BEAST: Expanding Sustainable Data Infrastructure for High-Enthalpy Facilities

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Abstract

Reproducible, data-driven thermal protection system (TPS) research requires that experimental records from high-enthalpy testing be consistently structured, traceable, and accessible across campaigns and institutions. In practice, however, arcjet and plasma facilities data remain largely fragmented: raw diagnostics are stored in ad hoc formats, material sample histories are disconnected from test conditions, and metadata standards are absent, precluding systematic cross-campaign analysis and long-term reuse.
BEAST (Backend for Experiment Analysis, Storage, and Traceability) is an open-source, web-based platform that addresses these limitations by providing a unified, queryable infrastructure for high-enthalpy ground-test data [1]. First presented at the 15th Ablation Workshop [2], BEAST has since undergone significant development. The platform ingests and structures multi-channel time-series diagnostics, facility configurations, and material property records within a common provenance model, ensuring end-to-end traceability from raw sensor acquisition to reduced experimental quantities. A versioned material library links specimen identity and processing history to the specific runs in which each sample was tested. An integrated modeling workbench enables training and evaluation of regression models directly on archived experimental data, supporting condition interpolation and the construction of empirical material response databases.
Beyond its original deployment at NASA Ames Research Center, BEAST has been designed to be **facility-agnostic**, with ongoing efforts to extend its adoption to other facilities. Its **modular architecture** accommodates heterogeneous diagnostic setups and facility types, and its future open-source distribution allows institutions to build on a common data standard rather than maintaining isolated, bespoke solutions.
BEAST is further integrated within a broader ecosystem of companion tools: **arcjetCV** [3] extracts recession rates and shock standoff distances from high-speed video using computer vision, and **miniSTARscan** [4] provides sub-minute, portable photogrammetric surface reconstruction of test articles before and after exposure. All tools share a common data schema, enabling seamless ingestion of surface geometry, imagery, and time-series data into a single, coherent experimental record.

keyword: *High-enthalpy testing, data management, thermal protection systems, ablation, material traceability, experimental database*

BEAST Overview

BEAST brings everything a **high-enthalpy test facility** needs into one browser-accessible, provenance-aware platform, turning scattered, ad hoc test data into a **centralized**, **queryable** record.
Built on a modular **Python/Django architecture**, the platform ingests heterogeneous data types (EU time-series, video, images, PDFs, 3D scans), applies automated calibrations and error flags, and generates run-summary reports without manual intervention.
It implements the **FAIR principles** of data stewardship: data is Findable via hierarchical browse and REST API, Accessible through web-based SAML authentication, Interoperable with standard formats (CSV, HDF5, JSON, Excel), and Reusable through a cross-linked provenance schema.
The home page puts it all one click away: jump into any active campaign, check facility status at a glance, browse materials, or launch a new model, with recent activity surfaced first.

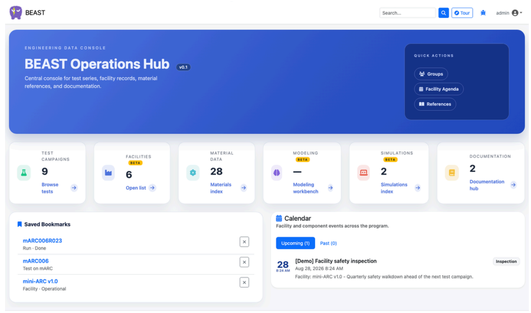

Figure 1: BEAST home dashboard

BEAST Vision

- **Facility-agnostic standard:** Beyond its original deployment at NASA Ames, BEAST provides a shared data standard for high-enthalpy test facilities across institutions.
- **Adaptable architecture:** Its modular Python/Django architecture supports different diagnostic setups and apparatus topologies through configurable channel mapping, unit normalization, and facility-specific metadata.
- **Open-source :** Distributed as open-source software, BEAST supports community-wide adoption and contributes to the NASA Arc Jet Modernization (AJM) project.
- **Connected analysis ecosystem:** BEAST integrates with arcjetCV for video-based recession rate and shock standoff extraction, and miniSTARscan for photogrammetric surface reconstruction.
- **End-to-end pipelines:** A shared data schema enables automated ingestion of 3D reconstructions and recession tracks, linking raw acquisition to model training and database construction.
- **Unified provenance:** A single provenance chain connects geometry, imagery, time-series data, calibrations, and model outputs into one reusable experimental record.
- **Uncertainty quantification:** BEAST tracks measurement uncertainty and calibration drift across facilities, runs, and diagnostics to support validation of TPS models at previously untested conditions.
- **Scalable data access:** A browser-based interface and REST API make experimental records easier to search, retrieve, compare, and reuse across teams and facilities.
- **Machine-learning readiness:** Structured, provenance-linked datasets provide a foundation for future ML model development, benchmark construction, and data-driven discovery in thermal protection system research.
- **Long-term data stewardship:** BEAST preserves experimental records with consistent metadata, traceable processing history, and reusable formats, ensuring that high-value test data remains accessible and interpretable beyond individual campaigns or facilities.

Key Features

Test Campaign

- **Structured campaigns** organize tests, runs, and multi-channel diagnostics (heat flux, pressure, temperature, radiometry, video) under one queryable schema
- Native TDMS, CSV, and HDF5 **ingestion** via pluggable facility modules, with automatic channel mapping and unit normalization
- **Diagnostic time-series** viewer with multi-run comparison workspace for cross-run analysis

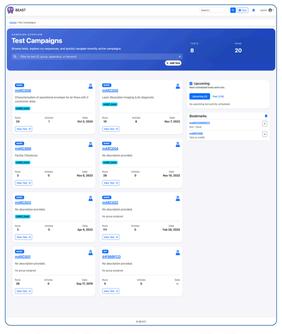

Figure 2: Test Campaigns hub in BEAST

Facility Management

- Facility topology tracks apparatus, subsystems, components, and connections, with live **operational status**
- **Configuration** snapshots link the exact component and connection state to each run for full as-tested traceability
- **Incident** and **issue** tracking, calibration history, and procedure documentation kept alongside facility records
- **Interactive** facility topology graph visualizes apparatus, subsystems, and connections

Figure 3: Facility map in BEAST

Simulation

- **Simulation records** (CFD, FEM, TPS/ablation, Monte Carlo) linked directly to their validating tests, runs, and conditions
- Solver-tagged **result plots** (PATO, OpenFOAM) stored alongside the experimental data they compare against
- Direct simulation-to-test **comparison** within the same provenance-aware database
- Simulation and validating test data **exportable** together as CSV, JSON, or HDF5 for downstream analysis

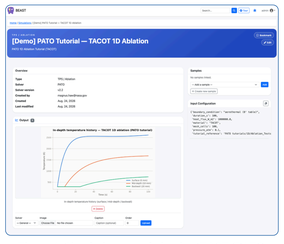

Figure 4: Simulation record view in BEAST (PATO ablation tutorial)

Material Database

- Versioned **specimen records** spanning fabrication through post-test characterization and archival
- Pre-test mass, dimensions, composition, and surface finish hard-linked to the specific run and test conditions
- **3D scans** (miniSTARscan) and recession data (arcjetCV) integrated into every specimen record
- Full **provenance** links each specimen to its raw diagnostics and reduced experimental quantities

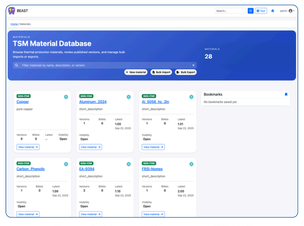

Figure 5: Material Database in BEAST

Modeling

- **Train** polynomial, Gaussian process, or neural regression models directly on archived data no export or reformatting
- **Interpolate** across heat flux, pressure, and enthalpy space to build empirical TPS response databases at untested conditions
- Full model versioning: datasets, hyperparameters, and metrics stored alongside weights for reproducibility and **comparison**

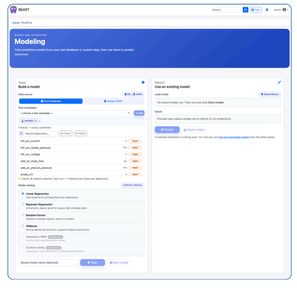

Figure 6: Simulation detail view in BEAST

Documentation

- Wiki-based knowledge base organizes procedures and reference material into categories, topics, and articles
- Facility **procedures**, calibration notes, and file attachments linked directly to the equipment they describe
- Published **references** (papers, reports) connected to the tests, runs, and test articles that cite them
- **Calibration** records and per-measurement data-quality flags cross-referenced with facility procedures

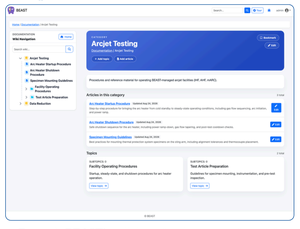

Figure è: BEAST's collaborative documentation wiki,

References

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