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Building FAIRmetadata mapping model for scientific instruments in the Ukrainian research information system: recovery of research infrastructures

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Introduction

Open research infrastructures depend not only on physical facilities but on structured, interoperable, and reusable metadata describing the resources that enable research [1, 2]. While Current Research Information Systems (CRIS) have matured in managing projects, publications, funding, researchers, and organizations, scientific instruments, the core operational units of research infrastructures, remain largely underrepresented as standardized metadata entities [3]. The Barcelona Declaration on Open Research Information and the FAIR principles [4] emphasize transparency and interoperability of research information systems. However, the practical application of FAIR for physical scientific instruments in national CRIS contexts remains limited [5].

Ukraine represents a critical case. Since the Russian invasion, a substantial proportion of research infrastructure and scientific instruments has been damaged or rendered inaccessible [6]. According to the February 2023 report on damage to property and facilities of scientific and higher education institutions, published by the Ministry of Education and Science of Ukraine (MESU), around 35% of the RI was damaged and destroyed [2]. 116 institutions were partially damaged and 4 were destroyed, while 11 institutions are located in the occupied territory and are not able to provide the data. At the same time, Ukraine's EU accession process has intensified its commitment to integration into the European Research Area, shaped by the European Strategy Forum on Research Infrastructures roadmap [7]. In this context, the absence of structured, instrument-level metadata directly affects reconstruction planning, funding transparency, and interoperability with European research infrastructures.

Background and Related Work

The euroCRIS community has advanced CERIF as the European standard for structuring research information across entities and relationships. CERIF enables formal modeling of organizations, persons, projects, funding, and outputs within interoperable CRIS ecosystems [8].

Recent implementations have extended CRIS architectures to include research infrastructure objects. For example, the Flemish regional CRIS introduced a CERIF-based research infrastructure entity and implemented PID-based “golden record” merging strategies to reconcile distributed institutional records [9]. These approaches demonstrate that CRIS can move beyond publication-centric systems toward infrastructure-aware architectures. However, instrument-level modeling remains limited. While CERIF allows representation of equipment and facilities, practical implementation across national CRIS systems varies significantly. No globally adopted PID standard exists for scientific instruments, and institutional metadata practices are heterogeneous [3].

Ukrainian Research Information System (URIS|NAUKA) (https://nauka.gov.ua/en/) standardizes metadata for researchers, projects, and organizations, but does not include a harmonized instrument-level entity. Before 2022, there was no centralized registry of scientific instruments. A survey among research institutions documented thousands of instruments, yet data remained fragmented, inconsistent, and disconnected from URIS [10].

The absence of Structured instrument metadata produces systemic consequences: (1) Scientific instruments are difficult to locate or verify for grant applications. (2) There is no traceable linkage between instruments, funded projects, and resulting publications. (3) Damage status and operational condition are not systematically documented. (4) Cross-institutional sharing and international collaboration are hindered. Without standardized instrument-level documentation, recovery planning and integration into European research infrastructures are constrained [6,7]. Currently, there is no centralized registry to determine what is currently outstanding, making it difficult for researchers to find scientific instruments, confirm infrastructure for grant applications, or renew collaborations [11].

URIS focuses on standardizing research metadata but does not include a standardized, up-to-date registry of research instruments [8]. Records are often fragmented, incomplete, and lacking data on status, institutional location, or access guidelines [12]. This fragmentation, increased by the effects of the war effort, complicates coordination and limits Ukrainian integration into EU research systems [13].

Currently, there are no comprehensive studies on how Ukrainian researchers face these obstacles and what improvements they prioritize. While studies have noted decreased productivity due to infrastructure gaps [3], they do not address issues related to metadata or CRIS system.

Implementation Phases and Research Design

The implementation proceeds through three sequential, interdependent phases, moving from system-level assessment to institutional workflow analysis, and culminating in the development and validation of a CRIS-integrated metadata model for scientific instruments.

The **first phase** establishes a national overview of the condition, availability, and documentation of scientific instruments in post-war Ukraine. A structured content analysis of 10-15 governmental, institutional, and international reports identifies categories of instrument-related damage (destruction, relocation, partial functionality, loss of access), documentation gaps, absence of persistent identifiers, regulatory inconsistencies, and interoperability barriers affecting CRIS integration.

These findings inform a nationwide online survey targeting researchers, laboratory managers, administrators, and IT professionals. The survey collects structured data on current instrument registration practices, metadata fields in use, update cycles, reporting obligations, and technical compatibility with the national CRIS. Sampling prioritizes institutional diversity across disciplines, regions, and levels of war-related damage. This phase produces a typology of instrument-level damage and metadata fragmentation, a national dataset on documentation practices, and selection criteria for institutional case studies.

The **second phase** focuses on institutional governance and metadata workflows. Four to six institutions are selected to ensure diversity in disciplines and in the impact on infrastructure. Semi-structured interviews (15-20) examine internal instrument inventories, data ownership structures, validation processes, reporting to ministries or funders, barriers to persistent identifier assignment, and interaction with the national CRIS. The analysis results in institutional data-flow diagrams, governance constraint matrices, and a stakeholder-defined minimal viable metadata set for scientific instruments.

The **third phase** translates empirical findings into a structured metadata mapping model designed for integration into the national CRIS. A comparative analysis of MERIL [14] and NEKIFUT informs harmonization of metadata fields, classification structures, validation mechanisms, PID logic, and alignment with FAIR principles. Based on this analysis, a standardized metadata schema for scientific instruments is developed, defining mandatory and optional attributes, controlled vocabularies, validation rules, update cycles, and mechanisms for linking to projects, publications, and organizations within the CRIS environment. To demonstrate feasibility, a pilot dataset of 60-100 scientific instruments is created in open, machine-readable formats (CSV/JSON). The pilot tests CERIF compatibility, PID-based golden-record merging logic, interoperability with the national CRIS, and machine-readability for future analytics. The result is a FAIR-compliant, CRIS-ready metadata model for scientific instruments, supported by a validated pilot dataset and an implementation guide for national deployment.

Instrument Entity and Metadata Core

The proposed model introduces a formal Scientific Instrument entity within URIS's national CRIS architecture and relationship modeling. Scientific instruments are conceptualized as physical equipment, facility-level research resources, or ICT-based tools essential for conducting experiments and producing scientific data. By formally embedding instruments as structured CRIS entities, the model elevates them from locally maintained inventories to interoperable research information objects [15]. The metadata core is designed to ensure both technical interoperability and governance usability. Each instrument is assigned a persistent identifier through a national PID prototype, enabling unambiguous referencing across institutions. Core attributes include instrument type and classification, operational condition and damage status, hosting organization, responsible person, funding source, geographic location, and access mechanisms. The entity is further linked to projects and publications within the CRIS environment, allowing traceability of infrastructure use and research outputs.

Governance and Sustainability Model

The governance framework follows a federated model that balances institutional autonomy with national coordination. Individual institutions retain ownership and responsibility for their instrument data, including updates and validation. URIS functions as the aggregation, harmonization, and exposure layer, ensuring standardized metadata structures and interoperability. Sustainability is ensured through the use of open, non-proprietary data formats, alignment with FAIR principles, and compatibility with broader European infrastructures such as the European Open Science Cloud. By avoiding vendor lock-in and relying on open standards, the model supports long-term maintainability, extensibility, and integration into European research information ecosystems.

AI-Readiness and Strategic Impact

Structured and standardized instrument metadata significantly enhances machine-readability and analytical potential. By harmonizing core attributes, the model enables infrastructure capacity mapping, detection of equipment duplication across institutions, evidence-based funding prioritization, and scenario modelling for reconstruction planning. Moreover, CRIS-integrated instrument metadata allows for integration with European infrastructure analytics and data-driven policy tools.

Future Steps

Future work includes formal validation of the Scientific Instrument entity, golden-record merging workflows and expansion of the pilot dataset across institutions and disciplines. The next stage involves operational deployment within the Ukrainian Research Information System, including API exposure and compatibility testing with European infrastructure registries. In the longer term, the project aims to institutionalize instrument-level metadata governance and contribute to European discussions on persistent identification of scientific instruments, providing a scalable framework for crisis-affected research systems.

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