Project Specification

Documentation¶

Specifications¶

Constitution¶

This document serves as the supreme law for the project, defining the core values, architectural principles, and decision-making processes that guide all development and specification efforts.

Vision¶ To create a robust, scalable, and maintainable system that meets the user's needs with precision and elegance.

Document Classification¶ This document contains both normative and informative content.

- **Normative** sections define binding rules that MUST be followed.
- **Informative** sections provide guidance, context, or rationale.

Unless explicitly stated otherwise, sections under "Specification Conventions" are normative.

Requirements Language¶ The key words "MUST", "SHALL", "SHOULD", "MAY", and "MUST NOT" are to be interpreted as described in RFC 2119 and RFC 8174.

Core Principles¶

1. **Simplicity**: Favor simple solutions over complex ones. Avoid over-engineering.
2. **Consistency**: Maintain uniformity in code style, naming conventions, and documentation.
3. **Transparency**: All decisions and significant changes must be documented and open for review.

4. **User-Centricity**: The needs of the end-user are paramount in every design decision.

Architectural Guidelines¶

- **Modularity**: The system should be composed of loosely coupled, highly cohesive modules.
- **Separation of Concerns**: Each component should have a distinct and well-defined responsibility.
- **Scalability**: Design consistently with future growth in mind, but implement for today's requirements.
- **Security First**: Security considerations are integral to the design phase, not an afterthought.

Decision Making¶ Decisions are made based on technical merit and consensus. When consensus cannot be reached, the project lead has the final authority. All architectural decisions (ADRs) must be recorded.

Documentation Structure¶ The documentation is organized into the following directories, each serving a specific purpose:

- **doc/spec: Contains the detailed system specifications.**
    - **overview**: High-level summary of the project.
    - **terminology**: Definition of specific terms and abbreviations.
    - **background**: Context, motivations, and problem statement.
    - **scope**: Project boundaries (in-scope and out-of-scope).
    - **actors**: Users and external systems interacting with the project.
    - **use-cases**: Description of functional scenarios and user stories.
    - **functional-requirements**: Specific behaviors and functions the system must support.
    - **non-functional-requirements**: Quality attributes such as performance, security, and reliability.
    - **constraints-and-assumptions**: Limitations and known prerequisites.
    - **data-model**: Entity definitions, database schemas, and data flow.
    - **interface-requirements**: UI/UX guidelines and API definitions.
    - **error-handling**: Strategies for handling exceptions and failures.

    - **future-considerations**: Roadmap and potential future enhancements.

- **doc/adr**: Architecture Decision Records. Used to record significant architectural decisions, context, and consequences.

Specification Conventions¶ To ensure traceability and maintainability of the specifications, the following conventions SHALL be observed.

Identifier Scope¶ All identifiers SHALL be globally unique within the project. Identifiers MUST NOT be reused across different categories.

Identifier Assignment¶

- **Target**: IDs SHALL be assigned to all normative requirements (FR, NFR), use cases (UC), constraints (CON), data entities (DATA), API endpoints (API), and error definitions (ERR).
- **Granularity**: Assign IDs to semantic units, not every paragraph or section.
- **Format**: IDs SHALL follow the format `<Category>-<Domain>-<Number>`. * Examples: `FR-AUTH-001`, `NFR-PERF-003`, `UC-LOGIN-001`.
- **Stability**: IDs SHALL NOT change even if the section title or minor wording changes.
- **Deprecation**: If a requirement is removed, keep the ID and mark it as `(Deprecated)`.

Dependency Model¶ The specification elements are related by the following dependency model.

- Use Cases (UC) provide the business or user justification for Functional Requirements (FR). Every Functional Requirement SHALL be traceable to at least one Use Case.
- Functional Requirements (FR) define the system's externally observable capabilities and SHALL serve as the central anchor for traceability.
- Error Definitions (ERR) define failure outcomes for Functional Requirements. ERR specifies what happens when an operation fails, not the capability itself. Every Error Definition SHALL be referenced by at least one FR.
- Constraints (CON) define externally imposed, mandatory conditions that restrict or qualify Functional and Non-Functional Requirements. Constraints SHALL NOT be derived from Functional Requirements. Constraints MAY restrict how errors are handled or disclosed.

- Non-Functional Requirements (NFR) define measurable quality attributes of Functional Requirements. Every Non-Functional Requirement SHALL be associated with at least one Functional Requirement. NFRs MAY define retry policies and observability for error conditions.
- Dependencies between UC, FR, ERR, CON, and NFR SHALL form a directed acyclic graph. Cyclic dependencies are prohibited.

Traceability Source of Truth¶

- "Impacts" sections SHALL NOT be used. Reverse traceability (e.g., CON → FR/NFR) SHALL be derived by tooling from explicit references.
- Normative traceability SHALL be expressed only by forward references: UC → FR, FR → NFR/CON/ERR, NFR → CON, and (optionally) ERR → CON.
- Constraints (CON) SHALL be declarative and SHALL NOT enumerate impacted elements.

Cross-Referencing¶

- **Syntax**: Define targets using `.. _ID:` before the header. Reference using `:ref:`ID``.
- **Direction**: Follow the reference hierarchy: Use Case -> Functional Requirement -> (API / IF, Data Entity, Error, Constraint). Avoid circular references.
- **Prohibitions**: * Functional Requirements SHALL NOT reference Use Cases. * Use Cases SHALL NOT establish normative references to Interface or API specifications (mentions only). * Data Models SHALL NOT reference API endpoints. * Error Definitions SHALL NOT introduce new requirements.
- **Semantics**: * "Realized by" references in Functional Requirements indicate an example implementation mapping and do not constitute a strict normative dependency.

Usage Coverage¶

- **FR Coverage**: All Functional Requirements (FR) MUST be referenced by at least one Use Case (UC). Orphan guidelines are considered incomplete specification.
- **UC Completeness**: All Use Cases (UC) MUST reference at least one Functional Requirement (FR). Empty Use Cases are prohibited.
- **Interface Utility**: All Interfaces and APIs MUST be referenced by at least one Functional Requirement (FR). Orphan Interfaces are prohibited.

Use Case Structure¶ Use Cases (UC) SHALL follow the narrative structure: **Actor -> Entry Point (Informative) -> Goal**. - **Actor**: A defined Actor. - **Entry Point**: A narrative mention of the interface (e.g., "via the Console"). **SHALL NOT** use `:ref:` to link to Interface specifications. - **Goal**: The value or outcome achieved, formally supporting a **Functional Requirement**.

AI Authoring Rules¶ When generating or modifying documentation:

- New identifiers SHALL NOT be introduced without explicit instruction.
- Existing identifiers SHALL NOT be renamed or repurposed.
- AI-generated content MUST reference existing identifiers where applicable.
- If no suitable identifier exists, the AI SHALL flag the gap instead of inventing one.

Change Management¶

- Editorial changes that do not alter meaning SHALL retain the same identifier.
- Semantic changes SHALL result in a new identifier.
- Deprecated identifiers SHALL remain documented and MUST NOT be reused.

Documentation Format¶

- **Tables**: Tables SHALL be written using the reStructuredText "Simple Tables" format (using === borders) for readability. - Exception: Complex grids that require spanning cells may use "Grid Tables".

Amendment Policy¶ This constitution may be amended as the project evolves. Amendments require a comprehensive review and approval by the core maintainers.

Overview¶

Concept¶ This document outlines the core concept, actors, and scope of the Control Plane System, derived from the initial concept interview.

Actors¶

- **Tenant User (TERM-ACTOR-USER)**: A user of the customer (tenant) who accesses the SaaS applications. Uses this system for authentication.

- **Platform Operator (TERM-ACTOR-OPS)**: A service provider user who manages subscriptions, configures tenants, and controls feature flags for the SaaS applications.
- **Auditor (TERM-ACTOR-AUDIT)**: A user responsible for reviewing audit logs provided by the system.

Scope¶ In-Scope

- Issuance of authentication tokens for SaaS applications.
- Delivery of Feature Flags to control application functionality.
- Collection and provision of monitoring and audit logs.
- Recording of billable events/operations.

Out-of-Scope

- Actual billing and payment processing (e.g., invoice generation, credit card processing via Stripe). These will be handled by an external system based on the recorded events.

Primary Use Case¶ Tenant Provisioning by Platform Operator The single most critical scenario is where a **Platform Operator** configures a new tenant and immediately makes the subscribed features available for use. This use case validates the core value of the control plane: rapid and centralized onboarding.

Terminology¶

Terminology¶ This section defines key terms and abbreviations used throughout the specification.

Control Plane (TERM-SYS-CP)¶ The system described in this specification. It provides centralized management functions such as authentication, feature flagging, and auditing for multiple B2B SaaS applications.

Managed Application (TERM-APP-TARGET)¶ The B2B SaaS applications that are managed by the Control Plane (TERM-SYS-CP). These applications delegate authentication and feature control to the Control Plane. Also referred to as “Target Application” or “B2B SaaS”.

Background¶

Motivation¶ There is a growing need to manage multiple B2B SaaS applications efficiently. Currently, common control plane elements such as User Management (CIAM), Feature Flag management, and monitoring are fragmented or duplicated across applications.

The goal is to centralize these controls to reduce development and operational costs while ensuring consistency across all managed SaaS products.

Scope¶

Scope¶ This section defines the functionalities that are In-Scope and explicitly Out-of-Scope for the project.

In-Scope¶ Authentication (FR-AUTH)¶

The system SHALL provide a centralized authentication mechanism (issuance of tokens) for all managed SaaS applications.

Feature Flag Management (FR-FLAG)¶

The system SHALL provide a mechanism to deliver feature flags to applications, enabling dynamic control of functionality.

Logging and Auditing (FR-LOG)¶

The system SHALL collect operational logs and provide them to Auditors. The system SHALL record billable operational events.

Out-of-Scope¶ Payment Processing¶

The system SHALL NOT handle handling of actual payments (e.g., credit card transactions) or invoice generation. This is delegated to an external billing system.

Platform Operator Management¶

The management of Platform Operator accounts (registration, deletion, identity management) and their authentication to the Control Plane (IF-OPS-CONSOLE Operator Console) is Out-of-Scope for this specification. These functions are delegated to an external Identity Provider (IdP) and managed by an external team. The system assumes a valid identity is provided via the IdP integration.

Actors¶

Actors¶ This section defines the primary actors interacting with the system.

ACT-USER Tenant User¶ A user belonging to a tenant organization who accesses the managed B2B SaaS applications. This actor primarily interacts with the authentication services.

Roles:

- **Owner**: The primary contact for the tenant. Has full authority, including contract modification (subscription changes) and SSO configuration. Can invite and delete other users.

- **Administrator**: A delegated administrator. Can invite and delete users but cannot modify contracts or configure SSO.
- **User**: A standard user with access to applications but no administrative privileges.

ACT-OPS Platform Operator¶ An internal user of the service provider responsible for managing the control plane. Responsibilities include tenant onboarding, subscription management, and feature flag configuration.

ACT-AUDIT Auditor¶ An external or internal compliance officer responsible for reviewing audit logs generated by the system.

ACT-DEV Developer¶ The engineer or system administrator responsible for deploying and configuring the Managed Application. Interacts with the system to register applications and manage API credentials.

ACT-BILLING External Billing System¶ A third-party system or internal finance application responsible for processing invoices. Interacts with the system to retrieve billing events.

Use Cases¶

Tenant Provisioning & Lifecycle¶

UC-PROV-001 Tenant Provisioning¶ **Actor**: Platform Operator

Description: The Platform Operator creates a new tenant configuration and enables subscribed features, allowing the tenant to immediately access the Managed Application.

Trigger: A new customer subscription is confirmed.

Preconditions:

1. The Platform Operator is logged in.

Postconditions:

1. A new tenant entity is created in the Control Plane.
2. Initial Tenant User (Role: Owner) is provisioned.
3. Feature flags corresponding to the subscription plan are active.

Scenario:

1. The Platform Operator navigates to the **Operator Console**.
2. The Platform Operator enters tenant details (Name, Domain, Plan) and the email address for the initial Owner.

3. The Platform Operator selects the Managed Application to enable.
4. The Platform Operator selects the “Provision” action.
5. The Control Plane creates the tenant and the initial Tenant User (Role: Owner).
6. The Control Plane enables access to the Managed Application.

Related Requirements:

- Flag Configuration
- User Invitation
- Contract Modification
- Control Plane Auditing

UC-TENANT-SUSPEND Tenant Suspension¶ **Actor**: Platform Operator

Description: The Platform Operator suspends a tenant’s access to the managed application, usually due to non-payment or policy violation.

Trigger: The Platform Operator selects “Suspend Tenant” in the **Operator Console**.

Preconditions:

1. The Platform Operator is logged in.
2. The target tenant is currently Active.

Postconditions:

1. The Tenant status is updated to Suspended.
2. All Users under the tenant are immediately denied access.

Scenario:

1. The Platform Operator searches for the tenant in the **Operator Console**.
2. The Platform Operator selects the “Suspend” action.
3. The Platform Operator provides a reason (optional).
4. The Platform Operator confirms the action.
5. The Control Plane invokes the suspension logic.

Related Requirements:

- Tenant Status Management
- Control Plane Auditing

UC-OPS-TENANT-DELETE Tenant Deletion¶ **Actor**: Platform Operator

Description: The Platform Operator permanently deletes a tenant and all associated data upon contract termination or deletion request.

Trigger: The Platform Operator selects "Delete Tenant" in the **Operator Console**.

Preconditions:

1. The Platform Operator is logged in.
2. The target tenant exists.

Postconditions:

1. The Tenant enters a 30-day grace period (recoverable).
2. After the grace period, all tenant data is permanently deleted.

Scenario:

1. The Platform Operator searches for the tenant in the **Operator Console**.
2. The Platform Operator selects the "Delete" action.
3. The Platform Operator confirms the action with explicit acknowledgment.
4. The Control Plane marks the tenant for deletion (30-day grace).
5. After the grace period, the Control Plane permanently deletes all related data.

Related Requirements:

- Tenant Deletion
- Control Plane Auditing
- Data Subject Rights

Tenant Administration¶

UC-TENANT-USER-DELETE User Deletion¶ **Actor**: Tenant User (Role: Owner, Administrator)

Description: The Tenant User (Role: Owner or Administrator) removes a user from the tenant organization.

Trigger: The Tenant User selects "Delete User" in the **Tenant Administration Console**.

Preconditions:

1. The Tenant User is logged in with sufficient privileges.

2. Target user exists.

Postconditions:

1. Target user is removed from authentication and cannot access applications.
2. All active Sessions for the user are invalidated.

Scenario:

1. The Tenant User selects the user to remove.
2. The Tenant User confirms deletion.
3. The Control Plane removes the user.
4. The Control Plane invalidates existing sessions.

Related Requirements:

- User Deletion
- Control Plane Auditing

UC-TENANT-USER-UPDATE User Role Update¶ **Actor**: Tenant User (Role: Owner, Administrator)

Description: The Tenant User (Role: Owner or Administrator) modifies the role of an existing user within the tenant organization.

Trigger: The Tenant User selects "Edit Role" in the **Tenant Administration Console**.

Preconditions:

1. The Tenant User is logged in with sufficient privileges.
2. Target user exists.

Postconditions:

1. Target user's role is updated.
2. All active Sessions for the user are invalidated.

Scenario:

1. The Tenant User selects the user to update.
2. The Tenant User selects the new role.
3. The Tenant User saves the changes.
4. The Control Plane validates the permissions (e.g., cannot downgrade own role if last Owner).
5. The Control Plane updates the user record.

6. The Control Plane invalidates existing sessions to enforce new permissions.

Related Requirements:

- User Role Management
- Control Plane Auditing

UC-TENANT-USER-STATUS-UPDATE User Status Update¶ **Actor**: Tenant User (Role: Owner, Administrator)

Description: The Tenant User (Role: Owner or Administrator) changes the status of a user (e.g., to Disabled to block access).

Trigger: The Tenant User selects “Disable User” or “Enable User” in the **Tenant Administration Console**.

Preconditions:

1. The Tenant User is logged in with sufficient privileges.
2. Target user exists.

Postconditions:

1. Target user’s status is updated.
2. If Disabled, all active Sessions for the user are invalidated.

Scenario:

1. The Tenant User selects the user to update.
2. The Tenant User toggles the status (e.g., Active to Disabled).
3. The Tenant User saves the changes.
4. The Control Plane validates the action.
5. The Control Plane updates the user record.
6. The Control Plane invalidates sessions if required.

Related Requirements:

- User Status Management
- Control Plane Auditing

UC-TENANT-SESSION-REVOKE Session Revocation¶ **Actor**: Tenant User (Role: Owner, Administrator)

Description: The Tenant User (Role: Owner or Administrator) invalidates a specific user’s active sessions to force re-authentication.

Trigger: The Tenant User selects “Revoke Sessions” for a user in the **Tenant Administration Console**.

Preconditions:

1. The Tenant User is logged in with sufficient privileges.
2. The target User exists.

Postconditions:

1. All active Sessions for the target User are invalidated.
2. The target User is required to log in again.

Scenario:

1. The Tenant User identifies the target user in the **Tenant Administration Console**.
2. The Tenant User initiates the session revocation.
3. The Control Plane invalidates all tokens associated with the user.

Related Requirements:

- Session Management
- Control Plane Auditing

UC-TENANT-INVITE User Invitation¶ **Actor**: Tenant User (Role: Owner, Administrator)

Description: The Tenant User (Role: Owner or Administrator) invites a new user to join their tenant organization. The invited user receives an email to set up their account.

Trigger: The Tenant User selects "Invite User" in the **Tenant Administration Console**.

Preconditions:

1. The Tenant User is logged in with Owner or Administrator role.
2. The invited email address does not already exist in the tenant.

Postconditions:

1. An invitation email is sent to the specified address.
2. A user record is created with "Invited" status.

Scenario:

1. The Tenant User enters the email address and role (Admin or User) of the new user.
2. The Tenant User submits the invitation.
3. The Control Plane validates the input and permissions.

4. The Control Plane sends the invitation email.

Related Requirements:

- User Invitation
- Control Plane Auditing

UC-TENANT-INVITE-RESEND Invitation Resend¶ **Actor**: Tenant User (Role: Owner or Administrator)

Description: The Tenant User resends an invitation to a user whose previous invitation expired or was not received.

Trigger: The Tenant User selects "Resend Invitation" for a pending invitation.

Preconditions:

1. The Tenant User is logged in with Owner or Administrator role.
2. A pending or expired invitation exists for the target user.

Postconditions:

1. The previous invitation is invalidated.
2. A new invitation with fresh expiration is created.
3. A new invitation email is sent to the user.

Scenario:

1. The Tenant User views the list of pending invitations.
2. The Tenant User selects "Resend" for the target user.
3. The Control Plane invalidates the old invitation.
4. The Control Plane creates a new invitation and sends the email.

Related Requirements:

- Invitation Resend
- Control Plane Auditing

UC-TENANT-SSO SSO Configuration¶ **Actor**: Tenant User (Role: Owner)

Description: The Tenant User (Role: Owner) configures an external Identity Provider (OIDC) to enable Single Sign-On for their users.

Trigger: The Tenant User initiates "SSO Setup" in the **Tenant Administration Console**.

Preconditions:

1. The Tenant User is logged in with Owner role.
2. The Tenant User has the necessary metadata (Client ID, Issuer URL) from their IdP.

Postconditions:

1. The tenant is configured to use the specified IdP.
2. Subsequent logins from this tenant's domain can use SSO.

Scenario:

1. The Tenant User enters IdP details (Issuer URL, Client ID, Client Secret).
2. The Control Plane verifies the IdP configuration (discovery).
3. The Control Plane saves the configuration.

Related Requirements:

- Tenant SSO Configuration
- Control Plane Auditing

Access Management¶

UC-LOGIN Tenant User Login¶

Actor: Tenant User

Description: The Tenant User logs in to the system or a managed application using their credentials or an external IdP.

Trigger: The Tenant User attempts to access a protected resource.

Preconditions:

1. The Tenant User account exists and is active.

Postconditions:

1. The Tenant User receives an authentication token.
2. The Tenant User gains access to the application.

Scenario:

1. The Tenant User navigates to the **Universal Login Page**.
2. The Tenant User selects authentication method (Password or SSO).
3. If Password: The Tenant User enters email and password.
4. If SSO: The Tenant User is redirected to IdP and authenticates.
5. The Control Plane validates credentials.
6. The Control Plane issues an authentication token.

Related Requirements:

- Supported Authentication Methods
- Session Management

UC-LOGOUT Tenant User Logout¶ **Actor**: Tenant User

Description: The Tenant User explicitly terminates their session to secure their access.

Trigger: The Tenant User selects “Logout” in the **Universal Login Page** or Managed Application.

Preconditions:

1. The Tenant User has an active Session.

Postconditions:

1. The Session is invalidated.
2. The user is redirected to the public login page.

Scenario:

1. The Tenant User initiates the logout action.
2. The Control Plane invalidates the session token.
3. The Control Plane redirects the user.

Related Requirements:

- Session Management
- Control Plane Auditing

UC-AUTH-RESET Password Reset¶ **Actor**: Tenant User

Description: The Tenant User initiates a password reset flow when they have forgotten their credentials.

Trigger: The Tenant User selects “Forgot Password” on the **Universal Login Page**.

Preconditions:

1. The Tenant User has a registered account with an email address.
2. The account is configured for password authentication.

Postconditions:

1. The Tenant User has updated their credential.
2. All existing Sessions are invalidated.

Scenario:

1. The Tenant User enters their email address on the **Universal Login Page**.
2. The Control Plane sends a password reset link/token to the email.
3. The Tenant User clicks the link and enters a new password.
4. The Control Plane updates the credential store.
5. The Control Plane invalidates all active sessions for the user.

Related Requirements:

- Password Reset
- Control Plane Auditing

Audit Management¶

UC-AUDIT-EXPORT Audit Log Export¶ **Actor**: Auditor

Description: The Auditor exports system audit logs for compliance review.

Trigger: The Auditor selects "Export Logs" within the **Auditor Console**.

Preconditions:

1. The Auditor is logged in with Auditor privileges.

Postconditions:

1. A CSV file containing the requested logs is downloaded to the Auditor's device.

Scenario:

1. The Auditor navigates to the "Audit Logs" view in the **Auditor Console**.
2. The Auditor selects the date range and filters for the export.
3. The Auditor initiates the download.
4. The Control Plane queries the log storage.
5. The Control Plane formats the data as CSV and streams the response.

Related Requirements:

- Audit Log Collection
- Audit Log Export

UC-AUDIT-RECORD-CP Control Plane Event Recording¶ **Actor**: Control Plane

Description: The Control Plane records internal state changes (e.g., provisioning, user management) as audit logs to ensure traceability of operator and admin actions.

Trigger: A state-changing operation is successfully completed by any Actor.

Preconditions:

1. The operation (e.g., Tenant Provisioning, User Deletion) has succeeded.

Postconditions:

1. An audit log entry describing the event is persisted.

Scenario:

1. An Actor (Operator, Tenant Owner) performs an action (e.g., "Provision Tenant").
2. The Control Plane executes the detailed business logic.
3. The Control Plane generates an audit log event containing Actor ID, Action, Resource, and Timestamp.
4. The Control Plane persists the log entry.

Related Requirements:

- Control Plane Auditing

System Integration¶ This section describes the automated interactions between Managed Applications and the Control Plane.

UC-SYS-APP-AUTH Feature Flag Retrieval¶ **Actor**: Managed Application (System)

Description: The Managed Application retrieves the active feature flags for its tenant to enable/disable functionality dynamically.

Trigger: The Managed Application starts up or periodic refresh interval elapses.

Postconditions:

1. The Managed Application receives the current set of flags.

Scenario:

1. The Managed Application requests flags from the Control Plane.
2. The Control Plane identifies the tenant (via keys or context).
3. The Control Plane returns the flag configuration.

Related Requirements:

- Flag Delivery

UC-SYS-BILL-REPORT Billing Event Reporting¶ **Actor**: Managed Application (System)

Description: The Managed Application reports a billable event to the Control Plane for tracking.

Trigger: A user performs a billable action within the Managed Application.

Postconditions:

1. The event is persisted in the Control Plane.

Scenario:

1. The Managed Application detects billable event.
2. The Managed Application sends event data to the Control Plane.
3. The Control Plane validates and stores the event.

Related Requirements:

- Billing Event Persistence
- Billing Event Ingestion

UC-SYS-LOG-REPORT Audit Log Reporting¶ **Actor**: Managed Application (System)

Description: The Managed Application sends its security and operation logs to the Control Plane for centralized auditing.

Trigger: The Managed Application generates a log entry.

Postconditions:

1. The log entry is collected by the Control Plane.

Scenario:

1. The Managed Application generates a log.
2. The Managed Application streams/sends the log to the Control Plane.
3. The Control Plane ingests the log.

Related Requirements:

- Audit Log Collection

UC-SYS-BILL-EXPORT Billing Data Export¶ **Actor**: External Billing System (System)

Description: The External Billing System retrieves billing events from the Control Plane to generate invoices and perform reconciliation.

Trigger: Scheduled job or on-demand request from the External Billing System.

Postconditions:

1. The External Billing System receives the requested Billing Events.

Scenario:

1. The External Billing System requests billing events for a specified period/tenant.
2. The Control Plane authenticates and authorizes the request.
3. The Control Plane retrieves matching events from the data store.
4. The Control Plane returns the event data to the External Billing System.

Related Requirements:

- Billing Data Export

System Deployment¶

UC-DEV-REGISTER Application Registration¶ **Actor**: Developer

Description: The Developer registers the Managed Application with the Control Plane to obtain credentials for API access. This is typically done as part of the initial system deployment.

Trigger: The Developer initiates the "Register System" workflow (via CLI or script).

Preconditions:

1. The Developer has administrative access to the Control Plane infrastructure.

Postconditions:

1. A Managed Application record is created.
2. An API Access Key is issued and returned to the Developer.
3. The Managed Application is configured with the key.

Scenario:

1. The Developer submits the application metadata (Name, Environment).
2. The Control Plane creates the application record.

3. The Control Plane generates a client ID and secret.
4. The Control Plane stores the hashed secret.
5. The Control Plane returns the ID and Secret to the Developer.

Related Requirements:

- Application Registration
- API Key Management

UC-DEV-UPDATE Application Update¶ **Actor**: Developer

Description: The Developer updates the configuration or status of a Managed Application. This includes disabling the application to prevent access.

Trigger: The Developer initiates a deployment or CLI command to update the application.

Preconditions:

1. The Developer has valid administrative credentials.
2. The target Managed Application exists.

Postconditions:

1. The Managed Application record is updated.
2. If status is set to Disabled, all API access is blocked.

Scenario:

1. The Developer submits the update request (e.g., set status to Disabled).
2. The Control Plane validates the request.
3. The Control Plane updates the application record.
4. The Control Plane applies the new state (e.g., blocking incoming API calls).

Related Requirements:

- Application Lifecycle Management

Functional Requirements¶

Authentication & Authorization¶

FR-AUTH-001 Supported Authentication Methods¶ The Control Plane (TERM-SYS-CP) SHALL support the following authentication methods for Tenant Users:

- OpenID Connect (OIDC)

- Password-based authentication

Realized by:

- Universal Login Page

Quality Attributes:

- Encryption in Transit
- MFA
- Least Privilege
- Adaptive Authentication
- Availability SLO

Error Conditions:

- Invalid Credentials
- MFA Required
- Rate Limit Exceeded

FR-AUTH-003 Tenant SSO Configuration¶ The Control Plane (TERM-SYS-CP) SHALL allow a Tenant Owner (role of ACT-USER Tenant User, see Roles) to register an external Identity Provider (IdP) for Single Sign-On (SSO). The configuration SHALL be stored in SSO Configuration.

Realized by:

- Tenant Administration Console

Quality Attributes:

- Encryption in Transit
- Key Management
- Least Privilege
- Availability SLO

Error Conditions:

- Access Denied
- Invalid Input
- Conflict

FR-AUTH-004 Password Reset¶ The Control Plane (TERM-SYS-CP) SHALL allow Tenant Users (using password authentication) to request a password reset via their registered email address. The Control Plane (TERM-SYS-CP) SHALL allow authenticated Tenant Users to change their password. Upon successful password reset or change, the system SHALL invalidate all active Sessions for the user.

Realized by:

- Universal Login Page

Quality Attributes:

- Encryption in Transit
- MFA
- Key Management
- Availability SLO

Error Conditions:

- Invalid Credentials
- Business Rule Violation
- Rate Limit Exceeded

FR-AUTH-005 Session Management¶ The Control Plane (TERM-SYS-CP) SHALL establish a Session upon successful user authentication. The Control Plane (TERM-SYS-CP) SHALL support session invalidation triggers including explicit logout and administrative revocation.

Realized by:

- Universal Login Page
- Tenant Administration Console

Quality Attributes:

- Encryption in Transit
- Encryption at Rest
- Least Privilege
- Availability SLO

Error Conditions:

- Access Denied
- Session Expired

FR-AUTH-006 Password Policy Configuration¶ The Control Plane (TERM-SYS-CP) SHALL allow each Tenant to configure password complexity requirements (e.g., minimum length, required character types).

Constrained by: CON-SEC-001 Configurable Password Policy

Realized by:

- Tenant Administration Console

Quality Attributes:

- Encryption in Transit
- Encryption at Rest
- Least Privilege
- Availability SLO

Error Conditions:

- Access Denied
- Invalid Input

Tenant Administration¶

FR-TENANT-001 User Invitation¶ The Control Plane (TERM-SYS-CP) SHALL allow Tenant Owners and Administrators to invite new Users to their Tenant. This process SHALL create a User Invitation record.

- Invitations SHALL have a configurable expiration period (default: 7 days).
- Expired invitations SHALL be marked as invalid and cannot be used for registration.

Realized by:

- Tenant Administration Console

Quality Attributes:

- Encryption in Transit
- Least Privilege
- User Scalability
- Availability SLO

Error Conditions:

- Access Denied
- Conflict

- Business Rule Violation

FR-TENANT-002 User Deletion¶ The Control Plane (TERM-SYS-CP) SHALL allow Tenant Owners and Administrators to delete Users from their Tenant. When a user is deleted, the system SHALL invalidate all active Sessions for that user.

Realized by:

- Tenant Administration Console

Quality Attributes:

- Encryption in Transit
- Encryption at Rest
- Least Privilege
- Availability SLO

Error Conditions:

- Access Denied
- Resource Not Found

FR-TENANT-003 Contract Modification¶ The Control Plane (TERM-SYS-CP) SHALL allow only Tenant Owners to modify the tenant's subscription contract (specifically Tenant.plan).

Realized by:

- Tenant Administration Console

Quality Attributes:

- Encryption in Transit
- Least Privilege
- Tenant Scalability
- Availability SLO

Error Conditions:

- Access Denied

FR-TENANT-004 User Role Management¶ The Control Plane (TERM-SYS-CP) SHALL allow Tenant Owners and Administrators to modify the Roles of existing Users within their Tenant. When a role is updated, the system SHALL invalidate all active Sessions for the target user.

Realized by:

- Tenant Administration Console

Quality Attributes:

- Encryption in Transit
- Least Privilege
- Availability SLO

Error Conditions:

- Access Denied
- Resource Not Found

FR-TENANT-006 User Status Management¶ The Control Plane (TERM-SYS-CP) SHALL allow Tenant Owners and Administrators to modify the Status of existing Users (e.g., Enable, Disable). When a user is Disabled, the system SHALL invalidate all active Sessions for that user.

Realized by:

- Tenant Administration Console

Quality Attributes:

- Encryption in Transit
- Least Privilege
- Availability SLO

Error Conditions:

- Access Denied
- Resource Not Found

FR-TENANT-007 Invitation Resend¶ The Control Plane (TERM-SYS-CP) SHALL allow Tenant Owners and Administrators to resend an invitation to a user whose invitation has expired or was not received.

- Resending SHALL invalidate the previous User Invitation and create a new one.
- The new invitation SHALL have a fresh expiration period.

Realized by:

- Tenant Administration Console

Quality Attributes:

- Encryption in Transit
- Least Privilege

- Availability SLO

Error Conditions:

- Access Denied
- Resource Not Found

Feature Flag Management¶

FR-FLAG-001 Flag Configuration¶ The Control Plane (TERM-SYS-CP) SHALL allow ACT-OPS Platform Operator to configure Feature Flags for each Tenant.

Realized by:

- Operator Console

Quality Attributes:

- Encryption in Transit
- Least Privilege
- Tenant Scalability
- Availability SLO

Error Conditions:

- Access Denied
- Resource Not Found

FR-FLAG-002 Flag Delivery¶ The system SHALL provide an interface via API-FLAG Feature Flag API for Managed Application (TERM-APP-TARGET) to retrieve the current state of Feature Flags.

Realized by:

- API-FLAG Feature Flag API

Quality Attributes:

- Encryption in Transit
- Key Management
- Availability SLO
- Load Balancing and Failover

Error Conditions:

- Invalid Credentials
- Rate Limit Exceeded

Billing & Usage¶

FR-BILL-001 Billing Event Persistence¶ The Control Plane (TERM-SYS-CP) SHALL persistently record billable events triggers received via FR-BILL-002 Billing Event Ingestion as Billing Events.

Realized by:

- API-BILL Billing Event API

Quality Attributes:

- Encryption in Transit
- Encryption at Rest
- Data Residency
- Tenant Scalability
- Availability SLO
- Backup and Redundancy

Error Conditions:

- Internal Error
- Service Unavailable

FR-BILL-002 Billing Event Ingestion¶ The system SHALL provide an API (API-BILL Billing Event API) that allows Managed Application (TERM-APP-TARGET) to report billable events (corresponding to Billing Events).

Realized by:

- API-BILL Billing Event API

Quality Attributes:

- Encryption in Transit
- Key Management
- Availability SLO
- Load Balancing and Failover

Error Conditions:

- Invalid Credentials
- Invalid Input
- Rate Limit Exceeded

FR-BILL-003 Billing Data Export¶ The Control Plane (TERM-SYS-CP) SHALL provide an interface for External Billing Systems to retrieve Billing Events for invoicing and reconciliation purposes.

Realized by:

- API-BILL Billing Event API

Quality Attributes:

- Encryption in Transit
- Key Management
- Least Privilege
- Data Residency
- Availability SLO

Error Conditions:

- Invalid Credentials
- Access Denied
- Resource Not Found

Audit & Logging¶

FR-LOG-001 Audit Log Collection¶ The Control Plane (TERM-SYS-CP) SHALL collect security and operational logs from all components via API-LOG Audit Log API and persist them as Audit Logs.

Realized by:

- API-LOG Audit Log API

Quality Attributes:

- Encryption in Transit
- Encryption at Rest
- Data Residency
- Availability SLO
- Backup and Redundancy
- Continuous Monitoring

Error Conditions:

- Internal Error
- Service Unavailable

FR-LOG-002 Audit Log Export¶ The Control Plane (TERM-SYS-CP) SHALL allow ACT-AUDIT Auditor to export Audit Logs in CSV format.

Realized by:

- Auditor Console

Quality Attributes:

- Encryption in Transit
- Least Privilege
- Data Residency
- Availability SLO

Error Conditions:

- Access Denied
- Internal Error

FR-LOG-003 Control Plane Auditing¶ The Control Plane (TERM-SYS-CP) SHALL record its own state-changing operations (e.g., Tenant Provisioning, User Management) as Audit Logs.

Quality Attributes:

- Encryption at Rest
- Data Residency
- Availability SLO
- Continuous Monitoring

Error Conditions:

- Internal Error

Platform Operations¶

FR-OPS-001 Tenant Status Management¶ The Control Plane (TERM-SYS-CP) SHALL allow ACT-OPS Platform Operator to modify the status of a Tenant (e.g., Active, Suspended). When a Tenant is Suspended, the system SHALL revoke access for all Users associated with that tenant.

Realized by:

- Operator Console

Quality Attributes:

- Encryption in Transit

- Least Privilege
- Tenant Scalability
- Availability SLO

Error Conditions:

- Access Denied
- Resource Not Found

FR-OPS-002 Tenant Deletion¶ The Control Plane (TERM-SYS-CP) SHALL allow ACT-OPS Platform Operator to permanently delete a Tenant and all associated data upon contract termination or deletion request.

- Upon deletion request, the tenant SHALL enter a 30-day grace period (recoverable).
- After the grace period, all tenant data SHALL be permanently and irrecoverably deleted.
- Deleted data includes: Users, Sessions, Audit Logs, Billing Events, and configuration.

Constrained by: CON-COMP-001 Data Subject Rights

Realized by:

- Operator Console

Quality Attributes:

- Encryption in Transit
- Least Privilege
- Availability SLO

Error Conditions:

- Access Denied
- Resource Not Found
- Resource Gone

FR-OPS-003 Data Retention Enforcement¶ The Control Plane (TERM-SYS-CP) SHALL automatically enforce data retention policies:

- Audit Logs SHALL be retained for a minimum of 7 years, then securely deleted.
- Billing Events SHALL be retained for a minimum of 5 years, then securely deleted.

Constrained by: CON-DATA-002 Audit Log Retention, CON-DATA-003 Billing Data Retention

Realized by:

- Control Plane (TERM-SYS-CP) (automated process)

Quality Attributes:

- Encryption at Rest
- Data Residency
- Availability SLO

Error Conditions:

- Internal Error

System Operations¶

FR-SYS-001 Application Registration¶ The Control Plane (TERM-SYS-CP) SHALL allow ACT-DEV Developer to register a new Managed Application. The system SHALL generate a unique Application ID upon registration.

Quality Attributes:

- Encryption in Transit
- Key Management
- Least Privilege
- Availability SLO

Error Conditions:

- Access Denied
- Invalid Input
- Conflict

FR-SYS-002 API Key Management¶ The Control Plane (TERM-SYS-CP) SHALL allow ACT-DEV Developer to issue API Access Keys for a registered Managed Application. The system SHALL display the Client Secret only once upon issuance. The system SHALL allow ACT-DEV Developer to revoke existing keys.

Quality Attributes:

- Encryption in Transit
- Encryption at Rest
- Key Management

- Least Privilege
- Availability SLO

Error Conditions:

- Access Denied
- Resource Not Found

FR-SYS-003 Application Lifecycle Management¶ The Control Plane (TERM-SYS-CP) SHALL allow ACT-DEV Developer to update the configuration of a Managed Application. The Control Plane (TERM-SYS-CP) SHALL allow ACT-DEV Developer to change the Status (e.g., Disable) to block access.

Quality Attributes:

- Encryption in Transit
- Least Privilege
- Availability SLO

Error Conditions:

- Access Denied
- Resource Not Found

FR-SYS-004 Operator JIT Provisioning¶ The Control Plane (TERM-SYS-CP) SHALL automatically provision a User record for Platform Operators upon their first successful authentication via the external Identity Provider.

- The provisioned user SHALL have `tenant_id` set to NULL (platform-level user).
- The user's `id` SHALL be used as `actor_id` in Audit Logs.
- Subsequent logins SHALL reuse the existing user record.

Quality Attributes:

- Encryption in Transit
- Least Privilege
- Availability SLO
- Continuous Monitoring

Error Conditions:

- Invalid Credentials
- Internal Error

FR-SYS-005 System Health Monitoring¶ The Control Plane (TERM-SYS-CP) SHALL provide a Dashboard or API for Platform Operators to view the real-time health status of system components.

- Status SHALL include connectivity to downstream dependencies (DB, Identity Provider, Event Bus).
- Status SHALL include Error Rates and P99 Latency of key services.

Quality Attributes:

- Continuous Monitoring
- System Health Alerting

Non-Functional Requirements¶

This section defines quality attributes that apply across the system.

Security¶

NFR-SEC-001 Encryption in Transit¶ All network communications SHALL use TLS 1.2 or higher.

Constrained by: CON-SEC-003 Encryption in Transit

NFR-SEC-002 Encryption at Rest¶ All persistent data SHALL be encrypted using AES-256 or equivalent algorithm.

Constrained by: CON-SEC-004 Encryption at Rest

NFR-SEC-003 Multi-Factor Authentication¶ The system SHALL support Multi-Factor Authentication (MFA) for user login. MFA options SHALL include TOTP (Time-based One-Time Password) and WebAuthn.

Constrained by: CON-SEC-005 Multi-Factor Authentication

NFR-SEC-004 Key Management¶ The system SHALL implement secure key management practices including:

- Automated key generation using cryptographically secure methods.
- Periodic key rotation (at least annually).
- Secure key destruction upon expiration or revocation.

Constrained by: CON-SEC-006 Key Management

NFR-SEC-005 Least Privilege¶ The system SHALL enforce the principle of least privilege:

- Users and services SHALL be granted only the minimum permissions required.
- Separation of duties SHALL be implemented for sensitive operations.

Constrained by: CON-SEC-007 Least Privilege

NFR-SEC-006 Adaptive Authentication¶ The system SHOULD implement adaptive (risk-based) authentication that considers:

- User location and device.
- Time of access.
- Behavioral patterns.

When elevated risk is detected, additional authentication factors SHALL be required.

Constrained by: CON-SEC-008 Adaptive Authentication

Data¶

NFR-DATA-001 Data Residency¶ Customer data SHALL be stored exclusively in data centers located in Japan or the European Union.

Constrained by: CON-DATA-001 Data Residency

Capacity¶

NFR-CAP-001 Tenant Scalability¶ The system SHALL scale to support a minimum of 1,000 concurrent active Tenants.

Constrained by: CON-CAP-001 Tenant Capacity

NFR-CAP-002 User Scalability¶ The system SHALL scale to support a minimum of 10,000 Users per Tenant.

Constrained by: CON-CAP-002 User Capacity per Tenant

Availability¶

NFR-OPS-001 Service Level Objective¶ The system SHALL maintain 99.9% availability, excluding scheduled maintenance windows.

Constrained by: CON-OPS-001 Availability SLO

NFR-OPS-002 Maintenance Scheduling¶ Scheduled maintenance windows SHALL be defined and communicated to stakeholders in advance. (Details TBD)

Constrained by: CON-OPS-002 Maintenance Window

NFR-OPS-003 Load Balancing and Failover¶ The system SHALL implement:

- Load balancing to distribute traffic across multiple instances.
- Automatic failover to prevent single points of failure.
- Geographic redundancy where feasible.

Constrained by: CON-OPS-003 Load Balancing and Failover

NFR-OPS-004 Backup and Redundancy¶ The system SHALL implement backup and recovery capabilities:

- Automated regular backups (at least daily).
- 3-2-1 backup rule (3 copies, 2 different media, 1 offsite).
- Backup encryption.
- Regular restore testing (at least annually).

Constrained by: CON-OPS-004 Backup and Redundancy

Performance¶

NFR-PERF-001 Authentication Latency¶ Authentication requests SHALL complete within the following latency targets:

- P95 (95th percentile): < 1000ms
- P99 (99th percentile): < 2000ms

This includes password verification, OIDC/SSO flows, and MFA validation.

Constrained by: CON-PERF-001 Response Time and Throughput

NFR-PERF-002 API Latency¶ General API requests SHALL complete within the following latency targets:

- P95 (95th percentile): < 500ms
- P99 (99th percentile): < 1000ms

Constrained by: CON-PERF-001 Response Time and Throughput

NFR-PERF-003 UI Responsiveness¶ User interface interactions SHALL provide feedback within the following targets:

- Page transitions: < 2 seconds
- Interactive elements: < 400ms perceived response

Constrained by: CON-PERF-001 Response Time and Throughput

NFR-PERF-004 Authentication Throughput¶ The authentication system SHALL support a minimum throughput of:

- 5,000 authentication requests per second (RPS)

This ensures capacity for peak login periods across all tenants.

Constrained by: CON-PERF-001 Response Time and Throughput

Monitoring¶

NFR-MON-001 Continuous Monitoring¶ The system SHALL implement continuous monitoring capabilities:

- Real-time network traffic analysis.
- User and Entity Behavior Analytics (UEBA) for anomaly detection.
- Automated alerting for suspicious activities.

Constrained by: CON-MON-001 Continuous Monitoring

NFR-MON-002 System Health Alerting¶ The system SHALL proactively notify Platform Operators via multiple channels (Email, Slack, PagerDuty) when:

- Error rate exceeds defined thresholds (e.g., > 1% in 5 minutes).
- Latency (P99) exceeds defined SLOs.
- System health checks fail.

NFR-MON-003 Synthetic Monitoring¶ The system SHALL implement Synthetic Monitoring (Canary) to verify critical customer journeys (Login, Tenant Creation) at regular intervals (e.g., every 5 minutes), independent of real user traffic.

Constraints and Assumptions¶

This section documents the mandatory conditions imposed on the system.

Security Constraints¶

CON-SEC-001 Configurable Password Policy¶ The Control Plane (TERM-SYS-CP) SHALL allow each Tenant to configure password complexity requirements (e.g., minimum length, character types).

Rationale: Compliance with Japan's Act on the Protection of Personal Information (APPI).

CON-SEC-002 Audit Log Provision¶ The Control Plane (TERM-SYS-CP) SHALL provide audit logs recording access to and modifications of personal data.

Rationale: Compliance with Japan's Act on the Protection of Personal Information (APPI).

CON-SEC-003 Encryption in Transit¶ All communications between components and external systems SHALL be encrypted using TLS 1.2 or higher.

Rationale: NIST CSF 2.0 / ISO 27001 - Encryption in transit.

CON-SEC-004 Encryption at Rest¶ All persistent data SHALL be encrypted at rest using AES-256 or equivalent.

Rationale: NIST CSF 2.0 / ISO 27001 - Encryption at rest.

CON-SEC-005 Multi-Factor Authentication¶ The system SHALL support Multi-Factor Authentication (MFA) for user login.

Rationale: NIST CSF 2.0 - Strong authentication.

CON-SEC-006 Key Management¶ The system SHALL implement secure key management practices.

Rationale: NIST CSF 2.0 - Data protection.

CON-SEC-007 Least Privilege¶ The system SHALL enforce the principle of least privilege.

Rationale: NIST CSF 2.0 - Access control.

CON-SEC-008 Adaptive Authentication¶ The system SHOULD implement adaptive (risk-based) authentication.

Rationale: NIST CSF 2.0 - Context-aware security.

CON-SEC-009 Error Disclosure¶ Error responses SHALL NOT reveal sensitive internal details including:

- Stack traces or internal exception messages

- Database query details
- Internal service names or versions
- User existence confirmation (for security-sensitive operations)

Rationale: NIST CSF 2.0 / OWASP - Information disclosure prevention.

Data Constraints¶

CON-DATA-001 Data Residency¶ All customer data SHALL be stored exclusively in data centers located in Japan or the European Union.

Rationale: GDPR / APPI - Cross-border data transfer restrictions.

CON-DATA-002 Audit Log Retention¶ Audit Logs SHALL be retained for a minimum of 7 years to comply with Japanese accounting laws and APPI requirements.

Rationale: Legal compliance (Japan Accounting Law, APPI).

CON-DATA-003 Billing Data Retention¶ Billing Events SHALL be retained for a minimum of 5 years to comply with tax regulations.

Rationale: Legal compliance (Tax regulations).

Capacity Constraints¶

CON-CAP-001 Tenant Capacity¶ The system SHALL support a minimum of 1,000 active Tenants.

Rationale: Business scalability requirement.

CON-CAP-002 User Capacity per Tenant¶ The system SHALL support a minimum of 10,000 Users per Tenant.

Rationale: Business scalability requirement.

Operational Constraints¶

CON-OPS-001 Availability SLO¶ The system SHALL target a Service Level Objective (SLO) of 99.9% availability, excluding scheduled maintenance windows.

Rationale: Business continuity requirement.

CON-OPS-002 Maintenance Window¶ Scheduled maintenance windows SHALL be defined and communicated in advance. (Details TBD)

Rationale: Operational planning.

CON-OPS-003 Load Balancing and Failover¶ The system SHALL implement load balancing and automatic failover.

Rationale: NIST CSF 2.0 - Availability.

CON-OPS-004 Backup and Redundancy¶ The system SHALL implement backup and recovery capabilities following the 3-2-1 rule.

Rationale: NIST CSF 2.0 - Recovery.

Monitoring Constraints¶

CON-MON-001 Continuous Monitoring¶ The system SHALL implement continuous monitoring and anomaly detection.

Rationale: NIST CSF 2.0 - Detection.

Development Constraints¶

CON-DEV-001 Secure Software Development Lifecycle¶ All software development SHALL follow Secure SDLC practices:

- Security by Design principles.
- Static and dynamic code analysis.
- Code review for security vulnerabilities.
- Dependency vulnerability scanning.

Rationale: NIST CSF 2.0 - Software integrity.

CON-DEV-002 Supply Chain Risk Management¶ The project SHALL implement Cyber Supply Chain Risk Management (C-SCRM):

- Inventory of third-party dependencies.
- Regular vulnerability assessment of dependencies.
- Risk evaluation of third-party service providers.

Rationale: NIST CSF 2.0 - Supply chain security.

Compliance Constraints¶

CON-COMP-001 Data Subject Rights¶ The system SHALL support data subject rights as required by GDPR and Japan APPI:

- Right to access personal data.
- Right to rectification.
- Right to erasure (right to be forgotten).
- Data portability.

Rationale: Legal compliance with privacy regulations.

Performance Constraints¶

CON-PERF-001 Response Time and Throughput¶ The system SHALL meet performance targets for latency and throughput to ensure a responsive user experience.

Rationale: User-Centricity principle - responsive systems improve user satisfaction.

Data Model¶

Schema Definitions¶ This section defines the core data entities managed by the Control Plane.

Tenants¶ Represents a customer organization subscribed to the Managed Application.

Field	Type	Description
id	UUID	Unique identifier for the tenant.
name	String	Display name of the organization.
domain	String	Unique domain identifier for the tenant (e.g., `acme`).
plan	Enum	Subscription plan (e.g., `Free`, `Pro`, `Enterprise`).
status	Enum	Account status (`Active`, `Suspended`).
created_at	Timestamp	Record creation time.

Users¶ Represents an individual user belonging to a Tenant or the Platform.

Field	Type	Description
id	UUID	Unique identifier for the user.
tenant_id	UUID	Foreign Key to Tenants. Null for Platform Operators.
email	String	Unique email address used for login.
role	Enum	Access level (Roles).

Field	Type	Description
status	Enum	User status (`Invited`, `Active`, `Disabled`).

Roles¶ Enumeration of defined user roles.

- **Owner**: Full access to tenant configuration, billing, and user management.
- **Administrator**: Access to user management and tenant configuration (excluding billing).
- **User**: Access to the Managed Application features only.
- **Operator**: (Platform level) Full access to the Control Plane.

Feature Flags¶ Controls the availability of features for specific tenants.

Field	Type	Description
id	UUID	Unique identifier.
tenant_id	UUID	Foreign Key to Tenants.
key	String	Feature identifier (e.g., `ai_module_enabled`).
value	Boolean	State of the feature (True/False).

Audit Logs¶ Immutable record of system events for security and compliance.

Field	Type	Description
id	UUID	Unique identifier.
timestamp	Timestamp	Time when the event occurred.
actor_id	String	ID of the user or system component initiating the action.
actor_type	Enum	Type of actor (`User`, `Operator`, `System`).
action	String	Description of the operation (e.g., `tenant.create`).
resource	String	Identifier of the target resource.
outcome	Enum	Result of the operation (`Success`, `Failure`).
metadata	JSON	Additional context (e.g., previous values, IP address).

Managed Applications¶ Represents a registered Managed Application instance that interacts with the Platform APIs.

Field	Type	Description
id	UUID	Unique identifier.

Field	Type	Description
name	String	Name of the application.
owner_id	String	Identifier of the Developer or owner.
status	Enum	Registration status (`Active`, `Disabled`).

API Access Keys¶ Credentials used by Managed Applications to authenticate against Control Plane APIs.

Field	Type	Description
id	UUID	Unique key identifier (KID).
app_id	UUID	Foreign Key to Managed Applications.
key_hash	String	Secure hash of the API Secret.
scopes	String[]	List of allowed API scopes (e.g., `bill:write`, `log:write`).
created_at	Timestamp	Issuance time.
expires_at	Timestamp	Expiration time (optional).

SSO Configuration¶ Stores the Identity Provider details for a Tenant.

Field	Type	Description
id	UUID	Unique identifier.
tenant_id	UUID	Foreign Key to Tenants.
issuer_url	String	OIDC Issuer URL.
client_id	String	Client Identifier at IdP.
secret	String	Encrypted Client Secret.
created_at	Timestamp	Configuration time.

User Invitations¶ Tracks pending invitations for new users.

Field	Type	Description
id	UUID	Unique identifier.
tenant_id	UUID	Foreign Key to Tenants.
email	String	Target email address.
role	Enum	Proposed role (Roles).
token	String	Unique token sent via email.
expires_at	Timestamp	Token expiration time.
status	Enum	Invitation status (`Pending`, `Accepted`, `Expired`).

Billing Events¶ Raw records of billable activities reported by applications.

Field	Type	Description
id	UUID	Unique identifier.
tenant_id	UUID	Foreign Key to Tenants.
app_id	UUID	Foreign Key to Managed Applications.
event_type	String	Type of billable action (e.g., `api_call`, `storage_gb`).
quantity	Integer	Amount consumed.
timestamp	Timestamp	Event occurrence time.

User Sessions¶ Represents an active login session for a User.

Field	Type	Description
id	UUID	Unique identifier for the session.
user_id	UUID	Foreign Key to Users.
token	String	Secure session token or JWT reference.
created_at	Timestamp	Session creation time.
expires_at	Timestamp	Session expiration time.
status	Enum	Session status (`Active`, `Revoked`).

Interface Requirements¶

User Interfaces¶ This section defines the primary User Interfaces (UI) provided by the Control Plane.

IF-OPS-CONSOLE Operator Console¶ **User**: ACT-OPS Platform Operator **Description**: The administrative web portal for Platform Operators. Provides capabilities for tenant provisioning, feature flag management, and system monitoring.

IF-TENANT-CONSOLE Tenant Administration Console¶ **User**: ACT-USER Tenant User (Owner, Admin) **Description**: The self-service web portal for Tenant Administrators. Provides capabilities to list users, manage roles and status (e.g., Disable), revoke sessions, send invitations, configure SSO, and view subscription details.

IF-AUDIT-CONSOLE Auditor Console¶ **User**: ACT-AUDIT Auditor **Description**: The compliance and observation portal for Auditors. Provides read-only access to system audit logs and reporting capabilities.

IF-LOGIN-UI Universal Login Page¶ **User**: ACT-USER Tenant User, ACT-OPS Platform Operator, ACT-AUDIT Auditor **Description**: The centralized login page presented to all users. Supports input for Email/Password, redirects for SSO/OIDC authentication, and provides access to password reset workflows.

Interface Requirements¶ This section defines the external interfaces provided by the system.

API-BILL Billing Event API¶ **Type**: REST API **Direction**: Bidirectional (Managed Application (TERM-APP-TARGET) <-> Control Plane (TERM-SYS-CP) / ACT-BILLING External Billing System <- Control Plane (TERM-SYS-CP)) **Purpose**: To report billable operations from managed applications and to retrieve billing events for invoicing. **Payload**: SHALL include Tenant ID, Timestamp, Event Type, and Quantity.

API-LOG Audit Log API¶ **Type**: REST API **Direction**: Input (Managed Application (TERM-APP-TARGET) -> Control Plane (TERM-SYS-CP)) **Purpose**: To report security and operational events for audit purposes. **Payload**: SHALL include Timestamp, Actor ID, Event Type, Resource ID, Outcome, and IP Address.

API-FLAG Feature Flag API¶ **Type**: REST API **Direction**: Output (Control Plane (TERM-SYS-CP) -> Managed Application (TERM-APP-TARGET)) **Purpose**: To retrieve the active feature flags for a specific tenant. **Caching**: Managed apps SHOULD cache this response to minimize latency.

Error Handling¶

This section documents error definitions. Errors define failure outcomes for Functional Requirements - what happens when an operation fails.

Error Definition Structure¶ Each error SHALL include:

- **Description**: Semantic meaning of the error
- **Triggers**: Conditions that cause the error
- **Outcome**: Observable result when the error occurs
- **Related Requirements**: FRs that may produce this error
- **Constraints**: CONs that restrict error handling (if applicable)

Authentication & Authorization Errors¶ ERR-AUTH-401 Invalid Credentials¶

Description: Authentication failed due to invalid credentials.

Triggers:

- Incorrect password
- Invalid or expired authentication token
- Unknown username/email

Outcome:

- Authentication is denied
- No session is established

Constraints:

- Error Disclosure

ERR-AUTH-403 Access Denied¶

Description: An authenticated user attempted an operation they are not authorized to perform.

Triggers:

- Insufficient role or permissions
- Attempting to access another tenant's resources
- Disabled user account

Outcome:

- Operation is rejected
- No state change occurs

Constraints:

- Error Disclosure

ERR-AUTH-440 Session Expired¶

Description: The user's session has expired or been invalidated.

Triggers:

- Session timeout
- Administrative session revocation
- Password change
- User deletion or disabling

Outcome:

- Current operation is rejected
- User must re-authenticate

ERR-AUTH-461 MFA Required¶

Description: Multi-factor authentication is required but not provided.

Triggers:

- MFA is enabled for the user/tenant
- Adaptive authentication detected elevated risk

Outcome:

- Authentication flow pauses
- User is prompted for MFA verification

Constraints:

- MFA

Validation Errors¶ ERR-VAL-400 Invalid Input¶

Description: The request contains invalid or malformed input data.

Triggers:

- Missing required fields
- Invalid data format
- Value out of allowed range

Outcome:

- Operation is rejected
- No state change occurs

ERR-VAL-409 Conflict¶

Description: The operation conflicts with existing state.

Triggers:

- Duplicate email address in invitation
- Attempting to create a resource that already exists
- Concurrent modification conflict

Outcome:

- Operation is rejected
- Existing state is preserved

ERR-VAL-422 Business Rule Violation¶

Description: The operation violates a business rule or policy.

Triggers:

- Password does not meet complexity requirements
- Invitation has expired
- Tenant capacity exceeded

Outcome:

- Operation is rejected
- No state change occurs

Resource Errors¶ ERR-RES-404 Resource Not Found¶

Description: The requested resource does not exist.

Triggers:

- Invalid resource ID
- Resource has been deleted
- Resource belongs to a different tenant

Outcome:

- Operation is rejected
- No state change occurs

Constraints:

- Error Disclosure

ERR-RES-410 Resource Gone¶

Description: The resource previously existed but has been permanently deleted.

Triggers:

- Tenant has been deleted (past grace period)
- Data retention policy applied

Outcome:

- Operation is rejected
- Resource cannot be recovered

Rate Limit Errors¶ ERR-RATE-429 Rate Limit Exceeded¶

Description: The client has exceeded the allowed request rate.

Triggers:

- Too many requests in a short period
- Authentication attempt rate limiting
- API call quota exceeded

Outcome:

- Current request is rejected
- Client should wait and retry

Constraints:

- Response Time and Throughput

System Errors¶ ERR-SYS-500 Internal Error¶

Description: An unexpected internal error occurred.

Triggers:

- Unhandled exception
- Database connection failure
- Dependency service unavailable

Outcome:

- Operation fails
- State may be inconsistent (should be recoverable)

Constraints:

- Error Disclosure

ERR-SYS-503 Service Unavailable¶

Description: The service is temporarily unavailable.

Triggers:

- Scheduled maintenance
- System overload
- Failover in progress

Outcome:

- Operation is rejected

- Client should retry later

Constraints:

- Maintenance Window

Future Considerations¶

Roadmap¶ This section outlines potential future enhancements and features that are currently out of scope but may be considered for future releases.

FC-AUTH-SAML SAML Authentication Support¶ **Status**: Future Consideration **Description**: Support for Security Assertion Markup Language (SAML) 2.0 based Single Sign-On (SSO). Currently, the system only supports OIDC for simplicity and modern standards compliance, but SAML remains a common requirement for enterprise customers.

Architecture Description¶

Purpose This document describes the architecture of the system, focusing on *how* it satisfies the requirements defined in the Specification.

Stakeholders - Developers - Architects - System Operators

Viewpoints This documentation follows the **arc42** template and utilizes **C4 model** diagrams.

Contents:

Introduction and Goals¶

This section outlines the driving forces behind the architecture.

Requirements Overview¶ The system's functional and non-functional requirements are detailed in the Specification.

See Background and Motivation for the project context.

Quality Goals¶ The architecture prioritizes the following NFR categories:

- Security
- Performance
- Availability

Refer to the specific NFR documents for detailed metrics.

Architecture Constraints¶

This section references the constraints that limit the architectural freedom.

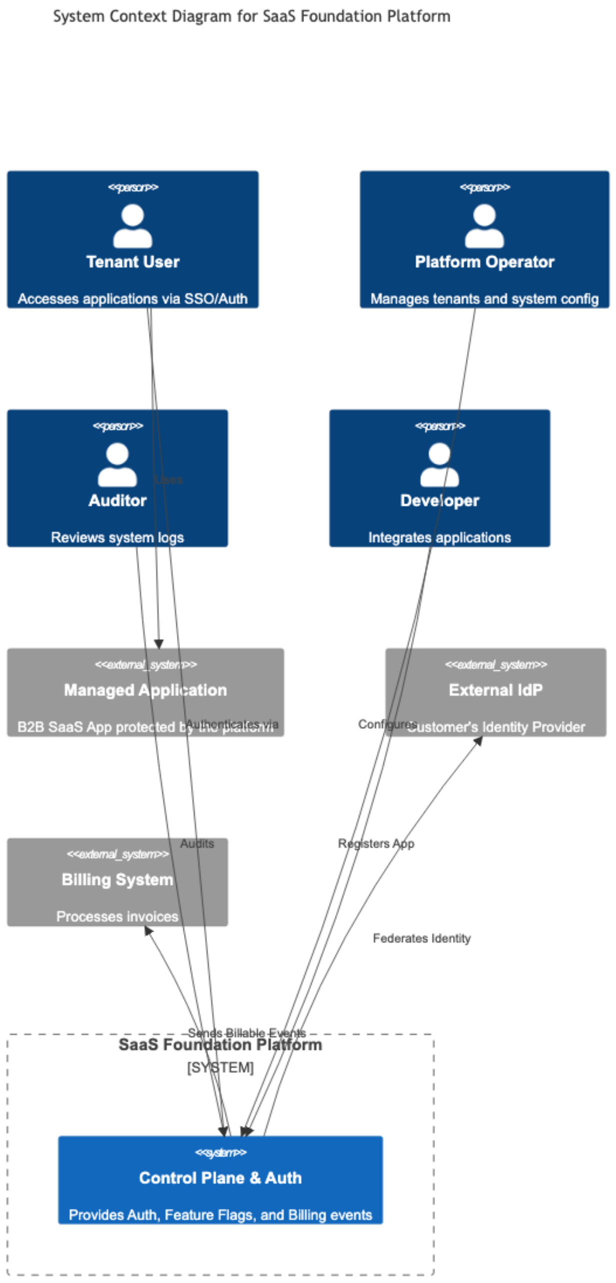
No New Constraints This architecture documentation introduces **no new constraints**. All binding constraints are defined in the Specification.

Normative Constraints¶ Refer to Constraints and Assumptions for the authoritative definitions.

- **Constraints**: CON-* declarations.
- **Assumptions**: ASM-* declarations.

Context View¶

This section describes the system's boundaries and interactions with external actors and systems.



System Context Diagram (level 1)¶

External Elements¶ The following actors and systems interact with the SaaS Foundation Platform.

Actors¶

- [**CTX-ACT-001**] **Tenant User**: ACT-USER
- [**CTX-ACT-002**] **Platform Operator**: ACT-OPS
- [**CTX-ACT-003**] **Auditor**: ACT-AUDIT
- [**CTX-ACT-004**] **Developer**: ACT-DEV

External Systems¶

- [**CTX-EXT-001**] **Managed Application**: TERM-APP-TARGET
- [**CTX-EXT-002**] **External Billing System**: ACT-BILLING
- [**CTX-EXT-003**] **External Identity Provider**: OIDC-compliant IdP (e.g., Azure Entra ID). * See [ADR-AUTH-002] Select Azure Entra ID External Identities for Authentication.

Scope Boundaries¶

- **In-Scope**: Authentication, Feature Flags, Logging (See Scope).
- **Out-of-Scope**: Payment Processing, Operator IdP Management.

Solution Strategy¶

This section describes the fundamental decisions and solution strategies that shape the architecture.

Architectural Patterns¶ The system follows a **Modular Monolith** or **Service-Oriented Architecture (SOA)** approach, centered around a centralized **Control Plane**.

- **Separation of Concerns**: The Control Plane is strictly separated from the Managed Applications.
- **API-First**: All functionality is exposed via defined APIs (API-*).

Quality Goals Strategy¶ This strategy addresses the key NFRs as follows:

- **Security**: Centralized Authentication (FR-AUTH) ensures consistent identity management across all apps. See NFR-SEC-*.
- **Auditability**: Sync/Async event recording (FR-LOG) ensures all critical actions are traceable.

- **Extensibility**: Feature Flags (FR-FLAG) allow dynamic feature management without redeployment.

Technology Independence¶ This architecture does not mandate specific programming languages or frameworks, provided they satisfy the Interface Requirements.

Building Block View¶

This section decomposes the system into its building blocks (modules, components). The architecture follows a **Microservices** approach utilizing **Managed Services** (see [ADR-ARCH-001] Adopt Microservices Architecture).

Level 1: System Whitebox (Container View)¶

Component Description¶

- **[BB-UI-001] Web Console (SPA)**: * **Responsibility**: Single Page Application providing Administrative interfaces for Operators and Tenants. * **Related FRs**:
    - Operator Console
    - Tenant Administration Console
    - Auditor Console
    - Universal Login Page
  - **Related NFRs**: * UI Responsiveness
- **[BB-API-001] API Gateway**: * **Responsibility**: Entry point for all external requests. Handles routing, rate limiting, and authentication offloading. * **Related FRs**:
    - API Key Management
  - **Related NFRs**:
    * Load Balancing and Failover
    * Authentication Latency
- **[BB-AUTH-001] Auth Service**: * **Responsibility**: Manages user identities and credentials via External IdP. * **Related FRs**:
    - Supported Authentication Methods
    - Tenant SSO Configuration
    - Password Reset
    - Session Management

    - Password Policy Configuration
  - **Related NFRs**:
    * Multi-Factor Authentication
    * Adaptive Authentication
    * User Scalability
- [**BB-TNT-001**] **Tenant Service**: * **Responsibility**: Manages Tenant lifecycle (onboarding, configuration, suspension). * **Related FRs**:
    - User Invitation
    - User Deletion
    - Contract Modification
    - User Role Management
    - User Status Management
    - Invitation Resend
    - Tenant Status Management
    - Tenant Deletion
    - Operator JIT Provisioning
  - **Related NFRs**:
    * Tenant Scalability
    * Data Residency
- [**BB-FLG-001**] **Feature Flag Service**: * **Responsibility**: Delivers dynamic configuration and feature toggles to the Application. * **Related FRs**:
    - Flag Configuration
    - Flag Delivery
  - **Related NFRs**:
    * API Latency
- [**BB-BIL-001**] **Billing Service**: * **Responsibility**: Aggregates usage metrics and interfaces with external Billing System. * **Related FRs**:
    - Billing Event Persistence
    - Billing Event Ingestion
    - Billing Data Export
  - **Related NFRs**:

    * Backup and Redundancy

- **[BB-AUD-001] Audit Service**: * **Responsibility**: Ingests and archives security and operational logs. * **Related FRs**:
    - Audit Log Collection
    - Audit Log Export
    - Control Plane Auditing
  - **Related NFRs**:
    * Continuous Monitoring
- **[BB-OBS-001] Observability Platform**: * **Responsibility**: Centralized collection and visualization of Metrics, Logs, and Traces. Handles Alerting and Synthetics. * **Related FRs**:
    - System Health Monitoring
  - **Related NFRs**: * System Health Alerting * Synthetic Monitoring * Continuous Monitoring
- **[BB-CICD-001] CI/CD Service**: * **Responsibility**: Automation of Build, Test, Security Scanning, and Deployment processes. * **Related NFRs**:
    - Availability SLO (Deployment Safety)
  - **Decision**: [ADR-OPS-002] CI/CD Platform Selection
- **[BB-EVT-001] Event Bus**: * **Responsibility**: Asynchronous message broker for decoupling services (Publish/Subscribe pattern). * **Related FRs**:
    - Infrastructure component supporting all Event-Driven FRs.
  - **Related NFRs**:
    * Load Balancing and Failover

Internal Structure¶ The internal structure of each microservice follows a standard **Layered / Hexagonal Architecture** to ensure testability and consistency. For the detailed component pattern, see [ADR-ARCH-001] Adopt Microservices Architecture.

Runtime View¶

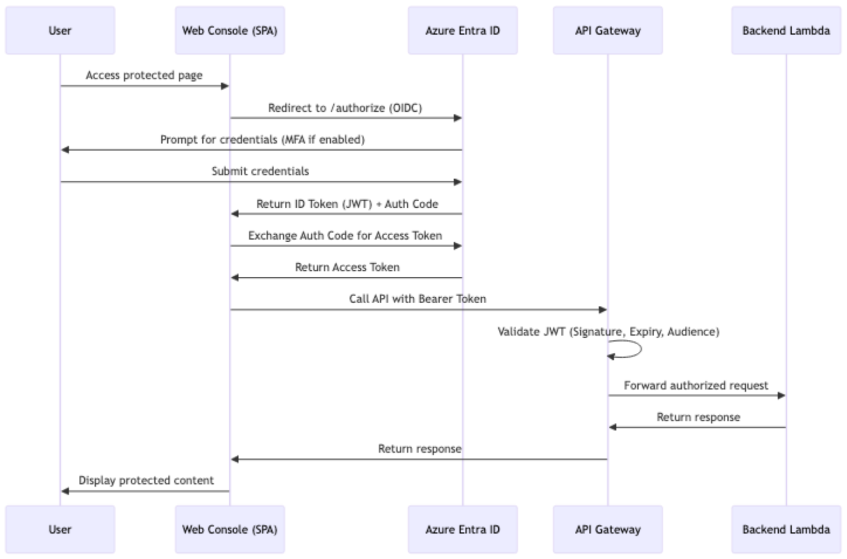
This section describes concrete behavior and interactions between building blocks in the form of **scenarios**. Each scenario shows the “time-axis story” of how components collaborate to fulfill a requirement, governed by Cross-Cutting rules.

RT-001 User Login (OIDC)¶

Scenario¶ A user authenticates via the external Identity Provider (Azure Entra ID) and gains access to the Web Console.

Actors¶

- User
- Web Console (SPA)
- Auth Service (External IdP)
- API Gateway


User
Web Console (SPA)
Azure Entra ID
API Gateway
Backend Lambda
Access protected page
Redirect to /authorize (OIDC)
Prompt for credentials (MFA if enabled)
Submit credentials
Return ID Token (JWT) + Auth Code
Exchange Auth Code for Access Token
Return Access Token
Call API with Bearer Token
Validate JWT (Signature, Expiry, Audience)
Forward authorized request
Return response
Return response
Display protected content
User
Web Console (SPA)
Azure Entra ID
API Gateway
Backend Lambda

Flow¶

Cross-cutting¶

- CC-AUTH-001 (Delegate Auth to External IdP)
- CC-AUTH-002 (Stateless JWT validation)
- CC-LOG-001 (Correlation ID propagated)

Requirements¶

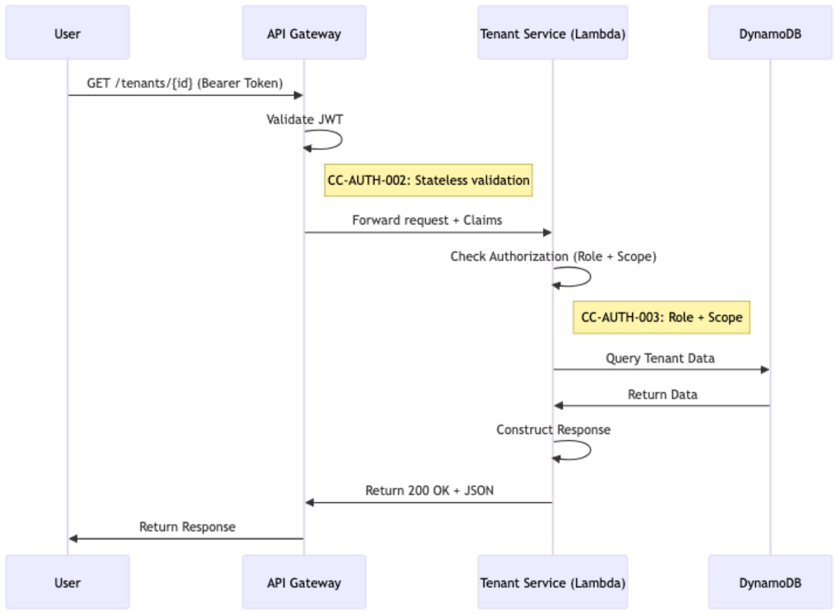
- FR-AUTH-001 Supported Authentication Methods (Supported Authentication Methods)
- NFR-PERF-001 Authentication Latency (Authentication Latency)

RT-002 Authenticated API Request¶

Scenario¶ An authenticated user makes a REST API call to retrieve tenant information.

Actors¶

- User
- API Gateway
- Tenant Service



Flow¶

Cross-cutting¶

- CC-AUTH-002 (Stateless JWT)
- CC-AUTH-003 (Role + Scope Authorization)
- CC-LOG-001 (Correlation ID)
- CC-API-001 (REST + JSON)

Requirements¶

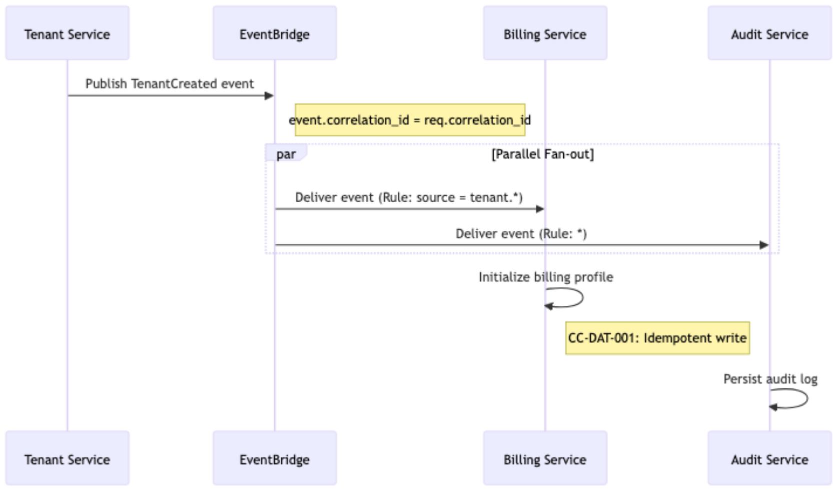
- FR-TENANT-001 User Invitation (User Invitation / Tenant context)
- NFR-PERF-002 API Latency (API Latency)

RT-003 Async Event Processing¶

Scenario¶ A domain event (e.g., TenantCreated) is published and consumed by multiple services asynchronously.

Actors¶

- Tenant Service
- Event Bus
- Billing Service
- Audit Service



Flow¶

Cross-cutting¶

- CC-LOG-001 (Correlation ID propagation)
- CC-DAT-001 (Idempotent writes)
- CC-DAT-002 (Eventual Consistency)

Requirements¶

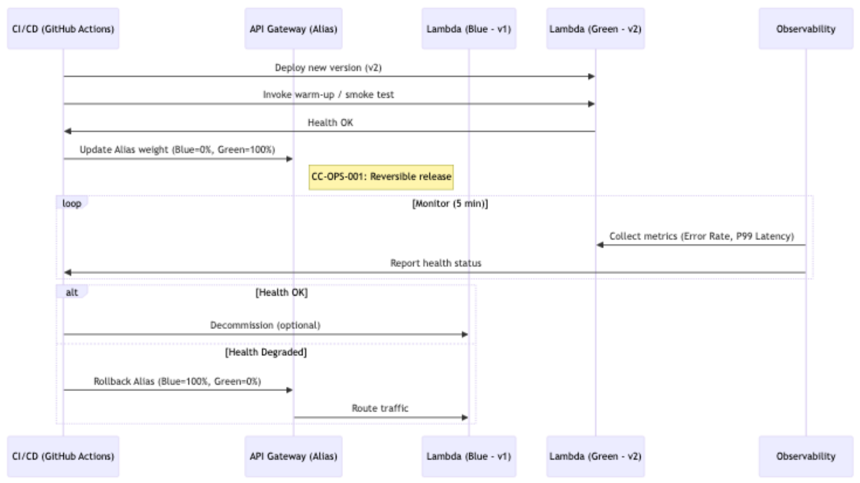
- FR-BILL-002 Billing Event Ingestion (Billing Event Ingestion)
- FR-LOG-001 Audit Log Collection (Audit Log Collection)
- NFR-OPS-003 Load Balancing and Failover (Failover / Event Delivery)

RT-004 Blue-Green Switchover¶

Scenario¶ A new version is deployed to Production using Blue-Green deployment. Traffic is switched from Blue (old) to Green (new).

Actors¶

- CI/CD Service
- API Gateway
- Observability Platform



Flow¶

Cross-cutting¶

- CC-OPS-001 (Reversible release)
- CC-OPS-002 (Immutable artifact)
- CC-OBS-001 (SLI/SLO driven)

Requirements¶

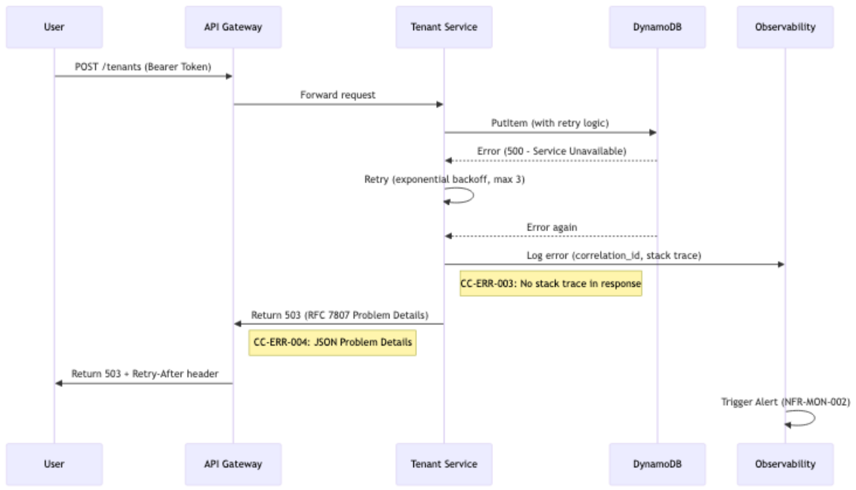
- NFR-OPS-001 Service Level Objective (Availability SLO)
- NFR-OPS-002 Maintenance Scheduling (MTTR)

RT-005 Error Handling Flow¶

Scenario¶ An API request fails due to a downstream service error. The system logs the error, returns a structured response, and retries if applicable.

Actors¶

- User
- API Gateway
- Tenant Service
- Observability Platform


User
API Gateway
Tenant Service
DynamoDB
Observability
POST /tenants (Bearer Token)
Forward request
PutItem (with retry logic)
Error (500 - Service Unavailable)
Retry (exponential backoff, max 3)
Error again
Log error (correlation_id, stack trace)
CC-ERR-003: No stack trace in response
Return 503 (RFC 7807 Problem Details)
CC-ERR-004: JSON Problem Details
Return 503 + Retry-After header
Trigger Alert (NFR-MON-002)

Flow¶

Cross-cutting¶

- CC-ERR-001 (Map to HTTP codes)
- CC-ERR-002 (Business vs System errors)
- CC-ERR-003 (No stack trace exposure)
- CC-ERR-004 (RFC 7807)
- CC-LOG-001 (Correlation ID)

Requirements¶

- NFR-OPS-001 Service Level Objective (Availability SLO)
- NFR-MON-002 System Health Alerting (System Health Alerting)

Deployment View¶

This section describes the technical infrastructure where the system executes. The system is deployed on **AWS (Amazon Web Services)** using a completely

Serverless model to minimize operational overhead (ADR-ARCH-001). Network strategy follows a **No-VPC / Identity-Based Security** model relying on IAM and TLS (ADR-INF-001).

Infrastructure Level 1¶

Mapping to Infrastructure¶ This table maps the conceptual building blocks to concrete AWS Managed Services.

- **[DEP-AWS-001] API Gateway**: * **AWS Service**: Amazon API Gateway * **Mapping**: BB-API-001 * **Configuration Details**:
    - HTTP APIs (v2) for lower latency and cost.
- **[DEP-AWS-006] Web Console (SPA)**: * **AWS Service**: CloudFront + S3 + Lambda@Edge + **Amazon API Gateway + AWS Lambda** * **Mapping**: BB-UI-001 * **Configuration Details**:
    - Hosting for static assets (React/TS). Lambda@Edge for security headers.
    - **BFF (Backend for Frontend)**: Specific API endpoints (e.g., config, session) served via APIGW + Lambda.
- **[DEP-AZU-001] Auth Service**: * **AWS Service**: Azure Entra ID (External) * **Mapping**: BB-AUTH-001 * **Configuration Details**:
    - External Identities (CIAM). OIDC integration.
- **[DEP-AWS-002] Compute (Lambda)**: * **AWS Service**: AWS Lambda * **Mapping**: BB-TNT-001, BB-BIL-001, BB-AUD-001 * **Configuration Details**:
    - Python 3.x runtime. Deployed via Terraform.
  - **Decision**: [ADR-TECH-001] Language and Runtime Selection, [ADR-TECH-002] Infrastructure as Code (IaC) Tool Selection
- **[DEP-AWS-003] Data Store**: * **AWS Service**: Amazon DynamoDB * **Mapping**: BB-TNT-001, BB-BIL-001 (Persistence) * **Configuration Details**:
    - On-Demand Capacity mode.
  - **Decision**: [ADR-DATA-001] Data Persistence Strategy
- **[DEP-AWS-004] Event Bus**: * **AWS Service**: Amazon EventBridge * **Mapping**: BB-EVT-001 * **Configuration Details**:
    - Custom Registry for domain events.
- **[DEP-AWS-005] Feature Flags**: * **AWS Service**: AWS AppConfig * **Mapping**: BB-FLG-001 * **Configuration Details**:

    - Freeform configuration profile.

- **[DEP-AWS-007] Observability & Archive**: * **AWS Service**: CloudWatch Logs / S3 * **Mapping**: BB-AUD-001, BB-OBS-001 * **Configuration Details**:
    - CloudWatch for real-time logs (Retention: 30 days). S3 Glacier for long-term audit archive (Retention: 7 years).
- **[DEP-AWS-008] Backup**: * **AWS Service**: AWS Backup * **Mapping**: BB-TNT-001, BB-BIL-001 * **Configuration Details**:
    - Centralized backup policy. DynamoDB PITR (Point-in-Time Recovery) enabled (35 days).
- **[DEP-AWS-009] Web Application Firewall**: * **AWS Service**: AWS WAF * **Mapping**: BB-UI-001 (CloudFront), BB-API-001 (API Gateway) * **Configuration Details**:
    - Protects against common web exploits (OWASP Top 10) and bots. Managed Rules enabled.

Environment Strategy¶ To ensure stability, we utilize a multi-account strategy with strict promotion rules (CC-OPS-002).

Environment	Purpose & Configuration	References
[DEP-ENV-001] Development	**Purpose**: Integration testing for developers.	• Development Methodology
[DEP-ENV-002] Staging	**Purpose**: Pre-production verification (E2E, Load Tests).	• CC-OPS-002
[DEP-ENV-003] Production	**Purpose**: Live traffic. High Availability.	• NFR-OPS-001 Service Level Objective

Deployment Strategy¶ We adopt **Blue-Green Deployment** to achieve Zero Downtime and Immediate Rollback capabilities.

- **[DEP-OPS-001] Blue-Green Switchover**: * **Mechanism**: Traffic shifting via API Gateway Stages / Lambda Aliases. * **Procedure**:
    1. Deploy new version (Green) alongside active version (Blue).
    2. Run Smoke Tests against Green endpoint.

    3. Update Routing Weight to 100% Green.
    4. Monitor Error Rates (Red Metrics).
    5. *If success*: Deprovision Blue after stabilization period.
    6. *If failure*: Atomically revert Routing to 100% Blue.
  - **Decision**: [ADR-OPS-001] Deployment Strategy Implementation
  - **Decision**: [ADR-OPS-001] Deployment Strategy Implementation
  - **Principles**: CC-OPS-001 (Reversibility), CC-OPS-003 (DB Compatibility).
- **[DEP-OPS-002] CI/CD Pipeline**: * **Automated Flow**:
    1. **Pull Request**: Run Linting (Ruff), Unit Tests (Pytest), and Security Scans (Trivy).
    2. **Merge to Main**: Trigger Build Artifact (Lambda Zip).
    3. **Deploy Dev**: Deploy to Development environment. Run Integration Tests.
    4. **Promote Staging**: Deploy same artifact to Staging (CC-OPS-002). Run E2E / Load Tests.
    5. **Manual Approval**: Operator approves promotion to Production.
    6. **Promote Production**: Trigger Blue-Green Deployment (DEP-OPS-001).
  - **Mechanism**: GitHub Actions Workflows.
  - **Decision**: [ADR-OPS-002] CI/CD Platform Selection
  - **Principles**: CC-OPS-002 (Immutable), CC-OPS-004 (Pipeline as Code).

NFR Satisfaction¶ This deployment structure supports:

- **Availability**: Relies on AWS Multi-AZ availability for Lambda, DynamoDB, and API Gateway (implicitly HA).
- **Scalability**: All selected services (Lambda, DynamoDB On-Demand) scale to zero and burst automatically.
- **Operational Efficiency**: No servers to patch or manage (NoOps).

Cross-cutting Concepts¶

This section describes the **Design Constitution**: the permanent rules and principles that apply across all architectural building blocks.

Authentication and Authorization¶ *Delegate identity management to specialized providers.*

Development Methodology¶ *AI Agents as primary developers.*

- **Rule [CC-DEV-001]**: Technology selection SHALL prioritize **AI Proficiency** (accuracy of LLM code generation) and **Ecosystem Maturity** over human learning curves. * **Decision**: [ADR-TECH-001] Language and Runtime Selection (Python), [ADR-TECH-002] Infrastructure as Code (IaC) Tool Selection (Terraform).

Authentication and Authorization¶

- **Rule [CC-AUTH-001]**: Authentication SHALL be delegated to an External Identity Provider (OIDC compliant). * **Decision**: [ADR-AUTH-002] Select Azure Entra ID External Identities for Authentication (Azure Entra ID). * **Root**:
    - FR-AUTH-001 Supported Authentication Methods (Auth Methods)
- **Rule [CC-AUTH-002]**: Services SHALL be Stateless. Trust Identity/Access Tokens (JWT) verified via public keys. * **Root**:
    - NFR-CAP-002 User Scalability (User Scalability)
    - NFR-PERF-001 Authentication Latency (Auth Latency)
- **Rule [CC-AUTH-003]**: Authorization SHALL use a Role + Scope model. * **Role**: Coarse-grained access (e.g., TenantAdmin, User). * **Scope**: Fine-grained permissions (e.g., billing:read). * **Root**:
    - FR-AUTH-003 Tenant SSO Configuration (SSO Config)
    - NFR-SEC-005 Least Privilege (Least Privilege)

Error Handling¶ *Consistent error reporting for machine and human consumption.*

- **Rule [CC-ERR-001]**: Internal exceptions SHALL be mapped to standard HTTP error codes. * **Root**:
    - NFR-OPS-001 Service Level Objective (Availability SLO)
- **Rule [CC-ERR-002]**: Business Errors (e.g., “Insufficient Funds”) SHALL be distinguished from System Errors (e.g., “DB Connection Failed”).
- **Rule [CC-ERR-003]**: Internal stack traces SHALL NOT be exposed in API responses (Security). * **Root**:

    - NFR-SEC-001 Encryption in Transit (Information Leakage Prevention)

- **Rule** [**CC-ERR-004**]: All errors SHALL follow standard JSON Problem Details format (RFC 7807).

Logging and Auditing¶ *Traceability across the distributed system.*

- **Rule** [**CC-LOG-001**]: A **Correlation ID** is MANDATORY for all internal and external requests. It MUST be propagated across service boundaries. * **Decision**: [ADR-ARCH-002] Service Communication Pattern (Sync vs Async). * **Root**:
    - NFR-MON-001 Continuous Monitoring (Continuous Monitoring)
- **Rule** [**CC-LOG-002**]: Personally Identifiable Information (PII) SHALL NOT be logged. * **Root**:
    - NFR-DATA-001 Data Residency (Data Privacy)
- **Rule** [**CC-LOG-003**]: Security events (login, permission changes) SHALL be emitted to the Audit Log. * **Root**:
    - FR-LOG-003 Control Plane Auditing (Control Plane Auditing)

Security¶ *Identity as the new perimeter.*

- **Rule** [**CC-SEC-001**]: Zero Trust Model. Do not rely on network perimeter (VPC) for security. * **Decision**: ../../adr/network-strategy (No VPC). * **Root**:
    - NFR-SEC-005 Least Privilege (Least Privilege)
- **Rule** [**CC-SEC-002**]: TLS 1.2+ is MANDATORY for all data in transit, including internal service-to-service communication. * **Decision**: ../../adr/network-strategy. * **Root**:
    - NFR-SEC-001 Encryption in Transit (Encryption in Transit)
- **Rule** [**CC-SEC-003**]: Secrets SHALL be injected at runtime (e.g., via environment variables) and NEVER checked into source code. * **Root**:
    - NFR-SEC-004 Key Management (Key Management)

Data and Transaction¶ *Resilience over strict consistency.*

- **Rule** [**CC-DAT-001**]: Write operations SHALL be **Idempotent** to allow safe retries. * **Root**:
    - NFR-OPS-003 Load Balancing and Failover (Failover)

- **Rule [CC-DAT-002]**: **Eventual Consistency** is accepted. Distributed Transactions (2PC) are PROHIBITED. * **Root**:
  - NFR-CAP-001 Tenant Scalability (Tenant Scalability)

API Design¶ *Standardized interfaces.*

- **Rule [CC-API-001]**: APIs SHALL follow REST principles and use JSON as the data format.
- **Rule [CC-API-002]**: API versioning strategy SHALL avoid breaking changes (prefer backwards-compatible additions).

Observability¶ *Measure what matters.*

- **Rule [CC-OBS-001]**: Monitoring SHALL be driven by Service Level Indicators (SLIs) and Service Level Objectives (SLOs). * **Root**:
  - NFR-OPS-001 Service Level Objective (SLO)
- **Rule [CC-OBS-002]**: Metrics SHALL follow the RED method (Rate, Errors, Duration). * **Root**:
  - NFR-MON-001 Continuous Monitoring (Continuous Monitoring)

Deployment and Operations¶ *Minimize risk through reversibility and consistency.*

- **Rule [CC-OPS-001]**: Releases SHALL be **Reversible**. * New deployments MUST NOT destructively alter the previous version's resources until the successful switchover is confirmed. * **Decision**: [ADR-OPS-001] Deployment Strategy Implementation (Blue-Green). * **Root**:
  - NFR-OPS-002 Maintenance Scheduling (MTTR)
- **Rule [CC-OPS-002]**: Deployment Artifacts SHALL be **Immutable** (Build Once, Deploy Many). * The same built artifact (container image, lambda zip) MUST be promoted from Staging to Production. Configuration is injected via environment variables. * **Root**:
  - NFR-SEC-002 Encryption at Rest (Supply Chain Security)
  - **Root**: * NFR-OPS-001 Service Level Objective (Availability)
- **Rule [CC-OPS-004]**: CI/CD Pipelines SHALL be defined as Code (**Pipeline as Code**). * Workflows MUST be versioned alongside the application code to ensure the build process evolves with the software. * **Decision**: [ADR-OPS-002] CI/CD Platform Selection (GitHub Actions). * **Root**:

  - NFR-OPS-002 Maintenance Scheduling (MTTR - Revert of pipeline logic)

Architecture Constitution¶

This document defines the rules and conventions specifically for the architecture documentation.

Relationship to Main Constitution This constitution inherits all principles from the Main Specification Constitution. In case of conflict, the Main Constitution takes precedence for spec-related matters, while this document governs architectural decisions.

Architectural Decision Records (ADRs) - All significant architectural decisions MUST be recorded as ADRs in doc/adr. - ADRs SHOULD follow the Madr template.

Diagramming Standards - **Format**: Diagrams SHOULD be defined using Mermaid.js code blocks where possible for version control. - **Model**: The C4 model (Context, Containers, Components, Code) SHALL be used for structural views.

References - Architecture views MUST reference Functional Requirements (FR) and Non-Functional Requirements (NFR) using their identifiers. - Architecture views SHOULD NOT restate requirement text.

ID Naming Convention - Architectural Elements and Rules SHALL be assigned unique Reference IDs to facilitate traceability.

- **CTX-{Element}**: Context View Elements
- **BB-{Component}**: Building Block Elements
- **RT-{Number}**: Runtime View Scenarios (e.g., RT-001)
- **DEP-{Topic}**: Deployment Elements
- **CC-{Topic}-{Number}**: Cross-cutting Rules (e.g., CC-AUTH-001)

Architectural Views and Their Roles¶ This project adopts a layered architecture documentation model. Each view has a clearly defined purpose and scope. Views SHALL NOT overlap in responsibility.

Specification (Requirements Layer)¶

- Functional Requirements (FR), Non-Functional Requirements (NFR), Constraints (CON), and Error Definitions (ERR) define **what the system must do** and **under what conditions**.
- Specification documents are the **single source of truth** for requirements.

- Architecture documents SHALL NOT redefine or restate requirements.

Context View (C4 Level 1)¶ **Purpose**: - Define the system boundary and its external environment.

Scope: - External actors and external systems - High-level interactions across the system boundary

Rules: - The Context View SHALL NOT describe internal structure. - Use cases and actors SHALL be referenced, not restated.

Building Block View (C4 Level 2 / 3)¶ **Purpose**: - Allocate responsibilities to architectural building blocks.

Scope: - Major deployable units (containers) and their responsibilities - Relationships between building blocks - Mapping of responsibilities to Functional Requirements (by reference)

Rules: - Building Blocks represent **responsibility-bearing units**, not technologies. - Specific Cloud Managed Services (e.g., AWS Cognito) SHALL NOT be named; use generic terms (e.g., IdP) instead. - Implementation technologies SHALL NOT be specified. - Each Functional Requirement SHALL have a clear architectural owner.

Runtime View¶ **Purpose**: - Explain how building blocks collaborate at runtime to fulfill key scenarios. - Demonstrate Cross-cutting Concepts "in action".

Scope: - Representative interaction flows (5-10 key scenarios) - Responsibility transitions between building blocks - Normal and exceptional execution paths (by reference to ERR)

ID Convention: - **RT-{Number}**: Runtime Scenario identifier (e.g., RT-001, RT-002)

Required Structure (per Scenario): 1. **Scenario**: Brief description of the runtime behavior. 2. **Actors**: List of Building Blocks and external systems involved. 3. **Flow**: Step-by-step sequence, preferably as a **Mermaid Sequence Diagram**. 4. **Cross-cutting**: Which CC rules are "active" during this flow. 5. **Requirements**: Related FR/NFR references.

Typical Scenarios: - User Login (Authentication flow) - Authenticated API Request - Async Event Processing (Pub/Sub) - Blue-Green Switchover (Traffic Switching Behavior) - Error Handling / Retry Flow

Rules: - Runtime Views SHALL NOT redefine Functional Requirements. - Error semantics are defined in ERR and SHALL be referenced only. - Focus on **time-axis stories**: "Who calls whom, in what order, under what rules."

Architecture Decision Records (ADR)¶ **Purpose**: - Record significant architectural decisions and their rationale.

Scope: - Decisions involving trade-offs, alternatives, or long-term impact - Technology choices, architectural patterns, and deployment strategies

Rules: - ADRs are created when multiple viable options exist. - Architecture Views SHALL reference ADRs where decisions affect the structure. - ADRs SHALL NOT redefine requirements.

Deployment View¶ **Purpose**: - Describe how building blocks are deployed onto physical or cloud infrastructure.

Scope: - Environments, regions, and network boundaries - Infrastructure components (e.g., cloud services) - Mapping of building blocks to deployment units

Rules: - Deployment Views MAY reference specific platforms or services (e.g., AWS). - This is the primary view for mapping abstract building blocks to concrete Cloud Managed Services. - Deployment Views SHALL demonstrate how NFRs and CONs are satisfied. - No new Functional Requirements SHALL be introduced.

Cross-cutting Concepts¶ **Purpose**: - Define the **"Design Constitution"**: the permanent rules, principles, and mechanisms that apply consistently across all architectural elements. - It is the "Physical Laws" of the system that every component must obey.

Scope (Typical Topics): 1. **Authentication & Authorization**: (e.g., "Delegate to External IdP", "Role + Scope model"). 2. **Error Handling**: (e.g., "Map internal exceptions to standard error codes"). 3. **Logging & Auditing**: (e.g., "Mandatory Correlation ID", "No PII in logs"). 4. **Security**: (e.g., "Zero Trust", "TLS everywhere"). 5. **Data & Transactions**: (e.g., "Idempotency", "Eventual Consistency", "No Distributed Tx"). 6. **API Design**: (e.g., "REST + JSON", "Versioning rules"). 7. **Observability**: (e.g., "SLI/SLO driven").

Rules: - **DO NOT** write component-specific specific logic (Use Building Block View). - **DO NOT** write ADR rationale or history (Use ADRs). - **DO NOT** write generic best practices; only document rules adopted by this system. - Cross-cutting Concepts should be viewed as **"Permanent Rules extracted from ADRs"**. - Consistent with NFRs (Requirements) and ADRs (Decisions).

Operational Rules: 1. **Promotion**: If an ADR is referenced 2-3 times with the same reasoning across different contexts, it is a candidate for promotion to a Cross-cutting Concept (CC). 2. **Stability**: Once promoted to a CC, the rule represents a stable "Institution". The original ADR may be detached or superseded to prevent regression. 3. **Exceptions**: Any ADR that violates a Cross-cutting Concept MUST be explicitly labeled as an **"Exception ADR"** with strong justification.

Dependency Direction¶ The dependency direction between documents SHALL be strictly maintained:

- Specification → Architecture Views
- Architecture Views → ADRs
- Architecture Views → Deployment Views

Reverse dependencies SHALL NOT exist.

Architecture Decision Records¶

This directory contains the Architecture Decision Records (ADRs) for the project.

Creating a new ADR: Create a new file in decisions/ named NNNN-short-title.rst following the structure defined in ADR Constitution.

Indices¶

ADR Constitution¶ This document defines the rules and conventions for Architecture Decision Records (ADRs).

Mandatory ADRs¶ Before implementation begins, the following core architectural decisions MUST be made and recorded (Minimum 3-5 records ideal):

1. **Language / Runtime Selection**: (e.g., Python, Node.js, Go)
2. **Communication Pattern**: Synchronous (REST/gRPC) vs Asynchronous (Messaging).
3. **State Management**: Stateful vs Stateless architecture.
4. **Data Persistence**: Datastore selection (Relational, NoSQL, etc.).
5. **Authentication**: Concrete authentication method (OIDC, JWT, Session).

Directory Structure & Naming¶ ADRs are stored in doc/adr/decisions/ and follow a strict naming convention to ensure ordering.

Structure:

```
doc/adr/
|-- constitution.rst       # This file (Rules)
|-- index.rst              # Table of Contents
|-- decisions/             # Stored decisions
    |-- language-selection.rst
    |-- database-selection.rst
    `-- ...
```

Naming Convention: - Filename: `short-title.rst` - Title: `[ADR-{Category}-{Number}] Title Case Name` - **Format**: `ADR-{Category}-{Number}`

  - `Category`: 3-4 letter code (e.g., `ARCH`, `AUTH`, `DATA`, `INF`, `TECH`).
  - `Number`: Monotonic integer within category (e.g., 001).

- **Example**: `[ADR-AUTH-001] Select Auth Provider`

Required Structure¶ ADRs SHOULD follow the **Madr** template structure. Key sections include:

1. **Context and Problem Statement**: What is the issue? Why is it a problem?
2. **Decision Drivers**: Forces, constraints, and requirements driving the decision.
3. **Considered Options**: List of alternatives evaluated (including "do nothing").
4. **Decision Outcome**: The selected option and the justification (Rational).
5. **Consequences**: * **Positive**: Benefits, improvements. * **Negative**: Trade-offs, new debts, complexity.

[ADR-ARCH-001] Adopt Microservices Architecture¶

Status¶ Accepted

Context¶ The SaaS Foundation Platform aims to provide a robust, scalable foundation for future applications. However, the development and operations team size is limited. Minimizing the "undifferentiated heavy lifting" of infrastructure management is a critical success factor.

We need an architecture that allows us to: 1. Drastically reduce operational overhead (NoOps / LowOps). 2. leverage "best-of-breed" managed services for standard functions (e.g., Auth, Billing) rather than building them from scratch. 3. Scale different domains (e.g., high-traffic public API vs. low-traffic internal admin) independently.

Decision¶ We will adopt a **Microservices Architecture**, implemented primarily through **Event-Driven Serverless Components** and **Managed Services**.

Rules: 1. **Managed Service First**: We will prefer fully managed services (SaaS/PaaS) over self-hosted components. 2. **Function as a Service (FaaS)**: Custom logic will be deployed as stateless functions (e.g., AWS Lambda) to eliminate server management. 3. **Event-Driven**: Services will decouple via an Event Bus to allow independent evolution and scaling.

Rationale¶

Primary: Operational Efficiency (NoOps) By adopting a microservices style where each "service" maps closely to a managed cloud resource (e.g., Auth Service -> Cognito, API Layer -> API Gateway), we shift the burden of availability, patching, and scaling to the cloud provider.

Secondary: Scalability & Isolation The "Control Plane" has distinct scaling profiles. Authentication and Tenant Resolution must be extremely low latency and high availability, whereas Billing is asynchronous and bursty. Microservices allow applying the right tool (and cost structure) to the right problem.

Consequences¶ Positive: - Significant reduction in infrastructure maintenance tasks. - Ability to use "best-for-job" managed services (e.g., DynamoDB for high-scale, RDS for relational).

Negative: - **Integration Complexity**: Debugging across distributed services is harder; requires robust Distributed Tracing (see FR-LOG). - **Vendor Lock-in**: Heavy reliance on specific managed services makes porting to another cloud provider difficult (accepted risk).

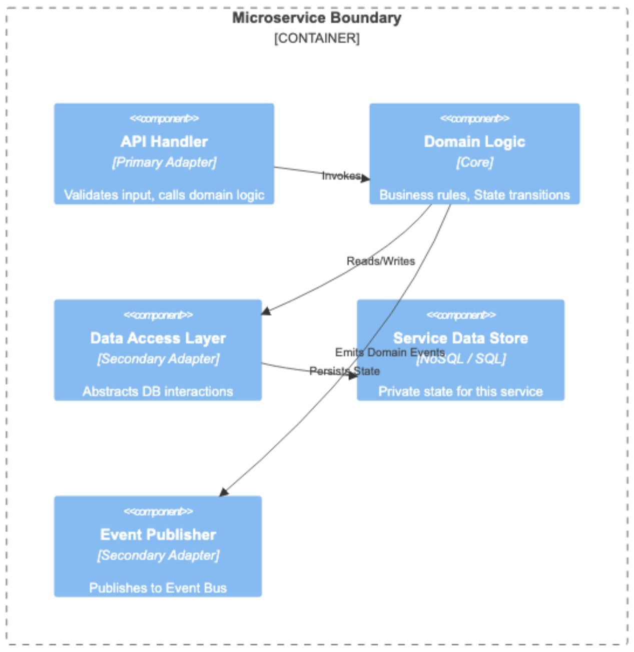
Internal Structure¶ To ensure testability and consistency across microservices, we enforce a standard **Layered / Hexagonal Architecture**.

Decision: All microservices SHALL be structured with the following layers:

1. **Transport / Adapter Layer (API Handler)** - Responsibility: Receive events (HTTP/EventBridge), validate input, invoke Domain Logic. - Technology: AWS Lambda Handler, API Gateway integration.
2. **Domain Logic Layer (Core)** - Responsibility: Implement business rules, state transitions, and invariants. - Constraint: **PURE CODE**. No dependencies on AWS SDKs or external frameworks.
3. **Data Access / Infrastructure Layer (Repository)** - Responsibility: Persist state, publish events, call external APIs. - Technology: DynamoDB SDK, HTTP Clients.

Component Diagram:

Generic Microservice Component Diagram



[ADR-AUTH-001] Authentication Method Implementation¶

Context and Problem Statement¶ We need to define *how* authentication is implemented. Specifically, the mechanism for transmitting identity and validating it across the Control Plane and Managed Apps.

Decision Drivers¶

- Security standards compliance (OAuth2 / OIDC)
- Statelessness
- Compatibility with SPA / Mobile clients
- Ease of revocation

Considered Options¶

- JWT (JSON Web Tokens) - Access/Refresh Token pattern
- Server-side Code Sessions (Cookie-based)
- API Keys (for M2M only)

Decision Outcome¶ [Proposed]: JWT (Access/Refresh Tokens)

Positive Consequences¶

- Stateless verification by services
- Standardized (OIDC compatible)

Negative Consequences¶

- Token revocation complexity
- Token size

[ADR-AUTH-002] Select Azure Entra ID External Identities for Authentication¶

Status¶ Accepted

Context¶ The platform requires a secure, scalable, and standards-abiding Identity Provider (IdP) to manage external users (Tenants). We need to support: 1. OpenID Connect (OIDC) standards. 2. Branded login pages. 3. Reasonable cost scaling.

The candidates considered were: - **AWS Cognito**: Native integration with AWS. - **Auth0**: Developer-friendly, feature-rich. - **Azure Entra ID External Identities**: Microsoft's CIAM solution.

Related Requirements¶

- Satisfies Supported Authentication Methods
- Satisfies Multi-Factor Authentication
- Satisfies Adaptive Authentication

Decision¶ We will use **Azure Entra ID External Identities** as the primary Authentication Provider for external users.

Rules: 1. The Auth Service component in the architecture maps to Azure Entra ID. 2. The API Gateway will validate JWTs issued by Azure Entra ID.

Rationale¶

1. **Cost Efficiency**: **Auth0** is significantly more expensive at scale for B2C/SaaS use cases compared to platform-native solutions. Azure Entra ID offers a generous free tier (MAU based) and competitive pricing.
2. **Usability & Developer Experience**: **AWS Cognito** is known for its steep learning curve, limited customization options for hosted UI, and AWS-specific idiosyncrasies that can complicate standard OIDC flows. **Azure Entra ID** provides a robust, enterprise-grade identity foundation with better documentation and standard compliance than Cognito, making it easier to implement and maintain. Although it adds a multi-cloud element (AWS + Azure), the identity layer is logically separate enough that the integration overhead is manageable via standard OIDC.

Consequences¶ Positive: - Lower cost than Auth0. - Better standards compliance and DX than Cognito. - Leveraging Microsoft's security expertise.

Negative: - **Multi-Cloud Complexity**: We introduce a dependency on Azure while running infrastructure on AWS. This requires managing credentials and billing across two clouds. - **Latency**: Potential slight increase in latency for token validation if public keys are fetched across cloud boundaries (negligible in practice with caching).

[ADR-OPS-002] CI/CD Platform Selection¶

Context and Problem Statement¶ We need a Continuous Integration and Continuous Deployment (CI/CD) platform to automate the build, test, and release processes of our Serverless application. The platform must enable our "Build Once, Deploy Many" principle and integrate seamlessly with our source control.

Decision Drivers¶

- **Integration**: Tight integration with Source Code Management (Pull Requests, Code Review).
- **Maintenance**: Minimal operational overhead (SaaS preferred).
- **Security**: Secure handling of Cloud Provider credentials (OIDC).
- **Parallelism**: efficient execution of concurrent test suites.

Considered Options¶

- **GitHub Actions** (SaaS)
- **GitLab CI** (SaaS/Self-hosted)
- **Jenkins** (Self-hosted)

- **AWS CodePipeline/CodeBuild** (AWS Native)

Decision Outcome¶ Chosen Option: GitHub Actions

Justification: GitHub Actions is the natural choice as our code resides in GitHub. 1. **Unified Experience**: CI/CD workflows are defined in the same repository (.github/workflows) and results are visible directly in Pull Requests. 2. **Security**: Native support for **OIDC (OpenID Connect)** allows us to authenticate with AWS/Azure without storing long-lived access keys (Keyless Authentication). 3. **NoOps**: Fully managed SaaS runners eliminate the need to maintain build servers (unlike Jenkins). 4. **Ecosystem**: Extensive marketplace of Actions simplifies tasks like "Setup Python", "Login to AWS", "Terraform Apply".

Positive Consequences¶

- **Developer Velocity**: Fast feedback loops on PRs.
- **Security**: Reduced attack surface via OIDC.
- **Simplicity**: Single pane of glass for Code and Pipeline.

Negative Consequences¶

- **Vendor Lock-in**: Workflow syntax is specific to GitHub.
- **Limits**: SaaS concurrency limits may require upgrading plans (handled via scaling to self-hosted runners if needed).

[ADR-ARCH-002] Service Communication Pattern (Sync vs Async)¶

Context and Problem Statement¶ The system consists of a Control Plane and potentially distributed managed applications or agents. We need to decide how these components communicate, specifically balancing coupling, latency, and reliability.

Decision Drivers¶

- Loose coupling between services
- Latency requirements for user-facing actions
- System resilience and handling of downtime
- Complexity of operations

Considered Options¶

- Synchronous REST/gRPC only
- Asynchronous Messaging (Event-driven) primarily
- Hybrid (Sync for queries, Async for mutations)

Decision Outcome¶ [Proposed]: [Option]

Positive Consequences¶

- ...

Negative Consequences¶

- ...

[ADR-DATA-001] Data Persistence Strategy¶

Context and Problem Statement¶ We need to select the primary data storage technology for the Core Database (Tenants, Users, Config). While the domain has some relational aspects, the system prioritizes "Serverless" characteristics (scale-to-zero, minimal operations) and consistent performance at scale.

Decision Drivers¶

- **Operational Overhead**: Must minimize database management (NoOps).
- **Scaling Characteristics**: Must handle "bursty" traffic and scale to zero (Cost efficiency).
- **Performance**: Consistent single-digit millisecond latency regardless of scale.
- **Ecosystem**: Integration with AWS Lambda and EventBridge (Event-Driven Architecture).

Considered Options¶

- **Amazon DynamoDB** (NoSQL, Serverless)
- **Amazon Aurora Serverless v2** (PostgreSQL, Relational)
- **Amazon RDS for PostgreSQL** (Provisioned Relational)

Decision Outcome¶ **Chosen Option**: **Amazon DynamoDB**

Justification: DynamoDB is the only option that fully aligns with our **Serverless First** strategy ([ADR-ARCH-001] Adopt Microservices Architecture). Unlike Aurora Serverless, DynamoDB offers true "pay-per-request" pricing and eliminates connection management overhead common with Lambda + RDBMS. We accept the trade-off of "Eventual Consistency" (see Cross-cutting Concepts [CC-DAT-002]) and lack of joins in exchange for predictable performance and operational simplicity.

Positive Consequences¶

- **True Serverless**: No instance provisioning or scaling management.

- **Performance**: Consistent low latency at any scale.
- **Event Integration**: Native DynamoDB Streams integration for Event Sourcing patterns.

Negative Consequences¶

- **Modeling Complexity**: Requires "Single Table Design" or denormalization; no SQL joins.
- **Consistency**: Strong consistency requires explicit configuration (Read consistency).
- **Query Flexibility**: Limited ad-hoc query capabilities compared to SQL.

[ADR-OPS-001] Deployment Strategy Implementation¶

Context and Problem Statement¶ We need to define a deployment strategy for the production environment that ensures system availability and allows for rapid recovery in case of failures. The system serves critical business operations, requiring high availability during updates.

Decision Drivers¶

- **Zero Downtime**: Updates must not interrupt active user sessions or API calls.
- **Rollback Speed**: Ability to instantly revert to the previous known good state.
- **Risk Mitigation**: Ability to verify changes in a production-like environment before switching traffic.
- **Complexity**: Operational complexity of the deployment pipeline.

Considered Options¶

- **Rolling Deployment**: Gradually replace instances.
- **Blue-Green Deployment**: Provision parallel environment and switch traffic.
- **Canary Deployment**: Gradually shift traffic percentage.
- **Recreate**: Stop old, start new (Downtime).

Decision Outcome¶ **Chosen Option**: **Blue-Green Deployment** (Serverless variant)

Justification: Blue-Green deployment offers the optimal balance between safety and complexity for our Serverless architecture. 1. **Instant Rollback**: Switching traffic back to the "Blue" (previous) version is an atomic

DNS/Routing change. 2. **Verification**: The "Green" (new) version can be fully automated E2E tested in the production environment before receiving real traffic. 3. **Serverless Fit**: With Lambda/API Gateway, creating parallel environments (Versions/Aliases) is cheap and fast compared to VM-based replication.

Positive Consequences¶

- **Safety**: Zero downtime updates guaranteed by atomic switchover.
- **Confidence**: Testing against production configuration reduces "it works on my machine" issues.
- **NoOps**: Fits natively with AWS Lambda Aliases and Weighted Traffic.

Negative Consequences¶

- **Cost**: Transiently doubled resource usage (though negligible for Serverless/Scale-to-Zero).
- **Database Complexity**: Schema changes must be backward compatible to support both Blue and Green versions simultaneously.

[ADR-TECH-002] Infrastructure as Code (IaC) Tool Selection¶

Context and Problem Statement¶ We need to select an Infrastructure as Code (IaC) tool to define, deploy, and manage our Serverless resources (Lambda, API Gateway, DynamoDB) on AWS. The tool must support our "Serverless First" strategy and allow for reproducible environment deployments.

Decision Drivers¶

- **Multi-cloud Support**: Must manage resources on AWS (Compute/Data) and Azure (Authentication).
- **Ecosystem Maturity**: Industry standard, wide module availability.
- **State Management**: Robust handling of remote state and locking.
- **Serverless Support**: Ease of packaging and deploying Lambda functions.

Considered Options¶

- **AWS SAM** (Serverless Application Model) - AWS native, simple YAML.
- **AWS CDK** (Cloud Development Kit) - AWS native, imperative Python/TS.
- **Terraform** (OpenTofu) - Cloud-agnostic, declarative HCL.
- **Serverless Framework** - 3rd party tool.

Decision Outcome¶ **Chosen Option**: **Terraform**

Justification: While AWS SAM is excellent for pure AWS Serverless projects, our architecture explicitly depends on **Azure Entra ID** (ADR-AUTH-002). Terraform allows us to define and manage both AWS and Azure resources in a single, unified codebase (Infrastructure as Code). 1. **Unified Workflow**: terraform apply manages the entire stack (IdP config + AWS Compute). 2. **Maturity**: Extensive providers for both AWS and Azure. 3. **Python Support**: Although Terraform uses HCL, we can use terraform-aws-modules/lambda to handle Python dependency packaging elegantly.

Positive Consequences¶

- **Single Source of Truth**: IAM, Database, and Identity Provider (Azure) all in one place.
- **Vendor Agnostic Core**: Familiar syntax and workflow regardless of cloud provider.
- **State Management**: Robust state locking via S3/DynamoDBBackend.

Negative Consequences¶

- **Lambda Developer Experience**: "Local invoke" is not as native as SAM. (Mitigation: Use SAM CLI with Terraform hook or Unit Tests).
- **Boilerplate**: HCL can be more verbose than SAM for simple functions.

[ADR-TECH-001] Language and Runtime Selection¶

Context and Problem Statement¶ We need to select the primary programming language and runtime environment for the backend services Control Plane. This decision is governed by **Rule [CC-DEV-001]** (AI-First Development).

Decision Drivers¶

- **AI Code Generation Accuracy**: Code must be generated reliably and correctly by AI agents.
- **AWS Integration**: First-class support in AWS Lambda and SDKs (Boto3).
- **Execution Performance**: Cold start limits and runtime overhead.
- **Ecosystem Maturity**: Availability of libraries (PowerTools) to reduce custom code.

Considered Options¶

- **Python 3.12+** (with Pydantic/PowerTools)
- **Rust** (AWS Lambda Rust Runtime)

- **TypeScript** (Node.js 20.x)
- **Go** (Golang 1.21+)

Decision Outcome¶ **Chosen Option**: **Python 3.12+**

Justification: While **Rust** provides superior runtime efficiency (memory/CPU) and is ideal for "Serverless First" from a resource perspective, we select **Python 3.12+** for the following reasons in an AI-driven development context: 1. **LLM Proficiency**: Large Language Models have significantly more training data for Python/Boto3/Lambda patterns than Rust/AWS-SDK-Rust. This maximizes the success rate of AI-generated code. 2. **Ecosystem Support**: aws-lambda-powertools-python and boto3 are the de-facto standards for AWS, offering richer features and faster updates than their Rust counterparts. 3. **Hybrid Approach**: The AI Agent can easily refactor individual performance-critical Lambda functions to **Rust** if observability data indicates a bottleneck, but the default should be the language where the AI is most competent (Python).

Positive Consequences¶

- **High Quality Generation**: AI produces idiomatic, correct code with high probability.
- **Rich Ecosystem**: Immediate access to mature libraries.

Negative Consequences¶

- **Runtime Overhead**: Higher memory/CPU usage than Rust.
- **Cold Starts**: Slower than compiled binaries (mitigated by Provisioned Concurrency or future optimization to Rust).

[ADR-INF-001] Adopt Identity-Based Security (No VPC) for Serverless Compute¶

Status¶ Accepted

Context¶ In a traditional server-based architecture, network isolation (VPC) is the primary defense boundary. However, we are adopting a **Serverless Architecture** (ADR-0006) using fully managed services like AWS Lambda, DynamoDB, and Cognito.

Deploying these serverless resources into a VPC introduces significant challenges: 1. **Complexity**: Requires managing subnets, NAT Gateways, and Route Tables. 2. **Cost**: NAT Gateways incur high hourly and data processing charges. 3. **Performance**: Potential cold start overhead (though improved in recent years) and added network hops. 4. **Redundancy**: Most AWS managed services (DynamoDB, S3, Cognito, EventBridge) are accessed via public HTTPS endpoints protected by IAM, meaning VPC traffic often exists just to reach a public endpoint anyway.

Related Requirements¶

- Satisfies Encryption in Transit
- Satisfies Least Privilege
- Satisfies Availability SLO (Proxy for NoOps/Maintainability)

Decision¶ We will **NOT** deploy Serverless Compute components (e.g., Lambda functions) into a Virtual Private Cloud (VPC). Instead, we will adopt an **Identity-Based Security (Zero Trust)** model.

Rules: 1. **Identity per Function**: Each Lambda function must have a dedicated IAM Execution Role with least-privilege permissions. 2. **Encryption Everywhere**: All data in transit must be encrypted via TLS (standard for AWS APIs). 3. **No Persistent Network**: We accept that functions run in the provider's managed network space.

Rationale¶

Primary: Operational Efficiency (NoOps) Removing the VPC layer eliminates an entire class of infrastructure to manage (Subnets, NACLs, NATs). This aligns perfectly with our goal of minimizing operational overhead.

Secondary: Cost Optimization Eliminating NAT execution costs significantly reduces the "idle cost" of the platform.

Exceptions¶ A VPC **MAY** be introduced in the future ONLY if: 1. We need to access a resource that *only* resides in a VPC (e.g., RDS, ElastiCache, or an on-premise connection via VPN/DirectConnect). 2. Compliance requirements explicitly mandate network-layer isolation for specific processing.

Currently, we use DynamoDB (HTTPS) and generic APIs, so no exception applies.

Consequences¶ Positive: - Simplified architecture diagram. - Reduced AWS bill (No NAT Gateway). - Reduced Terraform/CloudFormation code complexity.

Negative: - **Security Perception**: "No VPC" can raise eyebrows with traditional security auditors. We must clearly document our reliance on IAM and Encryption as compensatory controls.

[ADR-ARCH-003] State Management (Stateful vs Stateless)¶

Context and Problem Statement¶ We need to determine if the backend services should maintain session or application state in memory (Stateful) or delegate all state to external stores (Stateless). This impacts scalability and deployment strategies.

Decision Drivers¶

- Horizontal scalability
- Deployment ease (Blue/Green, Canary)
- Complexity of state synchronization
- Resources efficiency

Considered Options¶

- Stateless (Recommended for Cloud Native)
- Stateful (Sticky sessions)

Decision Outcome¶ [Proposed]: Stateless

Positive Consequences¶

- Easy to scale out
- Resilience to instance failures

Negative Consequences¶

- External store dependency (Redis/DB) for temporary state