version of the AWIPS software tailored for use by the university community.

In addition, Unidata develops and supports numerous other software packages to help scientists and educators manage and use geoscience data:

Siphon: The Siphon project is a collection of Python utilities for downloading data from Unidata data technologies. Siphon's current functionality focuses on access to data hosted on a THREDDS Data Server. Siphon is still in an early stage of development.

McIDAS: The Man-computer Interactive Data Access System (McIDAS) is a large, research-quality suite of applications used for decoding, analyzing, and displaying meteorological data. The older McIDAS-X system, developed by the University of Wisconsin's Space Science Engineering Center and supported by Unidata, is gradually being replaced by the IDV and by McIDAS-V (which is based on the IDV).

UDUNITS: Unidata's UDUNITS supports conversion of unit specifications between formatted and binary forms, arithmetic manipulation of units, and conversion of values between compatible scales of measurement.

Rosetta: The Rosetta project at the UPC is an effort to improve the quality and accessibility of observational data sets collected via datalogging equipment. Rosetta helps scientists transform unstructured ASCII data files of the type commonly generated by datalogging equipment into the netCDF format and other well-documented formats, while minimizing disruption to existing scientific workflows.

What is the impact on technology transfer?

While Unidata's mission is to support the academic research and education community, all software packages developed by Unidata are freely available and open source.

What is the impact on society beyond science and technology?

Unidata technologies help community members reach out to their own communities, facilitating the provision of meteorological data and displays through dozens of popular web sites. For example, the College of DuPage, Iowa State University, University of Wyoming, University of Oklahoma, and University of Utah's Mesowest all make extensive use of Unidata services in their outreach. In addition, several museums (the Boston Museum of Science and San Francisco's Exploratorium among them) make use of either data or software provided by Unidata.

What percentage of the award's budget was spent in a foreign country?

Nothing to report.

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Changes/Problems

Changes in approach and reason for change

Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them

Nothing to report.

Changes that have a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.

Change in primary performance site location

Nothing to report.

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