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# Instantiation of the Damara Tern Platform for Advanced Materials and Manufacturing Technologies Program Collaborative Data Management


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OAK RIDGE National Laboratory

ORNL IS MANAGED BY UT-BATTELLE LLC FOR THE US DEPARTMENT OF ENERGY

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Advanced Materials and Manufacturing Technologies Program

# INSTANTIATION OF THE DAMARA TERN PLATFORM FOR ADVANCED MATERIALS AND MANUFACTURING TECHNOLOGIES PROGRAM COLLABORATIVE DATA MANAGEMENT

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## ABBREVIATIONS

| | |
|---|---|
| AMMT | Advanced Materials and Manufacturing Technologies |
| LPBF | laser powder bed fusion |
| MDDC | Multi Dimensional Data Correlation |
| ORNL | Oak Ridge National Laboratory |

# ABSTRACT

This work package focused on deploying an instance of the Damara Tern platform to support Advanced Materials and Manufacturing Technologies (AMMT) program collaborative research activities. The objectives were to provide selected AMMT collaborators with access to a shared environment for capturing operations, trackables, and associated metadata and to implement data entry functionalities that reflect site-specific procedures. Key activities included creating configurable, schema-driven entry forms and validating the data collection process. The report details the deployment process, the platform infrastructure, and the implemented data entry workflows. This work provides a reference for end users and establishes a foundation for future production-scale deployments.


# 1. INTRODUCTION

This report summarizes the deployment and initial use of the Damara Tern platform for the AMMT program as part of a targeted work package to support cross-site data capture and collaboration. The work package aimed to provide selected AMMT collaborators with access to a shared instance of Damara Tern, enabling them to record operations, trackables, and associated metadata and reflect the specific procedures and practices of participating laboratories.

The primary focus of the work package was twofold: (1) deploy the platform in an environment accessible to collaborators and (2) implement schema-driven data entry functionalities. These entry forms allow administrators to define operation types, machines, and procedure-specific metadata fields, which enables contributors to consistently capture detailed experimental conditions and parameters.

By delivering this initial instance, the work package established a functional platform for AMMT program collaborators to explore, validate, and contribute data. This work package also demonstrated how the system can accommodate domain-specific customizations. As a result, the work package provided a tested foundation for future production-scale deployments and broader cross-site collaboration.

# 2. AMMT PROGRAM PLATFORM DEPLOYMENT AND INFRASTRUCTURE

## 2.1 DAMARA TERN OVERVIEW

Damara Tern is a web-based application developed under the AMMT program’s Multi Dimensional Data Correlation (MDDC) initiative to capture, organize, and explore metadata generated along the manufacturing digital thread. The application provides a unified environment for recording, retrieving, and analyzing information related to manufacturing operations.

Implemented using the Python Django framework, Damara Tern offers a web interface for entering and exploring data and an object–relational model for structuring operations, trackables, and related entities. The generic, operation-centric design of the platform ensures high flexibility, extensibility, and the potential for automation and advanced queries. This application creates a consistent framework for managing diverse manufacturing workflows.

At the core of Damara Tern is the operation–trackable model, which provides a flexible and consistent way to represent complex manufacturing processes:

- *Operations* record actions performed by machines or users, such as printing, curing, testing, or annotation.

- *Trackables* represent the physical or digital entities subjected to these actions, including materials, builds, parts, or digital twins.

By linking operations to trackables, the platform preserves the process history and relationships between components. This information enables users to reconstruct the digital thread of a manufacturing workflow. Figure 1 illustrates the main data categories recorded within the Damara Tern database. Importantly, only metadata are stored in the database, and the actual experimental data (e.g., time series, images, documents) reside on external disk storage and are referenced in the metadata. This structure maintains traceability without overloading the database.

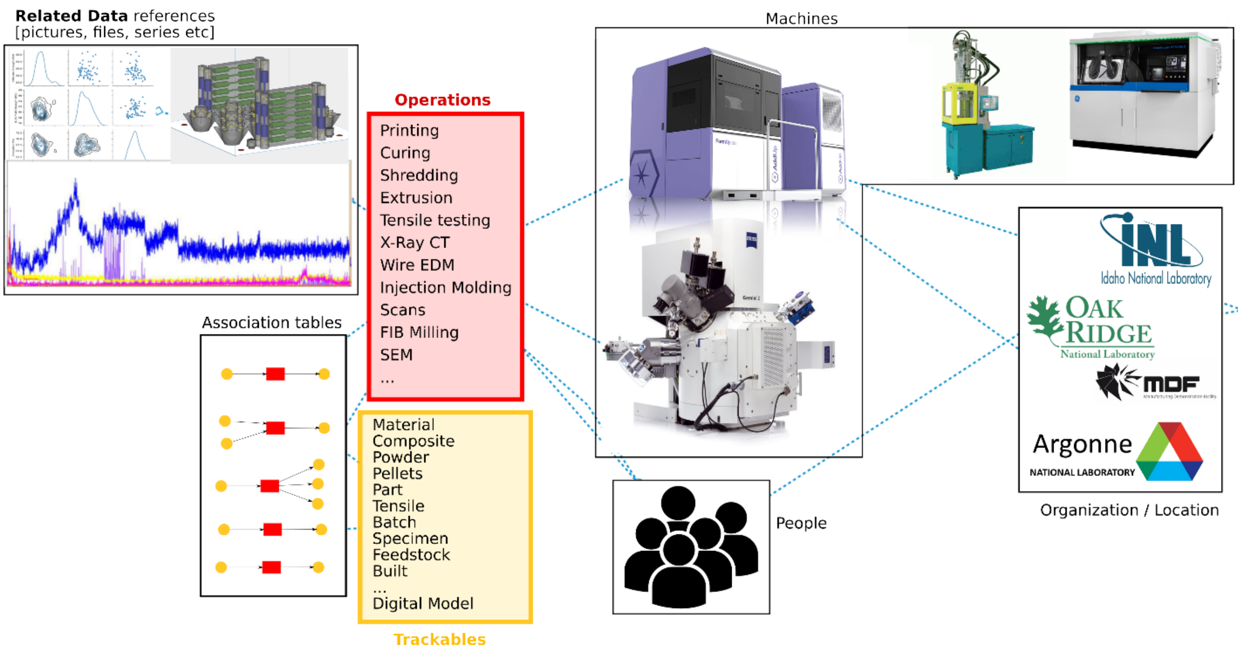



**Figure 1. Overview of the main components in the Damara Tern data model.** Entity categories include operations, trackables, machines, related data, and people and affiliations. The core entities—*operations* and *trackables*—are linked through association tables that capture input/output relationships. These tables enable reconstruction of the digital thread as a graph of processes and entities.

## 2.2 SOFTWARE INFRASTRUCTURE AND DEPLOYMENT

A dedicated Damara Tern instance was deployed to support external access to enable AMMT program partners to explore and test the platform beyond the secure Oak Ridge National Laboratory (ORNL) intranet. The original prototype remains hosted on the ORNL Manufacturing Demonstration Facility internal network, but this external instance was provisioned specifically for collaborative development and evaluation. It can be accessed at https://damaratern-ammt.ornl.gov.

The platform runs on a dedicated virtual machine with all components containerized using Docker. The architecture consists of four main containers:

- PostgreSQL—database storage
- Nginx + Gunicorn—web server
- Redis—caching and queue management
- Django—application framework

To manage application data, a dedicated AMMT program disk share hosts migrated datasets and new uploads. The database stores only metadata, and the actual files (e.g., images, time series, documents) are stored on the dedicated disk, with paths referenced in the metadata to preserve the digital thread.

To ensure reliable updates and consistency across instances, the platform is maintained via a continuous integration/continuous delivery (CI/CD) pipeline, which automates build, test, and deployment steps for development and production environments. Dynamic test instances allow developers to validate new features, and stable branches are deployed to the dedicated AMMT program instance. This pipeline ensures that updates are applied consistently and that all running environments remain reproducible and validated.

## 2.3 AUTHENTICATION AND USER ACCESS

Access to the Damara Tern platform is managed through lightweight directory access protocol authentication using UCAMS (for ORNL users) or XCAMS (for external collaborators) credentials. External contributors must request an XCAMS account at https://xcams.ornl.gov/ before they can log in.

The platform implements a role-based access control system that governs visibility and data entry permissions:

- *Viewer*—read-only access to metadata and operation/trackable records
- *Contributor*—can add data to existing operations and trackables but cannot modify core objects
- *Operator*—full access to create, edit, and manage operations, trackables, and associated metadata

Access is also scoped by affiliation, distinguishing *internal* (vetted) and *external* users, and citizenship/ US status to support cross-site collaboration and control exposure of sensitive content. Although this instance currently hosts only nonsensitive data, the system is designed to accommodate future scenarios requiring finer-grained restrictions.

Upon logging in for the first time with an XCAMS account, external collaborators are initially granted *External Viewer* permissions, limiting their access to only publicly released datasets. An introduction banner guides users to submit requests for elevated access via the feedback form, which is sent to platform administrators. Once vetted, the user can be granted *Internal* as well as *Contributor* or *Operator* roles, expanding the range of functionality available on the platform.

## 2.4 INITIAL DATA AND DATASET MIGRATION

The deployed Damara Tern instance includes seeded and migrated datasets to support immediate testing and collaboration. These datasets provide a foundation for data entry and exploration and include two main categories:

- Prerequisite objects—Essential component and reference information required before creating operations and trackables. This information includes operation types, machines, institutions, and locations migrated from the existing ORNL instance to ensure consistency with the internal platform.

- Historical operations and trackables—Data from previous additive manufacturing builds associated with the AMMT program and its predecessor, the Transformational Challenge Reactor program. Migration scripts were developed to translate and recreate operations and trackables in the external instance to preserve the digital thread of the manufacturing process.

All datasets stored in the database contain only metadata, and larger experimental files (e.g., images, time series, documents) remain on the disk and are referenced via file paths in the metadata. As part of this work package's deployment, a copy of the existing data was made onto the dedicated AMMT program disk share. This setup allows external contributors to access and add data in a testing environment while preserving the integrity of the original ORNL disk share. This method also prevents pollution of the production data with test entries and ensures that only nonsensitive data are made available.

The initial datasets ingested into the platform include 117 builds, more than 4,000 trackables (e.g., builds, build plates, parts, powder), and over 4,000 operations. These numbers continue to grow as additional data are migrated, with the primary bottleneck being transferring large experimental files to the dedicated disk share.

# 3. DATA ENTRY FUNCTIONALITIES

## 3.1 EXTENDING THE GENERIC OPERATION STRUCTURE

The Damara Tern platform is built on a generic operation–trackable model, in which any process step (i.e., operation) can be linked to one or more physical or digital entities (i.e., trackable). This model ensures flexibility and broad applicability, but specific manufacturing and testing workflows often require additional fields or parameters.

Each operation created in the system includes a standard set of metadata for identification and traceability. These metadata cover the operation name, type, machine, operators, status, start and end times, associated projects and principal investigators, Controlled Unclassified Information (CUI) or sensitivity label, and optional notes.

To support more detailed workflows, the platform enables schema-based extensions of operation metadata. Each operation type (e.g., laser powder bed fusion [LPBF], heat treatment, tensile test) can be associated with a JSON-based schema that defines additional fields. At runtime, these schemas are used to dynamically generate data entry forms in the web interface. The field values collected through these forms are stored in a JSON field of the operation record in the database. Figure 2 shows an example of such a schema created within the administrator interface and the resulting entry form.

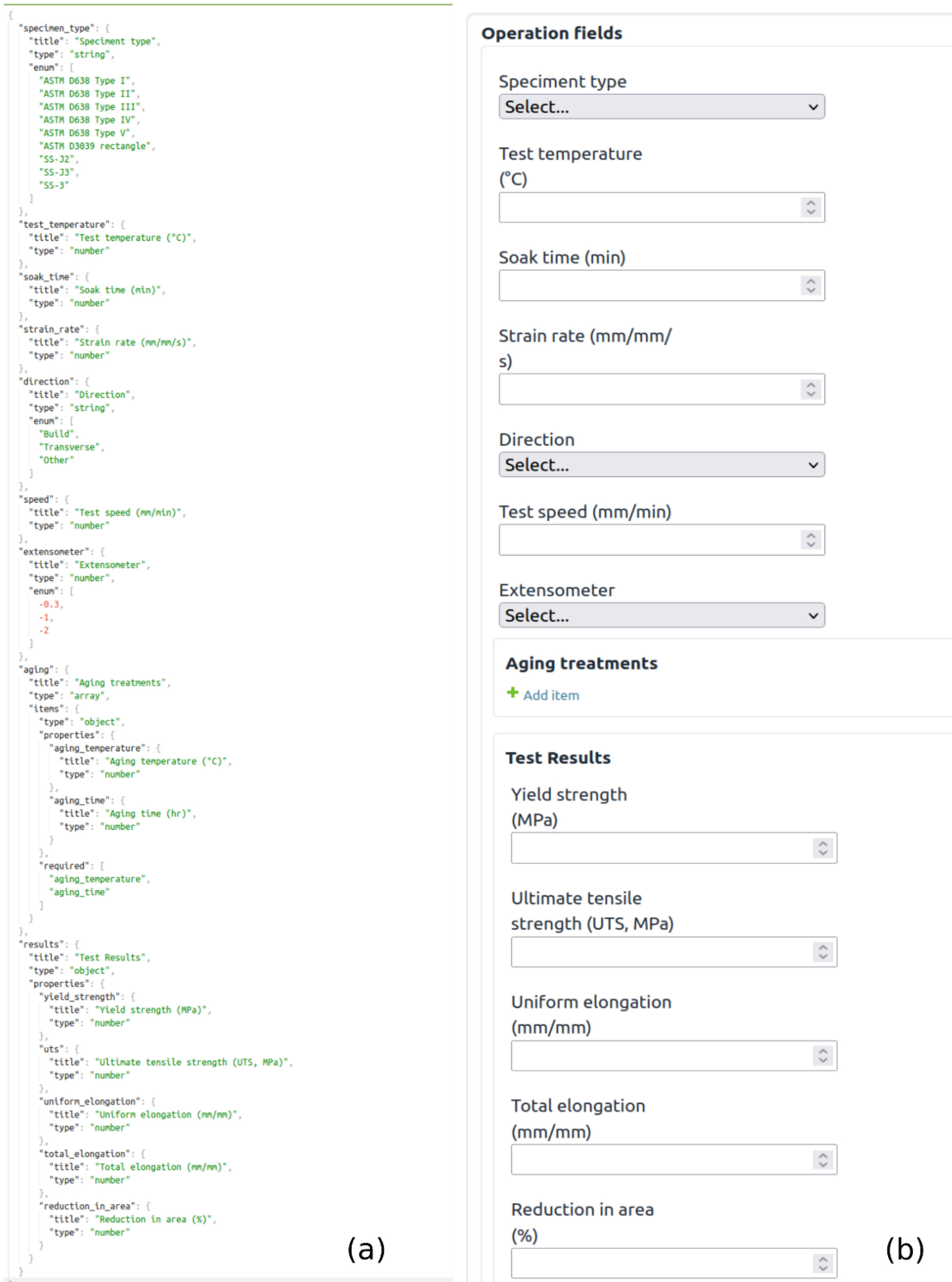


**Figure 2. Example of schema-driven metadata entry for the tensile testing operation type.**

(a) The JSON-like schema defined in the administrator interface. (b) The corresponding metadata entry form dynamically generated in the web interface, showing operation-specific fields for tensile test data capture.

This schema-driven approach allows administrators to define and update operation-specific requirements without altering the underlying database structure or application code. New operation types and machines can be added within minutes, and specialized fields can be introduced as needed to capture metadata relevant to execution conditions, reproducibility, or operator-reported results. For example, a build operation may include information about build plate type or powder layer thickness, and a tensile test may capture test speed, load rate, and failure mode.

Schemas can be defined at three levels: operation type, machine, and machine–operation type. Operation type schemas describe parameters common to all operations of a given type, such as layer thickness for LPBF processes. Machine schemas capture parameters specific to a given piece of equipment, such as SmartFusion settings available only on EOS systems. Finally, machine–operation type schemas allow system-specific overrides when a particular machine requires deviations from the default operation type schema. Figure 3 illustrates an example of schema-based entry forms dynamically generated to guide users in recording the appropriate metadata for an operation.

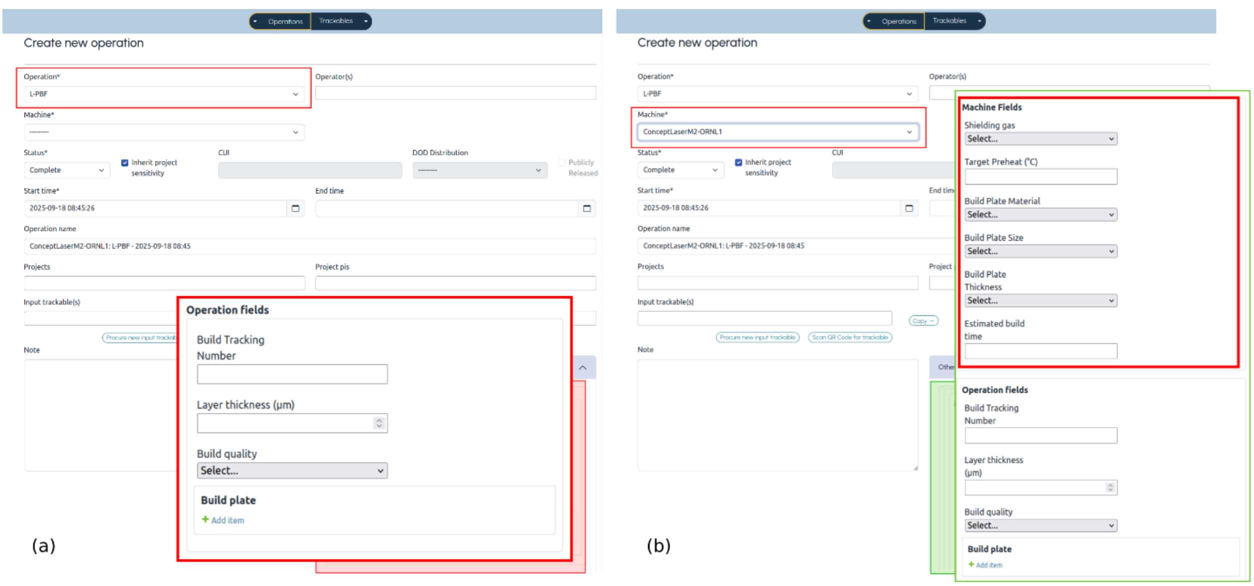



**Figure 3. Example of a schema-based operation entry form in the Damara Tern platform.** (a) When the LPBF operation type is selected, the form is dynamically populated with metadata fields specific to LPBF processes (enlarged and highlighted in red). (b) Selecting a machine appends the form with machine-specific metadata fields tailored to the chosen system.

By combining these layers at runtime, the platform ensures general consistency and machine-specific flexibility. This design enables reproducibility of processes and lays the groundwork for future search and query features, in which metadata can be used to filter and analyze operations across sites.

Through this mechanism, Damara Tern provides a unified yet extensible structure for capturing essential metadata and supports domain-specific customization required by various manufacturing workflows.

## 3.2 AMMT PROGRAM COLLABORATION-DRIVEN CUSTOMIZATIONS

Leveraging the platform’s schema-based flexibility, this work package focused on extending Damara Tern to support AMMT program-specific operations and machines, enabling detailed metadata capture tailored to partner experiments.

A list of machines owned by AMMT program partners was created. Additionally, three new operation types were introduced: *Creep Testing*, *Fatigue*, and *Creep-Fatigue*. For each of these operation types, metadata fields were extracted from spreadsheets provided by collaborators to capture the critical parameters needed to track and document the performed tests. Corresponding JSON schemas were developed to generate data entry forms tailored to these operation types, which ensured consistency and usability for end users. Two existing operation types, *Tensile Test* and *Heat Treatment*, were revisited to incorporate additional metadata fields suggested by collaborators' spreadsheets.

The resulting data entry forms were presented to collaborators for feedback, and the schemas were refined accordingly to reflect practical use and completeness. Finally, several operations and associated trackables were created, processed, and ingested into the AMMT program-dedicated instance. Remote collaborators were then able to interact with their tangible data within the platform and demonstrate how data are captured, structured, and visualized.

## 4. INTERFACE OVERVIEW AND USER WORKFLOWS

This section presents an overview of the Damara Tern interface and illustrates the workflows available to AMMT program users for consulting and entering data. The screenshots and examples assume a logged-in user with both *Internal* and *Operator* permissions, which allows access to all available data as well as full visibility of views, actions, and entry options within the platform.

### 4.1 BASIC NAVIGATION AND DATA CONSULTATION

Upon logging in, users are presented with the main navigation menu on the front page (Figure 4), which provides direct access to the core views and functionalities of the platform, including operation and trackable lists, creation forms, and search filters. As users progress through their workflow, a persistent navigation bar with drop-down menus is available at the top of the interface (Figure 5). This menu provides quick access to the same options, allowing users to switch between pages seamlessly when consulting or entering data.

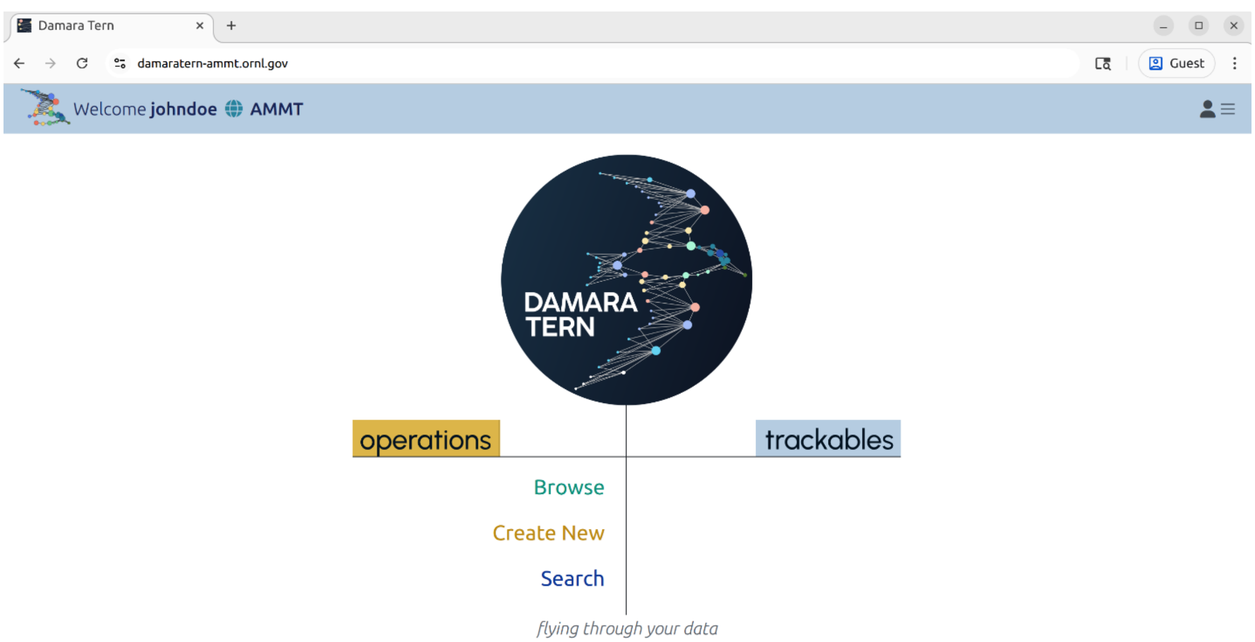



**Figure 4. Damara Tern home page after login.**

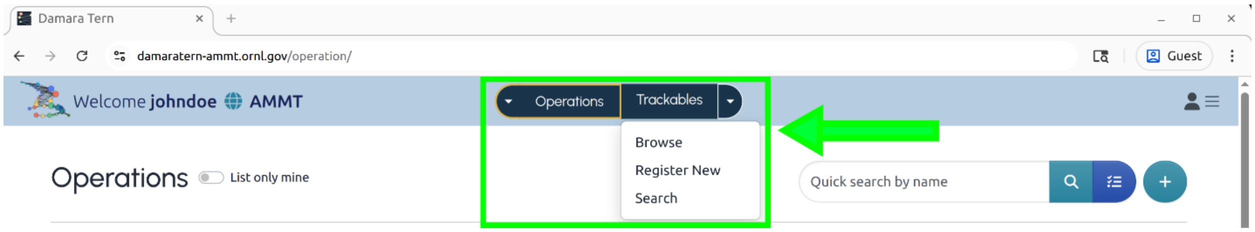
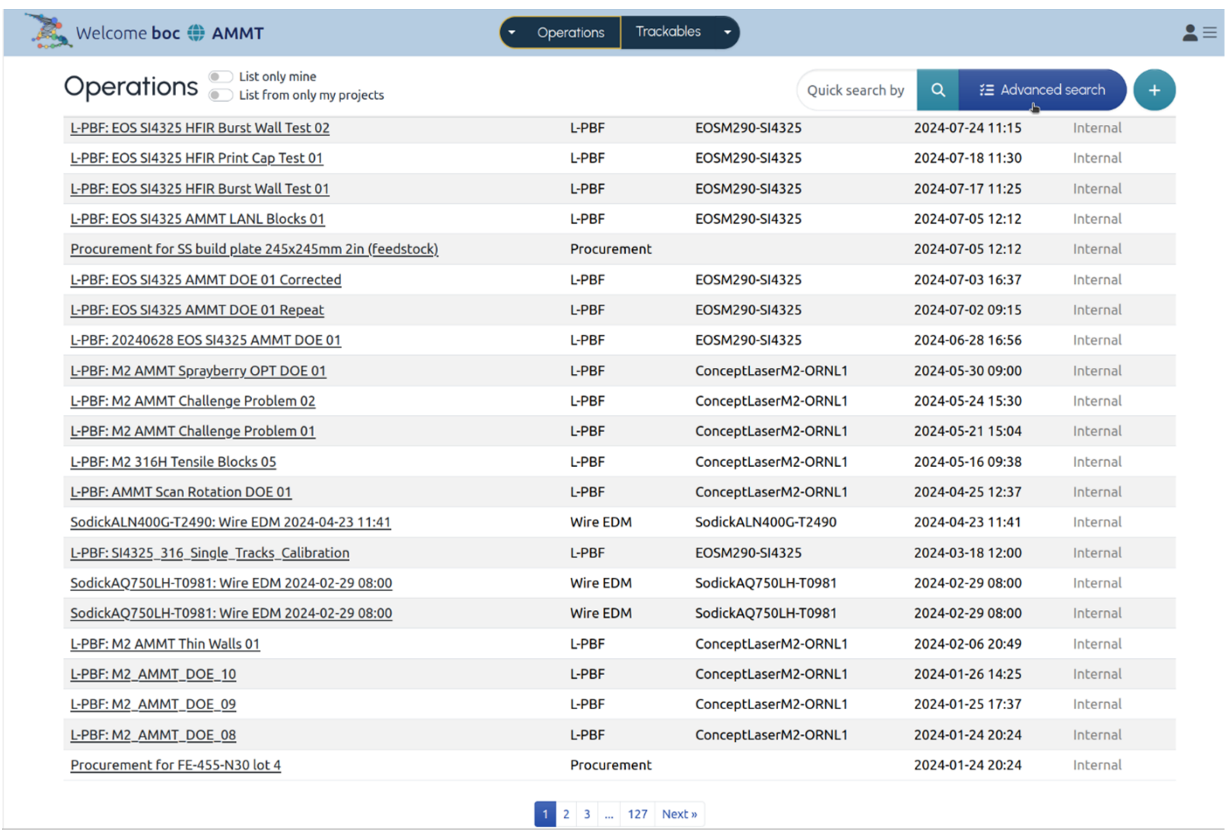



**Figure 5. Navigation bar.** The interactive drop-down menu (highlighted in green) allows easy access to the list as well as the search and creation form.

The list pages (for both operations and trackables) serve as the primary entry point for consulting existing data. From these pages, users can browse records, apply search filters to narrow down results, and open detail pages to examine specific objects. Access is automatically governed by each user's role and data sensitivity labels, ensuring that only authorized records are visible. Figure 6 illustrates an Operations list page; search fields and buttons at the top right of the page provide operators with direct access to quick filters, advanced search tools, and data entry forms. A trackable advanced search form, opened from the Trackables list page, is presented in Figure 7.




| | | | | |
|---|---|---|---|---|
| L-PBF: EOS SI4325 HFIR Burst Wall Test 02 | L-PBF | EOSM290-SI4325 | 2024-07-24 11:15 | Internal |
| L-PBF: EOS SI4325 HFIR Print Cap Test 01 | L-PBF | EOSM290-SI4325 | 2024-07-18 11:30 | Internal |
| L-PBF: EOS SI4325 HFIR Burst Wall Test 01 | L-PBF | EOSM290-SI4325 | 2024-07-17 11:25 | Internal |
| L-PBF: EOS SI4325 AMMT LANL Blocks 01 | L-PBF | EOSM290-SI4325 | 2024-07-05 12:12 | Internal |
| Procurement for SS build plate 245x245mm 2in (feedstock) | Procurement | | 2024-07-05 12:12 | Internal |
| L-PBF: EOS SI4325 AMMT DOE 01 Corrected | L-PBF | EOSM290-SI4325 | 2024-07-03 16:37 | Internal |
| L-PBF: EOS SI4325 AMMT DOE 01 Repeat | L-PBF | EOSM290-SI4325 | 2024-07-02 09:15 | Internal |
| L-PBF: 20240628 EOS SI4325 AMMT DOE 01 | L-PBF | EOSM290-SI4325 | 2024-06-28 16:56 | Internal |
| L-PBF: M2 AMMT Sprayberry OPT DOE 01 | L-PBF | ConceptLaserM2-ORNL1 | 2024-05-30 09:00 | Internal |
| L-PBF: M2 AMMT Challenge Problem 02 | L-PBF | ConceptLaserM2-ORNL1 | 2024-05-24 15:30 | Internal |
| L-PBF: M2 AMMT Challenge Problem 01 | L-PBF | ConceptLaserM2-ORNL1 | 2024-05-21 15:04 | Internal |
| L-PBF: M2 316H Tensile Blocks 05 | L-PBF | ConceptLaserM2-ORNL1 | 2024-05-16 09:38 | Internal |
| L-PBF: AMMT Scan Rotation DOE 01 | L-PBF | ConceptLaserM2-ORNL1 | 2024-04-25 12:37 | Internal |
| SodickALN400G-T2490: Wire EDM 2024-04-23 11:41 | Wire EDM | SodickALN400G-T2490 | 2024-04-23 11:41 | Internal |
| L-PBF: SI4325_316_Single_Tracks_Calibration | L-PBF | EOSM290-SI4325 | 2024-03-18 12:00 | Internal |
| SodickAQ750LH-T0981: Wire EDM 2024-02-29 08:00 | Wire EDM | SodickAQ750LH-T0981 | 2024-02-29 08:00 | Internal |
| SodickAQ750LH-T0981: Wire EDM 2024-02-29 08:00 | Wire EDM | SodickAQ750LH-T0981 | 2024-02-29 08:00 | Internal |
| L-PBF: M2 AMMT Thin Walls 01 | L-PBF | ConceptLaserM2-ORNL1 | 2024-02-06 20:49 | Internal |
| L-PBF: M2_AMMT_DOE_10 | L-PBF | ConceptLaserM2-ORNL1 | 2024-01-26 14:25 | Internal |
| L-PBF: M2_AMMT_DOE_09 | L-PBF | ConceptLaserM2-ORNL1 | 2024-01-25 17:37 | Internal |
| L-PBF: M2_AMMT_DOE_08 | L-PBF | ConceptLaserM2-ORNL1 | 2024-01-24 20:24 | Internal |
| Procurement for FE-455-N30 lot 4 | Procurement | | 2024-01-24 20:24 | Internal |

**Figure 6. Operations list page.**

The page displays a searchable table of existing operations records. Quick and advanced search options are available in the upper-right corner of the page. Contributor-level users can create new operations using the + button.

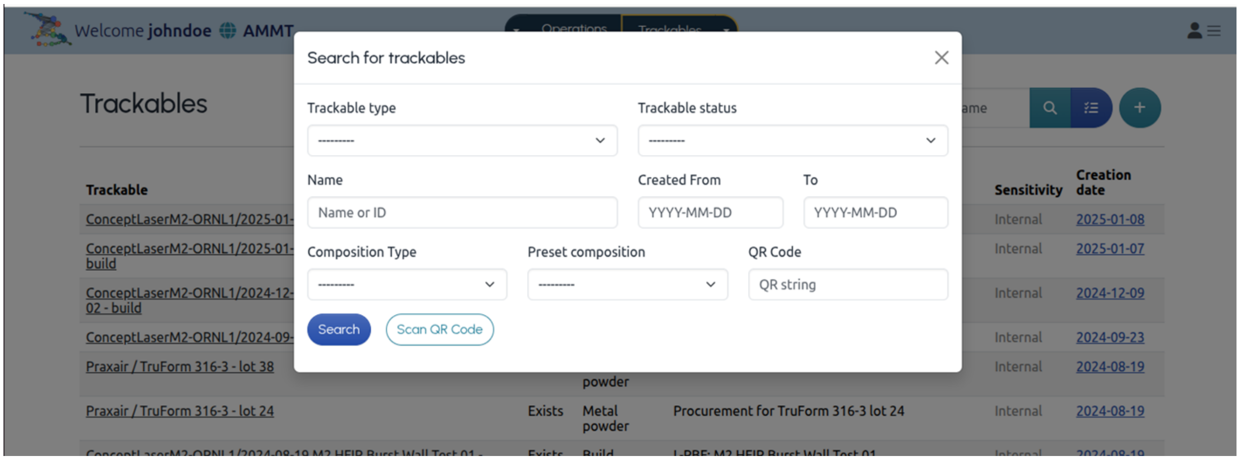



**Figure 7. Advanced trackable search form opened as a modal from the Trackables list page.**

Once a user has narrowed their search to a specific object, they can access its detail page by clicking on the name of the operation or trackable. Two types of detail pages are available: *operation detail pages* and *trackable detail pages*.

- **Operation detail pages** display all metadata associated with a given operation, including required fields, machine- or operation-specific metadata, and the list of linked input and output trackables (used or produced by the operation). Related documents, images, or data files, which are stored on external storage, can be viewed or downloaded from the page. Figure 8 illustrates an example of an Operations detail page, with key sections highlighted and labeled for reference.

  Users can also preview and browse available data folders, exploring files interactively (illustrated in Figure 9). Damara Tern provides built-in visualization support for a variety of file types, including images, TIFF files, HDF5 datasets, STL models, CSV previews, and tensile test–specific plotting options. Users with appropriate roles may also edit metadata, update input/output trackables, and upload or link new files.

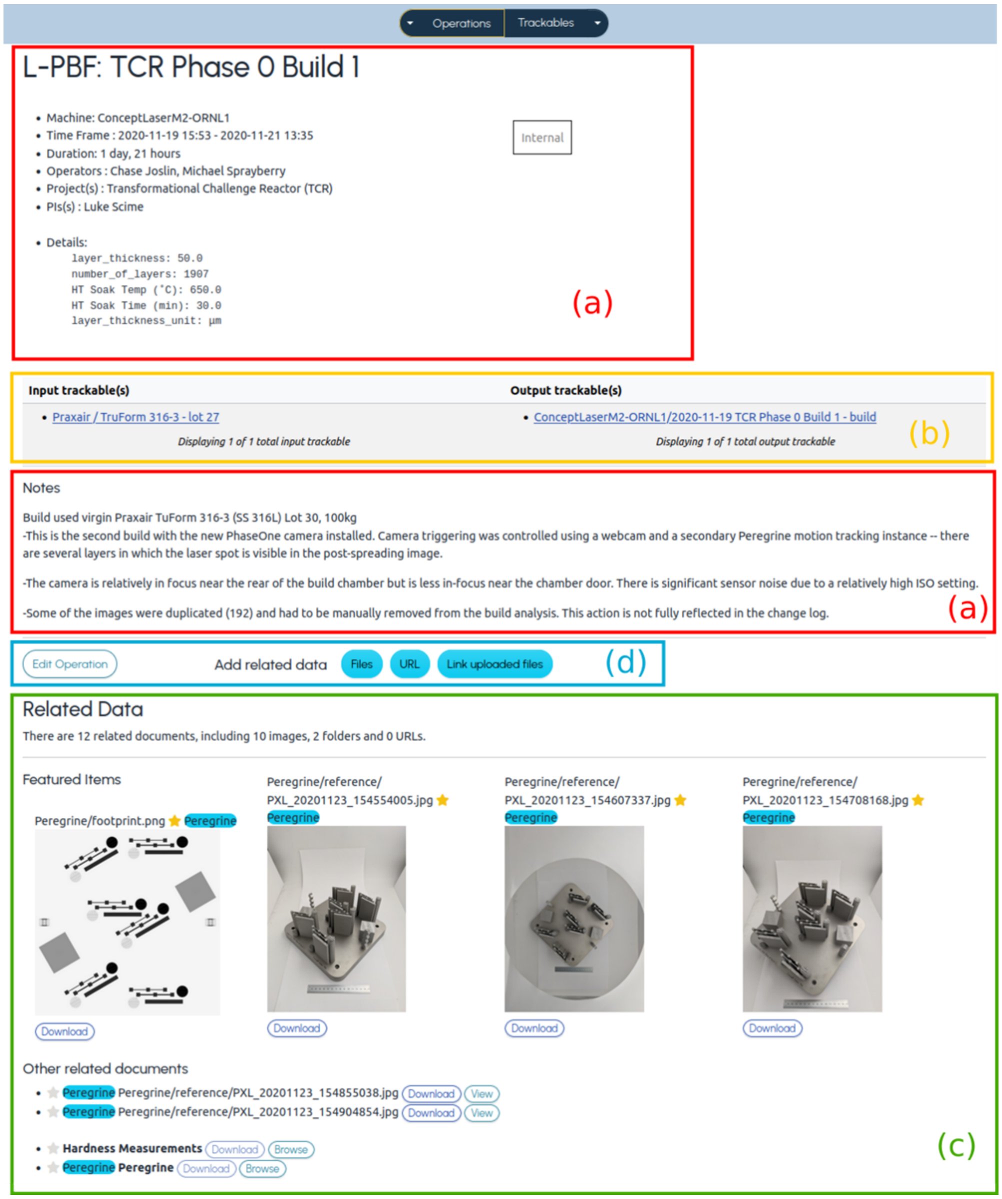



**Figure 8. Operation detail page in Damara Tern.** Key sections of the page are highlighted and labeled: (a, red boxes) Operation information section—displays general and schema-driven metadata fields and notes describing the operation. (b, blue box) Input/output trackables—lists the trackables used or produced by the operation, with links to navigate to their detail pages. (c, green box) Related data section—provides access to related files accessible for consultation and download. The section provides consultation features such as featured item, folder browsing, and data preview. (d, yellow box) Actions and editing controls—visible for authorized users and enables operation edit and uploading or linking of new related files.

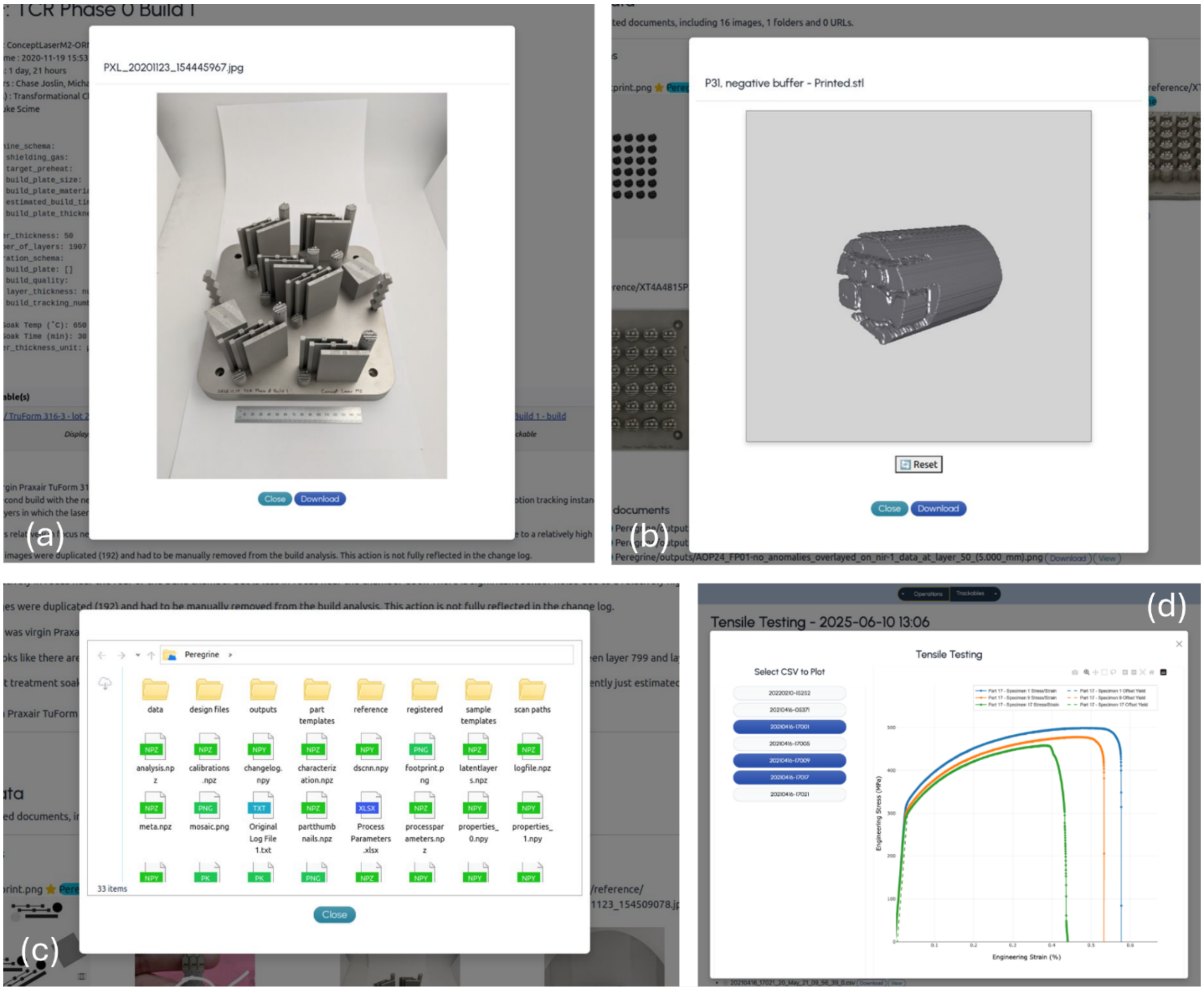



**Figure 9. Examples of embedded preview and browsing functionality available within the Operations detail page.**

(a) Image file preview, (b) intercative STL model viewer, (c) data folder exploration, and (d) tensile test comparison plot.

- **Trackable detail pages** display the metadata associated with a given trackable, its originating operation, and the list of operations applied to it or its predecessor trackables (Figure 10). A key feature is the trackable history graph, which situates the trackable within the broader digital thread by showing parent and child trackables, along with their associated operations. Users can interactively navigate to parent or child trackable pages or to related operations directly through the graph. This interactive visualization facilitates exploring the trackable's history and relationships, making complex dependencies easier to understand.

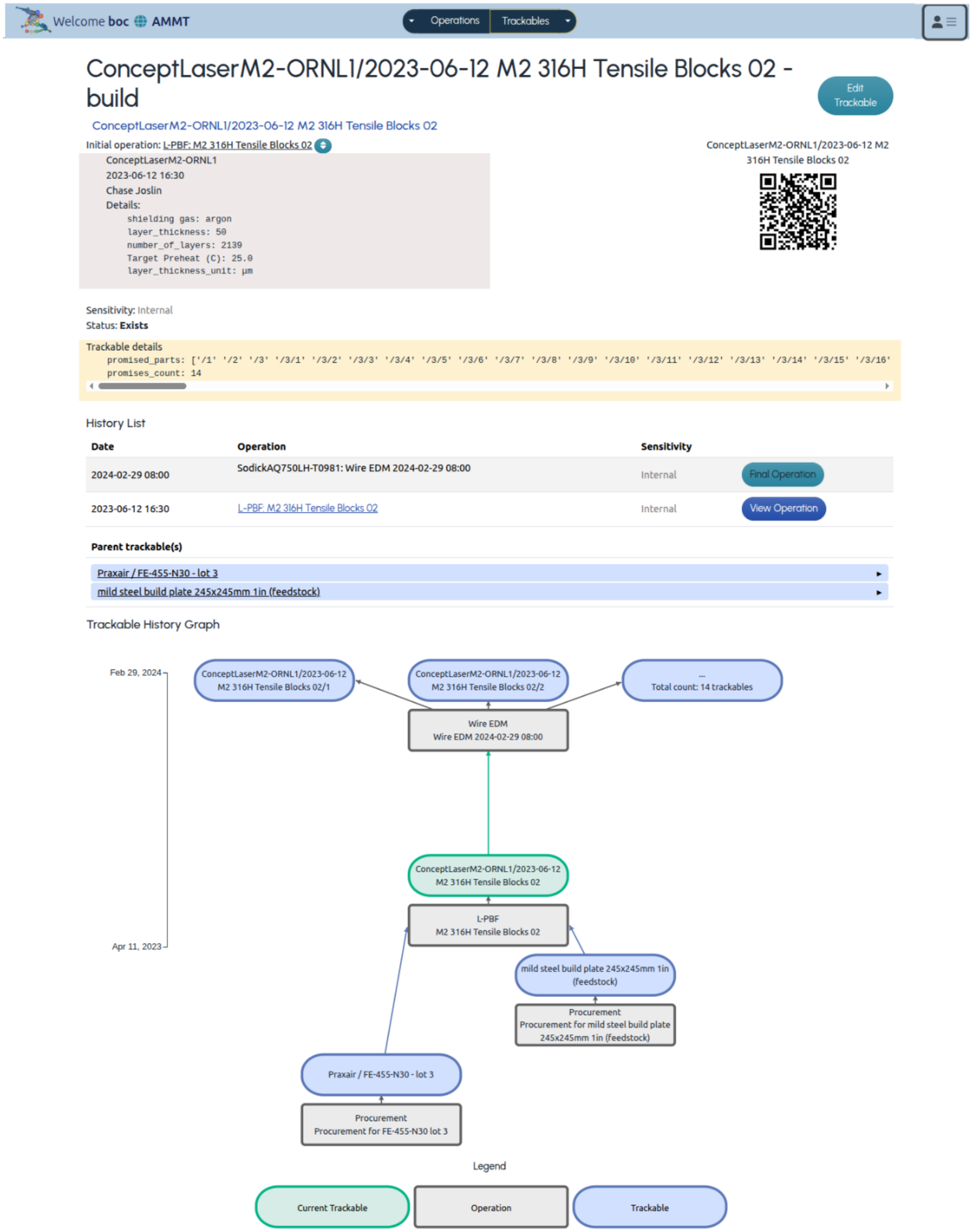



**Figure 10. Trackable detail page.** The page presents the trackable's information, including key identifiers, properties, attributes, and its initial operation (procurement or creation). An operation list provides a table of all operations the trackable has undergone, with links to their detail pages and summary panels. When relevant, the parent trackable is also listed. Finally, an interactive history graph visualizes the trackable's digital thread, showing parent and child trackables and associated operations. Elements in the graph can be clicked to navigate to corresponding detail pages.

Together, these navigation and detail pages provide users with a straightforward way to browse, filter, and view data captured in the system, forming the basis for consultation and the data entry workflows presented in Section 4.2.

## 4.2 DATA ENTRY

In addition to browsing and consulting data, users with the appropriate permissions can contribute new information to Damara Tern. Data entry follows three main workflows: (1) contributing related files to existing operations, (2) creating new operation records, and (3) creating new trackable records.

### 4.2.1 Contributing Data to Existing Operations

In Damara Tern, supporting files and documents are always attached to operations rather than directly to trackables. Operations occur at specific, timestamped points in time, capturing the state of one or more trackables as inputs or outputs.  Since trackables may evolve across multiple operations, linking files at the operation level ensures that each file is contextualized to the trackable's state at that moment within the digital thread. For trackable-specific information, an annotation operation—where the trackable is both input and output—can be used to record additional or documents with a timestamp.

Users may add related files to an operation in two main ways:

1. Directly uploading—Files or folders can be uploaded directly through the upload form (Figure 11), which opens as a modal on the operation detail page.
2. Linking existing files—Files generated or copied into the default data path for the operation (e.g., by integrated analytic software) can be linked to the record using the *Link uploaded files* button, which is available in the operation detail page menu shown in Figure 8(d).

Both approaches ensure that related documents, images, and datasets are permanently associated with the correct operation in the database and that the actual files remain stored on external disk storage or are referenced via URL.

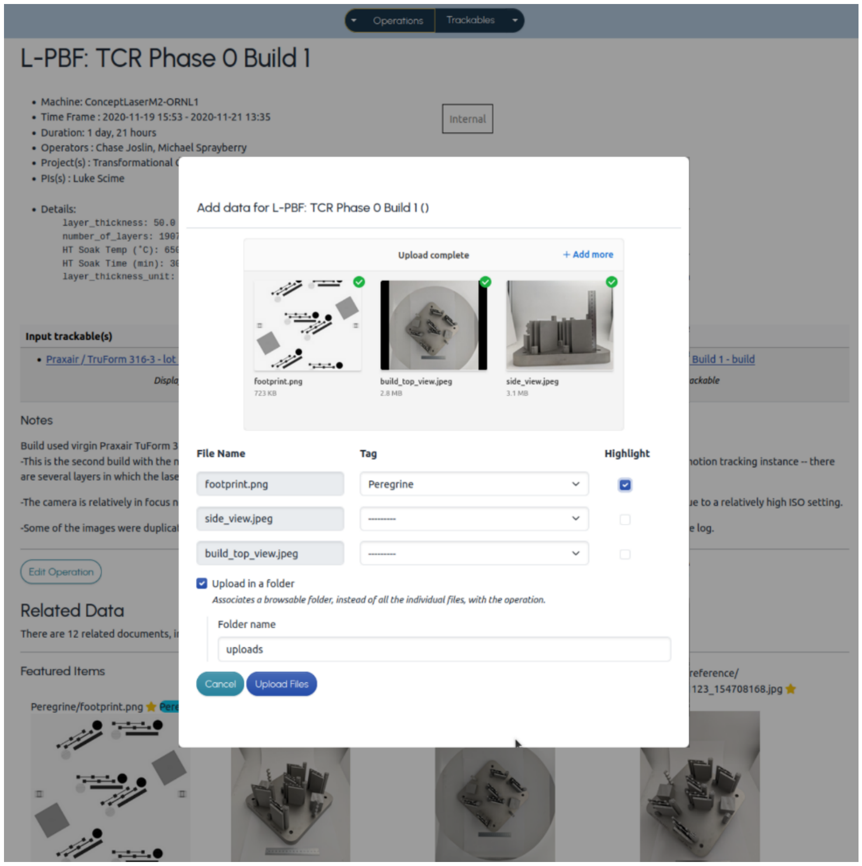



**Figure 11. Example of upload modal form used to upload files to an operation.**

### 4.2.2 Creating Operation Records

The operation creation form (illustrated in Figure 12) is accessible from the drop-down menu at the top of the interface, the home navigation list, or directly from the operation list page. Creating a new operation requires completing the generic metadata fields—such as operation type, machine, project, operator, status, and sensitivity—followed by, when applicable, the schema-driven fields defined for the selected operation type and machine, as introduced in Section 3.1.

The input and output trackables associated with the operation can be specified in three ways: (1) selecting them from the list of existing trackables valid for the chosen operation type, (2) retrieving them via a QR code scan, or (3) creating new ones on the fly using modal forms accessible from the same page (described in Section 4.2.3).

Once the form is submitted, the user is automatically redirected to the newly created *Operation Detail* page. At this point, the operation is integrated into the digital thread of the selected trackables.

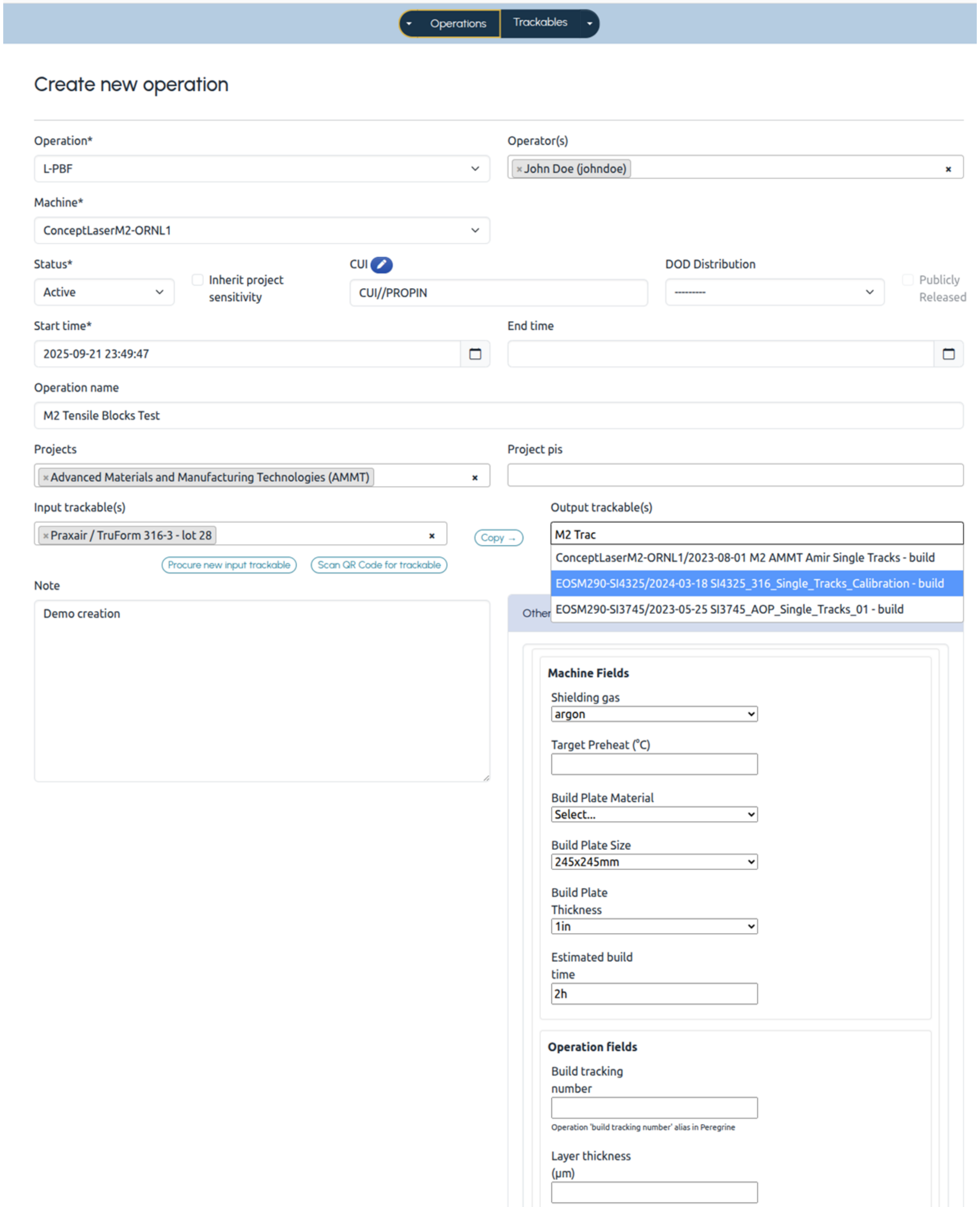



**Figure 12. Operation creation form.** The selected operation type and machine dynamically populate the *Other Fields* metadata section with schema-driven fields. Input and output trackables can be selected from existing records, retrieved via QR code scan, or created on the fly using the *Procure New Trackable* or *Create Resulting Trackable* options.

### 4.2.3 Creating Trackable Records

Trackables represent physical items, such as materials, specimens, or builds, as well as digital models. Creating a new trackable is restricted to users with *Operator* permissions and can be performed in two ways:

- Procurement trackable form—used for items purchased or procured externally (e.g., metal powder from a vendor). This form (illustrated in Figure 13) is accessible from the navigation bar, the Trackables list page, or via a modal in the Input Trackable section of the Operation creation page. The form submission generates the trackable and its associated procurement operation, which is automatically linked as the initial operation for the trackable. The form combines metadata fields for the trackable (e.g., name, ID, QR code) and for the operation (e.g., project, operator). These metadata allow full traceability from the point of procurement. Procured trackables have their history, starting with the associated procurement operation.

- Resulting trackable form—used for items produced as outputs of operations (e.g., LPBF builds). This form (Figure 13) is available as a modal in the Output Trackable section of the Operation creation page. Only trackable-specific entries are required. Multiple twin trackables can be generated simultaneously within the form, each with unique identifiers, QR codes, and nicknames. Once trackables are created, they are automatically added to the Output Trackable field of the Operation form from which the modal was launched, and the initial operation for each new trackable is updated once the operation is saved, ensuring full integration into the digital thread for traceability.

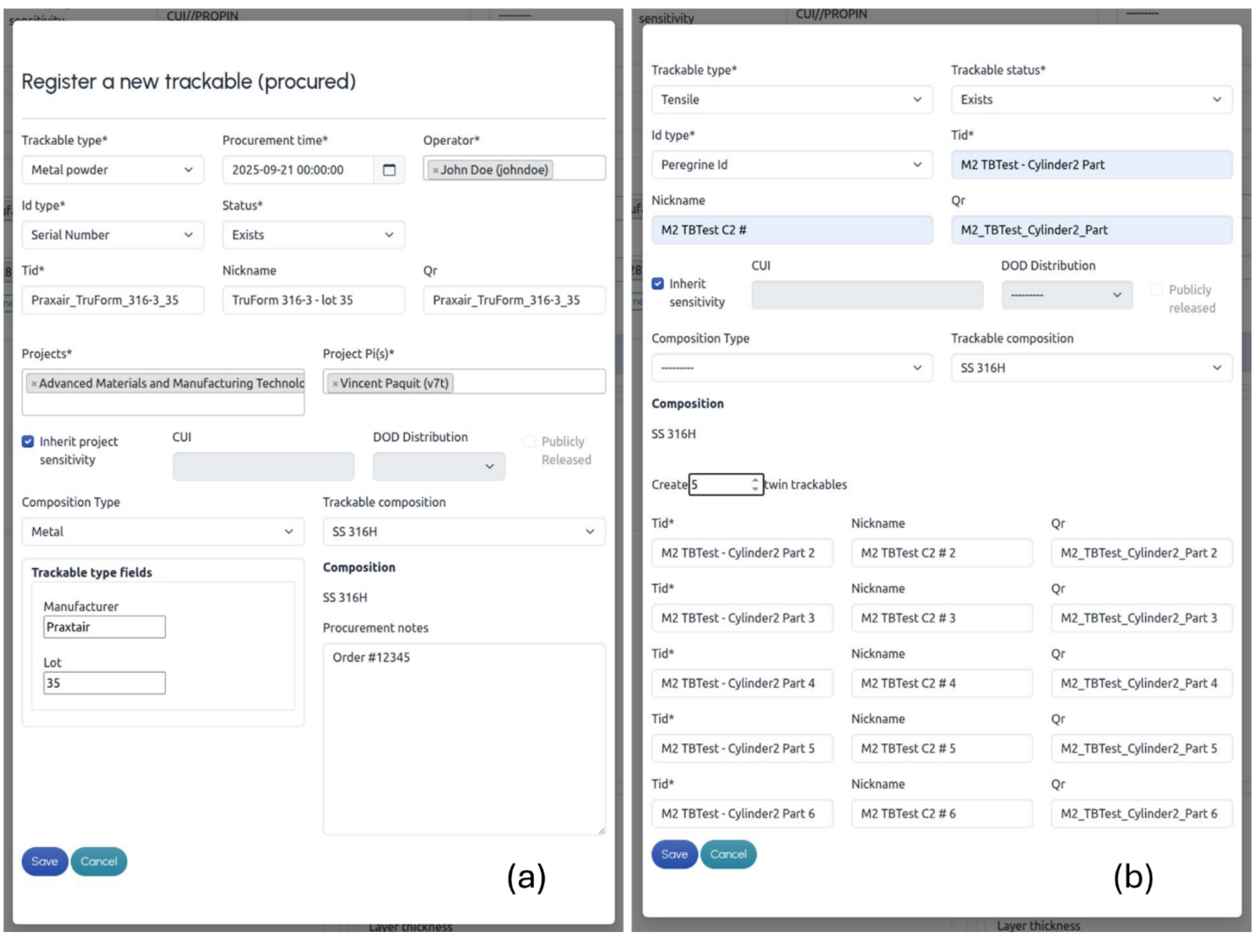



**Figure 13. Trackable creation forms example.** (a) Procurement form—submission generates the trackable and its initial procurement operation. (b) Resulting trackable form—in this example, six trackables (one main + five twins) are created and automatically added to the Output Trackable field of the Operation form.

# 5. CONCLUSION

This work package successfully deployed an initial instance of the Damara Tern platform for AMMT program collaborative research. This instance of Damara Tern provides a shared environment for capturing operations, trackables, and associated metadata. By implementing configurable, schema-driven data entry forms, the platform enables contributors to record experimental procedures and results consistently that reflect the specific requirements of participating laboratories.

This deployment demonstrated the platform's ability to accommodate generic and operation-specific metadata, supporting flexible and extensible data capture workflows. Contributors were able to create new operations and trackables, attach related documents, and interact with the digital thread linking inputs and outputs. These capabilities established a structured foundation for traceability and data organization.

Overall, the work package delivered a functional and validated instance of Damara Tern and offered a reference for end users and a tested framework for future production-scale deployments. The platform is now positioned to support ongoing AMMT program research activities, facilitate cross-site collaboration, and serve as a basis for further development of domain-specific functionalities.