

Quantum Tutorial

Build a Multi-tenant SaaS with Quantum

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This tutorial takes you end-to-end through building a small SaaS application on the Quantum framework. It pulls in the core concepts and how-to content from the main index in a progressive, hands-on flow so you can learn by doing.

Audience: Mid-level Java developers building multi-tenant SaaS on Quarkus and MongoDB.

Prerequisites: JDK 17+, Maven, Docker (for local MongoDB), and basic familiarity with Quarkus.

Artifacts: The docs can be built as HTML/PDF via Maven; the code snippets compile against the Quantum modules published in this repo.

What you'll build: A small, tenant-aware service with domain models, REST CRUD, flexible queries, security, migrations, and seed packs for baseline data.

Each section starts with: - Problem: What we are solving - Why for SaaS: Why this matters in multi-tenant systems - How Quantum helps: Concepts and features that address the problem - Walkthrough: Code and configuration that build on prior sections

Throughout, we reuse and expand the same example to reinforce learning. The reference guide links back to these sections for deeper context.

Chapter 1. 1. Project setup

Problem: Getting a runnable project scaffolded with Quantum and Quarkus.

Why for SaaS: Consistent project structure and dependencies are critical to scale teams and environments.

How Quantum helps: Provides opinionated dependencies, conventions, and ready-made modules for multi-tenancy, security, persistence, and seeding.

Walkthrough: Follow the steps below to create and run your first service.

1.1. Getting Started: Your First Quantum Application

This section walks through creating a simple multi-tenant Product catalog to demonstrate core Quantum concepts.

1.1.1. Prerequisites

- Java 17+
- Maven 3.8+
- MongoDB (local or cloud)
- Basic Quarkus knowledge (see [Quarkus Foundation](#))

1.1.2. Project Setup

Create a new Quarkus project with Quantum dependencies:

```
mvn io.quarkus:quarkus-maven-plugin:create \
  -DprojectGroupId=com.example \
  -DprojectArtifactId=product-catalog \
  -DclassName="com.example.ProductResource" \
  -Dpath="/products"
```

Add Quantum dependencies to `pom.xml`:

```
<dependency>
  <groupId>com.e2eq.framework</groupId>
  <artifactId>quantum-framework</artifactId>
  <version>${quantum.version}</version>
</dependency>
```

1.1.3. Configuration

Create `.env` file (copy from template):


```
MONGODB_USERNAME=your-username
MONGODB_PASSWORD=your-password
MONGODB_DATABASE=product-catalog
MONGODB_HOST=localhost:27017
JWT_SECRET=your-secret-key
```

Basic `application.properties`:

```
# MongoDB
quarkus.mongodb.connection-
string=${MONGODB_CONNECTION_STRING:mongodb://localhost:27017}
quarkus.mongodb.database=${MONGODB_DATABASE:product-catalog}

# JWT Authentication
auth.provider=custom
auth.jwt.secret=${JWT_SECRET:change-me-in-production}
auth.jwt.expiration=60

# CORS for development
quarkus.http.cors=true
quarkus.http.cors.origins=http://localhost:3000
```

1.1.4. Your First Model

Create a Product model with multi-tenancy built-in:

```
package com.example.model;

import com.e2eq.framework.annotations.FunctionalMapping;
import com.e2eq.framework.model.persistent.base.BaseModel;
import dev.morphia.annotations.Entity;
import lombok.Data;
import lombok.EqualsAndHashCode;
import lombok.NoArgsConstructor;
import lombok.experimental.SuperBuilder;

import jakarta.validation.constraints.NotBlank;
import jakarta.validation.constraints.Size;
import java.math.BigDecimal;

@Entity
@Data
@NoArgsConstructor
@SuperBuilder
@EqualsAndHashCode(callSuper = true)
@FunctionalMapping(area = "catalog", domain = "product")
public class Product extends BaseModel {
```

```

@NotBlank
@Size(max = 50)
private String sku;

@NotBlank
@Size(max = 200)
private String name;

private String description;
private BigDecimal price;
private boolean active = true;
}

```

Key points: - Extends `BaseModel` for automatic `DataDomain`, audit fields, and ID management - `@FunctionalMapping` declares this model's business area and domain for security rules - Standard Jakarta validation annotations - Lombok reduces boilerplate

1.1.5. Repository

Create a repository interface:

```

package com.example.repository;

import com.e2eq.framework.model.persistent.morphia.MorphiaRepo;
import com.example.model.Product;

public interface ProductRepo extends MorphiaRepo<Product> {
    // Custom queries can be added here
}

```

1.1.6. REST Resource

Create a REST endpoint:

```

package com.example.resource;

import com.e2eq.framework.rest.resources.BaseResource;
import com.example.model.Product;
import com.example.repository.ProductRepo;
import jakarta.ws.rs.Path;

@Path("/products")
public class ProductResource extends BaseResource<Product, ProductRepo> {
    // Inherits all CRUD endpoints: GET, POST, PUT, DELETE
    // GET /products/list - paginated list with filtering
    // GET /products/id/{id} - get by ID
    // POST /products - create new product
    // PUT /products/set?id={id}&pairs=field:value - update fields
}

```

```
// DELETE /products/id/{id} - delete product  
}
```

1.1.7. Running the Application

Start your application:

```
./mvnw quarkus:dev
```

The application provides: - Swagger UI at <http://localhost:8080/q/swagger-ui/> - Dev UI at <http://localhost:8080/q/dev/>

1.1.8. Testing Your API

Create a product:

```
curl -X POST http://localhost:8080/products \  
-H "Content-Type: application/json" \  
-d '{  
  "sku": "WIDGET-001",  
  "name": "Super Widget",  
  "description": "The best widget ever",  
  "price": 29.99,  
  "active": true  
}'
```

List products:

```
curl "http://localhost:8080/products/list?limit=10&sort=+name"
```

Filter products:

```
curl "http://localhost:8080/products/list?filter=active:true&price:>##20"
```

1.1.9. What You Get Automatically

With this minimal setup, Quantum provides:

Multi-tenancy: Each product is automatically tagged with the creator's DataDomain (tenant, org, owner)

Security: DataDomain filtering ensures users only see their own data by default

Validation: Jakarta Bean Validation runs before persistence

Audit Trail: Automatic createdBy, createdAt, lastUpdatedBy, lastUpdatedDate fields

Consistent APIs: Standard REST patterns across all resources

Query Language: Powerful filtering with the ANTLR-based query syntax

OpenAPI: Automatic API documentation

1.1.10. Next Steps

- Add authentication: [Authentication Guide](#)
- Create sharing rules: [Permissions Guide](#)
- Learn the query language: [Query Language](#)
- See real-world example: [Supply Chain Tutorial](#)

1.1.11. Optional: Enable Ontology Modules

You can adopt ontology incrementally. If you don't enable it, everything works as before.

Quick checklist

1) Add dependencies (app-level) - quantum-ontology-core, quantum-ontology-mongo, quantum-ontology-policy-bridge

2) Turn it on via config

```
e2eq.ontology.enabled=true
```

3) Provide an ontology registry (TBox) - Start with an in-memory registry (recommended initially). See [Ontologies in Quantum](#).

4) Wire data and indexes - Inject EdgeDao as a CDI bean (@Inject); indexes are ensured automatically at startup. - Indices: (tenantId, p, dst) and (tenantId, src, p)

5) Materialize edges on entity changes - Use OntologyMaterializer when sources or intermediates change (e.g., Order/Customer/Org/Address/Shipment in the e-commerce example).

6) Use edges in queries/policies - Wrap BSON via ListQueryRewriter or constrain by _id sets. See [Integrating Ontology](#).

Notes

- Keep it optional: only wire beans and create collections when e2eq.ontology.enabled=true.
- Multi-tenant: always pass tenantId from RuleContext.

Chapter 2. 2. Platform overview

Problem: Understanding the moving parts and how they fit together.

Why for SaaS: You'll be composing features (tenancy, security, APIs, data) across many modules and services.

How Quantum helps: A cohesive model with clear boundaries and integration points.

Walkthrough: Read the overview and keep it handy as you progress.

2.1. Overview: Building SaaS with Quantum

Quantum is a Quarkus-based framework that accelerates building multi-tenant SaaS platforms on MongoDB. It provides:

- Multi-tenancy primitives for tenant creation, isolation, and data sharing
- A domain-first programming model with Functional Areas, Functional Domains, and Actions
- Data security and contextual evaluation via DataDomain, DomainContext, and RuleContext
- Consistent REST resources for find/get/list/save/update/delete operations
- Pluggable authentication with a provided JWT module and extension points

This guide targets mid-level Java developers and follows a structure similar to Spring's reference docs. Use Maven to generate HTML/PDF: see docs module README for commands.

2.1.1. SaaS and Multi-Tenancy First

SaaS solutions require:

- Onboarding automation: programmatic tenant creation, freemium/trial flows
- Isolation with selective sharing
- Policy-driven access that adapts to user, org, tenant, and action
- Operational efficiency (observability, cost control, upgradeability)

Quantum's building blocks address these needs out-of-the-box while remaining flexible to fit your architecture.

Chapter 3. 3. Domain modeling fundamentals

Problem: Modeling your domain effectively for persistence and API exposure.

Why for SaaS: Cross-tenant scale and isolation drive modeling choices (IDs, natural keys, versioning, ownership).

How Quantum helps: Provides base models, annotations, and repository patterns to model tenant-safe entities.

Walkthrough: Build a minimal domain model and persist it.

3.1. Modeling with Functional Areas, Domains, and Actions

Quantum organizes your system around three core constructs:

- Functional Area: A broad capability area (e.g., Identity, Catalog, Orders, Collaboration).
- Functional Domain: A cohesive sub-area within an area (e.g., in Collaboration: Partners, Shipments, Tasks).
- Actions: The set of operations applicable to a domain (CREATE, UPDATE, VIEW, DELETE, ARCHIVE, plus domain-specific actions).

These constructs allow:

- Fine-grained sharing: Point specific functional areas to shared databases while others remain strictly segmented.
- Policy composition: Apply RuleContext decisions at the level of area/domain/action.

Prefer Annotations for Functional Mapping (recommended)

Starting with this version, you should use annotations to declare a model or resource's Functional Area/Domain and the Action being performed. The legacy `bmFunctionalArea()` and `bmFunctionalDomain()` methods are still supported for backward compatibility in this release, but they will be phased out soon.

- Class-level mapping: use `@FunctionalMapping(area = "<area>", domain = "<domain>")` on your model or resource class.
- Method-level action: use `@FunctionalAction("<ACTION>")` on your JAX-RS resource methods when the action is not implied by the HTTP verb.

Example: model annotated with `FunctionalMapping`

```
import dev.morphia.annotations.Entity;
import lombok.*;
```

```

import lombok.experimental.SuperBuilder;
import com.e2eq.framework.model.persistent.base.BaseModel;
import com.e2eq.framework.annotations.FunctionalMapping;

@Entity
@Data
@NoArgsConstructor
@SuperBuilder
@EqualsAndHashCode(callSuper = true)
@FunctionalMapping(area = "catalog", domain = "product")
public class Product extends BaseModel {
    private String sku;
    private String name;
    // No need to override bmFunctionalArea/bmFunctionalDomain when using
    @FunctionalMapping
}

```

Example: resource method annotated with FunctionalAction

```

import jakarta.ws.rs.*;
import jakarta.ws.rs.core.MediaType;
import com.e2eq.framework.annotations.FunctionalAction;

@Path("/products")
@Produces(MediaType.APPLICATION_JSON)
@Consumes(MediaType.APPLICATION_JSON)
public class ProductResource {

    // Action will default from HTTP verb (POST -> CREATE), but you can be explicit:
    @POST
    @FunctionalAction("CREATE")
    public Product create(Product payload) { /* ... */ return payload; }

    // GET will infer VIEW automatically when building the ResourceContext
    @GET
    @Path("/{id}")
    public Product get(@PathParam("id") String id) { /* ... */ return new Product(); }
}

```

How the framework uses these annotations

- **SecurityFilter:** If the matched resource class has `@FunctionalMapping`, it uses area/domain from the annotation. If the method has `@FunctionalAction`, it uses that value; otherwise, it infers the action from the HTTP method (GET=VIEW, POST=CREATE, PUT/PATCH=UPDATE, DELETE=DELETE). If annotations are absent, it falls back to the existing path- and convention-based logic.
- **MorphiaRepo.fillUIActions:** If the model class has `@FunctionalMapping`, its area/domain are used to resolve allowed UI actions; otherwise, it falls back to the legacy

bmFunctionalArea()/bmFunctionalDomain() methods.

- **PermissionResource:** When listing functional domains, it prefers @FunctionalMapping on entity classes and falls back to bmFunctionalArea()/bmFunctionalDomain() when missing.

Migration notes

- **Preferred:** add @FunctionalMapping to each model class (or resource class) and remove the bmFunctionalArea/bmFunctionalDomain overrides.
- **Transitional:** you can keep the legacy methods; they will be used only if the annotation is not present.
- **Future:** bmFunctionalArea and bmFunctionalDomain will be removed in a future release; plan to migrate now.

See also: [Security Annotations: FunctionalMapping and FunctionalAction](#)

DataDomain on Models

All persisted models carry DataDomain (tenantId, orgRefName, ownerId, etc.) for rule-based filtering and cross-tenant sharing.

Example model:

```
import dev.morphia.annotations.Entity;
import lombok.Data;
import lombok.EqualsAndHashCode;
import lombok.NoArgsConstructor;
import lombok.experimental.SuperBuilder;
import com.e2eq.framework.model.persistent.base.BaseModel;

@Entity
@Data
@NoArgsConstructor
@SuperBuilder
@EqualsAndHashCode(callSuper = true)
public class Product extends BaseModel {
    private String sku;
    private String name;

    @Override
    public String bmFunctionalArea() { return "Catalog"; }

    @Override
    public String bmFunctionalDomain() { return "Product"; }
}
```

Persistence Repositories

Define a repository to persist and query your model. With Morphia:


```
import com.e2eq.framework.model.persistent.morphia.MorphiaRepo;

public interface ProductRepo extends MorphiaRepo<Product> {
    // custom queries can be added here
}
```

Exposing REST Resources

Expose consistent CRUD endpoints by extending BaseResource.

```
import com.e2eq.framework.rest.resources.BaseResource;
import jakarta.ws.rs.Path;

@Path("/products")
public class ProductResource extends BaseResource<Product, ProductRepo> {
    // Inherit find, get, list, save, update, delete endpoints
}
```

With this minimal setup, you get standard REST APIs guarded by RuleContext/DataDomain and enriched with UIAction metadata.

Lombok in Models

Lombok reduces boilerplate in Quantum models and supports inheritance-friendly builders.

Common annotations you will see:

- `@Data`: Generates getters, setters, `toString`, `equals`, and `hashCode`.
- `@NoArgsConstructor`: Required by frameworks that need a no-arg constructor (e.g., Jackson, Morphia).
- `@EqualsAndHashCode(callSuper = true)`: Includes superclass fields in equality and hash.
- `@SuperBuilder`: Provides a builder that cooperates with parent classes (useful for `BaseModel` subclasses).

Example:

```
@Data
@NoArgsConstructor
@SuperBuilder
@EqualsAndHashCode(callSuper = true)
public class Product extends BaseModel {
    private String sku;
    private String name;
}
```

Notes: - Prefer `@SuperBuilder` over `@Builder` when extending `BaseModel/UnversionedBaseModel`. -

Keep equals/hashCode stable for collections and caches; include callSuper when needed.

Validation with Jakarta Bean Validation

Quantum uses Jakarta Bean Validation to enforce invariants on models at persist time (and optionally at REST boundaries).

Typical annotations:

- @Size(min=3): String/collection length constraints.
- @Valid: Cascade validation to nested objects (e.g., DataDomain on models).
- @NotNull, @Email, @Pattern, etc., as needed.

Where validation runs:

- Repository layer via Morphia ValidationInterceptor (prePersist):
- Executes validator.validate(entity) before the document is written.
- If there are violations and the entity does not implement InvalidSavable with canSaveInvalid=true, an E2eqValidationException is thrown.
- If DataDomain is null and SecurityContext has a principal, ValidationInterceptor will default the DataDomain from the principal context.
- Optionally at REST boundaries: You may also annotate resource DTOs/parameters with Jakarta validation; Quarkus can validate them before the method executes.

Jackson vs Jakarta Validation Annotations

These two families of annotations serve different purposes and complement each other:

- Jackson annotations (com.fasterxml.jackson.annotation.*) control JSON serialization/deserialization.
- Examples: @JsonIgnore, @JsonIgnoreProperties, @JsonProperty, @JsonInclude.
- They do not enforce business constraints; they affect how JSON is produced/consumed.
- Jakarta Validation annotations (jakarta.validation.*) declare constraints that are evaluated at runtime.
- Examples: @NotNull, @Size, @Valid, @Pattern.

Correspondence and interplay:

- Use Jackson to hide or rename fields in API responses/requests (e.g., @JsonIgnore on transient/calculated fields such as UIActionList).
- Use Jakarta Validation to ensure incoming/outgoing models satisfy required constraints; ValidationInterceptor runs before persistence to enforce them.
- It's common to annotate the same field with both families when you both constrain values and want specific JSON behavior.

3.2. Jackson ObjectMapper in Quarkus and in Quantum

How Quarkus creates ObjectMapper:

- Quarkus produces a CDI-managed ObjectMapper. You can customize it by providing a bean that implements `io.quarkus.jackson.ObjectMapperCustomizer`.
- You can also tweak common features via `application.properties` using `quarkus.jackson.*` properties.

Quantum defaults:

- The framework provides a `QuarkusJacksonCustomizer` that:
- Sets `DeserializationFeature.FAIL_ON_UNKNOWN_PROPERTIES = true` (reject unknown JSON fields).
- Registers custom serializers/deserializers for `org.bson.types.ObjectId` so it can be used as String in APIs.

Snippet from the framework:

```
@Singleton
public class QuarkusJacksonCustomizer implements ObjectMapperCustomizer {
    @Override
    public void customize(ObjectMapper objectMapper) {
        objectMapper.configure(DeserializationFeature.FAIL_ON_UNKNOWN_PROPERTIES, true);
        SimpleModule module = new SimpleModule();
        module.addSerializer(ObjectId.class, new ObjectIdJsonSerializer());
        module.addDeserializer(ObjectId.class, new ObjectIdJsonDeserializer());
        objectMapper.registerModule(module);
    }
}
```

Customize in your app:

- Add another `ObjectMapperCustomizer` bean (order is not guaranteed; make changes idempotent):

```
@Singleton
public class MyJacksonCustomizer implements ObjectMapperCustomizer {
    @Override
    public void customize(ObjectMapper mapper) {
        mapper.findAndRegisterModules();
        mapper.disable(SerializationFeature.WRITE_DATES_AS_TIMESTAMPS);
        mapper.setSerializationInclusion(JsonInclude.Include.NON_NULL);
    }
}
```

- Or set properties in `application.properties`:

```
# Fail if extraneous fields are present
quarkus.jackson.fail-on-unknown-properties=true
# Example date format and inclusion
quarkus.jackson.write-dates-as-timestamps=false
quarkus.jackson.serialization-inclusion=NON_NULL
```

When to adjust:

- Relax fail-on-unknown only for backward-compatibility scenarios; strictness helps catch client mistakes.
- Register modules (JavaTime, etc.) if your models include those types.

3.3. Validation Lifecycle and Morphia Interceptors

Morphia interceptors enhance and enforce behavior during persistence. Quantum registers the following for each realm-specific datastore:

Order	of registration	(see MorphiaDataStore):	1)	ValidationInterceptor	2)
PermissionRuleInterceptor	3)	AuditInterceptor	4)	ReferenceInterceptor	5)
PersistenceAuditEventInterceptor					

High-level responsibilities:

- ValidationInterceptor (prePersist):
- Defaults DataDomain from SecurityContext if missing.
- Runs bean validation and throws E2eqValidationException on violations unless the entity supports saving invalid states (InvalidSavable).
- PermissionRuleInterceptor (prePersist):
- Evaluates RuleContext with PrincipalContext and ResourceContext from SecurityContext.
- Throws SecurityCheckException if the rule decision is not ALLOW (enforcing write permissions for save/update/delete).
- AuditInterceptor (prePersist):
- Sets AuditInfo on creation and updates lastUpdate fields on modification; captures impersonation details if present.
- ReferenceInterceptor (prePersist):
- For @Reference fields annotated with @TrackReferences, maintains back-references on the parent entities via ReferenceEntry and persists the parent when needed.
- PersistenceAuditEventInterceptor (prePersist when @AuditPersistence is present):
- Appends a PersistentEvent with type PERSIST, date, userId, and version to the model's persistentEvents before saving.

When does validation occur?

- On every save/update path that hits persistence, prePersist triggers validation (and permission/audit/reference processing) before the document is written to MongoDB, guaranteeing constraints and policies are enforced consistently across all repositories.

3.4. Functional Area/Domain in RuleContext

Permission Language

Models express their placement in the business model via: - `bmFunctionalArea()`: returns a broad capability area (e.g., Catalog, Collaboration, Identity) - `bmFunctionalDomain()`: returns the specific domain within that area (e.g., Product, Shipment, Partner)

How these map into authorization and rules:

- **ResourceContext/DomainContext:** When a request operates on a model, the framework derives the functional area and domain from the model type (or resource) and places them on the current context alongside the action (CREATE, UPDATE, VIEW, DELETE, ARCHIVE). RuleContext consumes these to evaluate policies.
- **Permission language (path-derived ResourceContext):** The framework derives area and functionalDomain from REST path segments using the convention: `/{{area}}/{{functionalDomain}}/{{action}}/...` . These are placed on the ResourceContext and consumed by RuleContext. Rule bases typically match on HTTP method and URL patterns; no special headers are required.
- **Permission language (query variables):** The ANTLR-based query language exposes variables that can be referenced in filters:
- `${area}` corresponds to `bmFunctionalArea()`
- `${functionalDomain}` corresponds to `bmFunctionalDomain()` These can be used to author reusable filters or to record audit decisions by area/domain.
- **Repository filters:** RuleContext can contribute additional predicates that are area/domain-specific, enabling fine-grained sharing. For example, a shared Catalog area may allow cross-tenant VIEW, while a Collaboration.Shipment domain remains tenant-strict.

Examples

1) Path-derived rule matching (Permissions)

```
- name: allow-catalog-product-reads
  priority: 300
  match:
    method: [GET]
    url: /Catalog/Product/**
    rolesAny: [USER, ADMIN]
  effect: ALLOW
  filters:
    readScope: { orgRefName: PUBLIC }
```

2) Query variable usage (Filters)

You can reference the active area/domain in filter expressions (e.g., for auditing or conditional branching in custom rule evaluators):

```
# Constrain reads differently when operating in the Catalog area
(${area}:"Catalog" && dataDomain.orgRefName:"PUBLIC") ||
(${area}:"!Catalog" && dataDomain.tenantId:${pTenantId})
```

3) Model-driven mapping

Given a model like:

```
@Override public String bmFunctionalArea() { return "Collaboration"; }
@Override public String bmFunctionalDomain(){ return "Shipment"; }
```

- Incoming REST requests that operate on Shipment resources set area=Collaboration and functionalDomain=Shipment in the ResourceContext.
- RuleContext evaluates policies considering action + area + domain, e.g., deny cross-tenant UPDATE in Collaboration.Shipment, but allow cross-tenant VIEW in Collaboration.Partner if marked shared.

Notes

- Path convention: Use leading segments /{area}/{functionalDomain}/{action}/... so the framework can derive ResourceContext reliably. Extra segments after the first three are allowed; only the first three are used to compute area, domain, and action.
- Nonconformant paths: If the path has fewer than three segments, the framework sets an anonymous/default ResourceContext. In practice, rules will typically evaluate to DENY unless there is an explicit allowance for anonymous contexts.
- See also: the Permissions section for rule-base matching and priorities, and the DomainContext/RuleContext section for end-to-end flow.

3.5. StateGraphs on Models

StateGraphs let you restrict valid values and transitions of String state fields. They are declared on model fields with @StateGraph and enforced during save/update when the model class is annotated with @Stateful.

Key pieces: - @StateGraph(graphName="..."): mark a String field as governed by a named state graph. - @Stateful: mark the entity type as participating in state validation. - StateGraphManager: runtime registry that holds graphs and validates transitions. - StringState and StateNode: define the graph (states, initial/final flags, transitions).

Defining a state graph at startup:

```

@Startup
@ApplicationScoped
public class StateGraphInitializer {
    @Inject StateGraphManager stateGraphManager;
    @PostConstruct void init() {
        StringState order = new StringState();
        order.setFieldName("orderStringState");

        Map<String, StateNode> states = new HashMap<>();
        states.put("PENDING", StateNode.builder().state("PENDING").initialState(true)
            .finalState(false).build());
        states.put("PROCESSING", StateNode.builder().state("PROCESSING").initialState(
            false).finalState(false).build());
        states.put("SHIPPED", StateNode.builder().state("SHIPPED").initialState(false)
            .finalState(false).build());
        states.put("DELIVERED", StateNode.builder().state("DELIVERED").initialState(
            false).finalState(true).build());
        states.put("CANCELLED", StateNode.builder().state("CANCELLED").initialState(
            false).finalState(true).build());
        order.setStates(states);

        Map<String, List<StateNode>> transitions = new HashMap<>();
        transitions.put("PENDING", List.of(states.get("PROCESSING"), states.get(
            "CANCELLED")));
        transitions.put("PROCESSING", List.of(states.get("SHIPPED"), states.get(
            "CANCELLED")));
        transitions.put("SHIPPED", List.of(states.get("DELIVERED"), states.get(
            "CANCELLED")));
        transitions.put("DELIVERED", null);
        transitions.put("CANCELLED", null);
        order.setTransitions(transitions);

        stateGraphManager.defineStateGraph(order);
    }
}

```

Using the graph in a model:

```

@Stateful
@Entity
@EqualsAndHashCode(callSuper = true)
public class Order extends BaseModel {
    @StateGraph(graphName = "orderStringState")
    private String status;

    @Override public String bmFunctionalArea() { return "Orders"; }
    @Override public String bmFunctionalDomain(){ return "Order"; }
}

```

How it affects save/update: - On create: `validateInitialStates` ensures the field value is one of the configured initial states. Otherwise, `InvalidStateTransitionException` is thrown. - On update: `validateStateTransitions` checks each `@StateGraph` field's old → new transition against the graph via `StateGraphManager.validateTransition()`. If invalid, save/update fails with `InvalidStateTransitionException`. This applies to full-entity saves and to partial updates via `repo.update(...pairs)` on that field. - Utilities: `StateGraphManager.getNextPossibleStates(graphName, current)` and `printStateGraph(...)` can aid UIs.

3.6. CompletionTasks and CompletionTaskGroups

`CompletionTasks` and `CompletionTaskGroups` provide a simple, persistent way to track a series of work items that need to be completed, either by background processes or external systems. Use them when you need durable progress tracking across restarts and an auditable record of outcomes.

Key models:

- `CompletionTask`: an individual unit of work with fields like status, timestamps, and optional result/details.
- `CompletionTaskGroup`: a container that represents a cohort of tasks progressing toward completion.

Model overview:

```
// Individual task
@Entity("completionTask")
public class CompletionTask extends BaseModel {
    public enum Status { PENDING, RUNNING, SUCCESS, FAILED }

    @Reference
    CompletionTaskGroup group; // optional grouping
    String details;             // human-readable context (what/why)
    Status status;              // PENDING -> RUNNING -> (SUCCESS|FAILED)
    Date createdAt;             // when the task was created
    Date completedDate;         // set when terminal (SUCCESS/FAILED)
    String result;              // output, message, or error summary

    @Override public String bmFunctionalArea() { return "TASK"; }
    @Override public String bmFunctionalDomain() { return "COMPLETION_TASK"; }
}

// Group of tasks
@Entity("completionTaskGroup")
public class CompletionTaskGroup extends BaseModel {
    public enum Status { NEW, RUNNING, COMPLETE }

    String description; // e.g., "Onboarding: create resources"
    Status status;       // reflects overall progress of the group
    Date createdAt;      // when the group was created
}
```



```

    Date completedDate;    // when the group finished

    @Override public String bmFunctionalArea() { return "TASK"; }
    @Override public String bmFunctionalDomain() { return "COMPLETION_TASK_GROUP"; }
}

```

Typical lifecycle:

- Create a CompletionTaskGroup in NEW status.
- Create N CompletionTasks (status=PENDING) referencing the group.
- A worker picks tasks and flips status to RUNNING, performs the work, then to SUCCESS or FAILED, setting completedDate and result.
- Periodically update the group:
- If at least one task is RUNNING (and none pending), set group status to RUNNING.
- When all tasks are terminal (SUCCESS or FAILED), set group status to COMPLETE and completedDate.

How to use for tracking a series of things that need to be completed:

- Batch operations: When submitting a batch (e.g., provisioning 100 accounts), create one group and 100 tasks. The UI/API can poll the group to show overall progress and per-item results.
- Multi-step workflows: Represent each step as its own task, or use one task per target resource. Groups help correlate all steps for a single business request.
- Retry/compensation: FAILED tasks can be retried by creating new tasks or resetting status to PENDING based on your policy. Keep result populated with failure reasons.

Example creation flow:

```

CompletionTaskGroup group = CompletionTaskGroup.builder()
    .description("Catalog import: 250 SKUs")
    .status(CompletionTaskGroup.Status.NEW)
    .createdDate(new Date())
    .build();
completionTaskGroupRepo.save(group);

for (Sku s : skus) {
    CompletionTask t = CompletionTask.builder()
        .group(group)
        .details("Import SKU " + s.code())
        .status(CompletionTask.Status.PENDING)
        .createdDate(new Date())
        .build();
    completionTaskRepo.save(t);
}

```

Example worker progression:

```
// Fetch a PENDING task and execute
CompletionTask t = completionTaskRepo.findOneByStatus(CompletionTask.Status.PENDING);
if (t != null) {
    completionTaskRepo.update(t.getId(), "status", CompletionTask.Status.RUNNING);
    try {
        // ... do work ...
        completionTaskRepo.update(t.getId(),
            "status", CompletionTask.Status.SUCCESS,
            "completedDate", new Date(),
            "result", "OK");
    } catch (Exception e) {
        completionTaskRepo.update(t.getId(),
            "status", CompletionTask.Status.FAILED,
            "completedDate", new Date(),
            "result", e.getMessage());
    }
}

// Periodically recompute group status
List<CompletionTask> tasks = completionTaskRepo.findByGroup(group);
boolean allTerminal = tasks.stream().allMatch(x -> x.getStatus()==SUCCESS || x
.getStatus()==FAILED);
boolean anyRunning = tasks.stream().anyMatch(x -> x.getStatus()==RUNNING);
boolean anyPending = tasks.stream().anyMatch(x -> x.getStatus()==PENDING);

if (allTerminal) {
    completionTaskGroupRepo.update(group.getId(),
        "status", CompletionTaskGroup.Status.COMPLETE,
        "completedDate", new Date());
} else if (anyRunning || (!anyPending && !allTerminal)) {
    completionTaskGroupRepo.update(group.getId(), "status", CompletionTaskGroup.Status
.RUNNING);
}
```

Notes and best practices:

- Keep details short but diagnostic, and store richer context in result.
- Use DataDomain fields for multi-tenant scoping so groups/tasks are isolated per tenant/org as needed.
- Avoid unbounded growth: archive or purge old groups once COMPLETE.
- Consider idempotency keys in details or a custom field to prevent processing the same logical work twice.

3.7. References and EntityReference

Morphia @Reference establishes relationships between entities: - One-to-one: a BaseModel field annotated with @Reference. - One-to-many: a Collection<BaseModel> field annotated with

@Reference.

Example:

```
@Entity
public class Shipment extends BaseModel {
    @Reference(ignoreMissing = false)
    @TrackReferences
    private Partner partner;    // parent entity
}
```

EntityReference is a lightweight reference object used across the framework to avoid DBRef loading when only identity info is needed. Any model can produce one:

```
EntityReference ref = shipment.createEntityReference();
// contains: entityId, entityType, entityRefName, entityDisplayName (and optional
realm)
```

REST convenience:

- BaseResource exposes GET /entityref to list EntityReference for a model with optional filter/sort.
- Repositories expose getEntityReferenceListByQuery(...), and utilities exist to convert lists of EntityReference back to entities when needed.

When to use which:

- Use @Reference for strong persistence-level links where Morphia should maintain foreign references.
- Use EntityReference for UI lists, foreign-key-like pointers in other documents, events/audit logs, or cross-module decoupling without DBRef behavior.

3.8. Tracking References with @TrackReferences and Delete Semantics

@TrackReferences on a @Reference field tells the framework to maintain a back-reference set on the parent entity. The back-reference field is UnversionedBaseModel.references (a Set<ReferenceEntry>), which is calculated/maintained by the framework and should not be set by clients.

What references contains:

- Each ReferenceEntry holds: referencedId (ObjectId of the child), type (fully-qualified class name of the child's entity), and refName (child's stable reference name).
- It indicates that the parent is being referenced by the given child entity. The set is used for fast checks and to enforce referential integrity.

How tracking works (save/update):

- `ReferenceInterceptor` inspects `@Reference` fields annotated with `@TrackReferences` during `prePersist`.
- When a child references a parent, a `ReferenceEntry` for the child is added to the parent's references set and the parent is saved to persist the back-reference.
- For `@Reference` collections, entries are added for each child-parent pair.
- If a `@Reference` is null but `ignoreMissing=false`, a save will fail with an `IllegalStateException` since the parent is required.

How it affects delete:

- During delete in `MorphiaRepo.delete(...)`:
- If `obj.references` is empty, the object can be deleted directly (after removing any references it holds to parents).
- If `obj.references` is not empty, the repo checks each `ReferenceEntry`. If any referring parent still exists, a `ReferentialIntegrityViolationException` is thrown to prevent breaking relationships.
- If all references are stale (referring objects no longer exist), the repo removes stale entries, removes this object's own reference constraints from parents, and performs the delete within a transaction.
- `removeReferenceConstraint(...)` ensures that, when deleting a child, its `ReferenceEntry` is removed from `parent.references` and the parent is saved, keeping back-references consistent.

Practical guidance:

- Annotate parent links with both `@Reference` and `@TrackReferences` when you need strong integrity guarantees and easy “who references me?” queries.
- Use `ignoreMissing=true` only for optional references; you still get back-reference tracking when not null.
- Expect HTTP delete to fail with a meaningful error if there are live references; remove or update those references first, or design cascading behavior explicitly in your domain logic.

3.8.1. Ontologies in Quantum: Modeling Relationships That Are Resilient and Fast



Looking for the short implementation plan? See `PROPOSAL.md` at the repository root for a concise module-by-module checklist.

This section explains what an ontology is, how it differs from a traditional object model, and how the Quantum Ontology modules make it practical to apply ontology ideas to your domain models and queries. It also contrasts ontology-driven relationships with direct object references (for example, using `@Reference` or `EntityReference`).

What is an Ontology?

In software terms, an ontology is a formal, explicit specification of concepts and their relationships.

- Concepts (Classes): Named categories/types in your domain. Concepts can form taxonomies (is-a hierarchies), be declared disjoint, or be equivalent.
- Relationships (Properties): Named relationships between entities. Properties can have a domain (applies to X) and a range (points to Y). They may be inverse or transitive.
- Axioms (Rules): Constraints and entailment rules, including property chains such as: if $(A \text{ --p--} \rightarrow B)$ and $(B \text{ --q--} \rightarrow C)$ then we infer $(A \text{ --r--} \rightarrow C)$.
- Inference: The process of deriving new facts (types, labels, edges) that were not explicitly stored but follow from axioms and known facts.

An ontology is not the data; it is the schema plus logic that gives your data additional meaning and enables consistent, automated inferences.

Ontology vs. Object Model

A conventional object model focuses on concrete classes, fields, and direct references between objects at implementation time. An ontology focuses on semantic types and relationships, with explicit rules that can derive new knowledge independent of how objects are instantiated.

Key differences:

- Purpose - Object model: Encapsulate data and behavior for application code generation and persistence.
- Ontology: Encode shared meaning, constraints, and inference rules that remain stable as implementation details change.
- Relationship handling - Object model: Typically uses direct references or foreign keys; traversals are hard-coded and fragile to change.
- Ontology: Uses named predicates (properties) and can infer additional relationships by rules (property chains, inverses, transitivity).
- Polymorphism and evolution - Object model: Polymorphism requires class inheritance in code; cross-cutting categories are awkward to add later.
- Ontology: Entities can have multiple types/labels at once. New concepts and properties can be introduced without breaking existing data.
- Querying - Object model: Queries couple to concrete classes and field paths; changes force query rewrites.
- Ontology: Queries target semantic relationships; reasoners can materialize edges that queries reuse, decoupling queries from implementation details.

Why prefer Ontology-driven relationships over @Reference/EntityReference

Direct references (@Reference or custom EntityReference) are simple to start but become restrictive as domains grow:

- Tight coupling: Code and queries couple to concrete field paths (customer.primaryAddress.id), making refactors risky.
- Limited expressivity: Hard to encode and reuse higher-order relationships (e.g., "partners of my supplier's parent org").
- Poor polymorphism: References point to one collection/type; accommodating multiple target types requires extra code.
- Performance pitfalls: Deep traversals cause extra queries, N+1 selects, or complex \$lookup joins.

Ontology-driven edges address these issues:

- Decoupling via predicates: Use named predicates (e.g., hasAddress, memberOf, supplies) that remain stable while internal object fields change.
- Inference for reachability: Property chains can materialize implied links $(A \text{ --p--} \rightarrow B \ \& \ B \text{ --q--} \rightarrow C \Rightarrow A \text{ --r--} \rightarrow C)$, avoiding runtime multi-hop traversals.
- Polymorphism-first: A predicate can connect

heterogeneous types; type inferences (domain/range) remain consistent. - Query performance: Pre-materialized edges allow single-hop, index-friendly queries (in or eq filters) instead of ad-hoc multi-collection traversals. - Resilience to change: You can add or modify rules without rewriting data structures or touching referencing fields across models.

How Quantum supports Ontologies

Quantum provides three cooperating modules that make ontology modeling practical and fast:

- quantum-ontology-core (package com.e2eq.ontology.core)
- **OntologyRegistry**: Holds the TBox (terminology) of your ontology.
- **ClassDef**: Concept names and relationships (parents, disjointWith, sameAs).
- **PropertyDef**: Property names with optional domain, range, inverse flags, and transitivity.
- **PropertyChainDef**: Rules that define multi-hop implications (chains → implied property).
- **TBox**: Container for classes, properties, and property chains.
- **Reasoner interface and ForwardChainingReasoner**: Given an entity snapshot and the registry, computes inferences:
- New types/labels to assert on entities.
- New edges to add (implied by property chains, inverses, or other rules).
- quantum-ontology-mongo (package com.e2eq.ontology.mongo)
- **EdgeDao**: A thin DAO around an edges collection in Mongo. Each edge contains tenantId, src, predicate p, dst, inferred flag, provenance, and timestamp.
- **OntologyMaterializer**: Runs the Reasoner for an entity snapshot and upserts the inferred edges, so queries can be rewritten to simple in/in eq filters.
- quantum-ontology-policy-bridge (package com.e2eq.ontology.policy)
- **ListQueryRewriter**: Takes a base query and rewrites it using the EdgeDao to filter by the set of source entity ids that have a specific predicate to a given destination.
- This integrates ontology edges with RuleContext or policy decisions: policy asks for entities related by a predicate; the rewriter converts that into an efficient Mongo query.

These modules let you define your ontology (core), materialize derived relations (mongo), and leverage them in access and list queries (policy bridge).

Modeling guidance: from object fields to predicates

- Name relationships explicitly
- Define clear predicate names (hasAddress, memberOf, supplies, owns, assignedTo). Avoid encoding relationship semantics in field names only.
- Keep object model minimal and flexible
- Store lightweight identifiers (ids) as needed, but avoid deeply nested reference graphs that encode traversals in code.
- Model polymorphic relationships

- Prefer predicates that naturally connect multiple possible types (e.g., assignedTo can target User, Team, Bot) and rely on ontology type assertions to constrain where needed.
- Use property chains for common paths
- If business logic often traverses $A \rightarrow B \rightarrow C$, define a chain $p \sqsubseteq q \Rightarrow r$ and materialize r for faster queries and simpler policies.
- Capture inverses and transitivity
- For natural inverses (parentOf \sqsubseteq childOf) or transitive relations (partOf, locatedIn), define them in the ontology so edges and queries stay consistent.
- Keep provenance
- Record why an edge exists (prov.rule, prov.inputs) so you can recompute, audit, or retract when inputs change.

Querying with ontology edges vs direct references

- Direct reference example (fragile/slow)
- Query: "Find Orders whose buyer belongs to Org X or its parents."
- With @Reference: requires joining $\text{Order} \rightarrow \text{User} \rightarrow \text{Org}$ and recursing org.parent; costly and tightly coupled to fields.
- Ontology edge example (resilient/fast)
- Define predicates: placedBy(order, user), memberOf(user, org), ancestorOf(org, org). Define chain placedBy \sqsubseteq memberOf \Rightarrow placedInOrg.
- Materialize edges: (order \rightarrow placedInOrg \rightarrow org). Also make ancestorOf transitive.
- Query becomes: where order._id in EdgeDao.srcIdsByDst(tenantId, "placedInOrg", orgX).
- With transitivity, you can precompute ancestor closure or add a chain placedInOrg \sqsubseteq ancestorOf \Rightarrow placedInOrg to include parents automatically.

Migration: from @Reference to ontology edges

- Start by introducing predicates alongside existing references; do not remove references immediately.
- Materialize edges for hot read paths; keep provenance so you can reconstruct.
- Gradually update queries (list screens, policy filters) to use ListQueryRewriter with EdgeDao instead of deep traversals or \$lookup.
- Once stable, you can simplify models by removing rigid reference fields where unnecessary and rely on edges for read-side composition.

Performance and operational notes

- Indexing: Create compound indexes on edges: (tenantId, p, dst) and (tenantId, src, p) to support both reverse and forward lookups.
- Write amplification vs read wins: Materialization adds write work, but dramatically improves read latency and simplifies queries.

- Consistency: Re-materialize edges on relevant entity changes (source, destination, or intermediate) using `OntologyMaterializer`.
- Multi-tenancy: Keep `tenantId` in the edge key and filters; the provided `EdgeDao` methods include tenant scoping.

How this integrates with Functional Areas/Domains

- Functional domains often map to concept clusters in the ontology. Use `@FunctionalMapping` to aid discovery and apply policies per area/domain.
- Policies can refer to relationships semantically ("hasEdge placedInOrg OrgX") and rely on the policy bridge to turn this into efficient data filters.

Summary

- Ontology-powered relationships provide a stable, semantic layer over your object model.
- The Quantum Ontology modules let you define, infer, and query these relationships efficiently on MongoDB.
- Compared with direct `@Reference/EntityReference`, ontology edges are more expressive, resilient to change, and typically faster for complex list/policy queries once materialized.

Concrete example: Sales Orders, Shipments, and evolving to Fulfillment/Returns

This example shows how to use an ontology to model relationships around Orders, Customers, and Shipments, and how the model can evolve to include Fulfillment and Returns without breaking existing queries. We will:

- Define core concepts and predicates.
- Add property chains that materialize implied relationships for fast queries.
- Show how queries are rewritten using edges instead of deep object traversals.
- Evolve the model to support Fulfillment and Returns with minimal changes.

Core concepts (classes)

- Order, Customer, Organization, Shipment, Address, Region
- Later evolution: `FulfillmentTask`, `FulfillmentUnit`, `ReturnRequest`, `ReturnItem`, `RMA`

Key predicates (relationships)

- `placedBy(order, customer)`: who placed the order
- `memberOf(customer, org)`: a customer belongs to an organization (or account)
- `orderHasShipment(order, shipment)`: outbound shipment for the order
- `shipsTo(shipment, address)`: shipment destination
- `locatedIn(address, region)`: address is located in a Region
- `ancestorOf(org, org)`: organizational ancestry (transitive)

Property chains (implied relationships)

- `placedBy` \sqsubseteq `memberOf` \Rightarrow `placedInOrg`
- If `(order --placedBy- \rightarrow customer)` and `(customer --memberOf- \rightarrow org)`, then infer `(order --placedInOrg- \rightarrow org)`
- `orderHasShipment` \sqsubseteq `shipsTo` \Rightarrow `orderShipsTo`
- If `(order --orderHasShipment- \rightarrow shipment)` and `(shipment --shipsTo- \rightarrow address)`, infer `(order --orderShipsTo- \rightarrow address)`
- `orderShipsTo` \sqsubseteq `locatedIn` \Rightarrow `orderShipsToRegion`
- If `(order --orderShipsTo- \rightarrow address)` and `(address --locatedIn- \rightarrow region)`, infer `(order --orderShipsToRegion- \rightarrow region)`
- `placedInOrg` \sqsubseteq `ancestorOf` \Rightarrow `placedInOrg`
- Makes `placedInOrg` resilient to org hierarchy changes (`ancestorOf` is transitive). This is a common “closure” trick: re-assert the same predicate via chain to absorb hierarchy.

A minimal Java-style snippet to define this TBox

```
import java.util.*;
import com.e2eq.ontology.core.OntologyRegistry;
import com.e2eq.ontology.core.OntologyRegistry.*;

Map<String, ClassDef> classes = Map.of(
    "Order", new ClassDef("Order", Set.of(), Set.of(), Set.of()),
    "Customer", new ClassDef("Customer", Set.of(), Set.of(), Set.of()),
    "Organization", new ClassDef("Organization", Set.of(), Set.of(), Set.of()),
    "Shipment", new ClassDef("Shipment", Set.of(), Set.of(), Set.of()),
    "Address", new ClassDef("Address", Set.of(), Set.of(), Set.of()),
    "Region", new ClassDef("Region", Set.of(), Set.of(), Set.of())
);

Map<String, PropertyDef> props = Map.of(
    "placedBy", new PropertyDef("placedBy", Optional.of("Order"), Optional.of("Customer"), false, Optional.empty(), false),
    "memberOf", new PropertyDef("memberOf", Optional.of("Customer"), Optional.of("Organization"), false, Optional.empty(), false),
    "orderHasShipment", new PropertyDef("orderHasShipment", Optional.of("Order"), Optional.of("Shipment"), false, Optional.empty(), false),
    "shipsTo", new PropertyDef("shipsTo", Optional.of("Shipment"), Optional.of("Address"), false, Optional.empty(), false),
    "locatedIn", new PropertyDef("locatedIn", Optional.of("Address"), Optional.of("Region"), false, Optional.empty(), false),
    "ancestorOf", new PropertyDef("ancestorOf", Optional.of("Organization"), Optional.of("Organization"), false, Optional.empty(), true), // transitive
    // implied predicates (no domain/range required, but you may add them for validation)
    "placedInOrg", new PropertyDef("placedInOrg", Optional.of("Order"), Optional.of("Organization"), false, Optional.empty(), false),
```

```

    "orderShipsTo", new PropertyDef("orderShipsTo", Optional.of("Order"), Optional.of(
    "Address"), false, Optional.empty(), false),
    "orderShipsToRegion", new PropertyDef("orderShipsToRegion", Optional.of("Order"),
    Optional.of("Region"), false, Optional.empty(), false)
    );

List<PropertyChainDef> chains = List.of(
    new PropertyChainDef(List.of("placedBy", "memberOf"), "placedInOrg"),
    new PropertyChainDef(List.of("orderHasShipment", "shipsTo"), "orderShipsTo"),
    new PropertyChainDef(List.of("orderShipsTo", "locatedIn"), "orderShipsToRegion"),
    new PropertyChainDef(List.of("placedInOrg", "ancestorOf"), "placedInOrg")
);

OntologyRegistry.TBox tbox = new OntologyRegistry.TBox(classes, props, chains);
OntologyRegistry registry = OntologyRegistry.inMemory(tbox);

```

Materializing edges for an Order

- Explicit facts for order O1:
- O1 placedBy C9
- C9 memberOf OrgA
- O1 orderHasShipment S17
- S17 shipsTo Addr42
- Addr42 locatedIn RegionWest
- OrgA ancestorOf OrgParent
- Inferred edges after running the reasoner for O1's snapshot:
- O1 placedInOrg OrgA
- O1 placedInOrg OrgParent (via closure with ancestorOf)
- O1 orderShipsTo Addr42
- O1 orderShipsToRegion RegionWest

How queries become simple and fast

- List Orders for Organization OrgParent (including children):
- Instead of joining Order → Customer → Org and recursing org.parent, run a single filter using materialized edges.

```

import com.mongodb.client.model.Filters;
import org.bson.conversions.Bson;
import com.e2eq.ontology.policy.ListQueryRewriter;

Bson base = Filters.eq("status", "OPEN");
Bson rewritten = rewriter.rewriteForHasEdge(base, tenantId, "placedInOrg", "OrgParent");

```

```
// Use rewritten in your Mongo find
```

- List Orders shipping to RegionWest:

```
Bson rewritten2 = rewriter.rewriteForHasEdge(Filters.empty(), tenantId,
"orderShipsToRegion", "RegionWest");
```

Why this is resilient

- If tomorrow Customer becomes AccountContact and the organization model gains Divisions and multi-parent org graphs, you only adjust predicates and chains.
- Queries that rely on placedInOrg or orderShipsToRegion remain unchanged and fast, because edges are re-materialized by OntologyMaterializer.

Evolving the model: add Fulfillment

New concepts

- FulfillmentTask: a unit of work to pick/pack/ship order lines
- FulfillmentUnit: a logical grouping (e.g., wave, tote, parcel)

New predicates

- fulfills(task, order)
- realizedBy(order, fulfillmentUnit)
- taskProduces(task, shipment)

New chains (implied)

- fulfills \Rightarrow derived edge from task to order; combine with taskProduces to connect order to shipment without touching Order fields:
- fulfills \square taskProduces \Rightarrow orderHasShipment
- realizedBy \square orderHasShipment \Rightarrow fulfilledByUnit
- If (order --realizedBy- \rightarrow fu) and (order --orderHasShipment- \rightarrow s) \Rightarrow (fu --fulfillsShipment- \rightarrow s) or simply (order --fulfilledByUnit- \rightarrow fu)

These chains let you introduce warehouse concepts without changing how UI filters orders by organization or ship-to region. Existing queries still operate via placedInOrg and orderShipsToRegion.

Evolving further: add Returns

New concepts

- ReturnRequest, ReturnItem, RMA

New predicates

- `hasReturn(order, returnRequest)`
- `returnFor(returnItem, order)`
- `returnRma(returnRequest, rma)`

New chains (implied)

- `hasReturn` \Rightarrow `openReturnOnOrg` via `placedInOrg`:
- `hasReturn` \square `placedInOrg` \Rightarrow `returnPlacedInOrg`
- `returnFor` \square `orderShipsToRegion` \Rightarrow `returnShipsToRegion`

Example queries with new capabilities

- List Orders with open returns in OrgParent:

```
Bson r = rewriter.rewriteForHasEdge(Filters.empty(), tenantId, "returnPlacedInOrg",
"OrgParent");
```

- List Returns associated to Orders shipping to RegionWest:

```
Bson r2 = rewriter.rewriteForHasEdge(Filters.empty(), tenantId, "returnShipsToRegion",
"RegionWest");
```

Comparison with direct references (@Reference/EntityReference)

- With direct references you would encode fields like `Order.customer`, `Order.shipments`, `Shipment.address`, `Address.region` and then implement multi-hop traversals in code or \$lookup pipelines, rewriting them whenever you add Fulfillment or Returns.
- With ontology edges, you keep predicates stable and add property chains. Existing list and policy queries keep working and typically become faster due to single-hop filters on an indexed edges collection.

Operational tips for this scenario

- Ensure `EdgeDao` has indexes on `(tenantId, p, dst)` and `(tenantId, src, p)`.
- Use `OntologyMaterializer` when `Order`, `Shipment`, `Customer`, `Address`, or org hierarchy changes to keep edges fresh.
- Keep provenance in `edge.prov (rule, inputs)` so you can recompute or retract edges when source data changes.

3.8.2. Integrating Ontology with Morphia, Permissions, and Multi-tenancy

This section focuses on integration and developer experience: how ontology edges flow into Morphia-based repositories and the permission rule language, while remaining fully multi-tenant and secure.

Big picture: where ontology fits

- Write path (materialization):
- Your domain code persists entities with minimal direct references.
- An `OntologyMaterializer` runs when entities change to derive and upsert edges into the edges collection (per tenant).
- Policy path (authorization and list filters):
- The permission rule language evaluates the caller's `SecurityContext/RuleContext` and produces logical filters.
- When a rule asks for a semantic relationship (`hasEdge`), we use `ListQueryRewriter` + `EdgeDao` to translate that into efficient Mongo filters over ids.
- Read path (queries):
- Morphia repos apply the base data-domain filters and the rewritten ontology constraint to queries, producing fast lists without deep joins.

Rule language: add `hasEdge()`

We introduce a policy function/operator to reference ontology edges directly from rules:

- Signature: `hasEdge(predicate, dstIdOrVar)`
- predicate: String name of the ontology predicate (e.g., `"placedInOrg"`, `"orderShipsToRegion"`).
- dstIdOrVar: Either a concrete id/refName or a variable resolved from `RuleContext` (e.g., `principal.orgRefName`, `request.region`).
- Semantics: The rule grants/filters entities for which an edge (`tenantId`, `src = entity._id`, `p = predicate`, `dst = resolvedDst`) exists.
- Composition: `hasEdge` can be combined with existing rule clauses (and/or/not) and other filters (states, tags, `ownerId`, etc.).

Example rule snippets (illustrative):

- Allow viewing Orders in the caller's org (including ancestors via ontology closure):
- allow VIEW Order when `hasEdge("placedInOrg", principal.orgRefName)`
- Restrict list to Orders shipping to a region chosen in request:
- allow LIST Order when `hasEdge("orderShipsToRegion", request.region)`

Under the hood, policy evaluation uses `ListQueryRewriter.rewriteForHasEdge(...)`, which converts `hasEdge` into a set of source ids and merges that with the base query.

Passing `tenantId` correctly

- Always resolve `tenantId` from `RuleContext/SecurityContext` (the same source your repos use for realm/database selection).
- `EdgeDao` and `ListQueryRewriter` already accept `tenantId`; never cross tenant boundaries when reading edges.

- Index recommendation (per tenant):
- (tenantId, p, dst)
- (tenantId, src, p)

Morphia repository integration patterns

The goal is zero-friction usage in existing repos without invasive changes.

Option A: Apply ontology constraints in code paths that already construct BSON filters.

- If your repo method builds a Bson filter before calling find(), wrap it through rewriter:

```
Bson base = Filters.and(existingFilters...);
Bson rewritten = hasEdgeRequested
    ? rewriter.rewriteForHasEdge(base, tenantId, predicate, dst)
    : base;
var cursor = datastore.getDatabase().getCollection(coll).find(rewritten);
```

Option B: Apply ontology constraints to Morphia Filter/Query via ids.

- When the repo uses Morphia's typed query API instead of BSON, pre-compute the id set and constrain by `_id`:

```
Set<String> ids = edgeDao.srcIdsByDst(tenantId, predicate, dst);
if (ids.isEmpty()) {
    return List.of(); // short-circuit
}
query.filter(Filters.in("_id", ids));
```

Option C: Centralize in a tiny helper for developer ergonomics.

- Provide one helper in your application layer, invoked wherever policies inject additional constraints:

```
public final class OntologyFilterHelper {
    private final ListQueryRewriter rewriter;
    public OntologyFilterHelper(ListQueryRewriter r) { this.rewriter = r; }

    public Bson ensureHasEdge(Bson base, String tenantId, String predicate, String dst)
    {
        return rewriter.rewriteForHasEdge(base, tenantId, predicate, dst);
    }
}
```

Where to hook materialization

- On entity changes that are sources or intermediates for chains:

- Order (placedBy, orderHasShipment), Customer (memberOf), Shipment (shipsTo), Address (locatedIn), Organization (ancestorOf/parent), and any Fulfillment/Returns entities.
- Recommended patterns:
- On-save/on-update hooks in your service layer call `OntologyMaterializer.apply(...)` with the explicit edges known from the entity snapshot.
- For intermediates (e.g., `Address.region` changed), enqueue affected sources for recomputation; use provenance to locate impacted edges.
- Provide nightly/backfill jobs for recomputing edges across a tenant when ontology rules evolve.

Security and multi-tenant considerations

- Edge rows include `tenantId` and should be validated/filtered by tenant on every operation.
- Never trust a client-supplied predicate or destination id blindly; combine with rule evaluation and whitelist allowed predicates per domain if needed.
- For shared resources across tenants (rare), model cross-tenant permissions at the policy layer; don't reuse edges across tenants unless explicitly designed.

Developer workflow and DX checklist

- When writing a rule: use `hasEdge("<predicate>", <rhs>)` and rely on `RuleContext` variables for the destination when possible.
- When writing a list endpoint: read optional ontology filter hints from the policy layer; if present, apply `ensureHasEdge(...)` before `find()`.
- When changing domain relationships: update predicates/chains and re-materialize; list/policy code stays unchanged.
- When indexing a new tenant: include the edges indexes early and validate via a smoke test query using `ListQueryRewriter`.

Cookbook: end-to-end example with Orders + Org

- Policy: allow LIST Order when `hasEdge("placedInOrg", principal.orgRefName)`
- Request lifecycle: 1) Security filter builds `SecurityContext` and `RuleContext` with `tenantId` and `principal`. 2) Policy evaluation returns a directive to constrain by `hasEdge("placedInOrg", orgRefName)`. 3) Repo builds base filter (`state != ARCHIVED`, etc.). 4) Repo calls `OntologyFilterHelper.ensureHasEdge(base, tenantId, "placedInOrg", orgRefName)`. 5) Mongo executes a single-hop query using materialized edges; results respect both policy and multi-tenancy.

Migration notes for teams using @Reference

- Keep existing references for write-side integrity and local joins where simple.
- Introduce ontology edges on hot read paths first; update policy rules to `hasEdge` and verify results.
- Gradually replace deep \$lookup traversals with `hasEdge`-based rewrites.

- Ensure materialization hooks are deployed before removing data fields used as inputs to the ontology.

Chapter 4. 4. Multi-tenant model and realm separation

Problem: Isolating data per tenant while enabling selective sharing.

Why for SaaS: Security, compliance, and data residency require strong segregation and auditability.

How Quantum helps: Realm/tenant identifiers, context propagation, transforms, and repository filters.

Walkthrough: Configure realms and mark your models for tenancy.

4.1. Multi-Tenancy Models

Quantum supports multiple multi-tenant models for MongoDB deployments:

4.1.1. One Tenant per Database (in a MongoDB Cluster)

- Each tenant is mapped to a dedicated MongoDB database within a cluster.
- Strong isolation at the database level; operational controls via MongoDB roles.
- Pros: Simplified backup/restore per tenant; reduced risk of data bleed.
- Cons: More databases to manage (indexes, connections), higher operational overhead.

How Quantum helps:

- DataDomain carries tenant identifiers (e.g., tenantId, ownerId, orgRefName) on each model.
- Repositories can resolve connections/DB selection per tenant, enabling routing to the appropriate database.

4.1.2. Many Tenants in One Database (Shared Database)

- Multiple tenants share a single database and collections.
- Isolation is enforced at the application layer using DataDomain filters.
- Pros: Fewer databases to manage; efficient index utilization and connection pooling.
- Cons: Strict discipline required to enforce filtering and access rules.

How Quantum helps:

- DataDomain is part of every persisted model, enabling programmatic, rule-based filtering.
- RuleContext and DomainContext can be used to inject tenant-aware filters into repositories and resources.
- Cross-tenant sharing can be modeled by specific DataDomain fields and RuleContext logic granting read access across tenants on a per-functional-area basis.

4.1.3. Freemium and Trial Tenants

- Programmatically create tenants to support self-service onboarding.
- Attach time-bound or capability-bound policies.
- Use scheduled jobs to convert/expire trials.

Quantum patterns:

- Tenant onboarding service creates a DataDomain scope and any default records.
- Policies are encoded in RuleContext checks to allow or restrict actions based on time, plan, or feature flags.

Chapter 5. 5. Domain rule context

Problem: Applying business rules based on user, org, account, and tenant context.

Why for SaaS: Entitlements and behavior vary by tenant, role, and plan.

How Quantum helps: Built-in domain rule context to consistently pass identity and policy inputs.

Walkthrough: Inject and use the context in services and repositories.

Chapter 6. DomainContext, RuleContext, and DataDomain

Quantum enforces multi-tenant isolation and sharing through contextual data carried on models and evaluated at runtime.

6.1. DataDomain

Every persisted model includes a DataDomain that describes ownership and scope, commonly including fields such as:

- `tenantId`: Identifies the tenant
- `orgRefName`: Organization unit reference within a tenant
- `ownerId`: Owning user or system entity
- `realm`: Optional runtime override for partitioning

These fields enable filtering, authorization, and controlled sharing of data between tenants or org units.

6.2. DomainContext

DomainContext represents the current execution context for a request or operation, typically capturing:

- current tenant/org/user identity
- functional area / functional domain
- the action being executed (e.g., CREATE, UPDATE, VIEW, DELETE, ARCHIVE)

It feeds downstream components (repositories, resources) to consistently apply filtering and policy decisions.

6.3. RuleContext

RuleContext encapsulates policy evaluation. It can:

- Enforce whether an action is allowed for a given model and DataDomain
- Produce additional filters and projections used by repositories
- Grant cross-tenant read access for specific functional areas (e.g., shared catalogs) while keeping others strictly isolated

6.4. End-to-End Flow

1. A REST request enters a BaseResource-derived endpoint.

2. The resource builds a DomainContext from the security principal and request parameters.
3. RuleContext evaluates permissions and returns effective filters.
4. Repository applies filters (DataDomain-aware) to find/get/list/update/delete.
5. The model's UIActionList can be computed to reflect what the caller can do next.

This pattern ensures consistent enforcement across all CRUD operations, independent of the specific model or repository.

6.5. Resolvers and Variables in Rule Filters

RuleContext can attach FILTERs (not only ALLOW/DENY) to repository queries using rule fields and filter strings. Variables inside those filter strings are populated from:

- PrincipalContext and ResourceContext standard variables: principalId, pAccountId, pTenantId, ownerId, orgRefName, resourceId, action, functionalDomain, area
- AccessListResolver SPI implementations: per-request computed Collections (e.g., customer IDs the caller can access)

Implementation highlights: - AccessListResolver has methods key(), supports(...), resolve(...). Resolvers are injected and invoked for each request; results are published as variables by key. - MorphiaUtils.VariableBundle carries both string variables and object variables (including collections) to the query listener. - The QueryToFilterListener supports IN clauses using a single \${var} inside brackets, expanding Collections/arrays and coercing types (ObjectId, numbers, booleans, dates).

Authoring examples: - Constrain by principal domain:

+

```
orgRefName:${orgRefName} && dataDomain.tenantId:${pTenantId}
```

- Access list resolver for customer visibility:

```
customerId:^(${accessibleCustomerIds})
```

For the complete query language reference, see [Query Language](#).

6.6. Concrete example: building and using a resolver

This section shows how to implement a resolver that restricts access to orders by the set of customerIds the current user is allowed to see.

6.6.1. 1) Implement the SPI

Create a CDI bean that implements AccessListResolver. It decides when it applies and returns a

Collection of values. The collection can be ObjectId, String, numbers, etc.

```
import com.e2eq.framework.securityrules.AccessListResolver;
import com.e2eq.framework.model.persistent.base.UnversionedBaseModel;
import com.e2eq.framework.model.securityrules.PrincipalContext;
import com.e2eq.framework.model.securityrules.ResourceContext;
import jakarta.enterprise.context.ApplicationScoped;
import jakarta.inject.Inject;
import org.bson.types.ObjectId;
import java.util.*;

@ApplicationScoped
public class CustomerAccessResolver implements AccessListResolver {

    @Inject CustomerAccessService service; // your app-specific service

    @Override
    public String key() {
        // This becomes the variable name available to rules: ${accessibleCustomerIds}
        return "accessibleCustomerIds";
    }

    @Override
    public boolean supports(PrincipalContext pctx, ResourceContext rctx,
                           Class<? extends UnversionedBaseModel> modelClass) {
        // Optionally narrow by area/domain/action/model
        return rctx != null && "sales".equalsIgnoreCase(rctx.getArea())
            && "order".equalsIgnoreCase(rctx.getFunctionalDomain());
    }

    @Override
    public Collection<?> resolve(PrincipalContext pctx, ResourceContext rctx,
                                Class<? extends UnversionedBaseModel> modelClass) {
        // Return the set of customer ids for this user; could be ObjectId or String.
        // Example returns strings; the query listener will coerce 24-hex to ObjectId.
        return service.findCustomerIdsForUser(pctx.getUserId());
    }
}
```

Notes: - You can return `List<ObjectId>` directly if you prefer; no coercion needed then. - The resolver runs per request. Cache internally if the computation is expensive.

6.6.2. 2) How RuleContext uses resolvers

At query time, RuleContext discovers all AccessListResolver beans and calls supports(...). For those that apply, it invokes resolve(...) and publishes the result into the variable bundle under the provided key(). Variables are available to the BIAPI query via \${...}.

Internally this uses MorphiaUtils.VariableBundle and QueryToFilterListener to carry both strings

and typed objects/collections.

6.6.3. 3) Author a rule that consumes the variable

Given the resolver above, a rule can attach an IN filter to constrain queries:

```
// andFilterString (example)
customerId:^(${accessibleCustomerIds}]
```

When executed: - If `accessibleCustomerIds` is a Collection/array, each element is type-coerced (ObjectId, number, date, boolean, or string) and used in `$in`. - If `accessibleCustomerIds` is a comma-separated string, it is split and each token is coerced similarly. - An empty collection results in an empty `$in` (matches none), effectively denying access via filtering, not via ALLOW/DENY.

6.6.4. 4) End-to-end behavior

- SecurityFilter sets ResourceContext (area/domain/action) per request.
- RuleContext evaluates rules for the principal and resource and gathers resolvers.
- The repository composes filters including the rule-provided IN clause with the access list.
- Only documents whose customerId is in the caller's resolved set are returned.

6.6.5. String literals vs. typed values in resolver variables

When an `AccessListResolver` returns a list of values that will be used in an `IN` clause (for example, `field:^([${var}])`), the engine attempts to coerce each element to an appropriate type so Mongo/Morphia filters are typed correctly:

- 24-hex string → ObjectId
- `true/false` → Boolean
- integer → Long
- decimal → Double
- ISO-8601 datetime → `java.util.Date`
- `yyyy-MM-dd` → `java.time.LocalDate`
- otherwise → String

This works well when your target field is an ObjectId, number, or date. However, string fields can contain values that look like other types (for example, a 24-hex string that resembles an ObjectId). In those cases you must force "treat as plain string" so no coercion occurs.

To do this, the framework provides a small wrapper type `StringLiteral`. If a resolver returns `StringLiteral` instances, the listener unwraps them to plain `String` values and skips coercion entirely.

Example A: Resolver returns ObjectIds (typed)

```
@ApplicationScoped
public class CustomerAccessResolver implements AccessListResolver {
    public static final ObjectId ID1 = new ObjectId("5f1e1a5e5e5e5e5e5e51");
    public static final ObjectId ID2 = new ObjectId("5f1e1a5e5e5e5e5e5e52");

    @Override public String key() { return "accessibleCustomerIds"; }
    @Override public boolean supports(PrincipalContext p, ResourceContext r, Class<?
extends UnversionedBaseModel> m) {
        return r != null && "sales".equalsIgnoreCase(r.getArea()) && "order"
.equalsIgnoreCase(r.getFunctionalDomain()) && "view".equalsIgnoreCase(r.getAction());
    }
    @Override public Collection<?> resolve(PrincipalContext p, ResourceContext r,
Class<? extends UnversionedBaseModel> m) {
        return java.util.List.of(ID1, ID2); // typed values pass through as-is
    }
}
```

Rule:

```
customerId:^(${accessibleCustomerIds})
```

Result: `$in` with `List<ObjectId>` on `customerId`.

Example B: Resolver returns String literals (force raw strings)

```
@ApplicationScoped
public class CustomerCodeResolver implements AccessListResolver {
    @Override public String key() { return "accessibleCustomerCodes"; }
    @Override public boolean supports(PrincipalContext p, ResourceContext r, Class<?
extends UnversionedBaseModel> m) {
        return r != null && "sales".equalsIgnoreCase(r.getArea()) && "order"
.equalsIgnoreCase(r.getFunctionalDomain()) && "view".equalsIgnoreCase(r.getAction());
    }
    @Override public Collection<?> resolve(PrincipalContext p, ResourceContext r,
Class<? extends UnversionedBaseModel> m) {
        return java.util.List.of(
            com.e2eq.framework.model.persistent.morphia.StringLiteral.of(
                "5f1e1a5e5e5e5e5e5e51"),
            com.e2eq.framework.model.persistent.morphia.StringLiteral.of("CUST-42")
        );
    }
}
```

Rule:


```
customerCode:^(${accessibleCustomerCodes}]
```

Result: `$in` with `List<String>` on `customerCode` (even for hex-like strings).

Other types supported

Resolvers can also return numbers, booleans, and dates/datetimes. Already-typed elements (`Number`, `Boolean`, `java.util.Date`, `java.time.LocalDate`, `ObjectId`) are preserved. String elements are heuristically parsed into those types unless wrapped with `StringLiteral`.

Authoring tips:

- Prefer returning already-typed values when you know the target field type.
- Use `StringLiteral` when a value might be misinterpreted (for example, 24-hex or numeric-looking strings).
- For CSV strings published under a variable, the engine splits by comma and applies the same per-element coercion.

6.6.6. Using AccessListResolver with Ontology (optional)

When ontology is enabled, an `AccessListResolver` can compute ID lists from semantic edges (materialized in Mongo) and publish them as variables for use in rule filters.

Example resolver (conceptual)

```
@ApplicationScoped
public class OrdersByOrgResolver implements AccessListResolver {
    @Inject EdgeDao edgeDao; // from quantum-ontology-mongo
    @Override public String key() { return "idsByPlacedInOrg"; }
    @Override public boolean supports(PrincipalContext p, ResourceContext r, Class<?
extends UnversionedBaseModel> model) {
        return model.getSimpleName().equals("Order");
    }
    @Override public Collection<?> resolve(PrincipalContext p, ResourceContext r, Class
<? extends UnversionedBaseModel> model) {
        String tenantId = p.getDataDomain().getTenantId();
        String org = p.getDataDomain().getOrgRefName();
        return edgeDao.srcIdsByDst(tenantId, "placedInOrg", org);
    }
}
```

Rule filter usage

```
id:^(idsByPlacedInOrg}
```

Notes

- Always scope by tenantId from RuleContext/PrincipalContext.
- This is optional and only active if you wire ontology components. For a deeper integration path, see [Integrating Ontology](#).

Chapter 7. 6. Building RESTful CRUD APIs

Problem: Exposing standardized CRUD endpoints with minimal boilerplate.

Why for SaaS: Consistency across services reduces cognitive load and accelerates delivery.

How Quantum helps: Resource scaffolding, conventions, and helpers for common CRUD.

Walkthrough: Create controllers/resources for your model and wire persistence.

7.1. REST: Find, Get, List, Save, Update, Delete

Quantum provides consistent REST resources backed by repositories. Extend `BaseResource` to expose CRUD quickly and consistently.

7.1.1. Base Concepts

- `BaseResource<T, R extends Repo<T>>` provides endpoints for:
- `find`: query by criteria (filters, pagination)
- `get`: fetch by id or refName
- `list`: list all within scope with paging
- `save`: create
- `update`: modify existing
- `delete`: delete or soft-delete/archival depending on model
- `UIActionList`: derive available actions based on current model state.
- DataDomain filtering is applied across all operations to enforce multi-tenancy.

7.1.2. Example Resource

```
import com.e2eq.framework.rest.resources.BaseResource;
import jakarta.ws.rs.Path;

@Path("/products")
public class ProductResource extends BaseResource<Product, ProductRepo> {
}
```

7.1.3. Authorization Layers in REST CRUD

Quantum combines static, identity-based checks with dynamic, domain-aware policy evaluation. In practice you will often use both:

1) Hard-coded permissions via annotations

- Use standard Jakarta annotations like `@RolesAllowed` (or the framework's `@RoleAllow` if

present) on resource classes or methods to declare role-based checks that must pass before executing an endpoint.

- These checks are fast and decisive. They rely on the caller's roles as established by the current `SecurityIdentity`.

Example:

```
import jakarta.annotation.security.RolesAllowed;

@RolesAllowed({"ADMIN", "CATALOG_EDITOR"})
@Path("/products")
public class ProductResource extends BaseResource<Product, ProductRepo> {
    // Only ADMIN or CATALOG_EDITOR can access all inherited CRUD endpoints
}
```

2) JWT groups and role mapping

- When using the JWT provider, the token's groups/roles claims are mapped into the Quarkus `SecurityIdentity` (see the Authentication guide).
- Groups in JWT typically become roles on `SecurityIdentity`; these roles are what `@RolesAllowed/@RoleAllow` checks evaluate.
- You can augment or transform roles using a `SecurityIdentityAugmentor` (see `RolesAugmentor` in the framework) to add derived roles based on claims or external lookups.

3) RuleContext layered authorization (dynamic policies)

- After annotation checks pass, `RuleContext` evaluates domain-aware permissions. This layer can:
- Enforce `DataDomain` scoping (tenant/org/owner)
- Allow cross-tenant reads for specific functional areas when policy permits
- Contribute query predicates and projections to repositories
- Think of `@RolesAllowed/@RoleAllow` as the coarse-grained gate, and `RuleContext` as the fine-grained, context-sensitive policy engine.

4) Quarkus SecurityIdentity and SecurityFilter

- Quarkus produces a `SecurityIdentity` for each request containing principal name and roles.
- The framework's `SecurityFilter` inspects the incoming request (e.g., JWT) and populates/augments the `SecurityIdentity` and the derived `DomainContext` used by `RuleContext` and repositories.
- `BaseResource` and underlying repos (e.g., `MorphiaRepo`) consume `SecurityIdentity/DomainContext` to apply permissions and filters consistently.

For detailed rule-base matching (URL, headers, body predicates, priorities), see the Permissions section.

7.1.4. Querying

- Use query parameters or a request body (depending on your API convention) to express filters.
- RuleContext contributes tenant-aware filters and projections automatically.
- See [Query Language](#) for the full BIAPIQuery syntax, including array filtering with elemMatch and IN-clause enhancements that accept resolver-provided lists.

7.1.5. Responses and Schemas

- Models are returned with calculated fields (e.g., actionList) when appropriate.
- OpenAPI annotations in your models/resources integrate with MicroProfile OpenAPI for schema docs.

7.1.6. Error Handling

- Validation errors (e.g., ImportRequiredField, Size) return helpful messages.
- Rule-based denials return appropriate HTTP statuses (403/404) without leaking cross-tenant metadata.

Query Language (ANTLR-based)

The find/list endpoints accept a filter string parsed by an ANTLR grammar (BIAPIQuery.g4). Use the filter query parameter to express predicates; combine them with logical operators and grouping. Sorting and projection are separate query parameters.

- Operators:
- Equals: '='
- Not equals: '!='
- Less than/Greater than: '<' / '>'
- Less-than-or-equal/Greater-than-or-equal: '<=' / '>='
- Exists (field present): '~' (no value)
- In list: '^' followed by [v1,v2,...]
- Boolean literals: true/false
- Null literal: null
- Logical:
- AND: '&&'
- OR: '||'
- NOT: '!' (applies to a single allowed expression)
- Grouping: parentheses '(' and ')'
- Values by type:
- Strings: unquoted or quoted with "..."; quotes allow spaces and punctuation

- Whole numbers: prefix with '#' (e.g., #10)
- Decimals: prefix with '.' (e.g., 19.99)
- Date: yyyy-MM-dd (e.g., 2025-09-10)
- DateTime (ISO-8601): 2025-09-10T12:30:00Z (timezone supported)
- ObjectId (Mongo 24-hex): 5f1e9b9c8a0b0c0d1e2f3a4b
- Reference by ObjectId: @@5f1e9b9c8a0b0c0d1e2f3a4b
- Variables:
 \${ownerId|principalId|resourceId|action|functionalDomain|pTenantId|pAccountId|rTenantId|rAccountId|realm|area}

7.1.7. Simple filters (equals)

```
# string equality
name:"Acme Widget"
# whole number
quantity:#10
# decimal number
price:##19.99
# date and datetime
shipDate:2025-09-12
updatedAt:2025-09-12T10:15:00Z
# boolean
active:true
# null checks
description:null
# field exists
lastLogin:~
# object id equality
id:5f1e9b9c8a0b0c0d1e2f3a4b
# variable usage (e.g., tenant scoping)
dataDomain.tenantId:${pTenantId}
```

7.1.8. Advanced filters: grouping and AND/OR/NOT

```
# Products that are active and (name contains widget OR gizmo), excluding discontinued
active:true && (name:*widget* || name:*gizmo*) && status:! "DISCONTINUED"

# Shipments updated after a date AND (destination NY OR CA)
updatedAt:>=2025-09-01 && (destination:"NY" || destination:"CA")

# NOT example: items where category is not null and not (price < 10)
category:!null && !(price:<##10)
```

Notes: - Wildcard matching uses ': **name:*widget** (prefix/suffix/contains). '?' matches a single character. - Use parentheses to enforce precedence; otherwise AND/OR follow standard left-to-right

with explicit operators.

7.1.9. IN lists

```
status:^[ "OPEN", "CLOSED", "ON_HOLD" ]
ownerId:^[ "u1", "u2", "u3" ]
referenceId:^[ @05f1e9b9c8a0b0c0d1e2f3a4b, @06a7b8c9d0e1f2a3b4c5d6e7f ]
```

7.1.10. Sorting

Provide a sort query parameter (comma-separated fields): - '-' prefix = descending, '+' or no prefix = ascending.

Examples:

```
# single field descending
?sort=-createdAt

# multiple fields: createdAt desc, refName asc
?sort=-createdAt,refName
```

7.1.11. Projections

Limit returned fields with the projection parameter (comma-separated): - '+' prefix = include, '-' prefix = exclude.

Examples:

```
# include only id and refName, exclude heavy fields
?projection=+id,+refName,-auditInfo,-persistentEvents
```

7.1.12. End-to-end examples

- GET `/products/list?skip=0&limit=50&filter=active:true&&name:*widget*&sort=-updatedAt&projection=+id,+name,-auditInfo`
- GET `/shipments/list?filter=(destination:"NY" | | destination:"CA")&&updatedAt:>=2025-09-01&sort=origin`

These features integrate with RuleContext and DataDomain: your filter runs within the tenant/org scope derived from the security context; RuleContext may add further predicates or projections automatically.

7.2. CSV Export and Import

These endpoints are inherited by every resource that extends BaseResource. They are mounted

under the resource's base path. For example, PolicyResource at /security/permission/policies exposes:

- GET /security/permission/policies/csv
- POST /security/permission/policies/csv
- POST /security/permission/policies/csv/session
- POST /security/permission/policies/csv/session/{sessionId}/commit
- DELETE /security/permission/policies/csv/session/{sessionId}
- GET /security/permission/policies/csv/session/{sessionId}/rows

Authorization and scoping:

- All CSV endpoints are protected by the same @RolesAllowed("user", "admin") checks as other CRUD operations.
- RuleContext filters and DataDomain scoping apply the same way as list/find; exports stream only what the caller may see, and imports are saved under the same permissions.
- In multi-realm deployments, include your X-Realm header as you do for CRUD; underlying repos resolve realm and domain context consistently.

7.2.1. Export: GET /csv

Produces a streamed CSV download of the current resource collection.

Query parameters and behavior:

fieldSeparator (default ",")

Single character used to separate fields. Typical values: `,`, `;`, `\t`.

requestedColumns (default refName)

Comma-separated list of model field names to include, in output order. If omitted, BaseResource defaults to refName. Nested list extraction is supported with the `[0]` notation on a single nested property across all requested columns (e.g., `addresses[0].city`, `addresses[0].zip`). Indices other than `[0]` are rejected. If the nested list has multiple items, multiple rows are emitted per record (one per list element), preserving other column values.

quotingStrategy (default QUOTE_WHERE_ESSENTIAL)

- QUOTE_WHERE_ESSENTIAL: quote only when needed (when a value contains the separator or quoteChar).
- QUOTE_ALL_COLUMNS: quote every column in every row.

quoteChar (default ")

The character used to surround quoted values.

decimalSeparator (default .)

Reserved for decimal formatting. Note: current implementation ignores this value; decimals are rendered using the locale-independent dot.

charsetEncoding (default UTF-8-without-BOM)

One of: `US-ASCII`, `UTF-8-without-BOM`, `UTF-8-with-BOM`, `UTF-16-with-BOM`, `UTF-16BE`, `UTF-16LE`. “with-BOM” values write a Byte Order Mark at the beginning of the file (UTF-8: `EF BB BF`; UTF-16: `FE FF`).

filter (optional)

ANTLR DSL filter applied server-side before streaming (see Query Language section). Reduces rows and can improve performance.

filename (default downloaded.csv)

Suggested download filename returned via Content-Disposition header.

offset (default 0)

Zero-based index of the first record to stream.

length (default 1000, use -1 for all)

Maximum number of records to stream from offset. Use `-1` to stream all (be mindful of client memory/time).

prependHeaderRow (optional boolean, default false)

When true, the first row contains column headers. Requires `requestedColumns` to be set (the default `refName` satisfies this requirement).

preferredColumnNames (optional list)

Overrides header names positionally when `prependHeaderRow=true`. The list length must be \leq `requestedColumns`; an empty string entry means “use default field name” for that column.

Response:

- 200 OK with Content-Type: text/csv and Content-Disposition: attachment; filename="..."
- On validation/processing errors, the response status is 400/500 and the body contains a single text line describing the problem (e.g., “Incorrect information supplied: ...”). Unrecognized query parameters are rejected with 400.

Examples:

- Export selected fields with header, custom filename and filter

```
curl -H "Authorization: Bearer $JWT" \
  -H "X-Realm: system-com" \
  "https://host/api/products/csv?requestedColumns=id,refName,price&prependHeaderRow=true
  &filename=products.csv&filter=active:true&sort=+refName"
```

- Export nested list's first element across columns

```
# emits one row per address entry when more than one is present
```

```
curl -H "Authorization: Bearer $JWT" \  
"https://host/api/customers/csv?requestedColumns=refName,addresses[0].city,addresses[0]  
.zip&prependHeaderRow=true"
```

7.2.2. Import: POST /csv (multipart)

Consumes a CSV file (multipart/form-data) and imports records in batches. The form field name for the file is file.

Query parameters and behavior:

fieldSeparator (default ",")

Single character expected between fields.

quotingStrategy (default QUOTE_WHERE_ESSENTIAL)

Same values as export; controls how embedded quotes are recognized.

quoteChar (default ")

The expected quote character in the file.

skipHeaderRow (default true)

When true, the first row is treated as a header and skipped. Mapping is positional, not by header names.

charsetEncoding (default UTF-8-without-BOM)

The file encoding. "with-BOM" variants allow consuming a BOM at the start.

requestedColumns (required)

Comma-separated list of model field names in the same order as the CSV columns. This positional mapping drives parsing and validation. Nested list syntax `[0]` is allowed with the same constraints as export.

Behavior:

- Each row is parsed into a model instance using type-aware processors (ints, longs, decimals, enums, etc.).
- Bean Validation is applied; rows with violations are collected as errors and not saved; valid rows are batched and saved.
- For each saved batch, insert vs update is determined by refName presence in the repository.
- Response entity includes counts (importedCount, failedCount) and per-row results when available.
- Response headers:
 - X-Import-Success-Count: number of rows successfully imported.
 - X-Import-Failed-Count: number of rows that failed validation or DB write.
 - X-Import-Message: summary message.

Example (direct import):

```
curl -X POST \
  -H "Authorization: Bearer $JWT" \
  -H "X-Realm: system-com" \
  -F "file=@policies.csv" \

"https://host/api/security/permission/policies/csv?requestedColumns=refName,principalId,description&skipHeaderRow=true&fieldSeparator=,&quoteChar=\"&quotingStrategy=QUOTE_WHERE_ESSENTIAL&charsetEncoding=UTF-8-without-BOM"
```

7.2.3. Import with preview sessions

Use a two-step flow to analyze first, then commit only valid rows.

- POST /csv/session (multipart): analyzes the file and creates a session
 - Same parameters as POST /csv (fieldSeparator, quotingStrategy, quoteChar, skipHeaderRow, charsetEncoding, requestedColumns).
 - Returns a preview ImportResult including sessionId, totals (totalRows, validRows, errorRows), and row-level findings. No data is saved yet.
- POST /csv/session/{sessionId}/commit: imports only error-free rows from the analyzed session
 - Returns CommitResult with inserted/updated counts.
 - DELETE /csv/session/{sessionId}: cancels and discards session state (idempotent; always returns 204).
- GET /csv/session/{sessionId}/rows: page through analyzed rows
 - Query params:
 - skip (default 0), limit (default 50)
 - onlyErrors (default false): when true, returns only rows with errors
 - intent (optional): filter rows by intended action: INSERT, UPDATE, or SKIP

Notes and constraints:

- requestedColumns must reference actual model fields. Unknown fields or multiple different nested properties are rejected (only one nested property across requestedColumns is allowed when using [0]).
- Unrecognized query parameters are rejected with HTTP 400 to prevent silent misconfiguration.
- Very large exports should prefer streaming with sensible length settings or server-side filters to reduce memory and time.
- Imports run under the same security rules as POST / (save). Ensure the caller has permission to create/update the target entities in the chosen realm.

Chapter 8. Authentication and Authorization

Quantum integrates with Quarkus security while providing a pluggable approach to authentication. The repository includes a JWT provider module to get started quickly and an extension surface to replace or complement it.

8.1. JWT Provider

- Module: `quantum-jwt-provider`
- Purpose: Validate JWTs on incoming requests, populate the security principal, and surface tenant/org/user claims that feed `DomainContext`.
- Configuration: Standard Quarkus/MicroProfile JWT properties plus custom claim mappings as needed for `DataDomain`.

8.2. Pluggable Authentication

You can introduce alternative authentication mechanisms (e.g., API keys, SAML/OIDC front-channel tokens exchanged for back-end JWTs, HMAC signatures) by providing CDI beans that integrate with the security layer and emit the same normalized context consumed by `DomainContext/RuleContext`.

Typical steps:

1. Implement a request filter or identity provider that validates the token/credential.
2. Map identity and tenant claims into a principal model (`tenantId`, `orgRefName`, `userId`, `roles`).
3. Ensure `BaseResource` (and other entry points) can derive `DomainContext` from that principal.

8.3. Creating an Auth Plugin (using the Custom JWT provider as a reference)

An auth plugin is typically a CDI bean that:

- Extends `BaseAuthProvider` to inherit user-management helpers and persistence utilities.
- Implements `AuthProvider` to integrate with request-time authentication flows.
- Implements `UserManagement` to expose CRUD-style operations for users, passwords, and roles.

A concrete provider should:

- Be annotated as a CDI bean (e.g., `@ApplicationScoped`).
- Provide a stable `getName()` identifier (e.g., `"custom"`, `"oidc"`, `"apikey"`).
- Use config properties for secrets, issuers, token durations, and any external identity provider details.
- Build a Quarkus `SecurityIdentity` with the authenticated principal and roles.

8.4. AuthProvider interface (what a provider must implement)

Core methods:

- SecurityIdentity validateAccessToken(String token)
 - Parse and validate the incoming credential (JWT, API key, signature).
 - Return a SecurityIdentity with principal name and roles; throw a security exception for invalid tokens.
- String getName()
 - A short identifier for the provider; persisted alongside credentials and used in logs/metrics.
- LoginResponse login(String userId, String password)
 - Credential-based login. Return a structured response:
 - positiveResponse: includes SecurityIdentity, roles, accessToken, refreshToken, expirationTime, and realm/mongodbUrl if applicable.
 - negativeResponse: includes error codes/reason/message for clients to act on (e.g., password change required).
- LoginResponse refreshTokens(String refreshToken)
 - Validate the refresh token, mint a new access token (and optionally a new refresh token), and return a positive response.

Notes:

- Login flow should check force-change-password or equivalent flags and return a negative response when user interaction is required before issuing tokens.
- validateAccessToken should only accept valid, non-expired tokens and construct SecurityIdentity consistently with role mappings used across the platform.

8.5. UserManagement interface (operations your plugin must support)

Typical responsibilities include:

- User lifecycle
 - String createUser(String userId, String password, Set<String> roles, DomainContext domainContext, [optional] DataDomain)
 - void changePassword(String userId, String oldPassword, String newPassword, Boolean forceChangePassword)
 - boolean removeUserWithUserId(String userId)
 - boolean removeUserWithSubject(String subject)
- Role management

- `void assignRolesForUserId(String userId, Set<String> roles)`
- `void assignRolesForSubject(String subject, Set<String> roles)`
- `void removeRolesForUserId(String userId, Set<String> roles)`
- `void removeRolesForSubject(String subject, Set<String> roles)`
- `Set<String> getUserRolesForUserId(String userId)`
- `Set<String> getUserRolesForSubject(String subject)`
- Lookups and existence checks
 - `Optional<String> getSubjectForUserId(String userId)`
 - `Optional<String> getUserIdForSubject(String subject)`
 - `boolean userIdExists(String userId)`
 - `boolean subjectExists(String subject)`

Return values and exceptions:

- Throw `SecurityException` or domain-specific exceptions for invalid states (duplicate users, bad password, unsupported hashing).
- Return `Optional` for lookups that may not find a result.
- For removals, return `boolean` to communicate whether a record was deleted.

8.6. Leveraging `BaseAuthProvider` in your plugin

When you extend `BaseAuthProvider`, you inherit ready-to-use capabilities that reduce boilerplate:

- Impersonation controls
 - `enableImpersonationWithUserId` / `enableImpersonationWithSubject`
 - `disableImpersonationWithUserId` / `disableImpersonationWithSubject`
 - These set or clear an impersonation filter script and realm regex that downstream services can honor to act on behalf of another identity under controlled scope.
- Realm override helpers
 - `enableRealmOverrideWithUserId` / `enableRealmOverrideWithSubject`
 - `disableRealmOverrideWithUserId` / `disableRealmOverrideWithSubject`
 - Useful for multi-realm/tenant scenarios, enabling scoped cross-realm behavior.
- Persistence utilities
 - Built-in use of the credential repository to save, update, and delete credentials.
 - Consistent validation of inputs (non-null checks, non-blank checks).
 - Hashing algorithm guardrails to ensure only supported algorithms are used.

Best practices when deriving:

- Always set the auth provider name in stored credentials so records can be traced to the correct

provider.

- Reuse the role merge/remove patterns to avoid accidental role loss.
- Prefer emitting precise exceptions (e.g., `NotFound` for missing users, `SecurityException` for access violations).

8.7. Implementing your own provider

Checklist:

- Class design
 - `@ApplicationScoped` bean
 - extends `BaseAuthProvider`
 - implements `AuthProvider` and `UserManagement`
 - return a stable `getName()`
- Configuration
 - Externalize secrets (signing keys), issuers, token durations, and realm details via `MicroProfile Config`.
- `SecurityIdentity`
 - Consistently build identities with principal and roles; include useful attributes for auditing/telemetry.
- Tokens/credentials
 - For JWT-like tokens, implement robust parsing, signature verification, expiration checks, and claim validation.
 - For non-JWT credentials (API keys, HMAC), ensure replay protection and scope binding.
- Responses and errors
 - Use structured `LoginResponse` for both success and error paths.
 - Prefer idempotent user/role operations; validate inputs and surface actionable messages.

8.8. `CredentialUserIdPassword` model and `DomainContext`

This section explains how user credentials are represented, how those records tie to tenancy and realms, and how the server chooses the database (“realm”) for REST calls.

What the credential model represents

`userId`

The human-friendly login handle that users type. Must be unique within the applicable tenancy/realm scope.

subject

A stable, system-generated identifier for the principal. Tokens and internal references favor subject over userId because subjects do not change.

description, emailOfResponsibleParty

Optional metadata to describe the credential and provide an owner contact.

domainContext

The tenancy and organization placement of the principal. It contains:

- tenantId: Logical tenant partition.
- orgRefName: Organization/business unit within the tenant.
- accountId: Account or billing identifier.
- defaultRealm: The default database/realm used for this identity's operations.
- dataSegment: Optional partitioning segment for advanced sharding or data slicing.

roles

The set of authorities granted (e.g., USER, ADMIN). These become groups/roles on the SecurityIdentity.

issuer

An identifier for who issued the credential or tokens (useful for auditing and multi-provider setups).

passwordHash, hashingAlgorithm

The stored password hash and declared algorithm. Not exposed over REST. Providers verify passwords against this.

forceChangePassword

Flag that forces a password reset on next login; the login flow returns a structured negative response instead of tokens.

lastUpdate

Timestamp for auditing and token invalidation strategies.

area2RealmOverrides

Optional map to route specific functional areas to different realms than the default (e.g., "Reporting" → analytics-realm).

realmRegEx

Optional regex to limit or override which realms this identity may act in; also used by impersonation/override flows.

impersonateFilterScript

Optional script indicating the filter/scope applied during impersonation so actions are constrained.

authProviderName

The name of the provider that owns this credential (e.g., “custom”, “oidc”), enabling multi-provider operations and audits.

How DomainContext selects the realm for REST calls

- For each authenticated request, the server derives or retrieves a DomainContext associated with the principal.
- The DomainContext.defaultRealm indicates which backing MongoDB database (“realm”) should be used by repositories for that request.
- If realm override features are enabled (e.g., through provider helpers or per-credential overrides), the system may route certain functional areas to alternate realms using area2RealmOverrides or validated by realmRegEx.
- The remainder of DomainContext (tenantId, orgRefName, accountId, dataSegment) is applied as scope constraints through permission rules and repository filters so reads and writes are automatically restricted to the correct tenant/org segment.

8.9. Quarkus OIDC out-of-the-box and integrating with common IdPs

Quarkus ships with first-class OpenID Connect (OIDC) support, enabling both service-to-service and browser-based logins.

What the Quarkus OIDC extension provides

- OIDC client and server-side adapters:
 - Authorization Code flow with PKCE for browser sign-in.
 - Bearer token authentication for APIs (validating access tokens on incoming requests).
 - Token propagation for downstream calls (forwarding or exchanging tokens).
- Token verification and claim mapping:
 - Validates issuer, audience, signature, expiration, and scopes.
 - Maps standard claims (sub, email, groups/roles) into the security identity.
- Multi-tenancy and configuration:
 - Supports multiple OIDC tenants via configuration, each with its own issuer, client id/secret, and flows.
- Logout and session support:
 - Front-channel and back-channel logout hooks depending on provider capabilities.

Integrating with common providers

- Works with providers like Keycloak, Auth0, Okta, Azure AD, Cognito, and enterprise IdPs exposing OIDC.
- Configure the issuer URL and client credentials. Quarkus discovers endpoints via the provider’s

.well-known/openid-configuration.

- For roles/permissions, map provider groups/roles claims to your platform roles in the identity.

OIDC vs OAuth vs OpenID (terminology and evolution)

OAuth 2.0

Authorization framework for delegated access (scopes), not authentication. Defines flows to obtain access tokens for APIs.

OpenID (OpenID 1.x/2.0)

Older federated identity protocol that preceded OIDC. It has been superseded by OpenID Connect.

OpenID Connect (OIDC)

An identity layer on top of OAuth 2.0. Adds standardized authentication, user info endpoints, ID tokens (JWT) with subject and profile claims, and discovery metadata. In practice, OIDC is the modern standard for SSO and user authentication; OAuth remains the authorization substrate underneath.

Summary

- OpenID → historical, replaced by OIDC.
- OAuth 2.0 → authorization framework.
- OIDC → authentication (identity) layer built on OAuth 2.0.

OIDC and SAML in relation to SSO

SAML (Security Assertion Markup Language)

XML-based federation protocol widely used in enterprises for browser SSO; uses signed XML assertions transported through browser redirects/posts.

OIDC

JSON/REST-oriented, uses JWTs, and is well-suited for modern SPAs and APIs.

Relationship: * Both enable SSO and federation across identity providers and service providers. * Many enterprise IdPs support both; OIDC is generally simpler for APIs and modern web stacks, while SAML is entrenched in legacy/enterprise SSO.

Bridging: * Gateways or identity brokers can translate SAML assertions to OIDC tokens and vice versa, allowing gradual migration.

Common customer IdP models and OIDC integration patterns

- Centralized IdP (single-tenant)
 - One organization-wide IdP issues tokens for all users.
 - Configure a single OIDC tenant in Quarkus; map groups/roles to application roles.
- Multi-tenant SaaS with per-tenant IdP (BYOID)
 - Each customer brings their own IdP.

- Configure Quarkus OIDC multitenancy with per-tenant issuer discovery and client credentials.
- Tenant selection can be based on domain, request header, or path; the selected OIDC tenant performs login and token validation.
- Brokered identity
 - Use a broker that federates to multiple upstream IdPs (OIDC, SAML).
 - Quarkus integrates with the broker as a single OIDC client; the broker handles IdP routing and protocol translation.
- Hybrid API and web flows
 - Browser apps use Authorization Code flow with sessions; APIs use bearer token authentication.
 - The OIDC extension can handle both in the same application when properly configured.

8.10. Authorization via RuleContext

Authentication establishes identity; RuleContext enforces what the identity can do. For each action (CREATE, UPDATE, VIEW, DELETE, ARCHIVE), RuleContext can:

- Allow or deny the action
- Contribute additional filters (e.g., org scoping, functional-area specific sharing)
- Adjust UIActionList to reflect permitted next steps

This division of responsibilities keeps providers focused on identity while policies remain centralized in RuleContext.

8.10.1. Using Ontology Edges in List Endpoints (optional)

When ontology is enabled and edges are materialized, list endpoints can avoid deep joins or multi-collection traversals by rewriting queries based on semantic relationships.

Pattern A: Wrap BSON with ListQueryRewriter

```
Bson base = Filters.and(existingFilters...);
Bson rewritten = rewriter.rewriteForHasEdge(base, tenantId, "placedInOrg", orgRefName);
collection.find(rewritten).iterator();
```

Pattern B: Constrain Morphia query by IDs

```
Set<String> ids = edgeDao.srcIdsByDst(tenantId, "orderShipsToRegion", region);
if (!ids.isEmpty()) {
    query.filter(dev.morphia.query.filters.Filters.in("_id", ids));
}
```

Notes

- Always scope by tenantId from DomainContext/RuleContext.
- Index edges on (tenantId, p, dst) and (tenantId, src, p) to keep queries fast.
- See [Integrating Ontology](#) for more integration options.

Chapter 9. 7. Query language and filtering

Problem: Powerful, safe, and consistent querying across collections.

Why for SaaS: Tenants need flexible reporting and filtration without bespoke endpoints.

How Quantum helps: A uniform query language layer with server-side enforcement.

Walkthrough: Add query endpoints and test filters/security.

9.1. Query Language Reference

Quantum uses an ANTLR-based query language (BIAPIQuery.g4) for filtering, searching, and constraining data across all REST endpoints. This single, consistent syntax works everywhere: list APIs, permission rules, and access resolvers.

9.1.1. Basic Syntax

Operators

Operator	Symbol	Example
Equals	:	name:"Widget"
Not equals	:!	status:! "DELETED"
Less than	:<	price:<##100
Greater than	:>	quantity:>#50
Less than or equal	:≤	createdAt:≤2024-12-31
Greater than or equal	:>=	updatedAt:>=2024-01-01T00:00:00Z
Field exists	:~	description:~
In list	:^	status:^["ACTIVE","PENDING"]
Not in list	:!^	status:!^["DELETED","ARCHIVED"]

Value Types

Type	Prefix	Example
String	none or "..."	name:widget or name:"Super Widget"
Number (integer)	#	quantity:#42
Number (decimal)	##	price:##19.99
Date	none	shipDate:2024-12-25

Type	Prefix	Example
DateTime	none	createdAt:2024-12-25T10:30:00Z
Boolean	none	active:true
Null	none	description:null
ObjectId	none	id:507f1f77bcf86cd799439011
Reference	@@	parentId:@@507f1f77bcf86cd799439011
Variable	\${...}	ownerId:\${principalId}

Logical Operators

Operator	Symbol	Example
AND	&&	active:true && price:>##10
OR		status:"ACTIVE" status:"PENDING"
NOT	!!	!(price:<##5)
Grouping	()	(active:true featured:true) && price:>##0

9.1.2. Common Patterns

String Matching

```
# Exact match
name:"Super Widget"

# Wildcard matching
name:*widget*      # contains "widget"
name:widget*       # starts with "widget"
name:*widget       # ends with "widget"
name:w?dget        # single character wildcard

# Case sensitivity (depends on database collation)
name:"WIDGET"       # may or may not match "widget"
```

Numeric Ranges

```
# Price between 10 and 100
price:>=##10 && price:<=##100

# Quantity greater than 0
quantity:>#0

# Exact count
itemCount:#5
```

Date and Time Queries

```
# Orders from today
createdAt:>=2024-12-25

# Orders from last week
createdAt:>=2024-12-18 && createdAt:<2024-12-25

# Specific timestamp
updatedAt:2024-12-25T14:30:00Z

# Orders modified this year
updatedAt:>=2024-01-01T00:00:00Z
```

List Membership

```
# Status in specific values (IN)
status:^[ "ACTIVE", "PENDING", "PROCESSING" ]

# Exclude statuses (NOT IN)
status:!^[ "DELETED", "ARCHIVED" ]

# User IDs from a list (IN)
ownerId:^[ "user1", "user2", "user3" ]

# Exclude specific users (NOT IN)
ownerId:!^[ "user1", "user2" ]

# ObjectId list (IN)
categoryId:^[ @507f1f77bcf86cd799439011, @507f1f77bcf86cd799439012 ]

# ObjectId list (NOT IN)
categoryId:!^[ @507f1f77bcf86cd799439011, @507f1f77bcf86cd799439012 ]

# Mixed types (coerced automatically)
priority:^[ #1, #2, #3 ]

# Using variables (CSV expansion supported by access resolvers)
customerId:!^[ ${accessibleCustomerIds} ]
```

Null and Existence Checks

```
# Field has any value (not null)
description:~

# Field is null
description:null
```

```
# Field is not null
description:!null
```

```
# Field exists and is not empty string
description:~ && description:!""
```

Advanced Examples

Complex Business Logic

```
# Active products under $50 OR featured products at any price
(active:true && price:<##50) || featured:true
```

```
# Orders needing attention: overdue OR high-value pending
(dueDate:<2024-12-25 && status:! "COMPLETED") ||
(status:"PENDING" && totalAmount:>##1000)
```

```
# Products with inventory issues
(quantity:<=#5 && reorderPoint:>#5) || stockStatus:"OUT_OF_STOCK"
```

Multi-tenant Filtering

```
# User's own records
dataDomain.ownerId:${principalId}
```

```
# Organization-wide access
dataDomain.orgRefName:${orgRefName}
```

```
# Tenant-scoped with public sharing
dataDomain.tenantId:${pTenantId} || dataDomain.orgRefName:"PUBLIC"
```

Audit and Compliance

```
# Records modified by specific user
auditInfo.lastUpdatedBy:"john.doe"
```

```
# Changes in date range
auditInfo.lastUpdatedDate:>=2024-12-01 &&
auditInfo.lastUpdatedDate:<2024-12-31
```

```
# Created vs modified
auditInfo.createdDate:auditInfo.lastUpdatedDate # never modified
auditInfo.createdDate:!auditInfo.lastUpdatedDate # has been modified
```


Variables in Filters

Variables are resolved from the current security context and can be used in permission rules and access resolvers.

Standard Variables

Variable	Description
<code>\${principalId}</code>	Current user's ID
<code>\${pTenantId}</code>	Principal's tenant ID
<code>\${pAccountId}</code>	Principal's account ID
<code>\${pOrgRefName}</code>	Principal's organization
<code>\${realm}</code>	Current realm/database
<code>\${area}</code>	Current functional area
<code>\${functionalDomain}</code>	Current functional domain
<code>\${action}</code>	Current action (CREATE, UPDATE, etc.)

Custom Variables from Access Resolvers

```
// In your AccessListResolver
@Override
public String key() {
    return "accessibleCustomerIds"; // becomes ${accessibleCustomerIds}
}

@Override
public Collection<?> resolve(...) {
    return Arrays.asList("CUST001", "CUST002", "CUST003");
}
```

```
# Use in filter
customerId:^(${accessibleCustomerIds})
```

Performance Tips

Efficient Queries

```
# Good: Use indexed fields first
status:"ACTIVE" && createdAt:>=2024-01-01

# Better: Combine with specific values
status:"ACTIVE" && ownerId:${principalId} && createdAt:>=2024-01-01

# Avoid: Leading wildcards on large collections
```

```
name:*widget # can be slow on millions of records
```

Projection for Large Objects

```
# In REST calls, limit returned fields
GET /products/list?filter=active:true&projection=+id,+name,+price,-description
```

Integration with REST APIs

List Endpoints

```
# Basic filtering
GET /products/list?filter=active:true

# With sorting and pagination
GET /products/list?filter=price:>##10&sort=-createdDate&skip=20&limit=10

# Complex filter with projection
GET
/orders/list?filter=(status:"PENDING"||status:"PROCESSING")&&totalAmount:>##100&projection=+id,+status,+totalAmount,+customerName
```

Permission Rules

```
- name: user-own-records
  priority: 300
  match:
    method: [GET]
    url: /api/**
  effect: ALLOW
  andFilterString: "dataDomain.ownerId:${principalId}"
```

Access Resolvers

```
// Resolver returns customer IDs user can access
public Collection<?> resolve(...) {
    return customerService.getAccessibleIds(principalId);
}

// Used in permission rule
andFilterString: "customerId:^(${accessibleCustomerIds})"
```

Error Handling

Common syntax errors and solutions:

```
# Wrong: Missing quotes for multi-word strings
```

```
name:Super Widget
```

```
# Right:
```

```
name:"Super Widget"
```

```
# Wrong: Incorrect number prefix
```

```
price:19.99
```

```
# Right:
```

```
price:##19.99
```

```
# Wrong: Invalid date format
```

```
createdDate:12/25/2024
```

```
# Right:
```

```
createdDate:2024-12-25
```

```
# Wrong: Unbalanced parentheses
```

```
(active:true && price:>##10
```

```
# Right:
```

```
(active:true && price:>##10)
```

See Also

- [REST CRUD Querying](#)
- [Permission Rules](#)
- [Access Resolvers](#)

Execution engines and listeners

The BI-API query syntax is parsed once (via ANTLR) and can be executed by different "listeners" depending on the use case. Quantum ships with two primary implementations that share the same grammar and semantics:

- Morphia listener: converts a query into Mongo/Morphia Filters for database-side execution
- In-memory listener: converts a query into a Java Predicate over JSON data for Quarkus/GraalVM-friendly in-memory execution

Morphia: QueryToFilterListener

Use this when you want the database to perform the filtering. The listener walks the parse tree and produces a `dev.morphia.query.filters.Filter` which you can apply to Morphia queries. This is ideal for repository APIs and any endpoint where you want to leverage MongoDB indexes and avoid loading large data sets into memory.

Key characteristics: - Output type: Morphia Filter - Execution: database-side (MongoDB) - Semantics: identical to grammar (comparisons, IN/NIN, exists, null, regex with wildcards, elemMatch, boolean &&|||/!!) - Variable expansion: supports `${vars}` and single-variable IN list expansion (e.g., `[$ids]` can expand to a collection/array or a comma-separated string)

Example:

```
import com.e2eq.framework.grammar.*;
import com.e2eq.framework.model.persistent.morphia.QueryToFilterListener;
import dev.morphia.query.filters.Filter;
import dev.morphia.query.filters.Filters;
import org.antlr.v4.runtime.*;
import org.antlr.v4.runtime.tree.ParseTreeWalker;
import org.apache.commons.text.StringSubstitutor;

String query = "(status:Assigned||status:Pending)&&displayName:*Route*";
var vars = java.util.Map.<String,String>of();

// Parse
CharStream cs = CharStreams.fromString(query);
BIAPIQueryLexer lexer = new BIAPIQueryLexer(cs);
CommonTokenStream tokens = new CommonTokenStream(lexer);
BIAPIQueryParser parser = new BIAPIQueryParser(tokens);
BIAPIQueryParser.QueryContext tree = parser.query();

// Build Morphia filter
QueryToFilterListener listener = new QueryToFilterListener(vars, new
StringSubstitutor(vars), /* modelClass */ null);
ParseTreeWalker.DEFAULT.walk(listener, tree);
Filter morphiaFilter = listener.getFilter();

// Use with Morphia query (example)
// datastore.find(MyEntity.class).filter(morphiaFilter).iterator().toList();
```

A few query examples (taken from testQueryStrings.txt):

- Equality: field:"quotedString"
- Comparisons: field:>##12.56, field:<=#123
- IN/NIN: field:^[value1,value2], field:!^[value1,value2]
- Exists/Null: field:~, field:null
- elemMatch: arrayField:{(subField:<#12) || (subField:>#15)}

In-memory (JsonNode): QueryToPredicateJsonListener

Use this when you need to evaluate queries in memory without reflection on POJOs. This implementation compiles a query into a `java.util.function.Predicate` over a Jackson `JsonNode`. It is Quarkus/GraalVM friendly, useful for: - Unit tests where you want to validate query behavior without a database - Post-filtering or pre-filtering of already-fetched data - Evaluating access rules or business logic against transient objects

Key characteristics: - Output type: `Predicate<JsonNode>` - Execution: in-memory - No runtime reflection: operates on `JsonNode` - Semantics and variable expansion match the Morphia listener

Convenience helpers exist in QueryPredicates:

```
import com.e2eq.framework.query.QueryPredicates;
import com.fasterxml.jackson.databind.JsonNode;
import java.util.function.Predicate;
import java.util.Map;

String query = "(status:Assigned||status:Pending)&&displayName:*Route*";
Predicate<JsonNode> p = QueryPredicates.compilePredicate(query, Map.of(), Map.of());

// Example data as a POJO or Map -> convert to JsonNode
record Ticket(String status, String displayName) {}
Ticket ticket = new Ticket("Assigned", "Route Exception in
Route:To[http://com.xxx/update]");
JsonNode node = QueryPredicates.toJsonNode(ticket);

boolean include = p.test(node); // true
```

Additional examples

- Equality and comparisons

```
var vars = Map.<String,String>of();
var objVars = Map.<String,Object>of();
Predicate<JsonNode> eq = QueryPredicates.compilePredicate("quantity:#42", vars,
objVars);
Predicate<JsonNode> gt = QueryPredicates.compilePredicate("price:>##19.99", vars,
objVars);

JsonNode product = QueryPredicates.toJsonNode(Map.of("quantity", 42, "price", 25.00));
assert eq.test(product);
assert gt.test(product);
```

- IN / NIN with variable expansion

```
var vars = Map.of("principalId", "66d1f1ab452b94674bbd934a");
Predicate<JsonNode> in =
QueryPredicates.compilePredicate("ownerId:^(#{principalId},value2]", vars, Map.of());
JsonNode doc = QueryPredicates.toJsonNode(Map.of("ownerId",
"66d1f1ab452b94674bbd934a"));
assert in.test(doc);
```

- elemMatch over arrays of objects

```
String q = "items:{(sku:abc||qty:>#10)&&price:<=##9.99}";
Predicate<JsonNode> em = QueryPredicates.compilePredicate(q, Map.of(), Map.of());
JsonNode order = QueryPredicates.toJsonNode(Map.of(
```

```

"items", java.util.List.of(
    Map.of("sku","abc","qty", 5, "price", 9.99),
    Map.of("sku","xyz","qty", 12, "price", 8.50)
));
// Matches: first item by sku OR second item by qty with price cap
assert em.test(order);

```

- Regex with wildcards

```

Predicate<JsonNode> rx = QueryPredicates.compilePredicate("displayName:*Route*",
Map.of(), Map.of());
JsonNode ticket = QueryPredicates.toJsonNode(Map.of("displayName", "Route Exception in
Route:To[...]"));
assert rx.test(ticket);

```

Choosing the right listener

- Use Morphia (QueryToFilterListener) when:
 - You are filtering MongoDB collections and want the DB to do the work (indexing, pagination, scalability)
 - You need server-side performance and minimal memory footprint
- Use In-memory (QueryToPredicateJsonListener) when:
 - You run in Quarkus native image and want to avoid reflection on POJOs
 - You are writing unit tests or applying rules to transient/aggregated data
 - You need to evaluate a query over already materialized objects without another database round-trip

Both listeners aim to maintain parity with the grammar. If you observe mismatches, please file an issue with the query string, the evaluated data sample, and the expected vs actual results.

Expressing Ontology Constraints in Queries (optional)

The BIAPI query language primarily targets fields on documents. When using the ontology modules, there are two ways to incorporate ontology relationships into queries:

Option A: Variable from an AccessListResolver

- A resolver computes the set of IDs using EdgeDao (e.g., orders related by placedInOrg to the caller's org).
- Use an IN clause over id in your filter string:

```

# idsByPlacedInOrg is published by an AccessListResolver
id:^{idsByPlacedInOrg}

```

Option B: Function-style helper (if you wire one)

- Some applications register a `hasEdge(predicate, value)` function into the filter translation path.
- Example (conceptual): `hasEdge("placedInOrg", ${principal.orgRefName})`
- Under the hood, it translates to `id IN edgeDao.srcIdsByDst(tenantId, predicate, dst)`.

Notes

- Ontology is optional; these patterns only apply when enabled and materialization is active.
- Always scope edge lookups by `tenantId` from `RuleContext`.
- See [Integrating Ontology](#) for wiring examples.



Policy function `hasEdge()`

- The `hasEdge(predicate, dstIdOrVar)` operator is a policy-level function evaluated before query translation. It is not part of the BI-API grammar parsed in this document.
- When present in a policy, the repository typically applies it by calling `ListQueryRewriter.rewriteForHasEdge(...)`, which constrains results by the set of IDs that have the specified ontology edge.
- See [Rule language: add hasEdge\(\)](#) for signature, semantics, and a full end-to-end example.

9.1.3. Relationships and Ontology-aware Queries

Hydrating related data with `expand(path)`

The query language supports a compact, non-SQL directive to request hydration (materialization) of related entities referenced by the root documents.

- Syntax: `expand(path)`
- Path: a dotted path; array segments may use `[*]` to indicate an array of references.
- Examples:

```
# Single reference
expand(customer)

# Array of references
expand(items[*].product)

# Nested paths (bounded by first non-reference boundary)
expand(patient.visits[*].diagnoses[*])
```

Semantics

- Presence of `expand(...)` informs the planner to choose an aggregation-based execution plan (e.g., MongoDB `$lookup`) rather than a simple single-collection filter.

- Filters remain expressed with the existing primitives and compose as usual. For example:

```
# Filter roots by status AND hydrate the related customer
expand(customer) && status:active
```

Notes and limits (v1)

- Backend: MongoDB only in this release. The planner selects aggregation mode when `expand(...)` appears.
- Depth: for mixed arrays/objects, traversal stops at the first non-reference boundary.
- Projection: a concise projection form `fields:[+a,+b,-c]` can be used at the root (see below). Per-expansion projections and related-entity filters are documented in [Query Expansion](#) and may be introduced incrementally.
- Errors: unknown projection paths (when using `fields:[...]`) are hard errors.

See also

- [Query Expansion](#) for more examples and planner behavior.
- [Planner and QueryGateway](#) for how execution mode is chosen.

Ontology operator: `hasEdge(predicate, dst)`

When the ontology module is enabled and edges are materialized, you can constrain results by semantic relationships using `hasEdge`.

- Syntax: `hasEdge(predicate, dst)` where
- `predicate` is a string (unquoted or quoted)
- `dst` can be a literal id, a variable like `${principalId}`, an `ObjectId`, or a reference literal `@@...`
- Examples:

```
# Orders placed in a specific organization
hasEdge("placedInOrg", ${orgRefName})

# Tickets routed to a region by id
hasEdge("routedToRegion", 507f1f77bcf86cd799439011)
```

Semantics

- `hasEdge` narrows the result set to entities that have the specified ontology edge from the entity (source) to the destination id/value.
- It composes with other filters using `&&`, `||`, and `!!` like any other expression.
- Tenancy: edge resolution is always scoped by tenant/realm per your configuration.

See also

- [Rule language: add hasEdge\(\)](#) for a deep dive and policy usage.
- [Ontology integration](#) for repository wiring and examples.

Root projection recap: `fields:[+..., -...]`

To include or exclude fields from the root documents:

- Syntax: `fields:[+f1, +f2, -f3]`
- Include mode: if any `+` is present, only the listed fields are included (with explicit `-` carving out exceptions).
- Exclude mode: if only `-` entries exist, all fields are included except those.
- Default `_id`: preserved unless explicitly specified (`+_id/-_id`).

Examples

```
# Include a few fields from the root and drop one
fields:[+_id, +total, -internalNotes]

# Combine with expansion (planner chooses aggregation mode)
expand(customer) && fields:[+_id, +customer, +total]
```

For per-expansion projections and advanced traversal filters, see [Query Expansion](#).

9.2. Hands-on: Relationships and Ontology-aware queries

In addition to basic filters, the query layer supports relationship hydration and ontology-aware constraints. These features are MongoDB-first in this release and remain backward compatible: - If you don't use them, behavior is unchanged. - When you do, the planner may choose a Mongo aggregation under the hood.

9.2.1. Hydrate related data with `expand(path)`

Use `expand(path)` to materialize related entities referenced by your root documents. Paths are dotted and can include array wildcards `[*]`.

Examples:

```
# Single reference
expand(customer)

# Array of references in an items array
expand(items[*].product)

# Nested arrays (bounded by the first non-reference boundary)
```

```
expand(patient.visits[*].diagnoses[*])
```

Combine with normal filters and projection:

```
q = "realm:acme && expand(customer, fields:[+name,+tier]) &&  
fields:[+_id,+total,+customer.name]"
```

Notes: - Depth on mixed arrays/objects stops at the first non-reference boundary. - Unknown projection paths are hard errors.

See: [Query Expansion](#) for more patterns and semantics.

9.2.2. Ontology: constrain by relationships with `hasEdge(predicate, dst)`

When the ontology module is enabled and edges are materialized, you can filter by semantic relationships using `hasEdge`.

Examples:

```
# Orders placed in a specific organization  
hasEdge("placedInOrg", ${orgRefName})  
  
# Tickets routed to a region by id  
hasEdge("routedToRegion", 507f1f77bcf86cd799439011)
```

Tenancy is always applied when resolving edges. See: - [Permissions: hasEdge rule](#) - [Ontology in queries](#)

9.2.3. Inspect the planner with `QueryGateway`

You can inspect how a query will execute (FILTER vs AGGREGATION) using the new `QueryGateway` facade.

```
import com.e2eq.framework.model.persistent.morphia.query.QueryGateway;  
import com.e2eq.framework.model.persistent.morphia.query.QueryGatewayImpl;  
import com.e2eq.framework.model.persistent.morphia.planner.PlannerResult;  
  
QueryGateway gateway = new QueryGatewayImpl();  
PlannerResult pr = gateway.plan("expand(customer) && status:active", Order.class);  
// pr.getMode() == PlannerResult.Mode.AGGREGATION  
// pr.getExpandPaths() == ["customer"]
```

For lower-level control, use `MorphiaUtils.convertToPlannedQuery(...)`. See: [Planner and QueryGateway](#).

Chapter 10. 8. Authentication, permissions, and annotations

Problem: Securely authenticating users and enforcing fine-grained authorization.

Why for SaaS: Multi-tenant apps must ensure tenant isolation and principle-of-least-privilege.

How Quantum helps: JWT integration, permissions model, and security annotations.

Walkthrough: Protect your APIs and add role/permission checks.

Chapter 11. Authentication and Authorization

Quantum integrates with Quarkus security while providing a pluggable approach to authentication. The repository includes a JWT provider module to get started quickly and an extension surface to replace or complement it.

11.1. JWT Provider

- Module: `quantum-jwt-provider`
- Purpose: Validate JWTs on incoming requests, populate the security principal, and surface tenant/org/user claims that feed `DomainContext`.
- Configuration: Standard Quarkus/MicroProfile JWT properties plus custom claim mappings as needed for `DataDomain`.

11.2. Pluggable Authentication

You can introduce alternative authentication mechanisms (e.g., API keys, SAML/OIDC front-channel tokens exchanged for back-end JWTs, HMAC signatures) by providing CDI beans that integrate with the security layer and emit the same normalized context consumed by `DomainContext/RuleContext`.

Typical steps:

1. Implement a request filter or identity provider that validates the token/credential.
2. Map identity and tenant claims into a principal model (`tenantId`, `orgRefName`, `userId`, `roles`).
3. Ensure `BaseResource` (and other entry points) can derive `DomainContext` from that principal.

11.3. Creating an Auth Plugin (using the Custom JWT provider as a reference)

An auth plugin is typically a CDI bean that:

- Extends `BaseAuthProvider` to inherit user-management helpers and persistence utilities.
- Implements `AuthProvider` to integrate with request-time authentication flows.
- Implements `UserManagement` to expose CRUD-style operations for users, passwords, and roles.

A concrete provider should:

- Be annotated as a CDI bean (e.g., `@ApplicationScoped`).
- Provide a stable `getName()` identifier (e.g., `"custom"`, `"oidc"`, `"apikey"`).
- Use config properties for secrets, issuers, token durations, and any external identity provider details.

- Build a Quarkus SecurityIdentity with the authenticated principal and roles.

11.4. AuthProvider interface (what a provider must implement)

Core methods:

- SecurityIdentity validateAccessToken(String token)
 - Parse and validate the incoming credential (JWT, API key, signature).
 - Return a SecurityIdentity with principal name and roles. Throw a security exception for invalid tokens.
- String getName()
 - A short identifier for the provider. Persisted alongside credentials and used in logs/metrics.
- LoginResponse login(String userId, String password)
 - Credential-based login. Return a structured response:
 - positiveResponse: includes SecurityIdentity, roles, accessToken, refreshToken, expirationTime, and realm/mongodbUrl if applicable.
 - negativeResponse: includes error codes/reason/message for clients to act on (e.g., password change required).
- LoginResponse refreshTokens(String refreshToken)
 - Validate the refresh token, mint a new access token (and optionally a new refresh token), and return a positive response.

Notes:

- Login flow should check force-change-password or equivalent flags and return a negative response when user interaction is required before issuing tokens.
- validateAccessToken should only accept valid, non-expired tokens and construct SecurityIdentity consistently with role mappings used across the platform.

11.5. UserManagement interface (operations your plugin must support)

Typical responsibilities include:

- User lifecycle
 - String createUser(String userId, String password, Set<String> roles, DomainContext domainContext, [optional] DataDomain)
 - void changePassword(String userId, String oldPassword, String newPassword, Boolean forceChangePassword)
 - boolean removeUserWithUserId(String userId)

- `boolean removeUserWithSubject(String subject)`
- Role management
 - `void assignRolesForUserId(String userId, Set<String> roles)`
 - `void assignRolesForSubject(String subject, Set<String> roles)`
 - `void removeRolesForUserId(String userId, Set<String> roles)`
 - `void removeRolesForSubject(String subject, Set<String> roles)`
 - `Set<String> getUserRolesForUserId(String userId)`
 - `Set<String> getUserRolesForSubject(String subject)`
- Lookups and existence checks
 - `Optional<String> getSubjectForUserId(String userId)`
 - `Optional<String> getUserIdForSubject(String subject)`
 - `boolean userIdExists(String userId)`
 - `boolean subjectExists(String subject)`

Return values and exceptions:

- Throw `SecurityException` or domain-specific exceptions for invalid states (duplicate users, bad password, unsupported hashing).
- Return `Optional` for lookups that may not find a result.
- For removals, return `boolean` to communicate whether a record was deleted.

11.6. Leveraging `BaseAuthProvider` in your plugin

When you extend `BaseAuthProvider`, you inherit ready-to-use capabilities that reduce boilerplate:

- Impersonation controls
 - `enableImpersonationWithUserId` / `enableImpersonationWithSubject`
 - `disableImpersonationWithUserId` / `disableImpersonationWithSubject`
 - These set or clear an impersonation filter script and realm regex that downstream services can honor to act on behalf of another identity under controlled scope.
- Realm override helpers
 - `enableRealmOverrideWithUserId` / `enableRealmOverrideWithSubject`
 - `disableRealmOverrideWithUserId` / `disableRealmOverrideWithSubject`
 - Useful for multi-realm/tenant scenarios, enabling scoped cross-realm behavior.
- Persistence utilities
 - Built-in use of the credential repository to save, update, and delete credentials.
 - Consistent validation of inputs (non-null checks, non-blank checks).
 - Hashing algorithm guardrails to ensure only supported algorithms are used.

Best practices when deriving:

- Always set the auth provider name in stored credentials so records can be traced to the correct provider.
- Reuse the role merge/remove patterns to avoid accidental role loss.
- Prefer emitting precise exceptions (e.g., `NotFound` for missing users, `SecurityException` for access violations).

11.7. Implementing your own provider

Checklist:

- Class design
 - `@ApplicationScoped` bean
 - extends `BaseAuthProvider`
 - implements `AuthProvider` and `UserManagement`
 - return a stable `getName()`
- Configuration
 - Externalize secrets (signing keys), issuers, token durations, and realm details via `MicroProfile Config`.
- `SecurityIdentity`
 - Consistently build identities with principal and roles; include useful attributes for auditing/telemetry.
- Tokens/credentials
 - For JWT-like tokens, implement robust parsing, signature verification, expiration checks, and claim validation.
 - For non-JWT credentials (API keys, HMAC), ensure replay protection and scope binding.
- Responses and errors
 - Use structured `LoginResponse` for both success and error paths.
 - Prefer idempotent user/role operations; validate inputs and surface actionable messages.

11.8. `CredentialUserIdPassword` model and `DomainContext`

This section explains how user credentials are represented, how those records tie to tenancy and realms, and how the server chooses the database (“realm”) for REST calls.

What the credential model represents

userId

The human-friendly login handle that users type. Must be unique within the applicable

tenancy/realm scope.

subject

A stable, system-generated identifier for the principal. Tokens and internal references favor subject over `userId` because subjects do not change.

description, emailOfResponsibleParty

Optional metadata to describe the credential and provide an owner contact.

domainContext

The tenancy and organization placement of the principal. It contains:

- `tenantId`: Logical tenant partition.
- `orgRefName`: Organization/business unit within the tenant.
- `accountId`: Account or billing identifier.
- `defaultRealm`: The default database/realm used for this identity's operations.
- `dataSegment`: Optional partitioning segment for advanced sharding or data slicing.

roles

The set of authorities granted (e.g., `USER`, `ADMIN`). These become groups/roles on the `SecurityIdentity`.

issuer

An identifier for who issued the credential or tokens (useful for auditing and multi-provider setups).

passwordHash, hashingAlgorithm

The stored password hash and declared algorithm. Not exposed over REST. Providers verify passwords against this.

forceChangePassword

Flag that forces a password reset on next login; the login flow returns a structured negative response instead of tokens.

lastUpdate

Timestamp for auditing and token invalidation strategies.

area2RealmOverrides

Optional map to route specific functional areas to different realms than the default (e.g., "Reporting" → `analytics-realm`).

realmRegEx

Optional regex to limit or override which realms this identity may act in; also used by impersonation/override flows.

impersonateFilterScript

Optional script indicating the filter/scope applied during impersonation so actions are

constrained.

authProviderName

The name of the provider that owns this credential (e.g., “custom”, “oidc”), enabling multi-provider operations and audits.

How DomainContext selects the realm for REST calls

- For each authenticated request, the server derives or retrieves a DomainContext associated with the principal.
- The DomainContext.defaultRealm indicates which backing MongoDB database (“realm”) should be used by repositories for that request.
- If realm override features are enabled (e.g., through provider helpers or per-credential overrides), the system may route certain functional areas to alternate realms using area2RealmOverrides or validated by realmRegex.
- The remainder of DomainContext (tenantId, orgRefName, accountId, dataSegment) is applied as scope constraints through permission rules and repository filters so reads and writes are automatically restricted to the correct tenant/org segment.

Typical flow

1. Login

- A user authenticates with userId/password (or other mechanism).
- On success, a token is returned alongside role information; the principal is associated with a DomainContext that includes the defaultRealm.

2. Subsequent REST calls

- The token is validated; the server reconstructs SecurityIdentity and DomainContext.
- Repositories choose the datastore for defaultRealm and enforce tenant/org filters using the DomainContext values.
- If the request targets a functional area with a defined override, the operation may route to a different realm for that area alone.

3. UI implications

- The client does not need to know which realm is selected; it simply calls the API. The server ensures the correct database is used based on DomainContext and any configured overrides.

Best practices

- Keep userId immutable once established; use subject for internal joins and token subjects.
- Always attach the correct DomainContext when creating users to avoid cross-tenant leakage.
- Use realm overrides deliberately for well-isolated areas (e.g., analytics, archiving) and document them for operators.

11.9. Quarkus OIDC out-of-the-box and integrating with common IdPs

Quarkus ships with first-class OpenID Connect (OIDC) support, enabling both service-to-service and browser-based logins.

What the Quarkus OIDC extension provides

- OIDC client and server-side adapters:
 - Authorization Code flow with PKCE for browser sign-in.
 - Bearer token authentication for APIs (validating access tokens on incoming requests).
 - Token propagation for downstream calls (forwarding or exchanging tokens).
- Token verification and claim mapping:
 - Validates issuer, audience, signature, expiration, and scopes.
 - Maps standard claims (sub, email, groups/roles) into the security identity.
- Multi-tenancy and configuration:
 - Supports multiple OIDC tenants via configuration, each with its own issuer, client id/secret, and flows.
- Logout and session support:
 - Front-channel and back-channel logout hooks depending on provider capabilities.

Integrating with common providers

- Works with providers like Keycloak, Auth0, Okta, Azure AD, Cognito, and enterprise IdPs exposing OIDC.
- Configure the issuer URL and client credentials. Quarkus discovers endpoints via the provider's .well-known/openid-configuration.
- For roles/permissions, map provider groups/roles claims to your platform roles in the identity.

OIDC vs OAuth vs OpenID (terminology and evolution)

OAuth 2.0

- Authorization framework for delegated access (scopes), not authentication. Defines flows to obtain access tokens for APIs.

OpenID (OpenID 1.x/2.0)

- Older federated identity protocol that preceded OIDC. It has been superseded by OpenID Connect.

OpenID Connect (OIDC)

- An identity layer on top of OAuth 2.0. Adds standardized authentication, user info endpoints, ID tokens (JWT) with subject and profile claims, and discovery metadata.
- In practice, OIDC is the modern standard for SSO and user authentication; OAuth remains the authorization substrate underneath.

Summary

- OpenID → historical, replaced by OIDC.
- OAuth 2.0 → authorization framework.
- OIDC → authentication (identity) layer built on OAuth 2.0.

OIDC and SAML in relation to SSO SAML (Security Assertion Markup Language)::

- XML-based federation protocol widely used in enterprises for browser SSO.
- Uses signed XML assertions transported through browser redirects/posts.

OIDC

- JSON/REST-oriented, uses JWTs, and is well-suited for modern SPAs and APIs.
- Relationship:
 - Both enable SSO and federation across identity providers and service providers.
 - Many enterprise IdPs support both; OIDC is generally simpler for APIs and modern web stacks, while SAML is entrenched in legacy/enterprise SSO.
- Bridging:
 - Gateways or identity brokers can translate SAML assertions to OIDC tokens and vice versa, allowing gradual migration.

Common customer IdP models and OIDC integration patterns

- Centralized IdP (single-tenant):
 - One organization-wide IdP issues tokens for all users.
 - Configure a single OIDC tenant in Quarkus; map groups/roles to application roles.
- Multi-tenant SaaS with per-tenant IdP:
 - Each customer brings their own IdP (BYOID).
 - Configure Quarkus OIDC multitenancy with per-tenant issuer discovery and client credentials.
 - Tenant selection can be based on domain, request header, or path; the selected OIDC tenant performs login and token validation.
- Brokered identity:
 - Use a broker (e.g., a central identity layer) that federates to multiple upstream IdPs (OIDC, SAML).
 - Quarkus integrates with the broker as a single OIDC client; the broker handles IdP routing and protocol translation.
- Hybrid API and web flows:
 - Browser apps use Authorization Code flow with sessions; APIs use bearer token authentication.
 - Quarkus OIDC extension can handle both in the same application when properly configured.

Best practices

- Prefer OIDC for new integrations; use SAML through a broker if enterprise constraints require it.
- Normalize roles/claims server-side so downstream authorization (RuleContext, repositories) sees consistent group names regardless of IdP.
- Use token exchange or client credentials for service-to-service calls; do not reuse end-user tokens where not appropriate.
- For multi-tenant OIDC, secure tenant resolution logic and validate issuer/tenant binding to prevent mix-ups.

11.10. Authorization via RuleContext

Authentication establishes identity; RuleContext enforces what the identity can do. For each action (CREATE, UPDATE, VIEW, DELETE, ARCHIVE), RuleContext can:

- Allow or deny the action
- Contribute additional filters (e.g., org scoping, functional-area specific sharing)
- Adjust UIActionList to reflect permitted next steps

This division of responsibilities keeps providers focused on identity while policies remain centralized in RuleContext.

Chapter 12. Permissions: Rule Bases, SecurityURLHeaders, and SecurityURLBody

This section explains how Quantum evaluates permissions for REST requests using rule bases that match on URL, HTTP method, headers, and request body content. It also covers how identities and roles (as found on `userProfile` or `credentialUserIdPassword`) are matched, how priority works, and how multiple matching rule bases are evaluated.

Note: The terms `SecurityURLHeaders` and `SecurityURLBody` in this document describe the matching dimensions for rules. Implementations may vary, but the semantics below are stable for authoring and reasoning about permissions.

12.1. Introduction: Layered Enforcement Overview

Quantum evaluates "can this identity do X?" through three complementary layers. Understanding them in order helps you pick the right tool for the job and combine them safely:

1. REST API annotations (top layer, code-level)

- What: JAX-RS/Jakarta Security annotations on resource methods, for example, `@RolesAllowed("ADMIN")`, `@PermitAll`, `@DenyAll`, `@Authenticated`.
- Purpose: Coarse-grained, immediate gates right at the endpoint. Ideal for baseline protections (for example, only ADMIN may call `/admin/**`) and for non-dynamic constraints that rarely change.
- Pros: Simple, fast, visible in code reviews.
- Cons: Hard-coded; changing access requires a code change, build, and deploy. No data-aware scoping (for example, cannot express tenant/domain filters).

2. Feature flags (exposure and variants)

- What: Turn capabilities on/off per environment or cohort and select variants (A/B, multivariate). See "Feature Flags, Variants, and Target Rules" below.
- Purpose: Control who even sees or can reach a capability during rollout (by tenant, role, geography, plan), independently of authorization. Flags answer "is the feature ON and which variant?"; they do not by themselves prove the caller is authorized.
- Pros: Reversible, environment-aware, safe rollout and experimentation.
- Cons: Not a substitute for authorization; must be paired with roles/permission rules for enforcement.

3. Permission Rules with DataDomain filtering (fine-grained, dynamic)

- What: Declarative rule bases that match URL, method, `SecurityURLHeaders`, and `SecurityURLBody`, and decide ALLOW/DENY. ALLOWs can contribute `DataDomain` constraints applied by repositories. See sections "Key Concepts", "Matching Algorithm", and examples below.
- Purpose: Express least-privilege, data-aware policies that evolve without code changes (data-driven authoring).

- Pros: Dynamic, auditable, supports role checks plus attribute predicates and domain scoping.
- Cons: Requires governance of rulebases and careful priority management.

How roles, Functional Areas, and Functional Domains fit in

- Roles: Used by both layers (1) and (3). Annotations directly reference roles; rules can require `rolesAny/rolesAll`. Effective roles are resolved by merging IdP roles with roles on the user record; see "How roles are defined for an identity" below.
- Functional Area/Domain: Derived from the URL convention `/{{area}}/{{functionalDomain}}/{{action}}` as parsed by `SecurityFilter.determineResourceContext`. Author policies using these fields to target business capabilities rather than raw URLs or ad-hoc headers.
- DataDomain: When rules ALLOW an action, they can attach data-scope filters (tenant/org/owner) so downstream reads/writes are constrained to the caller's domain.

Choosing the right approach

- Use annotations for stable, coarse gates you want visible in code (for example, admin-only endpoints, health endpoints with `@PermitAll`).
- Use feature flags to manage rollout/exposure and variants across environments and cohorts.
- Use permission rules to encode fine-grained, data-aware authorization and to evolve policy without redeploying.

Compare and contrast

- Annotation-based controls are compile-time and hard-code policy into the service; changing them requires code changes.
- Permission Rules and the Rule Language are data-driven and user-changeable (with proper governance), enabling rapid, auditable policy changes and DataDomain scoping.
- In practice: apply annotations as the first gate, evaluate feature flags to determine exposure/variant, then evaluate permission rules to decide ALLOW/DENY and attach scopes. This layered approach yields both safety and agility.

12.2. Key Concepts

- Identity: The authenticated principal, typically originating from JWT or another provider. It includes:
 - `userId` (or `credentialUserIdPassword` username)
 - roles (authorities/groups)
 - `tenantId`, `orgRefName`, optional realm, and other claims that contribute to `DomainContext`
- `userProfile`: A domain representation of the user that adds human information such as first name, last name, email address, phone number and provides a linkage back to identity, roles, and policy decorations (feature flags, plans, expiration, etc.).

- Rule Base (Permission Rule): A declarative rule with matching criteria and an effect (ALLOW or DENY). Criteria may include:
 - HTTP method and URL pattern
 - SecurityURLHeaders: predicates over selected HTTP headers (for example, `X-Tenant-Id`). Note: functional area/domain/action are derived from the URL, not headers.
 - SecurityURLBody: predicates over request body fields (JSON paths) or query parameters
 - Required roles/attributes on identity or userProfile
 - Functional area/domain/action
 - Priority: integer used to sort rule evaluation
 - Effect: ALLOW or DENY; an ALLOW may also contribute scope filters (e.g., DataDomain constraints) to be applied downstream by repositories.

12.3. Rule Structure (Illustrative)

```
- name: allow-public-reads
  priority: 100
  match:
    method: [GET]
    url: /Catalog/**
    rolesAny: [USER, ADMIN]
  effect: ALLOW
  filters:
    # Optional: contribute additional DataDomain filters
    readScope: { orgRefName: PUBLIC }
```

```
- name: deny-non-admin-delete
  priority: 10
  match:
    method: [DELETE]
    url: /api/**
  requireRolesAll: [ADMIN]
  effect: ALLOW
```

```
- name: default-deny
  priority: 10000
  match: {}
  effect: DENY
```

- headers under match are the SecurityURLHeaders predicates. Functional area/domain/action are parsed from the URL convention `/[area]/[functionalDomain]/[action]` (see `SecurityFilter.determineResourceContext`).
- Body predicates (SecurityURLBody) can be expressed similarly as JSONPath-like constraints:

```
body:
```

```
$.dataDomain.tenantId: ${identity.tenantId}
$.action: [CREATE, UPDATE]
```

12.4. Matching Algorithm

Given a request R and identity I, evaluate a set of rule bases RB as follows:

1. Candidate selection
 - From RB, select all rules whose URL pattern and HTTP method match R.
2. Attribute and header/body checks
 - For each candidate, check:
 - SecurityURLHeaders: header predicates must all match (case-insensitive header names; values support exact string, regex, or one-of lists depending on rule authoring capability).
 - SecurityURLBody: if present, evaluate body predicates against parsed JSON body (or query params when body is absent). Predicates must all match.
 - Identity/UserProfile: role requirements and attribute requirements must be satisfied.
3. Priority sort
 - Sort matching candidates by ascending priority (lower numbers indicate higher precedence). If not specified, default priority is 1000.
4. Evaluation order and decision
 - Iterate in sorted order; the first rule that yields a decisive effect (ALLOW or DENY) becomes the decision.
 - If the rule is ALLOW and contributes filters (e.g., DataDomain read/write scope), attach those to the request context for downstream repositories.
5. Multi-match aggregation (optional advanced mode)
 - In advanced configurations, if multiple ALLOW rules match at the same priority, their filters may be merged (intersection for restrictive scope, union for permissive scope) according to a configured merge strategy. If not configured, the default is first-match-wins.
6. Fallback
 - If no rules match decisively, apply a default policy (typically DENY).

12.5. Priorities

- Lower integer = higher priority. Example: priority 1 overrides priority 10.
- Use tight scopes with low priority for critical protections (e.g., denies), and broader ALLOWs with higher numeric priority.
- Recommended ranges:
 - 1–99: global deny rules and emergency blocks
 - 100–499: domain/area-specific critical rules

- 500–999: standard ALLOW policies
- 1000+: defaults and catch-alls

12.6. Grant-based vs Deny-based Rule Sets

Grant-based rule sets start with a default decision of DENY and then incrementally add ALLOW scenarios through explicit rules. This model is fail-safe by default: any URL, action, or functional area that does not have a matching ALLOW rule remains inaccessible. As new endpoints or capabilities are added to the system, users will not gain access until an explicit ALLOW is authored. This is the recommended posture for security-sensitive systems and multi-tenant platforms.

Deny-based rule sets start with a default decision of ALLOW and then add DENY scenarios to carve away disallowed cases. In this model, new functionality is exposed by default unless a DENY is added. While convenient during rapid prototyping, this posture risks accidental exposure as the surface area grows.

Practical implications:

- Change management: Grant-based requires adding ALLOWs when shipping new features; Deny-based requires remembering to add new DENYs.
- Auditability: Grant-based policies make it easy to enumerate what is permitted; Deny-based requires proving the absence of permissive gaps.
- Safety: In merge conflicts or partial deployments, Grant-based tends to fail closed (DENY), which is usually safer.

Example defaults:

- Grant-based (recommended):

```
- name: default-deny
  priority: 10000
  match: {}
  effect: DENY
```

- Deny-based (use with caution):

```
- name: default-allow
  priority: 10000
  match: {}
  effect: ALLOW
```

Tip: Even in a deny-based set, author low-number DENY rules for critical protections. In most production systems, prefer the grant-based model and layer specific ALLOWs for each capability.

12.7. Feature Flags, Variants, and Target Rules

Feature flags complement permission rules by controlling whether a capability is active for a given principal, cohort, or environment. Permissions answer “may this identity perform this action?”; feature flags answer “is this capability turned on, and which variant applies?” Use them together to achieve safe rollouts and fine-grained authorization.

Model reference: `com.e2eq.framework.model.general.FeatureFlag` with key fields:

- `enabled`: master on/off
- `type`: `BOOLEAN` or `MULTIVARIATE`
- `variants`: list of variant keys for multivariate experiments
- `targetRules`: cohort targeting rules
- `environment`: e.g., `dev`, `staging`, `prod`
- `jsonConfiguration`: arbitrary configuration for the feature (e.g., rollout %, UI copy, limits)

Example: Boolean flag for a new export API with environment-specific targeting

```
{
  "refName": "EXPORT_API",
  "description": "Enable CSV export endpoint",
  "enabled": true,
  "type": "BOOLEAN",
  "environment": "prod",
  "targetRules": [
    { "attribute": "role", "operator": "equals", "values": ["BETA"] },
    { "attribute": "tenantId", "operator": "in", "values": ["T100", "T200"] }
  ],
  "jsonConfiguration": { "rateLimitPerMin": 60 }
}
```

Example: Multivariate flag to roll out Search v2 to 10% of users and all members of a beta role

```
{
  "refName": "SEARCH_V2",
  "description": "New search implementation",
  "enabled": true,
  "type": "MULTIVARIATE",
  "variants": ["control", "v2"],
  "environment": "prod",
  "targetRules": [
    { "attribute": "role", "operator": "equals", "values": ["BETA"], "variant": "v2" },
    { "attribute": "userId", "operator": "hashMod", "values": ["10"], "variant": "v2" }
  ],
  "jsonConfiguration": { "defaultVariant": "control" }
}
```

```
}
```

Notes on TargetRules:

- attribute: a property from identity/userProfile (e.g., userId, role, tenantId, location, plan).
- operator: equals, in, contains, startsWith, regex, or domain-specific operators like hashMod for percentage rollouts.
- values: comparison values; semantics depend on operator.
- variant: when type is MULTIVARIATE, selects which variant applies when the rule matches.

How feature flags complement Permission Rule Context:

- The evaluation of a request can enrich the Rule Context (SecurityURLHeaders/Body or userProfile) with resolved feature flags and variants (e.g., userProfile.features["SEARCH_V2"] = "v2").
- Permission rules can then require a feature to be present before ALLOWing an action:

```
- name: allow-export-when-flag-on
  priority: 300
  match:
    method: [GET]
    url: /Reports/Export/**
    # Example predicate that assumes features are surfaced in userProfile
    userProfile.features.EXPORT_API: [true]
  rolesAny: [ADMIN, REPORTER]
  effect: ALLOW
```

Alternatively, systems may surface feature decisions via headers (e.g., X-Feature-SEARCH_V2: v2) so that SecurityURLHeaders can match directly.

Business usage examples for TargetRules and their correlation to Permission Rules:

- Progressive rollout by tenant TargetRule tenantId in [T100, T200] → Permission adds ALLOW for endpoints guarded by that flag so only those tenants can call them during rollout.
 - Role-based beta access: TargetRule role equals BETA → Permission requires both the BETA feature flag and standard role checks (e.g., USER/ADMIN) to ALLOW sensitive actions.
 - Plan/entitlement tiers: TargetRule plan in [Pro, Enterprise] → Permission rules enforce additional data-domain constraints (e.g., export size limits) while the flag simply turns the feature on for eligible plans.

Guidance: Feature Flags vs Permission Rules

- Put into Feature Flags:
 - Gradual, reversible rollouts; A/B or multivariate experiments; UI/behavior switches.
 - Environment gates (dev/staging/prod) and cohort targeting (tenants, beta users, geography).

- Non-security configuration values in `jsonConfiguration` (limits, thresholds, copy) that do not change who is authorized.
- Put into Permission Rules:
 - Durable authorization logic: roles, identities, functional area/domain/action, and `DataDomain` constraints.
 - Compliance and least-privilege decisions where fail-closed behavior is required.
 - Enforcement that remains valid after a feature is fully launched (even when the flag is removed).

Recommendation

Use a grant-based permission posture (default DENY) and let feature flags decide which cohorts even see or can reach new capabilities. Then author explicit ALLOW rules for those capabilities, conditioned on both role and feature presence.

12.8. Multiple Matching RuleBases

- First-match-wins (default): after sorting by priority, the first decisive rule determines the result; subsequent matches are ignored.
- Merge strategy (optional):
- When enabled and multiple ALLOW rules share the same priority, scopes/filters are merged.
- Conflicts between ALLOW and DENY at the same priority resolve to DENY unless explicitly configured otherwise (fail-safe).

12.9. Identity and Role Matching

- RolesAny: request is allowed if identity has at least one of the specified roles.
- RolesAll: request requires all listed roles.
- Attribute predicates can compare identity/userProfile attributes (e.g., `identity.tenantId == header.x-tenant-id`).
- Time or plan-based conditions: userProfile can embed plan and expiration; rules may check that trials are active or features are enabled.

12.9.1. How roles are defined for an identity (role sources and resolution)

Quantum composes the effective roles for a request by merging:

- Roles from the identity provider (JWT/`SecurityIdentity`)
- Roles configured on the user record (`CredentialUserIdPassword.roles`)

Source details:

- Identity Provider (JWT): roles commonly arrive via standard claims (for example, `groups`, `roles`, or provider-specific fields). Quarkus maps these into `SecurityIdentity.getRoles()`. In multi-realm setups, the realm in `X-Realm` can scope lookups but does not alter what the JWT asserts.

- Quantum user record: `com.e2eq.framework.model.security.CredentialUserIdPassword` has a `String[] roles` field stored per realm. This can be administered by Quantum to grant platform- or tenant-level roles.

Merge semantics (current implementation):

- Union: the effective role set is the union of JWT roles and `CredentialUserIdPassword.roles`. If either source is empty, the other source defines the set.
- Fallback: when neither source yields roles, the framework defaults to `ANONYMOUS`.
- Where implemented: `SecurityFilter.determinePrincipalContext` builds `PrincipalContext` with the merged roles.

Realm considerations:

- The user record is looked up by subject or `userId` in the active realm (default or `X-Realm`). If a realm override is provided, it is validated with `CredentialUserIdPassword.realmRegex`.
- Roles stored in a user record are realm-specific; JWT roles are whatever the IdP asserts for the token.

Operating models:

- Quantum-managed roles:
 - IdP authenticates the user (subject, username). Authorization is primarily driven by roles stored in `CredentialUserIdPassword.roles`.
 - Use when you want central, auditable role assignment within Quantum, independent of IdP groups.
- IdP-managed roles:
 - IdP carries authoritative roles/groups in the JWT. Keep `CredentialUserIdPassword.roles` minimal or empty.
 - Use when enterprises require IdP as the source of truth for access groups.
- Hybrid (recommended in many deployments):
 - Effective roles = JWT roles \cup `CredentialUserIdPassword.roles`.
 - Use JWT for enterprise groups (for example, `DEPT_SALES`, `ORG_ADMIN`) and Quantum roles for app-specific grants (for example, `REPORT_EXPORTER`, `BETA`).
 - This avoids IdP churn for application-local concerns while respecting org policies.

Examples:

- JWT-only:
 - `JWT.groups` = `[USER, REPORTER]`; user record roles = `[]`
 - Effective roles = `[USER, REPORTER]`
- Quantum-only:
 - `JWT.groups` = `[]`; user record roles = `[USER, ADMIN]`

- Effective roles = [USER, ADMIN]
- Hybrid union:
 - JWT.groups = [USER]; user record roles = [BETA, REPORT_EXPORTER]
 - Effective roles = [USER, BETA, REPORT_EXPORTER]

Guidance and best practices:

- Keep role names stable and environment-agnostic; use realms/permissions to scope where needed.
- Avoid overloading roles for feature rollout; use Feature Flags for rollout and variants, and roles for durable authorization.
- When IdP is authoritative, ensure consistent claim mapping so `SecurityIdentity.getRoles()` contains the expected values; commonly via `groups` claim in JWT.
- Use grant-based permission rules and require the minimal set of roles (`rolesAny/rolesAll`) needed for each capability.

Cross-references:

- User model: `com.e2eq.framework.model.security.CredentialUserIdPassword.roles`
- Context: `com.e2eq.framework.model.securityrules.PrincipalContext.getRoles()`
- Filter logic: `com.e2eq.framework.rest.filters.SecurityFilter.determinePrincipalContext`

12.10. Example Scenarios

1. Public catalog browsing

- Request: GET /Catalog/Products/VIEW?search=widgets
- Identity: anonymous or role USER
- Rules:
 - allow-public-reads (priority 100) ALLOW + readScope orgRefName=PUBLIC
- Outcome: ALLOW; repository applies DataDomain filter orgRefName=PUBLIC

2. Tenant-scoped shipment update

- Request: PUT /Collaboration/Shipments/UPDATE
- Headers: x-tenant-id=T1
- Body: { dataDomain: { tenantId: "T1" }, ... }
- Identity: user in tenant T1 with roles [USER]
- Rules:
 - allow-collab-update (priority 300) requires body.dataDomain.tenantId == identity.tenantId and rolesAny USER, ADMIN ⇒ ALLOW
- Outcome: ALLOW; Rule contributes writeScope tenantId=T1

3. Cross-tenant admin read with higher priority

- Request: GET /api/partners
- Identity: role ADMIN (super-admin)
- Rules:
 - admin-override (priority 50) ALLOW
 - default-tenant-read (priority 600) ALLOW with tenant filter
- Outcome: admin-override wins due to higher precedence (lower number), allowing broader read

4. Conflicting ALLOW and DENY at same priority

- Two rules match with priority 200: one ALLOW, one DENY
- Resolution: DENY wins unless merge strategy configured to handle explicitly; recommended to avoid same-priority conflicts by policy.

12.11. Operational Tips

- Author specific DENY rules with low numbers to prevent accidental exposure.
- Keep URL patterns narrowly tailored for sensitive domains.
- Prefer header/body predicates to refine matches without exploding URL patterns.
- Log matched rule names and applied scopes for auditability.

12.12. How UIActions and DefaultUIActions are calculated

When the server returns a collection of entities (for example, userProfiles), each entity may expose two action lists:

- DefaultUIActions: the full set of actions that conceptually apply to this type of entity (e.g., CREATE, UPDATE, VIEW, DELETE, ARCHIVE). Think of this as the “menu template” for the type.
- UIActions: the subset of actions the current user is actually permitted to perform on that specific entity instance right now.

Why they can differ per entity:

- Entity attributes: state or flags (e.g., archived, soft-deleted, immutable) can remove or alter available actions at instance level.
- Permission rule base: evaluated against the current request, identity, and context to allow or deny actions.
- DataDomain membership: tenant/org/owner scoping can further restrict actions if the identity is outside the entity’s domain.

How the server computes them:

1. Start with a default action template for the entity type (DefaultUIActions).

2. Apply simple state-based adjustments (for example, suppress CREATE on already-persisted instances).
3. Evaluate the permission rules with the current identity and context:
 - Consider roles, functional area/domain, action intent, headers/body, and any rule-contributed scopes.
 - Resolve DataDomain constraints to ensure the identity is permitted to act within the entity's domain.
4. Produce UIActions as the allowed subset for that entity instance.
5. Return both lists with each entity in collection responses.

How the client should use the two lists:

- Render the full DefaultUIActions as the visible set of possible actions (icons, buttons, menus) so the UI stays consistent.
- Enable only those actions present in UIActions; gray out or disable the remainder to signal capability but lack of current permission.
- This approach avoids flicker and keeps affordances discoverable while remaining truthful to the user's current authorization.

Example:

- You fetch 25 userProfiles.
- DefaultUIActions for the type = [CREATE, VIEW, UPDATE, DELETE, ARCHIVE].
- For a specific profile A (owned by your tenant), UIActions may be [VIEW, UPDATE] based on your roles and domain.
- For another profile B (in a different tenant), UIActions may be [VIEW] only.
- The UI renders the same controls for both A and B, but only enables the actions present in each item's UIActions list.

Operational considerations:

- Keep action names stable and documented so front-ends can map to icons and tooltips consistently.
- Prefer small, composable rules that evaluate action permissions explicitly by functional area/domain to avoid surprises.
- Consider server-side caching of action evaluations for list views to reduce latency, respecting identity and scope.

12.13. How This Integrates End-to-End

- BaseResource extracts identity and headers to construct DomainContext.
- Rule evaluation uses URL/method + SecurityURLHeaders + SecurityURLBody + identity/userProfile to reach a decision and derive scope filters.

- Repositories (e.g., MorphiaRepo) apply the filters to queries and updates, ensuring DataDomain-respecting access.

12.14. Administering Policies via REST (PolicyResource)

The PolicyResource exposes CRUD-style REST APIs for creating and managing policies (rule bases) that drive authorization decisions. Each Policy targets a principalId (either a specific userId or a role name) and contains an ordered list of Rule objects. Rules match requests using SecurityURIHeader and SecurityURIBody and then contribute an effect (ALLOW/DENY) and optional repository filters.

- Base path: /security/permission/policies
- Auth: Bearer JWT (see Authentication); resource methods are guarded by @RolesAllowed("user", "admin") at the BaseResource level and your own realm/role policies.
- Multi-realm: pass X-Realm header to operate within a specific realm; otherwise the default realm is used.

12.14.1. Model shape (Policy)

A Policy extends FullBaseModel and includes: - id, refName, displayName, dataDomain, archived/expired flags (inherited) - principalId: userId or role name that this policy attaches to - description: human-readable summary - rules: array of Rule entries

Rule fields (key ones): - name, description - securityURI.header: identity, area, functionalDomain, action (supports wildcard "") - **securityURI.body: realm, orgRefName, accountNumber, tenantId, ownerId, dataSegment, resourceId (supports wildcard "")** - effect: ALLOW or DENY - priority: integer; lower numbers evaluated first - finalRule: boolean; stop evaluating when this rule applies - andFilterString / orFilterString: ANTLR filter DSL snippets injected into repository queries (see Query Language section)

Example payload:

```
{
  "refName": "defaultUserPolicy",
  "displayName": "Default user policy",
  "principalId": "user",
  "description": "Users can act on their own data; deny dangerous ops in security area",
  "rules": [
    {
      "name": "view-own-resources",
      "description": "Limit reads to owner and default data segment",
      "securityURI": {
        "header": { "identity": "user", "area": "*", "functionalDomain": "*", "action": "*" },
        "body": { "realm": "*", "orgRefName": "*", "accountNumber": "*", "tenantId":
```

```

"\"", "ownerId": "\"", "dataSegment": "\"", "resourceId": "\"" }
    },
    "andFilterString": "
dataDomain.ownerId:${principalId}&&dataDomain.dataSegment:#0",
    "effect": "ALLOW",
    "priority": 300,
    "finalRule": false
  },
  {
    "name": "deny-delete-in-security",
    "securityURI": {
      "header": { "identity": "user", "area": "security", "functionalDomain": "\"",
"action": "delete" },
      "body": { "realm": "\"", "orgRefName": "\"", "accountNumber": "\"", "tenantId":
"\"", "ownerId": "\"", "dataSegment": "\"", "resourceId": "\"" }
    },
    "effect": "DENY",
    "priority": 100,
    "finalRule": true
  }
]
}

```

12.14.2. Endpoints

All endpoints are relative to /security/permission/policies. These are inherited from BaseResource and are consistent across entity resources.

- GET /list
 - Query params: skip, limit, filter, sort, projection
 - Returns a Collection<Policy> with paging metadata; respects X-Realm.
- GET /id/{id} and GET /id?id=...
 - Fetch a single Policy by id.
- GET /refName/{refName} and GET /refName?refName=...
 - Fetch a single Policy by refName.
- GET /count?filter=...
 - Returns a CounterResponse with total matching entities.
- GET /schema
 - Returns JSON Schema for Policy.
- POST /
 - Create or upsert a Policy (if id is present and matches an existing entity in the selected realm, it is updated).
- PUT /set?id=...&pairs=field:value

- Targeted field updates by id. pairs is a repeated query parameter specifying field/value pairs.
- PUT /bulk/setByQuery?filter=...&pairs=...
 - Bulk updates by query. Note: ignoreRules=true is not supported on this endpoint.
- PUT /bulk/setByIds
 - Bulk updates by list of ids posted in the request body.
- PUT /bulk/setByRefAndDomain
 - Bulk updates by a list of (refName, dataDomain) pairs in the request body.
- DELETE /id/{id} (or /id?id=...)
- Delete by id.
- DELETE /refName/{refName} (or /refName?refName=...)
- Delete by refName.
- CSV import/export endpoints for bulk operations:
 - GET /csv – export as CSV (field selection, encoding, etc.)
 - POST /csv – import CSV into Policies
 - POST /csv/session – analyze CSV and create an import session (preview)
 - POST /csv/session/{sessionId}/commit – commit a previously analyzed session
 - DELETE /csv/session/{sessionId} – cancel a session
 - GET /csv/session/{sessionId}/rows – page through analyzed rows
- Index management (admin only):
 - POST /indexes/ensureIndexes/{realm}?collectionName=policy

Headers:

- Authorization: Bearer <token>
- X-Realm: realm identifier (optional but recommended in multi-tenant deployments)

Filtering and sorting:

- filter uses the ANTLR-based DSL (see REST CRUD > Query Language)
- sort uses comma-separated fields with optional +/- prefix; projection accepts a comma-separated field list

12.14.3. Examples

- Create or update a Policy

```
curl -X POST \
  -H "Authorization: Bearer $JWT" \
  -H "Content-Type: application/json" \
  -H "X-Realm: system-com" \
```

```
https://host/api/security/permission/policies \
-d @policy.json
```

- List policies for principalId=user

```
curl -H "Authorization: Bearer $JWT" \
      -H "X-Realm: system-com" \

"https://host/api/security/permission/policies/list?filter=principalId:'user'&sort=+refName&limit=50"
```

- Delete a policy by refName

```
curl -X DELETE \
      -H "Authorization: Bearer $JWT" \
      -H "X-Realm: system-com" \
      "https://host/api/security/permission/policies/refName/defaultUserPolicy"
```

12.14.4. How changes affect rule bases and enforcement

- Persistence vs. in-memory rules:
- PolicyResource updates the persistent store of policies (one policy per principalId or role with a list of rules).
- RuleContext is the in-memory evaluator used by repositories and resources to enforce permissions. It matches SecurityURIHeader/Body, orders rules by priority, and applies effects and filters.
- Making persisted policy changes effective:
- On startup, migrations (see InitializeDatabase and AddAnonymousSecurityRules) typically seed default policies and/or programmatically add rules to RuleContext.
- When you modify policies via REST, you have two options to apply them at runtime:
 1. Implement a reload step that reads policies from PolicyRepo and rehydrates RuleContext (for example, RuleContext.clear(); then add rules built from current policies).
 2. Restart the service or trigger whatever policy-loader your application uses at boot.
- Tip: If you maintain a background watcher or admin endpoint to refresh policies, keep it tenant/realm-aware and idempotent.
- Evaluation semantics (recap):
- Rules are sorted by ascending priority; the first decisive rule sets the outcome. finalRule=true stops further processing.
- andFilterString/orFilterString contribute repository filters through RuleContext.getFilters(), constraining result sets and write scopes.
- principalId can be a concrete userId or a role; RuleContext considers both the principal and all

associated roles.

- Safe rollout:
- Create new policies with a higher numeric priority (lower precedence) first, test with GET /schema and dry-run queries.
- Use realm scoping via X-Realm to stage changes in a non-production realm.
- Prefer DENY with low priority numbers for critical protections.

See also: - Permissions: Matching Algorithm, Priorities, and Multiple Matching RuleBases (sections above) - REST CRUD: Query Language and generic endpoint behaviors

12.15. Realm override (X-Realm) and Impersonation (X-Impersonate)

This section explains how to use the request headers X-Realm and X-Impersonate-* alongside permission rule bases. These headers influence which realm (database) a request operates against and, in the case of impersonation, which identity's roles are evaluated by the rule engine.

12.15.1. What they do (at a glance)

- X-Realm: Overrides the target realm (MongoDB database) used by repositories for this request. Your own identity and roles remain the same; only the data context (tenant/realm) changes for this call. This lets you “switch tenants” at the database level in deployments that use the one-tenant-per-database model.
- X-Impersonate-Subject or X-Impersonate-UserId: Causes the request to run as another identity. The effective permissions become those of the impersonated identity (potentially more or less than your own). This is analogous to sudo on Unix or to “simulate a user/role” for troubleshooting.

Only one of X-Impersonate-Subject or X-Impersonate-UserId may be supplied per request. Supplying both results in a 400/IllegalArgumentException.

12.15.2. How the headers integrate with permission evaluation

- Rule matching and effects (ALLOW/DENY) still follow the standard algorithm described earlier.
- With X-Realm (no impersonation):
 - The PrincipalContext.defaultRealm is set to the header value (after validation), and repositories operate in that realm.
 - Your own roles and identity remain intact; the rule base is evaluated for your identity and roles but in the specified realm's data context.
- With impersonation:
 - The PrincipalContext is rebuilt from the impersonated user's credential. The effective roles used by the rule engine include the impersonated user's roles; the platform also merges in the caller's security roles from Quarkus SecurityIdentity. This means permissions can be a superset; design policy rules accordingly.

- The effective realm for the request is set to the impersonated user's default realm (not the X-Realm header). If you passed X-Realm, it is still validated (see below) but not used to override the impersonated default realm in the current implementation.

12.15.3. Required credential configuration (CredentialUserIdPassword)

Two fields on CredentialUserIdPassword govern whether a user may use these headers:

- realmRegex (for X-Realm):
 - A wildcard pattern ("*" matches any sequence; case-insensitive) listing the realms a user is allowed to target with X-Realm.
 - If X-Realm is present but realmRegex is null/blank or does not match the requested realm, the server returns 403 Forbidden.
- Examples:
 - "*" → allow any realm
 - "acme-*" → allow realms that start with acme-
 - "dev|stage|prod" is not supported as-is; use wildcards like "dev*" and "stage*" or a combined pattern like "(dev|stage|prod)" only if you store a true regex. The current validator replaces "with "." and matches case-insensitively.
- impersonateFilterScript (for X-Impersonate-*):
 - A JavaScript snippet executed by the server (GraalVM) that must return a boolean. It receives three variables: username (the caller's subject), userId (caller's userId), and realm (the requested realm or current DB name).
 - If the script evaluates to false, the server returns 403 Forbidden for impersonation.
 - If the script is missing (null) and you attempt impersonation, the server rejects the request with 400/IllegalArgumentException.

Example impersonation script (allow only company admins to impersonate in dev realms):

```
// username = caller's subject, userId = caller's userId, realm = requested realm (or
current)
(username.endsWith('@acme.com') && realm.startsWith('dev-'))
```

Tip: Manage these two fields via your auth provider's admin APIs or directly through CredentialRepo in controlled environments.

12.15.4. End-to-end behavior from SecurityFilter (reference)

The SecurityFilter constructs the PrincipalContext/ResourceContext before rule evaluation:

- X-Realm is read and, if present, validated against the caller's credential.realmRegex.
- If impersonation headers are present:
 - The caller's credential.impersonateFilterScript is executed. If it returns true, the impersonated user's credential is loaded and used to build the PrincipalContext.
 - The final PrincipalContext carries the impersonated user's defaultRealm and roles (merged with the caller's SecurityIdentity roles), and may copy area2RealmOverrides from the impersonated

credential. - Without impersonation, the PrincipalContext is built from the caller's credential; X-Realm, when valid, sets the defaultRealm for this request.

12.15.5. Practical differences and use cases

- Realm override (X-Realm):
- Who you are does not change; only where you act changes. Your permissions (as determined by policies attached to your identity/roles) are applied against data in the specified realm.
- Use cases:
- Multi-tenant admin tooling that needs to inspect or repair data in customer realms.
- Reporting or backfills where the same service is pointed at different tenant databases per request.
- Impersonation (X-Impersonate-*):
- Who you are (for authorization purposes) changes. You act with the impersonated identity's permissions; depending on your configuration, additional caller roles may be merged.
- Use cases:
- Temporary elevation to an admin identity (sudo-like) for break-glass operations.
- Simulate what a given role/identity can see/do for troubleshooting or customer support.

Caveats: - Never set a permissive impersonateFilterScript in production. Keep it restrictive and auditable. - When using both X-Realm and impersonation in one call, be aware that the effective realm will be the impersonated user's default realm; X-Realm is not applied in the impersonation branch in the current implementation. - realmRegex must be populated for any user who needs realm override; leaving it blank effectively disables X-Realm for that user.

12.15.6. Examples

- List policies in a different realm using your own identity

```
curl -H "Authorization: Bearer $JWT" \  
-H "X-Realm: acme-prod" \  
"https://host/api/security/permission/policies/list?limit=20&sort=+refName"
```

- Simulate another user by subject while staying in their default realm

```
curl -H "Authorization: Bearer $JWT" \  
-H "X-Impersonate-Subject: 3d8f4e7b-...-idp-subject" \  
"https://host/api/security/permission/policies/list?limit=20"
```

- Attempt impersonation with a realm hint (validated by script; effective realm = impersonated default)

```
curl -H "Authorization: Bearer $JWT" \  
-H "X-Impersonate-Subject: 3d8f4e7b-...-idp-subject" \  
-H "X-Realm: acme-prod" \  
"https://host/api/security/permission/policies/list?limit=20"
```

```
-H "X-Realm: dev-acme" \  
-H "X-Impersonate-UserId: tenant-admin" \  
"https://host/api/security/permission/policies/list?limit=20"
```

Security outcomes in all cases continue to be driven by your rule bases (Policy rules) matched against the effective `PrincipalContext` and `ResourceContext`.

12.16. Data domain assignment on create: `DomainContext` and `DataDomainPolicy`

This section explains how Quantum decides which `dataDomain` is stamped on newly created records, why this decision is necessary in a multi-tenant system, what the default behavior is, and how you can override it globally or per Functional Area / Functional Domain. It also describes the `DataDomainResolver` interface and the default implementation provided by the framework.

12.16.1. The problem this solves (and why it matters)

In a multi-tenant platform you must ensure each new record is written to the correct data partition so later reads/updates can be scoped safely. If the `dataDomain` is wrong or missing, you risk leaking data across tenants or making your own data inaccessible due to mis-scoping.

Historically, Quantum set the `dataDomain` of new entities to match the creator's credential (i.e., the principal's `DomainContext` → `DataDomain`). That default is sensible in many cases, but real systems often need more specific behavior per business area or type. For example: - You may centralize HR records in a single org-level domain regardless of who created them. - Sales invoices for EU customers must live under an EU data segment. - A specific product area might always write into a shared catalog domain separate from the author's tenant.

These needs require a simple, deterministic way to override the default per Functional Area and/or Functional Domain.

12.16.2. Key concepts recap: `DomainContext` and `DataDomain`

`DomainContext` (on credentials/realms)

captures the principal's scoping defaults (realm, org/account/tenant identifiers, data segment). At request time this is materialized into a `DataDomain`.

`DataDomain`

is what gets stamped onto persisted entities and later used by repositories to constrain queries and updates.

If you do nothing, new records inherit the principal's `DataDomain`.

12.16.3. The default policy (do nothing and it works)

Out of the box, Quantum preserves the existing behavior: if no policy is configured, the resolver falls back to the authenticated principal's `DataDomain`. This guarantees compatibility with existing

applications.

Concretely: - ValidationInterceptor checks if an entity being persisted lacks a dataDomain. - If missing, it calls DataDomainResolver.resolveForCreate(area, domain). - The DefaultDataDomainResolver first looks for overrides (credential-attached or global); if none match, it returns the principal's DataDomain from the current SecurityContext.

12.16.4. Policy scopes: principal-attached vs. global

You can define overrides at two levels: - Principal-attached (per credential): attach a DataDomainPolicy to a CredentialUserIdPassword. The SecurityFilter places this policy into the PrincipalContext, so it applies only to records created by that principal. This is useful for VIP service accounts or specific partners. - Global policy: an application-wide DataDomainPolicy provided by GlobalDataDomainPolicyProvider. If present, this applies when the principal has no specific override for the matching area/domain.

Precedence: principal-attached policy wins over global policy; if neither applies, fall back to the principal's credential domain.

12.16.5. The policy map and matching

A DataDomainPolicy is a small map of rules: Map<String, DataDomainPolicyEntry> policyEntries, keyed by "<FunctionalArea>:<FunctionalDomain>" with support for "*" wildcards. The resolver evaluates keys in this order:

1. area:domain (most specific)
2. area:*
3. *:domain
4. : (global catch-all)
5. Fallback to principal's domain if no entry yields a value

Each DataDomainPolicyEntry has a resolutionMode: - FROM_CREDENTIAL (default): use the principal's credential domain (i.e., the historical behavior). - FIXED: use the first DataDomain listed in dataDomains on the entry.

Example policy definitions (illustrative JSON):

```
{
  "policyEntries": {
    "Sales:Invoice": { "resolutionMode": "FIXED", "dataDomains": [ {"orgRefName":
"ACME", "tenantId": "eu-1", "dataSegment": "INVOICE"} ] },
    "Sales:*": { "resolutionMode": "FROM_CREDENTIAL" },
    "*:HR": { "resolutionMode": "FIXED", "dataDomains": [ {"orgRefName":
"GLOBAL", "tenantId": "hr", "dataSegment": "HR"} ] },
    "*:*": { "resolutionMode": "FROM_CREDENTIAL" }
  }
}
```

Behavior of the above: - Sales:Invoice records always go to the fixed EU invoices domain. - Any other Sales:* creation uses the creator's credential domain. - All HR records go to a central HR domain. - Otherwise, default to the creator's domain.

12.16.6. How the resolver works

Interfaces and default implementation:

```
public interface DataDomainResolver {
    DataDomain resolveForCreate(String functionalArea, String functionalDomain);
}

@ApplicationScoped
public class DefaultDataDomainResolver implements DataDomainResolver {
    @Inject GlobalDataDomainPolicyProvider globalPolicyProvider;
    public DataDomain resolveForCreate(String area, String domain) {
        DataDomain principalDD = SecurityContext.getPrincipalDataDomain()
            .orElseThrow(() -> new IllegalStateException("Principal context not providing a data domain"));
        List<String> keys = List.of(areaOrStar(area)+":"+areaOrStar(domain), areaOrStar(area)+":*", ".*:"+areaOrStar(domain), ".*:*");
        // 1) principal attached policy from PrincipalContext
        DataDomain fromPrincipal = resolveFrom(policyFromPrincipal(), keys, principalDD);
        if (fromPrincipal != null) return fromPrincipal;
        // 2) global policy
        DataDomain fromGlobal = resolveFrom(globalPolicyProvider.getPolicy().orElse(null), keys, principalDD);
        if (fromGlobal != null) return fromGlobal;
        // 3) default fallback
        return principalDD;
    }
}
```

Integration point: - ValidationInterceptor injects DataDomainResolver and calls it in prePersist when an entity's dataDomain is null. - SecurityFilter propagates a principal's attached DataDomainPolicy (if any) into the PrincipalContext so the resolver can see it.

12.16.7. When would you want a non-global policy?

Here are a few concrete scenarios: - Centralized HR: All HR Employee records are written to a shared HR domain regardless of the team creating them. This supports a shared-service HR model without duplicating HR data per tenant. - Regulated invoices: In the Sales:Invoice domain for EU, you must write under a specific EU tenantId/dataSegment to satisfy data residency. Other Sales domains can keep default behavior. - Shared catalog: The Catalog:Item domain is a cross-tenant shared catalog maintained by a core team. Writes should go to a canonical catalog domain even when initiated by tenant-specific users. - VIP account override: A particular integration user should always write to a staging domain for testing purposes, while all others use defaults. Attach a small policy to just that credential.

12.16.8. Relation to tenancy models

The policy mechanism supports both siloed and pooled tenancy: - Siloed tenancy: Most domains default to FROM_CREDENTIAL (each tenant writes to its own partition). Only a few shared services (e.g., HR, catalog) use FIXED to centralize data. - Pooled tenancy: You may lean on FIXED policies more often to route writes into pooled/segment-specific domains (e.g., region, product line), while still enforcing read/write scoping via permissions.

Because the resolver always validates through the principal context and falls back safely, you can introduce overrides gradually without destabilizing existing flows.

12.16.9. Authoring tips

- Start with no policy and verify your default flows. Add entries only where necessary.
- Prefer specific keys (area:domain) for clarity; use wildcards sparingly.
- Keep FIXED DataDomain objects minimal and valid for your deployment (orgRefName, tenantId, and dataSegment as needed).
- Document any global policy so teams know which areas are centralized.

12.16.10. API pointers

- CredentialUserIdPassword.dataDomainPolicy: optional per-credential overrides (propagated to PrincipalContext).
- GlobalDataDomainPolicyProvider: holds an optional in-memory global policy (null by default).
- DataDomainPolicyEntry.resolutionMode: FROM_CREDENTIAL (default) or FIXED.
- DataDomainResolver / DefaultDataDomainResolver: the extension point and default behavior.

12.16.11. Ontology in Permission Rules (optional)

If you enable the ontology modules, you can author rules that constrain access by semantic relationships, not field paths. This keeps policies stable as your object model evolves.

Key idea

- Materialize edges in Mongo using OntologyMaterializer (e.g., placedInOrg, orderShipsToRegion).
- During rule evaluation, translate a semantic constraint like "has edge placedInOrg to OrgX" into a set of IDs, and combine that with your query.

How to use

- Preferred: author a rule with a semantic hint and let the application translate it via ListQueryRewriter.
- Minimal change path: publish a variable via an AccessListResolver and use an IN filter over _id.

Example (resolver + IN filter)

- Add an AccessListResolver that returns order IDs for which (tenantId, p="placedInOrg",

dst=orgRefName) exists.

- In your rule's AND filter string (query language), use: `id: ^${idsByPlacedInOrg}`

See also

- Ontology overview and examples: [Ontologies in Quantum](#)
- Integration with Morphia and multi-tenancy: [Integrating Ontology](#)

Operational notes

- Ontology is optional. Enable it per service when the config flag and dependencies are present.
- Always scope edge queries by tenantId sourced from RuleContext.
- Index edges on (tenantId, p, dst) and (tenantId, src, p) for performance.

Rule language: add hasEdge()

We introduce a policy function/operator to reference ontology edges directly from rules. This lets policies constrain access by semantic relationships instead of field paths.

Signature

- `hasEdge(predicate, dstIdOrVar)`

Parameters

- `predicate`: String name of the ontology predicate (e.g., "placedInOrg", "orderShipsToRegion").
- `dstIdOrVar`: Either a concrete destination id/refName or a variable resolved from RuleContext (e.g., `principal.orgRefName`, `request.region`).

Semantics

- The rule grants/filters entities for which an edge exists: (tenantId, src = entity._id, p = predicate, dst = resolvedDst).
- Multi-tenant safety: tenantId is always taken from RuleContext/DomainContext.

Composition

- `hasEdge` can be combined with existing rule clauses (and/or/not) and other filters (states, tags, ownerId, etc.).

Examples

- Allow viewing Orders in the caller's org (including ancestors via ontology closure):
- allow VIEW Order when `hasEdge("placedInOrg", principal.orgRefName)`
- Restrict list to Orders shipping to a region chosen in request:
- allow LIST Order when `hasEdge("orderShipsToRegion", request.region)`

Under the hood

- Policy evaluation resolves `dstIdOrVar` against `RuleContext` (for example, `principal.orgRefName` → "OrgP").
- The list/filter query is rewritten using `ListQueryRewriter.rewriteForHasEdge(...)`, which turns the predicate into a set of source ids and merges it with the base query efficiently.
- `EdgeDao` must be indexed on `(tenantId, p, dst)` and `(tenantId, src, p)` for performance.

Full end-to-end example (implementation pattern)

1) Author a rule (illustrative YAML/pseudocode)

```
- name: list-orders-by-org
  priority: 100
  match:
    method: [GET]
    url: /sales/order/list
  effect: ALLOW
  # semantic constraint expressed via hasEdge
  policy:
    hasEdge:
      predicate: placedInOrg
      dstVar: principal.orgRefName
```

2) Evaluate policy and apply constraint in the repository/list path

```
import com.e2eq.ontology.policy.ListQueryRewriter;
import com.e2eq.ontology.repo.OntologyEdgeRepo;
import com.mongodb.client.model.Filters;
import org.bson.conversions.Bson;

// Injected once per service when ontology is enabled (Quarkus CDI)
@jakarta.inject.Inject EdgeDao edgeDao;
ListQueryRewriter rewriter = new ListQueryRewriter(edgeDao);

// Inside your list method, after building the base filter
String tenantId = ruleContext.getRealmId(pctx, rctx); // or from DomainContext
String predicate = "placedInOrg";
String orgRefName = pctx.getDataDomain().getOrgRefName(); // resolves
principal.orgRefName

Bson base = Filters.and(existingFilters...);
Bson rewritten = rewriter.rewriteForHasEdge(base, tenantId, predicate, orgRefName);
var results = datastore.getDatabase().getCollection("orders").find(rewritten).
iterator();
```

3) Morphia-typed queries alternative

```
// If you're using Morphia's typed Query API
```

```

Set<String> ids = edgeDao.srcIdsByDst(tenantId, "placedInOrg", orgRefName);
if (ids.isEmpty()) {
    return java.util.List.of(); // short-circuit
}
query.filter(dev.morphia.query.filters.Filters.in("_id", ids));

```

Developer requirements and checklist

- Enable ontology (optional feature): set `e2eq.ontology.enabled=true` in your app and add module dependencies.
- Provide a TBox (OntologyRegistry) and run OntologyMaterializer on entity changes to keep edges up to date.
- Inject EdgeDao as a CDI bean (@Inject); indexes are ensured automatically at startup.
- Always pass tenantId from RuleContext/DomainContext; never cross tenants.
- When using variables on the RHS (dstIdOrVar), ensure the RuleContext exposes them (for example, principal.orgRefName or request.region).
- Monitor provenance (edge.prov) and re-materialize edges when intermediate nodes change.

Notes

- `hasEdge()` is a policy function; it is evaluated before constructing database filters. It is not part of the core BIAPI query grammar.
- If ontology is disabled, skip the rewrite (return base) or configure a no-op implementation so policies that include `hasEdge` are rejected early with a clear error message.

12.16.12. Security Annotations: FunctionalMapping and FunctionalAction

Quantum uses annotations to declare a model or resource's functional area, domain, and actions for security evaluation. This replaces the legacy `bmFunctionalArea()` and `bmFunctionalDomain()` methods.

@FunctionalMapping

Use `@FunctionalMapping` on model classes or resource classes to declare their business placement:

```

import com.e2eq.framework.annotations.FunctionalMapping;

@Entity
@FunctionalMapping(area = "catalog", domain = "product")
public class Product extends BaseModel {
    // No need to override bmFunctionalArea/bmFunctionalDomain
}

```

```

@Path("/products")
@FunctionalMapping(area = "catalog", domain = "product")

```

```
public class ProductResource extends BaseResource<Product, ProductRepo> {
    // All methods inherit area/domain from class annotation
}
```

@FunctionalAction

Use `@FunctionalAction` on JAX-RS resource methods when the action differs from the HTTP verb default:

```
@Path("/products")
public class ProductResource {

    @POST
    @FunctionalAction("CREATE") // Explicit, though POST implies CREATE
    public Product create(Product payload) {
        return productRepo.save(payload);
    }

    @GET
    @Path("/{id}")
    // No annotation needed - GET implies VIEW
    public Product get(@PathParam("id") String id) {
        return productRepo.findById(id);
    }

    @PUT
    @Path("/{id}/approve")
    @FunctionalAction("APPROVE") // Custom action beyond standard CRUD
    public Product approve(@PathParam("id") String id) {
        Product p = productRepo.findById(id);
        p.setStatus("APPROVED");
        return productRepo.save(p);
    }
}
```

Default Action Mapping

When `@FunctionalAction` is not present, actions are inferred from HTTP methods:

HTTP Method	Default Action
GET	VIEW
POST	CREATE
PUT	UPDATE
PATCH	UPDATE
DELETE	DELETE

How the Framework Uses These Annotations

SecurityFilter

- Reads `@FunctionalMapping` from the matched resource class for area/domain
- Reads `@FunctionalAction` from the method, or infers from HTTP method
- Falls back to path-based parsing if annotations are missing

MorphiaRepo.fillUIActions

- Uses `@FunctionalMapping` on model classes to resolve allowed UI actions
- Falls back to legacy `bmFunctionalArea()/bmFunctionalDomain()` methods

PermissionResource

- Prefers `@FunctionalMapping` when listing functional domains
- Falls back to legacy methods when annotation is missing

Migration from Legacy Methods

Current (Legacy) Approach

```
@Entity
public class Product extends BaseModel {
    @Override
    public String bmFunctionalArea() {
        return "Catalog";
    }

    @Override
    public String bmFunctionalDomain() {
        return "Product";
    }
}
```

New (Recommended) Approach

```
@Entity
@FunctionalMapping(area = "catalog", domain = "product")
public class Product extends BaseModel {
    // Clean - no method overrides needed
}
```

Transitional Support

You can use both during migration: - If `@FunctionalMapping` is present, it takes precedence - If missing, legacy methods are used as fallback - Plan to remove legacy methods in future releases

Best Practices

Consistent Naming

Use lowercase, kebab-case for areas and domains:

```
@FunctionalMapping(area = "supply-chain", domain = "purchase-order")
@FunctionalMapping(area = "catalog", domain = "product")
@FunctionalMapping(area = "identity", domain = "user-profile")
```

Resource vs Model Annotations

- **Prefer model annotations** for consistency across all usage
- Use resource annotations only when the resource handles multiple model types
- Avoid duplicating annotations on both model and resource for the same entity

Custom Actions

Define custom actions for business operations beyond CRUD:

```
@PUT
@Path("/{id}/publish")
@FunctionalAction("PUBLISH")
public Product publish(@PathParam("id") String id) { ... }

@POST
@Path("/{id}/duplicate")
@FunctionalAction("DUPLICATE")
public Product duplicate(@PathParam("id") String id) { ... }

@DELETE
@Path("/{id}/archive")
@FunctionalAction("ARCHIVE") // Soft delete vs hard DELETE
public void archive(@PathParam("id") String id) { ... }
```

Integration with Permission Rules

Annotations feed into permission rule matching:

```
- name: allow-catalog-reads
  priority: 300
  match:
    method: [GET]
    # Matches area/domain from @FunctionalMapping
    functionalArea: catalog
    functionalDomain: product
    rolesAny: [USER, ADMIN]
```

effect: ALLOW

```
- name: admin-only-approval
  priority: 100
  match:
    method: [PUT]
    functionalArea: catalog
    functionalDomain: product
    # Matches @FunctionalAction("APPROVE")
    action: APPROVE
  rolesAll: [ADMIN]
  effect: ALLOW
```

See Also

- [Modeling: Functional Mapping](#)
- [Permission Rules](#)
- [DomainContext and RuleContext](#)

Chapter 13. 9. Seed packs: Declarative tenant seeding

Problem: Provisioning repeatable, versioned baseline data for tenants.

Why for SaaS: Every tenant must start with known-good defaults; upgrades must be idempotent and auditable.

How Quantum helps: Seed packs with manifests, datasets, transforms, includes, archetypes, and a registry.

Walkthrough: Create a seed pack, apply it programmatically, and verify idempotency.

Chapter 14. Seed packs and declarative tenant seeding

Quantum 1.2 introduces a seed-pack subsystem that lets applications publish versioned baseline content without hard-coding values in `ChangeSet` beans or maintaining a separate "seed" tenant.

14.1. Introduction

14.1.1. The problem

In multi-tenant SaaS platforms, every new tenant must start with a known-good baseline of data: code lists, roles, default settings, reference values, and sometimes product- or region-specific content. Traditionally this baseline is scattered across ad-hoc SQL/Mongo scripts, hand-written bootstrap code, or a "template" tenant that is copied forward. These approaches are hard to version, review, test, and repeat reliably across environments.

Compounding the issue, tenants evolve over time. As modules are upgraded, their baseline content must be updated too. Without a disciplined mechanism, teams risk drift between environments and tenants, brittle migrations, and non-idempotent provisioning that causes duplicates or corruption.

14.1.2. Why this needs to be solved

- Operational consistency: Provisioning should be predictable, repeatable, and safe to re-run.
- Developer velocity: Changes to baseline data should be reviewed like code and travel with the module that owns them.
- Compliance and audit: You need to know exactly which version of seed content was applied to which tenant and when.
- Composability: Different product editions or SKUs need different combinations of baseline content without forked scripts.

14.1.3. How seed packs solve it

Seed packs provide a declarative, versioned, and composable way to describe tenant baseline data:

- A manifest (`manifest.yaml`) declares datasets, natural keys, transforms, required indexes, and optional includes/archetypes.
- Datasets point to JSON/NDJSON files that are upserted using natural-key filters, making runs idempotent.
- Transforms inject tenant/realm identifiers and can rewrite references deterministically.
- Includes compose other packs with exact versions or semantic version ranges, enabling dependency management.
- Archetypes bundle a named set of packs to represent product tiers or verticals.
- A registry records checksums per dataset so unchanged data is skipped on subsequent runs.

Together, these features make seeding safe, observable, and maintainable across development, test, and production.

The next section expands on why seed packs are beneficial and how to use them effectively.

14.2. Why seed packs?

- **Versioned + reviewable:** seed packs are plain files (YAML + JSON/NDJSON) that live next to your module code. Pull requests show exactly which records changed.
- **Composable:** packs can depend on other packs and expose named *archetypes* for different product editions or verticals.
- **Pluggable sources:** load packs from the filesystem, object storage, or even a curated seed database by providing a custom `SeedSource`.
- **Tenant-aware:** transforms inject tenant identifiers and remap references before persisting.
- **Idempotent:** a `SeedRegistry` tracks checksums per dataset so provisioning can be re-run safely.

14.3. High-level flow

1. `SeedLoader` discovers manifests via the configured `SeedSource` implementations (for example the provided `FileSeedSource`).
2. A manifest (`manifest.yaml`) declares datasets, required indexes, transforms, optional includes, and archetypes.
3. During provisioning a migration invokes `SeedLoader.apply(...)` with the packs (or archetype) that should be materialised for the tenant.
4. Records are parsed, transformed, and upserted through a `SeedRepository` implementation. The default `MongoSeedRepository` writes to the tenant realm using natural-key filters.
5. The `SeedRegistry` (backed by `_seed_registry` via `MongoSeedRegistry`) records the checksum so unchanged datasets are skipped on later runs.

14.4. Manifest quick reference

```
seedPack: logistics-core
version: 1.4.2
includes:
  - accounting-base@^1.1

datasets:
  - collection: codeLists
    file: datasets/codelists.ndjson
    naturalKey: [codeListName, code]
    upsert: true
    requiredIndexes:
      - name: uk_codeLists_name_code
        unique: true
        keys:
          codeListName: 1
          code: 1
    transforms:
      - type: tenantSubstitution
```

```

config:
  tenantField: tenantId
  orgField: orgRefName
  ownerField: ownerId
  realmField: realmId

archetypes:
- name: FulfillmentPlus
  includes:
    - logistics-core@^1.4
    - shipping-defaults@~2

```

14.5. Programmatic usage

```

SeedLoader loader = SeedLoader.builder()
    .addSeedSource(new FileSeedSource("local", Paths.get("seed-packs")))
    .seedRepository(new MongoSeedRepository(mongoClient))
    .seedRegistry(new MongoSeedRegistry(mongoClient))
    .build();

SeedContext ctx = SeedContext.builder(realmId)
    .tenantId(tenantId)
    .orgRefName(orgRef)
    .accountId(accountId)
    .ownerId(ownerId)
    .build();

loader.apply(List.of(
    SeedPackRef.range("logistics-core", "^1.4"),
    SeedPackRef.of("oms-defaults")
), ctx);

```

Callers can also use `loader.applyArchetype("FulfillmentPlus", ctx)` to resolve an archetype defined in any manifest.

14.6. Extensibility hooks

- Implement `SeedSource` to load manifests from custom storage (S3, Git, curated seed DB...).
- Register additional `SeedTransformFactory` instances with the builder to support bespoke transformations (for example JMESPath projections or deterministic ObjectId mapping).
- Swap in a different `SeedRepository/SeedRegistry` to write to alternative datastores or change the idempotency policy.

14.7. Operational tips

- Validate manifests in CI by running the loader against a disposable database.

- Keep seed pack versions aligned with module versions so upgrade paths are clear.
- Derive any ObjectIds deterministically from natural keys inside a transform so data can be re-applied without collisions.
- Use archetypes to model product tiers and optional modules: `TenantProvisioningService` can decide which archetype(s) to apply based on SKU.

14.8. Primary scenarios

1. Initial tenant provisioning

- Apply one or more seed packs to bootstrap a brand-new tenant (realm) with baseline code lists, roles, and default settings.
- Use `SeedPackRef.of("pack-name")` or `SeedPackRef.range("pack-name", "^1.4")` to control versions.

2. Updating a module to a new version

- Publish a new seed pack version (e.g., logistics-core 1.5.0) with incremental dataset changes.
- Re-run `loader.apply(...)` for the same tenant; unchanged datasets are skipped via `_seed_registry`, modified datasets are re-applied.

3. Idempotent re-apply during deployments

- Safe to invoke on every startup/migration. Upserts are driven by `naturalKey` and `upsert: true`.
- Keep natural keys stable; derive surrogate IDs deterministically in a transform if needed.

4. Selecting product tiers with archetypes

- Define archetypes in a manifest to bundle multiple seed packs under a named edition.
- Call `loader.applyArchetype("FulfillmentPlus", ctx)` to materialize the predefined stack for a tenant.

5. Composing packs with includes

- Use includes to depend on base packs (e.g., accounting-base@^1.1) and extend with your own datasets.
- Includes support exact (`=1.2.3`) and range (e.g., `^1.4`, `~2`) selectors via `SeedPackRef.parse("name@spec")`.

6. Partial refresh of specific datasets

- You can split large packs into multiple datasets and re-apply only the packs you want by passing a smaller list to `loader.apply(...)`.

7. Testing seed packs

- Add an integration test similar to `SeedLoaderIntegrationTest` that seeds into an ephemeral MongoDB and asserts collection state and `_seed_registry` entries.

14.9. Explicit examples

14.9.1. Example 1: Minimal manifest and NDJSON

```
seedPack: demo-seed
version: 1.0.0

datasets:
- collection: codeLists
  file: datasets/codeLists.ndjson
  naturalKey: [ code ]
  upsert: true
  requiredIndexes:
  - name: uk_codeLists_code
    unique: true
    keys:
      code: 1
  transforms:
  - type: tenantSubstitution
    config:
      tenantField: tenantId
      orgField: orgRefName
      accountField: accountId
      ownerField: ownerId
      realmField: realmId
```

Example NDJSON (datasets/codeLists.ndjson):

```
{"code": "NEW", "label": "New"}
{"code": "CLOSED", "label": "Closed"}
```

14.9.2. Example 2: Applying packs in code

```
SeedLoader loader = SeedLoader.builder()
    .addSeedSource(new FileSeedSource("local", Paths.get("seed-packs")))
    .seedRepository(new MongoSeedRepository(mongoClient))
    .seedRegistry(new MongoSeedRegistry(mongoClient))
    .build();

SeedContext ctx = SeedContext.builder("my-realm")
    .tenantId("tenant-123")
    .orgRefName("tenant-123")
    .accountId("acct-123")
    .ownerId("owner-123")
    .build();

loader.apply(List.of(
```



```
SeedPackRef.of("demo-seed"),  
SeedPackRef.range("logistics-core", "^1.4")  
, ctx);
```

14.9.3. Example 3: Using an archetype

```
archetypes:  
- name: FulfillmentPlus  
  includes:  
    - logistics-core@^1.4  
    - shipping-defaults@~2
```

Apply programmatically:

```
loader.applyArchetype("FulfillmentPlus", ctx);
```

14.9.4. Example 4: Exact version and includes in a manifest

```
seedPack: shipping-defaults  
version: 2.3.0  
includes:  
- accounting-base@=1.1.2  
- logistics-core@^1.5  
  
datasets:  
- collection: shippingMethods  
  file: datasets/methods.json  
  naturalKey: [ code ]
```

14.10. Troubleshooting

- Manifest parsing errors: Confirm manifest.yaml keys match SeedPackManifest fields; boolean flags like upsert and unique must be proper booleans.
- Duplicate key or unique index violations: Check naturalKey and requiredIndexes; ensure transforms don't change key fields inconsistently.
- Nothing changes on re-run: The _seed_registry may have recorded the same checksum; bump version or change dataset content.
- File resolution issues: Ensure FileSeedSource base path points to the correct seed-packs directory and file names match.

14.11. How seeds are applied automatically at startup

The framework now applies seed packs via a dedicated SeedStartupRunner, independent of schema

migrations. This runner discovers and applies the latest version of each seed pack for important realms (system/default/test) on application startup.

Key points: - Discovery: `SeedStartupRunner` constructs a `SeedLoader` with a `FileSeedSource` pointing at the configured seed root. Set `quantum.seed.root` (for tests we default to `src/main/resources/seed-packs`). The source walks the directory tree and locates every `manifest.yaml` file. - Selection: For each discovered seed pack name, the runner selects the latest semantic version and builds `SeedPackRef.exact(name, version)` for application. - Execution: The runner builds a `SeedContext` for the target realm and calls `loader.apply(refs, context)`. Indexes declared in the manifest are created before data is upserted. - Idempotency + repeatable: The `MongoSeedRegistry` stores a checksum per dataset in the realm's `_seed_registry` collection. If the checksum matches on a later run, the dataset is skipped; if it changes, the dataset is re-applied. - Concurrency safety: The runner uses a Sherlock distributed lock per realm to prevent concurrent execution across nodes.

Configuration snippet:

```
# test profile uses a local seed root
quantum.seed.root=src/test/resources/seed-packs
# control seed runner behavior
quantum.seeds.enabled=true
quantum.seeds.apply.on-startup=true
```

14.12. Transforms in depth

Transforms are small, composable functions that shape each dataset record just before it is written to the database. They let you keep dataset files generic and inject environment/tenant specifics or perform repeatable rewrites at apply time.

What a transform gets and returns: - Input: the current record (a Map), the `SeedContext`, and the Dataset definition - Output: the next record (Map) to be passed to the rest of the pipeline; return null or an empty map to drop the record

Where transforms are declared (manifest):

```
datasets:
- collection: codeLists
  file: datasets/codeLists.ndjson
  naturalKey: [ codeListName, code ]
  upsert: true
  transforms:
  - type: tenantSubstitution
    config:
      tenantField: tenantId
      orgField: orgRefName
      ownerField: ownerId
      accountField: accountNum
      realmField: realmId
```

Execution semantics: - Ordering: transforms are executed top-to-bottom for each record - Short-circuit: if any transform returns null or an empty map, the record is skipped and no write occurs - Overwrite rules: a transform can set or overwrite fields on the record; when `upsert=true`, the final transformed record replaces the existing one matched by `naturalKey` - Interaction with `naturalKey` and indexes: transforms run before `naturalKey` validation and index creation; do not remove fields listed in `naturalKey`, otherwise an error will be thrown during write

Built-in transform types: - `tenantSubstitution`: Injects identifiers from `SeedContext` into the record's `dataDomain.*` fields (`tenant/org/owner/account`) and sets `realmId` at the record root. Config keys in the manifest (defaults target `dataDomain.*`): - `tenantField`: key inside `dataDomain` to receive `tenantId` (default: `tenantId`) - `orgField`: key inside `dataDomain` to receive `orgRefName` (default: `orgRefName`) - `ownerField`: key inside `dataDomain` to receive `ownerId` (default: `ownerId`) - `accountField`: key inside `dataDomain` to receive account number (default: `accountNum`) - `realmField`: root-level field to receive `realmId` (default: `realmId`)

Notes and guarantees: - Optional values missing from `SeedContext` are simply omitted; existing record values are preserved unless you target the same field - Transforms operate on in-memory maps and cannot perform I/O by default; keep them deterministic so re-runs are idempotent - Compose multiple transforms when needed (for example: first `tenantSubstitution`, then a custom id computation) - To add new transform types, implement `SeedTransformFactory` and register it during `SeedLoader.builder()` with `registerTransformFactory("myType", new MyFactory())`; then declare - type: `myType` in the manifest

When to use transforms (and why): - Injecting tenant/realm identity: keep datasets source-controlled and generic; inject tenant IDs at apply time (`tenantSubstitution`) - Deterministic IDs: derive `_id` or other surrogate keys from `naturalKey` so upserts remain stable across environments - Normalization and defaults: add missing fields, convert formats, enforce enums before write - Reference remapping: translate human-readable codes in the dataset into datastore-specific identifiers (`ObjectIds`, `UUIDs`) in a repeatable way

Practical examples

1) Tenant identity injection (built-in) Manifest snippet:

```
transforms:
- type: tenantSubstitution
  config:
    tenantField: tenantId
    orgField: orgRefName
    ownerField: ownerId
    accountField: accountId
    realmField: realmId
```

Why: keep `codeLists.ndjson` portable across tenants; provisioning injects the right IDs based on `SeedContext`.

2) Deterministic _id from natural key (custom) - Goal: ensure stable MongoDB _id across re-applies and environments, derived from codeListName+code - Approach: implement a custom transform that computes a SHA-1/MD5 hash (or any deterministic function) and sets _id

Java registration:

```
SeedLoader loader = SeedLoader.builder()
    .addSeedSource(new FileSeedSource("local", Paths.get("seed-packs")))
    .seedRepository(new MongoSeedRepository(mongoClient))
    .seedRegistry(new MongoSeedRegistry(mongoClient))
    .registerTransformFactory("deterministicId", new DeterministicIdTransform.Factory())
    .build();
```

Manifest usage:

```
transforms:
- type: tenantSubstitution
- type: deterministicId
  config:
    sourceFields: [ codeListName, code ]
    targetField: _id
    algorithm: sha1
```

Why: makes upserts resilient and allows cross-environment joins by a stable key.

3) Foreign key remapping by code (custom) - Goal: dataset uses human-readable statusCode; transform maps it to a canonical statusId - Approach: custom transform with an in-memory map or deterministic derivation

Manifest usage:

```
transforms:
- type: mapCode
  config:
    field: statusCode
    target: statusId
    mapping:
      NEW: 100
      CLOSED: 900
```

Why: keeps datasets human-friendly while persisting efficient identifiers.

4) Defaulting and sanitization (custom) - Goal: ensure missing fields get defaults and strings are trimmed/lowercased - Approach: simple custom transform that fills defaults and cleans values

Manifest usage:

```

transforms:
  - type: defaults
    config:
      defaults:
        isActive: true
        locale: en_US
  - type: sanitize
    config:
      trim: [ label ]
      lowercase: [ email ]

```

Why: enforces consistency without editing large datasets.

Testing transforms: - Add integration tests that seed into an ephemeral DB and assert both record shape and `_seed_registry` entries - For custom transforms, add focused unit tests for edge cases (missing fields, nulls, unexpected types)

14.12.1. Creating your own transforms (example: DropIfTransform)

Custom transforms let you implement project-specific shaping logic. You implement two small interfaces and register the type on the SeedLoader builder. Below we walk through a simple "drop the record if a field equals a value" transform used in tests, called DropIfTransform.

Overview of the SPI: - SeedTransform: executes per-record and can return a new map (continue) or null/empty (drop this record). - SeedTransformFactory: builds a SeedTransform instance from the manifest's Transform definition (provides access to type and config map).

Minimal interfaces (simplified for clarity):

```

public interface SeedTransform {
    Map<String, Object> apply(Map<String, Object> record,
                             SeedContext context,
                             SeedPackManifest.Dataset dataset);
}

public interface SeedTransformFactory {
    SeedTransform create(SeedPackManifest.Transform transformDefinition);
}

```

Implementation: DropIfTransform - Behavior: if record[field] equals a configured value, return null to short-circuit the pipeline and skip writing the record; otherwise, pass the record through unchanged.

```

package com.example.seed.transforms;

import com.e2eq.framework.service.seed.*;
import java.util.Map;
import java.util.Objects;

```

```

public final class DropIfTransform implements SeedTransform {
    private final String field;
    private final String equalsValue;

    public DropIfTransform(String field, String equalsValue) {
        this.field = field;
        this.equalsValue = equalsValue;
    }

    @Override
    public Map<String, Object> apply(Map<String, Object> record, SeedContext context,
SeedPackManifest.Dataset dataset) {
        Object v = record.get(field);
        if (Objects.equals(Objects.toString(v, null), equalsValue)) {
            return null; // short-circuit: drop this record
        }
        return record;
    }

    public static final class Factory implements SeedTransformFactory {
        @Override
        public SeedTransform create(SeedPackManifest.Transform transformDefinition) {
            Map<String, Object> cfg = transformDefinition.getConfig();
            String field = Objects.toString(cfg.get("field"), null);
            String eq = Objects.toString(cfg.get("equals"), null);
            return new DropIfTransform(field, eq);
        }
    }
}

```

Registration on the SeedLoader builder:

```

SeedLoader loader = SeedLoader.builder()
    .addSeedSource(new FileSeedSource("local", Paths.get("seed-packs")))
    .seedRepository(new MongoSeedRepository(mongoClient))
    .seedRegistry(new MongoSeedRegistry(mongoClient))
    .registerTransformFactory("dropIf", new DropIfTransform.Factory())
    .build();

```

Manifest usage:

```

datasets:
- collection: codeLists
  file: datasets/codeLists.ndjson
  naturalKey: [ code ]
  upsert: true
  transforms:
  - type: dropIf

```

```
config:
  field: status
  equals: CLOSED
```

Notes and tips: - Validation: your factory should validate required config keys and fail fast with a clear error if missing/invalid. - Determinism: keep transforms pure and deterministic (no I/O) so seeding remains idempotent. - Short-circuit: returning null or an empty map drops the record; otherwise, the next transform in the list will receive the (possibly mutated) map. - Composition: you can chain several transforms; for example, first `dropIf`, then `tenantSubstitution`, then a custom `deterministicId`. - Packaging: test-only transforms can live under test sources; production transforms should be in main sources and registered where you construct the `SeedLoader` (for example, in a `ChangeSet` or a provisioning service).

14.13. Test walkthrough: `SeedLoaderIntegrationTest`

The `SeedLoaderIntegrationTest` demonstrates end-to-end seeding using the demo seed pack at `src/main/resources/seed-packs/demo-seed`.

What the test does: - Creates a `SeedLoader` backed by `FileSeedSource`, `MongoSeedRepository`, and `MongoSeedRegistry`. - Builds a `SeedContext` populated with tenant/realm details to exercise the `tenantSubstitution` transform. - Applies the pack reference `SeedPackRef.of("demo-seed")`, which resolves the latest version of that pack (1.0.0 in tests). - Asserts that 2 records were inserted into the `codeLists` collection and that the `tenantSubstitution` fields were populated from the context. - Verifies an entry was written to `_seed_registry` with the dataset checksum and `records: 2`. - Re-applies the same pack and asserts the record count remains 2, demonstrating idempotency (thanks to upsert + registry checksum).

Why these design choices: - NDJSON for datasets: allows streaming large datasets and simple line-by-line diffs in code review; arrays are also supported for smaller payloads. - Natural-key upsert: manifests declare `naturalKey` to form the filter for `replaceOne(..., upsert=true)` ensuring idempotent writes and predictable overwrites. - Transform pipeline: keeps dataset files free of environment-specific values; all tenant/realm specifics are injected consistently at apply time. - Registry-based skip: checksums per dataset avoid unnecessary writes when content hasn't changed—fast, safe re-runs during deployments. - Semantic-version selection: when multiple versions of a pack are available, the latest semver is used unless an exact version is requested.

Alternatives considered: - Store seed state in an external table keyed only by version. Rejected in favor of per-dataset checksums to detect content drift without bumping versions. - Hardcode seeding logic inside ad-hoc migrations. Rejected for lack of composability and poor reviewability. - Use inserts only (no upsert). Rejected due to lack of idempotence and difficulty correcting baseline data.

14.14. Archetypes explained

Archetypes are named compositions of seed packs that model a product edition, SKU, or vertical stack. Instead of listing several packs every time you provision a tenant, you define an archetype once in a manifest and then apply it by name.

What an archetype is in this context: - It lives inside a seed pack manifest under archetypes:. - It contains a list of includes (same syntax as top-level includes) referring to packs and version ranges. - When applied, the loader resolves those pack refs plus the hosting pack itself (the manifest that defines the archetype) so that local datasets are included as part of the archetype. - Resolution uses semantic version rules and deduplicates by pack name, respecting dependency order and preventing cycles.

When to use archetypes: - To represent product tiers (e.g., Community, Pro, Enterprise) that bundle different combinations of base packs and optional modules. - To group verticalized defaults (e.g., Logistics-Fulfillment, Healthcare-Core) without forcing consumers to know every underlying pack.

14.14.1. Example A: Define and apply an archetype in the same pack

Manifest (logistics-core/manifest.yaml):

```
seedPack: logistics-core
version: 1.4.2

includes:
  - accounting-base@^1.1

datasets:
  - collection: codeLists
    file: datasets/codelists.ndjson
    naturalKey: [ codeListName, code ]
    upsert: true

archetypes:
  - name: FulfillmentPlus
    includes:
      - logistics-core@^1.4      # self + constraints
      - shipping-defaults@~2
```

Applying it in code:

```
SeedLoader loader = SeedLoader.builder()
    .addSeedSource(new FileSeedSource("local", Paths.get("seed-packs")))
    .seedRepository(new MongoSeedRepository(mongoClient))
    .seedRegistry(new MongoSeedRegistry(mongoClient))
    .build();

SeedContext ctx = SeedContext.builder("my-realm").build();
loader.applyArchetype("FulfillmentPlus", ctx);
```

Notes: - applyArchetype looks up the latest manifest that defines an archetype named "FulfillmentPlus" across all discovered packs, resolves the include refs, and then applies the union. - If multiple manifests define the same archetype name, the latest semver manifest wins.

14.14.2. Example B: Cross-pack archetype in a dedicated "editions" pack

You can centralize product definitions into a thin pack that only defines archetypes and forward-references other packs:

Manifest (product-editions/manifest.yaml):

```
seedPack: product-editions
version: 1.0.0

archetypes:
  - name: Enterprise
    includes:
      - logistics-core@^1.5
      - shipping-defaults@~2
      - analytics-starter@^0.9
```

Apply in code:

```
loader.applyArchetype("Enterprise", ctx);
```

This keeps edition composition decoupled from individual module packs.

14.14.3. Resolution and ordering details

- Version matching: Each include can be exact (=1.2.3), a semver range (e.g., ^1.5, ~2), or omitted (latest). See `SeedPackRef.parse("name@spec")`.
- Deduplication: If multiple includes select the same pack name (possibly different versions), the highest version that satisfies all constraints is chosen; duplicates are applied only once.
- Dependency order: Includes are recursively resolved depth-first, while the loader guards against cycles and applies datasets in a stable order per resolved pack.

14.14.4. Interaction with `ApplySeedPacksChangeSet`

- The Apply Seed Packs change set scans the seed root and applies the latest version of every discovered pack to the realm. It does not automatically choose an archetype.
- Use `applyArchetype` programmatically (e.g., from a `TenantProvisioningService`) when you want to provision only the packs that belong to a specific edition.
- You can combine approaches: let migrations ensure baseline packs are present for all tenants; then, on tenant onboarding, call `applyArchetype(...)` to add edition-specific content.

14.14.5. Tenant provisioning with archetypes

The tenant provisioning API accepts an optional list of archetype names and will apply the corresponding seed packs during onboarding.

- Endpoint: POST /admin/tenants
- Request body fields (subset):
- tenantEmailDomain, orgRefName, accountId, adminUserId, adminUsername, adminPassword
- archetypes: optional array of strings (archetype names)
- Behavior:
- After running migrations and creating the admin user, each archetype is resolved across all manifests and applied using the same SeedLoader used elsewhere.
- If an archetype name is unknown, the request fails with 409/500 depending on context.

Example request:

```
{
  "tenantEmailDomain": "demo-archetype.example",
  "orgRefName": "demo-archetype.example",
  "accountId": "999999999",
  "adminUserId": "admin@demo-archetype.example",
  "adminUsername": "admin@demo-archetype.example",
  "adminPassword": "secret",
  "archetypes": ["DemoArchetype"]
}
```

On success, the new realm (demo-archetype-example) will have the datasets from the selected archetypes applied and recorded in the `_seed_registry`.

14.15. REST API for seed packs

The framework exposes admin-only endpoints to inspect and apply seed packs per realm (tenant DB). These are disabled to non-admin users via role checks.

Base path: /admin/seeds

Endpoints: - GET /admin/seeds/pending/{realm} - Lists pending seed packs for the realm. A pack is pending if any dataset checksum differs from the last applied or was never applied. - Optional query parameter: filter=pack1,pack2 to restrict by pack name. - Response example:

+

```
[
  {
    "seedId": "demo-seed@1.0.0",
    "seedPack": "demo-seed",
    "version": "1.0.0",
    "datasets": [
      {
        "collection": "codeLists",
        "file": "datasets/codelists.ndjson",
        "checksum":
      "..."}
    ]
  }
]
```

```
}  
]
```

- POST /admin/seeds/apply/{realm}
- Applies the latest version of all discovered packs (or only those matching filter).
- Query parameter: filter=pack1,pack2
- Response example:

```
{"applied":["demo-seed"]}
```

- POST /admin/seeds/{realm}/{seedPack}/apply
- Applies the latest version of a single pack by name. Idempotent: unchanged datasets are skipped.
- Response example:

```
{"applied":["demo-seed"]}
```

- GET /admin/seeds/history/{realm}
- Returns the per-dataset seeding history as recorded in the `_seed_registry` collection.

Authentication and roles: - All endpoints require role admin. In integration tests you can use `@TestSecurity(user="admin", roles={"admin"})`.

Configuration: - `quantum.seed.root`: filesystem path to the root folder where seed packs are discovered. In tests this defaults to `src/test/resources/seed-packs`. - `quantum.seed.apply.filter`: optional comma-separated list of pack names to limit automatic application by changeset.

14.16. Using MorphiaSeedRepository (Morphia-backed seeding)

Note about collection vs modelClass: - You can now omit collection in a dataset when you specify modelClass. The framework will derive the collection name from the Morphia mapping of the model class. - Derivation rules: if the model class has `@Entity` with a non-empty value, that value is used as the collection name; otherwise the simple Java class name is used. - This derived name is used consistently for logging, in the `_seed_registry` entries, and for the Mongo fallback path. - Backwards compatibility: specifying collection is still supported, and will override the derived name.

In addition to the default Mongo-based persistence, you can instruct the seeding pipeline to persist a dataset via a Morphia repository mapped to a concrete `UnversionedBaseModel`. This enables: - Automatic class discriminator fields (for example, Morphia's `_t`) and proper collection mapping. - Population of framework-managed fields (dataDomain, audit info, etc.) by the repository layer. - Consistent security filtering and validations applied by Morphia repos in normal runtime.

How to enable Morphia for a dataset: - Add `modelClass` to the dataset in `manifest.yaml` with the fully-qualified class name that extends `UnversionedBaseModel`. - Keep `naturalKey` and `transforms` as usual. The loader will still compute checksums and idempotently upsert.

Example manifest snippet:

```
seedPack: morphia-demo
version: 1.0.0

datasets:
  - collection: CodeList
    file: datasets/codeList.ndjson
    naturalKey: [category, key]
    upsert: true
    modelClass: com.e2eq.framework.model.persistent.base.CodeList
    transforms:
      - type: tenantSubstitution
        config:
          tenantField: tenantId
          orgField: orgRefName
          ownerField: ownerId
          accountField: accountNum
          realmField: realmId
```

Walkthrough (based on the integration test `MorphiaSeedRepositoryIntegrationTest`): - The test builds a `SeedLoader` with `MorphiaSeedRepository` and `MongoSeedRegistry` pointing at `src/test/resources/seed-packs`. - A `SeedContext` is created for a test realm. For repository-layer behavior (dataDomain, permissions), a minimal `SecurityContext` is also established in the test. - The loader applies `SeedPackRef.of("morphia-demo")`, which reads `datasets/codeList.ndjson` with two `CodeList` records. - The dataset declares `modelClass`, so `MorphiaSeedRepository` resolves the `CodeList` `MorphiaRepo` and attempts to save via Morphia. - If Morphia permission rules are not yet configured for the realm, `MorphiaSeedRepository` automatically falls back to a direct Mongo write, ensuring seeds still apply predictably but without Morphia-only fields. - The test then asserts that two documents exist in the `CodeList` collection and that `_seed_registry` has a matching history entry for the dataset checksum with records: 2.

Key behaviors and edge cases: - Indexes: When `modelClass` is present, `ensureIndexes` relies on Morphia mapping to enforce annotated indexes for the model. Any requiredIndexes declared in the manifest are still respected by the Mongo fallback. - Transforms: `tenantSubstitution` adds tenant context fields. When saving via Morphia, the repository adapts top-level tenant fields into `dataDomain.*` automatically for common models, and removes transient fields like `realmId` before mapping. - Permissions: If repository permissions prevent writes (for example, missing policies in a brand-new realm), `MorphiaSeedRepository` will log a warning and fall back to Mongo so seeding is not blocked. As you evolve policies, the Morphia path will be taken automatically on future runs. - Idempotency: Upsert semantics still honor `naturalKey` for both Morphia and Mongo paths, and `_seed_registry` records checksums so unchanged datasets are skipped.

See also: - Test source: quantum-

framework/src/test/java/com/e2eq/framework/service/seed/MorphiaSeedRepositoryIntegrationTest.java - Manifest and dataset: quantum-framework/src/test/resources/seed-packs/morphia-demo - Admin APIs: /admin/seeds to list pending, apply packs, and inspect history per realm.

14.17. Dataset URLs and routing (file:// and s3://)

Starting with Quantum 1.2.2, dataset files in a manifest can be specified either as:

- Relative paths (backward compatible): resolved relative to the manifest's own location as provided by its SeedSource (filesystem or S3).
- Absolute URLs with a scheme that identifies the source: currently supported schemes are file:// and s3://. The loader automatically routes these URLs to the appropriate SeedSource at runtime.

Notes: - If the dataset value contains "://", it is treated as a URL and routed by scheme. Otherwise it is treated as a relative path. - Using URLs allows you to mix sources inside a single manifest (e.g., some datasets from the local filesystem and others from S3). - This is extensible; additional schemes can be supported by adding optional modules in the future.

Examples:

```
seedPack: mixed-demo
version: 0.1.0

datasets:
  # Relative path (resolved relative to the manifest location)
  - collection: localDefaults
    file: datasets/defaults.ndjson
    naturalKey: [ key ]
    upsert: true

  # Absolute filesystem URL
  - collection: roles
    file: file:///opt/app/seed-packs/roles.ndjson
    naturalKey: [ code ]
    upsert: true

  # Absolute S3 URL
  - collection: carriers
    file: s3://my-seeds/mixed-demo/0.1.0/carriers.ndjson
    naturalKey: [ code ]
    upsert: true
```

Routing behavior: - Relative path: delegated to the SeedSource that loaded the manifest (unchanged behavior). - file:// URL: handled by FileSeedSource. - s3:// URL: handled by S3SeedSource (requires the optional quantum-seed-s3 module on the classpath).

14.18. S3 Seed Source (optional module)

The framework provides an optional SeedSource backed by Amazon S3, packaged in a separate module so you can include it only when needed:

- Module: `quantum-seed-s3`
- Class: `com.end2endlogic.quantum.seed.s3.S3SeedSource`
- Purpose: Discover seed pack manifests and datasets stored in S3; optionally assume an IAM role via STS if cross-account access is required.

14.18.1. When to use S3 vs. filesystem

Use S3 when any of the following apply: - You want a single canonical location for seed content shared across services and environments. - You need to distribute seed packs across many runtimes (containers, serverless) without baking files into images. - You want to leverage S3 features: versioning, object immutability, access logging, and cross-account sharing. - CI/CD pipelines or content teams publish seed packs independently from application deployments.

Filesystem may be simpler when: - Developing locally with small packs that live inside your project. - You prefer packs bundled within the application JAR/image and don't need central distribution.

Advantages of S3 over filesystem: - Centralized distribution and caching via S3/CloudFront. - Cross-account access with STS AssumeRole. - Object versioning and retention policies for auditability. - Decouples seed content delivery from app build artifacts.

14.18.2. S3 layout conventions

S3SeedSource expects the same on-disk structure as FileSeedSource, just hosted under a bucket + optional prefix. Each seed pack version is a folder containing a manifest file and any referenced datasets. For example:

- `s3://my-seeds/seed-packs/customer/1.0.0/manifest.yaml`
- `s3://my-seeds/seed-packs/customer/1.0.0/customers.ndjson`
- `s3://my-seeds/seed-packs/logistics-core/1.4.2/manifest.yaml`

Notes: - The manifest file name defaults to `manifest.yaml` but can be overridden. - Dataset file paths in the manifest are resolved relative to the manifest's key (folder).

14.18.3. Configuration and credentials

Constructor parameters for S3SeedSource: - `id`: Human-friendly source id (e.g., "s3-main"). - `bucket`: S3 bucket name. - `prefix`: Optional prefix under which seed packs live (e.g., "seed-packs/"). May be empty. - `manifestFileName`: Optional. Defaults to "manifest.yaml". - `region`: Optional AWS region. If omitted, AWS SDK v2 region resolution applies. - `roleArn`: Optional ARN of a role to assume via STS. If omitted/blank, the default credentials chain is used. - `roleSessionName`: Optional session name when assuming a role. Defaults to "quantum-seed". - `externalId`: Optional ExternalId for AssumeRole if the target role trust policy requires it. - `roleDuration`: Optional session duration for

AssumeRole; defaults to 30 minutes.

Credential modes: - Default credentials chain (no roleArn): The AWS SDK v2 uses environment variables, profile, ECS/EC2/Lambda task role, etc. - AssumeRole (roleArn provided): The source uses STS to assume the specified role before calling S3.

IAM considerations: - The credentials (base or assumed) must allow `s3:ListBucket` on the bucket (scoped to the prefix) and `s3:GetObject` for objects under the prefix. - For cross-account usage, grant the calling account `sts:AssumeRole` on the target role, and in the role's policy grant the S3 permissions above.

Minimal target role policy example:

```
{
  "Version": "2012-10-17",
  "Statement": [
    {
      "Effect": "Allow",
      "Action": ["s3:ListBucket"],
      "Resource": "arn:aws:s3:::my-seeds",
      "Condition": {"StringLike": {"s3:prefix": ["seed-packs/*"]}}
    },
    {
      "Effect": "Allow",
      "Action": ["s3:GetObject"],
      "Resource": "arn:aws:s3:::my-seeds/seed-packs/*"
    }
  ]
}
```

14.18.4. Usage examples

Create a loader that discovers packs from S3 with the runtime IAM role or local credentials:

```
import com.e2eq.framework.service.seed.*;
import com.end2endlogic.quantum.seed.s3.S3SeedSource;
import software.amazon.awssdk.regions.Region;

SeedLoader loader = SeedLoader.builder()
    .addSeedSource(new S3SeedSource(
        "s3-main",
        "my-seeds",
        "seed-packs/",
        "manifest.yaml",
        Region.US_EAST_1,
        null, // roleArn null => use default creds / runtime role
        null,
        null,
        null))
```

```
.seedRepository(new MongoSeedRepository(mongoClient))
.seedRegistry(new MongoSeedRegistry(mongoClient))
.build();
```

Assuming a cross-account role:

```
SeedLoader loader = SeedLoader.builder()
    .addSeedSource(new S3SeedSource(
        "s3-cross-account",
        "partner-seeds",
        "prod/",
        "manifest.yaml",
        Region.US_WEST_2,
        "arn:aws:iam::123456789012:role/SeedReadOnly",
        "quantum-seed-session",
        "external-id-abc123",
        java.time.Duration.ofMinutes(45)))
    .seedRepository(new MongoSeedRepository(mongoClient))
    .seedRegistry(new MongoSeedRegistry(mongoClient))
    .build();
```

Using the builder helper:

```
import com.end2endlogic.quantum.seed.s3.S3SeedSourceBuilder;

S3SeedSource s3 = new S3SeedSourceBuilder()
    .id("s3-main")
    .bucket("my-seeds")
    .prefix("seed-packs/")
    .region(Region.US_EAST_1)
    .build();
```

14.18.5. Defining datasets in the manifest (S3)

Manifests can reference S3 in two ways:

- Relative paths (backward compatible): when a manifest itself is loaded from S3, dataset files are resolved relative to the manifest's S3 key (folder), just like the filesystem source.
- Absolute URLs: you can specify s3://bucket/key URLs directly in any manifest. These are routed to S3 regardless of where the manifest was discovered from.

Example S3 manifest and dataset layout:

```
s3://my-seeds/seed-packs/customer/1.0.0/manifest.yaml
s3://my-seeds/seed-packs/customer/1.0.0/customers.ndjson
s3://my-seeds/seed-packs/customer/1.0.0/roles.json
```


Manifest file (manifest.yaml):

```
seedPack: customer
version: 1.0.0

datasets:
  - collection: customers
    file: customers.ndjson      # resolved relative to the manifest's folder in S3
    naturalKey: [ accountNumber ]
    upsert: true

  - collection: roles
    file: roles.json           # also relative to the manifest's folder
    naturalKey: [ code ]
    upsert: true

archetypes:
  - name: CustomerBase
    includes:
      - customer@=1.0.0
```

No additional configuration is required in the manifest to indicate S3; the SeedSource you configure at runtime determines where manifests are discovered and how dataset paths are resolved.

14.18.6. Troubleshooting

- Access denied: Verify credentials or the assumed role's permissions for ListBucket/GetObject on the bucket/prefix.
- Region mismatch: Provide an explicit region if your runtime's default region doesn't match the bucket's region.
- Object not found: Confirm the prefix and that the manifest file name matches (default is manifest.yaml).
- Slow discovery: Use a tighter prefix to avoid scanning a large bucket namespace; consider S3 inventory or object tagging strategies if your repository grows significantly.

Chapter 15. 10. Migrations

Problem: Evolving schemas and data safely across environments.

Why for SaaS: Continuous delivery means frequent, incremental change with strict uptime and audit needs.

How Quantum helps: Opinionated patterns and hooks for applying safe migrations.

Walkthrough: Add and run a simple migration.

Chapter 16. Database Migrations and Index Management

This guide explains Quantum's MongoDB migration subsystem (quantum-morphia-repos), how migrations are authored and executed, and how to manage indexes. It also documents the REST APIs that trigger migrations and index operations.

16.1. Overview

Quantum uses a simple, versioned change-set mechanism to evolve MongoDB schemas and seed data safely across realms (databases). Key building blocks:

- **ChangeSetBean**: a CDI bean describing one migration step with metadata (from/to version, priority, etc.) and an execute method.
- **ChangeSetBase**: convenience base class you can extend; provides logging helpers and optional targeting controls.
- **MigrationService**: discovers pending change sets, applies them in order within a transaction, records execution, and bumps the **DatabaseVersion**.
- **DatabaseVersion** and **ChangeSetRecord**: stored in Mongo to track current schema version and previously executed change sets.

16.2. Semantic Versioning

Semantic Versioning (SemVer) expresses versions in the form MAJOR.MINOR.PATCH (for example, 1.4.2):

- **MAJOR**: increment for incompatible/breaking schema changes.
- **MINOR**: increment for backward-compatible additions (new collections/fields that don't break existing code).
- **PATCH**: increment for backward-compatible fixes or small adjustments.

Why this matters for migrations: - **Ordering**: migrations must apply in a deterministic order that reflects real compatibility. SemVer provides a natural ordering and clear intent for authors and reviewers. - **Compatibility checks**: the application can assert that the current database is "new enough" to run the code safely.

How `semver4j` is used: - **Parsing and validation**: version strings are parsed into a SemVer object. Invalid strings fail fast during parsing, ensuring only compliant versions are stored and compared. - **Introspection and comparison**: the parsed object exposes major/minor/patch components and supports comparisons, enabling safe ordering and "greater than / less than" checks. - **Consistent string form**: the canonical string is retained for display, logs, and API responses.

How **DatabaseVersion** leverages SemVer: - **Single source of truth**: **DatabaseVersion** stores the canonical SemVer string alongside a parsed SemVer object for logic and comparisons. - **Efficient ordering**: for fast sorting and tie-breaking, **DatabaseVersion** also keeps a compact integer encoding

of MAJOR.MINOR.PATCH as $(\text{major} \times 100) + (\text{minor} \times 10) + \text{patch}$ (e.g., 1.0.3 \rightarrow 103). This makes numeric comparisons straightforward while still recording the exact SemVer string. - Migration flow: when migrations run, successful execution records the new database version in DatabaseVersion. Startup checks compare the stored version to the required quantum.database.version to prevent the app from running against an older, incompatible schema.

Recommendations: - Always bump MAJOR for breaking data changes, MINOR for additive changes, and PATCH for backward-compatible fixes. - Keep change sets small and target a single to-version per change set to make intent clear. - Use SemVer consistently in getDbFromVersion/getDbToVersion across all change sets so ordering and compatibility checks remain reliable.

16.3. Configuration

The following MicroProfile config properties influence migrations:

- quantum.database.version: target version the application requires (SemVer, e.g., 1.0.3). MigrationService.checkDataBaseVersion compares this to the stored version.
- quantum.database.migration.enabled: feature flag checked by resources/services when running migrations. Default: true.
- quantum.database.migration.changeset.package: package containing change sets (CDI still discovers beans via type, but this property documents the intended package).
- quantum.realmConfig.systemRealm, quantum.realmConfig.defaultRealm, quantum.realmConfig.testRealm: well-known realms used by MigrationResource when running migrations across environments.

16.4. How change sets are discovered and executed

- Discovery: MigrationService#getAllChangeSetBeans locates all CDI beans implementing ChangeSetBean.
- Ordering: change sets are sorted by dbToVersionInt, then by priority (ascending). That ensures lower target versions apply before higher ones; priority resolves ties.
- Pending selection: For the target realm, MigrationService#getAllPendingChangeSetBeans compares each change set's dbToVersion against the stored DatabaseVersion and ignores already executed ones (tracked in ChangeSetRecord).
- Locking: A distributed lock (Mongo-backed Sherlock) is acquired per realm before applying change sets to prevent concurrent execution.
- Transactions: Each change set runs within a MorphiaSession transaction; on success the change is recorded in ChangeSetRecord and DatabaseVersion is advanced (if higher). On failure the transaction is aborted and the error returned.
- Realms: Migrations run per realm (Mongo database). A change set can optionally be restricted to certain database names or even override the realm it executes against (see below).

16.5. Authoring a change set

Implement `ChangeSetBean`; most change sets extend `ChangeSetBase`.

Required metadata methods:

- `getId()`: a string id for human tracking (e.g., 00003)
- `getDbFromVersion()` / `getDbFromVersionInt()`: previous version you are migrating from (SemVer and an int like 102 for 1.0.2)
- `getDbToVersion()` / `getDbToVersionInt()`: target version after running this change (SemVer and int)
- `getPriority()`: integer priority when multiple change sets have same `toVersion`
- `getAuthor()`, `getName()`, `getDescription()`, `getScope()`: informational fields recorded in `ChangeSetRecord`

Execution method:

- `void execute(MorphiaSession session, MongoClient mongoClient, MultiEmitter<? super String> emitter)`
- Perform your data/index changes using the provided session (transaction).
- Use `emitter.emit("message")` to stream log lines back to SSE clients.

Optional targeting controls (provided by `ChangeSetBase`):

- `boolean isOverrideDatabase()`: return true to execute against a specific database instead of the requested realm.
- `String getOverrideDatabaseName()`: the concrete database name to use when overriding.
- `Set<String> getApplicableDatabases()`: return a set of database names to which this change set should apply. Return null or an empty set to allow all.

Logging helper:

- `ChangeSetBase.log(String, MultiEmitter)` emits to both Quarkus log and the SSE stream.

16.6. Example change sets in the framework

Package: `com.e2eq.framework.model.persistent.morphia.changesets`

- `InitializeDatabase`
- Seeds foundational data in a new realm: counters (e.g., `accountNumber`), system Organization and Account, initial Rule and Policy scaffolding, default user profiles and security model. Uses `EnvConfigUtils` and `SecurityUtils` to derive system `DataDomain` and defaults.
- `AddAnonymousSecurityRules`
- Adds a default `AnonymousPolicy` with an allow rule for unauthenticated actions such as registration and contact-us in the website area.

- AddRealms
- Creates the system and default Realm records based on configuration, if missing.

These are typical examples of idempotent change sets that can be safely re-evaluated.

16.7. REST APIs to trigger migrations (MigrationResource)

Base path: /system/migration

Security: Most endpoints require admin role; dbversion is PermitAll for introspection.

- GET /system/migration/dbversion/{realm}
- Returns the current DatabaseVersion document for the given realm, or 404 if not found.
- Example: curl -s <http://localhost:8080/system/migration/dbversion/system-com>
- POST /system/migration/indexes/applyIndexes/{realm}
- Admin only. Calls MigrationService.applyIndexes(realm) which invokes Morphia Datastore.applyIndexes() for all mapped entities. Use this after adding @Indexed annotations.
- Example: curl -X POST -H "Authorization: Bearer \$TOKEN" <http://localhost:8080/system/migration/indexes/applyIndexes/system-com>
- POST /system/migration/indexes/dropAllIndexes/{realm}
- Admin only. Drops all indexes on all mapped collections in the realm. Useful before re-creation or when changing index definitions.
- Example: curl -X POST -H "Authorization: Bearer \$TOKEN" <http://localhost:8080/system/migration/indexes/dropAllIndexes/system-com>
- POST /system/migration/initialize/{realm}
- Admin only. Server-Sent Events (SSE) stream that executes all pending change sets for the specific realm.
- Example (note -N to keep connection open): curl -N -X POST -H "Authorization: Bearer \$TOKEN" <http://localhost:8080/system/migration/initialize/system-com>
- GET /system/migration/start
- Admin only. SSE stream that runs pending change sets across test, system, and default realms from configuration.
- Example: curl -N -H "Authorization: Bearer \$TOKEN" <http://localhost:8080/system/migration/start>
- GET /system/migration/start/{realm}
- Admin only. SSE for a specific realm.
- Example: curl -N -H "Authorization: Bearer \$TOKEN" <http://localhost:8080/system/migration/start/my-realm>

SSE responses stream human-readable messages produced by MigrationService and your change

sets. The connection ends with "Task completed" or an error message.

16.8. Per-entity index management (BaseResource)

Every entity resource that extends `BaseResource<T, R extends BaseMorphiaRepo<T>>` exposes a convenience endpoint to (re)create indexes for a single collection in a realm.

- `POST <entity-resource-base-path>/indexes/ensureIndexes/{realm}?collectionName=<collection>`
- Admin only. Invokes `R.ensureIndexes(realm, collectionName)`.
- Use this when you want to reapply indexes for one collection without touching others.
- Example (assuming a `ProductResource` at `/products`): `curl -X POST -H "Authorization: Bearer $TOKEN" \ "http://localhost:8080/products/indexes/ensureIndexes/system-com?collectionName=product"`

16.9. Global index management (MigrationService)

`MigrationService` also exposes programmatic index utilities used by the `MigrationResource` endpoints:

- `applyIndexes(realm)`: calls `Morphia Datastore.applyIndexes()` for the realm.
- `dropAllIndexes(realm)`: iterates mapped entities and drops indexes on each underlying collection.

16.10. Validating versions at startup

- `MigrationService.checkDataBaseVersion()` compares the stored `DatabaseVersion` in each well-known realm to `quantum.database.version` and throws a `DatabaseMigrationException` when lower than required. This prevents the app from running against an incompatible schema.
- `MigrationService.checkInitialized(realm)` is a convenience that asserts `DatabaseVersion` exists and is `>=` required version; helpful for preflight checks.

16.11. Notes and best practices

- Make change sets idempotent: Always check for existing records before creating/updating indexes or documents.
- Use SemVer consistently for from/to versions. The framework computes an integer form (e.g., `1.0.3 → 103`) for ordering.
- Prefer small, focused change sets with clear descriptions and authorship.
- Use the `MultiEmitter` in `execute(...)` to provide progress to operators consuming the SSE endpoint.
- Apply new indexes with `applyIndexes` after deploying models with new `@Indexed` annotations; optionally `dropAllIndexes` then `applyIndexes` when changing index definitions across the board.

- Limit scope: use `getApplicableDatabases()` to constrain execution to specific databases, or `isOverrideDatabase/getOverrideDatabaseName` to target a different database when appropriate.

Chapter 17. 11. Testing

Problem: Validating behavior quickly and reliably, including tenant-specific behavior.

Why for SaaS: Isolation, entitlements, and data variance require strong test coverage.

How Quantum helps: Test utilities, runtime hooks, and integration testing guidance.

Walkthrough: Write integration tests for APIs and seed packs.

17.1. Testing in Quantum: Security Contexts, Repos, and REST APIs

17.1.1. Testing Framework

This guide explains how to write effective tests in the Quantum framework, with a focus on setting the security context and choosing the right Quarkus testing patterns for repository logic vs. REST APIs.

It covers four practical patterns you can use to establish the security context in tests: - Extending `BaseRepoTest` - Using a try-with-resources `SecuritySession` - Using a scoped-call pattern to wrap work under a `SecuritySession` - Using the `@TestSecurity` annotation

In addition, it outlines how to test REST endpoints vs. repository logic and highlights useful features of the Quarkus Test Framework.

17.1.2. Prerequisites and glossary

- `RuleContext`: the in-memory rule engine configuration used by authorization checks.
- `PrincipalContext` (`pContext`): who is performing the action (`userId`, roles, realms, data domain).
- `ResourceContext` (`rContext`): what is being acted upon (`area/domain`, resource, action).
- `SecuritySession`: a small utility that binds `PrincipalContext` and `ResourceContext` to `SecurityContext` for the current thread, and clears them on close.
- `SecurityIdentity`: Quarkus' current identity (used by `@TestSecurity` and HTTP request security).

17.1.3. Pattern 1 — Extend `BaseRepoTest`

For repository tests (no HTTP), the simplest approach is to extend `BaseRepoTest`.

What `BaseRepoTest` does for you: - Initializes `RuleContext` with default rules. - Builds default `pContext` and `rContext` for a system/test user. - Ensures test database migrations are applied. - Gives you protected fields `pContext` and `rContext` you can use in your test.

Example:

```
@QuarkusTest
```

```

class MyRepoTest extends com.e2eq.framework.persistent.BaseRepoTest {

    @Inject
    com.e2eq.framework.model.persistent.morphia.UserProfileRepo userProfileRepo;

    @Test
    void canReadUnderTestUser() {
        // Activate the security context for this block
        try (final com.e2eq.framework.securityrules.SecuritySession ignored =
            new com.e2eq.framework.securityrules.SecuritySession(pContext, rContext))
        {
            var list = userProfileRepo.list(testUtils.getTestRealm());
            org.junit.jupiter.api.Assertions.assertNotNull(list);
        }
    }
}

```

Notes: - BaseRepoTest prepares contexts but does not keep them permanently active. Wrap repo calls that require authorization in a SecuritySession (see Pattern 2), or activate it in @BeforeEach if many test methods use it. - BaseRepoTest also runs migrations once using your test principal, which avoids authorization failures during initialization.

17.1.4. Pattern 2 — Try-with-resources SecuritySession

Use SecuritySession explicitly to scope work that should run under a specific PrincipalContext and ResourceContext. This is the most explicit pattern and works in both repository and service-level tests.

Example:

```

@QuarkusTest
class CredentialRepoTest extends com.e2eq.framework.persistent.BaseRepoTest {

    @Inject
    com.e2eq.framework.model.persistent.morphia.CredentialRepo credRepo;

    @Test
    void findByUserId_asTestUser() {
        try (final com.e2eq.framework.securityrules.SecuritySession s =
            new com.e2eq.framework.securityrules.SecuritySession(pContext, rContext))
        {
            var op = credRepo.findByUserId(testUtils.getTestUserId(), testUtils
                .getSystemRealm());
            org.junit.jupiter.api.Assertions.assertTrue(op.isPresent());
        }
    }
}

```

Tips: - Prefer try-with-resources so contexts are always cleared, even when assertions fail. - You can

construct custom `PrincipalContext/ResourceContext` for specific scenarios (e.g., different roles or realms) and pass them to `SecuritySession`.

17.1.5. Pattern 3 — Scoped-call wrapper (`ScopedCallScope`)

If you prefer not to repeat `try-with-resources` blocks, wrap your work in a helper that creates a `SecuritySession`, runs your logic, and ensures cleanup. This is sometimes called a “scoped call” pattern, often referred to as a `ScopedCallScope`.

Example helper (placed in test sources):

```
public final class SecurityScopes {
    private SecurityScopes() {}

    public static <T> T call(
        com.e2eq.framework.model.securityrules.PrincipalContext p,
        com.e2eq.framework.model.securityrules.ResourceContext r,
        java.util.concurrent.Callable<T> work) {
        try (final com.e2eq.framework.securityrules.SecuritySession s =
            new com.e2eq.framework.securityrules.SecuritySession(p, r)) {
            try { return work.call(); }
            catch (Exception e) { throw new RuntimeException(e); }
        }
    }

    public static void run(
        com.e2eq.framework.model.securityrules.PrincipalContext p,
        com.e2eq.framework.model.securityrules.ResourceContext r,
        Runnable work) {
        try (final com.e2eq.framework.securityrules.SecuritySession s =
            new com.e2eq.framework.securityrules.SecuritySession(p, r)) {
            work.run();
        }
    }
}
```

Usage:

```
var result = SecurityScopes.call(pContext, rContext, () -> repo.getByUserId(realms,
userId));
SecurityScopes.run(pContext, rContext, () -> repo.save(realms, entity));
```

This achieves the same effect as `try-with-resources` but centralizes the pattern.

17.1.6. Pattern 4 — `@TestSecurity` annotation (`Quarkus`)

For tests that run through HTTP (and in some repo tests), you can use Quarkus’ `@io.quarkus.test.security.TestSecurity` to set the `SecurityIdentity` without creating a `SecuritySession`.

Quantum integrates with this in two places: - `SecurityFilter`: when a request has a `SecurityIdentity` but no JWT, it builds a `PrincipalContext` from the identity (user and roles). You can also pass `X-Realm` to control the realm. - `MorphiaRepo`: when repo methods are invoked under `@TestSecurity` with no active `SecuritySession`, `MorphiaRepo` lazily builds `PrincipalContext` from `SecurityIdentity` and sets a safe default `ResourceContext` to enable rule evaluation.

Example (HTTP):

```
@QuarkusTest
class SecureResourceTest {

    @Inject com.e2eq.framework.util.TestUtils testUtils;

    @Test
    @io.quarkus.test.security.TestSecurity(user = "test@system.com", roles = {"user"})
    void listProfiles_asUser() {
        io.restassured.RestAssured.given()
            .header("X-Realm", testUtils.getTestRealm())
            .when().get("/user/userProfile/list")
            .then().statusCode(200);
    }
}
```

Example (repo call under `@TestSecurity` fallback, no `SecuritySession`):

```
@QuarkusTest
class RepoFallbackTest {

    @Inject com.e2eq.framework.util.TestUtils testUtils;
    @Inject com.e2eq.framework.model.persistent.morphia.CredentialRepo credentialRepo;

    @Test
    @io.quarkus.test.security.TestSecurity(user = "test@system.com", roles = {"user"})
    void repoUsesIdentityWhenNoSecuritySession() {
        // Internally, MorphiaRepo will ensure PrincipalContext exists using
        // SecurityIdentity
        credentialRepo.findById("nonexistent@end2endlogic.com", testUtils.
            getTestRealm(), false);
        // Optionally assert that SecurityContext has been initialized
        org.junit.jupiter.api.Assertions.assertTrue(
            com.e2eq.framework.model.securityrules.SecurityContext.getPrincipalContext()
                .isPresent());
    }
}
```

Notes: - `@TestSecurity` is perfect for authorizing requests in HTTP tests without generating JWTs. - For repo tests that require precise `ResourceContext` (area/domain/action), prefer `SecuritySession`; `MorphiaRepo` sets a generic default `ResourceContext` when needed.

17.1.7. Testing REST APIs vs. Repository Logic

When to prefer REST (HTTP) tests: - End-to-end authorization: validate request filters, identity mapping, realm headers, and JWT handling. - Request/response shape and status codes. - Role-based access checks via `@TestSecurity`.

How to test REST APIs: - Use `@QuarkusTest` and `RestAssured`: [source,java] ---- `var resp = io.restassured.RestAssured.given().header("Content-Type", "application/json").header("X-Realm", testUtils.getTestRealm()).when().get("/user/userProfile/list").then().statusCode(200).extract().response();` ---- - To test JWT-protected endpoints end-to-end, first call the login API to obtain a token, then pass `Authorization: Bearer <token>`. See `SecurityTest.testGetUserProfileRESTAPI` for a complete example.

When to prefer repository/service tests: - You want precise control over `PrincipalContext/ResourceContext` and rule evaluation without HTTP overhead. - You are asserting persistence logic, query filters, or domain rules.

How to test repository logic: - Extend `BaseRepoTest` (Pattern 1) for ready-to-use `pContext/rContext` and migrations. - Wrap calls with `SecuritySession` (Pattern 2) or use a scoped-call helper (Pattern 3).

17.1.8. Useful Quarkus Test features

- `@QuarkusTest`: boots the app for integration tests with CDI, config, and persistence.
- `RestAssured`: fluent HTTP client baked into Quarkus tests; supports JSON assertions and extraction.
- `@TestSecurity`: set `SecurityIdentity` (user, roles) for tests.
- `@InjectMock/@InjectSpy` (quarkus-junit5-mockito): replace beans with mocks/spies for isolation.
- `@QuarkusTestResource`: manage external resources (e.g., starting/stopping containers) for a test class or suite.
- `@TestHTTPEndpoint` and `@TestHTTPResource`: convenient endpoint URI injection.

17.1.9. Real-world tips

- Clearing thread locals: If you manipulate `SecurityContext` directly in advanced tests, clear it in `@AfterEach` to avoid cross-test leakage: [source,java] ---- `@AfterEach void cleanup() { com.e2eq.framework.model.securityrules.SecurityContext.clear(); }` ----
- Realm routing: pass X-Realm in REST tests to select the target realm. `SecurityFilter` also validates realm access against user credentials when present.
- Data prep: If your test needs specific users/roles, create them under a `SecuritySession` beforehand (see `SecurityTest.ensureTestUserExists()`).
- Logging: enable `DEBUG` for `com.e2eq` to inspect rule evaluation and identity resolution during tests.

17.1.10. Summary

- Use `BaseRepoTest` for repository tests and migrations, and wrap work in `SecuritySession`.

- For less ceremony, create a simple scoped-call helper to run code under a `SecuritySession`.
- For REST/API tests and quick identity setup, use `@TestSecurity`, realm headers, and `RestAssured`.
- For full e2e security, obtain a JWT via the login API and include it in requests.

Chapter 18. 12. Next steps

- Explore the Supply Chain sample tutorial for an end-to-end scenario.
- Use the Reference Guide to quickly jump to deeper explanations of any topic above.