QUDT

QUDT Introduction

Quantities, Units, Dimensions and Types

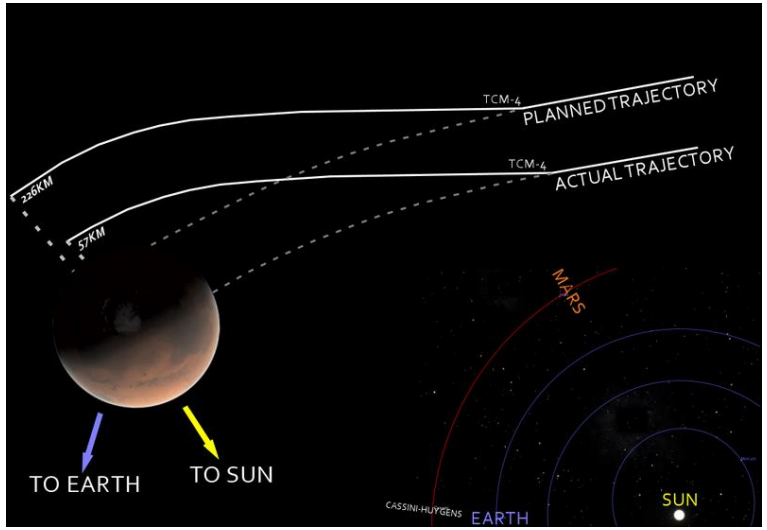
May 20, 2025

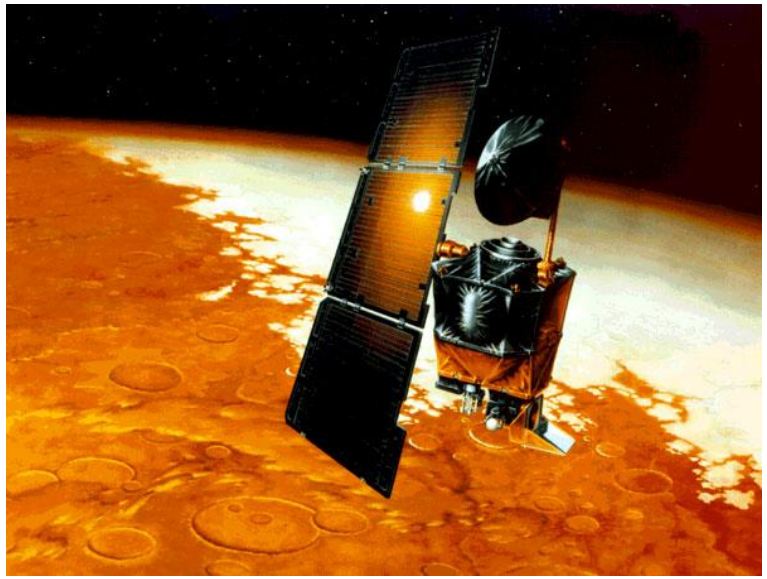
Steve Ray, CEO QUDT.org
Ralph Hodgson, President QUDT.org

A key NASA Motivation

NASA's metric confusion caused Mars orbiter loss

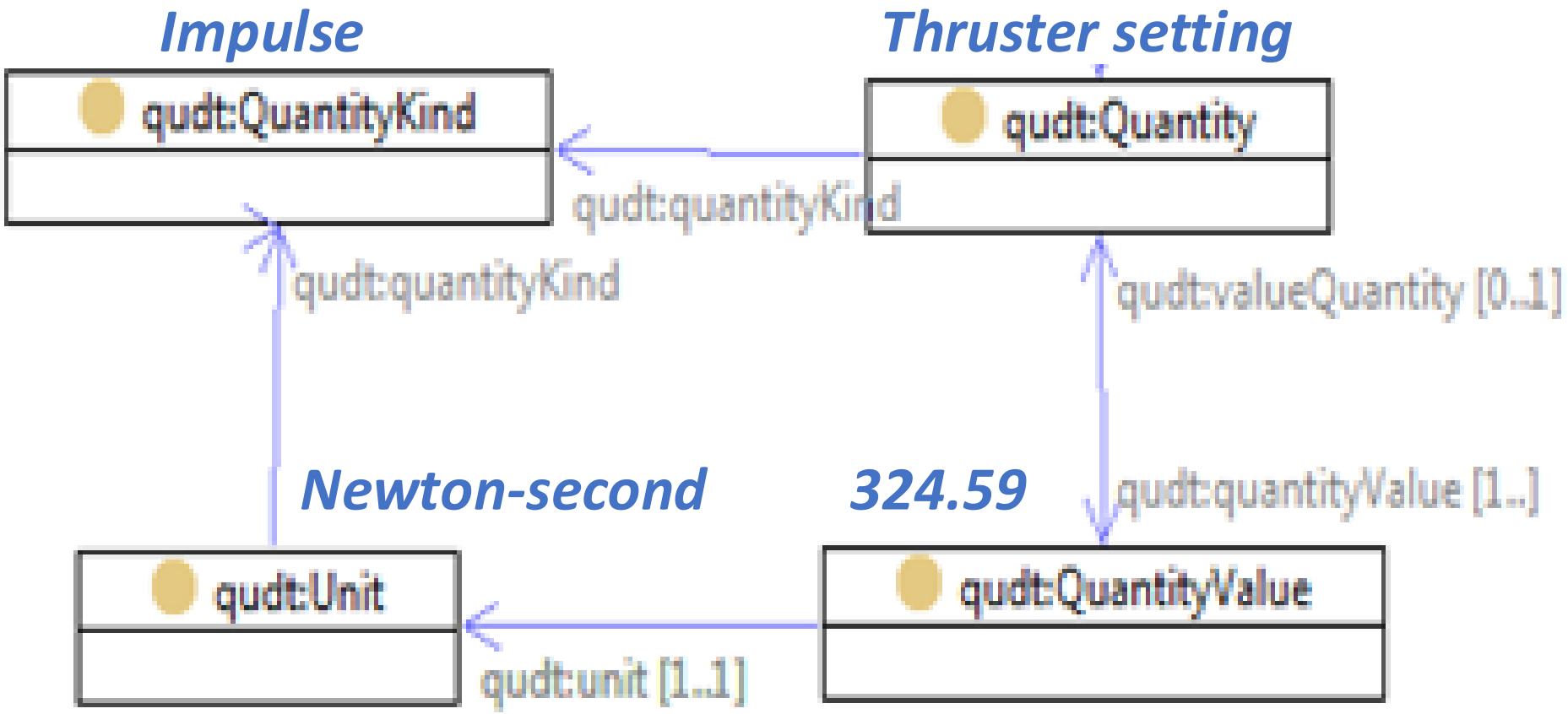
Web posted at: 1:46 p.m. EDT (1746 GMT)
(CNN) -- NASA lost a $125 million Mars orbiter because one engineering team used metric units while another used English units





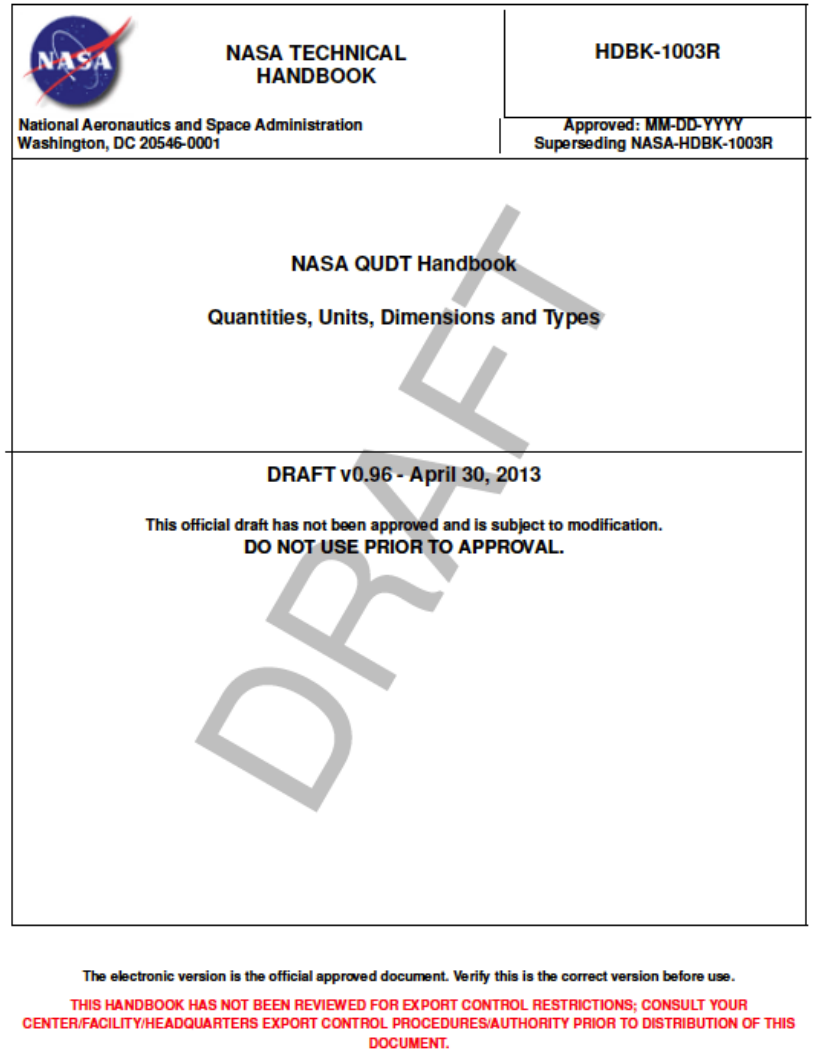
Machine-readable Metadata

"Thruster setting to Impulse with value 324.59 Newton-seconds"



NASA Motivations For the Constellation Program (Return to Moon and Mars)

- Model-based QUDT vocabularies and schemas expressed in W3C RDF and OWL standards.
- Provided as a QUDT Handbook and Interoperable machine-processable tools (NExIOM)



NASA TECHNICAL HANDBOOK

HDBK-1003R

National Aeronautics and Space Administration
Washington, DC 20546-0001

Approved: MM-DD-YYYY
Superseding NASA-HDBK-1003R

NASA QUDT Handbook

Quantities, Units, Dimensions and Types

DRAFT v0.96 - April 30, 2013

This official draft has not been approved and is subject to modification.
DO NOT USE PRIOR TO APPROVAL.

DRAFT

The electronic version is the official approved document. Verify this is the correct version before use.

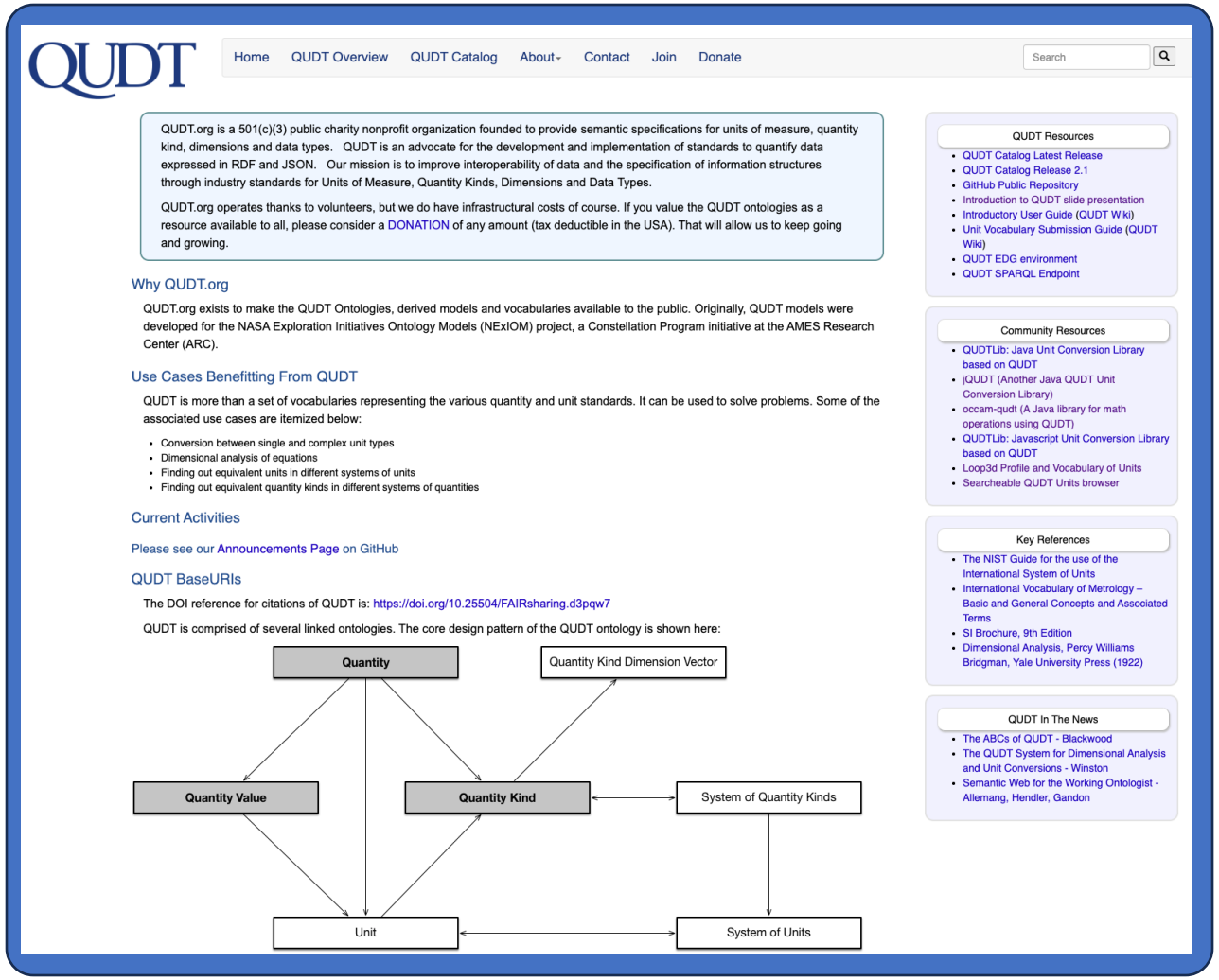
THIS HANDBOOK HAS NOT BEEN REVIEWED FOR EXPORT CONTROL RESTRICTIONS; CONSULT YOUR CENTER/FACILITY/HEADQUARTERS EXPORT CONTROL PROCEDURES/AUTHORITY PRIOR TO DISTRIBUTION OF THIS DOCUMENT.

NASA QUDT started with ISO-80000 standards

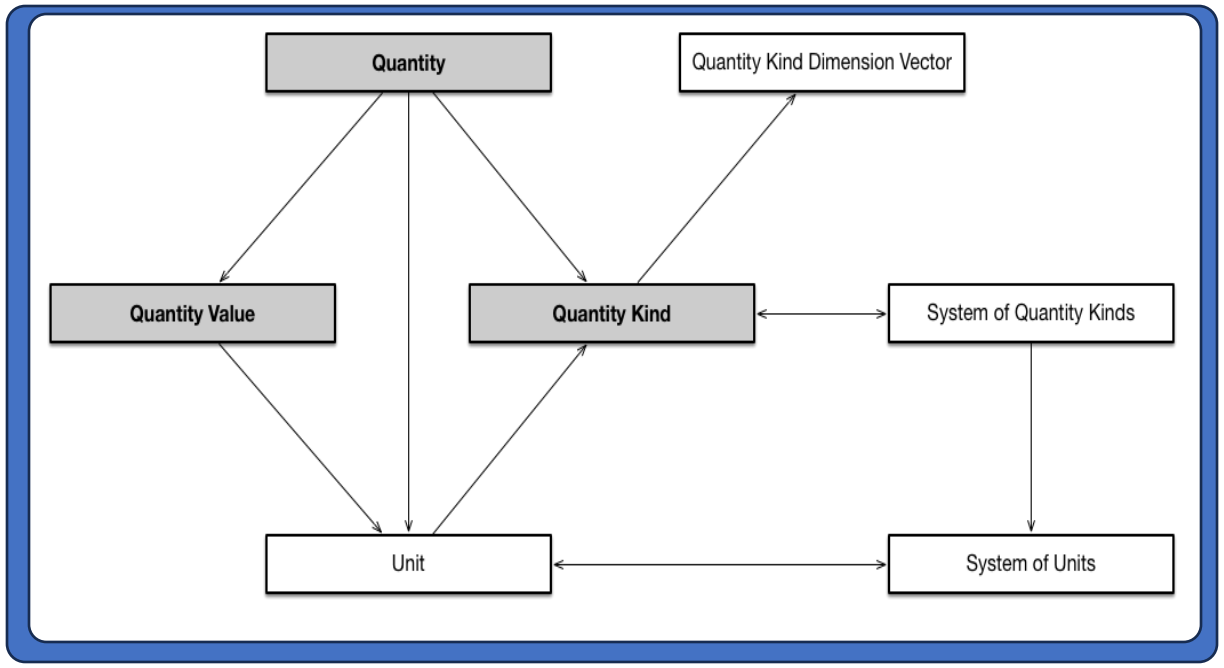
1. ISO-80000-01 2009 ISO 80000-1:2009 Quantities and units – Part 1: Generals
2. ISO-80000-01 2009/Cor 1:2011 ISO 80000-1:2009 Quantities and units – Part 1: General (Correction 1)
3. ISO-80000-02 2009 ISO 80000-2:2009 Quantities and units – Part 2: Mathematical signs and symbols to be used in the natural sciences and technology
4. ISO-80000-03 2006 ISO 80000-3:2006 Quantities and units – Part 3: Space and time
5. ISO-80000-04 2006 ISO 80000-4:2006 Quantities and units – Part 4: Mechanics
6. ISO-80000-05 2007 ISO 80000-5:2007Quantities and units – Part 5: Thermodynamics
7. ISO-80000-06 2008 IEC 80000-6:2008 Quantities and units – Part 6: Electromagnetism
8. ISO-80000-07 2008 ISO 80000-7:2008 Quantities and units – Part 7: Light
9. ISO-80000-08 2007 ISO 80000-8:2007 Quantities and units – Part 8: Acoustics
10. ISO-80000-09 2009 ISO 80000-9:2009 Quantities and units – Part 9: Physical chemistry and molecular physics
11. ISO-80000-09 2009/Amd 1:2011 ISO 80000-9:2009/Amd 1:2011
12. ISO-80000-10 2009 ISO 80000-10:2009 Quantities and units – Part 10: Atomic and nuclear physics
13. ISO-80000-11 2009 ISO 80000-11:2008 Quantities and units – Part 11: Characteristic numbers
14. ISO-80000-12 2009 ISO 80000-12:2009 Quantities and units – Part 12: Solid state physics
15. ISO-80000-13 2008 IEC 80000-13:2008 Quantities and units – Part 13: Information science and technology
16. ISO-80000-14 2008 IEC 80000-14:2008 Quantities and units – Part 14: Telebiometrics related to human physiology
17. ISO/DIS 80003-02 ISO/DIS 80003-2 Physiological quantities and their units – Part 2: Physics
18. ISO/DIS 80003-03 ISO/DIS 80003-3 Physiological quantities and their units – Part 3: Chemistry
19. ISO/NP 80003-02 ISO/NP 80003-7 Physiological quantities and their units – Part 7: Physicopharmacology
20. ISO/NP 80003-06 ISO/NP 80003-8 Physiological quantities and their units – Part 8: Chemopharmacology
21. ISO/NP 80003-08 ISO/NP 80003-8 Physiological quantities and their units – Part 8: Chemopharmacology

What is QUDT.org?

- QUDT.org publishes curated work:
  - for humans: as QUDT Web pages www.qudt.org
  - for machines: as RDF/OWL and SHACL Ontologies at www.qudt.org
- QUDT enables Web Services
  - for Conversions
  - for Error detection - consistency and correctness auditing for engineering reviews, reports and software code
  - for Dimensional analysis

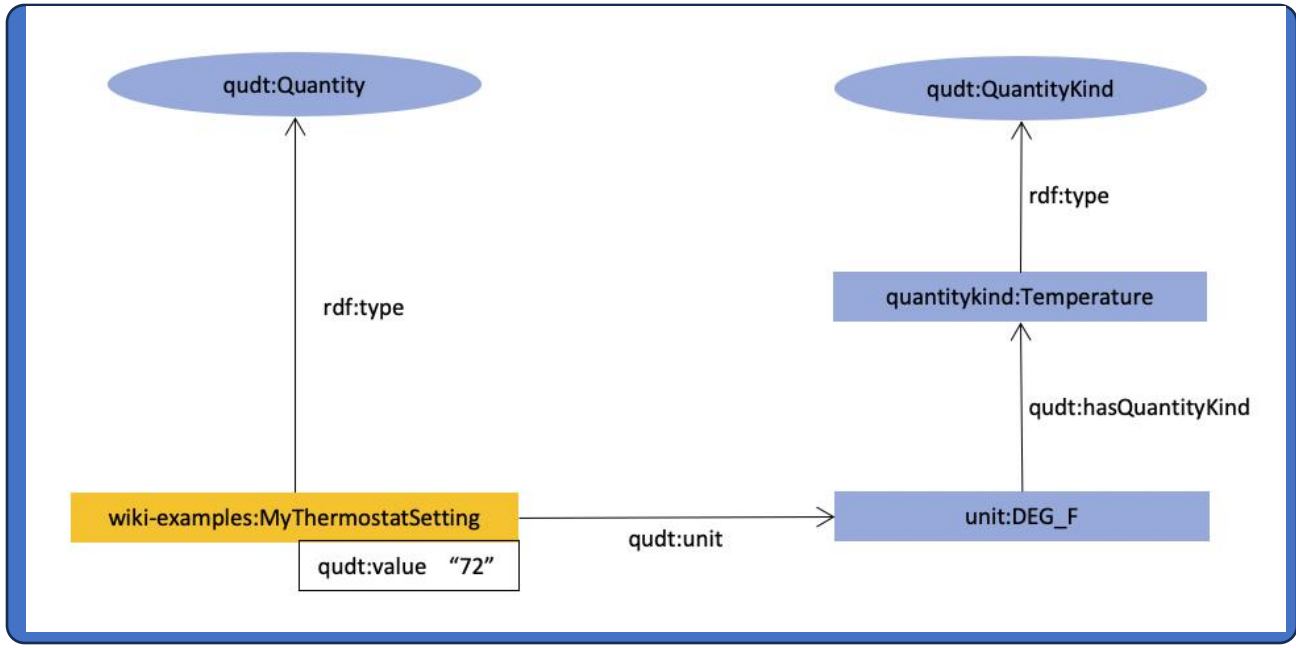


What is QUDT?



- Options for alignment between IDO and QUDT classes and vocabularies are being explored
- Will lead to improvements to IDO & QUDT

Example data:



Key Features of QUDT

- Exists as a set of FAIR-compliant modular graphs for
  - Schema (both OWL and SHACL)
  - Vocabularies of
    - 2807 Units
    - 1169 Quantity Kinds
    - 224 Dimension Vectors (for the 7 SI base dimensions)
    - 328 Physical Constants
    - 11 Systems of Units
    - 10 Systems of Quantity Kinds
- Fully resolvable URIs for all vocabulary instances, (with content negotiation), and for the entire graphs
- Defined grammar for unit URI names
- Encoded as Turtle RDF files
- Web-based browsing and SPARQL querying
- QUDT is licensed under a Creative Commons Attribution 4.0 International License

https://qudt.org/vocab/unit/A.html

https://qudt.org/vocab/unit/A.ttl

Adoption – Standards Activities

Sample standards activities adopting QUDT

- ASHRAE Standard 223 (Public Review underway) - building automation interoperability standard
- Australia and New Zealand Soil Data Standards
- Brick - open source semantic standard for building metadata
- Letter of Intent signed with POSC Caesar Association (PCA)

Harmonization activities

- IEC/SC3D
- ISO 23726-3 (IDO) with POSC Caesar Association (PCA)
  - PCA is a candidate as ISO 23726 Maintenance Agency

Cross-references from QUDT
- Digital SI
- IEC 61360
  (CDD, Common Data Dictionary)
- UNECE
- UCUM
- OM
- UDUNITS

Cross-references to QUDT
-Wikidata
-Semantic Arts

QUDT

Adoption – Sample of Organisations

- Commonwealth Scientific and Industrial Research Organisation (CSIRO) - geosciences and ecological research
- DSA Data Society Alliance (https://data-society-alliance.org/#top) in Japan (formerly DTA Data Trading Alliance) - Guidelines call for use of QUDT
- Siemens - Manufacturing (SCADA), Building Environments and SmartGrid Research, "Digital Twins," Enterprise-wide Ontology Library
- Corning - manufacturing line configuration
- Australian National Biodiversity data store (under development)
  - QUDT use is mandated
- Environmental Data Initiative (EDI) - mandates QUDT use
  - See https://github.com/EDIorg/Units-WG
- Industrial Ontology Foundry (https://industrialontologies.org/)
- Semantic Arts - consulting firm specializing in data-centric transformation

QUDT

Community Software Contributions

Tools and libraries based on QUDT:

https://github.com/egonw/jqudt

- Java Library to deal with QUDT units and conversions between them.

https://github.com/qudtlib/qudtlib-java and https://github.com/qudtlib/qudtlib-js

- Java and JavaScript libraries supporting factorization of units

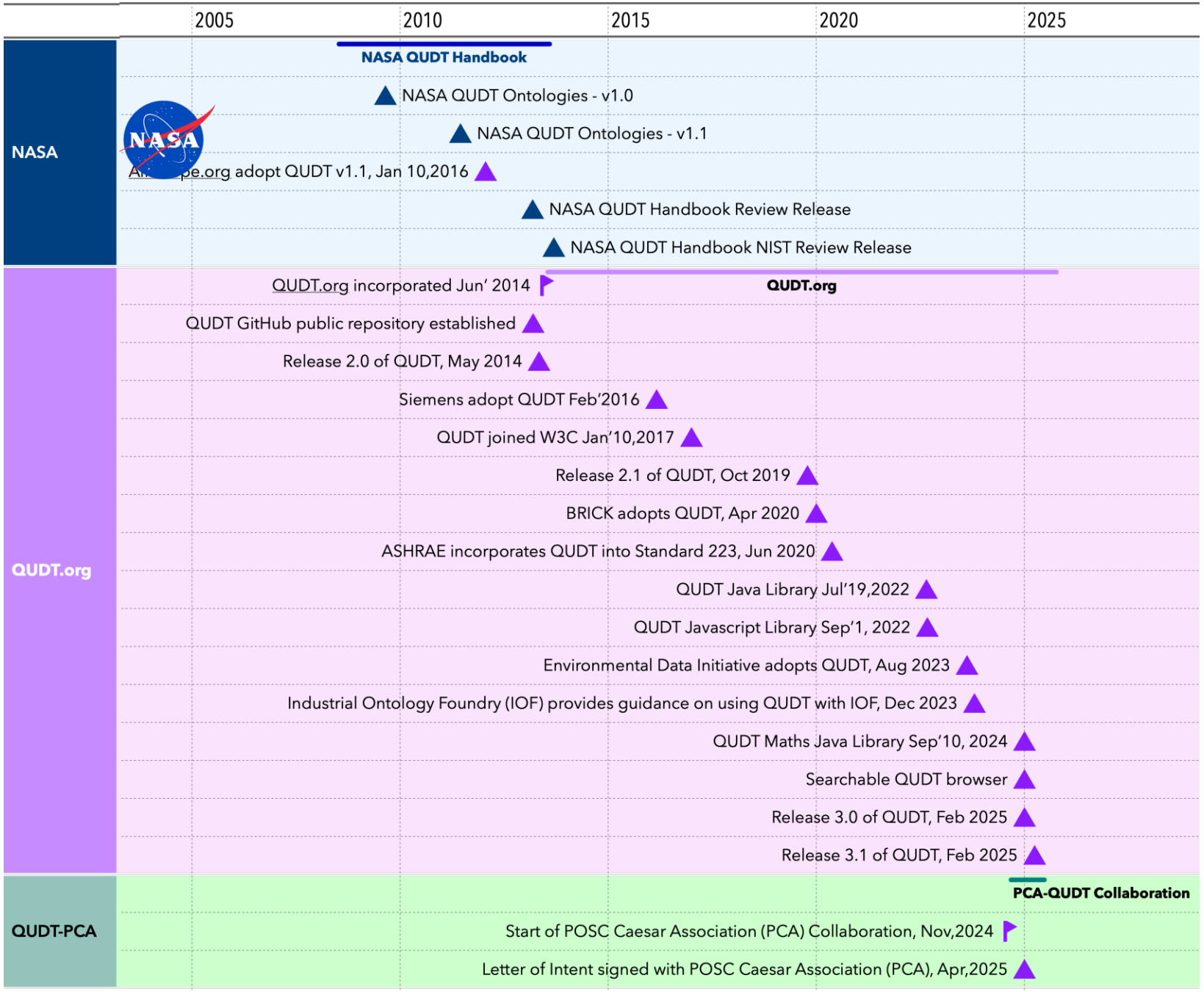
https://github.com/occamsystems/occam-qudt

- Java library for math operations using QUDT

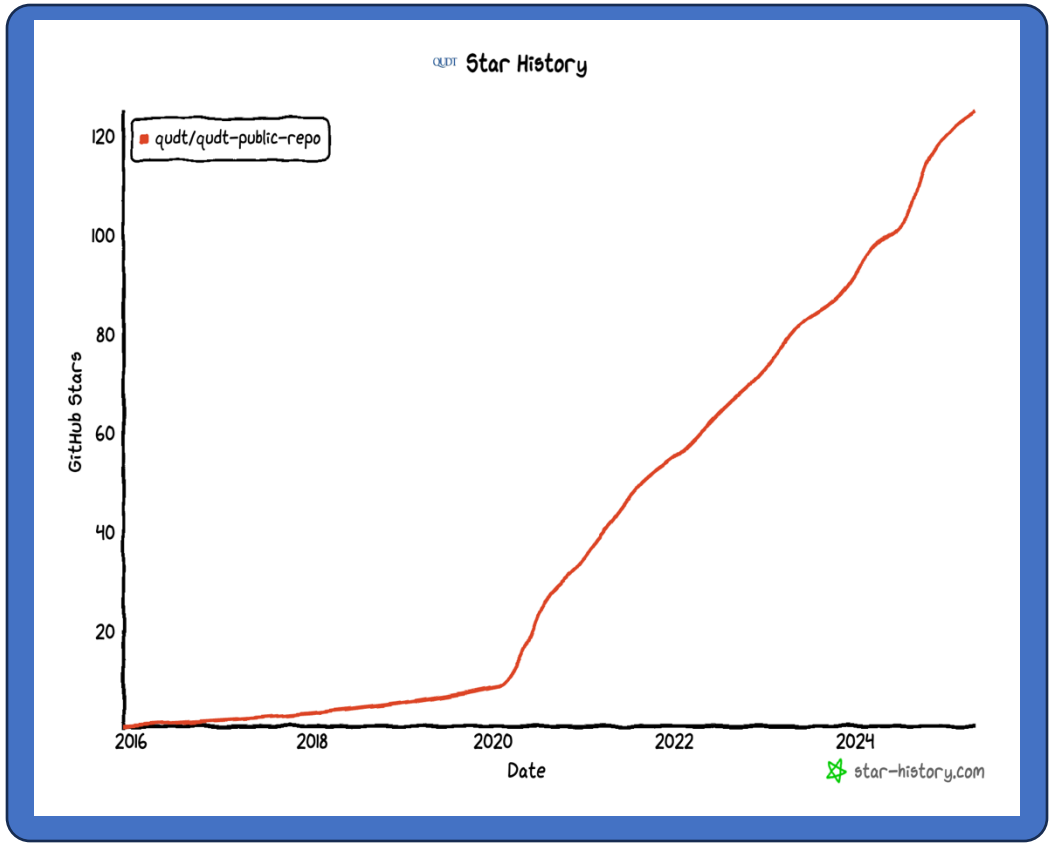
Registries and repositories:

- TriplyDB
- LOV
- FAIRSharing.org
- BioPortal
- EcoPortal

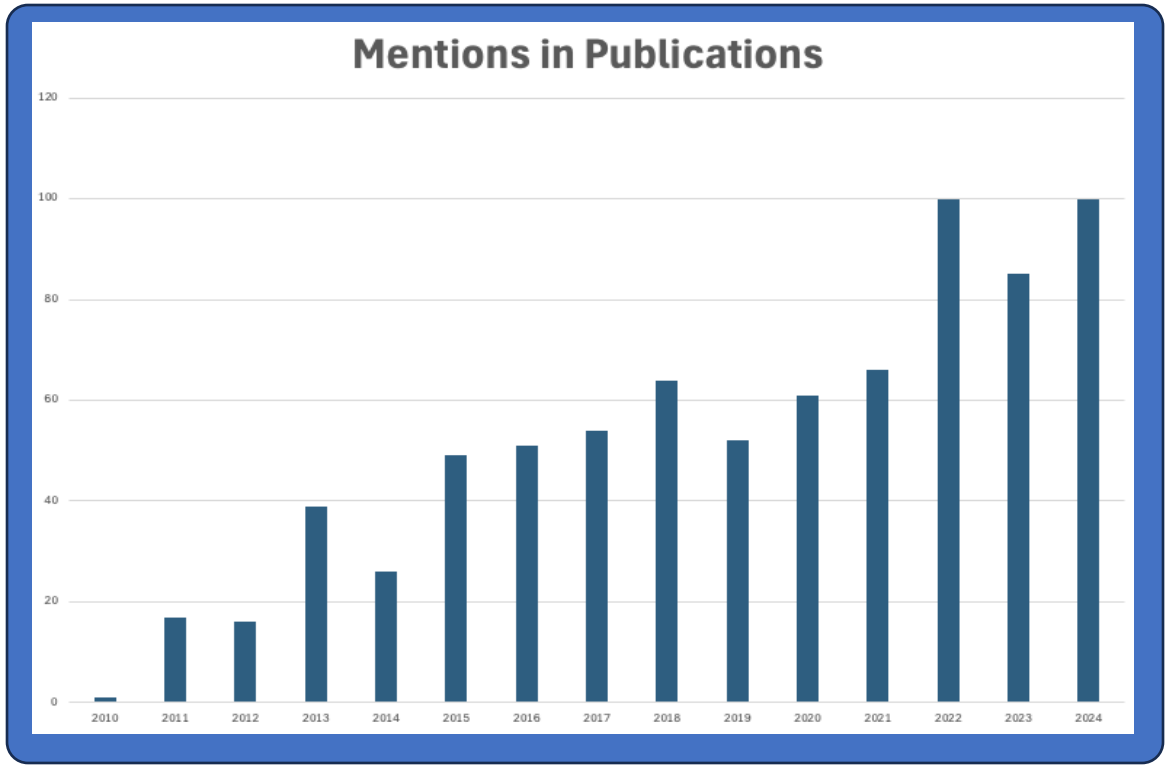
QUDT


2005
2010
2015
2020
2025
NASA
NASA QUDT Handbook
NASA QUDT Ontologies - v1.0
NASA QUDT Ontologies - v1.1
pe.org adopt QUDT v1.1, Jan 10,2016
NASA QUDT Handbook Review Release
NASA QUDT Handbook NIST Review Release
QUDT.org
QUDT.org incorporated Jun' 2014
QUDT.org
QUDT GitHub public repository established
Release 2.0 of QUDT, May 2014
Siemens adopt QUDT Feb'2016
QUDT joined W3C Jan'10,2017
Release 2.1 of QUDT, Oct 2019
BRICK adopts QUDT, Apr 2020
ASHRAE incorporates QUDT into Standard 223, Jun 2020
QUDT Java Library Jul'19,2022
QUDT Javascript Library Sep'1, 2022
Environmental Data Initiative adopts QUDT, Aug 2023
Industrial Ontology Foundry (IOF) provides guidance on using QUDT with IOF, Dec 2023
QUDT Maths Java Library Sep'10, 2024
Searchable QUDT browser
Release 3.0 of QUDT, Feb 2025
Release 3.1 of QUDT, Feb 2025
QUDT-PCA
PCA-QUDT Collaboration
Start of POSC Caesar Association (PCA) Collaboration, Nov,2024
Letter of Intent signed with POSC Caesar Association (PCA), Apr,2025

Interest Trends



GitHub “Stars”



Google Scholar

QUDT

Finding out more …

- https://qudt.org – Homepage
- https://github.com/qudt/qudt-public-repo – Github repository
- https://github.com/qudt/qudt-public-repo/wiki/User-Guide-for-QUDT – User Guide
- Email: info@qudt.org

Demo 1: Units of Force

```
SELECT DISTINCT ?qk ?qku (COALESCE(?labelEn, ?qkl) AS ?label)
WHERE {
    BIND (quantitykind:Force AS ?arg1) .
    ?qk rdf:type qudt:QuantityKind .
    FILTER (?qk = ?arg1) .
    ?qku qudt:hasQuantityKind ?qk .
   ?qku a qudt:Unit .
   ?qku rdfs:label ?qkl .
    OPTIONAL {
    ?qku rdfs:label ?labelEn .
    FILTER (lang(?labelEn) = "en")
  }
} ORDER BY ?qku
```

which results in 23 values for ?qku:

```
qk                  qku                     label
qudtqk:Force    unit:CentiN                 CentiNewton
qudtqk:Force    unit:DYN                    Dyne
qudtqk:Force    unit:DeciN                  DeciNewton
qudtqk:Force    unit:GM_F                   Gram Force
qudtqk:Force    unit:GigaN                  GigaN
qudtqk:Force    unit:KIP_F                  Kip
qudtqk:Force    unit:KiloGM-M-PER-SEC2      kilogram metre per second squared
qudtqk:Force    unit:KiloGM_F               Kilogram Force
qudtqk:Force    unit:KiloLB_F               KiloPound Force
qudtqk:Force    unit:KiloN                  Kilonewton
qudtqk:Force    unit:KiloPOND               Kilopond
qudtqk:Force    unit:LB_F                   Pound Force
```

Demo 2: Unit Conversion

```
SELECT DISTINCT ?toConvert ?label ?into (COALESCE(?labelEn, ?otherUnitLabel) AS ?otherlabel) ?multiplyB
WHERE {
BIND ("To convert" AS ?toConvert) .
BIND ("into" AS ?into) .
BIND ("multiply by" AS ?multiplyBy) .
BIND (unit:MilliGRAY as ?unit) .
?unit rdfs:label ?label .
?unit qudt:conversionMultiplier ?cm1 .
?unit qudt:hasQuantityKind/qudt:hasDimensionVector ?qkdv .
?otherUnit qudt:hasQuantityKind/qudt:hasDimensionVector ?qkdv .
?otherUnit a qudt:Unit .
FILTER (?otherUnit != ?unit) .
?otherUnit qudt:conversionMultiplier ?cm2 .
?otherUnit rdfs:label ?otherUnitLabel .
  OPTIONAL {
    ?otherUnit rdfs:label ?labelEn .
    FILTER (lang(?labelEn) = "en") .
}
BIND ((?cm1/?cm2) AS ?multiplier) .
}
ORDER BY ?otherlabel
```

Executing this query produces output that looks like this:

```
Milligray       into    BTU-IT-PER-lb                                   multiply by     0.000000429922
Milligray       into    British Thermal Unit (TH) per Pound             multiply by     0.000000430210433
Milligray       into    Calorie (international Table) per Gram          multiply by     0.00000023884589662
Milligray       into    Calorie (thermochemical) per Gram               multiply by     0.00000023900573613
Milligray       into    Erg per Gram                                    multiply by     10.0
```

Supporting information

- QUDT Supports Multiple Communities
- F.A.I.R.
- Governance Management
- Governance Policies, Principles, Processes, Issues, Measures
- Quality Assurance
- Current Developments

QUDT

Thank You

Contact us at:

info@qudt.org

QUDT Supports Multiple Communities

- Linked Data community
  - Resolvable URIs for graphs and individuals
  - Continuously updated
- Industrial User community
  - Versioning of Releases for embedding and managing within industrial applications
- Choice of OWL or SHACL representation for the schemas
- Explicit or dynamically inferred (SHACL) properties
  - E.g. “applicableUnits” for each QuantityKind
- Available for use with or without the need for reasoners

Future standards should keep these disparate needs in mind

F.A.I.R.

1. The FAIR Guiding Principles

Findable

- Globally unique identifiers for all concepts
- Metadata specified for each schema and vocabulary graph
- QUDT is registered with DOI, FAIRSharing.org, LOV, TriplyDB, BioPortal
- QUDT is cross-referenced by WikiData

Accessible

- A website is published at https://qudt.org/
- A SPARQL endpoint is available at http://www.qudt.org/fuseki
- A commercial exploration tool is available at http://www.qudt.org/edg/tbl
- All graphs, classes and vocabulary instances are resolvable on the web

Interoperable

- All artifacts are represented in standard languages
- All vocabularies are expressed using RDF (Resource Description Framework)
- QUDT schemas are expressed in both OWL and SHACL
- Includes cross-references to Digital SI, UCUM, UN-ECE, OM, IEC 61360, UDUNITS codes

Reusable

- Licensed under Creative Commons Attribution 4.0 International License
- Definitions are provided with normative and informative references

2. Symbols consistent with NIST SP811

3. Naming rules - as documented on GitHub Wiki

Governance Management

Provenance

- Provenance - source and expressions of derivation including supercedence
  - "Nothing gets deleted unless it is incorrect"
- Existing non-conformant URIs remain, but equivalent conformant URIs are added

Traceability

- to other units of measure vocabularies: UCUM, UNECE, OM, IEC 61360
- to normative and informative references, including SI Brochure – 9th Edition, ISO-80000, NIST SP811
- to compliance assurance certification verification and validation

Governance Processes

- **Versioning and Configuration Management**
  - Named graphs with major.minor.point identifiers for releases
  - Frequent repository updates using GitHub Pull Request mechanism
  - Release schedule approximately every 1-2 months or after major changes
- **Submission & Approval process**
  - Uses the GitHub Issues/Pull Request mechanism
  - Review/approval required by at least one Board member
- **Notification Processes**
  - Announcements on QUDT.org website and on GitHub
  - Discussion posts on the QUDT GitHub repository using Issues, Pull Requests, and GitHub Discussions

QUDT

Governance

Policies, Principles, Processes, Issues, Measures

Governance Policies

- Adherence to procedures for compliance with our legal status as a 501(c)(3) Non-profit charity, incorporated in the state of California
- Managed submission
- Adherence, where possible, to well-established symbols for units of measure, expressed in Unicode
- Grammar-based construction of UoM QNames

Quality Assurance

- **Issue Resolution**
  - Strategic - handled by QUDT.org Board
  - Technical - handled by Technical Advisory Board (TAB) when needed
- **Quality Processes**
  - How QUDT content is assessed for completeness, consistency and correctness
  - (SPARQL) Queries for QA V&V
  - Validation checks using (SHACL) rules
  - Continuous Integration (CI) workflow
- **Quality Measures**
  - consistency
  - completeness
  - correctness
  - compliance

QUDT

Current Developments

- **Profiles**
  - Community-Driven subsets of units and quantity kinds appropriate to domains and disciplines
- **Compact Unique Identifiers**
  - for telemetry, bandwidth-limited or memory-limited devices
- **Build Automation**
  - Validation
  - Web page publication
  - Release generation