

**FAIR Facilities and Instruments Workshop #3 Report:
Synthesizing Community Input Toward Recommendations**

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Executive Summary

Funded by the National Science Foundation's FAIR Open Science (FAIROS) program, this project is a Research Coordination Network (RCN) collaboration between the NSF National Center for Atmospheric Research, University of Colorado Boulder, and Florida State University. The project promotes community-wide discussions and encourages the adoption of best practices that recognize the large variability in persistent identifier (PID) implementations for research facilities and instrumentation. To build on intensive discussions established during the first two years of the project, the FAIR Facilities and Instruments RCN hosted its third in-person workshop at the NSF National Center for Atmospheric Research, in Boulder, CO, on September 22-24, 2025. Fifty individuals from academic institutions, national laboratories, nonprofit organizations, and private industry participated in discussions on progress and lessons learned, practical challenges and tracking PIDs, engaging with stakeholders not present in conversations to date, and identifying ways forward for a PID strategy.

Discussions at the workshop specifically focused on a draft of Recommendations for FAIR Facilities and Instruments that was circulated to all attendees before the workshop. Key outcomes included insights on how to improve the recommendations and on general takeaways related to PIDs for research facilities and instruments:

Key Points

1. Overarching Issues:
 - Workshop participants identified a gap between understanding what PID systems can do and knowing what specific actions different stakeholders should take to implement them effectively.
 - Responsibility for PID assignment often remains unclear, and successful implementation will likely require coordination across multiple stakeholders including offices of research, libraries, facility managers, and in some cases, manufacturers and publishers.
 - While some groups have achieved sophisticated automation of PID assignment, many facilities are still far from that level of maturity, raising questions about how to move from current practices toward more automated, FAIR-compliant workflows.
 - Across all stakeholder groups, there was demand for more specific guidance on implementation mechanics and decision-making processes for assigning PIDs.
2. Motivations for PIDs vary:
 - Making facilities and instruments discoverable through PIDs creates value even before extensive usage tracking is possible.
 - Establishing trust and validating provenance connections (e.g. relationships between scholarly entities) in an increasingly fraught knowledge ecosystem is a key use case for facility and instrument PIDs, particularly given concerns about generative AI and the proliferation of low-quality or fabricated data.

- Participants emphasized that funders and publishers are the main drivers of PID adoption—researchers typically will not provide information without policy requirements, as evidenced by data sharing becoming standard practice only after it became a mandated policy.
 - Participants saw potential value in “package PIDs”, namely, PIDs that point to compilations or lists of other related PIDs.
3. Community-endorsed guidelines for assigning PIDs are needed. These guidelines should:
- Clarify decision-making criteria for choosing among different PID systems.
 - Provide guidance on institutional roles and responsibilities, specifically identifying who should lead PID initiatives at the organizational level rather than leaving this to individual labs or researchers.
 - Provide governance recommendations that address succession, ownership, and responsibility for PIDs and their associated landing pages.
 - Provide leverage when advocating for institutional resources and policy changes, moving the conversation beyond individual preference to community standard practice.
4. Making PIDs actionable involves several types of effort:
- Landing pages serve important human-readable functions while PID metadata needs to establish machine-readable relationships, to support analysis and linking via computation.
 - Much of the detailed metadata for instruments and facilities best lives in linked resources—such as associated publications, datasets, or dedicated documentation pages—rather than being embedded in the PID metadata.
 - Reference publications should generally be cited in addition to facility or instrument PIDs.
 - Participants consistently requested concrete, detailed examples of successful PID implementations across different institutional contexts and facility types.
 - While participants recognized that decision trees and flowcharts could be useful, there was strong emphasis that these tools alone would be insufficient and should be complemented by narrative case studies organized by stakeholders.

As an outcome of the workshop, a next version of the project’s recommendations on assigning PIDs for research facilities and instruments was produced. It was then distributed to the workshop attendees for further comments. Following the post-workshop comment period, the RCN project team revised the recommendations again and made them publicly available here: <https://doi.org/10.5281/zenodo.18436644>



Introduction and Background

Persistent Identifiers (PIDs) are central to the vision of open science described in the FAIR¹ Principles. In recent decades, as open science has taken on greater visibility within scholarly research institutions, the use of PIDs has expanded significantly to encompass many purposes and resource types, including data sets, software, laboratory materials, physical samples, and people and organizations. PIDs have become a vital tool for enabling reproducibility, fostering collaboration, and facilitating access to scientific resources.

To take the next step in this progression, the FAIR Facilities and Instruments Research Coordination Network (RCN) focuses on the assignment of PIDs to research facilities and instrumentation. Providing PIDs for scientific instruments could increase transparency and enhance the discoverability of existing instruments, equipment, and data, in turn streamlining scientific research production and open science practices. PIDs also promise to increase the discoverability of existing research facilities and instrumentation, which may increase equity of access to instruments and data and provide a mechanism for designating credit for scientific

¹ FAIR Principles - Findable, Accessible, Interoperable, Reusable, <https://www.go-fair.org/fair-principles/>

outcomes that derive from specific instruments, laboratories, technical staff, and funding agencies.

Funded by the National Science Foundation's FAIR Open Science (FAIROS) RCN program, this project is led by a collaboration between the National Center for Atmospheric Research, University of Colorado Boulder, and Florida State University. The project is facilitating community-wide discussion and broad adoption of best practices that recognize the large variability in PID implementations. Key issues for this project cut across a number of broad concerns, including cultural, policy, institutional, and technical facets. Specific focuses of discussion include the 1) adoption of persistent identifiers for facilities, instruments, and instrument data; 2) implementation of PIDs within technical infrastructure for instrument tracking and discoverability; 3) exploration of downstream impacts of instrument use and data generation; and 4) increasing transparency of research that is based on the use of research facilities and instruments.

To finalize key project outputs and recommendations, the FAIR Facilities and Instruments RCN hosted its third in-person workshop at the NSF National Center for Atmospheric Research, in Boulder, CO, on September 22-24, 2025. Fifty individuals from academic institutions, national laboratories, nonprofit organizations, and private industry participated in the workshop. A small number of additional participants were able to join portions of the workshop remotely. Participants traveled or attended remotely from 14 states representing every region of the United States. Participants also represented a wide range of research disciplines, including biomedical science, geological science, environmental science, space science, materials science, and more. The project team and participants contributed to extensive notes from the presentations and breakout discussion sessions, which were used to produce this workshop report². For information about prior workshops hosted by this project, please see the reports from the events held in Sept. 2023 in Boulder, CO, and in Aug. 2024 in Tallahassee, FL³.

Report Structure

This report begins with a brief overview of the workshop scope, goals, and structure. We then provide a set of key observations and associated recommendations that derive from the workshop discussions. The report concludes with a set of appendices that describe important

² Workshop presentations are available at:

<https://ncar.github.io/FAIR-Facilities-Instruments/presentations#september-2025-workshop-at-nsf-ncar-mesa-laboratory>

³ Johnson, A., Julian, R., Mayernik, M., Mundoma, C., Murray, M., Ranganath, A., & Stossmeister, G. (2024). FAIR Facilities and Instruments Workshop #1 Report: Exploring Persistent Identifier Needs, Barriers and Incentives. NCAR Technical Note. (NCAR/TN-577+PROC). Boulder, CO: NSF National Center for Atmospheric Research. <https://doi.org/10.5065/zgsx-2d06>

Julian, R., Johnson, A., Mayernik, M.S., Mundoma, C., Murray, M., & Ranganath, A. (2024). FAIR Facilities and Instruments Workshop #2 Report: Recent Progress, Remaining Challenges, and Emerging PID Strategies. NCAR Technical Note. NCAR/TN-586+PROC. Boulder, CO: NSF National Center for Atmospheric Research. <https://doi.org/10.5065/jea7-yf24>

definitions of key terms discussed in the workshop, such as instrument, facility, and platform. The following appendices provide additional supplementary information related to the workshop:

- Appendix I - Definitions of key terms
- Appendix II - Workshop participants and steering committee members
- Appendix III - Workshop agenda
- Appendix IV - Breakout session discussion questions by workshop theme

Workshop Structure

The workshop was organized into four sessions, each designed to foster idea-sharing and in-depth discussions, and to discuss recommendations for implementing PIDs for research facilities and instrumentation. For each session, there were a set of 3-4 topical talks to provide ideas and real-world experiences, followed by discussions to dig into each specific topic. The first two sessions specifically focused on a document titled “Draft Recommendations For FAIR Facilities and Instruments RCN” that was circulated to all attendees before the workshop. Thus, any mention of “recommendations” below are referring to the draft reviewed by attendees. To avoid confusion, we do not include the draft recommendations document in this report. The final recommendations, which were revised based on input from workshop participants, are available in a separate document here: <https://doi.org/10.5281/zenodo.18436644>

SESSION 1 - General Recommendations & PID Systems – This session focused on fostering discussion on general recommendations related to PID implementations that would be applicable to all potential stakeholders, and discussions specific PID systems that are most relevant, including the Digital Object Identifier (DOIs), Research Resource Identifier (RRIDs), and Research Organization Registry (ROR) systems.

SESSION 2 - Stakeholder-Specific Recommendations – This session focused on fostering discussion on recommendations related to PID implementations that would be specific to particular stakeholder groups, such as instrumentation providers, data professionals, publishers, and others.

SESSION 3 - Connections Between PIDs for Related Resources – This session focused on motivations and approaches for establishing connections between related PIDs. Examples include connections between instruments and datasets that they produce, and between the people and organizations who manage research facilities and instrumentation.

SESSION 4 - Moving Forward – Strategies and Next Steps – A group-wide discussion to identify big-picture outcomes, actionable steps, and strategies for participants to engage their respective communities in advancing PID practices.

Each of the sessions featured some plenary speakers (slides from presentations can be found on the [project website](#)) followed by group discussions. For the first three sessions, breakout groups were organized with pre-selected questions to guide discussion. In each breakout

session, participants were asked to identify key takeaways to highlight for the full group and for this final report. The final session was conducted with the entire group to enable reflection on discussions in the earlier sessions, and to explore ways in which participants might engage with their intellectual and professional communities after the workshop.

Findings and Next Steps

This section describes discussions and takeaway points that took place during the breakout sessions at the workshop. The following sections are organized around the questions that were pre-organized for each breakout session. We highlight a key takeaway point in bold in each section.

Session 1: General Recommendations

Question 1: What takeaways or questions do you have from the presentations?

Participants expressed appreciation for the comprehensive overview of different PID systems but noted confusion about the specific recommendations each provider was making for implementation. There was recognition that while each PID system serves unique purposes, clearer guidance is needed on how these systems work together and when to use each one. Several groups emphasized the value of understanding PIDs as interconnected ecosystems rather than isolated tools, with the ability to link different types of research objects being a key benefit. Participants questioned who would be responsible for maintaining PIDs over the long term, particularly given the evergreen nature of these identifiers. There was also interest in understanding timelines for enhanced interoperability between different PID systems and the development of fields for specific parameters relevant to instruments and facilities. Overall, while participants found the presentations informative, ***they identified a gap between understanding what PID systems can do and knowing what specific actions different stakeholders should take to implement them effectively.***

Question 2a: How would these recommendations help you?

For facility managers and administrators, the recommendations provide a framework for demonstrating return on investment and tracking research outputs, which is essential for justifying continued funding and resource allocation. Several noted that standardized PID usage would make it significantly easier to measure institutional impact and track how facilities contribute to research publications and datasets. For those involved in building cyberinfrastructure and data management systems, the recommendations offer clear direction for project development and help orient new team members. Librarians saw the

recommendations as valuable tools for outreach work, helping them guide researchers toward appropriate PID adoption. The recommendations were also viewed as useful justification for feature requests to repository operators and data management software developers. Multiple participants noted that ***having community-endorsed guidelines would provide leverage when advocating for institutional resources and policy changes, moving the conversation beyond individual preference to community standard practice.***

Question 2b: What needs more explanation?

The most frequently cited need for additional explanation concerned decision-making criteria for choosing among different PID systems, particularly when use cases overlap or when different stakeholders might interpret facility types differently. Participants requested more detailed elaboration of each use case with clear examples that illustrate the distinctions between them. There was confusion about the overlapping concepts of attribution, traceability, and provenance, with questions about whether these represent different stakeholder perspectives (human versus machine) or fundamentally different types of information tracking. Several groups asked for more specific guidance on implementation mechanics, such as how to query DataCite for RRIIDs or how different PID systems can point to external documentation and metadata. Participants also sought clarity on the definitions of different facility types—particularly the distinction between core facilities, research facilities, and platforms—and how these definitions map to appropriate PID systems. The level of specificity in metadata requirements for different use cases was another area where participants felt more explanation would be valuable.

Question 2c: What other recommendations are needed? What is missing?

Participants identified several gaps in the recommendations that need to be addressed. Most prominently, ***there was a call for clear guidance on institutional roles and responsibilities, specifically identifying who should lead PID initiatives at the organizational level rather than leaving this to individual labs or researchers.*** Multiple groups requested more specific recommendations for publishers, including concrete language for author guidelines and workflows for handling PID requirements without becoming the "PID police." Participants also sought guidance on maintenance and lifecycle management, including best practices for tombstoning or retiring PIDs when facilities close or instruments are decommissioned. The recommendations were seen as needing more context-specific examples showing minimal viable implementations—what facilities should do if they can only allocate resources for one or three initial steps. There was interest in recommendations for tracking not just data and publications, but also the research conducted by facility staff themselves. Several groups emphasized the need for recommendations that address equity concerns, ensuring that small institutions and under-resourced facilities can see themselves in the implementation pathway and are not disadvantaged by resource-intensive requirements.

Question 2d: What more would you need (details, information, examples) to move forward with implementations?

Participants consistently requested concrete, detailed examples of successful PID implementations across different institutional contexts and facility types. These examples should illustrate complete workflows from initial assignment through ongoing maintenance, showing who is responsible for each step and what resources are required. Multiple groups asked for specific templates and forms that could be adapted for their contexts, such as publisher templates that funders could encourage or require, repository submission forms with appropriate PID fields, and standardized approaches for different types of facilities based on their funding sources. There was strong interest in seeing exemplar facilities that have implemented comprehensive PID systems, with documentation of their processes and outcomes that others could learn from. Participants wanted guidance on practical integration questions, such as how to incorporate PIDs into electronic lab notebooks, how to handle situations where compute facilities process data that then moves to other repositories, and how to track both the use of facilities and the outputs generated. Several groups emphasized the need for language and justification materials that could be used when advocating to university leadership or other decision-makers, including strong case statements with specific examples of how and why PID adoption benefits institutions beyond general principles of good practice.

Question 3: When choosing a PID - What should somebody do if all of the use cases apply?

Participants acknowledged this as a challenging scenario but offered several approaches. The most common suggestion was to let metadata requirements drive the decision—identifying what specific metadata needs to be captured and then selecting the PID system best suited to accommodate those requirements. Several groups recommended adopting a principle of consistency: once a PID system has been established for a particular use case within a community or institution, continue using that system rather than introducing additional PID types that could create confusion. There was recognition that in many situations, multiple PIDs might be appropriate or necessary, with different identifiers serving different stakeholder needs and linking to one another to create an ecosystem of interconnected research objects. ***Some participants advocated for a pragmatic approach captured in the phrase "get an identifier"—emphasizing that having some PID is better than having none, and that users shouldn't be paralyzed by the decision of which system is theoretically optimal.*** The metadata associated with each PID type and the community norms within specific disciplines were also mentioned as important factors in making this choice. Overall, there was agreement that clearer use case definitions and decision support tools would help address situations where multiple PIDs seem applicable.

Question 4: What decision-support tools would be most helpful?

While participants recognized that decision trees and flowcharts could be useful, there was strong emphasis that these tools alone would be insufficient and should be complemented by narrative case studies organized by stakeholder type. Multiple groups stressed that decision trees are only helpful if they are comprehensive and foolproof, and that oversimplified diagrams might create more confusion than clarity. There was particular interest in visual tools that could be printed as posters and displayed in facilities, potentially with customizable elements where individual facilities could add their own specific PID information. Participants repeatedly called for concrete examples and narrative best practices that show how different types of organizations have successfully implemented PIDs, as these story-based approaches may be more accessible than purely algorithmic decision aids. Templates for common scenarios were frequently mentioned as valuable tools, including templates for publisher workflows, repository submissions, and funder reporting requirements. Several groups suggested that a living document hosted on a platform like README or Read the Docs, maintained by a community of practice, would be more valuable than static guidance documents. There was also interest in tools that could be endorsed and promulgated by professional societies, with some discussion of award or badge systems that could incentivize adoption by recognizing exemplary implementations.

Question 5: What metadata is needed for each use case? Where should the metadata live?

Participants grappled with the tension between comprehensive metadata and practical implementation, with multiple groups endorsing a "minimum viable metadata" approach that captures essential information without creating burdensome requirements. **There was recognition that much of the detailed metadata for instruments and facilities might best live in linked resources—such as associated publications, datasets, or dedicated documentation pages—rather than being embedded directly in the PID record itself.** The concept of PIDs serving primarily as linkers between research objects was emphasized, with minimal metadata in the PID record and richer information accessible through the connections it enables. Different use cases were seen as requiring different metadata elements: traceability requires information about parent organizations and institutional affiliations; attribution needs funding information and contributor details; reproducibility depends on links to publications, datasets, and methodological documentation; and provenance requires capturing relationships with other relevant research objects.

Some participants noted that existing PID systems like DataCite already have mechanisms for linking to external metadata schemas, and that leveraging these capabilities might be more practical than trying to accommodate all necessary metadata within a single PID system. There was concern that overly demanding metadata requirements could become barriers to adoption, with the recognition that some level of metadata standardization is necessary for machine actionability but that perfection should not become the enemy of completion. The challenge of maintaining metadata over time was also noted, particularly for instruments that undergo modifications or facilities that evolve in their capabilities and configurations.

Session 2: Stakeholder Recommendations

Question 1: What takeaways or questions do you have from the presentations?

Participants appreciated seeing concrete examples of PID implementation in action, particularly presentations that showed automated workflows and data traceability systems. There was interest in understanding how to replicate successful implementations, with some questions about the processes used by groups that had built comprehensive PID systems for microscopy and other scientific domains. Several groups raised concerns about duplication of effort, noting that RRIDs may be created without facility operators' knowledge through various projects and platforms, leading to potential confusion about which PID should be considered authoritative. The persistent ambiguity around facility definitions emerged again, with participants struggling to understand when something should receive an RRID versus a ROR identifier, and whether some entities might legitimately need both.

There was recognition that FAIR principles mean different things to different communities and may change over time, with acknowledgment that some research communities are far more advanced in implementation than others. Questions about data availability statements and where facilities should be cited in publications—whether in reference sections, acknowledgments, or methods—revealed ongoing uncertainty about citation practices.

Participants emphasized that while some groups have achieved sophisticated automation, many facilities are still far from that level of maturity, raising questions about how to move from current practices toward more automated, FAIR-compliant workflows.

Question 2a: How would these recommendations help you?

All groups saw potential value on our draft recommendations, but also saw room for improvement. For researchers working with complex data workflows, the recommendations provide a framework for building data traceability from field samples through various types of analysis, helping to guide best practices and show communities what data is emerging from facilities. The emphasis on leveraging PIDs and their metadata offers a pathway toward reducing redundant data entry, which is essential for convincing researchers to participate. For data professionals and repository managers, specific use cases and providing tools for visualizing progress toward recommendations would be valuable, particularly specifications like PIDINST that could help identify repositories demonstrating compliance with FAIR and related principles. PID infrastructure providers saw the recommendations as useful for making cases to prioritize certain features, such as including RRIDs in ROR records or accelerating timelines for enhanced interoperability. For facility and instrument providers, the recommendations offer validation for efforts to gain recognition and demonstrate return on investment, though participants stressed that guidance needs to be much more specific to be truly implementable. Publishers indicated that clear recommendations would help standardize expectations across

journals and societies, though implementation complexity varies depending on whether publishers have centralized control or work with diverse organizational partners.

Question 2b: What needs more explanation?

Across all stakeholder groups, there was demand for more specific guidance on implementation mechanics and decision-making processes. Facility and instrument providers requested clearer explanations of PID hierarchy, more guidance on who should be responsible for PID assignment at different administrative levels, and workflows for sunseting or tombstoning PIDs when facilities close or instruments are retired. They also emphasized the need for discipline-specific guidance, noting that engineering workflows differ significantly from medicine and health sciences. Data professionals sought clarification on limitations of repository fields for implementing PIDINST, questioning where and how this metadata should be captured, who maintains landing pages, and whether a specific PIDINST type of DOI is needed. The governance component was repeatedly identified as missing, with questions about succession planning, ownership, and long-term responsibility. PID infrastructure providers needed clarification on which PIDINST metadata guidelines specific systems should align with, particularly when those systems do not identify certain types of objects. There was also confusion about the technical requirements for machine readability and resolvability, with requests for clear definitions that would support integration with knowledge graphs and other emerging technologies. Publishers wanted more explanation of how citation of instruments and facilities should work across the entire ecosystem, including guidance for reference management systems and clarity on where citations should appear in different sections of publications.

Question 2c: What other recommendations are needed? What is missing?

Multiple groups identified the need for governance recommendations that address succession, ownership, and responsibility for both PIDs and their associated landing pages. There was strong demand for guidance on PID lifecycle management, including processes for tombstoning, sunseting, and updating PIDs as facilities evolve or close. Participants requested specific recommendations for different scenarios using a "good, better, best" framework that would show what minimal, intermediate, and optimal implementations look like. Data professionals emphasized the need for clarity about where PIDs should be captured when ideal infrastructure is not available, acknowledging that sometimes README files may be the only option even if not ideal. There were calls for specific templates and tools, including a Data Curation Network primer for PIDINST and customizable templates that different communities could adapt. Publisher-specific recommendations were identified as sparse, with needs for concrete author guideline language and workflows that could be implemented across diverse journal management systems. Recommendations for addressing the scale challenges of large datasets and multiple README files were requested, as was guidance on controlled vocabularies that are not yet linked to PIDs in many life sciences repositories. Several groups requested more explicit discussion of incentives at multiple levels—for researchers, manufacturers, institutions, and other stakeholders. There was also recognition that

recommendations should address how PIDs fit into protected research environments where FAIR does not necessarily mean open.

Question 2d: What more would you need (details, information, examples) to move forward with implementations?

Participants across all groups requested concrete, detailed examples showing PID implementation from start to finish. These examples should cover diverse scenarios including different facility types, funding sources, institutional structures, and disciplinary contexts, illustrating the complete workflow from initial PID creation through ongoing maintenance and eventual sunseting. There was particular interest in seeing "good, better, best" scenarios that would show what is achievable with different resource levels.

Researchers wanted to understand the specific processes used by groups that have successfully implemented automated workflows, including access to schemas, templates, and documentation that could be adapted for other scientific domains. Visual aids such as flowcharts that could guide metadata entry and point users to relevant resources were repeatedly requested. Data professionals sought tools for measuring and visualizing progress toward recommendations, as well as specific guidance on overcoming repository field limitations when implementing PIDINST. Publishers needed detailed author guideline language that could be incorporated into submission systems, along with disambiguation tools such as dropdown menus populated with existing facility PIDs.

Facility and instrument providers wanted outreach materials and toolkits for communicating value to researchers and administrators, including language for justifying resource allocation and demonstrating return on investment. Several groups requested examples of how to query existing PID systems to track usage and impact, such as finding all datasets that used a particular instrument or all publications that emerged from a specific facility. There was also interest in understanding the practical mechanics of creating landing pages, maintaining metadata, and establishing institutional workflows with appropriate contact points and procedures.

Question 3: In the ideal scenario, who should be responsible for creating and maintaining the PID and metadata for the item? Who do you think will actually take responsibility?

For facility-level PIDs, there was general consensus that facility managers should ideally be responsible, though the practical realities of institutional structures created significant complexity. Multiple groups suggested that offices of research are logically positioned to lead this work given their connection to facilities and their authority to encourage adoption and create standards, though some participants felt this responsibility might fall to libraries despite libraries often lacking resources for new work. The most practical suggestion was collaboration between

Vice Presidents for Research and libraries, with clear workflows and contact points established at the institutional level.

For instrument-level PIDs, the ideal scenario would involve manufacturers taking responsibility, potentially building on existing structures like serial numbers to create persistent identifiers. However, there was widespread skepticism about whether sufficient incentives exist for manufacturer participation, particularly for established large manufacturers. Participants suggested that smaller and newer manufacturers might be more willing to engage, and that modified or uniquely configured instruments might require facility or researcher-level PID creation. Across all groups, there was recognition of a significant gap between who should ideally be responsible and who will actually take responsibility, with concerns that researchers will only act if explicitly required to do so, and that institutional structures often lack designated parties to lead these efforts. ***The reality of decentralized academic environments means that responsibility often remains unclear, and successful implementation will likely require coordination across multiple stakeholders including offices of research, libraries, facility managers, and in some cases, manufacturers and publishers.***

Question 4: When does something become important enough to assign a PID?

This question generated diverse perspectives reflecting different stakeholder priorities and contexts. For researchers, the answer often depends on whether something will be referenced in publications or datasets, with the understanding that anything contributing to reproducibility or traceability probably warrants a PID. There was discussion about whether individual lab groups or research teams should receive PIDs, recognizing that the boundary between what constitutes an assignable entity is not always clear. From a facility perspective, the question relates to whether the facility or instrument provides a distinct service or capability that others might want to cite or track, with recognition that even small or emerging capabilities could become important over time. Data professionals emphasized that the decision should be driven by discoverability needs and whether tracking usage and impact would provide value to stakeholders. Publishers framed the question in terms of what information is needed for proper attribution and reproducibility, suggesting that if readers would need to know about a facility or instrument to understand or replicate the research, it merits a PID.

There was also discussion about the costs and sustainability of PID systems, with recognition that assigning PIDs to everything is neither feasible nor necessary. Several participants suggested that the threshold should be relatively low—that it is better to have PIDs for things that might become important rather than waiting for definitive proof of importance, since retroactive PID assignment is more difficult. ***The concept emerged that PIDs become part of discovery mechanisms, and that making facilities and instruments discoverable through PIDs creates value even before extensive usage tracking is established.*** Overall, there was recognition that different communities and contexts will have different thresholds, and that guidance should help stakeholders think through the decision rather than providing a universal rule.

Session 3: PID Connections

Question 1: What takeaways or questions do you have from the presentations?

Participants expressed interest in understanding the practical mechanics of creating and maintaining PID connections, such as connections between DOIs for resources, Open Research and Contributor Identifiers (ORCID), ROR identifiers for organizations, and others. There is difficulty in seeing whether linkages are actually happening and where breakdowns occur when expected connections do not appear. There was recognition that governance is an undervalued but critical aspect of PIDs in what institutions and researchers are paying for when they invest in PID systems. Multiple groups noted the tension between establishing systems (which is relatively straightforward) and maintaining them in practice, which requires sustained resourcing and dedicated personnel that many institutions lack.

Concerns were raised about the lack of standardization across repositories and publishers, particularly for novice users who struggle with inconsistent guidance on tracking publications and connecting research objects. The importance of relationship types between PIDs emerged as a key theme, with participants noting that vague relationships like "isrelatedto" provide little value compared to precisely defined linkages. There was surprise at the lack of consistency across institutions and a desire for more clarity about gray zones where different PID systems might overlap or compete. ***Participants also emphasized that funders and publishers are the main drivers of PID adoption—researchers typically will not provide information without policy requirements, as evidenced by data sharing becoming standard practice only after it became a mandated policy.***

Question 2: What are your main use cases or purposes for wanting PIDs to be connected?

The most frequently cited use case across groups was establishing trust and validating data provenance in an increasingly fraught knowledge ecosystem, particularly given concerns about generative AI and the proliferation of low-quality or fabricated data.

Attribution and credit emerged as central concerns, with participants noting that many contributors to the research process—including technicians, coders, software developers, and facility staff—currently receive no recognition through traditional citation mechanisms. Discovery and findability were identified as primary use cases, enabling researchers to locate instruments, understand what capabilities exist within their institutions or regions, and find comparable resources elsewhere. Institutional research information systems require PID connections for faculty promotion and tenure evaluations, hiring decisions, graduate student admissions, contracts, and grants administration. Minimal acceptable policies are needed for these use cases for a variety of environments.

Compliance and regulatory tracking represented another critical use case, with examples including groundwater well monitoring in California where multiple government bodies reference the same sites using different identifiers. Reproducibility depends on connecting specific instruments to experiments and datasets, with examples highlighting how calibration issues or subtle differences between identical instrument models can significantly impact research outcomes. Benchmarking facilities against one another using analytics about user numbers, publications, and capabilities was identified as an important but currently difficult task. Several participants discussed building knowledge graphs to aggregate institutional information and create semantic linkages, essentially creating recommendation systems for research resources similar to commercial platforms.

Question 3: In what cases would a "package PID" like a RAID be helpful and important? How do you see the "package PIDs" being used?

Participants saw potential value in package PIDs, though opinions varied about specific applications. The strongest support came for project-based environments where RAIDs could connect various PIDs associated with a single research effort, including data, instruments, facilities, publications, funders, and contributors. This would be particularly valuable for universities trying to track work happening across their institutions and for establishing equivalencies between internal identifiers and external PIDs—essentially creating a "Rosetta Stone" of connected identifiers. Package PIDs were seen as solutions to specific technical challenges, such as publishers' resistance to huge lists of individual dataset citations, which typically get relegated to supplemental materials that are not crawled or indexed.

For compliance scenarios like tracking groundwater wells referenced by different government bodies with different identifier systems, package PIDs could pull together legacy identifiers with current ones, maintaining continuity as administrative structures change. Concerns were raised about versioning challenges—whether package PIDs could effectively track instruments that undergo significant modifications over time, with some arguing that changed instruments should receive new PIDs while funders want continuous tracking. There was also some questioning about whether fully integrated PID ecosystems would even need package PIDs, or whether RAIDs represent a workaround for current ecosystem fragmentation.

Question 4: Where are PID connections most important: in PID metadata or in metadata available at the source (e.g. at PID landing page)?

This question generated discussion about the appropriate distribution of metadata across different locations. ***There was general agreement that landing pages serve important human-readable functions while PID metadata needs to support machine-actionable connections.*** Several participants argued against overloading PID metadata, suggesting that not everything needs to be embedded in the PID record itself and that the concept of "resource type" depends heavily on use case. The importance of having at least one additional relationship beyond simple location was emphasized, but concerns about duplication of

metadata and the challenges of keeping multiple locations synchronized led to caution about where information should reside.

Questions emerged about whether metadata should be manually or automatically updated and what processes exist for human verification and correction. There was recognition that concrete examples are needed to illustrate best practices for different scenarios. Some participants suggested that PID metadata should capture minimal essential information with richer detail available through linked resources, while others emphasized that certain critical connections must be machine-readable in the PID metadata to enable automated discovery and validation. The tension between control and flexibility was noted, with acknowledgment that different disciplines may require different approaches and that a finite set of options might be needed if one solution cannot work for everyone. Overall, the discussion revealed that this remains an area requiring clearer guidance about what constitutes appropriate metadata distribution for different use cases.

Question 5: When should a reference publication be cited *in addition to or instead of* the facility or instrument PID?

There was consensus that reference publications should generally be cited in addition to rather than instead of facility or instrument PIDs, with participants warning against perpetuating problematic practices from the existing scholarly communication ecosystem. Groups emphasized the importance of not overvaluing journal articles as the only valid form of scholarly communication or reinforcing systems based on impact factors and citation scores. Participants noted that it is much easier to assign a PID to an instrument than to write, publish, and obtain a PID for a paper about that instrument, and that focusing solely on publication citations fails to give credit to the people who created the data or maintain the instruments. Reference publications should only be cited when they provide additional relevant information, such as detailed assessments, reviews, or comparisons of instruments that would help researchers understand capabilities or methodologies. The static nature of articles was contrasted with the dynamic nature of data and instruments, which may change over time but still merit direct citation. Several participants explicitly stated that the community should not cave to the broken scholarly communication environment and should instead work to establish better practices around direct citation of research infrastructure. However, there was acknowledgment that current publisher requirements and tenure systems create strong incentives for article citations, making this cultural change challenging. The discussion also touched on how reference publications can cause confusion when it is unclear what aspect of the resource is being referenced or why a particular citation was chosen. Participants emphasized that software, data, and instruments deserve recognition in their own right and that building these citations into systematic processes—rather than treating them as secondary to article citations—is essential for proper attribution and reproducibility.

Conclusion

To make changes in the research ecosystem, it is necessary to understand the different stakeholders involved, along with their interests, concerns, and incentives. It is easy to understand why PIDs are useful to people in the infrastructure sector and to people who are looking at the research ecosystem from a larger point of view, whether for management or assessment purposes. It is still worth thinking more about how the typical researcher benefits from the efforts in our project and other similar projects to assign and use PIDs.

This workshop provided more insight into how the PID ecosystem is evolving, and how it might be optimally used to assign identifiers to research facilities and instruments. As discussed above, PID proliferation is real, and the PID ecosystem can be hard to understand, particularly for newcomers. Power dynamics are important in understanding the PID ecosystem: including the ongoing power and boundary negotiations between PID providers, the power dynamics of funder needs for impact measures for the facilities and instruments that they fund, and the power (or lack thereof) of facility and instrument providers to influence researcher citation behavior. Overall, there are still questions about who has the power to influence how researchers will adopt PIDs.

It was emphasized at the workshop, however, that the PID systems being discussed most prominently—DOI, RRID, ROR, ORCID—are all mature systems at this point with strong embedding in publisher workflows and other research information systems. Even if there is still uncertainty about the boundaries and optimal use cases for each type of identifier, potentially interested parties should not be paralyzed in choosing the right one to use. Regardless of which one is chosen, they all will likely provide some benefits, though it is important to recognize that these PID systems are still incomplete in their ability to measure impact. It was noted that compiling citations using these PIDs is still challenging.

Workshop discussions emphasized that generative AI tools are turning PIDs from being “nice to have” to “need to have,” as these tools are known to have problems with transparency and provenance. The emergence of these tools and their use within research contexts is raising questions about how they can be situated within the open science movement. Where do the responses from AI tools come from? What resources do they draw on? What sources back up their outputs? These questions make the PID work in our project and across the research sector particularly timely.

One potential benefit of PIDs that was emphasized at this workshop more than at previous project workshops was the idea that PIDs have a key role to play as linkers between research objects. As one participant said, “the PID superpower is how we link things together.” This can include linking related resources (such as instruments with the datasets they produce) as well

as linking the metadata in the PID's metadata record to richer metadata accessible elsewhere. Clarifying what knowledge and insights are to be gained from PID graphs is important to informing how they could and should be built. For example, PIDs might best serve as a mechanism to make connections between entities visible to external parties, whereas internal systems can be used to track and analyze these connections for purposes that are internal to a particular organization. Participants recognized that detailed metadata for instruments and facilities might best live in linked resources, like publications, datasets, or documentation pages, rather than in PID metadata itself. Landing pages serve human-readable functions while PID metadata supports machine-actionable connections; reference publications should generally be cited alongside PIDs. Participants also saw value in "package PIDs" pointing to compilations of related PIDs. While some groups have achieved sophisticated automation of PID assignment, many facilities are far from that maturity.

The workshop participants were in agreement that moving the community forward in PID implementation needs to be the next step of this coordination effort. Success will result when the community works together to move implementations forward across sectors. Funders and publishers are the main drivers of PID adoption—researchers typically will not provide information without policy requirements, as evidenced by data sharing becoming standard only after mandates. But it will be very difficult to make changes in publishers' workflow due to resource and attention limitations. In the few cases where changes are made, the motivations have to be clear and the work should be as "one-time" as possible. All stakeholder groups should hold themselves and each other accountable and measure progress through clear and open measures. It is especially important that we be attentive to potential extractive aspects of PIDs and the data ecosystem. This will require that we work on governance that is inclusive of broad groups and stakeholder interests.

Participants identified gaps between broad understanding of what PID systems can do and knowing what specific actions stakeholders should take to implement them. Community-endorsed guidelines would provide leverage when advocating for institutional resources and policy changes, moving conversations beyond individual preference to standard practice. Participants need help with decision-making criteria for choosing among PID systems and clarity on who should lead initiatives at the organizational level rather than leaving this to individual labs.

There was strong demand for concrete examples showing PID implementation from start to finish across different contexts and facility types. Decision trees and flowcharts were seen as useful but insufficient without narrative case studies organized by stakeholder type. All groups saw value in the project's draft recommendations while identifying room for improvement. Multiple groups identified the need for governance recommendations addressing succession, ownership, and responsibility for PIDs and their landing pages. Successful implementation will likely require coordination across offices of research, libraries, facility managers, and in some cases manufacturers and publishers.

Workshop participants noted several practical steps and actions they hope to take based on their workshop experiences:

- Expose ORCID IDs in PID metadata where possible
- Integrate PIDs into facility and instrument allocation workflows
- Share experiences in assigning PIDs
- Advocate for PIDs when launching new core facilities
- Continue community discussions at future meetings
- Evaluate package PIDs (like RAID and Complex Citation Objects) within facility and publisher PID workflows

Finally, participants also indicated various types of resources that would be useful to take these discussions to their own collaborators and communities:

- Grab and go slide decks or one page documents with key messages that can be distributed other colleagues
- Email list to continue discussions on these topics outside of workshops
- Visually oriented guidance documentation, such as a flowchart, to encapsulate the project recommendations (e.g. how the PIDs are created, used, and connected to other things, how repositories ingest metadata, etc.
- Position paper focused on describing why supporting facilities and instruments is important for research institutions
- For publishers, use cases and metrics on community adoption of PIDs would be helpful to incentivize further support within publication workflows
- Value statements for specific stakeholders—especially institutions, repositories, and researchers
- PID systems that work together to share information automatically—if you know one PID, can that help you find all the others
- Guidance for non-experts with clear definitions that are understandable to general audiences

Appendix I - Definitions

Here we provide our working definitions of a number of key terms, drawing where relevant on already established resources. These definitions were also used in our first workshop report (see reference in footnote 3 above). We emphasize that these definitions are provided to clarify the use of these terms within this report. Broadly, however, there are no standard definitions for “instruments” or other terms below that are widely and consistently agreed upon across the research sector.

- **Persistent identifier (PID)** - Also known as a digital persistent identifier (DPI or digital PID), a PID is “a unique digital identifier that permanently and unambiguously identifies a digital object or an individual.” A PID is globally unique, persistent, machine actionable, and has an associated metadata schema.⁴
- **Facility** - A place that provides researchers with access to specialized instruments, platforms and expertise to conduct their research. Examples include biotechnology laboratories, nanotechnology laboratories, and astronomical observatories. This definition also includes core facilities, shared facilities, shared research resources, and related terms.⁵ Some facilities are part of larger organizations (e.g. core facilities are part of universities) while others facilities are standalone organizations (e.g., national laboratories).
- **Instrument** - “A device used for making measurements, alone or in conjunction with one or more supplementary devices”⁶. Instruments also include devices that collect and create data, create other types of objects, and process and prepare samples. Instruments may have configurations or settings that change over time or in relation to specific experiments and might need to be recorded in the metadata. Instruments also need regular maintenance and calibration to ensure they continue performing correctly. Instruments can range in size, for example from small temperature sensors to more complex microscopes, X-ray MicroCT scanners, and RADAR and LIDAR devices.⁷
- **Platform** - An entity that might be a carrier or base for multiple instruments - e.g. a satellite that contains multiple instruments and generates multiple discrete data streams. Other examples include research aircraft, ships, uncrewed aerial systems, or ground-based systems that are deployed to collect varied types of data. For the purposes of these recommendations, networks of instruments are also included in this definition. An example is a seismic network that has multiple instruments deployed on different sites.

⁴ National Science and Technology Council (NSTC). 2022. *Guidance for Implementing National Security Presidential Memorandum 33 (NSPM-33) on National Security Strategy for United States Government-Supported Research and Development: A Report by the Subcommittee on Research Security*. Joint Committee on the Research Environment. <https://trumpwhitehouse.archives.gov/presidential-actions/presidential-memorandum-united-states-government-supported-research-development-national-security-policy/>

⁵ <https://sr.ithaka.org/publications/what-is-a-research-core/>

⁶ *International Vocabulary of Metrology. Basic and General Concepts and Associated Terms* (VIM 3rd edition, 2012). <https://www.bipm.org/en/publications/guides/#vim>

⁷ For the purposes of these recommendations, social science instruments (such as surveys) are not considered to be part of this definition. While PIDs may be valuable for social science instruments, many of the PID considerations for the types of instruments included in this definition do not apply to typical social science instruments.

Appendix II - Workshop Participants and Advisory Committee Members

Workshop Participants

NAME	ORGANIZATION
Adi Ranganath	University of Colorado Boulder
Amanda French	Crossref / ROR
Andrew Johnson	University of Colorado Boulder
Anita Bandrowski	UCSD / SciCrunch / RRID
Bill Manley	University of Colorado Boulder
Caterina Strambio-De-Castillia	UMass Chan Medical School
Chris Lenhardt	NSF NCAR
Claire Martin	StraboSpot
Claudius Mundoma	Stanford University
Dave Hart	NSF NCAR
David Butcher	National MagLab
David Elbert	Johns Hopkins University
Don Brower	University of Notre Dame
Doug Fils	UCSD / SDSC
Dylan Ruediger	Ithaka S+R
Edyta Vieth	UCSD / SciCrunch / RRID
Gary Motz	Yale Peabody Museum
Hannah Ake	California Water Data Consortium
Hazel Shapiro	Interagency Arctic Research Policy Committee (IARPC)
Huajin Wang	Carnegie Mellon University

J.J. Hill	Smithsonian Institution National Museum of Natural History/NoCTURN [NSF, RCN]
Jim Riley	EarthScope Consortium
Jon Petters	Virginia Tech
Karen Dedinsky	UW RAPID Facility
Kassidy Hof-Mahoney	Florida State University
Kristina Vrouwenvelder	American Geophysical Union
Lauren Marra	PLOS
Lauren Phegley	University of Pennsylvania
Marc Segers	AIP Publishing
Maria Esteva	Texas Advanced Computing Center
Mark Parsons	Earth Science Information Partners
Matt Harp	Arizona State University Library
Matt Mayernik	NSF NCAR
Matt Ramey	NSF NCAR
Matthew Murray	University of Colorado Boulder
Moira Downey	NC State University
Nate Herzog	CoreMarketplace
Neil Byers	US DOE Joint Genome Institute
Parul Tewatia	Scilifelab Data Centre
Rebecca Hudak	Rolling Deck to Repository (R2R)
Rebecca Ringuette	NASA's Heliophysics Digital Resource Library
Renaine Julian	Florida State University
Sarah Siddiqui	University of Rochester
Sean Wilkinson	Oak Ridge Leadership Computing Facility
Seonyoung Kim	WashU Medicine Becker Medical Library
Shawna Sadler	ORCID

Shelley Stall	American Geophysical Union
Ted Habermann	Metadata Game Changers
Thayumana Somasundaram	Florida State University
Tom Colella	Arizona State University

Advisory Committee Members

- **Anita Bandrowski** - Founder and CEO of SciCrunch
- **David S. Butcher** - FAIR data management specialist at the National High Magnetic Field Laboratory
- **Matthew Buys** and **Kelly Stathis** - Executive Director and Technical Community Manager at DataCite
- **Zach Chandler** - Director of Open Scholarship Strategy, Stanford Data Science Initiative, Stanford University
- **Nate Herzog** - CoreMarketPlace project lead at Vermont Genetics Network
- **Kevin Knudtson** - Past-President of the Association of Biomolecular Resource Facilities (ABRF)
- **Giri Prakash** - Section Head of the Earth System Informatics and Data Discovery section at Oak Ridge National Laboratory
- **Dylan Ruediger** - Senior Program Manager at Ithaka S+R
- **Shawna Sadler** - Engagement Manager, Outreach & Partnerships work, ORCID
- **Shelley Stall** - Vice President, Open Science Leadership, American Geophysical Union (AGU)

Appendix III - Workshop Agenda

Workshop presentation materials are available at:

<https://ncar.github.io/FAIR-Facilities-Instruments/presentations#september-2025-workshop-at-nsf-ncar-mesa-laboratory>

SEPT 22 - DAY 1 PM 12:30-5:00 PM : Introductions and High-Level Insights

- 12:30 - 1:00 Participants arrive and check-in
- 1:00 - 1:45 Workshop introduction & Project Progress
 - Matt Mayernik, FAIR Facilities and Instruments (FAIR F&I) Project Overview & discussion of key goals for the workshop
- 1:45 - 3:00 General Recommendations & PID Systems
 - Overview of general recommendations by FAIR F&I project team
 - (virtual) Maria Gould, DataCite
 - Amanda French, Research Organization Registry (ROR)
 - Anita Bandrowski, Research Resource Identification, RRID, initiative
- 3:00 - 3:30 Break
- 3:30 - 4:30 Breakout groups sessions - Topic: general recommendations
- 4:30 - 5:00 Breakout group reports and preview tomorrow

Sept 23 - DAY 2 9:00 AM - 5:00 PM: Stakeholder Recommendations & PID Connections

- 8:30 - 9:00 Participants arrive
- 9:00 - 10:45 Stakeholder-Specific Recommendations
 - Overview of stakeholder recommendations by FAIR F&I project team
 - Marc Segers, AIP Publishing
 - Nate Herzog, Core Marketplace
 - Caterina Strambio-De-Castillia, UMass Chan Medical School
 - David Elbert, Johns Hopkins Extreme Materials Institute
 - Moira Downey and Sarah Siddiqui, North Carolina State University and University of Rochester
- GROUP PICTURE
- 10:45 - 11:00 break
- 11:00 - 12:00 Breakout group sessions - Topic: specific stakeholder recommendations
- 12:00 - 1:15 Lunch
- 1:15 - 1:45 Breakout group reports
- 1:45 - 3:15 Topical talks - Connections Between PIDs for Related Resources
 - (virtual) Christine Kirkpatrick / Chris Erdmann, US Research Activity Identifier (RAiD) Pilot
 - David Hart, NSF National Center for Atmospheric Research
 - Neil Byers, US DOE Joint Genome Institute
- 3:15 - 3:30 Break
- 3:30 - Ted Habermann, Metadata Game Changers
- 4:00 - 5:00 Breakout group sessions - Topic: Connections between related resources using PIDs

**SEPT 24 - DAY 3 AM 9:00 - 12:00: What are the big picture outcomes and next steps?
How do we move forward and build upon these discussions with our communities?**

- 8:30 - 9:00 Participants arrive
- 9:00 - 9:15 Final day goals & Breakout group reports
- 9:15 - 10:30 Panel: Looking Forward From Different Stakeholder Perspectives
 - Mark Parsons, Earth Science Information Partners (ESIP)
 - Shawna Sadler, ORCID
 - Shelley Stall, American Geophysical Union
 - Dylan Ruediger, Ithaca S+R
- 10:30 - 10:45 Break
- 10:45 - 12:00 Final discussion, review next steps for workshop report, and requested participant actions

Appendix IV - Breakout Session Discussion Questions by Workshop Theme

SESSION #1 - Monday Sept 22 - GENERAL RECOMMENDATIONS

- What takeaways or questions do you have from the presentations?
- Regarding the Recommendations for All Stakeholders:
 - How would these recommendations help you?
 - What needs more explanation?
 - What other recommendations are needed? What is missing?
 - What more would you need (details, information, examples) to move forward with implementations, e.g. assigning PIDs to facilities or instruments?
- When choosing a PID - What should somebody do if all of the use cases apply?
- What decision-support tools would be most helpful? e.g. decision tree, flowchart, etc.
- What metadata is needed for each use case? Where should the metadata live, e.g. directly included as metadata for PID, or separate metadata that is accessible at the location where the PID resolves?

SESSION #2 - Tuesday Sept 23 - STAKEHOLDER-SPECIFIC RECOMMENDATIONS

- What takeaways or questions do you have from the presentations?
- Regarding the Recommendations for Specific Stakeholder Groups:
 - How would these recommendations help you?
 - What needs more explanation?
 - What other recommendations are needed? What is missing?
 - What more would you need (details, information, examples) to move forward with implementations, e.g. assigning PIDs to facilities or instruments?
- In the ideal scenario, who should be responsible for creating and maintaining the PID and metadata for the item? Who do you think will actually take responsibility?
- When does something become important enough to assign a PID?

SESSION #3 - Tuesday Sept 23 - PID CONNECTIONS

- What takeaways or questions do you have from the presentations?
- What are your main use cases or purposes for wanting PIDs to be connected?
- In what cases would a “package PID” like a RAID be helpful and important? How do you see the “package PIDs” being used?
- Where are PID connections most important: in PID metadata or in metadata available at the source (e.g. at PID landing page)?
- When should a reference publication be cited *in addition to* or *instead of* the facility or instrument PID? (This also applies to data and software.)