Cooperative Institute for Research in the Atmosphere
CIRA Review
July 11, 2023

Review Team:

Betsy Weatherhead, U. Colorado (retired) and Jupiter Intelligence
Bill Gail, past President American Meteorological Society
Eduardo Araujo-Pradere, Professor, Miami Dade College
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Tara Jensen, NCAR and Developmental Testbed Center

Executive Summary:

The Cooperative Institute for Research of the Atmosphere (CIRA) is a unique, highly productive research institute with expertise working on the interface between observations and modeling to support weather and climate. One of its strongest areas of expertise lies in using a broad range of approaches, including satellite remote sensing, Artificial Intelligence and innovative yet accessible visualization techniques, to make observations useful over a broad range of applications. It's notable how advanced CIRA is at working across disciplines and creating useful products. The collaborative spirit within CIRA is palpable, with strong relationships crossing University departments and federal agencies as appropriate. The state-of-the-art research, innovation across disciplines, and collaborative spirit results in an astounding workplace which most scientific institutes could only imagine attaining.

The Review Team unanimously agreed that, based on the information presented to them, CIRA deserves an "Outstanding" rating due to the excellence of the science, the clarity of the Leadership Team's vision, and the values presented and exhibited by the full CIRA community.

The Review Team found a few areas where refinement could strengthen these traits and assure that the effectiveness and productivity of CIRA can continue. These areas can be summarized as: refining the stated focus of CIRA to better reflect the full scope of expertise and scientific objectives of the institute; addressing DEI activities and opportunities in a more structured manner; and formalizing future planning so that CIRA can be well poised for changing and emerging opportunities in the coming years. The Review Team is clear that all of these efforts are intended to build on the success of CIRA and make its strengths and future directions more inclusive to the full atmospheric science research community.

BACKGROUND

Colorado State University acknowledges, with respect, that the land they are on today is the traditional and ancestral homelands of the Arapaho, Cheyenne, and Ute Nations and peoples. The Cooperative Institute for Research of the Atmosphere (CIRA), established in 1980, has seen

significant growth in both numbers of employees and on/off-site facilities. Today, CIRA is a highly respected research institute with approximately 180 employees located around the country. CIRA's mission is "To serve as a nexus for multi-disciplinary cooperation between NOAA research scientists and Colorado State University research staff, faculty and students, aligning NOAA-identified research theme areas with long-standing academic strengths of the University."

CIRA's Strategic Plan, which it developed to pursue NOAA's research themes for this Cooperative Institute in i) Satellite Algorithm Development, Training and Education, ii) Regional to Global Scale Modeling Systems, iii) Data Assimilation, iv) Climate-Weather Processes, and v) Data Distribution, is summarized with the following fourteen actions:

1. Entrain skills beyond the traditional meteorology disciplines in support of proposals and infrastructure development.
2. Diversify our funding to ensure long-term viability, complement NOAA research and enable inter-agency coordination and leveraging.
3. Maintain a theme-oriented program to improve the efficiency of our research and maintain core excellence in these areas.
4. Evolve research themes in coordination with NOAA priorities and in light of the long-term research trends and resident faculty expertise of CSU's Department of Atmospheric Science.
5. Exploit cutting-edge advances in engineering and computer science to develop cost-effective methods and techniques for data collection, analysis, and distribution.
6. Forge transitional pathways between basic and applied research, and develop applied research relevant to both our sponsors' missions and CSU's educational mission.
7. Assist national and international weather and climate managers in their selection, usage and optimization of satellite, aircraft, and ground sensors.
8. Partner with Federal and State agencies and laboratories to ensure our research is both cost-efficient and non-redundant at the national level.
9. Conduct research in an environment that is relevant and readily transferable to other operational prototyping activities.
10. Maintain employment opportunities that ensure CIRA staff have a well-defined and competitive promotion and career track.
11. Implement matrix management so CIRA employees can move freely between projects per the ever-changing project funding landscape.
12. Achieve equity and diversity of the CIRA workforce through intentional hiring practices and graduate student support, enhance employee cultural competencies via diversity awareness and other University-supplied training, and promote a welcoming and inclusive environment for all.
13. Provide high school and undergraduate employment opportunities in the form of student hourly appointments.
14. Provide consistent year-to-year opportunities to connect students with career opportunities in atmospheric research across the spectrum of academia, Federal and the private sector.

The Review Panel noted that CIRA's activities were well aligned with these stated Strategic Plan activities. The Panel also noted that CIRA often acted beyond the stated efforts to explore additional paths for supporting the general goals. As an example, CIRA is actively exploring a broad range of activities to advance the equity and diversity of the CIRA workforce in addition to those listed above. The Panel applauds these expanded efforts and encourages an additional effort at making these pro-active practices consistent throughout CIRA by more robustly monitoring various aspects of CIRA, including its many Diversity/Equity/Inclusion characteristics, to determine whether efforts are producing their desired outcomes.

CIRA is intentionally focused on NOAA's priorities and plans, particularly with NOAA's 2022-2026 Plan to build a Climate Ready Nation. CIRA, because of its success in multi-disciplinary research focused on atmospheric science has grown to serve additional agencies, resulting in a rich and focused set of projects which align with CIRA's Strategic Plan.

This document summarizes the Science Review, which is a required midterm juncture of the latest Cooperative Agreement that was established competitively in 2019. This represents the first formal Science Review for CIRA since 2013. The review itself consisted of two webinars, held on April 10th and April 24th, with the full review panel and leadership from CIRA as well as two full-day meetings at CIRA on May 23rd and 24th.

REVIEW PANEL

Dr. Betsy Weatherhead was asked to lead the CIRA Science Review in fall, 2022. After discussions with both Steve Miller, the CIRA Director, and Jennifer Mahoney, CIRA's assigned Technical Program Manager (TPM) and the Federal Supervisor for both the Administrative Review and the Science Review, the following four panelists were invited because of their expertise in atmospheric science and their respect in the community. Factors that went into consideration also included their diversity in professional backgrounds and experience to assure a well-rounded set of comments and recommendations. Betsy Weatherhead discussed the scope and focus for the Science Review with both Steve Miller and Jennifer Mahoney, and responded to requests for input on the proposed agenda.

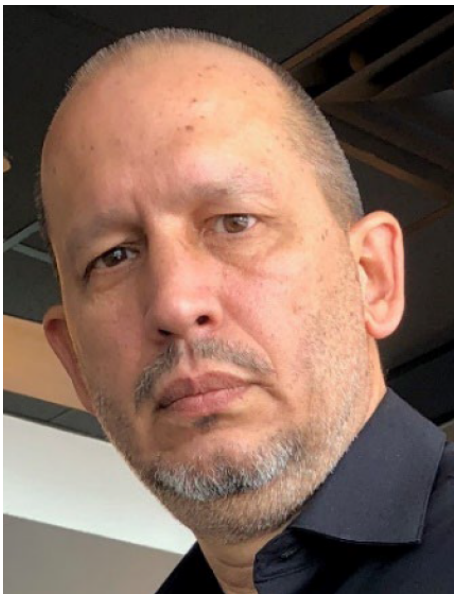
Betsy Weatherhead is an award-winning scientist whose career has focused on the value of Earth observations using advanced data analytics. She enjoys working in a cross-disciplinary manner with experts to address a range of challenging problems. Areas where she has worked include: Arctic climate change; ozone depletion and recovery; improving weather forecasting; verification and trend detection. Currently, she works for Jupiter Intelligence, advises on the Copernicus Climate Change Service, and co-leads the Keck Institute of Space Studies Continuity Team. For over ten years she has chaired the AGU Renewable Energy Sessions.

William B. Gail is an advisor and consultant to weather and remote sensing organizations. He was previously co-founder and CEO at Global Weather Corporation, an industry-leading provider of weather forecast services to the media, energy, and transportation industries, and product lead for weather and climate at Google. Prior to that he was a Director in the Startup Business Group at Microsoft, Vice President of mapping products at Vexcel Corporation, and Director of Earth science programs at Ball Aerospace. Dr. Gail received his undergraduate degree in Physics and his PhD in Electrical Engineering from Stanford University, where his research focused on physics of the Earth's magnetosphere. During this period, he spent a year as cosmic ray field scientist at South Pole Station.

Dr. Gail is a past-president and Fellow of the American Meteorological Society. He was the co-chair of the US National Academy of Sciences 2017 Earth Sciences Decadal Survey, served on their Board on Atmospheric Sciences and Climate, and has participated on many prior National Academies committees including the 2012 review of the National Weather Service and the 2007 Earth Sciences Decadal Survey. He serves or has served on a variety of other editorial, corporate, and organizational boards, including the US Commerce Data Advisory Council and NOAA Environmental Information Services Working Group (EISWG), and has testified in Congress on multiple occasions regarding weather issues. His book Climate Conundrums: What the Climate Debate Reveals About Us was released in 2014, and his opinion pieces have been published in The New York Times, USA Today, and elsewhere.

Tara Jensen is the Deputy Director of the National Center for Atmospheric Research (NCAR) node of the Developmental Testbed Center as well as a Project Manager II in NCAR's Research Applications Laboratory (RAL). She serves the broader community as the Chair of the AMS STAC Committee on Probability and Statistics. She did her graduate work at Colorado State University between 1991-1997. Tara has vast experience across Atmospheric Sciences, including managing small field campaigns, running quasi-real-time Numerical Weather Prediction (NWP) systems, and developing and evaluating NWP models through diagnostics and statistical analysis. For the past 8 years, she has been leading the Developmental Testbed Center (DTC) verification team in the development of the enhanced Model Evaluation Tools verification and diagnostics framework (METplus). This framework has its roots in tropospheric weather and Tropical Cyclone verification but over the years has been extended to also specifically include metrics for applications to all components of an Earth system modeling framework. Throughout her career, and especially through her work in verification, Tara has developed strong connections to many disciplines within the public, private, and academic sectors.

Maria J. Molina is an Assistant Professor within the Department of Atmospheric and Oceanic Science at the University of Maryland in College Park and an Affiliate Faculty with the University of Maryland Institute for Advanced Computer Studies. She is also affiliated with the Climate and Global Dynamics Division of the National Center for Atmospheric Research in Boulder, Colorado and an Adjunct Assistant Professor within the Department of Marine, Earth, and Atmospheric Sciences at North Carolina State University. Maria's research entails the use of machine learning and numerical modeling for questions within the domains of climate and weather extremes. She also serves as a member of the Scientific Steering Group (SSG) of the World Climate Research Programme (WCRP) for the Earth System Modelling and Observations (ESMO) Core Project, Vice-Chair of the AMS Scientific and Technological Activities Commission (STAC) Committee on Artificial Intelligence Applications to Environmental Science, academia ambassador for the AMS Committee for Hispanic and Latinx Advancement, and is a member of the AMS Board on Representation, Accessibility, Inclusion, and Diversity.



Eduardo Araujo-Pradere is a Professor with the Math and Sciences Department at Miami Dade College. Eduardo's research involves high atmosphere, ionosphere, and geomagnetic disturbed conditions. He has also worked extensively on data analysis and on Solar Minima and was the Chair of the Chapman Conference on Causes and Consequences of the Extended Solar Minimum. His STORM model is the current ISO model for the disturbed ionosphere, and part of the International Reference Ionosphere. Eduardo has received many acknowledgments for his work and is a recognized authority on science outreach and inclusion and diversity.

AGENDA

2023 CIRA Science Program Review – Agenda: Tuesday, 23 May 2023

Time	Agenda Item	Presenter	Location
7:30	**Travel to CIRA**		
8:00	*Review Team Executive Session*		**CIRA Satellite Conf. Room**
8:55	*CSU Welcome Video*	Steve Miller (Dir. CIRA)	CIRA Commons
9:00	CSU and NOAA Leadership Welcome Remarks	Emily Menashes (OAR DAA for Programs), Jennifer Mahoney (Dir NOAA/GSL), Alan Rudolph (VPR, Co-Chair of CIRA Exec. Board), David McLean (WSCOE Dean)	CIRA Commons
9:20	Overview of CIRA, Vision/Strategy and Initiatives	Steve Miller	CIRA Commons
9:50	*Discussion*		CIRA Commons
10:00	***Coffee Break***		CIRA Commons Upstairs
10:25	Tropical Cyclone Research - Highlights	Kate Musgrave	CIRA Commons
10:35	Satellite Training/Education - Highlights	Bernie Connell	CIRA Commons
10:45	Earth Prediction, Verification, Decision Support and Data Services Highlights	Bonny Strong (CIRA Acting Associate Director/Boulder) and Dana Uden	CIRA Commons
11:00	*Discussion*		CIRA Commons

11:10	Data Assimilation Highlight: GREMLIN in the HRRR	Kyle Hilburn and Amanda Back	CIRA Commons
11:25	Research Collaborations with the MDL -- Highlights	John Crockett and Jason Burks	CIRA Commons
11:40	Aviation Weather and Operations Proving Ground Highlights	Amanda Terborg	CIRA Commons
11:55	*Discussion*		
12:00	***Lunch (Catered)***	Executive Board & Review Team	CIRA Commons Upstairs CIRA Commons Downstairs
1:00	Advanced Satellite Imagery Applications and Public Outreach / Engagement	Curtis Seaman and Dakota Smith	CIRA Commons
1:15	NEAT Program Highlights	Prasanjit Dash	CIRA Commons
1:30	CIRA Machine Learning Initiative Highlights & Plans	Imme Ebert-Uphoff & Ryan Lagerquist	CIRA Commons
1:50	*Discussion*		CIRA Commons
2:00	Administrative Infrastructure Supporting the CIRA Science Program	Beth Kessler (CIRA Asst. Director)	CIRA Commons
2:20	CIRA Education, Outreach and DEIJ Highlights, Partnerships, Initiatives	Matt Rogers & Amanda Back	CIRA Commons
2:50	*Discussion*		
3:00	***-Walking Tour of CIRA Facilities (for Review Team)*** ***-CIRA Management Team meets with CIRA Executive Board***	Matt Rogers Steve Miller, Beth Kessler, Renate Brummer, Site Managers	CIRA/ATS Campus CIRA Satellite Conf. Room
3:30	***Coffee & CIRA Science Poster Session***		CIRA Main
4:30	*Review Team Meets with CIRA Leadership*	Director's Office + Site Managers	CIRA Satellite Conf. Room
5:00	*Review Team Executive Session*		CIRA Satellite Conf. Room
5:30	***Adjourn Day 1***		
7:00	***CIRA-hosted dinner with Review Team***	Reviewers & CIRA Leadership	**TBD**

2023 CIRA Science Program Review – Agenda: Wednesday, 24 May 2023

Time	Agenda Item	Presenter	Location
8:00	***Travel to CIRA***		
8:30	*Review Team Executive Session*	---	CIRA Satellite Conf. Room
8:55	***Cross-Agency Interactions and CIRA Strategic Initiatives***	Opening Remarks (Miller)	CIRA Commons

9:00	CIRA Data Processing Center: From CloudSat to INCUS	Phil Partain	CIRA Commons
9:15	OVERCAST: An Example of NOAA/NASA/DoD Synergy	Yoo-Jeong Noh	CIRA Commons
9:30	*Discussion*		
9:40	Societal Impacts Initiative Highlights & Plans	Andrea Schumacher and Valerie Were	CIRA Commons
10:00	Wildfire Initiatives at CIRA	Kyle Hilburn and Curtis Seaman	CIRA Commons
10:20	*Discussion*		CIRA Commons
10:30	***Coffee Break***		CIRA Commons
10:55	***CIRA Students & Postdoc Session***	Opening Remarks (Miller)	CIRA Commons
11:00	GeoXO: CIRA research on NOAA's future geostationary satellite system	J. Haynes / Katurah McCants	CIRA Commons
11:10	TC PRIMED	C. Slocum / Naufal Razin	CIRA Commons
11:20	Social-Scientific Approaches to TC Forecasting	A. Schumacher / Zoey Rosen	CIRA Commons
11:30	Frontiers in Coupled Earth System Science: Bioluminescent Milky Seas	S. Miller / Justin Hudson	CIRA Commons
11:40	Optical Flow applications at CIRA	J. Apke / Jack Tobin	CIRA Commons
11:50	*Discussion*		CIRA Commons
12:00	***Lunch (Catered)***		CIRA Commons Upstairs
1:00	*Review Team Executive Session*		CIRA Satellite Conf. Room
3:30	***Coffee Break***		CIRA Commons Upstairs
4:00	*Review Team Initial Feedback to CIRA Leadership (Debrief)*		CIRA Commons
5:00	***Meeting Adjourns***		

The Review Team is responding with Findings and Recommendations based on the four topic areas put forth by the Cooperative Institute Guidelines. The Review Team would suggest that these areas could be changed to better meet the challenges of the Cooperative Institutes more generally and CIRA in particular.

AREA 1. Science Plan

CIRA has shown remarkable effectiveness in adapting to the ever changing requirements of the atmospheric sciences community, particularly in developing useful tools, analytics that make use of Artificial Intelligence, and effectively incorporating social sciences. While planning for the future is extremely difficult, in part due to changing priorities and disruptive technologies, planning for change still has value because it builds on the collective wisdom of the broad range of scientists and board members who can help identify new trends and opportunities.

Finding 1.1: CIRA has an impressive range of core organizational strengths providing outstanding value to its funding partners; often CIRA's contributions are unique to CIRA's uniquely collaborative culture and skill sets. CIRA would benefit from further clarifying its many core organizational strengths that provide value (particularly value that can be considered unique to CIRA) to its funding partners. CIRA has a clear understanding about its expertise in relating remote sensing to modeling; but CIRA is less clear about its additional capabilities which are truly outstanding, including its rather special ability to foster cross-agency collaboration, provide early-stage user-access to prospective capabilities, work at difficult interfaces between disciplines and institutions, and to train early career research scientists for a future Federal career within NOAA.

Recommendation 1.1: CIRA should more formally assess, document and publicize its strengths and special capabilities, for use in communicating its value, for ensuring that projects contribute to NOAA's research themes as well as CIRA's own strategic goals, for ensuring it continues to prioritize projects appropriately, and to focus resources on what it does best.

Finding 1.2: CIRA routinely engages the Executive Board and Council of CIRA Fellows to determine and implement scientific priorities for the CI. However, it appears the CIRA Fellows are mostly affiliated with NOAA, CSU, CIRA, or other NOAA Cooperative Institutes. This may hamper CIRA's planning process by garnering a narrower slate of recommendations than might be provided if the CIRA Fellows were more diverse.

Recommendation 1.2: CIRA should consider if they would benefit from including more members external to NOAA, CSU, and CIRA in their CIRA Fellows roster. Additionally, they may want to examine its structure to assure input is diverse, evolving to address current challenges and opportunities and appropriate to CIRA's needs.

Finding 1.3: Institutional collaboration has been critical to CIRA's success and will grow in importance. A more formal process for seeking and implementing collaborations with other institutions would benefit CIRA.

Recommendation 1.3: CIRA should establish a strategic partnering plan, suitable for sharing externally. The plan should include:

- *Funding Partners.* A summary and assessment of how CIRA can contribute to potential funding partners, particularly CIRA's alignment with partner needs and how CIRA adds unique value to each partner and its goals.
- *Non-Funding Partners.* A summary and assessment of similar organizations (in particular, all NOAA Cooperative Institutes, along with others such as NCAR) describing how CIRA contrasts with and complements those organizations and the differentiated value CIRA can bring with respect to those partners.

Finding 1.4. Remote sensing data used by NOAA and other government agencies increasingly includes data elements provided from commercial sources. This is most evident in NOAA's programs that explore integration of Radio Occultation data, but other sources are anticipated as the commercial remote sensing industry grows. CIRA works with NOAA, NASA, EUMETSAT, the Japanese Meteorological Agency and the Korean Meteorological Agency datasets and interfaces with industry partners such as Raytheon, Lockheed Martin, and others in pursuit of mutual interests. CIRA has the capabilities to serve as a critical testing ground for new remote sensing capabilities.

Recommendation 1.4a: CIRA should consider expanding its science plan to include capabilities, controls and security protocols needed for working with commercial remote sensing data and should seek projects for applying CIRA's capabilities.

Recommendation 1.4b: While CIRA currently tests its products at different NOAA workshops/testbeds (such as the Hazardous Weather Testbed), it may want to put more emphasis on the unique success it has demonstrated on quickly taking projects from raw data through to usable information. This may include branding their capabilities and advertising them more broadly, but more directly, it may include setting up a toolbox approach to invite beta testing and allow users to help more directly with the development of the range of tools CIRA produces.

Finding 1.5: With facilities in Fort Collins, Boulder, Kansas City, Silver Spring, College Park, and Miami, CIRA has a geographically diverse footprint that provides opportunities for innovative research and growth as well as challenges to the cohesiveness of the institution. CIRA conducts weekly meetings with the leaders of all CIRA locations to facilitate coordination; CIRA also holds monthly seminars to promote self-awareness across the groups.

Recommendation 1.5: CIRA must continue to strengthen the collaboration between personnel in all locations in order to bring to bear the most robust satellite observation, atmospheric modeling, AI, and social science expertise upon NOAA's research portfolio. CIRA must also continue to ensure communication and processes are in place to fully enfranchise and leverage personnel in all locations.

AREA 2. Science Review.

CIRA continues producing world class science and appropriately incorporating social science into its projects with impressive effectiveness. The Review Team is as much impressed with the quality of the science as with the effectiveness of the ability of CIRA staff to produce tools that are then used by a wide range of consumers of atmospheric observations and models.

Finding 2.1: With increasingly tight government agency funding and growing competition for that money, communicating success and impact is important to CIRA's health.

Finding 2.2: CIRA tracks peer reviewed journal articles and presentations. Some of CIRA's most significant contributions involve community capacity building through development data analysis tools and decision support systems, along with complex multidisciplinary or multi-agency relationships. CIRA's initial efforts at engaging historically marginalized groups, working with new satellite observations and working across agencies are additional examples of CIRA's excellence which are not always fully appreciated. These contributions are more difficult to quantify and track and therefore may not result in as much community acknowledgment as they deserve.

Recommendation 2.1-2: CIRA should define and establish success metrics for ongoing organizational success monitoring, such as the number of CIRA projects effectively transitioned to NOAA operations, NOAA staffing positions, or other STEM positions in the field.

Finding 2.3: CIRA has considerable success in developing tools and capabilities from the ground up. Often these capabilities involve real-time observations, modeling, and effective communication of results to a broad range of users. CIRA's success in this difficult role means that various tools are at a range of maturity levels. Identifying the operational maturity/risk of CIRA's projects – perhaps with something equivalent to the Technology Readiness Level (TRL) scale used for technology risk assessment — would be a useful contribution for communicating broadly the stage of development for each project.

Recommendation 2.3: CIRA may consider developing a TRL-like scale, appropriate for its purposes, that identifies the maturity of its tools/applications/projects (or sub-projects) for end-use by its funding partners and collaborators.

Finding 2.4: CIRA is uniquely successful at making effective analysis tools and products that relate remote sensing to modeling. This is extremely hard to do, requiring appropriate access to real time data, expertise to understand when data are "good enough" for real time use, understanding the needs which are not currently being met and envisioning and carrying out a plan to meet the current needs. CIRA not only does this exceedingly well, it is one of the few groups in the world that consistently excels in this area. Many aspects go into this success, including CIRA's direct access to global satellite data and experience in handling such data; CIRA's personnel working closely with Subject Matter Experts around the nation, the collaborative problem solving and knowledge sharing spirit seen throughout CIRA and the vision of making sure the final results are meeting the pre-identified objectives.

Finding 2.5: CIRA continues to produce new science results with both peer reviewed papers offering new insights into how the atmosphere works in the Earth System and developing new tools for the community to explore observational and modeling results. In particular, CIRA's use of thoughtful/explainable Artificial Intelligence with its emphasis on new insights and making use of AI in a physically meaningful way, helps set standards for all other applications of AI.

Finding 2.6: CIRA's ability to build software solutions to provide a large capacity for complex data analysis and problem solving for the broad Earth Science community is impressive on many levels. The Review Panel firmly believes this contribution is as important as peer reviewed journal articles and deserves further recognition and commendation. CIRA's Slider tool is perhaps the most famous, accessible, and widely used tool CIRA has recently produced, but the full range of CIRA's tools are both impressive and reveal an institutional expertise which is exceedingly difficult to achieve.

Finding 2.7: CIRA uses Social Science in an appropriate way to both scope challenges for new tools and assess effectiveness of efforts to communicate insightful and potentially actionable information to end users. This is even more notable because CIRA does not have any full-time social science support from NOAA, and therefore needs to seek out appropriate expertise with each new project it develops and engage social scientists from its parent university and its external partners via its central funding or unfunded collaborations.

Finding 2.8: CIRA's use of Social Sciences is one of its successful approaches to assuring that their products are as effective in communication as possible. Working with other departments within the University has allowed CIRA to collaborate with experts that are directly relevant to the projects' success. CIRA should be commended on their resourceful use of University expertise–often unfunded–to achieve its goals of making their projects understandable and useful.

Finding 2.9: CIRA shows excellence in working with both observations and models across timescales from weather to climate. Within the review, CIRA's excellence in working with near-real time data in ways that make the data immediately useful to a wide range of end users is impressive. CIRA both supports and appreciates the exploratory process needed to yield such effective end-user products. Multiple researchers mentioned collaborating with other researchers within CIRA to overcome technical hurdles and achieve unique goals–giving testimony to the collaborative and team-oriented spirit of this CI.

Finding 2.10: CIRA's use of AI is one of the strong bright spots for the Institute and underscores the value of CIRA's collaboration within the University system. The efforts are both well published and well known within the broad scientific AI applications community. The rest of NOAA could benefit from further investment in this highly productive part of CIRA's research, which was seeded out of internal University investments.

AREA 3. Education / Outreach

CIRA demonstrates a strong appreciation for education at many levels: K-12, as well as college, graduate education and beyond. This dedication to the full spectrum of life-long education includes a high value for working closely with Colorado State University's Atmospheric Science Department, as well as other departments within the University. CIRA's STEM-oriented outreach efforts have resulted in unique, and potentially impactful events with historically marginalized groups in STEM. The innovation and breadth of these efforts–including events involved NOAA leadership–can be held up as positive examples for other Cooperative Institutes.

Finding 3.1: CIRA's multiple efforts at Education and Outreach are impressive and appear effective. This is even more impressive because CIRA does not specifically have a full-time person devoted to this effort. The summer NOAA Cooperative Research Programs (CoRP) Symposium which brought in students of historically marginalized identities to learn about career opportunities in STEM research, to directly engage with leaders in the field, and to experience flying drones is particularly impressive. Effectiveness of outreach is critical to success; clear goals and metrics of engagement or success will allow evaluation, prioritization, focus and improvements of each effort.

Recommendation 3.1: CIRA should continue to work with students in support of its dedication to education and outreach, but also because CIRA has demonstrated the ability to work successfully with students from a broad range of backgrounds and disciplines to further CIRA's scientific priorities. CIRA should consider using its demonstrated strengths in student engagement as an avenue for welcoming historically marginalized groups of people in its organization.

AREA 4. Science Management Plan

The Review Panel considered both how CIRA manages its scientific projects and how it manages its employees in this section of the review, in line with the understanding that "People do Science." The Review Panel looked for how current projects and people are supported as well as how planning for the future is addressed. CIRA's science covers a broad scope of weather to climate projects pulling in specific expertise, including AI and Social Sciences as needed.

Finding 4.1: The relationship between CIRA and Colorado State University is one of the strongest we know of between a Cooperative Institute and its hosting university. This supportive relationship results in better facilities for CIRA, better support for CIRA staff and better science from leveraging expertise from throughout the University. The tangible results of this supportive relationship include the new CIRA conference building and the joint publications with other departments. The less obvious benefits include the more supportive financial structures and the ability to work out issues which require attention, some of which arose during pandemic conditions.

Recommendation 4.1: While focusing on what it does best, CIRA should also pursue exploratory projects that may seem peripheral to its core expertise, with the goal of seeking appropriate realignment as needed. CIRA should continue to foster its close relationship with CSU to secure strategic investments in areas of technology, interdisciplinary research, and societal engagement.

Finding 4.2: CIRA Leadership shows a strong representation of women, although as with much of the atmospheric science community, minorities are under-represented. Individuals within CIRA seem generally happy with their career paths and results presented from a recent University-wide climate survey support this impression, however no systematic information (survey results, personnel complaint histories, etc.) were presented to the Review Panel. The University does have an Ombudsman and multiple paths and services for anonymous complaints and for conflict resolution. Early career individuals who participated in the review seemed very satisfied with the support they receive within CIRA, including mentoring, guidance, opportunities for career growth and networking.

Recommendation 4.2a: CIRA has grown to the extent that it should explore more formal methods for systematically tracking its employees' diversity, development and opportunities. CIRA should develop mechanisms to assure that all employees understand what opportunities are available to them for potential growth and leadership. Guidelines should be developed within CIRA for how affiliate students, early-, mid-, and late-career scientists and administrative support staff can succeed, access resources and flourish. This set of guidelines is particularly important both because of CIRA's geographically diverse personnel and because the evolving nature of science requires each individual to be ready for adaptation throughout their career.

Recommendation 4.2b: CIRA should track its Diversity, Equity and Inclusion (DEI) efforts with respect to historically marginalized populations and seek metrics that allow CIRA to understand when particular efforts have been successful. Potential metrics could include number of historically marginalized people engaged, indication of impact, engagement of CIRA employees from under-represented groups, number of marginalized people who transitioned to NOAA, etc.

Recommendation 4.2c: In line with CIRA's demonstrated dedication to education, CIRA should expand its current partnerships–with NOAA Investments as a key enabler–with an Hispanic Serving Institution, Minority Serving Institution, and/or an institution from Historically Black Colleges and Universities to identify specific students appropriate for internships or who may be encouraged to attend CSU and work with CIRA. This recommendation, if followed, could help develop the diverse hiring pool which will be important to NOAA in addressing its diversity goals. CIRA should also consider an external advisory committee to help identify effective issues to address diversity issues. Right now stories are anecdotal, but real progress requires investment.

Finding 4.3: CIRA's role as a cooperative institute between NOAA and CSU exists to provide a space for collaboration and innovation across a broad range of important science exploration and applications. Unfortunately, there appears to be a reduction in the effectiveness of this collaboration between University and Federal staff due to NOAA's cautionary posture, leading to NOAA Federal Employees' recusal from search committees and from providing feedback to annual appraisals of CIRA staff who work closely with NOAA throughout the year. These measures have introduced problematic challenges to CIRA and NOAA staff to interact as true partners under the Cooperative Agreement, despite the fact that University rules do not preclude such participation and input. This is hurting CIRA's ability to serve the nation and to support both the NOAA and CIRA staff.

Recommendation 4.3: CIRA should promote the effectiveness of strong NOAA-CIRA relationships whenever possible to remind NOAA of the high return on investment and unique value of the CIs in general. Some easy ways to consider include adding a section about Testbed and Proving Ground collaborations on their website and gathering statistics on research to operations transitions.

Finding 4.4: CIRA operates under a challenging funding cycle including primarily one year statements of work and plans. It is difficult to plan for and conduct scientifically robust research on a year by year basis. Additionally, having a one year planning cadence can impact the morale and efficiency of staff because they do not always know if the work they are performing in one year will continue to the next. Organizations with similar funding structures have found a recent move to two and three year planning to be much more conducive to effective research.

Recommendation 4.4: CIRA should continue to request that NOAA and other sponsors consider longer periods of performance for appropriate work plans with the understanding that the work plans and associated budgets may be reviewed on a year-by-year basis.

Finding 4.5. Future CIRA projects will arise from new directions and emerging initiatives of NOAA and other funding partners, such as those described in the 2021 *Priorities in Weather Research* report from NOAA's Science Advisory Board.

Recommendation 4.5: CIRA should formally track planning documents associated with its funding partners, beyond top-level strategic plans, and seek project opportunities reflecting the emerging needs.

Finding 4.6: CIRA has effectively developed strong ties to many NOAA testbeds, proving activities, and laboratories, as well as NCEP centers. These relationships allow for CIRA's cutting edge technology to be tested and improved in an iterative feedback process and provides mechanisms to get the technology in front of users more quickly. Overall, this is an incredible benefit to both NOAA and CIRA.

Recommendation 4.6: CIRA should use whatever means possible to convey to NOAA how important it is to have a collaborative relationship with federal staff rather than a contractual one. The partnership would benefit greatly from a revision to the current policies, with the understanding that NOAA is indeed not determining the outcome of hiring decisions nor employee actions and that these decisions have resided and will continue to reside within the sole jurisdiction of CSU and CIRA. Similarly, the partnership would benefit from an understanding from Federal program managers and line offices that CIRA is a entity within the CSU, and as such, they are bound by the policies and procedures set forth by the University.

Finding 4.7: CIRA has many projects in pre-operational phases for which informal end-user evaluation benefits both the project (end user feedback) and the end user (early access to new capabilities). Many of these have developed web-based or similar "beta" access to serve this purpose. A highly successful example of this is CIRA's SLIDER2, which effectively serves as a testing ground for working out problems in advance of broad public releases.

Recommendation 4.7: CIRA should aggregate SLIDER2 and other "beta" access projects into a "CIRA Sandbox", enabling simpler end-user access to CIRA's many beta-level capabilities and more clearly communicating CIRA's role as a preeminent developer of pre-operational capability for NOAA and other funding partners. Inclusion of project metrics, such as in the recommendation regarding TRL-like readiness levels, will help end-users understand the purpose of each project in the sandbox. This sandbox could be as simple as a common website for accessing demonstration capabilities.

Comments for NOAA

Some of the most critical points to be communicated to NOAA Leadership in light of the CIRA Review:

Comment 5.1: CIRA's Mission, Current Activities and Plans are well aligned with NOAA's Strategic Plans. CIRA has a few unique qualities which NOAA should be aware of and leverage appropriately.

Comment 5.2: CIRA has a strong track record and culture which allows for rapid development of analysis and decision support tools, particularly those making use of real-time satellite data.

Comment 5.3: CIRA has a strong relationship with its university and as such can be a useful partner in testing out new working/organizational models, particularly models that might explore closer relationships on staffing issues and financial issues.

Comment 5.4: CIRA has taken leadership in important DEI and social science issues; with directed NOAA investment, they could prove to be a model for how Cooperative Institutes can help NOAA address a range of Diversity, Equity and Inclusion issues.

Comment 5.5: NOAA has an opportunity to help improve the relationships between Cooperative Institutes (CIs) and NOAA. Specifically, NOAA could work with CIs to identify ways in which NOAA and CIs can work together appropriately to fulfill their intended missions. The partnership would benefit greatly from a revision to the current policies, with the understanding that scientific relationships require technical expertise from NOAA to contribute in some form to hiring decisions, employee actions and prioritization of scientific objectives of the CIs. The partnership would additionally benefit from an understanding from Federal program managers and line offices that Cooperative Institutes such as CIRA are entities within the universities, and as such, they are bound by the policies and procedures set forth by the University. Clarification on roles will greatly improve the effectiveness of the Cooperative Institutes to serve NOAA's mission.

Comment 5.6: NOAA and the country are receiving a tremendous benefit and high value from the Cooperative Institutes, including CIRA. A formal evaluation of this return on investment could benefit future decisions and appropriate uses for Cooperative Institutes. This evaluation may include development of a range of metrics to capture the full scope of value. Areas which could be considered include: CI's as scientific thought leaders for a range of science applications; CI's as tool developers to allow NOAA to provide services for the nation; CI's as rapid responders to unique scientific and engineering challenges; CI's as training areas for a more diverse future NOAA, CI's as form of communication on NOAA's mission and the evolving successes from NOAA's investments.

Comment 5.7: NOAA's complicated funding structure and constraints have strong, direct impacts on Cooperative Institutes. If alternative funding approaches to remove some of the barriers could be identified and addressed, this would benefit all involved. Important barriers under the current system include the concern for year-to-year funding which hinders scientific planning and success; short timelines for responding to funding opportunities; and limitations on uses for existing funding. Pooling of funds, advance prioritization of possible projects and creative use of NOAA-University relationships may offer unique possible solutions to this difficult challenge.

Comments on Review Process

The Review Panel enjoyed the process of learning more about CIRA's strengths; each member came away with the impression that CIRA is a true "jewel" in the CI system. The support from NOAA, including the CIAO, Jennifer Mahoney, Missy Petty and Cynthia Decker was extremely valuable. Logistical support by Sean Miller was seamless and effective. The panel would also like to acknowledge the tremendous amount of work put into preparing for the review by CIRA staff.

Direct and constructive communication with both Steve Miller and Renate Brummer made the Panel's ability to provide appropriate Findings and Recommendations more effective. The

"CIRA Review Binder" was a critical resource for understanding CIRA's structure, challenges and strengths.

The Panel applauds the CIAO for updating the handbooks for CI's and for CI Science Reviews. Unfortunately, the update handbook was made public after the CIRA review took place. Elements of the review process which were particularly appreciated by the panel included: in person review activities allowed for more direct communication and understanding of CIRA's culture; direct interaction with staff, students and alumni through presentations, posters and breaks allowed for a more clear understanding of CIRA's strengths, capabilities and dynamic nature; pre-review webinars were helpful for orientation to both CIRA and the review process; the diversity of the Review Panel brought tremendous strength to the final recommendations.

Conclusion

The review team was particularly impressed with CIRA, its leadership and its staff. The relationship between CIRA and Colorado State University is particularly strong and contributes to CIRA's success. CIRA's alignment with NOAA's mission is both strong and responsive, as NOAA's mission changes. The culture within CIRA is particularly positive, resulting in collaborations that are productive and state of the art. The Review Team unanimously agreed that, based on the information presented to them, CIRA deserves an "Outstanding" rating due to the excellence of the science, the clarity of the Leadership Team's vision, and the values presented and exhibited by the full CIRA community. Suggested areas for improvement primarily focus on codifying and strengthening what CIRA is already very good at. These areas include measuring success from its Diversity, Equity and Inclusion activities, codifying its development process as it designs new tools and products, and communicating CIRA's strengths more broadly. The review team appreciated the review process, interacting with the CIRA leadership and staff, NOAA support through the process, and learning more about this outstanding institution.